Council on Energy, Environment and Water

June 2014 | New Delhi, India

CEEW Working Paper 2014/10

Energy Access in India - Today, and Tomorrow

Karthik Ganesan and Rajeev Vishnu

ceew.in/publications

Thapar House
124, Janpath
New Delhi 110001
India

Tel: +91 11 40733300

info@ceew.in

Energy Access in India – Today, and Tomorrow

Authors
Karthik Ganesan and Rajeev Vishnu

CEEW Working Paper June 2014 ceew.in

A report on Energy Access in India – Today and Tomorrow

The Council on Energy, Environment and Water (CEEW) is an independent, not-for-profit, policy research institution. CEEW works to promote dialogue and common understanding on energy, environment and water issues in India, its region and the wider world, through high quality research, partnerships with public and private institutions, engagement with and outreach to the wider public. For more institution, visit http://www.ceew.in.

Council on Energy, Environment and Water
Thapar House, 124, Janpath, New Delhi 110001, India

ABOUT CEEW

The Council on Energy, Environment and Water (http://ceew.in/) is an independent, not-for-profit policy research institution. CEEW addresses pressing global challenges through an integrated and internationally focused approach. It does so through high quality research, partnerships with public and private institutions, and engagement with and outreach to the wider public. In June 2013, the International Centre for Climate Governance **ranked CEEW 15th globally** in its first ranking of climate-related think-tanks and **number 1 in India**. In January 2014, the Global Go To Think Tank Index ranked CEEW **1st in India in three categories**.

In little over three years of operations, CEEW has engaged in more than 45 research projects, published 32 peer-reviewed policy reports and papers, advised governments around the world over 50 times, engaged with industry to encourage investments in clean technologies and improve efficiency in resource use, promoted bilateral and multilateral initiatives between governments on 17 occasions, helped state governments with water and irrigation reforms, and organised more than 45 seminars and conferences.

Among its major completed projects, CEEW has: published the 584-page National Water Resources Framework Study for India's 12th Five Year Plan; written India's first report on global governance, submitted to the National Security Adviser; undertaken the first independent assessment of India's 22 gigawatt solar mission; analysed India's green industrial policy; written on the resource nexus and on strategic industries and technologies for India's National Security Advisory Board; facilitated the $125 million India-U.S. Joint Clean Energy R&D Center; published a business case for phasing down HFCs in Indian industry; worked on geoengineering governance (with UK's Royal Society and the IPCC); published reports on decentralised energy in India; evaluated storage technologies; created the Maharashtra-Guangdong partnership on sustainability; published research on energy-trade-climate linkages for the Rio+20 Summit; produced comprehensive reports and briefed negotiators on climate finance; designed financial instruments for energy access for the World Bank; designed irrigation reform for Bihar; and a multi-stakeholder initiative to target challenges of urban water management.

Among other initiatives, CEEW's **current projects include**: developing a countrywide network of hundreds of firms and stakeholders for energy access (an idea endorsed by Prime Minister Singh and President Obama in September 2013); modelling India's long-term energy scenarios; supporting the Ministry of Water Resources with India's National Water Mission; supporting the Planning Commission on industrial water; modelling exercises on energy-water linkages; a business case for greater energy efficiency and emissions reductions in the cement industry; etc.

CEEW's **work covers all levels of governance**: at the national level, it covers resource efficiency and security, water resources, and renewable energy; at the global/regional level, these include sustainability finance, energy-trade-climate linkages, technology horizons, and bilateral collaborations, including with China, Israel, Pakistan, and the US; and at the state/local level, CEEW develops integrated energy, environment and water plans, and facilitates industry action to reduce emissions or increase R&D investments in clean technologies.

Contents

List of Figures

List of Tables

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 upto 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 Vis-a Vis 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

[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 reside, 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 4. 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

[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, & Üçdoğrukb, 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).

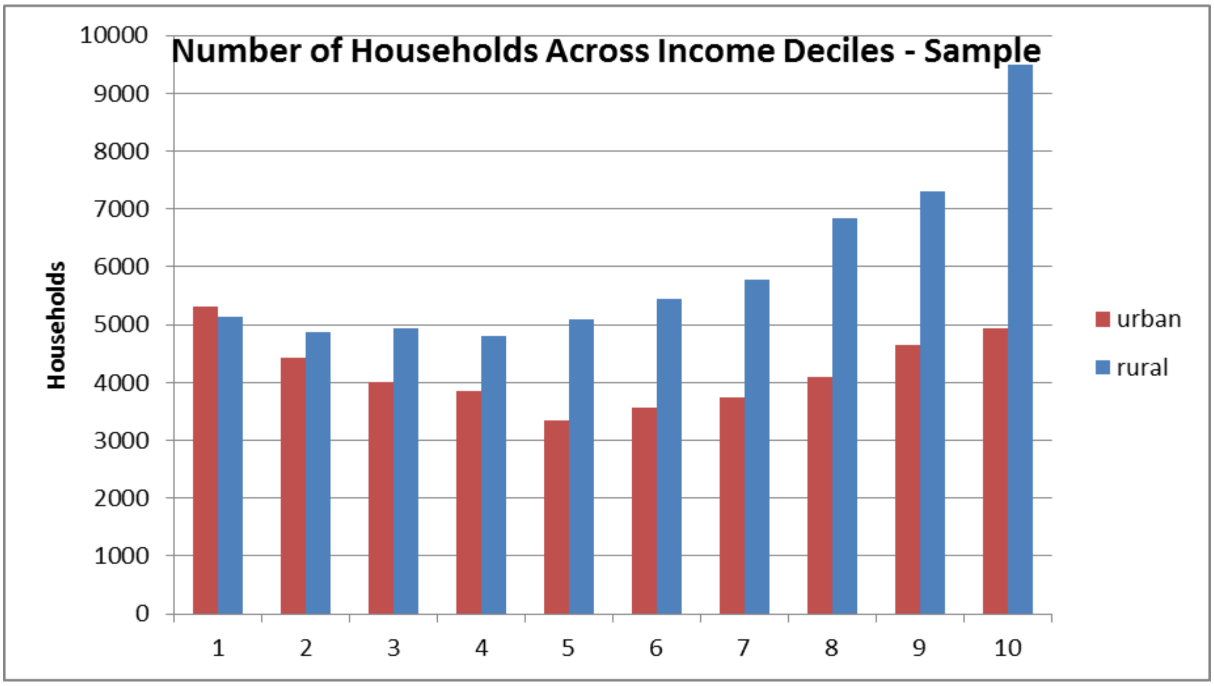
Data and Methodology

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[4] 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).

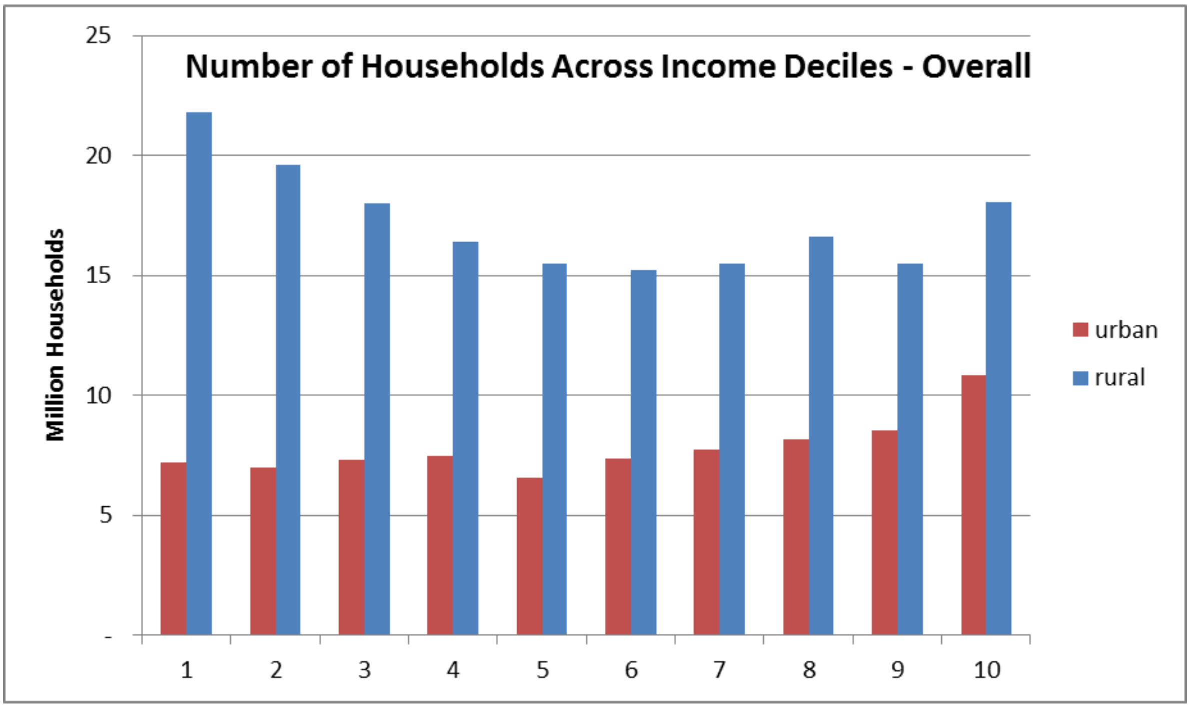
The 68th round comes close on the heels of the 66th round that was conducted in 2009-10, which also captured essentially an identical set of expenditure attributes as the 68th round. The sample size associated with the chosen round is to the tune of 101,654 households. To give a sense of the extent of 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

Figure 2: Household Distribution across Income Deciles (Population, after accounting for multiplier)



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.[5] 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.

[5] Based on interactions with experts and other users of NSS data

Characterisation of Household Energy Demand

The household sector in India consumes about 39%[6] 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.[7] .

illustrates the energy consumption pattern of households across economic groups and this in turn can be due to differences in lifestyles and other similar factors. Though rural monthly per capita purchased energy consumption is more than the urban, monthly per capita useful energy requirement suggests the opposite. This suggests that average efficiency of fuel consumption by urban households (52%) is much higher than that of rural (18%). Thus, low useful energy to purchased energy ratios arise from the the predominance of traditional biomass combined with in efficiencies of antiquated technology in the use of these traditional fuels. The details of the assumptions behind end use efficiency of the various fuels are provided in Appendix 1.

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

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

---

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

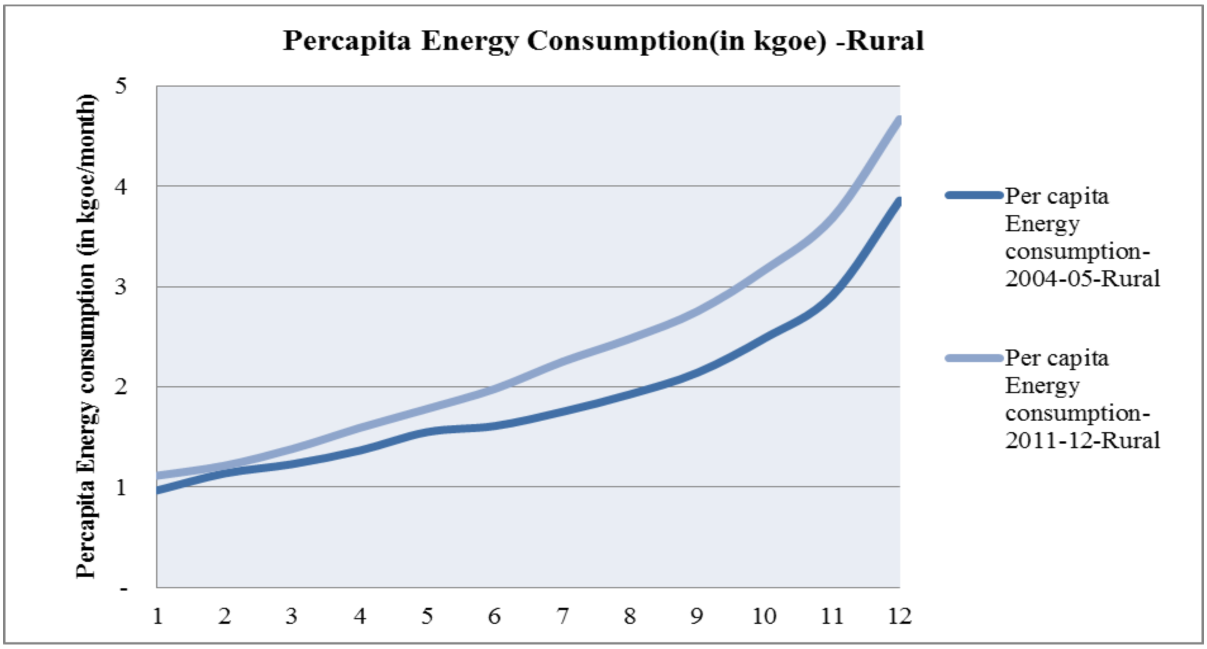
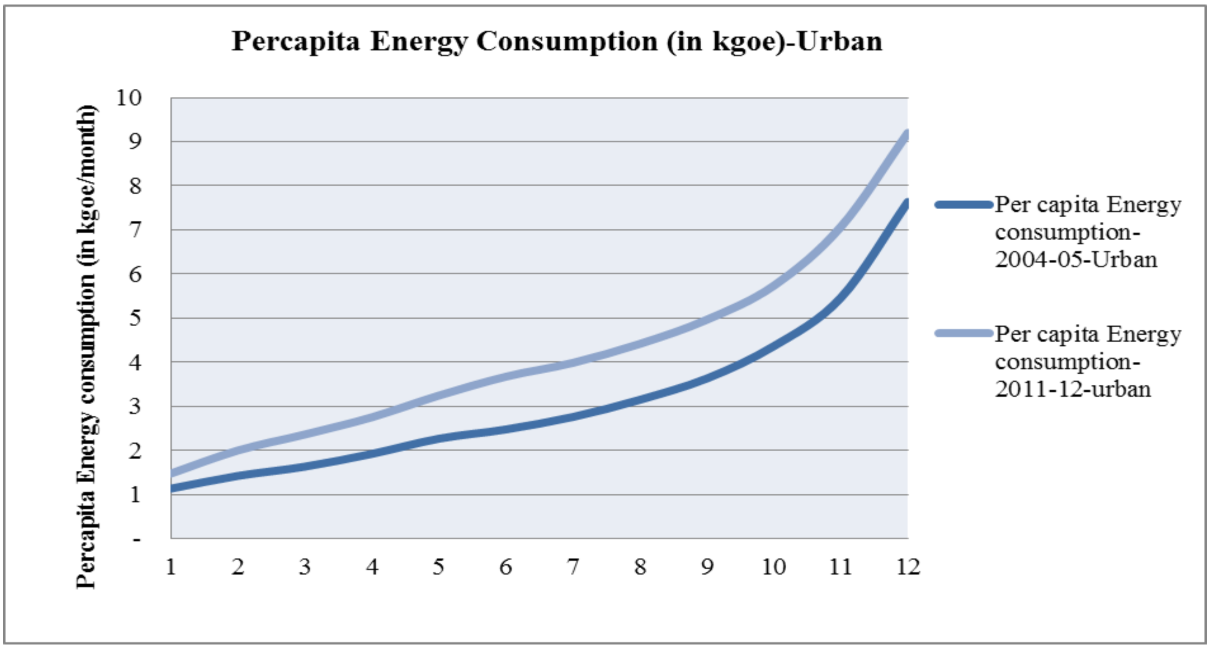


Figure 4: Per-capita Energy Consumption (in kgoe/month)-Urban



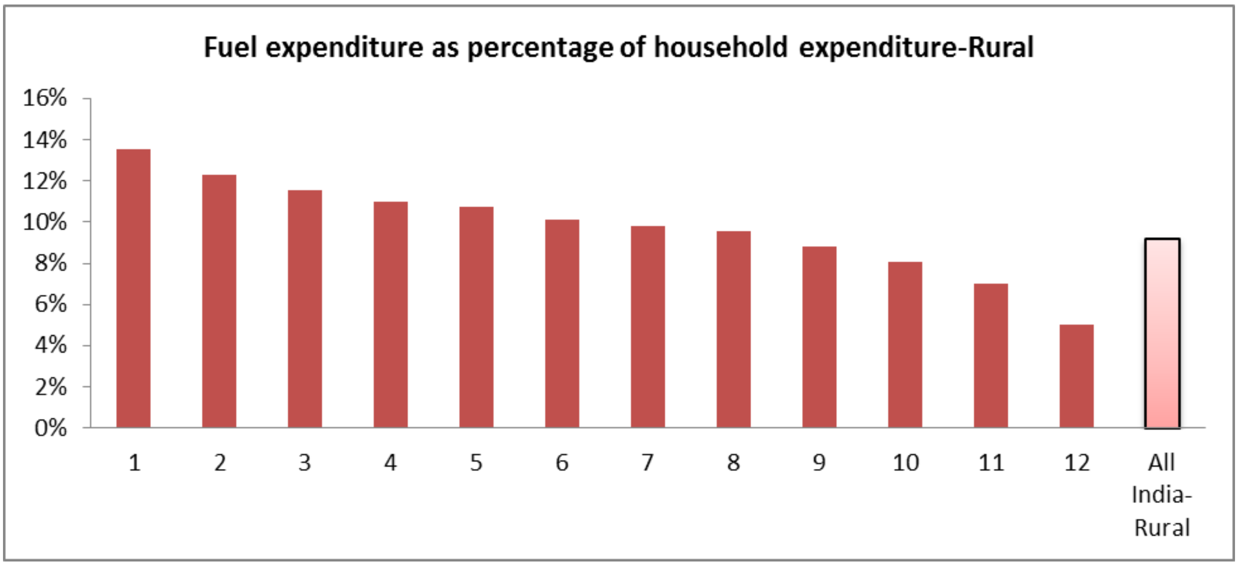
Fuel Expenditure Share

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 monotically with income.

