Framing The Audience: Describing Households That Invest in Energy Efficiency

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ABSTRACT

Energy efficiency program implementers that know who to target for energy efficiency measures will be more effective at implementing their programs. Online and in house energy audits can educate potential energy efficiency program participants and motivate energy saving behavior. How effective these audits are in getting customers to adopt energy efficiency measures and participate in programs is still in question. This paper describes how the online and in home energy audits drive program participation, and demonstrates what can be done with the information given by audit participants. Responses to the online audit are analyzed and used for developing a discreet choice econometric model. Home energy audits are both an effective marketing and market research tool.

Introduction

Households that purchase durables and make structural and aesthetic improvements to their homes weigh the short term and long term impacts of their decision. Households must choose to purchase standard or energy efficient appliances, and make standard or energy efficient improvements to their home. Household's make a qualitative choice between two alternatives. The choice depends upon the magnitude of the higher upfront capital cost of the efficient choice, and the energy expenditure savings that accumulate over time.

This paper focuses on residential energy efficiency. This paper is also an evaluation of the online Nexus HEA© (HEA) and Energy Trust's Home Energy Review (HER), two residential energy audit programs. The demographic and behavioral attributes of a sample of households are analyzed to determine if those who undertake energy saving measures are different from a sample of households that were found not to implement energy saving measures. Key attributes that increase the probability that a household will undertake energy efficiency measures in their home will be identified in this paper. Detailed household characteristics are presented and supplemented by an econometric model. The findings will contribute to the existing knowledge of the residential efficiency sector, and will be used to improve Energy Trust marketing and outreach efforts.

The Data

An important educational and marketing tool the Energy Trust employs is the Nexus HEA tool that models a home's energy use. The HEA is freely available on the websites of Energy Trust and three utilities in Oregon; Portland General Electric, Pacific Power, and NW Natural. The HEA is advertised by all four entities. Participants are presented with a series of questions about their housing characteristics, appliance inventories, efficiency levels, and energy consuming behavior. The responses are used to simulate a home's energy use and make recommendations to participants on how they can save energy in their home. If users are ratepayers of one the three participating utilities, and complete the HEA, participants are sent four free compact fluorescent light bulbs as an incentive to complete the tool. Participants are asked to provide name, address, email address, and utility account numbers, which allows the participants to be matched to recipients of energy efficiency incentives in Oregon, and to their electric and gas utility bills. These participants make up the population of households that are studied in this paper.

The household characteristics and demographic information made available by the HEA provides a rich set of data for analysis. A significant portion of the households who participated in the HEA are suspected to be good candidates for implementation of energy efficiency measures in their homes. The intention of this analysis is to identify which household attributes are correlated with program participation. Two sources of data allow the households who have implemented energy saving measures to be identified; Energy Trust of Oregon incentive recipients, and Oregon Residential Energy Tax Credit recipients. The Residential Energy Tax Credit is available to households who implement certain energy saving measures. Many Energy Trust participants also take advantage of the state tax credit, and many of the recipients of the tax credit take advantage of Energy Trust incentives. The overlap between these programs has been accounted for, as not to double count any household.

Participants of the HEA who have provided a valid address can be matched to recipients of either of the energy efficiency incentives. Participants who are successfully matched will be referred to in this paper as "action takers." HEA Participants who were not found to be recipients of incentives are referred to as "participants." While most of the participants have not implemented energy efficiency measures in their home, without a survey of these households, that assumption cannot be made.

Energy Trust also conducts Home Energy Reviews (HER) in which a Conservation Services Group (CSG) trained contractor visits a home and recommends measures that a household can take to save energy. HER's are free of charge and available upon request to single family households in Energy Trust service territory. The HER is meant to drive program participation and inform households of no cost and low cost energy saving measures. The Home Energy Reviewer typically installs up to ten compact fluorescent light bulbs, as well as faucet aerators and low flow showerheads. The HER is a comprehensive and personalized home energy audit that often leads to further program participation.

Additional sources of data provide a fine supplement to this analysis. The incorporation of electric and gas utility billing data will provide an answer to this question. HEA participants who provided valid electric and gas utility account numbers allows energy consumption data to be an important part of the model. Another potential determinant of undertaking energy saving actions may be geography. Zip codes given by the participants allow geographical trends to be identified.

A substantial number of households participated in the HEA. A total of 13,094 people took the HEA between August 2004 and May 2006. This population allows for a relatively large sample. This analysis combines data on the participants from four different sources. The sources are combined and cases with missing observations are removed[1]. The population available for analysis is a fraction of the survey population. 7,457 participants provided addresses which can be matched to Energy Trust and Residential Energy Tax Credit participant databases to identify participants who have taken energy efficiency action. 1,722 of the HEA participants were found to have implemented energy efficiency measures. This means that 23% of the HEA participants implemented energy saving measures. If only single family detached dwellings are considered for analysis, there are 1,425 action takers from a sample of 5,840 participants, or 24% of HEA users.

