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**Working Paper**

## Urban and rural households' energy use: Sets, shocks, and strategies in the Philippines

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DISCUSSION PAPER SERIES NO. 2018-01

# Urban and Rural Households' Energy Use: Sets, Shocks, and Strategies in the Philippines

*Connie B. Dacuycuy and Lawrence B. Dacuycuy*



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Urban and Rural Households' Energy Use:  
Sets, Shocks, and Strategies in the Philippines

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## **Abstract**

This paper aims to analyze the determinants of household energy portfolio in urban and rural areas and to determine how choices are affected by price shocks and weather variabilities in the Philippines. It confirms that energy switching is observed among high-income urban and rural households while energy stacking is observed among rural households in response to a heat index deviation and an LPG price shock. The paper also finds that households' energy portfolios have components comprising of modern sources as energy anchors and a component that is most likely to adjust in response to price and weather-related shocks.

**Keywords:** Energy portfolio, stacking, switching, energy anchors, shocks, Philippines

**JEL Code:** Q4, Q49, D12

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# Urban and rural households' energy use: Sets, shocks and strategies in the Philippines

*Connie Bayudan-Dacuycuy and Lawrence B. Dacuycuy\**

## 1. Introduction

For energy needs, households do rely on energy sets or portfolios consisting of modern and traditional components. In the literature, how household energy portfolios are chosen can be explained either by the energy switching or the energy stacking strategy. The energy switching strategy is conceptualized by the energy ladder model, which assumes that households behave as neoclassical consumers, so that their demand for cleaner and safer energy sources increases with income (Hosier and Dowd 1987). It assumes three phases: the first phase, which is marked by universal reliance on biomass; the second phase, where households move to “transition” fuels such as kerosene, coal and charcoal; and the third phase, where households switch to LPG, natural gas, or electricity (Heltberg 2004). In this model, the switching strategy suggests that traditional energy sources are used by the poor while modern energy sources are used by the rich.

The empirical literature, however, provides evidence showing that the transition from traditional to modern energy sources may not be strongly associated with improvements in income levels. Energy stacking strategy, or the use of traditional and modern energy sources, is being practiced in both rich and poor households. Stacking behavior may be associated with fluctuating energy prices (Hosier and Kipondya 1993), variations in culture and tradition (Rao and Reddy 2007), and may arise from supply constraints as households find it best to keep alternative sources as backups (Masera, Saatkamp and Kammen 2008).

Van der Kroon et al (2013) explain energy choices using a framework that revolves around three categories: *external environment* like climate and geographic location, *decision context* like government policies, and *household opportunity set* like characteristics and factor endowments. The household opportunity set is the building block of households' livelihood strategy and determines the capacity of households to reduce its vulnerability and restricts or broadens their window of opportunity (van der Kroon, Brouwer and Beukering 2013). Decision context is related to the functioning of consumer markets, which include the reliability of supply, number of distributors, and transaction costs related to distance to markets. The external environment includes geographical location that largely determines access to consumer markets.

This paper aims to analyze how household's choices of energy portfolio in urban and rural Philippines are affected by price and weather shocks. It is related to van der Kroon et al (2013) as it focuses on the role of external environment and decision context. It is also related to studies that attempt to analyze urban-rural energy choices within the context of energy stacking and switching strategies (Hosier and Dowd 1987; Hosier and Kipondya 1993; Heltberg 2004).

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Analyzing the effects of price shocks helps in understanding which types of intervention can be extended to urban and rural households. Analyzing the effects of weather variabilities is certainly relevant for the Philippines since it is one of the countries that is most vulnerable to the adverse effects of climate change, which has manifested itself in terms of increased precipitation/temperature in some areas and decreased rainfall/temperature in others. In the Philippines, few studies that investigate energy consumption include Bayudan-Dacuycuy (2017) who documents that households' energy consumption is affected by different weather fluctuation scenario.

This paper uses the Household Energy Consumption Survey dataset collected by the Philippine Statistics Authority and the Department of Energy and the weather data collected by the Philippine Atmospheric and Geophysical Astronomical Services Administration in 59 weather stations all over the country. It uses temperature and relative humidity data and their 30-year average values to come up with a measure of heat index deviation, which serves as a proxy for the variability in weather.

This paper is organized as follows: section II discusses households' energy use in the Philippines, Section III discusses the theoretical framework and empirical strategy. Section IV discusses data sources. Section V presents key variables used and the definition of terms. Section VI discusses results and the section VII summarizes and concludes.

## **2. Households' energy use in the Philippines**

To put energy use in the context of households in the Philippines, the 2011 Household Energy Consumption Survey (HECS) dataset is used. This is a nationwide survey conducted by the Philippine Statistics Authority and the Department of Energy to collect data on the household's usage of fuel and supply systems to assess the energy scenario in the Philippines. HECS collects information on the household head's information such as age, sex, educational attainment, job status, type/class of work, and occupation. HECS also collects information on the average family income and information on the number of floors, bedrooms, and bathrooms in the house. In addition to the use of different energy sources, household practices on energy conservation, and energy prices are also collected. The 2011 HECS has 20591 observations and 114 provinces.

### **2.1. Usage, any given energy source**

Table 1 presents the percentage of households using any one energy source. Estimates indicate that 81% use electricity and 38% use LPG<sup>1</sup> Households using charcoal, gas (consisting of diesel, gas, and kerosene), and organic sources (consisting of biomass and firewood) are at 10%, 19%, and 6%, respectively. These indicate that households use a combination of energy sources.

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<sup>1</sup>These estimates only reflect the respective proportions of households using individual sources, thereby explaining why proportions don't add up to 1.



**Table 1: Percentage of household using any given energy source**

<b>By urbanity</b>	All	Rural	Urban		
Electricity	81	75	89		
LPG	38	25	57		
Charcoal	10	6	15		
Gas	19	26	9		
Others	06	7	5		
<b>By head's educational attainment</b>	HS graduate or lower	At least college undergraduate			
Electricity	76	95			
LPG	28	71			
Charcoal	8	15			
Gas	22	10			
Others	6	6			
<b>By head's gender</b>	Female	Male			
Electricity	85	80			
LPG	47	36			
Charcoal	10	9			
Gas	16	20			
Others	5	6			
<b>By family income</b>	<10,000	10,000-29,999	30,000-59,999	60,000-99,999	>=100,000
Electricity	73	93	94	100	100
LPG	21	63	83	89	93
Charcoal	6	14	17	18	20
Gas	22	14	12	13	8
Others	6	6	6	4	6

Source: Authors' computation using HECS 2011

If samples are broken down by urbanity, a greater proportion of households in urban areas rely on electricity, LPG, and charcoal. The proportion of urban households using such energy sources is higher than the proportion pertaining to the full sample. The percentage of households using gas is 26%, which is higher in rural than in urban areas by 17 percentage points. In terms of organic sources, the percentage in rural areas is slightly higher at 7% compared with 5% in urban areas.

In cognizance of education's high correlation with income and the significant role of household heads in making allocation decisions, we characterize energy use based on the household head's educational attainment. High-educated heads refer to those who have attended at least college while low-educated heads refer to those who are at most high school graduates. The proportion of households headed by high-educated persons using electricity, charcoal, and LPG is higher than those with low-educated heads. However, the proportion of households with low-educated heads using gas is at 22% while the percentage of households using organic sources is the same under both categories of educational attainment at 6%. Results indicate that female-headed households use electricity, LPG, and gas relatively more than their male-headed counterparts. However, the difference between the respective preceding proportions become small when the samples are disaggregated by urbanity or by head's educational attainment. The proportion of male-headed households using gas is higher than female-headed households while the respective proportions of both male and female headed households using organic sources are similar.

Data show that electricity usage varies across family income, with the more affluent households having the highest proportion of electricity users. While LPG usage can also be observed across income groups, there are fewer households (21%) in the lowest income bracket that use LPG compared with those who belong to higher income brackets (83%). Similarly, charcoal usage is also observed to vary across income, although households using this energy source are fewer relative to those using electricity and LPG. Among households that use gas, those in the lowest income bracket represent the highest at 22%. The proportion of households that use organic sources is similar across income brackets.

Based on the preceding discussion, some patterns emerge. First, electricity is the most common energy source used in urban-based households with income of at least PhP10000 and headed by high-educated female heads. Second, LPG is another popular energy source which comes next to electricity in terms of household use. The popularity of both electricity and LPG can still be observed even in households belonging to the lowest income bracket. Third, gas, charcoal, and organic sources are the least used energy sources among households. Gas is used by most number of households with any one of the following attributes: have low-educated male heads, have income lower than PhP10000, and have resided in rural areas. Fourth, charcoal, gas, and organic sources are used even in high-income households, an indication of energy stacking.

