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Rural Energy Transitions: *Insights from Madhya Pradesh*

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Abstract

In India, around two-thirds of the population live in rural areas and are predominantly dependent on the primary sector for their livelihoods. Most rural households live on subsistence levels, enough only to meet their basic requirements. The most basic and critical requirement is that of food, after which come shelter and clothing among others. To meet these basic needs, access to energy of some form is essential.

This paper examines results from a pilot survey conducted as part of a study on rural household energy transitions in India. This paper aims to draw lessons from the pilot to better understand the determinants of current energy use patterns, causes for variations, designing appropriate methodologies to measure the impacts of these factors, and most importantly, arrive at useful policy recommendations.

Through the field experiences during the pilot survey and secondary literature it has been observed that levels and forms of fuel consumed by the household sector depend not only on incomes but also on various other factors such as size of settlements, households, geographic location, price of fuels, the availability and accessibility of modern commercial fuels, the efficiency of the end-use equipment and the socio-cultural environment that people live in which to a large extent drive household consumption patterns. Thus, given the vast size of the country and the myriad cultures and social constructs that exist, it is critical that these factors are addressed at various levels in the economy i.e. national, regional, district and household level, which may influence household energy choices as desirable.

Solutions need to have a participatory approach. There is a need to involve grass root level organizations as well as the intended beneficiaries in the planning process. While policies at the national level may provide important guidelines and the necessary framework, the implementation strategies need to be designed at the local level.

Communities also differ in their essential fabric. There are areas where community based solutions will be successful and others where these will not. Identifying the key services where interventions may be more successful particularly those that contribute to livelihood enhancement are essential. To address issues of availability, structural changes and improvements in the supply chain of the product/energy service would need to be ensured so as to create reliable and quality supply. Last but not the least, awareness building is essential for informing people about the various options available to them so that households can make informed energy choices that best suit their needs.

Introduction

Poverty is a state of deprivation. Poverty has been very often defined in terms of income poverty, i.e., number of people below the poverty line which has been measured using different methods, most recently in terms of the inadequacy of income to obtain a minimum level of calories. The World Bank (1994a, p. 9) also recognised, "Poverty is not only a problem of low incomes; rather, it is a multi-dimensional problem that includes low access to opportunities for developing human capital and to education..." (Tilak, 2005) The UNDP in this regard has also recently introduced the Multidimensional Poverty Index.

The realities of poor people are local, complex, diverse and dynamic. Though we cannot ignore the importance of income-poverty it is only one aspect of deprivation. Various participatory appraisals have confirmed various dimensions and criteria of disadvantage, ill-being and well-being as people experience them (Chambers, 1995).

In India, around two-thirds (Census of India, 2011) of the population live in rural areas and are predominantly dependent on the primary sector for their livelihoods. Most rural households live on subsistence levels, enough only to meet their basic requirements. The most basic and critical requirement is that of food, after which come shelter and clothing among others. To meet these basic needs, access to energy of some form is essential.

The relationship between energy and poverty has featured in many recent policy documents of various international agencies including the World Bank, United Nations Development Programme, World Energy Council and the UK's Department for International Development (DFID). All of these documents affirm that energy must be made a crucial part of all development and poverty alleviation projects and programmes [WEC 1999, WB 2000, UNDP 2000, DFID 2002]. As part of the Millennium Development Goals, the UN Commission for Sustainable Development 9th Session [CSD9 2002] also explicitly acknowledged that access to sustainable energy services is an essential element of sustainable development, stating that:

"To implement the goal accepted by the international community to halve the proportion of people living on less than US$1 per day by 2015, access to a multitude of affordable energy services is a prerequisite."

The United Nations had also declared 2012 as the *"International Year of Srustainable Energy for All".* Thus, the importance of energy in development policy cannot be undermined and it is critical to understand the factors that drive household energy consumption patterns so as to facilitate appropriate policy design and implementation.

If we observe household energy use patterns in India, the basic energy requirements are for domestic cooking, lighting and heating purposes. In rural India, most of the energy requirements for cooking are met through biomass fuels such as firewood, crop residue and dung-cakes, while for lighting, kerosene and electricity are the predominant energy sources. Within this, the mix is skewed more towards traditional biomass energy sources. Biomass fuels account for almost 80% of total household energy consumption in rural India. Use of biomass for household energy has considerable implications on the environment with increasing pressure on forests and associated natural resources apart from health impacts due to emission of smoke from burning biomass fuels leading to respiratory problems (indoor air pollution) (Edwards, et. al., 2004; Chengappa, et. al., 2007; Kanagawa & Nakata, 2007; Anozie et al, 2007).

The pattern of energy consumption in rural India has been widely analysed. This working paper examines results from a Pilot Survey conducted as part of the project supported by the Norwegian Ministry of Foreign Affairs as part of the Norwegian Framework Agreement (NFA). This paper aims to draw lessons from the pilot to better understand the determinants of current energy use patterns, causes for variations, designing appropriate methodologies to measure the impacts of these factors, and most importantly, arrive at useful policy recommendations.

1. Background and Profile of Survey Sites

Madhya Pradesh (MP) lies in central India; it is the second largest state in the country by area and sixth largest state in India by population. Population of MP is 7, 25, 97, 565 comprising 3, 76, 12, 920 males and 3, 49, 84, 645 females, contributing 6 percent to India’s total population1.According to Census 2011, MP along with the other eight Empowered Action Group (EAG) states2 has low literacy levels with high population growth.

MP is home to a large tribal population, which has been largely cut-off from mainstream development. This makes MP one of the least developed states in India, with an HDI value of 0.3753 (IAMR, 2011), which is below the national average of 0.467 (IHDR, 2011). The state's per-capita gross state domestic product (nominal GDP) is the fourth lowest in the country[4].

The population of Madhya Pradesh is a mix of a number of ethnic groups and tribes, castes and communities, including the indigenous tribals and relatively more recent migrants from states including the neighbouring state of Uttar Pradesh. The scheduled castes and the scheduled tribes constitute a significant portion of the population of the State. The main tribal groups in Madhya Pradesh are Gond, Bhil, Baiga, Korku, Bhadia (or Bhariya), Halba, Kaul, Mariya, Malto and Sahariya. More than 50 percent of the tribal population resides in the districts of Dhar, Jhabua and Mandla. In Khargone, Chhindwara, Seoni, Sidhi and Shahdol districts 30-50 percent population is of tribes.

The state of MP has 50 districts, which are grouped into 10 divisions[5] for administrative purposes. A primary survey was conducted in four districts chosen from four divisions of Madhya Pradesh. The districts for chosen for the pilot survey includes:

- Bhopal Division: Raisen district

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[1] Census 2011, http://www.censusindia.gov.in/2011-prov-results/data_files/mp/04population.pdf%2050%20No23.4.pdf

[2] The Government of India had constituted an Empowered Action Group (EAG) under the Ministry of Health and Family Welfare following 2001 census to stabilise population in eight states (called EAG states) that were lagging in containing population. EAG sates include Bihar, Jharkhand, Uttar Pradesh, Uttarakhand, Rajasthan, Madhya Pradesh, Chhattisgarh and Odisha.

[3] IAMR, P. (2011). India Human Development Report. Delhi: Oxford University Press.

[4] Gross State Domestic Product (GSDP) at Current Prices (as on 15-03-2012), Planning Commission of India.

[5] Bhopal division, Chambal division, Gwalior division, Indore division, Jabalpur division, Narmadapuram division, Rewa Division, Sagar division, Shahdol division, and Ujjain division

- Jabalpur Division: Mandla district
- Narmadapuram Division: Betul district
- Ujjain Division: Ratlam district

2. Village Profile and Data Collection

The districts for the pilot study were selected in consultation with the partner NGO's and government officials to get a good mix in the sample. While Betul and Mandla primarily represent tribal populations, Ratlam and Raisen are fairly developed towns. Ratlam is primarily an industrial town and Raisen being very near to the state capital, Bhopal, is also developed. Geographically all the four districts lie in different regions and represent different divisions with differing terrains.

The map of the state of Madhya Pradesh below (Figure 1) indicates the districts surveyed for the pilot study.

