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House insulation: Perceived needs and willingness in Central Asia

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ADB Working Paper Series

HOUSE INSULATION: PERCEIVED NEEDS AND WILLINGNESS IN CENTRAL ASIA

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and Hans Holzacker

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Abstract

This research aims to assess Central Asian households' willingness to insulate their homes and the factors influencing this decision by utilizing Central Asia Regional Economic Cooperation (CAREC) Institute data from the "Household Access to Energy in The Fergana Valley" survey, which was conducted in 2023. This study addresses key research questions regarding household decision-making processes and the impact of energy-saving behavior. The empirical findings reveal key factors influencing household insulation decisions. Urban residence negatively affects insulation decisions, indicating that such decisions are more likely to be made in rural than in urban areas. Older household heads are less likely to undertake insulation measures, while construction materials and heating sources significantly influence insulation decisions. Additionally, the energy-saving behavior index positively influences insulation decisions, indicating the potential for promoting energy-saving practices to encourage broader adoption of insulation measures. Given these empirical findings, the policy recommendations include developing tailored interventions to promote insulation practices for vulnerable groups with greater needs and willingness to insulate. These groups include rural households, those with higher heating expenditures, those using solid or fossil fuels for heating, and low- to middle-income households.

Keywords: heating, building retrofit, environmental awareness, fossil fuel, climate change mitigation, Central Asia

JEL Classification: Q4, Q5, R2, R3

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1. INTRODUCTION

A considerable final energy consumption in the residential sector contributes to greenhouse gas (GHG) emissions, emphasizing the critical role of residential-sector decarbonization in achieving GHG emissions reduction targets (Fernandez-Luzuriaga et al. 2022). This underscores a significant opportunity to reduce GHG emissions through measures such as improving house insulation and upgrading outdated equipment (Kattenberg, Eichholtz, and Kok 2023; Fernandez-Luzuriaga et al. 2022). Scholarly literature has extensively established the significant impact of residential energy consumption reduction on decarbonization efforts (Galvin 2014; Grimes et al. 2016; (Kattenberg, Eichholtz, and Kok 2023; McAndrew et al. 2021). For instance, Adan and Fuerst (2016) identified cavity wall insulation as an effective energy efficiency measure, resulting in a 10.5% reduction in annual gas consumption and an 8.0% reduction in annual total energy consumption in the year following installation. Consequently, it is important to analyze the key determinants influencing house insulation decision-making.

Empirical literature suggests that the extent of insulation and retrofit of residential properties rely heavily on homeowner knowledge regarding energy retrofit (Bobrova, Papachristos, and Cooper 2022; Hrovatin and Zorić 2018; Nair, Gustavsson, and Mahapatra 2010), as well as a range of other factors including financial status, past retrofit and insulation activities, home location, building age and type, and electricity expenditures (Dolšak, Hrovatin, and Zorić 2020). Additionally, regional climate disparities and economic activity, measured by GDP per capita, are identified as drivers of energy-efficient retrofits (Dolšak, Hrovatin, and Zorić. 2020). Household head characteristics such as age, income, and education (Friege 2016; Joyram, Govindan, and Nunkoo 2022; Kaya et al. 2021) and household heating systems significantly shape renovation decisions, indicating the need for tailored energy efficiency policies (Fernandez-Luzuriaga et al. 2022). Case analyses reveal that factors contributing to energy-saving awareness among users have positive effects in improving insulation performance (Fujisawa and Goto 2022). Therefore, in the widespread promotion of energy efficiency in the residential sector, an analysis of the perceptions and motivations shaping household decisions regarding insulation is crucial for achieving effective energy policy design.

Central Asia's high energy consumption, reliance on dirty fuels, and old residential buildings represent a critical research focus (IRENA 2022). With a growing population and rising residential energy consumption, the Central Asian region presents an interesting case for investigating the energy efficiency in the residential sector. For instance, the Kyrgyz Republic stands out as one of the most energy-intensive countries globally, with energy consumption in the residential sector quadrupling between 2010 and 2019, and it exhibits low residential energy performance, with about half of the residential building stock in the Kyrgyz Republic having been constructed before 1980 (IRENA 2022). While the Central Asian region is currently undergoing significant energy transitions, with a major focus on the electricity generation and distribution systems (CAREC Institute 2023), it has become imperative to analyze the residential sector for its decarbonization efforts.

This study aims to assess the willingness of Central Asian households to insulate their homes and the factors influencing this decision-making process. Additionally, it explores how energy-saving behavior can impact household decisions regarding the insulation of various components of the house. The study utilizes CAREC Institute data from the "Household Access to Energy in The Fergana Valley" household survey,

which was conducted in 2023. This research tries to answer the following research questions:

1. What factors influence household decision-making processes regarding home insulation?
2. How does energy-saving behavior impact household decisions to insulate various components of their homes?

To the best of our knowledge, this is the first study to conduct a comprehensive and comparative analysis of the house insulation intention of households in Central Asia, particularly in the Fergana Valley, which spans parts of Uzbekistan, the Kyrgyz Republic, and Tajikistan. Secondly, no previous research has quantified the effect of household energy-saving behavior on household decisions to insulate items in the home. Thirdly, this analysis examines the types of house insulation items, such as walls, roofs, windows, and doors, providing valuable insights for policy recommendations.

The rest of this paper is organized as follows. Section 2 presents the methodology used and data, Section 3 provides empirical results, and Section 4 concludes and provides policy recommendations.

2. METHODOLOGY

2.1 Data

This study utilizes data from the “Household Access to Energy in The Fergana Valley” household survey. This survey was conducted by the Central Asia Regional Economic Cooperation (CAREC) Institute in partnership with the Asian Development Bank Institute (ADBI) and the Public Opinion Research Institute. A total of 1,522 respondents were interviewed during July and August 2023, including 522 from the Kyrgyz Republic, 500 from Tajikistan, and 500 from Uzbekistan (Azhgaliyeva, Kodama, and Holzhacker 2023). The survey aims to generate detailed data about energy access in Uzbekistan, the Kyrgyz Republic, and Tajikistan, and information regarding the issues households face when they need energy for various purposes, like heating and cooking. The household survey collects data on the sociodemographic characteristics of the household head and detailed information on residential energy characteristics. In particular, the “Household Access to Energy in The Fergana Valley” survey (CAREC Institute 2023) comprises detailed information on the household heating system and its features, as well as the energy-saving behavior of the household and information sources regarding the awareness of renewables. Following initial control measures, the final dataset for analysis comprised 1,465 household observations, including 465 from the Kyrgyz Republic, and 500 each from Tajikistan and Uzbekistan.

2.2 Model Specification

To analyze the impact of household energy-saving behavior on the intention to insulate homes, we employed a probit model. This model is based on random utility theory, which states that household i will have the probability of a positive outcome, in our case the intention to insulate, if it maximizes its utility determined by a set of regressors (Hrovatin and Zorić 2018). The utility function of a household with regard to the intention to insulate can be expressed as:

$$U_i = X_i\beta + \varepsilon_i, \quad (1)$$

where U_i represents the utility of the i th household towards the intention to insulate. X_i is a vector of explanatory variables, β is a column vector of coefficients, and ε_i is the independently and identically distributed error term. The probability that household i intends to insulate their home can be modeled as:

$$P(y_i = 1|X_i) = \Phi(X_i\beta), \quad (2)$$

where Φ is the cumulative distribution function of the standard normal distribution. The parameters of the probit model are estimated using maximum likelihood estimation. The log-likelihood function for the probit model is as follows (Cameron and Trivedi 2022):

$$\ln L = \sum_{i=1}^N [y_i \ln \Phi(X_i\beta) + (1 - y_i) \ln (1 - \Phi(X_i\beta))]. \quad (3)$$

To interpret the results of the probit model, the marginal effects of the explanatory variables on the probability of the intention to insulate are calculated. Marginal effects present change in the probability of a positive outcome, in our case the intention to insulate, given a one-unit change in an explanatory variable, holding all other variables constant (Hrovatin and Zorić 2018), and are calculated as follows:

$$\frac{\partial P(y_i = 1|X_i)}{\partial X_i} = \phi(X_i\beta). \quad (4)$$

2.3 The Outcome Variable – Intention to Insulate

The outcome variable, y_i , represents the household head's intention to insulate items within the house. The construction of this variable is based on responses to questions in "Household Access to Energy in The Fergana Valley" household survey: "*In your opinion, is there a need to isolate (seal, patch, insulate) any of the following (a window, door, wall, or roof) in your household from heat/cold loss?*" and "*Do you plan to isolate (seal, patch, insulate) all the items you have chosen?*" Consequently, the household head's intention to insulate is determined by positive responses to both questions and coded as follows:

$$y_i = \begin{cases} 1, & \text{intention to insulate,} \\ 0, & \text{otherwise.} \end{cases}$$