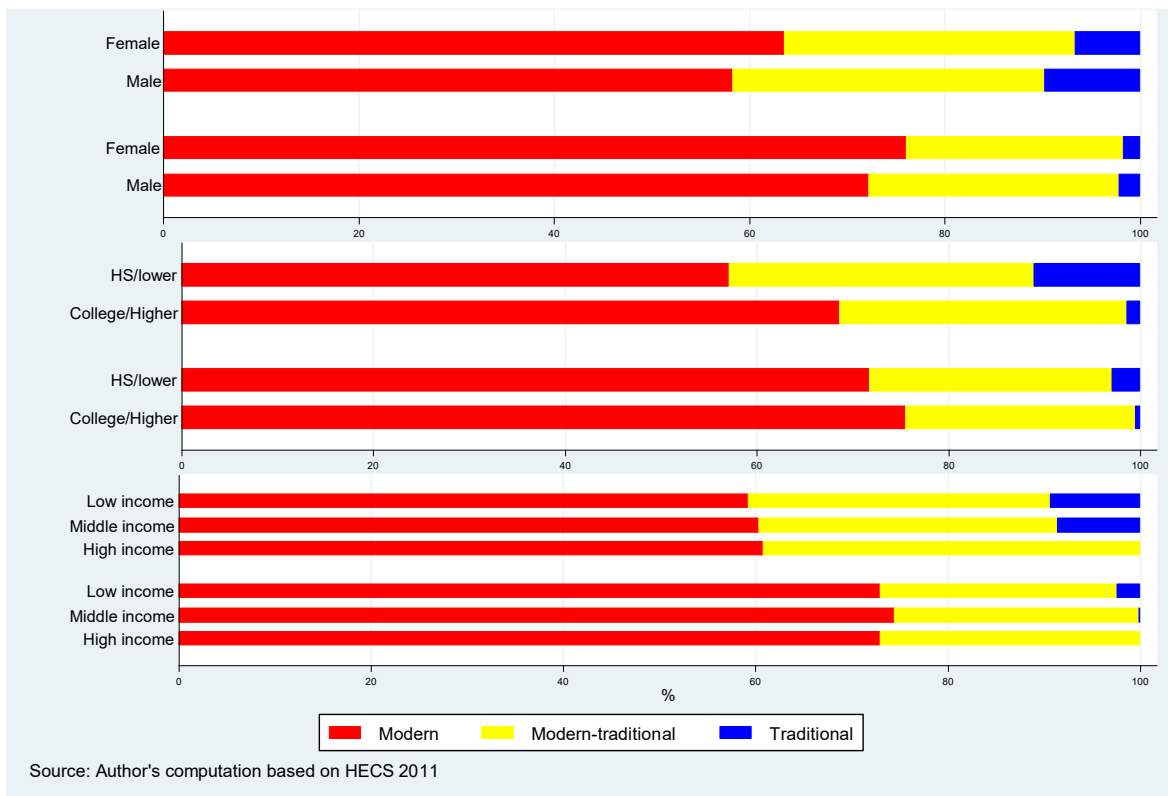
## *2.2. Usage, by energy type*

To investigate energy stacking further, we consider data on combinations of energy sources. To simplify the analysis, households are assumed to fall into any one of the following categories of energy type, namely: new only, new and traditional, and traditional only. New energy type consists of electricity and LPG while traditional energy type consists of charcoal, gas, and organic sources. From Figure 1, there is a high proportion of households that use new energy type exclusively. Similar observation is noted for households that use combinations of new and traditional energy sources. Considering the type of energy used by the household head's gender, the percentage of female-headed households in urban areas using new energy sources exclusively is at 76% while their male counterparts is at 72%. In rural areas, the proportions of female-headed and male-headed households that exclusively use new energy sources are lower at 64% and 58%, respectively. As expected, the proportion of households using traditional energy sources exclusively is higher in rural than in urban areas. In rural areas, the proportions of male-headed and female-headed households using traditional energy types exclusively are at 10% and 7%, respectively.

Compared to households with low-educated heads, households with high-educated heads have higher propensity to use new energy types exclusively. In urban areas, the proportions of exclusive users of new energy types for households headed by high-educated and low-educated persons are at 76% and 71%, respectively. The proportion of households that use traditional energy types exclusively is higher in rural areas than in urban areas. In rural areas, the proportions of exclusive users of traditional energy types for households headed by high-educated and low-educated persons are at 1% and 11%, respectively.

Looking at the household's energy use by income, the proportion of urban households using new energy sources exclusively is similar across income brackets, although it is noticeably higher than their rural counterparts. In urban areas, the proportion of households using new energy sources exclusively is around 74% while it is around 61% in rural areas.

**Figure 1: Usage, by energy type**

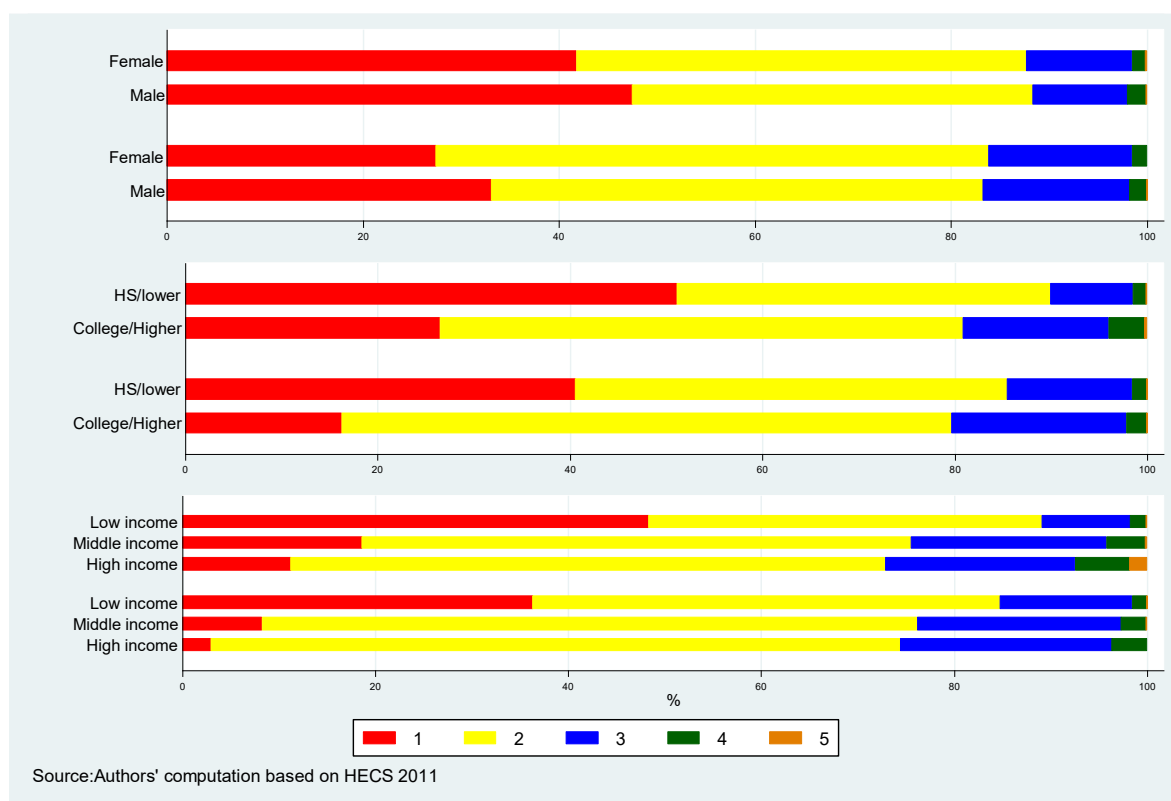


The percentage of households using traditional energy sources exclusively is higher in rural areas than in urban areas, although this is true only for low-income households (less than PHP29 999) and middle-income households (between PHP30 000 and PHP59 999). The proportions of households using traditional energy sources exclusively in rural and urban areas are around 10% and 2% respectively. High-income households in both rural and urban areas do not use traditional energy sources. However, 40% of high-income households in rural areas and 25% in urban areas use a mix of new and traditional sources.

### 2.3. Usage, by number and combination of energy sources

Households are also grouped according to the number of energy sources they use. Figure 2 indicates that a bigger proportion of households use one or two energy sources, and this can be observed regardless of the head's sex or educational attainment. Considering the number of energy sources used by the household's family income, households across income brackets use one energy source, but the percentage of users declines as households go up the income ladder. In urban areas, the percentage of low-income, middle-income, and high-income households using two energy sources is at 48%, 68%, and 71%, respectively. In rural areas, the percentage of low-income, middle-income, and high-income households using two energy sources is at 41%, 57%, and 62%, respectively. Households across income brackets also use three energy sources but the proportion of households using three energy sources is higher for households in higher income brackets.

**Figure 2: Usage, by number of energy sources**

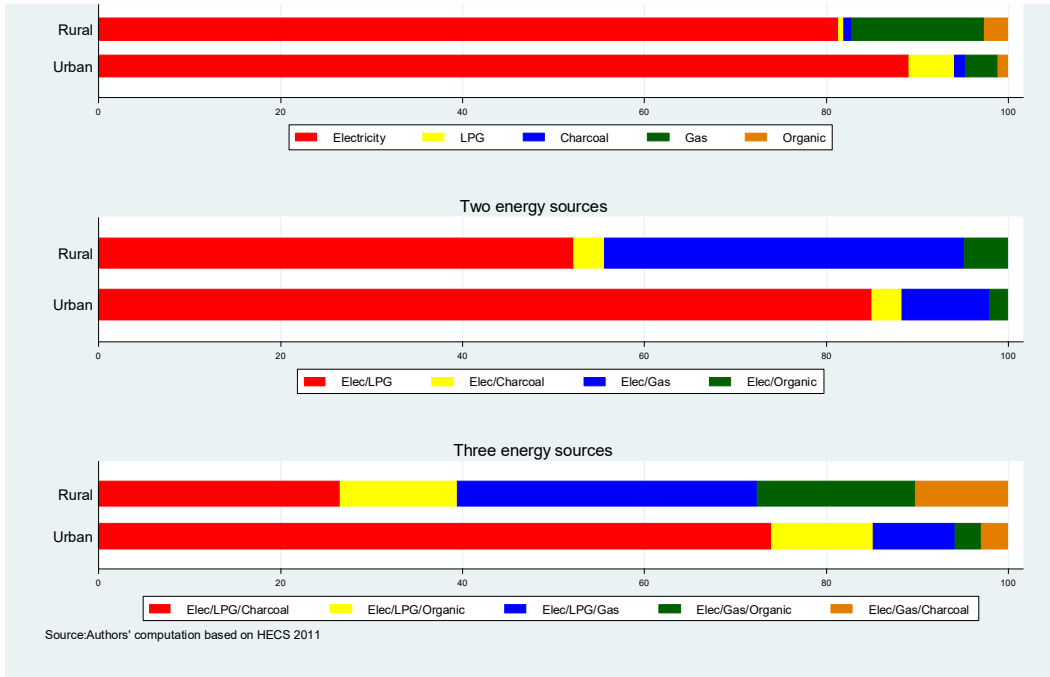


Rural and urban energy mix according to the number of energy source used in the household is presented in Figure 3. For households using one energy source, a sizable percentage of both urban and rural households use electricity. For households using two energy sources, the combination of electricity/LPG is used more in both rural and urban households. However, the percentage of users in urban areas is substantially higher at around 85% compared to 52% in the rural areas. Electricity/gas is a popular combination among rural households, with around 40% of the households using it. In urban areas, only 10% use this combination of energy sources. For users of three energy sources, 74%, 11%, and 9% of urban households use electricity/LPG with charcoal, organic sources, and gas, respectively. In rural areas, the combinations are more diverse. Around 33% of households use electricity/LPG/gas and 27% use electricity/LPG/charcoal. Around 17% use electricity/gas/organic sources, 12% use electricity/LPG/ organic sources, and 10% use electricity/gas/charcoal.

