Energy Access in India - Today, and Tomorrow

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A report on Energy Access in India – Today and Tomorrow

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## Contents

Executive Summary .................................................................................................................. 7  
  What is the status quo? ......................................................................................................... 7  
  What factors and decisions have led us here? ...................................................................... 8  
  What could the future look like? .......................................................................................... 9  
Background .......................................................................................................................... 11  
Motivation and Objectives ..................................................................................................... 14  
Literature Review .................................................................................................................... 16  
Data and Methodology .......................................................................................................... 19  
  Description of Data ............................................................................................................ 19  
  Methodology ...................................................................................................................... 21  
Characterisation of Household Energy Demand ..................................................................... 24  
  Fuel Expenditure Share ...................................................................................................... 26  
  Share of various fuels in the household energy basket ...................................................... 29  
  Geographical Variations in Fuel Consumption ................................................................... 35  
  Seasonal Variation in Overall Energy Consumption ........................................................... 36  
  Fuel Consumption and per-capita GDP (state) ................................................................... 37  
  Fuel Consumption and Urbanization Rates ......................................................................... 38  
  Variations in Fuel Consumption across Social and Religious groups ............................... 39  
  Choice of cooking and lighting fuel .................................................................................... 42  
  Energy Inequality in India .................................................................................................... 45  
  Household Energy Aspirations ............................................................................................. 47  
  Econometric Analysis of the per capita fuel consumption .................................................. 53  
What is the status of energy access in India? ......................................................................... 55  
Forecasting Energy Demand ................................................................................................. 56  
Conclusion ............................................................................................................................. 59  
Appendix 1: End Use efficiencies associated with fuels used in households ....................... 64  
Appendix 2: Per-capita consumption (Useful Energy) of fuels across states in kgoe/month .......... 64  
Appendix 3: Household Consumption of Fuels religion-wise ............................................. 67  
Appendix 4: Major policies and programmes for expanding rural energy access ................ 68  
Appendix 5: Price of Energy for various income groups (INR/kgoe useful) ........................... 70
List of Figures
Figure 1: Household Distribution across Income Deciles (Surveyed Sample)................................. 19
Figure 2: Household Distribution across Income Deciles (Population, after accounting for multiplier) ......................................................................................................................... 20
Figure 3: Per-capita Energy Consumption (in kgoe/month)-Rural......................................................... 25
Figure 4: Per-capita Energy Consumption (in kgoe/month)-Urban ....................................................... 26
Figure 5: Fuel expenditure as percentage of household expenditure-Rural ........................................ 26
Figure 6: Per capita Total Energy consumption across income fractiles ............................................. 27
Figure 7: Fuel Expenditure Share- Rural ................................................................................................. 28
Figure 8: Fuel Expenditure Share- Urban .............................................................................................. 28
Figure 9: Price of Energy for Urban and Rural households .................................................................... 28
Figure 10: Consumption share of expenditure on various fuel types (Rural) ....................................... 30
Figure 11: Consumption shares of fuel types based on expenditure (Rural) .......................................... 30
Figure 12: Share of expenditure on various fuel types (Urban) ............................................................ 31
Figure 13: Consumption shares of fuels based on useful energy (Rural) ............................................. 32
Figure 14: Consumption shares of fuels based on useful energy (Urban) ........................................... 32
Figure 15: Variation in Fuel Shares-Rural Households ........................................................................... 34
Figure 16: Variation in Fuel Shares- Urban Households ....................................................................... 35
Figure 17: Per-capita energy consumption split in Himalayan households ........................................... 36
Figure 18: Per-capita energy consumption vs. Per-capita GDP across states ....................................... 37
Figure 19: Per-capita consumption of firewood and forest cover across states ..................................... 38
Figure 20: Per-capita consumption of firewood and extent of urbanization across states ................. 38
Figure 21: Percentage of Urbanisation and fraction of fuel expenditure to total household expenditure ............................................................................................................................. 39
Figure 22: Per-capita fuel consumption across social groups in rural areas ........................................ 41
Figure 23: Per-capita fuel consumption across social groups in urban areas ..................................... 41
Figure 24: Percentage of households as per primary cooking fuel across fractiles (Rural) ............... 42
Figure 25: Percentage of households reporting various fuels as primary cooking fuel (Urban) ....... 43
Figure 26: Percentage of households as per primary lighting fuel across fractiles in rural areas ......... 43
Figure 27: Percentage of households as per primary lighting fuel across fractiles in urban areas ......... 43
Figure 28: Percentage of Households based on Primary Heating Fuel ............................................... 44
Figure 29: Percentage of Households based on Primary Lighting Fuel ............................................. 45
Figure 30: Lorenz Curve for Modern Fuels-Rural .................................................................................. 46
Figure 31: Lorenz Curve for Modern Fuels- Urban .............................................................................. 47
Figure 32: Total Energy consumption in households reporting kerosene as primary lighting fuel (Rural) ........................................................................................................................................... 49
List of Tables

Table 1: Total per capita Household Energy requirements for various economic classes .............................................................. 24
Table 2: Percentage change in per household consumption (relative to non-winter months) of various fuels between Himalayan States and rest of India ................................................................. 37
Table 3: Religious groups and Per-capita Income .................................................................................................................... 40
Table 4: Social Groups and Per-capita Income ............................................................................................................................. 42
Table 5: Gini coefficients for Modern Fuels ............................................................................................................................... 46
Table 6: Gini coefficients for Traditional Fuels .......................................................................................................................... 46
Table 7: List of Variables ....................................................................................................................................................... 54
Table 8: Expenditure elasticity of consumption of major fuel choices .......................................................................................... 54
Table 9: Future energy consumption breakdown by fuel type ............................................................................................... 57

Figure 33: Total fuel consumption in households reporting electricity as primary lighting fuel (Rural) .................................................................................................................................................. 50
Figure 34: Kerosene Consumption across rural households categorised by primary cooking fuel .................................................................................................................................................... 51
Figure 35: Electricity consumption across rural households categorise by primary cooking fuel ......................................................................................................................................................... 53
Executive Summary

What is the status quo?

Energy consumption at a household level is dictated by three key factors: affordability, availability and household characteristics. While extant policy is focused on making energy commodities affordable, addressing the latter elements is crucial to ensure a transition to cleaner and efficient fuels and technologies. Availability issues dominate the discourse in two specific contexts, specifically in the rural area.

The first is that rural households show a propensity to increase consumption (per capita) of solid fuels (firewood, dung cake, coal, charcoal) with increasing levels of income. This is prevalent in households all the way up to the 70th percentile (in income terms). This represents a population base of nearly half a billion people. While there has been an improvement over the last decade, as suggested by the decrease in reliance on traditional biomass at the highest income deciles, there is still a significant base that is looking to increase its energy footprint with an eye on biomass being the main source of that consumption.

The second is that the energy consumption aspirations of the population are not being met. For a given income level, the total energy/fuel consumption in households reporting kerosene as their primary lighting fuel was far lesser than those reporting electricity as their primary lighting fuel. Do they not have the same demands for energy services as other households in their income group to sustain their income levels? The only reasonable explanation is that the fuels they aspire to consume are just not available, despite their ability to pay for the same. The combination of kerosene and firewood Vs-a Vs electricity and LPG is not enabling people to move on to a higher energy trajectory and perpetuating energy poverty.

Given the availability driven picture, is it possible to provide a normative definition of households that have energy access and those that don’t? Given the uncertainty around the state of housing, technologies in use and varying geographical conditions across the length and the breadth of the country, it would instead be useful to highlight the disparity between rural and urban areas to provide a semblance of the task ahead- in alleviating energy poverty and improving energy access. Less than a quarter of the urban residents spend more than 50 per cent of their expenditure on energy towards unclean solid fuels and kerosene. In rural areas though, more than 80 per cent of the population apportions more than 50 per cent of their expenditure on energy towards solid fuels and kerosene. A convergence between rural and urban areas must be the medium target as urban residents are on the normatively higher trajectory and their consumption pattern captures aspiration levels better.
What factors and decisions have led us here?

While the predominant discourse in existing studies and interventions is on enabling the poor consume more and better quality fuels, there has not enough has been done to address perverse nature of prices enforced on poorer sections of society, further limiting their options.

A closer examination of the underlying prices in play reveals that rural dwellers pay more for every unit of useful energy that they consume, as compared to urban residents. The disturbing observation is that poorest households pay upto 35% higher prices than the richest households. While the consumption basket of poorer sections is made up traditional biomass and other solid fuels for which no subsidies are in place, richer households enjoy a consumption basket dominated by modern fuels like LPG and electricity, both of which have a large subsidy element. While this partly explains the observed trends, it is certainly regressive while also suggesting that the poor have the willingness to pay to consume energy.

The persistently higher prices have also ensured that inequality in consumption of clean fuels is widespread. In both rural and urban areas, the consumption of LPG and electricity is concentrated in the higher income groups and largely for reasons of availability as discussed earlier. However, there has been a marked decrease in the levels of inequality associated with the consumption of electricity. This would suggest that the rural electrification program has certainly delivered in some measure. LPG or piped natural gas consumption, as a result of the difficulties in last mile delivery, has witnessed a far less significant drop in inequality levels. Programs dedicated towards the increased spread of LPG have not been ambitious enough and have fallen well short of the targets set out.

Over the course of the last few years the contribution of imports has increased vis-à-vis LPG and natural gas. These imports have come at significantly higher prices than earlier. Despite this the per-capita availability (at the national level) has increased thereby indicating a growing appetite for cleaner heating and cooking fuels and the underlying utility associated with the consumption of these. With the significant fiscal burden associated with these fuels and the inequality related issues highlighted, a more targeted delivery mechanism – both physical and financial, is needed to ensure equitable and widespread penetration of these fuels in society.
What could the future look like?

A transition to cleaner and efficient fuels over the next few decades is evident and desirable. At projected rates of macroeconomic growth and population growth, the reliance on solid fuels (traditional biomass, coal and charcoal) is set to continue. Given that a bulk of the kerosene usage today is for lighting services, where electricity has yet to reach, this consumption will dwindle down to insignificant levels. The consumption of LPG/PNG and electricity on the other hand, are likely to witness a meteoric increase with the rising aspiration levels of the population, driven by higher incomes and use of appliances and an increasing awareness of the socio-economic benefits of consuming these fuels. While there are some factors that will drive this transition, it will not be realized without active intervention on part of the government.

The overall consumption of these solid fuels across households is likely to remain at existing levels (~123 MTOE). With the concomitant increase in population, there is clear downward trend in the per capita consumption of solid fuels. Between 2011 and 2051, a 25 per cent decrease in per capita consumption of solid fuels is expected, driven by increased efficiency in the consumption of these fuels and the shift away to cleaner sources. However, the divergence between rural and urban populations in the consumption of unclean solid fuels will persist. Solid fuels will constitute more than 50 per cent of the energy consumed in rural areas (in 2051); though significantly lower than the reliance today (88 per cent). Urban areas (today) on the other hand, rely on solid fuels for only 7 per cent of their energy needs.