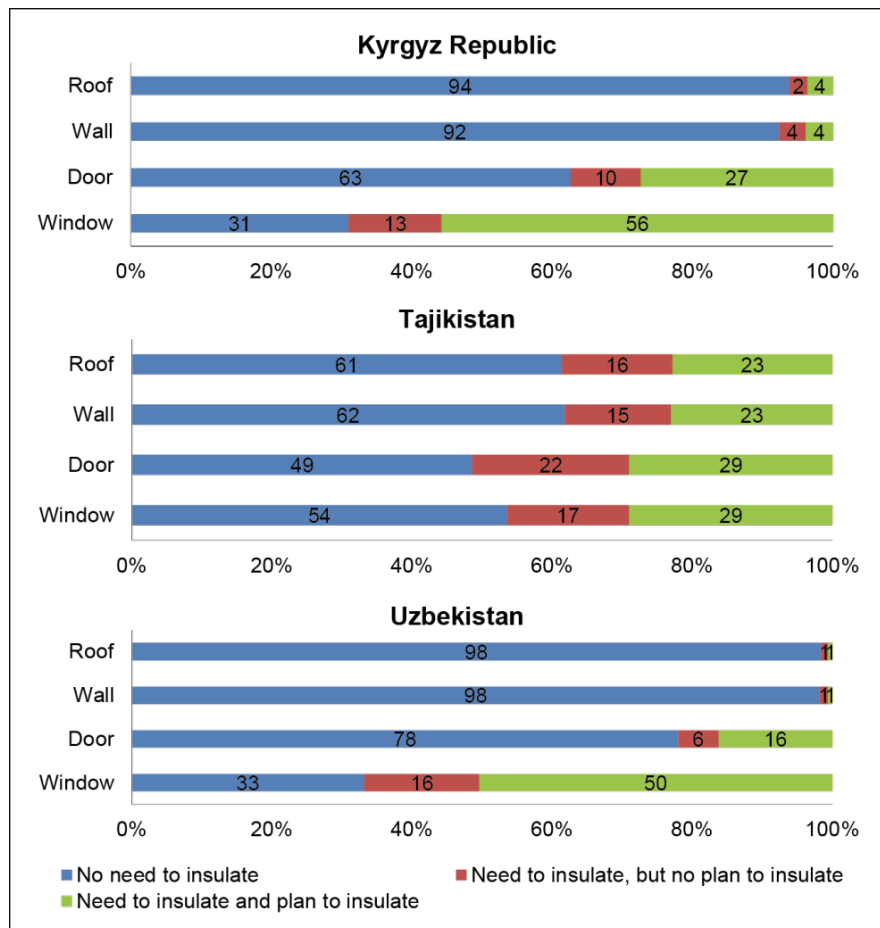
Specifically, "1" denotes the household head's acknowledgment of the necessity for insulation and explicit intention to undertake insulation of house items (the household head perceives a need for insulation and plans to insulate); "0" indicates that the household head does not perceive a need for insulation or does not plan to insulate. The intention to insulate encompasses various components, such as windows, doors, roofs, and walls. The objective of this study is to determine the factors motivating households to undertake insulation measures for these components. To address this, we estimate a probit model to analyze the household head's intention to insulate specifically in relation to windows, doors, roofs, or walls individually.

Table 1: Descriptive Statistics of Outcome Variables

	<i>N</i>	Mean	Std. Dv.	Min	Max	Description
<i>Intention to insulate (any item)</i>	1,465	0.488	0.500	0	1	1 = if the household perceives a need and plans to insulate a window, door, wall, or roof ; 0 = otherwise.
• Window	1,465	0.454	0.498	0	1	1 = if the household perceives a need and plans to insulate a window in the household from heat/cold loss.
• Door	1,465	0.243	0.429	0	1	1 = if the household perceives a need and plans to isolate a door in the household from heat/cold loss.
• Wall	1,465	0.094	0.292	0	1	1 = if the household perceives a need and plans to insulate a wall in the household from heat/cold loss.
• Roof	1,465	0.093	0.290	0	1	1 = if the household perceives a need and plans to insulate a roof in the household from heat/cold loss.

Sources: Authors' calculations, "Household Access to Energy in The Fergana Valley" data, CAREC Institute 2023.

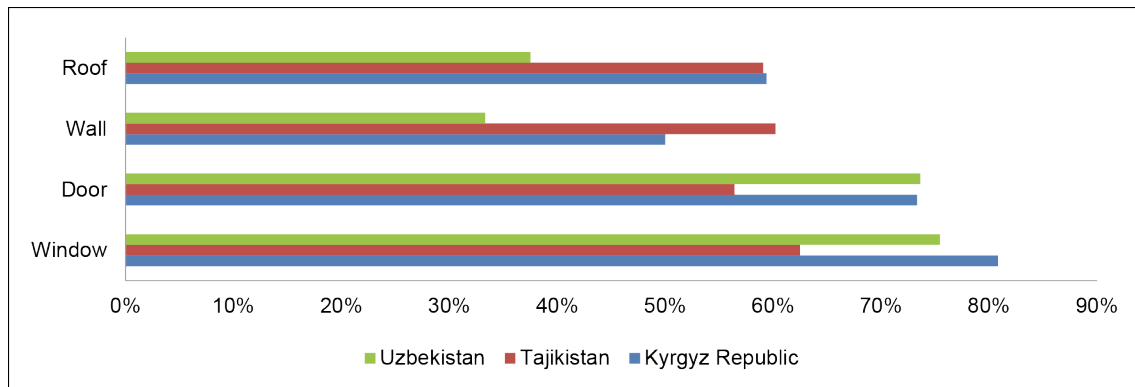
According to the descriptive statistics, almost half of the households are willing to undertake insulation of their homes. While the specific insulation items differ, most households (45%) are willing to insulate windows, 24% are willing to insulate doors, and only about 9% are willing to insulate the walls or roofs of their homes (refer to Table 1).

Figure 1: Perceived Need to Insulate

Windows are seen as the biggest priority for insulation. The percentages of items seen by households as requiring insulation are as follows: windows 61%; doors 37%; walls 16%; and roofs 15%.

Most household heads, out of those who see the need for insulation, plan to insulate doors and windows, rather than walls and roof.

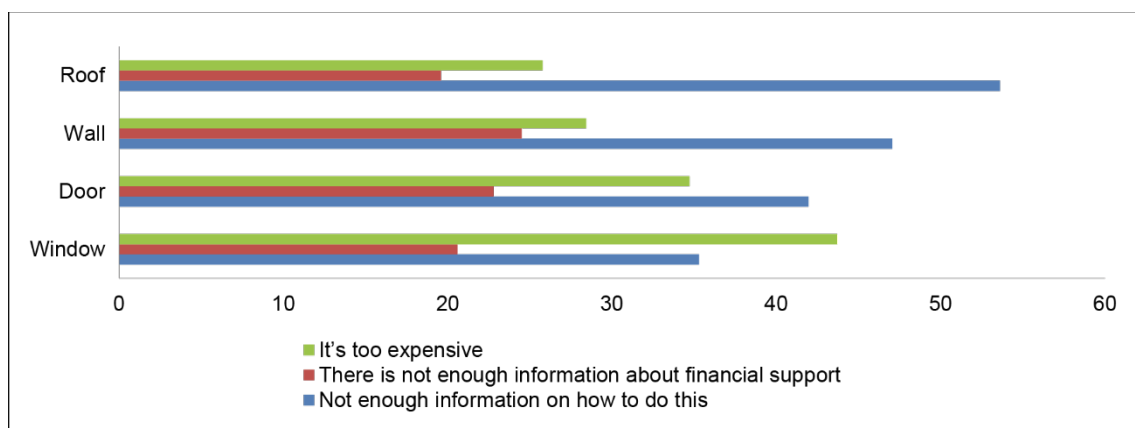
Figure 2: Plan to Insulate, % of Households Who See the Need



The main reasons why households do not plan any insulation, despite seeing the need, include: not enough information on how to do it (38%); it's too expensive (38%); and there is not enough information about what financial support is available (23%). The reasons vary across the areas of insulation needed (windows, doors, walls, and roof):

- “Not enough information on how to” insulate roof and walls
- “It’s too expensive” to insulate windows

Figure 3: If You Need but Do Not Plan Insulation, What Is the Main Reason?



2.4 Control Variables

The set of control variables, X_i , encompass various demographic and socioeconomic factors of the household and are divided into three groups.

Building Characteristics

The first group of explanatory variables pertains to the building characteristics of the household. The literature shows that the use of nonfossil fuel and newer and more expensive dwellings increases the probability of insulation (Meeks 1990). This is most likely due to the better value of investing in improvements of such dwellings. The binary variable “*residence*” indicates whether the household resides in an urban or rural area. The variable “*house age*” is measured in years, representing the duration the household has resided in the current dwelling. The variable “*living area*” is the approximate area of all living or heated premises of the house measured in square meters. Additionally, dummy variables are included to represent the materials that are mainly used to build the house, such as bricks, mudbricks, reed slabs, wood, concrete, and monolith. The variable “*sources of heating*” captures the sources of heating used by the household in the winter season, including electricity, gas, or alternative sources such as coal, oil, or firewood, etc. (in the estimation, electricity serves as the reference group for comparison purposes).

Household Characteristics

The second group of explanatory variables includes household socioeconomic and demographic characteristics, such as the age and gender of the household head, as well as their level of education. Household socioeconomic and demographic characteristics play a major role in insulation choice (De Cian et al. 2019). The literature shows that the groups of households that are more likely to insulate include higher-income households (Smiley 1979), younger households (Smiley 1979; Meeks 1990), those with no small children, and smaller families (Meeks 1990), which might point at the issue of credit constraints, having a male household head, and having an older household head (De Cian et al. 2019).

Household composition is represented by three variables: household size and the share of dependents, and both younger and elderly household members. Additionally, two variables are used to control for household economic condition: the average monthly heating expenditure during winter, covering all types of heating used by the household, and categorical income level (in the estimation, the highest income level serves as the reference group for comparison). The education level variable is treated as a continuous variable ranging from 1 (lowest education level) to 4 (highest education level).

