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Working Paper

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Economics Working Paper Series, No. 19/315

Provided in Cooperation with:
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Suggested Citation: Filippini, Massimo; Kumar, Nilkanth; Srinivasan, Suchita (2019) : Energy-related financial literacy and bounded rationality in appliance replacement attitudes: Evidence from Nepal, Economics Working Paper Series, No. 19/315, ETH Zurich, CER-ETH - Center of Economic Research, Zurich, https://doi.org/10.3929/ethz-b-000328611

This Version is available at:
https://hdl.handle.net/10419/207137

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Working Paper 19/315
March 2019

Economics Working Paper Series

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Energy-related financial literacy and bounded rationality in appliance replacement attitudes: Evidence from Nepal

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Last revision: March 1, 2019

Abstract

Bounded rationality is an example of an important behavioral failure responsible for the energy-efficiency gap, whereby agents under-invest in energy-efficient technologies. One means of addressing this is by improving the energy-related financial literacy of households, which is defined as the combination of energy knowledge and cognitive abilities that are needed in order for agents to take sound decisions with respect to investment in durables. This has been found to improve the ability of agents to calculate the lifetime costs of technologies. The objective of this paper is to evaluate the determinants of energy-related financial literacy of respondents from about 2000 urban households in the Terai region of Nepal, and to analyze whether this ability has an effect on replacement attitudes of households regarding inefficient technologies. Using a novel household survey data, we find that respondents have low levels of energy-related financial literacy. While we find differences in the role of some socio-economic determinants of energy-related financial literacy compared to previous studies from developed countries, we also find certain common results, such as female respondents having lower scores. Additionally, we find that higher levels of energy-related financial literacy, especially stronger computational abilities, lead to more rational attitudes with regards to replacement of old appliances. As development has brought, and continues to bring, more households in low and middle-income countries (LMICs) closer to technologies of their liking, ensuring the adoption of energy-efficient technologies may be critical for ensuring sustainable development in the decades to come, and higher energy-related financial literacy may be one means of achieving that.

JEL Classification: D12, D80, Q41, Q48

Keywords: Bounded rationality; Energy literacy; Financial literacy; Households; Nepal

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1 Introduction

Climate change is a global phenomenon, which requires concerted action in terms of reductions of greenhouse gas (GHG) emissions, by all sectors of society, whether residential, transport or commercial. Reducing energy consumption from fossil fuels is one means to achieve reductions in emissions. However, this is easier said than done, given the dominance of fossil fuels in the global energy mix (WER, 2016). Achieving energy efficiency in consumption is another important way to mitigate climate change, with the added benefit of being a (relatively) less costly measure to achieve GHG emission reduction targets (Stern, 2007).

Climate change also has unequal effects on developed countries and low and middle income countries (LMICs): overwhelming evidence suggests that poor people in developing countries are more likely to be affected by it, both because of their geography, but also because of their inability to cope with the damage caused by climate change (UNFCCC, 2017). Moreover, while LMICs have low levels of per capita energy consumption relative to developed countries, higher levels of expected future growth, along with the expected increases in their population imply that energy consumption (and the use of energy services) is likely to increase. This may have further repercussions on GHG emissions, and thus on climate change. It is vital that policy-makers then implement policies to improve energy-efficiency, in order to ensure sustainable development.

One (relatively) easy means of achieving energy-efficiency is by investing in energy-saving technologies. However, economic literature is abound with examples of under-investment in such technologies (and the resulting private and social losses). A range of market and non-market (e.g., behavioral psychology) failures are responsible for this "energy-efficiency gap", where individuals may make suboptimal investment decisions when the benefits and costs of owning a durable are distributed unevenly over time (Hausman 1979; Jaffe and Stavins 1994; Allcott and Greenstone 2012; Gillingham and Palmer 2014).

Important examples of market failures include uninternalized externalities from energy consumption, imperfect information as well as a lack of capital (or even hidden costs of investment in energy-efficient technologies) (Schleich, 2009). Such failures imply that consumers and firms may not be able to exploit privately-profitable energy efficiency investments. In a LMIC context, the high transaction costs of acquiring information on the attributes of new energy-saving technologies that are available to them, or of doing an investment analysis on their costs and benefits are important examples of market failures (Jeuland et al., 2015). Further, in settings where energy access is a serious concern, credit and information-related market failures, along with weak institutions, may further depress clean technology adoption (Pattanayak, 2018).

Behavioral failures that may result in the energy-efficiency gap often stem from the risk and uncertainty involved (such as high implied discount rates for investments in energy-efficiency), concerns regarding split incentives (such as the landlord/tenant problem) and bounded rationality (Schleich, 2009). While neoclassical economics assumes that rational decision-makers choose the optimal solution given their budget constraint and given all available alternatives, real-world decision makers may often fail to behave as "Homo Economicus".

One form of bounded rationality is the failure of agents to compute the life-cycle costs of durables correctly, when making decisions to invest in energy-saving technologies. Energy-efficient technologies usually have higher upfront costs than other appliances, despite their lower operating costs, which means that households need to have both the computational abilities, as well as energy-related knowledge in order to calculate the cost over the lifetime of the appliance. Blasch et al. (2018) coin a new term for this conjoint ability, namely energy-related financial literacy, which is the combination of energy-related knowledge and cognitive abilities (or computational skills) that agents need in order to take decisions with respect to their investment decisions in durables, for the production of energy

services and their consumption.

Although the per capita energy consumption in developing countries is usually quite low, one can expect, at least in urban areas, that agents will purchase more energy consuming appliances and vehicles as their disposable incomes increase when their countries witness economic growth and development (Wolfram et al., 2012). This implies that the risks of bounded rationality, and therefore of low levels of energy-related financial literacy, are likely to be high. However, little is known on the ability of agents to undertake an investment analysis before making these technological choices, which may have repercussions on the efficiency of the technologies that they end up purchasing. While there are some studies that have looked at the role of price-constraints or lack of information in hampering greater adoption of energy-saving technologies in LMICs, to the best of our understanding, this research has not considered whether these barriers may stem from a lack of ability of agents to do investment calculations when they face uncertainty and risks, and how low levels of education and literacy may play a role (Klapper et al., 2015).

A few studies in the context of developed countries have analyzed the effects of higher levels of energy-related financial literacy on the identification of the most (cost-)efficient technologies by respondents (Blasch et al. (2018); Blasch et al. (2017b,a,c)). However, very little is known on this in the LMIC context. We hypothesize this to be a significant gap in the energy and development literature. These investments are likely to influence the paths of energy consumption in developing countries in the coming decades. Thus, two pieces of policy-focused research are helpful: (1) what are the determinants of energy-related financial literacy in LMICs, such as Nepal (which is one of the poorest countries in the world, with a per capita annual income of USD 835); and (2) do higher levels of energy-related financial literacy have an impact on the replacement attitudes regarding inefficient appliances in the Nepali context? Furthermore, we also provide information on the levels of financial literacy for households in Nepal.

In 2017, households accounted for about 45% of the total electricity consumption in Nepal whereas only 65% of the population had access to the grid, even though this number has been steadily increasing by about 10% annually (NEA, 2017). The current electricity supply, predominantly based on run-of-the-river type hydropower plants, has been unable to meet Nepal's growing peak time demand. Demand side management measures to improve end-use efficiency at the household level may yield significant reductions in electricity consumption. Even though Nepal primarily uses hydropower, which is a renewable source of power, it is important to stress that achieving energy efficiency is a crucial goal in the Nepalese context. There are two reasons for this: 1) it will enable the Nepalese electricity authorities to reduce peak demand, and avoid load-shedding, which will have other related benefits such as reduced air pollution (given the rampant use of diesel-run generators due to frequent interruptions, for instance), and 2) it may improve the balance of payments situation due to reduced imports of fuel from India.

This study is the first, to our knowledge, to undertake an analysis of energy-related financial literacy in a developing country context. Using novel data from a survey conducted in the Terai region of Nepal (including the second largest city of Biratnagar) with the cooperation of the Nepal Electricity Authority (NEA), we provide descriptive evidence on the appliance stock, as well as energy-related literacy and financial knowledge of a sample of about 2000 households that have regular access to electricity, along with information on their environmental attitudes and behaviour. We then estimate the determinants of energy-related financial literacy using regression analysis. Lastly, we ascertain the impact of energy-related financial literacy on the replacement attitudes of households regarding their old and inefficient appliances.

In this paper, we find that the levels of appliance ownership are low for households in the region, as one can expect. We find that the levels of energy-related knowledge, as well as their computational skills and financial literacy is quite poor for the respondents in these households. Regarding the

determinants of energy-related financial literacy, in consistency with other studies, we find that there is a gender-gap, with females having lower levels of literacy than males. This finding has been confirmed in developed countries as well, with females scoring less on both measures of computational skills, as well as energy knowledge. Moreover, we also find that less-educated households have lower levels of energy-related financial literacy, while income is not found to be a significant determinant of this score, unlike in developed countries (Blasch et al., 2018).

While we do not observe replacement behaviour of these households in this cross-sectional analysis, we have information on how they usually behave when they have to replace an inefficient appliance. We find that higher levels of computational skills are correlated to the ability of households to behave rationally when they decide to replace. This suggests that it is important to understand the binding constraints towards greater energy-efficient technology adoption in a developing country context.

Our goal through this paper is to shed light on the barriers to higher levels of energy-related financial literacy, that are specific to LMICs, and also inform policy-makers about how limited levels of energy-related financial literacy may affect their attitudes towards replacement of old appliances. We feel that the insights we derive from study are a useful step towards the design of demand-side management policies that may address low literacy levels as a reason for bounded rationality of households.

The remaining sections are organized as follows. Section 2 reviews the literature on the topics of energy-related literacy and financial literacy in the context of household energy consumption and adoption of new appliances. Section 3 describes the survey and the dataset used. Section 4 discusses the empirical strategy and presents the econometric analysis. Section 5 presents the results and Section 6 concludes.