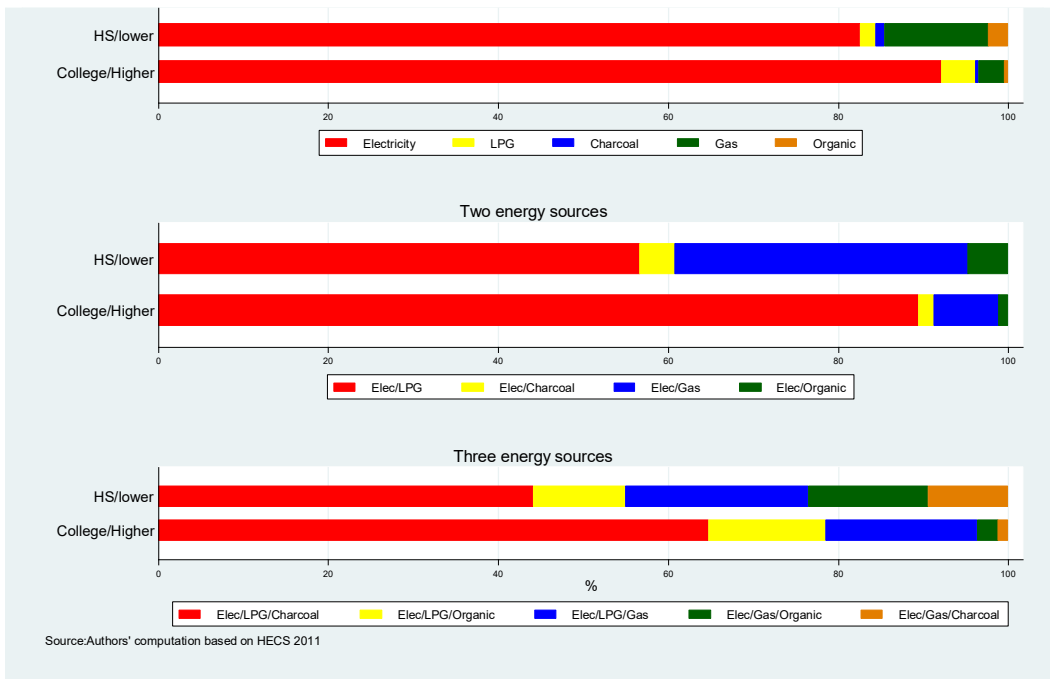
Based on Figure 4, electricity usage is evident in households headed by low-educated and high-educated heads, with the latter registering a much higher percentage. For households headed by high-educated persons and using two energy sources, 89% and 8% use electricity/LPG and electricity/gas, respectively. For households headed by low-educated persons, 57% and 34% use electricity/LPG and electricity/gas, respectively. Around 5% use electricity/charcoal and another 5% use electricity/organic sources. For households using three energy sources, electricity/LPG/charcoal is used by 65% and 44% of households headed by high-educated and low-educated persons, respectively. For households headed by high-educated persons, 13% and 17% use electricity/LPG in combination with organic sources and gas, respectively. For households headed by low-educated persons, 44% and 22% use electricity/LPG in combination with charcoal and gas, respectively. There are 14% and 10% of households that use organic

sources with electricity/gas and electricity/LPG, respectively. Another 9% use electricity/gas/charcoal.

**Figure 3: Number and combination of energy sources, by urbanity**



**Figure 4: Number and combination of energy sources, by head's educational attainment**



### 3. Theoretical framework and empirical strategy

Based on the energy use profiles described above, electricity has been established as the energy source common to most households in the country. However, results above also indicate that electricity is also used in combination with other energy sources. To lay down the appropriate framework, we anchor our empirical strategy to the theoretical framework found in Auffhammer and Mansur (2014). In this model, households are assumed to maximize their utility  $U = U(e, d, z | D_0(t), H)$  and they choose the optimal energy vector  $e$  from a set of feasible energy sources, durable equipment  $d$ , and numeraire good  $z$ .<sup>2</sup> Such choices are made conditional on household attributes,  $H$  and distribution of current temperature,  $D_0(t)$ . The critical assumption is that the distribution of temperature is known, which may act to condition purchase decisions on durable equipment and determine energy preference. Thus, deviations or shocks induce temporary changes in the distribution  $D_0(t)$ . Since utility is a latent variable, the econometric form is assumed to be linear in observed attributes or characteristics of decision-makers and energy sources. It may be non-linear with respect to the deviation of the weather variable from its long-run behavior. The result of the optimization process shows that each of the optimal outcome is dependent on temperature.

Following Cameron and Trivedi's (2005) standard latent variable interpretation of choices involving multinomial outcomes, let  $U_j = x_j' \beta + \varepsilon_j$  be latent process, where  $j$  identifies the mix of energy sources,  $x_j$  is a vector of variables including income, prices, household attributes, and weather-related measures while  $\varepsilon_j$  is an identically and independently distributed stochastic component. The observed dependent variable  $y = j$  represents the  $j$ th energy mix chosen by a household. Given that there are multinomial outcomes, the choice of the  $j$ th energy mix should yield higher utility than any other energy portfolio that could have been chosen. This means that if  $j$  is chosen, then it must be the case that  $U_j \geq U_k$  for all  $k \neq j$ . The probability that the  $j$ th energy portfolio will be chosen is given by  $\Pr[y = j] = \Pr(U_j \geq U_k, \text{ for all } j \neq k) = \Pr(U_{jk} - U_{ij} \leq 0)$ . Substituting the components of  $U_{jk}$  and  $U_{ij}$ ,  $\Pr(\varepsilon_k - \varepsilon_j \leq x_k' \beta - x_j' \beta)$ .

A suitable model for unordered categorical dependent variables, the multinomial logit regression, is used to analyze the effects of key variables on households' energy choices. Using this model, the conditional probability of choosing energy mix  $j$  is given by

$$\Pr(y_i = j | x_j') = \frac{\exp(x_j' \beta)}{1 + \sum_{j=1}^J \exp(x_j' \beta)}, j = 1, 2, \dots, J. \quad 1$$

where the linear index  $x_j' \beta$  is specified as

---

<sup>2</sup> Interpreted as a vector, let  $e \in \mathbb{R}^k$ . Since we don't observe actual quantities of energy source used as well as their relative intensities of use, we just focus on observed household behavior, whether a given household uses a particular portfolio or not. Let  $k = \text{cardinality}(E)$ , where the set  $E$  is given by  $\{I(\text{electricity}), I(\text{LPG}), I(\text{Charcoal}), I(\text{Gas}), I(\text{other sources})\}$ . Let  $I(\cdot)$  is an indicator function. If the household uses a energy source in its mix, then we assign the value 1, 0 otherwise. To show how it can be interpreted, suppose the household chooses Electricity/LPG/Charcoal, then this is represented by  $e = [1 \ 1 \ 1 \ 0 \ 0]'$ . If the household chooses only Electricity, then  $e = [1 \ 0 \ 0 \ 0 \ 0]'$ .

<sup>3</sup> We acknowledge that energy prices do vary with elements in the set of alternatives. While data structure shows that energy prices are alternative-varying attributes, estimation by mixed logit model is not feasible because household decisions based on multiple settings are not collected. Thus, the decision to use multinomial logit models is partly driven by estimation feasibility.

$$\begin{aligned} & \beta_{1j}headsex + \beta_{2j}headage + \beta_{3j}headcoll + \beta_{4j}headjob + \beta_{5j}tothhmem \\ & + \beta_{6j}q\_bedroom + \beta_{7j}q\_bathroom + \beta_{8j}q\_floorsqm + \beta_{9j}f1 + \beta_{10j}f2 \\ & + \beta_{11j}income + \beta_{12j}p\_elec + \beta_{13j}p\_lpg + \beta_{14j}p\_charcoal + \beta_{15j}p\_gas \\ & + \beta_{16j}p\_others + \beta_{17j}urban + \beta_{18j}HI\_de + \beta_{19j}HI\_devsq \end{aligned}$$

and where *headsex*, *headage*, *headcoll*, and *headjob* refer to the household head's sex age, college education or greater, and whether the head has a job, respectively. The variables *tothhmem*, *q\_bedroom*, *q\_bathroom*, *q\_floorsqm*, and *urban* refer to the total household members, number of bedrooms, bathrooms and floors/storey, and urbanity.

The variable *diff\_HI* is the difference between the current heat index (HI) from its normal value, which is defined as the 30-year (1981-2010) average. Changes in the mean temperature may cause changes in extreme temperature in Asia-Pacific. Specifically, for the Philippines, it is found that significant correlation exists between the mean temperature and the frequency of extreme temperature. However, relative humidity can interact with temperature to form the heat index, which is a human discomfort index that measures the temperature that the human body perceives or feels. Since the climate in the Philippines is characterized by elevated temperature, high humidity and abundant rainfall, the heat index appears to be an ideal weather variable that can be linked to consumption patterns of energy. Prolonged activity under the hot sun when the heat index is high can have severe consequences such as fatigue, heat cramps, heat exhaustion and heat stroke. People may be cautious to go out given this scenario and this can have severe implications on the households' energy choice and energy consumption.

Variables *f1* and *f2* are scores from the principal component analysis applied on the detailed data on the household's electricity use. Detailed discussion on the construction of *f1*, *f2*, and *diff\_HI* is provided in the discussion of explanatory variables in Section V. Variables *p\_elec*, *p\_lpg*, *p\_charcoal*, and *p\_organic sources* denote the price of electricity, LPG, charcoal, and organic sources, respectively. The sample is limited to households with heads aged 20-85.