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

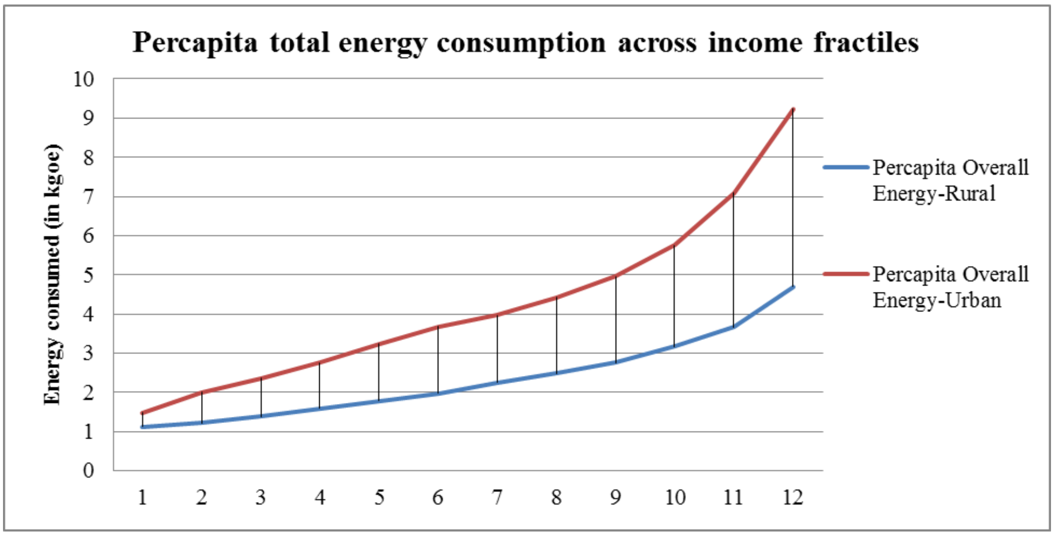
Figure 5: Fuel expenditure as percentage of household expenditure-Rural

[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.



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

(Productivity Commission, Australia, 2011). The same figure for United States was 7.5% in 2010 ((Ferdous, Pinjari, Bhat, & Pendyala, 2010)

Figure 7: Fuel Expenditure share- Rural

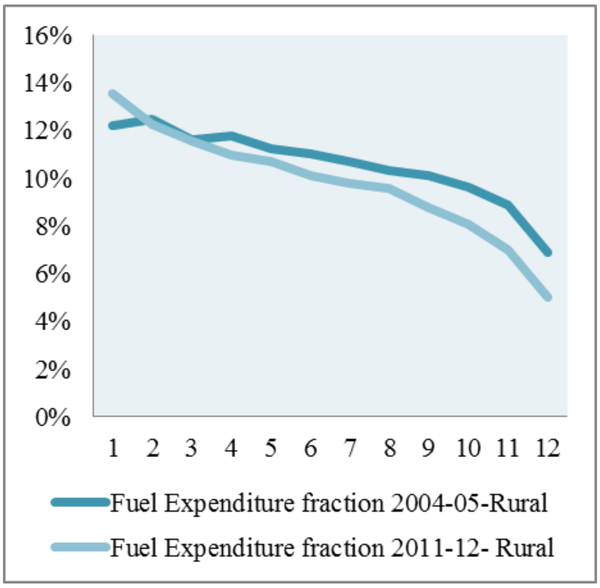
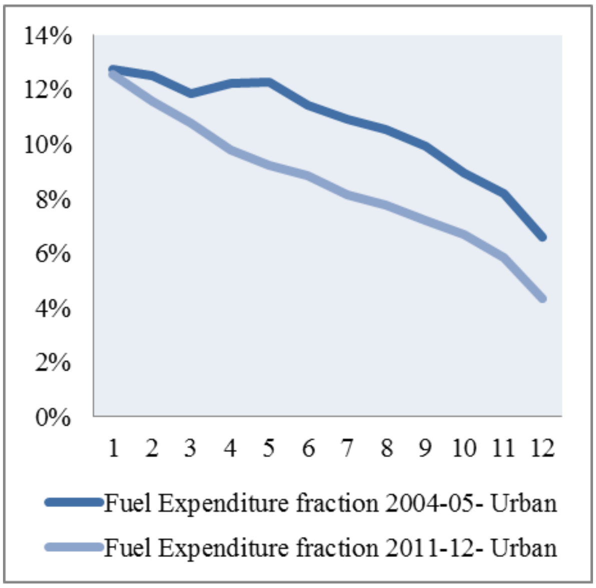


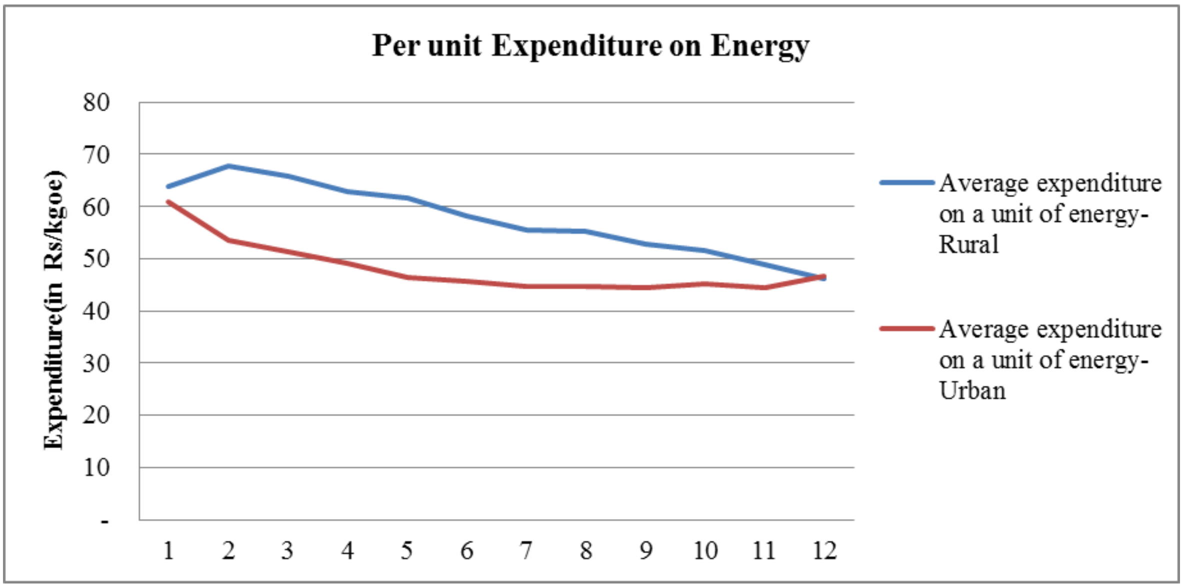
Figure 8: Fuel Expenditure Share- Urban



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.

Figure 9: Price of Energy for Urban and Rural households



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.

Figure 10: Consumption share of expenditure on various fuel types (Rural)

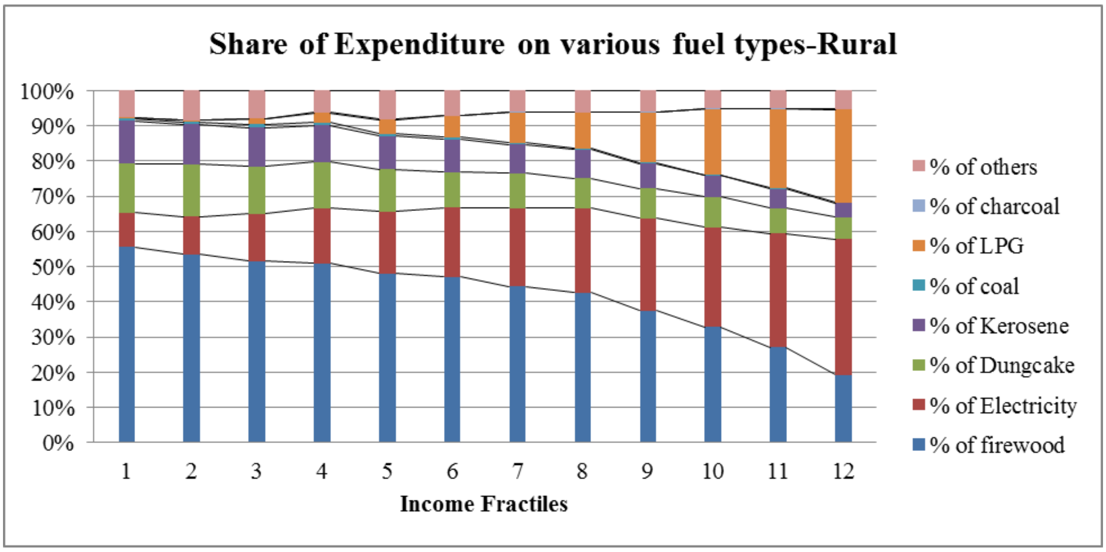
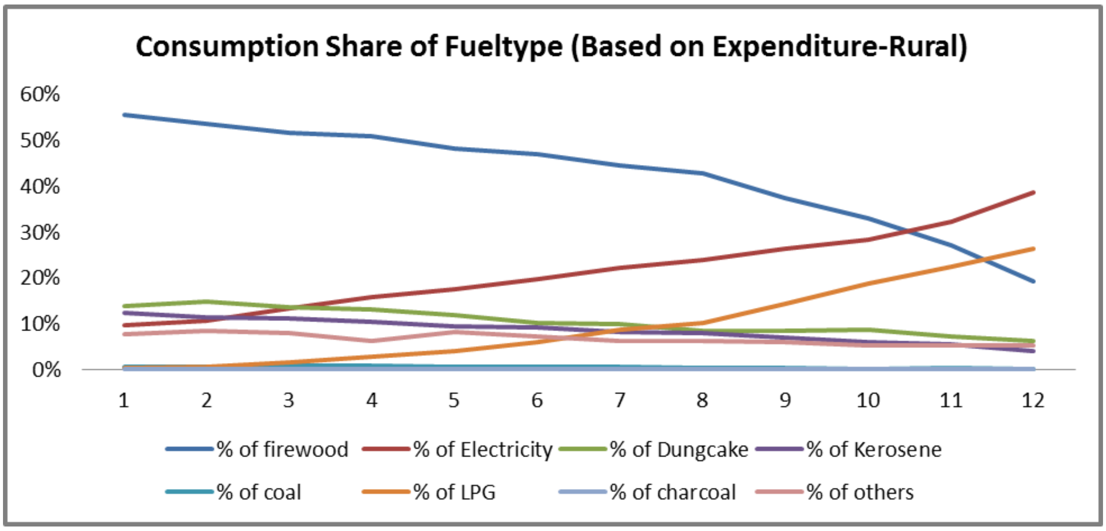


Figure 11: Consumption shares of fuel types based on expenditure (Rural)

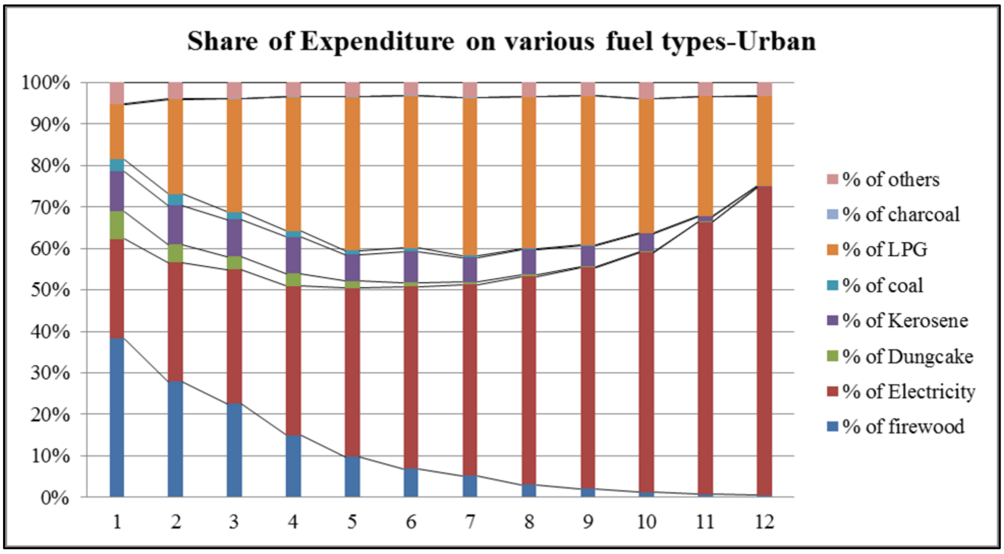


This may be a consequence of the satiation in the level of LPG consumption, indicating little marginal gain in utility with increasing LPG consumption (Figure 12). This observation is also substantiated by a comparison of absolute per capita expenditure on LPG across fractiles[9]. In urban areas firewood 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

[9] 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)

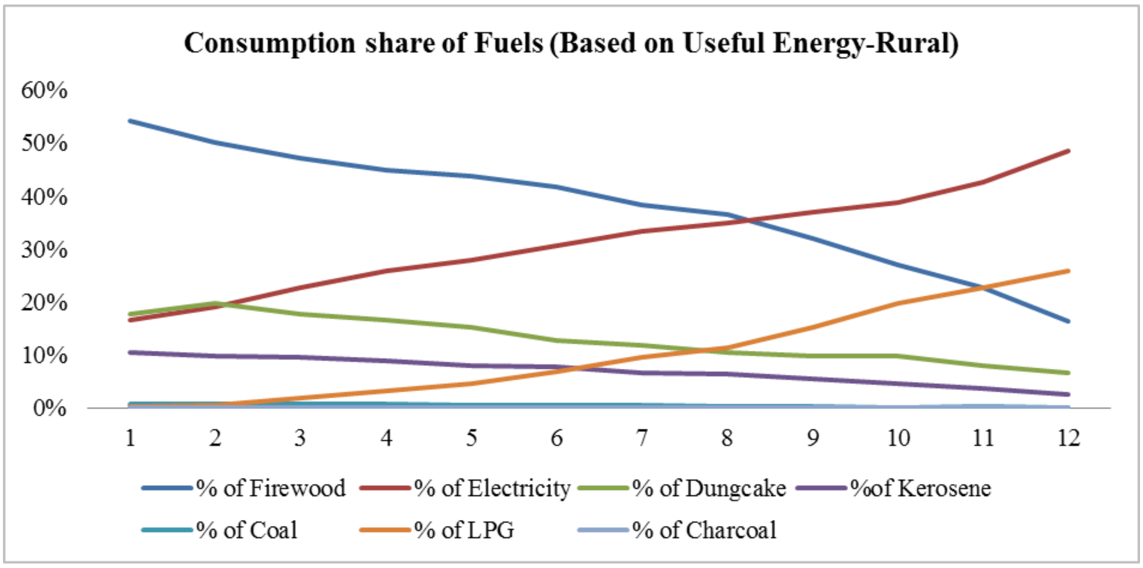
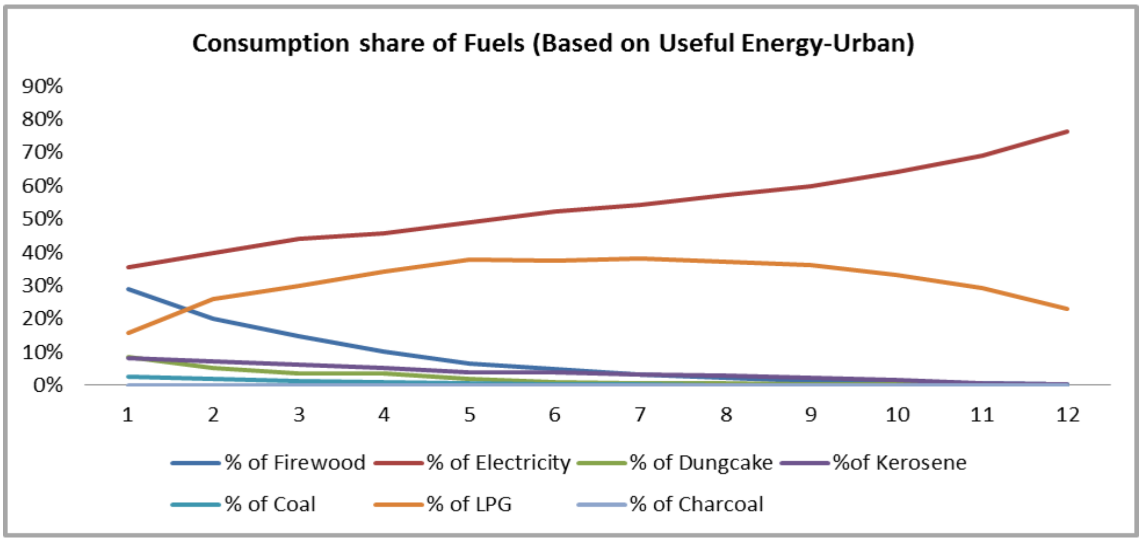


