Dynamics of household energy use in India: Economic and environmental implications

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Abstract
Traditionally, research on energy analysis has concentrated on the importance of a range of obvious technological variables such as accessibility of energy, initial cost of the utilizing device/technology, saving benefits, and adoption rates. The importance of this research is undeniable, but it has become increasingly evident that socio-economic variables are also the strongest predictors of energy use. Income, education, occupation and location of the household have now become the measures most frequently used by current researchers in order to formulate policies for promotion of sustainable energy use. Keeping this in mind, we analyse the dynamics of energy use in the household sector in India which consumes nearly 40 % of the total energy (excluding the energy use for personal transport) with a low efficiency of utilisation. Since energy production and utilisation contributes more than half of global emissions, it is important to target energy sector as a GHG abatement strategy. This paper aims to do so by analyzing energy requirements of households using a large database (1950 to 2000)[1]. Using the data the paper analyzes - (i) energy use by different categories of households (income-wise as well as by region - Urban and Rural) in India (ii) changes in energy consumption over time of different end-uses and energy carriers for different categories of households (iii) the underlying social, economic, structural and technical factors that determine changes in household energy use; (iv) impact of technology and fuel shifts, from inefficient -to efficient devices and from non-renewable to renewable sources on energy use and, (v) links between household energy use and environment.

Introduction

Central to the development of India's energy policy are questions of the size and economic efficiency of the household energy market. The household sector is one of the largest users of energy in India, accounting for about 40 per cent of final energy consumption (excluding energy used for transport) reflecting the importance of that sector in total national energy scenario (Reddy, 2003). During the past few decades, the Indian household sector has experienced many changes in energy consumption patterns, both in quantitative and qualitative terms (CMIE, 2001). This is due to the natural increase based on population growth and due to increase in economic activity and development. The experience of the last 20 years shows that growth in gross energy demand has by far exceeded the growth rates of population. While India's population grew by about two per cent per annum, from 1980 to 2000, the energy use grew by more than four per cent every year. This is due to increased incomes, urbanization and changing lifestyles. More user-friendly household appliances have penetrated rapidly resulting in increased energy consumption (Pachauri, 2004). It is natural for people to pursue a better life, which often means increased mobility, proper heating and cooling, and more appliances. The changes in lifestyles induces households shift to technologies that provides greater comfort, for example, firewood ---> kerosene ---> LPG. However, all the households can not afford this

1. Even through total energy consumption data is avaialable until 2005, end-use data for various sectors is not available. Hence the analysis is restricted until 2000.

Table 1: Final Energy use by sector (mtoe) – 1950-2000

Year	Residential	Industry	Transport	Agriculture	Total
1950	54	10	10	0.1	74.1
1960	66	14	12	0.8	92.8
1970	84	30	13	2	129
1980	96	52	16	5	169
1990	110	94	23	9	236
2000	146	138	42	12	338
Growth rate (%/ annum)	1.8	0.6	1.1	9.9	1.1

Source: CMIE, Economic Intelligence Service: Energy, 2001.

choice of fuels/energy carriers. Affordability and accessibility to modern energy carriers are the major barriers in selecting fuel for households from rural regions and urban poor. Hence, it is important to analyse household energy consumption patterns, study the causalities underlying the fuel choice and analyse the impacts on the economy and on the environment.

Much literature exists on the energy use and its implications, in particular economic and environmental. However, little work has been done on analysing the techno-economic-social framework for energy use. The need to address energy-economy-environment linkages is becoming increasingly important for proving services today by bringing together actors in the private, public and civil society sectors and reduce transaction costs. Planning, implementation, monitoring and evaluation framework should emphasise activities that relate to these actor linkages. This is especially important with respect to the security of energy supply in the long term. In such a framework, it may be necessary to include innovative, policy instruments in order to develop energy markets in a desired direction (economic efficiency, energy security, consumer satisfaction, environmental consideration). To achieve this goal a concerted effort is needed on the part of the many actors influencing energy supply and demand patterns.

Methodology

The present study depends on data from secondary sources. The data collected by the National Sample Survey (NSS) provide the base for the time series as well as cross-sectional study for rural as well as urban households (Anon, 2001). The survey provides the pattern of "primary" fuel use for each end use activity (e.g., cooking, lighting, etc.). The data are from the 92,486 households of which two thirds are from the rural region. In the case of energy use, data are analysed by selected socio-demographic variables such as region (rural and urban), education and occupation of the head of the household, religion, and more importantly the income status. One limitation of the data set is that the lack of information on income and instead household consumption expenditure is provided which is what we have used for examining the distribution of fuel use.

The methodological framework does not cover the entire fuel cycle, that is, fuel mining, processing, transporting, conversion, transmission and distribution, and end-use. Only the final end-use service is considered for solid (fuel wood, charcoal/coal, dung, etc.), liquid (kerosene), and gaseous fuels (LPG and biogas) and electricity. To cope with the lack of data and experience in the analysis of Indian energy sector, a combination of quantittaive and qualitative analysis is used. The end goal is to provide innovative proposals for the design of an energy system that takes into consideration the role of social and environmental considerations in providing an energy carrier with reliable supply and convienience of use.

