India: Access of the Poor to Clean Household Fuels

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Joint United Nations Development Programme (UNDP)/
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Acknowledgments

This report presents the results of the study "Access of the Poor to Clean Household Fuels in India," undertaken by the South Asia Environment and Social Development Department of the World Bank with support from the Energy Sector Management Assistance Programme (ESMAP), a joint program of the United Nations Development Programme (UNDP) and the World Bank. The financial assistance of the Government of the Netherlands through ESMAP is gratefully acknowledged.

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Abbreviations and Acronyms

APL	above the poverty line
BPL	below the poverty line
CO	carbon monoxide
CPI	consumer price index
ESMAP	Energy Sector Management Assistance Programme
FSU	first sampling unit
GDP	gross domestic product
GoAP	Government of Andhra Pradesh
LPG	liquefied petroleum gas
NSS	National Sample Survey
p.c.	per capita
PDS	public distribution system
PM	particulate matter
PM_{10}	particles with an aerodynamic diameter of less than 10 microns
$PM_{2.5}$	particles with an aerodynamic diameter of less than 2.5 microns
RS	reduced subsidy
RSPM	respirable suspended particulate matter
UNDP	United Nations Development Programme
WHO	World Health Organization

Units of Measure

kg	kilogram
km^2	square kilometers
MJ	megajoules
Rs	Indian rupees
?**g/m^3**	micrograms per cubic meter
?**m**	micron (one-thousandth of a millimeter)

Executive Summary

1 About three-quarters of all households in India, comprising more than nine-tenths of rural households and one-third of urban households, used traditional biomass—wood and dung—as a household fuel in 1999–2000. Approximately half a million premature deaths and nearly 500 million cases of illness are estimated to occur annually as a result of exposure to smoke emissions from biomass use by households in India, making indoor air pollution the third leading health risk factor. Young children (under five years of age) and women are affected disproportionately. Traditional biomass use has other adverse social impacts: principal among these is that biomass fuel collection can take long hours and entail significant drudgery, consuming time that could be used for other important activities such as childcare, school study, or leisure.

2 There are a number of options for mitigating the negative effects of traditional biomass use, ranging from behavioral change to better kitchen ventilation, more efficient stoves, or the use of cleaner fuels. One of the most effective measures is to switch to cleaner-burning fuels, liquid or gaseous, for all or most cooking. This study focuses on the two most commonly used commercial fuels in India that can mitigate the social costs of traditional biomass use: kerosene and liquefied petroleum gas (LPG). The objective of the study is to assess the effectiveness of the existing kerosene and LPG price subsidies in facilitating a shift to these fuels; the impact of subsidy phase-down and possible subsidy restructuring on household fuel-use patterns; and alternative policies to promote kerosene and LPG, with a special emphasis on the poor.

Kerosene and LPG Markets in India

3 The Government of India provides large universal price subsidies for kerosene and LPG. The subsidized fuels are handled exclusively by state oil companies. In 1993, the government allowed private marketers to begin selling kerosene and LPG, but at market-based, rather than subsidized, end-user prices. This unequal treatment of the private marketing companies has made it very difficult for them to expand their market share. The allocation of subsidized kerosene by the central government varies from state to state, with an urban bias in a number of states. Because LPG is a relatively expensive cooking fuel, and because most users reside in urban areas where there is more cash income and free biomass is often not readily available, the distribution of subsidized LPG historically has been confined largely to urban areas. It has also been seriously supply-constrained: until recently there was a long waiting list to sign up for subsidized LPG (in April 2000 the list extended to more than 6 million users).

4 The subsidies were scheduled to come down substantially by the time of downstream petroleum sector deregulation in April 2002, but partly on account of the recent

high international prices the subsidy phase-down has fallen behind schedule. In fiscal 2002–03 (April 1, 2002 to March 31, 2003) these subsidies, which previously had been managed through cross-subsidies from other petroleum products using the Oil Pool Account, were made explicit for the first time in the national budget. For LPG and kerosene, the Ministry of Finance allocated Rs 45 billion (approximately US$1 billion). Because of rising international prices, the actual subsidy was much higher, at more than Rs 100 billion, of which the government outflow was Rs 63 billion (Business Standard 2003a). The shortfall was picked up by the four state oil companies (Business Standard 2003b). The government has increased the explicit subsidy to Rs 81 billion for fiscal 2003–04 (Business Standard 2003c).

Approach

5 This study used the 1993–94 and 1999–2000 data from the National Sample Survey (NSS), the largest household survey in India. The NSS asked questions about the quantities and values of different household energy sources, including firewood, dung, kerosene, LPG, and electricity. To gain a better understanding of the determinants of household fuel use patterns, this study used the 1999–2000 NSS data to create detailed models of household energy consumption. The purpose was to quantify how different parameters influenced household fuel choice and the amounts of fuel consumed; the modeling was used also to estimate the impact of phasing down subsidies and introducing measures to protect the poor. A number of policy scenarios were investigated, including different degrees of subsidy phase-down and cash transfer to compensate for fuel price increases. To strengthen the conclusions drawn here, international experience with kerosene and LPG subsidies additionally was reviewed for comparison with the study findings.

Summary of Findings

6 The price subsidies for kerosene and LPG continue to be fiscally unsustainable and difficult to contain, as illustrated by the need to virtually double the initially planned subsidy amount in fiscal 2002–03 and to increase by 60 percent the subsidy allocation for fiscal 2003–04. These subsidies bear large opportunity costs. The subsidy figure of Rs 63 billion for fiscal 2002–03 was the same order of magnitude as the entire central government's spending on education—the Central Plan allocation for education was Rs 62 billion, of which Rs 43 billion was set aside for primary education (The Tribune 2003)—and markedly higher than the Rs 4 billion allocated for rural employment programs (The Hindu 2002). Furthermore, an analysis of NSS data suggests that these subsidies are of little help in meeting social policy objectives.

7 The subsidies appear seriously mistargeted. The price subsidy for LPG accrues disproportionately to the rich: three-quarters of the subsidy went to urban households in 1999–2000, four-fifths of whom were in the top half of the population by expenditure. The kerosene subsidy appears to carry a large leakage: as much as half of the subsidized kerosene in 1999–2000 is estimated to have been diverted to the black market or other sectors, most prominently the automotive diesel sector, at a cost to the central government of Rs 40 billion (close to US$1

billion). The consumption of subsidized kerosene that reaches households is at least distributed more or less uniformly across income groups. However, the ineffectiveness of the subsidy and its delivery mechanism is further illustrated by the finding from NSS that even the poorest households buy some market kerosene for lighting, even though the total amount of kerosene they use can be less than the allocated subsidized quota. Given the high level of diversion of subsidized kerosene and the concentration of LPG use among higher-income households, it must be concluded that subsidies for neither fuel are effective in promoting equitable access.

Household energy use patterns

8 In rural areas, biomass fuel use is prevalent across all income groups and remained virtually unchanged between 1993–94 and 1999–2000, with more than 90 percent of rural households using wood, dung, or both. Mirroring the findings in other countries, wood consumption rises with increasing income among rural households, so that increasing income alone would not necessarily help to reduce wood use for some time. Close to 60 percent of all rural households were using cash-free wood in 1999–2000. In contrast, the use of LPG and kerosene as the primary cooking fuel was essentially nonexistent among rural households in 1999–2000; this applies across all income groups with the exception of the richest 10 percent. In short, supply conditions in rural areas favor the use of biomass for cooking because of its low labor costs and the ready availability of free biomass. This suggests that the effectiveness of fiscal instruments, such as changing relative fuel prices or increasing income relative to fuel prices, in promoting a switch from traditional biomass to petroleum fuels in rural areas would have serious limitations.

9 In urban areas over the same period, biomass use declined markedly and kerosene consumption also fell slightly, largely in favor of LPG. In 1999–2000, one-fifth of all urban households were still using biomass as the primary fuel. The percentage of urban households relying on cash-free wood was a mere 7 percent, considerably less than the corresponding figure in rural areas. About one-fifth of urban households were paying on average Rs 100 per month to purchase wood. One-sixth of households used purchased wood as their primary cooking fuel. They paid on average Rs 137 per month for wood, kerosene, and LPG, compared to Rs 176 per month spent by those who used LPG as the primary cooking fuel. They were also, on average, poorer than those who cooked mainly with LPG. At the same time, there are families in the poorer (lower) expenditure deciles that cook primarily with LPG, and families in the richer (upper) deciles that cook mainly with purchased wood. This illustrates that factors other than price and affordability (most prominently supply constraints, especially given that as many as 13 million households were on the waiting list in December 1999; other factors include customs and education) play an important role in household fuel choice. With continuing urbanization and the increasing scarcity of biomass driving up the market price of fuelwood, more and more urban households purchasing wood for cash are expected to opt for cleaner and more convenient fuels, provided that there is an efficient and well-functioning downstream petroleum market with competitive prices and no supply constraints.

10 Most rural households and many urban households use multiple energy sources for cooking and lighting. According to the NSS data, many households use modest quantities of kerosene for cooking, augmenting this kerosene with some use of biomass fuels. Other studies, in India and elsewhere, support the observation that traditional and modern fuels increasingly coexist in the household energy mix. The social benefits, such as health and time savings for women and children, of partial fuel switching—whereby wood continues to be used and only partially substituted by cleaner fuels—need to be better understood. Specifically, the health benefits of the smoke-free indoor environment that is achieved by full fuel switching from traditional biomass are likely to be compromised by partial fuel switching, but the exact effects of different combinations of fuels and stove technologies are hardly known. The benefit in the terms of time savings, however, is broadly in line with the amount of biomass used, and accrues to women even with partial fuel switching. To the extent that partial fuel switching is the first step toward full fuel switching and may accelerate the switch, efforts to promote the switch may be justifiable even should their immediate social benefits be limited.

Examination of alternative subsidy schemes

11 Analysis of household fuel choice in India, examination of alternative policies to the current subsidy schemes, and a review of international experience suggest that it would be difficult, if not impossible, to design an effective subsidy scheme for LPG and kerosene. Cash transfer to the poor to compensate for the subsidy phase-down or elimination, normally a sensible policy on account of the freedom of choice it gives to the recipients, does not seem suitable for promoting a shift in cooking fuel use toward more expensive clean fuels, particularly in rural areas. Modeling of the NSS data, consistent with international evidence, indicates that rural households conversely may use more wood if a modest amount of cash is given to them. This highlights the facts that switching to cleaner fuels is not a budget priority for many households, and that, in combination with other mitigation measures, raising awareness about the health benefits of modern household energy options could be one of the most effective interventions to facilitate fuel switching.

12 In the case of LPG, an interesting example of a different subsidy is the Deepam scheme in Andhra Pradesh. The scheme waived the cylinder deposit fee for its beneficiaries, targeting women from households that are classified as below the poverty line (BPL) and who are members of women self-help groups. Most beneficiaries live in rural areas. An assessment undertaken in 2000–01 of this scheme showed that urban beneficiaries used much more LPG than rural beneficiaries, LPG was used most extensively when there were opportunities for earning cash income (such as the agricultural season), and that for most beneficiaries wood remained the primary cooking fuel. Most households found it difficult to manage the cash payments for cylinder refills even with the large subsidy prevailing at the time, resulting in incidental use of LPG for making tea or preparing meals for unexpected guests. Overall, and raising questions about its effectiveness, the scheme facilitated the uptake of LPG but failed to encourage the substantial and sustainable use of LPG by its intended primary beneficiaries, the rural poor.

13 Exploring alternative ways of providing the kerosene subsidy to the poor merits special consideration because households without connection to or the reliable supply of electricity have little choice but to continue using kerosene. In the longer term, this issue is expected to be addressed by greater access to and better quality of electricity service, but the situation in the interim is a cause for concern. This concern notwithstanding, it was not possible to identify a viable mechanism to better target and deliver the kerosene subsidy. The subsidy is inherently prone to significant leakage, as has been found consistently in countries with such subsidies, because kerosene is a perfect substitute for automotive diesel. The experience, notably of Nepal, further suggests that a coupon system, which in theory should enable better targeting and which can be effective for certain goods, does little to reduce kerosene leakage.