Only 718 households provided both a valid electric and gas utility account number. This sample of 718 will be used for the consumption model. The population of households who provided addresses make up a more robust model employing the household characteristics.

The HEA serves as an education tool as well as a marketing tool for energy efficient appliances as well as home improvement and weatherization repairs. Energy Trust and its utility partners want to know how many households may have been influenced to implement energy efficiency measures as a result of using the HEA. Households who have implemented energy efficiency measures before taking

[1] Households who provided an address and completed the Home Energy Analyzer may have done so to receive the free compact fluorescent light bulbs, so the population available for analysis may be seen to be the most highly motivated.

the HEA are assumed to have not been influenced by the tool, while those who participated afterwards were likely influenced by the measures recommended by the tool. Dates recorded by the HEA, Energy Trust, and Residential Energy Tax Credit allow the timing to be identified. Over half (56%) of participants implemented measures before completing the analyzer. These households were not influenced by the HEA to implement energy saving measures. Fewer than half (44%) of the action takers implemented energy efficiency measures after taking the HEA. It is assumed that these households were influenced by the tool to implement measures.

Action takers who implemented measures before taking the HEA were not driven to do so by the tool. However, many of these households have implemented additional measures which can be attributed to the HEA. 24% of action takers who implemented measures before taking the HEA, also implemented energy saving measures after using the tool. These households must be counted as influenced by the tool to implement an energy efficiency measure. The number of households that took action after using the tool is 964 of 7,457 households. The total action taking rate among all housing types is therefore 13% of the households who participated in the HEA.

The type of energy saving measures implemented are of interest in this analysis. Table 1 displays the number of measures available and installed. A HER is considered to be taking action even if they do not implement any energy saving measures. Energy Trust recommends the in home energy audit to households that want a more comprehensive audit than the HEA can offer. Participants of the HER may be acting upon a recommendation and are likely to exhibit energy efficient behavior. A majority of action takers only implemented one energy saving measure, however a modest number of households implemented two measures. Action takers who implemented more than two measures are a small fraction of the action taking population.

Table 1 – Measures Installed

Measure	Number of Measures Installed	Percent of Measures
Free CFL's	571	18%
Window	42	1%
Water Heater	38	1%
Fridge	28	1%
Insulation	134	4%
Heat Pump	42	1%
Boiler	1	0%
Gas Furnace	196	6%
Clothes Washer	937	30%
Home Energy Review	314	10%
Duct Work	143	5%
Lighting	197	6%
Dishwasher	259	8%
Weatherization	67	2%
Water	123	4%
TOTAL	**3,092**	**100%**

There is substantial demand for Home Energy Review's. Energy Trust conducted 1,966 HER's in 2005, and 5,767 HER's in 2006. The program targets homes that are at least 20 years old. It is believed that older homes are more likely to benefit from the HER and the reviewer's recommendations.

The rate of HER measure implementation is examined in similar fashion to the method used for HEA participants. The same menu of measures are available to a HER participant as a HEA participant, including state tax credit measures. Measures installed as part of the HER including CFL's, aerators, and showerheads are not considered action taking measures. Action taking measures must be implemented sometime after the HER.

The HER leads to higher levels of program participation than the HEA. Twenty two percent (1,692 of 7,733) of 2005 and 2006 HER participants went on to receive an incentive from Energy Trust or tax credit from the state of Oregon. Ceiling insulation is the most implemented measure which was installed by 45% of HER action takers. Floor and wall insulation were also installed by many households who installed ceiling insulation. Heating, ventilation, and air conditioning (HVAC) improvements and or replacement is second to insulation measures with 28% of households installing an efficient gas furnace or heat pump. There is a substantial amount of overlap in the installed measures, with more than one measure often installed at the same time.

The recommendations given by Home Energy Reviewers are adopted only a small percentage of the time. Recommendations for a particular measure result in action 4% of the time within the period studied on average. It is unlikely that action is taken immediately to address recommendations, given the large investment required for many of the measures. However, it does appear that households are increasingly likely to take action in the next year after the HER. The 35% rate of action for 2005 HER households is double that of the rate of action among 2006 HER households at 17%. It is common to wait at least one year to evaluate the effectiveness of audits. It is likely that the rate of action will increase two years after a Home Energy Review.

The amount of data available on the homes that participated in HER's is less substantial than data gathered from HEA participants. In addition, data from only half of the HER's conducted are available for analysis. The available data does identify some differences between action takers and participants. Action takers homes are significantly older and slightly larger than participant homes. Action takers are more likely to use gas for space and water heating fuel. Action takers are significantly more likely to have air conditioning in their homes. Households that replaced a gas furnace had a previous furnace that was an average of 28 years old. Households that installed insulation had low existing insulation levels. The average existing R – values for ceilings, walls, and floors was 17, 7.5, and 3 respectively. Households that implemented measures tend to be older, and larger, with outdated heating systems with little to no insulation in the walls and floors, and lacking in the ceiling.

