WP-2008-024

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November 2008
http://www.igidr.ac.in/pdf/publication/WP-2008-024.pdf

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Abstract

Provision of modern energy services for cooking (gaseous fuels) and lighting (electricity) is an essential component of any policy aiming to address health, education or welfare issues; yet it gets little attention from policy–makers. Secure, adequate, low-cost energy of quality and convenience is core to the delivery of these services. The present study analyses the energy consumption pattern of Indian domestic sector and conceptualizes availability, accessibility, and affordability indicators of modern energy services to households and describes the practical ways of evaluating them. A comprehensive analysis is done to estimate the cost for providing modern energy services to everyone by 2030. A public–private partnership-driven business model, with entrepreneurship at the core, is developed with innovative institutional, financing and pricing mechanisms for diffusion of energy services. This approach facilitates large–scale dissemination of energy efficient and renewable technologies like small–scale biogas/biofuel plants, and solar water heating systems to provide clean, safe, reliable and sustainable energy to rural households and urban poor. It is expected to integrate the processes of market transformation and entrepreneurship development involving government, NGOs, financial institutions and community groups as stakeholders.

Key words: Energy Service, Electricity, Biogas, Availability, Accessibility, Affordability

JEL Code(s): Q4, L94, L95, L98

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1. Introduction

Energy is linked to human development. Energy *per se* is not a need but end-use services derived out of energy is absolutely essential to deliver adequate living conditions, food, water, healthcare, education, shelter and employment. There exists a strong relationship between energy use and social and human development indicators (Reddy 2002 and Najam, *et al*, 2003). Use of modern energy services is synonymous with improved quality of life. It boosts efforts to reach MDG targets for poverty reduction, increased education and health and environmental sustainability. In India, large majority of rural households and poor in urban areas is deprived of the benefits of modern energy carriers like gaseous fuels for cooking and electricity for lighting. These households are deprived of the benefits of modern energy services because of three reasons (i) "unavailability", (ii) "inaccessibility" and (iii) "unaffordability". These reasons are the outcomes of poverty prevailing in the society, government's apathy towards to creating adequate energy infrastructure and constrained resources, energy as well as capital. The net result of these is that a significant section of Indian population is "Energy Poor". Lack of access to modern energy services is thus a major impediment to development. Inefficient cooking and lighting, which account for a significant amount of household energy use, is a clear example of this problem.

In India, the household sector is one of the largest users of energy 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). During the past few decades, it has experienced many changes in energy consumption patterns, both in quantitative and qualitative terms (CMIE, 2006). This is due to the natural increase based on population growth and due to increase in economic activity and development. However, use of modern energy services through gaseous fuels for cooking and to a significant extent, electricity for lighting has not reached the poor due to high initial cost of device and connection service and high operating costs. Thus, it is not a surprise to find that nearly 45% of rural households do not have access to electricity (though nearly 90% of the villages have been electrified) and nearly 70% do not have access to LPG. Nearly 90 percent of lower Monthly Per Capita Expenditure (MPCE) classes use cheap fuels like firewood, chips and dung cakes (NSSO, 2007). There are many factors to consider when evaluating the reasons and there are also many possible ways to achieve these desired objectives, some of which tend to be overlooked in conventional planning. Hence, to have access to modern energy services one has to device new mechanisms and look for innovative solutions.

The present study aims at developing a framework to universalize access to modern energy services, i.e., provision of gaseous fuels for cooking and electricity for lighting to Indian households in the long run. In this context, the paper conceptualizes availability, accessibility and affordability indicators and estimates the economics of providing these services where they are unavailable, inaccessible and unaffordable. The individual goals of this paper are to (i) study the existing energy use in the household sector, (ii) develop indicators of availability, accessibility, and affordability, (iii) estimate the number of needy households, (iv) estimate the economics of providing modern energy services to all, (v) estimate the environmental cost of such universalization, (vi) develop a public–private partnership business approach to supply these services, and (vii) suggest an enabling policy framework for implementation.

The study has chosen 2030 as the target year of universalization and assesses the cost implications of provision of such services to all the deprived households by then. The process of universalization of the access has been tracked through scenario construction using required data and assumptions. The economic valuation of the technologies has been conducted by estimating the cost and benefits of their establishment and deployment. The impact on climate change is also estimated through carbon emission accounting. A public–private-partnership approach has been developed through which entrepreneurs are encouraged to provide these services through the facilitation of large–scale diffusion of energy–efficient and renewable energy technologies (EERTs). This is being done through an innovative financing mechanism involving government utilities and financial institutions.

2. Methodology of the study

This study uses the National Sample Survey (NSS) data of 61st round on consumer expenditure conducted in 2004–05 for estimating the initial access levels. The questions specific to energy in the survey were on primary source of energy for cooking and lighting (NSSO, 2007). The other information required for the scenario development include: annual energy requirement (for cooking and lighting), carbon emission factors, cost of installation of biogas plants, distribution net work (laying of pipes, etc.), costs of electricity generation for different technology options, transmission and distribution and finally the cost of devices. The data for estimating these parameters has been obtained from government reports, catalogues, journal papers and from equipment manufactures. Two types of end-use technologies are considered: (i) bio gas for cooking and (ii) compact fluorescent lamp for lighting. Regarding electricity generation, we consider (i) centralized and (ii) decentralized supply. The capital and the operating costs of supplying modern energy carriers are estimated using the standard discounted cash flow method built in the spreadsheet. More specifically life cycle costing method is used for economic analysis.

The scenario based forecast of need for modern energy services has been done in two parts: unmet needs in the base year, conventionally termed the 'backlog' of need; and newly arising need, generated by the additional households. Indicators of availability, accessibility and affordability are developed. Present need for modern energy services represents the number of households who do not have such facility whereas future need constitutes demands from new households and increase in the stock and appliances in existing ones which require energy services. Both present and future needs are essential elements in an assessment of future energy demand.

A spreadsheet-based exercise has been carried out to forecast dwelling units, population estimates and energy use for future year scenarios for cooking and lighting. For universalization of services, a long time horizon is needed, hence we have fixed 2030–31 as the final target year for achieving provision of modern energy services to all, with checkpoints at every five-year time intervals for monitoring the progress, i.e., four five-year plans. The base year considered is 2010-11 since it takes at least a year to popularise the approach with other stakeholders before it comes to fruition. These two years are kept as a preparatory period before base year to popularize the model so that the same can be implemented for coming two decades (2010-30).

We assumed that the number of households will increase at an annual rate of 0.9 percent in rural and 3.4 percent in urban regions. We forecasted the number of deprived households in terms of availability, accessibility and affordability and the cooking and lighting service targets for different years. According to the approach followed, at every interval of five years the deprived households from the last phase are added to the additional new households to get the total targeted households. The cost of achieving the target has also been estimated. It includes the capital costs, infrastructure costs for distribution system and other recurring costs. Finally the estimates of unit cost of energy have been done. Regarding environmental benefits, we developed baseline as well as alternative carbon emission scenarios and overall GHG incremental benefits have been estimated.

3. Energy consumption in perspective

The demand for energy, particularly for commercial energy, has been growing rapidly with the growth of the economy, changes in the demographic structure, rising urbanization, socio-economic development, changing life styles, and the desire for attaining and sustaining self-reliance in some sectors of the economy. India is one of the few countries in the world that relies on coal as major source of energy. The total energy demand in 2006-07 stood at 22,571 PJ. Of the total, about 72.6 percent came from commercial sources and the rest from non-commercial sources such as fuel wood, crop waste, etc. Even though the share of non-commercial energy in total energy consumption has reduced significantly over the years it is maintaining a steady growth rate of 1.2 percent between 1980-81 and 2006-07 (Planning Commission, 2008).

The domestic sector in India is one of the largest users of energy accounting for 45 percent of the total primary energy use and 30 percent of final energy, with non commercial energy alone catering to 90 percent of all rural energy needs (Reddy, 2003, TERI, 2006). Household energy consumption is expected to increase in future along with growth in economy, rise in per capita incomes and changes in lifestyles (Pachuri, 2004, Reddy, 2004).