Energy-Saving Behavior and Information Source

The third group of explanatory variables captures the household energy-saving behavior and the sources of information regarding renewable energy. The energy-saving behavior index summarizes the energy-saving behaviors of a household (De Cian et al. 2019). The higher the score is, the more frequently the household implements energy-saving behaviors such as switching off the lights or appliances when not in use. The increasing energy-saving behavior index increases the probability of insulation (De Cian et al. 2019).

Table 2: Descriptive Statistics of Energy-Saving Behavior Index

	Total Sample					Kyrgyz Rep.		Tajikistan		Uzbekistan	
	<i>N</i>	<i>Mean</i>	<i>Std. Dev.</i>	<i>Min</i>	<i>Max</i>	<i>N</i>	<i>Mean</i>	<i>N</i>	<i>Mean</i>	<i>N</i>	<i>Mean</i>
Energy-Saving Behavior Index	1,465	5.726	1.493	0	9	465	5.746	500	5.466	500	5.966
• 1 = household members try to save energy	1,465	0.904	0.295	0	1	465	0.953	500	0.776	500	0.986
• 1 = household perceives the use of fossil energy as harmful to the environment and health	1,465	0.749	0.434	0	1	465	0.800	500	0.800	500	0.650
• 1 = household has energy-saving light bulbs	1,465	0.875	0.331	0	1	465	0.828	500	0.892	500	0.902
• 1 = household pays attention to the energy efficiency class of household appliances	1,465	0.777	0.417	0	1	465	0.641	500	0.874	500	0.806
• 1 = household head switches off appliances that are not in use	1,465	0.760	0.427	0	1	465	0.677	500	0.744	500	0.854
• 1 = household head turns off the lights if there are no people in the room	1,465	0.784	0.411	0	1	465	0.957	500	0.522	500	0.886
• 1 = household head uses fewer electrical appliances or watches less TV	1,465	0.550	0.498	0	1	465	0.576	500	0.552	500	0.524
• 1 = household head uses proper wiring and appliances	1,465	0.096	0.295	0	1	465	0.011	500	0.138	500	0.134
• 1 = household head uses energy-saving, energy-efficient appliances	1,465	0.230	0.421	0	1	465	0.303	500	0.168	500	0.224

Sources: Authors' calculations, "Household Access to Energy in The Fergana Valley" data, CAREC Institute 2023.

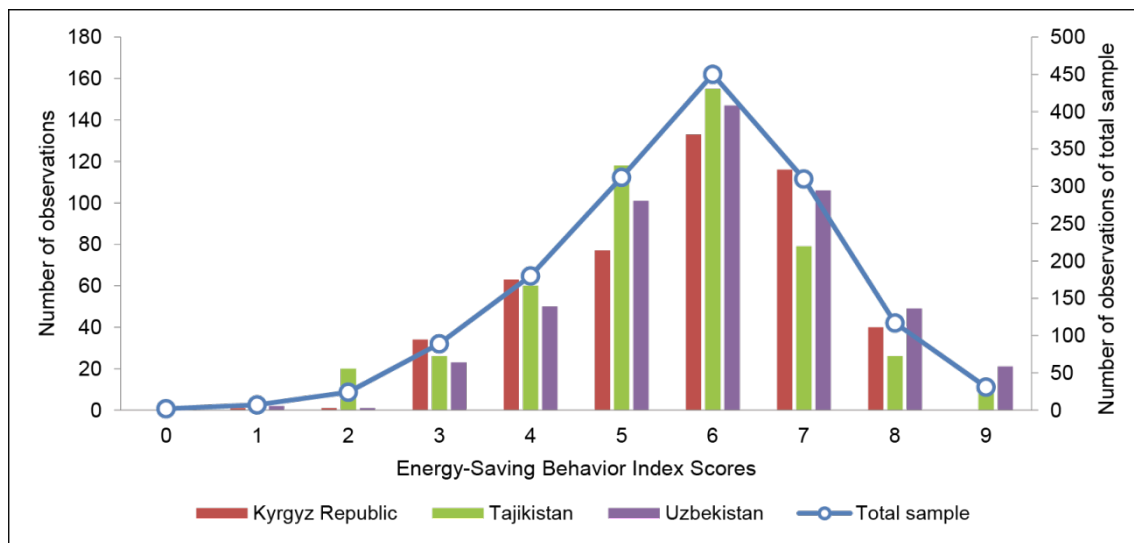
Following the literature, we have constructed the energy-saving behavior index by aggregating household positive responses to specific questions that assess energy-saving habits and environmental attitudes (Hrovatin and Zorić 2018; OECD 2014; Hori et al. 2013; Han and Cudjoe 2020). This index includes responses to questions about whether households try to save energy, consider the use of fossil fuels harmful to the environment and health, use energy-saving light bulbs, and pay attention to the energy efficiency class of household appliances (see Table 2). Additionally, it encompasses various energy-saving practices such as switching off unused appliances, turning off lights when not needed, using fewer electrical appliances or watching less TV, ensuring proper wiring and appliances, and using energy-efficient appliances (for detailed information about questions and coding of responses refer to Table A1 in the Annex). The index ranges from 0 to 9, depending on the number of positive energy-saving behaviors and environmental attitudes presented by the household.

According to the given descriptive statistics of the energy-saving behavior index in Table 1, the average score is 5.7 points, meaning that households in the Fergana Valley responded positively to nearly six out of nine questions regarding their energy-saving attitudes (see Figure 4).

Nearly 90% of households report that they try to save energy and use energy-saving bulbs, while about 70% of households perceive fossil energy as harmful, pay attention to energy efficiency, switch off appliances, and turn off lights when not in use; and 55% of households use fewer electrical appliances or watch less TV (see Table 2 and Figure 5). These proportions indicate a high willingness on the part of households to reduce energy consumption and save it. However, only 23% of households use energy-saving and energy-efficient appliances, and just 9% use proper wiring and appliances. This shows that the adoption of energy-efficient household items is notably

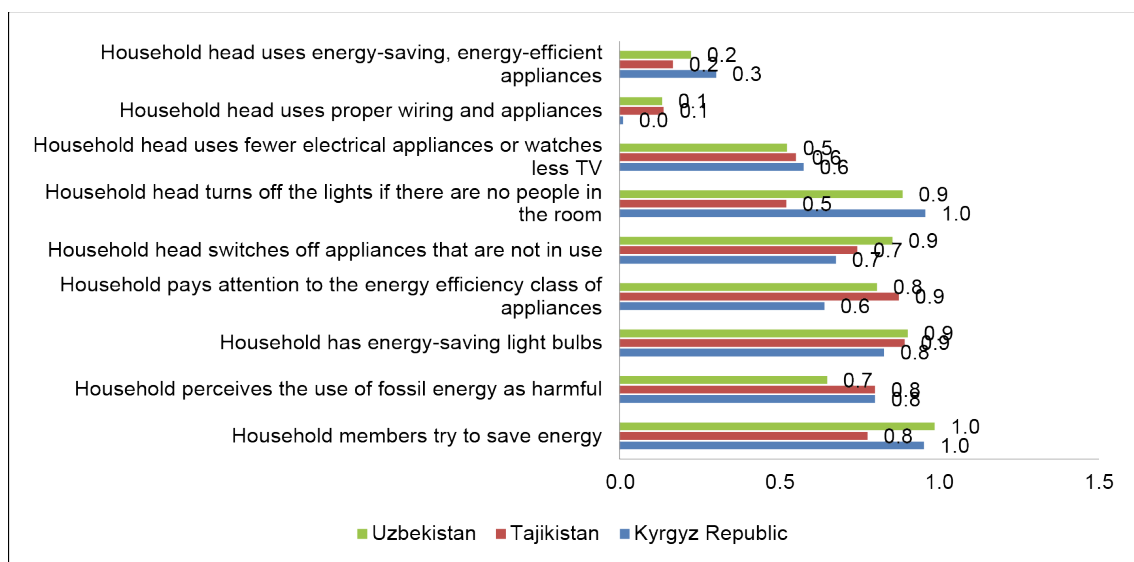
lower. Consequently, households in the Fergana Valley are more inclined to save energy through manual practices aimed at reducing energy consumption.

**Figure 4: Distribution of Energy-Saving Behavior Index Scores
(Number of Observations)**



Sources: Authors' calculations, "Household Access to Energy in The Fergana Valley" data, CAREC Institute 2023.