Household energy consumption in perspective

PATTERN OF CONSUMPTION

In India, energy use (delivered) is divided among five main sectors with households accounting for about 40 percent, the industrial sector 35 percent, and the commercial and transport sectors combined 20 percent. The rest is used by the agriculture sector. Energy use in all sectors stabilized in the 1980s and early 1990s. While early on wood and charcoal were the most important sources of energy, they are being replaced by coal and oil partly due to technological developments. Energy use from the seventies onwards has been influenced by various factors of which the oil shocks in the seventies and eighties had a marked influence, not only on the quantity of energy used but also on the services. Industrial sector, which was consuming five times that of household sector in 1950, is lagging behind in the year 2000. The sharp increases in the price of oil resulted in the diversification of energy use to other sources of energy like natural gas. Besides, activities were undertaken to develop and promote alternative sources of energy like solar and wind (Table 1).

The household sector is the major end user of energy a large share of which is through non-commercial fuels such as fuel wood, dung, etc. The household sector is using three times the energy than it used in 1950. But that's not because individuals are using more energy; it's entirely because there are more people. Table 2 presents a summary of the population, energy consumption, and per capita energy consumption from 1950 to 2000. The per capita consumption declined from 7.94 GJ in 1950 to 7.41 GJ in 1980, and further decreased to 6.02 GJ in 2000. Furthermore, the categories of residential energy consumption has been transforming from cheap but less efficient biomass fuels to more commercial energy (e.g. oil, gas and electricity) .This is due to population increase and lifestyles changes. Lifestyles link social structure to attitudes and behavior. The lifestyle perspective reveals the socio-cultural plurality of societies. In order to describe a lifestyle from a macro-perspective three dimensions have to be considered: (1) social status (termed as class), (2) attitudes and preferences (one might term this 'mentality'), and (3) behavior. Lifestyles are closely intertwined with consumption, but they encompass more than this. Lifestyles and lifestyle changes are drivers of

Table 2: Household Energy consumption (PJ) – 1950 – 2000

Year	Population (million)	Bio fuels	% of total	Kerosene	% of total	LPG	% of total	Electricity	% of total	Total	Per capita consumption (GJ)
1950	370	2884.5	98.18	50.4	1.72	0	0.00	2.7	0.09	2938	7.94
60	446	3348	96.26	124.2	3.57	0	0.00	5.85	0.17	3478	7.8
70	555	3906	95.71	157.5	3.86	2.7	0.07	14.85	0.36	4081	7.35
1980	687	4765.5	93.61	235.8	4.63	54	1.06	36	0.71	5091	7.41
1990	841	5242.5	90.62	301.5	5.21	117	2.02	123.75	2.14	5785	6.88
2000	1012	5130	84.19	382.5	6.28	288	4.73	292.5	4.80	6093	6.02

Source: CMIE, 2001

social change. People are not only consumers, they are ethical persons and political actors at the same time, and this affects energy consumption.

During the year 2000, households were using an estimated 6,093 PJ/year of energy given the average per capita fuel consumption of 6.02 GJ and estimated thermal efficiencies of energy use of 10 %, 40 % and 60 % for fuelwood, kerosene and LPG respectively. This quantity of energy is two times higher than that of 1950, but the per capita energy use is declining year after year. This may be due to the fact that modern energy carriers like LPG, with high efficiency of utilisation, is penetrating into the household market. This household survey did not fully allow for distinguishing fuelwood consumption between the buyers, gatherers and households who met their fuelwood needs by both buying and gathering.

Energy Use Activities

Households use energy for many purposes. Their consumption and the types of energy source depend on a variety of factors. These include the availability of energy sources and the disposable income. However, they also include many factors that can be understood only by analyzing the real needs and behaviour of energy consumers. A household's total energy consumption and mix of energy sources is the result of its attempt to meet its various energy needs. In rural areas biofuels (fuel wood, charcoal/coal, dung, etc.) are the major source for cooking while in urban areas LPG, along with kerosene, is the dominant fuel. In many households, same energy carrier is used for both cooking and water heating. Similarly, multiple carriers are used for a particular end-use. A common cooking fuel combination in urban areas, for example, is firewood and LPG while in rural parts firewood is often complemented with kerosene. Thus, a large number of households simultaneously use a variety of cooking fuels. Energy carrier use resembles a menu choice in which households choose both high-cost and low-cost items depending on their budgets, preferences, and needs. Where multiple energy carrier usage for cooking is common, promotion of kerosene and LPG may not induce the abandonment of bio fuels and may therefore generate fewer benefits than sometimes hypothesized.