3.1 Pattern of household energy use

The growth of the households and its distribution across various fuel-using categories for the past five decades both for final energy (FE) and useful energy[2] (UE) are enlisted in the following table (Table 1). Households increased at a rate of 2.39 percent per annum and there is also an increase in energy-consuming activities; hence there is an increase for demand for energy. In

[2] The useful energy is calculated by taking the efficiency of utilization: Biomass – 10%; kerosene, 40%, LPG – 70%; Electricity – 60%

terms of FE, though the total amount of energy consumed by the housing units increased two-fold from 2,938 in 1950 to 6,092 PJ in 2005, on a per housing-unit basis, the energy consumption was halved from 51 to 27 GJ in the same period. Virtually all of the decrease is the result of fuel shift from biomass[3] to commercial carriers thereby increasing the efficiency of utilization, which is also evident from the consideration of UE. By this measure, commercial fuels turn out to be the predominant energy source, not biomass. Over the period of 1950–2005, the share of UE of biomass has declined from 93 to 42 percent whereas the share of commercial energy (LPG, kerosene and electricity) has increased. In the same period, the per-household useful energy use has increased slightly. The increased efficiency of energy devices got largely offset due to increase in the energy activities and stock of appliances resulting in increase in energy use. Electricity is the source for almost all of the additional energy consumed by appliances.

Table 1: Household Final Energy (FE) and Useful Energy (UE) Consumption (PJ) (1950-2005)

Year	No. of Households (HH) (million)	Energy consumption by carrier type (PJ) (percent share in parentheses)								Total		Consumption / HH (GJ)	
		Biomass		Kerosene		LPG		Electricity					
		FE	UE	FE	UE	FE	UE	FE	UE	FE	UE	FE	UE
1950	57.58	2884.5 (98.2)	288.5 (93.0)	50.4 (1.7)	20.2 (6.5)	0.0	0.0	2.7 (0.1)	1.6 (0.5)	2938	310	51.02	5.39
1960	73.83	3348.0 (96.3)	334.8 (86.3)	124.2 (3.6)	49.7 (12.8)	0.0	0.0	5.9 (0.2)	3.5 (0.9)	3478	388	47.11	5.25
1970	95.34	3906.0 (95.7)	390.6 (84.1)	157.5 (3.9)	63.0 (13.6)	2.7 (0.1)	1.9 (0.4)	14.9 (0.4)	8.9 (1.9)	4081	464	42.80	4.87
1980	123.24	4765.5 (93.6)	476.6 (75.6)	235.8 (4.6)	94.3 (15.0)	54.0 (1.1)	37.8 (6.0)	36.0 (0.7)	21.6 (3.4)	5091	630	41.31	5.11
1990	152.11	5242.5 (90.6)	524.3 (65.4)	301.5 (5.2)	120.6 (15.1)	117.0 (2.0)	81.9 (10.2)	123.8 (2.1)	74.3 (9.3)	5784	801	38.03	5.27
2000	189.19	5130.0 (85.6)	513.0 (51.2)	282.0 (4.7)	112.8 (11.2)	288.0 (4.8)	201.6 (20.1)	292.5 (4.9)	175.5 (17.5)	5992	1003	30.13	5.30
2005	210.59	4950.0 (81.3)	495.0 (42.3)	265.0 (4.3)	106.0 (9.1)	427.0 (7.0)	298.9 (25.5)	450.0 (7.4)	270.0 (23.1)	6092	1170	26.79	5.56
CAGR (in %)	2.39	0.99		3.06		15.57		9.75		1.33	2.44	-1.16	-0.06

Source: Planning Commission (1991), CMIE (2006).

Carrier wise, till 1970, the primary energy source was wood and other biomass after which it was supplemented by kerosene. However by 1980, LPG, and electricity with their convenience of procurement and use, gained its share as a carrier of choice. So, after 1970 there has been a clear upward movement in the energy ladder where households switched to a

[3] Biomass here includes firewood and chips, and dung cake.

more convenient, efficient, modern and comfortable fuel. The energy ladder coincides with ‘social ladder’ as modern energy carriers are associated with self-esteem and social prestige whereas the inferior fuels are associated with lower standard of living and drudgery to household, particularly to women.

3.2 Energy for cooking

Cooking is the main energy end use service in Indian households. Energy carrier choice for cooking has changed as the country progressed and new technologies are introduced. For example, the percentage of housing units using LPG as their main cooking fuel increased by ten fold, from 1.2 percent in 1970 to 23.5 percent in 2005. Over the same period, the housing units that were mainly using charcoal (tabulated under others[4]) as cooking fuel became almost extinct from a considerable share of six percent. The households using kerosene as a cooking fuel increased initially, but the same is under decline now. Nevertheless, biomass remained the most preferred cooking fuel, used by more than four-fifths of housing units in 1983 and two-third in 2005, with a little change over the last two decades.

Table 2: Share of households using various carriers for cooking (1983-2005)

Energy carrier	Percentage share of households (HH) using various energy carriers				
	1983	1988-89	1993-94	1999-00	2004-05
Biomass	80.98	79.12	73.91	66.97	65.70
Kerosene	4.73	6.09	7.40	7.52	4.00
LPG	2.69	6.38	11.26	19.46	23.30
Others	11.60	8.30	5.82	5.38	4.61
No cooking	-	0.10	1.60	0.67	2.39
Total HH (Million)	124.15	140.17	157.04	180.65	208.00

Source: NSSO (1997, 2001 and 2007)

3.3 Energy for lighting

Lighting is an important household energy service as it is directly related to productivity and quality of life. Nearly 0.4 billion people in India—more than the world’s population in Edison’s time—still have no access to electricity. The majority of people who lack direct access are mostly from rural and remote areas. This was probably not the lighting future imagined by Edison who one’s opined that “we will make electricity so cheap that only the rich will burn candles” – this forward-looking statement is seemingly true for the industrialized world, not India, where almost half of the rural population and one-third of the total population is without electricity (Table 3). Unlike heating or cooking, lighting is the

[4] Others include coke, gobar gas, charcoal, electricity and any other fuel except firewood, chips, dung cake, LPG, and kerosene.

energy end-use that is associated exclusively with electricity. The extent of rural electrification varies widely from one state to another and from one region to the other, e.g. more than 90 percent villages of southern and western India are electrified, whereas in states like Uttar Pradesh, Bihar, Jharkhand, Orissa and in some north eastern states, less than 60 percent villages are electrified (CEA, 2006).

Table 3: Share of households using various energy carriers for lighting (1983-05)

Energy carrier	Percentage share of households using various energy carriers				
	1983	1987-88	1993-94	1999-00	2004-05
Electricity	27.10	36.46	49.68	60.16	66.24
Kerosene	70.90	61.80	49.55	38.95	33.09
Others	2.00	1.74	0.77	0.88	0.67
Total HH (Million)	124.15	140.17	157.04	180.65	208.00

Source: NSSO (1997, 2001 and 2007)

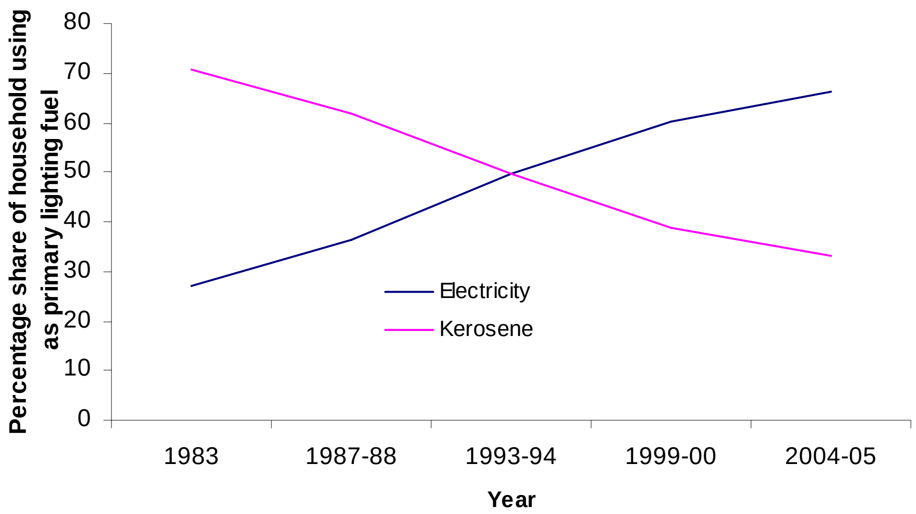

Fig 1: Share of kerosene and electricity as carrier for lighting (1983-05)

Lack of access to electricity in rural areas is same as lack of access to other types of infrastructure. In fact, it is often the same for rural or urban poor who lack access to modern energy services also lack access to telecommunications, clean water and other basic services. This interdependency is partly due to high service costs and lower ability to pay because of low income levels. During the start of the 80s, the share of households using electricity was only about 25% which increased steadily over the years. By 2005, the share reached about 65%. Yet, more than one third of the total households use kerosene as lighting fuel.