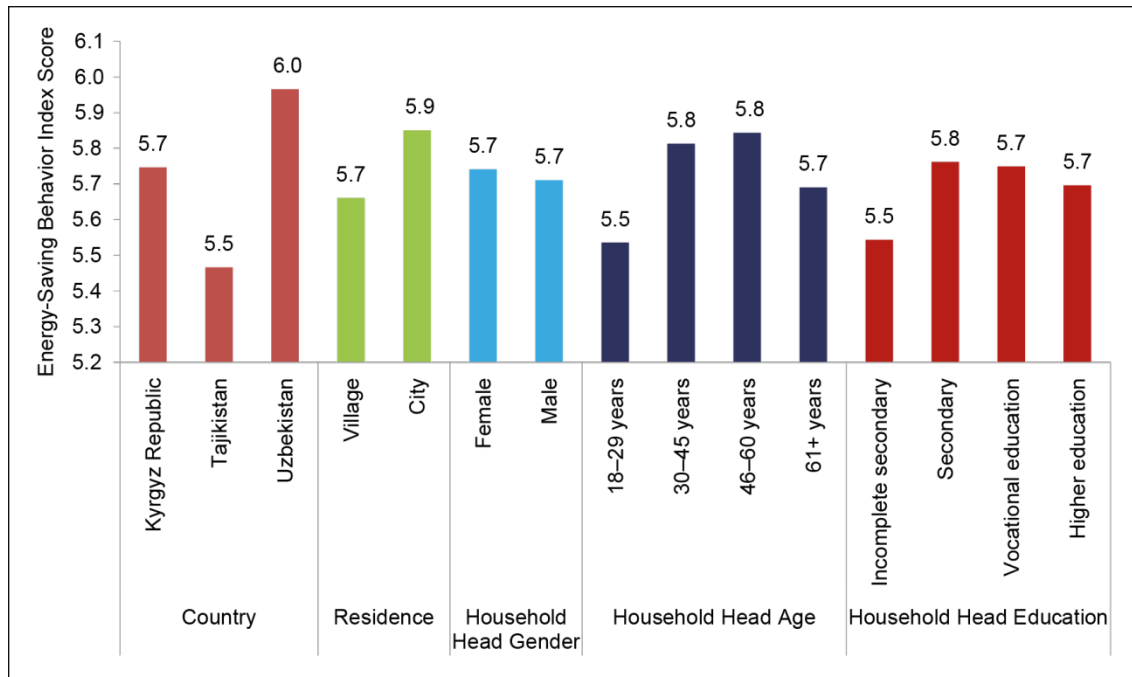
**Figure 5: Responses to Energy-Saving Behavior Questions
(Mean Values)**



Sources: Authors' calculations, "Household Access to Energy in The Fergana Valley" data, CAREC Institute 2023.

Analysis of the energy-saving behavior index across household and dwelling characteristics yields several insights. Firstly, there are regional differences among countries—the Kyrgyz Republic, Tajikistan, and Uzbekistan—with Uzbekistan exhibiting the highest share of energy-saving behavior. Additionally, disparities are observed across urban and rural areas, the household head's education levels, and age categories (see Figure 6).

Figure 6: ESB Index Across Country, Residence, and Household Head Characteristics
(Mean Values)



Sources: Authors' calculations, "Household Access to Energy in The Fergana Valley" data, CAREC Institute 2023.

The information sources about renewable energy presented with four variables and indicate whether the household head receives information from traditional media (such as television and newspapers), digital platforms (social networks, internet forums, or specialized websites), out-of-home advertising (such as street billboards, posters, banners, leaflets, advertising in public spaces, and public transport), or personal and social networks (including relatives, friends, and children learning in school). Each variable is coded as 1 if the household head receives information from the respective source and 0 otherwise. A detailed description of the explanatory variables is provided in Table A1 (Annex).

2.5 Descriptive Statistics

Table 3 presents the descriptive statistics of the outcome and explanatory variables. Approximately 34% of households in the Fergana Valley reside in rural areas, with the average age of their dwellings being around 37 years. This suggests that these homes were likely constructed during the Soviet Union era and thus may require renovation to meet contemporary standards of energy efficiency, such as insulation. The average living area is 56 square meters, and the primary construction materials include brick, wood, mudbrick, and concrete. During winter, the majority of households (61%) rely on coal, oil, and firewood for heating, while 30% use electricity and only 8% utilize gas.

Table 3: Descriptive Statistics

	<i>N</i>	<i>Mean</i>	<i>Std. Dev.</i>	<i>Min</i>	<i>Max</i>
<i>Explanatory Variables</i>					
1. Building characteristics:					
Residence (1 = City)	1,465	0.342	0.475	0	1
House age (years)	1,465	37.866	25.277	1	120
Living area (sq. meters)	1,465	56.42	36.839	9	250
Building materials:					
• Brick	1,465	0.706	0.456	0	1
• Mudbrick	1,465	0.279	0.449	0	1
• Reed fiberboard	1,465	0.025	0.155	0	1
• Wood	1,465	0.315	0.465	0	1
• Concrete	1,465	0.266	0.442	0	1
• Monolith	1,465	0.015	0.122	0	1
Sources of heating:					
• Coal, oil, firewood, etc.	1,465	0.610	0.488	0	1
• Gas (propane)	1,465	0.085	0.278	0	1
• Electricity	1,465	0.305	0.461	0	1
2. Household characteristics:					
HH head age	1,465	41.002	15.027	18	85
• 18–29 years	1,465	0.281	0.449	0	1
• 30–45 years	1,465	0.358	0.479	0	1
• 46–60 years	1,465	0.227	0.419	0	1
• 61+ years	1,465	0.134	0.341	0	1
HH head gender (1 = male)	1,465	0.504	0.500	0	1
HH head marital status (1 = married)	1,465	0.773	0.419	0	1
HH head education:					
• Incomplete secondary	1,465	0.070	0.256	0	1
• Secondary	1,465	0.395	0.489	0	1
• Vocational education	1,465	0.272	0.445	0	1
• Higher education	1,465	0.263	0.440	0	1
Household size	1,465	5.429	2.247	1	19
Number of children	1,465	1.911	1.492	0	10
Number of senior adults	1,465	0.777	0.928	0	5
Log of heating expenditure	1,465	9.325	3.068	3.219	15.425
Household income level:					
• Lowest income level	1,465	0.136	0.343	0	1
• Middle income level	1,465	0.238	0.426	0	1
• Highest income level	1,465	0.504	0.500	0	1
3. Household behavior and information source:					
Energy-saving behavior index	1,465	5.726	1.493	0	9
Renewable energy information sources:					
• Traditional media	1,465	0.722	0.448	0	1
• Digital media	1,465	0.646	0.478	0	1
• Out-of-home advertising	1,465	0.070	0.255	0	1
• Social networks	1,465	0.195	0.396	0	1

Sources: Authors' calculations, "Household Access to Energy in The Fergana Valley" data, CAREC Institute 2023.

The overview of the household heads' characteristics reveals that the average age is 41 years. There is an equitable gender distribution, with 50% being male. Furthermore, approximately 77% of household heads are married. In terms of educational attainment, nearly 40% have completed secondary education, 27% have received vocational training, and 26% possess higher education degrees, while the overview of the household characteristics indicates that the average number of household members is five, including approximately two children and one elderly dependent adult. The income level of households is categorized into three groups based on the questionnaire: lowest, middle, and highest. The proportion of households in the lowest-income category is 13%, while in the middle-income category it is 23%, and in the highest-income category it is 50%, which serves as the reference group for the analysis.

According to the descriptive statistics on where households acquire renewable energy information, 72% of household heads obtain information from traditional media and 64% from digital media. Meanwhile, 19.5% acquire information from social networks, including relatives, friends, and children learning in school. Additionally, only 7% of households obtain information from advertising sources such as street billboards, posters, banners, leaflets, and advertisements in public spaces and on public transport.

3. EMPIRICAL FINDINGS

3.1 Main Results

The estimation results of marginal effects from the probit models are presented in Table 4 (for detailed coefficient estimates and clustered standard errors, refer to Table A2 in the Annex). Focusing on household heads' intention to insulate, the first model assesses the impact of explanatory variables on the likelihood of carrying out at least one type of insulation in the home. The second and third models analyze the division of residence type into urban (city) and rural (village) areas, while the fourth and fifth models provide gender-specific analyses by dividing the total sample into male- and female-headed subsamples. Models six through nine estimate the likelihood of household heads insulating windows, doors, walls, or roofs individually.

Energy-Saving Behavior and Information Source

The main variable of interest, the energy-saving behavior index, exhibits statistically significant positive effects. This finding is as expected and consistent with the existing literature (De Cian et al. 2019). Household heads with more energy-saving behavior are more inclined to insulate windows and doors. This increase in the energy-saving behavior index holds significance regardless of household residence or head gender, indicating its crucial role in influencing household insulation decisions. In other words, the statistically significant positive impact of this index on insulation decisions suggests that households actively engaged in energy-saving practices are more likely to extend these efforts to insulation as well. However, energy-saving behavior is not statistically significant (at the 5% level of significance) for insulating walls and roofs. This is probably due to greater barriers to insulating walls and roofs.

In contrast, the variable representing renewable energy information sources demonstrates the least impact on household insulation decisions. Consequently, households acquiring information from traditional, digital media, or social networks are more likely to insulate only doors, while at the same time the traditional media exhibits a negative impact on the insulation of walls or roofs. These findings suggest that households exposed to information about renewables may primarily base their insulation decisions on door insulation rather than other items and suggest a need for targeted campaigns or information dissemination strategies tailored to addressing specific insulation needs.