2 Literature review

In this paper, we are interested in two interrelated types of literacy, which we argue are important in determining whether households are able to correctly value the benefits from the adoption of energy-efficient durables (such as appliances). The first is the idea of financial literacy, or computational ability in general, which would facilitate performing an investment analysis. The effects of higher levels of financial literacy have been extensively studied for both developed and developing countries, with regards to both retirement decisions (such as pensions) as well as the adoption of other financial products and services (Lusardi and Mitchell, 2007; Lusardi et al., 2009; Lusardi and Mitchell, 2011, 2014; Karakurum-Ozdemir et al., 2018; Xu and Zia, 2012). This literature finds an important role for financial literacy programs in determining both financial knowledge-related outcomes, but also in determining financial behavior. For instance, education through financial literacy programs have been found to have a profound effect on the likelihood of opening savings accounts (and the take-up of financial products in general), but also on financial proficiency scores and knowledge (Xu and Zia, 2012; Bruhn et al., 2014). However, except Blasch et al. (2018), few studies have considered whether this measure may have an impact on the adoption of energy-efficient technologies (or durables, in general).

Another aspect of literacy that may play a role in facilitating the ability of households to perform an investment analysis, which may then influence their adoption of energy-efficient durables, is their knowledge on energy-related matters, such as whether they are cognizant of the operating costs of appliances, or of possible savings from the use of energy-efficient technologies. This has been understudied in the literature, in comparison to the determinants of financial literacy, even in developed countries. Previous papers have studied the effects of environmental attitudes and behavior (Ameli and Brandt, 2015), as well as prices (Jacobsen, 2015) on energy-efficient adoption decisions, but less is known about the role of households' knowledge in determining these choices. Studies such as Brounen et al. (2013), as well as Kalmi et al. (2017) find that households suffer from low

levels of energy literacy (or energy knowledge) in the Netherlands and Finland respectively. One study that emphasized the importance of knowledge is Mills and Schleich (2012), who find that knowledge about energy consumption and energy-efficient technology options has a strong correlation with the household-level adoption of energy conservation practices, but not with adoption of energy-efficient appliances necessarily.

Recent studies have looked at the effect of being able to compute the lifetime costs of appliances on a household's decision to purchase energy-efficient appliances. Blasch et al. (2018) evaluate the determinants of energy-related financial literacy, and also show that higher levels of energy-related financial literacy have an effect on the share of energy-efficient technologies (in this case, light bulbs) adopted by households. They use data from a sample of European countries (Italy, the Netherlands and Switzerland) for their analysis, and propose the concept of 'energy-related financial literacy' which encompasses both energy-related knowledge and cognitive skills, to process available information in order to take informed energy-related investment decisions.

A stream of literature based on developed countries such as Switzerland has found that many households have poor levels of energy-related financial literacy, and this often leads to sub-optimal decisions regarding identification of the appliances having the lowest lifetime costs (Blasch et al., 2017b,a,c). These studies have also found a largely positive impact of enhancing both a household's energy knowledge, as well as their ability to do financial calculations, on their ability to identify the appliances having the lowest lifetime costs. Blasch et al. (2017a) show that more literate households are more likely to consume less electricity, and Blasch et al. (2017b,c) find that households having higher levels of literacy are more likely to calculate investment costs for themselves, rather than relying on simple rule-of-thumb heuristics.

Our paper is methodologically similar to that of Blasch et al. (2018), in that we are also seeking to understand the determinants of energy-related financial literacy, but in a LMIC context.[1] For developing countries, neither is there much evidence on the barriers towards greater adoption of energy-efficient technologies in general, nor is there much evidence on the determinants of energy-related financial literacy, or the ability of households to compute lifetime costs. We find this to be a big gap in the literature, especially because these countries suffer from already low levels of education and literacy (Klapper et al., 2015). Moreover, as their populations and incomes increase, LMIC households are more likely to purchase appliances and vehicles, which is likely to influence energy consumption pathways in the coming decades (Wolfram et al., 2012).

This paper attempts to fill this gap at least partially, by a) providing a descriptive analysis of appliance stock, financial literacy, and energy-related financial literacy, as well as replacement attitudes for our sample, and b) by analyzing the determinants of energy-related financial literacy for a sample of households in the Terai region of Nepal. While we do not have information on electricity consumption, or other types of behavior that may be interpreted as a direct outcome of having a high level of energy-related financial literacy such as replacement behavior, we also seek to c) evaluate the effects of higher levels of literacy on replacement attitudes of households regarding old and inefficient appliances. The results of this study provide important findings for us to undertake future experiments to study the effects of enhancing literacy in influencing households' adoption decisions.

[1] Kumar (2019) also look at the determinants of energy-related financial literacy (represented as latent clusters with low, mid and high level of literacy instead of a numeric score) for a large sample of Swiss respondents.

3 Data

The dataset comes from a household level survey conducted by the Centre for Energy Policy and Economics (CEPE), ETH Zurich in collaboration with Nepal Electricity Authority (NEA).[2] The survey was administered during the first quarter of 2018 with the help of the local NEA offices. A total of 2,042 respondents and households were part of the survey that was conducted in the Biratnagar region of Nepal including some of the nearby towns, e.g., Urlabari, Itahari, Duhabi and Dharan. These belong to the eastern Terai (lowland) region of Nepal. The survey was paper-based and in the local language (Nepali) and consisted of 31 questions spread over 6 pages. At the beginning of the survey, there was an introductory page with project information, incentives for participation, and a few basic instructions.[3]

The questions included in the survey were designed to collect information on household's socio-demographic characteristics, dwelling related attributes, capital stock, energy-related knowledge, computational skills, attitudes and behaviour towards electricity consumption and adoption of energy-efficient appliances. Below we present some descriptive statistics of the data.

3.1 Descriptive statistics

3.1.1 Socio-demographic and dwelling characteristics

Table 1 shows the percentage distribution of the basic socio-demographic characteristics of the respondents and households. Both genders are almost equally represented in the data. The typical respondent is married, lives in a joint family, both the respondent and the spouse are educated at the primary level (below high school), and the monthly household income is less than Rs. 20,000.[4] One in every three households declare that they regularly receive foreign remittance from a family member who works abroad.[5]

The median age of respondents in the household survey is found to be 43 years. Figure 3 in the appendix shows the share of the category of respondent's age as a percentage of the total 1,754 respondents who filled in their age on the survey form.

Table 2 presents features of the dwelling. Most respondents live in a single family house (97.5%) and in most cases the house is owned by a member of the household (95.2%). Almost half of the households belong to the town of Urlabari near Biratnagar in Nepal.

The median dwelling size is around 1,047 sq.ft and the median monthly rent for respondents who live in a rented residence is Rs. 3,000. The most frequent response to the question on total number of bedrooms and living rooms is 4. The same is true for the question on the total number of people regularly living in a household.

[2] The survey questionnaire was developed by CEPE and was based on the insights from some of our earlier household surveys on residential energy consumption (Blasch et al., 2017c, 2018).

[3] A copy of the survey questionnaire is included in the appendix. Further details on the project and the household survey could be found in the report "A descriptive overview of literacy, attitudes and behaviours towards energy consumption in Nepal" (Kumar, 2018).

[4] Rs. is Nepali Rupees. Rs. 1000 = USD 8.80 (exchange rate on 15.Feb 2019).

[5] As a share of GDP, Nepal was the 3rd largest recipient of remittances in the world in 2015 which accounted for 29% of its GDP (Sharma, 2017).

Table 1: Basic socio-demographic attributes of the survey sample.

Attribute		Percentage (%)	N#
Gender	*Male*	53.96	1972
	Female	46.04	
Marital Status	*Married*	89.66	2002
	Single	9.34	
	Divorced	1.00	
Type of household	*Joint*	79.47	1992
	Nuclear	19.88	
	Sharing apartment with friends	0.65	
Education	*Below high school*	60.26	1988
	Secondary school (class 10/12)	34.51	
	University	5.23	
Spouse's education	*Below high school*	64.54	1867
	Secondary (class 10/12)	29.35	
	University	6.11	
Monthly household income	*Less than 20,000*	57.39	2002
	20,000 - 50,000	26.12	
	More than 50,000	8.54	
	No answer/do not know	7.94	
Regular foreign remittance	*Yes*	32.44	1985
	No	67.56	

#sample excluding missing values from a total of 2,042 observations.

Table 2: Basic dwelling related attributes.

Attribute		Percentage (%)	N#
Town	*Urlabari*	45.44	2029
	Itahari	20.85	
	Duhabi	15.62	
	Dharan	14.39	
	Biratnagar	3.20	
	Other	0.49	
Dwelling type	*House*	97.48	1982
	Apartment/Flat	2.52	
Ownership	*Owned*	95.20	1981
	Rented	4.80	

#sample excluding missing values from a total of 2,042 observations.

3.1.2 Capital stock

The survey asked respondents if they owned certain types of household appliances, a motorcycle, or an inverter-battery system (or backup-system), and whether or not they are planning to buy or replace these durables in the next two years. Table 3 shows the share of responses to this question as percentages. We find that the share of households owning an electric rice cooker is more than 60%, followed by fridge (58.4%), motorcycle (39.5%), an inverter-battery based electricity backup system (21.4%), washing machine (8.9%), electric geyser (8.5%) and air-conditioner (4%). The share of households planning to add or replace one of these appliances in the next two years varies between

two to five percent.

Table 3: Capital stock and plan to add or replace in the next two years.

Appliance	Yes (%)	No (%)	Planned (%)	N#
Electric rice cooker	62.12	36.68	4.43	1985
Fridge	58.43	39.95	4.72	1970
Washing machine	8.90	89.74	3.86	1842
Motorcycle	39.46	60.43	3.01	1893
Electric geyser	8.51	90.57	2.76	1845
Inverter-battery system	21.43	77.93	2.36	1862
Air-conditioner	4.00	95.23	2.08	1824

#sample excluding missing values from a total of 2,042 observations.

