Keynote Paper

ENERGY EFFICIENCY IN THE HOUSEHOLD SECTOR: RIGHT DIOGNOSIS AND WRONG THERAPY

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Abstract Energy efficiency generates substantial financial savings while simultaneously improving environmental quality. Despite these benefits, developing countries like India are missing out on energy efficiency opportunities and instead concentrating on increased energy production. This paper identifies the efficient technologies in the household sector in India, and details their benefits to the consumer as well as to the society. It identifies the barriers that prevent the government from achieving its energy efficiency goals, analyzes programs that addresses these barriers, and explores the creation of an institutional mechanism.

Keywords: efficiency, energy, household, penetration, technology

1. INTRODUCTION

Many environmental programs have financial costs, but no financial benefits. Often this acts as a barrier that prevents the government from implementing environmental improvements. Energy efficiency, on the other hand, has both an environmental benefit and a positive financial return. Improving the energy efficiency of a system has multiple advantages, viz., efficiency of utilisation of natural resources, reducing air pollution levels, and lower spending by the consumer on energy related expenditure. Also, energy efficient technologies have consistently maintained a high rate of return. The size of these benefits depends upon the fuel mix that would have been used to produce the required energy service. The average discounted payback period for many of these technologies is around two years. Hence, from a financial perspective, energy efficiency programs are attractive investments. Reduced energy consumption also reduces air pollution, which reduces health risks and avoids pollution mitigation costs. Thus, energy efficiency improvements can reduce both economic and environmental costs associated with energy supply and consumption. Despite these significant benefits the government and the utilities are not integrating efficiency programmes into their planning process. From the conusmers' perspective several barriers prevent them from investing in cost-effective energy technologies. The reasons include (1) lack of initial investment for efficient technologies and (ii) lack of sufficient perceived incentives to pursue energy efficiency investments. As a result, the country is missing out on opportunities to save both in terms of energy and the environment. In the present paper, we assess the energy efficiency technologies and their implementation based on three criteria: (i) awareness: propagating the incentives to consumers, (ii) capital constraints: How readily available is funding; and (iii) institutional mechanism: the difficulties in the process of implementation? This new paradigm, with emphasis on energy efficiency, entails the demand for energy from consumer side and switches the focus from energy supply to demand management.

This present paper provides a methodological framework for individual technological options and estimates energy savings and the rate of return for the consumer. The costs and benefits have been assessed for different efficient technologies from the consumer as well as the government perspectives. The paper indicates that substantial savings can be achieved and environmental costs can be avoided if efficient technologies can be considered as an integral part of the government's long-range resource plan. A 10-year planning horizon is considered here to study the impact of various technologies on the economy as well as on the environment. This is an attempt to evolve a rational basis for deciding how each stakeholder can benefit from each technology so that costs and benefits can be shared among various stakeholders.

2. METHODOLOGICAL FRAMEWORK

We have developed a framework for analyzing various energy efficiency technologies available in India that are relevant for the residential sector. This criterion assesses the technologies with respect to the beneficiaries. Specifically, we assess the savings through each technological shift based on two criteria. (1) the rate of

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return on investment to the consumer and (2) total savings that typically accrue to the government and the society?

The end-use profile of energy use in the household sector has been taken from the survey conducted by the National Sample Survey Organisation (Anon, 2001). For each technology, the methodological framework takes into account: (i) technical characteristics; (ii) energy prices; (iii) investment costs and (iii) energy and environmental savings. The technology characteristics of the base and efficient options have been obtained from manufacturers' catalogs and discussions with consumers. The benefit-cost analysis has been carried out from the perspectives of the customer, the government and the society. The selected technologies have been classified into the following three categories:

1. Cooking

   i. Traditional wood stoves (10% efficiency)
   ii. Efficient wood stoves (30% efficiency)
   iii. Traditional Kerosene stoves (40% efficiency)
   iv. Efficient Kerosene Stoves (50% efficiency)
   v. LPG stoves (60% efficiency)
   vi. Biogas]

2. Water-heating

   i. Traditional wood stoves
   ii. Efficient wood stoves
   iii. Traditional Kerosene stoves
   iv. Efficient Kerosene Stoves
   v. Electric water heaters
   vi. Solar water heaters
   vii. Biogas

3. Lighting
   i. Incandescent Lamps (60 watt)
   ii. Fluorescent Lamps (40 watt)
   iii. Compact Fluorescent Lamps (13 watt)
   iv. Kerosene Lamps

The maximum penetration of a particular technology depends on the level of capital availability and also on the level of subsidy. There is likely a chance of some consumers not shifting to efficient technology at any time (even in the long run, *viz*., 10 years period) for a number of reasons. Hence, we have taken an unwilling percentage (i.e., the proportion of the households who will not adopt the technology) of about 20%. The rate at which a technology attains its long run market share is a function of the pace at which information and subsequent actions about it diffuse in the market. For any given technology there will be four phases, viz., learning curve, growth, saturation, and decline. Figure 1 describes the diffusion function of a technology among consumers.