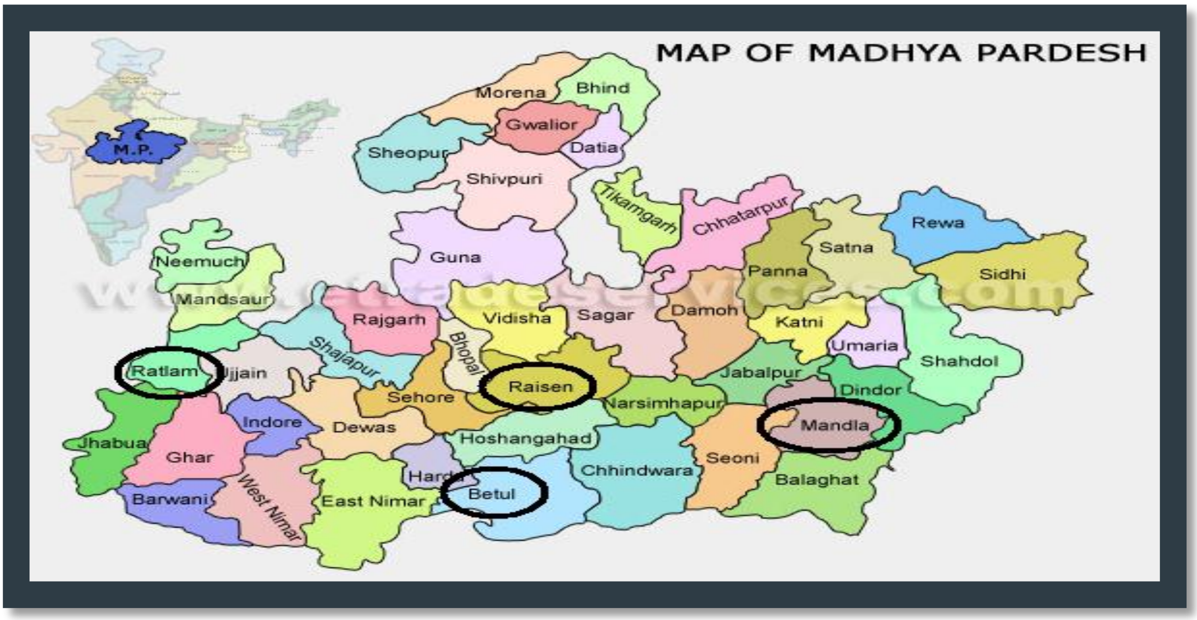

Figure 1 : District Map of Madhya Pradesh, India

Source: www.etradeservices.com

Data was collected for 200 households across the four districts on various indicators ranging from primary cooking fuel, primary activity for men and women, education level of the household, social status, economic status, and other related variables. The data collected at the household and village level was based on interviews with the village residents with the help of a pre-designed questionnaire. Two Blocks from each district were covered and two villages from each block were surveyed to maintain a good sample of the households.

Betul District

Betul is the southern district of Madhya Pradesh, lying on the Satpura plateau between the valley of the narmada on the north and the bearer plains on the south. The district's economy is primarily agrarian, based on forests since the district has a large forest cover and biodiversity. Industry-wise, Betul is well connected to the other districts by way of road and rail.

Box 1: Demographic Characteristics of Betul

- The district covers an area of 10,043 square kilometers and it has a population of 1575247 (2011 census), making for a population density of 157 per square kilometer.
- As per 2001 census, 81.43% of population lived in rural areas.
- Average literacy rate of Betul in 2011 stands at 70.14 compared to 66.38 in 2001.
- Sex ratio has improved to 970 (2011census) from 965 females per 1000 males (2001 census). Betul is a one of the tribal population districts of M.P. with 39% (2001 census) of total population belonging to ST groups.

Ratlam District

The district of Ratlam is situated in North-West region of Madhya Pradesh. It is bounded by Mandsaur District in North, Jhabua and Dhar on the South, Ujjain on the East, Chhitorgarh and Banswara District of Rajasthan on the West, Shajapur District of Madhya Pradesh and Jhalawar District of Rajasthan on the North.[6] Ratlam is divided in 6 Tehsils and 6 Blocks namely; Alot, Jaora, Piploda, Ratlam, Sailana and Bajna.

Box 2: Demographic Characteristics of Ratlam

- Ratlam has a total area of 4861 square kilometers
- According to the 2011 census, the population of district is 273,892. In view of this, the population density is 107 people per square mile (277/km²).

Raisen District

Raisen District lies in the central part of Madhya Pradesh. The district is one of the closest districts to the state capital of Bhopal. It is bounded in the west by Sehore district, in the north by Vidisha district, in the ease and south-east by Sagar district, in the south-east by Narsimhapur district, and in the south by Hoshangabad and Sehore district.[7] The distict is divided into 7 blocks namely, Sanchi-Raisen, Obdullaganj-Gohaganj, Silwani, Bareilly, Udaipura, Gairatganj and Begamganj.

Box 3: Demographic Characteristics of Raisen

- The total area of the District is 8,395 Sq. Km., which contains the 1.93 % of the State's area. The terrain in the district is plain and it has a good connectivity by roadways.
- The total population of Raisen is 13,31,699 with a growth rate of 18.4% (Census 2011).
- It has a literacy rate of 74.3 % (82.5% for males and 65.1% for females). There are 19 primary health centres in the district.
- There are only 6.3% households having access to piped drinking water source and 12.6% households using toilet facilities in rural areas.

Mandla District

Mandla is a tribal district situated in the east-central part of Madhaya Pradesh. The district lies almost entirely in the catchment of river Narmada & its tributaries. A district with a glorious history, Mandla comprises of numerous rivers and endowed with rich forests. The district's economy relies mainly on forests and natural resources, as well as tourism. In 2006, it was named as one of the most backward districts in India by the Ministry of Panchayati Raj and since then has been receiving funds under the Backward Regions Grant Fund Programme (BRGF).

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6 http://www.jhabua.nic.in/; http://districts.nic.in/disdetails.aspx?str_state=bXA; http://en.wikipedia.org/wiki/Jhabua_district

7 http://raisen.nic.in/

Box 4: Demographic Characteristics of Mandla

- The extreme length of the district is about 133 Kms. from north to south and extreme breadth is 182 Kms from east to west. It covers a total area of 8771 Sq.Km.
- It has a total population of 894236.
- It has a literacy rate of around 60%.

2.1 Villages covered in the pilot survey

The table below (Table 1) provides details on the blocks chosen in each district and the villages covered in each block with the sample sizes. Sixteen villages were chosen in the pilot survey.

1: List of villages chosen for sample survey

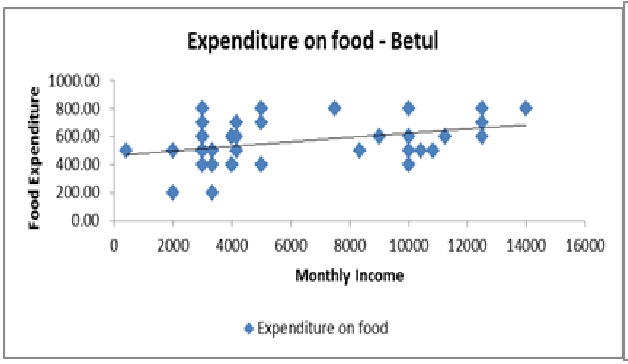
District	Block	Village	Sample Size	Total Sample Size	Dropped observations
Betul	Bhainsdehi	Chilkapur	13	50	4 (Nayegaon)
		Dhondi	12		
	Amla	Nayegaon	12		
		Umbada	13		
Mandla	Nainpur	Chiraidongri	15	50	None
		Dungria	10		
	Mandla	Limrua	15		
		Tharka	10		
Raisen	Begamganj	Mehgua and Sagauni	11	50	None
		Kokalpur	14		
	Obdullaganj	Ghat Kamariya	11		
		Semrikala	14		
Ratlam	Ratlam	Karamdi	15	50	1 (Karamdi)
		Kalmoda	15		
	Jaora	Baga Kheda	10		
		Sejawta	10		

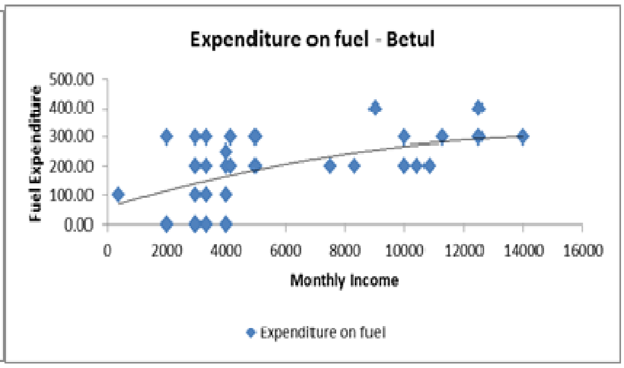
3. Analysis

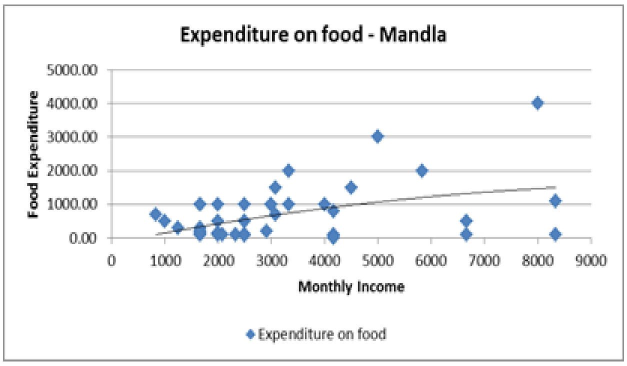
Examining the expenditure on food across households in rural India over time, it is observed that the percentage share of expenditure on food has been declining in the total outlay of the household (NSS 43rd Round – NSS 66th Round). This gives a positive indication to the effect of showing that over time a greater number of households are meeting their food requirements[8]. This has its bearings on the amount of cooking energy needed per household. The elasticity of expenditure on food is expected to decline as incomes increase (as postulated by Keynes in his "Consumption Hypothesis"[9]) and since cooking energy demand has a direct relation to the prevailing food habits, one would expect the elasticity of expenditure on energy to follow a trend similar to that of food. On the contrary, if a household is at subsistence levels, then there could be some extent of stickiness in the elasticity. While Keynes' hypothesis has been mentioned here, the authors are aware of its emphasis to total consumption and not particularly energy. Thus, the notion is being used here as way to set the background for looking at energy consumption patterns. Now, it is important to note here that the relationship between the elasticity of both food and fuel expenditures provides key insights.

