Implications of "Energy Poverty "of the poor in India

by

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Abstract:

This master's project examines the concept of energy poverty on micro level sample survey data collected from Indian households between November 2004 and October 2005. Energy poverty refers to the lack of access of poorer households' to sufficient volumes of efficient means of energy for their daily use. Using statistical analysis, the study identifies variables that can explain energy poverty of households – i.e. are statistically significant in a model of energy poverty. It uses data collected by a Living Standards Measurement Study (LSMS) called Indian Human Development Survey (IHDS) 2005 contains information on levels of living, poverty and inequality in Indian households from direct interview questionnaires. This survey was designed and implemented by the University of Maryland in collaboration with the National Council of Applied Economic Research (NCAER), New Delhi.

I model fuel type choice as a function of household consumption (as proxy for income), education level of adult female and male members, poverty, household size and place of residence. Consumption data is significant in defining choice of fuel type. Factors like education, place of living and household size are statistically significant in modifying the choices. The models conclude that use of polluting fuels is more prevalent in poorer households, household with lower education and in rural households. However, large family size is the biggest obstacle in adopting cleaner fuels.

I also model the health impact of smoke produced by biomass traditional stove, by controlling for education of adult men and women, place of cooking, ventilation and consumption level of households. I examine mortality and morbidities associated with smoke exposure on men, women, children and younger children separately. Economic status of the household and education of females are statistically significant explanatory variables in controlling the impact of exposure to smoke on morbidity levels. I also find that children's education is adversely affected by the health impacts of exposure to biomass based stove smoke.

Acknowledgements:

I would like to thank my advisor, Dr. Subhrendu Pattanayak of the Nicholas School of the Environment and the Sanford School of Public Policy at Duke University, for his guidance and support throughout the duration of this project. The success of this project is also due in large part to Daniela Miteva, doctoral candidate at the Nicholas School of Environment who helped me begin my analysis using STATA and also guided me on theoretical bases of my research. Thanks to the Inter-University Consortium for Political and Social Research for allowing me access to the Indian Human Development Survey 2005 data for my analysis. I extend a heartfelt thank you to my family. Lastly, I send a special thank you to my parents and I hope that they would be proud of my accomplishment.

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List of acronyms:

ALRI: Acute Lower Respiratory Infection

ARI: Acute Respiratory Infection

COPD: Chronic Obstructive Pulmonary Disease

DALYs: Disability Adjusted Life Years

GoI: Government of India

IAP: Indoor Air Pollution

IEA: International Energy Agency

IHDS: Indian Human Development Survey

HDPI: Human Development Profile of India

LPG: Liquefied Petroleum Gas

LSMS: Living Standards Measurement Study

MDG: Millennium Development Goals

NCAER: National Council of Applied Economic Research

UMD: University of Maryland

UMEAC: Universal Modern Energy Access Case

UNO: United Nations Organization

WHO: World Health Organization

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1. Introduction:

1.1 Objectives: What is energy poverty?

Energy is essential for doing any work. Poverty is defined variously as denial of choices and opportunities and state of relative reduced income and wealth (United Nations 1997). Dictionary definition of poverty is the state or condition of having little or no money, goods, or means of support. In that sense energy poverty is the denial of the use of energy for doing any work apparently arising out of having little or no access to energy. The link between energy and poverty has become apparent over the past few decades. Another definition of energy poverty is the threshold point at which energy consumption begins to rise with increases in household income. At or below this threshold point, households consume a bare minimum level of energy and should be considered energy poor. The income poor are likely to be energy poor, but not all of the energy poor are income poor. So there is a threshold level of income below that all households are likely to be energy poor. Therefore the household income is not a good predictor of energy poverty (Barnes and Samad 2011). It also appears that energy-poor households would cook food less than normal level for the average household and by implication consumes less food. That is an important implication of malnutrition and poor productivity prevalent in poor people.

2. Background:

2.1 Is there a link between energy poverty and climate change?

Climate change has been linked to the loss of carbon stored into the biomass of the forests through net loss or degradation of forest cover. This can potentially release more carbon into the atmosphere than can be sequestered by converting to biomass (DeFries and Pandey 2009). The study indicated that with growing urbanization will cause more households to shift to better and cleaner fuels. This will lessen the demand for firewood and leaf litter that serve as solid biomass generally used by rural households in traditional stoves. Implications of reduced fuel-wood demand for forest cover are less certain but the limited data suggests that urbanization will promote a transition to increasing forest cover in the Indian context. This suggests that over a period of time the net effect on carbon loss due to energy poverty would slow down and may actually get neutralized. Thus there is a link between climate change and energy poverty too.

2.2 Is there a link between energy poverty and development?

Generally developing countries are characterized by high cost and low availability of clean energy (United Nations 2010). According to the International Energy Agency analysis, around 1.5 billion people, i.e. a quarter of the world population, have no access to electricity (Bhide and Monroy 2011). It predicts that in the absence of vigorous new policies, 1.4 billion people will lack access to electricity in 2030 (Modi, S. et al. 2006).The Millennium Development goals set by the UN provide concrete, time-bound objectives for dramatically reducing poverty in its many dimensions by 2015—income poverty, hunger, disease, exclusion, and lack of infrastructure and shelter—while promoting gender equality, education, health, and environmental sustainability. The World Energy Outlook 2010 spells out an interim target that by 2015 only one billion people should be without access to electricity and only 1.7 billion should still be using traditional biomass for cooking on open fires or primitive stoves, rhyming with the MDG goal of eliminating poverty by 2015. If the business-as-usual scenario continues, by 2030, the worldwide electrification rate will not reach 100% and the number of people relying on the traditional use of biomass will rise to 2.8 billion. Its Universal Modern Energy Access Case (UMEAC) implies complete access to modern energy services by 2030. The World Bank estimated in 2006 that $860 billion would be needed to connect 600 million additional households to electricity grid to achieve universal access by 2030. Therefore development goals are intrinsically bound to the achievement of universal access to modern energy.

3. Health and educational effects of energy poverty:

3.1 What is the extent of health effects of energy poverty?

Use of bio mass for cooking is prevalent in many parts of the developing world. There is an established causation between several diseases such as Acute Lower Respiratory Infection (ALRI), Acute Respiratory Infection (ARI), Heart Disease and hypertension (Dherani, Pope et al. 2008). Causation for respiratory infections in traditional stove users varies (Perez-Padilla 2010). As per the World Health Organization (WHO), Indoor Air Pollution (IAP) may have caused 1.96 million premature deaths worldwide in 2004. Approximately 70% of Indian households, more than 160 million households, comprising about 770 million people are estimated to depend on polluting cook stoves that burn solid fuel, mainly wood or coal. It is also estimated that approximately 400,000 to 550,000 people primarily women and children die of the resulting indoor air pollution each year in India. This makes the cook stoves problem in India and the potential market for cleaner cook stoves amongst the largest in the world (Zhang 2009).

3.2 What is the situation in India and other developing countries?

In the developing world, the development needs are intrinsically linked to solving the question of energy poverty. This implies an increase in India's energy needs. Some of the future increase in energy needs could be met from renewable sources and some could be met through increasing efficiency. Lowering energy intensity of GDP growth through higher energy efficiency remains the biggest challenge before India in achieving energy security (Report 2009). Under Goal 7 of the Millennium Development Goals of ensuring environmental sustainability, indicator 27 is the measure of energy use per unit of GDP. Traditionally, total residential energy consumption in rural households always exceeds that of the urban households. The cause of this is attributed to the increasing dependence on inefficient solid fuels in the rural areas, while the urban areas switch to more efficient fuel sources (Bhide and Monroy 2011). As energy efficiency improves and energy poverty declines, there will be further decline in rural and urban energy efficiency differential. This is also one of the important challenges before the energy poverty conundrum, besides the main challenge to meet the energy needs of the rural households through efficient means of energy.

4. The Indian reality:

4.1 Poverty metrics in India:

India had approximately 195 million households as per the Census 2001. There was 27.5 % of population below the poverty line in 2004-2005, as per the Planning Commission of India. The poverty line was originally fixed in terms of income/food requirements in 1978. It was stipulated that the calorie standard for a typical individual in rural areas were 2400 calorie and was 2100 calorie in urban areas. Then the cost of the grains (about 650 gm) that fulfill this normative standard was calculated. This cost was the poverty line. In 1978, it was Rs. 61.80 per person per month for rural areas and Rs. 71.30 for urban areas. In 2004- 2005, it was calculated to be Rs. 356.30 per person per month for rural areas and Rs. 538.60 per person per month for urban areas (GOVERNMENT OF INDIA 2007). Therefore the Indian poverty line is the line of subsistence. It does not take into account expenses or the consumption actually made. It relies only on the availability of enough energy for an individual to survive. The origin of the bare minimum survival capacity for the poverty line lies in the Indian reality of famines in the colonial times that occurred regularly and caused loss of human lives (DANDEKAR, SUKHATME et al. 1993). There has been criticism of the absolute poverty concept since it does not account for the expenses on education, health and energy that an individual should make for living healthily. The average size of the Indian household was 5 as per the Census 2001, so, the poverty line as per the current definition for one household comes to Rs. 1, 781/- (approx. USD 40 @ Rs. 45 = 1 USD) per month for rural areas and Rs. 2, 693/- (approx. USD 60 @ Rs. 45 = 1 USD) per month for urban areas in 2004-2005. State level data is actually used to calculate state wide poverty line. Internationally, income of less than $ 1 per day per head (purchasing power parity) is defined as extreme poverty. As per these estimates about 45% of Indian population is extremely poor. If the daily income per head of $ 2 is considered to describe a family as poor then about 80% of Indian population is poor by this criterion.

4.2 Biomass availability in India:

Biomass availability in India has seen the following trend. There is a general shift across almost all income classes in shifting away from firewood. In rural areas, the use of LPG increased fourfold but 75% of households still rely on fuel wood. Despite the decline in percentage households using traditional fuels, fuel wood demand continued to increase from 1993 to 2005 at a national scale due to an increasing total number of households. However, 25% of states and union territories experienced declines in rural fuel wood demand and over 70% declines in urban fuel wood demand. Forest cover has remained steady or increased slightly over the time period; reaffirming the conclusion that fuel wood demand may lead to local degradation but not large-scale deforestation. At the state level, increases in percent forest cover between 2000 and 2004 are positively associated with percent of total households that are urban (corresponding to fewer percentage households using wood) but not related to changes in fuel wood demand. Plantations are a primary cause of increases in forest area, where benefits to ecosystem services such as biodiversity and hydrologic function are controversial. Results suggest that households will continue to climb the energy ladder with future urbanization, resulting in substantial development benefits and reduced exposure to indoor air pollution. Implications of reduced fuel wood demand for forest cover are less certain but the limited data suggest that urbanization will promote a transition to increasing forest cover in the Indian context (DeFries and Pandey 2010). Considering the poverty situation in India, compared to internationally accepted levels, the widespread use of biomass fuel in India is not surprising.

4.3 Interventions for biomass stove adoption:

The Indian government had launched the National Program on Improved Chulhas ('stoves') (NPIC) in the year 1984 but called it off in the year 2002. The program failed to cover rural households completely and the results were mixed. The improved stoves were considered an administrative liability handed over to the users at subsidized cost. So, the impact on the rural household's was minimal. However, in the year 2009, India re launched the improved stove program. Recently the X Prize Foundation, the Ministry of New and Renewable Energy (MNRE) and the Indian Institute of Technology Delhi devised a global competition to develop and deploy clean and efficient cook stoves. (Mishra, Smith et al. 2005; Venkataraman, Sagar et al. 2010)

5. Theoretical understanding of energy shares concept:

In India, per capita energy consumption is low as compared to the international standards. Second, more of the inefficient energy sources are consumed using inefficient traditional technology. Moreover, the concept of energy poverty implies that energy consumption by a household displays similar characteristics as that on food consumption. As in case of food expenses, expenditure on energy in the budget declines as the income of the household increases. This is the Engel's law. Applying Engel's Law to share of energy in the overall consumption of household, it is expected that energy share in the total consumption will rise for households having income up to a certain level. Beyond that income level, the energy expenses as a proportion of the total expenses of the household would fall. Unlike food expenses, there are no adult or children food items, but there are inferior or inefficient energy sources and superior or efficient energy sources. There are certain facts regarding use of energy in households. As income level rises, the share of energy in the total consumption will rise till certain income level. Secondly, the share of superior energy sources in the overall energy consumption will rise as income of household increases. So, there will be substitution of inferior energy sources by superior energy sources as income rises. This is the energy ladder concept. However, this substitution effect will depend upon the size of the household. Larger sized households will delay their substitution of inferior sources of energy by superior sources till their income level rises beyond a certain level. Secondly, as the family size rises the share of total energy consumption will not rise to the same extent for the same income levels. That in case of larger households, there will be fall in share of superior energy sources in the total energy consumption. There could be fall in the share of energy in the total consumption also for larger households at the same income level.

6. Survey methodology:

6.1 Historical background:

Modern household surveys began after World War II. Under the leadership of Mahalanobis at the Indian Statistical Institute in Calcutta, the Indian National Sample Survey (NSS) started the annual collection of household consumption data in 1950. In the late 1970s, it was becoming increasingly difficult for the World Bank—or for anyone else—to make well–supported statements about world poverty, especially statements that required internationally comparable data. There was no firm basis assessing such fundamental topics as the extent of poverty in the world, which countries were the poorest, or whether the inequality within and between nations was expanding or contracting. As a consequence to this, the Living Standards Measurement Study (LSMS) was begun in the World Bank in 1979 in the last months of the McNamara presidency. The original aim was to develop the World Bank's ability to monitor levels of living, poverty, and inequality in developing countries, to allow more accurate statements about the number of people in poverty around the world, and to permit more useful comparisons between countries. Traditional household surveys in developing countries have surveyed consumption in great detail, and the Indian NSS, the Indonesian Survei Sosial Ekonomi Nasional (SUSENAS), and many other surveys collect information on around 200 separate food items alone, both in physical quantity and monetary units, together with several dozen more nonfood items. The World Bank's Living Standard Surveys have usually been less detailed, on the grounds that the detail and the data on physical quantities are necessary only for calculating calorie and nutrient intake, but not to obtain accurate estimates of total consumption and living standards (Deaton 1997).

6.2 Indian Human Development Survey 2005:

Methodology of conducting the survey was through questionnaire implementation by direct face-to- face interviewing. There are two sets of questionnaire, the household questionnaire and household health and learning tests questionnaire. The interviews were held with the head of the household, married women in the household and with school going children. The survey instruments were translated into 13 Indian languages and were administered by local interviewers. The fieldwork was carried out by 24 collaborating institutions under the supervision of the National Council of Applied Economic Research (NCAER), New Delhi. Locally knowledgeable and linguistically fluent interviewers were hired by the collaborating institutions and trained by senior project personnel from NCAER and the University of Maryland. A team of one male and one female interviewer visited each home; women respondents were interviewed by women interviewers whenever possible. Fieldwork began in November 2004 and was mostly completed by October 2005.

6.2.1 Sampling frame:

The IHDS 41, 554 sample households comprise of several composite separate sub-samples that were each drawn somewhat differently. The basic division is between a re-interview sample of 13,900 households previously interviewed mostly in 1994-95 for the Human Development Profile of India and 27, 654 new households. Each division is comprised of distinct components. The HDPI survey included a sample of 33, 230 rural households that were eligible for re-sampling for IHDS. The IHDS goal was to re-interview half of these households. The HDPI sampling design was a complicated stratified sample so it was not possible simply to choose a random half of the villages for re-interviews: that would have resulted in some strata being over-represented and others under-represented. On the other hand, selecting a random half of the households within each stratum would have required revisiting almost all of the HDPI villages, a too costly option. A compromise was reached in which HDPI villages were randomly ranked within each district and households were sampled within each stratum according to this ranking.

6.2.2 Extent of rural coverage in the sampling frame:

HDPI only collected data in rural areas. Therefore, for the IHDS a new sample for urban areas was drawn. Towns were sampled from the 2001 Census list with probabilities proportional to their population. The list of towns was first sorted by population size within each State. The number of intervals for each State was calculated as the targeted number of households divided by 45 (the minimum sample size). The total urban population in each State was divided by this number of intervals to determine an interval size; a random starting point was selected within the first interval; and towns were selected if the interval fell within the town's cumulative population. Larger cities were selected multiple times with this method and the number of neighborhoods determined by this multiple.

7. Discussion on use of consumption or income as explanatory variable:

In the IHDS survey, consumption values are used to identify those households that are classified as "POOR" as per the Indian government's absolute poverty levels. The consumption variable "COPC" is constructed by aggregating data from 47 questions. At the least, such measurement requires data on consumption, income, household size, and prices. For broader concepts of living standards, we also want information on health, nutrition, and life expectancy, and on levels of education, literacy, and housing. Moving from measurement to modeling extends the scope a good deal wider. To understand consumption, we need to know about income and assets, and about their determinants, saving behavior, inheritances, education, and the opportunities for working in the labor market, on a farm, or in small businesses of one kind or another. When households are asked to report their income or consumption, a choice has to be made about the reference or reporting period. In this case, the reporting period is the month preceding the date of survey. It is generally held that for any given household, expenditures will vary from one reporting period to another, so that even in a "survey" that repeatedly interviewed the same household once a week for a year and used the weekly reports to calculate 52 annual estimates, not all would be the same (Deaton 1997).

7.1 Problems of using consumption data:

There are certain problems associated with the collection and use of consumption data in developing countries. Imputation of price is difficult if the quality of goods is not standardized. Additionally, there are often difficulties over the choice between buying and selling prices. Wealthy households hire workers, both domestic servants and agricultural workers, and in many cases supply them with food, explicitly or implicitly as part of their wages. Food expenditures for wealthy households will therefore usually include expenditures for items that are not consumed by the immediate family and for large agricultural households the discrepancy can be large. Consumption of home−produced items, typically food grown or raised on the farm or in kitchen gardens also create measurement problem. Such items, often referred to as *autoconsommation*, are properly recorded as both income and consumption, but are often difficult to value. Such errors will be common to measures of both income and consumption, since imputations are added to both. As a result, the same measurement error will be present in both dependent and independent variables. Comparison between various item totals from the Indian NSS consumption surveys with the independently obtained production−based totals of the amounts of various foods available for human consumption has been made (Minhas 1988; Minhas and Kansal 1989). While the results vary somewhat from food to food, and while it is important not to treat the production figures as necessarily correct, there is typically very close agreement between the two sets of estimates. Both are associated with the fact that most agricultural households are producers as well as consumers, and both reflect the difficulty of disentangling production and consumption accounts for people who have no reason to make the distinction.