Household Characteristics

We suspect households that implement energy efficiency measures will display distinct characteristics. Housing characteristics are very similar between action taking households and participants in the survey. A basic analysis of characteristics of the action taking and participant households provides insight, but no strong conclusions about what separates the two groups. Differences at the margin for each household calculated by the qualitative choice model provides stronger conclusions.

The first level of analysis of the survey data is to describe the sample of households and trends in key variables. This provides a snapshot of the sample. Significant differences in key characteristics between action takers and participants will be identified if they exist. These attributes are considered as potential variables in the qualitative choice model. If a characteristic is found to be the same between action takers and non-action takers, the statistic will be reported as that of all households.

The analysis is conducted on single family detached households who reported a valid address in the HEA. Households that are apartments, condos, mobile homes, and townhouses are not included in the analysis. Limiting the analysis to single family houses provides for a homogenous sample for analysis. Energy using characteristics are significantly different in the other housing types, as well as the energy saving measures that are available to them. Households who did not provide an address could not be matched to the tax credit and Energy Trust measure databases. These households may have implemented energy efficiency measures that cannot be identified by methods used in this analysis.

There are three levels to complete in the HEA. Level 1 is basic house information including name, address, square footage, levels, and number of inhabitants. Level 2 is the inventory of appliances. Level 3 goes into more detail regarding appliances, house characteristics and energy using behavior. Level 3 also includes a billing analysis which requires correct utility account numbers to link the given information to actual billing data. Action takers completed more of each level than participants. Part of the reason for this is that survey participants who left many answers blank were removed from the sample. It is surprising to note that only 8% of action takers, and 4% of participants completed level 3.

Significant differences exist in only a couple of house and household characteristics which are presented in Table 2 in the appendix. House size is significantly different between the two groups. Action takers homes tend to be larger than participant homes. This difference is statistically significant at the 95% confidence level, however the magnitude of the difference is not very large. A similar evaluation of the HEA for Pacific Power in Washington conducted by Quantec LLC, cited an average house size of 1,700 square feet (Quantec, p. I-5). House size is normally distributed, with over 30% of houses between 1,000 – 2,000 square feet. Significantly more action takers own their homes rather than rent. This is not surprising given the dis-incentive for renters to install energy efficient measures.

Heating is a major end use for homes in Oregon. It is suspected that the heating fuel is an important determinant of those who chose to implement energy efficiency measures. A majority of both groups use natural gas as a heating fuel. A greater proportion of action taking households use natural gas as a heating fuel. 71% of action takers and 58% of participants heat with natural gas. 21% of action takers and 27% of participants heat with electricity. There is a significantly greater proportion of participants that employ oil, propane, wood, and oil as primary heating fuel. Households who use these less common heating fuels cannot take advantage of Energy Trust incentives for insulation, windows, furnaces, heat pumps, weatherization and duct work. This is most likely the reason why these other heating types appear more predominantly in the participant group. A majority of both groups with electric heat use baseboard or resistance style heat, with participants using more baseboard style heat. A slightly greater proportion of action takers use electric forced air furnaces and heat pumps than non-action takers.

Secondary heating sources can have a noticeable effect on household energy consumption depending on their frequency and timing of use. Fireplaces are the most common secondary heating source for both groups. A greater proportion of action taking houses have fireplaces than participant houses. Action takers are more likely to use gas as a fireplace fuel, however a majority of both groups use wood as the main fireplace fuel. A greater proportion of participant households report having space heaters in their homes. The qualitative choice model reveals more about the influence of heating fuel on efficiency choice.

Air conditioning is a growing trend in Oregon. A greater share of new homes are constructed with central air conditioning than has traditionally been the case in Oregon. This has changed the peak load from winter to summer in recent years. A "Residential New Construction Characteristics and Practices Study" conducted by RLW Analytics for the Northwest Energy Efficiency Alliance indicates that 98% of new homes in the Northwest have central air conditioning, and 2% use room air conditioners (RLW, P. 81). HEA results indicate that 44% of action takers have central air conditioning systems, compared to 41% of participant houses who indicate the same. Participant households have a greater proportion of room air conditioners. 14% of action takers have at least one room air conditioner, and 19% of participants have at least one room air conditioner. Taking into account both central and room air conditioning, action takers are slightly less likely to have air conditioning in their homes. If the central air conditioner percentage is added to the room air conditioners, 58% of action takers and 60% of participant houses have air conditioning.