One of the important considerations in the analysis and the forecast was a concerted effort driven by equity considerations. Current consumption mix and trends indicate that states with more equitable distribution of modern fuels also tend to have higher levels of consumption of energy as a whole. While the linkages and causality associated with this could be through many channels, it is clear that equitable outcomes also result in higher standards and aspirations for all. Interestingly, states where households have a higher spend on modern and clean fuels also have to have a higher level of human development index (HDI).

Consumption of cooking fuels like LPG (or PNG) shows a tremendous increase in both rural and urban areas. There is a near five-fold growth in the per capita consumption of LPG in rural areas. A significant driver of this change in rural areas is the highest education levels attained by the adult women of the household. The impact of solid fuel usage on indoor quality and the resulting health consequences for the women and children of the household will drive the transition – but only through improved education and awareness of these impacts. Today urban areas, while representing a smaller chunk of the population consume nearly 60% of the LPG in the country. In future, while the disparity will remain, total LPG consumption will be equally split between rural and urban areas.
While electricity access and consumption in urban areas is very much on the rise, the demand from rural areas will outstrip the demand from urban areas. Increased income levels and appliance ownership penetration are the two main factors driving this surge in both rural and urban areas but to a lesser degree in the latter. Per capita electricity consumption is likely to triple in the next four decades in urban areas, with a possibility of growing seven-fold in rural areas.
Background

India is home to around 1.21 billion people (Census 2011) and it is estimated that more than 21% of them live below the poverty line (Planning Commission, 2013). This is an estimate based on the poverty line as prescribed by the Tendulkar Committee (2009), which estimated national poverty lines\(^1\) at INR 816 for rural areas and INR 1000 for urban areas. The poverty line estimates, while questionable, are as per National Communications and undeniably indicate that India has a long way to go in eradicating poverty and addressing the factors that have entrenched its presence over the last six decades.

Though the Millennium Development Goals (set in 2000) did not explicitly refer to energy access, in September 2010, the United Nations Secretary General Ban Ki Moon launched the target of universal energy access by 2030. He described the importance of energy access in poverty reduction and the role of energy services in meeting the Millennium Development Goals (MDGs):

“Universal energy access is a key priority on the global development agenda. It is a foundation for all the MDGs... Without energy services, the poor are cut off from basic amenities. They are forced to live and work in unhealthy, polluted conditions. Furthermore, energy poverty directly affects the viability of forests, soils and rangelands. In short, it is an obstacle to the MDGs.”

This throws into prominence the issue of energy access and the need for concrete action, rather than the notional idea of providing lifeline access to energy and such. Notwithstanding the variations in estimations of income poverty, there is a need to distinguish it from energy poverty. The former refers to the “lack of financial resources to live a tolerable life” (Bhide & Monroy, 2011), while the latter “is a lack of access to modern energy services. These services are primarily concerning household access to electricity and clean cooking facilities” (IEA, 2013). Equating income and energy poverty would be erroneous, as some ‘non-poor’ households, based on the income/expenditure poverty measure, may still be energy poor (Khandker, Barnes, & Samad, 2010).

The Census of India (2011) indicates that more than a third of the country’s households primarily rely on sources other than electricity for their lighting needs. It is very likely then, that these households almost have no other productive activity driven by electricity. Appliances penetration rates would be low as a result and there would be no way to pump clean water, refrigerate food and drugs and limited options for modern communication technologies like the internet. The Census also indicates that nearly two thirds of the households in the country use fuels such as firewood, dung-cake, charcoal and agricultural residue for their cooking needs (Census, 2011b). As a result of this lack of modern energy provisions, a large portion of

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\(^1\) Monthly expenditure per capita
household demand is met through energy sources which do not form part of the formal energy accounting process. The total non-commercial energy consumption in India (firewood, animal dung, agricultural residue, etc.) is estimated to be more than 150 MTOE, nearly 20%-25% of the total purchased energy consumption.\(^2\)

Despite these statistics emanating from credible organizations and established processes, there is an air of incredulity and uncertainty when one attempts to convey and comprehend the magnitude of energy poverty in India. Claims of 90% (and higher) village level electrification bear little weight, when the actual per capita consumption of electricity in the country is measured. India’s per capita energy consumption stands at 0.58 toe/person\(^3\) – well short of the world average of 1.8 toe/person and even less than the African average of 0.67 toe/person (WDI, 2011). Clearly, energy poverty is entrenched and needs to be addressed.

Unlike developed countries where energy demand has reached or is close to saturation stage, the latent demand for energy is significant in the country where the majority of energy demand still remains unmet. Numerous programmes have been rolled out in pursuit of the elusive goal of universal energy access. The Indian government has been cognizant of the role that energy access plays in alleviating income poverty and the importance accorded to addressing this has been greater than even the measures to ensure national level ‘energy security’ (Ahn & Graczyk, 2012). How successful they have been in their programmes requires an in-depth evaluation but evidence at this stage lends credence to fact that much remains to be done. An exhaustive list of energy access schemes and programmes that have been rolled out in the country (post-Independence) are highlighted in the Appendix. While most (if not all) pertain to the rural area, the primary scheme for urban dwellers has been the subsidised provision of energy commodities like LPG and kerosene (through the public distribution system). While there are signs that the subsidy will slowly be withdrawn, prices are still far from being decontrolled.

In the years immediately after Independence, the twin goals of social justice and a more equitable social order were seen to rely on greater economic equality. Given India’s closed hierarchical social system, the onus was on the state to ensure these favourable outcomes and as a result, many of Nehru’s own socialist leanings were built into the ‘ideology of the state’ and into the constitution of India. While this driver has a lot of history behind it, inclusive growth is also part of contemporary policy discourse within the country. The concept of inclusive development can be broadly defined as “growth coupled with equal opportunities” (Rauniyar & Kanbur, 2010). The explicit focus can be attributed to the rising income inequality in the country coupled with the modest improvements in poverty levels, as compared to other countries in Asia. This focus is evident more than anywhere else in India’s XII FYP (volume 1), which is titled “Faster, sustainable, more inclusive growth” (Planning

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\(^2\) Author estimates based on national communication on energy consumption and NSSO data

\(^3\) Author estimates based on population figures from Census 2011 and provisional energy consumption data for 2011-12 in Twelfth Five Year Plan draft document
Commission, 2012a). The title does indeed capture the basic vision and what the aspirations ought to be of the policy makers in the years to come.

In 2010, the Government of India hosted the Delhi International Renewable Energy Conference (DIREC) and over 13,700 participants from India and the world over attended the conference. A key outcome of the DIREC 2010 was a call to the Union Nations (UN) to designate 2012 as the International Year of Energy Access. Then, in recognition of the importance of energy access for sustainable economic development and supporting achievement of the Millennium Development Goals, the United Nations General Assembly designated 2012 as the "International Year of Sustainable Energy for All". Clearly, energy access is top priority for India’s policy makers.

The current approach to providing energy access to those who lack it is, from a poor person’s perspective, fractured and removed from reality. Centralised energy planning still assumes that the formal energy sector will be the principle means to ending energy poverty – delivering LPG (piped or bottled) and grid-based electricity. Subsidies in the consumption of these fuels (and more) have been the predominant practice in making them affordable to the masses. Reality, however, indicates something different. The provision from rural energy programmes is rarely sufficient for cooking and lighting, the most energy-intensive household activities. The Poor People’s Energy Outlook 2010 paints the lighter side of this rather grim situation - “millions of families who have been lucky enough to benefit from such a programme prepare their evening meal under the glow of an electric light – in a smoke-filled kitchen over an unimproved wood or dung-burning stove” (Practical Action, 2010). Planners attempts to provide energy access, only to the extent that it caters to household needs. The focus on providing the motive power for home-based industries is virtually inexistent. Nearly 18.3 million people in India are reported to be employed in household industries and this constitutes nearly 4% (Census 2011) of the working population of the country. Catering to their needs will certainly go a long way in alleviating income poverty and improving national productivity.
Motivation and Objectives

Given the vast chasm faced by the policy makers between advocating the eradication of energy poverty and the ability to provide for universal energy access, it is necessary to understand the status quo in more detail. The existing body of works in the area of energy poverty and energy access in India is immense. However, the continually changing economic landscape, technological advancement, developmental efforts through dedicated programs and the increasing aspiration levels of the households, there is need for a periodic revaluation of the status quo.

Energy is important both for economic development, but it also plays a major role in improving conditions at the household level. The notion of an energy poverty line is well-accepted around the world. There is a large body of literature on how to measure income poverty and the reliability of alternate measures. The idea of measuring an energy poverty line is similar, but there is no consensus on the methodological and conceptual issues that define it (Khandker, Barnes, & Samad, 2010).

There are several methods suggested to measure energy poverty. The first of these strives at deriving an “energy poverty line” or “fuel poverty line” from a conventional income or expenditure poverty measure. This can be done by determining energy use as a function of income (or expenditure), and by calculating the average level of energy use corresponding to an amount of income or expenditure specified by the official income or expenditure poverty line (i.e. the level specified as the minimum amount needed to meet basic needs) (Pachauri & Spreng, Energy use and energy access in relation to poverty, 2003). While this approach is computationally fairly simple, it only provides a single energy or fuel poverty line, i.e. a single number that is basically a transformation of the monetary poverty line, and does not, by itself, add any new insight.

Another approach to measuring energy poverty uses estimates for determining the direct energy required to satisfy basic needs (Goldemberg, Johansson, Reddy, & Williams, 1985; Pachauri & Spreng, 2003; Practical Action, 2010). One drawback, however, is the difficulty in pinning down the exact minimum level of energy required for basic needs, owing to the significant country and regional differences in cooking practices and heating requirements. Energy consumption is often location-specific due to the vast differences in climatic conditions worldwide. Furthermore, the minimum needs for physical quantities of energy are chosen somewhat arbitrarily (Khandker, Barnes, & Samad, 2010).

While the study of energy poverty and the associated ‘poverty-line’ in itself is not an end goal of the study, it forms an important corollary. Over the time-horizon that the study focuses on, the considerations must definitely be beyond energy access and rise above mere provision lifeline energy consumption. While this assumes mammoth proportions for the country’s
policy makers, the true challenge is in identifying what services people would require as their incomes rise and what would be the commensurate energy demands.

The objectives of this study are threefold:

1. **Characterization of the energy demand from households across the country (cross-sectional study)**

   Widespread income inequality, social barriers, rural – urban divide, seasonal and geographic variations and unequal distribution of resources across the country mean that energy demand has multiple dimensions to it. The first portion of the study will be an attempt at providing a glimpse (graphical) into the factors that contribute to this variation and to establish a clear relationship through a statistical analysis.

2. **A longitudinal study comparing the progressive increase in energy access over two discrete time intervals.**

   The second portion of the study will provide a comparative analysis of the energy demand between two periods for which data is available. One can understand the extent to which programs have been effective, the (price) elasticity of demand for specific fuels and possible watershed moments in the fuel mix for various groups. In addition this section will illustrate one possible approach to disaggregate the overall demand for various fuels into specific demand for cooking, lighting and appliances. This would be unique in its departure from the use of nominal per capita requirements for various service provisions in the household.

