CPD
Power and Energy Study
Towards Carbon Neutral Economy

Factors Determining Power and Energy Consumption Behaviour of Households in Bangladesh

A Cross-Section Analysis

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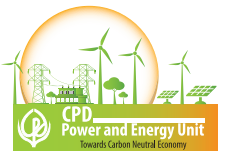

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Abstract

This comprehensive study investigates the multifaceted dynamics influencing household energy and power consumption behaviour in Bangladesh, using data from the Centre for Policy Dialogue's (CPD) Residential Energy Survey 2023. The study employed Principal Component Analysis (PCA) to create an energy and power consumption index using the expenditure variables and then fit the consumption index within a multivariate OLS regression model. Contrary to expectations, the study reveals that traditional demographic factors such as sex, age, and education of the household head do not significantly impact energy consumption patterns. Notably, education alone does not drive energy efficiency, but a distinct link emerges between households' knowledge about renewable energy and substantial energy savings which is a proxy for environmental consciousness. In addition, the study unveils a notable income stagnancy condition, challenging conventional assumptions about income-consumption dynamics and emphasising the significance of understanding nuanced relationships for effective policy interventions in promoting sustainable energy practices. The factors that households consider, such as the popularity of appliances, cost-saving priorities, and the energy efficiency of the appliances, significantly impact household energy and power consumption behaviour, highlighting potential areas for targeted policy interventions. Additionally, financial constraints and loan reliance correlate with lower energy consumption, opening avenues for inclusive energy conservation initiatives.

The study provides nuanced insights into the complex interplay of factors shaping energy behaviour, offering valuable guidance for policymakers, energy organisations, and researchers seeking to promote efficient and environmentally conscious energy consumption in Bangladesh.

Acknowledgements

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The authors also express their sincerest acknowledgment and appreciation to *Mr Avra Bhattachrajee*, Joint Director of Dialogue and Outreach at CPD, for his valuable support. Additionally, the team would like to thank *Mr HM Al Imran Khan*, Publication Associate, CPD, for his contributions in shaping, refining and finalisation of the manuscript.

Contents

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Acronyms

AC	Air Conditioner
BBS	Bangladesh Bureau of Statistics
BDT	Bangladeshi Taka
BPDB	Bangladesh Power Development Board
CEEW	Council on Energy, Environment and Water
CPD	Centre for Policy Dialogue
DSM	Demand Side Management
EE	Energy Efficient
EE&C	Energy Efficiency and Conservation
EECMP	Energy Efficiency and Conservation Master Plan
HIES	Household Income and Expenditure Survey
IDCOL	Infrastructure Development Company Limited
IMF	International Monetary Fund
KMO	Kaiser-Meyer-Olkin
LNG	Liquified Natural Gas
LPG	Liquified Petroleum Gas
MW	Megawatt
OLS	Ordinary Least Squares
PCA	Principal Component Analysis
RCT	Randomised Controlled Side
SREDA	Sustainable and Renewable Energy Development Authority
Std. Dev.	Standard Deviation
TV	Television

1. Introduction

The escalating demand for energy in Bangladesh, accompanied by the imperative for sustainable development, forms the backdrop for a critical examination of households' energy consumption behaviour. Over the past decade, the nation has experienced a significant surge in power generation capacity, responding to the surging demand for electricity and reaching an impressive 27,834 MW by September 2023 (BPDB, 2023; International Trade Administration, 2022). However, this remarkable growth has been met with challenges, particularly in the form of an energy crisis marked by austerity measures like load-shedding and gas rationing, highlighting the need for a sustainable approach to energy efficiency, conservation, and eco-friendly consumption behaviour.

The fuel mix of Bangladesh's power plants, heavily reliant on natural gas, faces a shift as the government aims to reduce dependence on domestic natural gas and increase the use of imported liquefied natural gas (LNG). Yet, the dwindling rate of new gas field exploration has led to a decline in reserves, necessitating critical decisions regarding primary sources for power generation (International Trade Administration, 2022). Simultaneously, Bangladesh actively pursues a goal to elevate its renewable energy capacity to 40 per cent of total power generation by 2041, introducing solar and wind power as promising options for immediate implementation (SREDA, 2023). While strides have been made in augmenting overall power generation capacity, lingering concerns about the sustainability of the energy sector persist.

With the residential sector consuming over half of the country's electricity, the potential for a 35.9 per cent reduction in energy usage through efficiency measures becomes evident (Alam, 2023). Yet, awareness remains a challenge, necessitating widespread campaigns (SREDA, 2021). The imminent approval of energy efficiency standards is promising, but substandard appliances in the market and rebound effects underscore the importance of a comprehensive regulatory approach (Alam, 2023). As Bangladesh seeks holistic solutions, fostering energy consciousness becomes imperative in navigating the complexities of its energy landscape. While keeping the notion in mind, this study also aims to evaluate whether using energy inefficient accessories has any impact on efficient energy consumption at the household level of Bangladesh.

With the world's largest solar home system programme, Bangladesh has provided electricity access to 20 million homes, constituting 16 per cent of the rural population (Cabraal, Ward, Bogach, & Jain, 2021). The Energy Efficiency and Conservation Master Plan, extending until 2030, delineates comprehensive strategies to expand energy efficiency and conservation (EE&C) programmes across the country (SREDA & Power Division, 2015). It is imperative for Bangladesh to augment energy efficiency and curtail wasteful energy consumption. Recognising that achieving energy savings goes beyond technological advancements, there is a concurrent need for a shift in people's energy consumption patterns.

In the contemporary landscape of increasing global energy demands and growing environmental concerns, understanding the intricacies of household energy consumption becomes paramount. This study holds significance as it navigates through multifaceted factors influencing energy and power consumption behaviour, aiming to provide a comprehensive perspective for sustainable energy policymaking. By scrutinising the role of education, awareness about eco-friendly behaviours, usage of energy efficient accessories, factors of considerations while purchasing appliances, socio-economic and demographic characteristics, the research contributes vital insights to the ongoing discourse on fostering energy-efficient practices. In an era where informed decisions and effective policies are crucial for a sustainable future, this study serves as a foundational exploration into the often complex and interwoven dynamics of household energy consumption.

Existing literatures on Bangladesh associated with this sector does not encompass the whole of Bangladesh, and hence, in identifying existing gaps in the literature, this research seeks to contribute to the ongoing discourse on households' energy consumption and devise effective policy solutions targeted to the whole country. By pinpointing areas where prior research falls short, the study aims to add new dimensions to the current understanding, paving the way for a more

holistic comprehension of the factors influencing energy usage within the domestic sphere.

Central to the focus of this study is the fundamental query: What are the key determinants influencing energy consumption patterns within households in Bangladesh? Through a systematic exploration of this pivotal question, this study aims to unravel the intricate dynamics of energy consumption behaviour. The anticipated outcome of this research is to furnish actionable insights tailored for policymakers and stakeholders actively involved in crafting a sustainable energy future for Bangladesh.

This study utilises data from CPD Residential Energy Consumption Survey 2023, conducted by Centre for Policy Dialogue (CPD), Dhaka to investigate whether various socio-economic and demographic factors such as household size, residential characteristics, education level, usage of energy efficient accessories have significant associations with household energy and power consumption behaviour. The household energy and power consumption behaviours were represented through indexing a few consumption variables and the index was constructed with the help of Principal Component Analysis (PCA). Afterward, a multivariate regression model was employed to complete the analysis, while controlling various econometric issues such as multicollinearity, serial auto-correlation, etc.

Following this introduction, Section 2 delves into a comprehensive literature review. Section 3 provides an in-depth exploration of the methodology, sub-sectioned into variables, conceptual framework, and an outlined data analysis plan. In Section 4, the results and findings are presented, including descriptive statistics, regression outcomes, and econometrics test summaries. Moving forward, Section 5 focuses on the policy implications, summarising key findings, offering recommendations, and addressing potential implementation challenges. Finally, Section 6 concludes the study, summarising main findings, highlighting contributions to existing literature, and suggesting potential avenues for future research.

2. Literature Review

Across literatures, energy consumption studies aim to understand the patterns and trends in energy usage, as well as the impact of various policies and factors on household energy consumption.

Policies and initiatives aimed at energy conservation play a crucial role in promoting projects that aim to minimise or decrease energy consumption during the operation of systems, machinery, or the production of goods and services (The World Bank, 2023). These measures influence household energy consumption by encouraging the selection of energy-efficient products during the purchasing phase and by disseminating information about the energy usage of various products (Matsumoto, Mizobuchi, & Managi, 2022). For example, countries emphasising energy efficiency have experienced benefits such as lower consumer costs and reduced emissions (Motherway, Klimovich, Rozite, & Bayer, 2022). However, it is important to take the current scenario of Bangladesh into account and investigate the factors that are influencing the consumption behaviour of Bangladeshi households with a view to identifying the key relevant drivers of the current scenario of the households' energy and power consumption behaviour.

Matsumoto, Mizobuchi, and Managi (2022) identified the primary obstacle to domestic energy conservation lies in the limited understanding of household energy consumption. Despite the varied energies used in daily life, the specific purposes for each remain unclear, and the link between household characteristics and energy use is not well-established. This knowledge gap poses a significant challenge to designing effective energy policies for carbon mitigation (Matsumoto, Mizobuchi, & Managi, 2022). Therefore, it is important to incorporate the educational level of the households in the study to investigate whether the households' level of awareness about efficient power and energy consumption behaviour is significant in Bangladesh or not.

Islam, Rayhan and Mojumder (2022) surveyed with 827 employees across 20 different industries to investigate the energy consumption behaviour of industrial staff, considering sociodemographic and behavioural aspects. Utilising exploratory factor analysis and reliability analysis, behavioural constructs are derived, encompassing personal consumption behaviour, technology adoption norms, training and supervision, openness to change, technological ignorance, energy self-efficacy, engagement, and responsibility. The impact of these constructs and sociodemographic variables on staff's consumption behaviour is analysed through descriptive statistics and a logistic regression model. Findings highlight the neglect of awareness-building programmes in training within Bangladesh's industries. The study reveals no significant differences in consumption behaviour based on gender, education level, age-group, or educational background (Islam, Rayhan, & Mojumder, 2022). This study covers the household level energy consumption across Bangladesh and showcases a more comprehensive scenario of the situation.

Existing literature has debated the impact of female-headed households on energy efficiency, with Klausner positing that they might be less disciplined and ordered in energy use. However, afterward, a multivariate study challenged this, finding no significant independent effect of the sex of the household head on electricity consumption, urging a reconsideration of gender-centric assumptions in the realm of household energy efficiency (DeFronzo & Warkov, 1979). The finding further strengthens the claim of Islam, Rayhan and Mojumder (2022). Another study conducted in Ghana found that supporting female-headed households to have access to more economic opportunities, as males tend to, will potentially lead to more efficient energy use (Adusah-Poku, Adams, & Adjei-Mantey, 2022). A study conducted in Bhutan found that clean energy use is significantly lower among de jure female-headed households (Senjawati, Susanti, Zadry, & Fithri, 2018). However, a study concluded that women have a higher influence on the behaviour of electrical energy consumption than men (Shrestha, Tiwari, Bajracharya, & Keitsch, 2021). Since the scenario of the sex of household head influencing efficient usage of power and energy is different across countries, it is important to investigate the scenario of Bangladesh as a whole.

Several studies have observed that energy consumption patterns are not necessarily determined by the age of the household head. For example, a study on aging and household energy demand in the United States suggested that rapidly increasing energy consumption between ages 30 and 55 may be due to a general behavioural change in the use of energy-consuming goods (Estiri & Zagheni, 2019). Another study found a positive correlation between energy consumption and the age of the household head, which could be explained by an increase in the income of the household head with age (Aslam & Ahmad, 2018). Therefore, while age may have some impact on energy consumption, it is not a decisive factor, and other variables such as income and behavioural changes may play a more significant role in shaping energy consumption patterns.

While numerous residential energy conservation measures exist, they have been categorised into three stages across literatures. The initial stage focuses on 'energy choices', aiming to encourage households to opt for low Carbon dioxide (CO_2) producing, preferably renewable energy. Governments influence these choices by altering energy prices through carbon pricing schemes. In the 'product purchase' stage, authorities can reduce household energy consumption by promoting energy-efficient products, often offering subsidies, and providing consumers with information on product energy usage. The last stage centres on the 'final energy consumption', emphasising efficient product utilisation. Governments implement energy conservation campaigns and educational programmes to guide households in using products in an energy-efficient manner (Motherway, Klimovich, Rozite, & Bayer, 2022; Nguyen, Nguyen, & Pham, 2023; Motherway, Klimovich, Rozite, & Bayer, 2022).

In their exploration of residential energy efficiency policies in Europe from 1980 to 2016, Aydin and Brounen (2019) revealed that the implementation of energy labelling requirements for appliances and the enforcement of more stringent building codes are pivotal factors contributing to a noticeable

reduction in household energy consumption (Aydin & Brounen, 2019).

Espey and Espey (2004) explored household energy consumption using broad macro-level data (Espey & Espey, 2004). Yet, some scholars, like Baker, Blundell and Micklewright (1989), asserted that findings from analyses relying solely on macro-level data, overlooking household diversity, may be less dependable (Baker, Blundell, & Micklewright, 1989). In this study, we address this concern by employing micro-level data, providing a more detailed understanding of household energy dynamics and enhancing the reliability of our results.

The literature review underscores the global discourse on household energy consumption, emphasising the pivotal role of policies and initiatives in shaping consumption patterns. While existing studies have delved into the impact of factors such as education, gender, and age on energy efficiency, a nuanced exploration specific to the context of Bangladesh has been lacking. The study aims to fill this gap by comprehensively investigating the multifaceted dynamics influencing energy and power consumption behaviour at the household level in Bangladesh. Unlike prior research, our micro-level analysis considers diverse factors, including education, awareness of renewable energy, factors of consideration while purchasing appliances, and socio-economic influences. This approach ensures a more detailed understanding of household energy dynamics, addressing the limitations of macro-level analyses and contributing valuable insights for tailored policy interventions in the context of Bangladesh.

3. Methodology

3.1 Data Source

The study utilised data from the CPD Residential Energy Consumption Survey 2023, a comprehensive investigation designed to gather recent and reliable information on home energy usage patterns. The study aimed to assess energy consumption patterns, identify factors influencing consumption behaviour, evaluate energy efficiency measures, and analyse regional and socio-economic disparities. A total of 500 households were randomly sampled from across the country, covering both rural and urban demographics. The questionnaire design drew inspiration from a Bangladesh Institute of Development Studies study titled 'Energy for Rural Households Towards a Rural Energy Strategy in Bangladesh', and 'Indian Residential Energy Consumption Survey 2020' conducted by Council on Energy, Environment and Water (CEEW) of India, encompassing both fuel and electricity consumption aspects. Additionally, the standard code of ethical conduct was maintained while surveying the respondents, and no financial incentives had been provided to the respondents.

3.2 Sample Selection

Households were selected based on a poverty map of Bangladesh, constructed using the Household Income and Expenditure Survey 2016 (HIES 2016). One low-poverty and one high-poverty sub-district were chosen from each division using computerised randomisation. The sample distribution followed the proportion of the total population in each division, considering both rural and urban households. To highlight regional disparities, contrasting figures were emphasised by selecting sub-districts with the highest and lowest poverty indices within each division. Primary survey targets were household heads, spouses, or individuals with a clear understanding of household dynamics. The detailed sampling distribution can be found in appendix 1.

3.3 Variables

Key variables considered in the study are listed in table 1:

Table 1 List of variables used in the study

Variable Indicators	Variable Names	Variable Indicators	Variable Names
gender	Gender of the household head	age	Age of the household head
numhh	Number of members in a household/ household size	dr	Dependency ratio within a household
student	Total number of students in a household	agri	Earning of households: agriculture
govt	Earning of households: government jobs	pvt	Earning of households: private jobs
self	Earning of households: self-employed	inc_5	Average monthly income of households: less than BDT 5,000
inc_10	Average monthly income of households: BDT 5,001 to BDT 10,000	inc_20	Average monthly income of households: BDT 10,001 to BDT 20,000
inc_30	Average monthly income of households: BDT 20,001 to BDT 30,000	inc_40	Average monthly income of households: BDT 30,001 to BDT 40,000
inc_50	Average monthly income of households: BDT 40,001 to BDT 50,000	inc_75	Average monthly income of households: BDT 50,001 to BDT 75,000
inc_100	Average monthly income of households: BDT 75,001 to BDT 100,000	inc_more100	Average monthly income of households: more than BDT 100,000
fan_number	Total number of fans in a household	tv_avail	Availability of TV in a household
ac_avail	Availability of AC in a household	refg_avail	Availability of refrigerator in a household
pump	Availability of water pump in a household	elc_machine_ mwoven	Availability of microwave oven in a household
elc_machine_ rcooker	Availability of rice cooker in a household	factors_cost	Factors of consideration while purchasing appliances: Cost savings
factors_ popular	Factors of consideration while purchasing appliances: Popularity	factors_ durable	Factors of consideration while purchasing appliances: Durability
factors_ engsav	Factors of consideration while purchasing appliances: Energy Savings	factors_ discount	Factors of consideration while purchasing appliances: Discount Offers
factors_ warranty	Factors of consideration while purchasing appliances: Warranty	factors_asales	Factors of consideration while purchasing appliances: After Sales Service
factors_ retailers	Factors of consideration while purchasing appliances: Retailers' Quality	loan	Whether the households took any loans to buy appliances or not
price_stat	Preference of pricing strategy regarding energy and gas	red_act	Whether the households adopt any act to reduce power and energy consumption
renewable_no	Awareness level regarding renewable energy: No idea	renewable_lil	Awareness level regarding renewable energy: Little

(Table 1 contd.)

