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Prediction of Electrical Energy Efficiency Using Information on Consumer's Activities

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Abstract *— Energy efficiency has been important since the latter part of the last century. The main object of this survey is to determine the energy efficiency knowledge among consumers. Two separate districts in Bangladesh are selected to conduct the survey on households and showrooms about the energy and seller also. The survey uses the data to find some regression equations from which it is easy to predict energy efficiency knowledge. The data is analyzed and calculated based on five important criteria. The initial target was to find some factors that help predict a person's energy efficiency knowledge. From the survey, it is found that the energy efficiency awareness among the people of our country is very low. Relationships between household energy use behaviors are estimated using a unique dataset of about 40 households and 20 showrooms in Bangladesh's Chapainawabganj and Bagerhat districts. Knowledge of energy consumption and energy efficiency technology options is found to be associated with household use of energy conservation practices. Household characteristics also influence household energy use behavior. Younger household cohorts are more likely to adopt energy-efficient technologies and energy conservation practices and place primary importance on energy saving for environmental reasons. Education also influences attitudes toward energy conservation in Bangladesh. Low-education households indicate they primarily save electricity for the environment while high-education households indicate they are motivated by environmental concerns.*

Keywords *— **Electrical energy, Regression, R-squared, Energy saving, Energy conservation.***

I. INTRODUCTION

The total population of Bangladesh is around 161 million, and it is one of the most populated countries in the world [1]. The rapid growth of urbanization has created a massive energy demand. Electric energy is essential in removing poverty, rising economic growth, and the country's development and security. Moreover, electric energy is the most used form of energy. Therefore, the proper use of electric energy is needed to enhance sustainable development. The appropriate use of electric energy means using energy-efficient appliances. Energy efficiency refers to reducing energy consumption by using less energy to attain the same amount of sound output. For example, higher star-rated air conditioning is more efficient than lower star-rated air conditioning. Now star rating is a measure of the energy efficiency of an appliance. It is a five-point scale.

The Bangladesh Parliament thus established the Sustainable and Renewable Energy Development Authority (SREDA) in May 2012 as the nation's nodal organization for promoting demand for energy efficiency and conservation in the country. The role of energy efficiency in fostering economic growth and energy security has only come to the forefront in the last

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two decades. Economic growth has always been linked to an increase in per capita energy consumption with little regard to how effectively the energy is utilized. Concerns over global warming and the need to reduce greenhouse gas emissions have forced mankind to consider decarburizing society through lowering fossil fuel use. The cornerstones of GHG emission reduction are energy efficiency and renewable energy. Whereas renewable energy remains expensive for developing countries, energy efficiency is a win-win option in most cases. In developing countries where energy efficiency is low, projects that increase energy efficiency can have a positive investment return. In most cases, energy efficiency projects have a payback period of less than five years, and in most cases, it is between one and two years if low-interest rate financing is available.

The reasons energy efficiency is most important for Bangladesh are (i) domestic natural gas is depleting very fast; (ii) despite having significant deposits of high-quality coal, the country is unable to mine it, due to technological limitations and international pressure; (iii) industries are prone to using low-efficiency inexpensive equipment and devices; (iv) extremely low level of maintenance of industrial equipment; (v) factory up-gradation is only undertaken when some failure or shutdown occurs; (vi) the apex agency called Sustainable and Renewable Energy Development Authority (SREDA), set up to oversee energy efficiency, is yet to undertake any concrete measures; and (vii) financial institutions are not aware of the investment possibilities in energy projects [2]

II. LITERATURE REVIEW

It was reported that the building stock in European countries accounts for over 40% of final energy consumption, of which residential use represents 63% of total energy consumption in the buildings sector. [7] In OECD countries, the energy-saving loss due to the energy efficiency gap is estimated to be 30% of the total potential energy saving of the measures. [8]

Twumasi et al. (2017) research is about determining the awareness of energy conservation measures in using different electrical equipment in an institution and their preparedness to reduce the consumption level. This research field was Kwame Nkrumah University of Science and Technology Kumasi [3]

The goal of Lin& Lai's (2011) research was to realize and calculate the actual analyses about the awareness for the energy-saving renovation of condominium residents. After analyzing they found the people of Taiwan are less aware of energy-saving behavior and environmental issues. They also found something exciting: the people are not very aware of energy-saving but are very interested in an energy-saving renovation. [4]