Table 4: Estimation Results of the Probit Models
(Marginal Effects)

	Intention to Insulate <u>Any Item</u>					Intention to Insulate:			
	Total Sample (1)	Residence		Gender		Window (6)	Door (7)	Wall (8)	Roof (9)
		(2) City	(3) Village	(4) Male	(5) Female				
Building characteristics:									
Residence (1 = City)	−0.0550*	−	−	−0.0200	−0.0880**	−0.0530*	−0.0250	−0.0330*	−0.0240
House age (years)	0.0010*	0.0010	0.0010	0.0000	0.0010*	0.0010*	0.0010**	0.0010***	0.0010***
Living area (sq. meters)	−0.0004	−0.0010	−0.00007	−0.0010*	0.0001	−0.0001	0.0004	0.001	0.0003
Building materials:									
• Mudbrick	0.0160	0.1200*	−0.0274	0.0570	−0.0260	0.0360	0.0500**	−0.0180	0.0070
• Reed fiberboard	−0.2410***	0.1860	−0.2880***	−0.3000**	−0.1900	−0.2170***	−0.0810	−0.0290	0.0080
• Wood	0.0840***	0.0210	0.1200***	0.1340***	0.0590	0.0970***	0.0340	0.0200	0.0240
Sources of heating (reference: Electricity)									
• Coal, oil, firewood, etc.	0.1450***	0.2290***	0.0990**	0.0980*	0.1830***	0.0960***	0.0730**	0.0470***	0.0080
• Gas (propane)	0.1610***	0.2520***	0.1010	0.2530***	0.1030	0.1000*	0.0160	0.0310	0.0640
Household characteristics:									
HH head age	−0.0020**	−0.0020	−0.0020*	−0.0020*	−0.0020	−0.0010	−0.0010	0.000002	−0.0010*
HH head gender (1 = male)	−0.0210	0.0090	−0.0370	−	−	−0.0120	−0.0160	0.0080	−0.0210
Education level	−0.0080	0.0010	−0.0100	−0.0020	−0.0090	−0.0050	−0.0150	−0.0100	0.0060
Household size	0.0120*	0.0100	0.0150*	0.0180**	0.0060	0.0110*	0.0080	0.0050	0.0000
Share of children in HH size	0.0760	0.2890**	−0.0520	−0.0780	0.2170**	0.0740	0.1400**	0.0430	0.1250***
Share of seniors in HH size	0.2320***	0.3390***	0.1810**	0.0950	0.3460***	0.1750**	0.1790***	−0.0120	0.0360
Log of heating expenditure	0.0240***	0.0180	0.0270**	0.0310**	0.0170	0.0380***	0.0110	0.0050	0.0180***
Household income (reference: Highest level):									
• Lowest income level	0.0620	0.1290**	−0.0010	−0.0190	0.1010*	0.0620	0.0170	−0.0250	−0.0070
• Middle income level	0.0710**	0.0800	0.0790**	0.1180***	0.0310	0.0750**	0.0600**	−0.0130	−0.0140
Household behavior and information source:									
Energy-saving behavior index	0.0340***	0.0500***	0.0260**	0.0310**	0.0410***	0.0340***	0.0460***	0.0080*	0.0030
Information sources about renewables:									
• Traditional media	0.0360	−0.0080	0.0740*	0.0510	0.0340	0.0340	0.0740***	−0.0420**	−0.0420**
• Digital media	0.0170	−0.0470	0.0410	−0.0160	0.0360	0.0210	0.0920***	−0.0040	−0.0090
• Social networks	−0.0340	−0.0590	−0.0180	−0.0450	−0.0210	−0.0290	0.0610**	−0.0350*	−0.0160
Region fixed effect	+	+	+	+	+	+	+	+	+
N	1,465	501	964	738	727	1,465	1,465	1,465	1,465
Log-likelihood	−933.05	−300.94	−614.99	−461.13	−457.50	−909.37	−727.86	−348.43	−338.12
Chi2	151.03	81.49	94.80	87.07	86.51	177.34	150.25	175.29	186.85
Prob.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R2	0.081	0.125	0.079	0.098	0.092	0.099	0.104	0.238	0.253

Note: *p < 0.10; **p < 0.05; ***p < 0.010.

Sources: Authors' calculations, "Household Access to Energy in The Fergana Valley" data, CAREC Institute 2023.

Household Characteristics

Among the socioeconomic characteristics of households, the household head's age negatively impacts insulation decisions, indicating that older household heads are less likely to carry out insulation. However, head gender and education level do not significantly influence insulation decisions. Conversely, increasing household size correlates with a higher propensity for insulation, particularly in rural settings and under male household heads. The existence of dependents within households also has a notable influence on insulation decisions. A greater presence of children within the household increases the likelihood of insulating doors and roofs, particularly in urban contexts and under female household heads. Conversely, an increasing proportion of seniors within households significantly influences the decision to insulate windows and doors, regardless of urban or rural location, particularly under female household heads. The positive impact of children and seniors on insulation could be due to a greater need for comfortable temperatures among those groups.

The increasing expenditure of households during the winter season indicates that household heads are more likely to undertake insulation measures, particularly in rural areas and under male household heads, with a higher propensity to insulate windows and roofs. Additionally, income level dummy variables suggest that households in the lowest and middle income groups are more inclined to intend to insulate than those in the highest income level group. Specifically, households in the lowest income level group in urban areas display a greater inclination towards insulation, especially if headed by females, while middle-income households exhibit a persistent and significant intention to insulate, particularly windows and doors, in rural areas and under male household heads. This income-related relationship with household insulation suggests that lower- and middle-income households are in greater need of insulation for their homes than those in higher income level groups, emphasizing their proactive attitude compared to their higher-income counterparts.

Dwelling Characteristics

According to the estimation results regarding dwelling (building) characteristics, household residence in urban areas significantly and negatively impacts insulation decisions, albeit at a 10% significance level. This indicates that insulation decisions are more likely to be made in rural than in urban areas. This effect is more pronounced among female-headed households, suggesting that female household heads in urban areas are less inclined to insulate their homes than those in rural areas. Interestingly, this significant negative impact is observed particularly in the insulation of windows and walls, implying that urban households are less likely to insulate windows or walls than their rural counterparts.

The age of the dwelling emerges as a significant determinant influencing decisions regarding insulation. As the years since construction increase, there is a corresponding rise in the likelihood of insulating windows, doors, walls, or roofs. Conversely, the size of the living area exhibits no statistically significant effects on insulation decisions. With regard to construction materials, estimation results reveal significant impacts on household insulation choices. Specifically, households situated in dwellings primarily constructed of mudbrick exhibit an increased likelihood of insulation, particularly in urban settings, with a focus on door insulation. Conversely, the adoption of reed fiberboard, a material with sustainable thermal properties, yields a negative and statistically significant impact on insulation decisions. This suggests that households equipped with energy-efficient building materials are less inclined to undertake insulation efforts. Notably, this effect is pronounced in rural areas and among male-headed households, particularly concerning decisions regarding window insulation.

On the other hand, when wood serves as the primary construction material, households are more inclined to insulate, especially if headed by males and situated in rural areas, with a particular focus on window insulation.

Another noteworthy finding is the significance of heating sources in influencing household insulation decisions. Homes utilizing coal, oil, firewood, etc. for heating during winter seasons are more inclined to express intent to insulate windows, doors, and walls, regardless of whether they are located in urban or rural areas and irrespective of household gender, than those using electricity for heating during winter. This suggests that households relying on coal, oil, and firewood as energy sources are more likely to undertake insulation measures. Additionally, households using gas (either pipeline or cylinder propane) are more inclined towards window insulation, particularly in urban areas and among male-headed households, than their counterparts using electricity for winter heating. The significance of the results in female-headed households may be attributed to the fact that women often serve as the primary caregivers for children and the elderly.

3.2 Robustness Analysis

To ensure the robustness of our analysis, we conducted complementary estimations, the results of which are presented in Table 5, depicting the probit model with marginal effects (for detailed information regarding coefficient estimates and clustered standard errors, refer to Table A3 in the Annex). As part of the robustness analysis, we transformed one of our explanatory variables, household age, which is continuous and exhibits a significant negative impact on insulation, into a categorical dummy variable. We categorized household age into four groups, namely 18–29, 30–45, 46–60, and 61+ years, with the youngest group (18–29) serving as the reference category in our analysis. We estimated a probit model and examined the consistency and robustness of the results for the explanatory variables.

As presented in Table 5, all coefficients exhibited consistent impacts and magnitudes. Specifically, the household age variable demonstrated a negative impact in the 46–60 years group and the 61+ years group, significant at the 10% significance level. The main variable of interest, the energy-saving behavior index, maintained a consistent positive impact on household insulation decisions regardless of the gender of the household head or rural-urban residence, positively influencing decisions to insulate windows and doors. Based on these findings, we conclude that the results presented are unbiased and robust.

4. CONCLUSION AND POLICY RECOMMENDATIONS

This study aims to assess the willingness of Central Asian households to insulate their homes and the factors influencing this decision-making process. Additionally, it explores how energy-saving behavior can impact household decisions regarding insulation of various components of the house. The study utilizes CAREC Institute data from the “Household Access to Energy in The Fergana Valley” household survey, which was conducted in 2023.