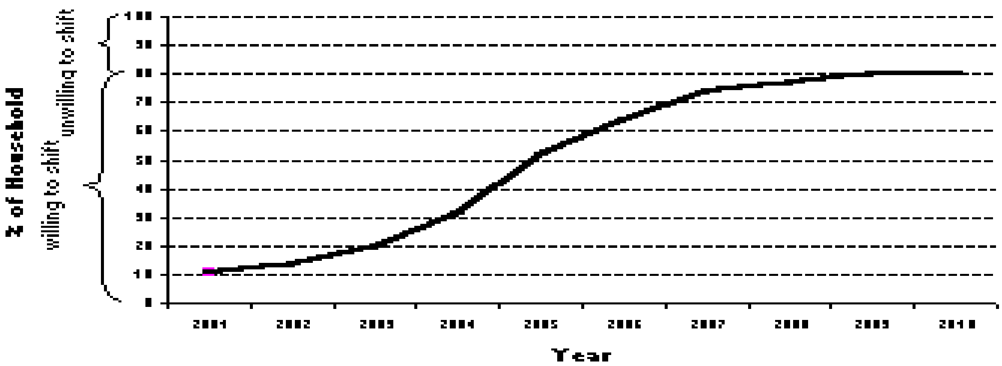

Fig.1 Technology Diffusion

3. INDIA'S ENERGY SCENARIO

India mainly depends on coal, oil and fuel wood for most of its energy needs. In the year 2000, the total energy demand stood at 1.5 million tera joules (MTJ). Of the total, about 65% came from commercial sources and the rest from non-commercial sources such as fuel wood, agriculture wastes, etc. Even though the share of non-commercial energy in total energy consumption has reduced significantly over the years its contributions are substantial. Households are the major consumers with nearly 44% of total energy followed by industry with around 40%. The rest is by the transport, agriculture and commercial sectors (CMIE, 2001). The rising energy demand and the need to conserve the resources have to be addressed as part of national development plans but this cannot be done without an understanding of energy utilisation pattern of various fuels/energy carriers and the actors involved. Figure 2 provides an insight into the energy sector of India, supply and distribution and end-use of energy carriers *viz*., firewood, coal, electricity, LPG and petroleum products like kerosene, petrol, diesel and fuel oil.

3.1 Household Energy Consumption

Over the past 50 years, energy demand in the residential sector has more than doubled at an average growth rate of around 2% per annum. This slow growth is mainly due to urbanization and its consequent substitution of traditional fuels with modern carriers such as LPG and electricity. From 1950 to 2000, the total energy consumption of the residential sector increased by a factor of 2.1 whle the increase in households is by a factor 3. This decrease in per capita consumption is mainly due to the changing mix of energy carriers. Many households that used to depend on wood- based fuels have shifted to modern energy carriers like LPG and electricity which is used efficiently. Thus, wood-based fuels which constituted 97% of the total residential energy consumption in 1950, accounted for only 75%t in 2000 (Table 1).

The pattern of utilisation of various fuels/energy carriers varies with income and also with region (rural and urban areas) (Anon, 2001. The survey data indicate that there is a variation in the contribution of different energy carriers to the energy mix of different income groups for cooking/heating. This is because the choice of an energy carrier by a household depends mostly on the capital cost of the device. Low-income households use firewood, charcoal, agricultural wastes, etc., whereas the high-income households use Liquified Petroleum Gas (LPG) and electricity. his trend is discernible for both rural as well as urban areas. This household data has been used to calculate the utilisation indices of various energy carriers. The utilisation index, defines the fraction of households in a particular income group which use a particular energy carrier. Values of the utilisation index show that the low-income groups (in rural as well as urban areas) depend mainly on firewood while the middle income groups depend on fuelwood in rural areas and on kerosene in urban areas. The high income groups depend mainly on LPG in urban areas. Kerosene and to a certain extent LPG seems to be penetrating into the rural households (Figurea 3A and 3B)