Figure 14: Consumption shares of fuels based on useful energy (Urban)



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

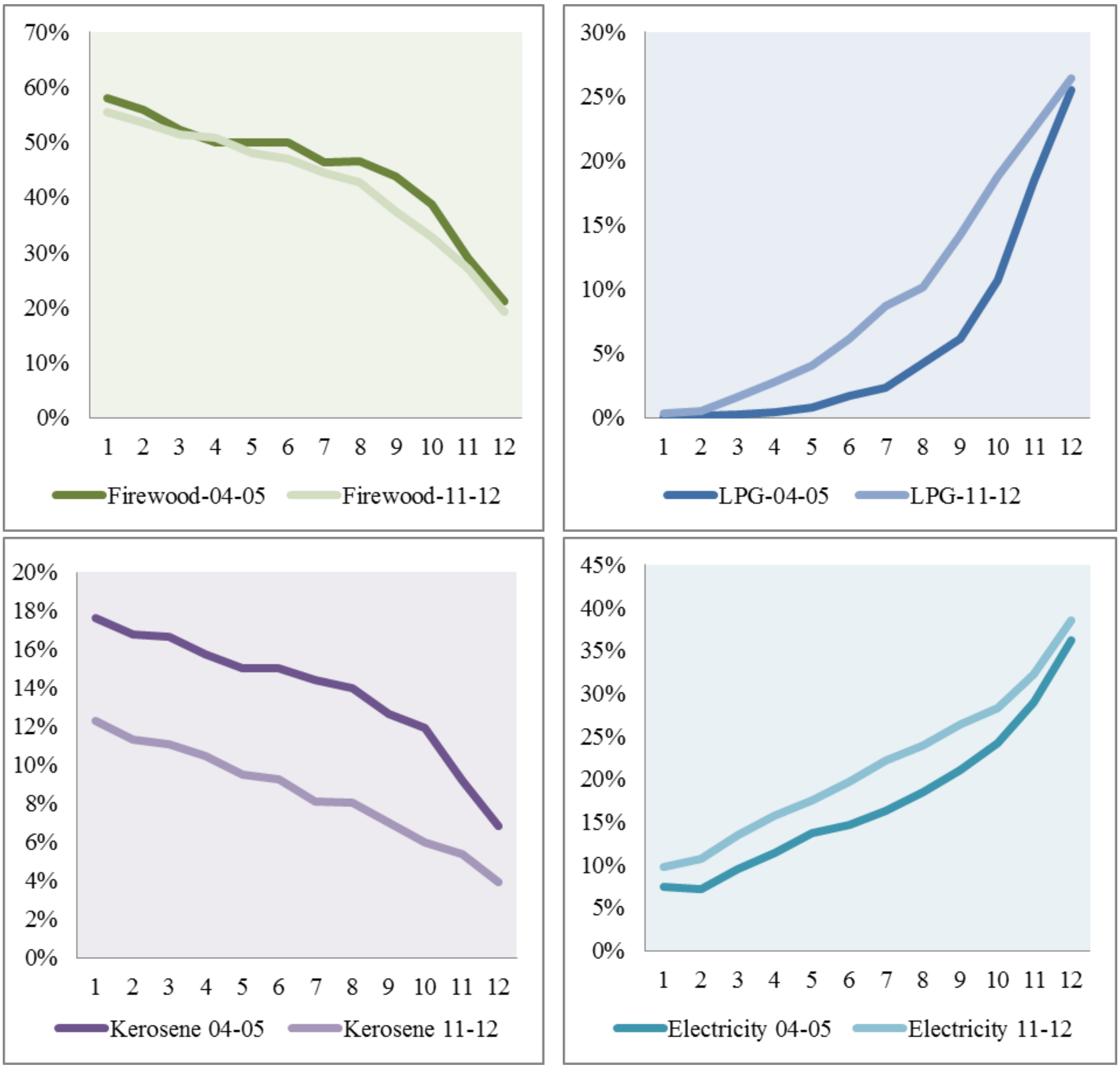
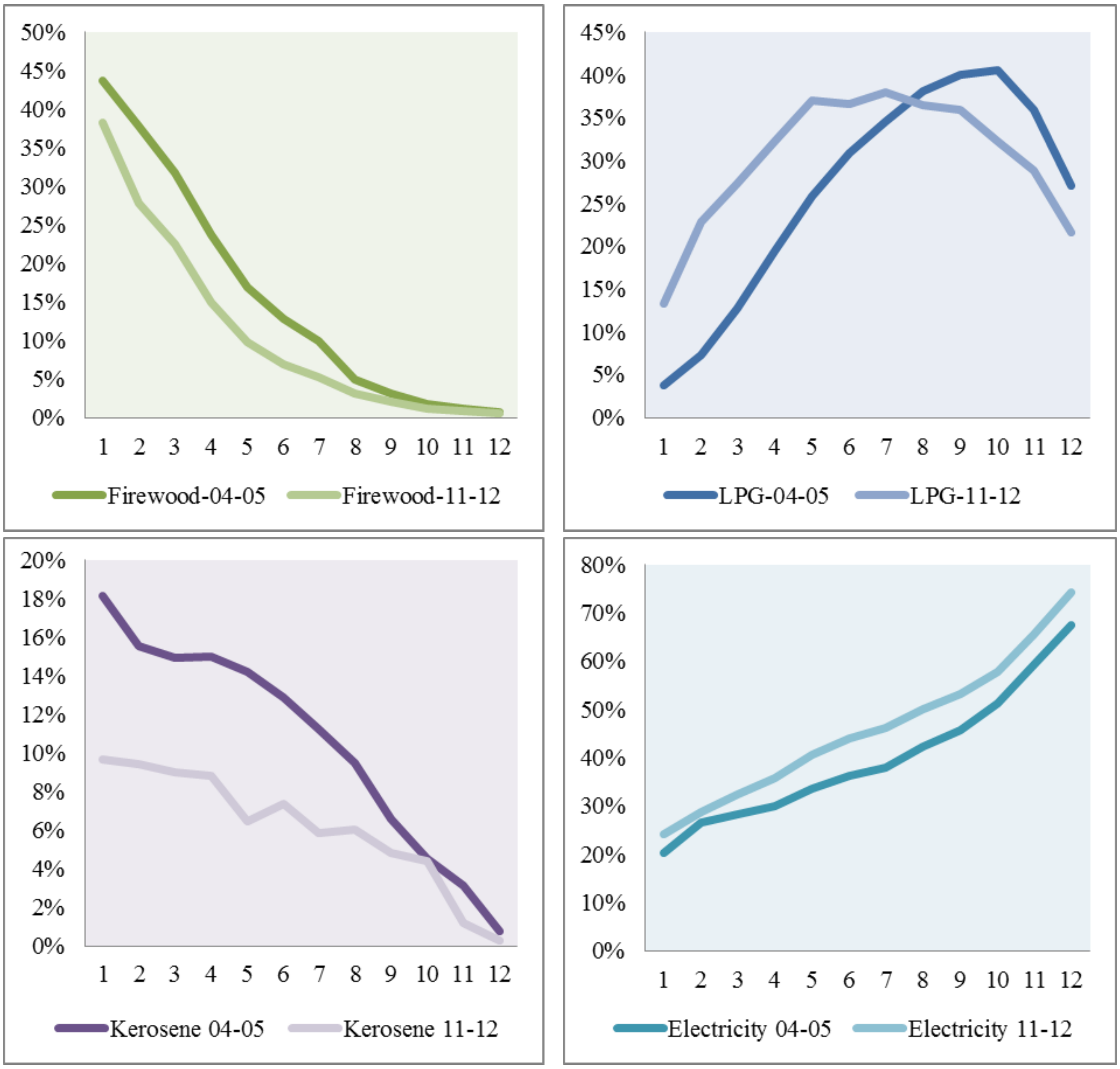


Figure 16: Variation in Fuel Shares- Urban Households



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

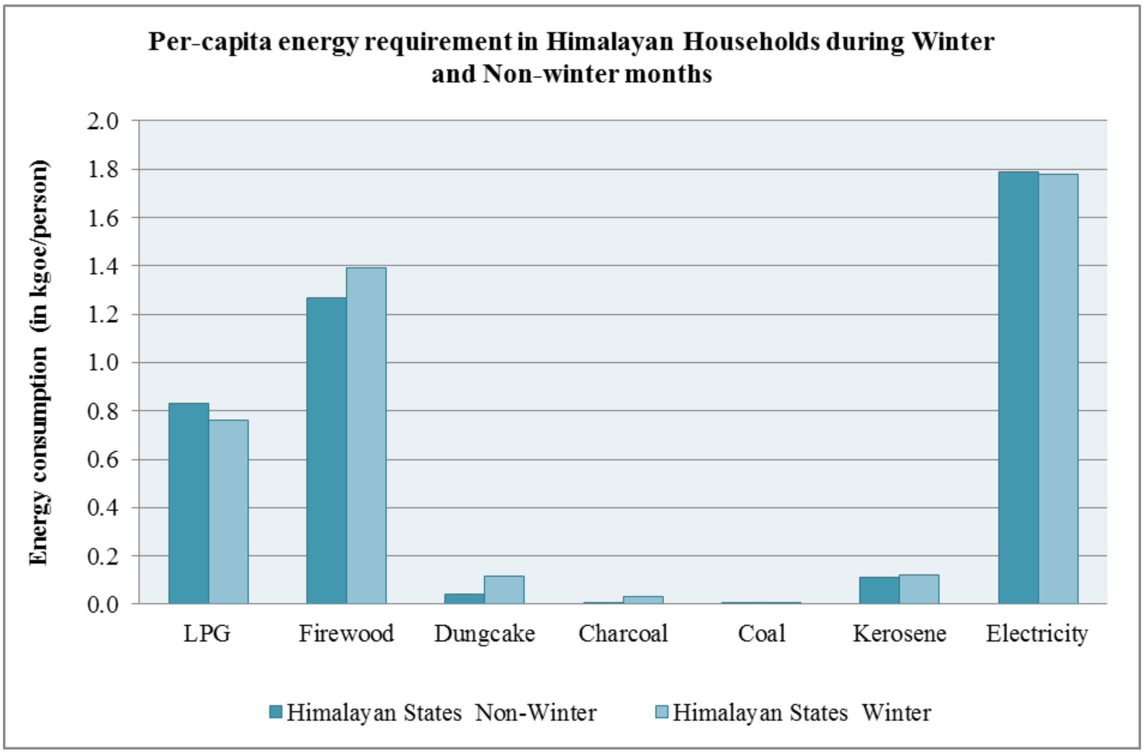


Table 2: Percentage change in per household consumption (relative to non-winter months) of various fuels between Himalayan States and rest of India

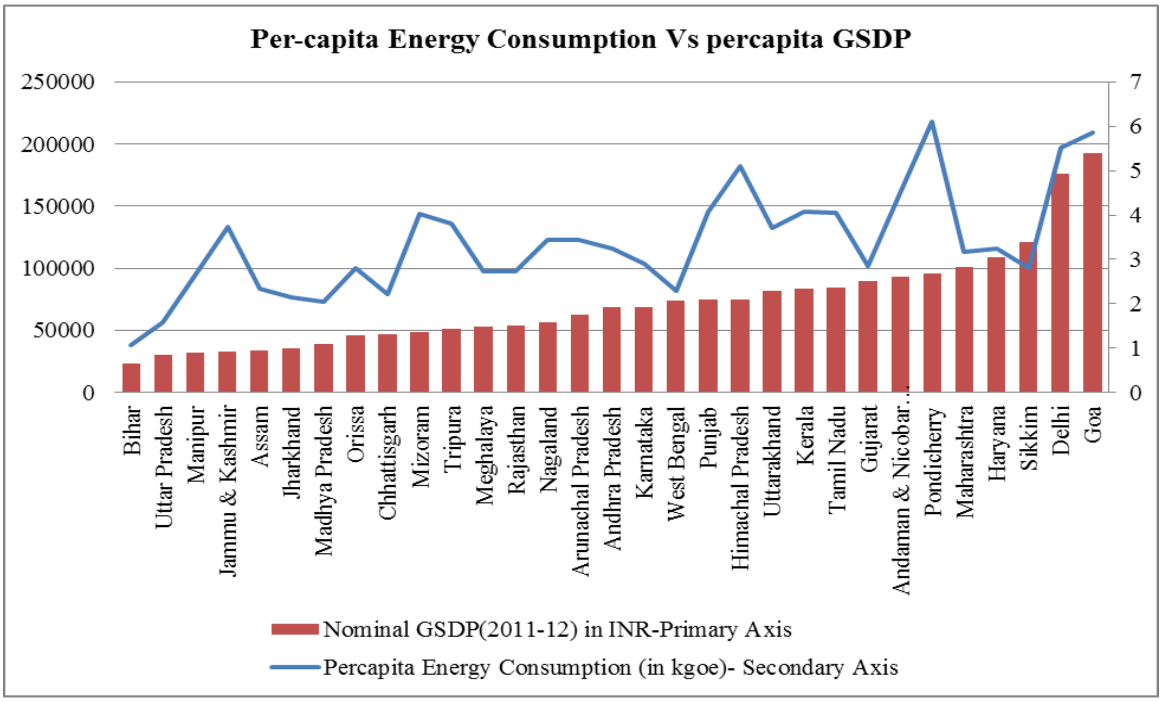
	LPG	Firewood	Dungcake	Charcoal	Coal	Kerosene	Electricity
Himalayan States	-6%	13%	206%	511%	-85%	14%	2%
Rest of India	0%	2%	8%	-21%	-12%	0%	-4%