3. **A forecast of residential energy consumption trends out till 2052 and the breakdown by fuel category**

   The final section of the study will be devoted to illustrating a choice model based methodology to provide a reliable forecast of residential energy consumption, reflecting the impact of exogenous macroeconomic changes to household incomes, aspiration levels, demographic changes, urbanization, growth in energy-use efficiencies and various other attributes.
Literature Review

Various studies have been done with respect to energy demand analysis. Some of them deal with a more aggregate level analysis at the country level or regional levels. These studies are mainly focused on the overall energy consumption driven by macroeconomic and other exogenously driven socio-economic factors like GDP or price indices (Biying, Zhang, & Fujiwara, 2011). In 2000, the IPCC published a set of scenarios in the Special Report on Emission Scenarios (SRES) (IPCC, 2000). Developed using global energy models, this report further explore to capture future pathways to greenhouse gas emissions. Various models used in SRES are comprehensively analysed by (Ruijven, Frauke Urban, Sluijs, Vries, & Vuuren, 2008) for their adaptability into developing country situations. These models (viz. AIM, ASF, IMAGE/TIMER, MARIA, MESSAGE, and MiniCAM) reflect the concepts of Environmental Kuznets curve and Energy ladder. They (Ruijven, Frauke Urban, Sluijs, Vries, & Vuuren, 2008) suggests that improvements can be made to SRES models by incorporating aspects of traditional fuels, electrification, economic structural change, income distribution, and informal economies.

Some of the other models which deal with aggregate level analyses are discussed below. International Energy Agency (IEA) uses World Energy Model (WEM) to replicate how energy markets work. It uses huge quantities of historical data on economic and energy variables as inputs. The WEM is designed to analyse global energy prospects, environmental impact of energy use, effects of policy actions and technological changes and investment in the energy sector (IEA, 2011). MARKAL/TIMES are model generators to represent the evolution over a period of usually 20 to 50 years, of an energy-environment system at the global or regional level. It includes all energy carriers involved with primary supplies conversion and processing, and end-use demand for energy services. The demand for energy services may be disaggregated by sector and by specific functions within a sector (Seebregts, Goldstein, & Smekens, 2001). Global Change Assessment Model (GCAM) is an integrated assessment model with both energy sector and land use modules; it is used to calculate emissions from energy and land use changes. The energy module is based on a partial equilibrium framework and tracks energy and emissions in partial equilibrium, taking GDP as an exogenous assumption and from it deriving energy demand, with the energy supply mix determined endogenously (Shukla & Chaturvedi, 2012).

Some of the other papers deals with disaggregate level analyses of energy demand. These models mostly used in the residential sector, present the effects of the influential socio-economic factors (like household income and household size) on the household energy use. One of the earliest works in this direction is on electricity consumption in Britain (Houthakker, 1951), where a linear demand model is estimated using econometric techniques. A very detailed analysis of such econometric models -from literature- used in estimating and
forecasting residential energy demand is provided by (Madlener, 1996). He describes various general econometric models used in such forecasting.

Log-linear models are used in various papers to estimate the amount of a fuel used conditional upon a household choosing to use that fuel (Pachauri, 2004; Filippini & Pachauri, 2004). In such methods approach is to regress the natural logarithm of energy consumption as a function of price, income etc. affecting the demand. Sometimes, translog models, in which the explanatory variables (price, income, etc.) also take a logarithmic form (and at times their quadratic forms too) along with the dependent variable, are also used. These models resemble a cobb-douglas function and are more based on economic principles. Log-linear and translog models are easy to estimate and directly interpretable. But the constant elasticity assumption often unrealistic and not really justifiable and static formulations dominate the models. Further, one cannot use single-equation regression models to simultaneously analyze households’ consumption of multiple types of fuel (Madlener, 1996).

Household production model is another approach used in estimating residential energy demand. The model uses a utility maximization framework where utility is assumed to be a function of two composite commodities directly yielding utility (Willett & Naghshpour, 1987). This methodology relies on the availability of rich and reliable micro-data which are usually not available (Madlener, 1996).

Residential Energy model- Global (REM-G) (Ruijven, et al., 2011; Daioglou, 2010) follows bottom-up approach of a chain from population and income trends to intermediate physical indicators and to end-use functions and energy use, and uses correlations derived from econometric studies and regression analysis. The model determines residential energy use for five end-use functions: cooking, water heating, space heating, lighting and appliances (including space cooling). It is assumed that these five end uses are basically driven by primary and intermediary variables viz. population, household expenditure, household size and temperature.

For cooking energy demand, an average consumption value (in MJ/capita/day) is assumed based on the historical analysis of data and other considerations like cultural food habits, family size, income etc. For appliances’ energy demand three different categories of appliances are included viz. food storage and processing, washing/cleaning and entertainment. Ownership levels are assumed to be driven by household expenditures. Gompertz equation is used to drive the appliance ownership growth. Space heating and cooling demand are modelled as a function of floorspace, heating degree days and heating intensity. Water heating is modelled as growth dependant on income towards a maximum value driven by household expenditures. For electrified households lighting demand is driven by floorspace and there is a choice between incandescent and compact-fluorescent bulbs. In households which lack access to electricity, lighting demand is met by a given quantity of kerosene. Lack of detailed data on
the use of energy for different end-use function limits understanding of energy use trends in developing countries (Ruijven, et al., 2011; Daioglou, 2010).

Another widely used group of models are the Qualitative choice models which use logit, probit or tobit approaches (Biying, Zhang, & Fujiwara, 2011; Özcana, Emrah, & Üçdoğruk, 2013; Ekholm, VolkerKrey, ShonaliPachauri, & KeywanRiahi, 2010). These models are relatively easy to use and offer considerable flexibility in dynamic model specifications. But these models are not based on the theoretical assumptions of utility maximization (Madlener, 1996). Dubin-McFadden model (Dubin & McFadden, 1984) uses multiple discrete-continuous choices to decide fuel choice and fuel consumption in the event of multiple options to choose from. A multinomial logit model of fuel choice is estimated in the first stage. The second stage estimates the amount of fuel demanded given the fuel chosen. This method has been used in some papers (Mansur, Mendelsohn, & Morrison, 2008). However, these two step estimation procedures are generally inefficient, and are also not based on a unified utility maximizing theory of multiple-discreteness. They also fail in capturing fundamental consumer behaviors (e.g., satiation effects) (Pinjari & Bhat, 2010).
Data and Methodology

Description of Data

Data on household consumption expenditure from the National Sample Survey (NSS) Round 68 (2011-12) and Round 61 (2004-05) will be the prime sources of data for the analysis proposed in the objectives. The former represents the most recent round and presents the status quo and the latter will be used in order to provide a temporal perspective of change in energy consumption and the costs of energy. The household expenditure data form the basis for calculating purchased energy requirements for different levels of household expenditures. The NSS is periodically conducted to collect household budget data from a large nation-wide sample of households by the interview method. The survey covers the entire area of the country, involving separate and comprehensive coverage of rural and urban areas, with the exception of some very interior areas (e.g. in this round some areas in Nagaland were not covered for lack of access).

The 68th round comes close on the heels of the 66th round that was conducted in 2009-10, which also captured essentially an identical set of expenditure attributes as the 68th round. The sample size associated with the chosen round is to the tune of 101,654 households. To give a sense of the extent of coverage, the overall number of households across India (as per Census 2011) is close to 250 million. The distribution of the number of households across income deciles in the sample and for the entire population is illustrated in the figures below (Figure 1 & Figure 2).

Figure 1: Household Distribution across Income Deciles (Surveyed Sample)

---

4 Energy embedded in the fuels purchased by the household
Household consumption as defined in the survey includes consumption of goods and services acquired through (a) purchases in the market, (b) receipts in exchange of goods and services, (c) subsistence production, and (d) transfer receipts such as gifts and loans. The household consumption expenditure schedule used for the survey collects information on quantity and value of household consumption with a reference period of the last 30 days preceding the date of the interview. This is for most consumables such as a food, energy, etc. For durable goods, clothing and footwear, data is additionally collected with a reference period of one year. For the purposes of our analysis, we have used data which represents a mixed reference period, so that consumption towards durables can be apportioned to the various months to reflect in the monthly data. In addition to the consumption information the survey provides vital information on the size of household, education levels of various members of the household, their age distribution, geographic indicators, whether rural or urban household, social grouping, ownership of specific goods (assets), etc.

The data on consumption of energy items is of particular interest for our analysis. The survey captures the consumption, in quantity and value terms, of 15 different ‘fuels’ that are commonly used in Indian households. They range from matches and candles to firewood and charcoal and on to commercially traded fuels like kerosene, LPG and electricity. For fuels like firewood, charcoal and dung-cake (animal origin), there are questions that require the specification of how much was produced at home and how much from market sources. The overall quality of data in the sample is high, with almost no missing values or incomplete records. There are records which
indicate houses which had no access to any energy source whatsoever and such records would not be part of the analysis. It is pertinent to observe that the survey collects information only on direct energy consumed within the household and does not account for energy consumption that is part of the ‘purchased’ products that form the overall consumption basket of the household. Concomitantly our analysis also makes no attempt to quantify this ‘indirect’ energy consumption of the household, which is likely to be significant and estimated in various studies previously (Murty et al., 1997; Parikh et al., 1997).

For the purpose of our study, we convert all the data on physical quantities of fuel consumed to equivalent kilograms of oil equivalent (kgoe). This is done through a simple multiplication with the calorific values of the various fuels. For commercially traded fuels, these values are consistent with national communications (CSO, Planning Commission), which are in turn consistent with internationally accepted range of values. For non-commercial fuels like firewood and other forms of biomass, we use calorific values as specified in nationally accepted publications such as the Integrated Energy Policy (Planning Commission, 2006b). The value arrived at through this simple process represents the total purchased energy provided by each fuel. However an important element that dictates the actual amount of productive energy delivered is the ‘efficiency of transformation’. This is a technology specific parameter and is dictated by the penetration of efficient stoves, lanterns, lighting sources, etc. The value obtained after accounting for efficiency related losses is termed ‘useful energy’. While an initial comparison is provided based on the total purchased energy figure, the study is ultimately about energy access and demand. This is more appropriately represented by the useful energy figure and reflects the true needs of the people across regions and income classes. Also, it is possible to represent the demand figures at the various levels either in per capita terms or in per household terms. At this stage we have chosen to represent the demand on a per capita basis as there is a significant variation in households’ sizes across income and social groups. It is also pertinent to note that the data in the survey covers expenses and consumption over the period of a month and throughout this study all analyses and representations denote these over a period of a month.

Methodology

The methodology for the first section of the study is a straightforward interpretation of data through aggregations to the required level, clustered according geographies, social groups, rural-urban division, income groups, etc. A visual inspection of the consumption across various groups is a quick and effective tool; in establishing the factors that are contribute significantly to the consumption of energy within a household.