## 4. Data sources

### 4.1. 2011 Household Energy Consumption Survey (HECS)

The main dataset used for this paper is the 2011 HECS, which is a nationwide survey conducted by the Philippine Statistics Authority and the Department of Energy to collect data on the household's usage of fuel and supply systems to assess the energy scenario in the Philippines. Section II provides details about this dataset.

### 4.2. Philippine Atmospheric and Geophysical Astronomical Services Administration (PAGASA)

The PAGASA dataset has the following features: First, there are several provinces that host multiple weather stations. Second, there are several provinces in which no weather station is present. In merging the PAGASA data with the HECS data, we address the first feature by selecting the weather station that is located in or in close proximity to the provincial capital. As an illustration, Palawan province, located in Luzon's Region 4A, has three stations, namely, Coron, Cuyo and Puerto Princesa. In this case, Puerto Princesa is chosen because it is the capital city.

To address the second feature and in view of the importance of accounting for similar weather patterns and enhancing data variability, we do not automatically remove households in provinces without weather stations. For example, Mountain Province and the provinces of La Union and Ifugao are assigned the weather station in Baguio City, Benguet while Tarlac is assigned the weather station in Cabanatuan, Nueva Ecija. Assigning adjacent weather stations to provinces without one maximizes the number of households included in the estimation sample. Without this assignment, 75 provinces will be dropped out of the sample. This translates to a sample loss amounting to 11 196 households.

Table 1A provides the mapping of the respective weather stations to provinces and cities. The first column lists the provinces in HECS while the second column lists the PAGASA weather station assigned to it. For provinces without weather stations, the air/straight distance between their capital and the nearby weather stations is computed using the following website: [http://distancecalculator.globefeed.com/Philippines\\_Distance\\_Calculator.asp](http://distancecalculator.globefeed.com/Philippines_Distance_Calculator.asp). The fourth column shows the distance corresponding to the third column. Out of the 114 provinces, there are 37 that have weather stations, 75 have been assigned nearby weather stations, and three that could not be reasonably mapped. The three provinces where a match could not be found in the PAGASA weather data include Guimaras, Batanes and Tawi-Tawi. Unlike rainfall that is likely localized, temperature and relative humidity are relatively stable across provinces. This means that the temperature and relative humidity data measured in another province can be used for adjacent provinces that do not have weather stations. Therefore, the assignment of weather stations done above is unlikely to introduce measurement errors. Nevertheless, provinces whose distance is greater than 80 kilometers from the assigned weather station are excluded. This resulted in 3035 observations dropped from the sample

The heat index (HI) is computed using the average of relative humidity (in percent) and temperature (represented by wet bulb readings, in degrees Celsius) in a public use file containing 59 weather stations of PAGASA. Temperature data are converted into Fahrenheit.<sup>4</sup> The heat index is then generated using the following formula<sup>5</sup>:

$$\begin{aligned}
 HI = & 42.379 + 2.04901523 * T + 10.14333127 * R - 0.22475541 * TR \\
 & - 6.83783 * (10^{(-3)}) * Tsq - 5.481717 * (10^{(-2)}) * Rsq \\
 & + 1.22874 * (10^{(-3)}) * TsqR + 8.5282 * (10^{(-4)}) * TRsq \\
 & - 1.99 * (10^{(-6)}) * TsqRsq
 \end{aligned}$$

where  $T$  is temperature in Fahrenheit,  $Tsq$  is squared temperature,  $R$  is relative humidity in percentage, and  $Rsq$  is squared relative humidity.

The data on normal values or the 30-year average (between 1981 and 2010) are also provided by PAGASA and are used to proxy for the long-run values. Heat index deviation (HID) is then computed as,  $HID = HI_{2011} - HI_{normal}$ , which represents weather fluctuation/variability. To recognize the nonlinear effects of the HI deviation, a squared HI deviation is also used as an additional weather-related variable. Squaring the deviation puts more weight on observations that are very far from the long-run average. This asymmetric treatment may prove useful in

<sup>4</sup> The formula to compute HI requires that relative humidity be in degree Fahrenheit. Once computed, we converted the HI into degree Celsius, since this is the measurement unit used in the Philippines.

<sup>5</sup> Taken from the National Weather Service-National Oceanic and Atmospheric Administration website.



providing a more complete characterization of the empirical effects of weather variables on energy choice and energy consumption.

## 5. Variables and definition of terms

### 5.1. Dependent variables

For the dependent variable, we reduce the dimension of the choice set which contains many feasibly observed combinations of energy choices. *Energy type* ( $y_{0i}$ ) is a variable with three categories, namely: new only, new and traditional, and traditional only. New energy type consists of electricity and LPG while traditional energy type consists of charcoal, gas, and organic sources. Gas refers to either gasoline, kerosene, or diesel. Organic sources refer to either biomass or firewood. The following shows the value composition of  $y_{0i}$ :

$$y_{0i} = \begin{cases} 1 & \text{if exclusively modern} \\ 2 & \text{if modern/traditional} \\ 3 & \text{if exclusively traditional} \end{cases} \quad 2$$

The *number of energy sources* used in the household is also accounted for and this variable takes five categories: one energy source up to five energy sources. To analyze energy use further, the *combination of energy used* is constructed for two and three energy sources. The categories for the combination of energy used are limited to up to three energy sources. There are around 1.6% of the sample (around 281) that use four energy sources and around 0.1% that use five energy sources and using these to limit the sample affects convergence.

Denoted by  $y_{2i}$ , energy source pairs include electricity/LPG, electricity/charcoal, electricity/gas, and electricity/ organic sources. Other possible combinations, such as LPG/charcoal and LPG/gas, only account for a very small portion of the sample. Out of the 7177 households that use two energy sources, there are 133 samples that are not included in any of the energy combinations identified.

$$y_{2i} = \begin{cases} 1 & \text{if electricity/LPG} \\ 2 & \text{if electricity/charcoal} \\ 3 & \text{if electricity/gas} \\ 4 & \text{if electricity/organic sources} \end{cases} \quad 3$$

Denoted by  $y_{3i}$ , the energy portfolios for three energy sources include electricity/LPG combined with either charcoal, gas, or organic sources and electricity/gas combined with either charcoal or organic sources. Like the two energy sources, other possible combinations account for a very small portion of the sample. Out of the 1942 households that use three energy sources, there are 43 samples that are not included in any of the identified energy combination.

$$y_{3i} = \begin{cases} 1 & \text{if electricity/LPG/charcoal} \\ 2 & \text{if electricity/LPG/organic sources} \\ 3 & \text{electricity/LPG/gas} \\ 4 & \text{if electricity/gas/organic sources} \\ 5 & \text{electricity/gas /charcoal} \end{cases} \quad 4$$

Note that the various choices do not have information on the intensity of usage and seasonal variations. However, the plausible response to shocks may depend on the functional versatility of an energy source and on its complementarity with other sources in the portfolio. For instance, the electricity/LPG mix can be an anchor since this address almost all the household's energy needs. In the event of a higher than normal heat index deviations, the energy source that needs to be added should broaden the range of usefulness and versatility of the chosen mix. Charcoal may be added if during extreme heat, the household decides to cook outdoor to balance the energy budget, as electricity costs may spike due to higher than normal demand for cooling. Adding gas does not augment the usefulness of existing energy anchors although it can rebalance excessive consumption of electricity for cooling purposes.

## 5.2. Explanatory variables

Following van der Kroon, Brouwer, and Beukering (2013), explanatory variables are grouped into household opportunity set, external decision context, and external environment. Key variables included in the household opportunity set are the household head's age and sex, a dummy for college education or higher, and a dummy if the head has a job. Attributes at the household level such as the total number of household members, number of bedrooms, number of bathrooms, number of floors, and family income are also included.

HECS has detailed data on household electricity usage. There are data that pertain to households use of electricity for lighting, cooking, ironing, laundry, and to power the radio, television, refrigerator, air conditioner, fan, pump, and other appliances. There are also data on how the same households use electricity, LPG, and organic sources for heating water. To aggregate such information, an index is constructed using the score generated by the principal component analysis (PCA). The PCA is a technique used to reduce the dimension of the data by creating uncorrelated indices or components, where each component is a linear weighted combination of the initial variables. The variance of each of the component is generated such that the first component contains the largest variation in the original data; the second explains additional but less variation and so on<sup>6</sup>. Positive scores generated by the PCA are associated with higher electricity usage. Based on the Kaiser criterion, two factors are retained since these factors have eigenvalues greater than one. The overall Kaiser-Meyer-Olkin measure of sampling adequacy is 0.90, which indicates that these assets contain enough similar information to warrant the principal component analysis.

Key variables that pertain to external decision context include energy prices. While HECS also collected data on energy prices, there are many missing values in the dataset. For example, LPG prices are available for 7890 observations, charcoal prices are available for 6508 observations and electricity prices are available for 16642 observations. Using these together in the estimation greatly reduces the sample. To work around this issue, energy prices are predicted using the tropical cyclone data that crossed the provinces in 2011, which are also obtained from PAGASA. Extreme weather events, such as tropical cyclones, affect energy prices by affecting the supply side. Typhoons can destroy trees to provide more sources for firewood and can bring about heavy rains to wash out possible sources of biomass. It also disrupts the processes to produce these energy sources. Firewood takes longer time to dry up

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<sup>6</sup> For technical details, see Filmer and Pritchett (2001). An application of PCA is on household assets to create an indicator for socioeconomic status in the absence of income and expenditure data such as those found in Filmer and Pritchett (2001).

and charcoal-making is disrupted. Heavy rains brought by typhoons can cause landslides or damages to roads, which can affect the transport of LPG. To constitute the variables associated with the tropical cyclone data, the provinces crossed by the tropical cyclones are identified. The number of tropical storms (a tropical cyclone with maximum wind speed of 62 to 88 kph) and the number of typhoons (a tropical cyclone with maximum wind speed of 118 to 220 kph) for each province are then counted.