3.4 Urban-Rural divide

A comparison of energy consumption levels in the urban and rural areas demonstrates various characteristics. In rural areas, biomass, 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 (Reddy, 2004). Table 4 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. The data demonstrate that rural households continue to depend on firewood and other non-commercial energy resources (biomass) even in 2005. The data show the percentage of households using various types of energy carriers for cooking for different years from 1983 to 2004-05. The table indicates that rural households continue to depend on biomass to the extent of 84 percent though urban households are gradually shifting to modern fuels for their cooking needs. Even then, approximately one fourth of households in urban areas depend on biomass for cooking needs in 2005.

Table 4: Change in fuel mix for cooking for in rural and urban region (1983-2005)

Fuel Type	Rural Households					Urban Households				
	1983	1987-88	1993-94	1999-00	2004-05	1983	1987-88	1993-94	1999-00	2004-05
Biomass	91.5	92.8	89.51	84.1	79.3	48.9	40.1	32.83	23.44	23.4
Kerosene	0.8	1.5	2.08	1.3	1.3	16.7	19.2	21.42	19.14	10.2
LPG	0.2	0.8	2.86	8.6	13.9	10.3	22.3	33.4	48.18	57.1
Others	7.5	4.9	5.02	4.7	3.8	24.1	18	7.95	8.56	4.4
No cooking	-	0	0.54	1.3	1.6	-	0.4	4.4	0.68	4.9

Source: NSSO (1997, 2001 and 2007)

A similar picture can be seen in urban-rural discrepancy in lighting (Table 5). It is discernable that there is a shift towards electricity from kerosene in both rural and urban areas but more prominently in urban areas. Still in 2005, almost half of the households in rural areas depend on kerosene for lighting purpose, whereas more than 90 percent households in urban areas use electricity. The shift towards electricity from kerosene is slow in rural areas due to the non-electrified villages and the high initial cost of electric connection.

Table 5: Change in fuel mix for lighting for in rural and urban region (1988-2005)

Fuel Type	Rural Households					Urban Households				
	1983	1987-88	1993-94	1999-00	2004-05	1983	1987-88	1993-94	1999-00	2004-05
Kerosene	83.00	74.00	89.51	50.60	44.40	34.00	27.00	16.50	10.30	7.10
Electricity	15.00	24.00	2.08	48.40	54.90	64.00	72.00	82.80	89.10	92.30
Others	2.00	2.00	2.86	1.00	0.70	2.00	1.00	0.70	0.60	0.60

Source: NSSO (1997, 2001 and 2007)

3.5 Energy-Income link

The data on households using various energy carriers for cooking and lighting in different income categories[5] present interesting results (Table 6). Households prefer to 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 income as well as energy ladder climbing. Thus, there is a strong positive relationship between growth in per capita income and household demand for commercial fuels. High-income households have a greater choice in selecting an energy carrier and many opt for cleaner and more efficient modern energy carriers such as electricity or LPG. Electricity is used for a greater variety of end-uses such as air-conditioning, refrigeration, etc. (other than heating). This reflects the increasing desire for comfort and discretionary energy consumption.

Table 6: Energy carrier mix for cooking and lighting for various income groups (2004-05)

End use	Energy carrier	Rural			Urban		
		Low Income	Medium Income	High Income	Low Income	Medium Income	High Income
Cooking	Biomass	91.28	85.94	57.55	52.21	13.02	1.66
	Kerosene	0.59	1.16	3.40	11.42	11.12	4.20
	LPG	0.73	7.65	33.10	26.46	67.77	82.00
	No cooking	1.56	0.66	3.20	2.40	4.63	10.59
	Electricity/others	5.84	4.59	2.75	7.51	3.46	1.55
Lighting	Kerosene	61.62	39.97	16.45	17.17	3.29	0.30
	Electricity	37.64	59.43	83.00	81.82	96.35	99.25
	Others (including no lighting)	0.73	0.60	0.55	1.00	0.36	0.45
Total households (Million)		58.58	71.89	14.46	25.19	31.56	6.31

Source: NSSO (2007)

The table shows that biomass usage is very widespread in rural areas in all the income groups. More than 90 percent of households in low-income group use biomass. Though more than 57 percent of high-income rural households use biomass, poor households tend to spend more time in collecting these fuels than those from higher income groups. Many households which can afford other fuels continue cooking with biomass, at least partly. The continued substantial reliance on biomass even by high-income households in rural areas leads to some skepticism whether development and income growth can displace solid fuels. Firewood is often a commercial good in urban areas, though it is more or less treated as an inferior good.

[5] It is assumed that <410, 410<x<890 and >890 are considered as lower, middle and high income categories for rural areas and the corresponding figure for urban area are <675, 675<x>1880, and > 1880.

The table indicates the urban characteristics of commercial carriers (LPG and electricity) becoming increasingly important to the energy portfolio of households.

Table 7 shows the share of income of the households spent on energy. The average level of income spent on different energy carriers is considerably higher for low-income consumers than other income groups. The table presents affordability factor. For cooking, it is no surprise that low and middle income group in rural area prefer firewood over kerosene/LPG as the cost for later is close to one fifth of their income, whereas former is available free of cost. Rural populace lives in an environment of imperfect or missing markets. Self-collected fuels do not have a monetary cost; their collection and use are guided by opportunity costs that depend on the productivity of labor in fuelwood collection vis-à-vis the opportunity to earn income in alternative employment. Among the high income groups, the cost share is comparable for firewood, kerosene and LPG; therefore, they switch to LPG for its cleanliness/efficiency. Also similar kind of observation is seen in urban area and in case of lighting. The high-energy budget in household consumption expenditure leaves the poor with little for other needs like food, health and education.

Table 7: Quantity of energy used (for cooking and lighting) and the share of income spent by various categories of households

Fuel	Unit	Quantity used/HH/ month						Price of unit (Rs.)	Share of income* spent (percent) by various categories of HH					
		Rural			Urban				Rural			Urban		
		Low	Middle	High	Low	Middle	High		Low	Middle	High	Low	Middle	High
Fuel wood	Kg	160	160	80[$]	150	75[$]	0[$]	1|1.5[&]	10.04	5.44	1.28	10.02	2.17	-
Kerosene[%]	L	12			10			17|19[&]	12.81	6.93	3.27	8.47	3.67	1.47
LPG[%]	kg	14						21	18.45	9.99	4.71	13.10	5.68	2.27
Kerosene[%] (lighting)	L	4			3			10/ 17|19[&^]	2.51	1.36	1.09	1.34	1.10	0.44
Electricity[&] (lighting)	kWh	30	60	90	60	120	180	#	3.01	3.26	2.89	6.68	6.96	5.00

Source: NSSO (2007)

[$]high and middle income groups in rural and urban area uses fuel wood to supplement the cooking fuel, hence use 50% of that used by other income groups; high income group in urban area do not use fuel wood

[&] price for rural and urban area are separated by |.

* income of different category is calculated by using the income of the median MPCE classes by NSSO (2007).

^ 10Rs (subsidized rate) per litre for low and middle income group in rural area and low income group in urban area and 25Rs (market rate) per litre for rest income groups.

Electricity prices are assumed to be different based on the consumption level and rural/urban area. The rates are 1.60Rs/unit for low and middle income group and 2.00Rs/unit for high income group in rural area and 2.50Rs/unit, 3.00Rs/unit and 3.6Rs/unit for low, middle and high income group in urban area.

[&]The consumption of electricity varies with income levels and the quantity for the middle is twice of low and high is assumed to be thrice of low-income groups.

[%] Though the fuel not used by all income groups, share of income is calculated for indicative purpose.