Impact of subsidy phase-down

14 The impact of subsidy elimination on poor, nonelectrified households using kerosene for lighting is estimated to be about Rs 30 per month (at the price levels observed in February 2003), or about 2 percent of the total household budget. (International oil prices were high in February 2003, and the long-term impact is expected to be smaller.) It is not obvious that this rather modest amount would justify a subsidy, especially since half of subsidized kerosene is diverted from its intended users. Given that many poor households would still likely have to buy some market kerosene, the overall impact would be even more modest.

15 The use by the poor of LPG and kerosene as primary cooking fuels was found in 2000 to be limited, even in urban areas. Phasing down price subsidies would diminish the ability of the urban poor and of low-middle-income households to use cleaner petroleum fuels. This concern does not, however, outweigh the problems associated with the current subsidies, especially given the positive impact on market competition and innovation of removing price subsidies.

16 The elimination of price subsidies would be expected to have a large impact on the structure and nature of the downstream petroleum sector in India, because historically only state oil companies have been permitted to market subsidized fuels. This fact has stifled the growth of private marketers for kerosene and LPG, substantially curtailing new entry and competition. International experience amply demonstrates that creating a market environment in which fair and healthy competition flourishes is the most effective way to expand the supply and availability of competitively priced kerosene and LPG. At a minimum, such a market environment should help to make more LPG and kerosene available to those households that are able and willing to pay to switch to these fuels.

17 A competitive market also would encourage market innovations and experimentation with different schemes to help households take up and use petroleum fuels. Schemes such as installment plans to cover the cylinder deposit fee have been tried in the past by private LPG marketers in India and have been helpful; they have however not lasted long, because private marketers cannot compete with the state oil companies selling heavily subsidized LPG. In Guatemala, where the LPG market is completely liberalized, installment

payment plans to cover the purchase of a suitable stove and to cover the cylinder deposit fee are common and are helping to facilitate LPG uptake among low-middle-income families.

A Way Forward

18 **There is a strong case for phasing out price subsidies for LPG and kerosene.** This study was motivated by the primary objective of facilitating access to clean fuels, given the significant health and social benefits of switching away from traditional biomass. Price subsidies have been found to be ineffective in expanding the uptake of LPG and kerosene as primary household fuels among the poor, and have proven fiscally unsustainable. Even given this social objective, phasing out the price subsidies for LPG and kerosene and fostering a vibrant, open, and competitive market for these fuels would appear to be a better approach. The conclusions of this study lend strong support to the announcement by the Ministry of Finance in June 2003 that the LPG and kerosene subsidies will be phased down in three years and eliminated by April 2006 (Business Standard 2003d).

19 **There are ways to ease the impact of subsidy phase-down on consumers**. Given the subsidy framework in India, subsidy phase-down would be easier for the government when international prices are low, when the subsidy element is small and the impact on households of the phase-down correspondingly small. When international prices are falling, by maintaining end-user prices constant the government may be able to effectively shrink the subsidy component to the point where its removal results in little or no price increase. By phasing down subsidies over three years, the proposal by the Ministry of Finance provides, in principle, sufficient opportunities to implement this approach and eliminate subsidies in a relatively smooth manner, avoiding large price shocks for consumers.

20 **No effective subsidy mechanism for kerosene or LPG seems to exist**. Neither the analysis of consumer energy choice in India nor international experience could point to any viable subsidy scheme for these petroleum fuels. This is because both kerosene and LPG have attractive alternative uses among the nonpoor, such as vehicle owners, and the poor may have other cash expenditure needs that, when traditional biomass is widely available, they consider a higher priority than modern cooking fuels. LPG furthermore is strongly favored by the rich as a cooking fuel. Any subsidy for these fuels, regardless of its design, therefore is subject to significant leakage, mistargeting, or both. In addition, unlike water, electricity, or natural gas networks, for which access is predicated on the larger community choosing to establish the necessary supply infrastructure, the distribution of kerosene and even LPG relies on the individual household’s ability and willingness to pay the start-up (stove and cylinder) and operating (fuel) costs. These operating costs furthermore are relatively high compared to the start-up costs (the ratio of the operating to start-up costs is much higher than for water, electricity or natural gas), limiting the effectiveness of subsidizing the start-up costs for the poor, as illustrated by the Deepam scheme. All these factors compound the difficulties of designing a subsidy to facilitate a shift by low-income households to kerosene or LPG.

21 **There is a need to identify other options to promote cleaner household energy, inside and outside the petroleum sector, that are more effective and viable.** The prospects for fuel switching, supported by government interventions, are distinctly different for urban and rural areas. Access to free or cheap biomass and the availability of income-generating opportunities for those currently spending time on biomass collection and cooking are critical factors in determining consumer choice, and clearly are more supportive of a shift to petroleum fuels in urban than in rural areas. To the extent biomass is traded for cash or has clear opportunity costs (such as during the harvesting and monsoon seasons) in rural areas it also is influencing fuel choice, albeit on a much smaller scale, both in terms of the percentage of households using commercial fuels and the relative share of these fuels in the total household energy mix. The following are some possible solutions and approaches that take account of these urban/rural differences:

?? **For LPG and kerosene, the best way to promote access and uptake in the long run is to liberalize the downstream petroleum market.** To this end, a necessary step is to phase out subsidies that cause market distortions, impede new entry and competition, and slow down the development of efficient markets.

?? **An important role of the government is to establish and enforce adequate technical and safety standards, and ensure consumer protection**, especially against under-filling of LPG cylinders. This merits special attention in the early days of rapid LPG market development, as international experience suggests that in a market with a large number of operators and little enforcement, accidents and commercial malpractice can become common.

?? **There are significant opportunities to facilitate a shift away from traditional biomass to clean fuels in urban and peri-urban areas, including among the poor.**

- Urban and peri-urban households would be among the primary beneficiaries of a fully liberalized, competitive market for LPG and kerosene which will increase the uptake of these fuels among those able to pay.
- There is also scope for expanding the market for these fuels by introducing incentives for low-middle-income households. Neither kerosene nor LPG is likely to become the primary cooking fuel of the poor, but households that are higher on the income ladder, not the very poor but who are nevertheless not rich, would consider switching to LPG if they could afford the cylinder connection fee. Market-based schemes to help these households pay the start-up cost of LPG could be quite effective. These schemes are more likely to be successfully implemented in a competitive market.
- For those poorer urban and peri-urban households that cannot afford LPG or kerosene but purchase wood for cash, improved (cleaner and more efficient) biomass stoves and fuels (such as biomass waste briquette technologies) may be a cheaper attractive option.

- In the long term, promoting the use of natural gas in cities with gas pipelines merits consideration, particularly in view of the recent gas discoveries in eastern India. Establishing a distribution network for household use is expensive. Nevertheless, natural gas is well suited for a targeted subsidy: diversion is difficult and there is the option of cross-subsidizing a small first block (lifeline tariff) by higher blocks. The gas tariff structure should be carefully designed to allow the urban poor to use natural gas to meet most of their household energy needs without unduly subsidizing middle- and upper-income households.

?? **Rural households are more difficult to deal with and require a concerted multisectoral approach over a long period of time.**

- Establishing an open and competitive market for petroleum fuels would also help, even though to a smaller extent than in urban areas.
- Fostering economic growth, employment opportunities (particularly for women), and rural infrastructure development have the collateral benefits also of facilitating fuel switching.
- Accelerating the viable expansion of rural electrification is of special importance, because in addition to reducing the need for kerosene for lighting it has in a number of countries been found to be strongly correlated with the uptake of clean fuels for cooking.
- Given that biomass will for the foreseeable future remain the principal option for rural India, the promotion of cleaner biomass-based household energy technologies (such as biomass briquettes, biogas, improved stoves, and other appliances) needs to be given greater attention. To be sustainable, solutions to rural household energy should be demand-driven and commercially oriented. In particular, it is important to determine what types of biomass-based and other cleaner energy technologies are likely to work for different economic circumstances and household preferences. Any technological alternatives to free or cheap traditional biomass will be widely adopted only if the incremental costs are affordable and outweighed by tangible nonmonetary benefits valued by the user.
- When seeking to facilitate a long-term shift to clean household fuels and other energy technologies, it is important to identify and target areas where the chances of switching are highest—that is, those with limited access to free biomass where many households must purchase wood for cash; areas where houses are electrified, and areas where there are income opportunities that enable households to purchase commercial energy products and services on a regular basis.

22 **Raising public awareness about the health costs of traditional energy would further facilitate the uptake of clean fuels**. One of the most important and effective

roles of the government is to educate the public about the adverse health impacts of traditional household energy and the benefits of using cleaner fuels, as well as other options including the benefits of increasing stove efficiency. In the early stage of consumer education, the government may consider providing seed money for the development of more efficient, more durable stoves. Public awareness of the adverse impact of indoor air pollution could encourage households to reduce their exposure to smoke emissions and, among those who can afford to switch out of traditional biomass, such as higher-income households in rural areas, to seriously consider switching to kerosene, LPG, or biomass-based clean technologies for cooking.

1

Background

1.1 According to the National Sample Survey (NSS) conducted in 1999–2000, more than 70 percent of all households in India used solid fuels? mostly biomass, such as firewood and dung, but also coke and coal? as their primary cooking fuels. Sixteen percent reported using mainly gaseous fuels. For convenience, cleanliness, and public health, gaseous fuels such as liquefied petroleum gas (LPG) or piped natural gas are the preferred fuels for cooking, followed by kerosene.

1.2 By far the most serious consequence of the household use of solid fuels in traditional stoves is the damage caused to health, in terms of increased morbidity and premature mortality. This disproportionately affects children and women. The air pollution level resulting from the combustion of solid fuels can in extreme cases be as much as two orders of magnitude higher than the levels considered acceptable for health. Solid fuels also are time-consuming to cook with, because it takes more time to get the fire going than when LPG or kerosene is used and it takes more time to clean up afterward, on account of soot deposition. For households using free biomass, biomass collection furthermore can entail significant drudgery and time. While biomass fuel in principle can be sustainable, its excessive use has led to deforestation in some parts of the world.

1.3 This work builds on an earlier ESMAP program, "India: Household Energy, Indoor Air Pollution, and Health," which examined the patterns of exposure to indoor air pollution arising from the domestic use of traditional biomass, and the different options for mitigating its health impact (World Bank 2002a). An important policy question that this new study attempts to address is under what circumstances the government could cost-effectively intervene to help accelerate a shift from traditional biomass to liquid and gaseous fuels, and how. The study was proposed at a meeting held in Delhi in November 2000 with the Planning Commission and the Oil Coordination Committee (now Petroleum Planning and Analysis Cell) of the Ministry of Petroleum and Natural Gas. Its scope was further discussed and agreed with these agencies in March 2001.

Health Impact of Exposure to Emissions from Solid Fuel Use

1.4 *The World Health Report 2002*, issued by the World Health Organization (WHO), estimates that indoor air pollution from household use of solid fuels is the fourth leading health risk in developing countries with high mortality (WHO 2002). Worldwide, exposure to smoke emissions from the household use of solid fuels is estimated to result in 1.6 million deaths annually. Recent estimates suggest that the annual impact of solid fuel use by households in India is approximately 500,000 deaths and nearly 500 million cases of illness (Von Schrinding and others 2001). The health effects that have been linked to household fuel smoke in developing countries include acute upper and lower respiratory illnesses (which are the leading cause of child mortality under the age of five in India), chronic bronchitis, chronic obstructive pulmonary disease, asthma, cataracts (of which India has the highest incidence among women), and tuberculosis.