3.2 Definition of literacy scores

Measurement of the level of energy-related knowledge and computational skills was one of the main objectives of the survey which consisted of several questions for this purpose. Below we present an overview of these questions and use the responses to construct three types of scores, following the approach in Blasch et al. (2018). Our first score is an index that measures energy knowledge, the second is a score of that we term "computational skills", which is a combination of financial literacy along with the ability to do a lifetime cost calculation. The final measure has been referred to as energy-related financial literacy, which is defined as a sum of the energy knowledge as well as computational skills scores of the respondents.

3.2.1 Energy-related knowledge

Questions on energy-related knowledge checked whether respondents knew the cost of electricity (in monetary terms) for some of the daily electricity consuming activities, or energy services, at home, and whether they were able to compare two energy services and determine which one consumed more electricity. The respondents were also asked how much they thought was the percentage of energy savings when using an LED bulb against an incandescent bulb.[6] These questions are described in Table 11 in the appendix and summary statistics on the correct responses are presented in Table 4.

The low mean values in Table 4 highlight a low level of energy-related knowledge among the Nepalese respondents in our sample. Among all questions, respondents seem to be better informed about comparison and savings on LED bulbs compared to regular incandescent bulbs. This is likely accredited to the fact that the NEA has been actively promoting the benefits of LED bulbs through advertisements and information campaigns since 2016 (NEA, 2017).[7]

The index capturing energy-related knowledge is created as the sum of the number of questions which the respondent answered correctly (theoretically, it can vary from 0 to 6, given that we ask

[6]For the questions about the monetary cost of energy services, respondents had to select one answer for each question among the given choices. The choices in Nepali Rupees (Rs.) were Rs. 0-5; Rs. 6-10; Rs. 11-20; Rs. 21-50; Rs. 50+ and DNK (Do not know). For the questions that provided respondents with two energy services and asked them which, in general, consumes more electricity, the choices consisted of each of the two energy services under comparison, one option that said both consume the same, and DNK. The choices for the savings on LED bulb against an incandescent bulb were 5-10%; 30-50%; 70-80%; and DNK.

[7]It is worth pointing out that a low level of energy-related knowledge is also common in developed economies as shown by Blasch et al. (2017b,c) for households in Switzerland and Blasch et al. (2018) for an European sample. The level of energy-related knowledge found in these studies are (only) slightly better than those found here.

Table 4: Energy-related knowledge.

	N	Mean	St. Dev.	Min	Max
Energy costs of a rice-cooker	1,766	0.122	0.327	0	1
Energy costs of a ceiling fan	1,763	0.107	0.309	0	1
Energy costs of a TV	1,747	0.218	0.413	0	1
Energy costs of a refrigerator	1,740	0.132	0.339	0	1
Compare: Incandescent vs. LED bulb	1,979	0.423	0.494	0	1
Savings: Incandescent vs. LED bulb	1,982	0.316	0.465	0	1

Notes: All variables are binary with 1 implying a correct response.

6 questions to measure the respondent's knowledge and energy-related awareness).[8] In our sample, a majority (almost 40%) of households incorrectly answer (or did not know the answer to) every question related to energy consumption.

3.2.2 Computational skills

The questionnaire contained a few questions to assess the level of financial literacy and computational skills. Some of these questions pertain to calculations of simple interest, compound interest as well as on the effects of inflation, which are standard in the financial literacy literature (Lusardi and Mitchell, 2014).[9] Additionally, we asked the respondents a question that sought to identify their ability to perform an investment analysis by means of comparing two appliances. This question captures whether households can compare two fridges, and identify the one having a lower lifetime cost (defined as the sum of the purchasing cost, and the operating costs).[10] These questions are described in Table 11 in the appendix and the summary statistics on correct responses are presented in Table 5.

Table 5: Financial literacy and computational skills.

	N	Mean	St. Dev.	Min	Max
Simple interest	1,922	0.136	0.343	0	1
Inflation	1,949	0.239	0.427	0	1
Compound interest	1,956	0.283	0.450	0	1
Lifetime cost comparison	1,962	0.093	0.291	0	1

Notes: All variables are binary with 1 implying a correct response.

Table 5 depicts a general low level of financial skills. Near about 30% respondents appear to be aware on how to calculate compound interest rate. Understanding of the interplay of rate of inflation and bank interest rate appears to be lower. The poor performance in the simple interest question when compared to the compound interest question is somewhat strange. It might be due to the use of a larger monetary amount (Rs 10,000) and a longer time duration (5 years) in the simple interest question, which, if true, again points to cognitive limitations of consumers in processing large

[8] We also ask a few additional questions on energy consumption of certain appliances, that have not been used to create this index, because of low ownership rates for these appliances such as washing machines (9%) and electric water heaters/geysers in our sample (8.5%).

[9] It is to be noted that the classic financial literacy literature considers three aspects: interest calculation, effect of inflation and risk-diversification (Lusardi and Mitchell, 2009). We do not ask a question on risk-diversification here as its role in the domain of appliance choice or household consumption is not apparent. Instead, we consider two separate questions related to simple and compound interest calculations to construct our index.

[10] This question is adapted from the RCT question in Blasch et al. (2017c).

numbers.[11] Lastly, respondents perform very poorly in the question concerning identification of the appliance with the lower lifetime cost – only about 1 in 10 answer this correct which highlights the inability of consumers to perform investment analysis in the domain of appliance choice.[12]

Our score measuring computational skills is constructed by summing up the number of above described questions that the household answered correctly in the survey, i.e. it varies from 0 to 4 and considers both financial knowledge as well as ability to perform a simple lifetime cost calculation of an appliance. Thus, the index attempts to represent the computational ability of the respondents. While it is closely related to a typical measure of financial literacy, we prefer it over financial literacy because it is more comprehensive – it incorporates a critical component of the ability to perform an investment analysis, namely, the ability to calculate and compare lifetime costs of appliances. Nevertheless, as a benchmark model in the empirical analysis, we consider a financial literacy score that varies from 0 to 3 (i.e. without considering the lifetime cost comparison question).

3.2.3 Energy-related financial literacy

The total number of questions that are answered correctly by the respondent pertaining to both energy knowledge, as well as computational skills, are the two components of the index of energy-related financial literacy. Theoretically, the index can vary from 0 to 10 (there are six questions aimed to capture energy knowledge and four questions for computational skills). In our data, the maximum score that households get is 8. Interestingly, 30% of households get a score of zero, namely they are unable to answer a single question correctly.

Following the arguments listed in Blasch et al. (2018), one means to justify combining these different components together in creating the energy-related financial literacy index, at least statistically speaking, is to check for a) the correlation between them, and b) the internal consistency of the scales that have been used to measure the two components. The pairwise correlation coefficient between the two different indices that we have used to measure energy-related financial literacy, namely energy knowledge and computational skills, is found to be 27.24%. The correlation coefficient between computational skills and energy knowledge is comparable to that of about 27% for the Swiss, Italian and Dutch population (Blasch et al., 2018). This may suggest that there may be common determinants of the two factors, such as income and education, that are closely related to one another in the context of developing countries.

In addition, Table 6 includes information on the Cronbach's alpha measures (which measure the internal consistency of the indices). From the results of Table 6, we find that the measures of Cronbach's alpha are high for each combination of measures that we use. This suggests the scale reliability, as well as internal consistency of these measures, when they are used as a group (Tavakol and Dennick, 2011).

Table 7 below presents the summary statistics on the energy knowledge index, the index for computational skills, as well as the energy-related financial literacy index, along with the benchmark score, which is the classical financial literacy index. We see that the mean scores are very low for the Nepalese sample, along both dimensions of energy knowledge and computational skills, and that no household attains scores of energy-related financial literacy which are higher than 8 (the theoretical

[11] On the other hand, this could also have happened due to an unwanted layout issue as this particular question started on pages 4 and ended on page 5 in the paper survey.

[12] It was originally planned to conduct a randomized controlled trial with this question by providing half of the respondents with a 1-page educational information on how to calculate the lifetime cost of a durable before they answered this question. Unfortunately, because of organizational limitations this could not be implemented. About 20% of the respondents still ended up with the 1-page educational information attached to end of the questionnaire, i.e. after all survey questions had already been asked. We specifically tested for any unintended effect of the 1-page educational information at the end of the survey on the response to this question, but we did not find any significant effect.

Table 6: Measures of Internal Consistency

Components	Energy knowledge	Skills	Energy-related Financial Literacy
Cronbach's alpha	0.617	0.324	0.434
Observations	2042	2042	2042

maximum is 10). Moreover, the low median scores suggest that a large share of the sample scores low.

Table 7: Summary Statistics on the Scores.

Score	Mean	Median	Std. Dev.	Min.	Max.	Obs.
Energy knowledge	1.214	1	1.372	0	6	2,042
Computational skills	0.717	0	0.867	0	4	2,042
Energy-related financial literacy	1.930	2	1.812	0	8	2,042
Financial literacy	0.627	0	0.786	0	3	2,042

3.3 Replacement attitudes

The survey also asked the respondents about what they would do in a hypothetical appliance replacement situation. The question that the households are asked, along with the potential responses, are listed below:

`Question` In case at least one of your major electrical appliances (e.g., fridge, washing machine or geyser) is 10 or more years old and inefficient, why did you not replace the appliance so far with a new more efficient one? Please choose which of the following statements is best applicable to you.

`Response 1` I only replace appliances when they stop working.

`Response 2` I have never really thought about it.

`Response 3` So far, I didn't inform myself because it is tedious to find out all the information.

`Response 4` I did an investment analysis, and found the current appliance to be more cost-effective.

`Response 5` High upfront costs prevent me from buying a new appliance, even though I realize that it might be more cost-effective in the long-run.

`Response 6` I do not own any old appliance.