7.2 Problems of using income data:

All of the difficulties of measuring consumption—imputations, recall bias, seasonality, long questionnaires—apply with greater force to the measurement of income, and a host of additional issues arise. Income is often a more sensitive topic than is consumption, especially since the latter is more obvious to friends and neighbors than the former. Accurate estimates of income also require knowledge of assets and their returns, a topic that is always likely to be difficult, and where respondents often have incentives to understate. Large number of households that are involved in agriculture or in family business, personal and business incomings and outgoings are likely to be confused. Such households do not need the concept of income, so that respondents will not know what is required when asked about profits from farms or own enterprises. Estimates of nonfarm self−employment income from the March round of the Current Population Survey (CPS) in the United States are 21 percent lower than independent estimates from fiscal sources, while the estimates for farm self−employment income are 66 percent lower (Coder 1991). Those close to subsistence, whose outgoings are close to incomings, are quite likely to report that income is zero. To get better estimates, the survey must collect detailed data on all transactions, purchases of inputs, sales of outputs, and asset transactions, and do so for the whole range of economic activities for wage earners as well as the self−employed. This is an enormous task, especially in countries where households are large and complex and where people are involved in a wide range of income generating activities. Survey−based estimates of income are often substantially less than survey−based estimates of consumption, even when national income estimates show that households as a whole are saving substantial fractions of their incomes, and even in industrialized countries where self−employment is less important and income easier to measure. Apart from some early experiments, the Indian NSS has not attempted to collect income data in their consumer expenditure surveys. And their consumption data has been shown to correlate to the production values. On the other hand, World Bank's experience with the various Living Standards Surveys as well as that of RAND with the Malaysian and Indonesian Family Life Surveys has been that it is possible to collect data on income components—accurately or inaccurately—without any effect on response rates.

7.3 Why use consumption as an explanatory variable:

Consumption data on specific commodities can be used to analyze who consumes how much of what, and can be used to examine the distributional consequences of price changes, whether induced by deliberate policy decisions or as a result of weather, world prices, or other exogenous forces. Measurement of consumption itself is a direct indicator so that there is no need to estimate behavioral responses or to construct the econometric models required to do so. In the context of measuring welfare in developing countries, there is a very strong case in favor of using measures based on consumption not income. Given also that annual income is required for a satisfactory estimate of living standards, an income−based measure requires multiple visits or the use of recall data, whereas a consumption measure can rely on consumption over the previous few weeks. Income, especially agricultural income, can be extremely variable, and a farmer's income in any month is a poor indicator of living standards in that month. Consumption and income are the standard measures of economic welfare, and they are often supplemented with other measures of well−being, such as nutritional and health status, life expectancy, and education. Because surveys collect data at the level of the household, and not the individual, poverty and welfare measures must be based on consumption and income totals for the household, not for the individual. Here, too, the households are being treated as the units whose welfare is being measured.

8. Analysis Methodology:

8.1 Data description:

8.1.1 Household and individual descriptors:

The number of family members of various age groups in the 41, 491 households for which valid data is available in the IHDS survey are as follows. The number of adult men, adult women and children are almost equal. The number of young children of age 5 years or below is approx one third of the adults’ male and female population. The IHDS survey provides detailed information on per capita monthly expenditure of households on consumption goods.

Table 1: Individual family members in sample households:

number of individuals	biomass stove users	high users of biomass stove (>=3 hours per day)	number of men (>15)	number of women (>14)	number of children (<15)	number of small children (<6)
215754	148582	104138	74086	73206	68462	24314
100%	69%	48%	34%	34%	32%	11%

8.2 Constructed variables:

8.2.1 Consumption (income proxy) as main explanatory variable:

IHDS asked a series of 47 questions about household consumption designed to estimate total household consumption expenditures. The first thirty, more frequently purchased items, used a 30-day time frame while the remaining 17 items used an annual time frame. The survey had constructed the consumption variable by collating data from these 47 items into the *COPC* variable that is the per capita per month consumption for the household. To understand the relation between shares of energy expenses of the household in the total monthly household expenses the per capita monthly expenses is multiplied with the number of persons in the household to get the total monthly household expenses (*copc*). Consumption data is one of the most important indicators of a household. The data set has large outliers hence the need to include several statistics to show the data characteristics.

8.2.2 Distribution of income proxy:

Table 2: Per capita monthly consumption expenditure (Rs.):

range	minimum	maximum	mean	standard deviation	median	p90	p99	p1	inter quartile range
39, 269	4	39, 273	955.1	1, 024.6	686	1, 799	4, 872	160	662

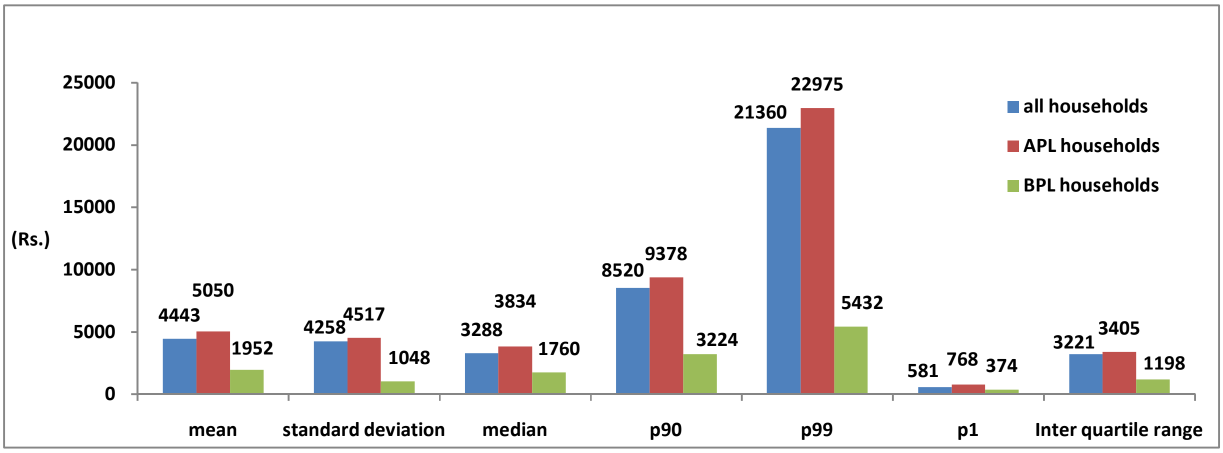
Table 3: Household monthly consumption expenditure (Rs.):

(In Rs.)	all households (valid data)	APL households	BPL households
number of households	41491	33366	8125
range	84826	84532	15088
minimum	32	326	32
maximum	84858	84858	15120
mean	4443	5050	1952
standard deviation	4258	4517	1048
median	3288	3834	1760
p90	8520	9378	3224
p99	21360	22975	5432
p1	581	768	374
Inter quartile range	3221	3405	1198

8.2.3 Poverty as a constructed explanatory variable:

The survey constructed a category of households called *POOR,* based on the state level poverty lines using the monthly consumption expenditure. The constructed variable *PCPL* was used to assign the households to the *POOR* category. This classification is done on the guidelines given by the Indian government to classify the below the poverty line (BPL) category of households. There is some overlap between the APL and BPL household consumption distribution because the actual classification of BPL is done on the basis of asset ownership and putative income.

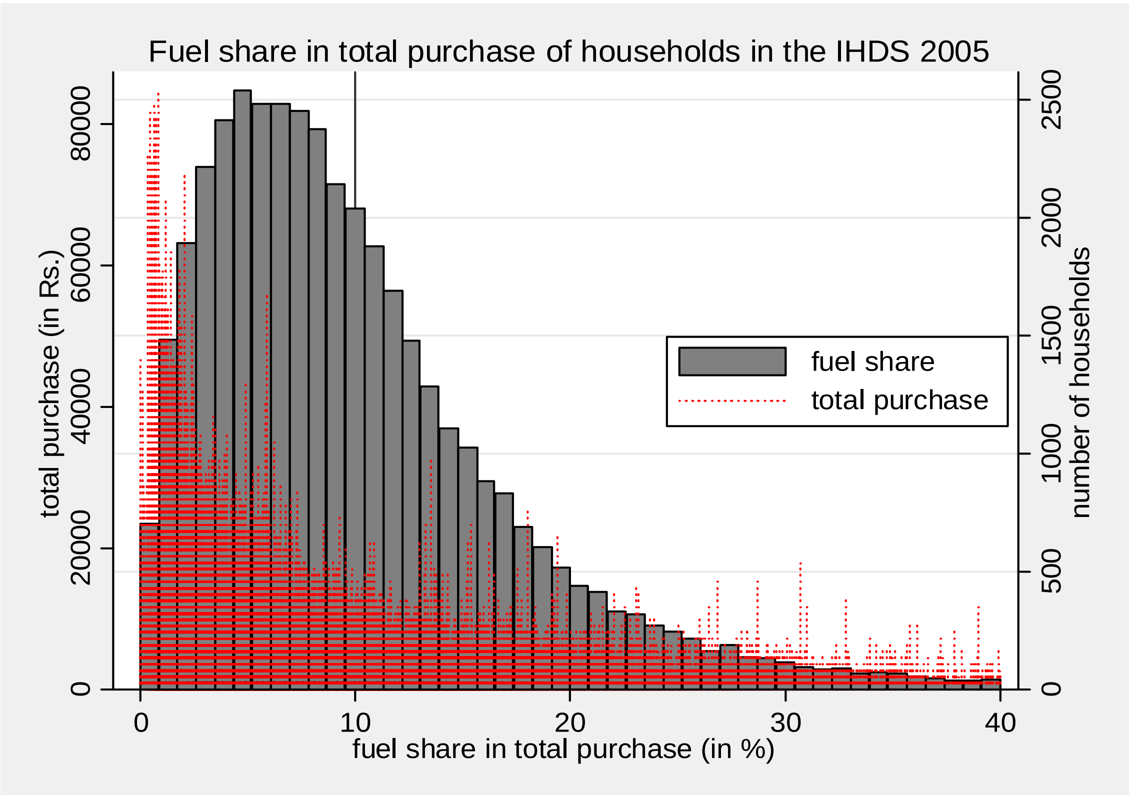
Figure 1: monthly household consumption for sample households:



8.3 <u>Fuel shares as response variable:</u>

Fuels used by the households are the solid biomass (includes firewood, farm residue, dung cakes), kerosene, coal (coke), Liquid Petroleum Gas (LPG), electricity. The energy poverty concept considers the movement from inferior fuels to the superior fuel as an inherent mechanism reflecting development. Here, solid biomass, coal (coke) and kerosene are considered polluting and inefficient fuels that occupy the lower rungs of the energy ladder. LPG and electricity are cleaner and efficient fuels. A household is considered not being energy poor if it uses the efficient and superior fuels. Indian households generally use electricity, and in its absence, kerosene for lighting purpose. Solid biomass and coal are used for cooking purposes. The IHDS collected information on monthly expenditure made by sample households in purchasing fuels for cooking or for lighting purposes. Besides, the survey has compiled the time taken separately by women, men and children in collecting solid biomass for cooking. The total cost incurred by a household on energy consumed will be sum of the actual monthly expenses made for purchasing the fuel. For fuel wood it includes the time costs of collecting firewood by at least one adult man or woman per household, if there is at least one adult man or woman in the household. The data for minimum wages is taken from the Indian government's Ministry of Labour annual Report for 2004-2005, the year of the survey. It is assumed that the loss of putative wages is at the rate of 50% of the minimum daily wage for equivalent time spent by the adult person who collects solid biomass. Since the survey did not collect data on the quantity of the fuel used by households, so the money value of fuel used by the households per month is used to calculate the share of energy expense in the total household monthly consumption expenditure.

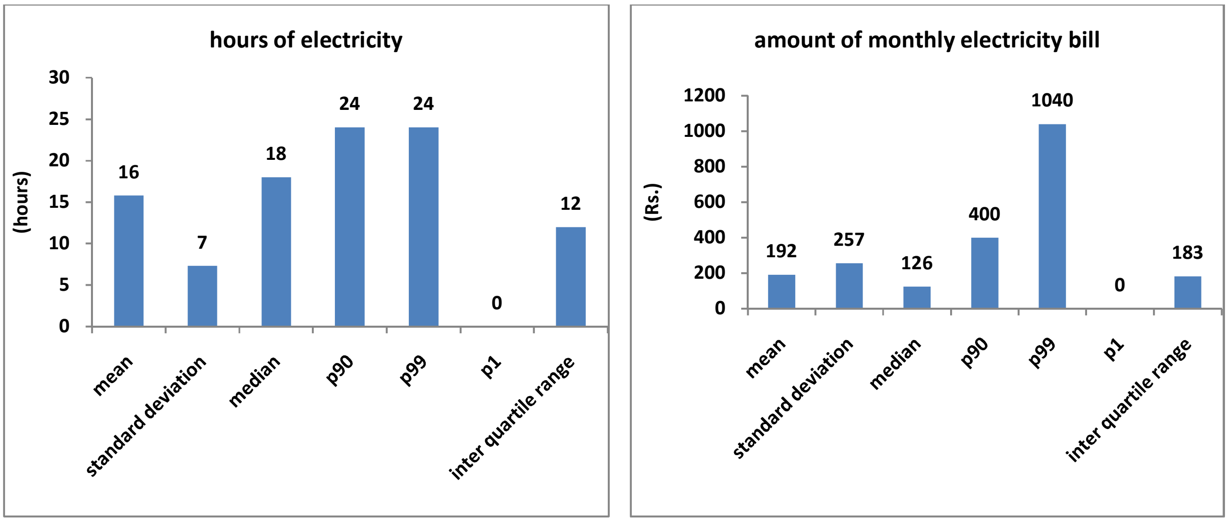
Figure 2: Fuel share with income proxy of all households:



8.3.1 Fuel shares and economic categories of households:

At the first stage of the analysis the distribution of the fuel use in the two economic categories is examined. The number and percentage of APL and BPL households using electricity, kerosene and biomass is large. Electricity and kerosene are used mostly for lighting. However, there are a large number of APL electricity users that use kerosene, reason being lack of dependability of electricity supply and cost variation.

Figure 3: Electricity availability:



The most significant gap between the two categories is in usage of LPG since most of BPL households lack access to LPG due to supply gaps and lump sum costing.

Figure 4: number of sample households using various fuels:

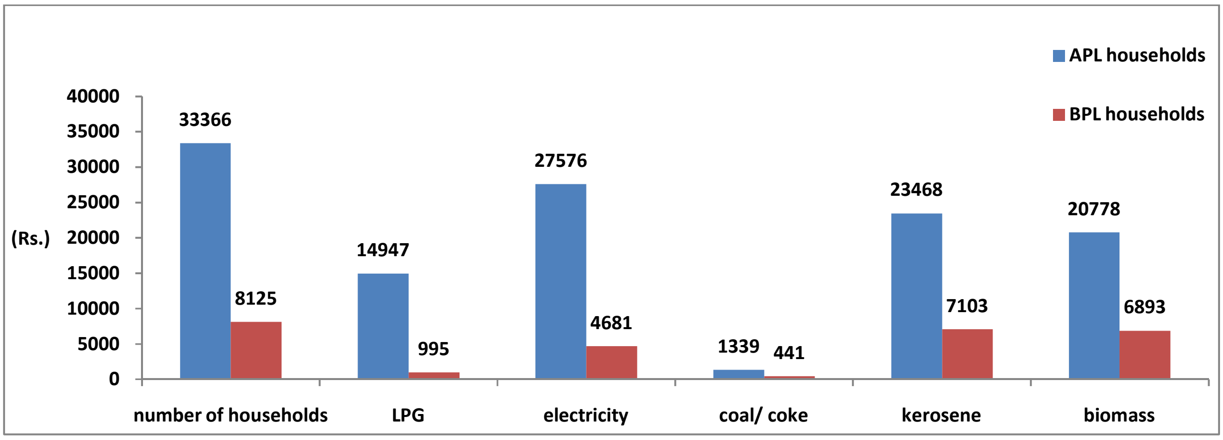


Figure 5: percentage of sample households using various fuels:

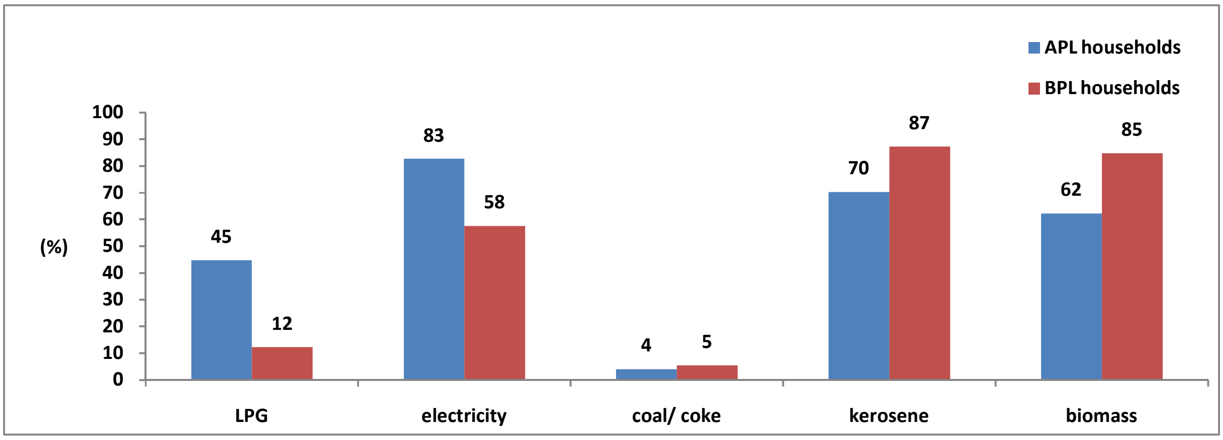
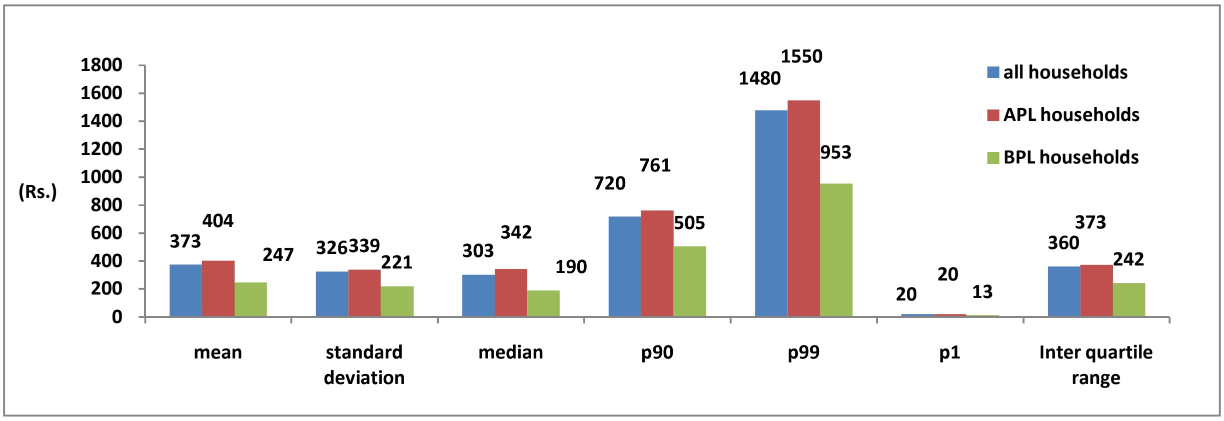


