# Urban Predictors of Household Participation in Energy-Saving Incentive Programs

By Rana Haverson and Cathy Ding

**Abstract**

As concerns over climate change intensify, efforts to improve residential energy efficiency have become a key focus of investment and research. While advancements in renewable energy technologies (such as solar panels and wind turbines) have reduced costs and increased accessibility, many households remain hesitant to adopt energy-saving upgrades. Local governments and energy providers often run free or reduced-cost incentive programs, hoping to increase homeowner engagement with energy-saving appliances. This study examines the factors influencing household participation in energy incentive programs across several U.S. metropolitan areas. Using survey responses (N=196) from residential communities in Ohio, New York, Pennsylvania, Maryland, Virginia, and the District of Columbia, we analyzed predictors of engagement, including property value, heating system type, and perceived barriers, such as time constraints and lack of contractor knowledge. Our Poisson regression analysis identified five significant predictors of participation, offering insights into the socioeconomic and logistical challenges that shape residential energy decisions. These findings highlight the need for targeted outreach and policy interventions to improve program accessibility and equity in energy-saving initiatives.

## Introduction

Renewable energy is being integrated into power grids and has the potential to match the efficiency, reliability, and convenience of fossil fuels. As technological efforts progress, however, the behaviors of energy consumers remain overlooked. The United States has 4% of the world population, yet accounts for 16% of the world's energy consumption. Compared to its Western counterparts, the United States consumes roughly double the amount of energy. The transition to renewable energy is critical to fighting climate change, but the success of this shift depends on homeowners' willingness to adopt new technologies. In recent years, clean energy sources and energy-saving appliances have become more affordable and efficient, yet many American homeowners continue to rely on nonrenewable energy sources and outdated appliances.

Additionally, discussions around improving energy efficiency have been dominated by a handful of industry professionals and academics. Despite growing policy and industry efforts to promote energy conservation, consumer behavior remains a major barrier to sustainability. In this paper, we attempt to shed light on the opinions of everyday suburban Americans on sustainable energy and energy efficiency, using collected data to determine predictors of participation in incentive programs and energy use habits.

This review assesses differences in residential energy use habits, participation in energy incentive programs, and attitudes toward energy efficiency programs across Ohio, Pennsylvania, New York, Maryland, Virginia, and the District of Columbia. It describes the statistical tests, applications, and methodology used in sampling and statistical analysis.

We address factors influencing participation, with graphs showing the correlation of home value, heating system, and cited barriers to previous household participation in energy-saving programs. Furthermore, this paper attempts to compare the results of our analysis with prior literature and propose solutions aimed at increasing future incentive participation.

**Literature Review**

American attitudes towards energy efficiency and renewables have been researched extensively. Many studies have named factors we found to be highly correlated with the adoption or lack thereof of energy-saving appliances, such as upfront cost, income, government incentives, and awareness. A study in Science Direct found that income and education levels positively correlate with energy efficiency upgrades (Meyers, 2015). Their research shows that costs are a significant barrier for middle-class families for new energy decisions. Major U.S. metropolitan cities are more willing to adopt new energy and prioritize sustainability (Sovacool, 2009).

However, the majority of these studies were done over 5 years ago. In recent years, technology has developed rapidly; current studies should attempt to capture the effects of new policies and technological advances. This survey tries to represent current attitudes of the average American household toward energy efficiency and green energy. To account for this, surveys were conducted in the suburbs of D.C., New York City, Richmond, and Cincinnati to reflect the US population spread and targeted middle to upper-middle class families in these areas. All data was collected from September 2024 to January 2025.

**Methodology**

A survey written by Linkmind Foundation sought to identify regional trends in public awareness and participation in local energy-saving programs. Data was collected using a combination of canvassing and convenience sampling. Our team solicited responses in areas including public libraries, aquatic centers, residential neighborhoods, and personal networks. Over 220 individual responses were recorded, representing households from six states and territories.