(Table 1 contd.)

Variable Indicators	Variable Names	Variable Indicators	Variable Names
renewable_mod	Awareness level regarding renewable energy: Moderate	renewable_gd	Awareness level regarding renewable energy: Good
educ_hh_below12	Highest education level within a household: Below 12th grades	educ_hh_post	Highest education level within a household: Post graduate or above
educ_hh_grad	Highest education level within a household: Graduate	educ_hh_12	Highest education level within a household: 12th Grades
lpg_size	The LPG cylinder size used in a household	bill_elc	Average monthly electricity bill
bill_gas	Average monthly gas bill	wood_cost	Average monthly cost on wood fuel

Source: CPD Residential Energy Survey and authors' calculation.

3.4 Data Analysis

As the first step of data analysis, the primary survey data is cleaned using STATA 16.0, Microsoft Excel, and RStudio. Then, a few variables, such as, dependency ratio, etc. are constructed along with some disaggregated dummy variables from categorical variables.

The data analysis plan unfolded in multiple steps, commencing with the creation of an index using PCA, amalgamating three expenditure variables (electricity bill, gas bill, and wood fuel cost). Since consumption can be represented by expenditure, it is justified to use the expenditure variables to construct an index that will show the households' energy and power consumption behaviour (Aguiar & Hurst, 2005). Additionally, this study employs Kaiser-Meyer-Olkin or KMO test to justify the indexation. Subsequently, a sophisticated multivariate regression model, specifically multivariate Ordinary Least Squares (OLS),

3.5 Specification of Econometric Model

A multivariate OLS model is employed for our purpose and the specification of the econometric model is given below:

$$
\begin{aligned}
cs_i = {} & \alpha_0 + \alpha_1 gender_i + \alpha_2 age_i + \alpha_3 dr_i + \alpha_4 numhh_i + \alpha_5 student_i + \alpha_6 agri_i + \alpha_7 govt_i \\
& + \alpha_8 pvt_i + \alpha_9 self_i + \alpha_{10} inc\_10_i + \alpha_{11} inc\_20_i + \alpha_{12} inc\_30_i + \alpha_{13} inc\_40_i \\
& + \alpha_{14} inc\_50_i + \alpha_{15} inc\_75_i + \alpha_{16} inc\_100_i + \alpha_{17} inc\_more100_i \\
& + \alpha_{18} fan\_number_i + \alpha_{19} tv\_avail_i + \alpha_{20} ac\_avail_i + \alpha_{21} refg\_avail_i \\
& + \alpha_{22} pump_i + \alpha_{23} elc\_machine\_mwoven_i + \alpha_{24} elc\_machine\_rcooker_i \\
& + \alpha_{25} factors\_cost_i + \alpha_{26} factors\_popular_i + \alpha_{27} factors\_durable_i \\
& + \alpha_{28} factors\_engsav_i + \alpha_{29} factors\_discount_i + \alpha_{30} factors\_warranty_i \\
& + \alpha_{31} factors\_asales_i + \alpha_{32} factors\_retailers_i + \alpha_{33} loan_i + \alpha_{34} price\_stat_i \\
& + \alpha_{35} red\_act_i + \alpha_{36} renewable\_lil_i + \alpha_{37} renewable\_mod_i + \alpha_{38} renewable\_gd_i \\
& + \alpha_{39} educ\_hh\_post_i + \alpha_{40} educ\_hh\_grad_i + \alpha_{41} educ\_hh\_12_i + \alpha_{42} lpg\_size_i \\
& + \mu_i
\end{aligned}
$$

Here, i = 1, 2, 3..... 500th household

μ_i = Residual term of the model for ''-th household and

cs_i = Consumption score of 'i'-th household

was employed to unravel the intricate relationships between various factors and the energy and power consumption score. In order to reduce noise in the regression model, some variables are dropped out from the analysis.

3.6 Statistical Tests

Heteroscedasticity Test: For testing heteroscedasticity, White's General Heteroscedasticity test will be conducted and if the variance of the errors is found heteroscedastic, White's Heteroscedasticity Constant Variance will be used to solve the issue (Gujarati & Porter, 2009).

Multicollinearity Test: For multicollinearity test, pair-wise correlation coefficient matrix is used and if the value of the pairwise correlation coefficient between two variables is greater than 0.8, there seems to have higher multicollinearity between two variables, and necessary treatments have to be undertaken to fix the issue (Gujarati & Porter, 2009).

Significance of the model: Since the study employs a multivariate OLS regression model, the value of adjusted R2 and F-value of the model will indicate whether the model is a good fit and significant or not.

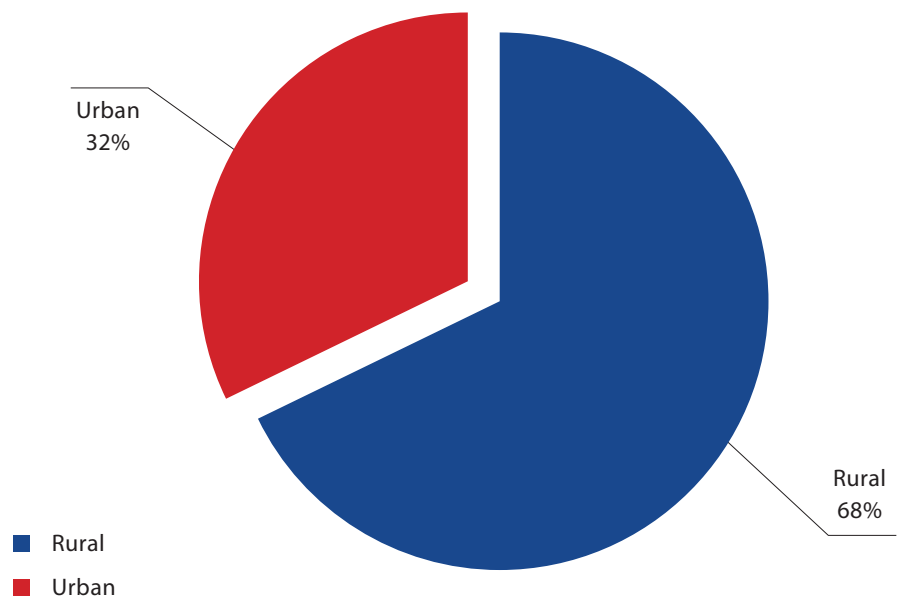
Test for Sampling Adequacy: In order to estimate whether the indexation of the variables is justified or not, Kaiser-Meyer-Olkin test for sampling adequacy will be employed and if the KMO value is more than 0.5, it can be said that the indexation is valid (SPSS, 2021).

4. Results and Findings

4.1 Descriptive Statistics

Drawing from the survey, this section presents key information about the sample, including demographic and socio-economic characteristics, environmental awareness levels, the utilisation of various machinery, consumption patterns of various fuels, and expenditures related to energy and power consumption.

Figure 1 **Sample distribution (urban-rural)**

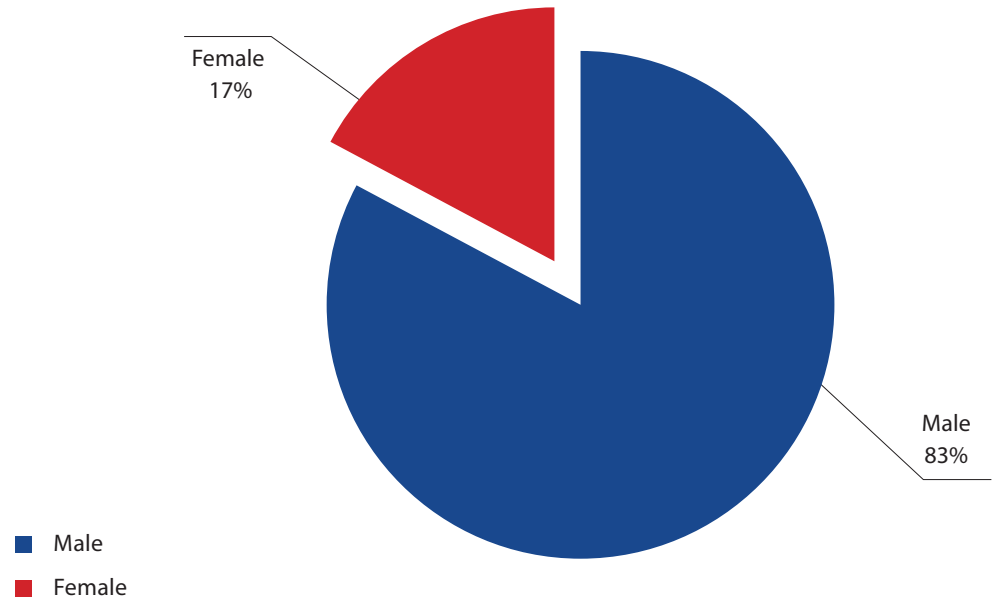


Source: Authors' calculation.

Urban-Rural Distribution

Figure 1 illustrates the distribution of nationwide surveyed households based on the rural and urban characteristics of their neighbourhoods. The distribution of the samples is also aligned with the urban-rural sample distribution of Household Income and Expenditure Survey (HIES) – 2016, where the urban households covered 30.36 per cent of the sample (BBS, 2023).

Figure 2 **Gender of households' primary earner**



Source: Authors' Calculation.

Sex of Households' Primary Earner

Figure 2 illustrates the distribution of sex across the nationwide surveyed households. This result is consistent with the findings of (HIES-2022), where the study found that 12.6 per cent households are female led (BBS, 2023).

Education Level of the Household

In this section, we categorised the highest education level into two groups: the highest education level of the household and the highest education level of the household head, presenting the results in Figure 3. The distribution of the highest education level among household heads is relatively even, ranging from illiterate to post-graduate levels. However, the highest education level among other household members shows a clear inclination towards higher education levels and minimal inclination towards lower education levels. This indicates that, even if the household head who themselves may not have pursued education, there is a consistent effort to ensure higher education for other members of the household.

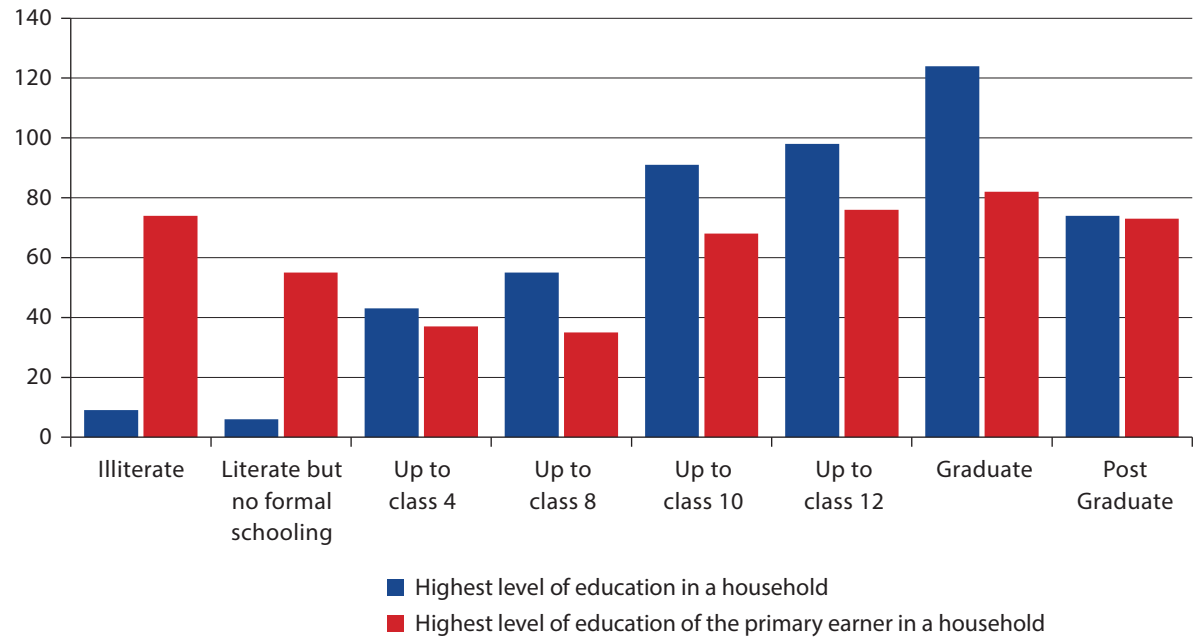
Age of Households' Primary Earner

The mean age of the household's primary earner is approximately 40.7 years, with a minimum age of 18 years and a maximum age of 70 years. Moreover, the mean age of the primary earner of rural and urban households stands at 41.58 years and 38.84 years, respectively.

Number of Members in the Households

From Table 2, it is evident that the distribution of the number of members in a household aligns with the

Figure 3 **Highest level of education**



Source: Author's calculation.

Table 2 **Number of members in the households (total and age-wise)**

	Mean	Proportion in the Total Population	Minimum	Maximum
Total number of members in a household	5.15	100%	1	16
Age-wise distribution of Number of members in a household				
Under 18 years old	1.48	28.7%	0	6
18 to 40 years old	2.28	44.34%	0	10
41 to 60 years old	1.17	22.8%	0	6
61 years old and above	0.23	4.2%	0	8

Source: Authors' calculation.

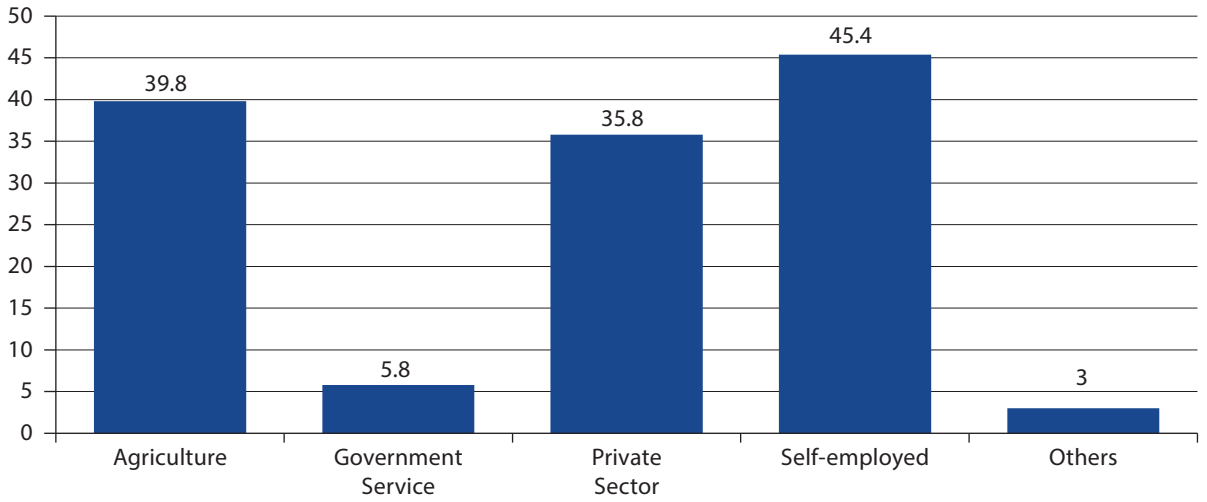
proportions observed in HIES 2022 for each age group relative to the total population. Additionally, the sample exhibits a mean household size of 5.15, slightly surpassing the figure found in HIES 2022, which stands at 4.26 (BBS, 2023). Furthermore, the mean number of students in the surveyed households is around 1, ranging from a minimum of 0 to a maximum of 5.

Earning Source of the Households

Figure 4 illustrates that a significant majority of households rely on agriculture, private sector and self-employment as their primary sources of income, reflecting the economy's high dependence on agriculture, private sector, businesses and informal jobs.

Figure 4 **Earning sources of the households**

(in per cent)



Source: Authors' calculation.

Households' Monthly Expenditure on Power and Energy

Table 3 provides a summary of the monthly household expenditures on electricity, gas, and wood fuel. Notably and logically, the average household expenditure on electricity surpasses that on gas or wood fuel. Moreover, it is observed in the study that the households' average electricity stands at the highest position during March to June and the lowest during November to February (See Appendix–2). Additionally, it can be seen from table 3 that the average monthly cost on wood fuel is almost equal between rural and urban neighbourhood, although the average monthly expenditure on electricity and gas is higher in the urban neighbourhood than the rural ones. It is unusual to find almost equal monthly wood cost in both urban and rural neighbourhood.

Moreover, from figure 5, we can see that the average monthly expenditure on electricity and gas increases in accordance with an increase in the income. However, average monthly expenditure on wood fuel decreases as income increases and it reaches BDT 0 (zero) for the income group that earns above BDT 75,000 monthly.