3.6 Social and environmental implications of energy use

Use of traditional fuels for cooking with the attendant pollution and the opportunity cost of gathering them impose a heavy burden of back breaking and time consuming job on people particularly women and girl children. The need to gather fuels may deprive the girl child from schooling. This “hard earned” energy is used very inefficiently, converting only about 10 per cent of the total into useful energy. Use of such inefficient and polluting fuels, overtime, increases the risks of eye infections and respiratory diseases. Lack of access to clean and convenient energy impacts the health of women and the girl child more adversely as they spend more time indoors and are primarily responsible for cooking. It is estimated that in rural north India 30 billion hours are spent annually in gathering fuel-wood and other traditional fuels. The economic burden of traditional biomass-based fuels, time to gather fuels, time lost in sickness, and cost of medicines is estimated to be around Rs 300 billion. An energy policy responsive to social welfare must address this issue (Planning Commission, 2008).

In case of lighting, one-third households in India use kerosene lamps as a substitute for electricity. But the efficiency and levels of illumination provided by the flame-based lamps are far lower than that of modern electric lighting, as a result, a substantial amount of primary energy use with little service received in return. Moreover, these lamps are a source of indoor air pollution. Absence of lighting decreases the productive hours in the household – study hours of children and working hours of adults. 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 lifestyles.

4. Availability, affordability and accessibility of modern energy services

4.1 Defining indicators

Providing modern energy services to the people who really need them is a way of improving their livelihoods. In 2005, nearly 35 percent of the households were without access to electricity (primarily in rural areas) and nearly 70 percent 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 centres in the near future. These households will continue to depend on firewood for cooking and kerosene for lighting with adverse environmental and health effects. The efforts at providing better access to basic energy needs of rural and urban poor are challenged by two main factors (i) Lack of information and awareness at various levels, and (ii) Lack of representation of the interest of the disadvantaged communities. From an equity perspective, the pertinent problems that come to the fore: (i) How to make available quality energy to meet the enhanced energy demands (ii) How to connect the households with supply? (iii) How to provide quality energy at an affordable price? And (iv) How to maintain the supply of energy in a sustainable way? To provide solutions to these problems, let us first conceptualize the relevant indicators.

The indicators of provision of modern energy services to households can be defined as follows:

(i) *Availability*: Availability indicates whether a particular energy service can be obtained in the same geographical location implying same village or town meaning that the household is very close to the energy service-centre and the distance between them should not be an excuse for non–provision of services. Availability will also include the adequacy factor, i.e. whether the services meets the consumer needs/expectations. A service not available is quantified as zero whereas adequately available service is unity, so that services partially meeting the needs/expectations scores between zero and one.

(ii) *Accessibility*: Accessibility indicates connection infrastructure, i.e. whether a particular energy service can reach the household. For instance, in case of electricity, a grid substation in the locality indicates availability; whereas the connection infrastructure to the household is indicative of accessibility. Like availability, accessibility takes a value zero for no connection and unity for full connection so that a partial connection lies between zero and one.

(iii) *Affordability*: Affordability indicates the ability to pay for a particular service, without having to forego other necessities (the price of service relative to the household's income). An increase in affordability is equivalent to an increase in income or decrease in price. Affordability indicator can be normalized between zero and one where zero indicates not at all affordable i.e. when price is more than income and unity signifies cent percent affordable i.e. when the service behaves as free good. A value between these two extreme situations will be the additive inverse of the proportion of income spent on the particular energy service.

Table 8 enlists the description of indicators and suggested a method of quantification. The expressions are given for biogas and LPG for cooking in rural and urban areas respectively and electricity for lighting in both the areas.

Table 8: Description of indicators and assumptions therein

Indicator	Description	Urban		Rural	
		Cooking	**Lighting**	**Cooking**	**Lighting**
Availability	Household's vicinity to energy service centre and sufficiency of energy service	(No. of effective[6] urban households in LPG network) / (total no. of urban households)	(No. of effective urban households in electrified towns) / (total no. of urban households)	(No. of effective rural households in biogas network) / (total no. of rural households)	(No. of effective rural households in electrified villages) / (total no. of rural households)
Accessibility	Household's connectivity to the supply of energy service.	(No. of urban households connected by LPG) / (total no. of urban households)	(No. of urban households electrified) / (total no. of urban households)	(No. of rural households connected by biogas) / (total no. of rural households)	(No. of rural households electrified) / (total no. of rural households)
Affordability	The ability of household to pay for the energy service.	Inverse of the fraction of the income spent by low income urban households	Inverse of the fraction of the income spent by low income urban households	Inverse of the fraction of the income spent by low income rural households	Inverse of the fraction of the income spent by low income rural households

4.2 Development of baseline scenario

2010-11 is considered as the base year for triggering the scenario. Approximately two years are kept as buffer before base year to popularize the model so that the same can be implemented for coming two decades (2010-30). Table 9 and 10 represents the share of households using different fuels for cooking and lighting in 2010-11. By 2010, nearly 60 million households will be without access to electricity (primarily in rural areas) and about 165 million without access to LPG. Considering the share of different carriers, there is a clear rise in energy ladder as one moves from rural to urban area or from lower income group to higher one.

For simplicity in calculations, in the study the following assumptions have been made.

1. LPG is not available in all the rural households
2. LPG is not accessible to all the low-and middle-income households.
3. LPG is not affordable to all low-income households in rural and urban areas and middle–income households in rural areas.
4. For electricity, a household is deprived because of the absence of infrastructure to have connectivity hence it is considered unavailable.

[6] The number of effective households represents the number of average-sized households whose energy requirements can be adequately fulfilled with the available resources.

Table 9: Share (percentage) of Households using particular energy for Cooking (2010-11)

	Firewood	LPG	Dung	Kerosene	Coal	Biogas	Electricity	Others	Total
Rural Households									
Low Income	46.02	0.73	4.44	0.11	0.25	0.01	0.00	3.48	50.13
Middle Income	61.95	10.02	6.44	0.63	0.29	0.16	0.02	4.21	83.08
High Income	10.94	14.51	1.36	0.53	0.09	0.17	0.02	1.85	35.01
Total (Million)	118.91	25.26	12.24	1.27	0.63	0.34	0.04	9.54	168.23
Urban Households									
Low Income	9.38	5.72	0.47	0.98	0.61	0.00	0.01	1.39	16.08
Middle Income	4.19	31.95	0.28	1.80	0.61	0.00	0.04	1.44	42.57
High Income	0.15	12.49	0.02	0.21	0.03	0.00	0.01	0.79	13.93
Total (Million)	13.72	50.16	0.77	2.99	1.25	0.00	0.06	3.62	72.57

Table 10: Number (Million) and share (Percent) of Households using particular energy for lighting (2010-11)

	Kerosene	Electricity	Others	Total
Rural Households				
Low Income	28.64	25.17	0.00	53.81
Middle Income	28.34	60.05	0.00	88.39
High Income	3.45	22.57	0.00	26.03
Total (Million)	60.44	107.79	0.00	168.23
Urban Households				
Low Income	2.38	18.91	0.02	21.31
Middle Income	0.79	39.28	0.02	40.08
High Income	0.03	11.15	0.00	11.18
Total (Million)	3.20	69.34	0.03	72.57

4.3 Development of future scenarios

Targeting is a method of providing modern energy services to the people who really need them—the rural households and urban poor. We need to estimate the target households and the costs of supplying services to them. It is assumed that the universal target of supplying these services will be by the year 2030 and the interim period is divided into four five-year plans with base year as 2010. About 100 million households will be newly added during 2010–2030 with annual per household requirement of 6–8 GJ depending on the type (LPG or biogas) or region (urban or rural). The number of households will increase at an annual rate of 0.9 percent in rural and 3.4 percent in urban regions. Increasing demand on energy for households living in cities results in growing availability, accessibility and affordability gap. It is estimated that a significant fraction of the population will not be served through extension of the electric grid and LPG service stations in the near future and continue to depend on firewood for cooking and kerosene for lighting with adverse environmental and health effects. Table 11 shows the availability, accessibility and affordability of modern energy services by households in base year 2010-11. Table 12 contains the basic data used for estimating the costs and benefits of economic and environmental implications across scenarios.

