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ECONOMIC AND SOCIAL DIMENSIONS OF HOUSEHOLD ENERGY USE: A CASE STUDY OF INDIA

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ABSTRACT

In recent years, it has become increasingly evident that socio-economic variables are the strongest predictors of energy use. Income, education, occupation and location have now become the measures most frequently used by current researchers. Using the data from the National Sample Survey (1983-2000), the present paper analyses the dynamics of energy end-use in household sector in India. The energy consumption is disaggregated according to social class (employment characteristics, access to resources) and income group for rural as well as urban households. It is observed that large variations in energy use exist across different sections of households urban/rural, low/high income groups, etc. The paper analyses the energy-poverty nexus, impacts of household energy use on livelihood and gender issues. The positive effects of innovation of energy efficiency and the required policies and specific proposals for government intervention to achieve the potential for energy efficiency are discussed.

1. INTRODUCTION

During the past few decades, India has experienced many changes in its energy consumption patterns - both in quantitative and qualitative terms (CMIE, 2001[1]). This is due to the natural increase based on population growth and due to the increase of economic activity and development. Household sector is one of the largest users of energy in India, accounting for about 30 per cent of final energy consumption (excluding energy used for transport) reflecting the importance of that sector in total national energy scenario (Reddy, 2003[2]). The pattern of household energy consumption represents the status of welfare as well as the stage of economic development. As the economy develops, more and cleaner energy is consumed. Household energy consumption is expected to increase in future along with growth in economy and rise in per capita incomes. The projected increases in household energy consumption are expected to result from changes in lifestyles (Pachuri, 2004[3]). Hence, it is important to analyze household energy consumption patterns in order to formulate policies for promotion of sustainable energy use. This paper aims to do so by quantitatively analyzing energy consumption of households using a large database on household consumption. More specifically, the main objectives of the paper are to analyze: (i) energy use by different categories of households in India, (ii) the underlying social and economic factors that determine changes in household energy use; (iii) nature of fuel selection, and (iv) impact of energy efficiency on household energy use. Even though, there has been some work on the importance of efficient technologies, less systematic research has been done on households and lifestyles. How far the socio-economic factors influence the fuel choice of a household? What is the role of technologies? The present paper provides new directions on studying these issues. The data collected by the National Sample Survey Organization (NSSO)[1] provide the base

[1] The National Sample Survey (NSS) is a continuous survey programme conducted by the National sample survey Organisation, Government of India, in the form of repeated rounds generally of one year. Each round normally contains four sub-rounds, each of three months duration. Normally in a round, about 10,000 samples villages and 5,000 urban blocks are covered, canvassing about 120 to 150 thousand households as per a scientifically drawn sample design

for the time series as well as cross sectional study for rural as well as urban households (Anon, 2001[4]). This data threw light on the pattern of consumption by different sections of the society and the consumption for different end-uses such as cooking, water heating and lighting. The data is disaggregated according to various end-use activities and expenditure groups. The methodological framework does not cover the entire fuel cycle, that is, fuel mining, processing, transporting, conversion, transmission and distribution, and the end-use. Only the final end-use service is considered.

2. RESULTS OF THE STUDY

2.1. Household energy consumption trends

Use of biofuels for cooking has been a noticeable feature of household energy consumption in India. Historical trends in household energy consumption for the period 1980-2000 indicate that a large number of households continue to depend on traditional fuels for cooking and water heating (CMIE, 2001[1]). The household sector is responsible for about 45% of total primary energy use in India, a large share of which is through non-commercial fuels such as fuelwood, dung, etc. Primary energy use increased more than 1.5 times between 1980 and 2000, from 4,760 to 6,786 peta joules (PJ). This reflects a change in the fuel mix. By 2000, the shares of oil and gas in the secondary energy use increased about three percentage points each over their 1980 levels - from 4.93 to 8.24% for kerosene, and from 1.13 to 4.22% for LPG (Table 1).