Table 4: Actual monthly expenditures on various fuels purchased by sample households:

(In Rs.)	all households	APL households	BPL households
range	9290	9290	6291
minimum	0	0	0
mean	373	404	246
standard deviation	326	339	221
median	303	342	190
p90	720	761	505
p99	1480	1550	953
p1	20	20	13
Inter quartile range	360	373	242

Figure 6: monthly fuel expenditure of sample households:

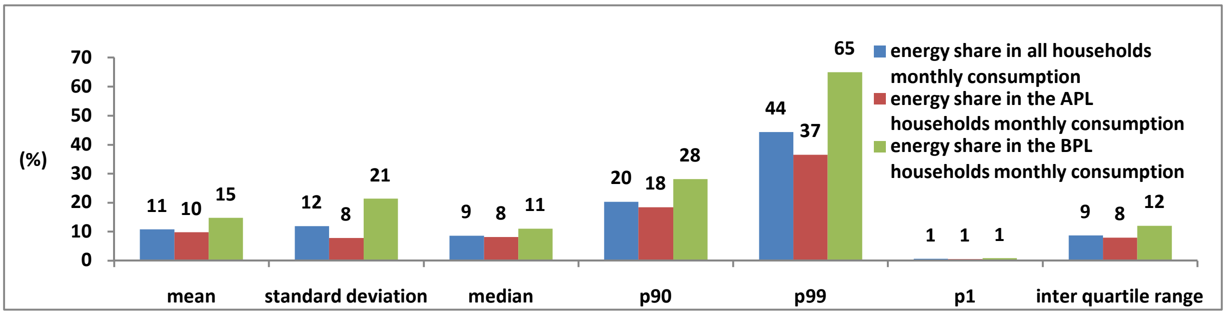


The percentage share of monthly energy expense in the total monthly consumption expenditure for sample households is as follows. Another major distinction between BPL and ALP households is in the larger share of energy of BPL households' than the APL households' in monthly consumption expenditure, indicating a parallel to the share of food expense in household monthly budget of poor households. Fuel share in the household budget of BPL households is approximately 50 % more than APL households. So, the poorer households spend larger share of their monthly consumption budget on fuels and most of it on inefficient and polluting fuels.

Table 5: energy shares in households of different economic categories:

(In percentage)	energy share in all households monthly consumption	energy share in the APL households monthly consumption	energy share in the BPL households monthly consumption
mean	11	10	15
standard deviation	12	8	21
median	9	8	11
p90	20	18	28
p99	44	37	65
p1	1	1	1
inter quartile range	9	8	12

Figure 7: fuel shares in the sample households' monthly consumption:



8.3.2 Distribution of various fuel shares in households' budget:

At the second stage of the analysis, the distributional expenditure of monthly household budget between various fuels for all, APL and BPL households using those fuels is examined. Biomass users share is comparable to the LPG users' share of the monthly fuel budget. Kerosene users' shares are smaller than electricity users because it is cheaper. Improved stove shares are much smaller than the traditional stoves because of lesser use. Average share of BPL households are larger for all the fuels, except electricity. This indicates that the BPL households have a rising need for electricity as consumption expenditure rises even though 60 % BPL households have access to electricity. This is reflected in the larger share of expenditure on kerosene in BPL households mostly for lighting purposes. Biomass traditional stoves take the largest share of the BPL monthly expenditure on energy.

Figure 8: shares of various fuels in the monthly fuel expenditure for all households:

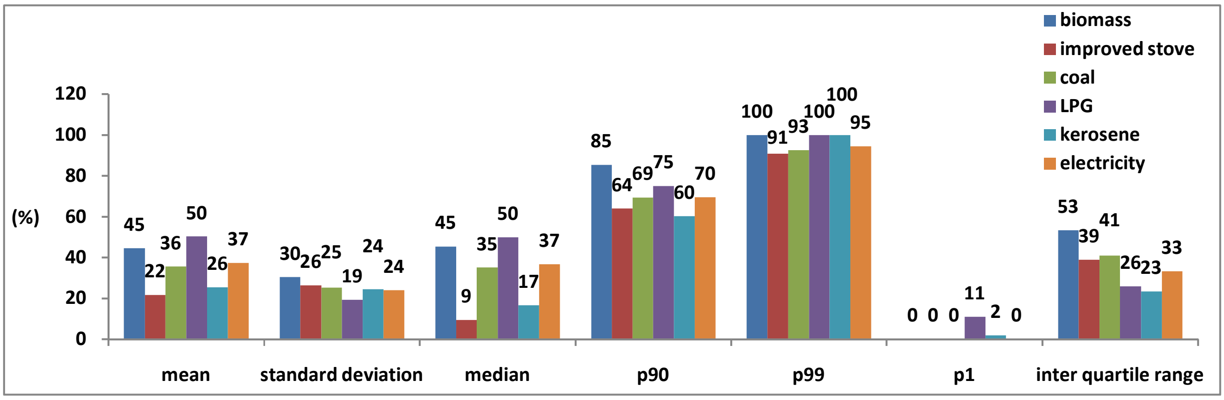


Figure 9: shares of fuels in the monthly fuel expenditure for APL households:

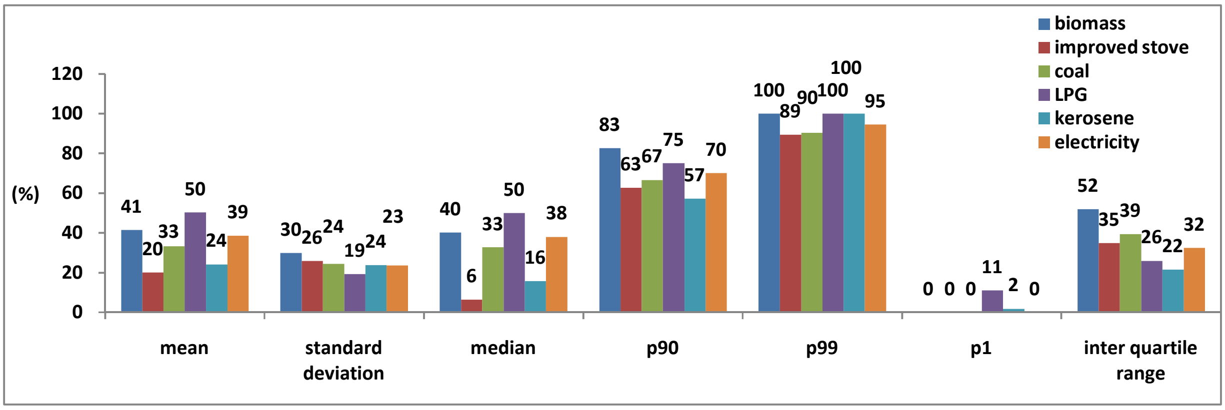
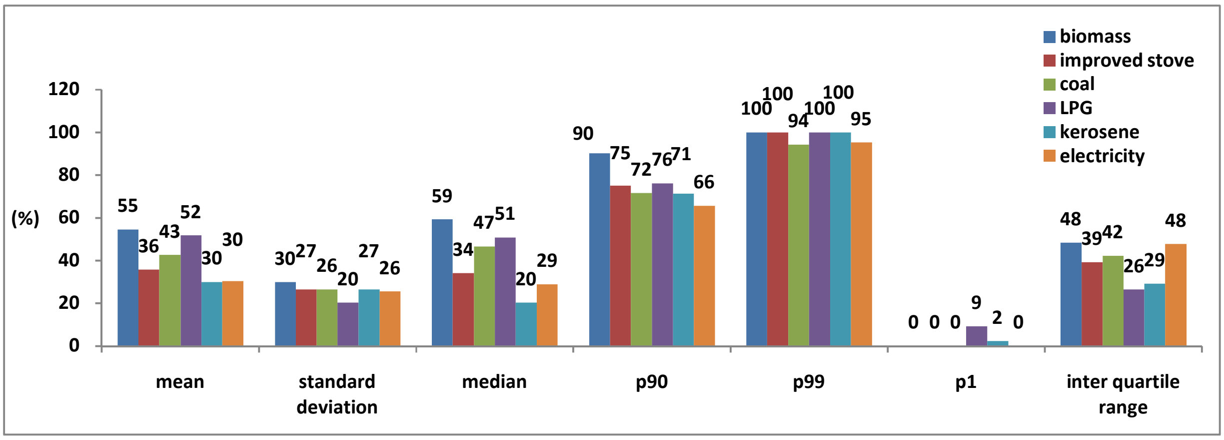


Figure 10: shares of fuels in the monthly fuel expenditure for BPL households:



8.3.3 Distribution of individual fuel shares in households' budget:

At this stage the distribution actual expenditure on various fuels by all households and by APL and BPL household is also examined in more detail. The actual monthly expenditure on various fuels (in Rs.) for the sample households is as follows: Households spend the most on LPG and the least on kerosene, because of is cheapness, the latter is mainly used for lighting by those who cannot afford or lack access to electricity. LPG costs almost double that of traditional biomass stove. Monthly expenditure on improved biomass stove is actually less than that on coal stove or traditional biomass stove. Electricity costs almost 2 to 4 times kerosene.

Figure 11: monthly expenditure on biomass stove:

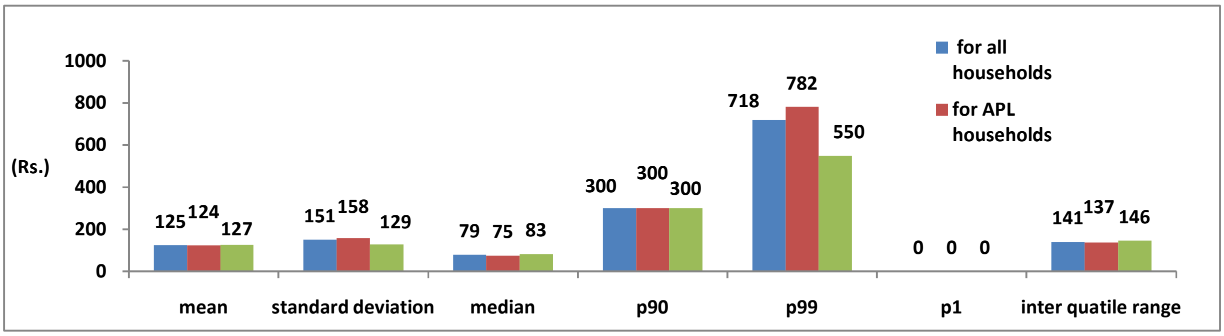


Figure 12: monthly expenditure on coal stove:

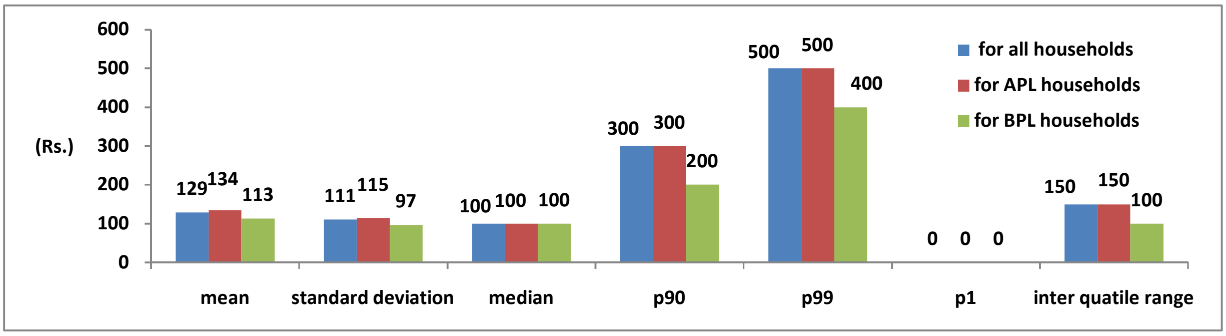


Figure 13: monthly expenditure on kerosene:

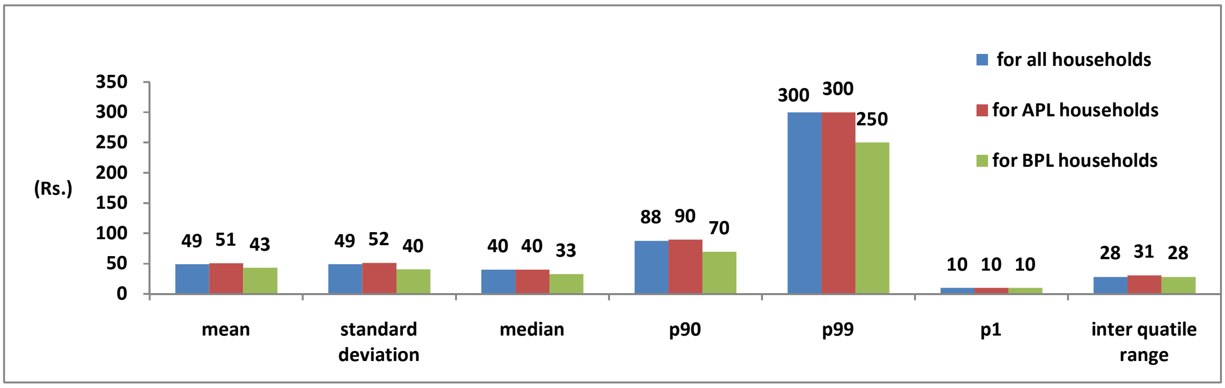


Figure 14: monthly expenditure on LPG (Rs.):

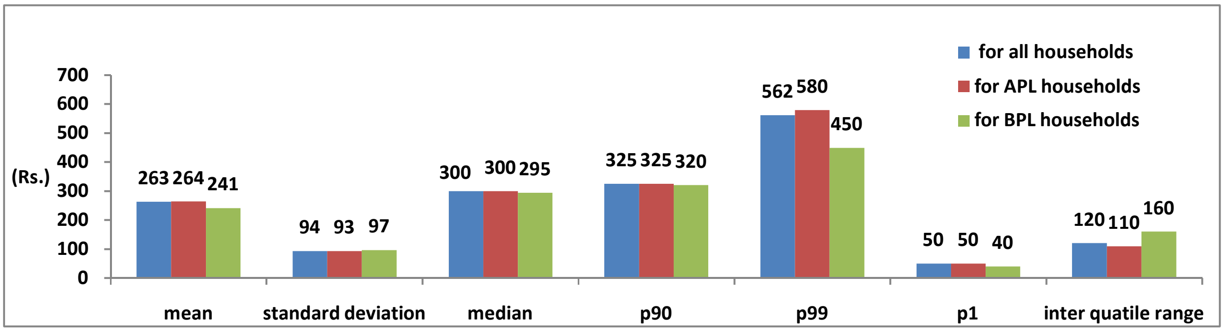


Figure 15: monthly expenditure on electricity (Rs.):

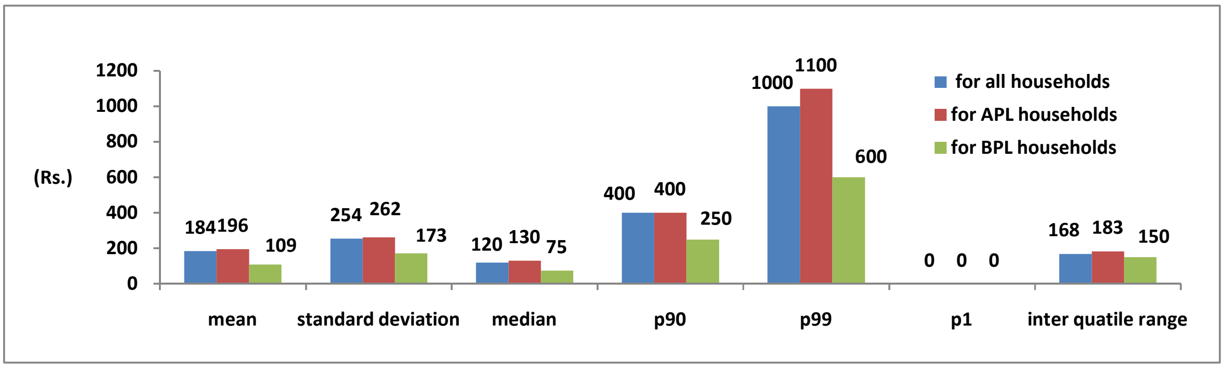
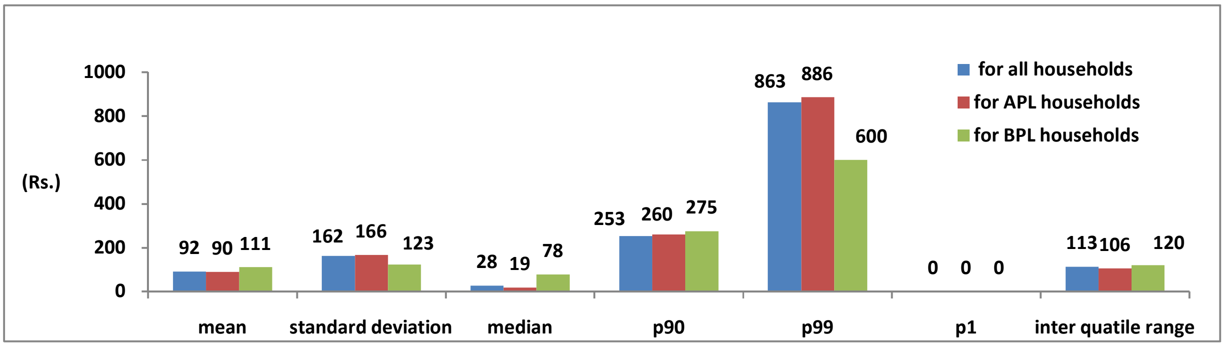


Figure 16: monthly expenditure on improved stove:



8.3.4 Comparison of individual fuel shares in different households' budget:

At this stage the comparative picture of the share of individual fuels in the monthly fuel budget of all households and APL and BPL households is also examined. Share of biomass in fuel budget is higher for BPL users than in APL. The share of expenditure on biomass fuels in improved stove is also larger in BPL households than the APL households though smaller than that on traditional stoves.

