Technological Substitution and Changes in the Household Energy Consumption Pattern: A Case Study of India

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ABSTRACT

The present paper analyses the dynamics of energy end-use in the household sector in India. Initially, the households energy usage patterns, types of energy carriers and the technologies in use are analysed using the data from the National Sample Survey (1983-2000). The energy consumption is disaggregated according to end-use activity 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 reasons for the gap between the possible and practical implementation of energy efficient measures, study the reasons for households not using the cost-effective technologies available to them, the benefits of innovation of energy efficiency, and the required policies and specific proposals for government intervention to achieve the potential for energy efficiency.

Introduction

During the past few decades, India has experienced many changes in its 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 the increase of economic activity and development. The experience of the last 20 years shows that gross energy demand has by far exceeded the growth rates of population. While the 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 life-styles. More user-friendly household appliances were 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 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 scene (Reddy, 2003). 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. The growth in demand has even offset all the savings achieved by energy efficiency improvements (through fuel shifts) within society at large. This highlights the importance of consumption growth as the driving force of energy demand. Household energy consumption is expected to increase in future together with economic growth and rising per capita incomes. The projected increases in household energy consumption are expected to result from changes in lifestyles (Pachuri, 2004). It is important to analyze household energy consumption patterns in order to formulate policies for promotion of sustainable energy consumption. This paper aims to do so by quantitatively analyzing energy requirements 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, economic, and technical factors that determine changes in household energy use; (v) nature of fuel shifts, and (iv) links between household energy use and environment.

The present study depends on secondary sources. The data collected by the National Sample Survey Organisation (NSSO)[1] provide the base for the time series as well as cross sectional study for rural as well as urban households (Anon, 2001). 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 survey deals with (i) social and basic necessities, (ii) energy carrier consumption and end-use, and (iii) household expenditure (considered as a proxy for income). 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. The primary data collection is aimed at obtaining information on the costs and benefits of various technologies.

Results of the Study

Household Energy Consumption Trends

Historical trends in household energy consumption for the period 1950-2000 are presented in Table 1. Use of biofuels for cooking has been a noticeable feature of household energy consumption in India. A large number of households continue to depend on traditional fuels for cooking and water heating. 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. During the past few decades, electricity consumption has grown faster than any other fuel and the growth rate of per capita household electricity consumption has outnumbered the growth rate of per capita income. Table 1 also demonstrates that other fuels (cow dung, coal, biogas, etc) appear to be major energy sources in rural areas, but their importance is declining.

Household Energy Use - Rural Urban Dichotomy

Disparities in household energy use exist between rural and urban populations and also between high and low income groups. In rural areas, traditional fuels, such as fuelwood, charcoal and agricultural waste, constitute a major portion of total household energy consumption, while in urban areas households use kerosene, electricity and LPG. The comparison of energy consumption levels in the urban and rural areas (1983-2000) demonstrates various characteristics. An analysis of some of the parameters can throw light on some of the crucial

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[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 duration (July-June). Each round normally contains four sub-rounds, each of three months duration. Normally, in a round, about 10,000 sample villages and 5,000 urban blocks are covered, canvassing about 120 to 150 thousand households as per a scientifically drawn sample design. The subject coverage for surveys is decided based on a ten-year programme. The subjectsf covered include employment and unemployment, consumer expenditure, housing condition of people, land holdings, live stock, enterprises, debt and investment, social consumption, demography, morbidity, disability, etc. Certain topics are repeated once in 5 years (like labour force and household consumer expenditure) while the other topics are covered once in 10 years in such a way that seven years out of the Ten Year Cycle are allotted for fixed subjects while the remaining 3 years are allocated to subjects of special interest.