About 42% of the respondents chose `Response 6`, i.e. they do not own any old appliance. This high share likely reflects the low ownership of major appliances that was also seen earlier in Table 3.[13] Around 27% selected `Response 2`, i.e. they never really thought about replacing an old appliance. The share of other options were – `Response 1` (9%), `Response 3` (10%), `Response 4` (7%), and `Response 5` (5%).

The answers to this question could be used to gain insights into the rationality of consumers, which is likely to vary across the sample. Households may exhibit irrational attitudes, boundedly rational attitudes, or rational attitudes. Therefore, based on the answers to this question, we choose to group our sample into three categories. The first group have what we term"irrational" replacement attitudes (respondents who selected `Response 2`). The second group are the "boundedly rational" (those who chose `Response 1` or 3), and lastly we identify the third group as "rational" (those who opted

[13]Note that the question asked about a major electrical appliance that is 10 or more years old. Given the low ownership of appliances in our survey conducted in 2018, it can be expected that a lower number of households may even have bought a major appliance before 2009.

Response 4 or 5). Hence, we are able to identify an ordinal nature, or ranking, among the three groups, i.e. "irrational" $<$ "boundedly rational" $<$ "rational". In the second part of the econometric analysis, we will use an ordered probit methodology in order to estimate the determinants of this replacement attitude with a particular focus on the role of our literacy based indices.[14]

4 Empirical model

In this section, we first present the empirical model pertaining to determinants of the different literacy scores. Next, we illustrate the empirical model to analyse the replacement attitudes. For the first model, we adopt an approach similar to that of Blasch et al. (2018), in using an ordered probit estimation to model energy knowledge, computational skills, and energy-related financial literacy (defined as the sum of the indices for energy knowledge, and computational skills). This is intuitive, given that the dependent variables for this set of estimations are scores, with a natural ordering (a higher score indicates a more "literate" respondent). This methodology assumes that there is a continuous, latent measure underlying the observable ordinal variable, and that it can be expressed as

$$y_i^* = X_i\beta + \epsilon_i \tag{1}$$

where y_i^* is a latent (continuous) variable measuring the literacy score of the respondents, X_i is a vector denoting the socio-economic characteristics of household i such as age, income, level of education, and dwelling-specific characteristics, β is the vector of parameters that need to be estimated. ϵ_i denotes the stochastic error term, which is assumed to be independently and identically distributed across households. This model is estimated using maximum likelihood estimation.

The probability that household i has reached literacy level of j (where j can vary from 0 to 10 in the case of the model estimating energy-related financial literacy), is given by

$$\begin{aligned} &Pr(y_i = j) = Pr(k_{j-1} < y_i^* \leq k_j) \\ &-\infty = k_0 < k_1 < ...k_j... < k_J = \infty, \quad j\,\epsilon\, 1, 2, 3, \ldots, J \end{aligned} \tag{2}$$

where the y_i's are the ordinal values of the literacy score, and the k_j's are the threshold parameters. We estimate this model separately for each score that we are interested in, namely the energy knowledge of the households, their skills score, and finally the energy-related financial literacy index. Lastly, as a benchmark, we also estimate the determinants of the score of financial literacy.

In the second part, we evaluate the impact of these literacy scores on the replacement attitudes amongst our sample of Nepalese households. While we do not observe their replacement behavior regarding old appliances, the households are asked about what they would do in a hypothetical appliance replacement situation. Recall that, based on the replacement attitude, we were able to group our sample into three categories – "irrational", "boundedly rational", and "rational". These groups exhibit an ordinal nature, i.e. "irrational" $<$ "boundedly rational" $<$ "rational". We also use, in this case, an ordered probit methodology to estimate the effects of literacy scores on the replacement attitudes of respondents.

We first estimate the effect of energy-related financial literacy on the level of rationality in replacement attitudes. This estimation can be represented by the expression for the ordered Probit regression, as we previously defined:

[14] Respondents who chose Response 6 to the question are not considered as they are not relevant in our analysis of determinants of replacement attitude.

$$r_i^* = E_i\alpha + X_i\beta + \nu_i \tag{3}$$

where r_i^* is a latent (continuous) variable measuring the replacement attitudes of the households, E_i is the energy-related financial literacy score of household i, and X_i denotes the same vector of socio-economic characteristics of household i that we used for the previous estimation. ν_i denotes the stochastic error term, which is assumed to be independently and identically distributed across households.

The probability that household i has reached a level of rationality j in terms of replacement attitudes (where j can vary from 1 (irrational) to 3 (rational)), is given by

$$\begin{aligned} &Pr(r_i = j) = Pr(s_{j-1} < r_i^* \leq s_j) \\ &-\infty = s_0 < s_1 < ...s_j... < s_J = \infty, \quad j \,\epsilon\, 1, 2, 3, \ldots, J \end{aligned} \tag{4}$$

where the r_i's are the ordinal values of the replacement attitudes as defined above, and the s_j's are the threshold parameters.

We then also estimate this model using the components of the energy-related financial literacy score separately, i.e. using the energy knowledge index along with the skills measure as independent variables. Our benchmark model once again incorporates the financial literacy score as an independent variable, and we show that the model with the components introduced separately is better than the benchmark model, both in terms of economic intuition, and statistical power of the models.

In the estimation in Eq. (3), one concern may be of endogeneity. However, it is less likely that replacement attitudes influence computational skills or energy knowledge as our dependent variable measures stated preferences in appliance replacement attitudes. Of course, given that we use cross-sectional data, it is not straightforward to rule out the possibility of correlated unobservables influencing both the dependent variable as well as our explanatory variables. Given the fact that we control for important determinants of both attitudes and literacy (such as education, income, as well as the total number of investments already made by households in appliances and personal mobility), the risk of endogeneity is reduced in this case.

5 Results

In this section, we first present the estimation results pertaining to determinants of the different literacy scores. Next, we look at the estimation results with appliance replacement attitudes as the outcome variable. Lastly, we present a discussion on the marginal effects and predicted probabilities following these estimations.

The results of the baseline model, which evaluates the determinants of the literacy scores are presented in Table 8 below, which includes the coefficients for the models estimated using the ordered probit methodology. In column (1), we present the results for the estimation of energy knowledge, column (2) includes the results of estimation of computational skills whereas column (3) presents the results of the estimation of the energy-related financial literacy index of households (as defined in the Section 3.2.3). The results of column (4) are those of the benchmark model, where we estimate financial literacy.

We find that older respondents, on average, have lower levels of energy knowledge, whereas they have higher levels of computational skills (as can be seen in columns (1) and (2)). The effect of age on energy-related financial literacy is insignificant (driven by these two opposing effects on the

components of the score). This is in contrast to the findings of Blasch et al. (2018), one of which was that older households have higher levels of energy-related financial literacy in the context of a sample of European countries. Younger respondents faring better on energy knowledge suggests that improvements in the quality of education (over time) may have arguably had an impact on energy knowledge, while the same cannot be said of computational and/or financial skills.

Table 8: Determinants of literacy scores.

Dependent variable	Energy knowledge index (1)	Skills (2)	Energy-related financial literacy (3)	Financial literacy (4)
Age	-0.005**	0.006***	-0.001	0.007***
	(0.002)	(0.002)	(0.002)	(0.002)
Whether female	-0.241***	-0.289***	-0.295***	-0.289***
	(0.061)	(0.067)	(0.060)	(0.068)
Whether a low income HH	-0.050	0.240***	0.045	0.257***
	(0.075)	(0.082)	(0.073)	(0.082)
Whether respondent has low level of education	-0.166***	-0.017	-0.155***	0.027
	(0.073)	(0.076)	(0.071)	(0.077)
Whether married	0.056	0.065	0.061	0.04
	(0.118)	(0.119)	(0.115)	(0.124)
Number of people living in the residence	0.006	0.006	0.004	-0.002
	(0.017)	(0.019)	(0.016)	(0.020)
Capital stock	0.075***	0.062**	0.088***	0.061**
	(0.025)	(0.030)	(0.025)	(0.030)
Whether house is owned	-0.048	-0.035	-0.064	-0.050
	(0.166)	(0.209)	(0.161)	(0.213)
Number of rooms in the house	0.002	-0.063***	-0.015	-0.072***
	(0.020)	(0.024)	(0.020)	(0.025)
Whether live jointly with extended family	-0.219***	0.02	-0.164**	0.068
	(0.083)	(0.088)	(0.081)	(0.087)
Observations	1386	1386	1386	1386

Notes: Dependent variable in columns (1) to (2) is the sum of the number of questions pertaining to energy knowledge and computational skills that the respondent answered correctly, respectively. In column (3), it is total number of questions pertaining to energy knowledge and computational skills (combined) that were answered correctly. In column (4), it is the financial literacy score. Ordered probit methodology is used for the estimations. Coefficients are reported in this table. The thresholds are all found to be significantly different from one another at the 1% level. We restrict the sample to those respondents in the age group 18-102, living in houses with less than 10 rooms and less than 12 people living in the household, in order to reduce noise in the regressions. Robust standard errors are reported in parentheses. *,** and *** respectively denote significance at 10%, 5% and 1% levels. The coefficient of the constant has not been reported.

One of the most important findings of this paper, which has been confirmed in previous studies from developed countries as well, is that on average, women fare much worse than men in these surveys, with scores of energy knowledge, skills, and energy-related financial literacy being lower for them than for male respondents (Lusardi and Mitchell, 2014; Blasch et al., 2018; Kumar, 2019). The variable is found to be significant at the 1% level in each model of Table 8. This finding has broad connotations in the context of the general educational gap between men and women, which is even more sharply-defined in developing countries. It also has implications for which group should be targeted by policy-makers for educational campaigns. The optimal policy measures should take into account the intra-household bargaining power of women in this context, and how much of a say they have in investment decisions for durables.