After an exhaustive inspection of all the possible factors through an exploratory search of the data, a few regression models are presented, to corroborate the visual inferences against significance levels as obtained from the statistical analysis. The significant attributes will then be the base attributes that will form part of the longitudinal study and the main divers of the forecasting model to estimate future energy consumption.
For the third section, a variety of frameworks could be used to forecast demand for energy at a household level. The methodology chosen for the study analyses the problem as a multiple discrete-continuous choice situation where households are essentially making a choice between spending on various fuels (which provide different end-use services) and consume them to varying degrees, driven by a fundamental feature of consumer choice – satiation through a diminishing marginal utility with increasing consumption. A specific implementation of the model using the utility maximization-base Kuhn-Tucker demand systems was proposed by Bhat (2005, 2008) and is particularly attractive as it provides a closed-form probability expression for the choice, a clear interpretation of the utility parameters and a convenient specification of the attributes of the alternatives at hand. An efficient forecasting methodology based on a non-iterative forecasting algorithm was also developed by Pinjari and Bhat (2009).

In addition to the important satiation effect, the model represents the elements of the choice that would (could) drive a move away from conventionally used fuels. These are a mix of attributes of the alternatives (the energy sources), the consumers and the prevailing policy on fuel supply. Relative prices and efficiencies of energy use capture the alternative specific attributes. Consumer specific attributes used in the model are the income levels of the household (represented by the future values of overall household spend), highest education level attained by the adult women in the households and the ownership of appliances. The two attributes of the prevailing ‘environment’ are captured by whether a household is in a rural or urban setting and the equity associated with consumption of modern and clean burning fuels. The second was chosen in the model as there are no specific inputs capturing the availability or supply of energy.

The first step of the analysis is the estimation of the attribute specific coefficients (which determine their impact on the choice, like in any regression model), the alternative specific constants, which largely determine the baseline utility of an alternative and finally the satiation parameters associated with the alternatives. In the case of household expenditure it must be stressed that a bulk of the expenditure (between 85 per cent – 94 per cent) is goods other than energy. This expense is referred to as outside good spend and is always a non-zero figure. The data used for the estimation is the expenditure pattern of households as determined by the NSS 68th Round Survey.

For the purposes of the estimation and the future forecasting exercise, the various fuel categories are grouped into four – solid, liquid, gas and electricity. Solids represent traditional biomass (firewood and dungcake), coal and charcoal. Liquids represent kerosene alone – whether sourced from the market or from the PDS. Gas represents the purchase of LPG (market or subsidized) and PNG (piped gas, if any samples exist within the data set). The reason for the aggregation into these broad categories is that the efficiency is determined by the technologies used in tapping these fuels. Unique efficiency values can be attributed to cookstoves (solids), hurricane lamps (liquids), gas stoves (gas), lighting devices and appliances (electricity) – increasing efficiencies in that order.
The dependent variables in the analysis are the amount spent on each fuel/energy source and not the consumption (physical quantity) itself. In addition, the spend on the outside good also forms part of the dependent variable list.

The independent variables in the estimation exercise are detailed subsequently. The prices were determined from the data and represent the relative price of a unit of purchased energy (as compared to electricity). The price of solid fuels was adjusted based on normative assumptions as the data does not capture the true cost of solid fuels. Efficiencies in the use of the various fuels were obtained from literature. Education level of adult women was scored from levels one through five (basic literacy through to post graduate degree). Overall monthly expenditure of the household, while not an explicit variable, governs the split between the outside good and the fuel alternatives in question (total expenditure = spend on outside good + spend on fuels). Appliance ownership is represented by whether a house has an appliance or not and not the actual number of appliances owned. Only three appliances are considered – air conditioners, refrigerators and washing machines. The categorization of whether a household is in rural or urban areas is captured by a factor variable (1 or 0). Finally, the attribute indicating the equity in consumption of the fuels is calculated at a state level and is calculated as 1 - Gini Coefficient associated with the consumption of LPG and electricity.

\footnote{Based on interactions with experts and other users of NSS data}
Characterisation of Household Energy Demand

The household sector in India consumes about 39% of the total energy supplied in the country, a large share (~ 77%) of this is through traditional biomass-based fuels like firewood, dungcake, charcoal etc., and not accounted for in the official statistics. The pattern of household energy consumption varies across rural and urban regions, states and various income groups. As already discussed in the previous sections, the study uses NSSO survey data for characterizing the household energy consumption.

Table 1: Total per capita Household Energy requirements for various economic classes

<table>
<thead>
<tr>
<th>Household Expenditure Group</th>
<th>Monthly Purchased energy requirement (in Kgoe) per Capita</th>
<th>Monthly Useful Energy requirement (in Kgoe) per Capita</th>
<th>Average Efficiency in Fuel Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom 20%</td>
<td>11.49</td>
<td>1.55</td>
<td>14%</td>
</tr>
<tr>
<td>Top 10%</td>
<td>16.38</td>
<td>4.53</td>
<td>28%</td>
</tr>
<tr>
<td>Average</td>
<td>13.73</td>
<td>2.41</td>
<td>18%</td>
</tr>
<tr>
<td>Urban</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom 20%</td>
<td>7.81</td>
<td>2.14</td>
<td>27%</td>
</tr>
<tr>
<td>Top 10%</td>
<td>10.16</td>
<td>8.20</td>
<td>81%</td>
</tr>
<tr>
<td>Average</td>
<td>7.67</td>
<td>4.01</td>
<td>52%</td>
</tr>
</tbody>
</table>

6 CEEW analysis based on a combination of commercial fuels data from (CSO, 2013) and NSSO 68th Round Survey on Household Expenditures

7 As the survey reports the quantity of consumption of each fuel type, it is pertinent to distinguish between the concepts of primary energy consumption and useful energy consumption. The efficiency factors are sourced from literature (Reddy, 2003) and are directly applied to the purchased energy consumption figure.
The variation across expenditure groups is an indication of the adoption of efficient modern fuel with increasing income, both in rural and urban households. This rate of adoption is more among high income groups in urban areas as suggested by the higher fuel efficiency values. These preliminary aggregations call for nuanced analysis of the data, which is attempted in the following sections.

In order to gain further insights into various sources of energy for heating and lighting among Indian households, we now consider how the consumption pattern has changed across years. For the same purpose, NSSO consumption expenditure data of Indian households collected under the 61st (2004-05) and 68th (2011-12) rounds are considered. Per capita Energy consumption of rural and urban households across income fractiles are represented in Figure 3 and Figure 4. As expected, energy consumption per capita shows an increasing trend. Rural households exhibit lower levels of energy consumption relative to the urban households.

Annual growth rates of per capita consumption increases with income in rural areas. These growth rates vary from 1-4% across fractiles. Interestingly, the same rates in urban areas follow a bell curve, i.e. initially increase (to a level of 5.5%) with income and decrease after a certain level. This may be attributed to the increasing levels of indirect energy consumption at higher income groups which compensates for direct energy requirements.

**Figure 3: Per-capita Energy Consumption (in kgoe/month)-Rural**

![Figure 3: Per-capita Energy Consumption (in kgoe/month)-Rural](image-url)
**Figure 4: Per-capita Energy Consumption (in kgoe/month)-Urban**

![Graph showing per-capita energy consumption](image)

**Fuel Expenditure Share**

Fuel expenditures as percentage of total household expenditure across income fractiles\(^8\), for rural households are represented in **Figure 5**. A similar trend can be observed for urban households as well. As evident from the chart, the fraction of household expenditure spent on fuel consumption decreases with income. While the bottom 20% of households spends 12% - 14% of their monthly expenditure on fuel, the same fraction is around 5-7% for the top 10% of households. On an average a rural household allocates 9% of its expenditure to direct energy consumption needs while an urban household spends 7 % of total expenditure for the same. Though percentage share of expenditure on fuel decreases with income, per-capita consumption of energy in absolute terms increases monotonically with income.

represents the per capita consumption of useful energy across income fractiles for urban and rural households.

---

\(^8\) Fractile is variation from the standard use of income deciles and quintiles. The twelve fractiles of the NSS expenditure classification refer to the declies, with a split in the first and the last deciles to capture the bottom five percentile and top 5 percentile as well. Fractile/group/class could be used interchangeably.

**Figure 5: Fuel expenditure as percentage of household expenditure-Rural**
In 2012, the share of fuel in household consumer expenditure was around 12-14% for the lowest income groups in both rural and urban areas. On an average, this share is less than 10% for rural households and less than 9% for urban households. With a rising MPCE it was seen to fall to about 5% in the top fractile class for rural India and 4% for urban India. The combined picture portrayed by increasing per capita fuel consumption (Figure 5 and Figure 6) and decrease share of spend on fuel (with increasing income) is indicative of more efficient fuels by the higher income groups.

Figure 6: Per capita Total Energy consumption across income fractiles

From a global perspective, this range of observed values is comparable to that of other developing countries (African Development Bank, 2012). However, households in developed countries like Australia spend around 1% - 3% of their household expenditure on fuels
Fraction of income expended on energy requirements by households decreases with income, i.e. low income households spend a significant portion of their income on meeting the energy requirements as compared to high income ones. This decrease is more pronounced in urban households. Figure 7 and Figure 8 indicate this variation across various income fractiles for the years 2004-05 and 2011-12. Over the last seven years, as seen in the comparative illustrations, for both rural and urban India, the fuel expenditure share has shown a decrease, indicating a movement towards the levels observed in developed economies.

The harsh reality though is reflected in Figure 9, where we see that lower income households pay a higher price for each unit of useful energy consumed, as compared to higher income groups. On an average the households in the lowest income group (rural) pay close to INR 65 per kgoe of useful energy while households in the highest group pay around INR 48, nearly 35% higher. This can be one of the biggest hindrances on the path to attain universal energy access as it can result in the ‘energy-poor’ falling into a low income equilibrium trap. One of the positive outcomes from an analysis of the price variations is that there is a sufficient willingness to pay (WTP) among poor rural households as well for energy services. This could make it easier for the roll out of off-grid renewable energy, which currently has a higher upfront cost and hence a higher per-unit cost of electricity produced.
While this section has explored only direct energy consumption in the households, indirect energy is embodied in all goods and services purchased by households. Indirect energy requirements increase more rapidly with income and hence, unlike the fraction of household spend on direct energy, that spent on indirect energy rises significantly from the lowest to the highest household expenditure group (Pachauri, 2005). This has, however, not been verified independently as part of our study with recent data.

**Share of various fuels in the household energy basket**

To understand the household fuel consumption basket better, we analyse the share of different fuel types in the entire fuel consumption basket based on expenditure and useful energy across rural and urban income fractiles.

**Analyses based on expenditure on fuels**

In rural households, firewood is the dominant fuel used across a majority of the households, barring those in the highest two income groups.