aspects that are directly linked to sustainability and environment protection (Sudhakara Reddy and Balachandra, 2002). Rural households use energy for multiple purposes from different sources. They collect energy from various sources: animals, forestland or open land surrounding their villages, local retailers, etc. Even though, fuelwood and other biofuels are mostly gathered in rural areas, in many urban regions, they have become traded goods. These multiple sources of energy are used for multiple purposes, viz., cooking, water heating, lighting etc. - predominantly for cooking and lighting purposes. Many households who use fuelwood for cooking also use it for water heating services. In the case of households who use kerosene and LPG for cooking, the water heating will be either through fuelwood or through electricity

Table 1. Fuel Mix in the Indian Household Sector (PJ) (1950-2000)

Fuel	1950		1980		2000		Growth Rate per Annum (%)
	PJ	% of total	PJ	% of total	PJ	% of total	
Firewood	2265	82.65	3689	84.47	4773	75.60	5.0
Coal/Charcoal	34	1.22	88	2.01	105	1.66	1.4
Kerosene	46	1.68	218	4.99	523	8.29	9.5
LPG	0.00	0.00	50	1.15	268	4.24	53.56
Electricity	2.5	0.09	33	0.77	385	6.1	76.5
Other biofuels[2]	394	14.36	289	6.62	260	4.11	-2.7
Total	2740	100.00	4367	100.00	6314	100.00	7.1

Source: Reddy (2003)

Table 2 reports changes in the use of different fuels for cooking in both rural and urban areas. In rural areas, although use of LPG for cooking has grown at a very high annual rate of 19.5 percent, it still accounts for only 5.4 percent of total energy use for cooking. A similar trend is seen for kerosene. The share of traditional fuels such as fuelwood and dung has marginally declined and their annual growth rates are slightly below zero. In the urban areas, LPG is the dominant fuel (44.2%) and its use is growing steadily. Fuelwood appears to be the second most important source of energy for cooking along with kerosene, although the growth rates for fuelwood are significantly negative. At the national level, fuelwood is still the most important fuel for cooking. However, the use of LPG and kerosene is growing rapidly. In the case of lighting, kerosene and electricity are the main carriers used. In rural areas, electricity is used by about 50% of the households while in urban areas the share is nearly 90%. The rest of the households depend mainly on kerosene. One of the main reasons for this trend is the high initial cost of obtaining electricity connection to the consumer. Other factors include lack of a distribution network, and failures of the electricity distribution system.

Table 2. Percentage of households using various fuels for cooking in different regions (1983-2000)

Rural		1983-84	1993-94	1999-2000	Growth rate (%)
	Fuelwood	76.7	76.2	75.5	-0.15
	Dung	14.5	13.5	10.6	-1.71

[2] Includes coal, dung, agricultural wastes, etc.

	Kerosene	0.8	2	2.7	6.85
	LPG	0.2	1.9	5.4	19.54
	Others	7.8	6.4	5.8	-1.93
Urban	Fuelwood	45.9	29.9	22.3	-4.15
	Dung	2.9	2.4	2.1	-1.9
	Kerosene	16.7	23.6	21.7	1.16
	LPG	10.3	29.6	44.2	8.52
	Others	24.2	14.5	9.7	-2.38
Total	Fuelwood	69.1	65.2	65.2	-1.27
	Dung	11.6	9.1	9.1	-1.76
	Kerosene	4.8	7.8	7.8	5.25
	LPG	2.7	9.4	9.4	16.45
	Others	11.8	8.6	8.6	-1.7

(Source: Based on NSSO estimates)

Table 3 contains the details of rural and urban population and household details for different years. In the year 1991, about 74.2 percent of the total population was living in the rural areas. This proportion has declined slightly to 72.2 percent in the last one decade. The family size has declined marginally in both rural and urban areas. This will increase the number of households at a rate higher than the population growth rate.