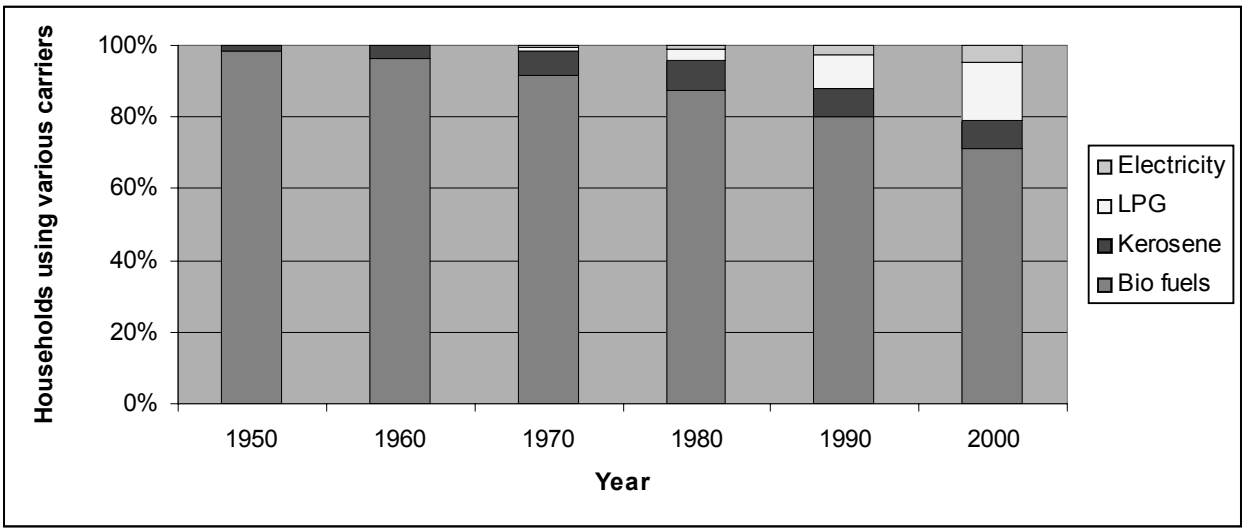
During 1950-1970, the primary energy source was wood, after which it was supplanted by kerosene. By 1980, the LPG, with its ease of transport, and convenience of use, has started penetrating into the household market. As the figure shows, between 1980 and 2000, the share of LPG using households had shown a significant increase with growth rates of around 15 per annum. During the same period, the share of households using kerosene has increased only marginally. In the case of biofuels, the share showed a declining trend, from 98 % to about 70 % (Figure 1). The quantity and the type of energy carrier used by a household depend on the lifestyle and the ability/willingness of the household to pay the consequent fuel costs. Households which have changed cooking fuels tend to have a higher total household expenditure, indicating that those with greater means are more likely to shift carriers, reflecting an ability to pay for replacement of equipment (especially when converting to LPG). However, this is only true given the current mix of fuel costs i.e. cost could become a more influential factor if the cost of the preferred alternative (electricity) became prohibitively high.

Understanding the causalities

It is interesting to have an insight into how households make energy choices. This will depend on household income, on household needs, on the prices and availability of equipment and fuel, on the "status value" of energy sources (e.g. "LPG is more modern") and on other factors. These are the choice factors that lie behind the quantitative data. Understanding energy choices could help in predicting future behaviour. The NFHS survey will not give those causalities directly, it only gives survey data. But one might be able to deduce causalities.

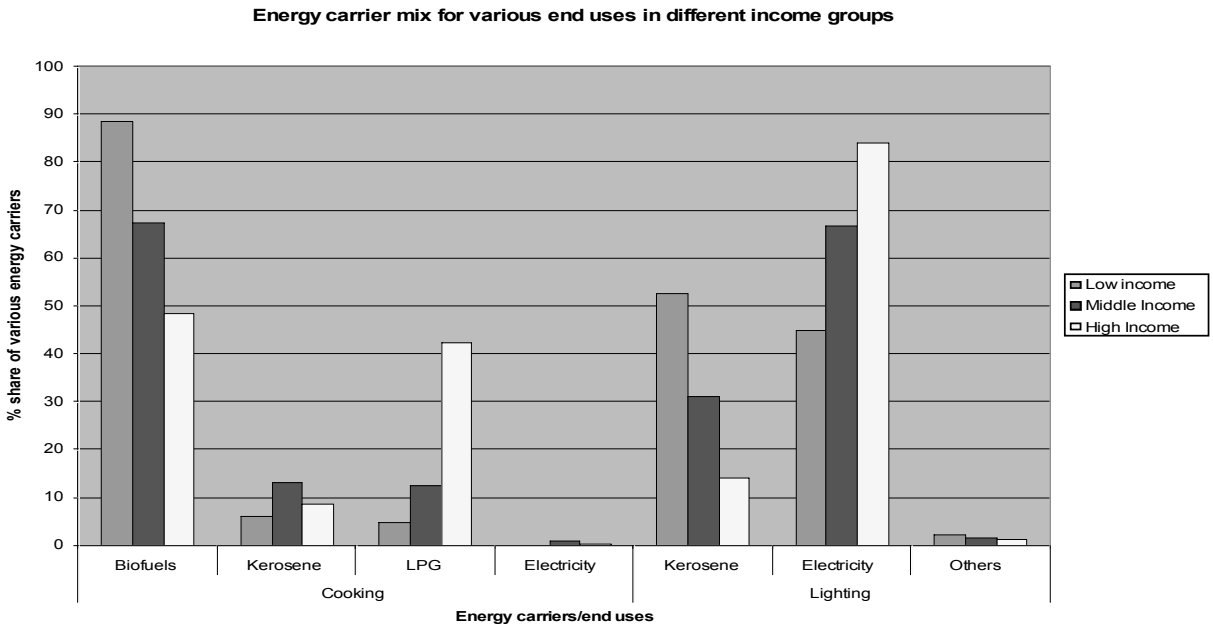
INCOME-ENERGY CARRIER CHOICE LINKAGES

Household carrier choice has changed as the country progressed and new technologies are introduced. The income of households influences energy consumption in many ways. Firstly, with the rise of income levels, energy consumption increases due to increase in the number of dishes prepared. Also supplementary items like vegetables, milk, meat etc. are added to food grains and more energy is required to cook the additional food. This results in the increasing use of energy. Secondly, with increasing incomes, the price of the fuel is less of a constraint. When multiple options are available, high-income households exercise choice in their energy carrier and opt for the cleaner and more efficient "modern" energy carriers of electricity or gas (LPG or biogas). Households shift to clean and convenient form of energy, such as LPG, provided it is available. These carriers do not have the negative health and time effects linked to biomass. These households are also able to afford the appliances that make use of these carriers. Many households use a mixture of modern and traditional fuels; each matched to a specific end-use such as cooking with LPG and fuel wood for heating water. With technological advances associated with end-use devices also moving in the same direction, the efficiency of energy use tends to improve with the ladder climbing. This reflects the



