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Why Rural Rich Remain Energy Poor

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Abstract:

The paper explores the rationale behind the complexities of energy poverty among different income groups in rural communities. We attempted to explain why rural rich, despite their relatively high purchasing power use energy sources which tend to categorize them as energy poor. Using the Energy Poverty Survey (EPS) - a dataset of more than 600 rural households from 27 different rural communities of Punjab, Pakistan, we presented the energy access situation in rural households among different income groups. Subsequently, we used binary logit regressions to assess access factors which could impact the energy source choices among different income groups. The limited significance of household income for traditional biomass use and high significance of community remoteness indicators imply that households give high importance on the proximity of energy sources available to them and, in many cases, will prefer to be in the state of energy poverty, than to use modern energy source like LPG.

Keywords: energy poverty, rural rich and poor, rural communities, Punjab, Pakistan, fuelwood, animal waste, plant waste, kerosene, liquid petroleum gas

JEL: Q01, Q42, I32

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1. Introduction

In Pakistan, and other developing countries, rural communities are often without access to modern energy sources like electricity and natural gas. In recent years, the expansion in electricity access has increased manifolds, however the inaccessibility to natural gas still remain as the major impediment for socio-economic development of these rural communities, due to high inconveniences experienced in collection and buying traditional biomass and other energy sources. Based on the access to electricity and natural gas, 4 types of rural communities have emerged, in countries like Pakistan, i.e., a) communities without electricity and natural gas, b) communities with electricity but without natural gas, c) communities without electricity but with natural gas, d) and communities with electricity and natural gas. The types, a and b are the ones, where rural households, either poor or rich, use variety of energy sources, particularly, for cooking and heating purposes. In a very limited manner, people move up the energy ladder when household income increases in these communities (Davis, 1995; Leach, 1987, 1988, 1992; Campbell at al., 2003). However, we often observe that higher income groups may continue to rely on traditional biomass (firewood, animal waste, plant waste) or use kerosene in addition to using modern and convenient energy source like LPG (Aburas & Fromme, 1991; Alberts et al., 1997; Haas et al., 2008; Joyeux and Ripple, 2007; Horst and Hovorka, 2008).

The issue of energy source choices in rural communities is examined in many studies. In most of the earlier studies, household income and consumption is used as the common determinants for explaining the energy poverty, followed by the pioneering research of Leach (1987, 1988). Leach, based on the national surveys, found that the consumption of biomass was related to income, household and settlement size and fuel prices in India, Pakistan and Bangladesh. Subsequently, other similar studies show that due to non-availability of conventional energy sources like on-grid electricity and natural gas, rural households, including richer one, adopt traditional biomass as a substitute for meeting household energy needs (Wuyan et al., 2007; Xiaohua and Zhenming, 1996, 1997; Masera and Navia, 1997; Tonooka et al., 2006)

We also observed that there is a clear distinction between the energy source choices and the energy source switching – also referred as fuel switching, in energy poor households. E*nergy source choices* refer to the energy options available to rural households, which they choose or

can choose to meet their household energy needs. Once a specific energy source is chosen by a particular household, three different scenarios are possible, a) household starts using it as a main energy source, b) household starts using it, but only occasionally, hence combining it with other energy source(s), also called as fuel stacking (Wuyan et al., 2007) and c) household stop using it and switch to other possible energy source(s)[1]. The first two scenarios clearly depend on available energy choices and number of related factors like income, price, household proximity etc, whereby households expands their types of energy sources to meet their energy needs, whereas the third scenario involves the discontinuation of previous energy source used by household and switch to available substitute(s) which could best provide them optimal combination of related factors (Davis, 1995; Campbell et al., 2003; Alberts et al., 1997; Horst and Hovorka, 2008; Wuyan et al., 2007; Xiaohua and Zhenming, 1996, 1997; Masera and Navia, 1997; Masera et al., 2000; Bhattacharyya, 2006; Gupta and Köhlin, 2006).

In this paper, we studied the factors responsible for different energy choices, that people living in rural communities (type a and b only) choose to meet their domestic energy needs. We used the binary *logit* models for 5 different energy sources (firewood, animal waste, plant waste, kerosene and LPG) included in our survey. The structure of the paper is as following. Section 2 offers an overview of energy sources and their respective use across the different income groups in rural Punjab. Section 3 discusses the dependent and independent variables used in our analysis. Section 4 discusses the model results for 5 different energy sources and their sub-categories. And finally section 5 states our conclusions with special attention to the question why rural rich remain energy poor.

2. Energy choices in rural communities of Punjab

Households in the rural Punjab of Pakistan use different types of energy sources in the absence of natural gas and electricity. In the absence of natural gas, rural households are left with different energy sources like firewood, animal and plant wastes etc to meet their domestic energy needs. Similarly, in the case where electricity is not accessible, kerosene is the most common alternative used in kerosene lanterns. Figure 1 represents an overview of energy sources available to households in rural communities. Based on the frequency of usage, the 'frequent users' represent household using a particular energy source as one of the main energy sources in their energy mix. On the other side, occasional users are households using a particular energy source intermittently, due to different reasons (access, price, supply, availability etc.).

Figure 2 shows that more than 52% households are frequent users and rely on buying the firewood from the nearby market, whereas nearly 40% households collect firewood and are frequent users. 5.5% of households are those which, at the same time, collect and buy firewood

[1] This further leads to 'fuel switching' phenomenon in rural households. For more information on fuel switching (Campbell et al., 2003; Alberts el al., 1997; Horst and Hovorka, 2008; Masera and Navia, 1997; Masera et al., 2000; Karekazi et al., 2008; Viswanathan and Kavi, 2005; Nautiyal and Kaechele, 2008)

from the market. Only 2.9% of firewood users have reported that they use firewood occasionally. In our sample of 640 households in Punjab, 90.9% of rural households reported that firewood is one of the energy sources among others. Firewood may be collected, bought or both collected and bought. Both activities require effort for buying firewood as people may have to go to nearby town or city.

Fig. 1: Hierarchy of Different Energy Source Choices Available to Rural Households