Table 11: Households deprived of modern energy services

Base year 2010-11	Cooking				Lighting			
	Rural		Urban		Rural		Urban	
	LPG	Biogas	LPG	Biogas	C	DC	C	DC
Total Households (Million)	168.23		72.57		168.23		72.57	
Households with services (Million)	25.26	0.34	50.16	0.00	107.79	0	69.34	0
Deprived Households (Million)	142.63		22.41		60.44		3.23	
Households deprived of availability (Million)	142.97		0		0		0	
Households deprived of accessibility (Million)	133.21		0		60.44		3.23	
Households deprived of affordability (Million)	133.21		16.08		0		0	
Households with specific services (%)	15.02	0.20	69.12	0.00	64.07	0	95.55	0
Households with services (%)	15.22		69.12		64.07		95.55	

Note: C- Centralised electricity; DC – Decentralised electricity

Table 12: Basic data and assumptions used in the scenarios

Items	Cooking				Lighting			
	Rural		Urban		Rural		Urban	
	LPG	Biogas	LPG	Biogas	C	DC	C	DC
Fuel/Electricity Cost (Rs. per kg or M^3 or kWh)	22.68	4.45	22.68	4.45	3.20	5.04	3.20	5.04
Fuel/Electricity Cost (Rs. per GJ)	493.04	193.27	493.04	193.27	889.3	1400.5	889.3	1400.5
Capital cost of the End-use devices (Rs.)	2100	462	2100	462	650	650	1050	1050
Annual Fuel (cooking)/Electricity (lighting) Usage per household (kg or M^3 or kWh)	128	292	168	292	50	50	100	100
Annual Fuel (cooking)/Electricity (lighting) Usage per household in GJ	5.9	6.7	7.7	6.7	0.2	1.2	4.6	2.3
Carbon Emission Factor (kg/GJ)	63.74	0.00	63.74	0.00	0.70	0.00	0.70	0.00

Note: C- Centralised; DC – Decentralised

The rate of increase of households in urban and rural areas and the cooking and lighting service targets for different years are given in Appendix 1. Universal access can be defined as the provision of affordable access to modern energy services for all those requesting it, regardless of where they live. Table 13 provides information on households to achieve the target of providing cooking and lighting energy services to every household by 2030. According to the approach followed here, at every interval of five years the deprived households from the last phase are added to newly added households to get the number of total targeted households. The target for the technology in cooking is also given at the beginning/end of each five-year phase. As we can see LPG will continue to dominate the urban areas whereas biogas is expected to dominate the rural regions. The technology targets for lighting is assumed to be 90% centralised and 10% decentralised power generation in rural areas and 100% centralised power generation in the urban areas.

Table 13: Target households and the technology choices

		Households (million)			Target for provision of services (million)						Technology targets (percent)	
		Total	Deprived		Incremental (Total)		Incremental (Programme)		Total Accessible		LPG	Biogas
			Cooking	Lighting	Cooking	Lighting	Cooking	Lighting	Cooking	Lighting		
2010 -11	Rural	168.23	142.63	60.44					25.60	107.79		
	Urban	72.57	22.41	3.23					50.16	69.34		
	Total	240.80	165.03	63.67					75.76	177.13		
2015 -16	Rural	176.81	114.93	44.20	36.28	24.82	25.40	15.39	61.88	132.61	50	50
	Urban	84.13	12.62	0	21.35	14.79	9.18	5.92	71.51	84.13	90	10
	Total	260.94	127.55	44.20	57.63	39.60	34.58	21.30	133.39	216.14		
2020 -21	Rural	184.91	73.96	27.74	49.06	24.57	35.33	15.23	110.95	157.18	40	60
	Urban	99.44	4.97	0	22.96	15.31	10.22	6.12	94.46	99.44	85	15
	Total	284.35	78.94	27.74	72.02	39.88	45.54	21.35	205.41	256.61		
2025 -26	Rural	192.43	19.24	9.62	62.24	25.63	46.06	15.89	173.19	182.81	30	70
	Urban	117.53	0	0	23.07	18.09	10.26	7.24	117.53	117.53	85	15
	Total	309.96	19.24	9.62	85.30	43.72	56.32	23.13	290.72	300.34		
2030 -31	Rural	200.05	0	0	27.06	17.44	20.03	10.81	200.25	200.25	30	70
	Urban	138.25	0	0	20.72	20.72	9.22	8.29	138.25	138.25	85	15
	Total	338.49	0	0	47.78	38.16	29.25	19.10	338.50	338.50		

The specific strategy that has been adopted is as follows:

(i) 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/photovoltaic or biomass combustion/ gasifier for lighting.

(ii) 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 for cooking and grid electricity for lighting.

(iii) for urban low income households for cooking and lighting—Incentives for LPG for cooking and grid electricity for lighting with incentives.

(iv) 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.

(v) no specific strategies for urban high-income households—may be higher prices for compensating subsidies given to other section of households.

Based on the above strategies, the target households for creating access to modern energy services have been further grouped into two classes. The first category consists of households who can pay for such access while the one consists of households who cannot afford such a transition. The latter category of households are part of the "Programme" and the focus of multi-stakeholder supported implementation strategy (Table 13). The cost estimates discussed in the next section are limited to these households that are part of the programme. The shares of these households are as follows:

- 60% of the incremental LPG using households and 80% of the incremental biogas using households in the rural areas for all the plan periods.
- 40% of the incremental LPG using households and 70% of the incremental biogas using households in the urban areas for all the plan periods.
- 60% of the incremental centralized grid connected households and 80% of the incremental decentralized households in the rural areas for all the plan periods.
- 40% of the centralized grid connected households and 70% of the incremental decentralized households in the urban areas for all the plan periods.

5. Energy Needs

The annual energy requirements for cooking and lighting are estimated for the households which are part of the "programme". These energy requirements are newly occurring needs during every plan period and are additional to the requirements of households which have become part of the programme during earlier plan periods. Therefore, these can be considered as incremental annual energy requirements. Similarly, the incremental installed capacity of electricity generation is also estimated. These estimates for the four plan periods are presented in Table 14.

Table 14: Incremental Annual Energy Requirements of Households part of the Programme

Requirements		Target years							
		2015-16		2020-21		2025-26		2030-31	
		Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Incremental annual energy	for cooking (TJ)	161557	69421	227498	76504	300037	76870	130471	69038
	for lighting (GWh)	769	592	762	612	795	724	541	829
Incremental installed capacity for lighting (MW)		170	127	169	131	176	155	120	177

6. Economics of Implementation

According to the implementation plan, modern energy services will be universally accessible to all the households by 2030. There will be a 40 percent increase in dwelling units over those of 2010, most of these emanating from urban regions. During first five year cycle the annual energy requirement for cooking works out to be 231 TJ for which the estimated annual cost is about Rs. 90 billion. The break up of costs is as follows: stoves (51 percent); construction of biogas plants (31 percent) and distribution system (23 percent). A total initial investment of 138 billion is required to create the infrastructure, where stoves, biogas plants and distribution system have 37, 36, and 27 percent of share. Both the annual costs and the initial investments required for implementation of the programme are tabulated in Table 15. The estimates are given separately for rural and urban households. The cost implications for the rural households are high because of the need for higher coverage. The investment increases till the third five-year phase, but decreases in the last while getting closer to the target (Table 15).

Table 15: Cost estimates of providing cooking services for households part of the programme (Rs. Billion)

Items	Target years							
	2015-16		2020-21		2025-26		2030-31	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Annualised Capital Cost - Stoves	4.81	3.56	5.80	3.68	6.45	3.70	2.80	3.32
Annualised Capital Cost - Biogas Plants	5.21	0.54	8.46	0.87	12.52	0.87	5.44	0.78
Annualised Capital Cost - Distribution System	3.87	0.40	6.29	0.64	9.30	0.65	4.05	0.58
Annualised Capital Cost - Total	13.90	4.49	20.54	5.19	28.27	5.22	12.29	4.68
Annual Recurring Cost	41.35	30.28	50.01	31.36	55.94	31.51	24.33	28.30
Annual Cost - Total	55.25	34.78	70.55	36.55	84.21	36.72	36.62	32.98
Initial Investment Required - Stoves	29.56	21.87	35.61	22.63	39.63	22.73	17.23	20.42
Initial Investment Required - Biogas Plant	45.11	4.64	73.19	7.49	108.32	7.53	47.10	6.76
Initial Investment Required - Distribution System	33.52	3.45	54.40	5.57	80.51	5.59	35.01	5.02
Total Investment Required	108.19	29.97	163.20	35.68	228.46	35.86	99.35	32.20

Similar calculations have been done for lighting (Table 16). The annual electricity use per household is assumed to be 50 kWh for rural households and 100 kWh for their urban counterparts. To achieve this target, the additional installed capacity required is 1225 MW with an annualized capital cost of approximately Rs.12 billion. The connection cost turns out be highest with 42 percent share followed by cost of device (CFL) and supply costs having 35 and 23 percent share respectively. The cost of generation comes next with 12 percent share and that of transmission and distribution cost share works together out to be 11 percent. In terms of investment the connection infrastructure has a share of more than 50 percent followed by supply which is more than 30 percent. Initial investment on CFL comes next with 18 percent share. The investment in generation and transmission and distribution requires 15 percent share in total investment.