Source: CMIE, 2001

Figure 1: Share of households using various main cooking fuels (1950-2000)



Source: Anon, 2003

Figure 2: Energy carrier mix for various end uses (2000-01)

increasing desire for comfort and discretionary energy consumption. Thus, with increasing income, households climb the "comfort ladder". Understanding the decision-making process within households when choosing energy carriers is important for designing effective interventions (Figure 2).

AVAILABILITY OF ENERGY CARRIER – URBAN-RURAL DICHOTOMY

Other than income, urbanization is an important factor that largely determines the quantity and the type of fuel used. In general, it leads to higher levels of household energy consumption, although it is difficult to separate the effects of urbanization from the increases in income levels. There is also a shift from traditional to commercial energy carriers, which are being used more efficiently. Several factors contribute to this trend. Efficiency and ease of utilization, comfort in transportation and storage of commercial carriers and importantly their easy accessibility in urban areas.

Nonetheless, the use of traditional fuels in many cities of the developing world remains high. In rural areas, there are a substantial number of middle and high income households who in principle could afford modern, clean and convenient fuels yet continue to rely fully or partly on traditional fuels. A number of plausible reasons have been advanced to account for this puzzle. Factors relating to the supply of modern fuels may curtail their full impact: households may be rationed because of aggregate supply shortages in fuel markets; large distances to retailers can be prohibitive, especially in rural areas; waiting lists for access to government-distributed fuels was a major issue until recently. Moreover, the affordability of modern fuels needs to be seen in light of the "lumpiness" of many modern fuel expenditures: whereas fuelwood costs are evenly spread

Table 3: Share of households using various primary energy carriers in Urban and Rural regions (2000-01)

Energy carrier	Income Group	Biofuels	Kerosene	LPG	Electricity	Total households (million)
	Low	73.54	25.28	0.94	0.24	17.25
	Middle	33.06	34.23	30.31	2.3	29.15
	High	6.25	5.08	87.29	1.38	7.95
Urban	Average	42.6	28.6	27.2	1.49	54.35
	Low	98.76	1.11	0.1	0.03	47.21
	Middle	91.36	3.72	4.41	0.51	69.26
	High	57.1	3.98	37.95	0.98	18.38
Rural	Average	89.3	2.83	7.41	0.4	134.85

Source: Anon, 2003

out, expenditures on LPG, natural gas, and electricity tend to come in spikes with particularly severe start-up costs. The uptake costs of LPG and natural gas are often thought to deter potential users, while kerosene can be purchased in small quantities. Better understanding of the obstacles for greater spread of clean cooking fuels would clearly be of policy interest.

A comparison of energy consumption levels in the urban and rural areas demonstrates various characteristics. An analysis of some of the parameters can throw light on some of the crucial aspects that are directly linked to sustainability and environment protection (Sudhakara Reddy and Balachandra, 2002). The Table presents the absolute urban-rural differences in energy use — most of which are positive and quite large in magnitude — which illustrates that the quality of energy use in rural areas lags far behind urban areas. The table indicates transitions in household energy consumption by fuel type in the urban and rural regions during the period 1990-2000. The table shows that biofuel usage is very widespread in rural areas in all the income groups. Many households which can afford other fuels continue cooking with biofuels, at least partly. The continued substantial reliance on biofuels even by high income households in rural areas leads to some scepticism whether development and income growth can displace solid fuels. Firewood is often a commercial good in urban areas, where most wood consumers purchase their firewood. Wood sold on markets is more or less an inferior good in urban areas. From Table 3 it can be observed that commercial carriers (kerosene, LPG and electricity) have become important to households' energy portfolio the farther they are from rural areas.

Lighting is an important energy service which allows productive and social activities to continue beyond sunset. About one third of total households in India still use kerosene lamps, usually wick lamps, although kerosene mantle lamps and caster oil lamps are also used. Most of these households are from rural regions and urban poor. Some argue that the problem of fuel-based lighting is not a priority given the costs of other end uses, such as cooking. While that perspective is certainly debatable, it is important to note that improving the quality and quantity of light available to households in rural region and urban slums would yield significant benefits - improved living standards (amenities and services) and quality of life. It allows children to study in the evening and women to gain some precious time for them or to extend income generating work into the evening hours. However, the high cost of electric connection ensures that kerosene remains the dominant fuel for the poor. Improved lighting involves substantial equipment costs, which include connection charges and electric light fittings, as a result of which many poor families cannot afford electric connections.