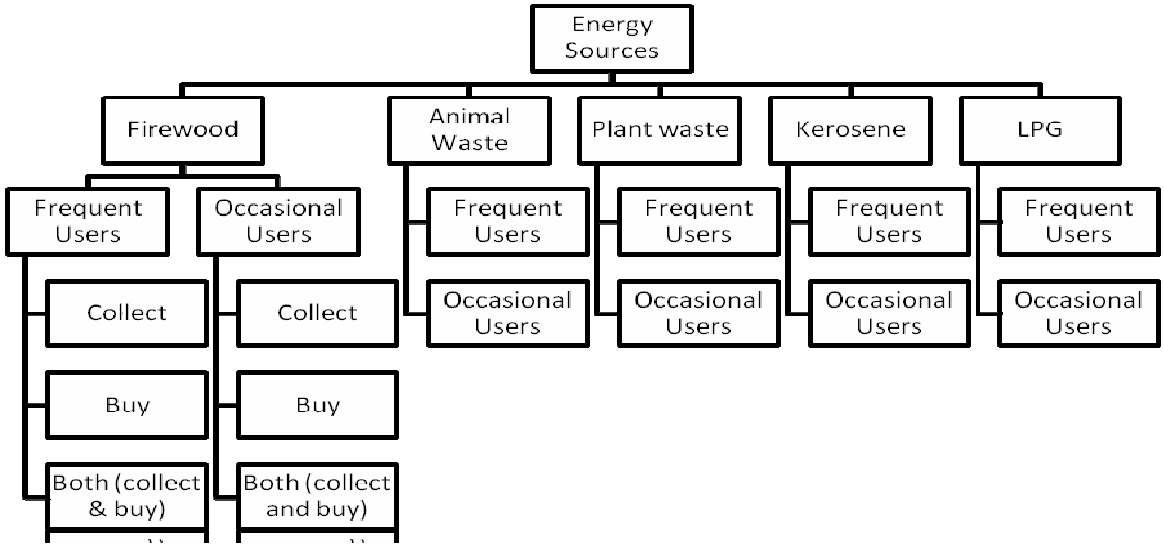
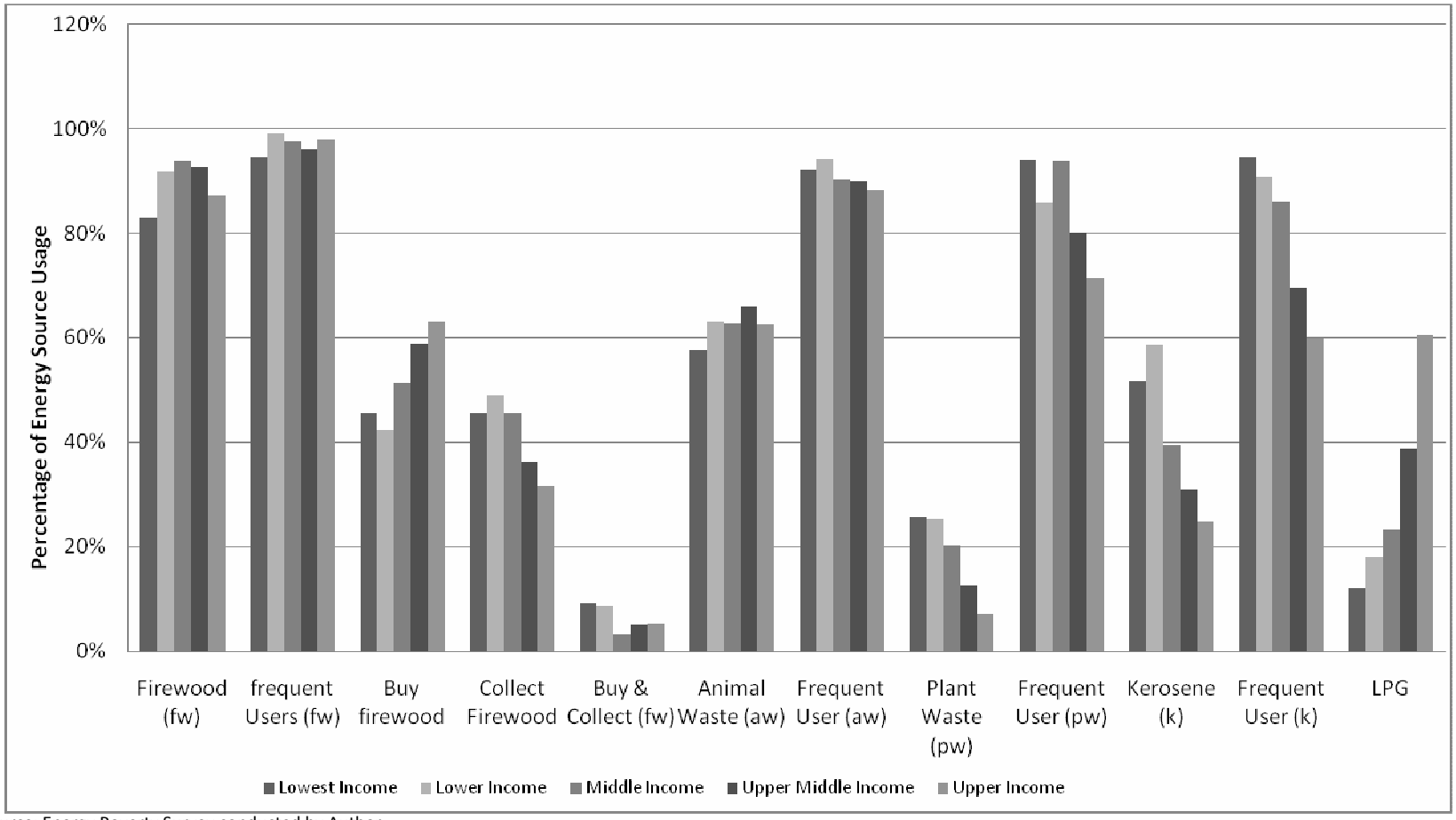


Figure 2 shows different income groups and their respective proportions (in %) using energy sources (listed on x-axis). When these income groups are compared, we can see that consumption levels are surprisingly equal across income groups. These consumption levels point to our main problem statement for the paper, which inquire the causes for such consumption consistency in different income groups, particularly for the traditional energy sources like firewood and animal waste. In other words, we aim to specifically analyze why rural rich remain energy poor despite of higher incomes? Apart from the infrastructural unavailability, what are the main factors in shaping energy choices available to rural households with different income levels? Why are certain energy sources given more priority than others in different income groups?

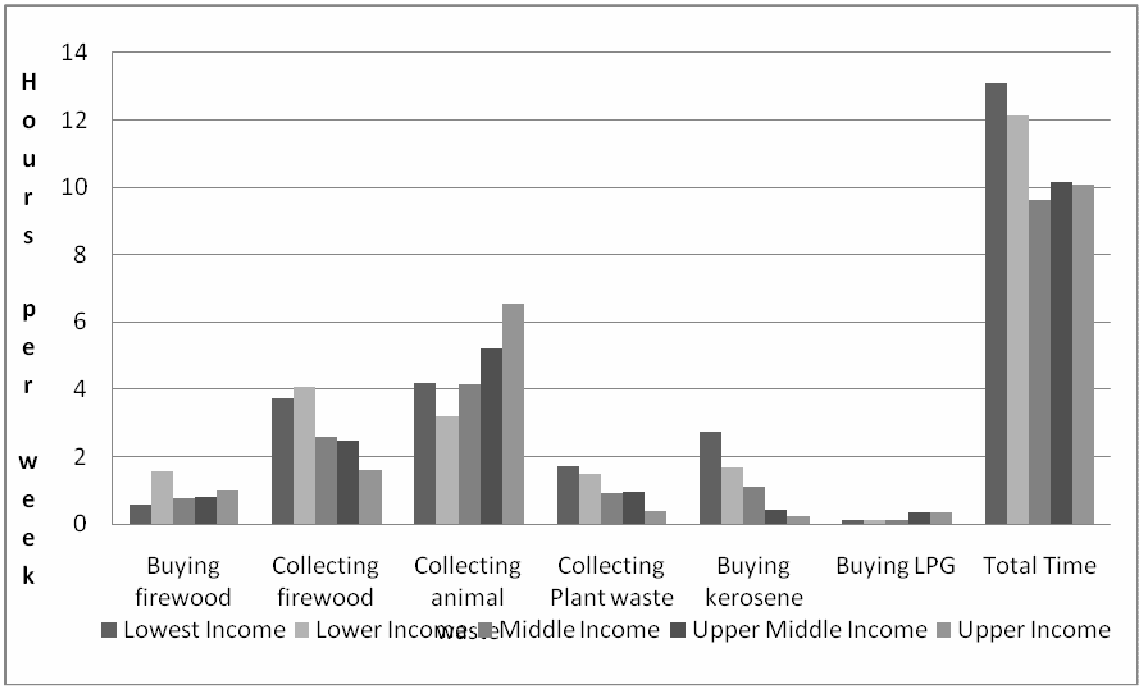
Figure 2: Proportion of Energy Sources in Different Income Groups