Table 16: Cost estimates of providing lighting services for households part of the programme (Rs. Billion)

Items	Target year							
	2015-16		2020-21		2025-26		2030-31	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Annualised Capital Cost – Supply	1.63	1.17	1.61	1.21	1.68	1.43	1.14	1.64
Annualised Capital Cost – Generation	0.95	0.60	0.94	0.60	0.98	0.60	0.67	0.60
Annualised Capital Cost – Transmission	0.44	0.38	0.43	0.40	0.45	0.47	0.31	0.54
Annualised Capital Cost – Distribution	0.24	0.19	0.24	0.19	0.25	0.23	0.17	0.26
Annualised Capital Cost – Final connection	3.73	1.43	3.69	1.48	3.85	1.75	2.62	2.01
Annualised Capital Cost – CFLs	2.39	1.84	2.37	1.90	2.47	2.25	1.68	2.58
Annualised Capital Cost – Total	7.75	4.44	7.67	4.58	8.00	5.30	5.44	5.98
Annual Recurring Cost	1.02	0.72	1.01	0.75	1.05	0.88	0.72	1.01
Annual Cost – Total	8.77	5.17	8.68	5.33	9.05	6.19	6.16	7.00
Installed Capacity Required (MW)	170.39	126.61	168.67	131.07	175.98	154.91	119.76	177.36
Initial Investment Required – Supply	15.38	11.68	15.22	12.09	15.88	14.29	10.81	16.36
Initial Investment Required – Generation	8.06	5.60	7.98	5.80	8.33	6.85	5.67	7.85
Initial Investment Required – Transmission	4.59	4.05	4.54	4.19	4.74	4.96	3.23	5.68
Initial Investment Required – Distribution	2.73	2.03	2.70	2.10	2.82	2.48	1.92	2.84
Initial Investment Required – Final Connection	33.85	13.01	33.51	13.47	34.96	15.92	23.79	18.23
Initial Investment Required – CFLs	10.00	6.21	9.90	6.43	10.33	7.60	7.03	8.70
Total Investment Required	59.23	30.90	58.63	31.99	61.17	37.81	41.63	43.29

7. Long term sustainability

7.1 Economic Transition and energy security

Modern cooking energy services through biogas offer the prospect of long-term sustainability in household energy consumption. The present pattern of household energy use (particularly fuelwood) is unsustainable since it degrades/deplete forest resources. Similarly use of kerosene cannot be continued indefinitely for cooking and lighting. By circumventing the need to import and subsidise expensive petroleum products to meet household demand, India can avoid the fluctuations of the unstable global petroleum market. Meeting energy needs through domestically produced biogas will thus provide an impetus for national economic development. A transition from insecure, imported and non renewable petroleum product with a more sustainable and secure system for household energy use can make the country more energy self-sufficient.

7.2 Environmental implications

Biogas burns efficiently and emits no smoke resulting in negligible indoor pollution compared to fuelwood. These inherently 'clean' characteristics are important from the perspective of indoor air pollution which is associated with biomass which produces large amounts of air-borne pollutants that cause serious health problems. Since biogas emits negligible amounts of emissions of toxic gases, the environmental benefits of shifting from biomass to biogas are significant. In addition, unsustainable sourcing of biomass has implications for GHG emissions. It is estimated that on an average, in India, 40% of the biomass is obtained from unsustainable means. Same assumption has been used while estimating CO_2 emissions from biomass cooking. Similarly, the shift from kerosene cooking and lighting to LPG/biogas and electricity respectively results in significant reductions in carbon emissions. Table 17 presents these estimates for all the plan periods.

Table 17: Carbon emissions mitigation potential of the programme (Million Tonnes)

Items	Target years							
	2015-16		2020-21		2025-26		2030-31	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Household Cooking								
Programme CO_2 Emissions	4.09	3.79	4.42	3.84	4.20	3.86	1.83	3.47
Baseline CO_2 Emissions	79.02	29.46	109.07	32.24	141.16	32.39	61.39	29.09
Alternative CO_2 Emissions	6.81	9.46	7.37	9.61	7.01	9.66	3.05	8.67
CO_2 Emissions Mitigation	72.21	20.00	101.71	22.63	134.16	22.74	58.34	20.42
Household Lighting								
Programme CO_2 Emissions	0.47	0.41	0.46	0.43	0.48	0.51	0.33	0.58
Baseline CO_2 Emissions	1.85	0.53	1.83	0.55	1.91	0.65	1.30	0.75
Alternative CO_2 Emissions	0.78	1.04	0.77	1.07	0.81	1.27	0.55	1.45
CO_2 Emissions Mitigation	1.38	0.12	1.36	0.12	1.42	0.14	0.97	0.17
Total CO_2 mitigation potential per year	**93.71**		**125.82**		**158.46**		**79.90**	

The carbon mitigation potentials are estimated by deducting the alternative CO2 emissions from the baseline emissions. The alternative CO2 emissions are those occurring after the provision of access to modern energy carriers (both programme and natural). The baseline emissions are those that would have occurred had there been no shift to modern energy carriers. The quantity of emission reduction in CO2 is expected to be 92.30 million tonnes per year during the plan period culminating in 2015-16. The estimated annual carbon mitigation potential is expected to increase during the plan period terminating in 2020-21 and reaching a peak by 2025-26 and subsequently declining to 79.90 million tonnes by 2030-31 because of less number of households requiring access to modern energy carriers. The annual carbon emission mitigation potential estimated for each of the plan period is incremental and they are additional to the annual mitigation potential of the earlier plan periods. Thus cumulatively, the annual CO2 mitigation potential of this programme is 457.89 million tonne from 2030-31 onwards.

8. Mechanism of implementation

Most development practitioners now recognise the need to relook at the rural livelihood needs which take into account the lifestyle needs of their urban counterparts. Access to markets and services are crucial for most village households to meet these needs. The positive impact of modern energy services is also crucial to local economic development. However provision of modern energy services may not be beneficial to the society in all circumstances. It can increase inequality and the vulnerability of groups with the least assets, particularly where land ownership is unequal and where government policies and subsidised credit institutions tend to benefit the already privileged urban élites and large farmers. Hence, there is a need to develop public–private–partnerships that take care of vulnerable sections of society and the constraints and opportunities they face. The role of local NGOs, entrepreneurs and government utilities as providers of social services (healthcare, education communication, energy, water and infrastructure) is critically important to achieve this goal.

Taking these considerations in mind, we develop a public–private–partnership–driven “business model” for the successful diffusion of modern energy services with innovative institutional, financing and pricing mechanisms. Some of the innovations adopted are: (i) changing from “investment subsidy” to “incentive–linked” delivery of services; (ii) selling “package of energy services” instead of “quantum of energy carriers”; and (iii) making “entrepreneurs” as diffusion targets and not millions of “end-users”.

Figure 2 shows the proposed mechanism and the feedback paths. It is designed to create viable and sustainable markets for the delivery of modern energy services in order to provide energy empowerment for rural population and urban poor. The partnership draws on combined strengths and collective action to mobilise public sector and small and medium entrepreneurs in ways that benefit society and organisations, improving social and economic conditions, and creating viable new markets for gaseous fuels and services. The approach is expected to integrate the processes of market transformation and entrepreneurship development involving the government, NGOs, financial institutions and community groups as stakeholders. Communities and local NGOs strengthen the effort by providing a critical support function at the project implementation level. The NGOs contribute by supporting technical assistance and capacity building. As the partnership succeeds, communities and individuals benefit through improved access to modern energy services, governments advance social and economic development objectives and private enterprise expands business opportunities–resulting in a win–win–win situation that is the ultimate aim of the energy empowerment challenge.