The survey included open-ended and multiple-choice questions that consisted of demographic information, contact information, home characteristics, past participation, and current attitudes toward local energy incentive programs.

Survey responses were recorded via Google Forms or on paper documents, which were later consolidated into a spreadsheet. This procedure was uniform across the greater Cincinnati, Richmond, New York City, and District of Columbia metropolitan areas. Data was then transferred into Excel for analysis. The survey consisted of twelve categorical questions (e.g., "What's keeping you from making energy-saving improvements in your home?", "What type of residence do you live in?") and two optional demographic questions: name and email. All categorical questions allowed respondents to reply “Other” and input a unique answer. The following data-cleaning modifications were applied to help facilitate analysis:

- All responses with missing or invalid geographical data (zip codes) were removed.
- Geographical information was transformed from unordered categorical data to ordinal data by substituting average property values within a given zip code for the zip code.
- Property Age was translated from categorical to ordinal data by mapping the categories 30+ years, 16-30 years, 15-5 years, and less than 5 years to the midpoint of each category (31, 23, 10, and 2 years, respectively).
- Home Type was encoded into binary values: single-family (1) and non-single-family (0)
- Responses for “Who is responsible for paying the electricity bill at your residence?” were encoded into binary values, respondent (1) and other (0).
- The Cooling System was encoded into binary values: central/heat pump (1) and other (0).
- Responses for the Heating System field were grouped into Electric, Heat pump, Oil/gas, and don’t know/other, then one-hot encoded.
- In the Home Type and Interest Count fields, 39 cells of missing data (NY) were replaced with randomly generated data following the distribution of filled data.
- The Received incentive category was converted from qualitative lists of items into the number of received items or programs listed.
- The Interest category was converted from qualitative lists into the number of incentives the respondent indicated interest in.
- Similar responses in the Preventing field were grouped together. Unique values were then one-hot encoded.

After these modifications, we were left with a modified spreadsheet containing 196 total responses- 39 of which were from NY, 62 from OH, 54 from VA, 1 from MD, 1 from PA, and 39 from DC. A Poisson regression with 21 predictor variables was conducted in R to analyze key factors influencing participation in energy incentive programs.

**Limitations**

The convenience sampling our survey relied upon may lead to selection bias, as individuals engaged in community spaces (e.g., libraries, aquatic centers) or those within our team’s personal networks likely differ in awareness, demographic information, or participation levels when compared to the general population.

38 survey responses with missing values in the Home Type and Interest Count fields were imputed by randomly drawing values from the completed responses. This preserved the existing distribution without introducing bias, but may not capture the true attitudes of these respondents. The survey was based on self-reported information, which is subject to recall bias. Some respondents may have inaccurately remembered past participation in energy programs or provided responses they believed were more socially acceptable.

In completing some of the data transformations, information may have been lost, and inaccuracies may have been introduced. Converting zip codes to the average home prices within them could ignore within-region housing differences: certain low-home-value participants could have been interpreted as high-home-priced or vice versa.

Our study was based on responses received from approximately 200 individuals, which provides valuable insight but may not be large enough to fully represent attitudes toward and participation in energy incentive programs across surveyed regions. Increasing sample size would improve model accuracy and predictive power; adding respondents from other urban centers would remove possible geographical bias. Despite its limitations, this study provides valuable information about energy incentive participation. In the future, we would aim to collect data on a broader scale, ideally through randomized surveys or partnerships with local governments and energy providers to increase response counts and improve representativeness.

**Results**

Only 28.061% of respondents reported previous participation in energy incentive programs, while 75% reported interest in participating in the future. Among the most commonly cited barriers to participation were cost (43.367%), needing more information (40.306%), time constraints (17.347%), and not knowing qualified contractors (16.327%).