Source: Energy Poverty Survey conducted by Author

During the data collection using the EPS, we found that many households, particularly with higher incomes, consider many factors in deciding for particular energy source. For such households, these factors are equally important as energy source price. Figure 3 shows the average time per week that different income groups are spending for collection and/or buying different energy sources on average. The amount of time (per week) that people spend on buying and collecting energy sources is considerable and differs per energy source across different income groups. Collecting animal waste takes most time (more than 6 hours or more on average per week) in upper income group, due to relatively high livestock ownership in rich households. Data shows that the average time spent for collecting firewood decreases as the household income increases. In the case of LPG, there is a slight increase in average time spent at higher incomes (upper middle and upper income groups) as compared to lower income groups. This is certainly due to the increased usage of LPG in higher income groups.

Figure 3: Average Time Spent (in hours) per week in Buying and Collecting Different Energy Sources



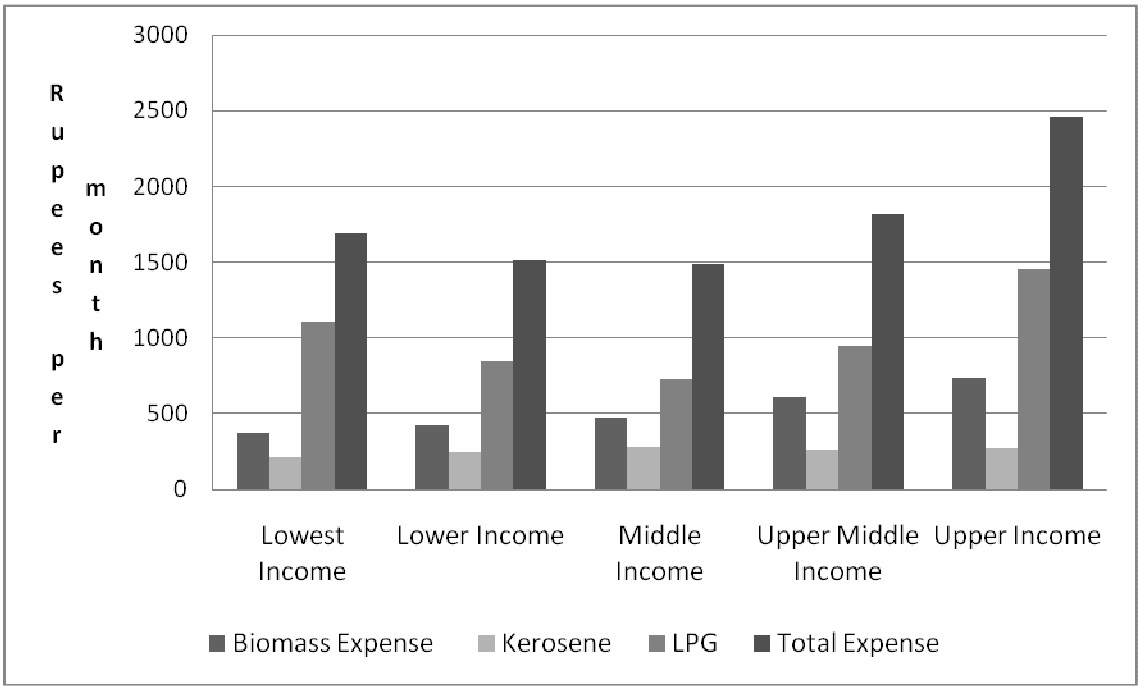
Source: Energy Poverty Survey conducted by Author

Figure 4 shows that kerosene expense in all income groups is rather equal, whereas there is gradual increase in biomass expense from the lowest income to the upper income group. Traditional biomass expense represents the combined expenses for firewood, animal and plant waste bought. We can see that people in the upper income group are spending twice as much as the lowest income group on biomass. This shows that instead of gradual decline of biomass expenditure in the upper income group, which is normally expected, it increases actually. Due to

its natural availability in rural setup, biomass still remains one of the preferred sources of energy in upper income groups, even when used in combination with LPG.

In the case of LPG, an interesting U-shaped curve corresponds to the bars representing LPG expenses in figure 4. On average, more than Rs. 1100 are spend on LPG in the lowest income group. Most households in this group do not use LPG. Out of 66 households categorized as the lowest income households, only 8 households reported that they are LPG users, representing 12.12% of entire group. The LPG expenses went down in the lower and the middle income group, whereas it started increasing in upper middle and upper income group. On average, energy expenses in the lowest income group are more than the lower and middle income group. These expenses tend to increase in the upper middle income and upper income groups, probably due to convenient energy sources like firewood bought (compared to firewood collected) and LPG.

Figure 4: Average Monthly Expenses by Different Income Groups for Different Energy Sources



Source: Energy Poverty Survey conducted by Author

3. Data and research method

We used our own survey, called the Energy Poverty Survey (EPS) to study the energy choices among rural households. The EPS was conducted during September 2008 and January 2009 in 11 different districts of Punjab province in Pakistan. In total, 640 households from 27 rural communities in 11 different districts of Punjab province were included using stratified random sampling. In the EPS, 19 rural communities were without any natural gas supply but with on-grid electricity, 6 rural communities were without any access to natural gas or electricity, whereas 2

of them were solar villages, but without any access to natural gas and on-grid electricity. Table 1 shows that almost all the rural communities in our sample are classified either as *poor* or *very poor*. Around 88% respondents belong to age group between 18 years and 60 years. The ratio of male to female is heavily biased towards the male respondents, due to the fact that the local culture does not allow females to interact with males other than their family members.

Table 1: Sample Profile: Some Fact and Figures

Province	Punjab	**Household Members**	
Districts	11	2 to 5	169 (26%)
Rural Communities (households)	27 (640)	6 to 10	388 (60%)
Communities with Electricity but no Natural Gas	19	11 to 15	66 (10%)
Communities without Electricity and Natural Gas	6	16 to 20	12 (2%)
Solar Communities without Electricity and Natural Gas	2	20 +	5 (1%)
Gender		**Community Prosperity Level**	
Male	599 (93.6%)	Very Poor	11
Female	41 (6.4%)	Poor	11
Age Groups		Neither Poor nor Rich	2
Below 18 Years	4 (0.6%)	Rich	0
18yrs to 30yrs	135 (21.1%)	Very Rich	0
30yrs to 45yrs	268 (41.9%)	Un-known	3
45yrs to 60yrs	164 (25.6%)		
60+	69 (10.8%)		

Source: Energy Poverty Survey conducted by Author

Using the binary variables for energy source choices, we used the binary logistic regression to study the effect of different factors on energy source choices made by rural households. In our logistic regression model, we included the community remoteness indicators (*td* and *cd*), type of occupations (*farmer*, *shop*), household size (*hs*), number of household members working (*nhmw*), constant income (*cons*_income) and most importantly, the income groups as the explanatory variables. The dependent and independent variables are discusses separately in the following sub-sections.