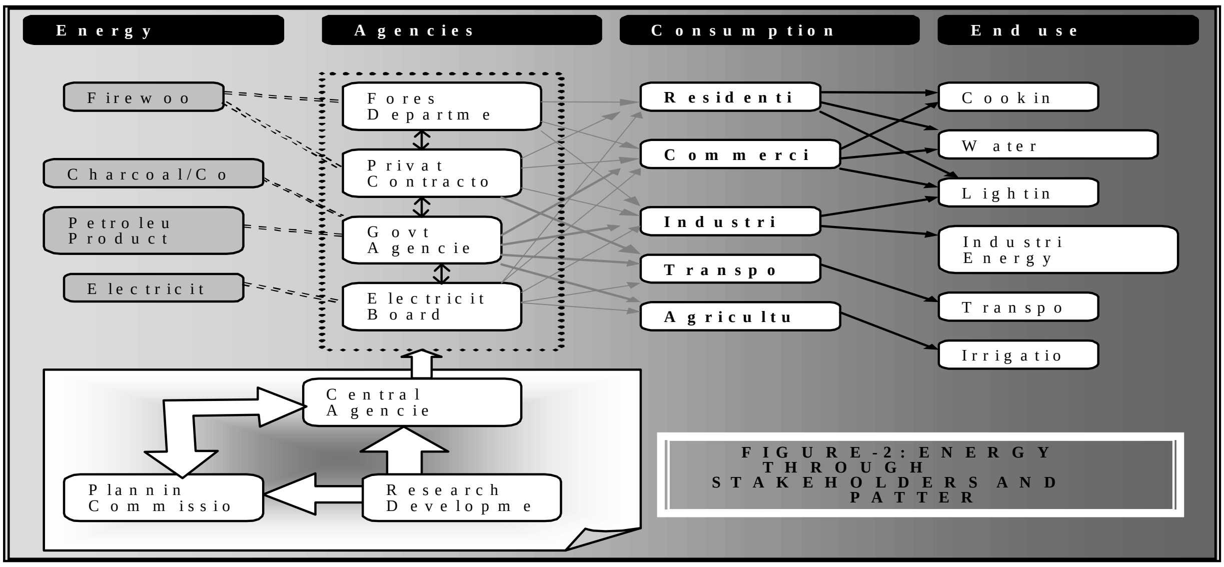

Fig. 2 Energy Flow

3.2 Energy Services

In the residential sector the major services include cooking, water heating and lighting. Cooking accounts for the largest share of residential energy consumption accounting for about half of the total. Among the major carriers, fuelwood is the major source of energy followed by kerosene and LPG. In the case of water heating, firewood and electricity are the main energy carriers used and for lighting, kerosene and electricity are used. Generally, rural areas depend on fuelwood for cooking and water heating while LPG and electricity are the main carriers in urban areas. The efficiencies with which these carriers are utilised (efficiency of the device) vary so also the capital costs. Since the capital cost of the efficient device is high, low-income households cannot afford to invest in it, even if the return on investment is high. In the present paper, we examine different energy carriers (in terms of devices) used by different households and calculate the Annualised Life Cycle Costs (ALCC) taking into consideration the capital cost of the device, its life, operating cost, energy carrier price, etc. A discount rate of 12% is used for calculating the ALCC. In calculating the ALCC it is assumed that the consumers do not anticipate any escalation in the prices of energy carriers. Table 2 gives the performance characteristics of these carriers and their utilising devices. As the data show, the cost for a consumer using a kerosene stove is less than those using firewood stove. This is because carriers such as firewood are being used with efficiencies as low as 10%.

4. ENERGY EFFICIENT TECHNOLOGIES

Energy Efficiency involves the replacement of inefficient technologies with efficient ones and fuel switching from non-renewables to renewable technologies. In recent years, this paradigm shift has emerged as one of the major concepts, which is technically feasible and economically promising. A significant reduction in energy bills of the consumers can occur, if these measures are adopted. The payback period for many of the technologies is less than two years. There are many proven technologies that can be considered for energy efficiency improvements. In the residential sector, major alternatives would be fuel switching - from firewood to kerosene/LPG for cooking, and replacement of existing inefficient devices with efficient ones (for cooking, lighting, water heating, etc.). Substantial energy and cost savings could be achieved through these measures. In the case of traditional fuels, most of the rural regions in India use them for cooking/heating with efficiencies as low as 10%. Efficiencies as high as 30% 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. The financial benefits alone make these programmes attractive. Also, energy efficiency produces positive environmental externalities. It reduces air pollution, which in turn reduces health risks and avoids pollution mitigation costs. The combined financial and environmental benefits justify devoting the government's time, effort, and resources to energy efficiency programmes in India. Here, we first quantify the total economic benefits of energy efficient technologies and then, we discuss the factors, which affect the size of these economic benefits.

4.1 Financial Benefits

It is assumed that consumer behaviour in choosing particular energy carrier is characterised by the capital cost of the energy utilising device and its availability (Reddy B.S, 1996). The capital cost of the device increases with increasing efficiency whereas the operating costs are more for the less efficient devices. Hence an initial large investment in the form of an efficient device would result in future savings. We examine here different energy carriers (in terms of devices) used by different households and calculates the Annualised Life Cycle Cost taking into consideration the capital cost of the device and its life, operating cost, operating efficiency, energy carrier price, etc. By determining how some of the carriers (in terms of efficient devices) used by the households must pay back the incremental investment, one has to find out the discounted payback period. The payback period (PP) is the number of years required to recoup the initial investment through the annual savings. The average discounted payback period for many of these technologies, at the current capital costs, is leas than two years (Table4) which usually considered warranting the investment. However, the PP may indicate that a shift to energy efficient devices is attractive, but it does not reveal the capacity of the household to make the initial investment. Such decisions are based upon the rate of return on investment (ROI). This ROI is based on the assumption that the consumer is offered several investment options and he prefers the one with the lowest investment. Since the ALCC includes capital cost, operation and maintenance costs, it is easy to compare the cost of appliances whose performance characteristics are similar. It is seen from Table 3 that on an average every hundred rupees of capital invested on efficient fuel wood and kerosene technologies the household gets an annual return of about Rs200 where as the shift from fuelwood to LPG fetches an annual rate of return of about Rs.1. In the case of lighting technologies, the average annual rate of return is about Rs.60. Thus, from a financial perspective, these technologies are attractive investments for an individual household.

4.2 Environmental Benefits

Energy efficiency creates an environmental benefit by reducing emissions of air pollutants. Environmental problems in India reflect the pattern of energy utilisation.. India's electricity is primarily generated by coal. Burning fossil fuels emits large amounts of airborne pollutants, primarily carbon dioxide, sulfur dioxide, and nitric oxides. Technological developments in energy demand and changes in fuel-mix are therefore of greatest significance for the environmental considerations. Since the environmental implications are significantly dependent on the type of energy carrier chosen, it is important to look at various carriers and their associated emissions. On the basis of consumption by various types of fuels, the CO_2 emissions were estimated using the emission coefficients (tC/toe): coal - 1.08; oil - 0.86 and gas 0.62. Table 3 indicates the level of emission reduction the household avoids each year as a result of energy efficiency technologies. For example, each household using fuelwood emits 580 kg less carbon dioxide per year than would have been emitted had efficient fuelwood technologies not been implemented. Thus, each year, more emission reductions accumulate, as more energy efficient technologies are adopted as the environmental benefits last for the life of the installed equipment. The last column of Table 3 indicates the avoided emissions for technologies adopted by the household.