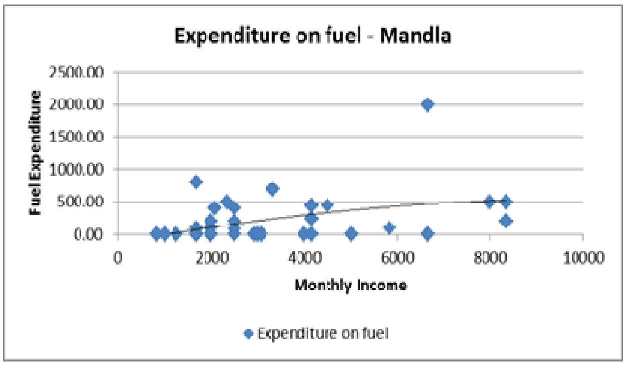
Depending on the level of elasticity, it gives a preliminary indication of the level of flexibility that exists at the household level in effecting a transition to modern fuels and this combined with data on fuel use patterns, would provide key insights into identifying the appropriate solutions, such that households are both willing to make a shift and benefitted from the design of the policy intervention. Ideally, for a household at the marginal level, the elasticity would be less flexible.

The graphs below (Figures 2 – 5) indicate the response of food expenditure and fuel expenditure to total income. Some interesting insights from these have been drawn which will form the basis for further discussion in this paper.









[8] It should be noted that households may be meeting their food requirements but not necessarily their nutritional requirements which is not the focus of this paper.

[9] Keynes consumption hypothesis states that "As income increases, the share of expenditure on food increases at a decreasing rate."

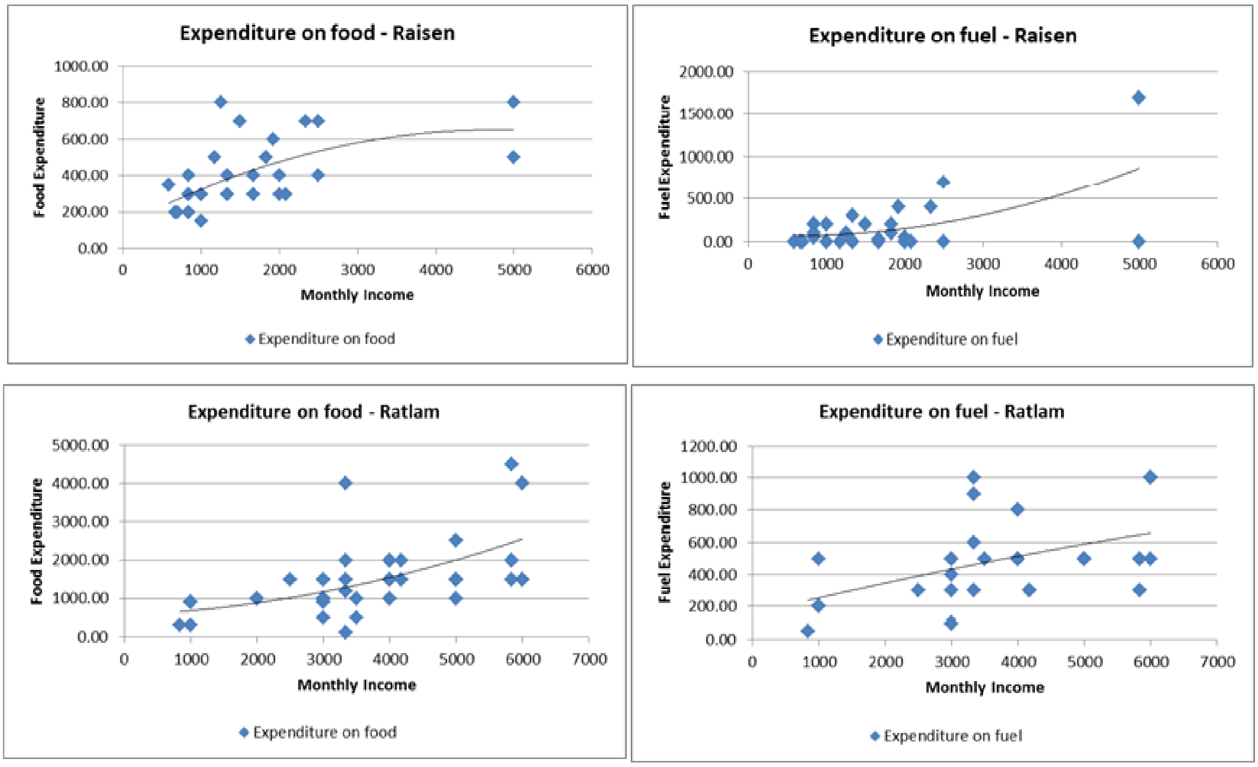


Figure 2: Response of food and fuel expenditure to total income in Betul, Mandla, Raisen and Ratlam
Source: Pilot Survey, TERI, 2012

If the responses of food and fuel expenditures to changes in income levels are observed, it is found that different responses emerge in different districts. While similar trends are found for food and fuel expenditures in Betul and Mandla districts, the trends in Raisen and Ratlam are different. Betul and Mandla districts indicate a declining trend in food expenditure as incomes increase and fuel expenditures too show a similar trend. This could be possibly be due to the fact that households are meeting their energy requirements given their income levels, and resource scarcity is not a problem because if it were, then the prices of fuels would rise, thus, indicating increasing shares of expenditures on fuel as incomes rise. In Raisen, it is observed that while the share of expenditure on food is decreasing with increasing income levels, the opposite is happening with expenditure on fuel. Rising fuel expenditure could mean that either richer households are making a shift to cleaner cooking fuels such as LPG which are more expensive than firewood and other biomass sources or the prices of biomass sources of energy are increasing due to scarcity, i.e. lack of availability at nearer distances.

There could be various other reasons apart from income that may be impacting the expenditure patterns on fuels for households. Through the field experiences during the pilot survey and secondary literature it has been observed that levels and forms of fuel consumed by the household sector depend not only on incomes but also on various other factors such as size of settlements, households, geographic location, price of fuels, the availability and accessibility of modern commercial fuels, the efficiency of the end-use equipment and the socio-cultural environment that people live in which to a large extent drive household consumption patterns. Thus, given the vast size of the country and the myriad cultures and social constructs that exist, it is critical that these factors are addressed at various levels in the economy i.e. national, regional, district and household level, which may influence household energy choices as desirable.

These have important policy implications, i.e. it indicates that variations exist in energy use and these are not driven primarily by income, thus making it imperative to understand in detail the causes for these differences so as to facilitate appropriate policy design and effective implementation.

3.1 Logit Regression

A logit model was set up to assess which household factors influence the choice of primary cooking fuel, in this case, fuelwood or LPG.

The dependent variable constructed for this study is the primary cooking fuel used by the household. It is taken as a binary variable, with value '0' if the household uses biomass fuels for cooking and value '1' if the household uses LPG as a cooking fuel. In our sample, we have considered only two categories for the dependent variable, as given the small sample sizes, there were not sufficient number of households to classify into further categories. Thus, to avoid any biased results and spurious relations from the model, the dependent variable has been taken as a binary variable. It is important to note that in rural India, households use a mix of fuels for meeting their cooking energy demands and thus in the analysis of the final survey data, given the large sample size, we will group households into multiple categories based on the different combination of fuels used for cooking purposes.

The independent variables taken in this model are described below.

Dependent Variable

- Primary Cooking fuel: The variable takes the value '0' if the household uses biomass fuel for cooking and value '1' if the household uses LPG for cooking.

Independent Variables

1) *Primary Occupation of Males (primarylivelihoodmen):* This variable captures the primary activity of the male member which reflects the major earnings of the household. This variable is a categorical variable and takes values from '0' to '6' with the lower values indicating informal jobs and the higher values indicating more formal and stable jobs. (Refer to Annexure 1 for details on categorical values)
2) *Social Status (socialstatus):* This variable is a categorical variable. It captures the different social categories that people are divided into. This variable is expected to play a crucial role as social status very often defines the access to common property resources (in this case, biomass fuels). More importantly, social status defines the way a person lives and the manner in which they are treated by the rest of the community. It is also to be noted that many government benefits are due to an individual or household based on their social status making the inclusion of this variable all the more important. The categories included are Scheduled Castes (SC), Scheduled Tribes (ST), Other Backward Classes (OBC) or General (Gen). (Refer to Annexure 1 for details on categorical values)

3) *MPCE class*[10] *(mpceclass):* Monthly per capita Expenditure (MPCE) class is taken as a proxy for income of the household. Households are categorized into different income groups based on their level of expenditure. This has been calculated in the same manner as the NSS data to maintain comparability. Households have been divided into 6 classes, with '1' being the poorest and '6' being the richest. (Refer to Annexure 1 for details on categorical values)

4) *Highest education level attained by the male member in the household (logedumale):* This variable is a continuous variable and reflects the educational status among the male members of the household. The variable is calculated as the maximum level of education achieved by any male member as on the date surveyed. The variable takes the value based on the level of education, for example, if the highest education attained among male members in a household is Standard X, then the variable takes the value '10' and so on.