Yue et al. (2011) conducted a survey that aimed to determine the energy consumption in three towns in Hangzhou and to test the building thermal performance in the rural area. Also, the findings are that energy consumption in an urban area is higher than in rural residential. Carry out renovation pilot of energy saving through giving government subsidy and providing free energy-saving materials and facilities, facilitate the development of new energy in new energy in the new rural areas, and formulate an award policy for using new energy, thus genuinely realizing energy saving and emission reduction of rural buildings [5]

McKenna et al. (2017) proposed a demand-side response (DSR) that refers to a measure and it provides flexibility to the energy system by shifting or reshaping loads [6]

A Canadian study examined the relationship between residential winter energy use and viewpoints and found that thermal comfort was the most important determinant of household energy use [9].

McLoughlin et al. divided the influencing factors into several groups: socio-demographic (income, age, population, time of staying at home, etc.); building physical parameters (household size, number of rooms, age of building, indoor temperature); user behavior factors (attitude, knowledge, motivation, etc.); electrical equipment (number of equipment, the age of electrical equipment, etc.); climatic aspects (location, weather condition, etc.) [10].

To better understand energy consumption in the home across a broad range of factors, an energy cultural framework proposed by Lutzenhiser (1992) took into account social norms and culture alongside the more traditional econometrics [11].

Dillman et al. (1983) conducted a household-level analysis of the adoption of energy-efficient technologies and conservation practices and found relatively scarce and are concentrated in

the US, Canada, and several individual EU countries. They examined the energy efficiency investment and adjustment in behavior using surveys of the US Western states. 12]

Curtis et al. (1984) analyze technology adoption and behavioral practices aimed at reducing household thermal energy and electricity use in Regina (Canadian

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Province of Saskatchewan), and Fergusen analyses the adoption of retrofitting measures for all of Canada. [13]

Poortinga et al. (2003) include an extensive list of technological measures and behavioral practices associated with thermal energy and power use in the Netherlands, while Scott (1997) focuses on several technology measures (e.g., hot water cylinder insulation and lighting) in a survey of Irish household [14].

Barr, Gilg, et al. (2005) distinguished explicitly between habitual behavior and technology adoption and stressed that energy-saving behavior needs to be considered within the broader context of environmental behavior. The adoption of efficient technologies and conservation measures is usually associated with reduced emissions of greenhouse gases and other pollutants that benefit others without compensating the energy savers [15].

Aydinalp et al. study have proposed models to explain determinants of residential electricity consumption, each of them axis individual strengths and weaknesses. The most commonly used are two approaches: top–down, bottom–up engineering, and bottom-up statistical regression models. In the early studies, bottom-up models were used for adopting an econometrics perspective attempting to explain aggregate consumption data based on a selected stock of appliances. Therefore, the effect of behavior and other variables such as climate are merged with the effect of appliances thus minimizing the number of data requirements for end-use consumption estimation [16].

Cayla et al. explained the decision-making process of the households, explaining how the consumers respond to changes in price and analyzing only a partial set of residential electricity consumption determinants, e.g., appliance stock, weather conditions, or behavior factors [17].

By changing the energy policy within the EU, district heating systems have been identified as one of the main instruments for achieving the goals of increasing energy efficiency and increasing the share of renewable energy sources in the energy mix, indicating the need for precise methods of estimating consumption and saving in this system [18]

III. METHODOLOGY

The study is based on analyzing how much electrical energy efficiency exists among people based on consumer activities of using home electrical appliances. Many families with moderately low income, high income, age, and education qualification apartments have been selected in the three districts Chapainawabganj, Bagherhat, and Jashore in Bangladesh. Data was collected from the local area of three districts in Bangladesh. Forty people from different houses and 20 owners/managers of the showroom have participated in this survey.

All households were surveyed through interviews. For the research, face-to-face interviews with 40 selected households and 20 showrooms were conducted. The preparation of the survey questionnaire we primarily divided into two parts. One of them is for the households, and another one is for the showroom. The total number of questions for the household is 38 and the number of questions for the showroom is 19. The number of participants for the survey is around 40 and are randomly selected in three districts of Bangladesh.