5. FUTURE SCENARIO

The dynamics of the process of substitution of efficient technology for inefficient one is important in a number of planning related activities which include the resource allocation for research and development, technological forecasting and assessment, etc. If such a technological substitution has been initiated, forecasts based on the relevant data indicate the rate at which the substitution will proceed in the future depending upon the economic conditions of the households. There may be other considerations if we look at the consumer and the government perspectives. Given these considerations, it is always debatable, whether it is really possible to estimate the expected level of market penetration of a given technology. This is because, the rate at which a technology penetrates into the market is a function of the pace at which information and subsequent actions about it diffuse in the market place. The basic concepts, which should apply to any market penetration, can be as follows: (i) Naturally occurring market penetration; and (ii) Government sponsored (intervention) market penetration. For any technology, maximum technically achievable market penetration is always greater than the maximum achievable market penetration. Keeping these facts in mind, a 10-year planning horizon (2001-2010) is considered in this paper. This 10-year perspective is important because, the rate of diffusion of technologies changes in the long run.

5.1 Naturally Occurring Market Penetration.

There are two major factors that influence the energy carrier shifts, viz., household income and availability of energy carrier. In the second case, rural to urban migration plays an important role since fuels like LPG are not available in most of the rural regions. It has also been observed that with increasing incomes households switch from one carrier to another, viz., fuelwood to kerosene, kerosene to LPG, etc . As can be seen in Figure 4D, the percentage of households using fuelwood is decreasing both in urban as well as in rural areas and that of LPG is increasing. During 1993-94, for instance, 2.12% of rural households and 26.48% of urban households were using LPG and in the year 2000 the share increases to 3.09 and 36.44. If the same trend continues the percentage of households using LPG in rural and urban areas would be 15.43 and 56.18. These carrier shifts takes place naturally and without the intervention by the external agency. Using these historic trends we have developed household energy scenario for 2010 assuming that all the past growth rates will continue in the future. This means that there would be no specific policy intervention from the government. According to this scenario, there would be reductions in fuelwood using households and a corresponding increase in LPG using households in all the income groups. Figure 3A and 3B describe these shifts in energy use.

5.2 Government Sponsored Programmes And The Technological Shift

If the efficient options are implemented, government saves money in terms of reduced oil imports, costs for fuel for power generation and the investments for new power plants and reduction in cutting forests. The consumer saves money in terms of reduced energy bills and the society saves money through reduced pollution levels and more money for welfare measures. Hence it is important for the government to intervene, prepare a programme for

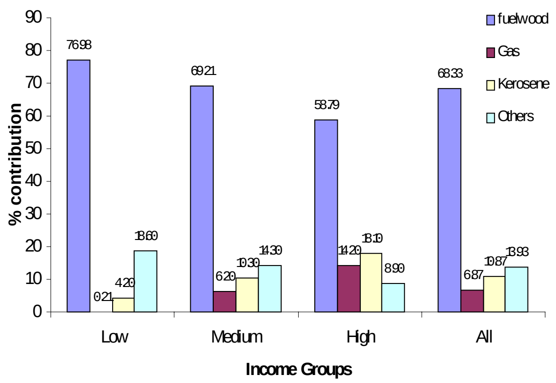

Fig. 3a Rural Scenario - Cooking(2000-

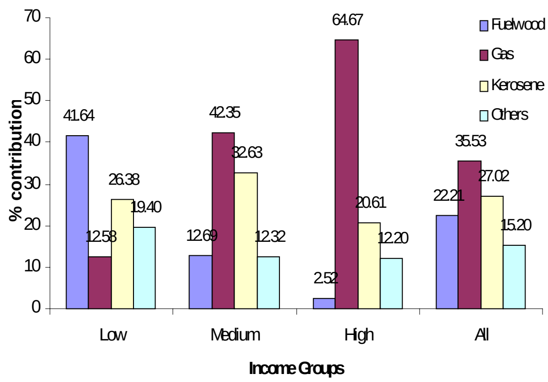

Fig. 3b Urban Scenario- Cooking(2000-01)

the speedy implementation of efficiency measures. This can be achieved by providing incentives to the consumers. Through the government intervention, the household can shift from an inefficient technology to and efficient technology (the carrier may be same or different). To estimate the scope of savings through a specific option, we need to identify only those options, which are cost-effective and provide benefits for all the stakeholders, viz., the consumer, the government and the Society. To estimate the costs and savings, the efficient option is compared with the base standard option. The costs and savings are multiplied by the number of households (who are likely to adopt these technologies) to obtain the total costs/savings. Incremental costs (the difference between the standard and efficient technology) include the capital, installation and incremental maintenance costs that is borne by the customer if he chooses the efficient option instead of standard one. Energy savings are obtained from the avoided energy costs (Rs) by multiplying with energy savings (kWh). As discussed in the methodology, for each technology, a certain unwilling percentage is assumed. An unwilling percentage of 20 is considered for each option. It is assumed that the long-range achievable market share is attained at the end of the 10-year period.