Table 1. Household Energy Consumption (PJ) 1980- 2000

Energy Carrier	1980	% of total	1990	% of total	2000	% of total
Bio-fuels	4436.80	93.21	4853.57	89.04	5527.88	81.46
Kerosene	234.67	4.93	380.48	6.98	559.17	8.24
LPG	53.79	1.13	111.75	2.05	286.37	4.22
Electricity	35.22	0.74	105.20	1.93	411.91	6.07
Total	4760	100.00	5451	100.00	6786	100.00

2.2. Energy Use - Rural Urban Dichotomy

Disparities in household energy use exist between rural and urban populations and also between high and low income groups. The energy consumption in the urban and rural areas (1983-2000) demonstrates various characteristics. In rural areas, biofuels, such as fuelwood, charcoal and agricultural waste, constituted a major portion of total household energy consumption, while in urban areas kerosene, electricity and LPG were the major energy carriers. Rural households collect fuel from various sources: animals, forestland or open land surrounding their villages, local retailers, etc while in many urban regions, these fuels have become traded goods. The energy carriers are used for multiple purposes, viz., cooking, water heating, lighting etc. Many households who use fuelwood for both cooking and water heating while other households, which use kerosene and LPG for cooking, the water heating is done with either fuel wood or electricity.

Table 2 presents the urban-rural differences in energy use for cooking — most of which are positive and quite large in magnitude — which illustrate that the quality of energy use in rural areas lags far behind urban areas. Biofuels are being consumed mostly by rural households because of their easy availability. They are considered to be inefficiently utilized and 90% are from the low and middle-income groups. The table indicates transitions in household energy consumption by fuel type in the urban and rural regions during the period 1983 - 2000. There is an evident decline in the use of biofuels and an increased diffusion of modern fuels such as LPG. In rural areas, although the use of LPG for cooking has grown rapidly, it still accounts for only about 6% of total households. A similar trend is seen in kerosene use. The share of biofuels has marginally declined. In urban areas, LPG is the dominant fuel (44.25% of total) and its use is growing steadily. Biofuels appear to be the second most important source of energy for cooking because of their relative affordability. Urban households prefer LPG and other energy sources. Rural households rely solely on biofuels since they do not possess the infrastructure for LPG supply. However, the use of LPG and kerosene is growing rapidly.

Table 2. Change in fuel mix for cooking in Rural and Urban regions (1983-200)

Fuel Type	**% of rural households**			**% of urban households**			**% of total households**		
	1983-84	1993-94	1999-2000	1983-84	1993-94	1999-2000	1983-84	1993-94	1999-2000
Biofuels	97.20	93.80	88.40	69.10	41.40	28.20	89.80	79.40	70.60
Kerosene	0.82	2.00	2.70	16.71	23.60	21.70	4.75	7.82	8.37
LPG	0.24	1.90	5.40	10.29	29.60	44.20	2.73	9.36	16.99
Electricity	1.74	2.30	3.50	3.90	5.40	6.90	2.72	3.42	4.04
Total	100	100	100	100	100	100	100	100	100

2.3. Household Income and the Energy ladder

The income of households influences energy consumption in many ways. Firstly, with the rise of income levels, energy consumption increases due to increase 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. Households prefer to use a clean and convenient form of energy, such as LPG. Due to the use of efficient devices, the total consumption of energy will not increase significantly. High-income households have opted for cleaner and more efficient "modern" energy carriers such as electricity or LPG. Many households use a mixture of modern and traditional fuels; each matched to a specific end use such as cooking with LPG and heating water with fuelwood. Although 80% of households in rural areas use biofuels, poor households spend more time in collecting these fuels than those in higher income groups. High-income households also purchase other high-grade fuels such as electricity, which are used for a greater variety of end-uses such as air-conditioning, refrigeration, etc (other than heating). The structural differences of energy carriers for cooking among different income categories present interesting results (Table 3)[2].