We found five significant predictors ($p < 0.05$) of participation in energy incentive programs, including average property value (Estimate = $3.06e^{-7}$, p = 0.0318), heat pump ownership (Estimate = $9.87e^{-1}$, p = 0.0001), oil or gas heating systems (Estimate = $9.27e^{-1}$, p = 0.0001), time constraints as a barrier (Estimate = $3.89e^{-1}$, p = 0.0036), and lack of knowledge about qualified contractors (Estimate = $5.81e^{-1}$, p = 0.0002).

| Variable | Estimate | Std. Error | Z Value | PR > \|Z\| |
|---|---|---|---|---|
| Property value | $3.057e^{-7}$ | $1.425e^{-7}$ | 2.146 | 0.032 |
| Heat pump | $9.871e^{-1}$ | $2.539e^{-1}$ | 3.888 | 0.000 |
| Oil/gas | $9.265e^{-1}$ | $2.418e^{-1}$ | 3.831 | 0.000 |
| Time | $3.890e^{-1}$ | $1.338e^{-1}$ | 2.908 | 0.004 |
| Contractors | $5.807e^{-1}$ | $1.570e^{-1}$ | 3.699 | 0.000 |

Fig 1. Coefficient table of significant predictors

Using the equation $\beta \times \Delta x = 3.057 \times 10^{-7} \times 100000$, we find that a $100,000 increase in property value is associated with an approximately 3.1% increase in expected rate of participation. Heating system and barrier-related factors displayed even stronger correlations.

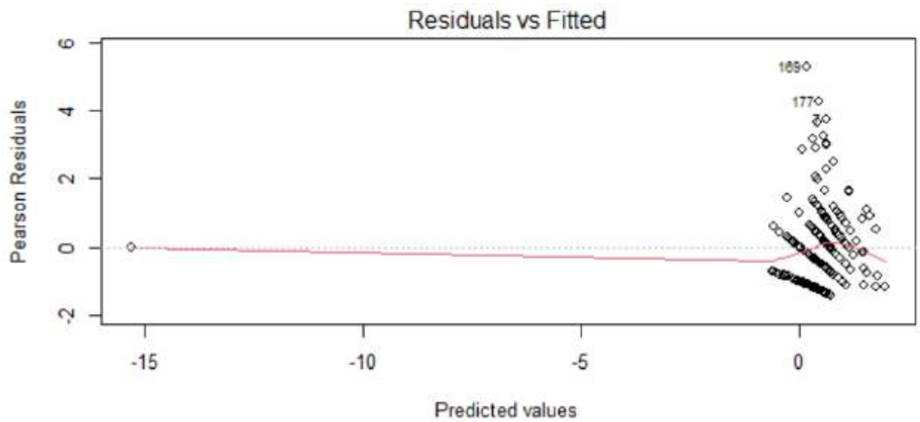


Fig 2. Residuals vs. Fitted

Residuals were randomly scattered around the horizontal line at y=0 and appeared relatively consistent across different fitted values, indicating that the assumptions of linearity and homoscedasticity were met. A few observations show higher residual values (around 4-6 on the y-axis), but these don't form a systematic pattern, allowing us to make the assumptions necessary for reliable statistical inference.

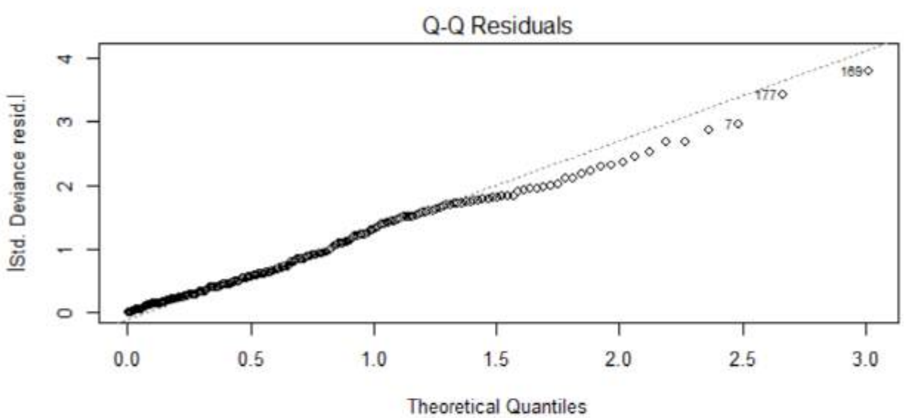


Fig 3. Q-Q Residuals

The Q-Q plot of residuals suggested the residuals were approximately normally distributed across most of the data range, with minor deviations only at the extremes. Central clustering of points along the theoretical line indicates good model fit for the bulk of observations. While the upper tail shows a few potential outliers, the overall pattern supports normality and model assumptions are reasonably well-met.