Regression analysis

Multiple linear regression, also known simply as multiple regression, is a statistical technique that uses several explanatory variables to predict the outcome of the response variable. Multiple linear regression aims to model the linear relationship between the explanatory and response variables. Multiple regression is the extension of ordinary least squares regression because it involves more than one independent variable. Regression allows us to estimate how a dependent variable changes as the independent variable changes. Multiple linear regression is used to estimate the relation between two or more independent variables and one dependent variable.

Regression is a statistical method that uses data analysis processes and explains the relationship between the dependent variable and one or more independent variables. The dependent variable is the variable that is being measured or tested in an example. The statistical analysis is carried out by using SPSS software in this work. This work aims to determine the factor that is liable for energy efficiency related to electrical appliances.

To analyze this data model, summary, Anova, unstandardized coefficient, residual statistics, Histogram, normal p.p plot, and scatter plot are used.

Formula and Calculation of Multiple Linear Regression

The common regression equation is expressed as follows:

$Y= b_0+ b_1X_1 +b_2X_2+.....bnXn$

Where,

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Y= dependent variable

X= independent variable

b_0= constant term

b_n= slope coefficients for each independent variable

For example, consider the following equation (1):

EEN= - 0.131*E_D+.459*PRC +1.291 (1)

EEN: Energy efficiency knowledge

E_D: Education

PRC: Put off/turn off rice cooker

The above model is called a first-order model with more than one independent variable. A first-order model is linear in the independent variable. EEN is the dependent variable. E_D and PRC are dependent variables. The values of -0.131 and 0.459 are slope coefficients for each independent variable. 1.291 is constant

Regression coefficient

The regression coefficient measures a unit change in the dependent variable when the independent variable changes. In the above example, the parameter b0= 1.291 is the EEN intercept of the regression plane. Suppose ED and PRC both are equal to zero, then b0= 1.291 represents the mean response EEN at ED=0, PRC=0. Otherwise, b0 does not have any particular meaning as a separate term in the regression model.

The response function is a straight line with slope b1=0.31. The same is true for any other values of PRC; only the intercept of the response function will differ. Where b1= 0.31 indicates that the mean response EEN increases by 0.31 with a unit increase in ED when PRC is held constant and vice versa.

Table:1 Parameters required to understand the regression analysis

Variables entered/removed			
Model	Variables Entered	Variables Removed	Method
1	Do you switch off the rice cooker a few minutes after switching to warm from a cook? education	.	Enter
Dependent variable: Do you know about energy efficiency? Independent variables: Do you switch–off the rice cooker a few minutes after switching to warm from a cook? Education.			

Dependent variable**:** Do you know about energy efficiency?

Independent variables: Do you switch off your rice cooker a few minutes after switching to warm from cook, Education.

Interpretation of regression analysis

P-value

P-values and coefficients in regression analysis tell you which relationships in my model are statistically significant and the nature of those relationships. The coefficients describe The mathematical relationships between each independent and dependent variable. The p values for the coefficients indicate whether these relationships are statistically significant. P-value is a statistical hypothesis test that determines the probability of extreme results of the statistical hypothesis test taking the Null Hypothesis to be correct. It is mainly used as an alternative to rejection points that provide the minor significance level at which the Null Hypothesis would be rejected. The significant level value of the P-value is more diminutive than usually 0.05. Thus in my regression analysis, the value is less than 0.05, so our model fits the data well. Show the table (1). The value of Sig is .002, which is less than the p-value (.050). It indicates a significant relationship exists between dependent and independent variables.

R- squared

R- R-squared is a goodness-fit measure for a linear regression model R- R-squared model measures the strength of the relationship between our model and the dependent variable on a convenient 0- 100% scale. After fitting a linear regression model to determine how well the model fits the data. If R^2 is 0.3 for equation (1), this

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implies that the energy efficiency knowledge can explain 30% of the variation in the chance of education and put off the rice cooker

Adjusted R^2 – is R^2 multiplied by an adjustment factor. This is used while comparing different regression models with the additional independent variable. This number is handy when deciding on the correct independent variable in multiple regression models. The standard error of the estimate measures the accuracy of predictions. In this case, the regression line is 40% accurate to forecasts.