The number of tropical storms and the number of typhoons, together with the dummies for each region, make up the explanatory variables to predict the price of electricity, LPG, charcoal, gas, and organic sources. The price of gas is the average of gas, kerosene and diesel prices while the price of organic sources is the average of biomass and firewood prices. Results to predict energy prices using OLS are presented in Table 2. It can be noted that the tropical cyclone data are significant predictors of energy prices. The prices of LPG and gas are positively affected by the frequency of tropical cyclones. The price of electricity is positively affected by the frequency of tropical storms, but it is negatively affected by the frequency of typhoons. While typhoons in 2011 have caused substantial devastation in private properties, infrastructure and in the agriculture sector, these typhoons also brought about heavy rains which possibly boost other alternative sources of electricity such as hydroelectric power. This could possibly explain the negative effect of the frequency of typhoon on the price of electricity. The price of charcoal is affected by the frequency of tropical storm and typhoon in similar magnitude but opposite in direction. This possibly reflects that tropical cyclones disrupt the processes of charcoal making on one hand, but these increase the supply of materials needed to produce charcoal on the other hand. The price of organic sources is negatively affected by the frequency of tropical storms. Comparison shows that the averages of both the original and the predicted prices are close to each other. For example, the average HECS electricity price is around PhP 8.9 while the average predicted electricity price is around PhP8.8. The average HECS price is around PhP67.6, PhP15.7, PhP66, and PhP6.9 for LPG, charcoal, gas, and organic sources, respectively. The predicted price is around PhP71, PhP16, PhP65, and PhP6.9 for LPG, charcoal, gas, and other energy sources, respectively.

**Table 2: OLS estimates of energy prices**

	Electricity	LPG	Charcoal	Gas	Organic sources
Number of tropical storms	0.190*** [0.034]	0.596*** [0.122]	0.805*** [0.211]	1.103*** [0.290]	-0.763** [0.354]
Number of typhoons	-0.087** [0.036]	0.486*** [0.126]	-0.816*** [0.237]	0.740** [0.316]	-0.281 [0.381]
N	16373	7777	6334	7656	2501
R-squared	0.336	0.589	0.174	0.116	0.099

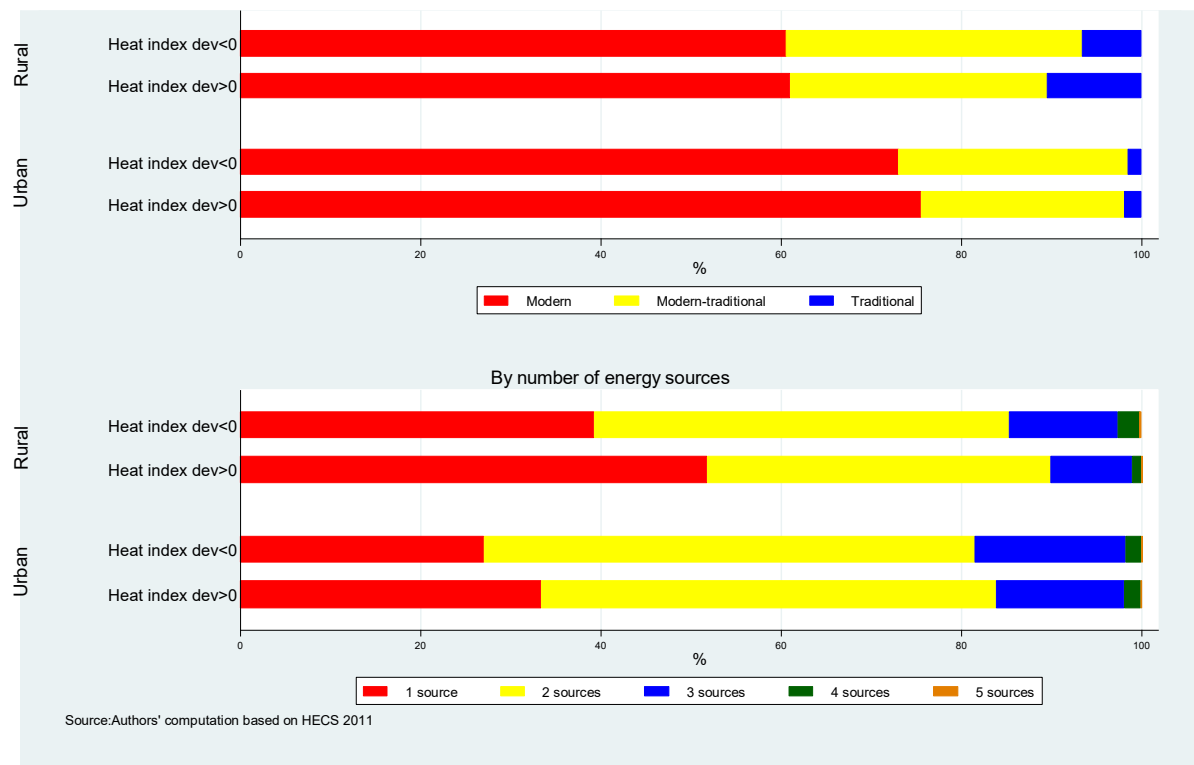
\*\*\*/\*\*/\* Significant at 1/5/10%. Figures in parentheses are standard errors. Standard errors are clustered around the enumeration area. Estimates are weighted OLS. Regional dummies are included as explanatory variables.

Key variables that form part of the external environment include the heat index deviation and a dummy for urban area. In terms of energy use, Figure 5 shows that there is a higher percentage of households in rural areas that use traditional energy sources exclusively when heat index deviation is above normal. In urban areas, the percentage of users is similar for heat index below or above the normal values. From the lower panel of Figure 5, there is a high percentage

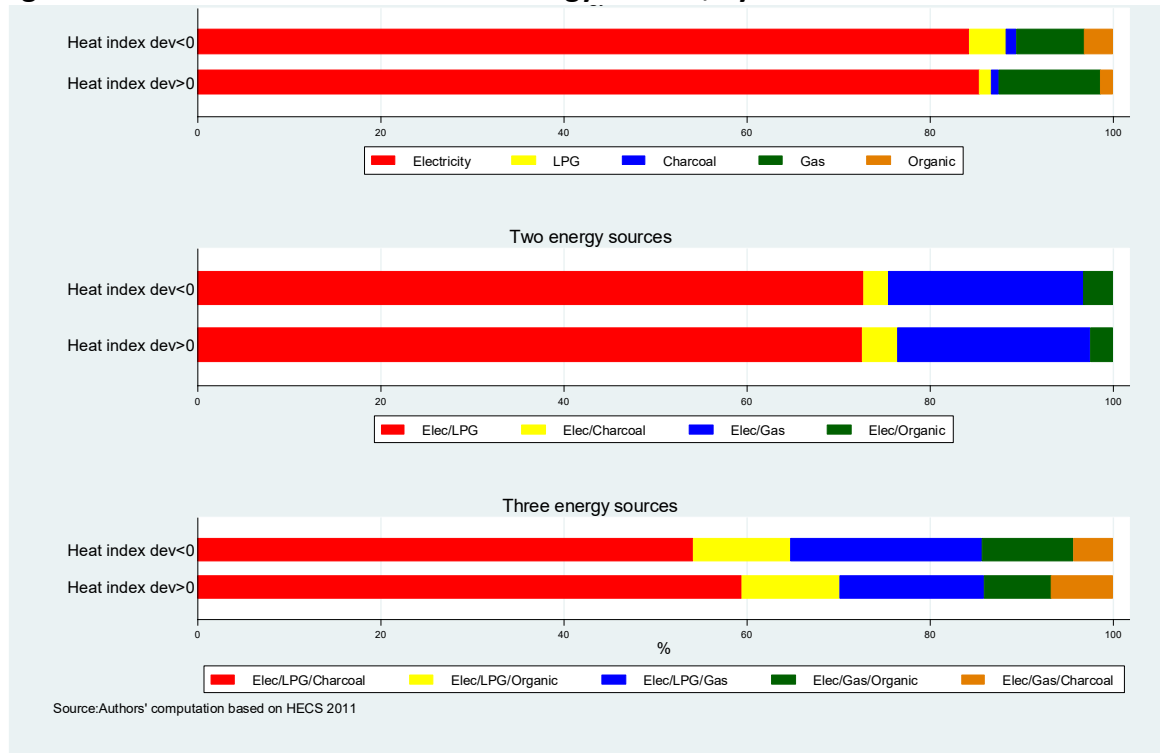
of urban households that experience below or above normal heat index and that use two energy sources.

In Figure 6, electricity is a popular choice among single energy users while electricity/LPG is a popular choice among users of two energy sources. For households that use three-energy sources, electricity/LPG/charcoal is a popular mix. The proportion using this mix is higher for users that experienced above normal heat index. Electricity/LPG/gas is used by households that experienced above or below heat index but the proportion of users is higher for the latter. Based on these patterns, energy choices are affected by weather events.

**Figure 5: Usage, heat index deviation and urbanity**



**Figure 6: Number and combination of energy sources, by heat index deviation**



## 6. Discussion of results

### 6.1. Prediction of usage of energy portfolios

Based on multinomial logit estimates, presented in table 2A in the appendix, the probability of using an energy mix is predicted. In this section, we conduct simulations to ascertain how choice probabilities would respond to changes in the values of heat index deviation and individual prices of energy sources. The aim of conducting simulation exercises is two-fold: to determine if the impact of shocks vary across urbanity and income class and to analyze the effects of weather and price shocks.

To facilitate the econometric exercise, the following household characteristics are used: the household is headed by an employed 40-year old male who has attained at least a college degree. Heat index deviation is assumed to be zero and the rest of the variables such as total household members, number of bedrooms, bathrooms, floor area, asset scores, and energy prices, are evaluated at their mean values. Households with these attributes are referred to as benchmark households in subsequent discussions. To assess the contribution of key variables, the choice probability is predicted by changing one attribute in the benchmark characteristics each time. The heat index is assumed to increase to seven degrees Celsius<sup>7</sup> and prices of electricity, LPG, and charcoal are assumed to increase by 10% from their respective means. Comparisons of predicted usages of energy types are presented in Figure 7, those of two energy

<sup>7</sup> This HID is presented since this is closest to the maximum value of HID in the data. We used several HID values and the patterns remain the same. Results are available from the authors upon request.

sources by high-income and low-income households are presented in Figures 8-9, and those of three energy sources are presented in Figures 10-11.