Income-Energy Carrier Linkages

The data on households depending on various energy carriers for cooking and lighting in various income categories present interesting results. The data provide information on the use of various fuels/energy carriers in different percapita monthly expenditure (PCME) classes. We have considered these PCME classes as proxies to income categories. Accordingly, in rural areas, households with expenditure Rs.< 380 per month have been considered as low income group while middle income groups are those in the range of Rs.380-775 PCME. Those with Rs.> 775 PCME have been categorised into high income groups. In the case of urban regions, the categroies are: low income (Rs.<575), middle income (Rs.575-1500) and high income (Rs.> 1500). It depends on the income of the household, availability of local resources and alternative fuels, price of fuels, etc.

Table 3. Details of Rural and Urban Population and Households

	1991	1993-94	1999-00	2000-01
Rural Population (Million)	622.81	656.31	728.82	741.66
Family Size (No.)	5.58	5.58	5.50	5.36
Rural Households (Million)	111.59	117.62	132.51	138.27

Urban Population (Million)	215.772	234.65	277.49	285.36
Family Size (No.)	5.34	5.34	5.32	5.31
Urban Households (Million)	40.418	43.94	52.16	53.69

As the data (Table 4) show, there is a variation in the contribution of different energy carriers to the cooking energy mix of different income groups. On the basis of the figures for the year 1999-2000, it can be seen that firewood, which is considered to be inefficiently utilized and hence produce high pollution levels, is being consumed mostly by the low and middle income groups because of its easy availability. Among those households, which depend on fuelwood, nearly 90% are from the low and middle-income groups. The high-income households use Liquified Petroleum Gas (LPG) and electricity. With increasing disposable income and changes in lifestyles, households tend to move from the cheapest and least convenient fuels (fuelwood, 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). 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 A.K.N. and Reddy B.S, 1994). Even though price of a fuel plays an important role in the household fuel shifts 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 fuelwood) and, hence, are opportunity costs. Another reason is that prices of commercial energy carriers such as kerosene are administered and hence do not reflect the real cost.

The choice of biofuels is often based on lack of accessibility and insufficient income to use LPG and electricity. Urbanization and increased family income has resulted in a shift from biofuels to the other forms of energy, known as "climbing the energy ladder". Thus, with higher incomes the residential fuel mix is shifting away from biofuels to kerosene and finally to electricity and gas. Electricity is the most convenient form of household energy as it makes the use of electric appliances possible. The affordability, and accessibility to LPG depends directly on the financial capabilities of the households, which is evident from the lower levels of consumption by the low-income groups. Kerosene is the second most important fuel with a significant portion of middle-income households depending on it.

Table 4. Share of Households Using Various Fuels in Different Income Groups - Cooking

	Energy carrier	1983-84	1993-94	1999-2000	Growth rate (%)
Low income	Firewood	31.2	30.5	25.1	-1.04
	Dung	3.4	3.9	3.1	-1.43
	Kerosene	0.4	2.1	2.3	6.93
	LPG	0.1	0.9	1.6	12.87
	Others	2.3	3.2	2.5	-7.3
Middle income	Firewood	27.2	26.6	29.6	-0.21
	Dung	3.3	3.8	4.1	-0.83

	Kerosene	1.8	3.9	4.9	-2.64
	LPG	0.7	4.6	9.9	23.5
	Others	5.8	2.5	2.9	-4.7
High income	Firewood	13.7	8.1	4.9	-8.06
	Dung	0.1	1.4	0.8	-4.3
	Kerosene	2.0	1.8	1.2	-2.43
	LPG	1.9	3.9	5.5	15.34
	Others	5.4	0.8	1.0	-4.5

(Source: Based on NSSO estimates)

Households in the low income group primarily use kerosene as a fuel for lighting while those in the middle and high income groups prefer electricity. Use of kerosene for lighting has been declining very rapidly in the high income group while the use of electricity for this purpose has been picking up in low and middle income groups in the recent times.

Thus, there is a clear-cut pattern of substitution of one carrier for another with increase in income -- solid fuels (charcoal and firewood) gives 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→kerosene→LPG/Electricity. With the technological advances associated with the end-use devices also moving in the same direction, the efficiency of energy use tends to improve with the ladder climbing. Thus, there is a strong positive relationship between growth in per capita income and growth in 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. Urbanization is an important determinant of both the quantity and the type of fuel used in developing countries. 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 that generally accompany urbanization. There is also a shift from traditional to commercial fuels. 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 among 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.