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

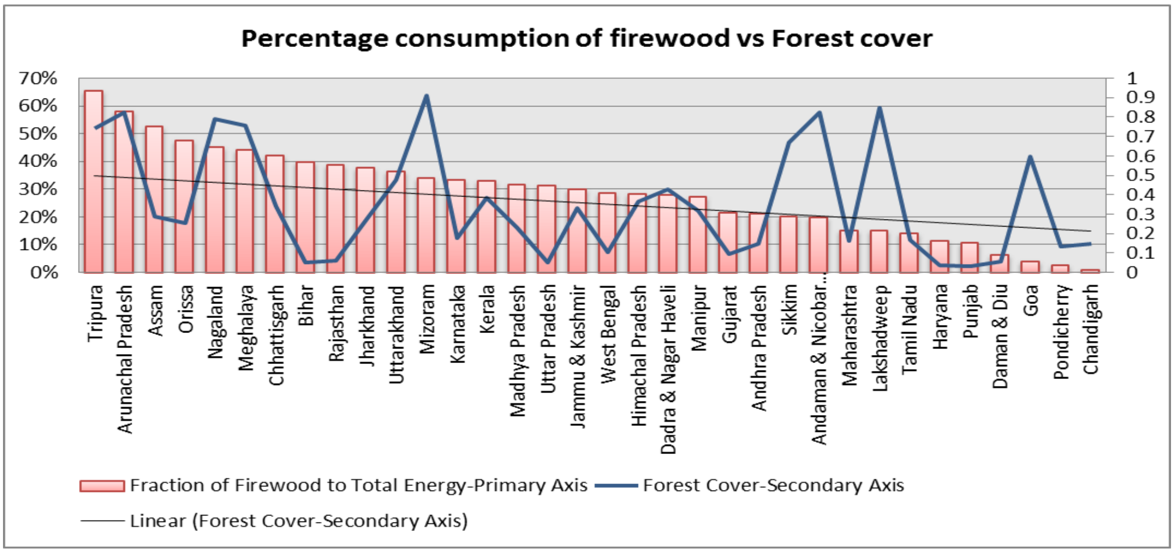
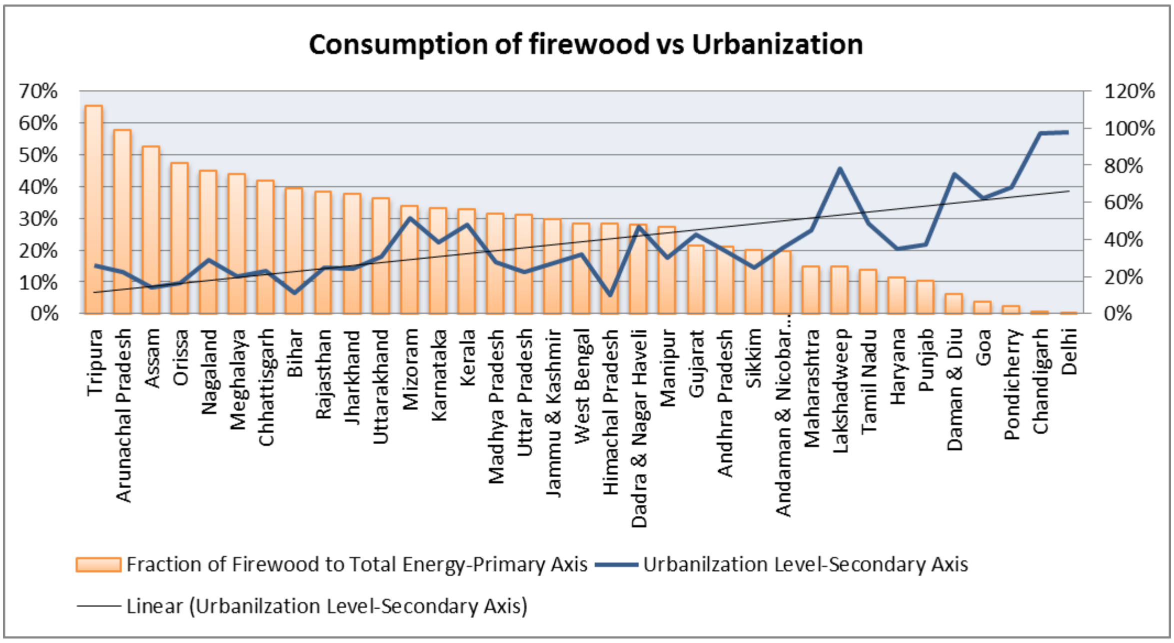


Figure 20: Per-capita consumption of firewood and extent of urbanization across states



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

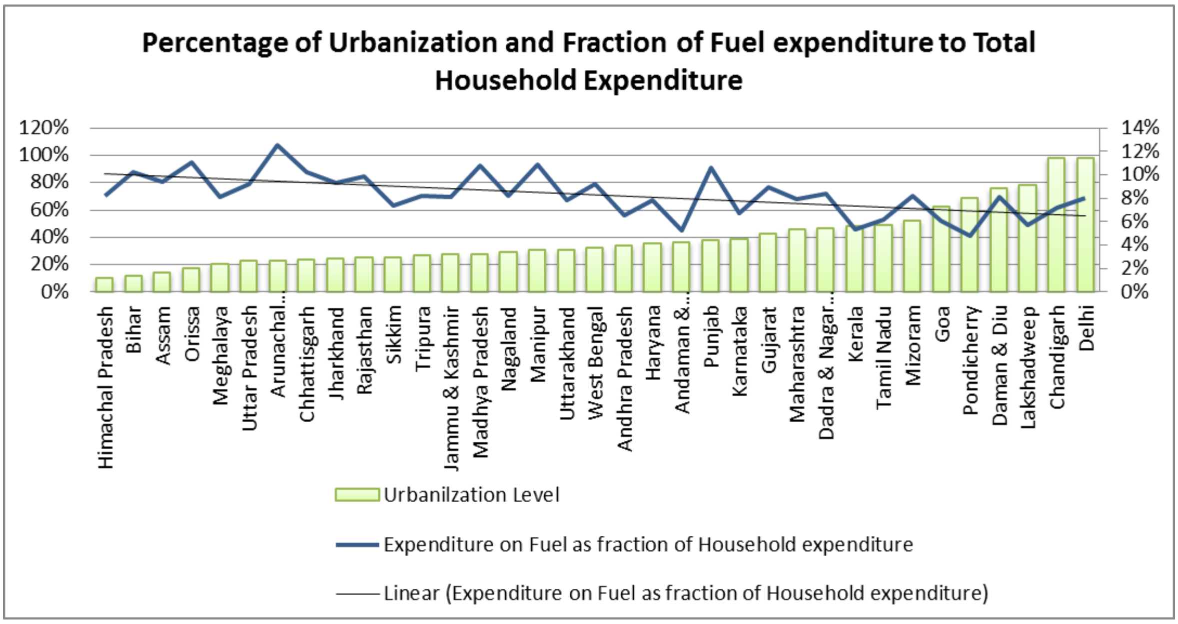
$$.Firewood\ share =$$

$$0.42(10.06^{*}) - 0.53 Urbanization(-6.79^{*}) + 0.18\ Forest\ cover(2.95^{*})$$

* 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 3: Religious groups and Per-capita Income

Religious Group	% Share in Population(Pan India)	Per capita Income (INR)
	Rural	
Hinduism	83%	1268
Islam	12%	1202
Christianity	2%	1712
Others-religion	2%	1975
	Urban	
Hinduism	77%	2575
Islam	17%	1781
Christianity	3%	3177
Others-religion	3%	3143

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

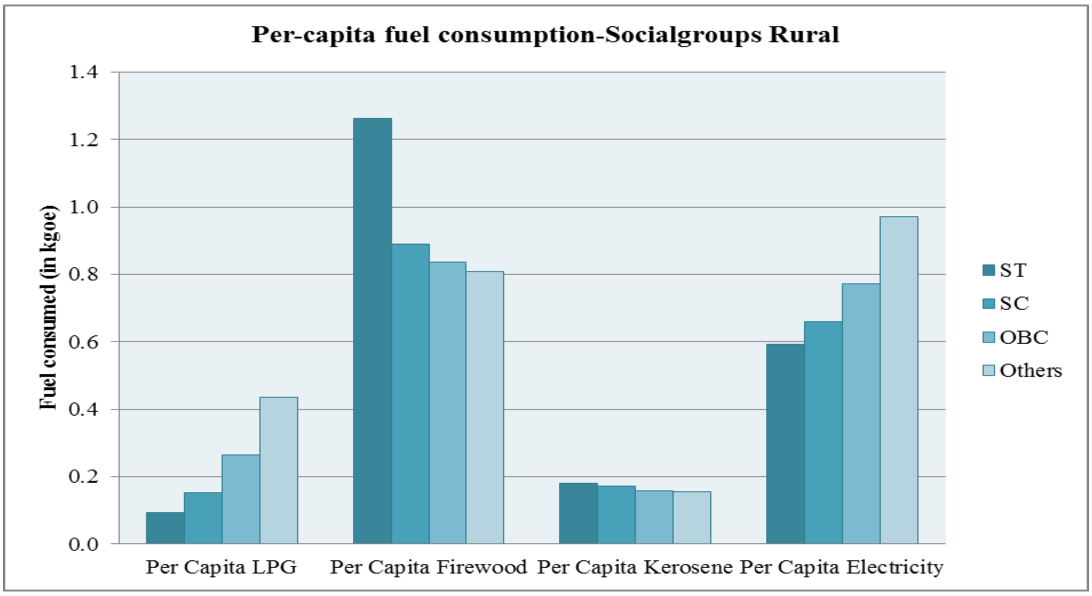


Figure 23: Per-capita fuel consumption across social groups in urban areas

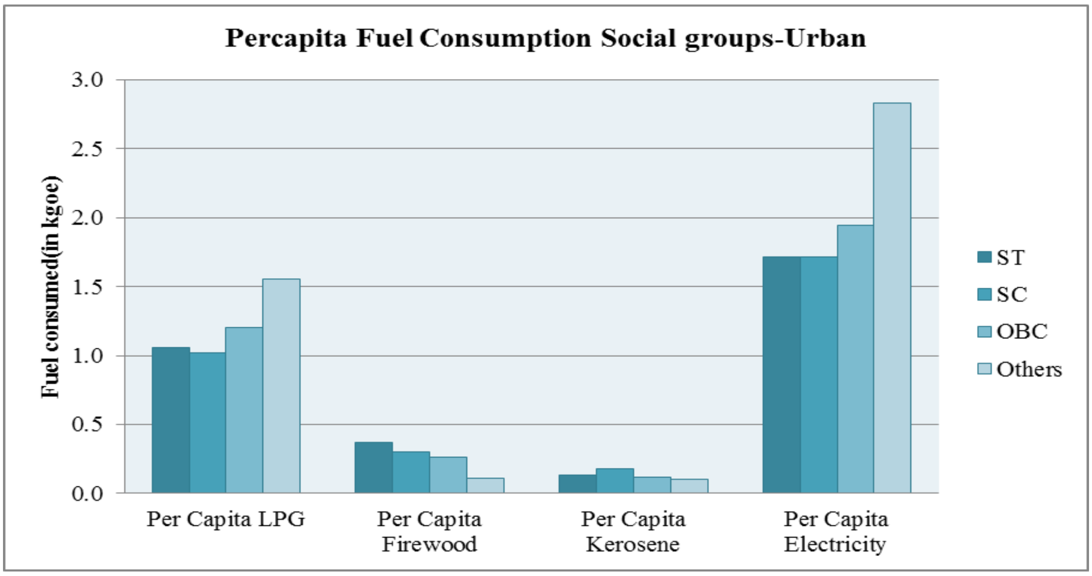


Table 4: Social Groups and Per-capita Income		
Social Group	**% Share in Population(Pan India)**	**Per capita Income (INR)**
	Rural	
ST	11%	1000
SC	21%	1133
OBC	45%	1289
Others	23%	1560
	Urban	
ST	3%	1991
SC	15%	1838
OBC	42%	2114
Others	40%	3109

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)

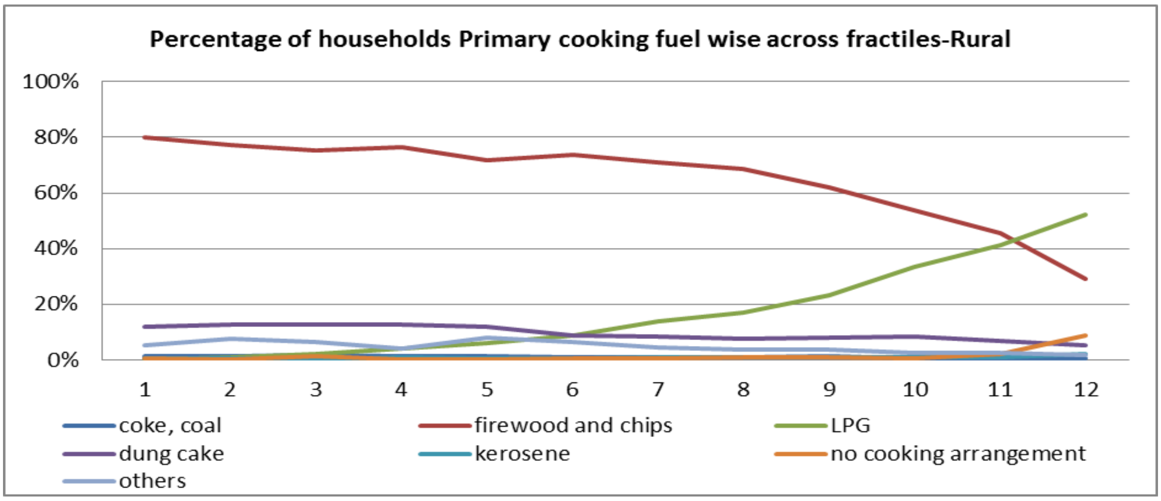


Figure 25: Percentage of households reporting various fuels as primary cooking fuel (Urban)

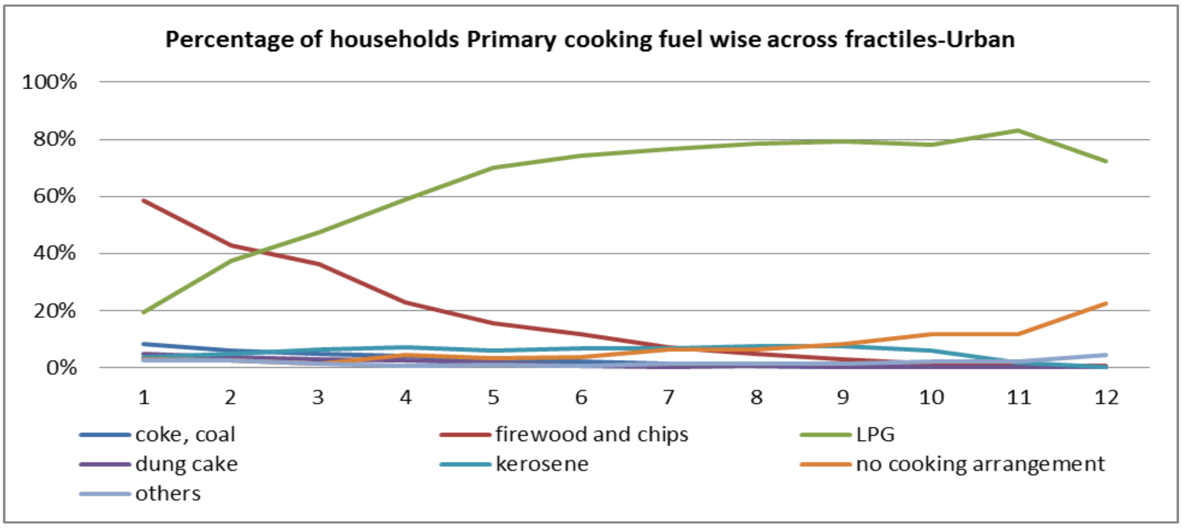


Figure 26: Percentage of households as per primary lighting fuel across fractiles in rural areas