5) *Highest education level attained by the female member in the household (logedufemale):* This variable is a continuous variable and reflects the educational status among the female members of the household. The variable is calculated as the maximum level of education achieved by any female member as on the date surveyed. The variable takes the value based on the level of education, for example, if the highest education attained among female members in a household is Standard X, then the variable takes the value '10' and so on.

6) *Household Size (loghhsize):* The size of the household is expected to affect the cooking energy demand and also have a bearing on the income distribution. Higher household size would mean greater energy demand. This variable takes the value of the number of family members in the household.

7) *Price of Firewood (logpfw):* Price of firewood will influence a household's decision in fuel choice. The price of firewood for all households within a village has been assumed the same. The price has been taken to be the average price of firewood being sold in the nearest market on a date closest to the date of survey. It should be noted that the price of firewood is difficult to capture as the markets are informal and the prices are determined by the seller based on their perception of the quality of wood being sold. Also, the scarcity of firewood determines the average level of the price of firewood in the local market.

8) *Price of Kerosene (logpsko):* Price of kerosene will influence a household's decision in fuel choice. The price of kerosene has been assumed to be the same for all households belonging to a village as the price of PDS kerosene is determined by the distribution centre, whereas the price of market kerosene is determined by the market rates. Again, the data has been collected at the market level as well.

9) *Price of LPG (logpLPG):* Price of LPG will influence a household's decision in fuel choice. LPG is an expensive option for households and we would expect a household to choose LPG as a primary cooking fuel only if it is made affordable or the household has sufficient income to afford a cylinder. The price of LPG was determined for the village based on the prices that were quoted by consumers from that village.

[10] Monthly per capita Expenditure (MPCE) class is taken as a proxy for income of the household. Households are categorized into different income groups based on their level of expenditure. This has been calculated in the same manner as the NSS data to maintain comparability.

10) *Land Size (logland):* This reflects ownership of land, as land availability will determine availability of freely accessible firewood. Moreover, land is an asset which can generate substantial income for the household thus playing an important role in determining fuel choice. This is a continuous variable measured as the log of land holding size reported.

11) *Electricity Access (elecaccess):* Electricity access can influence a household's fuel choice significantly. The presence of reliable and good quality supply of electricity allows a household to take up other activities even after sunset, thus prolonging the number of hours available for productive work in the day. This can impact household incomes significantly resulting in changing lifestyles and thus lead to changes in household expenditure patterns and possibly fuel choices as well. It is very important to focus on how we define 'electricity access'. In most of rural India, while there is provision for electricity supply, the supply hours are very erratic and very often people end up paying for electricity that has no use for them. For example, supply of electricity for 3 hours in the day from 10AM to 1PM has no use for the household members as all are out working, whereas the same three hours of supply from 6PM to 9PM or 7PM to 10PM would enable the household to take up productive activities or allow children to study and so on. Thus, given short hours of electricity supply, 'access' to a household is really defined as the when the value of the payment they make for an 'energy service' (in this case, electricity) is fully realised by productive use of the duration of supply. Thus, in this case, we have defined 'electricity access' for a household as a binary variable which takes the value '1', if, the household receives electricity supply anytime between 6PM to 10PM for at least 20 days a month; and, if it does not, then the variable take the value '0'.

12) *Time spent by women cooking and working (timelive):* This variable is a combination of the average time spent by women for cooking per day which is a continuous variable and the primary occupation of the woman which is a discrete or categorical variable. This variable was constructed on the premise that if the woman spends more time in income generating activities, and particularly in a regular salaried job, it could have a significant impact on the time that a woman allocates to domestic chores including cooking. We would expect that with a formal job which also translates into higher incomes than casual labour, there would be higher probability that a woman would be willing to choose cleaner fuels such as LPG for cooking. But given social and cultural factors also play a role in determining household fuel choice, there could be a possibility that a woman could continue using biomass fuels for cooking irrespective of the occupation type and the income generated, thus the combined effect of cooking time and occupation type of women in the household has been taken as a variable in the model to be tested.

Thus, the final model (Table 2) to be tested is specified below:

Logit Model(1)

Predicted Logit (lfp=1/0) (Choice of Primary cooking fuel) = α + β1(social status) + β2(primary livelihood for men) + β3(mpce class) + β4log(edumale) + β5log(edufemale) + β6(timelive) + β7log(hhsize) + β8log(pLPG) + β9log(psko) + β10log(pfw) + β11log(land) + β12(elecaccess)

2: Estimated Coefficients of the logit model(1)

Primary cooking fuel	Robust Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
socialstatus	-0.1432212	0.801239	-0.18	0.858	-1.713621	1.427178
primarylivelihoodmen	2.018577	0.885418	2.28	0.023**	0.2831907	3.753964
mpceclass	0.8372557	0.413984	2.02	0.043*	0.0258613	1.64865
Education of male (Log)[11]	2.393379	2.112356	1.13	0.257	-1.746763	6.533521
Education of female (Log)	1.726696	0.973183	1.77	0.076	-0.180708	3.634099
timelive	-3.242136	1.241909	-2.61	0.009***	-5.676233	-0.808039
loghhsize	2.145111	2.08919	1.03	0.305	-1.949626	6.239848
logpLPG[12]	-156.4151	35.97687	-4.35	0.000***	-226.9285	-85.90176
Logpsko	62.84464	56.72915	1.11	0.268	-48.34246	174.0317
Logpfw[13]	15.45975	37.37725	0.41	0.679	-57.79832	88.71782
Logland	2.163311	0.964814	2.24	0.025**	0.2723105	4.054312
elecaccess[14]	7.249156	2.177322	3.33	0.001***	2.981684	11.51663
_cons	760.6622	.	.	.	.	.

Number of Observations = 185

Pseudo R2 = 0.6750 Log pseudolikelihood = -14.4382

AIC*n = 54.877 BIC' = 2.666

Hosmer-Lemeshow chi2(8) = 0.36 Prob > chi2 = 1.0000

Area under ROC curve = 0.9851 Correctly classified = 96.76%

The results show that primary occupation of men, MPCE class, timelive (a joint variable of women's cooking time and the occupation type of women), price of LPG (log), land ownership (log of land holding size) and electricity access are found to be significant (at 95% confidence intervals) in influencing a household's decision in its choice of primary cooking fuel. These variables explain the likelihood of households to use LPG over firewood (biomass fuels) as the primary cooking fuel. The marginal effect of the 'primary livelihood activity of men' on the probability of using LPG as a primary cooking fuel is shown in Table 3 which is 0.000000356. This indicates that a unit increase in primary activity of men will increase the probability of the household to switch to a cleaner fuel (LPG) by 0.000000356. The odds ratio can be interpreted as the probability of switching/moving/substituting to cleaner form of energy to the probability of not switching/moving/substituting. This implies that, for a unit change in primary livelihood activity for

[11] The positive relation between education and fuel switching is as expected. As education levels increase, we expect that it would lead to improved livelihoods, better incomes, greater awareness – all of which could lead to a transition to cleaner fuels at the household level.

[12] We expect that as the price of LPG decreases, there would be greater chances of its uptake and usage, which is corroborated with the negative sign.

[13] Given that firewood is available at very low prices, very often at no cost in rural India, there will be a positive coefficient. This would change when the price of firewood becomes higher and closer to the price of LPG, i.e., there is a threshold price for firewood, after which the pattern of consumption would change. Thus, the fact that the firewood and LPG are substitutes is indicated by the opposite signs the coefficients have.

[14] Electricity access is expected to have an impact on fuel choice to the extent that with improved electricity access, there would be a greater chance of its productive use and thus leading to improved incomes which may lead to a transition to cleaner fuels such as LPG. Thus, the impact of electricity access though not direct, is critical, but it behaves like an instrumental variable in this case (as seen in Model 2) because as of now, the consumption levels are still quite low, thus not allowing for any productive use of electricity.

men, the odds of choosing cleaner cooking fuels are expected to change by a factor of 7.52, ceteris paribus. It can also be interpreted as, for every unit increase in primary livelihood activity for men, the odds of choosing a cleaner cooking fuel is expected to increase by about 652% [100*(7.52 – 1)], ceteris paribus.

The results also show that electricity access to the household and price of LPG play an important role in switching/moving/substituting to a cleaner fuel. This may be due to the fact that the households who have access to electricity reside closer to towns or are located centrally and hence, have greater chances of moving higher up the energy ladder. Secondly, the price of LPG influences a household's decision since rural households have income constraints which can be measured as the elasticity of fuel expenditure with respect to total expenditure of the household, i.e. priority of fuel as expenditure for a household.