**Table 5: Robustness Analysis Estimation Results of the Probit Models
(Marginal Effects)**

	<i>Intention to Insulate <u>Any Item</u></i>					<i>Intention to Insulate:</i>			
	Total Sample	Residence		Gender		Window	Door	Wall	Roof
	City	Village	Male	Female					
Building characteristics:									
Residence (1 = City)	−0.0550*			−0.0230	−	−0.0520*	−0.0240	−0.0310*	−0.0230
					0.0850**				
House age (years)	0.0010*	0.0007	0.0010	0.0001	0.0013*	0.0010*	0.0010**	0.0010**	0.0010**
								*	*
Living area (sq. meters)	−0.0003	−0.0008	−0.00008	−0.0009*	0.0001	−0.0001	0.0003	0.0001	0.0003*
Building materials:									
• Mudbrick	0.0160	0.1190*	−0.0270	0.0550	−0.0260	0.0370	0.0505**	−0.0170	0.0080
• Reed fiberboard	−	0.2030	−	−	−0.1920	−	−0.0820	−0.0260	0.0070
	0.2450**		0.2910**	0.3060**		0.2190**			
	*		*	*		*			
• Wood	0.0840**	0.0230	0.1190**	0.1330**	0.0580	0.0970**	0.0340	0.0210	0.0240
	*		*	*		*			
Sources of heating (reference: Electricity)									
• Coal, oil, firewood, etc.	0.1440**	0.2250**	0.0990**	0.0960*	0.1820**	0.0960**	0.0720**	0.0450**	0.0070
	*	*			*	*			
• Gas (propane)	0.1580**	0.2480**	0.0950	0.2510**	0.0980	0.0970*	0.0110	0.0220	0.0590
	*	*		*					
Household characteristics:									
HH head age (reference: 18–29 years group)									
30–45 years	−0.0460	−0.0640	−0.0310	−0.0260	−0.0650	−0.0350	−0.0210	−0.0230	−0.0240
46–60 years	−0.0350	−0.0480	−0.0290	−0.0840*	0.0160	−0.0100	0.0160	0.0190	−0.0180
61+ years	−0.0770	−0.0640	−0.0760	−0.0590	−0.0860	−0.0320	−0.0590	−0.0290	−0.0480*
HH head gender (1 = male)	−0.0200	0.0100	−0.0360			−0.0110	−0.0140	0.0090	−0.0210
Education level	−0.0080	0.0020	−0.0100	−0.0030	−0.0100	−0.0040	−0.0150	−0.0110	0.0060
Household size	0.0110*	0.0080	0.0160**	0.0180**	0.0050	0.0100	0.0080	0.0050	0.0010
Share of children in HH size	0.1000	0.3290**	−0.0450	−0.0990	0.2970**	0.1000	0.1710**	0.0700	0.1350**
		*			*				*
Share of seniors in HH size	0.2220**	0.3070**	0.1740*	0.0520	0.3500**	0.1660**	0.2040**	0.0090	0.0410
	*	*			*		*		
Log of heating expenditure	0.0240**	0.0190	0.0270**	0.0320**	0.0160	0.0380**	0.0100	0.0050	0.0180**
	*					*			*
Household income (reference: Highest level):									
• Lowest income level	0.0620	0.1280**	−0.0002	−0.0160	0.0980*	0.0630	0.0150	−0.0280	−0.0070
• Middle income level	0.0730**	0.0780	0.0820**	0.1170**	0.0300	0.0770**	0.0620**	−0.0110	−0.0120
				*					
Household behavior and information source:									
Energy-saving behavior index	0.0340**	0.0500**	0.0260**	0.0320**	0.0400**	0.0340**	0.0460**	0.0080	0.0030
	*	*		*	*	*	*		
Information sources about renewables:									
• Traditional media	0.0320	−0.0160	0.0710*	0.0500	0.0310	0.0310	0.0720**	−	−
							*	0.0440**	0.0430**
• Digital media	0.0220	−0.0370	0.0450	−0.0120	0.0410	0.0260	0.0910**	−0.0050	−0.0080
							*		
• Social networks	−0.0370	−0.0600	−0.0200	−0.0460	−0.0320	−0.0310	0.0570**	−	−0.0170
								0.0360**	
Region fixed effect	+	+	+	+	+	+	+	+	+
N	1,465	501	964	738	727	1,465	1,465	1,465	1,465
Log-likelihood	−934.19	−301.03	−615.93	−461.20	−456.60	−909.47	−726.47	−345.76	−338.28
Chi2	149.49	83.19	93.60	87.94	87.51	177.11	156.50	196.24	189.74
Prob.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R2	0.080	0.124	0.078	0.098	0.094	0.099	0.106	0.244	0.253

Note: *p < 0.10; **p < 0.05; ***p < 0.010.

Sources: Authors' calculations, "Household Access to Energy in The Fergana Valley" data, CAREC Institute 2023.

First, households depend heavily on fossil fuels for heating (except in Tajikistan). The majority of households (over 65%) are aware of the harmful impact of fossil fuel combustion on the environment and health, and most households (61%) see the need for insulating windows. Out of those who see the need for insulation (walls, doors, windows, or roof), the majority (69%) plan to insulate, while the rest do not have plans to insulate. Households do not plan to insulate (even though they see the need) due to the high cost or a lack of information about financial support (61%), and a lack of information on how to do this (38%). The lack of information is the main barrier to insulating doors, walls, and roofs, while the biggest barrier to insulating windows is the high cost.

Second, we calculated the household ESB index, which ranges from 0 to 9. The higher the score is, the more frequently the household implements energy-saving behaviors, such as switching off the lights or appliances when not in use to save energy. The indexes of Uzbekistan (6.0), the Kyrgyz Republic (5.7), and Tajikistan (5.5) are around the average of the whole sample.

Third, using the probit model analysis we found several key factors influencing household insulation decisions. Overall, the results vary across insulating windows, doors, walls, and roofs. Household heads with more energy-saving behavior are more inclined to insulate. However, this finding is statistically significant only for insulating windows and doors, and not walls and roof, which indicates *greater barriers to insulating walls and roofs comparing to windows and doors*, such as a lack of information on how to do this.

Socioeconomic characteristics also impact insulation decisions. Heads of households with a greater share of children and elderly are more likely to be willing to insulate, especially when headed by a female. *Households in rural, with greater expenditure on heating, using solid or fossil fuel for heating or from low- to middle-income groups are more likely to be willing to insulate.* The above groups demonstrate a greater inclination towards insulation, emphasizing the importance of addressing energy efficiency needs among vulnerable groups.

Given these empirical findings, the policy recommendations include developing tailored interventions to promote insulation practices for groups with greater needs and willingness to insulate. These groups include rural households, those with higher heating expenditures, those using solid or fossil fuels for heating, and low- to middle-income households. Financial support is mainly needed for insulating windows, while more information on how to insulate is required for doors, walls, and roofs. Although the majority of households (over 65%) are aware of the harmful impact of fossil fuel combustion on the environment and health, there is still a scope to increase awareness.

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ANNEX A

Table A1: Variables Description

Variables	Description
DEPENDENT VARIABLES	
House insulation intentions (any item)	1 = if the household perceives a need and plans to isolate (seal, patch, insulate) a window, door, wall, or roof in the household from heat/cold loss; 0 = otherwise. Household positively answers to both questions below: Q46. In your opinion, is there a need to isolate (seal, patch, insulate) any of the following (a window, door, wall, or roof) in your household from heat/cold loss? Q47. Do you plan to isolate (seal, patch, insulate) all the items you have chosen?
• Window insulation intentions	1 = if the household perceives a need and plans to isolate (seal, patch, insulate) a window in the household from heat/cold loss; 0 = otherwise.
• Door insulation intentions	1 = if the household perceives a need and plans to isolate (seal, patch, insulate) a door in the household from heat/cold loss; 0 = otherwise.
• Wall insulation intentions	1 = if the household perceives a need and plans to isolate (seal, patch, insulate) a wall in the household from heat/cold loss; 0 = otherwise.
• Roof insulation intentions	1 = if the household perceives a need and plans to isolate (seal, patch, insulate) a roof in the household from heat/cold loss; 0 = otherwise.
INDEPENDENT VARIABLES	
1. Building and location characteristics	
Residence	1 = if household resides in city; 0 = village.
House age	Years since house construction.
Area of residential premises	Approximate area of all living/heated premises/rooms of the house (in sq. meters).
Main building materials	
• Brick	1 = if brick was mainly used to build the house; 0 = otherwise.
• Mudbrick	1 = if mudbrick was mainly used to build the house; 0 = otherwise.
• Reed fiberboard	1 = if reed fiberboard was mainly used to build the house; 0 = otherwise.
• Wood	1 = if wood was mainly used to build the house; 0 = otherwise.
• Concrete	1 = if concrete was mainly used to build the house; 0 = otherwise.
• Monolith	1 = if monolith was mainly used to build the house; 0 = otherwise.
Sources of HH heating:	
• Electricity heating	1 = if household uses electricity to heat house in the winter season; 0 = otherwise.
• Gas heating	1 = if household uses natural gas from underground pipes or propane (gas in cylinders) to heat house in the winter season; 0 = otherwise.
• Conventional heating	1 = if household uses coal, or fuel oil/diesel/biofuels (pressed dung)/kerosene/firewood or waste and garbage (rubber, plastic, paper, etc.) to heat house in the winter season; 0 = otherwise.
2. Socioeconomic characteristics of the household	
Household head age	Household head age (in years).
Household head gender	1 = if household head is male; 0 = if household head is female.
Household head education:	
• Incomplete secondary	1 = if the household head's highest level of education is Incomplete secondary (9 classes); 0 = otherwise.
• Secondary	1 = if the household head's highest level of education is Secondary (11 classes); 0 = otherwise.
• Secondary specialized and vocational education	1 = if the household head's highest level of education is Secondary specialized or vocational education (college, technical school); 0 = otherwise.
• Higher education	1 = if the household head's highest level of education is Higher education (specialist, bachelor, master, candidate, doctor, PhD); 0 = otherwise.
Household head marital status	1 = if the household head is married; 0 = otherwise.
Household size	The number of household members.
Number of children	The number of children under the age of 16.
Number of senior adults	The number of household members aged over 57 years.