1.5 The most damaging pollutant—in terms of the combined effect of quantity and toxicity emitted during the combustion of solid fuels—is particulate matter. Numerous studies conducted worldwide have demonstrated that even at levels much lower than those observed with indoor air pollution, small particles, and especially those smaller than 2.5 microns (2.5 ? 10^{-6} meters), have statistically significant associations with morbidity and premature mortality. Epidemiological studies examining the relationship between ambient concentrations of particles and health outcomes increasingly are focusing on particles smaller than 10 microns (PM_{10}) and those smaller than 2.5 microns ($PM_{2.5}$; also called fine particles). A recent study, the largest to date, indicates that an increase in long-term exposure to $PM_{2.5}$ by 10 ?g/m^3 leads to a 4, 6, and 8 percent increase in the risk of all-cause mortality, cardiopulmonary mortality, and lung cancer mortality (Pope and others 2002). Table 1.1 gives an example of the numbers commonly used to assess the impact of the short-term (acute) and long-term (chronic) exposure to particulate air pollution in Mexico City (Cropper 2002). The table shows the health effect of increasing the daily average ambient concentration of PM_{10} by 10 micrograms per cubic meter (?g/m^3).

1.6 One problem with using the findings of epidemiological studies of urban air pollution on PM_{10} and $PM_{2.5}$ to estimate the impact of indoor air pollution is that particulate concentration levels and exposure patterns are can vary dramatically in the case of indoor air pollution. Mean concentration levels are much higher, and the variation between the peak concentration during cooking and concentrations during noncooking hours is considerably greater than variations typically observed in urban air. The health impacts of short but regular exposure to very high concentrations are not well understood. The relationships between air pollution and health effects, referred to as concentration–response functions, have been obtained for PM_{10} levels typically lower than 100 ?g/m^3, and often lower than 50 ?g/m^3. Transferring these concentration–response functions, obtained mainly in industrial countries, for application to indoor air pollution introduces a number of problems, including how to extrapolate these correlations to ambient concentration levels considerably above the maximum observed in the original studies and how to account for differences in confounding factors (other factors that affect health, such as dietary habits, income, education, and occupational exposure).

There are very few studies examining direct evidence correlating exposure to indoor air pollution with health outcomes (for an example, see Ezzati and Kammen 2001). Most studies have tried to correlate fuel use and personal activity patterns with health outcomes. Lack of data and analysis in this area is a serious limitation requiring of further investigation.

Table 1.1 Impact on Health of a 10 ? g/m³ Change in Daily Average PM_{10}

Health outcome	*Percentage change*
Morbidity: Acute exposure	
Hospital admissions due to respiratory problems	1.4
Hospital admissions due to cardiocerebrovascular problems	0.6
Hospital admissions due to congestive heart failure	1.2
Emergency room visits for respiratory problems	3.1
Respiratory symptoms	
Upper respiratory	4.4
Lower respiratory	6.9
Acute bronchitis	11.0
Effects in asthmatic	
Asthma attacks	7.7
Cough without phlegm (children)	4.5
Cough with phlegm (children)	3.3
Cough with phlegm and bronchodilator usage	10.2
Morbidity: Chronic exposure	
Additional cases of chronic bronchitis	3.6
Prevalence of chronic cough among children	0.30
Mortality: Acute exposure	3.8
Mortality: Chronic exposure	1.0

Source: Cropper (2002)

Exposure Patterns in Rural India

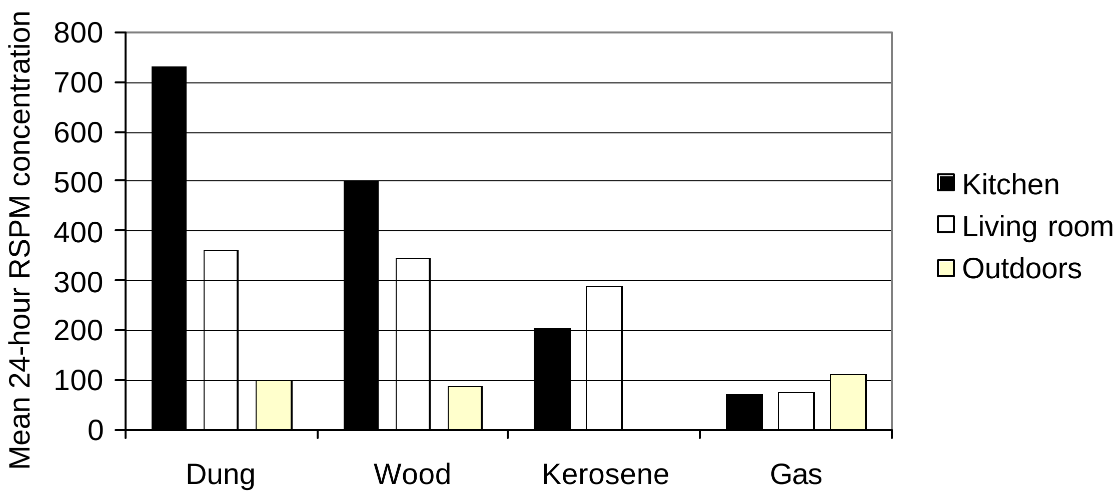
1.7 An exposure assessment study carried out in the state of Andhra Pradesh gives a good overview of the effects of ambient concentrations of small particles and varying exposure levels on different members of households using different fuels (World Bank 2002). In this study, concentrations of respirable suspended particulate matter (RSPM)—effectively, particles smaller than 4 microns (or PM_4) in this assessment—were measured in 412 households.[1] These

[1] Gravimetric measurements of RSPM approximate those of $PM_{2.5}$. In this study, the mass ratio of RSPM to PM_{10} ranged from 0.57 to 0.75, with a mean of 0.61.

households fell in roughly equal numbers into each of the four following kitchen configurations: an indoor kitchen without partitions from the living areas; an indoor kitchen with partitions from the living areas; a separate kitchen outside the house; and outdoor, open-air cooking. Unfortunately, it was not possible to have comparable numbers of households using different fuels. The most prevalent fuel type was wood (270 households), followed by dung with kerosene used for starting the fire or dung combined with wood (97 households), LPG or biogas (34 households), and kerosene (11 households).

1.8 RSPM concentrations in different parts of the house averaged over 24 hours as a function of household fuel type are shown in Figure 1.1. Of the four fuels studied, dung gave rise to the highest ambient concentrations in the kitchen area. Although still elevated, ambient concentrations inside gas-using houses were much lower than those in houses using other fuels. They also were lower than the outdoor levels, as gas essentially eliminates particulate emissions. The numbers in the figure should be compared to the 24-hour health-based PM$_{10}$ standard of 50 ?g/m^3 in the United Kingdom (to be achieved by end-2004) and 150 ?g/m^3 in the United States, and to the 24-hour PM$_{2.5}$ standard of 65 ?g/m^3 in the United States.[2]

Figure 1.1 RSPM Concentrations by Fuel Type (?g/m^3)



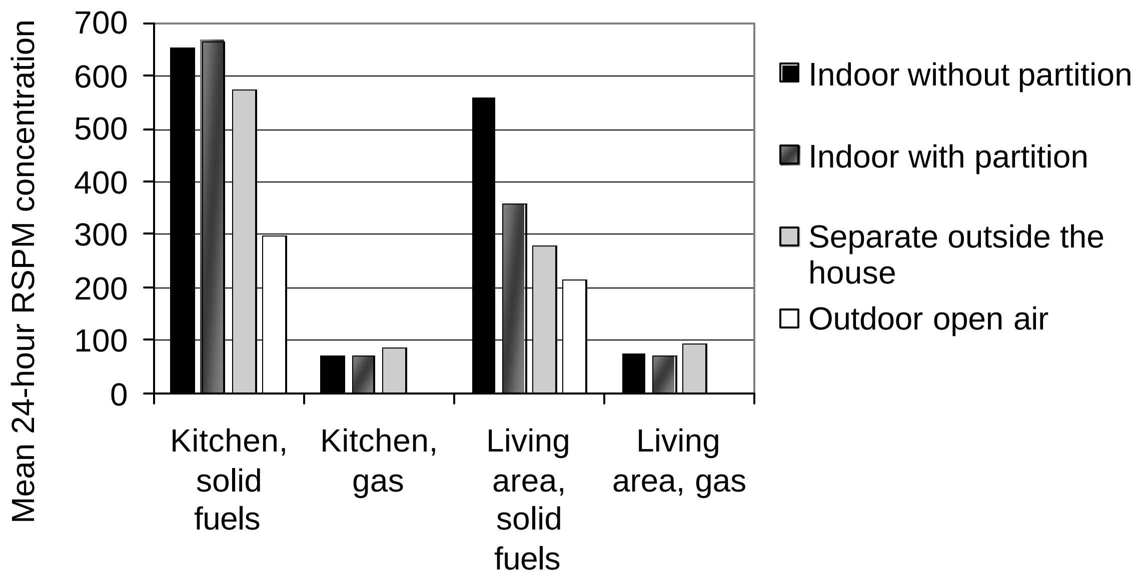
Note: Dung refers to households using dung and wood, or dung with small amounts of kerosene to start the fire.

1.9 The impact of different kitchen configurations on 24-hour ambient concentrations of RSPM for households using solid (dung, wood, or both) and gaseous fuels is illustrated in Figure 1.2. As expected, an indoor kitchen with no partitions led to ambient concentrations in living areas that are not markedly lower than those in the kitchen for solid-fuel-using households. This implies significant exposure of other household members, in addition to the cook. Outdoor open-air cooking, which would allow more rapid dispersion of particulate

[2] The WHO has no numerical health-based guidelines for particulate matter, on the grounds that no safe threshold level has been found.

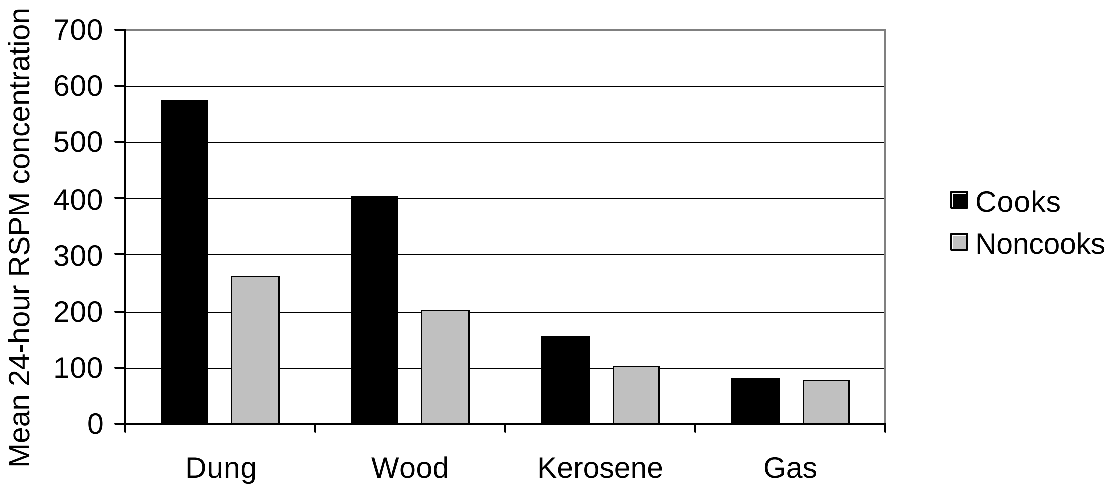
emissions from solid fuel use, lowered ambient concentrations, but these concentrations nonetheless remained alarmingly high where cooking was taking place, averaging 300 ?g/m³. Outdoor cooking next to the house also led to high indoor concentrations, averaging more than 200 ?g/m³. The impact on gas-using households of the use elsewhere in the village of solid fuels is suggested by the relatively high outdoor concentrations of RSPM. It is likely that the somewhat elevated concentrations of RSPM in gas-using households is due to these high background concentrations.