We do not find evidence to suggest that income is a significant determinant of energy knowledge, whereas it is found to be a significant determinant of skills and financial literacy (with low-income households having higher scores than high income households). There may be multiple reasons for these findings. One may be that in a LMIC context, lower-income households are more likely to be employed in the informal sector. These individuals are more likely to be in need of, and thereby also use, skills related to financial calculations, than individuals earning a higher income. Secondly, low-income households are more likely to be reliant on credit assistance, or aid in some

form, which often requires them to be able to perform simple financial calculations in return. Without further information on the nature of occupations of the respondents and their access to banks and informal financial arrangements in general, it is difficult to pinpoint the exact channel of influence. Having stated that, the result regarding the insignificance of the income variable for the estimation of energy-related financial literacy highlights that it may be critical to understand how the barriers towards higher knowledge and skills in a LMIC context may differ from those in developed countries.

We also find that the role of education in determining energy knowledge, as well as energy-related financial literacy, is positive and significant for our sample (as can be seen in columns (1) and (3)), while we do not find this effect in column (2). Higher levels of education are thus a strong determinant of higher levels of energy-related knowledge, but not of their ability to perform numerical computations (which are more likely to be influenced by lower income levels). Thus, unlike the findings of Blasch et al. (2018), the determinants of energy knowledge and computational skills in our sample are quite different.

In this analysis, we also control for the total "capital stock" of the households, namely the total number of investments that households have made in durables such as electrical appliances, back-up systems and personal mobility. Specifically, we sum the total number of appliances that households have already purchased (amongst rice cookers, fridges, washing machines, water heaters, and air-conditioners), as well as investments in inverter-battery systems, and in personal mobility (namely, whether they have already purchased a two-wheeler such as a motorcycle). This variable aims to capture the total number of assets that households have accumulated, with the potential to undertake an investment calculation. We find that this variable has a positive and significant effect on literacy scores across all models in Table 8.

Moreover, our results suggest that respondents who live with extended family (or with friends) have lower levels of energy knowledge (and energy-related financial literacy) than respondents who live in a single-family arrangement, while this is not observed in the results of column (2). There is also no significant difference in the levels of literacy between respondents that lived in rented versus owned households, although we do find that respondents that live in larger houses (with more rooms) are likely to have lower levels of computational skills, as can be inferred from column (2). This effect appears to be in line with the previous finding regarding the negative effect of income on financial literacy.

The results of the benchmark model in column (4) are similar to those of column (2), given the similarity of the dependent variables in the two estimations.

Next we examine the appliance replacement attitude of the respondents. Recall that the outcome variable is ordinal and depicts whether the respondent's attitude towards replacement of a major household durable is irrational, boundedly rational, or rational.

In Table 9, we present the results of the estimations using ordered probit methodology for estimating the effect of literacy scores on replacement attitudes. Column (1) includes the results of the model using the energy-related financial literacy score as an independent variable, column (2) uses its two components, namely energy knowledge as well as computational skills as independent variables, while in column (3), we present the results of the benchmark estimation using financial literacy as an independent variable.

We see from the results of column (1) that respondents having higher scores of energy-related financial literacy are more likely to exhibit rational replacement attitudes than respondents having low levels of literacy. This is in line with our intuition: higher scores of energy-related financial literacy imply that respondents are more likely to perform an investment calculation, or at least perceive the benefits from adopting energy-efficient technologies, compared to respondents having a lower score.

In the estimation results of column (2), we find that while energy knowledge is an insignificant

Table 9: Effect of literacy scores on replacement attitudes.

Column	(1)	(2)	(3)
Energy-related financial literacy	0.061***		
	(0.023)		
Energy knowledge		-0.042	
		(0.030)	
Financial literacy			0.372***
			(0.064)
Skills		0.356***	
		(0.056)	
Age	0.005	0.003	0.004
	(0.004)	(0.004)	(0.004)
Whether female	-0.069	-0.061	-0.046
	(0.094)	(0.094)	(0.094)
Whether a low income HH	0.107	-0.069	0.071
	(0.095)	(0.096)	(0.096)
Whether respondent has low level of education	0.002	-0.033	-0.031
	(0.096)	(0.097)	(0.096)
Whether married	0.351***	0.345**	0.346**
	(0.155)	(0.156)	(0.156)
Number of people living in the residence	-0.040	-0.039	-0.036
	(0.025)	(0.025)	(0.025)
Capital stock	0.010	-0.0001	-0.005
	(0.037)	(0.039)	(0.038)
Whether house is owned	-0.147	-0.128	-0.122
	(0.182)	(0.176)	(0.180)
Number of rooms in the house	0.036	0.045	0.046*
	(0.028)	(0.028)	(0.028)
Whether live jointly with extended family	-0.191**	-0.198**	-0.188**
	(0.105)	(0.105)	(0.104)
Observations	761	761	761
Akaike's Information Criterion	1482.122	1453.83	1454.603

Notes: Dependent variable in columns (1) to (3) is an ordered variable representing rationality in replacement attitudes (varying from 1 (irrational) to 2 (boundedly rational) to 3 (rational)). Ordered probit methodology is used for the estimations in columns (1) to (3). Coefficients are reported in this table. The thresholds are all found to be significantly different from one another at the 1% level. We restrict the sample to those respondents in the age group 18-102, living in houses with less than 10 rooms and less than 12 people living in the household, in order to reduce noise in the regressions. Robust standard errors are reported in parentheses. *,** and *** respectively denote significance at 10%, 5% and 1% levels. The coefficient of the constant has not been reported.

determinant of rationality, the ability to compute the lifetime costs of appliances as well as correctly answer questions on financial literacy, is more likely to lead to rationality in replacement attitudes of households (the variable is significant at the 1% level). We expect energy knowledge to play a minimal role in determining replacement attitudes, given the nature of questions they are asked to assess this (namely, costs of operating major appliances, and comparing the energy-efficiency of appliances). On the other hand, the significance of stronger computational skills in enabling households to make investment decisions in developing country contexts (such as in Nepal) is likely to be higher, especially when budget constraints may dictate replacement decisions. While we do not observe the impact of higher literacy levels on electricity consumption or replacement behavior itself, we are able to find a positive effect for computational skills on stated choices, namely in determining how rational households are in deciding whether to replace old and inefficient appliances.

Lastly, in column (3), we include the results of the benchmark model, which incorporates the measure of financial literacy as an independent variable. We find that the coefficient is positive, and significant at the 1% level. However, we find that the model in column (2) has a slightly lower value of the Akaike's Information Criterion (AIC), which suggests that it has higher statistical power than the model in column (3). Thus, higher computational skills (that include a measure for correct lifetime cost calculation) have a greater explanatory power in explaining rationality in replacement attitudes, than using the classic financial literacy index.

We also find that married respondents are more likely to exhibit rational replacement attitudes, whereas respondents that live with their extended families are less likely to do so. This suggests that household composition may play a role in determining appliance needs, as well as rationality in replacement attitudes.

Marginal effects and predicted probabilities

The marginal effects for the estimation in column (3) of Table 8 related to the determinants of energy-related financial literacy are provided in Table 10 below. The negative marginal effect due to being female is found to increase with increasing ERFL score, i.e. being a female additionally decreases the probability of possessing higher levels of energy-related financial literacy. Similarly, having a low level of education (below high school) additionally decreases the probability of having high levels of energy-related financial literacy. These findings support our key observations regarding the gender-gap in literacy levels, as well as importance of education in determining energy-related financial literacy in developing countries. Lastly, the number of investments made by households in appliances and personal mobility additionally increases the probability of possessing higher levels of energy-related financial literacy.

Next, we present the predicted probabilities with respect to the score variables for the replacement attitudes. Figure 1 shows the predicted probabilities for increasing values of energy-related financial literacy from the results of column (1) of Table 9 whereas Figure 2 shows the predicted probabilities for increasing values of energy knowledge (Fig. 2a) and computational skills (Fig. 2b) from the results of column (2) of Table 9. We find from the predicted probability plot in Figure 1 that higher levels of energy-related financial literacy are associated with an increase in the probability of belonging to the "boundedly rational" group, or the "rational group", whereas it is associated with a lower probability of belonging to the irrational group, which is intuitive.

The graphs in Figure 2 display the predicted probability plots for the model of column (2) of Table 9, which contain the results of the estimation using the two components of energy-related financial literacy (energy knowledge and computational skills) as independent variables. Figure 2a contains the plot for energy knowledge; we find that the level of energy knowledge does not significantly influence the probability of belonging to a particular attitude group, although it appears that in our case, higher

Table 10: Marginal effects: determinants of Energy-related financial literacy (ERFL).

Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ERFL score	0	1	2	3	4	5	6	7	8
Age	0.001	0.0002	-0.0002	-0.0006	-0.001	-0.002	-0.002	-0.003	-0.003
	(0.002)	(0.0005)	(0.0005)	(0.001)	(0.002)	(0.003)	(0.004)	(0.005)	(0.006)
Whether female	0.342***	0.064***	-0.070***	-0.174***	-0.322***	-0.488***	-0.603***	-0.713***	-0.867***
	(0.070)	(0.016)	(0.017)	(0.037)	(0.067)	(0.100)	(0.122)	(0.146)	(0.179)
Whether a low income HH	-0.052	-0.010	0.011	0.026	0.049	0.074	0.091	0.108	0.131
	(0.085)	(0.016)	(0.017)	(0.043)	(0.080)	(0.121)	(0.149)	(0.176)	(0.214)
Whether respondent has low level of education	0.180**	0.033**	-0.037**	-0.091**	-0.169**	-0.256**	-0.316**	-0.373**	-0.454**
	(0.082)	(0.016)	(0.017)	(0.042)	(0.077)	(0.116)	(0.144)	(0.170)	(0.206)
Whether married	-0.071	-0.013	0.015	0.040	0.067	0.101	0.125	0.148	0.179
	(0.133)	(0.025)	(0.028)	(0.068)	(0.126)	(0.190)	(0.235)	(0.278)	(0.338)
Number of people living in the residence	-0.005	-0.001	0.001	0.003	0.005	0.007	0.009	0.011	0.013
	(0.019)	(0.004)	(0.004)	(0.010)	(0.018)	(0.027)	(0.033)	(0.039)	(0.048)
Capital stock	-0.102***	-0.019***	0.021***	0.052***	0.096***	0.145***	0.179***	0.212***	0.257***
	(0.030)	(0.006)	(0.007)	(0.015)	(0.028)	(0.042)	(0.052)	(0.061)	(0.074)
Whether house is owned	0.075	0.014	-0.015	-0.038	-0.070	-0.106	-0.131	-0.156	-0.189
	(0.187)	(0.035)	(0.039)	(0.095)	(0.176)	(0.267)	(0.329)	(0.390)	(0.474)
Number of rooms in the house	0.017	0.003	-0.004	-0.009	-0.016	-0.025	-0.030	-0.036	-0.044
	(0.023)	(0.004)	(0.005)	(0.012)	(0.022)	(0.033)	(0.041)	(0.049)	(0.059)
Whether live jointly with extended family	0.190**	0.035**	-0.039**	-0.097**	-0.179**	-0.271**	-0.334**	-0.396**	-0.481**
	(0.094)	(0.018)	(0.020)	(0.048)	(0.088)	(0.134)	(0.166)	(0.197)	(0.238)
Observations	1386	1386	1386	1386	1386	1386	1386	1386	1386