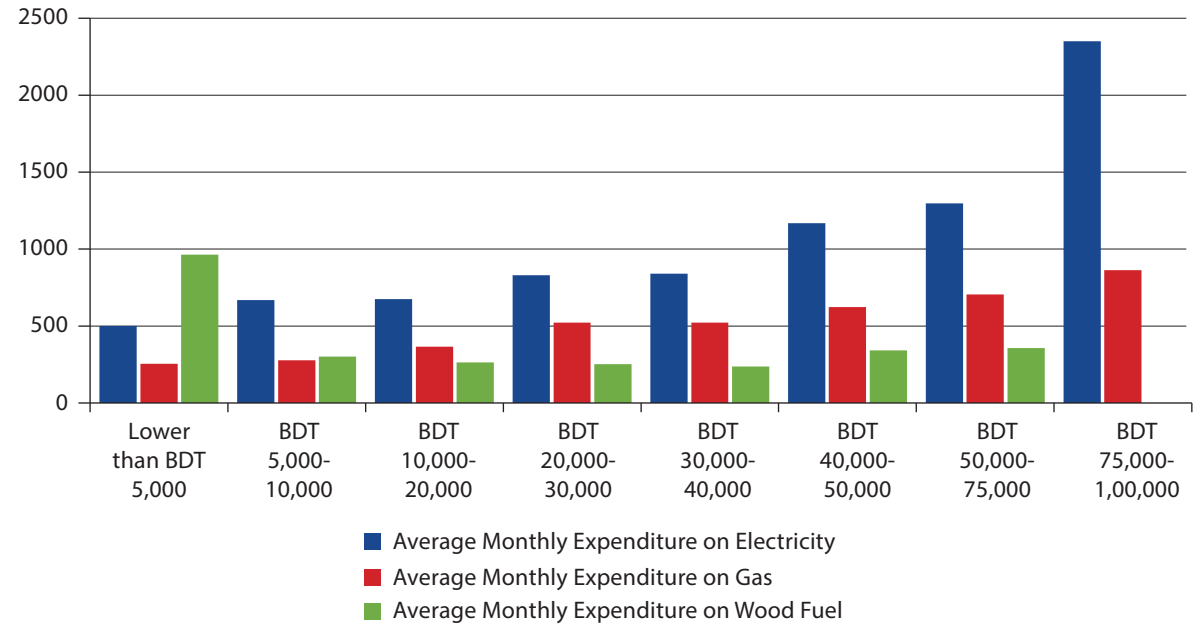
Table 3 **Households' monthly expenditure on power and energy**

	Mean	Std. Dev.	Min	Max
Monthly gas bill (in BDT)	455.516	545.3855	0	1,480
Monthly electricity bill (in BDT)	800.464	524.0531	200	5,000
Monthly wood-fuel cost (in BDT)	271.86	638.7723	0	8,000
Urban-Rural Disparity				
Monthly gas bill (in BDT)	956.17		726.52	
Monthly electricity bill (in BDT)	654.75		360.9	
Monthly wood-fuel cost (in BDT)	271.12		272.2	

Source: Authors' calculation.

Figure 5 **Monthly expenditure on power and energy by income groups**

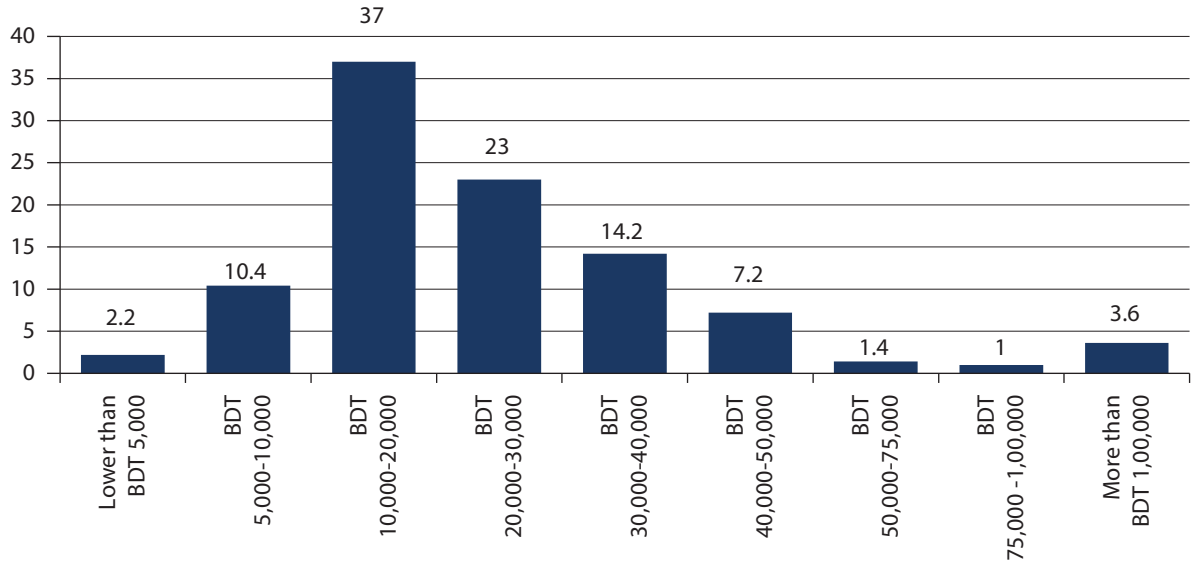
(in BDT)



Source: Authors' calculation.

Figure 6 **Household distribution across monthly income groups**

(in per cent)



Source: Authors' calculation.

Monthly Income of the Households

Figure 6 illustrates that the households surveyed have a high concentration in income ranged from BDT 10,000 to BDT 40,000, which is intuitively consistent with the mean monthly household income found in HIES – 2022, which is BDT 32,422 (BBS, 2023). Moreover, the high concentration around the middle income range also validates the representative attribute of the data.

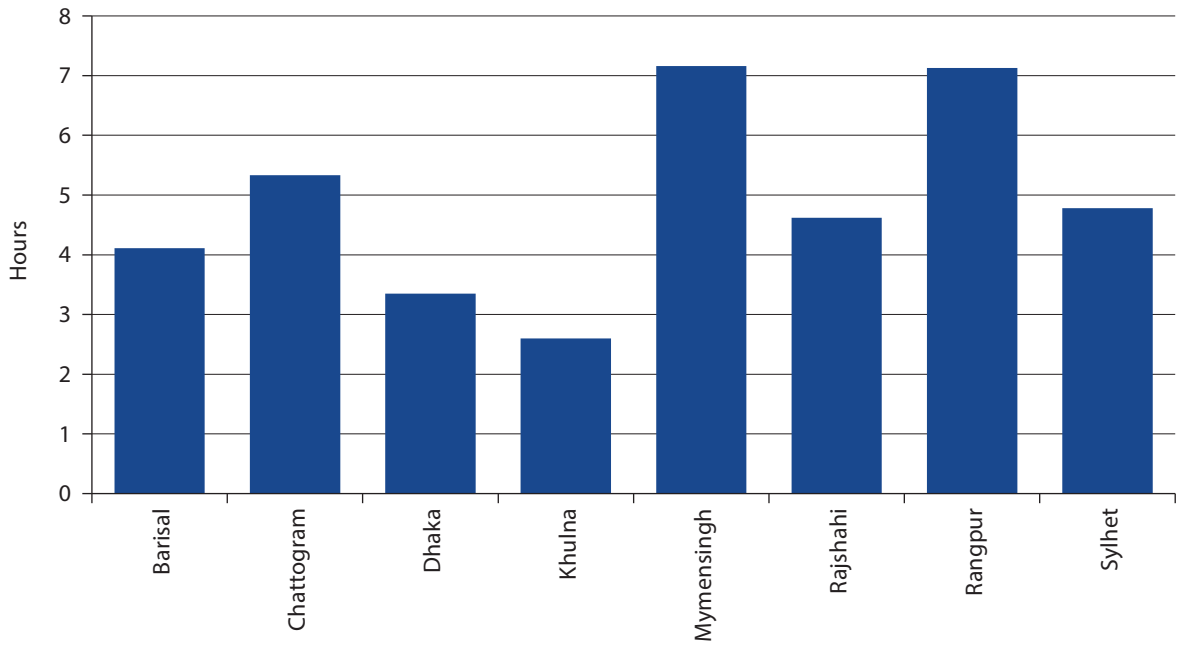
Availability of Grid Electricity in the households

According to the survey, 98 per cent of the households have electricity connection in their house, which is consistent with the figure from HIES–2022, that shows that 99.34 per cent of the households have electricity connection (BBS, 2023). Moreover, according to the survey, only 1 per cent of the households use solar electricity for lighting up their houses.

Daily Average Hours of Electricity Unavailability in the Households

The daily average hours of electricity unavailability in households exhibit a mean duration of 4.612 hours, with a minimum of 0 hours and a maximum of 13 hours. Although the maximum hours of electricity unavailability are consistent with the actual scenario, the depicted figure shows both consistent and contrasting result with the information reported by some newspapers in Bangladesh (Mohiuddin, 2023; Kaler Kantho, 2023; Unzum, 2023). However, considering the timeline of the study, the result is consistent with the actual scenario which makes the sample more representative of the actual scenario. From figure 7, it is evident that the average daily hours of electricity unavailability have a zonal distribution effect and it is consistent with the zone-wise hours of load shedding at evening peak, calculated from the official source (Moazzem, Quaiyyum, Preoty, &

Figure 7 **Average daily hours of electricity unavailability across divisions**



Source: Authors' calculation.

Jebunnesa, 2023). The consistency is illustrated by the fact that Mymensingh and Rangpur divisions have the longest hours of electricity unavailability in CPD's survey and in official data source. Again, it illustrates the representativeness of the data.

Number of Fans in the Households

From figure 8, it can be observed that, majority of the households have 2 fans in their house, with a mean of 2.6 fans per household. It is noteworthy that average number of fans in both rural and urban households are almost equal with a value of around 2.5.

Number of TVs in the Households

It is noticeable from figure 9 that majority of the households have Televisions in their house, with a good proportion of households owning one television. Only 31.4 per cent of the households reported having on televisions in their house. It is consistent with the actual scenario which states that as of 2019, 64 per cent of households in Bangladesh owned a television set (Beximco, 2021).

Availability of AC in the Households

From figure 10, it can be said that majority of the households do not own any air conditioner, reflecting the actual scenario of Bangladesh.

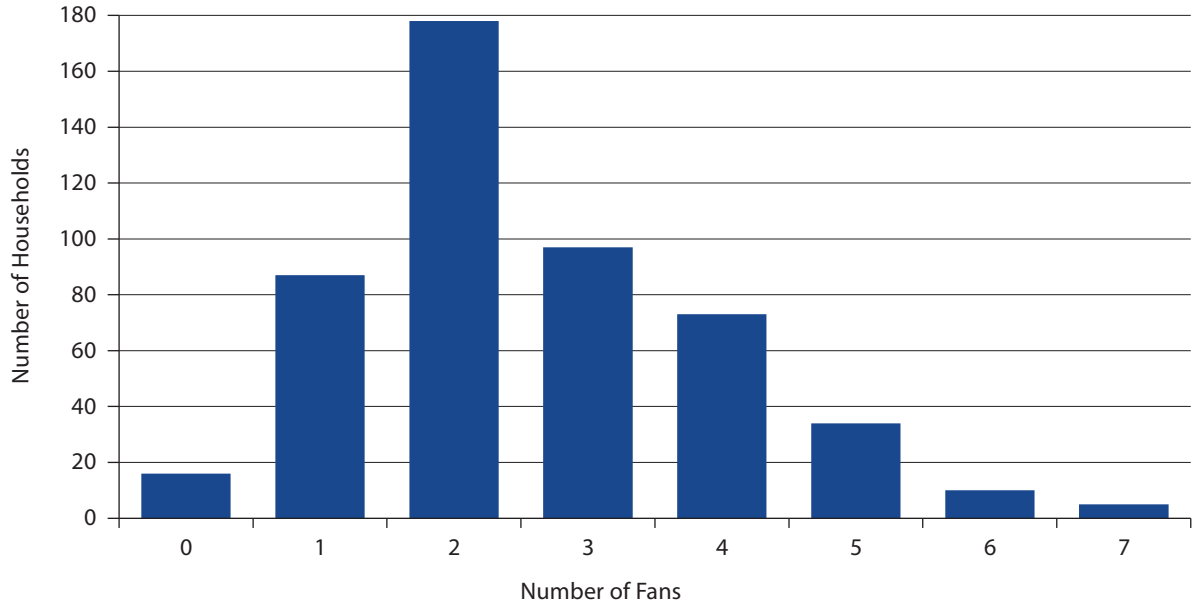
Number of Refrigerators in the Households

Figure 11 illustrates that the majority of surveyed households reported owning at least one refrigerator in their house, with 31.4 per cent of households indicating no refrigerators.

Number of Water Pump in the Households

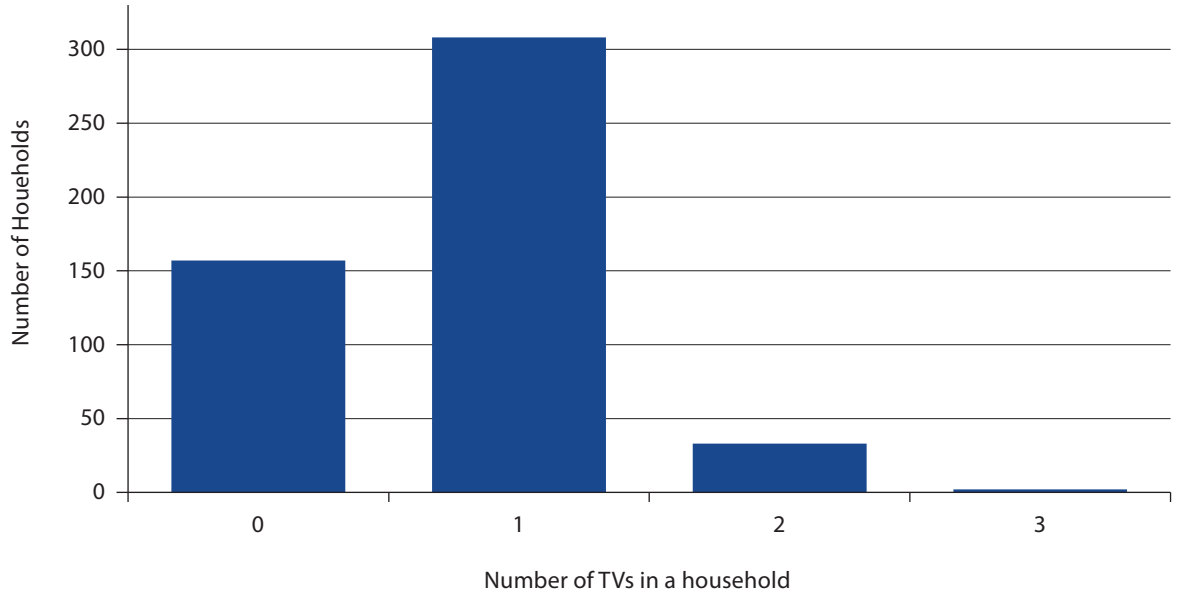
As indicated by figure 12, 41 per cent of the households reported owning water pump. This may reflect a significant reliance on private water supply systems or

Figure 8 **Number of fans in the households**



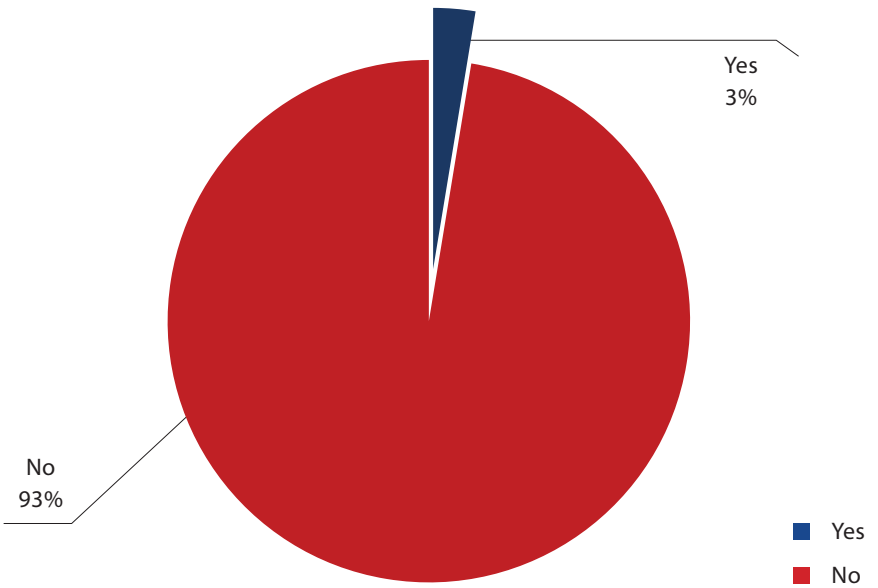
Source: Authors' calculation.