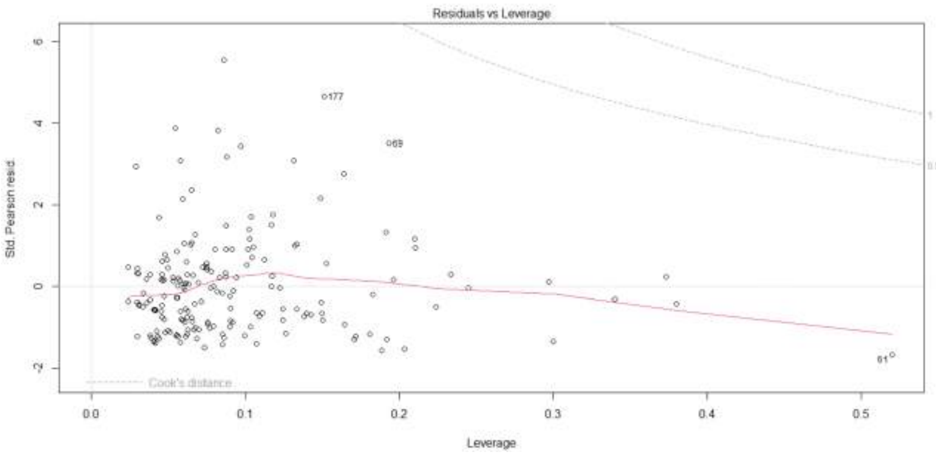


Fig 4. Residuals vs. Leverage

There were no data points with both high leverage and large residuals, as shown by the Residuals vs. Leverage plot. Most observations fall within the Cook's Distance contours, suggesting a lack of influential outliers. As the points are fairly evenly distributed, assumptions of linear regression are met. Overall, there is no evidence of points exerting undue influence on the model.

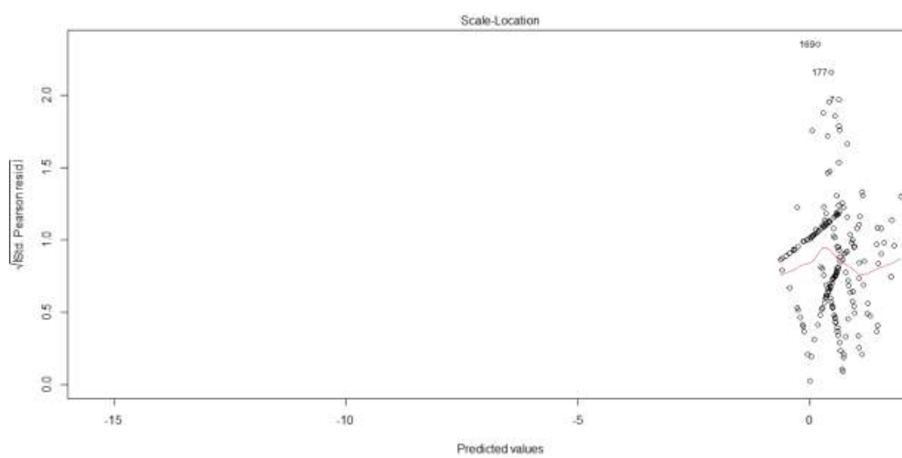


Fig 5. Scale-Location

The Scale-Location plot showed a relatively consistent spread, supporting the assumption of equal variance across predicted values.