Figure 1.2 Impact of Kitchen Configuration and Fuel Type on RSPM Concentrations (?g/m³)



1.10 The 24-hour averaged exposure to RSPM for cooks and noncooks is plotted in Figure 1.3. The use of dung leads to the highest exposure level, which is nearly 50 percent higher for the cook than that due to wood use. This suggests that fuel switching within biomass from dung to wood alone may bring about some health benefits. The largest reduction in exposure for all household members, especially for cooks, comes from switching to gas. The high background concentration of RSPM suggests that switching away from solid fuels could have health benefits not only for the members of the household using the fuel, but also to their neighbors.

Figure 1.3 24-Hour Exposure for Cooks and Non-Cooks (? g/m³)



Note: Dung refers to households using dung and wood, or dung with small amounts of kerosene to start the fire.

Mitigation Options

1.11 There are a number of options for mitigating the adverse impact of indoor air pollution. These include behavioral change to minimize exposure, better housing design, greater ventilation of smoke, and the use of stoves and fuels with lower emissions. Some of these approaches are low cost, but their health outcome is dependent on the behavior of household members as well as on the operation and maintenance of the hardware used. Others are higher cost but can virtually guarantee smoke elimination. Additionally, it is noteworthy from the above exposure study that a number of factors that could not be identified appeared to affect ambient RSPM concentrations: among households using the same solid fuels, the concentration of RSPM and consequently exposure levels varied dramatically from house to house. Identifying the factors that reduce indoor air pollution levels is an important area for further study.

1.12 Behavioral change may be the most promising option for those who cannot afford cleaner fuels, cleaner stoves, or redesigned kitchens. This requires that household members be educated about the aspects of cooking that damage health so that they, and especially small children, are as far as possible kept out of harm's way. Using less fuel by cooking more efficiently—achievable by perhaps the simplest expediency of using a lid to prevent heat escape—is a helpful step under all circumstances.

1.13 Opening windows, installing chimneys in the kitchen, and otherwise venting smoke helps to lower the pollution level. Separating the cooking area and the living areas at the construction stage of a house is another mitigation approach.

1.14 Better stoves with lower emissions can lower ambient concentrations, but it is important that such stoves be properly operated and maintained to keep emissions low. Cleaner solid fuels, such as charcoal, can also help.

1.15 These measures, while mitigating the health impacts of indoor air pollution, are interim solutions and are unlikely to bring exposure down to health-based standards. The use of liquid and especially gaseous fuels remains the most effective way of dramatically reducing the adverse impact of indoor air pollution. Kerosene is cleaner than solid biomass, and gaseous fuels, second only to electricity, are cleaner again. A number of industrial countries have virtually eliminated indoor air pollution by switching entirely to natural gas, LPG, and electricity. There are other clean fuel alternatives, such as biogas, but their commercial application and impact has been so far very limited. This study addresses the option of switching to clean commercial fuels.

Study Description

1.16 This study focuses on the two commonly used commercial fuels in India that are capable of reducing or avoiding the health damage caused by the traditional use of biomass: kerosene and LPG. The objective of the study was to consider the impact on household fuel use patterns of the phase-down and possible restructuring of subsidies on kerosene and LPG, and to assess alternative policies to promote LPG and kerosene, paying particular attention to the poor.

1.17 The study analyzed the data from the 50th (1993–94) and the 55th (1999–2000) round of the National Sample Survey (NSS), the largest household survey in India. The NSS asked questions about the quantities of and expenditure on different household energy sources, including firewood, dung, kerosene, LPG, and electricity. The descriptive statistics obtained using the data from the 50th round were used to study the historical progression of household fuel use patterns. The data from the 55th round were examined in detail to model fuel consumption as a function of several explanatory variables, including fuel prices, household expenditures, and estimates of fuel availability.

Structure of the Report

1.18 Chapter 2 describes the characteristics of kerosene and LPG and the historical evolution of their respective markets in India. Chapter 3 provides descriptive statistics of household fuel use patterns, summarizing the findings of the 50th and the 55th rounds of the NSS. Chapter 4 details the modeling of household fuel choice and consumption behavior using the data from the 55th round. Chapter 5 interprets the results in light of international experience and other studies and presents conclusions and recommendations.

2

Kerosene and LPG Markets in India

2.1 Kerosene and LPG are the two principal clean household fuels in India that have substituted biomass for cooking. Two other alternatives, natural gas and electricity, are not commonly used because of a lack of general availability for household use, in the case of natural gas, and much higher cost, in the case of electricity. Biomass-based clean fuels, such as biogas, have not yet been commercialized, although there is significant interest in India in exploring the potential of nonhydrocarbon alternatives.

Characteristics of Kerosene and LPG

2.2 Kerosene, a liquid, does not a as a consequence burn as cleanly as gaseous fuels. It nonetheless is considerably cleaner than the biomass used in traditional stoves. One of kerosene's main advantages is that it is far easier to transport and distribute than gaseous fuels and, unlike LPG, can be purchased in any quantity. For households with cash constraints, the ability to buy kerosene in small quantities is attractive. Kerosene stoves, however, typically are more expensive than wood stoves.

2.3 Kerosene can also be used in gaseous form, but to do so requires equipment that is more expensive that that used to burn it in liquid form. To gasify kerosene, the liquid is pressurized and then released to the atmosphere. Starting a high-pressure kerosene stove is more time-consuming than starting an LPG stove, but cooking with gasified kerosene otherwise is similar to cooking with LPG. It does not deposit soot. Kerosene burned in a wick stove as a liquid, in contrast, emits soot, although not as much as does traditional biomass. The prices of high-pressure kerosene stoves are higher than those of wick stoves. While a number of urban households cook with kerosene, rural households tend to use it predominantly for lighting. As such, the market for kerosene in rural areas is closely tied to power sector reform and the availability of an affordable and reliable supply of electricity.

2.4 LPG is used worldwide for cooking and heating, especially in areas without connection to piped natural gas. It is a clean fuel. Two disadvantages of LPG for low-income households are its relatively high start-up cost and the large (lumpy) cash outlays needed for cylinder refills.

2.5 What distinguishes LPG from other fuels is cylinder management. Because LPG has to be stored under pressure, metal cylinders are required. To cover the cost of cylinder manufacture, an initial deposit fee is required. This may be in excess of US$20, and to this must be added the purchase cost of an LPG stove and possibly also the cost of cylinder deliveries. The combination of the start-up cost and the cash outlay at each refill (which typically cannot be broken up into smaller installments) presents a serious barrier to the uptake and regular use of LPG by low-income households.

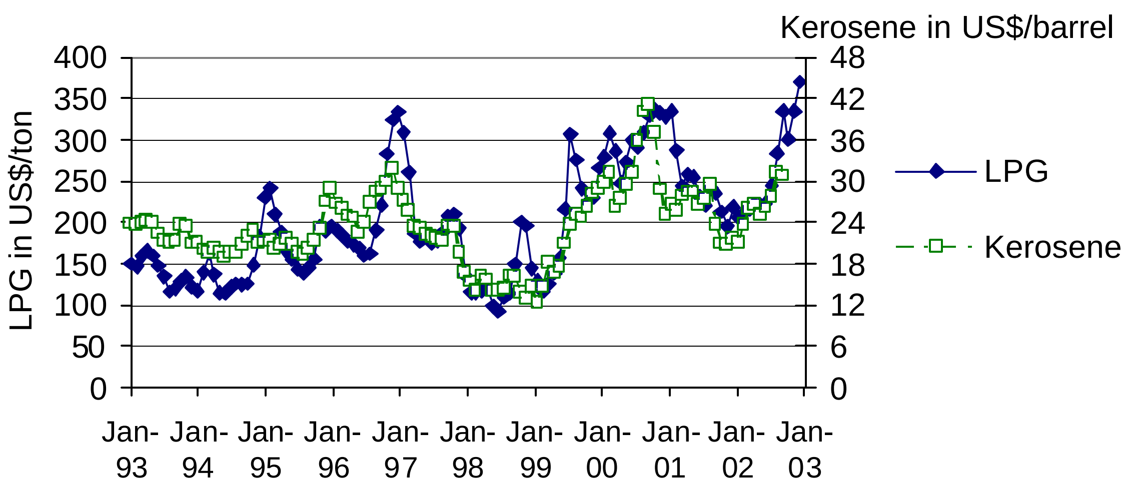
2.6 Another problem is assuring the reliable supply of refill cylinders. For small and remote markets, refills may be delivered once a week or once every other week. For those users that do not keep a second cylinder, this could mean going without fuel for as long as two weeks. Signing up for two cylinders to avoid running out of cooking fuel would further increase the start-up cost of LPG service. Again, this infrequent delivery of refill cylinders serves as a disincentive against switching entirely to LPG.

2.7 One option for reducing the "lumpiness" of LPG purchase is to provide smaller cylinders. With smaller cylinders, each refill costs less, potentially enabling low-income households to refill more regularly, and the initial cylinder deposit fee can be lowered. Smaller cylinders potentially yield double benefits: more regular LPG consumption by users, especially in rural areas, and a higher uptake rate of LPG. It is important to stress, however, that international experience with smaller cylinders is mixed: the negative aspects of small cylinders include (a) a much higher cost of cylinder management and hence higher per-unit LPG price and (b) the need for households to refill more frequently—a problem especially if cylinder delivery entails logistical difficulties (such as slow delivery or the need to arrange for cylinder pick-up when the dealership is far away).

2.8 For LPG dealers considering rural markets, low population density, poor road infrastructure, low LPG uptake, and low consumption among those who sign up for LPG can make it difficult to establish a commercially viable LPG distribution network. The lack of economies of scale in catering to rural domestic consumers is one of the main factors hindering ready access to LPG.

2.9 In a deregulated market, prices of kerosene and LPG are closely linked to their international prices, and these have fluctuated significantly in recent years. Figure 2.1 shows the average prices of kerosene and LPG in the Arabian Gulf for the past 10 years. The nominal price of kerosene ranged between the low of US$12 per barrel in February 1999 and a high of US$41 per barrel in October 2000. Similarly, the nominal price of LPG varied from a low of US$93 per metric ton in July 1998 to a high of US$370 in January 2003. Consumers in India have thus far been shielded from these large price fluctuations, but as the petroleum sector and pricing in particular become deregulated they will be increasingly exposed to the price volatility of the international market. Price fluctuations of this magnitude for something as essential as a cooking fuel would impose a disproportionate hardship on those, such as rural farming households, who do not have a reliable and steady source of cash income. Where wood is competing with kerosene and LPG (for example, in areas with depleted biomass), wood prices would also be expected to fluctuate in tandem with kerosene and LPG prices, but presumably not to the same extent. In rural areas where there is abundant biomass as an alternative, the viable use of LPG or kerosene as the primary cooking fuel would thus be restricted mainly to middle- and high-income families.

Figure 2.1 Average Arabian Gulf Prices of Kerosene and LPG



Source: Petroleum Economics Limited

Kerosene and LPG Markets in India

2.10 The Government of India historically has provided large universal price subsidies for kerosene (distributed through the Public Distribution System [PDS]) and LPG (sold by dealers working with state-owned oil companies). The subsidized fuels are handled exclusively by four state oil companies that have in the past enjoyed benefits over and above the price subsidies, including historically a guaranteed 12 percent return post-tax on net worth. This guaranteed fixed rate of return, and the assurance of a domestic market for LPG and kerosene, means that the focus in the past has tended to be on investment rather than on marketing and market analysis.

2.11 1993 marked the beginning of the liberalization of the petroleum sector, with the entry of the first private marketers. Private companies have historically been licensed to sell only imported fuels carrying no subsidies. In the 1990s, about one-half of the kerosene and one-third of the LPG consumed in India was imported. Subsidized fuel prices have been kept stable for the most part regardless of fluctuations in international prices, making it extremely difficult for private marketers to expand their market share. Private sector dealers realistically can be competitive only on the quality of service: offering no waiting list, a quick turnaround for refill cylinders, and home delivery of refill cylinders, for example. Even so, in the LPG sector typically only those households that do not have easy access to subsidized LPG, due either to there being a long waiting list or a lack of local dealers, have signed up with private dealers.