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 is due to the increase in the number of dishes prepared and the use of various appliances such as TV, microwave, AC, etc.

Table 5. Estimated Rural and Urban Energy Consumption per Household per Annum (GJ)

Region	Income group	Cooking	Water Heating	Lighting	Others	Total
Rural	Low Income	19.88	6.62	0.4	1.3	28.2
	Middle Income	19.09	6.26	0.87	1.5	27.72
	High Income	14.88	4.39	1.2	1.9	22.37
	Average	18.8	6.13	0.75	1.57	26.1
Urban	Low Income	14.46	4.45	1.22	3.24	23.37
	Middle Income	9.46	2.85	1.52	4.1	17.93
	High Income	7.34	0.5	2.52	5.5	15.86
	Average	10.8	2.51	1.56	4.28	19.05

From Table 6, it can be seen that, during the year 1999-2000, the rural population, consisting of 72 per cent of total households, used nearly 90 per cent of fuelwood and 74 percent of kerosene. As against this, the urban population consumes about 68 percent of LPG and about 65 percent of electricity. Since the environmental implications are significantly dependent on the type of energy carrier chosen, it is important to look at the demand of various carriers and their associated emissions. Table 6 also provides information on the environmental impacts of energy use.

Table 6. Quantity of Fuels Used in Rural and Urban Regions (1999-2000)

Type Of Energy	Per Capita Rural Consumption	Rural-Total	Per Capita Urban Consumption	Urban - Total	Total consumption	Total consumption (TJ)	Total CO_2 emissions (m.t)	% of total
Fuelwood	17.7 kg.	172 m.t	5.34 kgs	28 m.t	200 m.t	2762	287.06	56.45
Kerosene	0.82 l	13.75 m.l	1.34 l	4.8 m.l	18.6 m.l	836	36.54	7.18
Electricity	4.54 KWh	38.87 GWh	20.89 KWh	70.7 GWh	109.6 GWh	3944	164.03	32.26
LPG	0.14 kg	1.20 m.t	1.31 kg	2.5 m.t	3.7 m.t	168	15.65	3.08
Others						50	5.25	1.03
Total						7760	508.53	100.00

Impact of Fuel/Technology Shift

Substitution of inefficient technologies with efficient ones and switching of fuel from non-renewable to renewable technologies results in significant resource savings. Rising incomes lead to these shifts. In the choice of fuel, not only the fuel prices play a role, but also the price of devices and the convenience of use. Since urban users purchase fuelwood, they are sensitive to relative fuel prices so inter-fuel substitution can occur as their income level changes. Rural users generally use wood stoves of low efficiency which are mostly self-made from local material, and do not require financial expenditure. Besides their inefficiency, the use of traditional wood stoves can have serious health impacts, mainly due to smoke. Hence, it is important to consider fuel and technology (stoves) shifts. In the residential sector, major alternatives would be fuel shifts - from firewood to kerosene/LPG for cooking, and technology shifts - replacement of existing inefficient devices with efficient ones (for cooking, lighting, water heating, etc.). Efficiencies as high as 30% (from the existing 10%) can be achieved through improved stoves with negligible costs. This means that energy efficiency programmes have positive net present values, and high rates of return. Also, energy efficiency produces positive environmental externalities. It reduces air pollution, which in turn reduces health risks and avoids pollution mitigation costs.