There is a significant difference in the proportions of water heating fuel between the action takers and participants. 57% of action takers use natural gas for water heating fuel, whereas 48% of non-action takers use gas. The remaining households employ electricity as their water heating fuel. Only 1% of both groups indicated that they use another fuel for water heating, such as propane. Small proportions of all households indicate that they have a high efficiency water heater, or state that their water heater tank is insulated.

HEA participants were asked to describe the quantity and type, as well as use of lighting used in their homes. A slightly greater proportion of participants state that they are careful to turn unnecessary lights off. A greater proportion of action takers state that they "sometimes" leave unnecessary lights on. The wattage of light bulbs used between the two groups are virtually the same, as well the quantity of halogen lamps. Action takers indicate that they have significantly less wall and ceiling light fixtures than participants. Action takers have an average of 8.33 wall and ceiling fixtures, while participants have an average of 7.90 fixtures. The difference in means is statistically significant at the 95% confidence level.

Electric and Natural Gas Consumption

A household's energy consumption is thought to be a major indicator of efficiency choice in this analysis. There are two different ways to interpret energy consumption with regard to indicating energy efficient behavior. One perspective is that households with greater consumption are more likely to implement energy saving measures. Households with greater consumption would benefit more from energy saving measures, and are likely to have a greater number of areas they could implement energy saving measures. Households with greater consumption are also more likely to have larger homes with more appliances, and larger incomes. If this is assumed, these households have more income available to invest in energy saving measures. A counter perspective is that households with greater consumption are so because they do not implement energy saving measures or display energy efficient behavior. Additionally, the previously implemented energy saving measures and energy efficient behavior of action taking households may result in significantly reduced energy consumption. The lower consumption may show up in the billing analysis.

The most interesting and valid inferences in this paper involve household annual energy consumption. A majority of HEA Participants provided utility account numbers. Account numbers of Energy Trust participants supplemented the HEA account numbers when one was not given. Many of the self reported account numbers are not valid, however, enough billing histories were matched to participants for a fairly robust sample. The main reason for an invalid account number appears to be key punch errors. People have a difficult time entering long account numbers. It is assumed that the errors are random and do not bias the sample of households available for analysis. It should be noted that households with gas heat are considerably over represented in the sample of households for which both electric and gas heat billing histories are available. For this reason, consumption averages are calculated for all of the participants whose billing histories are available in that category. Sample sizes differ among all categories. The normalized annual consumption was calculated for each household, and is the unit of consumption for this analysis. This calculation of Normalized Annual Consumption is described in the appendix.

The billing data for these households is a cross section of consumption in the same period of time. The billing data is from the 12 month period of October 2005 – September 2006. Households who implemented energy saving measures previous to this twelve month period may have energy consumption that is biased downward due to their previous energy efficiency actions. However, the purpose of this analysis is to determine the effectiveness of the online and in home audit, and what characteristics may influence the decision to act. Almost all (93%) of the action takers took the HEA and implemented energy saving measures after October 2005, during the period of energy consumption used for this analysis. This method provides a glimpse of their consumption at the time of action.

Significant differences exist in the electric and gas consumption between action takers and participants. Tables 1-8 present the results of the energy consumption analysis. Households are grouped into two consumption categories; electric heat and gas heat. Households are further stratified into specific space and water heating categories because their consumption patterns are different. Households with different heating fuel for space and water heat display vastly different consumption patterns. In general, action takers display significantly lower electricity consumption, and in most categories display no difference in gas consumption. Differences in average consumption are verified statistically by calculating t-statistics using group averages of Normalized Annual Consumptions and their standard errors.

The current rate schedules published by each utility (Portland General Electric, Pacific Power, and NW Natural, 2007) were used to calculate participants energy costs. In general, there is no statistically significant difference in total energy costs between households that heat with electricity and natural gas. The electric rates for Portland General Electric are slightly higher than those of Pacific Power, so higher electric consumption may not always equate to higher average electricity costs depending on the proportion households in each utility territory per consumption group.

There is a significant difference in the electric consumption of households with gas heat. Action taking households with gas space heat use 10% less electricity than participant households. No difference is found in the gas consumption of households with gas heat. These results suggest that action taking households with gas heat use electricity more efficiently than their participant counterparts. The gas consumption is nearly identical, however because action taking households are known to be larger than participant households, action takers may be consuming gas more efficiently than participant households.

A majority of homes with electric or gas space heat use the same fuel for water heating, however a small proportion of homes use different fuels. Homes were grouped into four different categories to more precisely analyze differences in their energy consumption. There is not a significant difference in the electric normalized annual consumption of households with electric space and electric water heat. The sample size of homes with electric heat and gas water heat is so small that it cannot be reported with accuracy.

Similar to the less stratified group of homes with gas heat, action taking homes with gas space and water heat have significantly lower electric consumption than participant homes. Action taking homes with gas space and water heat use 8% less electricity than participant homes, and the difference is statistically significant. There is not a significant difference in the gas consumption, or total energy costs for this group.