3.1 Dependent Variables

The logistic regression model takes into account 11 different binary or dichotomous variables for 5 different energy sources, including firewood, animal waste, plant waste, kerosene and LPG. The first question asked to the respondents for each energy source is whether they are using the

particular energy source or not, which is represented by 1 as a user and 0 otherwise. We made a further distinction in the next question by asking the usage frequency to all energy source users except LPG, which is coded as 1 if household is a frequent user and 0 if an occasional user (see Table 2). Specifically in the case of firewood, rural households collect, buy or do both to access firewood. In the case when households collect firewood, they bear relatively high physical inconveniences without any costs for the firewood.

Table 2: Dependent Variables and their Description

Variable Code	Variable Name	Description
firewooduser	Household using firewood	1 if yes, 0 otherwise
FireAlways	Frequent firewood user	1 if yes, 0 otherwise. 0 also implies that household is occasional user.
Buy_firewood	Whether household buys firewood	1 if yes, 0 otherwise. 0 also implies that household collects firewood or collect and buy (both)
Collect_firewood	Whether household collects firewood	1 if yes, 0 otherwise. 0 also implies that household buy firewood or collect and buy (both)
A_waste_user	Household using animal waste	1 if yes, 0 otherwise.
Awaste_always	Frequent animal waste user	1 if yes, 0 otherwise. 0 also implies that household is occasional user.
P_waste_user	Household using plant waste	1 if yes, 0 otherwise.
P_waste_always	Frequent plant waste user	1 if yes, 0 otherwise. 0 also implies that household is occasional user.
K_user	Household using kerosene	1 if yes, 0 otherwise.
K_always	Frequent kerosene user	1 if yes, 0 otherwise. 0 also implies that household is occasional user.
LPG_user	Household using kerosene	1 if yes, 0 otherwise.

Source: Energy Poverty Survey conducted by Author

3.2 Independent Variables

3.2.1 Occupations

Eight different categories of occupations were identified, namely, unemployed (individuals), farming, (construction) labour[2], shopkeeper, government employees, private employees, retired individuals, and others including drivers, barbers, etc. Construction labour is found to be the most common profession among the rural households in all the districts, with 32% households associated with it. The second most common occupation is farming which includes almost 31% of households, followed by shop keeping (15.7%). Remaining 4 occupational categories were less than 7% separately. For that reason, initially we selected only three occupations for our model on different energy sources. However, a high co-linearity between *labourer* and other two

[2] In the EPS, the term *labourer* is used for the construction workers only as it is the most common profession among rural households. Whereas all other labour intensive professions common are included in *Others* category.

variables (occupations) was found, which led us to drop *labourer* from the econometric analysis, and thus only include *farmer* and *shop* as occupational variables.

Table 3: Independent Variables and their Description

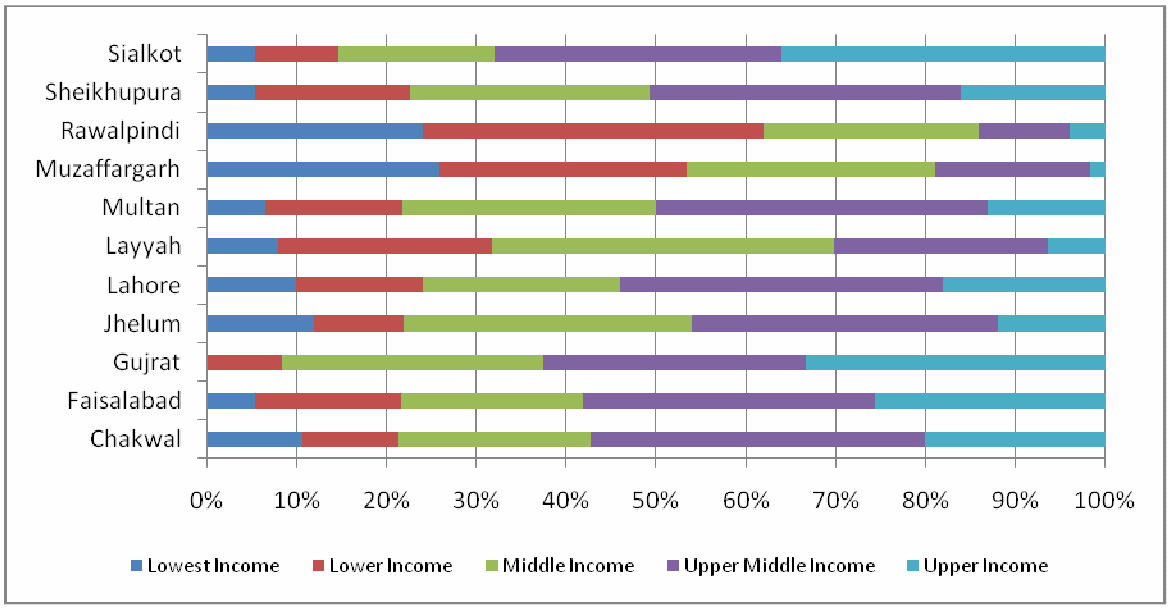
Variable Code	Variable Name	Description
Td	Town Distance	Village distance in kilometres from nearby town
Cd	City Distance	Village distance in kilometres from nearby city
hs	Household Size	Total number of household members within one dwelling
Nhmw	Number of Household Members working	Total number of households working (including farming)
const_income	Constant Income dummy	1 if yes, 0 otherwise. Whether the income remains constant during the year or not
Farmer	Occupation = Farming dummy	1 if yes, 0 otherwise. Main occupation of the respondent or household head
Shop	Occupation = Shop keeping dummy	1 if yes, 0 otherwise. As per above
lwstincome	Lowest Income class dummy	1 if yes, 0 otherwise. Group with income between Rs.1 and Rs. 3000
lwrincome	Lower income class dummy	1 if yes, 0 otherwise. Group with income between Rs. 3001 and Rs 5000
midincome	Middle income class dummy	1 if yes, 0 otherwise. Group with income between Rs. 5001 and Rs. 8000
upmidincome	Upper middle income class dummy	1 if yes, 0 otherwise. Group with income between Rs. 8001 and Rs. 12000
upincome	Upper income class dummy	1 if yes, 0 otherwise. Group with income between Rs. 12001 and above [Reference Category].

Source: Energy Poverty Survey conducted by Author

3.2.2 Income

Income of rural households is classified into 5 different groups, namely the lowest income group, lower income group, middle income group, upper middle income group, and the upper income group, based on the different income ranges. The lowest income group includes all the households, which has monthly household income (total household income) ranging from 1 rupee to 3000 rupees. Similarly, the lower income group includes all the households which have monthly household income ranging from Rs. 3001 to Rs. 5000, followed by the middle income group ranging from Rs. 5001 to Rs. 8000, the upper middle income group ranging from Rs. 8001 to Rs. 12000 and the upper income group to incomes above Rs. 12000. The explanatory variables corresponding to each income group are dichotomous variables that equal to 1 if the total household monthly income falls into that range category, otherwise zero.