ENERGY PRICING

Energy prices influence consumer choices and behaviour. Low energy prices, particularly of modern carriers like LPG and electricity increases their penetration, high energy prices resources, foster innovation, and encourage efficiency improvements. Since steam coal prices are less volatile than oil, coal remains a popular fuel for electricity generation. In addition, prices of coal are significantly lower that of oil. While internationally traded energy prices are an important factor (at more than $ 50 a barrel), the energy bills presented to consumers are considerably higher than the trade prices because most countries tax energy use. In general, India, taxes are high for commercial and industrial energy use than those for household energy use. Kerosene and LPG prices are much lower reflecting government subsidies. For a long time, they were almost constant. But after 1990, energy prices increased by an average 10 % per annum. In the case of biofuels, prices vary with the region. Rural prices are roughly about 1/3rd less than urban markets owing to higher marketing and transport costs. In larger urban centres, firewood prices tend to increase more as the commodity is not as transportable as kerosene or LPG. Even after the increase, their prices are still substantially below the market prices and do not reflect economic costs[2] (Table 4[3]).

Energy prices outpaced the Consumer Price Index (CPI) from 1990 through 2004. In 2004, fuelwood prices increased by 45 percent over 1990 prices whereas kerosene prices in 2004 increased marginally by 8 percent compared to 1990. LPG prices are 250 percent higher than prices in 1990. While the CPI increased about 9.4 percent per annum, the composite average of energy prices increased by about 153 percent between 1990 and 2000. The impact of energy prices on energy expenditures results in low income household energy expenditures

2.The Government of India provides large price subsidies for kerosene and LPG . Because LPG is a relatively expensive cooking fuel, and because most users reside in urban areas and free biomass is often not readily available, the distribution of subsidized LPG has been confined largely to urban areas. In fiscal 2002–03, for LPG and kerosene subsidy, the Ministry of Finance allocated Rs 45 billion (approximately US$ 1 billion). (Business Standard, 2003). It was assumed that there would be likely reductions in subsidy following the Electricity Act 2003. But, due to political compulsions, that is unlikely to happen.

3. Kerosene: Public Distribution System where prices are lower.

Table 4: Prices of energy carriers (1990-2005)

	1990		2005		% change per annum
Energy carrier	Rs/unit	Rs/GJ	Rs/unit	Rs/GJ	
Firewood (kg)	0.87	54.38	1.27	79.38	4.5
Electricity (kWh)	1.18	327.78	1.49	413.89	2.6
Kerosene -P.D.S. (litre)	3.53	78.44	8.00	180.0	0.8
LPG (kg)	6.75	150.00	18.05	400.0	25.0
Composite energy index	180		420		15.3
Consumer price index	191		372		9.4

Source: Anon 2000, Anon 2003 and Anon, 2006

Table 5: Energy use by Occupation

	% of households using various energy carriers Urban				
	Biofuels	Kerosene	Electricity	LPG	Total
Executives	15.76	11.64	1.90	70.70	100
Middle level employees	30.82	22.25	1.41	45.51	100
Lower level employees	42.71	18.41	0.88	38.00	100
Labourers	56.87	24.81	1.10	17.23	100
Others	48.51	18.81	0.67	32.00	100
	Rural				
Middle level Employees	72.80	9.85	0.86	16.49	100
Lower level employees	85.50	6.88	0.51	7.11	100
Land owners	94.38	3.29	0.19	2.13	100
Labourers	97.94	0.76	0.08	1.23	100
Others	92.74	2.31	0.10	4.85	100

Anon, 2003

surging upward. The price information has been standardized (price per GJ) to critically make accurate cost comparisons and chooses between different types of carriers.

OTHER FACTORS – OCCUPATION AND EDUCATION

Other than income and availability the energy carrier selection is influenced by factors such as education, occupation of the head of the household, caste and religion. This perspective is important when households use biomass they produce or collect themselves in an environment of imperfect or missing markets. Self-collected fuels do not have a monetary cost; their collection and use is guided by opportunity costs that depend on the productivity of labor in fuelwood collection vis-à-vis the opportunity cost of time in alternative employment. In what concerns the occupation of the household head, manual workers (labourers) have higher use of biofuels than that of non-manual (lower level employees). Comparing with manual and non-manual, the executives and middle-level employees generally use modern fuels. Using the five forms of occupation, we can observe a definite correlation between occupation and energy use, with a very strong relationship between attaining higher employment status and shift to modern energy carriers. However, this is applicable largely to urban regions where the availability of modern energy carriers is high. For example, 45 % of the households in the middle-level employee category use LPG in urban areas, while only 16.5 % use in rural regions. Similar results were found for other categories also (Table 5[4]). The reason for this is that the opportunity costs are higher and modern fuels offer significant time savings, particularly for the women (even after controlling for income).

The level of education of the head of the household may also be a factor affecting the quantity and type of energy used. This perspective helps explain why households with higher education have a greater tendency to use modern fuels, even, after accounting for income: their opportunity costs are higher and modern fuels offer significant time savings, particularly for women (of course, if supplies are sufficient, but the supplier is not reliable, the household still has a problem). This is often expressed in the ownership of more than one type of cooking device. Higher use of biofuels is recorded in households of lower education and of LPG and electrical appliances among the more educated households. It is quite evident that the share of literacy is high in urban households. It is interesting to know the influence of occupation and education independent of income levels, i.e., at same income levels – how education and occupation influence energy choices. This has a direct correlation between level of income, standard of living and education. In general, illiteracy rates are higher among rural population compared to urban residents. Thus, the use of modern fuels seems to increase with educational level and use of biofuels tends to decline with higher education. There is apparently some element of confounding, with respect to energy availability, be-

4. "Others" belong to specific socio-economic class (e.g. less skilled workers).