The only group of homes that overturns what is found in the less stratified consumption groups, is homes with gas space and electric water heat. There is a significant difference in gas consumption between action taking and participant homes. Action taking homes with gas space and electric water heat use 13% less electricity and 10% less gas. Total energy costs of action taking homes are also significantly different than participants homes (electricity costs are only significantly different at the 90% confidence level). Stratifying the consumption groups into more precise space and water heating groups, verifies and contributes additional information to the two more general consumption groups.

The consumption analysis shows that lower average annual energy consumption by action takers, suggests that implemented energy saving measures, and or their household's energy efficient behavior is resulting in lower total energy consumption. The magnitude of the difference is larger in energy and cost units as well as in statistical significance for households that heat with gas. Homes with electric space heat display no difference in energy consumption between action takers and participants. This initial analysis allows us to conclude with confidence that action takers with gas heat consume less electricity and gas than participants. However, the analysis of consumption was not conducted at the individual household level. The econometric model is needed to test this hypothesis.

The energy intensity of a home is the energy consumed per unit of home size. For this analysis, energy intensity is total energy cost per square foot of house. The lower the energy intensity, the more efficient a household is at consuming energy. In general, there is not a substantial difference in energy intensity between action takers and participants. There is a slight difference in the means and distribution of energy intensity for houses with gas heat, however the difference is not statistically significant. Action takers with gas heat have an average energy intensity of 0.92 $/Sqft while participants with gas heat have an average of 0.99 $/Sqft. The distribution of energy intensity is more spread out in the tails for participants than for action takers. This means that participants are more likely to have an abnormally high energy intensity. In fact, no action taking household has an energy intensity over 1.80 $/Sqft, while there are 16 participant households with an energy intensity greater than 1.8 $/Sqft with the highest being 3.77 $/Sqft. Action taking households do not display abnormally high energy intensity.

The Model

We seek to identify the probability that households will implement energy saving measures to their home given the available explanatory characteristics. Each household has a discreet qualitative choice to make regarding energy efficiency investment. Households with certain characteristics may be more likely to implement energy saving measures. The simple analysis of household characteristics does not give any strong conclusions about which characteristics are unique to the action taking households. The econometric model that follows will test the attributes that are suspected to be significant, and in what magnitude those attributes are influential.

Predicting human choice is a difficult task. Human behavior is not easily captured in or subject to the quantitative form. Decisions are typically made on a qualitative basis influenced by unobservable and exogenous factors. It is possible to represent these factors with suitable proxy variables. However, causation between the chosen variables and the dependent variable is often difficult to establish. However, this analysis does not require causation for the results to be useful. Having certain household characteristics does not in itself cause people to make energy savings investments. Having certain characteristics however, may increase the probability that households take action.

This model employs the probit method of estimation. The primary reason for choosing the probit model is the qualitative nature of our dependant variable, taking action or not taking action to implement energy efficiency in a home. For appliance purchases which the household will purchase regardless, the qualitative choice is between the standard model, or the energy efficient model. A model of this sort requires a binary or indicator (0 or 1) dependent variable, which is essentially a yes or no indicator. The most similar model on qualitative choice of residential appliances in the literature is a paper by Dubin and McFadden (Dubin, Mcfadden, 1974). In this model, the authors model the space and water heating portfolio choice of households. A binary dependant variable is created and estimated by the different capital and operating costs of the choices. Dubin and Mcfadden employ the discreet choice logit model to estimate the probabilities of space and water heating choice, which then enters their residential electricity demand model.

The efficiency of appliance holdings and heating choice are typically left out of residential energy demand models. Energy efficiency choice is assumed to be exogenous to the model. Dubin and Mcfadden show that including energy efficient choice can have significant explanatory power in a residential energy demand model. Energy efficiency choice may also be a proxy for unobservable energy saving consumption behavior. An authoritative review of econometric studies of energy demand behavior by Bohi and Zimmerman also alludes to the fact that all residential energy demand models assume that the appliance stock is given and perfectly elastic (Bohi & Zimmermann, p.112). Including appliance choice in an energy demand model makes it more dynamic.

The discreet choice model employs data from single family detached homes from HEA participants that provide a valid address that could be matched to Energy Trust, RETC, and billing history databases. Two different specifications of the model are presented here. A model making use of the energy consumption data is presented, and a model of household characteristics is presented. There are two reasons for doing this: 1) Energy consumption and their costs are correlated with many important household characteristics. 2) The sample of households in the housing characteristics model is much larger than the sample of households for which gas and electric consumption data is available.