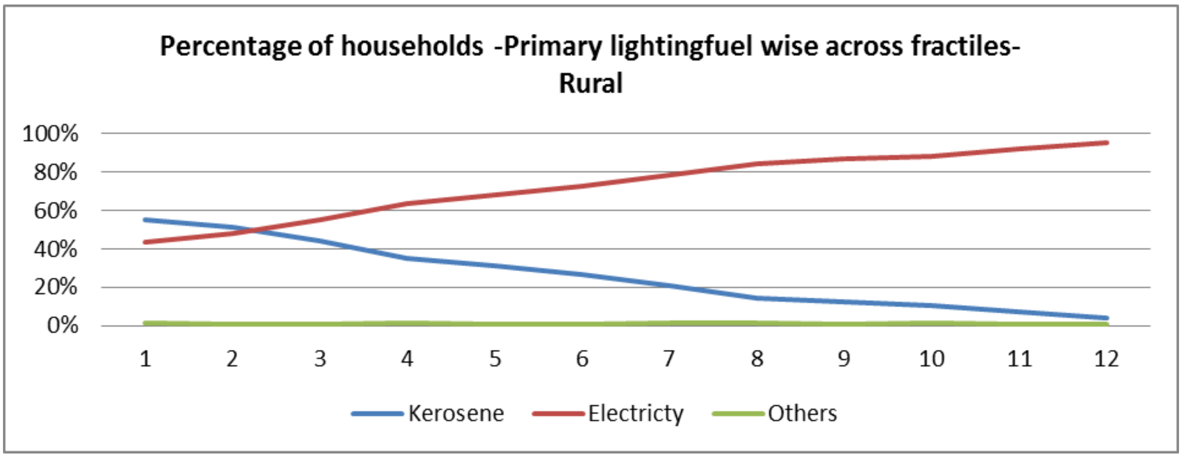
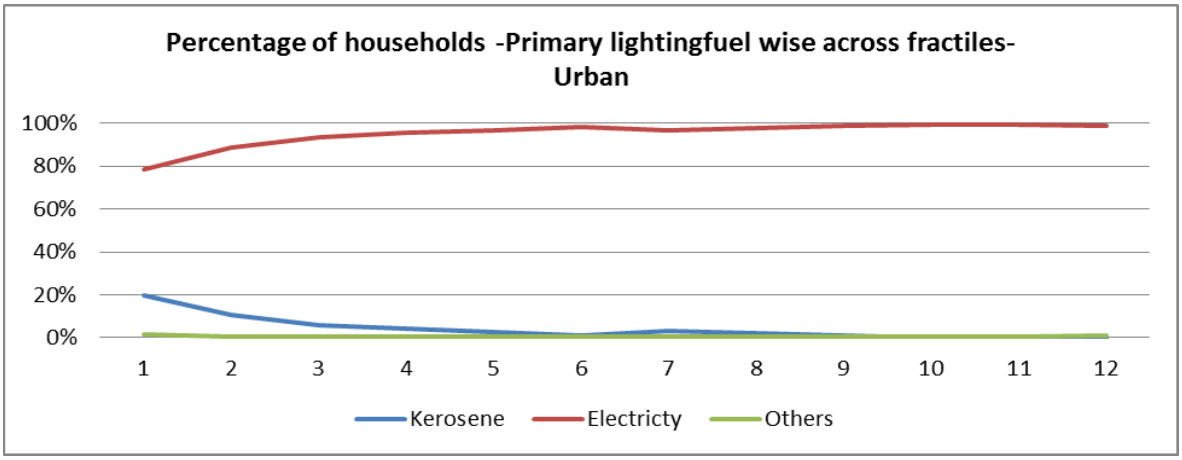
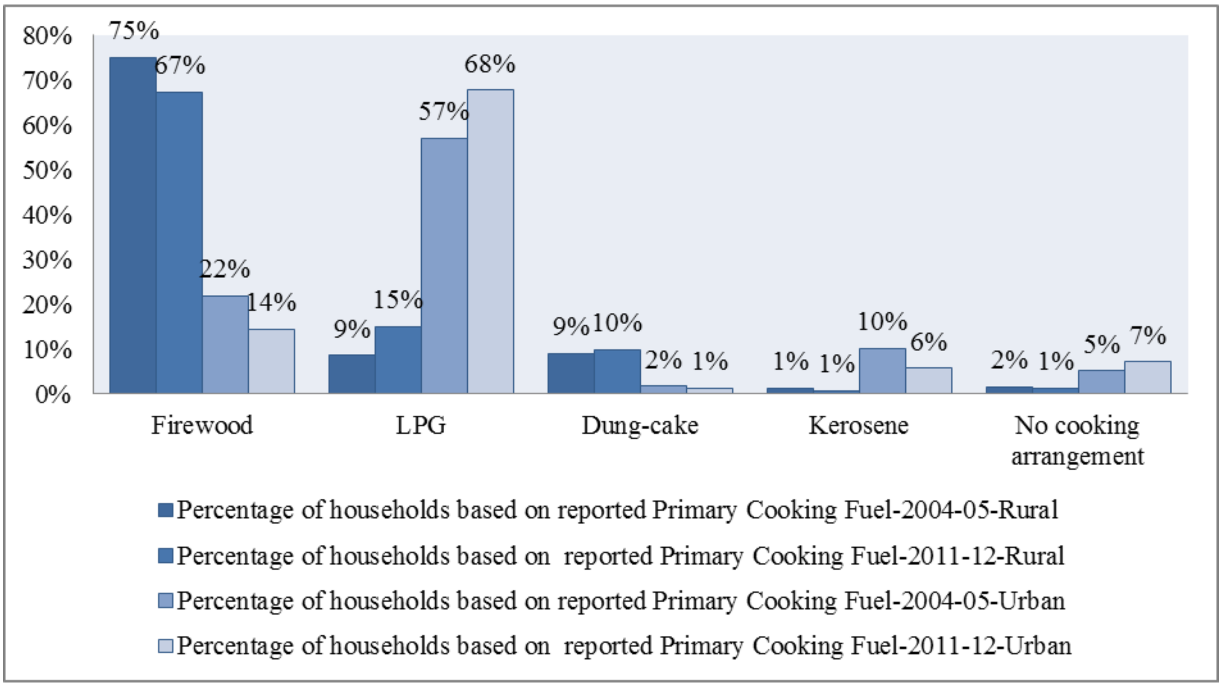


Figure 27: Percentage of households as per primary lighting fuel across fractiles in urban areas



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[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 (*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

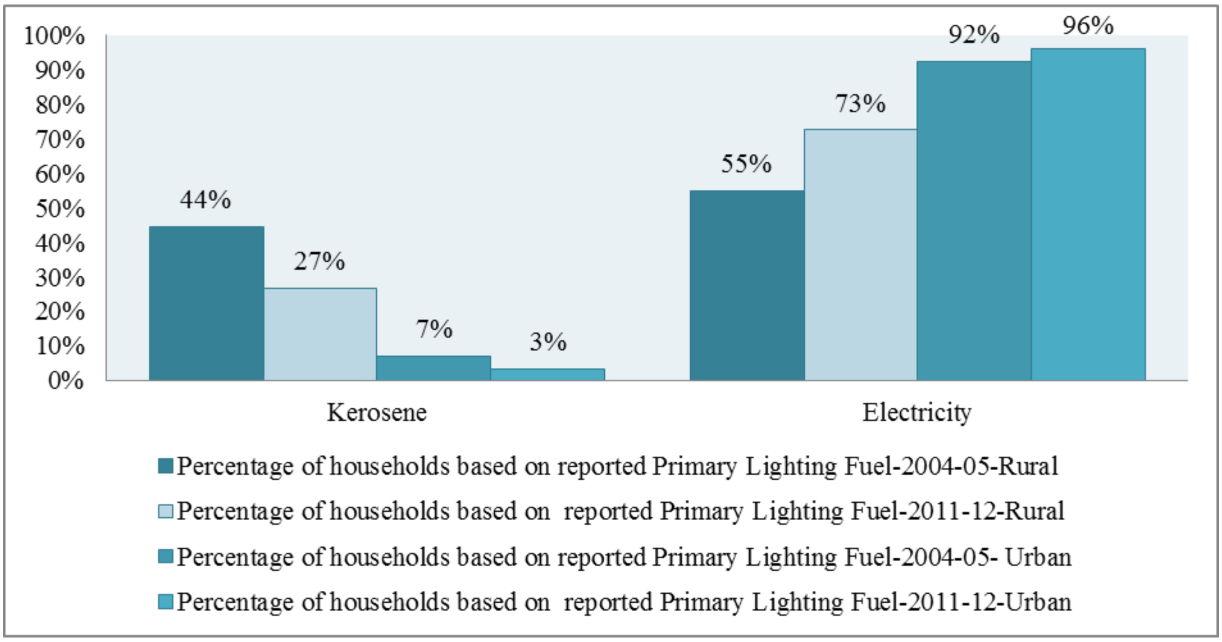


The graph above (Figure 28) gives a picture of the distribution of fuel use across rural and urban India. Among rural households, almost 77% households are still dependent on the most polluting traditional biomass fuels to meet their cooking fuel requirements. The cleaner cooking fuels such as LPG have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

---

[10] Primary here refers to the main fuel or the fuel of first choice and most often used

Figure 29: Percentage of Households based on Primary Lighting Fuel



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

Gini	*LPG 04-05*	*LPG 11-12*	*Electricity 04-05*	*Electricity 11-12*	*Total Useful Energy 04-05*	*Total Useful Energy 11-12*
Rural	0.72	0.50	0.42	0.22	0.25	0.10
Urban	0.41	0.17	0.41	0.28	0.31	0.19

Table 6 : Gini coefficients for Traditional Fuels

Gini	*Firewood 04-05*	*Firewood 11-12*	*Kerosene 04-05*	*Kerosene 11-12*	*Total Useful Energy 04-05*	*Total Useful Energy 11-12*
Rural	0.14	-0.07	0.15	-0.10	0.25	0.10
Urban	-0.27	-0.41	-0.04	-0.19	0.31	0.19

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

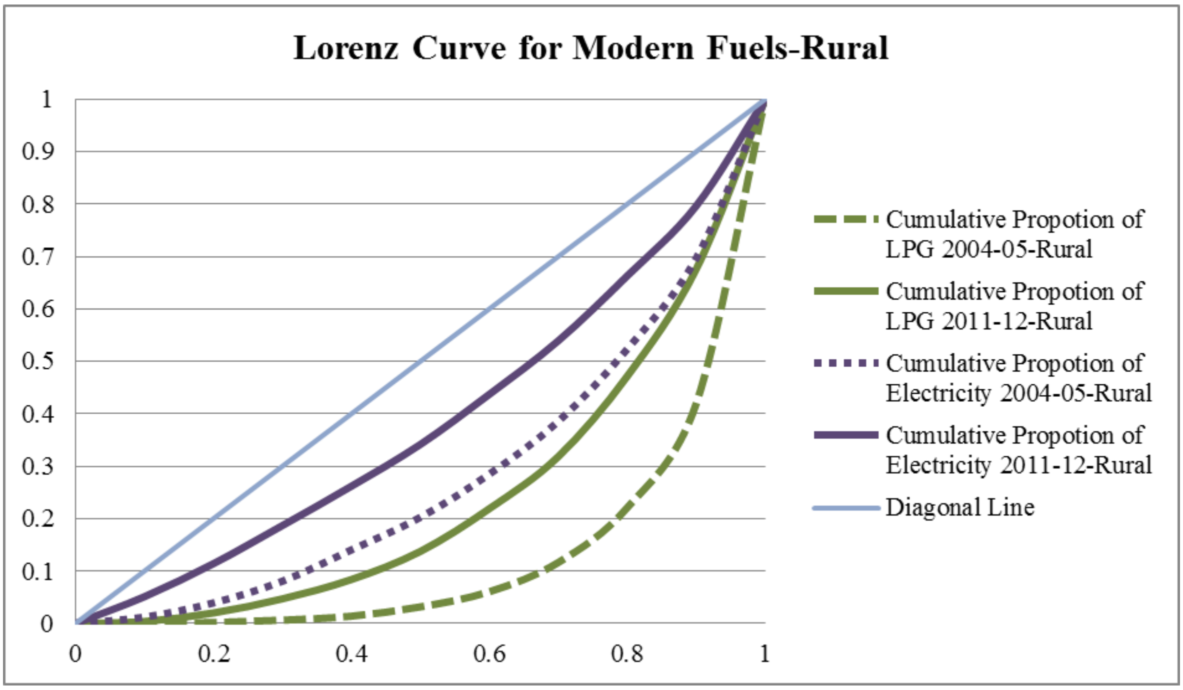
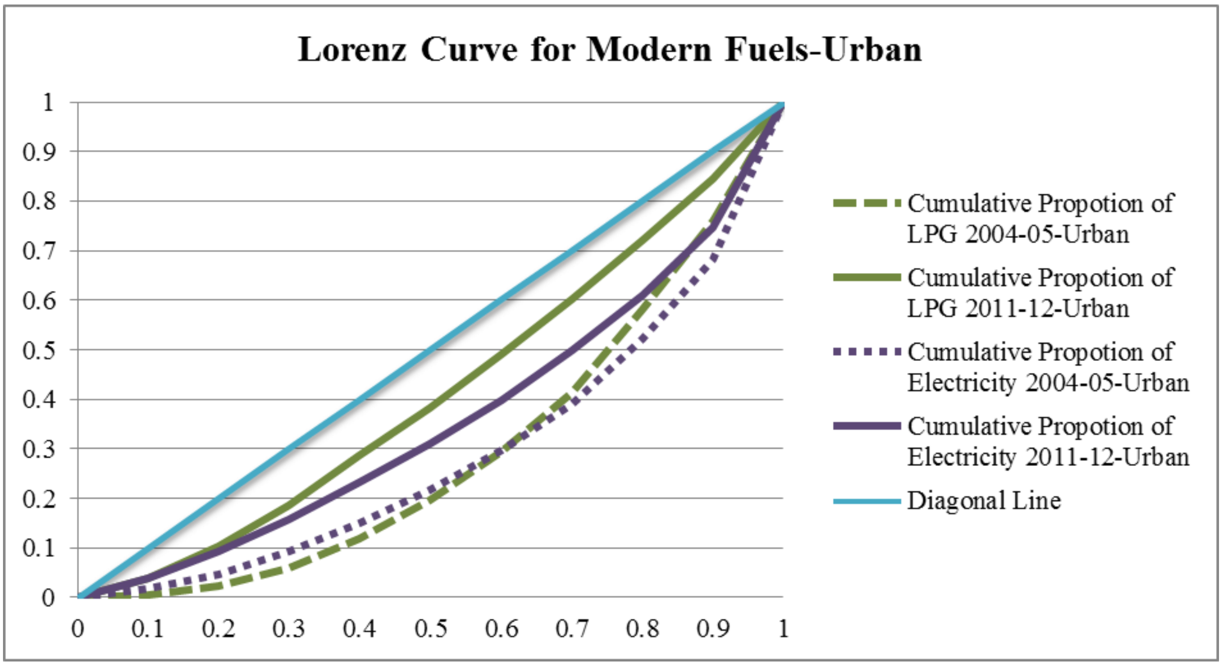


Figure 31: Lorenz Curve for Modern Fuels- Urban



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.

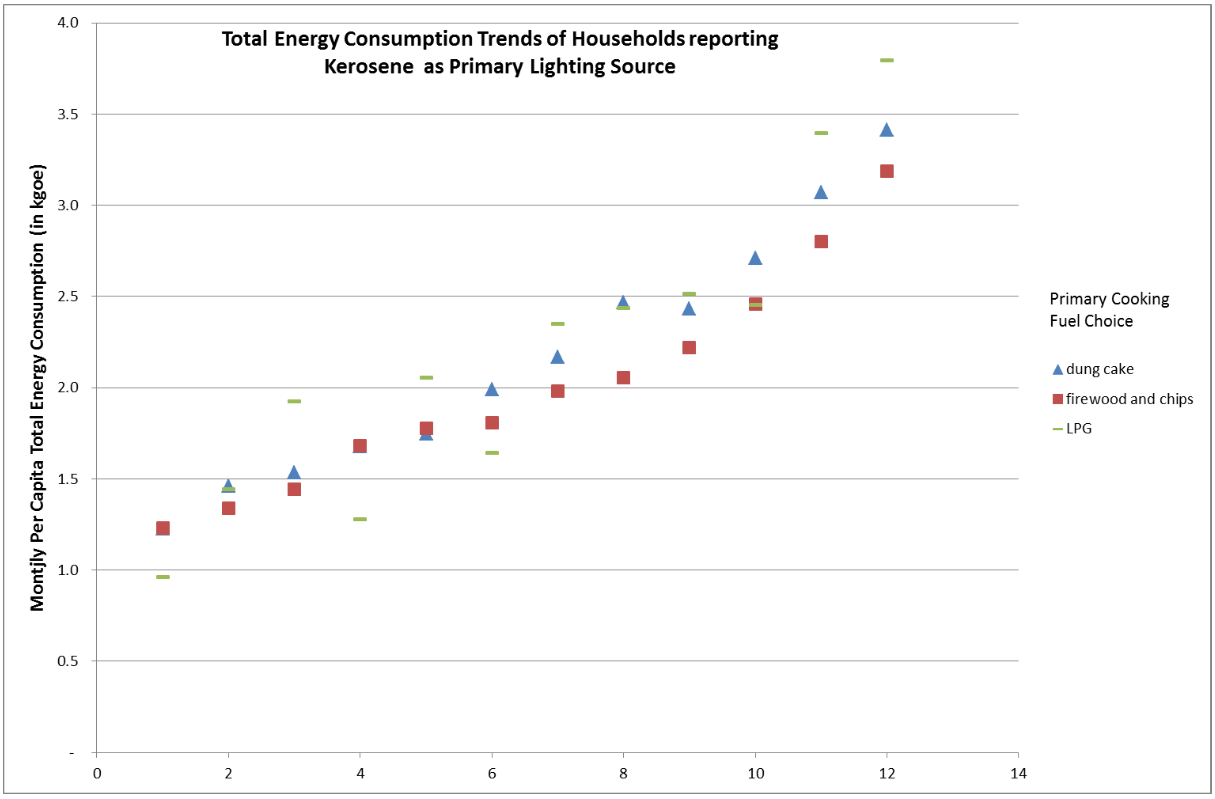
In order to understand what these aspiration levels could be, we focused on the consumption pattern of households based on their primary (reported) fuel used for lighting. On an average, nearly 99% of the households report either kerosene (~20%) or electricity (~79%) as their primary lighting sources. 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