Table 6: Energy carrier use by the level of education of the head of the household

	% of households using various energy carriers			
	No education	Primary	Secondary	Higher
Biofuels	89.57	79.03	58.26	25.90
Kerosene	5.29	9.02	12.43	8.81
Liquid petroleum gas	4.60	11.35	28.11	64.25
Electricity	0.53	0.61	1.11	1.04

Source: Anon, 2003

Table 7: Per capita consumption (GJ) of energy for various energy carriers (1950-2000)

Energy Carrier	1950	1960	1970	1980	1990	2000
Biofuels	7.77	7.93	7.40	6.50	5.74	5.25
Kerosene	0.14	0.29	0.26	0.34	0.45	0.48
LPG	0.00	0.00	0.02	0.08	0.13	0.28
Electricity	0.01	0.01	0.03	0.05	0.12	0.41
Total	7.91	8.23	7.71	6.97	6.44	6.02

Source: CMIE, 2001

tween region and educational level since urban localities are characterised by higher availability of modern energy carriers (Table 6).

PER CAPITA ENERGY CONSUMPTION

The most notable trend in household energy consumption in India is the declining trend of per capita use, which in 1950 had much higher energy consumption than in 2000. It decreased from 7. 91 GJ per person in 1950 to 6.42 GJ per person in 2000. The decrease in household energy use is predominantly the result of increased energy efficiency through fuel shifts (from inefficient to efficient carrier-using devices) (Table 7).

Most of the household energy is expended on cooking, water heating and lighting which accounts for about 95 per cent of the total household energy-use. Due to its subtropical and tropical climate, space heating is not a major component of energy-use in India and air-conditioning is still a luxury. With rising incomes, a growing share of household energy is used for fans and other electric appliances with the share of cooking declining. In the total energy use, cooking accounts for about two thirds, about one fourth for water heating and the rest for lighting and other end-uses.

The amount of energy used for a service depends on many factors such as the type of food cooked, the number of meals cooked, household size, the specific combination of energy source and cooking device (type of stove, cooking pans), and the way in which the device is used. By using the data in Table 5, a benchmark for the expected annual energy consumption for a typical household can be calculated by adding together the annual consumption estimates for each use. For example, to obtain a benchmark consumption for households that cover their basic needs using biofuels, we have to add cooking, water heating and lighting needs which work out to about 30 GJ of energy.

IMPACT OF ENERGY USE

Current methods of energy production, distribution and use are major contributors to environmental problems, including global warming and ecosystem degradation at the local, regional and global levels. It has impacts on forests, foreign exchange and air pollution (indoor and outdoor). Also, coal mining and processing for electric power generation, though making the country self-sufficient in electricity, are specific and significant sources of environmental pollution. The environmental impacts of energy use are not new. For centuries, wood burning has contributed to the deforestation of many areas. Even in the early stages of industrialisation, local air, water and land pollution reached high levels. What is relatively new is the acknowledgement of energy linkages to regional and global environmental problems, and of their implications.

IMPACT ON FORESTS

There is a difference between the usage of firewood in urban and rural areas. Rural households mainly depend on twigs and branches whereas urban areas use logs which usually require the felling of trees. Thus, urban firewood consumption has a much greater negative environmental impact as compared to rural use. Indian households consumed around 173 million tones of firewood during 1999-2000 out of which 155 million tonnes are from rural regions. Considering that only about 40 % of the fuelwood is through cutting trees, the amount of wood that is cut amounts to about 62 million tonnes. Hence the total wood that is consumed through felling of trees amount to about 80 million tones which corresponds to deforestation of about one million hectares per annum (Reddy A.K.N and Reddy B.S, 1983).

IMPACT ON THE TRANSPORT SYSTEM

The transport of various fuels into the selling centres involves truck and wagon traffic. In all, about 20 per cent of the trucks and 15 per cent of railway wagons are tied up for transporting energy carriers to the households. Thus, in a situation where

transport is often a constraint on the economy, a significant fraction of both road and rail transport is used for the supply of fuels. There is also another dimension one has to look into. To transport various energy carriers from source to destination requires energy in the form of diesel. Thus, transporting fuels costs significant quantities of energy (Reddy AKN and Reddy BS, 1983)

IMPACT ON FOREIGN EXCHANGE – ENERGY SECURITY

The 14 million litres of kerosene/year utilized for households needed about Rs. 90 billion at an international rate of $ 30 per barrel of crude (Feb. 2001 price). Since about two thirds of India's oil is imported and paid for in foreign exchange, it can be argued that about $ 1.4 billion/year was the foreign exchange expenditure on supplying kerosene to households with their energy requirements.

IMPACT ON ENVIRONMENT

The usage of fuel wood results in significant amount forest loss and their ability to absorb carbon dioxide. With the loss of forest cover the lost a carbon sequestration potential was 70 million tonnes. Similarly the impact of usage of kerosene, LPG and electricity (thermal-based generation) usage on the environment has been estimated as 50 million tonnes of carbon dioxide emissions (Reddy B.S and Balachandra P, 2003).