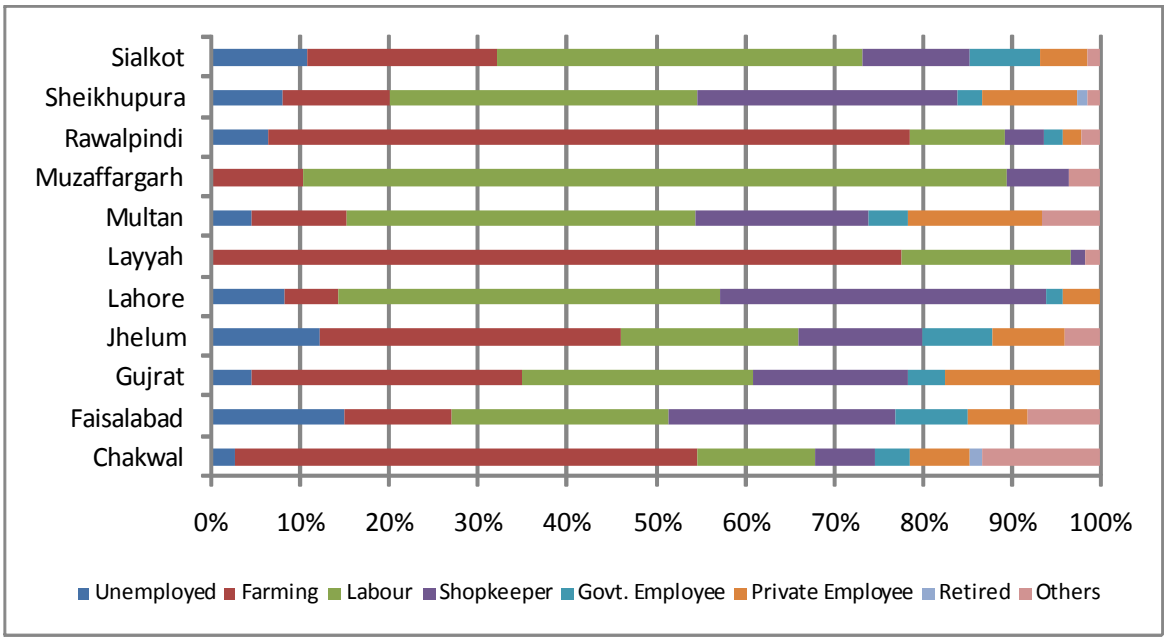
Figure 5: Proportion of Income Groups in Different Districts



Source: Energy Poverty Survey conducted by Author

Figure 5 shows the geographical distribution of different income groups in different districts of Punjab province. Muzaffargarh (25.9%) and Rawalpindi (24%) districts are the ones with highest proportion of poor people falling into the lowest income group. Sialkot and Gujrat districts are those with highest proportion of rich people representing upper income group, i.e., 36% and 33% respectively. It is also worth mentioning here that according to the set income criteria, none of the households sampled in Gujrat district belong to the lowest income group, hence the district only represents the remaining four income groups. To further analyse the source of such income patterns in different districts, figure 6 shows the break-up of occupations adopted by rural households. We can see that in the communities (Muzaffargarh and Rawalpindi) where poor income groups are in majority, farming is one of the major occupations, whereas in communities (Sialkot and Gujrat) with the majority of people belonging to upper income group, households have mostly reported as (construction) labourer, government and private employee households.

Figure 6: Occupations and their Proportions in Different Districts



Source: Energy Poverty Survey conducted by Author

Using a random sampling of rural households in our sampled rural communities, we can see that more than 10% rural households belong to the lowest income category (see table 4). Similarly, more than 17% households sampled in the EPS are categorized as the lower income households, whereas 26% are the middle income households. According to the set income criteria, we found that nearly 30% of rural households can be categorized as the upper middle income households, whereas remaining 17% can be classified as the upper income households. As income in rural household is seasonal, a specific question was also asked to know whether the household income remains constant throughout the year or not. As a result, a dichotomous variable *const_income* is used in the model, which equals one if the household has constant income throughout the year, and zero otherwise.

Table 4: Income Group Representation in All Districts

	Lowest Income	Lower Income	Middle Income	Upper Middle Income	Upper Income
Sample Mean	10.28%	17.32%	26.07%	29.42%	16.92%

Source: Energy Poverty Survey conducted by Author

3.2.3 Community Remoteness

Three different variables are used to measure the community remoteness, namely distance from nearest village (*vd*), distance from nearest town (*td*) and distance from nearest city (*cd*). To avoid the repetition of distance from village to village, we avoided to include adjacent villages in our sample. Also, due to relatively similar market situations in all adjacent villages, rural people tend

to visit nearest town or city for their energy needs. This gave us a reason to exclude village distance variable from our analysis, leaving us with two important indicators for analyzing the effect of community remoteness on energy source choices.

Table 5: Distance (in kilometres) of Town and City from Sampled Rural Community

	Minimum	Maximum	Mean
Town Distance	1	18	5.64
City Distance	3	50	20.64

Table 5 provides a snapshot of community remoteness that shows minimum, maximum and average distances in kilometres from rural community to most nearby town and city. On average, rural people travel more than 5 and 20 kilometres to reach town and city respectively. In the case where city is very far (more than 10 kilometres) from rural community, we assume that nearby town shall be preferred by rural people. Another important aspect is mode of transportation to access in such far-flung towns and cities. Particularly in lower income classes, rural people normally travel by foot. However, in some cases, they also use bicycles and animal carts, which make their access to town and city much more convenient. In upper income classes (upper middle and upper income group), use of motor bike and tractor is more common.

3.2.4 Household size and Number of household members working

Household size[3] (*hs*) represents the total number of household members, including all men, women and children living together in one dwelling. In our sample, we found that the average number of household members (*hs*) is more than 7, with minimum of two and maximum of 30 household members. In the case of number of household members working (*nhmw*), more than 48% household reported that at least 1 household member is working, either employed or self-employed and earning income corresponding to one of the income groups. Similarly, 20.4% and 15.2% reported 2 and 3 working members respectively. For the binomial logistic regression, we consider both, *hs* and *nhmw* as the important variables with possible impact on the energy access for households. Our priori is that household with higher *hs* might have convenient access by engaging more households members in collecting and buying traditional and non-traditional energy sources. On the other hand, households with higher *nhmw* might have lower access to traditional energy sources, as they might not be available due to their employment.

Apart from independent variables discussed earlier, we also included education variables, for respondent, other male and female members (separately) and other occupations like labourer. However, surprisingly, both types of variables turned out to be highly insignificant with high

[3] In the EPS, we only had data on household size, and not on household composition.

standard errors. Also, both of them were having co-linearity problems, which eventually forced us to exclude them from our final models and their sub-models.

4. Results: Different Energy Choices, Different Reasons

Household opt for different energy choices based on different factors relevant to that particular energy source. In this section, we discuss the factors relevant to each energy source based on the binomial *logit* regression results, as presented in Table 6.

4.1 Factors effecting household using firewood

Firewood is considered to be the most readily available and preferred energy source for rural households (Davis, 1995; Alberts et al., 1997; Pachauri and Jiang, 2008; Permana et al., 2008). This also holds true for the rural communities studied in Punjab where 90.9% of the households use firewood (bought or collected). In our analysis, we investigate the determinants of firewood use, both for occasional users and frequent users.