The model's residual deviance was 258.89 and its null deviance was 362.92, yielding a pseudo-$R^2$ value of 0.288. A further analysis of deviance was conducted, finding the following significant predictors at $p < 0.05$:

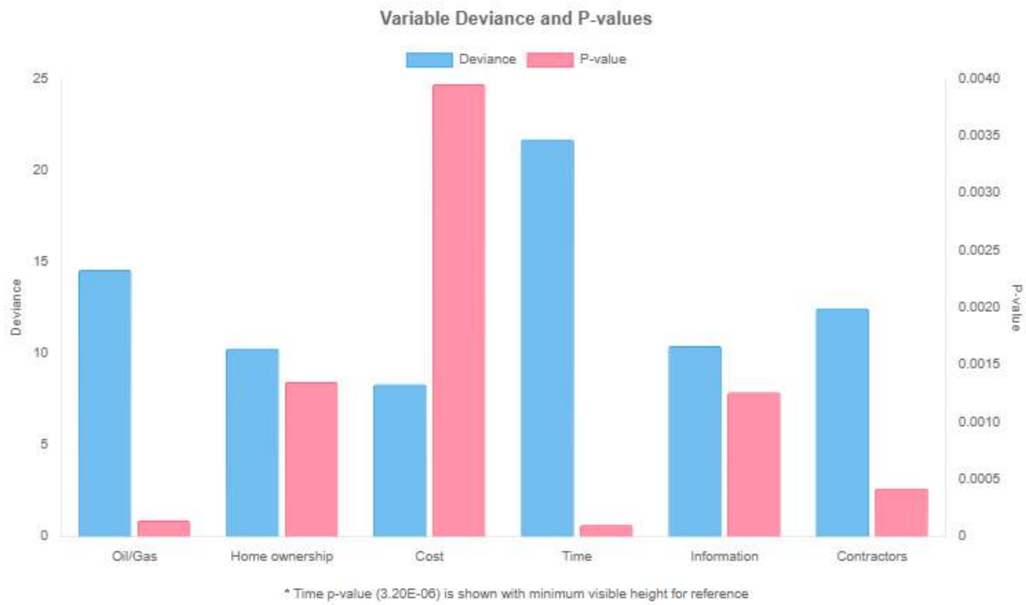


Fig 6. Analysis of deviance predictors

Figure 1 shows how each significant predictor affects expected interest count (via coefficient estimates), while Figure 6 displays significant predictors by how well they improve the model's fit (via deviance reduction and Chi-square p-values).

**Discussion**

We found that property value was positively associated with participation. This aligns with prior research, suggesting that higher-income households' increased access to resources and a greater likelihood of homeownership make them more likely to engage in energy-saving programs. This underscores the importance of addressing equity concerns: low-income households stand to benefit the most from energy-saving improvements, yet are also the most underrepresented due to financial barriers. Heat pump and oil/gas heating system ownership were both strong predictors of participation. This may suggest that homeowners with these systems are either more eligible for programs or more motivated to upgrade. Time constraints and lack of knowledge about qualified contractors' fields were also found to have a positive correlation with participation. While it seems counterintuitive, this could suggest that even past recipients of home energy assessments or smaller upgrades face significant logistical hurdles when navigating incentive programs. The diagnostic plots of the regression model support its reliability. The residuals vs. fitted values plot confirmed the assumption of linearity and consistent variance, and the Q-Q plot affirmed the near-normality of residuals. The scale-location and leverage plots did not suggest major violations of regression assumptions.

**Conclusion**

The regression analysis found five significant predictors of program participation, including average property value, heating system type, and common barriers such as time constraints and contractor access. These results suggest that material circumstances, along with informational obstacles, affect the likelihood of participation in energy incentives.

Our findings reflect the reality of energy program accessibility. While higher-income households and those with relevant systems (such as heat pumps) are more likely to participate, even those who do so face barriers that often discourage further involvement. Participation in energy incentive programs should be improved by addressing inequities in program access, increasing public outreach efforts, and supporting residents in navigating logistical challenges.

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