From Figure 7, the estimated probability of using modern energy sources exclusively is high at around 73%-75%. It can be noted that increases in the prices of electricity and charcoal do not affect the probability of using the combinations of energy types. However, the probability of using modern energy sources exclusively decreases by around 5 percentage points for households that have experienced LPG price increase and heat index deviation.

**Figure 7: Usage, by energy type predicted probability**



Source: Authors' computation based on HECS 2011

High-income benchmark households in rural and urban areas have a high probability of using electricity/LPG (around 99%, Figure 8). Heat index deviation and increases in the prices of electricity and charcoal do not introduce significant changes in the probability of using an energy portfolio. However, the probability of using other energy mix becomes higher for households that have experienced an increase in the LPG price compared to the benchmark households. In the LPG price increase scenario, energy combinations in high-income rural households are more varied than in high-income urban households.

Low-income benchmark households in urban areas have a high probability of using electricity/LPG as well (around 95%, Figure 9). An increase in the prices of electricity and charcoal do not introduce significant changes in the probability of using an energy mix. However, it can be noted that households that experienced heat index deviation have a lower probability of using electricity/LPG compared to benchmark households. The probability of using this energy mix is even lower for households subjected to a LPG price increase. Similar trends are observed for low-income rural households, although the magnitude is more pronounced and the probability of using electricity/gas is higher. Relative to benchmark households, the probability of using electricity/gas is around 5 percentage points higher for

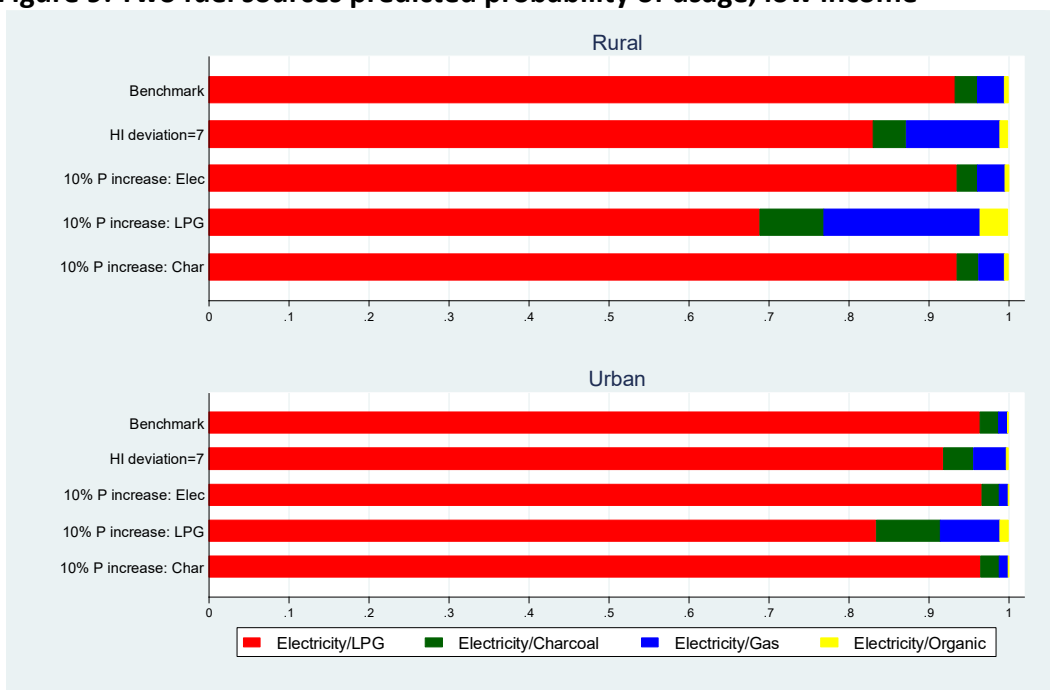
households that have experienced high temperature and around 14 percentage points higher for households that experienced a LPG price increase.

**Figure 8: Two fuel sources predicted probability of usage, high income**



Source: Authors' computation based on HECS 2011

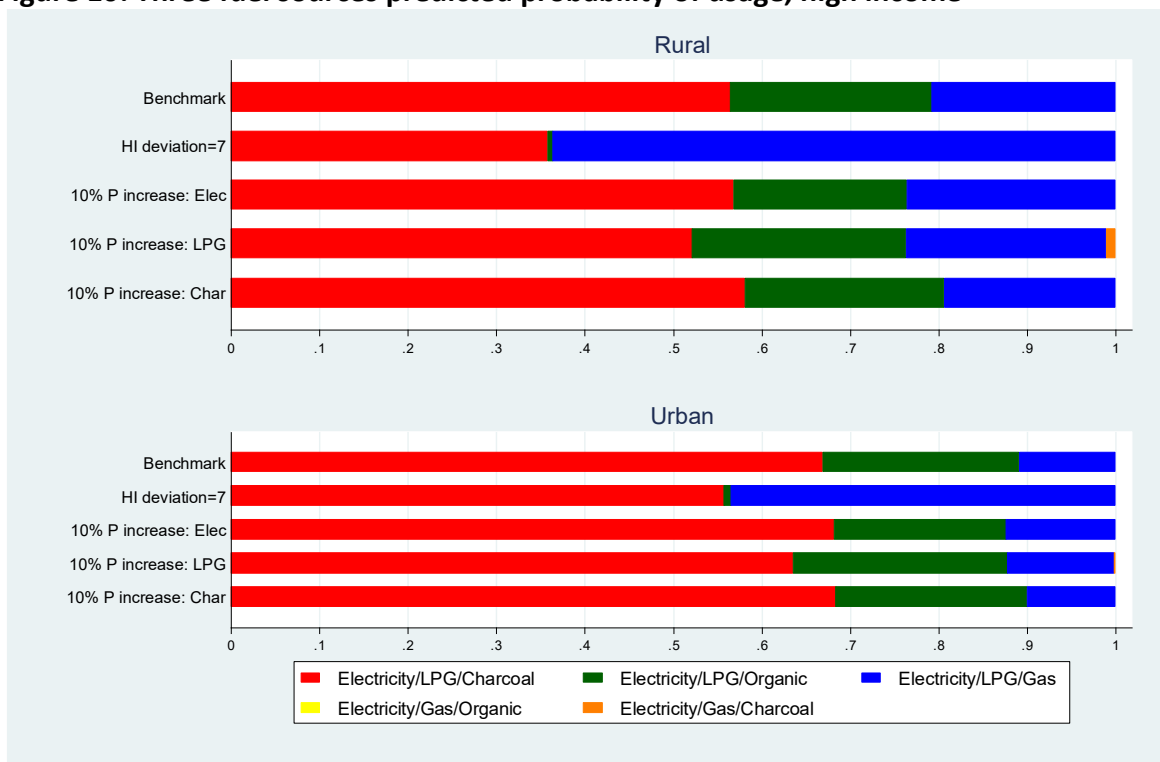
**Figure 9: Two fuel sources predicted probability of usage, low income**



Source: Authors' computation based on HECS 2011

For high-income benchmark households in urban areas that are using three energy sources, the probability of electricity/LPG/charcoal is around 70%, electricity/LPG/organic sources mix is around 20%, and electricity/LPG/gas is around 10% (Figure 10). It can be observed that the probability of using a given energy portfolio is relatively similar across scenarios. For households that experienced heat index deviation, the probability of using electricity/LPG/charcoal is reduced by more than 10 percentage points, electricity/LPG/gas surged by more than 30 percentage points, and electricity/LPG/organic sources became negligible.

**Figure 10: Three fuel sources predicted probability of usage, high income**



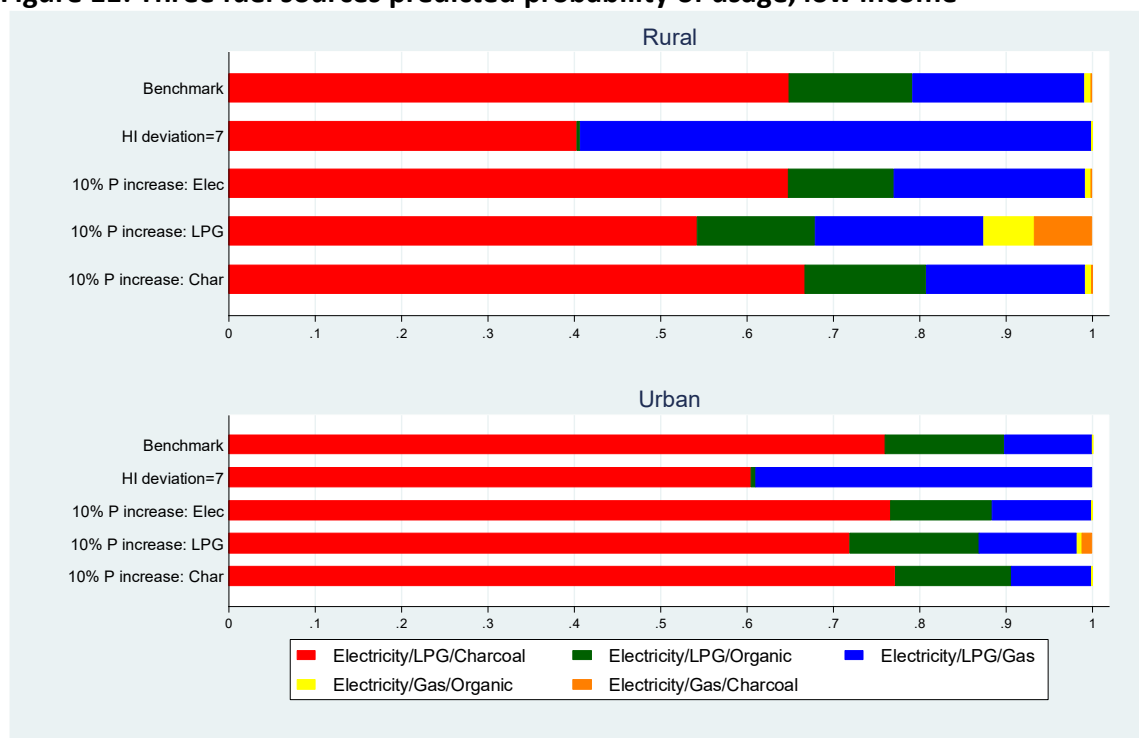
Source: Authors' computation based on HECS 2011

Similar trends can be observed for high-income rural households. For households that experienced heat index deviation however, the respective probabilities of using electricity/LPG/charcoal, electricity/LPG/gas, and electricity/LPG/organic are 15 percentage points lower, 40 percentage points higher, and negligible.