Figure 9 **Number of TVs in the households**



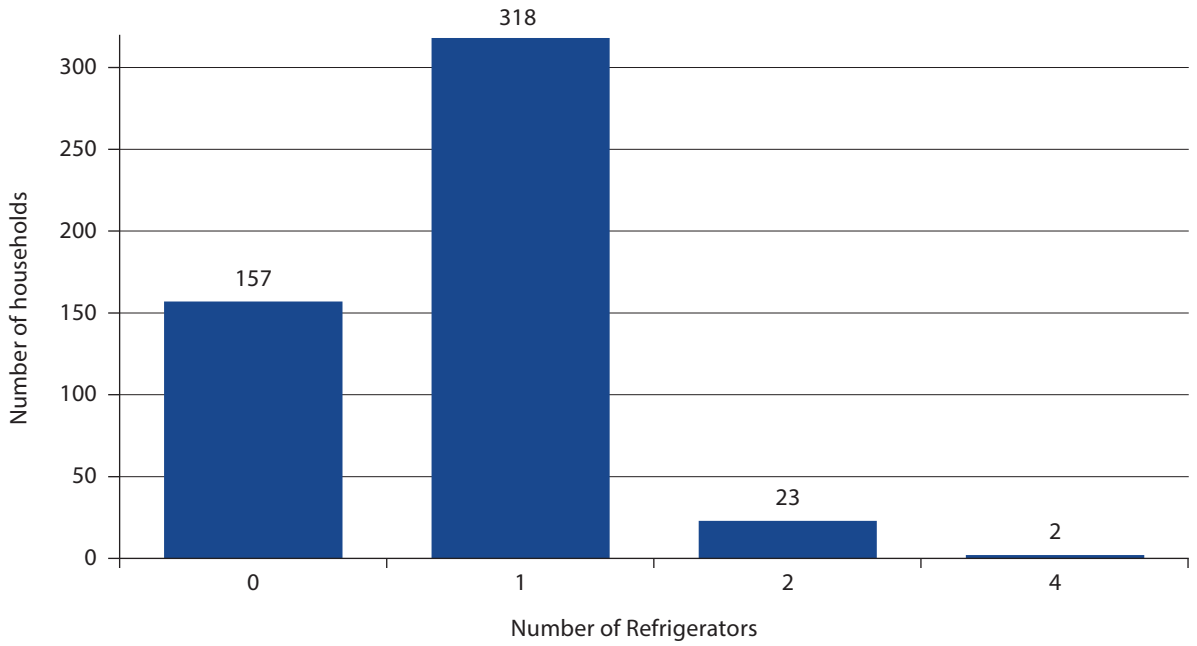
Source: Authors' calculation.

Figure 10 **Availability of AC in the households**



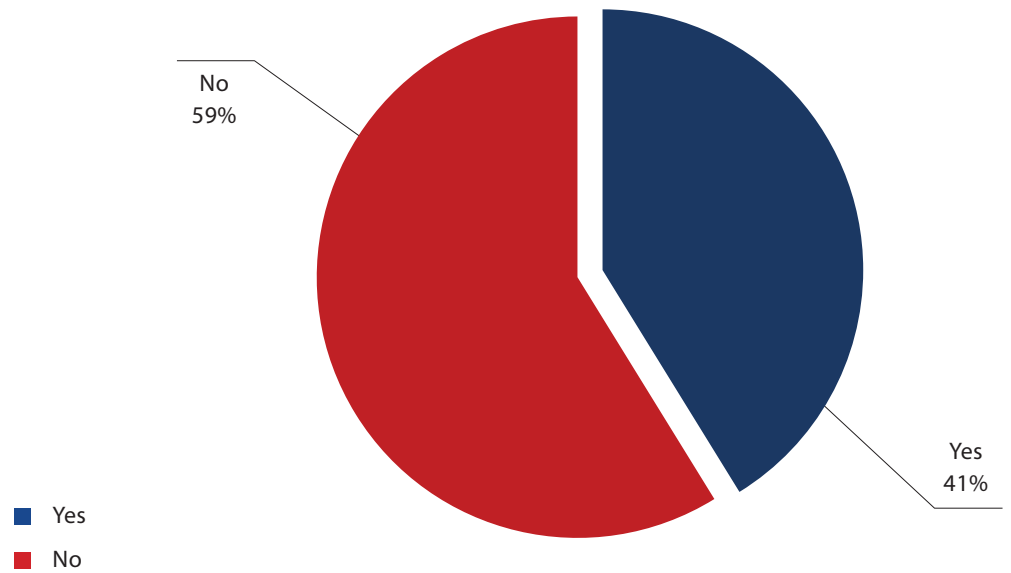
Source: Authors' calculation.

Figure 11 **Number of refrigerators in the households**



Source: Authors' calculation.

Figure 12 **Availability of water pump in the households**



Source: Authors' calculation.

an emphasis on water resource management at the household level (Argaw, Foster, & Ellis, 2003).

Factors the Households Consider while Purchasing Behaviour of Appliances and Machines

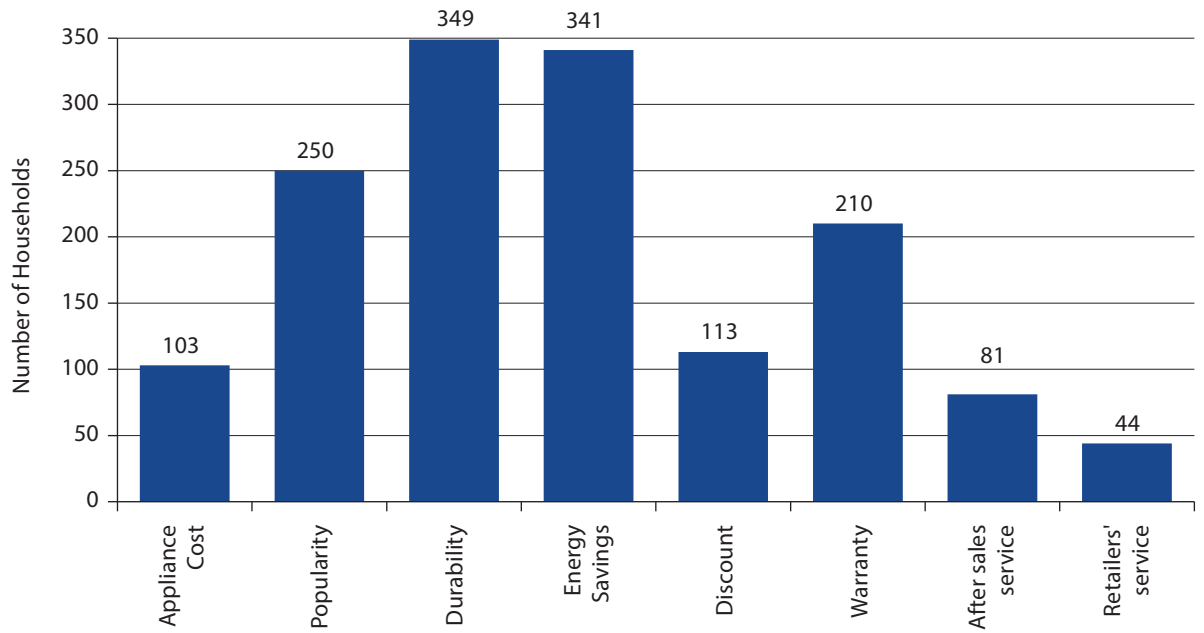
From Figure 13, it is evident that, when purchasing appliances or machines, the majority of households prioritise factors such as durability, popularity, warranty, and energy efficiency. This reflects a consumer emphasis on long-lasting, well-known, and energy-efficient products, possibly driven by a desire for reliability and sustainability in their purchases.

The data presented in Figure 14 indicates a notable absence of disparity between rural and urban households in their consideration of various factors during appliance purchases. This intriguing finding suggests a level of uniformity in the factors influencing purchasing decisions across diverse household settings.

Awareness Level of Households on Renewable Energy

Figure 15 indicates that nearly half of the surveyed households have no knowledge about renewable energy, while only 29.4 per cent consider themselves to have at least a moderate level of awareness. This situation is concerning, given that 77.4 per cent of the surveyed households have a member who has completed at least high school, and 39.6 per cent have reported having a household member who has achieved a university bachelor's degree, suggesting a potential gap in awareness despite higher education levels.

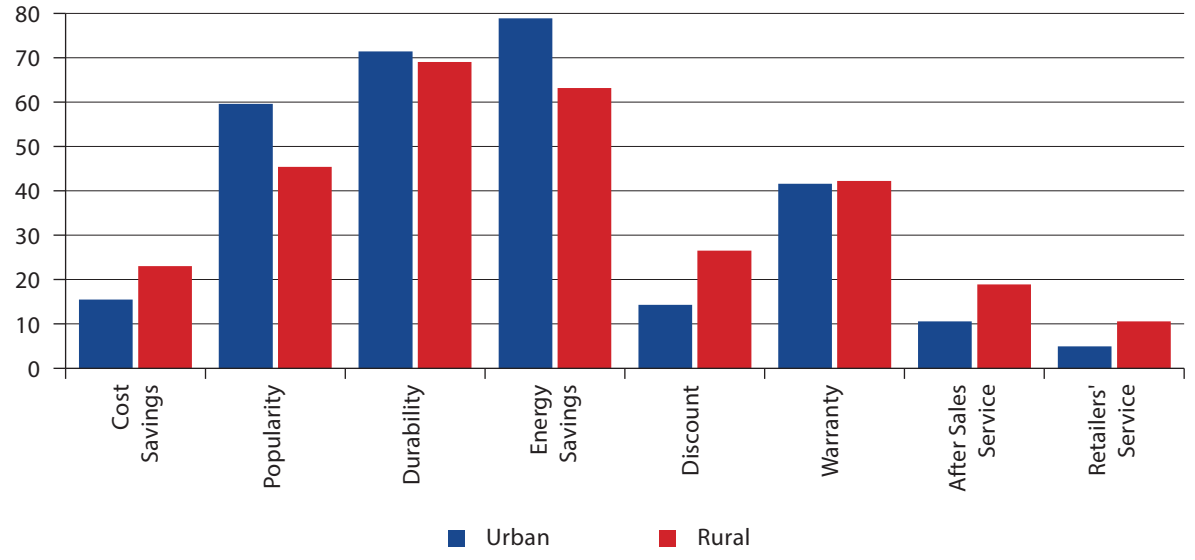
Figure 13 **Factors the households consider while purchasing behaviour of appliances and machines**



Source: Authors' calculation.

Figure 14 **Proportion of households across rural and urban neighbourhoods considering various factors while purchasing appliances**

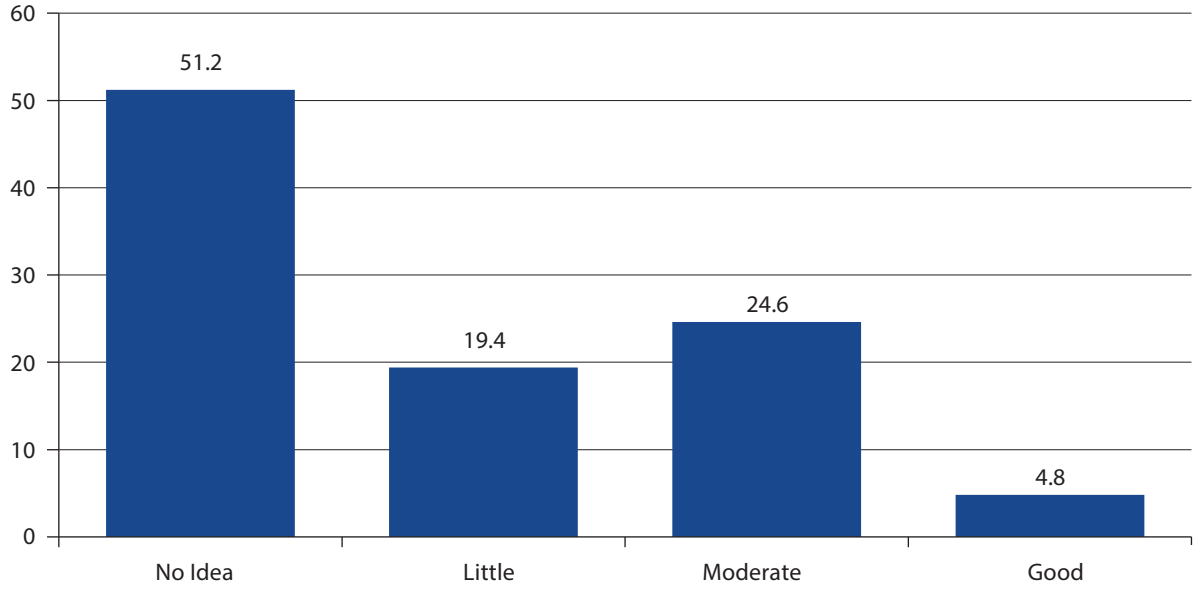
(in per cent)



Source: Authors' calculation.

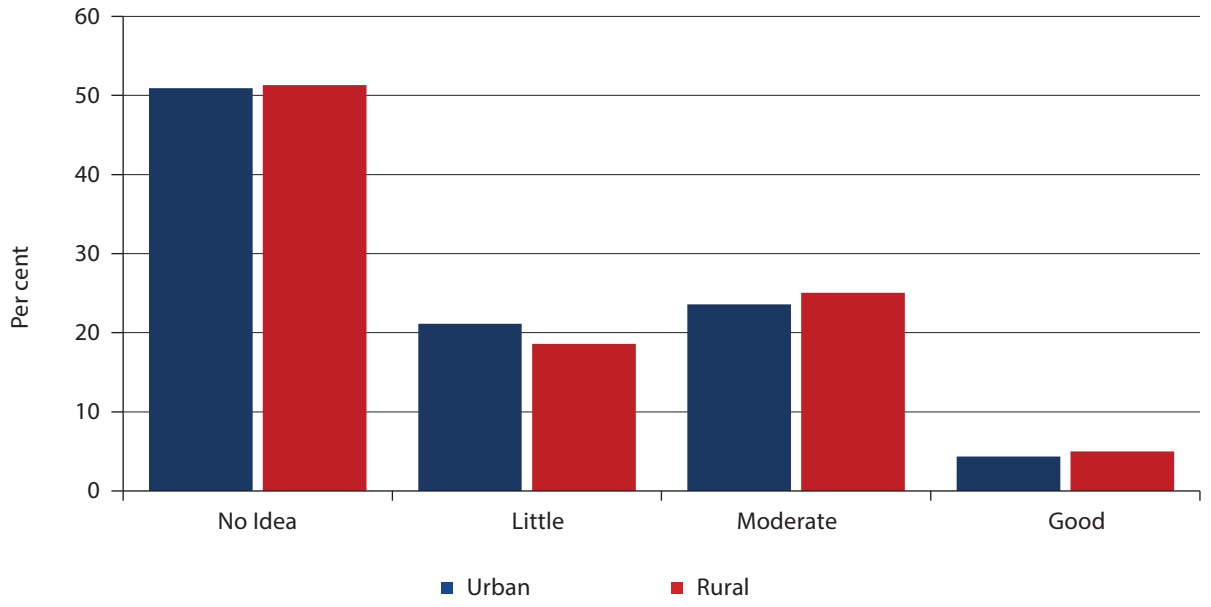
Figure 15 **Proportion of households across various awareness level on renewable energy**

(in per cent)



Source: Authors' calculation.

Figure 16 **Proportion of households across rural and urban neighbourhoods with various degree of awareness level about renewable energy**



Source: Authors' calculation.

Furthermore, as depicted in Figure 16, there is no significant distinction between rural and urban households when reporting a moderate to good level of awareness about renewable energy. However, it is noteworthy that the proportion of rural households with moderate to good awareness levels is slightly higher than that of urban households, presenting a somewhat contradictory observation. One plausible explanation for this phenomenon could be the proactive pursuit of alternative power and energy sources by rural households, driven by the more frequent occurrence of power and energy unavailability in rural areas.

Number of Households with Electricity-based Cooking Appliance

Figure 17 illustrates the fact that 27.8 per cent of the households use electric rice cooker and only 2 per cent of the households use microwave oven in addition to stove (gas based or plant based).

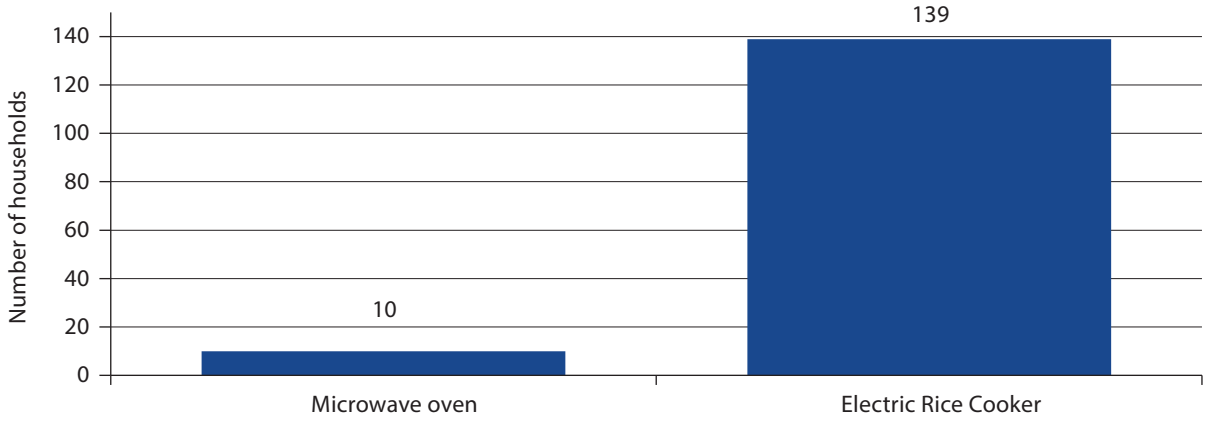
Connection Cost of LPG

Households with the Liquified Petroleum Gas (LPG) connections reported an average cost of BDT 3,279.032, ranging from a minimum of BDT 300 to a maximum of BDT 5,000.