Notes: Dependent variable in the estimation of this model is the energy-related financial literacy score (sum of correct answers related to energy knowledge and computational skills). Ordered probit methodology is used for the estimation. Marginal effects are calculated in terms of percentage changes in the ERFL score per unit increase in the independent variables, and are calculated at means. The thresholds are all found to be significantly different from one another at the 1% level. We restrict the sample to those respondents in the age group 18-102, living in houses with less than 10 rooms and less than 12 people living in the household, in order to reduce noise in the regressions. Robust standard errors are reported in parentheses. *,** and *** respectively denote significance at 10%, 5% and 1% levels.

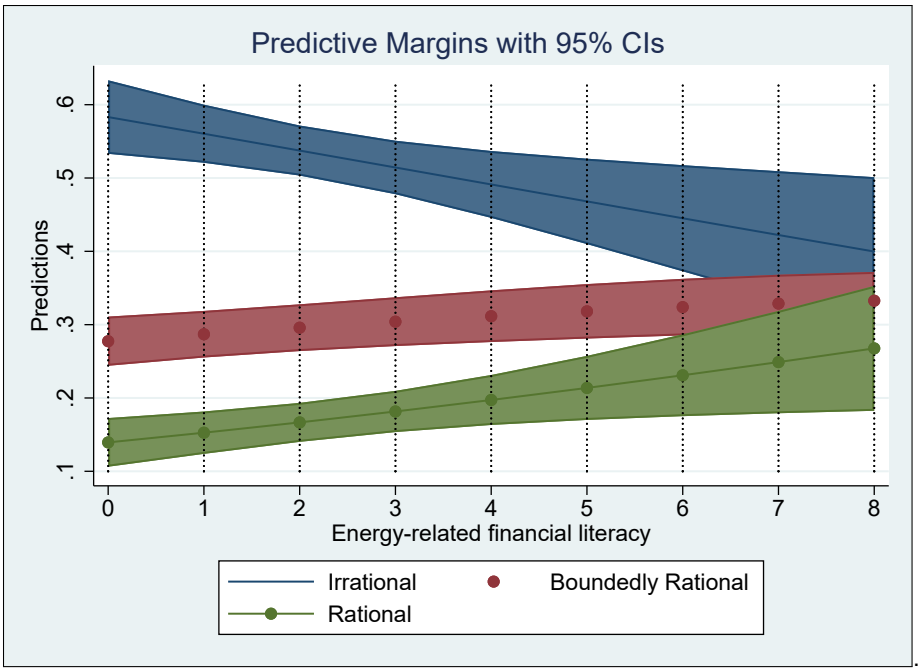
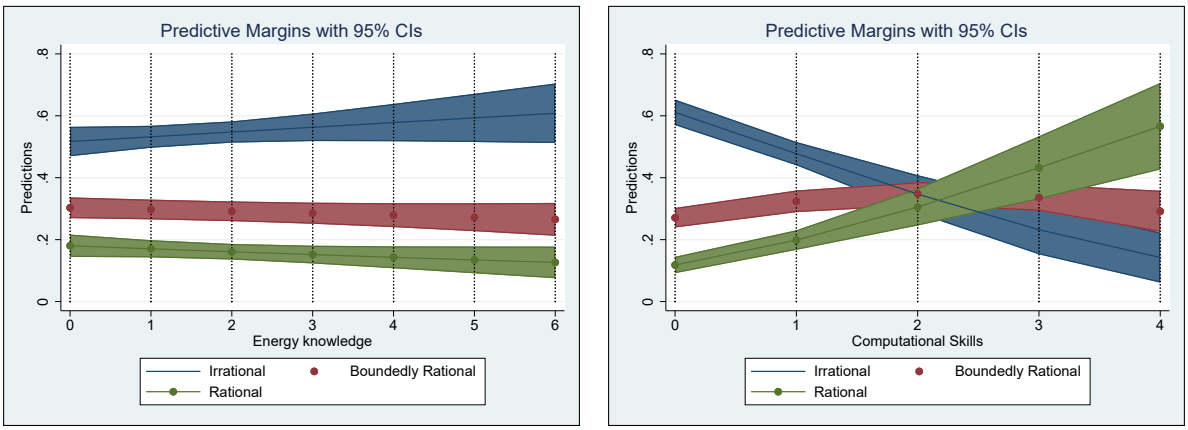


Figure 1: Effect of energy-related financial literacy on the predicted probabilities of replacement attitudes

levels of energy knowledge may be associated with slightly higher probabilities of belonging to the irrational group, and slightly lower probabilities of belonging to the boundedly rational or rational groups. On the other hand, in Figure 2b, we find that higher levels of computational skills have a strong role in determining rationality in replacement attitudes (with the predicted probability of being rational being more than 50% for those who answer all questions correctly). Furthermore, the likelihood of being irrational declines with increases in computational skills. Lastly, the likelihood of being boundedly rational first rises from low to medium levels of computational skills and then declines at higher levels in computational skills, i.e. among all levels of computation skills, the likelihood of belonging to the boundedly rational group is highest at medium levels of skills.



(a) Energy knowledge

(b) Computational skills

Figure 2: Effect of energy knowledge and computational skills on the predicted probabilities of replacement attitudes.

6 Conclusion and Policy Implications

Household level information on the adoption of appliances, environmental attitudes and behaviour within the residential sector is scarce for households in developing countries, as is information on the determinants of their knowledge on energy-related matters and computational skills. In this paper, using novel data from a survey of about 2000 households conducted in the Terai region of Nepal, we are able to shed some light on the determinants of energy-related financial literacy of respondents, and also identify its effect on replacement attitudes regarding old and inefficient appliances.

The initial results suggest low levels of energy-related financial literacy for our sample and we observe that important determinants such as age and income do not necessarily play a role in the same direction in determining them as they do for developed countries. For instance, we find that older respondents are more likely to have lower levels of energy knowledge and higher levels of financial literacy. Likewise, low-income households are more likely to have higher levels of financial literacy (a finding that is in contrast to what is observed in developed countries), whereas higher levels of education are a strong determinant of the energy knowledge (but not financial literacy). This suggests that it may be important, in a developing country-context, to understand the nature of occupations, as well as the formal banking and credit arrangements available to households.

At the same time, we are also able to confirm certain findings from the literature on developed countries, primarily the lower literacy levels for female respondents compared to male respondents. This finding has important repercussions for policymakers in the design of education policies catering to households in developing countries.

We also find that stronger computational skills are a strong determinant of rationality of households in replacement attitudes, which may have repercussions on their consequent adoption behavior as well. This is a critical finding, which sheds light on the nature of barriers in greater adoption of energy-efficient technologies in developing countries, but also has implications for policy design.

Thus, both the descriptive evidence, as well as the regression-based results of this paper provide a plethora of relevant findings on environmental and energy-related issues for policymakers in low and middle-income countries. The consequences of this study are especially far-reaching, as both development and population growth enable more households to purchase appliances. Our goal is to highlight, based on previous literature, that energy-related financial literacy is a one of the important determinants of households' decisions to adopt (or to replace) energy-efficient technologies. Moreover, while previous studies have shown the importance of financial literacy in influencing inter-temporal decision-making, we show that computational skills (more broadly defined, to include the ability to compute lifetime costs of durables) are a more significant determinant of replacement attitudes. Effective policy design, especially of educational or informational programs, may benefit from taking these findings into account.

This paper also brings to light the fact that a policy prescription that targets specific groups, or clusters of the population may not fit both developed country and developing country contexts identically. We find considerable differences in terms of the determinants of both energy knowledge and financial literacy from the results of Blasch et al. (2018), especially in terms of the roles played by age, education and income.

This research may be an important stepping stone in the future design of energy-related policies and educational programs, both for the NEA and for the government of Nepal. Further research will be fruitful in helping us pinpoint the complex behavioral factors, in addition to the typical barriers that prohibit further adoption of energy-efficient technologies in low and middle-income countries. Future work will study the role of simple educational tools and energy audits in enabling households or small business owners in developing countries to identify (and adopt) the most energy-efficient appliances.

Acknowledgements

We are grateful to the Nepal Electricity Authority (NEA) for collaborating with us on this project. NEA was not responsible for the survey design, analysis and interpretation of data, or in the writing of this report. The content does not necessarily represent the official views of the NEA. All omissions and remaining errors are our responsibility. Furthermore, we would like to thank Mr. Chandrakant Lal Das and the utility distribution office in Biratnagar, Nepal who provided local support in administering the household survey. Comments from participants of a seminar presentation at CEDECON, Tribhuvan University in January 2019 are gratefully acknowledged.