Figure 17: share of biomass in monthly expenditure on fuel:

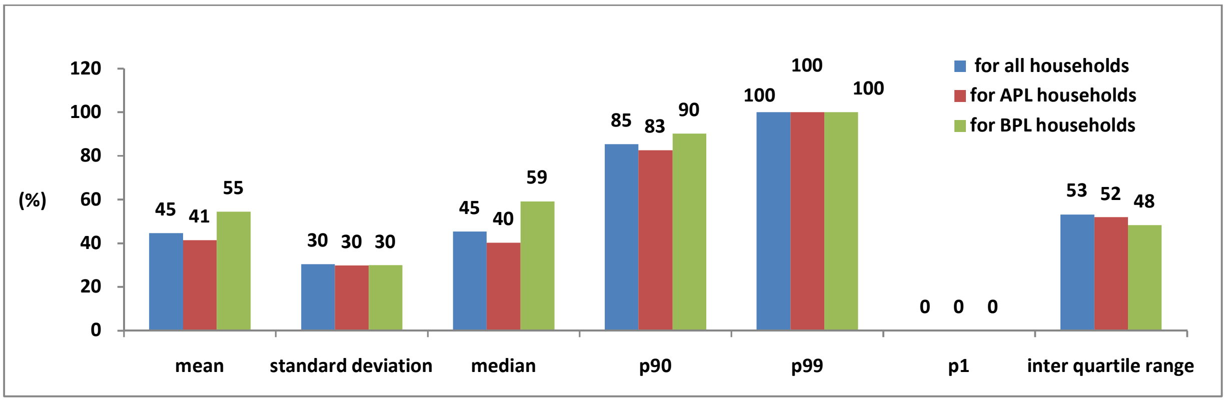


Figure 18: share of coal in monthly expenditure on fuel:

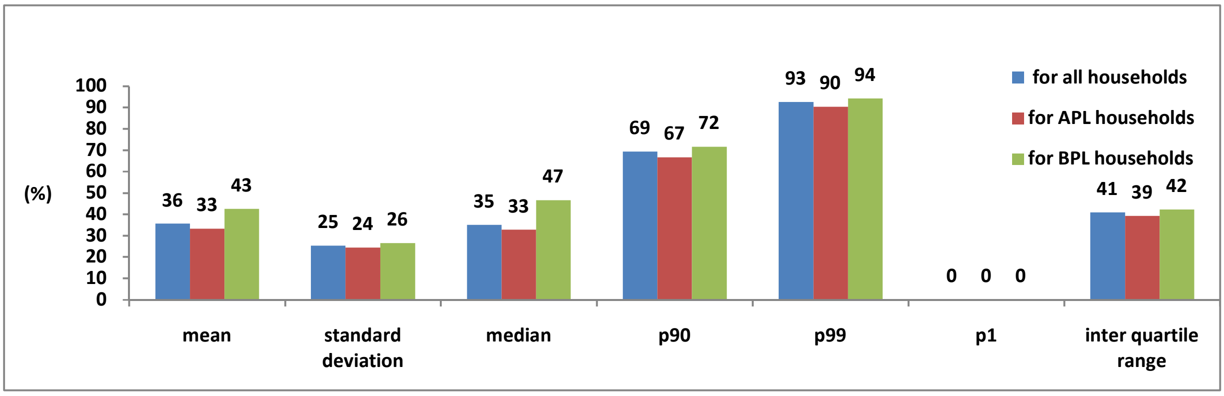


Figure 19: share of kerosene in monthly expenditure on fuel:

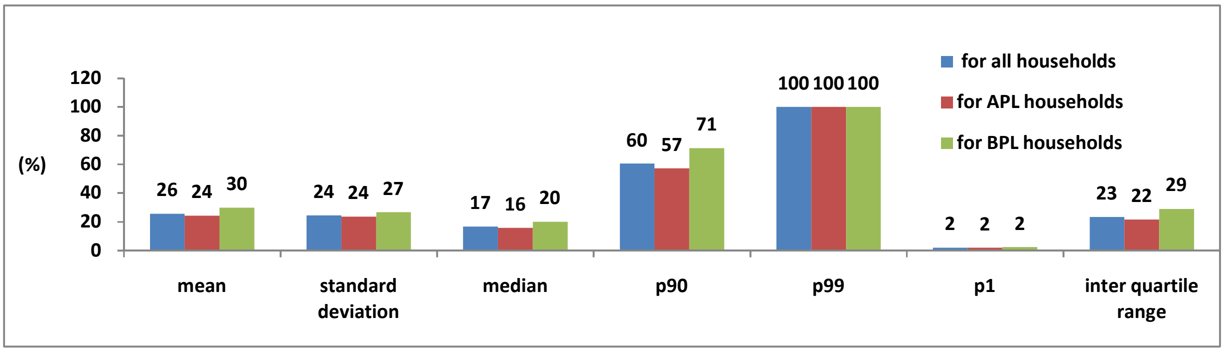


Figure 20: share of LPG in monthly fuel expenditure:

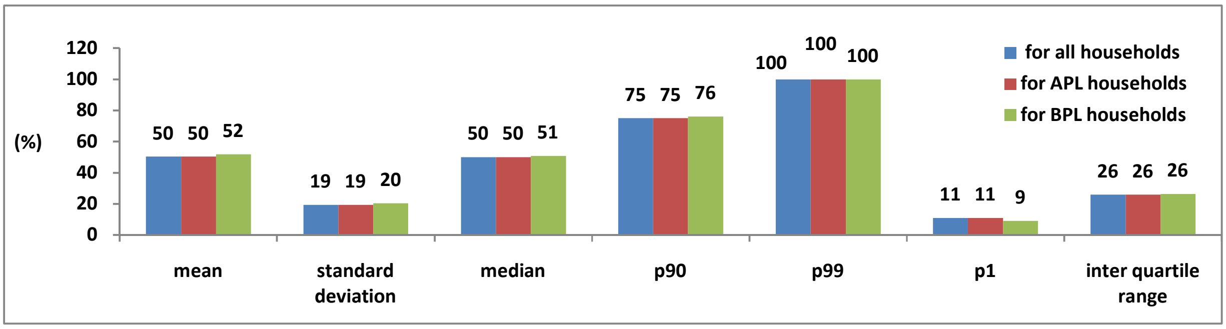


Figure 21: share of electricity in monthly fuel expenditure:

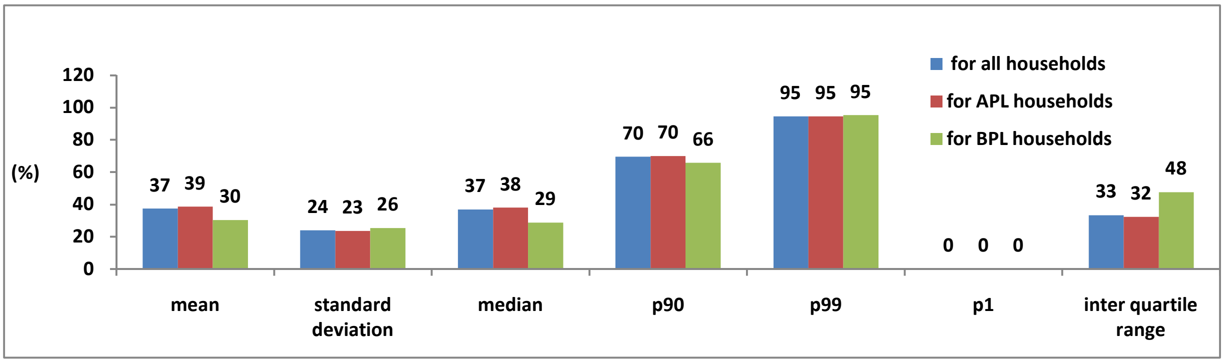
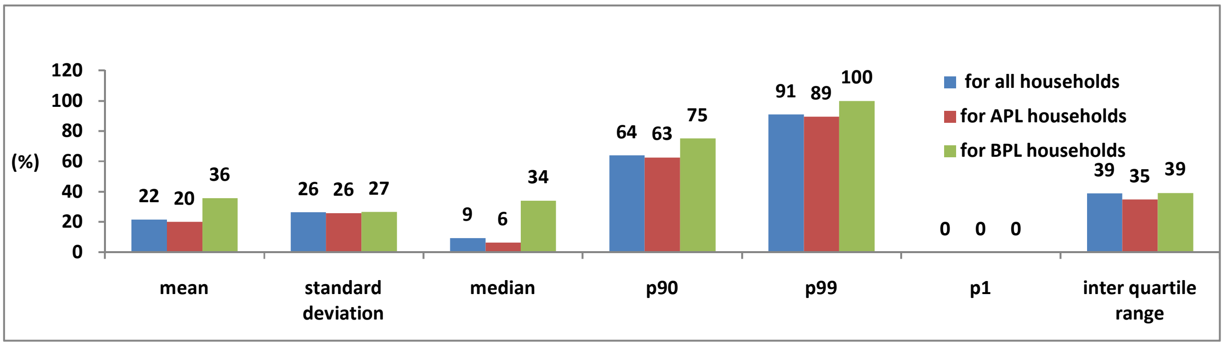


Figure 22: share of improved biomass stove costs in monthly fuel expenditure:



8.3.5 Distribution of fuel combination shares in households' budgets:

At this stage the actual energy scenario in the households is also examined. In reality, most of the households use combination of fuels for meeting their lighting and cooking needs. The largest group of households is those that use LPG for cooking and electricity for lighting purposes. The users of electricity for lighting and LPG for cooking typically come in the highest consumption category. On the second rung are the households that use electricity for lighting purposes in combination with either coal (coke) or biomass for cooking purpose. There is a large section of the sample households that use electricity for lighting and biomass for cooking. On the last rung are those households that use kerosene for lighting in combination with either coal (coke) or solid biomass for cooking purpose. The monthly expenses on two of the largest sections of the sample households using aforementioned combinations of fuels by the sample households are shown below:

Table 6: all households and APL and BPL households using LPG and electricity only:

	all households	APL households	BPL households
Number of households	6434	6113	299

Figure 23: actual monthly expenditure on LPG and electricity use of sample households:

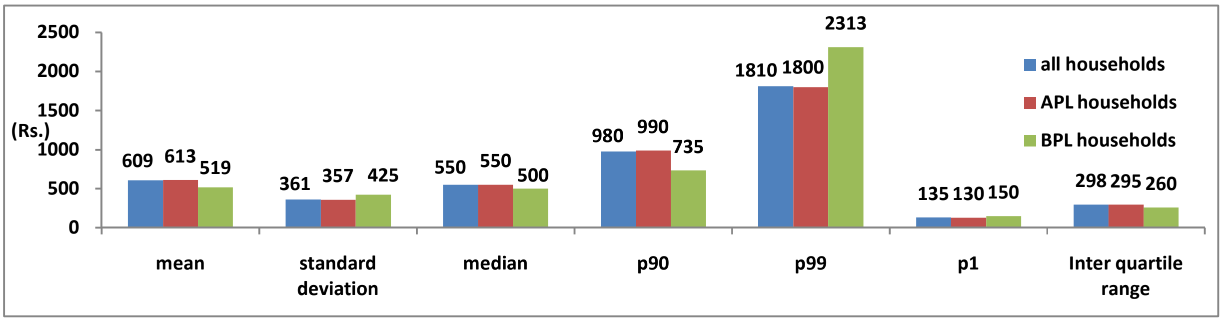
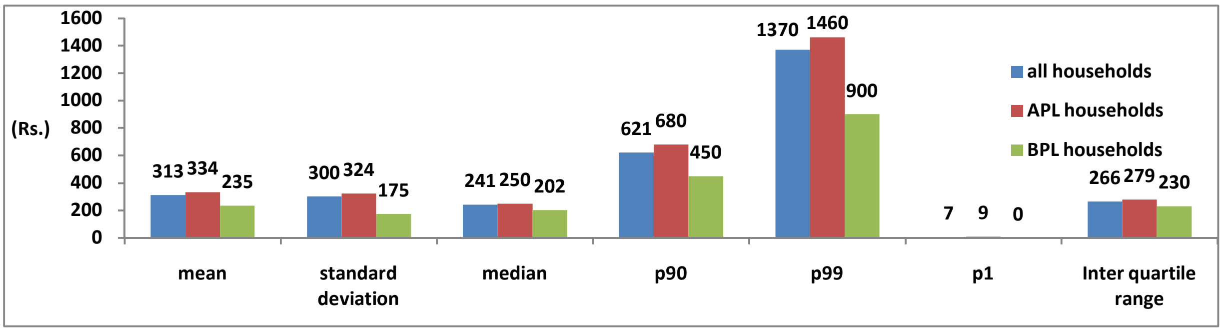


Table 7: all households and APL and BPL households using biomass and electricity only:

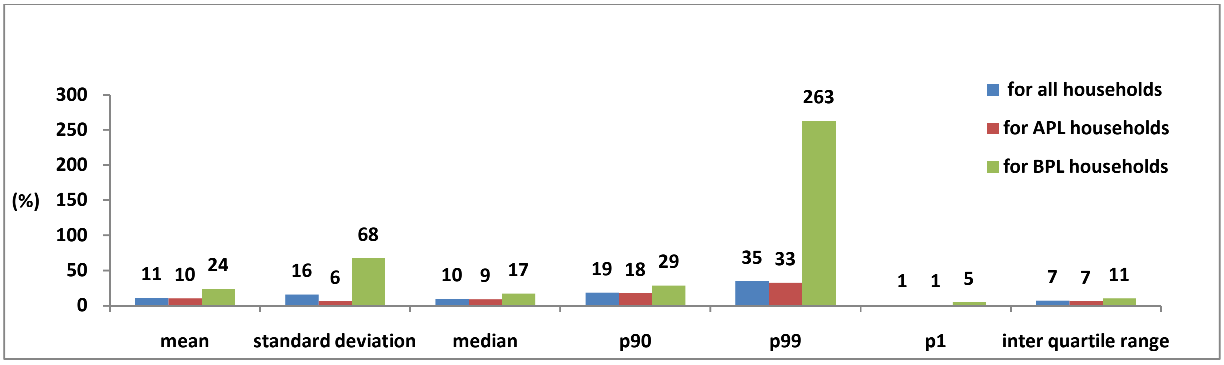
	all households	APL households	BPL households
Number of households	1812	1413	396

Figure 24: actual monthly expenditure on biomass and electricity use of sample households:



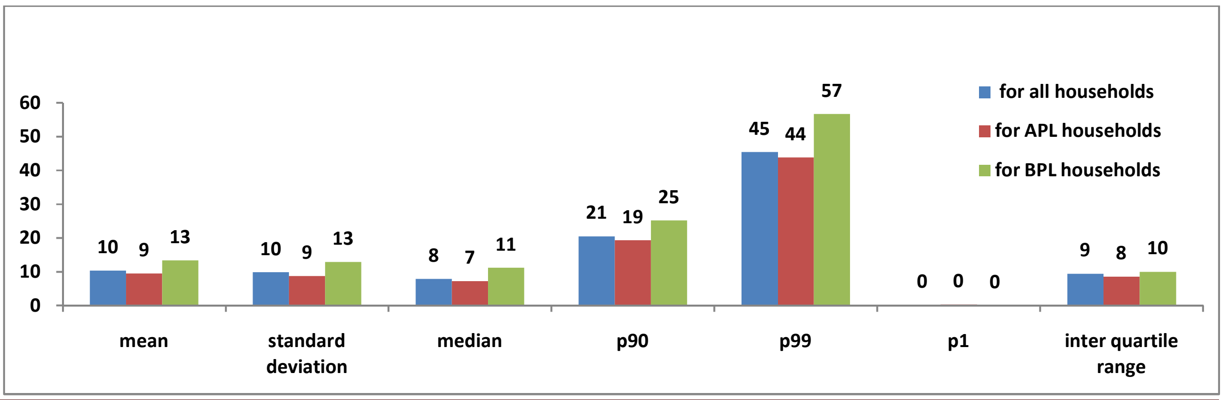
The expenditure on biomass and electricity is approx half of that on LPG and electricity. The shares of monthly expenditure on combinations of fuels in the total monthly consumption of sample households are shown below: These two charts display two ends of the spectrum of the energy poverty conundrum. The average share of LPG and electricity use in the monthly consumption expenditure of BPL households is two and half times that of APL households.

Figure 25: shares of LPG and electricity use in the monthly budget of sample households using these fuels only:



The standard deviation for this expense of BPL households is approx three times the mean expenses suggesting a large variability in the price structure, weak supply mechanism and possible procurement from illegal market sources. Lack of legal market access to clean and efficient fuels is another large contributor of energy poverty amongst poor households. The p 99 value exceeds the mean monthly consumption expenditure of BPL households by two and half times suggesting data unevenness in calculating consumption and income levels.