4.1.1 Households using firewood

In the first step, we took firewood user as a dependent variable, representing the dummy which equals to 1 if household uses firewood and zero otherwise. Using the independent variables listed in Table 3, we found that the community remoteness indicators (town [p-value ≤ 0.10] and city distance [p-value ≤ 0.01]), household size (p-value ≤ 0.01), farmer (p-value ≤ 0.01), lower (p-value ≤ 0.05), middle (p-value ≤ 0.05) and the upper middle income (p-value ≤ 0.10) group turned out to be significant for choosing firewood as an energy choice in our sample of 640 households. The estimated coefficient, which represent the log of odds ratio suggest that the odds of using firewood (collected or bought) are highest in the middle income group [exp (*midincome*) = 2.74] than other income groups. Similarly, in occupation related variables, the dummy variable for farmer tells us that the odds [exp (-0.862) = 0.422] of using firewood in farming households are 42% higher than households with other occupations (shop keeping). The *Nagelkerke* R^2 shows that our model is able to explain just 15% of the variation based on the given variables.

4.1.2 Frequent vs. Occasional Firewood Using Households

Rural households tend to make choices on usage frequency of energy source based on different factors. During our informal discussion with rural people, we found that for poor households time is less important than it is for rich households. On the other hand, rich households tend to choose energy sources with greater convenience and energy efficiency than its price. Interestingly, we found that they still use firewood and animal waste in combination with LPG to meet their domestic energy needs. We created a dichotomous dependent variable, representing the frequency of firewood usage in rural households, where 1 representing a frequent firewood usage and 0 representing an occasional firewood usage. The results in column 2 of table 6 shows that town distance (p-value ≤ 0.05), household size (p-value ≤ 0.10) and the upper middle

income group variables are significant for the choice of using firewood frequently or occasionally. Our results suggest that the increase in town distance negatively affects the frequency of firewood usage, as rural households are highly dependent on firewood sellers in the nearby town. Household size (*hs*) is positively significant, as expected, implying more household involvement in firewood buying and collecting activities. In the income related explanatory variables, only the upper middle income group variable turned out to be the significant one (p-value ≤ 0.05) with negative coefficient value, suggesting very low odds [exp (-1.825) = 0.16] for using firewood frequently when households fall in the upper middle income group.

4.1.3 Households buying firewood

The results for households buying firewood are given in the column 3 of table 6. The independent variable *buy firewood* is a dichotomous variable that equals to 1 if households buy firewood, and 0 if not. If the rural households do not buy firewood, this also implies that they are either collect firewood, or combine buying and collection. The results shows that the community remoteness variables (*td* and *cd*) are highly significant (p-value ≤ 0.01), along with the dummy variables for the lowest income group (p-value ≤ 0.10) and lower income group (p-value ≤ 0.05). The negative sign in the coefficients of *td* (town distance) and *cd* (city distance) suggests that with the increase in the community remoteness (in kilometres), the log odds to buy firewood decreases. This might be due to the market inter-linkages between the rural community and the nearby town and city, specifically for buying and selling firewood. This is true in many cases, as most of the firewood or wooden log stall[4] is only available in nearby town or city. The negative sign may also imply that with the increase of each unit of distance (kilometre), the probability to buy firewood among rural households decrease by the log odds of -0.06 for town and -0.057 for city. We may also transform the significant coefficient for the lowest income group (-0.827), which suggests that there is around 30% probability of buying firewood in the lowest income group, as compared to 70% probability of not buying it. Similarly, the probability computed from the log of odds ratio for the lower income group suggest the probability of buying firewood in the lowest income group is more than 31%, slightly higher than the lowest income group.

4.1.4 Households collecting firewood

For households collecting firewood and not buying it, distance of nearby town and city are found to be highly significant (both with p-value ≤ 0.01) and have positive influence on the dependent variable (collecting firewood). This implies that with the increase in distance from town and city, the odds of using collected firewood increases among rural households. The model also suggests that the tendency of using collected firewood among the lower income group is significant (p-value ≤ 0.10). The influence of *farmer* for firewood collection is as per our expectations. The

[4] Stalls where wooden logs are sold that can be used in furniture and firewood. This is very common practice in developing countries of South Asia (India, Pakistan, Bangladesh, Nepal, Sri Lanka) and Sub-Saharan Africa.

model suggests that the probability of using collected firewood is 40.4% in *farmer* households as compared to 0% in non-farmer household. In our dataset, farmers were usually not having access to 'free' firewood. In such cases, they also have to buy firewood to meet their domestic energy needs. Though, they have natural access to plant waste, due to its seasonal availability, they have to buy firewood and use it in addition to plant and animal wastes.

4.2 Factors explaining households using animal waste

More than 63% rural households are using animal waste as one of their energy source. Among the sample districts in the EPS, around 91% households in the Sialkot district reported to be using animal waste, followed by the Lahore district with 88%. Similarly, Rawalpindi and Layyah district turned out to have the lowest number of animal waste users, i.e., 86% and 75% rural households reported that they are not using the animal waste as an energy source. There are two main reasons for this. First, the rural communities in these districts are comparatively much poorer than rural communities in other districts. Secondly, their high dependence on agriculture results in much lower household income than other types of occupations. As a result, almost all of the animal waste produced domestically at a household level is used as a fertilizer in their agricultural land, allowing them to save their expenses on fertilizers. Moreover, it was also observed that due to comparatively high livestock ownership in rich households, animal waste becomes one of their natural energy choices, which is often considered as an exclusive source of energy for poor households

The ratio of rural household buying animal waste as an energy source is lower than the share of households buying firewood. We also found that if household owns livestock which produces waste usable as an energy source, household utilize it more often as an energy source than using it as a fertilizer. Moreover, in many cases, rural households use animal waste produced from their own livestock. Apart from buying animal waste, households also reported that in some cases, animal waste is earned as *income in kind* by female members of poor households who assist richer households with livestock ownership in cleaning the cattle shed and processing animal wastes to eventually make it combustible[5]. In our dataset, around 38% reported to buy it from the local sources like neighbour or households within their community, whereas only 1.2% reported using both ways, buying and collecting the animal waste from the community.

[5] In rural communities of Pakistan, there is no formal selling of animal waste which can be later used as animal waste. Usually, animal waste is processed and dried by the females in rural households. If a rural household with livestock ownership has surplus amount of animal waste, the females use their personal contacts with other female household members to sell or 'give away' animal waste. The practice in rich households (upper middle and upper income group) is slightly different, as the females from those households contact the females from household from low income groups (lowest and lower income group) and 'give away' the animal waste for free, if female members from low income household agree to process and clean the cattle shed.

4.2.1 Households using animal waste

In the case of households using animal waste, city distance and town distance appeared to be significant at 10% and 1% significance level respectively (see column 5 in Table 6). The results imply that lower the community remoteness, higher the chances of using energy source other than animal waste, as that increases the availability of other energy sources like firewood, kerosene, and liquid petroleum gas. In the estimates, we can also see that household income is without significant influence for the use of animal waste. In other words, this also implies that decision to use animal waste as an energy source is independent of the household social status, specifically in the case of rural communities.