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Appendix

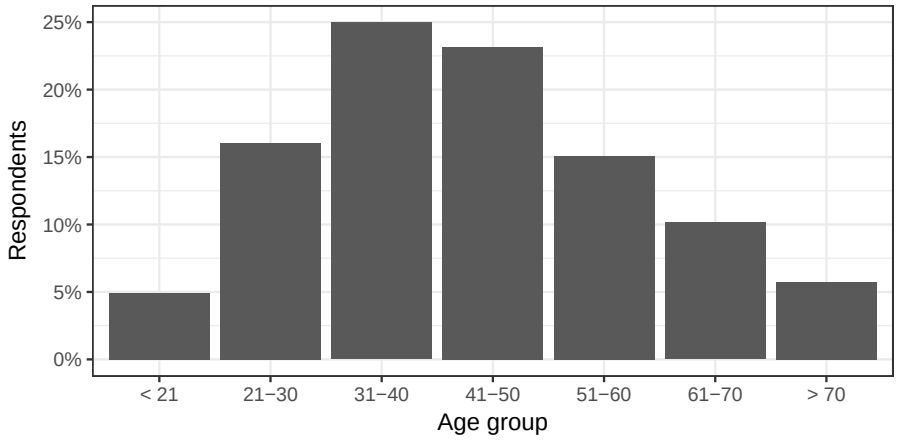

Figure 3: Survey respondents by age group.

Table 11: The survey questions related to energy-related knowledge and financial skills.

Identifier	Question description
Energy costs of a rice-cooker	How much does it cost: Cooking rice for 4 people with an electric rice-cooker, per cycle.
Energy costs of a ceiling fan	How much does it cost: Running a ceiling fan for 1 hour.
Energy costs of a TV	How much does it cost: Running a TV for 1 hour.
Energy costs of a refrigerator	How much does it cost: Running a fridge for 1 day.
Compare: Incandescent bulb vs. LED	Which of the two consumes more electricity: An incandescent bulb for 1 hour vs. an LED bulb for 1 hour?
Savings: Incandescent bulb vs. LED	How much is the energy savings from using an LED bulb compared to a regular incandescent bulb.
Simple interest	Assume that you have Rs 10,000 in a savings bank account which gives a 7% annual interest. How much would be the amount after 5 years if you left the money to grow? (Choices: more than 10,700 / exact 10,700 / less than 10,700 / DNK)
Inflation	If the savings account interest rate is 7% and the rate of inflation is 8%, how much would you be able to buy with the money account after 1 year? (Choices: less than today / same as today / more than today / DNK)
Compound interest	Imagine that you have Rs 1,000 in a savings bank account with 10% annual interest rate. How much money would be there in the account after 2 years?
Lifetime cost comparison	Suppose you own your home. Your fridge breaks down and you need to replace it. You can choose between two alternatives that are identical in terms of design, capacity and quality of the cooling system. **Fridge A** sells for Rs 8,000 and has an electricity consumption of 300 KWH per year. **Fridge B** sells for Rs 12,000 and has an electricity consumption of 280 KWH per year. Assume the average cost of electricity is Rs 10 per KWH, each of the two fridge models have a lifespan of 15 years and that you would get a return of 0 percent from any alternative investment of your money. **Which choice of purchase minimizes the total costs of the fridge over its lifespan?**

ETH
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Centre for Energy Policy and Economics
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विद्युत खपत तर्फको साक्षरता, आनीबानी र व्यवहार सम्बन्धी सर्वेक्षण

प्रिय सहभागीहरु,

यो सर्वेक्षण स्वीस फेडरेशन इन्स्टीच्युट अफ टेक्नोलोजीको सेन्टर फर इनर्जी पोलिसी एण्ड इकोनोमिक्स को प्रायोजनमा नेपाल विद्युत प्राधिकरणद्वारा प्रायोजित अनुसन्धान आयोजनाको एउटा भाग हो। यसमा भएका प्रश्नावलीहरु भर्न तपाईलाई करीव १० मिनेट समय लाग्नेछ। तपाईका सम्पूर्ण उत्तरहरुलाई गोपनीयतापूर्वक राखिने कुराको हामी प्रत्याभूति दिन्छौं।

यो सर्वेक्षण तयार गर्दा तपाईले रु. १,०००/- रकम बराबरको १०० विजेतालाई खरीद भौचरमध्ये एउटा भौचर बिराटनगर स्थित कुनै एक पसलबाट दैनिक उपयोग का सामान खरिद गर्न सकिने गरि जितने अवसर पाउनुहुनेछ। यो सर्वेक्षणमा भाग लिने सहभागीहरुबीच गोलाप्रथाको आधारमा विजेताको छनौट गरिनेछ र विजेताहरु लो कुन पसलबाट सामान लिने हो सोको जानकारी मो० न० / फोन द्वारा दिईने छ। उक्त गिफ्ट भौचर तपाईले आगामी गृष्म ऋतुमा पाउनुहुनेछ। कृपया भरिएको सर्वेक्षण फारम तपाईले जिम्मेवार व्यक्तिलाई जिम्मा दिनुहोला।

सम्पूर्ण प्रश्नको उत्तर तपाईले विना कुनै बाह्य सहायताले दिनुहुन अनुरोध गर्दछु।

यस सर्वेक्षणमा भाग लिनुभएकोमा तफाईलाई धन्यावाद ज्ञापन गर्दछु।

आयोजना टोली

ग्राहक संख्या:
(बिजुलीको बिल अनुसार) ☐

तपाईको नाम: ☐

लिंग: पुरुष ☐ महिला ☐

उमेर (वर्षमा): ☐

ठेगाना: ☐

मोवाईल न० / फोन न०: ☐

दस्तखत: ☐

तपाई र तपाईका घरका बारेमा

वैवाहिक स्थिति:
☐ एकल
☐ विवाहित
☐ परित्यक्त / परित्यक्ता

परिवारको प्रकार:
☐ न्युक्लियर परिवार
☐ संयुक्त परिवार
☐ मित्रहरुका बीचको साझा अपार्टमेन्ट

तपाईको शिक्षाको स्तर:
☐ माध्यमिक विद्यालयभन्दा मुनि
☐ उच्च माध्यमिक विद्यालय (कक्षा १० र १२ उत्तीर्ण)
☐ विश्वविद्यालय

यदि तपाई विवाहित भए, तपाईको जीवनसाथीको शिक्षाको स्तर:
☐ माध्यमिक विद्यालयभन्दा मुनि
☐ उच्च माध्यमिक विद्यालय (कक्षा १० र १२ उत्तीर्ण)
☐ विश्वविद्यालय

जम्मा घरायसी मासिक आम्दानी (रु. मा)
☐ २० हजारभन्दा कम
☐ २० हजार - ५० हजार
☐ ५० हजार भन्दा बढी
☐ उत्तर दिन चाहन्न / मलाई थाहा छैन।

यदि तपाईका परिवारका सदस्यमध्ये कोही विदेशमा बसेका भए, निजले नियमित रुपमा पठाउने विप्रेषण (रेमिटेन्स) का बारेमा तपाईलाई थाहा छ?
☐ छ
☐ छैन

निवासको किसिम:
☐ घर
☐ अपार्टमेन्ट / तला

निवासको स्वामित्वको अवस्था:
☐ आफनै निवास
☐ भाडाको निवास

यदि भाडा (बहाल) मा रहेको भए, बहाल रकम प्रतिमहिना: _____

निवासको आकार (वर्गफीटमा): _____

कोठाको कूल संख्या (शयन कक्ष र बैठक कक्ष): _____

तपाईको निवासमा नियमित रुपमा बस्ने मानिसहरुको जम्मा संख्या: _____

उपकरण तथा टिकाउ सामग्रीहरु

के तपाईसंग देहायका विद्युतीय उपकरणहरु वा टिकाउ सामग्रीहरु रहेका छन्? के तपाई आगामी २ वर्षभित्रै त्यस्ता उपकरण र सामग्री खरीद गर्ने तयारीमा हुनुहुन्छ?

	छ	छैन	आउने २ वर्षमा खरीद गर्ने/किन्ने योजनामा छु
विद्युतीय राइस कुकर	☐	☐	☐
फ्रिज	☐	☐	☐
लुगा धुने मेशिन	☐	☐	☐
मोटरसाइकल (दुईपांगे)	☐	☐	☐
विद्युतीय गिजर	☐	☐	☐
इन्भर्टर-ब्याट्री प्रणाली	☐	☐	☐
एयरकन्डीशन	☐	☐	☐

तपाईले सामान्यतया स्नानका लागि तातो पानी कसरी प्राप्त गर्नुहुन्छ ?
☐ विद्युतीय गिजर
☐ ग्यास सिलिण्डर गिजर
☐ सोलार गिजर
☐ म भान्छामा पानी तताउंछु।
☐ तातो पानीमा मेरो पहुंच छैन।

उर्जा सम्बन्धित ज्ञान र आर्थिक साक्षरता

तपाईले गत एक वर्षमा कति विद्युत खपत वापत रकम बुझाउनु भएको छ?
☐ रकम रु. _____
☐ मलाई थाहा छैन।

नेपालमा १ इकाइ यूनिट (किलोवाटआवर) विद्युत को शुल्क कति छ?
☐ रकम रु. _____
☐ मलाई थाहा छैन

तपाईको विचारमा देहायका सामग्रीहरुका लागि जम्मा विद्युतको खर्च (रु.) कति पर्छ होला? तलका बाकसमा चिन्ह लगाउनुहोस् ।

उपकरण को नाम	रु. मा					
	०-५	६-१०	११-२०	२१-५०	५०+	थाहा नभएको
४ जनाको लागि विद्युतीय राइस कुकरमा भात पकाउंदा	☐	☐	☐	☐	☐	☐
एउटा सिलींग पंखा १ घण्टा चलाउंदा	☐	☐	☐	☐	☐	☐
एयटा टेलिभिजन १ घण्टा चलाउंदा	☐	☐	☐	☐	☐	☐
एयटा फ्रिज १ दिन चलाउंदा	☐	☐	☐	☐	☐	☐
एक राउण्ड कपडा पूर्ण क्षमतामा लुगा धुने मेशिनमा धुंदा	☐	☐	☐	☐	☐	☐
४ जनाका लागि एयटा विद्युतीय गिजर तातो पानीका लागि चलाउंदा	☐	☐	☐	☐	☐	☐

देहायका सेटहरुमा घरायसी कार्यहरुमा साधारणतया सवभन्दा बढी विद्युत खपत हुने सामग्री कुन हो ?