Figure 10 and Figure 12 illustrate the share of various fuels in the energy basket, in expenditure terms. At lower fractiles households a significant portion of the energy expenditure is on firewood (more than 50%). As one moves up the income ladder, the (proportion of) expenditure on electricity and LPG increases progressively. Urban households have a larger share of expenditure on electricity and LPG across a majority of the income fractiles. The share of expenditure on LPG increases initially with increasing income but decreases after a certain income level.
This may be a consequence of the satiation in the level of LPG consumption, indicating little marginal gain in utility with increasing LPG consumption (Figure 12). This observation is also substantiated by a comparison of absolute per capita expenditure on LPG across fractiles. In urban areas firewood and kerosene are not the preferred fuel among the higher income groups. Even with a higher income at disposal, the higher income groups in rural India still use a

\[ \text{The rate of increase in LPG consumption (per capita) asymptotically moves towards zero at higher income fractiles} \]
significant proportion of traditional biomass-based fuels—like dung cake and firewood—and kerosene.

**Figure 12: Share of expenditure on various fuel types (Urban)**

Rural households in the lower fractiles spend a significant share of their fuel expenditure on firewood and kerosene consumption. As one move up the income ladder, firewood and kerosene are replaced with more efficient fuels *viz.* LPG and electricity. Urban households spend relatively smaller fractions on traditional biomass and kerosene even at lower income fractiles. This disparity in the spending patterns of rural and urban higher income groups should be recognized not as choices based merely on taste or lifestyle but also to the lack of the necessary infrastructure and resource to supply modern fuels like LPG and electricity.
Analyses based on useful energy demand

Shares of useful energy from derived from various fuels, across income fractiles are shown in Figure 13 and Figure 14. In rural areas, firewood and kerosene are the major fuels demanded by the lower income groups. At higher income levels, firewood and kerosene are replaced with cleaner and efficient fuels, viz. LPG and electricity. This shift takes place between the 8th and 9th income fractiles, indicating a rather slow shift in the demand for modern fuels.

Figure 13: Consumption shares of fuels based on useful energy (Rural)

In urban households, consumption shares of fuels (in kgoe terms) are similar to that obtained in the earlier analysis using expenditures. Satiation in LPG consumption (as explained earlier)
is observed in this analysis as well. Electricity and LPG constitute a bulk of the energy service demands of the households with increasing income, in these households.

Switch between traditional fuels and modern fuels occur only at higher fractiles. Even though this transition takes place at lower fractiles among urban households, in rural households this occurs at a much higher level. In fact the transition occurs at a much lower income fractiles for primary lighting fuels (between kerosene and electricity) than for primary cooking fuels (firewood and LPG). This presents a very challenging situation to the energy access scenario in the country. Supply side constraints of LPG are one of the primary reasons behind this predicament.

Variations in fuel shares (based on consumption) between the two NSS rounds are indicated in Figure 15 and Figure 16. The consumption of traditional bio-mass and kerosene indicate downward shifts between the two snap-shots. Electricity and LPG, on the other hand, shift upwards. This is a clear indication for the increasing penetration of modern fuels in India. This shift also implies that lower income levels are beginning to transition from traditional fuels to modern fuels occur, indicating an improved access scenario.

To a large extent, the success in case of electricity access can be attributed to programs like RGGVY (rural electrification programme) which was started in 2005 for developing rural electricity infrastructure and expanding the base of households connected to the grid. A similar story of transition cannot be said of LPG, as factors which govern a household’s choice of cooking fuel varies largely across sectors, regions and income levels. Schemes like the Rajiv Gandhi Gramin LPG Vitrak Yojana (RGGLVY) which started in 2009, have not sufficiently scaled up on account of lack of availability of LPG domestically and the large amount of subsidy that is currently provided to existing consumers. Adding more to this consumer base would straddle the government with a larger subsidy bill and could explain the slower roll out.
Figure 15: Variation in Fuel Shares-Rural Households
Geographical Variations in Fuel Consumption

The fuel consumption mix depends on a large number of economic, technical, socio-demographic, geographic and lifestyle factors. From the analysis presented thus far, fuel choices for direct energy requirement exhibit a significant variation between urban and rural areas. Thus, analysing the energy consumption at a state or region level would present additional insights into the various exogenous factors affecting a household’s choice of fuel basket like seasonal variation, rate of urbanization, forest cover in any particular region. Charts (in Appendix) represent the per-household consumption of four major fuels (firewood, electricity, LPG and kerosene) in various states across rural and urban sectors.
Seasonal Variation in Overall Energy Consumption

While most of the regions across the country exhibit a low variation in seasonal temperatures, some of the Himalayan states have a larger variation in temperature between summers and winters. Owing to this seasonal variation these states (Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh) are likely to consume more fuel in winters than what they do in summers. This can be attributed to the higher direct energy requirements for space and water heating during the period. Figure 17 represents the per household energy requirement (in kgoe) of various fuels in the Himalayan states during winter (December- March) and non-winter months (April-November).

Following table (Error! Reference source not found.) shows the percentage change in the per-household consumption of various fuel types during winter and non-winter months in the Himalayan states and rest of India. The Himalayan states show considerable increase in the use of traditional fuels (viz. firewood, charcoal, kerosene and dungcake) during winter months. This change is not significant for rest of India, possibly corroborating the earlier assumption of lower variations in seasonal temperatures. In fact the use of electricity shows a decrease in the winters (as compared to the summer) for the rest of India, as the summer months witness a higher space cooling demand.

Figure 17: Per-capita energy consumption split in Himalayan households
Fuel Consumption and per-capita GDP (state)

Gross domestic product (GDP) per capita is often considered as a proxy for economic affluence of a region. An economically affluent region is more likely to consume more energy. Figure 18 represents variation in per capita energy use with GDP per capita across Indian states. Per capita energy consumption goes up with increasing economic affluence.

Economically less affluent states consume least amount of energy per person. States with higher GDP per capita, like Maharashtra, Gujarat, Kerala and Tamil Nadu consumes higher quantities of energy per person. While the causality is possibly bidirectional, it is a clear indicator that at higher levels of GDP per capita, all sections of society will consume more energy on a per capita basis.

Figure 18: Per-capita energy consumption vs. Per-capita GDP across states
**Fuel Consumption and Urbanization Rates**

Factors like extent of forest cover in a particular region and urbanization percentage affects the choice of fuel type especially traditional biomass based fuels. As observed from Figure 19 and Figure 20, share of firewood in total energy consumptions is likely to increase with increase in forest cover and decrease with increasing rates of urbanization in state.

**Figure 19: Per-capita consumption of firewood and forest cover across states**

![Graph showing percentage consumption of firewood vs forest cover across states.](image)

**Figure 20: Per-capita consumption of firewood and extent of urbanization across states**

![Graph showing consumption of firewood vs urbanization across states.](image)

To gain better insights of the relationship a multinomial regression was carried out with percentage consumption of firewood (of population) as dependent variable and percentage of
forest cover and extent of urbanization as independent variables. The fitted equation is represented as below

\[ \text{Firewood share} = 0.42(10.06^*) - 0.53\text{Urbanization}(-6.79^*) + 0.18\text{Forest cover}(2.95^*) \]

* At 1% level of significance

This relation confirms our observations from the charts. Thus a state like Bihar or Uttar Pradesh with very low levels of urbanization is highly likely to exhibit a high dependency on traditional bio-mass fuels. A similar trend can be observed in Figure 21, with the share of expenditure on fuel consumption reducing with increasing levels of urbanization. This essentially means that average share of expenditure on fuel decreases with increasing levels of urbanization, which can be an indication of use more efficient fuels at higher levels of urbanization.

**Figure 21: Percentage of Urbanisation and fraction of fuel expenditure to total household expenditure**

Variations in Fuel Consumption across Social and Religious groups

In order to ascertain the effect of various cultural and life style factors on energy demand, we carry a brief analysis to explain the variations across social and religious groups found in India. Any noticeable (and statistically significant) variation will be accounted for in future analyses.
Variations across Religious groups

Variations in fuel consumption of various religious groups in India are presented graphically in Appendix. The three major religions are considered here. While there is no noticeable variation at the aggregated level, across religious groups, there are significant variations when one considers specific fuels for the analysis. These variations are brought out through specific examples below.

<table>
<thead>
<tr>
<th>Religious Group</th>
<th>% Share in Population(Pan India)</th>
<th>Per capita Income (INR)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rural</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hinduism</td>
<td>83%</td>
<td>1268</td>
</tr>
<tr>
<td>Islam</td>
<td>12%</td>
<td>1202</td>
</tr>
<tr>
<td>Christianity</td>
<td>2%</td>
<td>1712</td>
</tr>
<tr>
<td>Others-religion</td>
<td>2%</td>
<td>1975</td>
</tr>
<tr>
<td><strong>Urban</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hinduism</td>
<td>77%</td>
<td>2575</td>
</tr>
<tr>
<td>Islam</td>
<td>17%</td>
<td>1781</td>
</tr>
<tr>
<td>Christianity</td>
<td>3%</td>
<td>3177</td>
</tr>
<tr>
<td>Others-religion</td>
<td>3%</td>
<td>3143</td>
</tr>
</tbody>
</table>

While the group “Others-religion” constitutes three percent of total population but have a higher per capita income than the three large religious groups. The relatively high per household consumption of modern fuels (LPG and electricity) amongst “Others-religion” may be attributed to their higher levels of economic affluence (Table 3). Similarly, higher consumption of firewood by rural Christians may be linked to the fact that 45% of rural Christians are from the Orissa, Jharkhand, Chhattisgarh and North-eastern states, where the absolute consumption of firewood is very high. As a general rule though, we can conclude that religious groups have no significant impact on the choice of energy mix. This observation will be reflected throughout the report.

Variations across Social Groups

Variations in the fuel consumption basket across various social groups are analysed in this section. and Figure 23 indicate that the choice of fuel for consumption varies widely across social groups, especially in rural areas. Consumption pattern of groups Scheduled Tribes (ST) and Scheduled Caste (SC) and “Other backward Caste” (OBC) are highly skewed towards traditional biomass fuels. Relatively affluent group “Others” use more modern fuels like LPG and Electricity. The difference, while less pronounced in urban regions, is nevertheless noticeable. This can be due to the higher penetration of modern fuels in urban centres. While this difference is significant among social groups, not all of it can be attributed to inherent
choices. It is likely imposed by the systems inability to supply the requisite fuels. Without loss of generality, we can also state that the disparity between the social groups is linked to the underlying differences in economic status between the various groups.