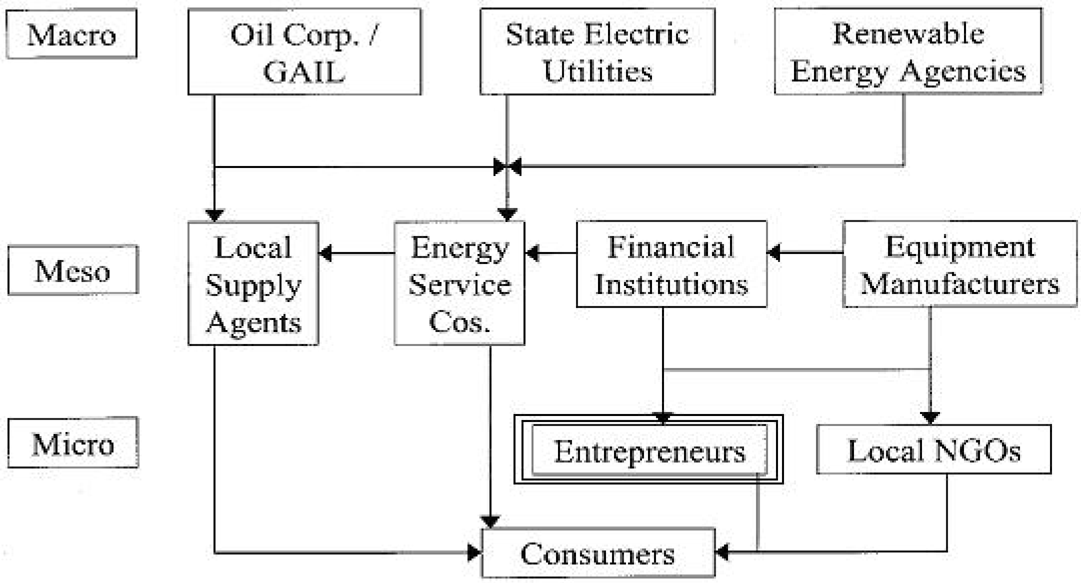

Fig 2: Shareholders linkages in proposed mechanism

The role of the government in this proposal is to design a mechanism to link all the stakeholders. It should first establish energy empowerment (EE) fund by diverting funds from kerosene subsidy. The piping and the grid connection infrastructure are huge and beyond the scope of individual entrepreneurs. So the cost of setting-up of infrastructure (i.e. piping for gaseous fuels, roads for transportation of LPG, transmission and distribution of electricity) has to be borne by the government (through EE fund), while the responsibility of operating and maintaining the distribution facilities along with the cost can be with entrepreneurs. Where modern energy service goals are demonstrably not achievable on a commercial basis, various service funding schemes (see Appendix 2) of the union government may be adapted to balance any unfair net cost burden. In many cases, no such scheme would be needed. Once the infrastructure is developed, it will be easy for the entrepreneur to install biogas plants and supply gas to the households directly. Similarly in urban regions, the government should develop infrastructure for natural gas supply and provide gas regulator free of cost to the poor. The government should involve NGOs to start target-oriented development programs, develop technology–specific prototype business plans and prepare a pool of entrepreneurs. It should also encourage entrepreneurs to manufacture products that are required for biogas plants and CFLs and should provide incentives. They should also regulate the quality of the products.

The role of electric utilities is to provide free electric connections to all the households belonging to low– and middle–income groups. Even though nearly all the villages are electrified only 55% of the rural households have electric connections. This is due to the high initial cost of connection. Once the electric connection is given and a CFL is fixed in a household, the supply of kerosene for rural lighting needs is no longer needed. The present kerosene subsidy has to be diverted to the infrastructure development. However, coordination is needed between the electric and oil utilities and the local entrepreneurs.

The financial institutions play a significant role in the scheme of things. They should ensure incentives, in the form of soft loans, to the entrepreneurs to install biogas plants and establish decentralised power generation systems. To achieve this, a financial mechanism (e.g., a renewable energy village bank) that could provide the entrepreneurs access to loans has to be designed. They should also provide soft loans to equipment manufacturers.

Entrepreneurs are at the core of the scheme of things. They setup micro-enterprises (energy service companies) to market energy–efficient devices or sell energy services. There can be different set of entrepreneurs for “production of energy carriers” and “marketing of energy services” or a single entrepreneur can do the both. The energy service companies established by these entrepreneurs are expected to be successful because of good understanding of consumer needs and environment, and hence focused on marketing and targeting. An affordable ‘connection fee,’ could be collected, offsetting some equipment costs. In addition, added benefits of soft loans, activity-oriented incentives and possibility of earning additional revenue through carbon credits can further enhance the profitability of these enterprises.

The role of equipment manufacturer is also important. They play a significant role in the spread of modern energy services. They can benefit from economies of scale by standardizing entire product lines for diverse markets, reducing a wide range of manufacturing and related costs. These cost savings are easily realized, since most product models are essentially identical from one market to another. They can also help entrepreneurs in sales and service operations in rural regions.

In a centralized planning and policymaking establishment, very little attention is paid to the actual needs of the target beneficiaries. The budget and requirements are normally estimated at macro level and the focus is on reaching the targets rather than analyzing and solving the problems. Hence, there is a need to build capacity among rural communities to recognize their needs, and educate them on the options available. Only those needs that are collectively recognized in such communities, if honored, would result in successful implementation of developmental projects. Non-governmental organizations (NGO) play a major role in bringing such communities together and work for their development. The NGOs are local-based and hence their knowledge is critical to the implementation of the projects and facilitates the delivery modern energy services. They can communicate the advantages to local customers. They can also assist in the following: (i) awareness campaigns on the importance of EE, (ii) involve other grass-root organizations and step-up demand for basic energy requirements, and (iii) lobby with government to get financing for setting up specific energy technology installations such as solar-heating systems.

The approach envisages the creation of a large pool of small-scale entrepreneurs who are closer to community (the targeted beneficiary). These entrepreneurs, trained by the NGOs, will be in a position to set up micro-enterprises (energy service companies) to produce energy carriers, market energy–efficient devices and sell energy services. The model also foresees the development of a cadre of trained technicians to provide backup/ service support to consumers which was hitherto considered as an element lacking in various govt/sectoral approaches to promote non-conventional energy thereby weaning away the public from adopting these programmes. The final outcome is expected to be a package of "energy services" rather than "energy technologies for meeting modern energy service needs of rural households and urban poor.

The model can eliminate the availability, accessibility and affordability gap in the following way. Entrepreneurs supported by financial institutions (in terms of soft loans) build the plants in villages and remote areas, which ensures availability of services. Typically, installing biogas plants exceed what a small entrepreneur can afford, the government has an indirect role in subsidizing the equipment manufacturers (a small entrepreneur) while financial institutions have direct role in providing loans to the entrepreneur. The exact size and capacity of the plants would vary depending on the requirement. The model provides employment to opportunities for thousands of people in the form of entrepreneurs, sales and service personnel, who have the aptitude to take challenge. Later, as the business expands for each entrepreneur, the employment base will increase significantly.

The approach focuses on building awareness and expertise on energy efficient and decentralized renewable technologies (EERTs); biogas plants for rural energy cooking services, LPG/natural gas for urban cooking and electricity through grid as well as decentralized renewable energy technologies that can help in providing clean, reliable and affordable energy services. Electricity and gaseous fuels can no longer be viewed as a luxury meant only for high-income groups. In most situations, both individual as well as the society will benefit from extending modern energy services. This approach seems to be a practical alternative to provide modern energy services to the rural households and urban poor.

9. Enabling policy framework

To make the model proposed here to work properly, the first and foremost factor is the involvement of all stakeholders and the availability of credit. The entrepreneurs, financial institutions and utilities (electric as well as oil) should join together to achieve the goal of universal access of modern energy services. Access to credit could provide energy empowerment in many ways. It can provide capital for purchasing devices for consumers and to install biogas plants and other distributed electricity generation technologies for entrepreneurs. Rural financial policy for enhancing household energy empowerment, therefore, implies the availability not only of credit for purchasing energy-utilizing devices, but also to help rural households manage their finances more efficiently and to accumulate assets. Credit groups, cooperative societies, and village banks can exploit the cost advantage that informal institutions have by incorporating or building on some of their screening, monitoring, and enforcement mechanisms. While these new institutions often serve the landless, or cater to credit demand related to farming, they also expand access to entrepreneurs. A key factor for success in developing and linking these financial institutions with the energy sector is the financial sector framework which enables the procurement of soft loans, loan disbursement and repayment, including the risk of loan default; provision of technologies that effectively respond to diverse demands of consumers; employment of locally adapted workforce which reduces transaction costs for screening, and flexibility in decision making and incentives for compliance at the grass root level.