2.12 Subsidized LPG historically has been supplied in 14.2 kg cylinders. Smaller, 5 kg cylinders were introduced several years ago but were withdrawn as a commercial failure. In August 2002, they were reintroduced. Until recently, the state oil companies marketed LPG only in towns and cities with a minimal population of 20,000. Having saturated these urban markets, they are now expanding into the rural areas where private marketers have historically operated. The government has been actively pursuing market expansion for the state oil companies, and has eliminated the LPG waiting list that as recently as April 2000 included 6 million potential customers. This closed to the private sector a segment of the market in which it could previously compete. The LPG market today is dominated by state oil companies.

2.13 Kerosene supplied through the PDS is sold at the "fair price" shops which sell subsidized goods. The allocation of subsidized kerosene by the central government varies from state to state and is based on historical patterns rather than on demand or on consideration of relative poverty levels. The allocation within a state depends on whether the household is in a rural or urban area, and typically on whether or not the household has taken up LPG. The lowest allocation quantity typically is set aside for those with double-cylinder connection (that is, households that have two LPG cylinders). Kerosene allocation by state and the quantities to which households falling under different categories were entitled in fiscal 1999–2000 are shown in Table 2.1. There is an urban bias in several states. As will be shown later, the amounts to which households, especially in rural areas, are entitled tend to be higher than what they can purchase in practice.

Table 2.1 Kerosene Allocation During Fiscal 1999–2000

		Household kerosene allocation (liters per month)					
		URBAN			*RURAL*		
		Households with			*Households with*		
States / Union Territories	*Allocation (metric tons)*	*no LPG*	*1 LPG cylinder*	*2 LPG cylinders*	*no LPG*	*1 LPG cylinder*	*2 LPG cylinders*
Northern Region							
Haryana	171,732	10	3	0	6	3	0
Himachal Pradesh	61,846	25	10	0	25	10	0
Jammu and Kashmir	111,764	10/15	10/15	10/15	2/5	2/5	2/5
Punjab	343,128	20	3	0	20	3	0
Rajasthan	443,179	10	2	0	10	2	0
Uttar Pradesh	1,410,902	8	3	3	8	3	3
Chandigarh	15,408	10/20	3	0			
Delhi	204,672	12/22	0	0	12/22	0	0
Sub Total	2,762,631						
Eastern Region							
Assam	272,628	5–6	5–6	5–6	5–6	5–6	5–6
Bihar	870,036	3–5	3	0	3–5	3	0
Manipur	22,854	5	5	5	5	5	5
Meghalaya	21,038	9.4	9.4	9.4	9.4	9.4	9.4
Nagaland	14,358	2–5	2–5	2–5	2–5	2–5	2–5
Orissa	381,693	4	4	4	4	4	4
Sikkim	7,896	2	2	2	2	2	2
Tripura	32,556	1	1	1	1	1	1
West Bengal	820,086	2	2	2	1	1	1
Arunachal Pradesh	10,919	4.5	4.5	4.5	4.5	4.5	4.5
Mizoram	8,148	3	3	3	2	2	2
Andaman and Nicobar	7,033	5–10	5–10	5–10	5–10	5–10	5–10
Sub Total	2,469,245						
Western Region							
Gujarat	837,292	8–16	2	0	7–10	2	0
Maharashtra	1,573,902	4–24	4	0	2–20	4	0
Goa	28,080	3	6	6	3	6	6
Diu	1,212						
Daman	1,224						

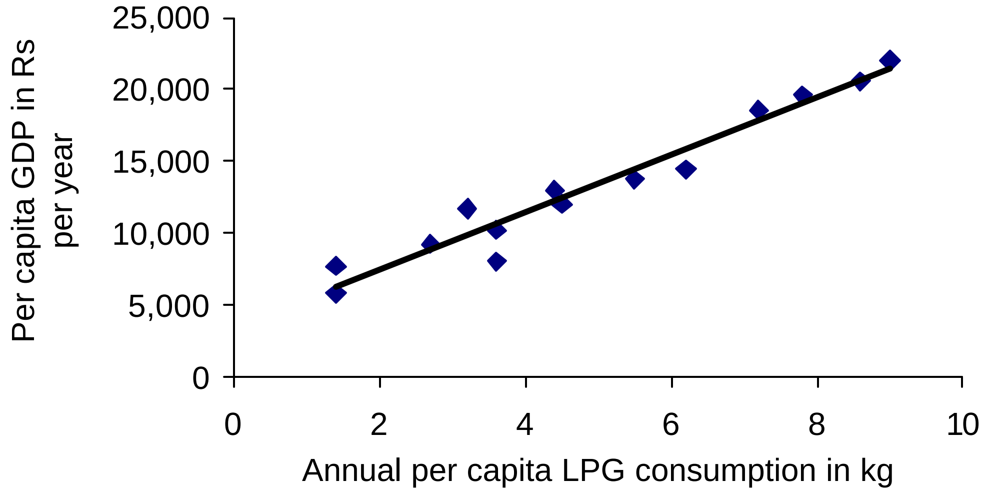
States / Union Territories	*Allocation (metric tons)*	*Household kerosene allocation (liters per month)* URBAN Households with *no LPG*	*1 LPG cylinder*	*2 LPG cylinders*	RURAL Households with *no LPG*	*1 LPG cylinder*	*2 LPG cylinders*
Dadar Nagar Haveli	3,240						
Madhya Pradesh	666,636	5	5	5	5	5	5
Sub Total	3,111,586						
Southern Region							
Andhra Pradesh	675,011	10–23	3	0	3	3	0
Karnataka	531,168	6–8	2	2	4	2	2
Kerala	302,076	6	3	3	6	3	3
Tamil Nadu	732,523	10–15	3	0	3–5	3	0
Pondicherry	15,360	7	2	2	7	2	2
Lakshwadweep	924	5	5	5	5	5	5
Sub Total	2,257,062						
All India Total	***10,600,524***						

Notes on household kerosene allocation: Data as of 1 January 2000. Jammu and Kashmir, the figures are for summer and winter; Chandigarh urban with no LPG, 10 liters for households with 2 members or fewer, 20 liters for households with more than 2 members; Delhi 12 liters for families with 1-5 members, 22 liters for family with 9 members or more; Sikkim 2 liters per family member; Tripura 1 liter per family member; Maharashtra, no LPG, first number minimum per person, second number per family with more than 7 members; Goa 3 liters per person for no LPG, 6 liters per card holder otherwise; Andhra Pradesh for no LPG, 23 liters for below poverty line white card holders, 10 liters for above poverty line pink card holders in Hyderabad, and 10 liters per household in the rest of the state in urban areas; Kerala 2 liters for electrified houses and 5 liters for non-electrified houses, with figures in the table for cooking purposes against permits.

Source: Oil Coordination Committee (now Petroleum Planning and Analysis Cell) of the Ministry of Petroleum and Natural Gas

2.14 The consumption of subsidized LPG is a strong function of income. Figure 2.2 shows LPG consumption in fiscal 1997–98, when the consumption of subsidized LPG was seriously constrained by supply problems. It is clear that proportionally the subsidy favored better-off households. This trend is confirmed in the analysis of the 1999–2000 household survey data, as Chapter 3 shows.

Figure 2.2 Annual per Capita LPG Consumption as a Function of Annual per Capita Gross Domestic Product (GDP) in 14 Indian States, Fiscal 1997–98



Notes: The data from the following states were used in this figure: Andhra Pradesh, Bihar, Gujarat, Haryana, Kanartaka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, and West Bengal. The annual per capita consumption includes all residents in the states, users as well as non-users of LPG.

Source: Oil Coordination Committee (now Petroleum Planning and Analysis Cell) of the Ministry of Petroleum and Natural Gas

2.15 In a gazette notification issued in November 1997, the government set a timetable for the staged phase-down of subsidies on kerosene and LPG. The stated policy called for the retention of smaller universal price subsidies: 33.3 percent for kerosene and 15 percent for LPG for household use. The subsidy phase-down was originally planned to be completed by the time of sector deregulation in April 2002, but has fallen behind schedule. The government later decided that the subsidy on domestic LPG and PDS kerosene would be provided on a specified flat rate basis from the Consolidated Fund from April 1, 2002.

2.16 Fiscal 2002–03 was the first time fuel subsidies were made explicit in the national budget. The subsidy for the petroleum sector was the second highest subsidy after that on food. For LPG and kerosene, the Ministry of Finance allocated Rs 50 billion (approximately US$1 billion), but rising international prices drove the actual subsidy up to more than Rs 100 billion, of which the government outflow was Rs 63 billion (Business Standard 2003a). The shortfall was picked up by the four state oil companies during the fiscal year, amounting to some Rs 30 billion between April and December 2002 alone (Business Standard 2003b). In interpreting these numbers it is important to note that they are inclusive of all government taxes, including import duties on kerosene and LPG. Another consideration is that about one-half of the kerosene and one-third of the LPG consumed are produced locally. These subsidy figures thus represent an upper bound rather than the actual costs to the government and oil companies. The unsubsidized prices in February 2003 based on import-parity were Rs 470 per cylinder of

LPG and Rs 16.5 per liter of kerosene (Business Standard 2003b). The market LPG and kerosene prices corresponded to these levels.

2.17 These subsidy figures are of the same order of magnitude as the central government's spending on education in fiscal 2002–03—the Central Plan allocation for education in fiscal 2002–03 was Rs 62 billion, of which Rs 43 billion was set aside for primary education (The Tribune 2003)—and markedly higher than the Rs 4 billion allocated for rural employment programs (The Hindu 2002). For fiscal 2003–04, the Ministry of Finance increased the kerosene and LPG subsidy to Rs 81 billion (Business Standard 2003c). In June 2003, however, the Ministry of Finance announced that the LPG and kerosene subsidies would be phased down in three years and eliminated by April 2006. The Ministry of Petroleum and Natural Gas was reported as favoring a five-year phase-down period to reduce the burden on the state oil companies from cost under-recovery as occurred in fiscal 2002–03 (Business Standard 2003d).

Fuel Expenditure Comparison

2.18 It is informative to compare the operating costs of LPG and kerosene with and without price subsidies. Ultimately what influences a household's choice is how much it would have to spend to do a given amount of cooking and other household activities. Here, cooking is taken for illustration purposes because it accounts for the majority of all household energy used (World Bank 2002b). Table 2.2 compares the cost per unit of energy delivered to the burner tip. The subsidized and unsubsidized prices of LPG and kerosene as informed by the Minister of Petroleum and Natural Gas Minister, Ram Naik, to the Ministry of Finance in February 2003 and reported in the Business Standard (2003) are used as retail prices. There is only a limited amount of in-field stove efficiency data available in India, and these data are the largest source of uncertainties in the calculations. While LPG stoves are required to be designed to operate at 60 percent efficiency or higher, field measurements show efficiencies considerably lower than the design specifications. The computation in the table assumes 50 percent stove efficiency for LPG, 35 percent for kerosene in wick stoves, and 40 percent for kerosene in high-pressure stoves (where kerosene is gasified before combustion). On the basis of the assumed efficiency figures, one 14.2 kg cylinder of LPG is equivalent to 21 liters of kerosene as a liquid and 19 liters gasified kerosene. Expressed in rupees per mega-joule (MJ) of energy delivered, LPG is more expensive than kerosene. The higher start-up cost of LPG makes LPG even more expensive. The last column shows the monthly expenditure of a household consuming the equivalent of one LPG cylinder a month.