While the results of the pilot survey have given some valuable insights on the challenges to energy access and household fuel choices which are discussed in detail in the subsequent section, the significance of 'electricity access' in determining primary cooking fuel choice was rather interesting. Electricity access is considered to be an important driver for household transitions towards cleaner energy forms as it impacts incomes and living styles of people, thus impacting the energy basket or fuel basket of households. But for this, the reliability and quality of electricity supply is very critical. In most studies[15], electricity has been included as a variable to test whether it impacts household fuel choices and it has been found to be significant. In the Indian context, while many households in the rural areas have provision for electricity supply, the reliability and quality is questionable. We have still not reached a situation where electricity access has begun to significantly impact incomes of households or rather the marginal benefit of one unit of electricity supplied has not yet exceeded the marginal cost of receiving that electricity. Given that most households did not have 'electricity access' as defined for the purposes of our study, we wanted to test the overall fit of the model if 'elecaccess' was dropped from the model as an explanatory variable. Thus, another logit model was set-up and run without 'electricity access' as an explanatory variable. The model to be tested (Table 3) is specified below:

Logit Model(2)

Predicted Logit (lfp=1/0) (Choice of Primary cooking fuel) = α + β1(social status) + β2(primary livelihood for men) + β3(mpce class) + β4log(edumale) + β5log(edufemale) + β6(timelive) + β7log(hhsize) + β8log(pLPG) + β9log(psko) + β10log(pfw) + β11log(land)

3: Estimated Coefficients of logit model(2)

Primary cooking fuel	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf. Interval]	
socialstatus	0.436772	0.4505063	0.97	0.332	-0.4462	1.319748
primarylivelihoodmen	0.874493	0.476518	1.84	0.066	-0.05947	1.808451
mpceclass	0.370944	0.2529367	1.47	0.142	-0.1248	0.866691
Education of male (Log)	2.884985	1.803539	1.6	0.11	-0.64989	6.419856
Education of female (Log)	0.77118	0.6645606	1.16	0.246	-0.53134	2.073694
timelive	-1.47028	0.5833322	-2.52	0.012**	-2.61359	-0.32697
loghhsize	-0.22916	1.319293	-0.17	0.862	-2.81493	2.356608

[15] Insert references of the papers .. multi country fuel choice and sri lanka and couple others with logit/probit models

Primary cooking fuel	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf. Interval]	
logpLPG	-103.023	12.38131	-8.32	0.000***	-127.29	-78.7559
logpsko	36.70411	19.78822	1.85	0.064	-2.08008	75.48831
logpfw	-0.98839	13.12615	-0.08	0.94	-26.7152	24.73838
logland	1.531942	0.5480256	2.8	0.005***	0.457831	2.606052
_cons	531.8787	.	.	.	.	.

Number of Observations = 185

Pseudo R2 = 0.4874 Log pseudolikelihood = -22.7753

AIC*n = 69.551 BIC' = 14.120

Hosmer-Lemeshow chi2(8) = 2.11 Prob > chi2 = 0.9775

Area under ROC curve = 0.9456 Correctly classified = 95.14%

In logit model(2), we find that 'timelive', 'price of LPG' (log) and 'land ownership' (log of land holding size) are found to be significant (at 95% confidence intervals) in influencing a household's decision in its choice of primary cooking fuel. If we test at 10% significance level (at 90% confidence intervals), we find that the variables found to significant become even more significant and additionally the 'primary livelihood activity for men' and price of kerosene (log) also become significant. The model estimates such as the log likelihood and the AIC and BIC do move in favourable directions but the changes are not very large to know whether electricity access is significant to impact the fit of the model.

Since the sample size is not very large and there are significantly large set of explanatory variables, we have used two basic guidelines in selecting the explanatory variables: First, including all possible set of variables to make the model useful for theoretical purposes and to obtain good predictive power; Second, to keep the model simple, as a counterbalance to the first goal. The other effect of having extra variables in the model that add little predictive power, perhaps because of overlapping a lot with the other variables, has disadvantages which may lead to multi-collinearity. The model may be more difficult to interpret, having many more parameters to be estimated. This can result in inated standard errors of the parameter estimates, and may make it impossible to assess the partial contributions of variables that are important theoretically. Thus, to avoid multi-collinearity we have tried to build a simple but comprehensive model since the data set is small. This model will further develop as the data set increases with the survey being carried out across different regions in India.

Thus the pilot analysis provides us with the following preliminary findings:

Affordability

There is an important role of income in determining household fuel choices, which is evident from the econometric model which indicates that both the income class to which the household belongs as well as the primary livelihood activity of men are significant determinants.

Prices of cleaner fuels will play an important role as well in determining fuel choices. In the case of pilot study, we find the price of LPG (Log) is significant in determining the choice of primary cooking fuel. We also expect LPG to be a substitute to firewood which is also indicated by the model with the coefficients of the prices of both fuels being inversely related.

Availability

The model indicates land holding size to be a significant determinant of primary cooking fuel choice. The ownership of land impacts household fuel choices in two ways. Firstly land is an asset and can significantly impact household income thus impacting energy choices. Secondly, if there exist ownership of land, greater is the access to biomass fuels which are freely available to the household; and thus, it could have a negative impact on the probability of the household's willingness to shift to cleaner fuels.

Gender

Most often it is the women of the household that are expected to spend time on collecting firewood and cooking. We would expect that if the women were able to engage themselves in income generating activities that would offset the opportunity cost of collecting firewood then it would improve the probability of the household transitioning to cleaner fuels. This would happen because as the women contribute greater shares of income to the household they would prefer spending lesser time on domestic chores like cooking, thus increasing the possibility of a shift towards cleaner fuels such as LPG which also take lesser time to cook than traditional biomass fuels such as firewood.

4. Energy Inequality

While econometric models are important in explaining the determinants of household fuel choices, it is also important to understand the inequalities in energy consumption, the insights of which when combined with other forms of analysis including the econometric models will give a holistic picture of the challenges of achieving universal energy access and also help inform policy and planning.

We have used the Gini coefficient (Refer to Annexure for calculation) to estimate both the income and energy inequality across the pilot sites. The energy inequality has been looked at separately for biomass fuel consumption (firewood, dung cake and crop residue), petroleum fuel consumption (kerosene and LPG), and electricity consumption. The figures below plot the energy inequality measures for different fuel types across income classes.

The graph below plots the Lorenz curve for income inequality and calculates the Gini Coefficient[16] as a measure of inequality. The Lorenz curve[17], L, for a cumulative income distribution F with mean μ is defined by

$$L(u) = \frac{1}{\mu} \int_0^u F^{-1}(t)dt, \; 0 \le u \le 1$$

We obtain a Gini coefficient of 0.44 which indicates fairly high inequality.

Given that income level is a significant determinant of energy choices, it would be useful to look at the relation between income and energy inequality.

[16] G is a measure of inequality, defined as the mean of absolute differences between all pairs of individuals for some measure. The minimum value is 0 when all measurements are equal and the theoretical maximum is 1 for an infinitely large set of observations where all measurements but one has a value of 0, which is the ultimate inequality (Stuart and Ord, 1994)

[17] Mogstad M, Aaberge R, *Robust Inequality Comparisons*, Journal of Economic Inequality, February 2010.

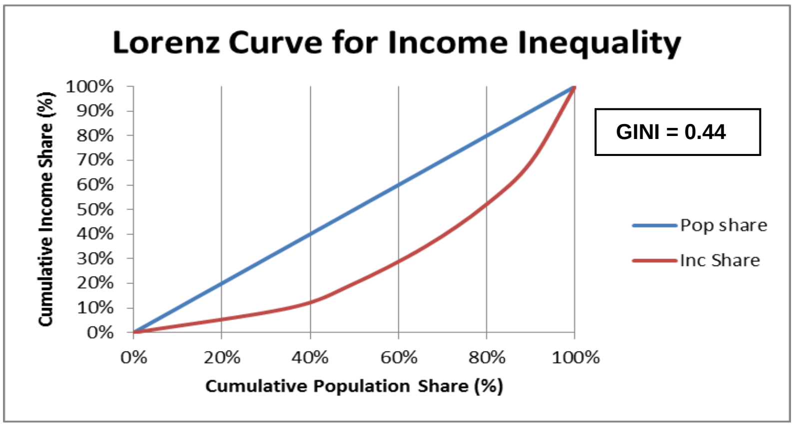


Figure 3 : Lorenz curve for income inequality among pilot sites sample data

Source: Primary Survey, TERI, 2012

The graphs below plot the energy inequality for biomass fuels (Figure 7) and petroleum products (Figure 8). They are plotted along with the income Gini as well to see the relationship between income and energy consumption. In the case of both biomass and petroleum fuel consumption, we find that there is an inverse relation between income inequality and energy inequality, i.e. where there is high income inequality, there is lower energy inequality and vice-versa. This pattern is similar to that found in the NSS data as well. This indicates that household fuel choice is not just determined by income but by factors other than income which includes certain socio-cultural factors. These socio-cultural factors are not always quantifiable and at times, very subjective. Thus, it is important to carefully analyse these variables and their impacts on household energy choices.