4.2.2 Frequent vs. Occasional animal waste using households

The column 6 in table 6 shows the *logit* regression results for the frequency of using the animal waste, in households which have already reported animal waste as one of their energy sources. Apart from the community remoteness indicators (both significant at 1%), number of household members working in a specific household also turned out to be significant at 5% significance level with a negative coefficient value, implying the frequent use of animal waste as an energy source decreases with an increase in employed household members. This might be due to the fact that animal waste requires relatively higher degree of household efforts to make the animal dung usable for burning. Therefore as the number of household members working in a household increases, the use of animal waste decreases but still remains as one of the energy source. From the given sample size of 406 households, we can also see that more than 63% households uses animal waste as one of the energy source to meet their household energy demand.

4.3 Factors explaining plant wastes usage

Contrary to our hypothesis, the use of plant waste among rural households is independent of land ownership. Instead, it has been observed that the relationship between the land ownership and the use of plant waste as an energy source turned out to be highly insignificant (χ^2=0.872, df=1, p-value = 0.350). Among 109 rural households using plant waste, 47% reported that they do not own any agricultural land. In general, less than 18% rural households use plant waste for energy purposes, as more effort and time is required to collect it. Also, plant waste is not considered as an efficient energy source in terms of energy produced by it for the cooking purposes, as compared to firewood and animal waste. Within different districts, 83% and 72% rural households in Muzaffargarh and Layyah district respectively were using plant waste in addition to other energy sources. On the other side, rural households in 4 districts, namely Rawalpindi, Gujrat, Lahore and Multan, were not using it at all.

4.3.1 Households using plant waste

In column 7 of table 6, a binary variable is used for plant waste using household, which equals to 1 if households are using plant waste and 0 otherwise. The result of *logit* regression shows that the all explanatory variables turned out to be significant except community remoteness

indicators, number of household members working and the upper middle income group. The results clearly show that the households with farming have higher odds of using plant waste as an energy source. Moreover, households with income having no seasonal impacts also reported higher log of odds ratio of using plant waste than those who are not. Due to high co-linearity of *shop* (shop keepers) variable with other occupations, it was dropped from the model.

The lowest (p-value ≤ 0.01), lower (p-value ≤ 0.01) and the middle income group (p-value ≤ 0.05), household size (p-value ≤ 0.01), constant income (p-value ≤ 0.05), farmer (p-value ≤ 0.01) and number of household members working (p-value ≤ 0.10) turned out to be significant. One of the reasons for significance of *hs* could be the possibility of household members to engage themselves in plant waste collection, especially females and children. Similarly, income groups with low income have higher log odds ratio of using plant waste than households with higher income. Similarly, the high significance of *farmer* implies that due to easy access of plant waste, log of odds ratio of using plant waste are relatively high among farming households than those who are not. With R^2 of 0.14, the model is still able to explain only 14% variation, implying that still there are many unknown factors for remaining 86% variation responsible for plant waste collection.

4.3.2 Frequent vs. Occasional plant waste using households

The results from 110 plant waste using households show that most of the variables were unable to explain the variation in dependent variable, except the constant income variable (p-value ≤ 0.05), shop variable (p-value ≤ 0.10) and the lower income group variable (p-value ≤ 0.10).

Table 6: Binomial Logit Regression Results for Different Energy Sources

Dependent Variables	Firewood				Animal Waste		Plant Waste		Kerosene		LPG
	(1) User	(2) Frequent vs. Occasional User	(3) Buy	(4) Collect	(5) User	(6) Frequent vs. Occasional User	(7) User	(8) Frequent vs. Occasional User	(9) User	(10) Frequent vs. Occasional Users	(11) User
td	-0.063*	-0.126**	-0.06***	0.055***	-0.048**	-0.098***	-0.043	0.167	-0.031	-0.312***	0.086***
	(0.033)	(0.049)	(0.021)	(0.021)	(0.02)	(0.034)	(0.029)	(0.15)	(0.021)	(0.055)	(0.021)
cd	0.052***	0.029	-0.057***	0.059***	-0.053***	-0.04***	0.008	0.03	0.062***	0.072***	-0.035***
	(0.015)	(0.022)	(0.008)	(0.008)	(0.007)	(0.015)	(0.009)	(0.041)	(0.008)	(0.017)	(0.008)
hs	0.184***	0.215*	-0.003			0.033	0.088**	0.087	-0.022	0.05	-0.013
	(0.063)	(0.113)	(0.031)	0.004 (0.031)	0.038 (0.032)	(0.057)	(0.036)	(0.108)	(0.032)	(0.065)	(0.031)
nhmw	-0.113	-0.235	-0.086			-0.244**	-0.16	-0.184		-0.229	-0.148**
	(0.12)	(0.183)	(0.074)	0.055 (0.075)	0.094 (0.074)	(0.12)	(0.103)	(0.355)	0.028 (0.073)	(0.148)	(0.075)
Const_income		0.968	-0.059		-0.2	-0.279	0.908**	2.024**	0.149	-0.346	-0.731***
	0.395 (0.36)	(0.593)	(0.26)	0.313 (0.273)	(0.257)	(0.512)	(0.377)	(0.972)	(0.25)	(0.565)	(0.244)
Farmer	-0.862***	0.67	0.394*	-0.389*		0.746	0.676***	-0.365		0.283	-0.679***
	(0.321)	(0.676)	(0.219)	(0.225)	0.179 (0.211)	(0.526)	(0.234)	(0.969)	0.289 (0.206)	(0.493)	(0.226)
Shop	-0.213	-0.301		-0.473	-0.619	-0.574		3.122*	-0.615	0.209	0.867*
	(0.69)	(1.121)	0.695 (0.524)	(0.524)	(0.449)	(0.87)		(1.705)	(0.557)	(1.175)	(0.473)
Income Groups											
Lwstincome	-0.17	-1.613	-0.827*		-0.02	0.929	1.389***	1.529	1.38***	2.409**	-2.688***
	(0.503)	(1.128)	(0.427)	0.375 (0.422)	(0.384)	(1.106)	(0.458)	(1.384)	(0.383)	(1.178)	(0.57)
Lwrincome	0.998**	-0.071	-0.779**			0.323	1.084***	2.479*	1.276***	1.151*	-1.753***
	(0.5)	(1.297)	(0.33)	0.61* (0.332)	0.261 (0.315)	(0.66)	(0.412)	(1.412)	(0.313)	(0.679)	(0.342)
Midincome	1.009**	-0.858	-0.209		0.32	-0.018	0.885**	0.569	0.468*	1.081*	-1.511***
	(0.443)	(0.936)	(0.28)	0.173 (0.284)	(0.269)	(0.483)	(0.384)	(1.216)	(0.275)	(0.62)	(0.275)
Upmidincome	0.723*	-1.825**	0.211	-0.266		0.231	0.566	-2.493		0.147	-0.666***
	(0.427)	(0.839)	(0.28)	(0.288)	0.124 (0.268)	(0.513)	(0.395)	(2.102)	0.309 (0.275)	(0.583)	(0.253)
Constant	0.236	2.904**	1.995***	-2.377***	1.478***	3.967***	-3.614***	0.167	-2.24***	1.402	1.592***
	(0.713)	(1.321)	(0.459)	(0.471)	(0.451)	(0.862)	(0.621)	(0.15)	(0.454)	(0.962)	(0.455)
Obs.	640	581	581	581	640	406	640	110	640	251	640
Nagelkerke R^2	.15	.13	.28	.28	.23	.22	.14	.29	.24	.42	.25

Reference category in Income groups = Upper Income group; Robust standard errors in parenthesis; *** = Significant at 1%, ** = Significant at 5%, * = Significant at 10%

4.4 Factors explaining kerosene usage

Households normally consume kerosene in lanterns or for igniting traditional biomass (Alberts et al., 1997; Rijal et al., 1990; Karekazi et al., 2008; Mirza, 2008). Figure 2 shows that more than 50% of households in the lowest income group and around 60% of households in the lower income group use kerosene as one of their energy sources. In each of the income groups, kerosene consumption went down due to the inconveniences involved, rather than buying power of higher income groups. Also, we observed that higher income groups tend to buy more convenient energy source like liquid petroleum gas, than kerosene for cooking purposes due to its relatively higher efficiency.