Durbin –Watson Value

The value of Durbin-Watson indicates the autocorrelation between variables.

ANOVA

An ANOVA test is a way to find out if survey or experiment results are significant. **Analysis of variance** (**ANOVA**) is a collection of statistical models, and their associated estimation procedures (such as the "variation" among and between groups) used to analyze the differences among means.

Test of Normality

Normality tests are used to determine if a data set is well modeled by a normal distribution and to compute how likely it is for a random variable underlying the data set to be typically distributed. More precisely, the test is a form of model selection and can be interpreted several ways; depending on one interpretation of probability in descriptive statistics terms, one measures the goodness of fit of a standard model to the data – if the fit is poor, then the data are not well modeled in that respect by a normal distribution, without making a judgment on any underlying variable. Shapiro–Wilk statistic value is more significant than 0.05. So we can say that there exists a strong normality among energy efficiency knowledge, education, and put-off rice cookers.

In the information approach to testing, normality is to compare a histogram of the sample data to a normal probability curve; the empirical distribution of the data (the Histogram) should be bell-shaped and resemble the normal distribution. This might be difficult to see if the sample is small. In this case, one might proceed by regressing the data against the quantiles of a normal distribution with the same mean and variance as the sample. The lack of fit to the regression line suggests a departure from normality. As it is shown in Figure 2.2 A histogram is most effective when we have approximately 20 or more data points. If the sample is too small, then each bar on the Histogram does not contain enough data points to show skewness or outliers reliably Histograms give a rough sense of the density of the underlying distribution of the data, and often for density estimation estimating the probability density function of the underlying variable.

A normal probability plot is a graphical technique to identify substantive departures from normality. This includes identifying outliers, skewness, kurtosis, a need for transformations, and mixtures. Normal probability plots are raw data, residuals from model fits, and estimate parameters. In a normal probability plot (also called a "normal plot"), the sorted data are plotted vs. values selected to make the resulting image look close to a straight line if the data are approximately normally distributed. Deviations from a straight line suggest departures from normality. The plotting can be manually performed by using a special graph paper called a normal probability paper. The normal probability plot should produce an approximately straight line if the points come from a normal distribution. This graph includes the addition of a dot plot. The dot plot is the collection of points along the left y-axis. These are the values of the residuals. The purpose of the dot plot is to indicate the distribution of the residuals which is shown in Figure 2.1.

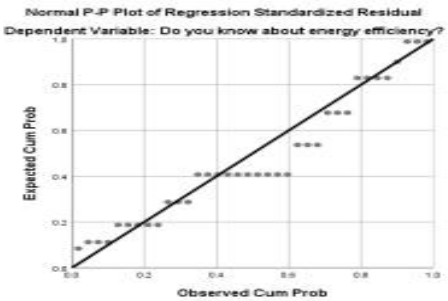

Fig.2.1: Normal p-p Plot

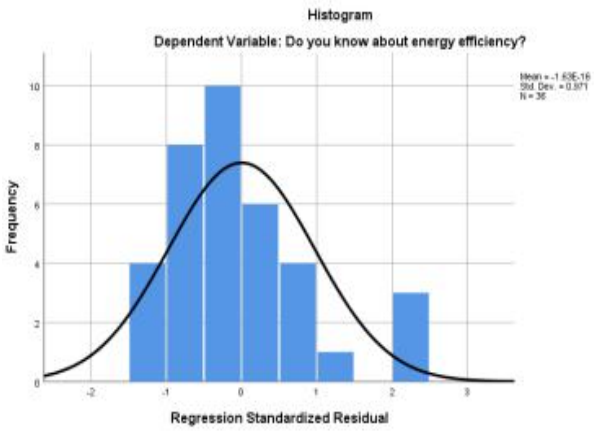

Fig.2.2: Histogram

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A scatter plot can be used either when one continuous variable is under the control of the experimenter and the other depends on it or when both continuous variables are independent. If a parameter is systematically incremented and/or decremented by the other, it is called the control parameter or independent variable and is customarily plotted along the horizontal axis. The measured or dependent variable is customarily plotted along the vertical axis. If no dependent variable exists, either type of variable can be plotted on either axis, and a scatter plot will illustrate only the degree of correlation (not causation) among variables. The scatter plot above represents the regression standardized residual vs. regression standardized predicted value. It seems to be the case that the points follow a linear pattern well, then we say that there is a high linear correlation as shown in Figure 2.3.