As the data (Table 3) showed, there was a variation in the contribution of different energy carriers to the cooking energy mix of different income groups. The high-income households use LPG and electricity. On the basis of the figures for the year 1983-2000, it can be seen that, with 2 increasing disposable income and changes in lifestyles, households tend to move from the cheapest and least convenient fuels (fuel wood, dung, etc.,) to more convenient and normally more expensive ones (kerosene) and eventually to the most convenient and usually most expensive types (LPG and electricity). Thus,

[2] The low-income group consists of households with a per capita income of less than Rs.6, 000, middle-income group (Rs.6 000 to 10,000) and high-income group (Over Rs.10, 000 per annum at the time of survey, i.e., (1999-2000).

there is a clear-cut pattern of substitution of one carrier for another with increase in income -- solid fuels (charcoal and firewood) give way to a liquid fuel (kerosene), which in turn is displaced by gas (LPG) and electricity, which are the most desirable energy carriers. With increasing disposable income and changes in lifestyles, households tend to move up the energy ladder (in terms of quality, convenience to use and cost) – biomass to kerosene and then to LPG/Electricity. 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.
Thus, we can observe positive relationship between growth in per capita income and household demand for commercial fuels. For most developing countries, demand for commercial fuels has risen more rapidly than per capita incomes since 1970. This reflects the increasing desire for comfort and discretionary energy consumption.

Table 3. Households using fuels for cooking in different income groups (1983-2000)

Energy Carrier	**% of households using various fuels in different income groups**			
		1983	1993-94	1999-2000
Low Income	Biofuels	96.2	93.8	91.0
	Kerosene	2.1	2.9	3.9
	LPG	0.6	1.1	1.7
	Electricity	1.1	2.2	3.4
	Total	100	100	100
Middle Income	Biofuels	92	90.6	89.8
	Kerosene	3.5	4.2	4.5
	LPG	1.8	2.1	2.2
	Electricity	2.7	3.1	3.5
	Total	100	100	100
High Income	Biofuels	88.4	80.5	61.0
	Kerosene	4.2	7.2	8.2
	LPG	4.0	8.5	22.6
	Electricity	3.4	3.8	8.2
	Total	100	100	100

In general, urbanization leads to higher levels of household energy consumption, although it is difficult to separate the effects of urbanization from the increases in income levels which generally accompany with each other. There is also a shift from traditional to commercial fuels along the gradient of income levels. Several factors that contribute to this trend include a decline in access to biomass fuels, inconvenience of transportation and storage, and improvement in the availability of commercial fuels in urban areas.

Nonetheless, use of traditional fuels in many cities of the developing world remains high in low-income groups. Another trend is a decline in the share of energy used for basic requirements such as cooking and lighting as incomes increase, while energy consumption for space heating, water heating, refrigeration, audio/video appliances, air conditioning and other modern uses grows.

In what concerns the occupation of the household head, manual workers (laborers) 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 an association between occupation and energy use - 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 4).

Table 4. Energy use by Occupation

Occupation	Biofuels	Kerosene	Electricity	LPG	Total
Urban					
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
Laborers	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
Low level employees	85.50	6.88	0.51	7.11	100
Land owners	94.38	3.29	0.19	2.13	100
Laborers	97.94	0.76	0.08	1.23	100
Others	92.74	2.31	0.10	4.85	100

The annual per capita energy consumption of low income households in urban areas does not differ significantly from that of the rural poor, since the main share of energy consumption in both cases goes to cooking and lighting. However, with rising incomes, the energy consumption patterns of urban households change significantly. This may be due to the increase in the number of dishes prepared and the use of various appliances such as TV, microwave, AC, etc. The main factors that determine the selection of energy carriers include: prices of fuels and the corresponding utilizing devices, disposable income of households; availability of fuels and cultural preferences (Reddy and Reddy, 1994[5]). It is not possible to study the effect of price, in India, where a major part of energy consumption is met by traditional fuels that are gathered informally and the costs consist mostly of time (for gathering fuel wood) and, hence, are opportunity costs. Another reason is that prices of commercial energy carriers such as kerosene and LPG are administered and hence do not reflect the real cost. On an average, a typical rural household consumes 30% more energy than its urban counterpart. But, if we consider the useful energy, this amount comes down significantly due to the inefficiency of energy use by the rural households. During the year 1999 – 2000, the rural population (consisting of 72 per cent of total households) used nearly 90 per cent of biofuels (172 million tonnes) and 74 percent of kerosene (13.75 million kilolitres). As against this, the urban population consumes about 68 percent of LPG and about 65 percent of electricity (Table 5).