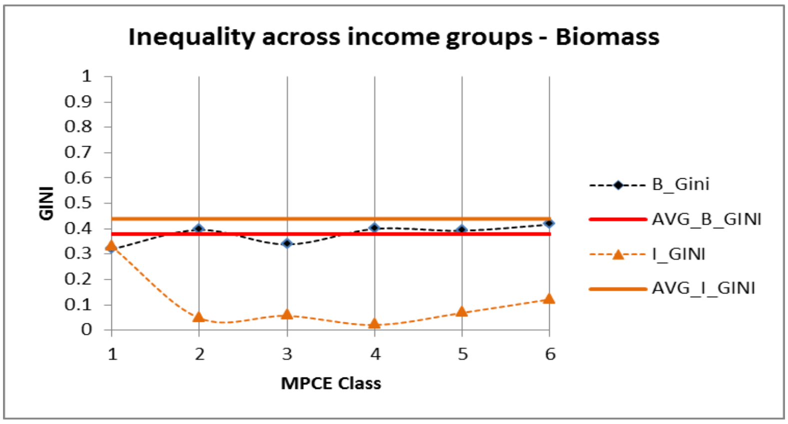


Figure 4 : Biomass inequality across income groups

Source: Primary Survey, TERI, 2012

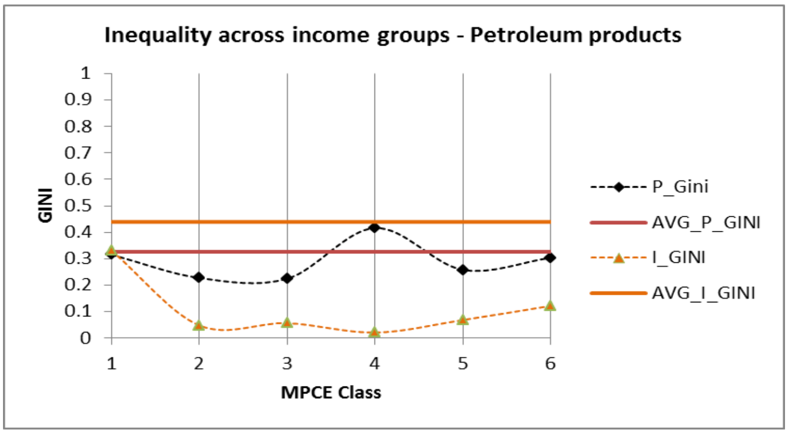


Figure 5: Petroleum fuels inequality across income groups

Source: Primary Survey, TERI, 2012

5. Addressing key issues of policy relevance

5.1 LPG interventions

Trends and determinants of LPG consumption

In this context, it is pertinent to mention that the choice of fuel is determined by the income of the household, price of the fuel in consideration and prices of other fuels (i.e. substitutes). In addition to these factors, usage of LPG is contingent not only on the availability of LPG itself but also on the presence of auxiliary support infrastructure in the form of roads and public transport such that ease of access to the fuel is maintained. Further, in rural India, choice of LPG is also affected by the perception and the food habits of the local population.

During the pilot analysis, it was found that availability is a major factor constraining the uptake of LPG as a fuel for cooking. However, even with households that do have access to LPG, a complete switch has not been witnessed and usage of LPG in combination with biomass is prevalent in some villages.

A logit model was set-up to assess which household factors may impact the choice of primary cooking fuel. The results show that primary occupation of men, MPCE or income class, joint effect of cooking time taken and the occupation type of women, price of LPG (log), land ownership (log of land holding size) and electricity access are found to be significant (at 95% confidence intervals) in influencing a household's decision in its choice of primary cooking fuel. These variables explain the likelihood of households to use LPG over firewood (biomass fuels) as the primary cooking fuel.

Over and above the constraints of availability and income, LPG is not used primarily due to the difference in taste of food and also the fact that unlike biomass which is extracted from the natural environment by most households, LPG is not available free of cost. Another factor that plays a major role in choice of LPG as a fuel is the level of education of the households. (Refer to Annexure for logit regression results)

Adoption of LPG in the energy basket is also prevalent in clusters. Villages where a few households started using LPG witnessed an increase in the inclusion of LPG in household energy baskets. This clearly reflects some form of imitation/demonstration effect among households. While uptake[18] is important, if the usage levels are low, then again, the benefits of transition may not accrue to the best extent possible. In the pilot survey, it was found that among those households reporting use of LPG, 70% households had reported significant reductions in their firewood consumption, while the remaining continued to use firewood predominantly, keeping the use of LPG limited to only cooking purposes for special occasions or when large number of guests are present at home.

Implications for policy design

Due to its relatively high prices, LPG may not be able to completely replace biomass as a cooking fuel in probably the next decade. On the other hand, universal subsidies have also not been able to increase the penetration of LPG. This is corroborated by the fact that households which are

[18] A distinction has been assumed in the meanings of uptake and usage. Uptake only refers to ownership, whereas usage refers to not just ownership, but also to actual consumption.

purchasing firewood in many cases eventually spend more for LPG than what they would if firewood was replaced with LPG. This could perhaps be due to the fact that expenditure of firewood can be staggered into several instalments whereas LPG cylinders have a large one-time cost. To address this, supply of smaller cylinders, which are less expensive than the traditional 14.2 kg cylinders in rural areas will also be useful.

Moreover, availability and ease of access greatly limit the usage of LPG in rural India. It was found that people travel significant distances to purchase an LPG cylinder, very often giving up a day's worth of work and wage, only to return empty handed as the cylinder would not be available to them. Thus, many people feel that given the uncertainty in availability of a cylinder, they might as well continue using firewood which is economically still less burdensome. As a policy recommendation, establishment of more LPG agencies as entrepreneurships and distribution centres would be very useful.

Uptake of LPG will depend on the awareness and education levels of the households. Since a clear bandwagon/imitation effect has been observed, demonstration projects and awareness building activities will help in affecting a shift towards LPG consumption.

5.2 Improved cookstoves vs. biogas

Given the trends of energy consumption patterns, particularly in the case of cooking in rural India, biomass is and probably in all likelihood will remain the predominant energy source. Thus, it becomes imperative to look for a solution that can efficiently convert the available biomass to useful energy.

While, on the one hand, improved cookstoves were introduced as a solution to generate health benefits for people due to the excessive exposure to smoke from burning of biomass fuels for cooking as well as reduce the amount of firewood being used with improved efficiency over the traditional chulha, on the other hand, biogas is seen as a viable option for meeting cooking energy needs of households, given the easy availability of bio-waste in the form of dung from the large number of livestock in rural areas in India as well as significant amount of crop residue.

But in both cases, the two technology options faced challenges when it came to uptake at the household level.

Improved cookstoves have been looked at as an important solution in addressing the issue of energy transitions for cooking among rural households especially in India since the launch of the National Program for Improved Cookstoves (NPIC) in 1985. Since then, we have come a long way with the launch of the National Improved Cookstoves Initiative in 2009, which was to build over the experiences of the NPIC.

It should be noted that even though improved cookstoves are only an interim solution, they will continue to be very significant towards facilitating household energy transitions. Most rural households in India use a mix of fuels to meet their energy demands and thus, the technology option should be such that it is affordable and meets the requirements of the end-user. Improved cookstoves as a solution will be successful given certain conditions and otherwise, may not necessarily be the best choice. The most predominant issues which have resulted in a low uptake of this technology have been related to problems of affordability, design and after-sales services for improved cookstoves.

Through the pilot survey, it was observed that for many households affordability is a major issue when it came to purchasing improved cookstoves, thus, a lot of the uptake depends on how the cookstove is financed. Apart from that, the perceived health benefits do not seem as a strong enough reason for rural households irrespective of income levels or social backgrounds to purchase or use an improved cookstove over the traditional chulha.

If biogas is considered as a solution, historically, in India, greater focus has been given to community biogas plants. While this was a feasible option about a decade ago or earlier, in the recent times, families have become smaller, and very often some members of a family are moving to other villages or nearby towns in search of better livelihood opportunities. This has led to people selling off their shares of land or renting them out to the smaller farmers or the landless, thus leading to lesser land holdings per household. Also, as family sizes have reduced, and more distinct families have settled in the villages, the social dynamics change significantly, leading to changes in the level of social capital observed. Community biogas plants require a group of households to come together and ensure the regular running of the biogas plant by taking equal responsibility and therefore have the associated issues of ownership and mutual trust.

Community biogas plants are certainly more cost effective than individual biogas plants. A detailed assessment is needed at the local level to understand the existing social dynamics in order to target households and set up a model which would focus on individual household level biogas plants, with the first targets being those households with large number of livestock especially cattle, or on community biogas plants wherein the villagers are willing to take equal responsibility. Alternatively, it may also be pertinent to examine the option of establishing community biogas plants based on models of entrepreneurship as a means of livelihood generation.

Thus, while biogas plants may be another key solution in addressing the larger issue of energy access, the acceptability or uptake of this as a technology option depends on household choices and perceptions. For example, there were households in the villages of Ratlam district who reported that since the biogas came from animal waste, they could not use it for cooking, and if one was to add human waste from toilets into the pit, then certain households may not consider biogas as an option. During the pilot survey, a household with a biogas plant was identified, wherein the waste from the toilet also went into the pit along with the animal waste. The household reported efficient functioning of the biogas plant. But, on the other hand, it was also found that in some villages where biogas is already being used by a few households, there is a general acceptability of the technology as an option.