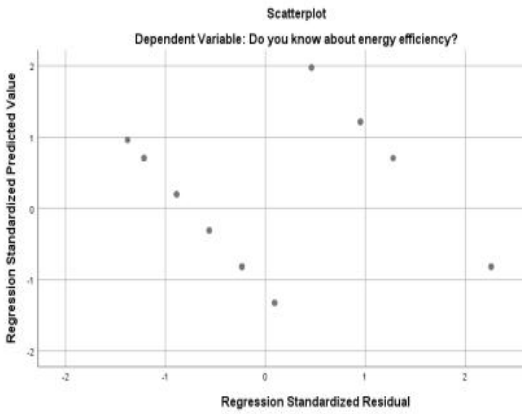

Fig.2.3: Scatterplot

Data Set

Given in the appendices. There are 40 Questionnaires for households and 19 Questionnaires for showrooms. There are two parts consist in the Questionnaire like, personal information and consumer activities. Age, Education level, income source, monthly income, and position in the showroom are included in the personal information. To make easy analysis to understand all answers to questions "Yes" and "No" responses have been converted to "1" and "0" respectively.

IV. RESULT

The regression equation for household (1)

ED= -.764*OC-1.040*PEST+7.075 (1)

Where, ED-(Education), OC-(Occupation) PEST-(Practices energy saving technique)

Table: 2 Declaration value of the variables for (equation 1)

Education	value	Occupation	value	PEST	value
PSC	1	Service	1	Yes	1
JSC	2	Business	2	No	2
SSC	3	Student	3		
HSC	4	Other	4		
BSc	5				
MSc	6				

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Table: 3 Parameters to understand the regression analysis

Parameter			value
R			0.681
R Square			0.464
Adjusted R Square			0.435
Durbin-Watson			1.98
T-test		Constant	9.998
		Occupation	-4.975
		Energy Saving technique	-2.721
Sig		Constant	.000
		occupation	.000
		Energy Saving technique	.010
Unstandardized Coefficient B		Constant	7.07
		Occupation	-.754
		Energy Saving Technique	-1.040
Collinearity	Tolerance	Constant	
		Occupation	1.000
		Energy Saving Technique	1.000
	Variance Inflation factor	Constant	
		Occupation	1.000
		Energy Saving Technique	1.000

R squared (R^2) is a statistical measure representing the proportion of the variance for a dependent variable explained by an independent variable in regression models. R^2, in this case, is 46 %, which implies that education can explain 30% of the variation in the chance of occupation and practices energy-saving techniques. The Criteria of regression analysis such as autocorrelation, normality, No or little Multi-collinearity, Linear relationship, and Homoscedasticity are shown in Appendix B1.

The regression equation for household (2)

ESI= -0.052*ED + 0.180*EBPM - 1.25*PEST + 1.164 (2)

$R^2 = 0.516$

Where

ESI (Energy saving is important), ED (Education), EBPM (Energy bills per month) PEST (Practices energy saving technique)

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Table: 4 Declaration value of the variables for (equation 2)

Energy bills per month	Value	Education	value	Energy saving important	value	Practices energy saving technique	value
100-500Tk	1	PSC	1	Yes	1	Yes	1
500-1000Tk	2	JSC	2	No	2	No	2
1000-1500Tk	3	SSC	3				
1500-2000Tk	4	HSC	4				
Above 2000Tk	5	BSc	5				
		MSc	6				

V. DISCUSSION

A relation has been found by which a clear idea can be built of how people use their electrical appliances. Some equation has been developed between the education and energy-saving techniques for minimizing the total monthly bill. Now it can easily predict the energy efficiency knowledge of a seller by using his position and educational background. The total sample size is 40. Calculating the data with five individual assumptions, which check no autocorrelation, linearity, normality, multi-collinearity, and Homoscedasticity.