We have prepared a residential energy scenario for the year 2010 A.D on the assumption that the government takes various policy initiatives to increase the penetration of efficient technologies. According to the scenario, the total energy consumption is expected to increase at an average of about 1.5% per annum**.** If the efficiency measures are not implemented, the total consumption is expected to increase at an average of 2% up to the year 2010. The share of fuelwood consumption in total energy requirements will reduce significantly. The demand reduction by the terminal year for fuel wood is 38 million tonnes. This decrease is due to the fuel shifting (fuelwood to kerosene/LPG) and energy efficiency programmes. According to the scenario, the cumulative energy 3,230 PJ by the year 2010 A.D. The costs involved for each technology include capital cost, installation cost and maintenance cost. These costs vary from one option to another. The customer discount rate is used to compute the present value of the costs to the households of adopting the efficient option. The total incremental costs for all these options amounts to Rs 2,427 million.

When compared with 2000, the avoided CO_2 emissions in 2010 will be reduced by 72 million tonnes. However, to achieve these economic as well as environmental goals an integrated set of *implementable* measures and initiatives are required. The following section deals with the required measures (Table 4).

5.3 Factors that Affect Efficient Technology Penetration

A question that such results often arouse is "if it is so economically beneficial and environmentally sound, why don't customers adopt energy efficient technologies on their own?" and "why the government doesn't take initiatives to spread awareness about energy efficiency and help in reducing the energy consumption levels"?. Obviously there must be some barriers to adoption. From the consumers' perspective, the availability of capital for the installation of efficient technology, limitations of information, availability about the costs and benefits of the efficient technologies, and uncertainties about the future energy carrier prices are the major barriers.

In the case of electric utilities, even though they are aware about the benefits of energy efficiency, they have always sought more generation and more power plants, which is a wrong therapy. This is because the highest profit for utilities would accrue from "filling in the valleys", viz., increasing base demand and reducing the peak. Ideally, utilities would like the total electricity sales to grow (since that is the source of their income) with a flat demand schedule (since peak demand is the most expensive to produce). This means that utilities want the reduction of kilowatt usage (the measure of demand), but like to increase kilowatt-hours of usage (the measure of electricity consumption). Energy efficiency actually addresses kilowatt-hour usage, since utilities have no realistic means of addressing peak demand directly. To address this problem, the government should to allow the utilities to charge the consumers the real price of electricity. This means that that each consumer would have to be charged for its

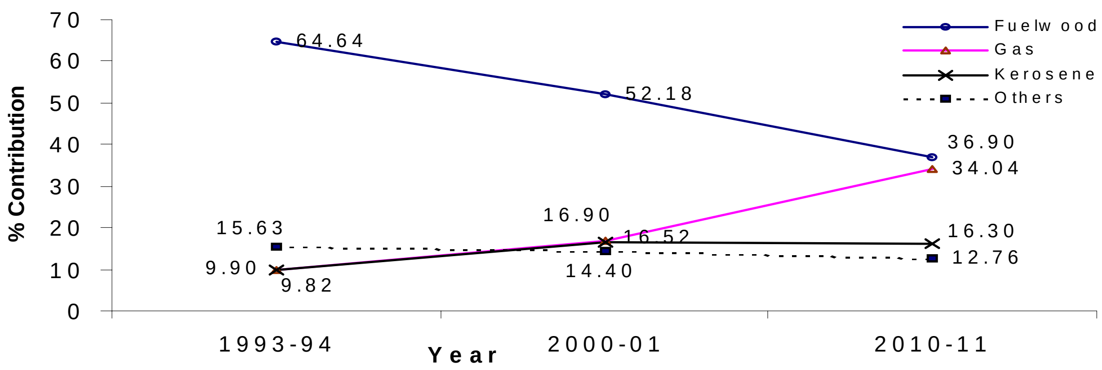

Figure-4d: Trends in energy use-All Income Group (1993-2010)

resource usage so that he could rationally decide how much energy to use based on its real cost thus reducing the energy. This type of pricing can be applied to petroleum products also.

The results suggest that income dependent energy utilisation is a characteristic of a stratified society. As society becomes more egalitarian, this phenomenon will disappear. Although substitution of efficient technologies can be envisaged as an evolutionary process, the government should provide significant subsidies or other financial assistance to eliminate the use of inefficient devices. Since efficient devices are expensive, reduction in capital costs through subsidies, rebates, etc., can induce poorer households to shift to more efficient and energy conserving devices. This will also reduce the stress on natural resources.

Another possibility will be for the government or electricity boards to install energy efficient equipment in households and collect the payments in monthly installments so that the generation costs could be avoided. However, the consumer's knowledge regarding the costs, benefits, etc., also plays a significant role in the faster diffusion of efficient technologies. The government should try to educate the consumers in understanding the trade-off between the capital cost of the efficient device and the future energy savings.

6. LEARNING TO ADOPT: THE BASIC REQUIREMENTS

6.1 Government Perspective

Cost of capital affects the energy efficiency programmes. To promote energy efficiency, the government should seek ways to lower its cost of capital. Since the government can issue tax-exemption to finance efficiency programmes, its cost of capital is low. Therefore, it can evaluate energy efficiency programmes at a favorably low discount rate. As the interest rates increase, the net present value of energy efficiency programmes diminishes. To make energy efficiency programmes appear more attractive, the government should provide subsidies to households belonging to low and middle income groups. Subsidies represent transfers between the state governments and the consumer. They neigther increase social welfare, nor the benefits of efficiency programmes. Nevertheless, implementing energy efficiency programmes generates positive environmental externalities by improving air quality. Often, there is not necessarily a correlation between the size of the subsidy and the size of the market penetration of a technology, a subsidy increases the return on a state's capital investment. This may change the state's decision criteria to allow the implementation of programmes with longer payback periods. That is, the government, which must expend the effort and initiative to undertake conservation measures, does not reap the benefits of their efforts.