In the present paper, we analyse the feasibility of all the technological alternatives in terms of their costs and benefits. This will allow us to compare the returns from traditional technologies/fuels with efficient technologies/fuels. For example, if a standard technology for cooking activity is replaced by an efficient one, the energy/family/year saved will be to the tune of 50 to 300 per cent depending on the type of technology that is being replaced. Moreover, a tonne of emissions averted in the household sector will generally cause a greater reduction in human exposure than a tonne of outdoor emissions averted in the industrial sector. However, this comes at a considerable cost. To estimate the long-term economic and environmental benefits, it is necessary to link each specific technological option to a particular emission reduction scenario with the accompanying costs. The use of efficient devices demonstrates the advantages of environmental benefits in terms of reducing the emission levels as well as the incremental costs. Thus, the cost and benefits of reducing a tonne of emissions in technological (inefficient to efficient) shifts might be more than a tonne of emissions averted while shifting from one fuel to another (kerosene to LPG). To estimate these we resort to conduct a set of technology assessments, comparing emissions and economic costs of each fuel/technology substitution on a per-unit-delivered-energy basis (Table 7). The technologies chosen represent the realistic alternatives that are available in India.

Table 7. Impact of Technology Shifts

From	To	Investment (Rs.)	Cost Savings (Rs.)	Annual Rate of Returns (%)	ROI (%)	Payback Period (Years)	Incremental Cost (Rs.)	Energy Saved (GJ)	Unit Cost of Energy Saved (Rs./GJ)	CO_2 Emission Abated (kg)
Cooking:										
WST (10%)	WSE (30%)	250	965.9	64.11	386.36	0.26	34.1	16.0	2.13	1680.0
WST (10%)	KST (30%)	125	-629.1	-41.76	-503.78	-0.20	19.1	14.2	1.34	1829.8
WST (10%)	KSE (50%)	250	-94.3	-6.26	-37.72	-2.65	34.1	17.5	1.95	2061.5
KST (30%)	KSE (50%)	250	784.0	32.59	313.60	0.32	15.0	3.3	4.56	231.7
WST (10%)	Biogas stove (55%)	10000	-31.4	-2.09	-12.58	-7.95	1308.1	19.4	67.43	2520.0
WST (10%)	Solar cooker	500	1440.9	95.64	288.17	0.35	59.1	21.7	2.73	2520.0
KST (30%)	Solar cooker	500	2339.9	97.27	467.99	0.21	40.1	7.5	5.34	690.2
WST (10%)	LPG stove (70%)	2000	-883.1	-58.64	-44.17	-2.26	256.4	16.5	15.54	2056.0
KST (30%)	LPG stove (70%)	2000	-577.9	-38.36	-28.9	-3.46	237.3	2.3	103.50	226.2
Water Heating:										
WST (10%)	WSE (30%)	250	255.9	50.52	102.36	0.98	34.1	4.6	7.35	487.2
WST (10%)	KST (30%	125	-227.9	-45.0	-182.36	-0.55	19.1	4.6	4.11	603.4
WST (10%)	KSE (50%)	250	-18.4	-3.64	-7.37	-13.57	34.1	6.0	5.71	697.0
WST (10%)	Biogas (55%)	10000	-560.7	-110.68	-5.61	-17.84	1271.6	5.7	223.1	840
WST (10%)	SWH	15000	-1465.5	-289.29	-9.77	-10.24	1965.5	8.0	245.69	840.0
WST (10%)	EWH	2800	-2649.1	-522.92	-94.61	-1.06	449.1	4.8	94.35	212.5
KST (30%)	EWH	2800	-2314.0	-274.93	-82.64	-1.21	430.0	0.1	3583.43	-390.8
EWH	SWH	15000	1183.6	37.51	7.89	12.67	1516.4	3.2	468.03	627.5
Cooking and Water Heating (combined):										
WST (10%)	WSE (30%)	250	1266	63.1	506.36	0.2	34.1	20.8	1.64	2184
WST (10%)	Biogas	10000	591.9	34.48	6.92	14.45	1308.1	25.2	51.91	1360
Lighting:										
IB (60 W)	CFL (13 W)	175	142	67.13	81.12	1.23	15.7	0.2	83.05	36.6
IB (60 W)	FL (13 W)	175	24.5	11.58	13.61	7.35	-26.2	0.1	-47.38	10.1
FL (36 W)	CFL (13 W)	175	117.5	62.82	67.12	1.49	-13.2	0.1	-98.43	26.0
KL	FL (36 W)	180	319.4	63.07	177.44	0.56	-35.9	1.5	18.7	112.8
KL	CFL (13 W)	175	436.9	86.27	242.69	0.41	-4.0`	113	-1.93	138.7