Table 18: Framework for providing universal energy services

	Stages				
	1	**2**	**3**	**4**	**5**
Stages	**Initial Infrastructure Development**	**Wide spread geographical Reach**	**Mass market take-up**	**Remote Infrastructure**	**Enhancement**
Target range	Very low income	Low income	Lower middle income	Upper middle income	High income
Entrepreneurs take-up	< 20%	20% - 50%	50% - 70%	100%	100%
Typical electric utility preoccupations	Large scale capital investment	Technical network improvements	Growing the network	Marketing	Profitability
Main constraints on infrastructure expansion	Investment funds, appropriate technology and skills	Limited demand due to high costs and use of alternative technologies	Manpower for infrastructure development to meet mass demand	Affordability of service to poorer households	Market appeal
Universal service goal type	Technological (acquire new technology)	Geographic (maintain urban-rural regional parity)	Economic (stimulate economy)	Social (achieve political cohesion)	Libertarian (individual right to have modern energy services)
Examples of universal service and universal access goals	Electricity connection where demand warrants	Service available in all places over a certain population; wider spread adoption of modern energy services	Widespread residential take-up in all villages except in remote regions	Modern energy services affordable to all; service adaptable to special regions (e.g remote and hilly)	Everyone can meet basic energy needs; public access to services such as street lighting
Typical public policy measures (universal service)	License to all eligible entrepreneurs	Divert existing kerosene/electricity subsidy to infrastructure development	Special packages to vulnerable sections	Targeted subsidies	Identify and meet non-market demand.
Typical funding source for entrepreneurs	Involve financial institutions to provide soft loans to entrepreneurs	Self-generated funds by each entrepreneurs	Encourage manufacturing industry (award competitiveness)	Expand services	Special interest funds (e.g., region disability)
Importance of modern energy services	Alternatives to modern energy carriers still prevail (biomass)	Status symbol; also valued highly by low income groups	Vital practical tool for majority	Access is a life style need	Individual access a social necessity

From a policy perspective, government support for building rural financial institutions ought to be, in principle, not judged on the prospect of achieving financial sustainability of the institution itself, but on the economic sustainability of the public investment. Economic sustainability of a policy implies that scarce public funds are used to maximize social returns. In many rural settings of developing countries, long-term support for building and maintaining rural financial institutions that serve the poor may have higher cost–benefit ratios in short and long run rather than some other competing policy instruments. The proposed framework for providing modern energy services, at different stages, is shown in Table 18.

Lack of information and awareness at individual, social, and government levels dampens the sense of urgency that is desired to address the universalisation of energy services. Academic activism can make a positive difference to the problem of lack of information and awareness. The study proposes this activism by interacting with focused interest groups or NGOs that provide intellectual and research based inputs in rural areas, which can be used by prospective consumers, equipment manufacturers and policy makers. The mechanism acts as a melting pot of ideas and innovations, and these ideas would be proactively propagated to the grass-root groups by way of training programs and workshops. It works towards bridging the distance between the government, the producers, academic expertise and the consumers.

10. Conclusions

In India, more than 75 per cent among rural households (mainly low- and middle-income groups) use biomass (largely fuel wood) with adverse health and environmental impacts. Women and children collect and carry loads of fuel wood and sometimes covering distances as far as 5 km. on foot. This “hard-earned” energy is used very inefficiently, converting only about 10 per cent of the total into useful energy. The linkage between poverty, living conditions, livelihoods, and the way energy is used is clear from these observations. The Indian household energy problem is not primarily one of scarcity of energy per se, but inefficient conversion to obtain the desired services. 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 fuel wood becomes more difficult as land degradation spreads. The supply of fuel wood, especially to urban areas, is a contributing factor to deforestation and land degradation. Given the magnitude of these problems and issues, are there solutions that are sustainable?

During the past decade or so, modern energy services have become an aspiration for many households and have become social necessity. Hence, provision of reliable, accessible, and affordable modern energy resources is fundamental to economic growth and sustainable development. "Climbing of development ladder" (biomass → gaseous fuels for cooking; kerosene → electricity for lighting) can solve the problems pertaining to energy-poverty, livelihoods, gender and other related issues. Access to modern energy provides; the productive capacity for stimulating economic development and reduce conditions of poverty while improving health, air quality, comfort, education, and hardships imposed on women and children. Hence there is a need for new approaches for energy empowerment through provision of modern services.

Even though energy resources are abundant, there is no improvement in the production, conversion, creation of favourable logistical conditions and making it accessible and affordable (both in technical and economic terms) to all. This is due to lack of proper financial and institutional mechanisms. Public–Private–Partnership entrepreneur model suggested here can bring together the best of each partner's capacities and capabilities. These partnerships reflect the skill sets and resources of each partner, and can be developed with a long-term view appropriate to energy investment. This can be achieved by targeting the groups, the people who really need the service, and help entrepreneurs/energy service companies to provide them the required energy service i.e., *service to the right people for the right use*. Through implementation of such schemes economic efficiency and rural growth can be achieved by supplying sufficient energy at least cost to the poor. Further, energy supply and demand management can be achieved in an environmentally sustainable manner.

The approach to provide modern energy services can be used as a framework for planning appropriate policy measures at different levels of economic and social development. The approach presented here is conceptually sound although some features can be revised. One of the biggest challenges has been the extent to which accessibility can be a realistic objective for universal service access policy. Wide geographic reach is now thought to be achievable on a purely commercial basis even in rural regions. The focus for affordability will be to ensure that moderate rates are offered for services so that households can have them without much hardship. Attracting investment remains a prime concern, though it may now be joined by a strong desire to spread access much more widely for both economic and political reasons. Affordability objectives may therefore include lower rates for poor as well as private packages that are attractive to rich households. Finally the service starts to be of real social importance, and affordability of services to everyone can become a reasonable and achievable goal. Wider access to energy services is a necessary condition for meeting most of the targets outlined in the millennium declaration. Of course, the driving policy goal is to provide investment. The focus on services will be to ensure that funds are made available at moderate rates of interest to entrepreneurs to provide access to modern energy services at affordable cost and convenience.

The approach illustrated in this paper can be used to achieve goals of this kind, without the need for funding from global entities. It is a practical one, based on the premises that: whether or not a service is used by a particular household depends primarily on the service accessibility, household income level, price of energy carrier and the device used. Also, market and individual preferences play an important role. Problems arise if total revenues are inadequate to cover total costs, but it is normal practice for categories of users to contribute to revenues and costs in different ways at different times.

Appendix 1: Assumptions for future years

Year	Rural		Urban	
	Cooking	Lighting	Cooking	Lighting
	Target for provision of services (percent)			
2010-11 to 2015-16	35	80	85	100
2015-16 to 2020-21	60	90	95	100
2020-21 to 2025-26	90	100	100	100
2025-26 to 2030-31	100	100	100	100
	Household increase rate			
2010-11 to 2015-16	1.0		3.0	
2015-16 to 2020-21	0.9		3.4	
2020-21 to 2025-26	0.8		3.4	
2025-26 to 2030-31	0.8		3.3	

Appendix 2: Policy initiatives by the Government

Initiative	Details	Cost sharing
Remote village electrification programme,	Small/micro hydro, biomass gasification, SPV power and home lighting, Bio-diesel and biogas engines	
Kutir Jyothi	Household lighting	Government bears the entire cost of service connection and internal wiring and is provided to the states as a grant
Pradhan Mantri Gramodaya Yojana -	Connectivity for rural electrification projects in less electrified states	Financing through loans (90%) and grants (10%). States have flexibility to decide allocation
Accelerated Rural Electrification Programme -	Designed for electrification of non-electrified villages.	States can borrow funds from financial institutions and receive interest subsidies from Central govt.
National policy for rural electrification	Bulk purchase of power and management of rural distribution through local participation	
Rajiv Gandhi Grameen Vidyutikaran Yojana	Aims to develop rural distribution backbone and to create village electrification infrastructure by installing at least one distribution transformer in each village within next five years Provide free electricity connection to all rural households below poverty line	Govt. will provide 90% of capital cost as grant. Projects will be managed by franchisees, which can be local level organisations (such as NGOs, rural committees, etc.) or private entrepreneurs For commercial viability of the franchisees, revenue subsidy and suitable bulk power purchase tariffs will be determined.

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