Low energy prices make efficiency programmes less financially attractive. But the government should not set energy efficiency policy based on current or "expected" prices because energy prices are volatile and unpredictable. Low energy prices reduce the financial benefits of energy efficiency programmes because as energy prices fall, the annual savings from conserved energy falls. If energy prices were expected to rise, the government would be wise to undertake more energy efficiency programmes. Economic theory predicts a slow rise in real energy prices over time. But energy prices do not follow economic theory, and energy inflation is more volatile than general price inflation.

6.2 Customer Perspective

The main requirements for the effective penetration of efficient technologies include: the customer (i) must be aware of the technology, (ii) must be convinced of its technical soundness, (iii) must be convinced of its cost-effectiveness, (iv) must have access to the necessary finances, and (v) would like to be insured against the risk of failure. Most goals of the energy efficiency technologies cost money. The conservation is a money-saving practice, and the economic incentive to save money should result in practices, which keep up with efficient technology. The consumer discount rates (higher for low energy technologies) indicate that there are barriers to economically rational practices. That is, if the barriers are removed, technologies will become efficient without any further political incentives, without any further legislative or executive action, and without any further funding of any kind. In order to expect rational economic behavior from consumers, they must be subject to the real costs of their energy use. That is, each consumer would have to be charged for its resource usage so that the consumer could rationally decide how much energy to use based on its real If the payback period for a conservation programme is more than a year, consumers s are further discouraged from undertaking the improvements, because they must get the additional funding, and then, if the capital expenditures are successful at reducing their operating expenditures, their budget is reduced in subsequent budget cycles.

6.3 Recommendations

(i) Provide Better Incentives. The single largest barrier that prevents the implementation of energy efficiency programmes is that state agencies do not receive financial rewards for their energy conservation efforts. Energy conservation reduces government spending by avoiding generation costs, but if the Government does not share these savings with the state agencies such as electric utility or the department of forests, the agency has little reason to incur the transaction costs of implementing these programmes in the first place. If the government is committed to promoting energy conservation, it has to implement incentive based policies. The agencies also need to know not only that they are guaranteed a portion of the savings, but also that they may use their portion to finance programmes that they otherwise could not afford. The government also should begin to reward state utilities that implement conservation programmes, and make known their intention to continue to offer rewards.

The agencies in turn should provide monetary incentives to personnel or departments, which take the initiative to reduce energy generation. By sharing the savings with employees and public officials there will be a strong incentives to identify cost-saving measures. Creating such incentives will push efficiency programmes and can overcome many of the bureaucratic barriers by making the long process personally worthwhile. The government should also prioritize state facilities by energy efficiency and perform audits the facilities that are most likely to produce the highest energy efficiency improvement.

Subsidies make energy efficiency programmes financially attractive because with a subsidy, the return on the investment increases. With a portion of the savings, the agency will more readily devote its resources to energy efficiency programmes. To do so, the agency needs to know how many technologies exist and how much capital is required to implement these technologies. The agency can evaluate the total requirement and receives a substantial amount seed-money, it should focus on issuing direct loans to the consumers. Substantial equity begins to make loans economically viable. A revolving fund can be formed to provide loans out of its capital accounts, directly to the consumer. When one borrower repays its obligation, the fund can issue a subsequent loan to an additional borrower. A revolving fund's level of capitalization limits the number of programmes that it can undertake when it chooses to issue direct loans. In other words, because loans come directly from its seed-money, the utility could only loan as much money as it had to lend. Depending on the need for capital requirements the fund administrators could choose to subsidize loans, to break even on its loans, or to generate operating profits. This decision will determine the number of future programmes that the utility will be able to undertake.

(ii) Create Awareness First of all customer awareness campaigns must be mounted. These should not only tell consumers to "save energy" but also how to do it. Although a comprehensive list of various technologies are available most of the data are old and outdated. The consumer needs to know how many energy conservation opportunities exist, and what the capital needs are to pursue these opportunities. The information constraint inherent with dealing with multiple small, decentralized facilities. The government should conduct workshops/training programmes for the consumers. They should write to superintendents of public schools, state colleges, and private school headmasters. They should submit press releases to newsletters of hospital associations and so on.

(iii) Develop Institutional Mechanism A decentralized institutional mechanism is required so that quick decision-making can be possible. This allows various agencies to act on their own initiative, so that lag times and delays would be minimized, since the agencies would stand to gain by acting quickly. However, changing institutional practices has high political costs, but the benefits that accrue through decentralized decision-making results in more efficient outcomes. Another thing the government should do is to identify outdated institutional practices and think about appropriate solutions for barriers to implementation of efficient technologies. A programme should be developed separating operating expenses from capital expenditures, discourages inefficiency, and creates incentives for energy conservation resulting in environmental friendly practices. The consumers are encouraged to perform an "energy audit" to determine where they can conserve these resources. Often capital expenditures would conserve energy, and the savings in electricity bills would pay for the capital improvements. The alternative solution is to address the underlying disincentives, so that economic motivation replaces political motivation as the driving force for implementing conservation programmes.