continued on next page

Table A1 *continued*

Variables	Description
Heating expenditure	The average monthly heating expenditure of the household in winter (including all types of heating used in winter over the past three heating seasons, in national currency).
Log of heating expenditure	The natural logarithmic form of heating expenditure variable.
Household income level (dummy variables):	
• Lowest income level	Household monthly income (local currency): less than KGS12,000; less than TJS1,400; less than UZS2,000,000.
• Middle income level	Household monthly income (local currency): KGS12,001–20,000; TJS1,401–2,400; UZS2,000,001–3,200,000.
• Highest income level	Household monthly income (local currency): more than KGS20,000; more than TJS2,400; more than UZS3,200,000.
3. Household behavior and information sources	
Energy saving behavior index	<p>Q39. Do you and your household members try to save energy? 1 = household head or household members try to save energy; 0 = otherwise.</p> <p>Q40. Do you think that the use of fossil energy (coal, oil, gas) is harmful to the environment and the health of your family? 1 = household head thinks that the use of fossil energy (coal, oil, gas) is harmful to the environment and the health of his/her family; 0 = otherwise.</p> <p>Q41. Do you have energy-saving light bulbs in your house? 1 = household head uses energy-saving light bulbs in his/her house; 0 = otherwise.</p> <p>Q44. Do you pay attention to the energy efficiency class of household appliances? 1 = household head pays attention to the energy efficiency class of household appliances; 0 = otherwise.</p> <p>Q45. What energy saving methods do you use? 1 = switch off appliances that are not in use; 0 = otherwise. 1 = turn off the lights if there are no people in the room; 0 = otherwise. 1 = use fewer electrical appliances or watch less TV; 0 = otherwise. 1 = proper wiring and appliances; 0 = otherwise. 1 = use energy-saving, energy-efficient appliances; 0 = otherwise.</p>
Renewable energy information sources:	
• Traditional media	1 = if the household head receives information from traditional media sources (television, newspapers, radio); 0 = otherwise
• Digital media	1 = if the household head receives information from digital media sources (social networks, Internet forums, specialized websites); 0 = otherwise
• Out-of-home advertising	1 = if the household head receives information from out-of-home advertising sources (street billboards, posters, banners, leaflets, advertising in public spaces, public transport); 0 = otherwise.
• Personal and social networks	1 = if the household head receives information from personal and social networks (relatives, friends, children learning in school); 0 = otherwise.

Sources: Authors' calculations, "Household Access to Energy in The Fergana Valley" data, CAREC Institute 2023.

**Table A2: Probit Model Estimation Results for the Intention to Insulate
(Coefficient Estimates)**

		Intention to Insulate <i>Any Item</i>				Intention to Insulate:			
	Total Sample	Residence		Gender		Window	Door	Wall	Roof
		City	Village	Male	Female				
Building characteristics:									
Residence (1 = city)	−0.152* (0.081)	–	–	−0.055 (0.114)	−0.244** (0.117)	−0.149* (0.082)	−0.090 (0.093)	−0.252* (0.133)	−0.190 (0.125)
House age (years)	0.003* (0.001)	0.002 (0.002)	0.003 (0.002)	0.000 (0.002)	0.004* (0.002)	0.003* (0.001)	0.003** (0.002)	0.007*** (0.002)	0.007*** (0.002)
Living area (sq. meters)	−0.001 (0.001)	−0.003 (0.002)	−0.000 (0.001)	−0.002* (0.001)	0.000 (0.001)	−0.000 (0.001)	0.001 (0.001)	0.001 (0.001)	0.002* (0.001)
Building materials:									
• Mudbrick	0.044 (0.084)	0.351* (0.180)	−0.075 (0.098)	0.159 (0.119)	−0.072 (0.123)	0.102 (0.085)	0.177** (0.088)	−0.137 (0.125)	0.059 (0.113)
• Reed fiberboard	−0.662*** (0.235)	0.544 (0.775)	−0.788*** (0.249)	−0.840** (0.326)	−0.527 (0.345)	−0.613*** (0.237)	−0.288 (0.243)	−0.222 (0.363)	0.065 (0.341)
• Wood	0.231*** (0.078)	0.062 (0.136)	0.328*** (0.100)	0.374*** (0.113)	0.165 (0.114)	0.273*** (0.079)	0.123 (0.087)	0.152 (0.126)	0.187 (0.129)
Sources of heating (reference: Electricity)									
• Coal, oil, firewood, etc.	0.398*** (0.101)	0.671*** (0.183)	0.272** (0.127)	0.275* (0.149)	0.510*** (0.139)	0.271*** (0.101)	0.261** (0.117)	0.359*** (0.137)	0.061 (0.134)
• Gas (propane)	0.442*** (0.155)	0.738*** (0.211)	0.277 (0.287)	0.709*** (0.234)	0.287 (0.212)	0.281* (0.155)	0.056 (0.185)	0.238 (0.468)	0.502 (0.375)
Household characteristics:									
HH head age	−0.006** (0.003)	−0.006 (0.005)	−0.006* (0.003)	−0.006* (0.004)	−0.006 (0.004)	−0.003 (0.003)	−0.003 (0.003)	0.0001 (0.004)	−0.008** (0.004)
HH head gender (1=male)	−0.058 (0.069)	0.026 (0.122)	−0.102 (0.085)	–	–	−0.035 (0.069)	−0.057 (0.076)	0.060 (0.107)	−0.165 (0.108)
Education level	−0.023 (0.039)	0.002 (0.072)	−0.027 (0.047)	−0.005 (0.056)	−0.026 (0.056)	−0.014 (0.039)	−0.052 (0.042)	−0.074 (0.052)	0.046 (0.055)
Household size	0.032* (0.018)	0.030 (0.034)	0.042* (0.022)	0.051** (0.026)	0.017 (0.025)	0.030* (0.018)	0.029 (0.019)	0.040 (0.026)	0.004 (0.027)
Share of children in HH size	0.209 (0.196)	0.845** (0.337)	−0.144 (0.249)	−0.218 (0.288)	0.603** (0.275)	0.208 (0.197)	0.499** (0.221)	0.326 (0.323)	0.987*** (0.334)
Share of seniors in HH size	0.637*** (0.194)	0.992*** (0.343)	0.496** (0.241)	0.266 (0.278)	0.962*** (0.279)	0.493** (0.196)	0.640*** (0.219)	−0.089 (0.321)	0.285 (0.329)
Log of heating expenditure	0.066*** (0.025)	0.052 (0.041)	0.074** (0.032)	0.086** (0.035)	0.047 (0.034)	0.108*** (0.026)	0.039 (0.032)	0.040 (0.058)	0.145*** (0.046)
Household income level (reference: Highest level):									
• Lowest income level	0.169 (0.110)	0.379** (0.178)	−0.003 (0.148)	−0.052 (0.162)	0.281* (0.157)	0.175 (0.111)	0.059 (0.127)	−0.190 (0.198)	−0.057 (0.194)
• Middle income level	0.194** (0.084)	0.233 (0.162)	0.216** (0.100)	0.329*** (0.119)	0.085 (0.122)	0.211** (0.084)	0.216** (0.088)	−0.099 (0.131)	−0.107 (0.132)
Household behavior and information source:									
Energy-saving behavior index	0.094*** (0.024)	0.146*** (0.046)	0.071** (0.029)	0.088** (0.034)	0.113*** (0.035)	0.096*** (0.025)	0.164*** (0.028)	0.065* (0.039)	0.023 (0.037)
Renewable energy information sources (reference: Out-of-home advertising or none):									
• Traditional media	0.100 (0.086)	−0.024 (0.152)	0.202* (0.107)	0.142 (0.123)	0.096 (0.124)	0.097 (0.087)	0.265*** (0.098)	−0.325** (0.147)	−0.332** (0.150)
• Digital media	0.046 (0.077)	−0.137 (0.144)	0.113 (0.095)	−0.046 (0.115)	0.100 (0.108)	0.058 (0.078)	0.327*** (0.089)	−0.028 (0.120)	−0.068 (0.119)
• Social networks	−0.094 (0.088)	−0.174 (0.151)	−0.049 (0.113)	−0.126 (0.126)	−0.058 (0.127)	−0.082 (0.089)	0.218** (0.094)	−0.269* (0.141)	−0.128 (0.147)
Region fixed effect	+	+	+	+	+	+	+	+	+
Constant	−1.429*** (0.312)	−1.98*** (0.570)	−1.25*** (0.386)	−1.31*** (0.435)	−1.66*** (0.463)	−1.925*** (0.327)	−3.02*** (0.373)	−3.03*** (0.571)	−3.52*** (0.508)
N	1,465	501	964	738	727	1,465	1,465	1,465	1,465
Log-likelihood	−933.05	−300.94	−614.99	−461.13	−457.50	−909.37	−727.86	−348.43	−338.12
Chi2	151.03	81.49	94.80	87.07	86.51	177.34	150.25	175.29	186.85
Prob.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R2	0.081	0.125	0.079	0.098	0.092	0.099	0.104	0.238	0.253

Note: Clustered robust standard errors presented in parentheses. *p < 0.10; **p < 0.05; ***p < 0.010.

Sources: Authors' calculations, "Household Access to Energy in The Fergana Valley" data, CAREC Institute 2023.