Table 2.2 Cost of Using LPG and Kerosene

Fuel	*Price*	*Stove efficiency*	*Rs/MJ*	*Equivalent quantity*[5]	*Rs/month*[6]
LPG	Rs 241/cylinder[3]	55%	0.67	14.2	241
LPG	Rs 469/cyliner[4]	55%	1.31	14.2	469
kerosene[1]	Rs 9/liter[3]	40%	0.52	21	188
kerosene, high pressure[2]	Rs 9/liter[3]	45%	0.47	19	167
kerosene	Rs 16.54/liter[4]	40%	0.96	21	345
kerosene, high pressure	Rs 16.54/liter[4]	45%	0.85	19	307

[1] Kerosene used as a liquid; [2] Kerosene used in a high-pressure stove; [3] Subsidized price in New Delhi as of February 2003; [4] Unsubsidized price; [5] Fuel quantity required to deliver the same amount of energy to the cooking pot; [6] Rs per month per household for purchasing the quantity indicated under "Equivalent quantity"

2.19 At the subsidized retail price levels observed in February 2003, which are regarded as unsustainable by both the finance and petroleum ministries, it costs about Rs 240 per month to cook with LPG. This assumes cooking uses one cylinder a month, which is representative of urban households. The figures of Rs 170 and 190 for cooking with kerosene are not realistic, because few households are able to purchase 20 liters of PDS kerosene every month: rather, it is likely that the bulk of the kerosene used for cooking comes from the parallel kerosene market. Absent price subsidies, it would have cost Rs 310–350 per month to cook with kerosene and Rs 470 per month using LPG at the international price levels in February 2003.

2.20 In February 2003 world prices were among the highest ever. The above calculations therefore show what households might have to pay at times if prices were not subsidized, fuel tax levels remained the same, and prices were allowed to fluctuate in tandem with international prices. The LPG price in February 2003, for example, was 45 percent higher than the average of the preceding two years. However, even if the prices are adjusted accordingly, the monthly expenditures remain higher than those at the subsidized prices. As Chapter 3 shows, these compare to about Rs 110 per month for the value of wood (purchased) used by wood-using households found in the 55th round of the NSS, adjusted for the consumer price index (CPI). All the figures on kerosene and LPG expenditure in Table 2.2 are markedly higher than the expenditures on fuels reported in the 1999–2000 NSS, even by high-income urban families (see Table 3.14). Increasing in-field stove efficiency though the use of improved stove design and better stove maintenance and operation could considerably lower the cost of using kerosene and LPG.

2.21 The world price of crude oil is expected to decline from the high level of early 2003, and with it the prices of kerosene and LPG. Short-term and even occasional prolonged price hikes nonetheless also can be expected. The subsidies are planned to be phased down in the coming years, but the political challenges remain formidable. This study is intended to serve as an analytical basis to inform this process.

3

Household Energy Use Patterns

3.1 This chapter gives descriptive statistics about household energy use patterns as a function of sector (rural or urban), household income, and the year in which the data were collected. Household energy use was examined using the 50th and the 55th rounds of the NSS. These surveys are conducted from July to June of the following year. The sample for the 50th round, conducted in 1993–94, sampled 115,394 households, consisting of 69,225 rural and 46,169 urban households of a total of 132.2 million rural and 45.7 million urban households. The corresponding figures for the 55th round, conducted in 1999–2000, were 71,385 rural and 48,924 urban households, representing 137.4 million and 51.4 million households, respectively. Detailed descriptions of how the raw data were handled are given in Annex 1. Although the data from the 55th round are not strictly comparable to those from previous years because of changes in survey design, no expenditure adjustments were made because they were expected to have only a marginal effect.

Primary Cooking and Lighting Energy Sources

3.2 Table 3.1 shows the household use of different primary energy sources for cooking and lighting in 1993–94 and 1999–2000. For cooking, firewood dominated among rural households, with dung a distant second. The use of LPG and kerosene was small, even in 1999–2000. In contrast, the dominant fuel in urban areas shifted from wood in 1993–94 to LPG in 1999–2000. By 1999–2000 wood was the second most commonly used primary cooking fuel in urban areas, with twice as many households using LPG. Wood was closely followed by kerosene. For lighting, the observed pattern in both rural and urban areas was an increase in reliance on electricity as the primary lighting fuel, at the expense of kerosene. Most rural households nonetheless used kerosene rather than electricity for lighting even in 1999–2000.

Table 3.1 Primary Cooking and Lighting Energy Sources (percentage of households)

	1993–94		*1999–2000*	
Primary Energy	*Rural*	*Urban*	*Rural*	*Urban*
Cooking				
Coke, coal	1.3	5.6	1.5	4.1
Firewood and chips	80.1	30.3	75.4	22.2
LPG	1.8	29.7	5.4	44.1
Gobar gas	0.4	0.1	0.3	0.5
Dung	10.4	2.7	10.6	2.1
Charcoal	0.0	0.2	0.0	0.1
Kerosene	1.9	22.9	2.7	21.7
Electricity	negligible		0.1	0.4
Others	3.5	2.4	2.7	0.7
No cooking arrangement	0.7	6.2	1.1	4.2
Lighting				
Kerosene	58.3	15.9	50.5	10.2
Other oil	0.3	0.1	0.3	0.1
Gas	0.0	0.1	0.1	0.1
Candles	0.1	0.1	0.1	0.0
Electricity	38.0	83.4	48.4	88.9
Others	0.5	0.1	0.1	0.1
No lighting arrangement	2.8	0.2	0.5	0.3

Note: Census 2001, conducted in February 2001, showed higher dung use in rural areas (2.8 percent), firewood and crop residues separately accounted for (combined total of 77.2 percent in rural areas and 24.8 percent in urban), and lower use of electricity for lighting (43.5 percent in rural, 87.6 percent in urban). See http://www.censusindia.net/.

3.3 While reliance on wood declined in both urban and rural areas, in rural areas the use of dung as the primary cooking fuel did not change between the two periods. Given the much higher damage to health likely to be caused by dung use relative to wood, this is a concern. The proportion of rural households using traditional biomass declined by 4.5 percent from 90.5 in 1993–94 to 86 percent in 1999–2000. The corresponding fall in urban areas was 8.7 percent, from 33 percent to 24.3 percent.

3.4 Household energy use patterns were analyzed further as a function of per capita(p.c.) expenditure decile, which was calculated by computing the total household expenditure divided by the household size. In the case of the 55th round (see also Chapter 4), total household expenditures were further adjusted by interstate cost-of-living differences. The households were then ranked in order of increasing per capita expenditure and divided into 10 groups—the per capita expenditure deciles—each containing the same number of households unless indicated otherwise. Decile 1 corresponds to the bottom 10 percent, and decile 10 to the top 10 percent. The expenditure decile statistics for 1999–2000, showing lower expenditure levels in rural than urban areas in a given decile, and a higher concentration in the lower deciles and lower concentration in the upper deciles of rural households, when deciles are defined nationally, are given in Annex 1.

3.5 The share of households using wood, dung, kerosene and LPG as their primary cooking fuels in 1999–2000 are shown in Figure 3.1 (rural) and Figure 3.2 (urban) as a function of per capita expenditure decile. The sharp contrast between rural and urban areas is immediately clear. Wood use dominated among all rural households. Its use by urban households, however, declined rapidly with increasing expenditure, falling to less than one-fifth of households by decile 5. Dung use was virtually independent of expenditure in rural areas and was nearly constant at about 11 percent, whereas in urban areas its use was small and declined rapidly. Kerosene was used by more than one-fifth of urban households between decile 2 and decile 8. Its use was limited in rural areas where less than one-tenth of households used it as the primary cooking fuel, even in the top decile. LPG use increased rapidly with increasing per capita expenditure in urban areas, exceeding 50 percent of households by decile 6 and reaching nearly 80 percent in decile 10. Its use was very limited in rural areas until about decile 7 but rose rapidly in the top two deciles. Even in decile 10, however, LPG use was limited to fewer than 30 percent of households.

Figure 3.1 Primary Cooking Fuels in Rural India, 1999–2000

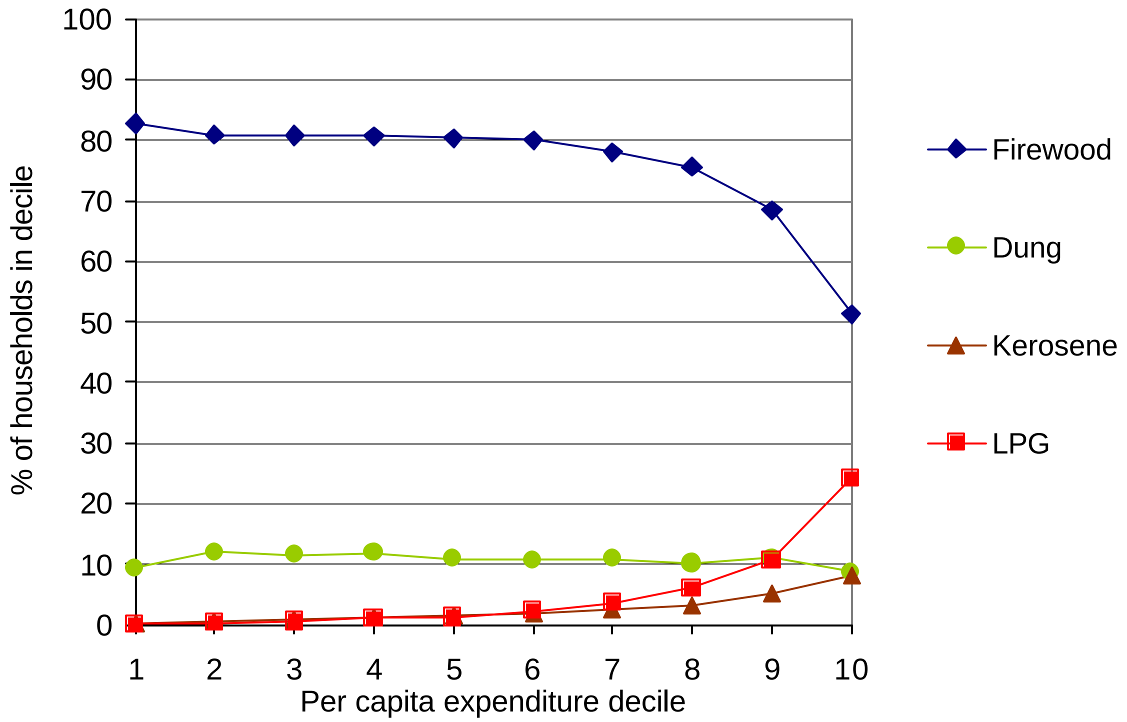
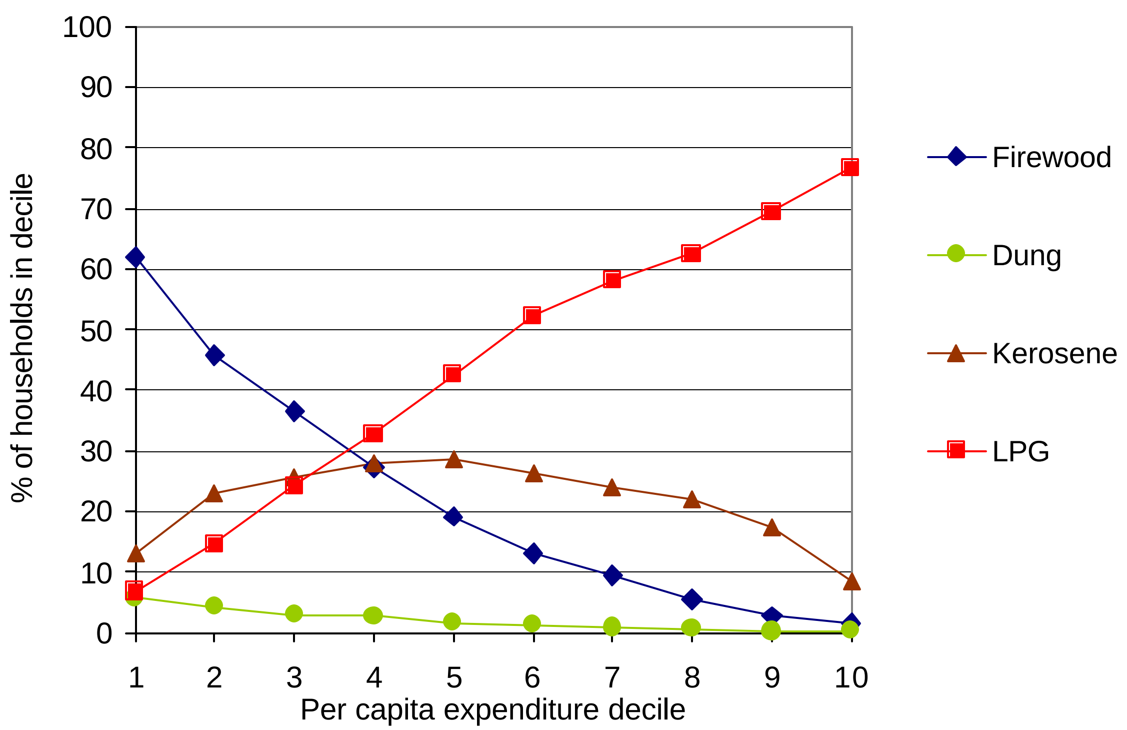
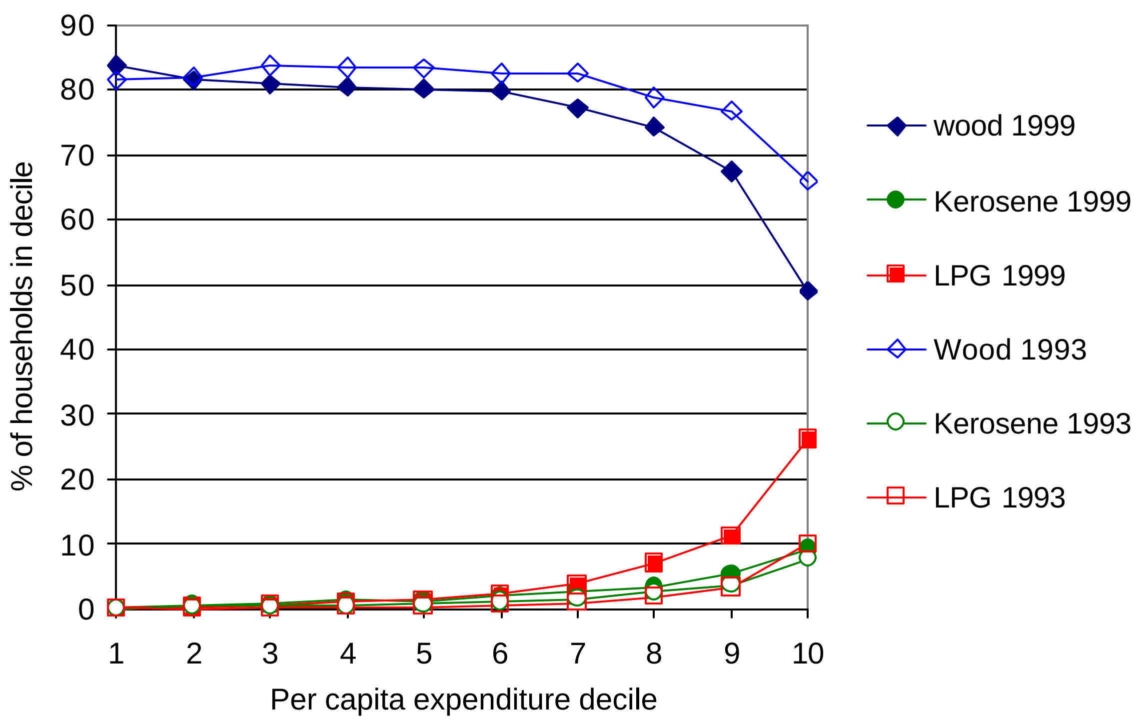