2.4. Implications of household energy consumption

There is a difference between the usage of biofuels in urban and rural areas. Rural households depend on twigs and branches whereas urban households 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. India consumes around

200 million tonnes of biofuels (mainly firewood) per annum (Table 5) which corresponds to deforestation of about a million hectares (assuming that the growing stock per hectare in such a forest has a high value of 120 tonnes/ha) (Reddy AKN and Reddy BS 1983). This indicates that about 200 hectares of forest would have to be cleaned each day to keep the Indian households supplied with its firewood demand if the wood is being obtained non-renewably by clearing forests. Similarly the impact of kerosene usage on the economy and environment is significant. Assuming that 60% of kerosene consumed has been imported, it is seen that the burden of using kerosene has been roughly estimated at about 1500 million US dollars during 2000-2001 (assuming a price of US$ 30 per barrel of crude oil) From environment perspective carbon emissions from the residential sector are estimated to be about 42 million tonnes (Sudhakara Reddy and Balachandra, 2003).

Table 5. Quality of fuels used in Rural and Urban regions (1999-2000)

	Rural		**Urban**	
Type of Energy	Per capita Consumption	Total	Per capita Consumption	Total
Biofuels	17.7 kg	172 m.t	5.34 kg	28 m.t
Kerosene	0.821	13.75 m.kl	1.34 L	4.8 m.kl
Electricity	4.54 KWh	38.87 GWh	20.89 KWh	70.7 GWh
LPG	0.14 kg	1.20 m.t	1.31 kg	2.5 m.t

	Total		
Type of Energy	Actual units	TJ	% of total
Biofuels	200 m.t	2762	56.45
Kerosene	18.6 m.kl	836	7.18
Electricity	109.6 GWh	3944	32.26
LPG	3.7 m.t	168	3.08
Others		50	1.03
Total		7760	100

It has long been established that that in many regions, there is an increasing shortage of fuelwood supply. This adds to the burden of fuel collection. Several hours a day are spent in collecting these fuels by women and children (Pachari S 2004). It means that this time cannot be used for other livelihood activities. It also negatively affects children's learning by keeping them away from school. Although nearly every household in rural areas uses some biomass as an energy carrier, poor households spend more time in collecting than those in higher income groups. Hence, it is important to look at the energy dimension to poverty. The consequences for the poor are that precious time is used on collecting low quality fuels, which are then used at low efficiency, reducing their ability to accumulate the financial resources they need to invest in strategies for improving their livelihoods. The low efficiency of utilization of biofuels damages people's quality of life and imposes enormous costs on the community. The most direct effects are in relation to the health of people living and cooking in one-room homes. Energy has also an equity dimension. Poor households use less useful energy per household than wealthier ones in absolute terms. One consequence is that less food is being cooked and less water is boiled for drinking and other hygienic purposes. This increases the likelihood of water-borne diseases, which in turn, reduces the ability of poor people to improve their livelihoods, by not only preventing adults from working effectively but also negatively affecting their health (Reddy AKN and Reddy BS, 1983).