The regression results in the column 9 of table 6 confirm that the odds of using kerosene is highly influenced by the city distance, and whether household is classified as the lowest or the lower income group household (p-value ≤ 0.01 for each). The transformation of log of odds ratio into probability shows that the probability of using kerosene in the lowest income group is nearly 80%, whereas for the lower income group it falls to 78%. The estimates for the middle income group also turned out to be significant at 10%, suggesting that the probability of using the kerosene in the middle income group is nearly 61%. This gradual decline in the probability of using kerosene can be attributed to the physical efforts and travelling involved for rural households.

The column 10 in Table 6 shows that the decision for using kerosene frequently or occasionally in rural households depends on the community remoteness and the household status. The negative estimate for town distance, represented as the log of odds suggests that with the increase of town distance, the odds for frequent use of kerosene declines. However in the case of city distance, the positive sign of log of odds might suggest that with the increase of distance between city and rural community, households might prefer to use kerosene more frequently than compared to a situation when city is close by. One possible explanation for this could be that when rural communities are distant, kerosene might become available within community market through shops and small grocery stores. The relative high value for *Nagelkerke* R^2 for frequent vs. occasional kerosene user (column 10 of table 6) shows the model is far better in prediction than all other models for energy sources.

4.5 Factors explaining LPG usage

The liquid petroleum gas or more commonly referred as the LPG, is one of the most common substitutes for natural gas in relatively affluent households, as it involves relatively higher initial costs for stove, gas cylinder and some accessories (Xiaohua and Zhenming, 1996; Heltberg, 2004; Hosier and Kipyonda, 1993; Karekazi, 1994). In 2000 and 2008, Masera et al. and Horst and Hovorka respectively, found that albeit the upper income households use LPG as a substitute energy source in the absence of natural gas, still it is not a complete substitute as they continue

using traditional biomass in combination to LPG. The descriptive results from our dataset also confirm this fact. We found that more than 32 % households reported to be using the LPG in absence of natural gas, in combination with other energy sources, like firewood, animal and plant waste. As shown in the Figure 2, the use of LPG tends to increase from the lowest income group till the upper middle income group, and then a decline in the upper income group.

The column 11 in Table 6 shows the *logit* results for the LPG usage in 640 rural households. Except household size variable, all explanatory variables turned out to be highly significant, however most of them with negative signs. The community remoteness variables (town distance and city distance) suggest that with the increase of city distance, the odds for using the LPG decreases, but in the case when town distance increases, the odds for using the LPG increases, which is somehow unexplainable. Similarly, coefficients for constant income and farmer also suggest that LPG usage is probably not common when households have constant incomes and are associated with farming profession. In the case of different income groups, the coefficient estimates with negative sign show an apparent increase in the probability of using LPG when household income increases. The transformation from log of odds to probability for using LPG explains that there is nearly 6.3% chance of LPG usage in the lowest income group, whereas it is more than 34% in the upper middle income group household.

5 Conclusions

In this paper, we have attempted to analyse the rationale of energy choices among different income groups in rural communities of Punjab. To better understand the energy access in rural households, we differentiated the energy source usage into different sub-categories. The approach of distinguishing households on the base of usage (frequent vs. occasional user) and the type of energy access (buy or collect) has helped us to understand the degree of energy mixes that households with different incomes use to meet their domestic energy needs.

Our results propose multiple conclusions. Firstly, we conclude that the choice of energy sources among different households are not only affected by the household income, but is also subjective to other important determinants like the community remoteness and household's major occupation. One of the important facts validated by descriptive and regression results is the diminishing role of household status for choosing the traditional energy sources. Our results suggest that the role of income becomes more important when household decide to include expensive and advance energy source like LPG in their energy mix. In our dataset, we find that traditional energy sources are preferred by all households, regardless of their household income. Nevertheless, as the price of energy source increases, income starts playing its influential role in deciding for a particular energy source. This finding questions the linear and unidirectional approach adopted by the energy ladder, where it is assumed that households tend to shift towards modern energy sources with the increase in their income (Wuyan et al., 2007; Xiaohua and Zhenming, 1996; Karekazi, 2002; Reddy, 1995).

Secondly, we also conclude that community remoteness is an important determinant for energy source choice in rural households. The high significance of the community remoteness indicators in almost all energy sources (except plant waste) suggests that rural households tend to avoid the inconveniences associated in energy access as it may not only involve transporting specific energy source (LPG cylinders, fuel wood bundles or wood logs) but also incur financial costs, requires tremendous physical efforts, engage household members and their time. Thirdly, other variables like household size (*hs)*, number of household members working (nhmw) and constant income (*cons_income*) also turned out to be significant in some cases. Particularly in the case of firewood and plant waste usage, household size is revealed as an important factor for deciding whether to choose these energy sources in energy mix or not.

Finally, our results also suggest that use of each energy source can be attributed not only to household and community related factors, but also to peculiar access factors relevant to a particular energy source. In the case where households decide for animal waste and plant waste, different factors turned out to be significant in either case. Based on our results, we conclude that the use of animal waste by a rural household is dependent on community remoteness, whereas using plant waste can be attributed to income group of a household, household major occupation and household size.

In general, our results also correspond to earlier studies, especially that of Horst and Hovorka (2008), Masera et al (2000) and Rao and Reddy (2007) from two perspectives. Firstly, rural households in general, do not follow the unidirectional approach of using energy sources, i.e., a shift from traditional biomass towards modern energy source like LPG, with the increase in household income. Instead, a mix of energy sources is used, even by richer households who can even afford LPG as the only energy source. Secondly, household income and size, along with community remoteness indicators turned out significant factors for determining the energy choices among rural households.

From energy policy perspective, we believe that developing countries need to improve the energy access factors for rural communities, particularly to develop rural energy markets, which can provide improved energy access in remote villages. Moreover, we also stress diffusion of cooking (and heating) technologies at household level, through active participation of local governments, non-governmental organizations and pro-poor business entities.

The study is also subject to its limitations. Due to limitations of the EPS, we are not able to explain fuel or energy switching phenomenon which is highly interconnected with energy choices available to rural households. Also, due to scope of our research objectives, we are not able to include previous energy usage history of rural households, which might be critical to further understand the energy choices and subsequent fuel switching phenomenon in rural households.

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