Figure 3.2 Primary Cooking Fuels in Urban India, 1999–2000



3.8 The historical trends for cooking fuel use in rural India, comparing 1993–94 with 1999–2000, are shown in Figure 3.3. Wood is by far the dominant fuel, with little change in wood use among the bottom seven expenditure deciles. There was a marked increase in LPG uptake, with a corresponding decline in wood use, only among the top 20 percent of rural households. The use of kerosene as the primary cooking fuel remained virtually unchanged and insignificant across all income groups.

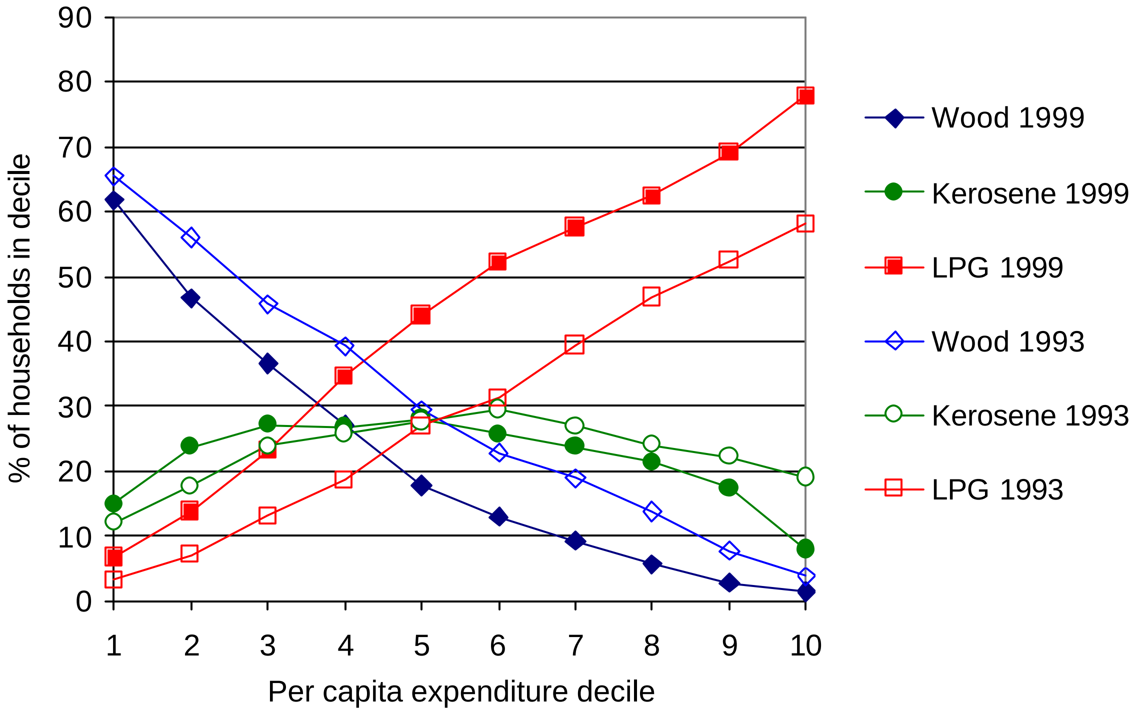
Figure 3.3 Historical Progression of Primary Cooking Fuel Choice in Rural India (comparison of 1993–94 and 1999–2000 NSS Data)



Note: To make 1993 and 1999 data comparable, expenditure deciles are based on nominal expenditures.

3.6 The historical progression for primary cooking fuels in urban areas is shown in Figure 3.4. The trends observed are generally consistent with increasing income and LPG availability in the intervening years (and possibly wood depletion in some areas). The increase in the uptake of LPG as the primary cooking fuel is especially striking. The urban poor appear to have shifted out of wood to kerosene, but for the majority of urban households the decline in wood use appears to have been a result of taking up LPG. Without more detailed data it is impossible to tell if the shift was from wood directly to LPG or if households “climbed up the energy ladder” by going from wood to kerosene and then on to LPG. Among the top income groups, there was a clear shift from kerosene to LPG.

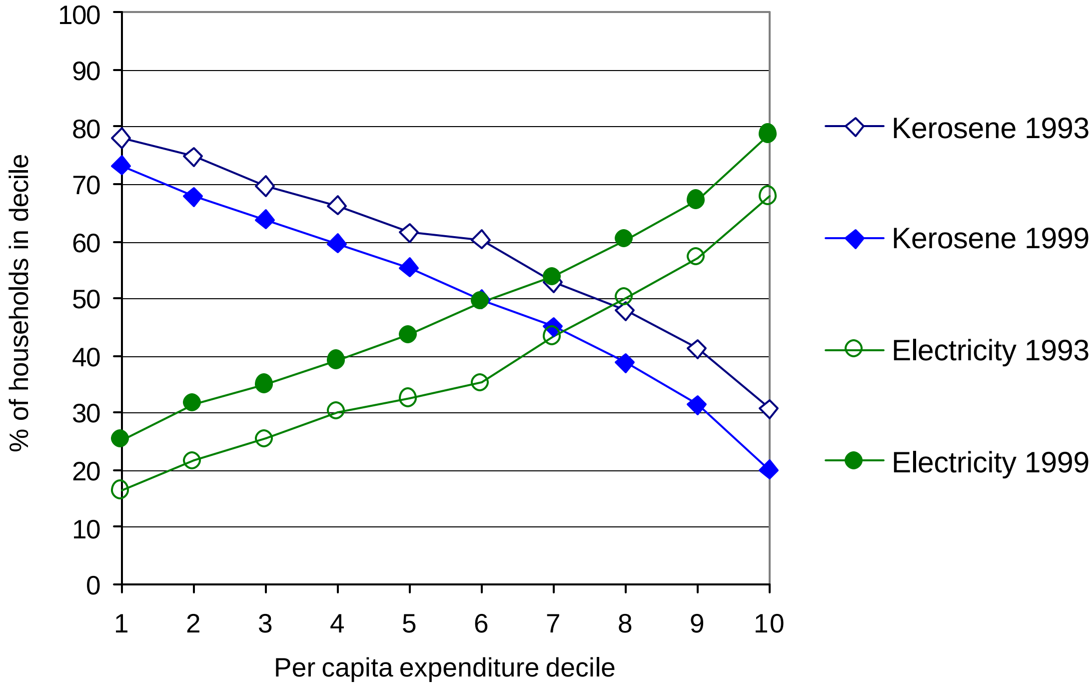
Figure 3.4 Historical Progression of Primary Cooking Fuel Choice in Urban India (comparison of 1993–94 and 1999–2000 NSS Data)



3.7 Similar trends were observed in a number of earlier studies of household energy use patterns in India (see, for example, Alam and others 1998 and World Bank 1999). A study in Hyderabad (World Bank 1999), based on a primary survey conducted in 1994, in particular provides complementary insights. The study found rapid interfuel substitution in urban Hyderabad as households switched from wood to kerosene and from kerosene to LPG. This happened despite the fact that there was little real income growth in the preceding 15 years. In part, it was able to take place because of changes in relative fuel prices between 1981 and 1994, when the price of firewood in Hyderabad rose faster than the prices of LPG and kerosene, and by the liberalization of energy markets, which resulted in increased fuel availability. The overall patterns of energy use hide significant differences among income groups, however. Kerosene and wood dominated energy use in the lower income groups. The use of wood declined rapidly with increasing income, to the point where it was used by only a very small percentage of the population. In contrast, kerosene was a staple fuel for low-income households. The use of both LPG and electricity was strongly dependent on the level of income, accounting for about half of total energy use in the middle-income ranges and for more than 90 percent of total energy use in the highest income groups.