The dependant variable (0 or 1) represents with a 1, a household that has implemented an energy efficiency measure. The independent variables are a combination of indicator and numerical variables. The model is estimated using maximum likelihood estimation. The parameters are then translated into their more understandable marginal effects. The probability of implementing an energy efficiency measure is calculated at each observation given the explanatory variables. A probability greater than .50 indicates that the household is likely to implement an energy saving measure. For our purposes, we would like to know if a household is more or less likely to implement an energy saving measure than the average household. The marginal effects are expressed in terms of a unit change in the explanatory variable, which changes the probability of implementing an energy efficiency measure by x from the sample average. The marginal effects are calculated at the means of explanatory variables as recommended by Greene (Greene, p. 668). A short discussion of this appears in the appendix.

The specification of the energy consumption model is: **Action = α + β1 (Total Energy Cost / Square Footage) + β2 Old House + β3 Pool + β4 Rent + ε**

The Variables are: Action = 1 or 0, 1 if took action to implement energy efficiency measures, 0 otherwise;**Total Energy Cost =** Annual household energy cost for electric and gas consumption. This is the Normalized Annual Consumption multiplied by the marginal cost of fuel for each fuel source summed together (refer to appendix for explanation); **Square Footage =** The square footage of house; **Old House =** 1 or 0, 1 if older than 40 years, 0 otherwise; **Pool =** 1 or 0, 1 if household owns pool, 0 otherwise; **Rent** = 1 or 0, 1 if inhabitant rents house, 0 if inhabitant owns house

The total energy cost represents both the energy consumption of the household, and the economic cost to the household of consuming the energy. The energy cost is divided by square footage to control for the influence of house size in the model. The variable now represents the relative energy intensity per square foot of home. Our consumption analysis would suggest that as energy cost per square feet increases, the probability of implementing an energy efficiency measure should decrease.

Owning a home is thought to greatly increase the payback of implementing an energy efficiency measure, therefore increasing the probability of taking action. Renters are not likely to make permanent energy efficiency improvements to their homes, as they have no incentive to do so. Renters can and do buy energy efficient appliances that they can take with them when they move to a different home. Renters can also take advantage of a home energy review that informs households of immediate and temporary energy saving measures. The rent variable is a dummy variable signifying that the household rents. There are a significant number of renters who implemented energy saving measures, and we want to include this in the model.

The HEA does not gather household income from the participants. There are a number of suitable proxy variables that are likely to be correlated with household income. Economic theory would suggest that households with a higher income have the upfront capital needed to invest in energy saving measures. Model one tests this hypothesis. Square footage is likely to be correlated with household income. Larger homes should be positively correlated with a higher household income. Owning a pool is very likely to be correlated with a higher household income. The consumption model employs a dummy variable that identifies households with a pool to investigate an income effect in the model.

Old homes are more likely to benefit from energy saving measures than new homes. Many old homes were not built with wall, floor, or attic insulation. Old homes are likely to have older windows with substantial heat loss, and more likely to have developed air leaks over time. The consumption model employs a dummy variable for houses that are older than 40 years old. Homes older than 40 years are chosen because the HEA asks participants about the age of their home, and this was the oldest category that could be chosen.

The marginal effects of the explanatory variables appear in Table 1. The average probability of any household in the model being an action taking household is 32%. The ratio of total energy cost to square footage is an index of energy intensity per home. If energy intensity increases by one dollar per square foot, the probability of taking action decreases by 12%. If the home is older than 40 years, the probability that the household is an action taker increases by 4%. If the household owns a pool, the probability of taking action decreases by 10%. It must be noted that the old home and pool variables are not significant in the model. These variables appear due to their theoretical significance. If the people living in the house are renters, the probability of taking action decreases by 28%. As expected, this means that renting decreases the probability of taking action to only 3%.

Table 11 - Marginal Effects for Consumption Model
Average Probability of Taking Action = 32%

Variable	Change in probability of taking action	T – Ratio (>2 = significant)
Energy Cost / Sqft	- 12%	-2.94
Pool	-10%	-1.21
Old House	4%	1.17
Rent	- 28%	-2.58

The results of this model verifies our hypothesis that action takers consume less total energy per year and have lower energy costs during the time of action, relative to house size than participant homes. In this sample of homes, decreasing the dollars spent on energy per square foot increases the likelihood that the home is an action taking household. Action taking households may use energy more efficiently because they have implemented energy saving measures that lower their annual consumption, or they practice unobservable energy efficient behavior.

Housing characteristics and appliances are the main determinants of energy consumption. The HEA has provided us with many variables which are significant drivers of energy use, and have significant explanatory power in determining which households are likely to be action takers. Many variables are correlated with each other, so the final specification of the model employs variables that are the most statistically significant, and most important theoretically.