Figure 22: Per-capita fuel consumption across social groups in rural areas

![Per-capita fuel consumption - Social groups Rural](image)

Figure 23: Per-capita fuel consumption across social groups in urban areas

![Per-capita fuel consumption - Social groups Urban](image)
Table 4: Social Groups and Per-capita Income

<table>
<thead>
<tr>
<th>Social Group</th>
<th>% Share in Population(Pan India)</th>
<th>Per capita Income (INR)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rural</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST</td>
<td>11%</td>
<td>1000</td>
</tr>
<tr>
<td>SC</td>
<td>21%</td>
<td>1133</td>
</tr>
<tr>
<td>OBC</td>
<td>45%</td>
<td>1289</td>
</tr>
<tr>
<td>Others</td>
<td>23%</td>
<td>1560</td>
</tr>
<tr>
<td><strong>Urban</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST</td>
<td>3%</td>
<td>1991</td>
</tr>
<tr>
<td>SC</td>
<td>15%</td>
<td>1838</td>
</tr>
<tr>
<td>OBC</td>
<td>42%</td>
<td>2114</td>
</tr>
<tr>
<td>Others</td>
<td>40%</td>
<td>3109</td>
</tr>
</tbody>
</table>

*Choice of cooking and lighting fuel*

The NSS survey also captures the primary choice of fuel for lighting and cooking needs. The primary choice is as stated by households and are not based on the underlying expense incurred in the consumption of fuel. Percentages of households reporting each of these fuels are given in illustrations below (Figure 24 through Figure 27). Primary cooking fuel in rural households is firewood for lower and middle income fractiles while for high income groups LPG is the preferred choice of cooking fuel. Among urban households only the bottom two income fractiles prefer firewood as the major cooking fuel. Lighting fuel choices comprises mainly of kerosene and electricity. Among rural households lower income groups prefer kerosene as major source of lighting but we observe a trend reversal among the higher income groups. In urban households, electricity dominates as the primary lighting fuel across all income groups.

*Figure 24: Percentage of households as per primary cooking fuel across fractiles (Rural)*
Figure 25: Percentage of households reporting various fuels as primary cooking fuel (Urban)

Figure 26: Percentage of households as per primary lighting fuel across fractiles in rural areas

Figure 27: Percentage of households as per primary lighting fuel across fractiles in urban areas
Accessing cleaner and efficient fuels is a major challenge among households in India especially at lower income households and rural areas. The graphs below (Figure 28 & Figure 29) indicate the share of households reporting the various primary\textsuperscript{10} fuels for cooking and lighting, both in rural and urban areas. For cooking, percentage of households using the four major reported primary cooking fuels (\textit{viz.} Firewood, LPG, Dung-cake and Kerosene) are illustrated and for lighting the same is done for the two major lighting fuels (Kerosene and Electricity). As can be noted, access to cleaner fuels is limited and the use of traditional biomass fuels is predominant among rural households.

**Figure 28: Percentage of Households based on Primary Heating Fuel**

![Graph showing percentage of households based on primary heating fuel](image)

The graph above (Figure 28) gives a picture of the distribution of fuel use across rural and urban India. Among rural households, almost 77\% households are still dependent on the most polluting traditional biomass fuels to meet their cooking fuel requirements. The cleaner cooking fuels such as LPG have are popular amongst 15\% of rural households. In comparison, almost 68\% urban households indicate LPG as primary cooking fuel.

\textsuperscript{10} Primary here refers to the main fuel or the fuel of first choice and most often used
The disparity in case of lighting is shown in Figure 29. Lighting patterns vary greatly across rural and urban households. This is particularly evident in case of electricity. Only 73% of rural households indicate electricity as their primary source of lighting. In comparison, more than 96% households predominantly use electricity for lighting purposes.

Both in the case of lighting and cooking, a visible shift to cleaner fuels is evident. The higher rates of electrification and increased access to LPG, as highlighted earlier have led to the shifts. However, firewood usage still persists and penetration of LPG has not increased as much as electricity.

**Energy Inequality in India**

In many developing countries the disparities between the affluent sections and the poorer sections of society are as large as those between the developing and the industrialized countries. Equity in energy consumption assumes importance as it governs the quality of life at across the income spectrum and the disaggregated data available through the NSS enables us to study this. Energy inequality can be measured in terms of type of fuel used, quantity of energy used (useful energy or purchased energy), prices of fuel and energy access.

The Lorenz curve and Gini coefficient are widely used in economics to estimate income inequality. We use analogies of the same by using useful energy consumed as the metric to analyse the extent of energy inequality in India across rural and urban sectors (as detailed in
Jacobsona, Milmana, & Kammen, 2005). Error! Reference source not found. compares the Energy Gini coefficient of modern fuels viz. LPG and Electricity. Error! Reference source not found. represents the same for traditional fuels like Kerosene and Firewood. The Lorenz curves are plotted in Figure 30 and Figure 31.

Table 5: Gini coefficients for Modern Fuels

<table>
<thead>
<tr>
<th>Gini</th>
<th>LPG 04-05</th>
<th>LPG 11-12</th>
<th>Electricity 04-05</th>
<th>Electricity 11-12</th>
<th>Total Useful Energy 04-05</th>
<th>Total Useful Energy 11-12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>0.72</td>
<td>0.50</td>
<td>0.42</td>
<td>0.22</td>
<td>0.25</td>
<td>0.10</td>
</tr>
<tr>
<td>Urban</td>
<td>0.41</td>
<td>0.17</td>
<td>0.41</td>
<td>0.28</td>
<td>0.31</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Table 6: Gini coefficients for Traditional Fuels

<table>
<thead>
<tr>
<th>Gini</th>
<th>Firewood 04-05</th>
<th>Firewood 11-12</th>
<th>Kerosene 04-05</th>
<th>Kerosene 11-12</th>
<th>Total Useful Energy 04-05</th>
<th>Total Useful Energy 11-12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>0.14</td>
<td>-0.07</td>
<td>0.15</td>
<td>-0.10</td>
<td>0.25</td>
<td>0.10</td>
</tr>
<tr>
<td>Urban</td>
<td>-0.27</td>
<td>-0.41</td>
<td>-0.04</td>
<td>-0.19</td>
<td>0.31</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Gini coefficients show that inequality is very prominent in the distribution of modern fuels like LPG and Electricity which indicates that lowest income groups still lack access to modern efficient and clean fuels. Distribution of LPG was highly uneven in both Urban and rural areas during 2004-05. In urban areas this inequality has decreased considerably (from 0.41 to 0.17). Rural areas exhibit decreasing levels of inequality in LPG consumption over the years but a very high value nevertheless (0.50).

Figure 30: Lorenz Curve for Modern Fuels-Rural
A negative gini coefficient for firewood and kerosene indicates that the consumption of such fuels is highly concentrated towards the lower income fractiles.

Lorenz curve analysis of modern fuels highlight significant bias in the energy distribution in the country, especially in rural areas. In case of rural LPG distribution, the bottom 40% of population consumes 8% of the total rural LPG consumption (in 2004-05, the same figure was 1.4%). Corresponding figures in urban LPG consumption is 28% which is indicates a more equitable distribution. The high level of inequality (in rural areas) can also be attributed to the affordability factor. LPG being a costly fuel won’t be readily affordable to the low income households. If not addressed through suitable measures, this inequity can become entrenched and jeopardize efforts to transition to universal use of cleaner fuels.

**Household Energy Aspirations**

The evidence so far is indicative of the wide variation across various attributes in the per-household (or per capita) consumption of energy. While there are a variety of methods to estimate life-line consumption of energy or levels below which people are deemed energy poor, we believe that it is the consumption patterns that people ‘aspire to’, that will drive the energy demand at the household level. Fuels such as firewood, wood chips, dungcake and other traditional biomass find exclusive use in providing cooking and heating needs.
Electricity is primarily used in lighting and running household appliances. Kerosene alone represents a problem in that; it could potentially be used both for cooking and lighting needs, although the former is bound to be limited. Once we are able to apportion the use of kerosene between the two main competing services (cooking and lighting), we could potentially estimate these aspiration levels both from a cooking and lighting perspective.

In order to understand what these aspiration levels could be, we focused on the consumption pattern of households based on their primary (reported) fuel used for lighting. On an average, nearly 99% of the households report either kerosene (~20%) or electricity (~79%) as their primary lighting sources. Among the houses that reported kerosene as their primary source of lighting, consumption of various fuels was done by comparing in groups based on their primary choice of fuel for cooking – firewood (~70%) and dung-cake (~20%). While these two fuels had the lion’s share as primary choices for cooking, a large share (~7%) of households reported using ‘other’ fuels for cooking and it’s not clear what these others are. Among the houses that reported electricity as their primary source of lighting, consumption of various fuels was done by comparing in groups based on their primary choice of fuel for cooking – firewood (~66%), LPG (~19%) and dung-cake (~9%). These three fuels together were reported as the primary cooking fuel in nearly 94% of the households in the rural area.11

The following paragraphs present an analysis of the aspirations for rural households. For, a given income level, the total energy/fuel consumption in households reporting kerosene as their primary lighting fuel was far lesser than those reporting electricity as their primary lighting fuel (Figure 32 & Figure 33).

11 The numbers presented in this paragraph do not make a differentiation between rural and urban and are for the country as a whole.
This is consistently so across all income fractiles, for each of the primary cooking fuel groups and the difference is as high as 70% in the higher income fractiles. This is a surprising statistic as this difference exists within households belonging to the same income fractile. How do households that have a similar range of incomes consume so much lesser energy (in the case of houses using kerosene for lighting)? Do they not have the same demands for energy as other households in their income group to sustain their income levels?

For any given primary lighting fuel choice (kerosene or electricity) and income class, the total energy consumption does not vary significantly, across cooking fuel categories, but it masks the disparity in consumption of ‘clean fuels’. In the case of household using electricity primarily for lighting, the electricity consumption is higher among those households using LPG as primary cooking fuel. These households consume lesser kerosene and a lesser amount of combusting fuels (which are primarily used for cooking). This also indicates the transition to cleaner and more efficient fuels in these households.
Conversely, in households that primarily rely on kerosene for lighting purposes, the majority of the consumption is driven by the use of cooking fuel. So in the case of dung cake and firewood dependent households (for cooking) the major share of consumption was in this. That, cooking / heating fuels constitute a bulk of any households consumption is a well-established fact.

The consumption of kerosene (per capita) in households reporting electricity as primary lighting fuel is depicted in Figure 34. From the figure it is clear that for each income fractile under consideration, those households that report LPG as their primary cooking fuel, have the lowest per capita consumption of kerosene (in kgoe). It is also clear that even at its highest, kerosene accounts for a mere 0.18 kgoe/ capita of the consumption in a household. It’s a very small fraction and typically less than 7% of the overall energy consumption in these households.
This is in contrast to the consumption trends of electricity in these households (Figure 35). Here, consumers of LPG are also the largest consumers of electricity (on a per capita basis). It is very likely that the inverse relationship shown in electricity consumption (as compared to kerosene) indicates that households that consume lesser electricity utilise the kerosene as a substitute for some of the services rendered by the use of electricity, namely lighting. The amount of kerosene consumed, would leave little for cooking purposes in any case.

**Figure 34: Kerosene Consumption across rural households categorised by primary cooking fuel**

![Kerosene Consumption Trends of Households reporting Electricity as Primary Lighting Source](image)

Given that lighting is required on a constant basis (especially in the early morning hours and after sunset) and appliances can be utilised when there is electricity supply, this hypothesis gets further backing, considering that kerosene can provide the necessary lighting (albeit of lower quality, but readily) during blackouts.