IMPACT ON HUMAN HEALTH

Air pollution has become a major concern in India in recent years particularly for those households which are dependent on biomass fuels. Studies indicate high risk such as respiratory infections (ARI), chronic obstructive pulmonary disease (COPD), lung cancer and also tuberculosis (TB), asthma, and blindness. Conservative estimates indicate that some 400–550 thousand premature deaths can be attributed annually to use of biomass fuels in these population groups. Using a disability-adjusted lost life-year approach, the total is 4–6 % of the Indian national burden of disease, placing indoor air pollution as a major risk factor in the country (Parikh J et al, 1999)

Climbing the Comfort ladder

Comfort ladder[5] represents the levels of shift in energy utilization, i.e. with each step of the ladder the comfort levels increase progressively. The first step of the comfort ladder is occupied by about 0.6 billion people who rely on traditional energy sources, including biofuels. Due to lack of access to quality energy services, they have been deprived of the unprecedented comfort, mobility and productivity afforded by modern methods of energy use. Lack of electricity usually means inadequate illumination and few labour-saving appliances, as well as limited telecommunications and possibilities for commercial enterprise. This has a drastic influence on their life styles. Greater access to electricity and modern fuels and stoves for cooking can enable people to enjoy both short-term and self-reinforcing, long- term advances in their quality of life. During the last three decades rural electrification programmes have great impact on rural population. However there is great need to cater to un-served population, whose number remains constant. An effective strategy to address the energy needs of rural populations is to promote the climbing of "comfort" ladder. This implies moving from simple biomass fuels (dung, crop residues, firewood) to the most convenient and efficient form of energy appropriate to the task at hand—usually liquid or gaseous fuels for cooking and heating and electricity for most other uses. Providing quality energy services to the needy is based on the forces that bring about these changes.

In order to achieve the goal of optimal stable state of actor influence leading to the highest level in the comfort ladder, their needs and priorities need to be analysed accurately. First and most important step is substituting commercial for traditional fuels. As basic energy needs are met, consumer priorities shift to other, often higher quality services. Households can climb the ladder quickly, due to shifts in technologies. This leads to an increasing stress on cleanliness, for environmental and health reasons on the one hand and the growing value placed on flexibility, saving time and avoiding disruptions on the other. Indicators to denote the household's place in comfort ladder are necessary to estimate possible shifts due to interrelationship among the actors. There are two types of indicators which can be used for providing comfortable energy services, viz., "affordability" and "accessibility". Affordability indicates whether a household can afford a particular comfort level under the existing conditions such as cost of device, price of fuel, etc. For example, low-income groups cannot "afford" to have electricity or LPG due to the high initial cost of device and high operating costs. Accessibility indicator denotes whether a household, cannot access a particular comfort level even if the fuel is affordable. For example, household from remote and sparsely populated regions find it uneconomical to access electricity and LPG services.

Discussion

To increase the "comfort level" of the households in terms of energy services, the government should target the needy - the rural households and urban poor. These comfort levels can be achieved by providing gaseous fuels for cooking and electricity for lighting. There are two types of indicators which can be used for providing "these energy services", viz., "affordability" and "accessibility". The first category is from low-income groups who cannot "afford" to have electricity or LPG due to the high initial cost of device and high operating costs. The second category is from remote and sparsely populated regions where it is uneconomical to provide electricity and LPG services.

Table 8 shows the affordability and accessibility of a comfort level by household. In 2003 for example, nearly 65 million households are without access to electricity (primarily in rural areas) and nearly 125 million households without access to LPG. It is estimated that a significant fraction of the population will not be served through extension of the electric grid and LPG service stations.

While enabling easy climbing of the comfort ladder and at the same time to reduce the negative impacts of energy use on the economy and environment we have to design an alternative mechanism in which the key element is to provide required en-

5. There is a possibility of increase in energy demand (eg refrigeration demand) in the higher steps of the ladder. This issue has not been addressed here since the focus is on main end-uses such as cooking and lighting.

Table 8: Affordability and Accessibility

			Households (million)			
Region	End use	Income group	Un-affordable+ Inaccessible **(UI)**	Un-affordable+ accessible **(UA)**	Affordable+ Inaccessible **(AI)**	Affordable + Accessible **(AA)**
Urban	Cooking/ water heating	Low		17.15		
		Middle				27.84
		High				7.37
	Lighting	Low		16.89		
		Middle				27.9
		High				7.6
Rural	Cooking/ water heating	Low	46.8	0.22		
		Middle			64.7	2.9
		High			13.8	35.8
	Lighting	Low	32.1	15		
		Middle			32	35.8
		High			4.1	13.44

Source: Derived based on the reports from the Planning Commission, Government of India, 2005

ergy services to a household at an affordable cost. A descriptive approach is considered here. Policy maker's influence through the design of various polices which are implemented by the energy supply companies. Household budget directly influences the fuel choice whereas availability and price are influenced by energy companies.

Based on the above Table we can deduce the fuel chose necessary under various combinations of affordability and accessibility for different combination of HH parameters such as income and end use service. The minimum services that are to be provided are cooking/water heating and lighting. To be efficient and clean the carriers that should be considered are gas for cooking, solar energy for water heating and electricity for lighting. The strategy that may be adopted is as follows:

For rural low-income households who do not have access to gas and electricity for cooking and lighting — decentralized renewable energy technologies (RETs) such as biogas/producer gas for cooking and electricity generated through solar energy/ photovoltaics or biogas lighting with appropriate incentives to the entrepreneurs to construct community biogas plants and solar water heating systems.