The more general consideration is that consumers would become responsible for making their own decisions on efficient technologies. Given an economic incentive, consumers would adopt efficient technologies as soon as the present value of such programmes became positive (i.e., as soon as the long-term benefits outweighed the short-term costs). The government cannot be expected to provide incentives to each programme, regardless of the benefits to the society, since many programmes are too small for a centralized agency to handle.

(iv) Remove Barriers to implementation. The primary barriers to energy efficiency are financial and bureaucratic. State agencies do not propagate efficiency because they do not have access to capital and other resources necessary to achieve efficiency -- that's the financial barrier. The agencies also do not practice efficiency because they are subject to rules which disallow them from following economic incentives -- that's the bureaucratic barrier. If financing were available for efficiency programmes, state agencies would implement them, given an internal environmental motivation or an external political motivation.

"Reinventing" is necessary to remove the bureaucratic barriers: the budget would have to allow agencies to spend their funds as they see fit, and to keep any savings that they generate. If the bureaucratic barriers are removed, economic motivation would combine with both environmental motivation and political motivation in achieving the goal.

7. CONCLUSIONS

An energy efficiency scenario has been developed for the household sector in India with a ten-year perspective, i.e 2010A.D. The scenario uses the data from the National Sample Survey and from equipment manufacturers' catalogs. According to this scenario, by the year 2010 A.D, energy saving of 3,230 PJ during the year 2010 is possible. The equivalent cost of saved energy is Rs 7,000/GJ which is much lower than the capital investment required for supplying energy, typically ranging around ten times higher. From the consumer point of view most of the technologies are cost effective with a payback period of about two years. Also, energy efficiency programs offer the largest rewards to the society in the form of emission reductions. To achieve the goal of efficiency, an institutional mechanism should be evolved through which the existing fragmented limited scale markets should be transformed into a greater and more flexible one. Such an institution should act as a coordinator between various stakeholders such as the customer, electric utility, energy supply agencies, equipment manufacturers and other key players. For this to happen, new tools and new rules must be explored that can overcome the critical market barriers to promote energy efficiency programmes.

Implementation of energy efficient technologies, particularly in India, is a slow process and requires joint efforts all the stakeholders as well as financial institutions. Each of these groups must be educated and convinced of efficiency benefits. Indian consumers often require demonstrations of each and every aspect of a new idea or technology before they can be convinced of its value. This need for a hands-on understanding of new concepts and technologies by all stakeholders slows the rate of efficient technologies' acceptance and program implementation. Demonstrations, seminars, workshops and one-on-one interaction with customers and counterparts should be used for effective penetration of efficient technologies. Secondly, the Indian consumer and social climate is very different from that of developed countries where energy efficiency programmes were developed and where they have been most widely implemented. Thus, energy efficiency program concepts, program details, and energy efficient technologies developed in the West often need to be modified for India.

In the light of all the changes that the energy industry is undergoing, the usefulness of integrated resource planning, and its success in meeting the goals of the customer, the government and the society will be based largely on the quantum of involvement of all players in this field --- electric utilities, oil companies, forest departments, consumers, equipment manufacturers, financial institutions, researchers, planners and finally the government.

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Table 1: Energy consumption by residential sector (mtoe)

Energy Carrier	1950	% of total	1960	1970	1980	1990	2000	% of total
Fuelwood	63.48	97.02	75.28	86.2	95	102	114	77.76
Coal/Charcoal	0.77	1.18	1.08	1.4	2.12	3.44	4.5	3.07
Kerosene	1.12	1.71	2.76	3.15	5.24	8.5	12.5	8.53
LPG		0.00		0.3	1.2	2.5	6.4	4.37

Table 2: Annualized Life Cycle Cost of various energy utilizing devices

Option	Capital cost (Rs.)	Life (years)	Energy consumption (family/ year)	Units	Price of energy (Rs/Unit)	Energy Cost per Year	ALCC (Rs. per year)	Total Annual Cost (Rs.)
Cooking								
Traditional wood stoves	25	5	1000	Kgs	1.5	1500	6.9	1506.9
Traditional Kerosene stoves	125	7	150	Litres	8	1200	27.4	1227.4
LPG stoves	2000	25	75	Kgs	17.25	1294	255.0	1548.7
Water Heating:								
Traditional wood stoves	25	5	500	Kgs	1.5	750	6.9	756.9
Traditional Kerosene stoves	125	7	80	Litres	8	640	27.4	667.4
Electric water heater	2500	20	360	kWhs	3	1080	334.7	1414.7
Lighting (at 5 Hours Usage per Day):								
Incandescent Lamps (60 Watt)	12	1000	109.5	kWhs	3	328.5	23.9	352.4
Incandescent Lamps (100 Watt)	13	1000	182.5	kWhs	3	547.5	25.9	573.4
Fluorescent Tube (36 Watt)	180	8000	84.0	kWhs	3	251.85	55.2	307.0
Kerosene lamps	100	7	48.0	Litres	8	384	21.9	405.9

*In the case of Fluoresecnt Tube, the tube has a life of 6000 Hrs and the Choke has a life of 13000 Hrs.Therefore, an average life of 8000 Hrs. is used.