3. DISCUSSION - EFFICIENCY OF ENERGY UTILIZATION

While moving up the energy ladder is necessary for economic development, improved access to modern energy carriers alone can not ensure development. In this context, the concept of energy efficiency and the introduction of renewable energy technologies can be widely viewed as important elements of economic and environmental policy. In the case of extraction and conversion of primary energy and the transmission and distribution of energy carriers, the specific energy use can be reduced by about 20 to 50 per cent with technological and fuel shifts. These are less expensive and increasing energy supply on per unit of energy basis, even if we exclude external environmental impacts (Reddy, 2003[6]). By replacing the existing inefficient technologies with efficient ones and by non-renewable fuels with renewables, the amount of energy needed for basic services can be reduced significantly. These savings would be not only in the form of reduced expenditure on fuels, but also on improved indoor air quality, as well as on global benefits accrued by reducing the emission of greenhouse gases, such as CO2. There would be also savings in the form of reduction in cutting of forests as well. While industries respond rapidly to market forces, through efficient use of energy, households are much slower to respond, for a variety of reasons. One reason may be that low-income households under-invest in energy efficiency technology, partly because they face formidable information barriers, partly because they cannot observe many of the costs of energy they use. Cost and accessibility clearly seem to be the main reasons of this shifting. At the consumption end of the cycle, we have to understand that the demand for energy is basically a derived demand, which depends on (i) prices of energy and the cost of energy using device, (ii) technology and related variables defining the efficiency of use; and (iii) incomes of consumers, and other actors in the system. Since, the demand for energy is a function of various energy services required such as cooking, lighting, etc, technology that is used to obtain these services is determined by the prices of energy and the costs of utilizing device that provides a particular service. To study the cost of utilization of energy carriers, we have to compare the performance of various technologies. The factors that affect the cost of utilization are the purchase cost of device which usually represents a lump sum initial payment and the annual cost of operating the fuel stove. This is composed of the annual consumption of fuel plus the annualized cost of the cooking equipment usually referred to as the annualized life cycle cost (ALCC). Table 6 gives the performance characteristics of various technologies in terms of their fuel utilization. If we consider the cost in terms of useful energy, then the firewood using households are paying slightly higher than those of the LPG using households, even though the number of items prepared by the latter is more than the former. So, if there is a shift from fuelwood to kerosene/LPG and from kerosene to LPG the operating costs do not vary significantly. Among all the carriers, biogas seems to be the cheapest. Thus, a shift from fuelwood to biogas offers the best savings in terms of operating costs. The increase in useful energy through greater efficiency can offset many negative impacts. Much of this drudgery could easily be reduced by the application of modern energy forms and efficient utilization of biofuels. Energy carriers can also be considered as material assets. Therefore having access to sufficient amounts of good quality energy will contribute to reducing a household’s vulnerability. Also, energy poverty results from a combination of low household income, unaffordable energy costs and inefficient heating devices. Energy efficiency seems to be the only rational solution to energy poverty and that Government should direct much greater resources to improving the energy efficiency of the devices.

Even though, the diffusion of energy efficient measures (EE) is widely viewed as an important element of economic and environmental policy, , there is little agreement on specific goals and the strategies to attain them. The lack of consensus stems from the fact that there are differing views about the role of EE and the means of implementing it. How much one will actually benefit from EE depends on how one approaches the issue. Also, the success in the diffusion of EETs depends on how well various actors help each other, and how well their actions are integrated. There is an argument that questions the existence of a simple causal linkage between the diffusion of EET and its contribution to a decrease in energy use: The general perception is that the efficient use of energy leads to an increase in the use of energy which is called the “rebound effect”. This may partly offset the savings in energy use achieved by the EE improvements (Schipper 2000[7]). However, in practice, the rebound effect may not be high enough to subtract the potential contributions of EE to the reduction of resource use or the carbon emissions (Greening *et al* 2000[8], 399 and Laitner 2000[9]). Nonetheless, energy efficient technologies may need to be reinforced by market instruments; and a continued measurement and explaining effort should be put on to the rebound effect. Actually, energy efficiency gains can increase energy consumption by two means: by making energy appear effectively cheaper than other inputs; and by increasing economic growth, which pulls up energy use.’ The debate is inconclusive because of the gulf between energy analysts and policy makers, although there have been attempts to seek common ground.