Size of LPG Cylinders across Households

Figure 18 illustrates the fact that 14 per cent of the households who have LPG connection have reported using large size (14 KG) cylinders whereas the rest reported to use small size (less than or equal 5 KG) cylinders. Our analysis reveals a notable trend where 84.38 per cent of rural households using LPG cylinders opt for small-sized ones, while in urban areas, 89.66 per cent of LPG users choose small-sized cylinders. This discrepancy adds an interesting layer to the contrasting consumption patterns between rural and urban settings.

Figure 17 **Number of households with electricity-based cooking appliance**

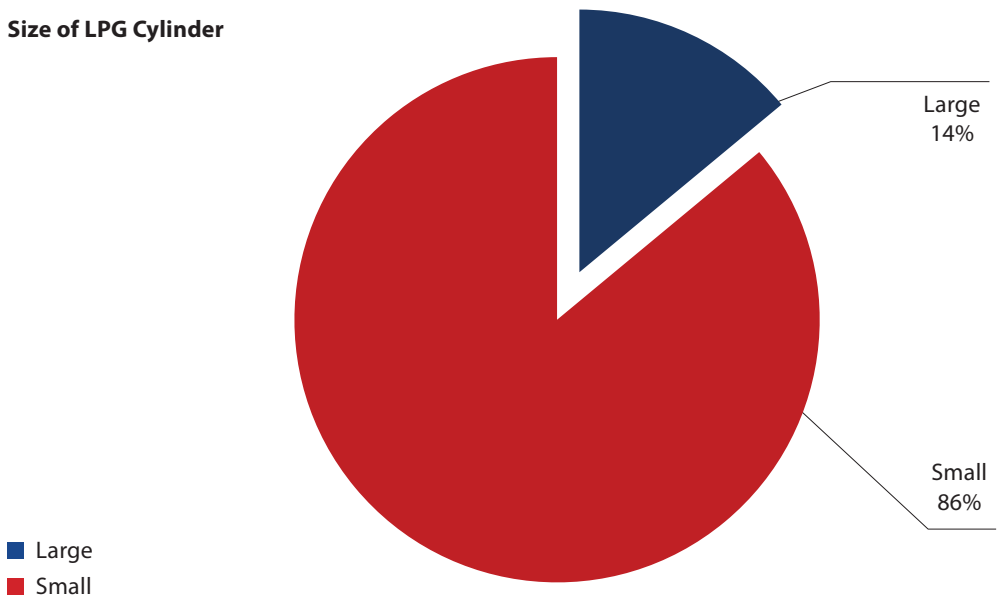


Source: Authors' calculation.

Whether the Households Took Any Loan to Buy Appliances and Machine or Not

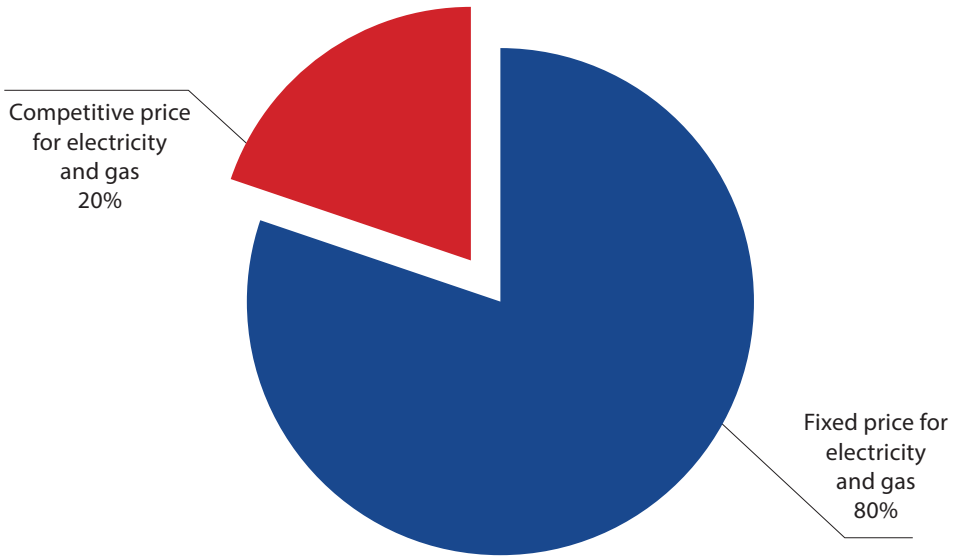
From the study it can be illustrated that 94 per cent of the households reported not taking loans to buy appliances and machines. This finding suggests that a significant majority of households did not rely on loans for the purchase of appliances and machines, reflecting a preference for other financial means or resources for such acquisitions.

Figure 18 **Size of LPG cylinders used in the households**



Source: Authors' calculation.

Figure 19 **Households' preference for pricing strategy**



Source: Authors' calculation.

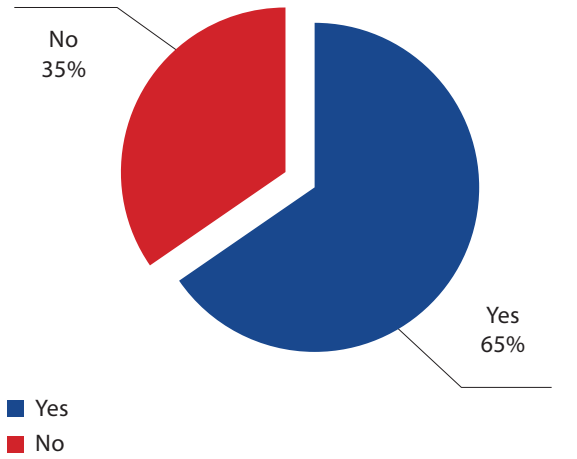
Households' Preference for Pricing Strategy

From the study, it can be stated that 20 per cent of the households prefers competitive pricing strategy for electricity and gas over fixed pricing strategy (see figure 19). The fact that only 20 per cent of households prefer a competitive pricing strategy for electricity and gas, while the remaining 80 per cent opt for a fixed strategy, suggests that a significant majority of households prioritise stability and predictability in their energy expenses. This preference for fixed pricing indicates a preference for consistent, predetermined costs, possibly to better manage and budget for household expenses without being affected by market fluctuations. Additionally, our examination reveals that 77.88 per cent of residents in rural areas advocate for a fixed price strategy for power and energy, whereas 85.1 per cent of their urban counterparts prefer the same. This unexpected finding suggests that rural households may be more receptive to embracing a market-based pricing strategy, challenging common assumptions. Moreover, approximately 86 per cent of respondents advocating for a fixed pricing strategy have a monthly income below BDT 40,000. This implies a possible concern among lower and middle-income families about the uncertainties associated with variable pricing strategies. Similarly, among the respondents who prefer a market-based pricing strategy, 90.91 per cent have a monthly income below BDT 40,000. This indicates a correlation between the preference for market pricing and lower income levels among the surveyed population. In conclusion, it can be said that this result might arise because of high concentration of sample being aligned towards the aforementioned range of income. Hence, it can be said intuitively that monthly income does not have any association with households' preference of pricing strategy of power and energy.

Households that Took Initiatives to Reduce Expenditure on Electricity and Gas

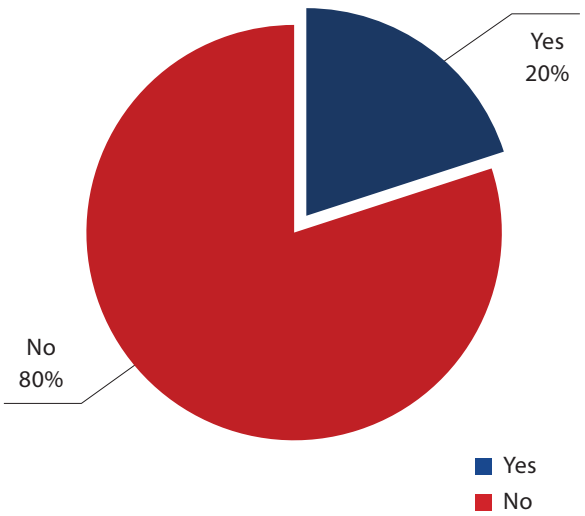
Figure 20 illustrates the fact that 65 per cent of the households took initiative to reduce expenditure on electricity and gas as a fighting measure against the increasing cost or expenditure on electricity and gas, and the rest did not. This suggests a level of financial awareness and adaptability among the majority, demonstrating their responsiveness to economic challenges by actively seeking ways to curtail energy-related expenses. In term of rural-urban disparity, no

Figure 20 **Number of households that took initiatives to reduce expenditure on electricity and gas**



Source: Authors' calculation.

Figure 21 **Households' willingness to pay for renewable energy**



Source: Authors' calculation.

significant difference can be seen in this case. In this case, we cannot clearly draw any conclusion whether monthly income of a household is associated with the decision of a household taking initiatives to reduce expenditures on electricity and gas or not.

Households' Willingness to Pay for Renewable Energy

The data depicted in Figure 21 indicates that a mere 20 per cent of the households expressed a willingness to pay for renewable energy. In contrast, a substantial majority of households showed a reluctance to incur additional costs for renewable energy. This suggests a prevailing hesitancy or lack of inclination among the surveyed households to invest in or prioritise renewable energy sources, possibly influenced by cost considerations or other factors. In this scenario, it is evident that a relatively smaller proportion of urban households (15 per cent) are inclined to pay extra for renewable energy compared to their rural counterparts (22 per cent). Additionally, it can also be found in our analysis that monthly income of a household does not affect the decision in this case.

4.2 Econometric Soundness of the Model

In order to check econometric soundness of the study, the following issues are investigated: multicollinearity, homoscedasticity, indices validation, and significance level of the model.

Multicollinearity

From appendix 3 (table no. 7), it can be concluded that since there is no correlation coefficient between two variables across explanatory variables which has a value more than or equal to 0.80, there exists no multicollinearity among the explanatory variables.

Heteroscedasticity

From appendix 4 (table no. 8), it can be said that based on the p-value of 0.4655 obtained from White's test for homoskedasticity, we fail to reject the null hypothesis. Therefore, there is not enough evidence to suggest

that there is unrestricted heteroskedasticity. In simpler terms, based on this test, it does not appear that there is evidence of heteroskedasticity, and we may consider the data to be homoscedastic.

Sampling Adequacy

From appendix 5 (table no. 9), it can be seen that the overall KMO is greater than 0.5, suggesting moderate sampling adequacy for conducting factor analysis on these variables. The individual KMO values for each variable are in the moderate range, indicating that each variable contributes somewhat to the overall sampling adequacy. Hence, it is justified to use Principal Component Analysis to estimate an index that represents the consumption behaviour of the households.

Overall Significance of the Model

According to the post-estimation result tabulated in appendix 6 (table no. 10), the statistical tests applied to the multivariate regression model indicate its overall significance, particularly demonstrated by a noteworthy adjusted R-square of 0.4472, which implies that the model is effective in capturing and explaining a substantial portion of the variability in the observed data.

4.3 Results and Findings

Although the rural-urban dimension is dropped out from the regression model in order to reduce the noise of the model, it is obvious and established through previous literatures conducted in Bangladesh that the urban households will consume more power and energy than the rural households (Baul, Datta, & Alam, 2018; Foysal, et al., 2012; Miah, Foysal, Koike, & Kobayashi, 2011).

Starting with a summary of our findings, we will dive into the details. Firstly, the study reveals that demographic factors such as the sex and age of the household head exhibit limited independent influence on power and energy consumption. Surprisingly, household size, while significantly associated, shows a negative relationship with energy consumption, suggesting larger households tend to be more energy-efficient collectively. Income dynamics showcase nuanced patterns, challenging traditional income-consumption assumptions, with a spike in consumption observed for higher income brackets. Appliance ownership, cost considerations, popularity, and financial aspects also contribute to diverse consumption patterns. Intriguingly, knowledge about renewable energy emerges as a significant factor, emphasising the role of environmental

Table 4 Summary of regression results

VARIABLES	(1) Consumption_score	VARIABLES	(1) Consumption_score
gender	0.209 (0.198)	pump	0.0803 (0.166)
age	0.00477 (0.00668)	elc_machine_mwoven	1.444*** (0.445)
dr	-0.301 (0.215)	elc_machine_rcooker	0.278* (0.164)
numhh	-0.117*** (0.0355)	factors_cost	0.356* (0.192)
student	0. (0.107)	(0.107)	0.280* (0.154)
agri	-0.264 (0.166)	factors_durable	-0.229 (0.170)
govt	-0.716** (0.292)	factors_engsav	0.466*** (0.156)

(Table 4 contd.)

(Table 4 contd.)

VARIABLES	(1) Consumption_score	VARIABLES	(1) Consumption_score
pvt	-0.338*	factors_discount	0.00389
	(0.179)		(0.184)
self	-0.0370	factors_warranty	-0.00533
	(0.174)		(0.171)
inc_10	0.00940	factors_asales	-0.127
	(0.477)		(0.222)
inc_20	0.515	factors_retailers	-0.254
	(0.443)		(0.237)
inc_30	0.590	loan	-0.500*
	(0.464)		(0.280)
inc_40	0.884*	price_stat	-0.168
	(0.475)		(0.221)
inc_50	0.893*	red_act	0.168
	(0.528)		(0.156)
inc_75	0.349	renewable_lil	0.0497
	(0.678)		(0.221)
inc_100	5.004***	renewable_mod	-0.438**
	(1.005)		(0.181)
inc_more100	1.328**	renewable_gd	-0.822**
	(0.534)		(0.327)
fan_number	0.0613	educ_hh_post	-0.191
	(0.0656)		(0.237)
tv_avail	-0.00241	educ_hh_grad	-0.0613
	(0.187)		(0.199)
ac_avail	0.0871	educ_hh_12	-0.317
	(0.514)		(0.209)
refg_avail	0.445*(	lpg_size	0.187
	0.264)		(0.289)
pump	0.0803	Constant	-0.542
	(0.166)		(0.627)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: CPD Residential Energy Survey and authors' calculation.

awareness. Importantly, the size of the LPG cylinder does not impact consumption behaviour. These findings offer a comprehensive understanding of the multifaceted aspects shaping household energy consumption, contributing to a nuanced perspective for policymakers and researchers alike. The summary of the regression result can be found below in table 4.

The results of the regression analysis, presented in table 4, indicate that the sex of the household head is not significantly associated with power and energy consumption behaviour, holding other factors constant. Intuitively, since the energy and power consumption behaviour does not determine the sex of the household head or the selection of a household head based on

their gender, it implies that a causal relationship might exist from the sex of the household head to decision-making process regarding consumption patterns. However, our analysis reveals that there exist no association between these two factors.

The results of the regression analysis, presented in table 4, indicate that the sex of the household head is not significantly associated with power and energy consumption behaviour, holding other factors constant. Intuitively, since the energy and power consumption behaviour does not determine the sex of the household head or the selection of a household head based on their sexes, it implies that the decision-making process regarding consumption patterns might be determined by the sex of the household head. In other words, intuition suggests a one-way causal relationship from the sex of the household head to power and energy consumption behaviour, but it can be said that the sex of the household head does not play a significant role in determining the efficiency or inefficiency aspect of power and energy consumption behaviour in the households.

Similarly, holding other factors constant, the age of the household head does not exhibit any significant association with power and energy consumption behaviour, according to the regression analysis results. Intuitively, since power and energy consumption cannot determine the age of the household head, we can strongly assume a unidirectional determining relationship between the household head's age to their energy and power consumption behaviour but as we have seen that the age of the household head is not a determining factor in shaping the efficient or inefficient usage of power and energy within the household.

In terms of household size, holding other factors constant, we can find a significant association between number of members in a household and energy consumption behaviour. However, our analysis suggests a negative association between them. This suggests that, on average, larger households tend to exhibit more energy-efficient consumption behaviour. This implies a collective effort in reducing energy and power consumption within households. Additionally, the analysis indicates that the dependency ratio, representing the proportion of dependent members in a household relative to those who are not dependent, does not exhibit a statistically significant relationship with energy and power consumption behaviour when other factors are controlled. Interestingly, the positive significant relationship between the total number of students in a household and energy consumption behaviour unveils a distinct aspect, holding other factors constant. The increase in energy consumption is likely tied to the additional power and energy needs associated with educational activities. So, it can be concluded that what matters in shaping household energy and power consumption behaviour is the total number of members and students in a household, and the dynamics of dependency within a household do not matter.