Figure 26: shares of biomass and electricity use in the monthly budget of sample households' using these fuels only:



Amongst those households that use electricity for lighting and biomass for cooking, the BPL households' share in the monthly consumption expenditure is more than the APL households by approx 50%. There appears to be greater reliability in using this combination of fuels than the previous pair as standard deviations for APL and BPL households are comparable.

8.4 Health effects and educational attainment of children as response variables:

8.4.1 Individual as an unit of analysis:

Regarding the study of health effects by the smoke produced by inefficient combustion of solid biomass on the inmates' of the households and the effect on the educational attainment of the children the following modus operandi was adopted. Adulthood in rural and semi-urban India comes early with teenagers handling farm related activities and doing odds livelihood jobs for home. So, individuals aged 15 and above were assumed to be adults for the purpose of this survey while those younger than 6 years are treated as small children. Children included small children too.

8.4.2 Health effects as response variables:

On the health effects, individual is considered the unit of study. The survey questionnaire has considered cough and breathlessness as short morbidity. Self declaration was used as a means to determine morbidity. It is assumed that short morbidity, as per the survey questionnaire, could be an indicator of occurrence of COPD or ARI. Occurrence of short morbidity of either one or both of cough and breathlessness in men, women, children and small children in households using bio mass burning cook stoves for three hours or more daily is clubbed together as a separate dependent variable and modeled separately for the four categories of individuals. Hypertension, heart disease, cataract and cancer are major morbidities believed to have smoke-related causation. So, occurrence of either one or more of the four diseases viz. heart disease, hypertension, cancer or cataract in the four categories of individuals living in households using bio mass burning cook stove is clubbed together to create a dependant variable for the four categories of individuals and modeled separately. So, in total there are eight models summarized in this paper.

8.4.2.1 Stove design:

The households using biomass cook stove of simplest technology, the three brick cook stove and the traditional stove without chimney are assumed to cause the same level of pollution effects on the inmates of the house. Thus, individuals living in households using anyone of the two varieties of cook stoves are considered as smoke-affected individuals. Those households using cook stoves for more than three hours daily are considered to be highly exposed to smoke. Those individuals living in such high-use households having short morbidity (as per the survey) were separated to study the effect of independent variables on their health conditions. For the individuals suffering from major morbidity, normal exposure was considered as enough since major diseases take longer period to develop and normal exposure over longer period of time is believed to have the requisite causation level.

8.4.2.2 Smoke exposure:

All members of households using biomass burning traditional stoves were assumed to be equally exposed to stove smoke. Men, women, children and young children have different levels of vulnerabilities to pollution. So the four categories of individuals are treated separately to understand and model adverse affect of pollution. Smoke exposure is the main element of the model. Short morbidities are self declarations of having a cough and / or breathlessness in the past one month of the survey interview. It is assumed that the short morbidities are indicators of COPD and / or respiratory infections.

8.4.2.3 Smoke related morbidities:

Adverse effect of smoke has been proved to be a strong causation for Acute Respiratory Infection (ARI), (Smith, Samet et al. 2000; Ezzati and Kammen 2001b; Bruce, Rehfuess et al. 2006), chronic obstructive pulmonary disease (COPD), (Bruce, Perez-Padilla et al. 2000), lung cancer(Mumford, He et al. 1987; Smith, Liu et al. 1993) and heart disease (Stanek 2010). Therefore, the health model uses occurrence of these diseases as indicator of health effect of stove smoke. The tables below indicate higher vulnerabilities of young children to smoke effect health problems.

Table 8: Impact of smoke exposure on children of age five and less (Small children):

number of small children	number of small children in biomass stove HH	number of small children in high users of biomass stove HH	number of all small children with short morbidity	number of small children with short morbidiy in high users of bio mass stove HH	number of all small children with major morbidity	number of small children with major morbidity in biomass stove HH
24314	18071	13084	4955	2699	13	9
100%	74%	54%	20%	11%	0.05%	0.04%

Table 9: Impact of smoke exposure on all children of age fourteen and less:

number of children	number of children in biomass stove HH	number of chilldern in high users of biomass stove HH	number of all children with short morbidity	number of children with short morbidiy in high users of bio mass stove HH	number of all children with major morbidity	number of children with major morbidity in biomass stove HH
68462	50275	36548	9114	4850	72	53
100%	73%	53%	13%	7%	0.1%	0.07%

Since younger children are more likely to spend most of their waking hours with their mothers, who are also the household cooks' so their exposure to stove smoke is likely to be severe too.

Table 10: Impact of smoke exposure on all children of age fourteen and less:

number of children	number of girl children	number of boy children	number of girl children in biomass stove HH	number of boy children in bio mass stove HH	number of girl children with short morbidity	number of boy children with short morbidity
68462	32743	35719	24100	26175	4177	4937
100%	48%	52%	35%	38%	6%	7%

Children of adolescent age, particularly boys will be exposed less to smoke and than girls of comparative age who could also be helping their mother do cooking. But the boys have more morbidities than girls. Women are considered to bear the main impact of the smoke exposure to the use of solid biomass burning cook stoves since they are the main persons cooking food.

Table 11: Impact of smoke exposure on women (females of age fifteen and more):

number of women	number of women in biomass stove HH	number of women in high users of biomass stove HH	number of all women with short morbidity	number of women with short morbidiy in high users bio mass stove HH	number of all women with major morbidity	number of women with major morbidity in biomass stove HH
73206	49045	33551	5301	2571	2794	1599
100%	67%	46%	0.07%	0.035%	0.04%	0.02%

Table 12: Impact of smoke exposure on men (males of age fifteen and more):

number of men	number of men in biomass stove HH	number of men in high users of biomass stove HH	number of all men with short morbidity	number of men with short morbidiy in high users of bio mass stove HH	number of all men with major morbidity	number of men with major morbidity in biomass stove HH
74086	49262	34039	3271	1614	1947	1021
100%	66%	46%	0.04%	0.02%	0.03%	0.01%

The men have lesser exposure to stove smoke and so have lesser morbidities of either type at both the high and low levels of smoke exposure. This is an indicator of men having less interest in improving the general health of women and children since they are unlikely to be affected as severely as most of them.

8.5 <u>Other explanatory variables for health effects as response variable:</u>

8.5.1 <u>Education level:</u>

Education levels in households of women, in particular and men in general are assumed to be indicators of gender relations and female empowerment. This element may create a distinction between households where men or women have better education levels than elsewhere. Therefore, education as a liberator acting as an independent variable or not is a critical factor. However, education as a deciding factor has its limitations too, as it needs certain favorable social conditions to operate independently. In these eight models, education level in both men and women was considered as high for passing grade six or more.

8.5.2 <u>Size of home, cooking place etc.:</u>

The size of the home and the place of cooking and availability of ventilation were considered as important elements in deciding pollution levels and thus directly affecting health of inmates. Cooking outside the house, having separate kitchen or having ventilation in the place of cooking were considered as having same effect on household pollution level. In these models, House size was considered as big if the number of rooms in the house were more than 2.

8.6 Educational attainment index as response variable:

IHDS survey used several indicators for measuring the educational attainment of the children. This analysis designed the following six indicators for formulating the overall education indicator for children. Of the six, the following four indicators are positive indicators that have increasing index number with positive gains in educational attainment.

1. School enrolment status of the children.
2. Classroom performance of children.
3. Classroom enjoyment of children.
4. Children praised in the classroom.

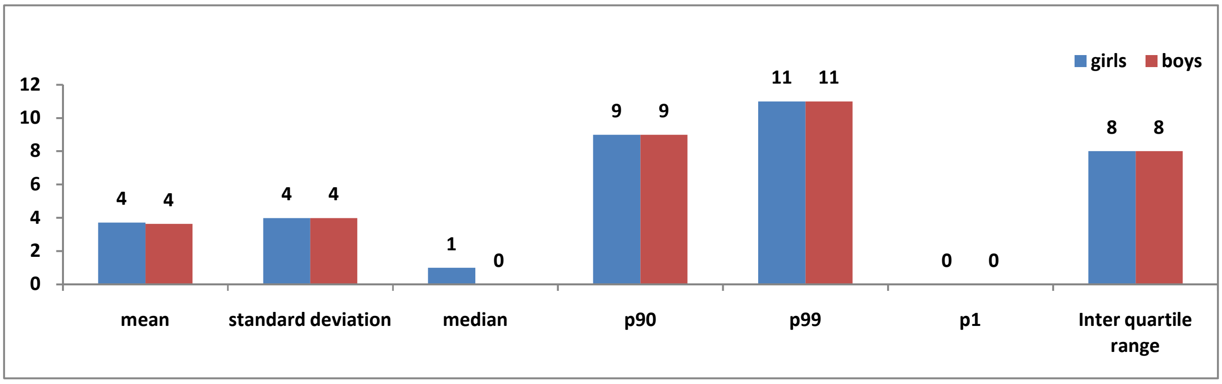
The following two indicators were designed to indicate negative losses in education process with increasing index numbers.

1. Grades repeated by children.
2. Punishment or beatings of children in classroom.

8.6.1 Design of index of educational attainment:

The overall education attainment indicator was designed by adding the four positive indicators and subtracting the last two indicators to give the educational attainment of a child. The IHDS provided information on these indicators for the first two children in the household. In order to determine the educational attainment for girl and boy children, indicators for girl and boy children were separately compiled for the first two children. Thereafter, educational attainment indicators for girl and boy children were computed separately to arrive at the composite index. Interestingly, girls and boys have equal educational attainment, though girls spend more time collecting firewood and possibly also doing household chores.

Figure 27: educational attainment index:

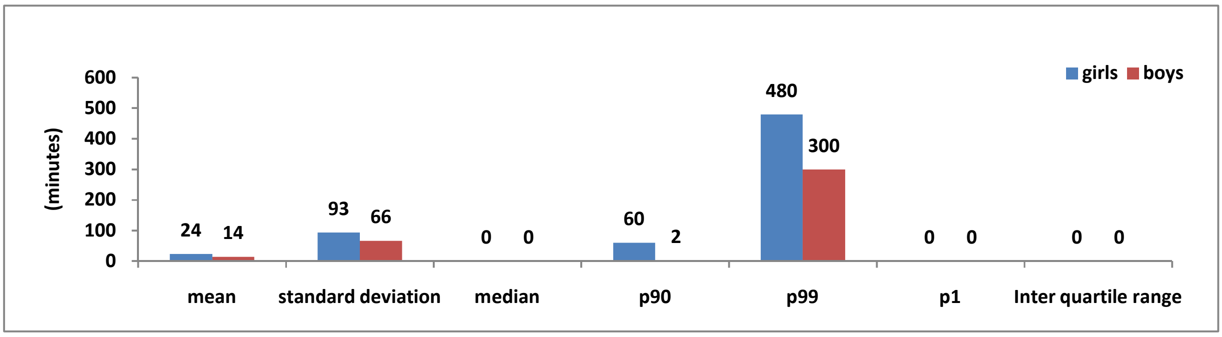


8.7 Explanatory variables for educational attainment as response variable:

8.7.1 Time spent in collecting fuel wood:

Time spent by the girl and boy children in collecting firewood was another indicator used to test educational attainment of children. Mean time spent collecting firewood by girls was 70% more than boys.

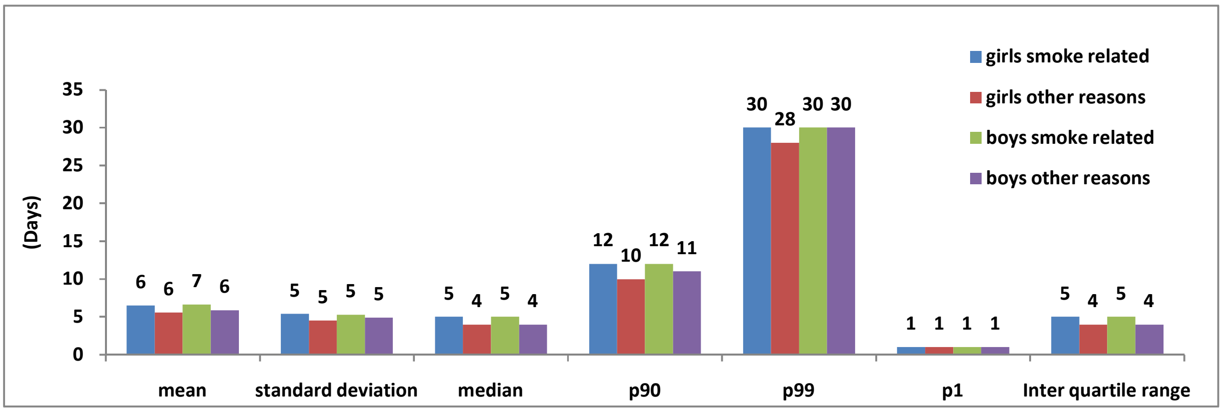
Figure 28: time taken collecting firewood per week (in minutes):



8.7.2 Number of sick days in the month preceding the survey:

The number of days in the month preceding the interview for which the children were sick due to smoke related morbidities or for other reasons like diarrhea, fever etc. is indicated below. It is assumed that morbidities in children exposed to smoke are due to adverse effects of stove smoke only. There are no major differences in the occurrence of morbidities due to smoke exposure or due to other reasons.

Figure 29: sick days in last month:



9. Models on energy poverty:

The *Appendix on understanding energy poverty* has results on correlation, regression and elasticities of total fuel share, clean and mixed fuel shares with income proxy computed to understand and develop the models discussed in this section. The control variables were added separately in the models discussed in the appendix to understand their individual impact on the response variable. The results obtained in the appendix confirm those obtained in this section with models using income proxy and other control variables to explain individual and total fuel shares in household consumption.

9.1 Models on fuel shares and fuel purchase with income proxy:

Initially the share of fuel purchase by a household in the total purchases made were regressed with explanatory variables of highest education level of adult female and adult male in the household, number of family members in the household and whether they live in urban or rural areas. All the regression coefficients were significant at 1%. There is an indication of declining share of spending on fuels with income while the absolute spending on fuels actually increases with income. However, the elasticity coefficient of fuel share with proxy income is not significant indicating that the magnitude and direction of decline may not be valid over the entire distribution of income proxy for the sample households.

	fuel shares in total purchases	fuel spending
Income proxy	-0.0005	0.02
p value	0.000	0.000
female education	0.06	8.6
p value	0.000	0.000
male education	0.02	6.8
p value	0.000	0.003
family size	-0.2	7.9
p value	0.000	0.000
urban background	2.6	143
p value	0.000	0.000
constant	11.9	100.2
p value	0.000	0.000
R^2	0.13	0.25
p value	0.000	0.000
elasticity	-0.25	0.22
p value	0.481	0.000

Households with educated adults and urban households are likely to have large increase in fuel shares as well as in actual fuel spending. Presence of large number of family members is likely to make the fuel share in the overall household purchases smaller. This indicates that share of non-fuel items in the budget, possibly food share, may rise to meet the needs of their food consumption.

9.2 Models of various fuel shares and income proxy with control variables:

9.2.1 For all households:

Table 13: OLS regression models of various fuels' shares with income proxy and control variables for all households:

	biomass	LPG	electricity	kerosene	LPG & electricity	biomass & electricity
Income proxy	-0.001	0.0008	0.001	-0.001	0.002	-0.00005
p value	0.000	0.000	0.000	0.000	0.000	0.172
female education	-1.2	1.2	0.6	-0.7	1.8	-0.5
p value	0.000	0.000	0.000	0.000	0.000	0.000
male education	-1.01	0.9	0.7	-0.5	1.5	-0.3
p value	0.000	0.000	0.000	0.000	0.000	0.000
family size	0.9	-1.2	-0.4	0.6	-1.7	0.5
p value	0.000	0.000	0.000	0.000	0.000	0.000
urban background	-17.8	17.2	6.3	-6.7	23.4	-11.5
p value	0.000	0.000	0.000	0.000	0.000	0.000
constant	47.8	4.6	17.4	27.9	22.1	65.2
p value	0.000	0.000	0.0000	0.000	0.000	0.000
R^2	0.28	0.36	0.14	0.13	0.42	0.08
p value	0.000	0.000	0.000	0.000	0.000	0.000
elasticity	-0.05	0.12	0.13	0.41	0.17	-0.004
p value	0.999	0.997	0.000	1.000	0.000	0.173

While the share of fuel in the purchase made by households is likely to decline with income proxy, individual fuel shares move differently. The share of inferior fuels like biomass and kerosene is likely to decline with income while that of superior fuels like LPG and electricity is likely to increase. The elasticity coefficient of electricity and LPG share is also significant at 1% indicating their increasing share in household budget across the distribution of income proxy of sample households. Educated and urban households have increasing shares of superior fuels and decreasing shares of inferior fuels. Family size is likely to inhibit this trend and bigger families are likely to increase their share of expenditure on inferior fuels. However, this trend is not universal across the distribution of income proxy as the elasticity coefficients of inferior fuel shares are not significant.