For low-income urban households, the respective probabilities of using electricity/LPG/charcoal, electricity/LPG/organic sources, and electricity/LPG/gas are around 75%, 14%, and 11%, respectively (Figure 11). An increase in the prices of electricity and charcoal do not introduce significant changes in the probability of using energy portfolios. However, the probability of using electricity/LPG/charcoal is around 18 percentage points lower and that of using electricity/LPG/gas is around 33 percentage points higher for households that experienced heat index deviation.



**Figure 11: Three fuel sources predicted probability of usage, low income**



Source: Authors' computation based on HECS 2011

Similar trends are observed in low-income rural households although the magnitude is now more pronounced. For example, the probability of using the combination of electricity/LPG/charcoal is 11 percentage points lower for households that experienced a LPG price. For these households, it can be noted that the probabilities of using electricity/LPG combined with either organic sources or gas are like those of the benchmark households but the probabilities of using some combinations (electricity/gas combined with either organic sources or charcoal) are evident as well.

## 6.2. Summary

Based on the exercise concerning two-energy users, energy switching is a strategy by high-income households in both rural and urban areas. However, energy stacking is observed in low-income households in both rural and urban areas and this is evident in cases of heat index deviation and LPG price shock. However, energy stacking more evident as a result of the latter.

Results pertaining to three energy users automatically lends support to the energy stacking hypothesis since only two modern energy sources (electricity and LPG) are included in the households' energy mix. However, there are several points that need to be highlighted. *One*, households use modern energy sources as anchors of their energy portfolio. Adding a third energy source may be plausibly interpreted as a way for households to address shocks such as price increase and heat index deviation. For example, a sudden increase in heat index may necessitate a more intensive use of electricity to power air conditioning units and electric fans while LPG will still be used for cooking primarily due to convenience. To complete the energy mix, charcoal or gas may be a third energy source that can be added. Gas, like kerosene, can be used for heating water, cooking foods, starting fire, and lighting lamps while charcoal's use

is limited to cooking foods. An increase in electricity usage resulting from shocks, such as heat index deviation, needs to be moderated and gas is a more likely option because it offers lighting possibilities. Thus, the source's degree of functional versatility may play a role in the decision to stack energy sources.

*Two*, a weather shock, represented by HI deviation, invariably results in a significant reduction in the respective probabilities of using electricity/LPG/charcoal and electricity/LPG/organic sources, with the latter's probability approaching zero. The exercise indicates that electricity/LPG/gas is the most likely energy portfolio for households affected by higher than normal heat index. While this is observed in both high-income and low-income households, the increase in the probability of using electricity/LPG/gas is more evident among rural households. These results can be explained by the state of electricity cooperatives, the main service providers in rural areas, and the possible role of adaptive behavior of households. Electric cooperatives have poor operational performance (Cariaga et al, 2009) due to losses resulting from transmission and theft and poor state of governance (Matsuda, forthcoming). Hence, electricity supply in rural areas is unreliable due to frequent outages or voltage reduction. Weather- and climate-related factors that can induce excess demand for electricity are likely to aggravate outages. In the Philippines, Bayudan-Dacuycuy (2017) documented that households use multiple energy sources in different weather fluctuation scenarios.

In the event of shocks to heat index deviation, it is plausible that rural households adjust to the perceived unreliability of electricity supply by including gas into their energy mix since gas can be used as an alternative source for lighting. This is consistent with Masera, Saatkamp and Kammen (2008) who argued that fuel stacking may result from supply constraints and households find it best to keep alternative sources as backups. In urban areas, electricity providers immediately respond to potential and actual problems resulting from weather- and climate-related factors to ensure commercial establishments and business districts experience minimal disruptions. Hence, urban households do not need to stack their energy mix with gas as much as rural households do.

*Three*, energy price shocks, except for shocks related to LPG, have effects on the probabilities of using energy mixes similar to the effects observed using the benchmark attributes. In the case of electricity price shock, demand is inelastic since households cannot readily find alternative energy sources that can perform all the functions of this energy source. Charcoal price shocks appear to exert minimal influence on the probabilities possibly because charcoal is relatively cheap.

*Four*, high-income households in both urban and rural areas that experience price shocks and the benchmark households have similar probabilities of using an energy mix. However, this is not the case for low-income rural households that experience an increase in the LPG price. The energy portfolio of these households has become varied by including electricity/gas combined with either charcoal or organic sources. This is an evidence that households use fuel stacking to adapt to fluctuations in energy prices, a result that is consistent with Hosier and Kipondya (1993).

## 7. Summary and conclusions

Relative to a set of benchmark characteristics, this paper analyzes the impact of energy price shocks and heat index deviation on the conditional probabilities of using a given energy portfolio.

The evidence points to several important findings that have implications on factors that affect energy portfolios in the urban and rural Philippines. *One*, both energy switching and stacking are strategies observed among Philippine households. Consistent with the energy switching literature, high-income households in both urban and rural areas use modern energy mix. Consistent with the energy stacking research, low-income rural households use a combination of modern and traditional sources and this is observed in the face of LPG price shock and heat index deviation.

*Second*, there are identifiably clear anchors embedded in energy portfolios, with a component that is most likely to adjust in response to price and weather-related shocks. With electricity and LPG as energy anchors, factors such as the degree of reliability of electricity providers, the households' adaptive behavior, and the functional versatility of an energy source are likely to play a role when households choose the additional energy source that will complete the households' energy portfolio. This is evident in the higher probability of including gas in the energy mix of high- and low-income rural households that face price and weather-related shocks.

*Three*, of all the price shocks considered, LPG price shock delivers a more substantial effect in altering the probability of using an energy portfolio. This is evident in the energy mix of poor rural households that experienced LPG price increase, which includes electricity/gas as energy anchor.

These results highlight the importance of electricity as an energy source. Modern energy sources are used as anchors and gas is included as a third source in the energy portfolio. Given that the use of gas can have negative health consequences, results of the paper also emphasize the government's role in ensuring that every household in the country has access to electricity especially in rural areas where the probability of including gas in the energy mix is high. The rural electrification program in the country has been recently intensified by the National Electrification Administration through new policies aimed to maximize the use of microgrids and solar home systems. To operate, microgrids connect to the main grid but can switch off and use local sources to generate energy. When switched off from the main grid, microgrids can be powered by solar panel or other local energy sources. Hence, microgrids will help ensure steady stream of electric supply and bring down its costs.

The introduction of microgrids is highly relevant now that the effects of climate change are manifesting in terms of more pronounced variability of precipitation and temperature relative to their long-run averages and in more frequent and stronger tropical cyclones. Adaptation to climate change is inevitable and the use of microgrids to harness the effects of climate change as additional energy sources is a good form of adaptation. In the future, non-traditional local sources can also be explored such as the saline solution that can power lamps. It should be improved and upscaled so that its technology can have wider scope and application.

However, the introduction of new ways to intensify rural electrification program entails thorough assessment of the governance of electric cooperatives. Past World Bank studies document that the poorest performing cooperatives have the highest incidence of political interference. A recent World Bank study (Matsuda, forthcoming) concludes that cooperatives need strong general managers to manage these interferences and to effectively implement changes. The government should look carefully into these issues.

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## APPENDIX

**Table 1A: Mapping of HECS provinces with the PAGASA weather stations**

HECS Province/City	Weather Station	Capital to weather station	Straight line/air distance (in kms)§
Taguig	NAIA, Pasay City	Taguig-Pasay City	3.59
City of Paranaque	NAIA, Pasay City	Paranaque-Pasay City	3.91
City of Makati	NAIA, Pasay City	Makati City-Pasay City	4.55
San Juan	Science Garden, Quezon City	San Juan-Quezon City	4.94
Cagayan de Oro City	Lumbia Airport, Misamis Oriental	CDO-Lumbia Airport	5.63
Misamis Oriental (Excluding Cagayan de Oro City)	Lumbia Airport, Misamis Oriental	CDO-Lumbia Airport	5.63
Pateros	NAIA, Pasay City	Pateros-Pasay City	6.86
City of Mandaluyong	Science Garden, Quezon City	Mandaluyong City-Quezon City	7.16
City of Las Pinas	NAIA, Pasay City	Las Pina-Pasay City	8.18
City of Marikina	Science Garden, Quezon City	Marikina City-Quezon City	8.53
City of Pasig	Science Garden, Quezon City	Pasig City-Quezon City	8.69
Laguna	Sangley Point, Cavite	Imus-Sangley	10.11
Quezon (Excluding Lucena City)	Tayabas, Quezon	Lucena-Tayabas	11.04
Malabon	Science Garden, Quezon City	Malabon-Quezon City	11.49
Navotas	Science Garden, Quezon City	Navotas-Quezon City	11.59
City of Muntinlupa	NAIA, Pasay City	Muntinlupa City-Pasay City	12.09
Kalookan City	Science Garden, Quezon City	Kalookan City-Quezon City	12.54
Nueva Ecija	Cabanatuan, Nueva Ecija	Palayan City-Cabanatuan	19.76
City of Valenzuela	NAIA, Pasay City	Valenzuela City-Pasay City	21.1
Abra	Vigan, Ilocos Sur	Bangued-Vigan	23.77
Bulacan	Science Garden, Quezon City	Bulacan-Quezon City	24.32
Saranggani	General Santos, South Cotabato	Saranggani-General Santos	28.76
Rizal	Science Garden, Quezon City	Rizal-Quezon City	28.9
Sorsogon	Legaspi City, Albay	Sorosogon-Legaspi	33.55
La Union	Baguio City, Benguet	San Fernando City-Baguio City	33.68
Siquijor	Dumaguete City Negros Oriental	Siquijor-Dumaguete	33.89
Tarlac	Cabanatuan, Nueva Ecija	Tarlac City-Cabanatuan	40.43
Kalinga	Tuguegarao, Cagayan	Kalinga-Tuguegarao	41.23
Aklan	Roxas City, Capiz	Aklan-Roxas City	43.61
Leyte (Excluding Ormoc City)	Tacloban City, Leyte	Leyte-Tacloban City	44.43
Ormoc City	Tacloban City, Leyte	Ormoc-Tacloban City	44.43
Iligan City	Lumbia Airport, Misamis Oriental	Iligan City-Lumbia Airport	45
Cotabato	Davao City, Davao Del Sur	Cotabato-Davao City	46.85
South Cotabato (Exc General Santos City(Dadiangas))	General Santos, South Cotabato	Koronadal-General Santos	55.54
Basilan	Zamboanga City, Zamboanga	Basilan-Zambonaga City	55.65
Lanao del Sur (Excluding Marawi City)	Lumbia Airport, Misamis Oriental	Marawi-Lumbia Airport	56.15
Agusan del Sur	Butuan City, Agusan Del Norte	Prosperidad-Butuan City	56.9
Nueva Vizcaya	Baguio City, Benguet	Bayombong-Kennon Road	59.51
Occidental Mindoro	San Jose, Occidental Mindoro	Mamburao-San Jose	60.33
Olongapo City	Iba, Zambales	Olongapo-Iba	62.23
Angeles City	Iba, Zambales	Angeles to Iba	67.32
Catanduanes	Legaspi City, Albay	Virac-Legaspi	70.46
Biliran	Tacloban City, Leyte	Naval-Tacloban City	70.51
Eastern Samar	Guiuan, Eastern Samar	Borongan-Guiuan	71.26
Isabela (Excluding City of Santiago)	Tuguegarao, Cagayan	Isabela City-Tuguegarao	71.84
Isabela City	Tuguegarao, Cagayan	Isabela City-Tuguegarao	71.84
Compostela Valley	Davao City, Davao Del Sur	Nabunturan-Davao City	72.68
Apayao	Tuguegarao, Cagayan	Apayao-Tuguegarao	73.79
Marinduque	Tayabas, Quezon	Boac-Tayabas	74.42
Zamboanga del Sur (Excluding Zamboanga City)	Dipolog, Zambonanga Del Norte	Pagadian-Dipolog	75.66
Aurora	Casiguran, Aurora	Baler-Casiguran	75.91
Pampanga (Excluding Angeles City)	Iba, Zambales	San Fernando City-Iba	77.38
Ifugao	Baguio City, Benguet	Lagawe-Baguio City	78.65