Table 3: Costs and Benefits through various technologies

From	To	Incremental 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)	Carbon savings
Cooking:										
Traditional wood stoves	Efficient wood stoves	225	937.7	62.22	416.75	0.24	37.3	16.0	2.33	0.58
Traditional wood stoves	Traditional Kerosene stoves	100	279.5	18.55	279.55	0.36	20.5	17.3	1.19	0.63
Traditional Kerosene stoves	Efficient Kerosene Stoves	125	543.1	44.25	434.51	0.23	16.9	3.2	5.35	0.06
Traditional wood stoves	Biogas	9975	-133.1	27.34	6.18	16.17	1268.1	23.8	53.33	0.86
Traditional Kerosene stoves	Biogas	9875	-652.6	-66.09	-6.61	-15.13	1247.6	5.2	240.99	0.10
Traditional wood stoves	LPG stoves	1975	-357.6	-23.73	-18.10	-5.52	248.1	20.1	12.35	0.63
Traditional Kerosene stoves	LPG stoves	1875	-637.1	-51.91	-33.98	-2.94	227.6	2.8	80.29	0.05
Water Heating:										0.00
Traditional wood stoves	Efficient wood stoves	225	337.7	44.61	150.08	0.67	37.3	8.8	4.24	0.32
Traditional wood stoves	Traditional Kerosene stoves	100	153.5	20.29	153.55	0.65	20.5	9.6	2.14	0.18
Traditional Kerosene stoves	Efficient Kerosene Stoves	125	415.1	68.80	332.11	0.30	16.9	2.4	6.94	0.05
Traditional wood stoves	Solar water heaters	11975	-1005.0	-132.77	-8.39	-11.92	1755.0	12.8	137.11	0.46
Traditional Kerosene stoves	Solar water heaters	11875	-1158.5	-192.00	-9.76	-10.25	1734.5	3.2	535.34	0.06
Traditional wood stoves	Biogas	9975	616.9	27.34	6.18	16.17	1268.1	23.8	53.33	0.86
Traditional wood stoves	Electric water heater	2475	-641.8	-84.79	-25.93	-3.86	311.8	11.5	27.10	0.42
Traditional Kerosene stoves	Electric water heater	2375	-795.4	-131.82	-33.49	-2.99	291.4	1.9	149.88	0.04
Electric water heater	Solar water heaters	9500	-363.1	-25.96	-3.82	-26.16	1443.1	1.3	######	0.02
Lighting (at 5 Hours Usage per Day):										0.00
Incandescent Lamps (60 Watt)	Compact Fluorescent Lamp (10 Watt)	163	241.3	68.48	148.05	0.68	21.5	0.3	68.11	0.005
Incandescent Lamps (100 Watt)	Compact Fluorescent Lamp (18 Watt)	217	404.2	70.50	186.29	0.54	33.8	0.5	64.22	0.009
Incandescent Lamps (100 Watt)	Fluorescent Tube (36 Watt)	209	253.5	44.21	121.30	0.82	42.1	0.4	118.76	0.006

Table 4: Impact of efficient technologies

Region		**Shift**			**Savings**					
Rural	**Income group**	**From**	**To**	**Incremental investment**	**Wood (million tonnes)**	**Coal (nillion tonnes)**	**Oil (million tonnes)**	**Savings (PJ)**	**Avoided emissions**	**Cost of avoided emissions (Rs/tonne)**
Cooking/heating	Low-income	Traditional Wood stoves	Eff.stoves	810.51	16.99			271.89	8.16	99.38
		Traditional Kerosene stove	Eff.stoves	16.91			0.03	1.20	0.02	757.30
	Middle income	Traditional Wood stoves	Eff.stoves	270.17	5.74			91.84	2.75	98.07
		Traditional Wood stoves	Biogas	219.51	4.46			71.43	2.14	102.45
		Traditional Kerosene stove	Eff.stoves	84.55			0.15	6.94	0.13	653.11
		Traditional Wood stoves	LPG	118.20	2.55			40.82	1.22	96.54
	High income	Traditional Wood stoves	Eff.stoves	33.77	0.69			10.99	0.33	102.41
		Traditional Wood stoves	Biogas	50.66	1.03			16.49	0.49	102.41
		Traditional Wood stoves	LPG	82.74	1.72			27.48	0.82	100.36
		Traditional Kerosene stove	Eff.stoves	236.74			0.39	17.60	0.33	720.59
		Traditional Wood stoves	Solar water heaters	91.18		1.89		54.80	1.04	87.74
Lighting		Lighting	CFL			52.5		1522.50	31.50	0.00
Total				2014.94	33.18	54.39	0.57	2133.98	48.95	41.17
Urban										
Cooking	Low-income	Traditional Wood stoves	Eff.stoves	191.52	3.88			62.08	1.86	102.85
		Traditional Kerosene stove	Eff.stoves				0.237	0.01	0.20	0.00
	Middle income	Traditional Wood stoves	Eff.stoves	41.832	0.847			13.55	0.41	102.91
		Traditional Kerosene stove	Eff.stoves				0.299	0.01	0.22	0.00
		Traditional Wood stoves	LPG	178.92	0.363			5.81	0.17	1027.00
		Electrical water-heater	Solar water heaters					0.00	0.00	
	High income	Electrical water-heater						0.00	0.00	
Lighting		Lighting	CFL			35		1015.00	21.00	0.00
	Total			412.272	5.09	35	0.536	1096.459	23.86	17.28
	Grand total			2427.22	38.27	89.39	1.11	3230.44	72.81	33.34