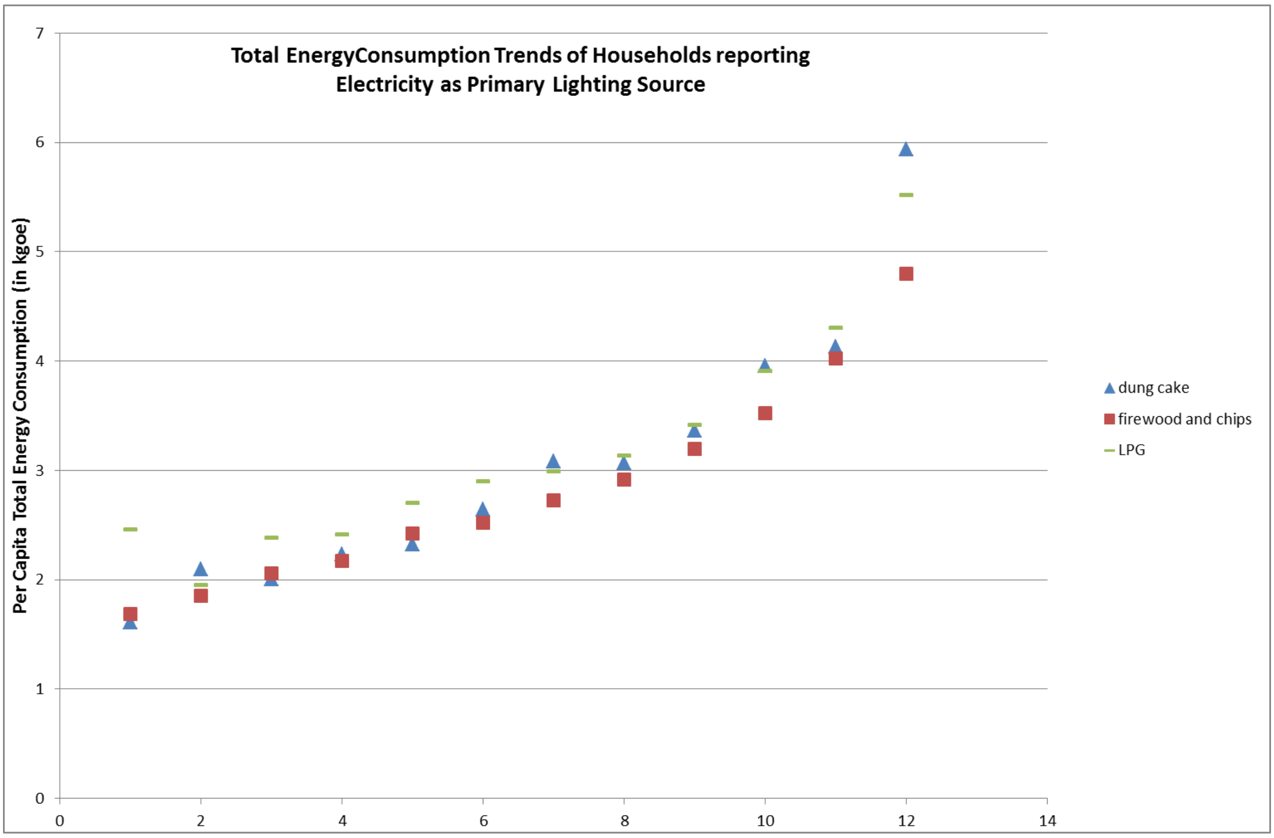
Figure 32: Total Energy consumption in households reporting kerosene as primary lighting fuel (Rural)



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.

Figure 33: Total fuel consumption in households reporting electricity as primary lighting fuel (Rural)

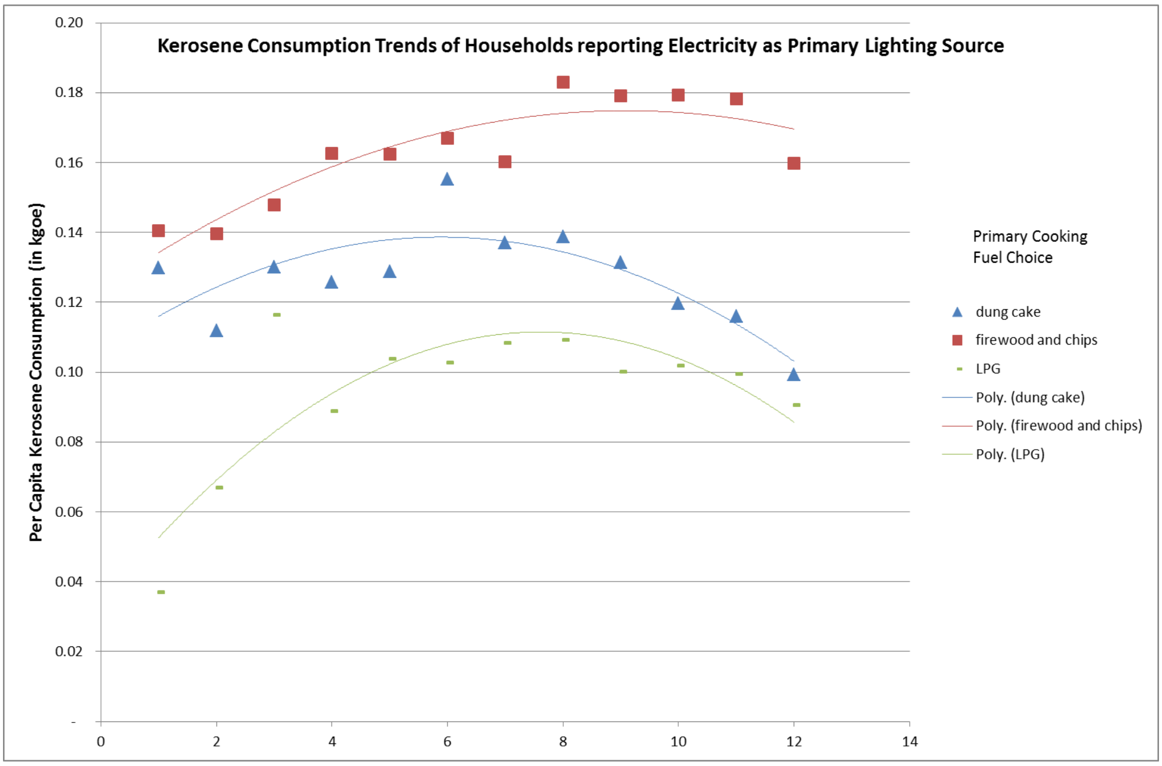


Conversely, in households that primarily rely on kerosene for lighting purposes, the majority of the consumption is driven by the use of cooking fuel. So in the case of dung cake and firewood dependent households (for cooking) the major share of consumption was in this. That, cooking / heating fuels 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



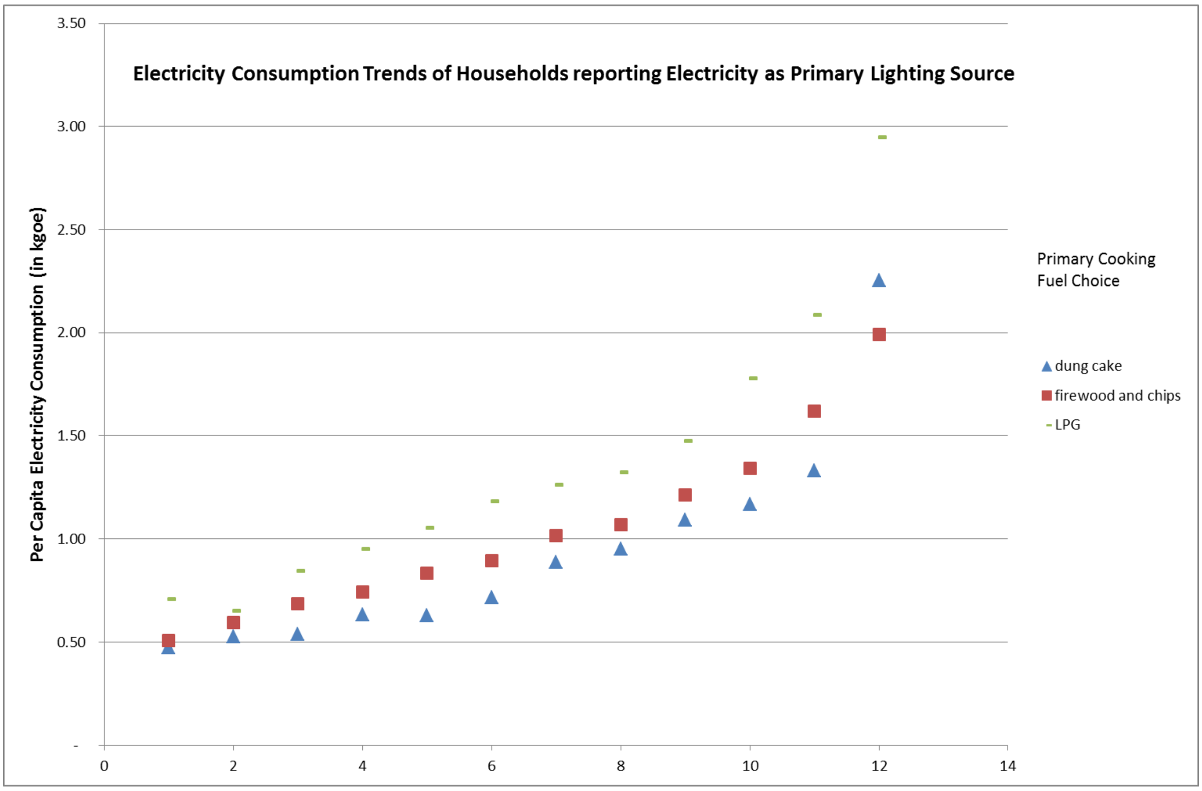
Given that lighting is required on a constant basis (especially in the early morning hours and after sunset) and appliances can be utilised when there is electricity supply, this hypothesis gets further backing, considering that kerosene can provide the necessary lighting (albeit of lower quality, but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

Table 7: List of Variables	
Variables	**Definition**
lnpercapitaenergy	Log of Percapita consumption of useful energy at household level
lnMPCEMRP	Log of Monthly percapita expenditure
lnpercapitafirewood	Log of Percapita useful energy consumption at household level from firewood
lnpercapitakerosene	Log of Percapita useful energy consumption at household level from kerosene
lnpercapitaLPG	Log of Percapita consumption of useful energy at household level from LPG
lnpercapitaelectricty	Log of Percapita useful energy consumption at household level from electricity
Sector	Factor variable used, indicates whether the household belongs to Rural/Urban sectors- Values will be 1 for rural and 2 for urban
IncomeFractile	Factor variable, indicates the income percentile group which a particular household belongs to. Values vary from 1 to 12.

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 8: Expenditure elasticity of consumption of major fuel choices		
Fuel-type		**Expenditure elasticity of consumption**
Firewood	*Rural*	0.233*
	Urban	0.127*
Kerosene	*Rural*	0.223*
	Urban	0.409*
LPG	*Rural*	0.509*
	Urban	0.335*
Electricity	*Rural*	0.787*
	Urban	0.807*
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[12] were increased at rates at which they grew between the 61st and 68th 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 61st and 68th 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.

[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 9: Future energy consumption breakdown by fuel type

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

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 back-cast 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

African Development Bank. (2012). *A Comparison of Real Household Consumption Expenditures and Price Levels in Africa.* African Development Bank.

Ahn, S.-J., & Graczyk, D. (2012). *Understanding Energy Challenges in India: Policy,Players and Issues.* Paris: International Energy Agency.

Bhide, A., & Monroy, C. R. (2011). Energy poverty: A special focus on energy poverty in India and renewable energy technologies. *Renewable and Sustainable Energy Reviews*, 1057-1066.

Biying, Y., Zhang, J., & Fujiwara, A. (2011). Representing in-home and out-of-home energy consumption behavior in Beijing. *Energy Policy 39*, 4168-4177.

Census 2011. (2013). *Census of India*. Retrieved August 24, 2013, from Census of India: http://www.censusindia.gov.in/2011census/PCA/PCA_Highlights/pca_highlights_india.html

Census. (2011b). *Census of India Dashboard*. Retrieved August 24, 2013, from Devinfolive: http://www.devinfolive.info/censusinfodashboard/website/index.php/pages/kitchen_fuelused/total/Households/IND

CSO. (2013). *Energy Statistics 2013.* New Delhi: Central Statistics Office, Ministry of Statistics and Programme Implementation.

Daioglou, V. (2010). *Resedential Energy Use Scenarios.* MSc Thesis.

Dubin, J. A., & McFadden, D. L. (1984). An Econometric Analysis of Residential Electric Appliance Holdings and Consumption. *Econometrica, Vol. 52, No. 2* , 345-362.

Ekholm, T., VolkerKrey, ShonaliPachauri, & KeywanRiahi. (2010). Determinants of household energy consumption in India. *Energy Policy*.

Ferdous, N., Pinjari, A. R., Bhat, C. R., & Pendyala, R. M. (2010). A Comprehensive Analysis of Household Transportation Expenditures Relative to Other Goods and Services: An Application to United States Consumer Expenditure Data.

Filippini, M., & Pachauri, S. (2004). Elasticities of Electricity Demand in Urban Indian Households. *Energy Policy*, 429-436.

Goldemberg, J., Johansson, T. B., Reddy, A. K., & Williams, R. H. (1985). Basic Needs and Much More with One Kilowatt per Capita. *Ambio*, 199-200.

Houthakker, H. S. (1951). Some Calculations on Electricity Consumption in Great Britain. *Journal of the Royal Statistical Society. Series A (General)*, 359-371.

IEA. (2011). World Energy Model – Methodology and Assumptions.

IEA. (2013). *Energy Poverty*. Retrieved August 24, 2013, from International Energy Agency: http://www.iea.org/topics/energypoverty/

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

Jacobsona, A., Milmana, A. D., & Kammen, D. M. (2005). Letting the (energy) Gini out of the bottle: Lorenz curves of cumulative electricity consumption and Gini coefficients as metrics of energy distribution and equity. *Energy Policy*.

Khandker, S. R., Barnes, D. F., & Samad, H. A. (2010). *Energy Poverty in Rural and Urban India - Are the Energy Poor also Income Poor?* Washington, D.C: The World Bank.

Madlener, R. (1996). Econometric Analysis of Residential Energy Demand: A survey. *The Journal of Energy Literature*.

Mansur, E. T., Mendelsohn, R., & Morrison, W. (2008). Climate change adaptation: A study of fuel choice and consumption in the US energy sector. *Journal of Environmental Economics and Management vol. 55, issue 2*, 175-193.

Özcana, K. M., E. G., & Üçdoğrukb, Ş. (2013). Economic and demographic determinants of household energy use in Turkey. *Energy Policy*.

Pachauri, S. (2004). An analysis of cross-sectional variations in total household energy requirements in India using micro survey data. *Energy policy*, 1723–1735.

Pachauri, S. (2005). An analysis of cross-sectional variations in total household energy requirements in India using micro survey data. *Energy policy*, 1723–1735.

Pachauri, S., & Spreng, D. (2003). Energy use and energy access in relation to poverty. *Economic and Political Weekly*.

Pinjari, A., & Bhat, C. (2010). An Efficient Forecasting Procedure for The MDCEV Model. *3rd Innovations in Travel Modeling (ITM) Conference.* Arizona .

Planning Commission. (2006b). *Integrated Energy Policy: Report of the Expert Committee.* Government of India. New Delhi: Planning Commission.