Table 6. Costs and benefits through technology shifts

Option	Efficiency (%)	Capital cost (Rs.)	Life (years)	Energy consumption (family/year)		Price of energy (Rs/Unit)	Energy Cost per Year	Annual Cost (Rs.)	Total CO2 Emissions (kg/year)
Cooking:				**Actual units**	**GJ**				
Traditional wood stove	13	25	5	1500 kg	24	1	1500	1506.6	2520.00
Efficient wood stove	35	250	10	500 kg	8	1	500	540.7	840.00
Trad. Kerosene stoves	30	125	7	280 litres	9.8	8.5	2380	2405.7	690.21
Efficient K.Stoves	45	250	10	186 litres	6.51	8.5	1581	1621.7	458.50
Biogas Stove	55	500	15	0.1 cu.m	2.3	0	0	65.7	0.00
LPG stoves	60	2000	15	165 kg	7.5075	17.59	2901.7	3164.7	464.04
Traditional wood stove	13	25	5	500 kg	8	1	500	506.6	840.00
Water heating									
Efficient wood stove	35	250	10	210 kg.	3.36	1	210	250.7	352.80
Traditional Kerosene	30	125	7	96 litre	3.36	8.5	816	841.7	236.64
Efficient K. Stoves	45	250	10	58litre	2.03	8.5	493	533.7	142.97
Biogas Stove	55	500							
Solar water heaters		15000	15		0	0	0	1972.1	0.00
Electric water heater		2800	10	900 kWh	3.24	3	2700	3155.7	627.48
Lighting									
Incandescent Lamps	60 W	12	1000 hrs	65.7 kWh	0.2365	3	197.1	211.5	45.81
Incandescent Lamps	100 W	13	1000 hrs	109.5 kWh	0.3942	3	328.5	344.1	76.34
Compact Flúor. Lamp	13 W	175	10000 hrs	13.1 kWh	0.0473	3	39.42	69.5	9.16
Fluorescent Tube	36 W	222	8000 hrs.	50.4 kWh	0.1813	3	151.11	195.4	35.12
Traditional K. Lamps	5	15	5	36.0 litres	1.26	8	288	292.0	88.74

5. CONCLUSIONS

The comparison of energy consumption patterns in urban and rural households and from different income groups for years 1983-2000 demonstrates various characteristics. Noncommercial fuels constitute more than half of the total household energy use, and more than 75 per cent in rural regions. Low and middle-income groups and low-income groups in urban regions are the main users of these biofuels (mainly fuelwood). The Indian household energy problem is not primarily a problem of the scarcity of energy per se, but inefficient energy conversion to obtain the desired services. The consequence of such utilization is the serious health hazards of inhaling the smoke from fuels used for cooking. This inefficiency of utilization is an indicator for many of its elements, such as poor education, bad health care, the hardship imposed on women and children, etc. The gathering of fuelwood becomes more difficult as land degradation spreads. The supply of fuelwood, especially to urban areas, is a contributing factor to deforestation and land degradation. Given the magnitude of these problems and issues, are there solutions, which are sustainable? One aspect should be considered is the efficient use of energy. In the case of extraction and conversion of primary energy and the transmission and distribution of energy carriers, the specific energy use can be reduced by about 20 to 50 per cent with technological and fuel shifts. These might be less expensive and increasing energy supply on a per unit of energy basis, even if we exclude external environmental impacts.

In developing countries like India, the potential for demand reduction is often even larger. The poor often do not have access to the efficient fuel/technology and depend on their own labor, on animal power or fuelwood, and other types of biomass, which have a high price in terms of human time, and labor. They also have health and gender impacts, which are usually more severe on women. Hence the strategy of climbing the "efficiency ladder" (wood stove efficient wood stove/Biogas stove efficient kerosene stove LPG stove and electric geyser/solar water heater) means ***addressing energy development, poverty, social justice, equity and gender issues as parts of the same political process of development***. It involves bridging the gap between changing attitudes and environmental degradation and the patterns in the use and reuse of the earth's resources.

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