Households that report kerosene as their primary lighting source rarely use kerosene for cooking purposes as well, as evident from the sample. In these households, electricity use is minimal and the use of other fuels constitutes nearly 80% of the energy consumed in the household. It can be inferred that kerosene in these households goes only towards lighting and very little if any to cooking.
From the broader connotations of ‘clean’ and efficient attached to these two fuels (viz. LPG and Electricity), it is evident that the consumption basket represented by the group that consumes primarily LPG and electricity, with minimal reliance on kerosene and other fuels represents the aspiration level for households in each income fractile. After all, they consume more of the ‘efficient’ fuels this way and given the favourable underlying price differential (
Appendix 5) associated with cleaner fuels (albeit with the subsidies) they would be better off consuming these cleaner fuels, provided they had sufficient access to these.

**Figure 35: Electricity consumption across rural households categorised by primary cooking fuel**

Econometric Analysis of the per capita fuel consumption

In order to substantiate the graphical analyses done in the previous sections regression analyses were performed with per capita fuel consumption of four main fuels as the dependent variables and monthly per-capita expenditure as the primary determinant while controlling for sector (rural/urban). Literature indicates that income is the single most important factor that influences energy consumption. The following table contains the definitions of various variables used for the regression analysis.
Unsurprisingly, all variables used in the analysis were significant determinants of the per capita energy consumption in both rural and urban areas. Using regression analysis, expenditure elasticity is calculated of the four major fuel choices—firewood, kerosene, LPG and electricity. All the elasticity values are less than one, which indicates that a percentage increase in monthly per capita income will be accompanied by a less than proportionate percentage increase in the consumption of the fuel choice. Very low values of elasticities in firewood indicate that it is the least preferred fuel choice with increasing income. This is more evident in case of urban households. Consumption of electricity increases at a much higher rate, compared to other fuels in both rural and urban areas. These results are in concordance with the graphical observation made in previous sections.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>lnpercapitaenergy</td>
<td>Log of Per capita consumption of useful energy at household level</td>
</tr>
<tr>
<td>lnMPCEMRP</td>
<td>Log of Monthly per capita expenditure</td>
</tr>
<tr>
<td>lnpercapitafirewood</td>
<td>Log of Per capita useful energy consumption at household level from firewood</td>
</tr>
<tr>
<td>lnpercapitakerosene</td>
<td>Log of Per capita useful energy consumption at household level from kerosene</td>
</tr>
<tr>
<td>lnpercapitaLPG</td>
<td>Log of Per capita consumption of useful energy at household level from LPG</td>
</tr>
<tr>
<td>lnpercapitaelectricity</td>
<td>Log of Per capita useful energy consumption at household level from electricity</td>
</tr>
<tr>
<td>Sector</td>
<td>Factor variable used, indicates whether the household belongs to Rural/Urban sectors- Values will be 1 for rural and 2 for urban</td>
</tr>
<tr>
<td>IncomeFractile</td>
<td>Factor variable, indicates the income percentile group which a particular household belongs to. Values vary from 1 to 12.</td>
</tr>
</tbody>
</table>

Source: CEEW Analysis
What is the status of energy access in India?

The analysis in the preceding sections indicates that there is a large disparity in the consumption of energy across income groups, social groups and between rural and urban households. While the difference is perceptible, setting a threshold to determine those who have access and those who don’t is still tricky. Determining who has access and who does not becomes an attempt in differentiating energy poverty and energy access. From our understanding of the data at hand, energy poverty is determined by two factors – the ability to pay for the requisite amount of energy and the access to the desired forms of modern energy. This feeds into the definitions discussed in the opening sections of the report where the discussion centred on the prevalence of income poverty and energy poverty. It is easily seen why many households consume less than their desired level of modern fuels. In addition to their inability to pay for energy, India suffers from a chronic shortage of modern fuels (viz. LPG/gas and electricity) and many households are forced to fill the gap with traditional biomass and unclean fuels like kerosene and coal. This is a problem of access and the problem of identifying access reduces to the identification of households that spend less than a ‘specific’ proportion of their expenditure on clean fuels. On an average, across the country the median spend on clean fuels is ~50% (of the expenditure on fuels as a whole). Given the uncertainty around the state of housing, technologies in use and varying geographical conditions across the length and the breadth of the country, it would be useful to highlight the disparity between rural and urban areas to provide a semblance of the task ahead- in alleviating energy poverty and improving energy access. Less than a quarter of the urban residents spend more than 50 per cent of their expenditure on energy towards unclean solid fuels and kerosene. In rural areas though, more than 80 per cent of the population apportions more than 50 per cent of their expenditure on energy towards solid fuels and kerosene. A convergence between rural and urban areas must be the medium target as urban residents are on the normatively higher trajectory and their consumption pattern captures aspiration levels better.

When we compare the price of fuels in terms of INR per useful unit of energy (kgoe), we find that traditional fuels are as expensive if not more than modern fuels. The lower conversion efficiencies of traditional fuels and the technologies associated with them bring their prices on par with modern fuels. If the affordability factor is accounted for, the only plausible explanation for these households spending less than 50% of the fuel expenditure on modern fuels is a result of insufficient availability. As much as 80% and 21% of the population in rural and urban areas respectively are deemed to have insufficient access to clean energy. While the willingness is there to pay (implicit in the prices), the requisite infrastructure to supply these fuels to the people who demand them is not there. That really is the most crucial factor playing a role in the low levels of energy access in the country.
Forecasting Energy Demand

As mentioned earlier, the KT demand modelling systems are based on resource allocation formulation, wherein the decision making mechanism is assumed to be driven by an allocation of the limited amount of resources to consume various alternatives so as to maximize the utility derived out of the consumption. A stochastic utility framework is used in recognition of the analysts’ lack of awareness of all factors affecting the consumers’ decisions. In theory, the model allows us to capture random variations in choices, and assuming that this unobserved heterogeneity is Gumbel distributed allows for a closed form consumption probability expression which is exploited in the estimation and forecasting process.

In order to forecast, a view on the projected (future) values of all the independent variables is required. Households in the sample that are currently in rural areas are assumed to be that way in the future too, but their representation (through the multiplier) of the population changes in order to reflect future split of population between rural and urban areas. For example a household that in Gujarat (in Ahmedabad district) that is currently representing 30,000 urban households would in the later years represent a larger proportion (say 50,000) urban households and more populations move to urban areas.

Efficiencies of traditional cookstoves are increased in a linear manner, reaching a maximum of 35% by the year 2041. Relative prices\textsuperscript{12} were increased at rates at which they grew between the 61\textsuperscript{st} and 68\textsuperscript{th} Round of the NSS survey.

Future values of monthly per capita expenditure (MPCE) for households in the various income categories were arrived at based on historically observed elasticity of MPCE growth with respect to macroeconomic GDP growth figures. A three parameter Gompertz function is used to model ownership patterns and is based on data from the 61\textsuperscript{st} and 68\textsuperscript{th} rounds of the NSS. Ownership is modeled as a function of MPCE as opposed to income in the classic Gompertz functions. The progression in education was less evident from historical data and normative assumptions were made around the increased levels of education attained by the adult women of the households. As a rule of thumb, women in 20 per cent of the households (as represented by each household in the sample) were assumed to increase their maximum education levels by one level, every five years (in line with the discrete time steps of the forecasting process). Finally, the equity levels were assumed to grow by five per cent (of prevailing values at a state level), every five years. While the last two are limiting assumptions, they also have a significant impact on the consumption patterns and specific policies that lead to a rise in average education levels and a focus on equity will certainly yield different forecasts.

\textsuperscript{12} Not modeled as an independent variable like the others. It is used to normalize the baseline utility, which then governs whether an alternative is chosen and if it is, how much of it is consumed
A final but important element of the forecasting process is the simulated error term draws \((e_k)\). While these are not captured in the data itself, their role is to account for the unexplained factors that go into making the choice. For each household, five simulated error terms are drawn which plays a significant role in determining the utility associated with the various alternatives (including the outside-good) available to the consumer. Given that the forecasting sample has close to 102,000 households, nearly 510,000 error terms are drawn from a Gumbel distribution (generated from an underlying uniform random distribution).

This process is repeated 50 times for each household, in order to capture the variations in the error terms and the average is reported as the forecast for each household. Larger the number of draws (Halton draws), more reliable the forecast is expected to be. These are then multiplied with the modified multipliers which indicate the population represented by each household and a total spend on the various alternatives and outside good is obtained. The spend is then converted to energy terms by applying the prevailing prices (which were assumed and used as input) and this gives an idea of the energy consumption arising from the corresponding spending.

More details on the forecasting algorithm and methodology can be found in Pinjari and Bhat, 2009. (pg. 11-12). The forecasts arrived at using the methodology described above, conditional on the assumptions made, is detailed in in table below.

<table>
<thead>
<tr>
<th>Year</th>
<th>Solid</th>
<th>Gas</th>
<th>Liquid</th>
<th>Electricity</th>
<th>Total MTOE</th>
<th>Population (million)</th>
<th>GDP Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011 (data)</td>
<td>123.48</td>
<td>12.48</td>
<td>5.75</td>
<td>16.20</td>
<td>158</td>
<td>1,201</td>
<td>-</td>
</tr>
<tr>
<td>2011 (back cast)</td>
<td>115.15</td>
<td>14.48</td>
<td>5.32</td>
<td>17.90</td>
<td>153</td>
<td>1,201</td>
<td>-</td>
</tr>
<tr>
<td>2016</td>
<td>120.62</td>
<td>17.35</td>
<td>6.75</td>
<td>26.24</td>
<td>171</td>
<td>1,278</td>
<td>8.5%</td>
</tr>
<tr>
<td>2021</td>
<td>124.30</td>
<td>23.30</td>
<td>7.56</td>
<td>32.30</td>
<td>187</td>
<td>1,370</td>
<td>8.4%</td>
</tr>
<tr>
<td>2026</td>
<td>128.89</td>
<td>29.20</td>
<td>5.45</td>
<td>45.90</td>
<td>209</td>
<td>1,439</td>
<td>8.2%</td>
</tr>
<tr>
<td>2031</td>
<td>141.20</td>
<td>34.50</td>
<td>4.78</td>
<td>59.07</td>
<td>240</td>
<td>1,523</td>
<td>8.0%</td>
</tr>
<tr>
<td>2036</td>
<td>141.31</td>
<td>41.43</td>
<td>3.54</td>
<td>75.41</td>
<td>262</td>
<td>1,580</td>
<td>7.9%</td>
</tr>
<tr>
<td>2041</td>
<td>136.51</td>
<td>55.65</td>
<td>2.54</td>
<td>96.57</td>
<td>291</td>
<td>1,651</td>
<td>6.4%</td>
</tr>
<tr>
<td>2046</td>
<td>130.38</td>
<td>65.44</td>
<td>2.51</td>
<td>121.83</td>
<td>320</td>
<td>1,695</td>
<td>6.0%</td>
</tr>
<tr>
<td>2051</td>
<td>127.88</td>
<td>70.70</td>
<td>2.31</td>
<td>143.63</td>
<td>345</td>
<td>1,751</td>
<td>6.0%</td>
</tr>
</tbody>
</table>

Source: CEEW Analysis
From the forecast it is evident that the use of solid fuels (in the form of traditional biomass) is likely to remain at current levels, though per capita consumption will show a significant decline. The use of gas (either as LPG or PNG) shows phenomenal growth, specifically in the rural areas accompanied by a steady decline in the (already low) use of liquid fuels such as kerosene. The more obvious and expected growth is in the demand for electricity from higher standards of living and increase ownership of modern appliances. As can be seen, the backcast of the base year data yields a slight variation in the consumption of biomass. While this can be attributed to the stochastic error terms, a bias in the model estimation towards gas based fuels is a plausible explanation, specifically through the use of the scale multiplier term, to convert sample figures to represent the population as a whole.
Conclusion

The first section of the report provided a detailed breakdown of the energy access scenario in the country. Despite six decades of independence and nearly two decades into the post-liberalization era, the situation in terms of energy access remains grim. Nearly 20% of the households in the country consume no electricity and of these nearly 94% are in rural areas. The situation when it comes to cooking fuels is less optimistic. Nearly two thirds of the households in the country do not consume any LPG and nearly 85% of these households are in the rural areas where firewood is the predominant (possibly preferred) form of cooking fuel. This has serious consequences for the indoor air quality in the households and the health of women and children who are often exposed to the emissions from firewood burning and kerosene fumes that result from their respective usage.