Table A3: Robustness Analysis for the Intention to Insulate
(Probit Model Coefficient Estimates)

	<i>Intention to Insulate Any Item</i>					<i>Intention to Insulate:</i>			
	Total Sample	Residence		Gender		Window	Door	Wall	Roof
		City	Village	Male	Female				
Building characteristics:									
Residence (1 = city)	−0.151* (0.081)	–	–	−0.065 (0.114)	−0.237** (0.117)	−0.146* (0.082)	−0.086 (0.093)	−0.242* (0.133)	−0.185 (0.125)
House age (years)	0.003* (0.001)	0.002 (0.002)	0.003 (0.002)	0.000 (0.002)	0.004* (0.002)	0.003* (0.001)	0.003** (0.002)	0.007*** (0.002)	0.007*** (0.002)
Living area (sq. meters)	−0.001 (0.001)	−0.003 (0.002)	−0.000 (0.001)	−0.002* (0.001)	0.000 (0.001)	−0.000 (0.001)	0.001 (0.001)	0.001 (0.001)	0.002* (0.001)
Building materials:									
• Mudbrick	0.045 (0.084)	0.349* (0.179)	−0.074 (0.098)	0.154 (0.118)	−0.072 (0.123)	0.104 (0.085)	0.181** (0.088)	−0.132 (0.125)	0.064 (0.113)
• Reed fiberboard	−0.672*** (0.235)	0.594 (0.774)	−0.796*** (0.248)	−0.856*** (0.321)	−0.536 (0.346)	−0.619*** (0.237)	−0.293 (0.241)	−0.203 (0.362)	0.054 (0.334)
• Wood	0.231*** (0.079)	0.066 (0.137)	0.325*** (0.100)	0.373*** (0.113)	0.160 (0.114)	0.274*** (0.079)	0.123 (0.087)	0.160 (0.127)	0.188 (0.129)
Sources of heating (reference: Electricity)									
• Coal, oil, firewood, etc.	0.396*** (0.101)	0.660*** (0.183)	0.270** (0.127)	0.269* (0.149)	0.507*** (0.139)	0.270*** (0.101)	0.257** (0.117)	0.350** (0.137)	0.057 (0.134)
• Gas (propane)	0.435*** (0.155)	0.726*** (0.210)	0.260 (0.290)	0.703*** (0.234)	0.274 (0.212)	0.273* (0.156)	0.041 (0.186)	0.170 (0.488)	0.469 (0.375)
HH head age (reference: 18–29 years group)									
• 30–45 years	−0.127 (0.092)	−0.188 (0.171)	−0.084 (0.113)	−0.074 (0.132)	−0.180 (0.132)	−0.098 (0.094)	−0.075 (0.102)	−0.175 (0.131)	−0.186 (0.132)
• 46–60 years	−0.097 (0.098)	−0.141 (0.178)	−0.081 (0.120)	−0.234* (0.139)	0.045 (0.142)	−0.029 (0.098)	0.059 (0.109)	0.147 (0.154)	−0.142 (0.157)
• 61+ years	−0.210 (0.130)	−0.186 (0.227)	−0.209 (0.161)	−0.166 (0.186)	−0.239 (0.185)	−0.089 (0.131)	−0.212 (0.145)	−0.225 (0.201)	−0.377* (0.211)
HH head gender (1 = male)	−0.054 (0.069)	0.030 (0.122)	−0.099 (0.085)	– (0.085)	– (0.085)	−0.032 (0.069)	−0.051 (0.076)	0.068 (0.107)	−0.166 (0.107)
Education level	−0.021 (0.039)	0.006 (0.072)	−0.026 (0.047)	−0.008 (0.056)	−0.028 (0.056)	−0.012 (0.039)	−0.054 (0.042)	−0.084 (0.053)	0.045 (0.056)
Household size	0.031* (0.018)	0.024 (0.034)	0.043** (0.022)	0.051** (0.026)	0.014 (0.025)	0.028 (0.018)	0.029 (0.019)	0.041 (0.026)	0.004 (0.027)
Share of children in HH size	0.276 (0.212)	0.962*** (0.372)	−0.122 (0.266)	−0.277 (0.310)	0.829*** (0.305)	0.283 (0.213)	0.611** (0.238)	0.542 (0.350)	1.068*** (0.360)
Share of seniors in HH size	0.609*** (0.203)	0.899** (0.369)	0.476* (0.249)	0.146 (0.297)	0.974*** (0.294)	0.469** (0.204)	0.732*** (0.225)	0.068 (0.321)	0.320 (0.316)
Log of heating expenditure	0.066*** (0.025)	0.055 (0.041)	0.073** (0.032)	0.089** (0.036)	0.044 (0.035)	0.108*** (0.026)	0.036 (0.032)	0.039 (0.057)	0.146*** (0.046)
Household income level (reference: Highest level):									
• Lowest income level	0.171 (0.110)	0.373** (0.178)	−0.001 (0.148)	−0.045 (0.162)	0.274* (0.157)	0.177 (0.111)	0.054 (0.128)	−0.214 (0.197)	−0.054 (0.194)
• Middle income level	0.201** (0.084)	0.230 (0.161)	0.223** (0.100)	0.329*** (0.120)	0.084 (0.122)	0.217** (0.085)	0.221** (0.088)	−0.086 (0.131)	−0.093 (0.130)
Household behavior and information source:									
Energy-saving behavior index	0.094*** (0.024)	0.145*** (0.046)	0.070** (0.029)	0.090*** (0.034)	0.111*** (0.035)	0.096*** (0.025)	0.164*** (0.029)	0.063 (0.039)	0.023 (0.037)
Renewable energy information sources (reference: Out-of-home advertising or none):									
• Traditional media	0.089 (0.086)	−0.046 (0.153)	0.195* (0.107)	0.141 (0.123)	0.086 (0.124)	0.087 (0.087)	0.257*** (0.098)	−0.342** (0.146)	−0.342** (0.150)
• Digital media	0.061 (0.078)	−0.109 (0.143)	0.122 (0.096)	−0.034 (0.116)	0.113 (0.108)	0.073 (0.079)	0.326*** (0.089)	−0.042 (0.120)	−0.065 (0.120)
• Social networks	−0.101 (0.089)	−0.176 (0.152)	−0.054 (0.114)	−0.128 (0.126)	−0.090 (0.128)	−0.087 (0.089)	0.206** (0.094)	−0.282** (0.142)	−0.135 (0.147)
Region fixed effect	+	+	+	+	+	+	+	+	+
Constant	−1.597*** (0.302)	−2.11*** (0.553)	−1.41*** (0.375)	−1.45*** (0.422)	−1.83*** (0.449)	−2.020*** (0.318)	−3.12*** (0.365)	−3.03*** (0.570)	−3.73*** (0.507)
N	1,465	501	964	738	727	1,465	1,465	1,465	1,465
Log-likelihood	−934.19	−301.03	−615.93	−461.20	−456.60	−909.47	−726.47	−345.76	−338.28
Chi2	149.49	83.19	93.60	87.94	87.51	177.11	156.50	196.24	189.74
Prob.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R2	0.080	0.124	0.078	0.098	0.094	0.099	0.106	0.244	0.253

Note: Clustered robust standard errors presented in parentheses. *p < 0.10; **p < 0.05; ***p < 0.010.

Sources: Authors' calculations, "Household Access to Energy in The Fergana Valley" data, CAREC Institute 2023.

Table A4: Matrix of Correlations of Explanatory Variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
(1) Residence	1.0																							
(2) House Age	0.2	1.0																						
(3) Living Area	0.0	0.0	1.0																					
(4) Mudbrick	-0.2	0.0	0.0	1.0																				
(5) Reed Fiberboard	-0.1	0.0	0.0	0.1	1.0																			
(6) Wood	0.0	0.0	-0.1	0.2	0.0	1.0																		
(7) Coal, Oil, Firewood	-0.2	-0.1	0.0	0.1	0.0	0.1	1.0																	
(8) Gas Heating	0.3	0.1	-0.1	-0.1	0.0	0.1	-0.4	1.0																
(9) HH Head Age	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.1	1.0															
(10) Age_30_45	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	1.0														
(11) Age_46_60	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.1	0.4	-0.4	1.0													
(12) Age_61	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.7	-0.3	-0.2	1.0												
(13) HH Head Gender	0.0	-0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	1.0											
(14) Education Level	0.1	0.0	0.1	-0.1	-0.1	-0.1	-0.1	0.0	-0.1	0.1	0.0	-0.1	0.1	1.0										
(15) HH Size	-0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	-0.1	0.1	0.0	-0.1	1.0									
(16) Share Of Children	-0.1	-0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.4	-0.2	0.0	0.0	0.0	0.4	1.0								
(17) Share Of Seniors	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	-0.1	-0.1	0.4	0.0	0.0	0.0	-0.3	1.0							
(18) Log(Heating.Exp.)	0.3	0.2	-0.1	-0.3	0.0	0.2	0.2	0.3	0.2	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.0	1.0						
(19) Lowest Income Level	0.1	0.0	-0.1	-0.1	-0.1	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.0	-0.1	-0.2	-0.1	0.2	0.1	1.0					
(20) Middle Income Level	-0.1	0.0	0.0	0.1	0.0	-0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	1.0				
(21) ESB Index	0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	-0.1	0.1	1.0			
(22) Traditional Media	0.0	0.1	0.1	0.1	-0.1	0.0	-0.2	0.0	0.1	-0.1	0.1	0.1	0.0	0.1	-0.1	-0.1	0.1	-0.1	0.0	-0.1	0.0	1.0		
(23) Digital Media	0.0	-0.1	0.0	0.0	0.0	0.0	-0.1	0.0	-0.2	0.1	-0.1	-0.2	0.0	0.1	0.0	0.0	-0.1	0.0	-0.1	0.0	0.1	-0.2	1.0	
(24) Social Networks	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.0	1.0