The analysis indicates that households with monthly incomes between BDT 5,000 and 30,000 do not exhibit a significant difference in energy and power consumption behaviour compared to the base category (income less than BDT 5,000). However, there is a noteworthy increase in energy consumption for households earning between BDT 30,000 and 40,000, as well as those with incomes exceeding BDT 40,000. It is interesting to observe that the energy and power consumption remains relatively stable in the income range of BDT 50,000 to 75,000. Surprisingly, consumption starts increasing again for households with incomes exceeding BDT 75,000. In a nutshell, the analysis provides valuable insights into the nuanced relationship between income levels and energy consumption dynamics within the studied households and underscores the discontinuation of traditional income-consumption behaviour. However, the Keynesian consumption-income essence is maintained.

From our analysis, a noteworthy and consistent finding, aligning with previous literature, has emerged. The energy and power consumption behaviour of a household does not exhibit any significant relationship with the highest level of education within the household. As depicted in Table 10 of Appendix 9, the highest level of education obtained within a household, regardless of varying levels such as post-graduation, graduation, above college, and below college, does not demonstrate a significant change in their energy and power consumption behaviour. However, our analysis revealed a distinct pattern

concerning households' knowledge of renewable energy. We found that households with moderate to good knowledge about renewable energy exhibit substantial energy and power consumption savings behaviour compared to households with little to no idea about renewable energy. Since knowledge about renewable energy is a reflection of an individual's environmental awareness, the aforementioned findings illustrate that, although the overall education level does not play a significant role in shaping the energy and power consumption behaviour of households, awareness of the environment and renewable energy seems to influence a significant energy and power-efficient relationship across households. This breakthrough suggests a strong and effective policy intervention in motivating households to adopt efficient consumption behaviour.

Households relying on government and private jobs tend to engage in more energy-efficient consumption behaviour. On the other part, holding other factors, households, dependent on agriculture and self-employment, do not exhibit a statistically significant relationship with energy consumption behaviour, indicating potential areas for targeted energy conservation interventions in these sectors.

Households that have previously taken loans to purchase machines or appliances show a negative significant relationship with energy consumption behaviour. In simpler terms, households facing financial constraints and resorting to loans are more likely to consume less energy and power. Conversely, it can be inferred that households consuming less energy and power are more inclined to take loans for the acquisition of appliances or electric machines.
Households that actively consider and prioritise cost savings in their appliance purchases demonstrate a significant relationship with increased power and energy consumption, even when other factors are held constant. The findings suggest that households prioritising cost savings during purchases, typically opting for lower-priced appliances, paradoxically end up consuming more energy and power. In support of the proposition, holding other things constant, households that prioritise saving energy or purchasing energy efficient appliances during machinery purchases display a surprising association with increased energy and power consumption behaviour. Despite their intention to save energy, their actual consumption patterns suggest a gap between perception and behaviour. This incongruence highlights an information gap, indicating that there may be a need for policy interventions to align consumer perceptions with more energy-efficient choices.

Similarly, households that factor in the popularity of appliances and machines during their purchase decisions exhibit a significant association with energy and power consumption behaviour. This implies that the emphasis on the popularity of appliances, while influencing their choices, is linked to an increased consumption of power and energy, highlighting a noteworthy dynamic in the interplay between consumer choices and energy consumption patterns. This poses an effective space of policy focal point or intervention to improve the consumption scenario which will be discussed later.

On the contrary, when controlling for other variables, households that prioritise factors such as durability, discount offers, warranty, after-sales service, and the quality of retailers in their appliance purchasing decisions do not exhibit a discernible pattern in their energy and power consumption behaviour that reflects their respective perceptions.

From our analysis, it is evident that, holding other factors constant, the number of fans, and availability of televisions, air conditioners, and water pumps in a household does not exhibit any significant relationship with the energy and power consumption behaviour. In simpler terms, the use of fans, TVs, and air conditioners in households does not correspond to a distinct energy and power consumption pattern. Contrastingly, again, holding other factors constant, households equipped with refrigerators, microwave ovens, and rice cookers show a significant association with energy and power consumption scores. This implies that the ownership and use of specific appliances, such as refrigerators, microwaves, and rice cookers, play a more influential role in shaping the energy consumption behaviour of households. In conclusion, the type of appliances present in a household seems to have a more discernible impact

on energy and power consumption patterns than common items like fans, televisions, air conditioners, and water pumps.

The analysis reveals that the pricing strategy of power and energy does not significantly influence households' consumption behaviour. Irrespective of their energy and power consumption patterns, the majority of households prefer a fixed price for electricity and gas. Similarly, households who adopted strategies to consume less energy and power do not show any significant relationship with their power and energy consumption pattern. In other words, their strategies to decrease consumption are failing since we can observe an insignificant relationship between the households which adopted strategies to consume, and their actual energy and power consumption behaviour.

Lastly, the size of the LPG cylinder does not impose a relationship with the energy and power consumption behaviour, holding other factors constant. In other words, regardless of the size of the LPG cylinder used, households exhibit similar energy and power consumption behaviour when other influencing factors are taken into account.

4.4 Discussion

Sex of the Household Head: The finding that the sex of the household head is not significantly associated with power and energy consumption behaviour bears important implications for understanding the dynamics of energy use within households. Contrary to some expectations, this result suggests that the decision-making process related to consumption patterns is independent of the sex of the household head. In practical terms, it means that both male and female household heads can play equally influential roles in shaping energy consumption behaviour, and sex of the household head may not be a determining factor in promoting energy efficiency or conservation. This finding is consistent with previous literature, which was conducted on the individuals involved in the industrial sector of Bangladesh (Islam, Rayhan, & Mojumder, 2022). Although opposite results can be found from previous literature, our finding is also consistent with literature across the world (DeFronzo & Warkov, 1979). Several factors may contribute to the lack of significant association between the sex of the household head and power and energy consumption behaviour. It is plausible that the responsibility for energy-related decisions and practices is distributed among various members of the household, irrespective of the gender of the household head since it is evident from previous studies that female households across various countries play a significant role in shaping the energy and power consumption behaviour (Adusah-Poku, Adams, & Adjei-Mantey, 2022; Shrestha, Tiwari, Bajracharya, & Keitsch, 2021; Senjawati, Susanti, Zadry, & Fithri, 2018).

Age of the Household Head: The finding suggests that the age of the household head, per se, does not play a decisive role in shaping energy consumption patterns. This challenges common assumptions that older household heads might have more conservative or efficient energy practices. Our finding is consistent with previous literature on Bangladesh and previous literature across countries (Islam, Rayhan, & Mojumder, 2022; Estiri & Zagheni, 2019). However, there are some literatures which showed the contrasting result (Aslam & Ahmad, 2018). It should be taken into consideration that the difference emerges because of different country contexts.

Household Size, Dependency Ratio and Number of Students in a Household: The negative association between household size and energy consumption behaviour contradicts common assumptions and suggests a collective effort toward energy efficiency within larger households. One possible explanation could be shared responsibilities and awareness within larger family units, leading to more conscious energy use. This finding challenges stereotypes about larger households being inherently less energy-efficient, highlighting the need to consider the dynamics within such households. However, a similar finding can be found in a study conducted in Iran in 2019 (Soltani, et al., 2019).

The lack of a significant relationship between the dependency ratio and energy consumption implies that the proportion of dependents in a household, relative to non-dependents, does not independently influence energy behaviour. This challenges the notion that dependency dynamics are a primary driver of energy consumption. Instead, individual

behaviours and choices within households may play a more crucial role in determining energy use patterns (Piao & Managi, 2023).

The positive association between the total number of students in a household and its energy consumption underscores the specific impact of educational activities on energy needs. This finding has significant implications for households with students, emphasising the importance of targeted energy efficiency measures in educational settings. As educational practices evolve with technology, households with students may experience an increased demand for energy due to digital learning tools and electronic devices (Estiri & Zagheni, 2019).

Primary Earning Source of a Household: The observed energy-efficient behaviour in households relying on government and private jobs could be attributed to factors such as standardised practices, workplace awareness, or the influence of policies promoting energy conservation within these sectors. In contrast, the lack of a significant association in households depending on agriculture and self-employment might be linked to varied work settings, less standardised practices, or a potential need for targeted awareness campaigns tailored to these sectors. Addressing these specific factors could enhance energy conservation efforts across diverse occupational backgrounds. In contrast, the variability in income associated with agriculture and self-employment could lead to less predictable energy use patterns, potentially hindering the adoption of energy-efficient practices. The result can be found consistent in accordance with previous studies (Soltani, et al., 2019).

Income Groups: The lack of significant difference in energy consumption between households with incomes from BDT 5,000 to 30,000 suggests a stability in energy usage among lower-income groups. This may be attributed to a baseline level of essential energy needs that remains consistent across these income categories. The observed increase in energy consumption for households earning between BDT 30,000 and 40,000 signifies a potential shift in consumption patterns. This could be influenced by an improved financial capacity to afford additional appliances or engage in energy-intensive activities. The relatively stable energy consumption within the income range of BDT 50,000 to 75,000 suggests a potential saturation point. Households in this bracket may have met their essential energy needs and adopted more sustainable practices, contributing to a consistent consumption pattern. The unexpected increase in consumption for households with incomes exceeding BDT 75,000 is a notable finding. This may indicate a transition to a more affluent lifestyle, characterised by increased use of energy-intensive amenities or luxury items. The maintenance of the Keynesian consumption-income essence implies that, on average, as incomes rise, so does consumption up to a certain threshold. Beyond this point, other factors such as lifestyle choices or energy-efficient practices may come into play. This finding is supported by research in the United States, which shows that rising income inequality has been just as influential as energy-efficiency programs in reducing electricity consumption (Scheier & Kittner, 2022; Robertson, 2022; Theisen, 1993).

Availability of Various Appliances in the Households: The analysis underscores the nuanced relationship between household appliances and energy consumption. Common items such as fans, televisions, and air conditioners exhibit no discernible pattern, while specific appliances like refrigerators, microwaves, and rice cookers demonstrate a significant association with energy consumption. The significant association with cooking-related appliances, such as microwave ovens and rice cookers, emphasises the influential role of cooking activities in shaping energy consumption behaviour. Cooking processes involve sustained energy use, contributing distinctly to household consumption. Appliances associated with cooking, such as microwaves and rice cookers, involve longer usage durations compared to items like fans and televisions. This sustained usage contributes to a more noticeable impact on overall energy consumption. Differences in technological efficiency among appliances may play a role. Energy-efficient technologies in certain appliances could lead to reduced energy consumption, while older or less efficient models may contribute more significantly to energy use. Consumer preferences and awareness play a crucial role in appliance selection. Although our findings are not consistent with most of the literatures since the lifestyle of Bangladeshi households

differs significantly from that of other countries, the behaviour can be explained by the previous literatures just as we stated above (Office of Energy Efficiency and Renewable Energy, 2018).

Factors of Considerations while Purchasing Appliances: The identified association between households prioritising cost savings during appliance purchases and increased energy consumption introduces a paradox. Despite the intention to save on upfront costs, these households end up exhibiting higher power and energy consumption patterns. Households prioritising cost savings may focus on the immediate purchase price rather than considering the long-term operational costs. Energy-efficient appliances may have a higher upfront cost but offer significant savings over their lifespan. The incongruence between the intention to save energy and the actual consumption patterns suggests a potential misperception among consumers. There may be a lack of awareness or accurate information regarding the energy efficiency of appliances, leading to unintended consumption behaviours. Consumers may not fully understand or prioritise energy labels and efficiency ratings during the purchasing process. An enhanced understanding of the implications of these labels can lead to more informed choices aligned with energy conservation goals. The findings emphasise the importance of appliance efficiency ratings and labels. Consumers may prioritise cost savings without considering the long-term operational costs associated with less energy-efficient appliances. Moreover, there is a scope of facing Jevons paradox: implementing energy-efficient enhancements results in a net increase in overall energy consumption (Jevons, 1865). Nevertheless, a rebound effect can be observed, leading to an upsurge in energy consumption after an enhancement in energy efficiency (Freire-González & Puig-Ventosa, 2015). The availability and affordability of energy-efficient options in the market play a crucial role. If energy-efficient appliances are not readily accessible or are perceived as expensive, consumers may opt for lower-priced alternatives, contributing to unintended energy consumption.

The identified association between households prioritising the popularity of appliances and increased energy consumption suggests a correlation between consumer preferences for popular brands or models and higher energy usage. This consumer behaviour may be driven by factors such as trends, advertising, or brand influence. The influence of marketing strategies and current trends on consumer choices may drive the preference for popular appliances. Consumers may prioritise popularity without fully considering the energy implications of their choices. The desire to align with popular choices may lead households to opt for appliances that, despite their popularity, may not necessarily be energy-efficient. Consumers may not have sufficient visibility into the energy efficiency features of popular appliances. On the contrary, households that prioritise factors such as durability, discount offers, warranty, after-sales service, and the quality of retailers do not show a distinct pattern in energy and power consumption behaviour. This suggests that considerations related to the longevity and reliability of appliances may not inherently influence energy consumption. Consumer perceptions and priorities in purchasing decisions may need alignment. If energy efficiency is not perceived as a significant factor in the popularity of appliances, households may not actively consider it in their choices.

Households Taking Loans to Buy Appliances: The negative significant relationship between households taking loans and energy consumption behaviour suggests that financial constraints influence energy consumption patterns. Households facing economic challenges may adopt energy-saving measures due to budgetary constraints. The inverse relationship implies that households with lower energy consumption are more inclined to take loans for appliances. This behavioural aspect may stem from a conscious effort to minimise upfront costs, aligning with a financial strategy that prioritises cost-saving. Additionally, households prioritising cost minimisation may deliberately choose to consume less energy to mitigate financial burdens. Taking loans for appliances becomes a strategy to spread costs over time while still adhering to budget constraints. Economic strain can act as a driver for efficiency, compelling households to adopt measures that contribute to both financial savings and reduced energy consumption. This interplay showcases the adaptive nature of consumer behaviour in response

to economic challenges (Freire-González & Puig-Ventosa, 2015; Faure & Schleich, 2020; Klemick, Kopits, & Wolverton, 2015).

Preference of Pricing Strategies within Households: The finding suggests that the preference for a fixed pricing strategy remains predominant among households, indicating a resistance to variable pricing approaches. The lack of a significant association between adopted strategies and actual consumption behaviour raises questions about the effectiveness of current strategies in influencing households to reduce their energy and power usage. This misalignment emphasises the need for more targeted and impactful approaches to encourage energy-saving behaviours. Several factors may contribute to the observed lack of alignment between adopted strategies and actual consumption behaviour. It could be attributed to a lack of awareness, insufficient incentives, or barriers preventing households from implementing their intended strategies effectively (Sanders, 2023).

Education and Awareness Level: The finding that the highest level of education within a household is not significantly associated with energy and power consumption behaviour aligns with existing literature (Islam, Rayhan, & Mojumder, 2022). This suggests that the traditional notion linking education to energy-saving behaviour may not hold true in this context. However, the significant relationship between households' knowledge about renewable energy and their energy and power consumption patterns introduces a new dimension. It indicates that awareness and knowledge, rather than formal education, play a crucial role in influencing households towards more energy-efficient behaviours. The limited impact of formal education on energy and power consumption behaviour might be influenced by the fact that educational attainment alone does not address the contextual factors and external conditions that shape decision-making within households. Factors such as economic constraints, habitual practices, and the availability of energy-efficient technologies may play a more prominent role in influencing energy behaviours. Conversely, the robust relationship between knowledge about renewable energy and energy-efficient behaviours suggests that practical awareness empowers individuals to make informed choices. This knowledge may equip households with the tools needed to navigate the complexities of energy-related decisions, fostering a conscious and purposeful approach to energy consumption.

LPG Cylinder Size: The lack of a significant relationship between the size of LPG cylinders and energy and power consumption behaviour implies that, within the studied context and controlling for other relevant factors, the physical capacity of the LPG cylinder does not play a decisive role in shaping households' energy usage patterns. Several factors may contribute to this result. Firstly, the size of the LPG cylinder may not directly impact the efficiency of energy utilisation in appliances or devices. The actual consumption of energy might be more closely linked to the specific appliances in use, the frequency of usage, and individual behaviours rather than the physical capacity of the LPG cylinder.

5. Policy Implications, Recommendations, and Conclusion

5.1 Policy Implications and Recommendations

The policy implications and recommendations based on the findings of the study are as followed:

- **Shifting Focus from Gender to Household Dynamics for Effective Conservation Strategies**

From a policy perspective, these findings suggest that interventions aimed at promoting energy efficiency or conservation should focus on household-level dynamics rather than emphasising the gender of the household head. The energy sector in Bangladesh lacks comprehensive gender-responsive policies, indicating a shortage of initiatives specifically targeting women's participation. Some major policy plans such as Energy Efficiency and Conservation Master Plan up to 2030, National Solar Energy Roadmap 2021-2041, Mujib Climate Prosperity Plan Decade 2030, Power System Master Plan 2010, etc. does not include any sex responsiveness in their plans and do not directly address women's energy needs (Schneider, Barman, & Nahar, 2022). Additionally, the Energy Efficiency and Conservation Master Plan

(EECMP) in Bangladesh, while addressing various aspects of household energy efficiency, currently overlooks the intricate dynamics within households. Policy initiatives could benefit from acknowledging the shared responsibility of all household members in influencing energy consumption patterns. Furthermore, awareness campaigns and educational programmes should be designed to address the household as a unit, recognising that both men and women can contribute significantly to achieving energy-related goals.