Planning Commission. (2012a, March). *Draft Twelfth Five Year Plan 2012-17.* Retrieved February 20, 2013, from http://planningcommission.gov.in/plans/planrel/12thplan/welcome.html

Planning Commission. (2013, July 23). *Press Note on Poverty Estimates, 2011-12*. Retrieved August 24, 2013, from Planning Commission: http://planningcommission.nic.in/news/pre_pov2307.pdf

Practical Action. (2010). *Poor People's Energy Outlook.* Warwickshire: Practical Action.

Productivity Commission, Australia. (2011). *Patterns of Household Expenditure.*

Rauniyar, G., & Kanbur, R. (2010). *Inclusive Developmtne: Two Papers on Conceptualization, Application, and the ADB Perspective.* Manila: Asian Development Bank.

Reddy, B. S. (2003). Overcoming the energy efficiency gap in India's household sector. *Energy Policy*, 1117-1127.

Ruijven, B. J., Vuurena, D. P., Vriesa, B. J., Isaaca, M., Sluijsb, J. P., Lucasa, P. L., et al. (2011). Model projections for household energy use in India. *Eenrgy Policy*.

Ruijven, B. V., Frauke Urban, R. M., Sluijs, J. P., Vries, B. D., & Vuuren, D. P. (2008). Modeling Energy and Development: An Evaluation of Models and Concepts. *World Development Vol. 36, No. 12,*, 2801–2821.

Seebregts, A. J., Goldstein, G. A., & Smekens, K. (2001). Energy/Environmental Modeling with the MARKAL Family of Models.

Shukla, P. R., & Chaturvedi, V. (2012). Low carbon and clean energy scenarios for India: Analysis of targets approach. *Energy Economics 34*, S487–S495.

WDI. (2011). *World Development Indicators.* Retrieved January 20, 2013, from http://data.worldbank.org/data-catalog/world-development-indicators

Willett, K. D., & Naghshpour, S. (1987). Residential demand for energy commodities: A household production function approach. *Energy Economics Volume 9, Issue 4,* , 251–256.

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

Fuel	Efficiency in Use
Traditional Biomass	10%
Coal/ Coke	10%
LPG	60%
Kerosene	35%
Electricity	100%

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

Rural

State	LPG	Traditional Biomass	Kerosene	Electricity
Andaman & Nicobar Islands	0.72	1.32	0.39	1.69
Andhra Pradesh	0.47	0.94	0.13	1.41
Arunachal Pradesh	0.63	2.31	0.12	0.43
Assam	0.31	1.35	0.19	0.38
Bihar	0.11	0.45	0.17	0.20
Chandigarh	1.74	0.02	0.09	3.71
Chhattisgarh	0.03	1.08	0.14	0.66
Dadra & Nagar Haveli	0.17	1.37	0.21	1.25
Daman & Diu	0.94	0.27	0.35	2.59
Delhi	1.75	0.02	0.00	2.85
Goa	1.45	0.37	0.21	3.36
Gujarat	0.25	0.93	0.23	0.97
Haryana	0.54	0.51	0.06	1.33
Himachal Pradesh	0.68	1.59	0.05	2.58
Jammu & Kashmir	0.57	1.38	0.14	1.39
Jharkhand	0.05	0.99	0.19	0.48
Karnataka	0.23	1.34	0.18	0.71
Kerala	0.71	1.49	0.07	1.53
Lakshadweep	0.00	0.89	0.29	3.69
Madhya Pradesh	0.11	0.78	0.17	0.62

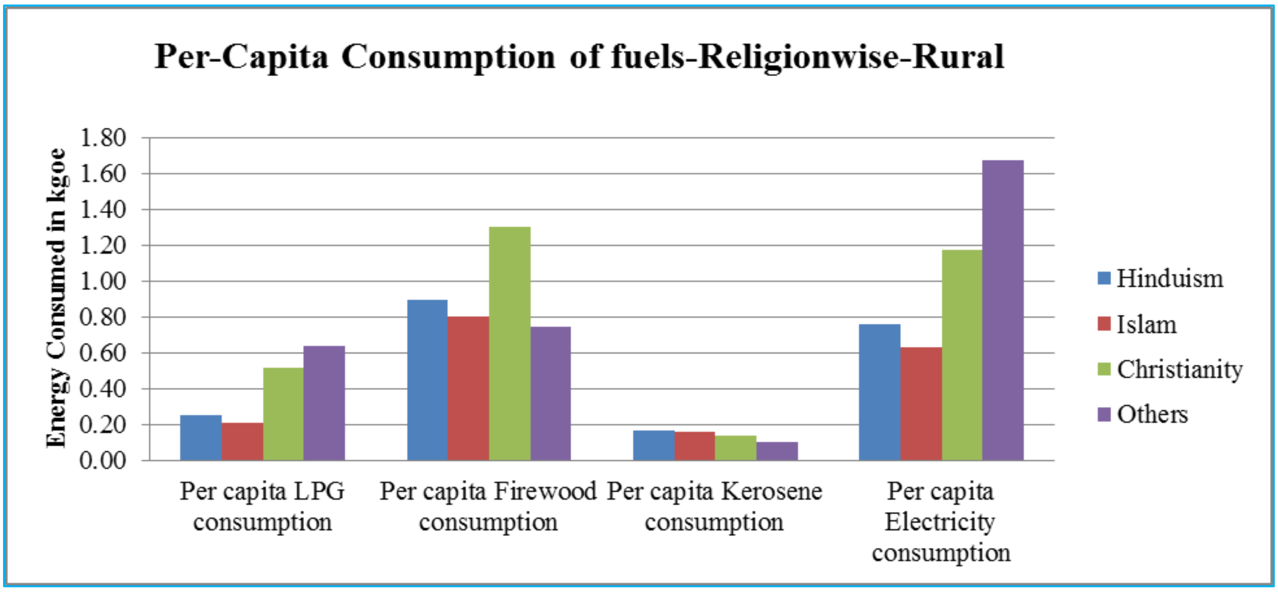
Maharashtra	0.42	0.80	0.19	0.97
Manipur	0.55	0.89	0.10	1.06
Meghalaya	0.11	1.45	0.13	0.87
Mizoram	0.71	2.27	0.11	0.84
Nagaland	0.78	1.85	0.03	0.73
Orissa	0.07	1.44	0.18	0.88
Pondicherry	1.35	0.21	0.17	3.57
Punjab	0.76	0.61	0.08	2.02
Rajasthan	0.19	1.30	0.15	0.82
Sikkim	0.92	0.68	0.09	0.98
Tamil Nadu	0.65	0.88	0.19	1.50
Tripura	0.13	2.74	0.21	0.65
Uttar Pradesh	0.11	0.57	0.15	0.33
Uttarakhand	0.58	1.68	0.14	1.13
West Bengal	0.14	0.83	0.21	0.54

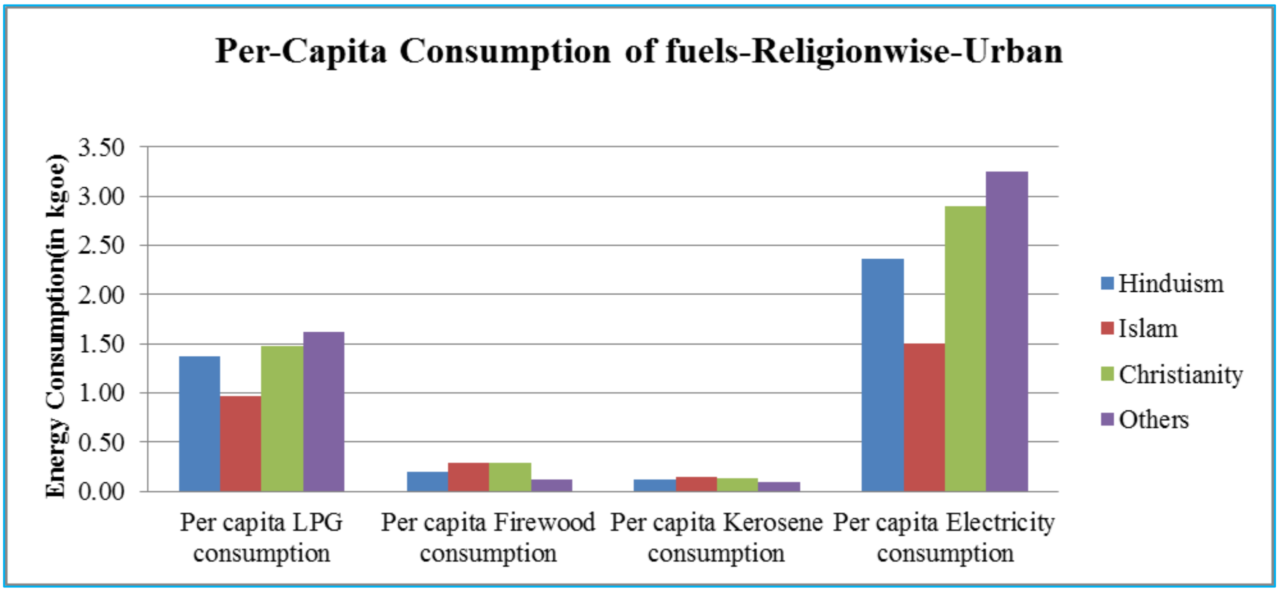
Urban

State	LPG	Traditional Biomass	Kerosene	Electricity
Andaman & Nicobar Islands	1.63	0.14	0.29	3.01
Andhra Pradesh	1.34	0.15	0.07	2.26
Arunachal Pradesh	1.77	0.73	0.07	0.72
Assam	1.60	0.23	0.13	1.19
Bihar	1.09	0.21	0.13	0.85
Chandigarh	1.59	0.04	0.16	2.61
Chhattisgarh	0.77	0.36	0.10	1.88
Dadra & Nagar Haveli	1.21	0.33	0.09	2.19
Daman & Diu	1.31	0.28	0.15	2.90
Delhi	1.68	0.01	0.02	3.88
Goa	1.99	0.08	0.09	4.15
Gujarat	1.14	0.15	0.13	2.10
Haryana	1.73	0.05	0.02	3.25
Himachal Pradesh	1.65	0.25	0.11	4.70
Jammu & Kashmir	1.49	0.23	0.11	2.66
Jharkhand	1.08	0.13	0.11	1.66
Karnataka	1.31	0.31	0.14	1.92
Kerala	1.26	0.95	0.06	2.59
Lakshadweep	0.64	0.97	0.34	5.57

Madhya Pradesh	1.12	0.26	0.10	1.62
Maharashtra	1.44	0.09	0.17	2.39
Manipur	0.98	0.27	0.07	1.29
Meghalaya	1.28	0.27	0.10	1.67
Mizoram	1.97	0.32	0.08	1.72
Nagaland	1.44	1.02	0.02	1.05
Orissa	0.97	0.73	0.16	2.10
Pondicherry	1.74	0.11	0.08	4.59
Punjab	1.70	0.11	0.07	3.21
Rajasthan	1.18	0.27	0.06	2.14
Sikkim	1.72	0.01	0.04	1.58
Tamil Nadu	1.52	0.18	0.16	3.21
Tripura	1.45	1.07	0.18	1.41
Uttar Pradesh	1.11	0.22	0.10	1.70
Uttarakhand	1.66	0.35	0.09	2.09
West Bengal	1.28	0.18	0.26	1.90

Appendix 3: Household Consumption of Fuels religion-wise





Appendix 4 : Major policies and programmes for expanding rural energy access

Policy/ Programme	Objectives, Scope and Impacts
Supply of kerosene through public distribution system (PDS) with quantity restriction, in 1957	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.
Subsidies on household cooking fuels like kerosene and LPG in late 1960s	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
National Project on Biogas Development (NPBD) in 1982	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
National Programme on Improved Chulhas (NPIC) or cookstoves in 1983	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
Expanding rural lighting energy access Rural electrification corporation (REC) established in 1969	Support rural electrification schemes & 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
Minimum Needs Programme in 1974	Provided100% loans from the central government for last mile connectivity for rural electrification projects in less electrified states
Kutir Jyoti (bright hut) Scheme in 1988	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
Pradhan Mantri Gramodaya Yojana (Prime minister's village development programme) in 2000	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
Rural Electricity Supply Technology Mission in 2002	Electrification of all villages and households progressively by year 2012 through renewable energy sources and decentralized technologies, in addition to conventional grid connection
Accelerated Rural Electrification Programme (AREP) in 2003	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
The Electricity Act 2003	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 [
Accelerated Electrification of One lakh villages and One crore households in 2004	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
National Electricity Policy in 2005	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
Rajiv Gandhi Grameen Vidyutikaran Yojana (rural electrification programme) in	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.

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 Vitrak 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 distributer 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

sector	Income Fractile	Prices (INR/kgoe useful)				
		LPG	Firewood	Electricity	Kero PDS	Kero Market
rural	1	52.59	53.19	30.79	54.01	95.14
rural	2	44.88	57.48	30.25	54.06	96.49
rural	3	44.52	58.18	31.78	53.82	98.25
rural	4	44.81	58.78	31.99	53.25	96.07
rural	5	45.32	56.85	32.83	53.76	95.39
rural	6	44.95	56.64	32.86	53.10	96.46
rural	7	44.26	56.18	32.54	52.59	95.60
rural	8	43.83	57.49	33.97	52.55	96.56
rural	9	44.03	55.17	33.99	52.19	94.78
rural	10	43.63	56.25	34.07	51.60	94.26
rural	11	44.20	53.26	33.98	51.68	99.94
rural	12	43.69	49.80	34.42	51.60	97.91
urban	1	45.19	70.66	36.88	51.89	97.16
urban	2	43.66	68.29	36.10	51.57	99.73
urban	3	44.40	73.43	36.15	51.36	105.81
urban	4	43.93	67.98	37.14	51.21	112.38
urban	5	44.00	65.93	37.87	50.99	108.16
urban	6	43.53	64.40	37.97	51.52	122.56
urban	7	43.65	66.99	37.84	50.18	115.79
urban	8	43.50	60.19	39.11	50.63	126.26
urban	9	43.57	66.18	39.70	51.44	125.68
urban	10	43.53	54.17	40.86	51.28	156.18
urban	11	43.16	53.34	42.11	52.32	115.13
urban	12	43.30	52.18	45.52	50.10	115.17

CEEW PUBLICATIONS

Books/Reports

- Karthik Ganesan, Poulami Choudhury, Rajeev Palakshappa, Rishabh Jain, and Sanyukta Raje (2014) Assessing Green Industrial Policy: The India Experience, CEEW-IISD Report, April
- Vaibhav Gupta, Karthik Ganesan, Sanyukta Raje, Faraz Ahmed, and Arunabha Ghosh (2013) Strategic Industries and Emerging Technologies for a Future Ready India, Report submitted to India's National Security Advisory Board, Prime Minister's Office, December
- Rishabh Jain, Poulami Choudhury, Rajeev Palakshappa, and Arunabha Ghosh (2013) RE+: Renewables Beyond Electricity, CEEW-WWF Report, December
- Rudresh Sugam and Arunabha Ghosh (2013) *Urban Water and Sanitation in India: Multi-stakeholder Dialogues for Systemic Solutions*, CEEW-Veolia Report, November, pp. i-147
- Rajeev Palakshappa, Arunabha Ghosh, Poulami Choudhury, and Rishabh Jain (2013) Developing Effective Networks for Energy Access- An Analysis, CEEW-USAID Report, October
- Nirmalya, Choudhury, Rudresh Sugam and Arunabha Ghosh (2013) 2030 Water Resources Group National Water Platform: Preliminary Investigation of the Possible Roles, Functions and Potential Governance, New Delhi Council on Energy Environment and Water-Water Resources Group Report, September, pp. i-25
- Arunabha Ghosh et al. (2012) *Concentrated Solar Power: Heating Up India's Solar Thermal Market under the National Solar Mission*, Report (Addendum to Laying the Foundation for a Bright Future: Assessing Progress under Phase I of India's National Solar Mission), September, New Delhi, Council on Energy, Environment and Water; and Natural Resources Defense Council
- Arunabha Ghosh, with Himani Gangania (2012) *Governing Clean Energy Subsidies: What, Why and How Legal?*, August, Geneva: International Centre for Trade and Sustainable Development
- Rudresh K. Sugam, and Arunabha Ghosh (2012) *Institutional Reform for Improved Service Delivery in Bihar: Economic Growth, Agricultural Productivity, and a Plan for Reorganising the Minor Water Resources Department*, Research Report submitted to the Government of Bihar, July, New Delhi: Council on Energy, Environment and Water, and International Growth Centre, Patna
- Council on Energy, Environment and Water; and Natural Resources Defense Council (2012) *Laying the Foundation for a Bright Future: Assessing Progress Under Phase 1 of India's National Solar Mission*, Interim Report, April, pp. i-37
- Arunabha Ghosh, Arundhati Ghose, Suman Bery, C. Uday Bhaskar, Tarun Das, Nitin Desai, Anwarul Hoda, Kiran Karnik, Srinivasapuram Krishnaswamy, Radha Kumar, Shyam Saran (2011) *Understanding Complexity, Anticipating Change: From Interests to Strategy on Global Governance*, Report of the Working Group on India and Global Governance, December, pp. i-70
- Martin A. Burton, Rahul Sen, Simon Gordon-Walker, and Arunabha Ghosh (2011) *National Water*