For rural low-income households (in electrified villages and villages with access to LPG) for cooking and lighting access – Decentralized renewable energy technologies (RETs) such as biogas/producer gas for cooking with incentives to the entrepreneurs to construct community biogas plants and solar water heating systems.

For urban low income households for cooking and lighting – Incentives for LPG for cooking and electricity for lighting.

For rural middle and high income households who have access for gas and electricity but could not afford to opt for them for cooking and lighting - Decentralized RETs for cooking and electricity for lighting.

No specific strategies for urban middle and high-income households– Higher prices (based on the quantity of consumption) for compensating subsidies given to other section of households.

The success of implementation of basic energy service scheme depends on how well various stakeholders help each other, and how well their actions are integrated. The benefits of such schemes will be lost if they cannot be set up on a financially sustainable basis. Subsidies to entrepreneurs may well be essential, but they need to be applied with great care so that they make markets rather than destroy them. Competitors may be able to gain access to subsidies that enable them to sell their products below cost. Many schemes in the past which were set up by the government, aid agencies or NGOs collapsed when the support stopped. Hence, the new schemes need to be reinforced by market instruments; and a continued measurement and explaining effort should be put to implement them. Although the climate is growing more favourable to such schemes, the existing regulatory framework is often the major barrier to development. It can be hostile, contradictory or uncertain. The existing infrastructure of training institutions, or finance in India are non existent or inaccessible. Without changes to this policy environment, the flow of private sector finance and innovation will be restricted. These areas should focus on future analysis, innovation and reform.

This approach presented here can change perceptions of policy makers encouraging them to engage with the social and political context of their activities in a productive way. It can provide practical ways to monitor, document, and assess and thus legitimise crucial institutional strengthening activities. It has several policy implications: (i) effective and sustainable development should be legitimized and rewarded, (ii) development interventions should include social-oriented tools in development planning, implementation, monitoring and evaluation, and (iii) development agencies should employ and integrate professional staff with actor-oriented social science skills (e.g. evaluation specialists) into their mainstream activities.

CONCLUSIONSThe main theme of the paper is to address the role of economic, social and environmental factors in influencing a household's fuel choice. This approach first analysed the existing energy consumption patterns. Shifts in the levels of comfort ladder are used as outcome, and related to changes in these factors. Affordability and accessibility are used as two indicators with different levels, a combination of which is used as a determinant of the level in the comfort ladder level. A strategy based on the needs and priorities is designed, that enables the household to overcome the constraints posed by the accessibility-affordability combination level. Here we observe that the actors have different influence on individual and social interests. The role of these factors presented here can help to address this issue according to which the framework can be conceptualised and analysed. This is very important aspect influencing the strategy for implementation.

References

Anon, 2006, Annual Report, Indian Oil Corporation, New Delhi.

Anon, 2003. Results of the National Family Health Survey, International Institute of Population Studies, Mumbai, India.

Anon, 2002, The world health report 2002 - Reducing Risks, Promoting Healthy Life, World Health Organisation, Geneva.

Anon, 2000, Results of the National Sample Survey, National Sample Survey Organisation, New Delhi.

Anon, 1999, The challenge of rural energy poverty in developing countries, World Energy Council, London.

Business Standard, June 15, 2003.

Clinch J.P and Healy J.D. 2000 Cost Benefit Analysis of Domestic Energy Efficiency, *Energy Policy*, 29 (1).

Centre for Monitoring Indian Economy (CMIE). 2001. *India's Energy Sector*, New Delhi.

Greening, Lorna A., David L. Greene, and Carmen Difiglio, 2000. 'Energy efficiency and consumption-the rebound effect-a survey'. *Energy Policy*, Vol. 28, (6/7).

Koopm C.C and Veldo D.W.Te, 2001. "Bridging the Energy Efficiency Gap", *Energy Economics,* 23 (1).

Laitner, John A., 2000. "Energy efficiency: rebounding to a sound perspective". *Energy Policy*, Vol. 28, (6/7).

Pachauri, S 2004. "An analysis of cross sectional variations in total household energy requirements in India using micro survey data", *Energy Policy*, forthcoming.

Parikh J, Smith K, and Laxmi V, 1999, Indoor Air Pollution: A Reflection on Gender Bias, , Economic and Political Weekly, Vol. XXXIV, No.9.

Planning Commission, Government of India, 2005 – This reference is incomplete?

Reddy. A K N and Reddy. Sudhakara B, 1994. "Substitution of energy carriers for cooking in Bangalore", *Energy - The International Journal*, 19 (5).

Reddy A.K.N and Reddy B.Sudhakara, 1983, Energy in a stratified society - A case study of firewood in Bangalore", *Economic and Political Weekly*, Vol. *XVII*, No. 41.

Schipper, Lee, 2000. 'On the rebound: the interaction of energy efficiency, energy use and economic activity. An introduction'. *Energy Policy*, Vol. 28(6/7).

Sudhakara Reddy B and Balachandra P. 2002. "Sustainable Energy Planning for India Revisited", *Economic and Political Weekly,* Vol. 37(52).

Sudhakara Reddy and P. Balachandra. 2003. "Integrated Energy-Environment-Policy Analysis", *Utilities Policy,* Vol. 11(2)

Sudhakara Reddy B, 2003 "Overcoming the energy efficiency gap in India's residential sector, *Energy Policy,* Vol. 31(11).