- **Rethinking Age-Centric Approaches in Energy Efficiency Policies**

This finding highlights the importance of adopting a nuanced approach in energy efficiency policies. Policies solely targeting specific age groups may not effectively address the diverse factors influencing energy consumption behaviour. Educational programmes promoting energy-efficient practices should be designed to reach a broad audience, acknowledging that age alone might not be a reliable predictor of energy behaviour. Additionally, there is a notable absence of programmes or policies in Bangladesh that specifically adopt age-centric approaches in addressing energy-related issues.

- **Moving Beyond Household Size and Dependency Ratios**

Policymakers should recognise the diversity within households and avoid generalisations based on size or dependency ratios. Energy efficiency campaigns could benefit from promoting collective responsibility within larger households, emphasising shared awareness and practices. Additionally, targeted programs for households with students should focus on educating both students and their families about energy-efficient practices associated with modern learning tools. Moreover, the government can take initiatives to incentivise the retailers, producers, sellers, importers and other selling-side entities to introduce energy and power efficient appliances in Bangladesh.

- **Strategic Energy Initiatives for Middle-Income Households: Incentives, Insights, and Responsible Consumption Patterns**

Bangladesh has implemented policies and initiatives targeting the energy behaviour of middle-income households. These efforts are designed to enhance energy efficiency, alleviate energy poverty, and ensure universal access to electricity. These demand-side programmes include policies such as subsidies, incentives to invest in renewable energy equipment, etc (Khan, 2019). However, our findings illustrate the necessity for targeted campaigns focusing on energy-efficient practices could benefit households with incomes exceeding BDT 30,000. These initiatives should emphasise the importance of responsible energy use and offer practical tips for reducing consumption. Policymakers may consider providing incentives or subsidies to encourage energy-efficient technologies for households in the middle-income range. This could reinforce existing responsible consumption patterns. Further research into the specific behaviours influencing energy consumption in different income brackets is crucial. Policies informed by behavioural insights can effectively address the motivations and barriers unique to each income group.

- **Sustainable Energy Conservation Strategies Tailored for Agricultural and Self-Employed Sectors**

The solar irrigation programme in Bangladesh, executed by the Infrastructure Development Company Limited (IDCOL), a public non-bank financial institution, aims to furnish irrigation facilities to rural off-grid areas. Through solar irrigation systems, the programme seeks to diminish reliance on fossil fuels and alleviate the demand for electricity from the national grid during irrigation seasons (Hossain & Karim, 2020). There are currently no policies specifically tailored for households' dependent on agriculture or engaged in self-employment, such as small enterprises. To address the observed disparity, targeted energy conservation interventions should be designed for households engaged in agriculture

and self-employment. These interventions could include educational programmes highlighting energy-efficient practices tailored to the specific needs and challenges of these sectors. Financial incentives or subsidies for adopting energy-efficient technologies, especially in energy-intensive processes related to agriculture, could encourage positive behavioural changes. Policymakers should consider the economic fluctuations associated with agriculture and self-employment when designing interventions. Strategies that account for the variable income nature of these sectors could be more effective in promoting sustained energy conservation.

- **Empowering Consumers through Enhanced Energy Efficiency Standards and Informative Campaigns to Foster Sustainable Choices in Appliance and Machinery Consumption**

While Bangladesh has implemented policies and programmes to enhance household energy efficiency, such as the Energy Efficiency and Conservation Master Plan (EECMP), there is a lack of emphasis on recognising the full potential of energy-saving behaviours as a demand-side management strategy in residential areas within the national DSM programme. The EECMP incorporates measures like energy efficiency standards, subsidies for housing renovation, and incentives for purchasing energy-efficient appliances and renewable energy equipment, along with energy taxes (Khan, 2019). Moreover, the government established an 'EE Labelling Programme Committee' in order to identify the energy efficient appliances and promote them and they are currently running the programme (SREDA & Power Division, 2015). Our study strengthens the idea that policymakers should consider strengthening energy efficiency standards for appliances and machinery. This involves setting clear benchmarks and promoting the adoption of energy-efficient technologies. Stringent standards can drive manufacturers to produce appliances with reduced energy consumption. Launching targeted consumer education campaigns can bridge the information gap. These initiatives should focus on raising awareness about the long-term cost benefits of energy-efficient appliances. Providing consumers with accessible and understandable information about energy labels and ratings is crucial. Introducing financial incentives, such as rebates or tax credits, for the purchase of energy-efficient appliances can encourage households to prioritise efficiency over upfront costs. Financial rewards can help offset the initial higher price of energy-efficient models. Enhancing the transparency of labelling for appliances, clearly indicating energy efficiency, can guide consumers toward making informed decisions. Standardised and easily comprehensible labels empower consumers to compare the energy performance of different models.

- **Financial Incentives and Consumer Education to Influence Energy-efficient Appliances Adoption, Balance Economic Benefits and Ensure Environmental Sustainability**

While the EE&C school programme is a valuable initiative, our study underscores the importance of recognising that household energy consumption behaviour is predominantly influenced by the household head or primary earner, whose average age is around 40. To comprehensively address energy-saving practices, there is a need for a more inclusive program and extensive social campaigning. While media campaigns are part of the plan, they may not be sufficient to generate widespread awareness, emphasising the necessity for a broader and more targeted approach to reach the entire household demographic (SREDA & Power Division, 2015). Policymakers can explore initiatives that provide financial assistance or favourable loan terms specifically for the purchase of energy-efficient appliances. This encourages households to invest in sustainable choices without compromising their financial stability. Implementing comprehensive consumer education programmes can raise awareness about the long-term cost benefits of energy-efficient appliances. Empowering households with knowledge can influence their decisions, prompting them to prioritise energy efficiency when seeking financial support. Collaborative efforts between financial institutions and environmental agencies can promote the integration of financial and environmental goals. Creating synergy in these sectors can lead to holistic

solutions that address both economic constraints and energy efficiency.

- **Consumer Education and Strategic Partnerships with Manufacturers to Harmonise Popular Choices with Energy Efficiency, Fostering Sustainable Consumption Patterns**

Implementing consumer education programmes that highlight the energy efficiency of popular appliances can guide households to make choices that align with both their preferences for popular items and the goal of energy conservation. This involves promoting awareness about energy labels and ratings. Although existing policies cover the area of raising awareness among the residential consumer about energy efficient behaviours, our study suggests that collaborating with appliance manufacturers to integrate energy efficiency features into popular models can create a win-win scenario. Manufacturers can capitalise on consumer trends, and consumers can enjoy popular choices with the added benefit of reduced energy consumption. Enhancing communication and visibility of energy-related attributes can bridge the gap between popularity and energy-conscious choices. Introducing incentives, such as discounts or promotions, for energy-efficient popular appliances can drive consumer choices toward more sustainable options. Financial rewards can encourage the adoption of energy-efficient models without compromising popularity.

- **Campaigns and Incentives to Align Household Energy Consumption Behaviour with Pricing Strategies, Addressing the Gap between Intention and Actual Behaviour**

As the government of Bangladesh is moving towards adopting a market-based pricing strategy in accordance with the IMF conditionality, it is important to build readiness among the consumers on which the pricing strategy will be imposed. To address the discrepancy in pricing strategy, policymakers should consider refining existing strategies and introducing more effective measures to motivate households to reduce their energy consumption. Tailored educational campaigns, incentives, and outreach programmes may be necessary to bridge the gap between intention, behaviour, and knowledge about various pricing strategies, fostering a more sustainable energy consumption pattern among households.

- **Targeted Awareness Programmes to Enhance Knowledge about Renewable Energy, Environmental Conservation, and Sustainable Living for More Impactful Energy Efficiency Outcomes**

The inclusion of educating the population about renewable sources and environment-friendly behaviours in the EECMP up to 2030 is justified by our findings (SREDA & Power Division, 2015). The divergence in results between general education and knowledge about renewable energy has crucial policy implications. Policymakers should reassess strategies that exclusively focus on increasing formal education levels without incorporating targeted awareness programmes. Implementing initiatives that specifically enhance knowledge related to renewable energy, environmental conservation, and sustainable living may yield more substantial and tangible outcomes in terms of energy efficiency. Policy interventions should consider innovative educational campaigns, workshops, and outreach programmes tailored to increase households' awareness of renewable energy technologies and their benefits. These initiatives could encompass information about available incentives for adopting energy-efficient practices, practical tips for reducing energy consumption, and the environmental impact of different energy sources.

- **Minimal Impact of LPG Cylinder Size on Energy Conservation Goals**

Policymakers and energy-related organisations may not need to focus extensively on regulating or incentivising specific sizes of LPG cylinders to achieve energy conservation goals.

5.2. Conclusion

Looking ahead, the study suggests that with a larger sample size, implementing quasi-experimental impact evaluations or if possible, randomised controlled trial (RCT) could provide a robust methodology for assessing the influence of awareness campaigns on consumption patterns and other key factors, offering a more nuanced understanding of the causal

relationships at play in household energy behaviour. Moreover, future research could explore the long-term impact of targeted awareness campaigns on energy consumption patterns, considering factors such as education, income, and appliance preferences. This avenue holds the potential for refining and tailoring interventions to enhance their effectiveness in promoting sustainable energy consumption. In conclusion, this study presents a holistic investigation into the complex landscape of household energy and power consumption behaviour, unearthing intricate relationships among diverse factors. The findings make substantial contributions to existing literature by underscoring the pivotal roles of environmental awareness, appliance ownership, and purchasing preferences in melding patterns of energy usage. While certain demographic aspects, including the sex and age of the household head, and income levels, exert influence, their standalone impact is constrained. The intriguing revelation of the absence of a significant association between LPG cylinder size and energy consumption challenges conventional assumptions, opening avenues for revaluation. Future research directions could delve into the subtleties of behavioural dynamics, cultural influences, and the efficacy of interventions, enriching our understanding of sustainable energy practices. Policymakers, energy-related organisations, and researchers can glean valuable insights from this study to advance efforts in promoting not only efficient but also environmentally conscious energy consumption practices.

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Appendices

Appendix 1: Sample Distribution Across Sub-Districts (Upazilas) and Divisions

The sample distribution across sub-districts is given in the following table:

Table 5 **Sample distribution across divisions and sub-districts**

Divisions	Upazila	Frequency	Percentage
Chattogram	Alikadam	45	9.00
Mymensingh	Bhaluka	15	3.00
Barisal	Bhola Sadar	13	2.60
Sylhet	Borolekha	14	2.80
Rangpur	Char Rajibpur	27	5.40
Barisal	Dashmina	14	2.80
Rangpur	Debigonj	28	5.60
Dhaka	Demra	92	18.40
Mymensingh	Dewanganj	22	4.40
Dhaka	Goalanda	50	10.00
Chattogram	Halishahar	47	9.40
Khulna	Harinakunda	29	5.80
Khulna	Kushtia Sadar	26	5.20
Rajshahi	Panchbibi	32	6.40
Rajshahi	Porsha	33	6.60
Sylhet	Sulla	13	2.60
	Total	**500**	**100.00**

Source: Authors' Calculation.

Appendix 2: Average Monthly Spending (in BDT) on Electricity during Different Periods of a Year

Table 6 **Average monthly spending (in BDT) on electricity during different periods of a year**

Month	Mean (In BDT)	Std. Dev.	Minimum	Maximum
March to June	1,002.14	849.4634	100	6,000
July to October	998.798	985.8074	25	9,000
November to February	896.456	843.4849	100	8,000

Source: Authors' Calculation.

Appendix 3: Result of Multicollinearity Test (Pair-Wise Correlation Coefficient Matrix)

The result of the multicollinearity test using a pair-wise correlation coefficient matrix is tabulated below in parts:

Table 7 Table of multicollinearity test

	dr	gender	age	numhh	student	agri	govt
dr	1.00**						
gender	-0.02	1.00**					
age	-0.08	-0.03	1.00**				
numhh	0.23	-0.02	0.06	1.00**			
student	0.47	0.07	-0.02	0.56	1.00**		
agri	0.00	-0.11	0.22	0.15	0.05	1.00**	
govt	-0.07	-0.05	0.07	0.04	0.01	-0.01	1.00**
pvt	-0.07	-0.08	-0.18	-0.01	-0.05	-0.16	-0.11
self	0.04	0.11	-0.07	0.05	0.08	-0.35	-0.16
inc_5	-0.01	0.08	0.06	-0.05	-0.06	0.07	-0.04
inc_10	0.04	0.04	0.10	-0.06	-0.08	0.15	-0.08
inc_20	0.11	-0.09	-0.03	-0.07	0.04	0.14	-0.15
inc_30	-0.09	-0.06	-0.09	0.01	-0.05	-0.11	-0.03
inc_40	-0.03	0.01	0.01	0.06	-0.05	-0.04	0.17
inc_50	-0.04	0.04	0.04	0.10	0.09	-0.10	0.20
inc_75	0.04	0.04	0.02	0.18	0.23	-0.10	0.12
inc_100	-0.04	0.11	-0.06	-0.03	0.01	-0.08	0.06
fan_number	-0.15	-0.04	0.15	0.31	0.10	0.00	0.24
tv_avail	-0.15	0.05	-0.08	0.01	-0.07	-0.29	0.11
ac_avail	-0.06	0.03	0.06	-0.02	-0.02	-0.08	0.17
refg_avail	-0.09	0.06	-0.02	0.07	-0.01	-0.33	0.17
pump	-0.05	-0.16	0.07	0.04	-0.04	0.11	0.12
elc_machine_mwoven	-0.06	0.01	0.01	-0.01	-0.03	-0.06	0.21
elc_machine_rcooker	-0.16	-0.06	-0.02	0.02	-0.04	-0.03	0.21
factors_cost	-0.08	-0.06	-0.07	0.10	0.05	0.06	0.06
factors_popular	-0.10	-0.14	-0.09	-0.04	-0.02	0.03	0.04
factors_durable	-0.04	-0.20	-0.02	-0.02	-0.03	0.12	0.07
factors_engsav	-0.07	0.10	-0.06	0.01	0.01	-0.09	-0.01
factors_discount	-0.15	-0.03	0.01	0.04	-0.06	0.13	0.01
factors_warranty	-0.19	-0.07	-0.07	-0.02	-0.08	0.05	0.08
factors_asales	-0.08	-0.03	0.00	-0.07	-0.07	0.08	-0.02

(Table 7 contd.)

(Table 7 contd.)

	dr	gender	age	numhh	student	agri	govt
factors_ retailers	0.02	-0.10	0.00	-0.02	-0.02	0.12	0.01
loan	0.04	-0.03	-0.07	0.06	0.05	-0.05	-0.06
price_stat	0.03	0.03	-0.01	0.10	0.04	-0.08	-0.11
red_act	0.02	-0.06	-0.07	-0.03	-0.04	-0.16	0.00
renewable_lil	-0.03	-0.09	-0.10	-0.10	0.00	-0.13	-0.06
renewable_ mod	0.00	-0.09	0.02	0.05	0.06	0.11	0.18
renewable_gd	0.07	0.02	-0.02	0.01	0.04	0.09	0.06
educ_hh_post	-0.15	-0.01	0.08	0.05	-0.04	0.05	0.16
educ_hh_grad	-0.12	0.12	0.12	0.02	-0.04	-0.03	0.10
educ_hh_12	-0.06	-0.04	-0.15	0.00	-0.03	-0.13	-0.01
lpg_size	0.03	-0.08	-0.07	-0.11	-0.05	0.04	-0.14

	inc_50	inc_75	inc_100	fan_ number	tv_avail	ac_avail	refg_avail
inc_50	1.00**						
inc_75	-0.03	1.00**					
inc_100	-0.03	-0.01	1.00**				
fan_number	0.22	0.20	0.04	1.00**			
tv_avail	0.11	0.08	0.07	0.29	1.00**		
ac_avail	0.10	0.19	-0.02	0.19	0.11	1.00**	
refg_avail	0.17	0.04	0.07	0.36	0.41	0.11	1.00**
pump	0.03	0.04	-0.08	0.33	0.14	0.09	0.06
elc_machine_ mwoven	0.13	0.10	-0.01	0.13	0.10	0.52	0.10
elc_machine_ rcooker	0.14	0.12	-0.06	0.34	0.23	0.18	0.12
factors_cost	-0.01	0.02	-0.05	0.23	0.05	0.07	-0.01
elc_machine_ rcooker	0.02	0.02	-0.10	0.16	0.12	0.01	0.13
factors_durable	-0.04	-0.03	-0.15	0.07	-0.05	0.03	-0.05
factors_engsav	0.04	0.01	0.07	0.06	0.11	0.00	0.07
factors_discount	-0.04	-0.02	-0.05	0.12	0.07	0.06	-0.07
factors_ warranty	-0.05	-0.03	-0.09	0.11	0.10	0.01	0.03
factors_asales	0.05	-0.01	-0.04	0.13	-0.02	0.06	-0.05
factors_retailers	-0.06	0.02	-0.03	0.10	-0.09	-0.05	-0.14
loan	-0.04	-0.03	-0.03	-0.03	-0.01	0.01	0.06
price_stat	0.02	0.02	0.05	-0.06	0.05	0.05	0.07
red_act	-0.04	-0.05	-0.07	-0.02	0.02	-0.04	0.05

(Table 7 contd.)