The house characteristics model specification is: **Action = α + β1 log(Square Footage) + β2 AC's + β3 Second Fridge + β4 Gas Heat + β5 Rent + ε**

The Variables Are: Square Footage = Square footage of the house; **AC's =** The number of room air conditioners in the household; **Second Fridge =** 1 or 0, I if has a second fridge, 0 otherwise**; Gas Heat** = 1 or 0, 1 if gas heat, 0 if otherwise; **Rent** = 1 or 0, 1 if inhabitant rents house, 0 if inhabitant owns house

These household characteristics are shown to be correlated with households taking or not taking action to implement energy saving measures in their home. Action takers have a larger average house size in square feet than participants. The square footage variable will verify or overturn this hypothesis.

Owning a second fridge is a proxy for energy using behavior. Households that are energy conscious may be less likely to have a second fridge. Households with two fridges are also likely to have increased holdings of other common appliances. Having a second fridge is highly correlated with the quantity of light fixtures, number of inhabitants, and the number of showers per week, and the number of televisions.

The number of room air conditioners represents households that do not have central air conditioning, but use window mounted air conditioners. Most houses built at least ten years ago in Oregon do not have central air conditioning. Central air conditioning is not a significant variable for this reason. The number of room air conditioners represents a households desire for air conditioning. The basic analysis suggests that action takers are thought to have less of a desire for air conditioning. Similar to the second fridge variable, this variable also is a proxy for energy using behavior. Energy conscious households may not desire air conditioning, the model tests this hypothesis.

The basic analysis suggests that households with gas heat should be more likely to be action takers than households with electric or other heating fuels. The model will reveal if this hypothesis holds up at the individual household level. The house characteristics model includes a dummy variable that represents a house with gas space heating. The rent variable which was included in the consumption model, also appears in the house characteristics model. It adds significant explanatory power to the model, and is not correlated with other independent variables.

The probability of a house in the sample population of 5,840 taking action is 30%. The marginal effects are a change in the probability from the average probability. A 1% increase in square footage, increases the probability of taking action by 5%. The model verifies our hypothesis that action takers have larger homes. If a household adds a room air conditioner to its stock of appliances, the probability that it is an action taking household decreases by 3%. The model verifies our hypothesis that action takers are less likely to have air conditioning. Households that have two fridges are 4% less likely to be action takers. If a house is heated with natural gas, the probability that the household is an action taker increases by 10%. The model verifies our finding in the basic analysis that households with gas heat are more likely to be action takers. Finally, if a household is renting the home, the probability that it is an action taker decreases by 20%. A household that rents only has a 10% probability that it has or will implement an energy saving measure in their home.

Table 12 - Marginal Effects for House Characteristics Model
Average Probability of Taking Action = 30%

Variable	Change in probability of taking action	T – Ratio (>2 = significant)
Square Feet	5%	2.63
Air Conditioners	- 3%	-2.34
Second Fridge	-4%	-2.01
Gas Heat	10%	7.57
Rent	-20%	-7.19

The House Characteristics model verifies findings from the basic analysis. The square footage, air conditioning, gas heat, and rent variables in the model all have the correct sign and agree with the preliminary findings. The second fridge variable was not found to be influential in the basic analysis, but is found to have explanatory power in the model. Qualitative choice regression modeling allows influential household and demographic characteristics to be identified at the household level, where influence at the aggregate level was not identified.

Conclusion

Qualitative choice modeling is a powerful tool to explain human behavior. This type of modeling, as with any other econometric modeling is not with out its weaknesses however. A good model is best used to supplement a more general statistical analysis of data, and refute or verify the hypotheses reached. The probit model verified hypotheses that were developed from a basic analysis of the households and their characteristics. The model also found one significant variable that was not found to be important in the basic analysis.

Some inferences can be made regarding the demographics and characteristics of action takers. Action takers are shown to have slightly larger homes than participants, but lower energy consumption for those with gas heat. Larger household energy consumption decreases the probability of taking action, as does owning a pool and having the amenities of air conditioning and a second fridge. This suggests that action takers may be middle income households that are energy conscious. These households are not conspicuous consumers, and appear to own less appliances than participants. Households that do not take action appear to have significantly more consumption as a result of increased appliance holdings, that are more likely to be standard efficiency models.

The fact that households with higher levels of consumption and increased appliance holdings are less likely to implement energy saving measures disagrees with economic theory. Unobservable forces are at work. Further analysis is required to determine to what extent environmental benefits and long term societal benefits cause households to act. Environmental concern is entirely absent from this analysis, but is arguably the most important unobservable factor.