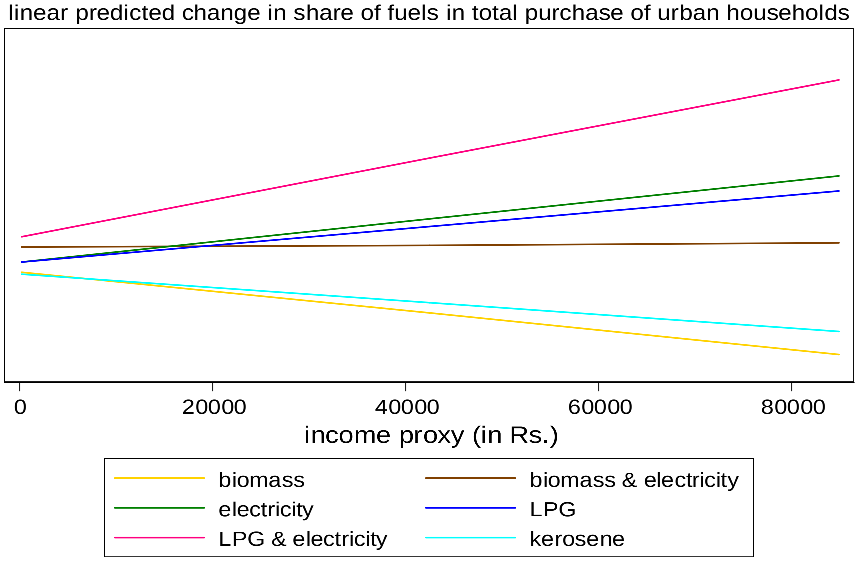
9.2.2 For urban households:

Table 14: OLS regression models of various fuels' shares with income proxy and control variables for urban households:

	biomass	LPG	electricity	kerosene	LPG & electricity	biomass & electricity
Income proxy	-0.0005	0.0002	0.0008	-0.0004	0.001	0.003
p value	0.000	0.000	0.000	0.000	0.000	0.000
female education	-0.9	1.05	0.5	-0.5	1.6	-0.4
p value	0.000	0.000	0.000	0.000	0.000	0.000
male education	-1.1	1.3	0.5	-0.7	1.9	-0.5
p value	0.000	0.000	0.000	0.000	0.000	0.000
family size	1.4	-1.5	-0.3	0.1	-1.8	1.2
p value	0.000	0.000	0.000	0.189	0.000	0.000
constant	24.1	23.7	25.2	22.2	48.9	49.4
p value	0.000	0.000	0.000	0.000	0.000	0.000
elasticity	0.4	0.03	0.1	-0.27	0.07	0.04
p value	1.000	0.000	0.000	0.985	0.000	0.000

The models indicate that the superior fuels share are increasing in urban households thereby indicating that at their present level of consumption the households are not meeting their needs of superior fuels. Hence they are likely to classify as "energy poor". Since urban households are more likely to use more of superior fuels than rural households so it can be surmised that the rural households by implication are likely to classify as "energy poor" too.

Figure 30: Linear predicted change in share of fuels with income proxy in case of urban households:

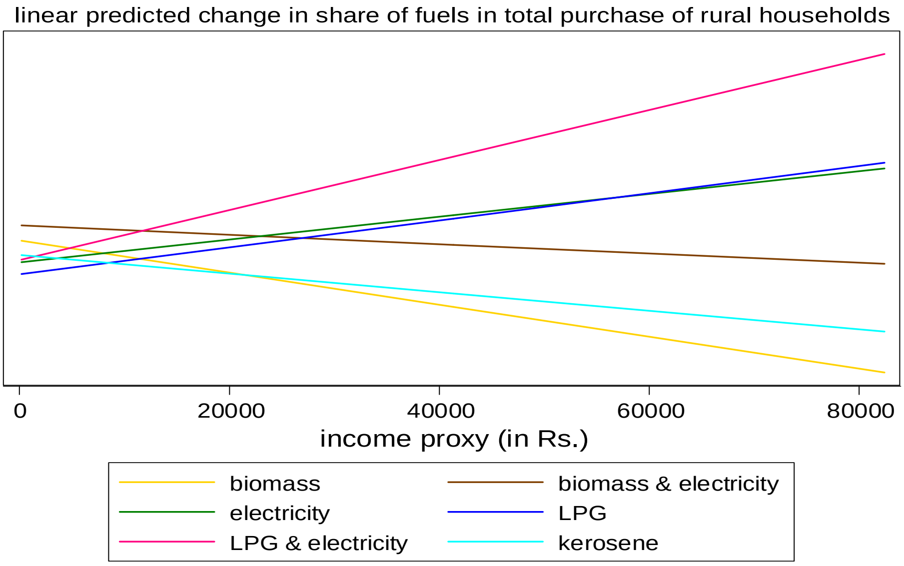


9.2.3 For rural households:

Table 15: OLS regression models of various fuels' shares with income proxy and control variables for rural households:

	biomass	LPG	electricity	kerosene	LPG & electricity	biomass & electricity
Income proxy	-0.001	0.001	0.001	-0.001	0.002	-0.0004
p value	0.000	0.000	0.000	0.000	0.000	0.000
female education	-1.3	1.3	0.8	-0.8	2.1	-0.5
p value	0.000	0.000	0.000	0.000	0.000	0.000
male education	-0.9	0.6	0.7	-0.4	1.4	-0.2
p value	0.000	0.000	0.000	0.000	0.000	0.000
family size	0.8	-1.2	-0.6	0.9	-1.8	0.3
p value	0.000	0.000	0.000	0.000	0.000	0.000
constant	49.9	3.7	16.9	27.4	20.7	66.9
p value	0.000	0.000	0.000	0.000	0.000	0.000
R^2	0.13	0.22	0.09	0.07	0.26	0.01
p value	0.000	0.000	0.000	0.000	0.000	0.000
elasticity	-0.074	0.89	0.15	0.18	0.26	-0.024
p value	0.982	0.997	0.000	0.998	0.000	0.000

Figure 31: Linear predicted change in share of fuels with income proxy in case of rural households:



From the indicated regression results, it is seen that share of superior fuels in the urban as well as rural households is increasing. The elasticities are positive and significant for LPG and electricity shares in case of both the models reiterating that the shares of superior fuels are likely to increase across the distribution of income proxy. In both urban as well as rural households, education level of adults is the biggest mover for superior fuels and adults' female education level is a bigger mover than adults' male education levels. In rural areas, educated females are more likely to opt for cleaner fuels than in urban areas. The biggest negative reason for households' opting for inferior fuels is to provide for bigger families. So, with larger family size kerosene is likely to replace electricity as the fuel for lighting up houses. Similarly, bigger families are more likely to use biomass for cooking than LPG. There is likely to be increase in the share of expenses on superior fuels as income levels, education levels and urbanization increases in the sample population, so at present level of consumption the sample households are likely to classify as “energy poor”.

If the sample survey can be considered to represent the country then broad conclusion on similar lines can be drawn about Indian households in general.

10. Implications of energy poverty on health:

Health effects were examined on individuals in households using traditional biomass stoves. The exposure levels were examined at high (for households using biomass stove for at least 3 hours or more) and at normal (for households using biomass stove for 1 hour or more).

10.1 The explanatory variables were:

1. Level of exposure to smoke (high or normal)
2. Highest level of female and male education
3. Level of exposure of smoke to women
4. Ventilation and cooking place
5. Income, consumption and poverty levels

10.2 Relation between health effects and smoke effect:

10.2.1 Relation between respiratory health and smoke effect:

Occurrence of respiratory diseases impact the small children, all children, women and men in progressively stronger degrees indicating higher vulnerabilities of young children and occupational hazards of cooking for women. Educated women are unable to prevent smoke exposure and consequent respiratory infection in their children, though they are able to check and reduce their personal morbidities.

Table 16: OLS regressions of occurrence of short morbidities (respiratory infections) in family members of sample households using traditional biomass stoves:

with the following variables	small children	all children	women	men
high exposure to smoke	0.21	0.13	0.08	0.05
p value	0.000	0.000	0.000	0.000
highest female education	0.001	0.004	-0.001	-0.0002
p value	0.043	0.000	0.034	0.556
highest male education	-0.00003	0.002	-0.001	-0.002
p value	0.954	0.002	0.077	0.000
house size	-0.001	-0.003	-0.002	-0.0006
p value	-0.004	0.000	0.000	0.108
high exposure to women	-0.0005	-0.0002	0.08	-
p value	0.463	0.813	0.000	-
ventilation	0.002	0.004	0.002	0.002
p value	0.000	0.000	0.000	0.000
cooking away from living area	0.001	0.003	-0.0005	-0.001
p value	0.002	0.000	0.369	0.121
income	-8E-09	-1E-08	-9E-09	-1E-08
p value	0.001	0.001	0.000	0.000
poverty	-0.004	-0.01	-0.004	-0.003
p value	0.000	0.000	0.000	0.000
consumption	6E-07	6E-07	1E-06	9E-07
p value	0.036	0.101	0.000	0.000
constant	-0.0001	-0.002	0.002	0.002
p value	0.791	0.006	0.000	0.000

Residents of bigger houses have lesser morbidities because of dilution effect as well as affluence. The survey seems to have interpreted ventilation incorrectly. Alternatively, women and children may get more exposure if they consider the kitchen area to be ventilated, leading to higher all around morbidities. Sample households have as high or higher smoke concentrations in open areas indicating higher morbidities associated with cooking away from living area. Perhaps the open spaces are children play area. Income has negative association with morbidities. Consumption has positive association with morbidities in women, indicating low priority in using clean fuel or lack of access / availability.

10.2.2 Relation between major smoke related morbidities and smoke effect:

Table 17: OLS regressions of occurrence of major morbidities in family members of sample households using traditional biomass stoves:

with the following variables	small children	all children	women	men
short morbidity	0.00003	0.0003	0.21	0.21
p value	0.763	0.048	0.000	0.000
normal exposure to smoke	0.0005	0.001	0.03	0.02
p value	0.000	0.000	0.000	0.000
highest female education	0.00002	0.00001	0.003	0.002
p value	0.515	0.893	0.000	0.000
highest male education	-0.00001	-0.00006	-0.0003	-0.001
p value	0.658	0.425	0.439	0.036
house size	5E-06	5E-06	0.0005	0.0005
p value	0.865	0.865	0.232	0.096
normal exposure to women	6E-06	0.00001	0.03	-
p value	0.867	0.889	0.000	-
ventilation	-0.00004	0.0001	-0.001	-0.001
p value	0.267	0.351	0.0308	0.011
cooking away from living area	-3E-06	-0.00004	0.003	0.002
p value	0.933	0.581	0.000	0.000
income	-1E-10	-4E-10	-7E-09	-3E-09
p value	0.414	0.265	0.002	0.054
poverty	-0.00003	-0.0001	-0.002	-0.002
p value	0.337	0.237	0.000	0.000
consumption	-5E-10	3E-08	-2E-06	1E-06
p value	0.978	0.503	0.000	0.000
constant	0.00002	0.0001	-0.003	-0.002
p value	0.568	0.500	0.000	0.000

All family members' exposed to smoke are more susceptible to major morbidities. Adults have more chances to acquire major morbidities if they are pre-diseased with respiratory infections. Educated women have positive and growing association with major morbidities for themselves and for their men with higher exposure levels that seems to indicate lack of access to clean fuels despite awareness. Here, ventilation in cooking area has negative influence on major morbidities in women and men. Income and poverty exert negative influence on major disease occurrence in women and men. Consumption, however, exercises, opposite influence on women and men. While it reduces incidences in women, it supports higher incidences in men, indicating external stimuli propping major diseases in them.

11. Implications of educational attainment for children:

In order to understand the impact of use of biomass as fuel in traditional stove on the educational attainment of children, correlation and regression coefficients of the constructed educational attainment index with exposure to smoke and with time spent in collecting firewood were computed. The correlation coefficients of educational attainment index with smoke exposure are more negative for boy children than girl children, indicating more negative effect of smoke on boy children's academic performance.

11.1 Relation between educational attainment index and smoke effect:

Table 18: correlation of educational attainment index in children in biomass stove using sample households (x = not significant):

	for girl children	for boy children
with exposure to stove smoke	-0.03	-0.04
with time spent collecting firewood	0.007	x
with number of sick days	x	x

Girls spend more time collecting firewood but the correlation coefficient has positive correlation with their educational attainment index. There could be some misinterpretation of data in translating from the interview to the coding or perhaps the visit to collect firewood could be utilized for studying as well. Correlation coefficients for explanatory variables for girls and boy children were computed. They do not appear to be excessively correlated.

Table 19: correlation coefficients of explanatory variables for girl children:

	with smoke exposure	with sick time with short morbidity
with time spent collecting firewood	0.0639	0.0189
with sick time with short morbidity	0.0742	
correlation coefficients of explanatory variables for boy children		
	with smoke exposure	**with sick time with short morbidity**
with time spent collecting firewood	0.0642	0.0264
with sick time with short morbidity	0.0742	

However, OLS regressions show that girls' education suffers more than boys' with smoke exposure. The single variable regression model is significant at 1%.

Table 20: OLS regression of educational attainment index in children in biomass stove using sample households:

	for girl children	for boy children
with exposure to stove smoke	-0.61	-0.58
p value	0.000	0.000
constant	7.7	7.7
p value	0.000	0.000
R^2	0.01	0.01
p value	0.000	0.000

Explanatory variables for time for collecting firewood and time the child was sick with short morbidities were added to the models for girl children and boy children. The models with control variables indicate that the educational attainment for boys is more adversely affected than girls' educational attainment index.

Table 21: OLS regression of educational attainment index of children in biomass stove using sample households:

	for girl children	for boy children
with exposure to stove smoke	-0.66	-0.78
p value	0.038	0.016
with time for collecting firewood	0.001	-0.003
p value	0.083	0.004
with sick time with short morbidity	0.0005	-0.05
p value	0.423	0.048
constant	8.1	7.9
p value	0.000	0.000
R^2	0.06	0.04
p value	0.000	0.000
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity		
chi^2	0.09	0.72
p value	0.7698	0.3967

Though the two models are significant at 1%, Breusch-Pagan / Cook-Weisberg test for heteroskedasticity was done to see if the error terms do not have equal variance. The computed values of chi^2 and p terms indicated that the error terms did not have constant variance for the two models. This could be because certain explanatory variable(s) have large variability (Greene 2008). The variable of collection time of fuel wood had excessive variation as the requirement of biomass by households using traditional stoves cover a large range; this could be a factor in introducing heteroskedasticity in error terms. As a result, the standard errors and the p values may not be accurate. Both the model, the p value of the heteroskedasticity test is significant at 10%, though the value of chi^2 is somewhat high for boys' model.

Log transformation of explanatory and dependent variables did not correct the heteroskedasticity of error terms. Next, robust standard errors were used, but still the p values were not significant. The models with robust errors were not significant too. Assuming that the error terms vary with the explanatory variable for collecting time of fire wood, weighted least square procedure was used to correct heteroskedasticity. This explanatory variable was used as a divisor to divide the independent and all dependent variables and then OLS regression was done to estimate the model.

11.2 Model using weighted least square procedure:

The coefficient of the reciprocal of the explanatory variable used for making transformation in the transformed equation is intercept of the original equation. The intercept of the transformed equation is the coefficient of the explanatory variable used in the transformation. Both the models are significant and the error terms have equal variance (homoskedastic). But the main explanatory variables are not significant. In case of girl children, the coefficient of transformed firewood collecting time is less positive than for boys. Also, for girl children coefficient of transformed sick time is more negative than for boys.

Table 22: OLS regression of ratio of educational attainment index of children to firewood collecting time in biomass stove using sample households:

	for girl children	for boy children
with ratio of exposure to stove smoke to firewood collecting time	0.2	-0.5
p value	0.942	0.589
with firewood collecting time (intercept of transformed equation)	0.03	0.04
p value	0.000	0.000
with ratio of sick time with short morbidity to firewood collection time	-0.15	-0.08
p value	0.037	0.103
with reciprocal of firewood collecting time (intercept of original equation)	3.7	4.2
p value	0.148	0.000
R^2	0.33	0.41
p value	0.000	0.000
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity		
chi^2	749.3	461.9
p value	0.000	0.000

This indicates that the firewood collecting and sick time affects girl children more adversely than boys'. Overall the model has standard errors with constant variance. The models are significant at 1%.

12. Conclusions:

12.1 On energy poverty:

There is a strong parallel between relation of food share and energy share with household consumption expenditure. With growing affluence, food share in the household budget declines. Similarly, energy share in the household budget should decline too. Analysis of sample data households indicates that the energy share of the BPL households' consumption budget is more than the APL households'. Fuel share in the household budget of BPL households is approximately 50 % more than APL households. However, the picture is not that simple and there are two prominent departures from an analogy between the food share and energy share.

All sources of energy are not equivalent. There are inferior and polluting sources of energy like the solid biomass that are used by the poor and those who lack access to the superior fuels like LPG and electricity. So, with growing affluence, the share of inferior fuels is likely to decline and the households are likely to use more of superior fuels. The poorer households use a large portion of their fuel budget on inefficient and polluting sources of energy. This is the first major departure from the food budget analogy. Substitution of inferior energy sources by superior energy sources as income increases is the energy ladder concept that is found valid in the sample data.

Large numbers of APL as well as BPL households occupy two levels on the energy ladder. This is the second difference between food and energy shares in household budget. Even several APL households (62%) use an inferior fuel, the solid biomass as cooking fuel. So, they cannot be said to be free from energy poverty completely except that their share of expenditure on energy in their monthly budget is lesser than the BPL households and their share of inferior fuel is lesser. At the same time several BPL households (58%) have access to one superior energy source, the electricity. This makes determining the point of changeover to complete freedom from energy poverty a challenge.

Looking at the actual energy usage in the sample data, it is clear that the households use more than one fuel, generally a fuel for a particular usage. Electricity or its cheaper substitute kerosene is used for lighting usage, while LPG is substituted by solid biomass sources or coal for cooking usage. In case there is decline in share of a combination of fuels, the decline in use of that fuel should be indicated in negative correlation and regression coefficients. The coefficients of elasticities of change in share of that pair of fuels in the consumption expenditure with change in consumption expenditure should indicate elastic behavior to show changing shares.

Analyzing change in overall energy share with consumption levels, decline in energy shares for BPL households are tenfold more that of APL households. But the trend does not indicate that decline in shares are elastic, though the coefficients are less inelastic for BPL than for APL households. One indication of being free from energy poverty is declining share of superior fuels in APL households. The negative regression coefficients of fuel budget for share of LPG and electricity in the fuel budget of APL households indicate that their share is likely to decline. However, the coefficients of elasticities were determined to be highly inelastic. Also, the elasticities for change in the share of LPG and electricity in the consumption expenditure with change in fuel budget were determined to be inelastic and positive.

Another way to determine the shift from energy poverty is to examine the change in the share of biomass and electricity in the fuel budget with changing consumption level and changing fuel budget. While the share of biomass and electricity in consumption budget declines with increase in consumption, their share in the consumption budget expands into the non-fuel side of the consumption budget with increase in fuel spending at constant consumption budget. Elasticities' coefficients of share of biomass and electricity in monthly consumption budget of the households with monthly consumption budget are not significant and that with monthly fuel budget are inelastic.