Re-survey of 8 selected households was carried out to clarify behavioral factors that might influence the changes in electricity consumption. Although respondents said they had not introduced many saving measures, the reduction in electricity consumption is high (13%). That means electricity in households has been saved, but people do not feel the saving action or do not want to recognize that they might have taken some measures. The main factors for motivation to undertake energy-saving actions are "saved money," "spirit of competition", and "information on real examples of how to save." People's attitude regarding smart meters is positive, but it is not the primary motivator to decrease their electricity consumption [20].

The purpose of this study was to explore the best prediction model for determining the energy efficiency knowledge of different number households within the local area of Bangladesh. Data for the study was collected from 40 households and 19 showrooms. The Autocorrelation assumption is checked using model summary, which showed that no autocorrelation exists between independent and dependent variables. The Normality assumption is checked using a normal probability plot, which shows that almost all the points lie at a realistic straight diagonal line (from left to top right) which suggests that there is strong normality among variables. Also, the Linearity assumption is checked where almost we have seen that all points lie on a straight line in a normal probabilistic plot. Also, in the scatter plot, the points are roughly rectangular distributed where almost all the points lie on the center line. There is no presence of outliers in this data. This is because the facts are seen almost in the same cluster in the scatter plot. All regression equations showed a statistically significant relationship between the independent and dependent variables because the p-values of all independent variables were lower than 0.05.

It was found that the best-fit regression model is

EEN= -.131*E_D+.459*PRC +1.291

EEN – Energy efficiency knowledge

E_D- Education

PRC-Put off the rice cooker

The equation above shall be used to predict energy efficiency knowledge. It has been discovered that energy efficiency knowledge by people varies within different households

It turns out that low-income families do not have much of an energy efficiency connoisseur. The reason is that the rate of education within them is low. They are not aware of the issue of energy saving. Many of them do not

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know how to use electrical appliances effectively. When we collected the data, many of them provided false information, even if they used to attach their mobile charger to the switchboard. Not many people know when the Rice cooker has to stop. The issue of energy saving in the middle-income family that is reasonably aware. They provided correct information on the subject of electrical appliances. They are reasonably highly educated. That is why their energy efficiency is higher than others.

And the most important thing in high-income families is energy-saving which works consciously. They know the proper use of electrical appliances. Because they are highly educated. From the above discussion, it is understood that where the education level is high their energy efficiency knowledge is higher. There are many electrical appliance showrooms in Bangladesh. We have collected data from showrooms of some districts like Chapainawabganj, Bagherhat, and Jashore. We have seen that all the devices sold in the electrical showroom have less than five stars but are of good quality. Most showroom owners have low levels of education. Due to this, energy efficiency knowledge is less in them.

From the above discussion, it can be said that Bangladesh has a lack of education due to this, energy efficiency knowledge is low among us. For this, the government has to take various steps to increase the education level among people in Bangladesh regarding energy efficiency.

VI. CONCLUSION

Energy efficiency has been an essential part since the latter part of the last century. The main object of this survey is to determine the energy efficiency knowledge among consumers. Two separate districts in Bangladesh are selected to conduct the study on households and showrooms. Using the data, some regression equation is found from which it is easy to predict energy efficiency knowledge. The data is analyzed using SPSS software and calculated based on five important criteria. The initial target was to find some factors that help expect a person's energy efficiency knowledge. The survey shows the number of household energy use behaviors is estimated using a unique dataset of about 40 households and 20 showrooms in Chapainawabganj and Bagerhat districts in Bangladesh. It was found that the knowledge of energy consumption and energy efficiency technology options is associated with household use of energy conservation practices. Household characteristics also influence household energy use behavior. Younger household cohorts are more likely to adopt energy-efficient technologies and energy conservation practices and place primary importance on energy saving for environmental reasons. Education has a significant influence on attitudes toward energy conservation in Bangladesh. Households with less educated members indicate they primarily save electricity for economic factors, while highly educated households indicate they are motivated by environmental concerns.

Limitation

Short time duration for collecting data. Due to the data limitation, of all sample sizes, the output of regression analysis is sometimes not very precise. On the other hand, it was found that some people were not interested in providing energy consumption-related data.

Future work

In the future, it will help people to reduce their energy consumption. The work can be extended in a large margin for calculating the overall energy efficiency awareness over the country using a large sample size

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