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Appendix

Table 2
House Characteristics - Single Family Detached

Characteristic	Action Takers	Participants
House Size	1,938 sqft s.e.- 19.5	1,840 sqft s.e. - 10.7
House Age Over 40 Years	40%	41%
House Levels (Avg.)	1.56	1.50
Number of People (Avg.)	2.82	2.82
Have Attic	79%	78%
Have Basement	89%	89%
Have Pool	8%	8%
Own House	97%	90%
Cook Top Fuel	74% Electric 25% Gas 1% Other	81% Electric 17% Gas 2% Other
Double Paned Windows	None - 12% A few - 8%	None - 14% A few - 7%

	Many - 55% All - 26%	Many - 54% All - 25%
Storm Windows	None - 31% A few - 55% Many - 3% All - 11%	None - 29% A few - 55% Many - 5% All - 11%
Attic Insulation Levels	Poor - 4% Good - 27% Excellent- 67%	None - 5% Good - 28% Excellent- 65%
Wall Insulation Levels	None - 18% Some - 51% A lot - 15% 13.5 - 11% 16.5 - 5%	None - 18% Some - 51% A lot - 16% 13.5 - 11% 16.5 - 4%

Table 3
Electric and Gas Consumption – Electric Heat

	Action Takers	Participants	% Difference and T- Stat
NAC Electricity	19,583 kWh N= 90	19,061 kWh N = 365	3% t = 0.61
NAC Gas	N/A	N/A	N/A

Table 4
Electric and Gas Consumption Costs – Electric Heat

	Action Takers	Participants	% Difference and T - Stat
Annual Electricity Cost	$1,665	$1,620	3% t = 1.03
Annual Gas Cost	N/A	N/A	N/A

Table 5
Electric and Gas Consumption – Gas Heat

	Action Takers	Participants	% Difference and T - Stat
NAC Electricity	8,722 kWh N= 272	9,602 kWh N = 628	10% t = 3.49
NAC Gas	695 Therms N= 570	693 Therms N = 978	0.2% t = 0.15

Table 6
Electric and Gas Costs – Gas Heat

	Action Takers	Participants	% Difference and T - Stat
Annual Electricity Cost	$748	$778	4% t = 1.36
Annual Gas Cost	$980	$978	0.2% t = 0.11
Avg. Total Energy Cost	$1,728	$1,756	

Table 7
Electric and Gas Consumption – Gas Space and Gas Water Heat

	Action Takers	Participants	% Difference and T - Stat
NAC Electricity	8,158 kWh N= 205	8,806 kWh N = 460	8% t = 2.42
NAC Gas	745Therms N= 436	726 Therms N=754	3 t = 1.27

Table 8
Electric and Gas Costs – Gas Space and Gas Water Heat

	Action Takers	Participants	% Difference and T - Stat
Annual Electricity Cost	$ 710	$717	1% t = 0.29
Annual Gas Cost	$1050	$1023	3% t = 1.29

Avg. Total Energy Cost	$1,760	$1,740	

Table 9
Electric and Gas Consumption – Gas Space and Electric Water Heat

	Action Takers	Participants	% Difference and T - Stat
NAC Electricity	kWh 10,447 N= 67	kWh 11,780 N = 168	13% t = 2.36
NAC Gas	533 Therms N = 134	585 Therms N=224	10% t = 2.6

Table 10
Electric and Gas Costs – Gas Space and Electric Water Heat

	Action Takers	Participants	% Difference and T - Stat
Annual Electricity Cost	$865	$946	10% t = 1.65
Annual Gas Cost	$ 751	$ 825	10% t = 2.55
Avg. Total Energy Cost	$1,616	$1,771	

Normalized Annual Consumption

The consumption for each household was calculated by taking monthly meter reads from October 2005 – September 2006 for households that had a full one years worth of data available. One year was considered to be 360 – 370 days, since meter reads are not always on the same length. To normalize the consumption to account for this, the kWh and therm consumption was summed for the 12 months and then divided by 365 to get an average daily consumption rate. This was then multiplied by 365 to get the normalized annual consumption (NAC).

Energy Cost Calculations

The cost estimates employed the marginal cost of electricity and gas as published on each utilities regulatory affairs portion of their websites. The NAC for each participant with billing data was multiplied by their respective marginal rates. The marginal rates used are:
Portland General Electric - $0.0961 / kWh
Pacific Power - $0.0755 / kWh
NW Natural Gas - $1.41 / Therm

Dummy Variables in Probit Model

Dummy variables have a slightly different interpretation in their marginal effects, because it may not be proper to examine the marginal effect at the mean of a dummy variable. The dummy variable equivalent of an average is the mode of the variable in the sample. This would be the typical case, or an average case in the sample of observations. However, Green counters this hypothesis by stating that, "Simply taking the derivative with respect to the binary variable as if it were continuous provides an approximation that is often surprisingly accurate" (Green, p. 668). The distribution of ones and zeros in the samples presented are heavily skewed distributions, so taking the average of the binary variable will not vastly differ in its marginal effect from using the mode of the binary variable. Both of the models presented here employ the marginal effect of a dummy variable at the modes, however, the difference is within one percent of calculating the dummy variables at the mean.