The impact of adding explanatory variables like family size, education level and place of residence on the share of energy in the consumption budget and fuel budget was examined. Family size reduced the share of energy share in consumption by expanding non-fuel consumption when the budget was fixed. Education increased the share of fuel possibly due to shift to expensive superior fuels, but the share of pair of LPG and electricity did not indicate elastic coefficients with education. Urban residence increased the share of fuels in household budget but the direction of change in share was not established because correlation and regression coefficients were not significant.

To conclude, overall the direction of change in the share of inferior fuels is likely to be declining and that of superior fuels is likely to be inclining with income proxy. There is, however, a general decline in the energy share with income proxy. The elasticities of inferior (biomass) fuel share as well as superior (LPG) fuel shares in consumption were inelastic because of different reasons. Family size appears to be an important determinant of the type of fuel shares in the household budget. Variability in supply and lack of reliable supply channels for superior fuels could possibly reduce the occurrence of energy poverty in vast majority of APL households. The BPL households could also benefit from supply of superior fuels in smaller packets and through mechanisms for direct and easy transactions to purchase efficient fuels. Unlike the Linear approximate Almost Ideal Demand System (LA-AIDS) study using micro data of more than 100,000 households sampled across India, where price elasticities of more than 1 were computed for fuel wood while that for kerosene, LPG and electricity were generally less than one, in this case the elasticities of change in share of fuels were always computed to be less than one (Gundimeda and Kohlin 2008). However, the findings of another study in Kolkata, India that found weak cross-price elasticities at work to displace entrenched polluting fuels in favor of efficient fuels like LPG using subsidies rather than by improving supply channels and by improved awareness about their adverse health impact seems more relevant for this study (Gupta and Kohlin 2006).

12.2 On implications for health of women and children:

Health effects' models on family members of households using traditional stoves using biomass underline greater sensitivity and vulnerabilities of children, particularly young children to smoke exposure. Since they are more likely to remain with their mothers who are cooking, so even for educated women, the young children cannot escape morbidities associated with smoke exposure. Women have more major morbidities of all the members being directly exposed to cook stove smoke. However, women do not find space for decision making to use cleaner fuels even if affordable, could be at work here, as in case of patriarchal society in Sudan (El Tayeb Muneer and Mukhtar Mohamed 2003). Surprisingly, ventilation and open cooking places actually indicate higher disease incidences, pointing at living practices where open spaces might also be children play area and/ or sitting area for women and men. There are studies elsewhere in developing countries indicating that open spaces close to the houses using bio mass cook stoves are likely to be as polluted as the inner spaces. Bolivian case is an example in hand (Albalak, Keeler et al. 1999). As affluence reduces the use of inferior fuels but only in degrees, so there are mixed results with income, consumption and poverty as explanatory variables. On the whole, higher income levels reduce the incidences of morbidities to certain extent.

12.3 On implications for educational attainment of children:

The girl children spend more time (mean 70%) than boy children in collecting firewood. They spent almost the same time to cope with morbidities as the boy children. Their educational attainment index was determined to equal that of boy children. The analysis indicated that while the girl children are more likely to display poor academic performance as a result of time spent in collecting firewood and the time spent sick, the boy children are likely to have large negative effect of any of those conditions. The results of school level examinations in India indicate that the girls outperform boys almost always. This makes the case for the higher pressures and strain on the girls in home as well as education field. Considering the social bias against girl children, their higher academic performance is indicative of the need to provide social reforms in this area.

13. Further research:

Since the IHDS survey is a living situation survey so it does not focus exclusively on energy choices and use of traditional biomass stoves. It did not seek information in the questionnaires on the quantity of fuels used by the households. Indian biomass fuels and coal have large range of calorific values so it was not possible to compute energy equivalent of the money spent in purchasing these fuels. As per the questionnaire, electricity, LPG and kerosene were purchased by the sample households from several sources, including illegally by some of them, so it was not possible to compute the exact quantity of fuels used by these households. As a result the comparative energy usages were computed on the money value of the share of fuels in the total consumption, based on the premise that higher money value consumption has a linear relation to energy consumption. The distinction between BPL households and APL households is artificial but it does indicate a watershed level in the share of energy in the household consumption. Computing the elasticities of changing share of non-fuel food items in the consumption budget of the sample households would have shed more light on the results obtained for elasticities of change in share of fuels in household expenditure and the effect that expanding fuel budget within fixed household budget has on non-fuel food budget of the households.

Health conditions were self declaration by the adult women and men of the households. The questionnaire did not ask the interviewee who cooked mostly in the family. That would have helped determine exactly the health effects on the person most exposed to biomass smoke. So, the assumption that all family members are equally exposed to the number of hours the cooking is done was made. Therefore, the regression coefficients could be on the higher side for the men and also older children, particularly boys who are likely to spend a considerable portion of their free time outdoors.

There is need to examine through intensive analysis using cohorts in the survey data to see the effect of smoke stove on educational attainment of children, particularly girl children. The influence of time loss in collecting fuel wood, in smoke-related morbidities and in smoke exposure perhaps needs to be captured more clearly by a revised survey.

References:

1) Albalak, R., G. J. Keeler, et al. (1999). "Assessment of PM10 Concentrations from Domestic Biomass Fuel Combustion in Two Rural Bolivian Highland Villages." Environmental Science & Technology **33**(15): 2505-2509.
2) Barnes, D. F. and H. A. Samad (2011). "Energy poverty in rural Bangladesh." Energy Policy **39**(2): 894-904.
3) Bhide, A. and C. R. Monroy (2011). "Energy poverty: A special focus on energy poverty in India and renewable energy technologies." Renewable and Sustainable Energy Reviews **15**(2): 1057.
4) Bruce, N., R. Perez-Padilla, et al. (2000). "Indoor Air Pollution in Developing Countries: A Major Environmental and Public Health Challenge." Bulletin of the World Health Organization **78**: 1078-1092.
5) Bruce, N., E. Rehfuess, et al. (2006). "Indoor Air Pollution." Disease Control Priorities in Developing Countries **II**(New York: Oxford University Press): 793-816.
6) Coder, J. (1991). "Exploring non-sampling error in the wage and salary income data from the March current population survey." Household and Household Economic Statistics Division, Bureau of the Census, Washington D.C.
7) DANDEKAR, V. M., P. V. SUKHATME, et al. (1993). "Report of The Expert Group on Estimation of Proportion and Number of Poor."
8) Deaton, A. (1997). The analysis of household surveys [electronic resource] : a microeconometric approach to development policy, Baltimore, MD : Published for the World Bank [by] Johns Hopkins University Press, c1997.
9) DeFries, R. and D. Pandey (2010). "Urbanization, the energy ladder and forest transitions in India's emerging economy." Land Use Policy **27**(2010): 130-138.
10) Dherani, M., D. Pope, et al. (2008). "Indoor air pollution from unprocessed solid fuel use and pneumonia risk in children aged under five years: a systematic review and meta-analysis." Bulletin of the World Health Organization **86**: 390-398C.
11) El Tayeb Muneer, S. and E. W. Mukhtar Mohamed (2003). "Adoption of biomass improved cookstoves in a patriarchal society: an example from Sudan." The Science of The Total Environment **307**(1-3): 259-266.
12) Ezzati, M. and D. Kammen (2001b). "An Exposure-Response Relationship for Acute Respiratory Infections as a Result of Exposure to Indoor Air Pollution From Biomass Combustion in Kenya." The Lancet **358**: 619-624.
13) GOVERNMENT OF INDIA, P. I. B. (2007). "POVERTY ESTIMATES FOR 2004-05."
14) Greene, W. H. (2008). "Econometric Analysis - 6th ed.".
15) Gundimeda, H. and G. Kohlin (2008). "Fuel demand elasticities for energy and environmental policies: Indian sample survey evidence." Energy Economics **30**(2008): 517-546.
16) Gupta, G. and G. Kohlin (2006). "Preferences for domestic fuel: Analysis with socio-economic factors and rankings in Kolkata, India." Ecological Economics **57**(2006): 107-121.
17) Minhas, B. S. (1988). "Validation of large scale sample survey data: case of NSS household consumption expenditure " Sankhya **Series B**(50 supplement): 1-63.
18) Minhas, B. S. and S. M. Kansal (1989). "Comparison of NSS and CSO estimates of private consumption : some observations based on 1983 data " The Journal of Income and Wealth **11**: 7-24.
19) Mishra, V., K. Smith, et al. (2005). "Effects of Cooking Smoke and Environmental Tobacco Smoke on Acute Respiratory Infections in Young Indian Children." Population & Environment **26**(5): 375-396.

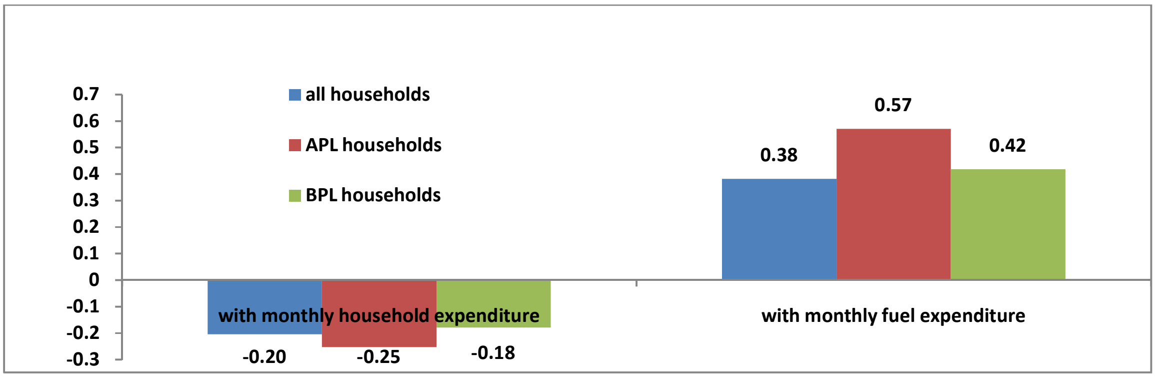
20) Modi, V., M. S., et al. (2006). "Energy and the Millennium Development Goals." Energy Sector Management Assistance Programme, United Nations Development Programme, UN Millennium Project, and World Bank New York.
21) Mumford, J. L., X. Z. He, et al. (1987). "Lung Cancer and Indoor Air Pollution in Xuan Wei, China." Science **235**(4785): 217-220.
22) Perez-Padilla, R. S., A; Riojas-Rodriguez, H (2010). "Respiratory health effects of indoor air pollution [Review article]." The International Journal of Tuberculosis and Lung Disease **14**: 1079-1086.
23) Report, M. D. G.-I. C. (2009). "Mid Term Statistical Appraisal." Central Statistical Organization. Ministry of Statistics and Programme Implementation.Government of India.
24) Smith, K., Y. Liu, et al. (1993). "Indoor Air Pollution in Developing Countries." Epidemiology of Lung Cancer(Lung Biology in Health and Disease)(New York: Marcel Dekker.).
25) Smith, K. R., J. M. Samet, et al. (2000). "Indoor air pollution in developing countries and acute lower respiratory infections in children." Thorax **55**(6): 518-532.
26) Stanek, L. W., Sacks, Jason D , Dutton, Steven J. , Ross, Mary (2010). "A Review of the Current State of Science for Health Effects of Particulate Matter " EM **n/a**(September).
27) United Nations (1997). "Poverty in the human development: perspective: concept and measurement." Human Development Report **Chapter I**(1997): 15-23.
28) United Nations (2010). "The Real Wealth of Nations:Pathways to Human Development." Human Development Report **Overview**(2010): 1-9.
29) Venkataraman, C., A. D. Sagar, et al. (2010). "The Indian National Initiative for Advanced Biomass Cookstoves: The benefits of clean combustion." Energy for Sustainable Development **14**(2): 63-72.
30) Zhang, Y. (2009). "Household energy use, indoor air pollution, and health impacts in India: A welfare analysis." **0501**(0117): n/a.

Appendix: Understanding energy poverty

I. Relation between fuel share and income proxy:

In order to determine the consumption expenditure levels that pertain to decreasing share of individual fuel or combination of fuels containing at least one inferior fuel and / or to determine increasing share of superior fuel(s), correlation and regression coefficients of share of energy expense in the total monthly household expenditure is analyzed.

Figure Appendix-1: correlation of share of energy in monthly household expenditure:



Overall the share of energy expense fall as the monthly consumption increases, this corroborates the use of Engel's law to explain expenditures on energy by households. In case of BPL population, the smaller negative correlation of expenditure on energy with monthly consumption expenditure is indicative of the poorer base line value of these households being of lower economic condition.

a. Regression results of fuel shares with income proxy:

The OLS regressions on share of fuel expenses in monthly consumption with the monthly consumption of sample households as explanatory variable are as follows. The OLS coefficients replicate correlation coefficients. The results are significant. The coefficient for monthly household expenditure for BPL households is ten times of APL households' coefficient, indicating a ten times faster decline in energy shares in the monthly household expenditure of BPL households with increase in the monthly budget. This could be due to shift to more efficient fuels that make the overall fuel share smaller in the following way. Initially BPL households use inefficient fuels and incur overall larger expenditures towards these fuels. LPG and electricity usage require them making larger payment at fixed points of time. With increase in consumption budget BPL households can afford making larger fixed payments. However, at lower consumption budget the smaller but periodic, may be, daily payments for biomass or kerosene actually makes their share of fuels in the consumption budget more than that of efficient (one-time-payment) fuels. So, the overall effect of the increase in consumption budget is decline in energy shares. This might mean a significant shift away from energy poverty for poorer households if they start using cleaner and efficient energy to light up their homes and to cook.

Table23: OLS regression on share of energy in monthly household expenditure:

	all households	**APL households**	**BPL households**
with monthly household expenditure	-0.0005	-0.0004	-0.004
p value	0.000	0.000	0.000
constant	13.3	12.0	21.8
p value	0.000	0.000	0.000
R^2	0.04	0.06	0.03
p value	0.000	0.000	0.000
OLS regression on share of energy in monthly household expenditure			
with monthly energy expenditure	0.01	0.01	0.04
p value	0.000	0.000	0.000
constant	5.5	4.4	4.7
p value	0.000	0.000	0.000
R^2	0.15	0.33	0.18
p value	0.000	0.000	0.000

In case of BPL households' energy shares rise 4 times with increase in monthly energy expense than in case of APL households indicating a higher baseline deficit in the former. This is again due to initial poorer economic condition of the BPL households.

Table 24: elasticities of shares of energy in monthly energy expenditure:

	all households	APL households	BPL households
with monthly energy expenditures	0.4209	0.4735	0.5879

Elasticities of monthly energy expenditures are positive and significant. The values are less than one for the shares of energy expenditures indicating inelastic change in energy shares in monthly household expenditure with change in monthly energy expenditure. Expenditures on energy are considered inevitable hence the inelasticity. In case of BPL households, the share of energy in the monthly consumption expenditures with monthly energy expenditure is less inelastic than in case of APL households. This indicates greater propensity for change in energy usage with changing economic condition for poorer households. Elasticities of energy shares with monthly household expenditure are not significant (table not included).

II. Analysis of share of clean fuels:

One important indicator of movement away from energy poverty is the shift to clean and efficient fuels of electricity for lighting and LPG for cooking. To demonstrate this effect, the share of the superior fuels should decline indicating need fulfillment at the current level of consumption.

a. ***Relation between share of clean fuels in fuel budget and income proxy:***

So, next, correlation and regression results of the share of combinations of superior fuels (electricity and LPG) and superior fuel (electricity) with at least one inferior fuel (kerosene, coal or solid biomass) with the monthly consumption expenditure are compared:

Table 25: correlation of shares of LPG and electricity use in monthly household expenditure (x= not significant):

	all households	APL households	BPL households
with monthly household expenditure	x	x	x
with monthly fuel expenditure	-0.0325	-0.0341	x

The share of LPG and electricity users, that is the combination of two efficient and superior fuels used by the supposedly energy rich, has a negative correlation coefficient with the household fuel budget for all households (-0.0325) as well for APL (-0.0341) households. BPL households' shares are not significant in correlation with changing fuel budget. The correlation coefficients with monthly household expenditure are also not significant.

The regressions coefficients also indicate the same relation. This suggests that the share of LPG and electricity expenditure does not relate significantly to the monthly consumption expenditure. It also suggests that the share of LPG and electricity falls very slowly with the rise in fuel budget of households. In order to determine if the fall in share is due to increase in fuel budget or due to actual decline in the share of LPG and electricity, the coefficients of elasticities of change in the share of LPG and electricity with change in monthly fuel budget need to be computed.

Table 26: OLS regression of share of combination of LPG and electricity in monthly fuel expenditure:

	all households	APL households	BPL households
with monthly household expenditure	-0.00001	-0.00001	-7.00E-06
p value	0.149	0.201	0.944
constant	99.6	99.5	99.7
p value	0.000	0.000	0.000
R^2	0.0003	0.0003	0.00
p value	0.149	0.201	0.945
OLS regression of share of combination of LPG and electricity in monthly fuel expenditure			
with monthly fuel expenditure	-0.0004	-0.0004	0.000
p value	0.009	0.008	0.551
constant	99.70	99.70	99.600
p value	0.000	0.000	0.000
R^2	0.001	0.0010	0.001
p value	0.009	0.008	0.551

The elasticities of share in LPG and electricity with change in monthly fuel budget are negative and very close to zero suggesting highly inelastic behavior. So, it is not likely that that the share of LPG and electricity is falling with the change in monthly fuel budget indicative of a significant decline. Elasticities of fuel share with monthly consumption expenditure were not computed since the regressions coefficients were not significant.

Table 27: elasticities of share of combination of LPG and electricity in monthly fuel expenditure:

	all households	APL households	BPL households
with monthly fuel expenditures	-0.002	-0.003	0.0009
p value	0.009	0.008	0.550

So, the sample households do not indicate increasing household expenditure corresponding to falling shares of this pair of efficient fuels. Regression and correlation coefficients for actual expenditure for electricity and LPG for both APL and BPL households with the monthly consumption expenditure are positive, indicating that for every level of consumption, the households need to spend more for securing clean and efficient energy (table not included).

b. <u>Relation between share of clean fuels in total budget and income proxy:</u>

Next, correlation and regression results of share of expenditure on combination of LPG and electricity in monthly household expenditure with monthly household expenditure and monthly fuel budget are computed. Here the correlation coefficients are significant.