(Table 7 contd.)

	inc_50	inc_75	inc_100	fan_ number	tv_avail	ac_avail	refg_avail
renewable_lil	-0.06	-0.06	-0.05	-0.10	0.04	0.02	-0.02
renewable_mod	0.00	0.05	-0.06	0.03	-0.14	0.02	-0.04
renewable_gd	0.01	0.05	-0.02	0.03	-0.07	-0.04	-0.13
educ_hh_post	0.12	0.05	0.07	0.26	0.04	0.07	0.08
educ_hh_grad	0.14	0.05	0.08	0.23	0.14	0.11	0.14
educ_hh_12	-0.04	-0.06	-0.05	-0.02	0.04	-0.02	0.08
lpg_size	-0.12	-0.06	-0.03	-0.40	-0.32	-0.06	-0.63

	pump	elc_ machine_ mwoven	elc_ machine_ rcooker	factors_ cost	factors_ popular	factors_ durable	factors_ engsav
pump	1.00**						
elc_machine_ mwoven	0.08	1.00**					
elc_machine_ rcooker	0.26	0.20	1.00**				
factors_cost	0.19	0.10	0.39	1.00**			
elc_machine_ rcooker	0.20	0.00	0.11	0.08	1.00**		
factors_durable	0.29	0.00	0.09	0.04	0.20	1.00**	
factors_engsav	-0.05	-0.06	0.03	0.11	0.04	-0.04	1.00**
factors_discount	0.25	0.09	0.26	0.27	0.20	0.05	0.03
factors_ warranty	0.17	0.02	0.22	0.22	0.35	0.17	0.17
factors_asales	0.04	0.09	0.20	0.30	0.17	-0.10	0.04
factors_retailers	0.04	0.01	0.04	0.05	0.08	0.02	0.00
loan	-0.01	-0.04	0.07	0.04	-0.03	0.00	0.01
price_stat	-0.05	0.04	-0.13	-0.11	-0.22	0.07	0.04
red_act	0.04	-0.04	0.12	-0.06	-0.01	0.05	-0.05
renewable_lil	0.05	0.04	-0.04	0.04	0.23	0.17	0.04
renewable_mod	0.12	-0.02	0.00	-0.08	0.11	0.11	-0.08
renewable_gd	-0.02	0.03	0.11	0.07	0.04	-0.08	0.05
educ_hh_post	0.06	0.02	0.23	0.16	-0.02	-0.04	0.07
educ_hh_grad	0.03	0.15	0.17	0.05	0.04	-0.04	-0.07
educ_hh_12	0.01	-0.03	-0.05	-0.01	0.03	0.04	0.00
lpg_size	-0.43	-0.07	-0.21	-0.14	-0.14	-0.16	0.04

	factors_ discount	factors_ warranty	factors_ asales	factors_ retailers	loan	price_stat	red_act
factors_discount	1.00**						
factors_warranty	0.38	1.00**					
factors_asales	0.35	0.15	1.00**				

(Table 7 contd.)

(Table 7 contd.)

	factors_ discount	factors_ warranty	factors_ asales	factors_ retailers	loan	price_stat	red_act
factors_retailers	0.03	0.06	0.21	1.00**			
loan	-0.02	-0.01	0.00	-0.08	1.00**		
price_stat	-0.09	-0.13	-0.39	-0.36	0.00	1.00**	
red_act	0.01	0.00	-0.03	-0.06	0.06	-0.06	1.00**
renewable_lil	0.10	0.23	0.06	0.08	-0.08	-0.12	-0.05
renewable_mod	-0.01	0.06	0.01	0.10	0.01	-0.18	0.04
renewable_gd	0.12	0.07	0.28	0.06	-0.02	-0.29	0.09
educ_hh_post	0.04	0.01	0.06	0.05	-0.08	-0.02	-0.01
educ_hh_grad	0.04	-0.02	0.02	-0.06	-0.01	-0.03	-0.08
educ_hh_12	0.01	0.05	0.02	0.02	0.02	-0.03	0.06
lpg_size	-0.12	-0.06	-0.02	0.15	0.07	-0.12	-0.09

	renewable _lil	renewable _mod	renewable _gd	educ_ hh_post	educ_ hh_grad	educ_ hh_12	lpg_size
renewable_lil	1.00**						
renewable_mod	-0.28	1.00**					
renewable_gd	-0.11	-0.13	1.00**				
educ_hh_post	-0.08	-0.06	0.01	1.00**			
educ_hh_grad	-0.06	-0.01	-0.02	-0.24	1.00**		
educ_hh_12	0.09	0.07	-0.06	-0.21	-0.28	1.00**	
lpg_size	0.11	0.12	-0.04	-0.15	-0.05	0.06	1.00**

0.8>**

Source: Authors' Calculation

Appendix 4: Result of Heteroskedasticity Test

Table 8 **Result of heteroskedasticity test**

White's test for Ho: homoskedasticity			
against Ha: unrestricted heteroskedasticity			
Cameron & Trivedi's decomposition of IM-test			
Source	chi2	df	p
Heteroskedasticity	186	185	0.4655
Skewness	46.92	42	0.2780
Kurtosis	0.67	1	0.4118
Total	234.05	228	0.3856

Source: Authors' Calculation

Appendix 5: Sampling Adequacy Test

Table 9 Sampling adequacy test

Kaiser-Meyer-Olkin measure of sampling adequacy	
Variable	kmo
bill_gas	0.5183
bill_elc	0.5155
wood_cost	0.5885
Overall	0.5232

Source: Authors' Calculation

Appendix 6: Econometric Soundness of the Model

Table 9: Result of econometric soundness of the model

Table 10 Result of econometric soundness of the model

Statistics	Values
Prob > F	0.0000
R-squared	0.5727
Adjusted R-squared	0.4472

Source: Authors' Calculation

Appendix 7: Variable Descriptions

The description of the variables used in this study is enlisted below:

Table 11 Variable descriptions

Variable Indicators	Variable Names	Variable Explanation
gender	Gender of the household head	The variable is taken into consideration because the study wants to investigate whether there is any gender disparity in the energy and power consumption pattern.
age	Age of the household head	This variable is vital in exploring whether there is a significant association between the age of the household head and their approach to energy usage.
numhh	Number of members in a household/ household size	This variable serves as a crucial factor in understanding whether larger or smaller households exhibit distinct energy and power consumption behaviours, contributing valuable insights to the overall research objective.

(Table 11 contd.)

(Table 11 contd.)

Variable Indicators	Variable Names	Variable Explanation
dr	Dependency ratio within a household	The Dependency Ratio (dr) is calculated by considering the number of household members below 18 years old and above 60 years old, divided by the number of members in the age range between 18 and 60. It helps assess whether households with a higher proportion of dependent members tend to exhibit different energy usage patterns compared to those with a lower dependency ratio.
student	Total number of students in a household	This variable is included to examine the relationship between educational activities and energy consumption behaviour.
agri	Earning of households: agriculture	If agri = 1, then the households' earning source of a household is agriculture. Otherwise (when agri = 0), the households earn from different sources. This variable is crucial for examining the energy consumption Behaviour of households based on their primary economic activities, particularly highlighting potential differences in energy-efficient behaviours between households reliant on agriculture and those with diverse income sources.
govt	Earning of households: government jobs	If govt = 1, then the households' earning source of a household are government jobs. Otherwise (when govt = 0), the households earn from different sources.
pvt	Earning of households: private jobs	If pvt = 1, then the households' earning source of a household are private jobs. Otherwise (when pvt = 0), the households earn from different sources.
self	Earning of households: self-employed	If self = 1, then the households' earning source of a household are privately self-employed. Otherwise (when self = 0), the households earn from different sources.
inc_5	Average monthly income of households: less than BDT 5,000	If inc_5 = 1, then the households fall in the income category of an average monthly income of BDT 5,000 and below. If 0, otherwise. This is the base category of the income groups. The variables of the income groups are enlisted categorically.
The		
inc_10	Average monthly income of households: BDT 5,001 to 10,000	If inc_10 = 1, then the households fall in the income category of an average monthly income from BDT 5,001 to 10,000. If 0, otherwise.
inc_20	Average monthly income of households: BDT 10,001 to 20,000	If inc_20 = 1, then the households fall in the income category of an average monthly income from BDT 10,001 to 20,000. If 0, otherwise.
inc_30	Average monthly income of households: BDT 20,001 to 30,000	If inc_30 = 1, then the households fall in the income category of an average monthly income from BDT 20,001 to 30,000. If 0, otherwise.
inc_40	Average monthly income of households: BDT 30,001 to 40,000	If inc_40 = 1, then the households fall in the income category of an average monthly income from BDT 30,001 to 40,000. If 0, otherwise.
inc_50	Average monthly income of households: BDT 40,001 to 50,000	If inc_50 = 1, then the households fall in the income category of an average monthly income from BDT 40,001 to 50,000. If 0, otherwise.
inc_75	Average monthly income of households: BDT 50,001 to 75,000	If inc_75 = 1, then the households fall in the income category of an average monthly income from BDT 50,001 to 75,000. If 0, otherwise.

(Table 11 contd.)

(Table 11 contd.)

Variable Indicators	Variable Names	Variable Explanation
inc_100	Average monthly income of households: BDT 75,001 to 100,000	If inc_100 = 1, then the households fall in the income category of an average monthly income from BDT 75,001 to 100,000. If 0, otherwise.
inc_more100	Average monthly income of households: more than BDT 100,000	If inc_more100 = 1, then the households fall in the income category of an average monthly income of more than BDT 100,000. If 0, otherwise.
fan_number	Total number of fans in a household	This information is gathered to assess whether the quantity of fans within a household correlates with distinctive energy and power consumption patterns.
tv_avail	Availability of TV in a household	If tv_avail = 1, it implies that there is at least one TV in a household. If 0, otherwise.
ac_avail	Availability of AC in a household	If ac_avail = 1, it implies that there is at least one AC in a household. If 0, otherwise.
refg_avail	Availability of refrigerator in a household	If refg_avail = 1, it implies that there is at least one refrigerator in a household. If 0, otherwise.
pump	Availability of water pump in a household	If pump = 1, it implies that there is at least one water pump in a household. If 0, otherwise.
elc_machine_mwoven	Availability of microwave oven in a household	If elc_machine_mwoven = 1, it implies that there is at least one microwave oven in a household. If 0, otherwise.
elc_machine_rcooker	Availability of rice cooker in a household	If elc_machine_rcooker = 1, it implies that there is at least one rice cooker in a household. If 0, otherwise.
factors_cost	Factors of consideration while purchasing appliances: Cost savings	If factors_cost = 1, it means that the households consider the cost-saving aspect of an appliance while purchasing an appliance. If 0, they do not consider this factor. This variable aims to investigate whether prioritising cost savings during appliance purchases has an association with energy and power consumption behaviour.
factors_popular	Factors of consideration while purchasing appliances: Popularity	If factors_popular = 1, it means that the households consider the popularity aspect of an appliance while purchasing an appliance. If 0, they do not take this factor into consideration. This variable aims to identify whether the popularity of appliances significantly influences the energy and power consumption behaviour of households.
factors_durable	Factors of consideration while purchasing appliances: Durability	If factors_durable = 1, it means that the households consider the durability aspect of an appliance while purchasing an appliance. If 0, they do not take this factor into consideration. This variable helps assess whether the preference for durable appliances influences energy and power consumption patterns.
factors_engsav	Factors of consideration while purchasing appliances: Energy Savings	If factors_engsav = 1, it means that the households consider the energy-saving aspect of an appliance while purchasing an appliance. If 0, they do not take this factor into consideration. It aims to explore whether the prioritisation of energy-efficient features during the buying process correlates with distinct energy and power consumption patterns.
factors_discount	Factors of consideration while purchasing appliances: Discount Offers	If factors_discount = 1, it means that the households consider the discount aspect of an appliance while purchasing an appliance. If 0, they do not take this factor into consideration. This information is crucial in evaluating how cost-related considerations during appliance purchases may influence energy and power consumption behaviour.

(Table 11 contd.)

(Table 11 contd.)

Variable Indicators	Variable Names	Variable Explanation
factors_ warranty	Factors of consideration while purchasing appliances: Warranty	If factors_warranty = 1, it means that the households consider the warranty aspect of an appliance while purchasing an appliance. If 0, they do not take this factor into consideration. This variable is included to investigate if the consideration of warranty as a factor during appliance acquisition relates to specific energy and power consumption behaviours.
factors_ asales	Factors of consideration while purchasing appliances: After Sales Service	If factors_asales = 1, it means that the households consider the after-sales-service aspect of an appliance while purchasing an appliance. If 0, they do not take this factor into consideration. This information is crucial for understanding how certain considerations during the purchasing process impact subsequent energy and power consumption patterns.
factors_ retailers	Factors of consideration while purchasing appliances: Retailers' Quality	If factors_retailers = 1, it means that the households consider the retailers' quality aspect of an appliance while purchasing an appliance. If 0, they do not take this factor into consideration. It serves as a metric to evaluate whether the perceived quality of retailers influences the energy and power consumption behaviour of households.
loan	Whether the households took any loans to buy appliances or not	If loan = 1, the households have taken loans to buy appliance. If 0, otherwise. This information is crucial to examine the relationship between financial constraints, appliance ownership, and energy consumption patterns.
price_stat	Preference of pricing strategy regarding energy and gas	If price_stat = 1, then the households prefer fixed price rate for power and energy. If 0, the households prefer flexible or free market price rate for power and energy. This variable helps uncover whether there is a correlation between pricing strategy preference and actual energy and power consumption patterns, providing insights into the impact of pricing structures on consumer behaviour.
red_act	Whether the households adopt any act to reduce power and energy consumption	If red_act = 1, then the households took actions to reduce power and energy consumption within their households. If 0, they have not taken any action. This variable helps discern whether households actively engage in strategies to reduce energy usage and if these practices align with their actual power and energy consumption behaviour, providing valuable insights into the effectiveness of such initiatives.
renewable_ no	Awareness level regarding renewable energy: No idea	If renewable_no = 1, then the households have no idea about renewable energy. If 0, otherwise. This variable will act as the base level of the categorical variable reflecting the awareness level about the renewable energy. It helps identify whether households with limited knowledge about renewable energy exhibit distinct patterns in their energy usage, providing insights into the role of environmental awareness in shaping consumption behaviour.
renewable_ lil	Awareness level regarding renewable energy: Little	If renewable_lil = 1, then the households have little idea about renewable energy. If 0, otherwise.
renewable_ mod	Awareness level regarding renewable energy: Moderate	If renewable_mod = 1, then the households have moderate level of idea about renewable energy. If 0, otherwise.
renewable_ gd	Awareness level regarding renewable energy: Good	If renewable_gd = 1, then the households have good level idea about renewable energy. If 0, otherwise.

(Table 11 contd.)

(Table 11 contd.)

Variable Indicators	Variable Names	Variable Explanation
educ_hh_below12	Highest education level within a household: Below 12th grades	If educ_hh_below12 = 1, then the highest level of education within a household is below 12th grade. If 0, otherwise. This variable will serve as the base category of the categorical variables reflecting the highest level of education within a household. Education is often linked to environmental awareness, and understanding this connection can provide insights into the role of knowledge in shaping energy-conscious behaviours.
educ_hh_post	Highest education level within a household: Post graduate or above	If educ_hh_post = 1, then the highest level of education within a household is postgraduate or above. If 0, otherwise.
educ_hh_grad	Highest education level within a household: Graduate	If educ_hh_grad = 1, then the highest level of education within a household is graduate from bachelor's degree. If 0, otherwise.
educ_hh_12	Highest education level within a household: 12th Grades	If educ_hh_grad = 1, then the highest level of education within a household is 12th grade graduate. If 0, otherwise.
lpg_size	The LPG cylinder size used in a household	If lpg_size = 1, the households use large size cylinders. If 0, otherwise. Examining this variable helps identify if there is any association between LPG cylinder size and the overall energy and power consumption behaviour of households.
bill_elc	Average monthly electricity bill	This variable is expressed in BDT. This variable is included to construct the consumption score index because it is related to electricity usage within households.
bill_gas	Average monthly gas bill	This variable is expressed in BDT. This variable is included to construct the consumption score index because it is related to gas usage within households.
wood_cost	Average monthly cost on wood fuel	This variable is expressed in BDT. This variable is included to construct the consumption score index since the financial aspect of using wood as a fuel source and its potential influence on overall energy and power consumption is relevant.

Source: CPD Residential Energy Survey.

'Factors Determining Power and Energy Consumption Behaviour of Households in Bangladesh: A Cross-Section Analysis' sheds light on the intricacies of household energy consumption in Bangladesh, exploring factors influencing patterns and behaviors. From debunking gender-centric assumptions to unraveling the impact of education and awareness, the study navigates diverse facets. Notably, it emphasizes the need for nuanced policy interventions, considering income brackets, education, and regional variations. The findings not only unravel existing energy dynamics but also pave the way for future initiatives targeting sustainable energy practices in the vibrant tapestry of Bangladeshi households.

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