Surigao del Sur	Hinatuan, Surigao Del Sur	Tandag-Hinatuan	80.76
Zamboanga Sibugay	Zambonaga, Zamboanga Del Sur	Ipil-Zamboanga del Sur	85.18
Mountain Province	Baguio City, Benguet	Bontoc-Baguio City	87.15
Misamis Occidental	Lumbia Airport, Misamis Oriental	Oroquieta-Lumbia Airport	89.38
Masbate	Legaspi City, Albay	Masbate City-Legaspi City	90.04
Bataan	Iba, Zambales	Balanga-Iba	91.19
Davao Oriental	Davao City, Davao Del Sur	Mati-Davao City	91.54
Camiguin	Lumbia Airport, Misamis Oriental	Mambajao-Lumbia Airport	92.3
Camarines Sur (Excluding Naga City)	Virac, Catanduanes	Pili-Virac	93.02
Lanao del Norte (Excluding Iligan City)	Lumbia Airport, Misamis Oriental	Tubod-Lumbia Airport	93.13
Sultan Kudarat	General Santos, South Cotabato	Sultan Kudarat-General Santos	94.13
Iloilo (Excluding Iloilo City)	Roxas City, Capiz	Iloilo-Roxas City	94.48
Iloilo City	Roxas City, Capiz	Iloilo City-Roxas City	94.48
City of Santiago	Tuguegarao, Cagayan	Santiago City-Tuguegarao	101.55
Bacolod City	Roxas City, Capiz	Bacolod city-Dumaguete	104.27
Negros Occidental (Excluding Bacolod City)	Roxas City, Capiz	Bacolod city-Dumaguete	104.27
Antique	Roxas City, Capiz	San Jose de Buenavista-Roxas City	124.85
Cotabato City	Davao City, Davao Del Sur	Cotabato City to Davao City	129.28
Sulu	Zamboanga City, Zamboanga	Jolo-Zambonaga City	153.13
Quirino	Tuguegarao, Cagayan	Quirino-Tuguegarao	175.05
Batangas	Ambulong, Batangas		
Baguio City	Baguio City, Benguet		
Benguet (Excluding Baguio City)	Baguio City, Benguet		
Agusan Norte (Excluding Butuan City)	Butuan City, Agusan Del Norte		
Butuan City	Butuan City, Agusan Del Norte		
Oriental Mindoro	Calapan, Oriental Mindoro		
Northern Samar	Catarman, Northern Samar		
Samar (Western)	Catbalogan, Western Samar		
Camarines Norte	Daet, Camarines Norte		
Pangasinan	Dagupan City, Pangasinan		
Davao	Davao City, Davao Del Sur		
Davao City	Davao City, Davao Del Sur		
Davao Sur (Excluding Davao City)	Davao City, Davao Del Sur		
Zamboanga del Norte	Dipolog, Zamboanga Del Norte		
Negros Oriental	Dumaguete City Negros Oriental		
General Santos City(Dadiangas)	General Santos, South Cotabato		
Maguindanao	General Santos, South Cotabato		
Zambales (Excluding Olongapo City)	Iba, Zambales		
Ilocos Norte	Laoag, Ilocos Norte		
Albay	Legaspi City, Albay		
Marawi City	Lumbia Airport, Misamis Oriental		
Southern Leyte	Maasin, Southern Leyte		
Cebu (Excluding Cebu City)	Mactan International Airport, Cebu		
Cebu City	Mactan International Airport, Cebu		
Bukidnon	Malaybalay, Bukidnon		
Pasay City	NAIA, Pasay City		
Manila	Port Area, Manila		
Palawan	Puerto Princesa, Palawan		
Romblon	Romblon, Romblon		
Capiz	Roxas City, Capiz		
Cavite	Sangle Point, Cavite		
Quezon City	Science Garden, Quezon City		
Surigao del Norte	Surigao, Surigao Del Norte		
Bohol	Tagbilaran City, Bohol		
Cagayan	Tuguegarao, Cagayan		
Ilocos Sur	Vigan, Ilocos Sur		
Naga City	Virac, Catanduanes		
Zamboanga City	Zamboanga City, Zamboanga		
Batanes			
Guimaras			
Tawi-Tawi			

§Taken from [http://distancecalculator.globefeed.com/Philippines\\_Distance\\_Calculator.asp](http://distancecalculator.globefeed.com/Philippines_Distance_Calculator.asp).

**Table 2A: Multinomial logit estimates: energy types, two-energy sources, and three-energy sources**

	Energy type		Two-energy sources			Three-energy sources			
	Modern And traditional	Exclusively traditional	Elec/Char	Elec/Gas	Elec/Org	Elec/LPG/Org	Elec/LPG/gas	Elec/Gas/Org	Elec/Gas/Char
Low-income	0.086 [0.070]	-0.562* [0.314]	0.622** [0.266]	0.807*** [0.169]	0.514* [0.295]	-0.163 [0.293]	0.197 [0.256]	1.851*** [0.536]	1.086** [0.537]
High-income	0.124 [0.104]	-0.32 [1.014]	-0.427 [0.561]	-1.853*** [0.605]	-0.149 [0.696]	0.443 [0.334]	0.388 [0.335]	-13.811 [591.390]	-0.714 [1.330]
Price: electricity	0.095*** [0.033]	-0.373*** [0.096]	-0.156 [0.125]	0.05 [0.086]	-0.091 [0.139]	-0.295* [0.165]	0.217 [0.166]	-0.428 [0.293]	0.201 [0.334]
Price: LPG	0.043*** [0.008]	-0.014 [0.030]	0.157*** [0.035]	0.238*** [0.022]	0.236*** [0.036]	0.016 [0.037]	0.019 [0.032]	0.268*** [0.068]	0.438*** [0.094]
Price: charcoal	0.01 [0.009]	-0.184*** [0.033]	-0.033 [0.035]	-0.036* [0.021]	-0.038 [0.037]	-0.061 [0.040]	-0.140*** [0.041]	-0.120* [0.069]	0.025 [0.078]
Price: gas	-0.045*** [0.012]	-0.019 [0.047]	-0.079* [0.048]	-0.036 [0.029]	-0.082* [0.048]	0.019 [0.054]	0.007 [0.046]	-0.131 [0.094]	0.201* [0.109]
Price: organic sources	-0.108*** [0.020]	-0.186*** [0.068]	0.008 [0.071]	-0.306*** [0.053]	0.028 [0.080]	-0.045 [0.085]	-0.323*** [0.091]	-0.262 [0.163]	-0.139 [0.191]
Urban	-0.197*** [0.070]	-0.618*** [0.265]	-0.195 [0.273]	-1.147*** [0.176]	-1.324*** [0.307]	-0.197 [0.293]	-0.824*** [0.269]	-2.509*** [0.576]	-1.982*** [0.570]
Heat index deviation	-0.037** [0.015]	0.005 [0.045]	-0.075 [0.065]	-0.063* [0.037]	-0.076 [0.061]	-0.213** [0.094]	-0.072 [0.062]	-0.359** [0.145]	-0.062 [0.125]
Heat index deviation^2	0.013*** [0.004]	0.036*** [0.010]	0.022 [0.018]	0.037*** [0.010]	0.024 [0.016]	-0.034 [0.033]	0.042*** [0.016]	0.009 [0.041]	-0.02 [0.033]

\*\*\*/\*\*/\* Significant at 1/5/10%. Figures in parentheses are standard errors. Left-out category for energy type is exclusively modern, for two-energy sources is electricity/LPG, and for three-energy sources is electricity/LPG/charcoal. Additional explanatory variables include household head's sex, age, educational attainment, job status, total household members, number of bedrooms, number of bathrooms, number of floors/storeys, and asset indices.