With increasing income per-capita energy consumption rises, but the fraction of income expended to meet energy requirements decreases simultaneously. Thus, removal of energy poverty assumes foremost importance in alleviating income poverty; else a significant share of household income in poor households will be diverted to meet sustenance energy demand. Our analysis also indicates that the price useful energy consumed by a poorest household is costlier than that by a richest household by more than 35%. The choice of fuel varies with income and hence the share of expenditure on various fuels. On an average, as one moves up the income ladder, more efficient fuels like LPG and electricity are preferred to firewood and kerosene.

The fuel consumption mix depends on a large number of economic, technical, socio-demographic, geographic and lifestyle factors. For example, Himalayan states which faces severe winter compared to rest of India consumes significantly more energy during winter than non-winter months. Extent of urbanization and economic affluence of a particular state can positively influence the per capita energy consumption. There exists a strong link between energy demand and household attributes such as household income (as represented by the expenditure), social status, location of household (rural/urban) etc.

There is also a large variation in consumption across the varied geography (political and physical) of India. This can be explained by the differential resource endowment of the states and the concomitant economic growth rates witnessed by each. While state specific policies have also played a key role, it may be necessary for targeted interventions by the central government to ensure national growth and aspirations have a commensurate impact on poorest states of the country. This will be a significant assumption going forward, in the estimation of future energy access pathways and the extent to which energy poverty is alleviated.

A transition to cleaner and efficient fuels over the next few decades is evident and desirable. At projected rates of macroeconomic growth and population growth, the reliance on solid fuels (traditional biomass, coal and charcoal) is set to continue. Given that a bulk of the
kerosene usage today is for lighting services, where electricity has yet to reach, this consumption will dwindle down to insignificant levels. The consumption of LPG/PNG and electricity on the other hand, are likely to witness a meteoric increase with the rising aspiration levels of the population, driven by higher incomes and use of appliances and an increasing awareness of the socio-economic benefits of consuming these fuels. While factors such as education levels of adult women and income levels contribute to the transition, it will not be realized without active intervention on part of the government. Equitable distribution of resources is a must if the aspirations of the lower income groups are to be realized and here the state must play a stronger role to ensure more efficient last mile delivery and a rationalized subsidy regime to ensure equality in outcomes and not just in the opportunities.
Bibliography


IPCC. (2000). *SPECIAL REPORT EMISSIONS SCENARIOS*. IPCC.


Appendix 1: End Use efficiencies associated with fuels used in households

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Efficiency in Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Biomass</td>
<td>10%</td>
</tr>
<tr>
<td>Coal/ Coke</td>
<td>10%</td>
</tr>
<tr>
<td>LPG</td>
<td>60%</td>
</tr>
<tr>
<td>Kerosene</td>
<td>35%</td>
</tr>
<tr>
<td>Electricity</td>
<td>100%</td>
</tr>
</tbody>
</table>

Appendix 2: Per-capita consumption (Useful Energy) of fuels across states in kgoe/month

<table>
<thead>
<tr>
<th>Rural State</th>
<th>LPG</th>
<th>Traditional Biomass</th>
<th>Kerosene</th>
<th>Electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andaman &amp; Nicobar Islands</td>
<td>0.72</td>
<td>1.32</td>
<td>0.39</td>
<td>1.69</td>
</tr>
<tr>
<td>Andhra Pradesh</td>
<td>0.47</td>
<td>0.94</td>
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Appendix 3: Household Consumption of Fuels religion-wise

Per-Capita Consumption of fuels-Religionwise-Rural

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<th>Energy Consumed in kgs</th>
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<th>Others</th>
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<tr>
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<tr>
<td>Per capita Electricity consumption</td>
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Per-Capita Consumption of fuels-Religionwise-Urban

<table>
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<th>Islam</th>
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<th>Others</th>
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<tr>
<td>Per capita Firewood consumption</td>
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## Appendix 4: Major policies and programmes for expanding rural energy access

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<tr>
<th>Policy/Programme</th>
<th>Objectives, Scope and Impacts</th>
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<td>Supply of kerosene through public distribution system (PDS) with quantity restriction, in 1957</td>
<td>Ensure benefits are reached to the poor and needy people. Households are allotted kerosene consumption quotas that vary by state and region (urban and rural), and whether they have an LPG connection or not. Nearly 40% of the PDS kerosene gets illegally diverted and is used to adulterate diesel and petrol for transport. Subsidy is prevalent to this day.</td>
</tr>
<tr>
<td>Subsidies on household cooking fuels like kerosene and LPG in late 1960s</td>
<td>Provide affordable access to modern fuels for the poor. Subsidy on LPG is available for all the consumers irrespective of their income levels. Subsidy on kerosene is available for those without an LPG connection. Thus, subsidies for both costing about Rs. 485 billion (in 2008) are not targeted at the poor.</td>
</tr>
<tr>
<td>National Project on Biogas Development (NPBD) in 1982</td>
<td>Disseminate family type biogas plants. Modern fuel for cooking and organic fertilizer to rural households, mitigate drudgery of women, reduce pressure on forest. Biogas plants built till 2009 is estimated at 4.17 million. Estimates suggest that only about 28% of them provide primary cooking fuel to relatively rich rural households.</td>
</tr>
<tr>
<td>National Programme on Improved Chulhas (NPIC) or cookstoves in 1983</td>
<td>Disseminate advanced biomass cookstoves. Efficient use of fuel wood and avoid deforestation, reduce drudgery for women and health hazards caused by indoor pollution. By 2003, over 35 million stoves had been built; however, the NPIC was found to be ineffective in promoting a shift to improved stoves therefore the funding was stopped in 2002.</td>
</tr>
<tr>
<td>Expanding rural lighting energy access</td>
<td>Support rural electrification schemes &amp; rural electricity co-operatives. Two major thrust areas of REC are irrigation pump electrification and village electrification. REC acts as the nodal agency for the centrally sponsored programmes.</td>
</tr>
<tr>
<td>Minimum Needs Programme in 1974</td>
<td>Provided 100% loans from the central government for last mile connectivity for rural electrification projects in less electrified states.</td>
</tr>
<tr>
<td>Kutir Jyoti (bright hut) Scheme in 1988</td>
<td>Provided a single point lighting connections to households below the poverty line (BPL). Connected nearly 7.2 million rural households to the grid till March 2006 with a total grant amount of about Rs. 6.12 billion.</td>
</tr>
<tr>
<td>Pradhan Mantri Gramodaya Yojana (Prime minister’s village development programme) in 2000</td>
<td>Rural electrification was one of the many programmes. It offered financing through loans (90%) and grants (10%). It was coordinated and monitored by the Rural Development Division of the Planning Commission.</td>
</tr>
<tr>
<td>Rural Electricity Supply Technology Mission in 2002</td>
<td>Electrification of all villages and households progressively by year 2012 through renewable energy sources and decentralized technologies, in addition to conventional grid connection.</td>
</tr>
<tr>
<td>Accelerated Rural Electrification Programme (AREP) in 2003</td>
<td>Interest subsidy of 4% was provided on loans availed by state governments/power utilities from financial institutions for carrying out rural electrification programme. It was limited to electrification of un-electrified villages, smaller settlements of lower-caste people and tribal villages, and through both conventional and non-conventional sources of energy.</td>
</tr>
<tr>
<td>The Electricity Act 2003</td>
<td>Specific directions for expanding rural electricity access and for the first time mentions rural electrification in a statute. Mandates universal service obligation and formulation of a national policy on rural electrification. States that the state and central governments shall jointly endeavor to provide electricity access to all [</td>
</tr>
<tr>
<td>Accelerated Electrification of One lakh villages and One crore households in 2004</td>
<td>Village and household electrification. Accelerated electrification of 100,000 villages and 10 million households by merging the interest subsidy scheme of AREP and Kutir Jyoti programme. Provision was made for providing 40% capital subsidy and the balance as loan assistance on soft terms from REC.</td>
</tr>
<tr>
<td>National Electricity Policy in 2005</td>
<td>Access to electricity for all households and demand for power to be fully met by 2012, and minimum lifeline consumption of 1 kWh/household/day by 2012.</td>
</tr>
<tr>
<td>Rajiv Gandhi Grameen Vidhyutikaran Yojana (rural electrification programme) in</td>
<td>Scheme for developing rural electricity infrastructure and expanding household electrification with 90% capital subsidy and 10% loan assistance. Final connection is provided free of cost for BPL households. The total cost of the programme is Rs.</td>
</tr>
</tbody>
</table>
2005 | 287 billion and the achievements as on April 2010 are electrification of 79,000 villages and 12 million rural households
Rural Electrification Policy in 2006 | The rural electrification policy elaborates on the issues mentioned in the national electricity policy and makes specific recommendations for effective implementation of the rural electrification programme
National Biomass Cookstoves Programme (NBCP) in 2009 | Claims to be different from the failed NPIC. The initiative stressed the setting up of state-of-the-art testing, certification and monitoring facilities and strengthening R&D programmes. The aim is to design and develop the most efficient, cost effective, durable and easy to use device.
Rajiv Gandhi Gramin LPG Vitruk Yojana (RGGLVY) in 2009 | Aims to eliminate ailments due to use of chulhas and to provide clean cooking fuel to rural women folk. By 2015, the scheme aims to have a minimum of one LPG distributor per block in the country, all districts to have 50% LPG coverage, all states to have minimum 60% LPG coverage and 75% LPG coverage in all of India.

Source: Adapted from Balachandra (2011) and updated subsequently
Appendix 5: Price of Energy for various income groups (INR/ kgoe useful)

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