Thus, whether it is improved cookstoves or biogas plants, it is important to relook at the implementation strategy of these programs. What is needed is a model that is designed to meet the requirements of the end-user to the maximum extent possible while at the same time ensuring affordability which would lead to better uptake of the technology.

5.3 Bandwagon and imitation effects

During interactions with field workers in the four districts of Madhya Pradesh that were surveyed as part of the pilot study, a question that perplexed the team was the prevalence of biogas over LPG. The two major reasons constraining the uptake of LPG were its cost and the taste of food cooked using LPG stoves. Most households reported a preference for taste of the food cooked on firewood than that cooked using LPG. However, a presence of household level biogas plants across villages, contradicts this fact. Further inquiry reveals that a certain level of imitation also determines the choice of cooking fuel.

The results from the pilot survey also corroborate this. It was found that among the villages across the four districts surveyed, the district of Mandla had the most equitable distribution of income. Of the households surveyed across 4 villages in this district, 12 households of the 30 surveyed in the villages of Limrua and Chiraidongri reported use of LPG. Also, among these only 5 households belonged to the highest income class. The other households were just on the borderline of the upper middle income category and the richer income class. This indicates that while households do report a preference for using firewood as a cooking fuel given certain choices of taste, some of them still use LPG on seeing other households belonging to their socio-economic group do so.

If biogas is used by some of the richer or larger households, then other households are also likely to at least partially switch to biogas from firewood rather than LPG and similarly in the case of LPG over biogas.

The imitation effect can be disaggregated into two phases. At lower income levels, the predominant use of biomass fuels is driven mainly by income constraints. But, once a certain income level is crossed, the energy choices of households are driven by factors other than income, i.e. the socio-economic environment they have lived in and cultural factors such as preferences of taste. When a household decides to shift away from biomass fuels, they prefer shifting to an alternative that they have seen before in their own village and are aware of. Thus, assuming that biogas is being used by a set of households in a village and if any other household decides to make a shift, it would prefer moving to biogas than LPG, given the choice, as they have seen it work successfully in their village. Similarly, if LPG was being used predominantly, then a household in its transitioning phase would decide to use LPG rather than biogas, as it is a tested energy source.

This clearly indicates a need to carry out more demonstration projects of various options available to households, so an informed decision can be made regarding energy choices.

Given that these insights emerged from a pilot survey with a limited sample size, the main larger household survey would be able to provide greater clarity on household choices and at what stages of household incomes do other factors play a role, i.e. among richer households, income may not be as important as socio-cultural factors, or it could even be that richer households would prefer using modern energy sources such as LPG, given their higher social status and aspirations for improved living standards.

5.4 RGGVY: Electricity Access – redefining the notion

The Integrated Energy Policy (IEP), Planning Commission, Government of India, highlights the importance of access to safe, clean, convenient and reliable energy as critical to people’s well-being.

The NSS data indicates an average consumption of about 30kWh per household per month in rural areas among low income households. This amounts to only about 30% of the average consumption in urban areas among similar income groups. However, the existing data provides no indication of the reliability and quality of supply. While analyzing inequalities in energy consumption across income groups and across regions in India, it was found that electricity consumption seemed to have a direct positive relation with income, i.e. higher incomes corresponded with higher electricity consumption and lower income inequality. In the pilot survey questionnaire, information on duration and timing of electricity supply, and the economic costs incurred for this supply was gathered. More than 70% of households in the districts of Mandla and Betul, which are predominantly tribal districts, indicated that electricity was mostly available during the day between 10AM and 2PM and given that all household members during these hours are out working on the fields or other jobs, the presence of electricity does not add substantially to the level of energy access of the household. The IEP also states that it recognizes that even the poorest households spend something on energy for lighting and hence can afford to pay a minimum amount for obtaining the lifeline electricity support.
From the pilot survey, it was found that each household in the two districts pays a fixed charge of about Rs.56 every month to the electricity authorities for usage of electricity. This actually results in becoming an economic burden for the household as they not only pay for electricity which they don't really benefit from, but they also need to buy kerosene over and above that given from the PDS at higher prices for meeting their lighting needs. Many households reported that even if the supply was given for only 2-3 hours in a day, it would be useful if it could be supplied in the evening, say, between 6PM - 9PM, as the households would greatly benefit from it given that with the improved lighting they could extend their productive hours in the day. This would at least justify the expense incurred by the household every month on 'electricity bills'.

There is a gap between what the IEP emphasizes on, and what is actually considered as electricity access. While the presence of an electricity connection is important, what is equally and probably much more critically important is the quality and reliability of supply of electricity, thus bringing out the need to relook at how we measure 'access'. The question that needs to be asked is if an electricity connection does not lead to a service, then should it still be termed as "access". Lifeline electricity would be justified only if it benefitted the household in terms of better lighting after sunset.

5.5 Interventions: designing the appropriate intervention

1. *<u>Creating more awareness programmes to sensitize people towards the issues related to energy use and availability and the importance of moving to cleaner forms of energy</u>*

While efforts are on to reduce biomass consumption for meeting domestic energy needs, a key component is awareness. Most often, the rural households make choices with limited information. Given that there are a number of issues associated with household fuel choices apart from income, it becomes all the more important to ensure that people are aware of all the options available to them and then make an informed choice. The greater the information, there would be greater chances that a household would make choices which are more sustainable. For this, awareness programs are essential.
From the pilot survey, while households were being interviewed about their willingness to pay for different cooking and lighting options, it was found that in some villages, respondents indicated willingness for using improved cookstoves when the benefits were explained. However, on

demonstration of the use of the appliance, they showed apprehension regarding the use of it, suggesting preference for the traditional chulha. There is a need to sensitize people on the issues associated with using biomass, why they should shift to cleaner fuels, benefits to the household, to the environment and the surroundings they live in. Also, these should be coupled with demonstration projects of various technology options available. Together, these would help households make an informed choice and would help facilitate the transitions to cleaner fuels significantly.

Awareness is also critical for adoption of energy efficient appliances such as CFL bulbs for lighting. During the field visits, it was observed that many houses in the districts of Mandla, Betul and Raisen were using CFL bulbs for lighting. On being asked, it was mentioned that the children had been told at school about the benefits of using CFL bulbs. Thus, awareness can also be created through including simple solutions for households in the school curriculum.

It is important to note that while awareness programs are important, without the other policy options mentioned earlier, it would not be a useful exercise. Thus, given the time and money that goes into conducting large scale awareness programs, it is critical for other policy parameters to take effect as well to ensure a successful program.

2. *Can intervention programmes such as livelihood programmes ensure the energy security and impact patterns of energy consumption at the household level or is there a path dependence to intervention programs?*

With the various government welfare programs aimed at improving people's livelihoods and ensuring that their minimum needs are met to the large number of civil society organizations running various intervention programs, there is a need to look into their impacts and see whether an intervention leads to improvements in only those parameters it focused on or does it also impact other parameters.
To illustrate this point further, suppose we take the example of a sanitation program. The main efforts in this intervention would be focused on improving the sanitation conditions. As these conditions improve, it could be possible that the households realize greater health benefits, especially in money terms (reduced health expenditure). Given these monetary savings, it is the household's choice to decide how they spend that money. At this point, what would be interesting to see is whether these savings lead to any impacts on household fuel choices. Suppose there is a change in household energy choices, then one could say that there does not exist a path dependence[19] to intervention programs or vice-versa. A similar analogy can be drawn to livelihood intervention programs as well. As alternate livelihoods lead to enhanced incomes, there could be an impact on household energy choices as well.

The main survey which would include looking at treatment and control groups from different intervention programs, would give critical insights into which types of intervention programs have impacts on household energy choices, either directly or indirectly and to what extent. It would also be able to identify the key features of different intervention programs and their impacts. This could serve

[19] Path dependence: Most intervention programs have an entry point, which is used as the foundation for their work at a particular site and to create a rapport with the beneficiaries. Now, a path dependence would indicate that the benefits being realised are limited to the entry point theme and the associated co-benefits are not realised in a manner such that the beneficiaries could capitalise on them. This to a large extent is dependent on the expertise of the implementing agency.

as a very important insight given the ongoing efforts to bring about synergy between various government welfare programs under the ambit of one umbrella program, i.e. the National Rural Livelihoods Mission (NRLM).

3. *Possible technology specific interventions*

Interventions should be designed keeping in mind the technology specific characteristics and reasons behind the lack of and failure of technology uptake.

Improved cook stoves

Improved cook stoves are expensive ranging between Rs 1500 and Rs 3000 depending on the model. In rural India most people are employed in the agriculture sector. The income flow therefore is intermittent and seasonal. Households face problems in making large upfront payments. Financing schemes would be helpful in such cases as this would enable household to spread the switchover cost over a longer period of time. Payment methods like staggered payments for improved cookstoves would be useful. SHGs could be used to issue loans to households for purchase of improved cookstoves.