Note: TWS - Traditional wood stove; EWS: Efficient wood stove; TKS: Traditional Kerosene stove; EKS: Efficient Kerosene Stove
SWH: Solar Water heater; EWH: Electric Water heater; IB: Incandescent Bulb; CFL – Compact Fluorescent Lamp, FL: Fluorescent lamp, KL: Kerosene lamp

The table provides the results of comparative analysis of economic costs and carbon emission levels of the chosen technology alternatives. The analysis assumes a family size of five people per household. In the case of lighting, the possible alternatives are incandescent bulbs (IB), fluorescent lamps (FL) and compact fluorescent lamps (CFL). The estimates of cost and carbon emission (indirect emissions due to the use of electricity generated mainly using coal) levels are made for substitution of fuels/technological alternatives. Observing the information provided in Table 7 one can state that the use of efficient devices promise environment friendly solutions in terms of reducing the total carbon content as a result of the reduced emissions. For cooking, as the table shows, replacing a traditional wood stove with an efficient one results in maximum reduction of CO_2 emissions while for lighting, an efficient CFL is the best alternative

Discussion

According to the study, the driving forces for energy-related household consumption are income and urbanization while the main cause of low energy efficiency in Indian households is poverty. This low efficient use 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. The increase in useful energy through greater efficiency can offset the negative impacts. The shift from low to high efficiency fuels/technologies increases the standards of comfort, cleanliness, and convenience. From an environmental sociology and anthropology perspective, the increased possession of goods and services becomes a symbol of status and success. In the consumer society, the consumer's self-respect depends strongly on his level of possession of these goods and the fuel/technology shift from the lower to higher order satisfies his/ her ego.

Diffusion of energy efficient technologies (EET) is widely viewed as an important element of economic and environmental policy. However, 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 EET and the means of implementing it. How much one will actually benefit from EET 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). However, in practice, the rebound effect may not be high enough to subtract the potential contributions of EETs to the reduction of resource use or the carbon emissions (Greening *et al* 2000, 399 and Laitner 2000). 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.

Conclusions

The comparison of values of energy consumption in urban and rural households and from different income groups for years 1983-2000 demonstrates various characteristics. Non-commercial fuels constitute more than half of the total household energy use, and more than 75 per cent among rural regions. Low and middle-income groups and low-income groups from urban regions are the main users of these biofuels (mainly fuelwood). Most of these fuels are collected by women and children who carry loads of fuelwood, and some times walking as far as five km. This "hard earned" energy is being used very inefficiently, converting only about 10 per cent of the total into useful energy. The linkage between poverty, human conditions, and the way energy is used is clear from the observations above. 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?

The one area that can 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 are less expensive than 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. Energy needs in India are different from those of the West because of differences in the requirement of energy services, e.g., space heating is important in the West whereas satisfaction of basic human needs such as cooking and lighting are paramount importance in India. The poor often do not have access to the efficient fuel/technology and depend on their own labour, on animal power or fuelwood, and other types of biomass, which have a high price in terms of human time, and labour. They also have health and gender impacts, which are usually more severe on women. Hence "climbing the efficiency ladder" (wood stove→ efficient wood stove → efficient kerosene stove → LPG stove and/or electric hot plate) should be the strategy that could have positive impact not only on the resources but also on the environment.

References

Anon, 2001. Results of the National Sample Survey Organisation for the Household Sector, *NSSO, Government of India*, New Delhi.

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.

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

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).