Table 28: correlation of shares of LPG and electricity in monthly household expenditure:

	all households	APL households	BPL households
with monthly household expenditure	-0.2053	-0.4382	-0.2269
with monthly fuel expenditure	0.1984	0.4105	0.2462

The correlation coefficients with monthly household expenditures are negative indicating that the share of superior pair of fuels decreases with rise in monthly household expenditure. However, it is not clear if the fall in their share is due to increase in consumption budget or due to decrease in fuel expenditure. Elasticities coefficients can explain the trend.

Table 29: OLS regression of share of LPG and electricity in monthly household expenditure:

	all households	APL households	BPL households
with monthly household expenditure	-0.0006	-0.005	-1.00E-02
p value	0.000	0.000	0.000
constant	15.3	14.1	61.3
p value	0.000	0.000	0.000
R^2	0.04	0.19	0.05
p value	0.000	0.000	0.000
OLS regression of share of LPG and electricity in monthly household expenditure			
with monthly fuel expenditure	0.01	0.01	0.04
p value	0.000	0.000	0.000
constant	5.7	6.0	3.8
p value	0.000	0.000	0.530
R^2	0.04	0.17	0.06
p value	0.000	0.000	0.000

The regression coefficients are also negative indicating fall in the share of LPG and electricity with rise in consumption. But correlation and regression coefficients with monthly fuel expenditure are positive, indicating rising share of this pair of fuels with rising fuel budget. Their shares could be expanding into shares of non-fuel commodities in the household basket. To know the extent of movement of their share with the change in consumption and energy budgets, elasticities coefficients are computed that are not significant with change in monthly consumption budget.

Table 30: elasticities of shares of LPG and electricity in monthly consumption expenditure:

	all households	APL households	BPL households
with monthly consumption expenditures	-0.431	-0.370	-3.06
p value	0.906	0.328	0.939
with monthly fuel expenditure	0.46	0.40	0.82
p value	0.398	0.000	0.002

The coefficient of elasticities for the share of LPG and electricity in the monthly consumption budget with monthly fuel budget are inelastic and significant with positive values, indicating that there is likelihood of small increase in their share in the monthly consumption budget with rising fuel budget, albeit within inelastic margins. For their shares to increase, the consumption expenditure has to remain static. So, no conclusion can be drawn on the relative movement of their shares with the fuel budget or the consumption budget. Therefore, it cannot be concluded that the share of electricity and LPG combination in the monthly fuel expenditure is actually declining. This corroborates the conclusion that sample households are not actually secure from energy poverty.

III. Relation between share of mixed fuels and income proxy:

Another way to examine energy poverty is to determine if the share of combination fuels with at least one inferior fuel is declining with rise in monthly consumption budget.

Table 31: correlation of shares of biomass and electricity use in monthly household expenditure:

	all households	APL households	BPL households
with monthly household expenditure	-0.2651	-0.2641	-0.2336
with monthly fuel expenditure	0.6019	0.7189	0.5610

Use of biomass for cooking and use of electricity for lighting represents lower end of the energy usage by the sample households. Share of biomass and electricity in the monthly consumption expenditure are negatively correlated with monthly consumption expenditure and positively correlated with monthly fuel budget.

Table 32: OLS regression of share of biomass and electricity in monthly household expenditure:

	all households	APL households	BPL households
with monthly household expenditure	-0.001	-0.005	-0.003
p value	0.000	0.000	0.000
constant	13.7	12.6	19.6
p value	0.000	0.000	0.000
R^2	0.07	0.07	0.05
p value	0.000	0.000	0.000
OLS regression of share of biomass and electricity in monthly household expenditure			
with monthly fuel expenditure	0.02	0.02	0.04
p value	0.000	0.000	0.000
constant	4.1	3.1	3.6
p value	0.000	0.000	0.000
R^2	0.36	0.52	0.31
p value	0.000	0.000	0.000

This means that with rising consumption expenditure the share of biomass and electricity in monthly consumption budget declines slowly indicating a movement away from energy poverty. However, their share in the monthly consumption budget rises as the monthly fuel expenditure rises if the consumption budget is static. Regression coefficients display the same trend as the correlation coefficients.

Elasticities coefficients of share of biomass and electricity in monthly consumption budget of the households with monthly consumption budget are not significant and that with monthly fuel budget are inelastic. So, there cannot be a statistical conclusion regarding significance of change in the share of biomass and electricity on this basis.

Table 33: elasticities of shares of biomass and electricity in monthly energy expenditure:

	all households	APL households	BPL households
with monthly consumption expenditure	-0.38	-0.51	-0.62
p value	0.136	0.722	0.150
with monthly fuel expenditure	0.51	0.58	0.64
p value	0.000	0.000	0.000

Conclusion cannot be drawn on the basis of the aforementioned analysis on the shift in preference with changing monthly consumption expenditure. The households do not display a significant movement away from inefficient fuels or a significant declining trend of share of inefficient fuels in the consumption basket. Thus it is likely that the households meet their need for more energy by consuming more of their present basket of fuel rather than shifting to better or efficient fuels. This means that the households are forced to cut consumption on other goods in their basket of consumption while expanding their share of the presently consumed combination of fuels. In case the consumption budget expands by expanding income or by reducing savings, the share of the presently consumed combination of fuels could be reduced in favor of combination of superior fuels. But the trend of shift to better fuels is not significant statistically, so no conclusion can be drawn regarding the consumption budget signal at which the switching happens. Possibly this is also dependent on other explanatory variables like family size, education level and place of residence.

IV. Relation between fuel share with income proxy and fuel budget:

a. With control variables of family size:

To examine whether shift to better fuel combination occurs with other explanatory variables included, separate OLS regressions models were run with one of the added variables besides consumption at a time. In case coefficients of elasticities for change in share of combination of fuels with change in consumption expenditure with one or more additional variable included are significant and are greater than 1, the direction and extent of change can be computed.

Table 34: correlation of energy share in monthly consumption expenditure

	all households	APL households	BPL households
with monthly household expenditure	-0.2044	-0.2529	-0.1790
with number of persons in the household	-0.1208	-0.1890	-0.1551

The correlation and regression runs with energy share in the monthly consumption budget with consumption and number of persons in the household indicate negative coefficients.

Table 35: OLS regression of energy share in monthly household expenditure:

	all households	APL households	BPL households
with monthly consumption expenditure	-0.0005	-0.0004	-0.003
p value	0.000	0.000	0.000
with number of persons in the household	-0.36	-0.38	-0.42
p value	0.000	0.000	0.000
constant	14.9	13.5	22.9
p value	0.000	0.000	0.000
R^2	0.05	0.08	0.03
p value	0.000	0.000	0.000

To further examine reducing energy share with increasing consumption, elasticities coefficients are computed to determine if it is due to reduced energy share or increase of consumption budget. Negative coefficient of variable household size, for larger families with smaller fuel shares, indicates expenditures on fuels being cut to accommodate non-fuel expenses. This effect is stronger in case of BPL households indicating that with larger family size poorer households will be further pushed down in to energy poverty.

Table 36: elasticities of energy share in monthly consumption expenditure:

	all households	APL households	BPL households
with monthly consumption expenditure	-0.22	-0.29	-0.54
p value	0.667	0.883	0.940
with number of persons in the household	-0.18	-0.24	-0.23
p value	0.881	0.634	0.921

V. Relation between fuel share and fuel budget:

a. With control variable of family size:

Next, correlation and regressions runs of energy shares with monthly fuel expenditures were computed to determine the validity of the aforementioned results. The correlation and regression coefficients are positive and significant with monthly fuel budget indicating increasing energy share if monthly consumption expenditure is static.

Table 37: correlation of fuel share in monthly consumption expenditure:

	all households	APL households	BPL households
with monthly fuel expenditure	0.3827	0.5709	0.4192
with number of persons in the household	-0.1208	-0.1890	-0.1551

With increasing family size the energy share in monthly consumption budget will reduce. This is possible due to expanding consumption of non-fuel items since the consumption budget is considered fixed. So, there is competition between spending on fuel or on non-fuel household necessities.

Table 38: OLS regression of fuel share in monthly consumption expenditure:

	all households	APL households	BPL households
with monthly fuel expenditure	0.01	0.01	0.040
p value	0.000	0.000	0.000
with number of persons in the household	-0.81	-0.95	-1.96
p value	0.000	0.000	0.000
constant	9.4	8.7	15.8
p value	0.000	0.000	0.000
R^2	0.17	0.41	0.23
p value	0.000	0.000	0.000

Elasticities coefficients are not significant so the conclusion is that the households do not take statistically significant decision on the question on expanding fuel or non-fuel spending within the constant consumption budget with the impact of household size.

Table 39: elasticities of fuel share in monthly consumption expenditure:

	all households	APL households	BPL households
with monthly fuel expenditure	0.46	0.57	0.72
p value	0.115	0.658	0.794
with number of persons in the household	-0.49	-0.99	-1.28
p value	0.644	0.942	0.930

VI. Relation between fuel share and income proxy:

a. With control variable of education level of adults:

Correlation and regression runs with the highest level of female and male education in the households as additional explanatory variables were computed.

Table 40: correlation of fuel share in monthly consumption expenditure:

	all households	APL households	BPL households
with monthly consumption expenditure	-0.2044	-0.2529	-0.1790
with highest female education	-0.0221	0.0116	0.0295
with highest male education	-0.0490	-0.0257	0.0085

Regression coefficients indicate that the share of fuels in the monthly consumption expenditure increases with the increase in female and male education. This could be an indication of growing affluence and not an indicator of decreasing energy poverty.

Table 41: OLS regression of fuel share in monthly consumption expenditure:

	all households	APL households	BPL households
with monthly consumption expenditure	-0.0006	-0.0005	-0.004
p value	0.000	0.000	0.000
with highest female education	0.14	0.15	0.41
p value	0.000	0.000	0.000
with highest male education	0.01	0.04	0.21
p value	0.466	0.000	0.001
constant	12.8	11.3	21.3
p value	0.000	0.000	0.000
R^2	0.04	0.07	0.04
p value	0.000	0.000	0.000

VII. Relation between fuel share and income proxy:

a. With control variable of education level of adults:

To see if the shift to clean and efficient energy also takes place, the usage of LPG and electricity with education levels will need to be computed. With growing affluence, the share of polluting energy consumed in the monthly household expenditure should actually reduce if the household is fulfilling their energy needs. Additionally, the use of clean and efficient fuels should increase indicating the end of energy poverty. That will actually suggest a movement away from being energy poor.

Table 42: elasticities of fuel share in monthly consumption expenditure:

	all households	APL households	BPL households
with monthly consumption expenditure	-0.32	0.08	-0.98
p value	0.970	0.999	0.992
with highest level of female education	0.061	0.07	0.14
p value	0.950	0.851	0.992
with highest level of male education	0.007	0.02	0.065
p value	0.928	0.992	0.534

The elasticity coefficients are uniformly not significant thus precluding any inference drawing conclusion on its basis.

VIII. Relation between fuel shares and income proxy:

a. with control variable of place of residence:

Next the place of residence, rural or urban is added as a variable to see its impact on the share of energy in the monthly household budget.

Table 43: correlation of fuel share in monthly consumption expenditure:

	all households	APL households	BPL households
with monthly consumption expenditure	-0.2044	-0.2529	-0.1790
with urban residence	0.0719	0.1125	0.0546

Share of energy in urban resident households is higher is the general trend. However, increased share is due to higher spending on clean and efficient energy or larger quantity of present combination of fuels generally used by the households will need to be investigated.

Table 44: OLS regression of energy share in monthly consumption expenditure:

	all households	APL households	BPL households
with monthly consumption expenditure	-0.0006	-0.0005	-0.005
p value	0.000	0.000	0.000
with urban residence	2.92	2.80	6.50
p value	0.000	0.000	0.000
constant	12.5	11.2	21.8
p value	0.000	0.000	0.000
R^2	0.05	0.09	0.05
p value	0.000	0.000	0.000

Elasticities coefficients are not significant so the magnitude of change cannot be estimated.

Table 45: elasticities of energy share in monthly consumption expenditure:

	all households	APL households	BPL households
with monthly consumption expenditure	-0.41	-0.035	-0.35
p value	0.947	0.999	0.993
with urban residence	0.12	0.09	0.13
p value	0.918	0.138	0.773

IX. Relation between share of clean fuels and fuel budget:

a. With control variable of family size:

Next, in order to see the impact of the size of the household on the fuel combinations used in households, correlation and regression runs are done. Since household size has the same effect as change in consumption budget, a proxy for income and variable monthly consumption expenditure variable (*copc*) includes the size of the household, being a product of per capita consumption expenditure (*COPC*) and number of persons (*NPERSONS*) in the household, so regressions are run with monthly fuel budget (*hh_cost_fuel*) only. Regression and correlation coefficients of share of fuel types in the monthly consumption expenditure with the monthly fuel budget and number of persons in the household is computed as follows:

Table 46: correlation of shares of LPG and electricity in monthly household expenditure (x = not significant):

	all households	APL households	BPL households
with monthly fuel expenditure	0.1984	0.4105	0.2462
with number of persons in the household	-0.0368	-0.1679	x

Correlation and regression coefficients of share of LPG and electricity in monthly household expenditure are positive and significant indicating increasing share with rise in fuel budget of the households.

Table 47: OLS regression of share of LPG and electricity in monthly household expenditure:

	all households	APL households	BPL households
with monthly fuel expenditure	0.01	0.01	0.04
p value	0.000	0.000	0.000
with number of persons in the household	-0.65	-0.90	-2.31
p value	0.000	0.000	0.142
constant	8.3	9.5	17.2
p value	0.000	0.000	0.116
R^2	0.05	0.24	0.07
p value	0.000	0.000	0.000

Increase in their share is at the expenses of non-fuel items in the basket since the consumption budget is constant. As the number of persons in the household increase, the share of the fuel expenditure declines indicating that the share of non-fuel commodities in the household basket would increase to meet the necessities of a large family, the consumption expenditure being static. Larger households' effect on fuel share is to reduce consumption expenditure.

Table 48: elasticities of shares of LPG and electricity in monthly consumption expenditure:

	all households	APL households	BPL households
with monthly fuel expenditure	0.50	0.49	0.04
p value	0.000	0.000	0.000
with number of persons in the household	-0.31	-0.50	-2.3
p value	0.000	0.051	0.142

So, larger families are less likely to escape from energy poverty by meeting their energy needs. This is unlikely to indicate the switching point since the overall effect is to reduce energy availability.

X. Relation between share of clean fuels and fuel budget:

a. With control variable of education level of adults:

Table 49: correlation of share of LPG and electricity in monthly household expenditure (x = not significant):

	all households	APL households	BPL households
with monthly fuel expenditure	0.1984	0.4105	0.2462
with highest level of female education	-0.0646	-0.1608	0.1121
with highest level of male education	-0.0786	-0.1939	0.0981

By adding the highest education levels of female and male adults in the household as explanatory variables, the model includes a social factor to influence the energy preference in the household.

Table 50: OLS regression of share of LPG and electricity in monthly household expenditure:

	all households	APL households	BPL households
with monthly fuel expenditure	0.01	0.01	0.04
p value	0.000	0.000	0.000
with female education	-0.22	-0.20	0.96
p value	0.000	0.000	0.274
with male education	-0.390	-0.320	0.680
p value	0.000	0.000	0.488
constant	10.6	10.6	-6.100
p value	0.000	0.000	0.497
R^2	0.06	0.27	0.06
p value	0.000	0.000	0.000

Education impacts share of LPG and electricity in inverse manner, possible indicating that fuels are used in more efficient manner so their share reduces. Other non-fuel items expand more within the constant consumption budget. Education does not play significant role in the BPL households in determining fuel shares. Elasticities coefficients are inelastic; some are insignificant, determining their marginal role in indicating direction of change.

Table 51: elasticities of shares of LPG and electricity in monthly consumption expenditure:

	all households	APL households	BPL households
with monthly fuel expenditures	-0.55	0.49	1.01
p value	0.000	0.000	0.898
with highest female education	-0.21	-0.21	0.22
p value	0.000	0.000	0.218
with highest male education	-0.39	-0.38	0.251
p value	0.000	0.000	0.474

XI. Relation between share of clean fuels and income proxy:

a. With control variable of place of residence:

Lastly, place of residence is added as an explanatory variable. The impact on correlation and regression coefficients is documented below:

Table 52: correlation of fuel share in monthly consumption expenditure (x = not significant):

	all households	APL households	BPL households
with monthly consumption expenditure	0.1984	0.4105	0.2462
with urban residence	x	x	x

Correlation and regression coefficients of urban residence are not significant indicating lack of statistical conclusion regarding the share of LPG and electricity use in urban households.

Table 53: OLS regression of share of LPG and electricity in monthly household expenditure:

	all households	APL households	BPL households
with monthly fuel expenditure	0.008	0.007	0.04
p value	0.000	0.000	0.000
with urban residence	0.26	-0.23	2.13
p value	0.673	0.298	0.928
constant	5.5	6.2	1.7
p value	0.000	0.000	0.000
R^2	0.04	0.17	0.06
p value	0.000	0.000	0.000

Regression coefficients not significant with share of LPG and electricity combination fuel in the monthly consumption expenditure with the households' place of residence. This is likely that their share is not changing as a general trend in the household budget with the place of residence. Elasticities' coefficients are also not significant, that is expected if the correlation and regression coefficients do not show any clear statistical trend. The share of these two fuels will rise if the households consume more of them being clean and efficient fuel. Expanding monthly fuel budgets indicate the increasing share of LPG and electricity in the consumption budget, a relation that does not indicate that the user households have met their needs.

Table 54: elasticities of shares of LPG and electricity in monthly consumption expenditure:

	all households	APL households	BPL households
with monthly energy expenditures	0.45	0.4	0.81
p value	0.000	0.000	0.002
with urban residence	0.02	-0.02	0.1
p value	0.672	0.300	0.928

So, they do not move away from the energy poverty conundrum since their clean energy needs are not being met completely. At the point their use of LPG and electricity begins to decline that these households would no longer be called energy poor, but it is not likely to happen since the elasticities of share of these fuels are not significant even in urban sample households.