Biogas plants

Community biogas plants have been known to fail in a lot of places due to the phenomenon of tragedy of commons, technology issues, institutional structures and finance among many others. Since the efforts of one individual accrue to everyone, individuals loose the motive to maintain the biogas plant. A possible solution to this is that a local entrepreneur could set up the biogas plant at a community level, and individual households could pay the entrepreneur a monthly fee for supply of gas for cooking and other needs *(IIT Delhi, 2006)*. The local entrepreneur would in turn source the required biomass from the villagers and farmers. This would ensure proper management of the biogas plant on a regular basis and ensure regular supply to the households as well. This would lead to significant savings in fuelwood and lead to health benefits for households. The survey would be able to bring out the ability and willingness of households to pay and participate in such a community biogas model. It would also help us identify certain site-specific reasons on the barriers and drivers to ensuring effective implementation of alternate technologies.

Improved Market mechanisms

While it is essential to cover the energy access gaps at the level of the end-user, it is also important to ensure that the manufacturers of alternate technology options are given appropriate incentives. There is a need to establish a robust market mechanism for the same, which entails the creation of an economically feasible value chain from the manufacturing of the product, to its delivery and after-sales services. For this it is critical to understand the needs of the end-user and their ability to pay.

6. Conclusion

The pilot survey in the four districts of Madhya Pradesh has provided us with useful insights. Though there are differences across the four districts in terms of social and cultural aspects, but due to the limited sample size, we have carried out the analysis inclusive of all the districts. Based on the detailed analysis, we have tested the following hypothesis

- Significant changes in income flows impact energy use patterns
  - *The analysis suggests that there is an important role of income in determining household fuel choices, which is evident from the econometric model which indicates that both the income class to which the household belongs as well as the primary livelihood activity of men are significant determinants.*
  - *In the given districts, land holding size was found to be a significant determinant of primary cooking fuel choice since the ownership of land impacts household fuel choices. As land is an asset, contributing to the higher household income and secondly providing the households with easy access to biomass fuel at almost negligible costs.*
- Higher the value of women's labour, lower the probability of collecting biomass fuels, and thus, lower the chance of using biomass fuels for cooking
  - *The joint variable 'timelive' in the logit model which represents the trade-off between the time spent by women in cooking and in income generating activities. High level of significance shows that if the women contribute significant income shares to the household, there is higher probability of the household switching to cleaner energy options.*
- Availability and the Prices of the fuels play an important role in determining household choice for the type of fuel.
  - *Prices of cleaner fuels play an important role in determining fuel choices. As we find the price of LPG (Log) is significant in determining the choice of primary cooking fuel.*

Observations from the pilot survey in Madhya Pradesh and the NSS data show that there exist variations with respect to the fuel used within the state. Madhya Pradesh is home to a large tribal population, which has been cut-off from mainstream development and has a mix of various ethnic groups and tribes, castes and communities, including the indigenous tribes and relatively more recent migrants from other states. Mandla and Betul districts have large tribal communities and are located far from urban centres and thus have different issues and concerns as compared to Ratlam and Raisen that are industrial towns and fairly urbanized as they were located near to the main urban. The NSS data too indicates significant regional variations. Thus, to address the issue of energy transitions, issues at the local level will have to be taken into consideration, further stressing the importance and role of local government institutions, so as to ensure effective policy making.

Solutions need to have a participatory approach. There is a need to involve grass root level organizations as well as the intended beneficiaries in the planning process. While policies at the national level may provide important guidelines and the necessary framework, the implementation strategies need to be designed at the local level.

Communities also differ in their essential fabric. There are areas where community based solutions will be successful and others where these won't. Identifying the key services where interventions may be more successful particularly those that contribute to livelihood enhancement are essential.

As mentioned earlier, to address issues of availability, structural changes and improvements in the supply chain of the product/energy service would need to be ensured so as to create reliable and quality supply.

Last but not the least, awareness building is essential for informing people about the various options available to them so that households can make informed energy choices that best suit their needs.

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ANNEXURES

Annexure 1: Categorical variables as defined for the regression analysis

Economic Status	Code
BPL	0
APL	1
Social Status	Code
GEN	0
SC	1
ST	2
OBC	3
Gender	Code
MALE	0
FEMALE	1
Occupation	Code
AGRICULTURE	0
DIALY WAGE/CASUAL LABOUR	1
SELF EMPLOYMENT	2
SERVICES	3
RENT FROM LAND	4
HOUSEWIFE/UNEMPLOYED	5
STUDENT	6
House Characteristics	
KUCCHA	0
PUCCA	1
OWN	0
RENTED	1
Income characteristics	Code
400-1000	0
1000-1500	1
1500-3000	2
3000-6000	3
6000-12000	4
Greater than 12000	5
PRIMARY COOKING FUEL	Code
Biomass (FW, Dung cake)	0
Petroleum Products (kerosene)	1
LPG	2
LPG + Biomass	3

PRIMARY LIGHTING FUEL	Code
Kerosene	0
Electricity	1
Kerosene + electricity	2
Solar + electricity	3

District	**Code**
Betul	1
Mandla	2
Raisen	3
Ratlam	4
Village	**Code**
Chilkapur	1
Dhondi	2
Nayegaon	3
Umbada	4
Chiraidongri	1
Chiraidongri (A)	1
Dungria	2
Dungria (B)	2
Limrua	3
Tharka	4
Ghat Kamariya	1
Kokalpur	2
Mehgua	3
Sagauni	3
Semrikala	4
Baga Kheda	1
Kalmoda	2
Karamdi	3
Sejawta	4

Annexure 2: GINI Coefficient[20]

The Gini coefficient was developed by the Italian Statistician Corrado Gini (1912) as a summary measure of income inequality in society. It is usually associated with the plot of wealth concentration introduced a few years earlier by Max Lorenz (1905). Since these measures were introduced, they have been applied to topics other than income and wealth, but mostly within Economics (Cowell, 1995, 2000; Jenkins, 1991; Sen, 1973).

G is a measure of inequality, defined as the mean of absolute differences between all pairs of individuals for some measure. The minimum value is 0 when all measurements are equal and the theoretical maximum is 1 for an infinitely large set of observations where all measurements but one has a value of 0, which is the ultimate inequality (Stuart and Ord, 1994).

When G is based on the Lorenz curve of income distribution, it can be interpreted as the expected income gap between two individuals randomly selected from the population (Sen, 1973). The Lorenz curve is plotted as the cumulative proportion of the variable against the cumulative proportion of the sample (i.e. for a sample of 30 observations the cumulative proportion of the sample for the 15th observation is simply 15/30). To get the cumulative proportion of the variable, first sort the observations in ascending order and sum the observations, then each kth cumulative proportion is the sum of all xi/xsum from i=1 to k.

The classical definition of G appears in the notation of the theory of relative mean difference:

$$G = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} \left| x_i - x_j \right|}{2n^2 \bar{x}}$$

- where, x is an observed value, n is the number of values observed and x bar is the mean value.

If the x values are first placed in ascending order, such that each x has rank i, the some of the comparisons above can be avoided and computation is quicker:

$$G = \frac{2}{n^2 \bar{x}} \sum_{i=1}^{n} i(x_i - \bar{x})$$

$$G = \frac{\sum_{i=1}^{n} (2i - n - 1) x_i}{n \sum_{i=1}^{n} x_i}$$

- where, x is an observed value, n is the number of values observed and i is the rank of values in ascending order.

[20] Cowell FA. *Measuring Inequality* (second edition, draft third edition (May 2000) at http://darp.lse.ac.uk/Frankweb/Frank/pdf/measuringinequality2.pdf, Hemel Hempstead: Harvester Wheatsheaf 1995.

Annexure 3: Policy Insights from the Pilot Survey

(1) Income measures may not be most relevant for targeting in interventions: The pilot survey findings validate the findings from NSS data analysis which is that there is an inverse relation between income inequality and energy inequality. While the econometric model indicates income as a significant factor, this does not conform to the data related to uptake and use of cleaner fuels. Designing clean energy transitions in rural India requires evidence-base of other social and cultural factors which will help in policy and programme design.

(2) Financing mechanisms and delivery models need to be supplemented by technical support: According to the pilot survey, most households indicate that financial assistance is not given to households for meeting specific requirements related to clean energy. Carefully thought out financing mechanism needs to be designed for a greater shift towards cleaner fuels with possibility of staggered payments.

(3) Information, Education and Communication (IEC) activities for clean energy options needs further strengthening: It was found that most households in Mandla and Raisen were using CFL bulbs. On being asked how they knew about it and why they were using it, they mentioned that the children were taught in school that these bulbs though a little more expensive than ordinary ones, consumes lesser electricity and thus would generate lower electricity bills. As for cooking options, the perceived environmental and health benefits of improved cookstoves are not deemed significant enough to outweigh the financial costs involved, while these are pressing issues at the macro level. There is need to strengthen awareness and education related policies and activities around clean cookstoves.

(4) Entrepreneur-led models could help in the revival of biogas programmes: Land availability is a significant concern for individual biogas plants. Success of community plants is questionable due to variable levels of social capital and trust regarding land as a common pool resource. Biogas programmes could be revived through entrepreneur-led models for biogas. The private sector and local NGOs can also play a role in operationalizing such interventions. Experience from TERI's initiatives in decentralized energy solutions could also be relevant in designing such interventions.

(5) Demonstration projects may lead to greater uptake: Bandwagon effects are visible in villages of Mandla and Betul. Another intervention related recommendation from the pilot survey is that demonstration projects may lead to greater uptake and acceptability of a particular technology.