सेट १: पूर्ण क्षमतामा एउटा लुगा धुने मेशिन र एउटा विद्युतीय राइस कुकर चलाउंदा
☐ लुगा धुने मेशिन
☐ विद्युतीय राईस कुकर
☐ दुवैले समान विद्युत खपत गर्छ
☐ मलाई थाहा छैन

सेट २: एक घण्टा टेलिभिजन र एक घण्टा सिलींग पंखा चलाउंदा
☐ टेलिभिजन
☐ सिलींग पंखा
☐ दुवैले समान विद्युत खपत गर्छ
☐ मलाई थाहा छैन ।

सेट ३: नियमित रुपमा एयटा चीम र एउटा एलइडी बल्ब चलाउंदा
☐ नियमित चीम
☐ एलइडी चीम
☐ दुवैले समान रुपमा चलाउंदा
☐ मलाई थाहा छैन

एउटा साधारण बल्ब को सट्टामा एउटा एलइडी लाइट बल्ब (समान उज्यालोपनका लागि) प्रयोग गर्दा तपाईको विचारमा कति उर्जा बचत हुन्छ।
☐ ५-१० प्रतिशत
☐ ३०-५० प्रतिशत
☐ ७०-८० प्रतिशत
☐ मलाई थाहा छैन

मानिलिनुस् कि तपाईको बैंक बचत खातामा रु.१०,०००/- बचत रहेको छ जसमा तपाई ७ प्रतिशत प्रतिवर्षका दरले ब्याज पाईरहनुभएको छ। यदि तपाईले उक्त रकम वृद्धि हुन छाडेको भए ५ वर्षपछि तपाईको खातामा कति रकम जम्मा हुनेछ।
☐ १०,७०० भन्दा बढी

☐ पूरै १०,७००
☐ १०,७०० भन्दा कम
☐ मलाई थाहा छैन

कल्पना गर्नुस् कि तपाईले बचत खातामा ७ प्रतिशत प्रतिवर्ष ब्यजा पाइरहनुभएको छ र मुद्रास्फिति ८ प्रतिशत प्रतिवर्षका दरले बढेको रहेछ, यस्तोमा तपाईले उपलब्ध बैंक खाता रकमबाट कति किनमेल गर्न सक्षम हुनुहुनेछ?
☐ आजको भन्दा बढी
☐ ठ्याक्कै आजको जति
☐ आजको भन्दा कम
☐ मलाई थाहा छैन

मानीलिनुस् कि तपाईको बचत खातामा रु.१,०००/- रहेको छ, जसमा १० प्रतिशत प्रतिवर्ष ब्याज पाउनुहुनेछ। आजको एक वर्ष र दुई वर्षपछि तपाईको खातामा कति रकम जमा हुनेछ।

एक वर्षपछि :
☐ १,००१
☐ १,०१०
☐ १,१००
☐ १,११०
☐ मलाई थाहा छैन

दुई वर्षपछि :
☐ १,१००
☐ १,११०
☐ १,२००
☐ १,२१०
☐ मलाई थाहा छैन

विद्युतीय खपत बानी तथा वातावरणीय प्रकृति

दैनिक रुपमा तपाईले आफ्ना देहायका गतिविधिहरु साधारणतया कसरी सम्पन्न गर्नुहुन्छ ?

	कहिल्यै गर्दिन	एकदमै कम	कहिलेकाहीं	प्राय:जसो	सधैं
कोठा छाड्ने बेलामा बत्ती र पंखा निभाउने	☐	☐	☐	☐	☐
चिसो पानीमा वाशिंग मेशिनमा लुगा धुने	☐	☐	☐	☐	☐
प्रयोगपछि सम्पूर्ण विद्युतीय उपकरणहरु बन्द गर्ने (जस्तै: टेलिभिजन र कम्प्युटरहरु)	☐	☐	☐	☐	☐

वातावरणसंग सम्बन्धित देहायका व्यवहारसंग तपाई कत्तिको सहमत हुनुहुन्छ?

	पूर्णत: असहमत	असहमत	अनिर्णित	सहमत	पूर्णत: सहमत
हाम्रो प्रकृतिको भविष्यको बारेमा म चिन्तित छु	☐	☐	☐	☐	☐
म आफ्नो विद्युतीय खपतलाई घटाउन चाहन्न यदि अरुले पनि यस्तो चाहँदैनन् भने	☐	☐	☐	☐	☐
वातावरणको हितमा म आफ्नो वर्तमान जीवनशैलीसंग कुनै पनि सम्झौता गर्न चाहन्न	☐	☐	☐	☐	☐

लगानीसम्बन्धी निर्णयहरु

मानिलिनुस् कि तपाईको आफ्नै घर छ। तपाईको फ्रिज बिग्रेर यसलाई फेर्नुपर्ने छ। यस सम्बन्धमा तपाईले समान किसिमको डिजाइन, क्षमता र गुणस्तर भएको चिस्याउने प्रक्रिया (कुलिंग सिस्टम) का लागि तलकामध्ये दुई विकल्पमध्ये एउटा रोज्न सक्नुहुनेछ।

फ्रिज क : रु.८,०००/- मूल्य पर्ने प्रतिवर्ष ३०० किलोवाट आवर (यूनिट) विद्युत खपत गर्ने
फ्रिज ख : रु.१२,०००/- मूल्य पर्ने प्रतिवर्ष २८० किलोवाट आवर (यूनिट) विद्युत खपत गर्ने

मानिलिनुस् कि औसत विद्युत मूल्य रु.१०/- प्रति किलोवाट आवर पर्छ, माथिका दुवै मोडेलका फ्रिजहरुको आयु १५ वर्षको रहेको छ र तपाईले आफ्नो रकमको शून्य प्रतिशत लाभ हासिल हुने कुनै वैकल्पिक लगानीमा हाल्नुभएको छ।

फ्रिजको आयु अनुसारको न्यूनतम जम्मा मूल्य बमोजिमको खरीदमा तपाईको छनौट कुन हुनेछ?
☐ फ्रिज क
☐ फ्रिज ख
☐ जम्मा मूल्यको आधारमा फ्रिज क र फ्रिज ख एउटै हुन्
☐ मलाई थाहा छैन

तपाईको निर्णयका लागि सबभन्दा महत्वपूर्ण कारण के हुनसक्थ्यो?
☐ फ्रिज ख भन्दा फ्रिज क कम मूल्यको रहेको छ
☐ फ्रिज ख को न्यून विद्युत खपत नै त्यसको उच्च मूल्यलाई सम्पुष्टि गरेको छ
☐ फ्रिज ख को न्यून विद्युत खपत मात्र त्यसको उच्च मूल्यलाई सम्पुष्टि गर्न सक्दैन
☐ मलाई थाहा छैन।

यदि तपाईको न्यूनतम कुनै एक मुख्य विद्युतीय उपकरण (जस्तै: फ्रिज, लुगा धुने मेशिन वा गिजर) १० वा बढी वर्ष पुरानो र अप्रभावकारी रहेको छ, तपाईले यसलाई प्रतिस्थापन गरी एउटा प्रभावकारी उपकरण किन लिनुहुन्न?
कृपया छान्नुहोस् कि कुन चाहिं वाक्यांश तपाईका लागि उपयुक्त हुन्छ।
☐ उपकरणले काम गर्न छाडेमा मात्र म त्यसलाई प्रतिस्थापन गर्छु
☐ मैले यसबारेमा केही सोचेको छैन।
☐ मैले यसबारेमा जानकारी नपाएकाले यसका बारेमा सम्पूर्ण जानकारी राख्नु मलाई आवश्यक रहेको छ।
☐ मूल्य र फाइदा दुवैको तुलना गर्दा मैले नयां उपकरण खरीद गर्नुभन्दा हाल भइरहेकै उपकरण मलाई फाइदाजनक छ।
☐ नयां उपकरणको उच्च मूल्यले मलाई खरीदबाट रोकिरहेको छ, यद्यपि दूरगामी रुपमा मेरो लागि यो फाइदाजनक रहेको छ।
☐ मसंग कुनै पुरानो उपकरण रहेको छैन।

सोच्नुस् कि तपाईको पुरानो टेलिभिजनले काम गर्छ तर धेरै विद्युत खपत गर्दछ र **तपाई यसलाई प्रतिस्थापन गर्न चाहनुहुन्छ**। के तपाई न्यून विद्युत खपत गर्ने नयां टेलिभिजन खरीद गर्न चाहनुहुन्छ? तलका मध्ये कुन कुराले तपाईलाई सबभन्दा बढी चित्त बुझेको छ।
☐ पुरानो टेलिभिजनले काम गरीरहेकाले म ढिलो गरी नयां टेलिभिजन खरीद गर्छु।
☐ मेरो पुरानो टेलिभिजन बिक्री भएमा मात्र म नयां टेलिभिजन खरीद गर्नेछु।
☐ म पसलमा गई पुरानो टेलिभिजन साटेर नयां टेलिभिजन लिने प्रयास गर्नेछु (जस्तै: साटासाट योजना)
☐ म मेरो पुरानो टेलिभिजन कसैलाई नि:शुल्क दिनेछु (जस्तै: नोकर, चालक, कनिष्ट कर्मचारी इत्यादि)
☐ म नयां टेलिभिजन खरीद गरी पुरानो मिल्काउन/फ्यांकने चाहन्छु।

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