Resources Framework Study: Roadmaps for Reforms, October, New Delhi: Council on Energy, Environment and Water, and 2030 Water Resources Group, pp i-68

- Martin A. Burton, Rahul Sen, Simon Gordon-Walker, Anand Jalakam, and Arunabha Ghosh (2011) *National Water Resources Framework Study: Research Report Submitted to the Planning Commission for the 12th Five Year Plan*, September, New Delhi: Council on Energy, Environment and Water, and 2030 Water Resources Group, pp. i-584
- Arunabha Ghosh (2010) *Harnessing the Power Shift: Governance Options for International Climate Financing*, Oxfam Research Report, October, pp. 1-90

Papers/Book Chapters

- Karthik Ganesan and Rajeev Vishnu (2014) 'Energy Access in India – Today, and Tomorrow', CEEW Working Paper 2014/10, June
- Vaibhav Chaturvedi and Son H Kim (2014) 'Long Term Energy and Emission Implications of Global Shift to Electricity-Based Public Rail Transit System', CEEW Working Paper 2014/9, May
- Karthik Ganesan (2014) 'The Indian Cement Industry: Pathways to Emission Reduction and Sustainability', CEEW Working Paper 2014/8, April
- Karthik Ganesan and Rajeev Vishnu (2014) 'Energy Access in India-Today, and Tomorrow', CEEW Working Paper 2014/7, April
- Vaibhav Chaturvedi, Priyadarshi R Shukla, and Karthik Ganesan (2014) 'Implications of Risk Perceptions for Long Term Future of Nuclear Energy in India: A Sensitivity Analysis around Nuclear Energy Cost within an Integrated Assessment Modelling Framework', CEEW Working Paper 2014/6, April
- Arunabha Ghosh (2014) 'Environmental Institutions, International Research Programmes, and Lessons for Geoengineering Research', Geoengineering Our Climate Working Paper, February
- Nirmalya Choudhury and Arunabha Ghosh (2013) 'Responsible Hydropower Development in India: Challenges for future', CEEW Working Paper 2013/5, December
- Rishabh Jain, Karthik Ganesan, Rajeev Palakshappa and Arunabha Ghosh (2013) 'Energy Storage for Off-Grid Renewables in India: Understanding Options and Challenges for Entrepreneurs', CEEW Report, July
- Arunabha Ghosh, and David Steven (2013) 'India's Energy, Food, and Water Security: International Cooperation for Domestic Capacity', in *Shaping the Emerging World: India and the Multilateral Order*, edited by Waheguru Pal Singh Sidhu, Pratap Bhanu Mehta, and Bruce Jones, Washington, D.C.: Brookings Press
- Rajeev Palakshappa et al. (2013) 'Cooling India with Less Warming: The Business Case for Phasing-Down HFC's in Room and Vehicle Air Conditioners,' Council on Energy, Environment and Water; Natural Resources Defense Council; The Energy and Resources Institute; and The Institute

for Governance and Sustainable Development, June

- Arunabha Ghosh (2013) 'Energy-Food-Water-Climate Nexus: Implications for India's National Security,' Paper submitted to India's National Security Advisory Board, Prime Minister's Office, March
- Vyoma Jha and Rishabh Jain (2012) 'Results-Based Financing for Off-grid Energy Access in India,' *Case-study on the Economics of Results-Based Financing in Study by Vivideconomics for Energy Sector Management Assistance Program (ESMAP)*, World Bank, Washington DC, November
- Arunabha Ghosh (2012) 'Industrial demand and energy supply management: A delicate balance,' *Empowering growth - Perspectives on India's energy future, A report from the Economist Intelligence Unit*: 26-32, October
- Arunabha Ghosh, Benito Müller, William Pizer, and Gernot Wagner (2012) 'Mobilizing the Private Sector: Quantity-Performance Instruments for Public Climate Funds,' *Oxford Energy and Environment Brief*, The Oxford Institute for Energy Studies, August, pp. 1-15
- Sachin Shah (2012) 'Institutional Reform for Water Use Efficiency in Agriculture: International Best Practices and Policy Lessons for India,' CEEW Working Paper 2012/3, April
- Arunabha Ghosh (2011) 'Seeking Coherence In Complexity: The Governance Of Energy By Trade And Investment Institutions,' *Global Policy* 2 (Special Issue): 106-119
- Arunabha Ghosh (2011) 'Strengthening WTO Surveillance: Making Transparency Work for Developing Countries,' in *Making Global Trade Governance Work for Development*, edited by Carolyn Deere-Birkbeck. Cambridge: Cambridge University Press
- Jason Blackstock, and Arunabha Ghosh (2011) 'Does geoengineering need a global response - and of what kind?,' *Background Paper*, Solar Radiation Management Governance Initiative, Royal Society UK, Chicheley, March

Policy Briefs & Legislative/Government Briefings

- Arunabha Ghosh and Karthik Ganesan (2014) 'National Wind Mission,' Briefing to MNRE Secretary, New Delhi, 4 February
- Arunabha Ghosh (2013) 'Strategic Industries and Emerging Technologies for a Future Ready India,' Briefing to India's National Security Adviser, Prime Minister's Office, New Delhi, 18 October; to National Security Advisory Board, Mumbai, 3 December; and to India's Planning Commission, New Delhi, 10 December
- Arunabha Ghosh (2013) 'Business Case for HFC Phase Down in India,' Briefing to Prime Minister's Office, New Delhi, 22 November
- Arunabha Ghosh, Rudresh Sugam, Nirmalya Choudhury (2013) 'Integrated Energy, Environment and Water Plan for Jharkhand: Preliminary Investigations and Propositions,' Briefing to the Government of Jharkhand, Ranchi, 18 September

- Nirmalya Choudhury (2013) 'Knowledge Hub under National Water Mission – Governance Issues', Briefing to the Ministry of Water Resources, Government of India, on the proceedings of the Working Group on Governance of the Knowledge Hub under the National Water Mission (a flagship mission of the Government of India under the National Action Plan on Climate Change), New Delhi, 26 August
- Nirmalya Choudhury (2013) 'Governance Issues towards Creating a Knowledge Hub under the National Water Mission,' Briefing for a multi-stakeholder roundtable discussion on creating a Knowledge Hub under the National Water Mission (a flagship mission of the Government of India under the National Action Plan on Climate Change), New Delhi, 14 August
- Arunabha Ghosh (2013) 'National Water Platform: Some Thoughts for Brainstorming Meeting,' Briefing to the Ministry of Water Resources, Government of India, on creating a Knowledge Hub under the National Water Mission (a flagship mission of the Government of India under the National Action Plan on Climate Change), New Delhi, 5 August
- Rudresh Sugam and Urvashi Sharma (2013) "Capacity building in the urban water sector," Issue brief for the Fifth CEEW-Veolia Water Roundtable on Urban Water Management, 5 July
- Arunabha Ghosh, Stephen O. Andersen, Bhaskar Deol, and David Doniger (2013) 'The Business Case for Avoiding & Replacing High-Global Warming Potential HFC Refrigerants While Phasing Out HCFC Refrigerants,' Briefing at the Montreal Protocol Open-Ended Working Group. Bangkok, 26 June
- Rudresh Sugam and Urvashi Sharma (2013) "Water data and measurement," Issue brief for the Fourth CEEW-Veolia Water Roundtable on Urban Water Management, 27 May
- Rudresh Sugam and Urvashi Sharma (2013) "Regulatory framework for urban water management in India," Issue brief for the Third CEEW-Veolia Water Roundtable on Urban Water Management, 9 April
- Rudresh Sugam and Urvashi Sharma (2013) "Private sector participation in water management and water for all," Issue brief for the Second CEEW-Veolia Water Round table on Urban Water Management, 11 February
- Arunabha Ghosh (2013) 'Renewable Energies and Trade: Addressing tensions and challenges,' Briefing to a high-level policy dialogue at the World Trade Organization meeting of Ambassadors, Geneva, 21 January
- Rudresh Sugam (2012) "Water Utility Management in the Urban Water Sector," Issue brief for the First CEEW-Veolia Water Roundtable on Urban Water Management, New Delhi, 20 December
- Karthik Ganesan (2012) "Climate Change and Business Leadership: Pathways to GHG Emissions Reduction and Sustainability in the Indian Cement Industry," Paper presented at the Third National ICRN Conference on Climate Change, Indian Institute of Science, Bangalore, 4 November
- Vyoma Jha (2012) "Trends in Investor Claims over Feed-in Tariffs for Renewable Energy,"

Investment Treaty News, July

- Arunabha Ghosh (2012) “Water governance priorities in India, South and East Asia, the case for integrated energy, environment and water plans, and Rio+20 goals,” Briefing to the Brazilian Federal Senate, Environment, Consumer Rights and Oversight Committee & Agriculture and Land Reform Committee, Rio de Janeiro, 20 June
- Arunabha Ghosh (2011) “Briefing on global governance to Ambassador Shivshankar Menon, National Security Adviser, Government of India,” Prime Minister’s Office, 20 December
- Arunabha Ghosh (2011) “Governing clean energy subsidies: Why legal and policy clarity is needed,” Bridges Trade BioRes, November
- Vyoma Jha (2011) “Cutting Both Ways?: Climate, Trade and the Consistency of India's Domestic Policies,” CEEW Policy Brief, August
- Arunabha Ghosh (2010) “Negotiating around Tradeoffs: Alternative Institutional Designs for Climate Finance,” European Climate Platform Report No. 10, Centre for European Policy Studies, Brussels, 9 December

Op-eds/Conference Papers/Other publications

- Arunabha Ghosh (2014) ‘Three Mantras for India’s Resource Security’ Seminar Magazine, June.
- Suresh P. Prabhu (2014) 'Idea 5: Let There Be Light, Always' Open Magazine, 22 March. Available at http://ceew.in/pdf/Idea%205%20_%20OPEN%20Magazine.pdf
- Suresh P. Prabhu (2014) 'Handling the energy crisis' The Hindu, 18 April. Available at http://ceew.in/pdf/CEEW-Handling-the-energy-crisis-SP-Article-in-The-Hindu-18Apr14.pdf
- Suresh P. Prabhu (2014) 'India's Green Growth needs Policy Push' Energy Next, 8 February. Available at http://ceew.in/pdf/Indias_Green_Growth_Needs_Policy_Push_Suresh_Prabhu.pdf
- Suresh P. Prabhu (2013) 'Strengthening the regulatory network' The Hindu, 3 December. Available at http://www.thehindu.com/opinion/op-ed/strengthening-the-regulatory-network/article5415035.ece
- Jake Schmidt, Stephen O. Andersen, Arunabha Ghosh, et al (2013) ‘Cooling India with Less Warming: The Business Case for Phasing Down HFCS,’ Fact Sheet, November.
- Arunabha Ghosh (2013) ‘More Lethal Greenhouse Gas’ The Times of India, 25 October. Available at http://timesofindia.indiatimes.com/home/opinion/edit-page/More-lethal-greenhouse-gas/articleshow/24675848.cms
- Arunabha Ghosh (2013) ‘Himalayan Ecosystems and Himalayan Cooperation: A Himalayan Effort Needed?’ Arctic Circle Forum. Reykjavik. 13 October.
- Suresh P. Prabhu (2013) 'Sharing the burden of going green' The Hindu, 17 May. Available at http://ceew.in/pdf/SPP-Sharing_the_burden_of_going_green-The-Hindu-17May2013.pdf

- Jamshyd N Godrej (2013) 'Bring in smart policies, clear the air on clean energy' The Economic Times, 17 April. Available at http://economictimes.indiatimes.com/opinion/comments-analysis/bring-in-smart-policies-clear-the-air-on-clean-energy/articleshow/19587149.cms
- Arunabha Ghosh and Ricardo Meléndez-Ortiz (2013) 'Want clean energy? Avoid trade disputes'Business Standard, 15 April. Available at http://www.business-standard.com/article/opinion/want-clean-energy-avoid-trade-disputes-113041500023_1.html.
- Arunabha Ghosh (2013) 'India's resource nexus: priorities for action' Mint, 10 April. Available athttp://www.livemint.com/Opinion/zAOvm6gwBKa6Bzr9DfSyxN/Indias-resource-nexus-priorities-for-action.html.
- Arunabha Ghosh (2013) 'Private Sustainability Finance: Need for cash, role of institutions' NYU – UAE MOFA Workshop on Climate Finance and Institutions. Abu Dhabi. 22 April.
- Sanyukta Raje and Vaibhav Gupta (2013) 'India-US Track II Dialogue on Climate Change and Energy: Enhancing Bilateral Cooperation between India and the US', Proceedings Report, 18-20 April.
- Arunabha Ghosh and Anjali Jaiswal (2012) 'What's eclipsing India's solar sector' Business Standard,11 August. Available at http://ceew.in/pdf/AG%20&%20AJ-Business_Standard_11Oct12.pdf
- Arunabha Ghosh (2012) ' Make it profitable to save resources' India Today, 26 March. Available athttp://ceew.in/pdf/AG-Make_it_profitable_to_save_resources-India_Today-26Mar12.pdf
- Arunabha Ghosh (2012) ' Leave polemics out of the water policy ' The Hindu, 19 March. Available at http://ceew.in/pdf/AG-Leave_polemics_out_of_the_water_policy-The_Hindu-19Mar12.pdf
- Arunabha Ghosh (2012) ' Innovation needs an ecosystem' Business Standard, 26 February. Available at http://ceew.in/pdf/AG-Innovation_Needs_an_Ecosystem-Business_Standard_26Feb12.pdf
- Jamshyd N Godrej (2011) 'ET Awards' Agenda for Renewal 2011: Energy, the new poverty, says Jamshyd Godrej, Chairman & MD, Godrej & Boyce' The Economic Times, 24 November. Available at http://articles.economictimes.indiatimes.com/2011-11-24/news/30437448_1_clean-energy-energy-security-comprehensive-energy-plan
- Jamshyd N Godrej (2011) 'Deregulation: Solving diesel conundrum' The Times of India, 28 January. Available at http://timesofindia.indiatimes.com/business/india-business/Deregulation-Solving-diesel-conundrum/articleshow/7375419.cms?referral=PM
- Arunabha Ghosh (2009) 'Climate for a win-win dialogue' The Financial Express, 22 December. Available at http://www.financialexpress.com/news/column-climate-for-a-winwin-dialogue/557335/0
- Arunabha Ghosh (2009) 'Street lessons in climate governance' The Financial Express, 18 December. Available at http://www.financialexpress.com/news/column-street-lessons-in-climate-governance/555484/0

- Arunabha Ghosh (2009) 'Red herrings in debates over climate finance' Opinio Juris, 15 December. Available at http://opiniojuris.org/2009/12/15/red-herrings-in-debates-over-climate-finance/
- Arunabha Ghosh (2009) 'Even climate is about the money' The Financial Express, 7 December
- Arunabha Ghosh (2009) 'Making Copenhagen count' the GEG blog, 7 December.

STAY CONNECTED

ceew.in/blog

C EEWIndia

@CEEWIndia

linkedin.com/company/council-
on-energy-environment-and-water

CEEWIndia

Council on Energy, Environment & Water

Council on Energy, Environment and Water,
Thapar House, 124, Janpath, New Delhi 110001, India

Tel: +91 (0)11 4073 3300 | Fax: +91 (0)11 4073 3399
info@ceew.in | www.ceew.in

Resource efficiency & security
ceew.in/resources

Renewables
ceew.in/renewables
ceew.in/solar
ceew.in/energyaccess

Water
ceew.in/water

Sustainability finance
ceew.in/susfinance

Technology horizons
ceew.in/technology
ceew.in/geoengineering
ceew.in/JCERDC

Energy-trade-climate linkages
ceew.in/etclinkages

Integrated energy,
environment & water plans
ceew.in/eewplans

International Cooperation