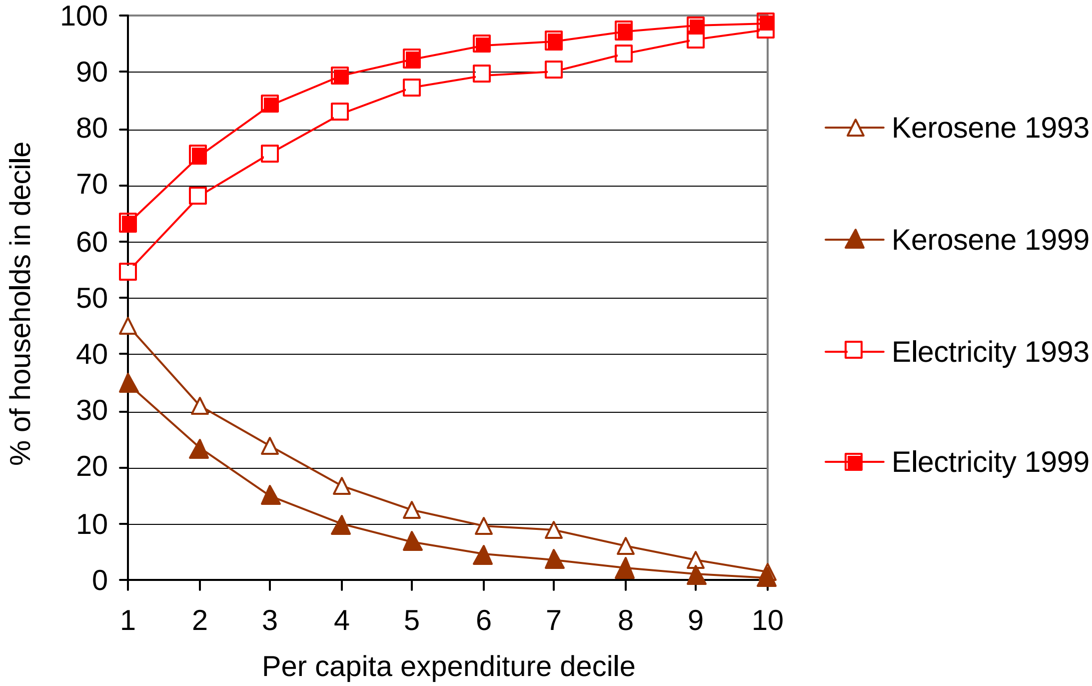
3.8 The historical progression for kerosene and electricity, the two dominant sources of energy for lighting, is shown in Figure 3.5 and Figure 3.6 for rural and urban households, respectively. In urban areas, the majority of households in every decile used electricity for lighting in both survey periods, but in rural areas this was the case only among the top three deciles in 1993–94 and the top five deciles in 1999–2000.

Figure 3.5 Historical Progression of Primary Lighting Energy Source in Rural India (comparison of 1993–94 and 1999–2000 NSS Data)



Note: To make 1993 and 1999 data comparable, expenditure deciles are based on nominal expenditures.

Figure 3.6 Historical Progression of Primary Lighting Energy Source in Urban India (comparison of 1993–94 and 1999–2000 NSS Data)



Uptake of Different Energy Sources

3.9 Many households used more than one energy source for cooking, and supplemented kerosene lamps for electricity where the power supply was unreliable. While primary energy sources give a good idea of which fuels are most commonly used, these figures could be misleading if the primary energy sources are supplemented significantly by other sources. Table 3.2 reports the percentages of households in rural and urban areas that reported positive consumption of various energy sources in 1993–94 and 1999–2000. All the percentage figures should be equal to or greater than those reported for primary energy sources. In the case of electricity, the percentage of households that reported positive consumption was lower than the percentage that claimed to use electricity as their primary lighting source, indicating either inconsistencies in the responses given or errors in the recording of data.

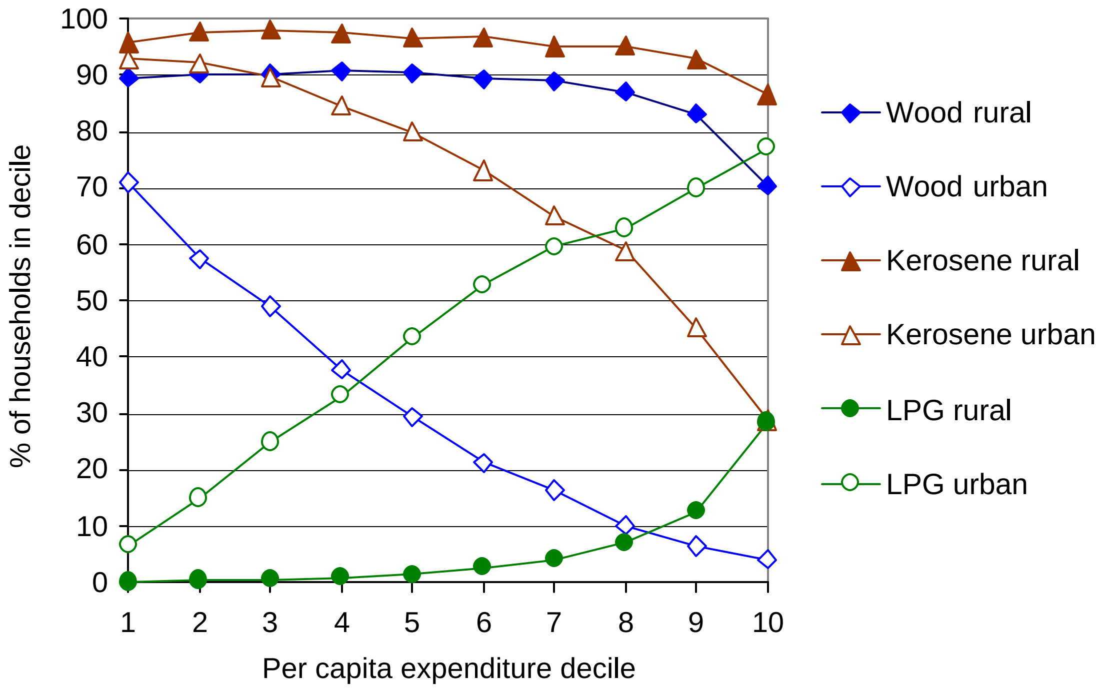
Table 3.2 Uptake of Different Energy Sources (percentage of all households)

	1993–1994			*1999–2000*		
Energy Source	*Rural*	*Urban*	*National*	*Rural*	*Urban*	*National*
Firewood and chips	87	37	74	86	30	71
Dung	44	15	36	47	10	37
Biomass (dung, wood, or both)	93	43	80	92	33	76
LPG	1	26	8	6	45	17
Total kerosene	86	76	83	95	71	88
PDS kerosene	61	53	59	76	48	68
Market kerosene	37	34	36	37	39	38
Coal, coke	1	5	2	1	2	1
Gobar gas	0	0	0	0.3	0.04	0.3
Charcoal	0.1	0.5	0.2	0.1	0.4	0.2
Electricity	28	63	37	46	81	56

3.10 Biomass use remained virtually unchanged between 1993–94 and 1999–2000 in rural areas, with more than 90 percent of all rural households using wood, dung, or both. Nationally, LPG uptake doubled between 1993–94 and 1999–2000, but remained limited to fewer than one-fifth of households: in 1999–2000, three-quarters of all households continued to use biomass. Kerosene uptake increased in rural areas but declined in urban areas between the two periods. The urban decline is primarily due to the reduced use of PDS kerosene—the uptake of market kerosene actually increased. The percentage of households using gobar gas or charcoal remained negligibly small.

3.11 The households that reported positive consumption are further divided into per capita expenditure deciles and their consumption shown in Figure 3.7 for wood, total kerosene, and LPG. Extensive use is evident of both wood and kerosene across all expenditure deciles in rural areas, with kerosene being used by more than 90 percent of households in all deciles except decile 10. Kerosene use also is extensive among the lower 50 percent of urban households. The use of kerosene as an energy source for both lighting and cooking makes interpretation of household data difficult, as the survey did not explicitly ask about the quantities of kerosene consumed for these two distinct purposes. Comparison with Figure 3.1 shows that most urban households that consume LPG use it as their primary cooking fuel.

Figure 3.7 Uptake of Wood, Kerosene, and LPG, 1999–2000



3.12 An alternative way of summarizing the data is to look at the distribution of individuals, as opposed to households, who live in houses using different fuels. From the point of view of exposure to smoke emissions and public health it is the number of people who are exposed that is important, and household figures may not represent this number well given that household size differs markedly (two-fold) between the top and bottom deciles. The distribution of individuals cannot, however, capture the fact that not everyone in the household is exposed to the same degree to ambient particulate concentrations. With these limitations in mind, individuals in rural and urban areas were grouped into 10 decile groups, each group containing the same number of individuals rather than households. The results are shown in Table 3.3.

3.13 Because the household size decreases with increasing per capita expenditure, the percentage of individuals living in households that consume fuels primarily used by the poor is greater than the corresponding percentage of households in this category. This is the case for both wood and dung, especially in urban areas where biomass use declines rapidly with increasing income. Most rural residents live in households that use wood and dung, and more than one-third of urban residents live in households that use wood. These high figures are a cause for concern. At the other end of the scale, the percentage of individuals living in households that consume fuels used primarily by the better-off is lower than the corresponding percentage of households in this group. (This generalization does not apply in the case of LPG use in urban areas. LPG-using households are larger than the average household in nearly every expenditure decile, the average size of LPG-consuming households being 4.8 persons, compared to the 4.3 persons per household that does not use LPG.)

Table 3.3 Percentage of Individuals in Each Decile Living in Households Using Different Fuels, 1999–2000

P.c. decile by	*RURAL*				*URBAN*				*NATIONAL*			
individual[1]	*Wood*	*Dung*	*Kero*	*LPG*	*Wood*	*Dung*	*Kero*	*LPG*	*Wood*	*Dung*	*Kero*	*LPG*
1	91	48	97	0	75	31	95	6	90	50	97	0
2	90	56	98	1	63	26	94	14	89	55	98	1
3	90	56	98	0	54	20	92	23	89	53	98	1
4	91	56	98	1	45	16	89	32	89	54	97	2
5	91	56	98	1	35	12	84	42	86	50	97	4
6	90	55	98	3	26	8	78	54	84	46	96	7
7	90	52	97	4	20	5	71	62	78	42	95	13
8	88	52	96	7	15	4	63	72	69	36	90	23
9	87	50	94	13	9	2	51	78	50	26	84	41
10	75	42	90	30	5	1	31	88	23	10	57	70
Average	88	52	96	6	35	12	75	47	75	42	91	17

Kero – kerosene. [1] Decile groups containing the same number of individuals rather than households.

Parallel Markets for Kerosene

3.14 The kerosene market in India merits special examination because of its extensive use, especially in rural areas, and because there was (and remains) a dual price structure at the time of the 50th and 55th rounds of NSS. The same applies to LPG, but unfortunately LPG consumers in the survey were not asked whether they purchased LPG from private or state oil company dealers. Because of the large scatter in the data it was not possible to categorize LPG consumers into those that purchased subsidized LPG and those that paid the market price. In contrast, kerosene consumers were asked how much PDS kerosene and how much kerosene from other sources the household purchased, both in monetary terms and quantity, during the last 30 days.

3.15 The percentage of kerosene-consuming households increased from 1993–94 to 1999–2000 in rural areas, but declined in urban areas. A lower bound to the availability of PDS was estimated by defining access to PDS as living in an area (in this case, the first sampling unit: a village in rural areas and a block in urban areas) where at least one household, including itself, purchased PDS kerosene. It is possible that PDS kerosene was available but that none of the households surveyed in the first sampling unit happened to be purchasing PDS kerosene, and the actual access figures therefore are likely to be higher than those recorded. Bearing this limitation in mind, access, defined in this way, increased in rural areas but remained static in urban areas. By 1999–2000, a greater proportion of rural households had access to PDS kerosene than their urban counterparts, suggesting that it became easier over this period to purchase PDS kerosene in rural areas. The fraction of rural households using PDS kerosene increased to three-quarters in 1999–2000, but declined to less than half in urban areas. These results are shown in Table 3.4.

Table 3.4 Household Uptake of Kerosene and Access to PDS (percentage of all households)

	1993–1994		*1999–2000*	
Households	*Rural*	*Urban*	*Rural*	*Urban*
Using kerosene	86	76	95	71
Having access to PDS kerosene[1]	85	89	95	89
Using PDS kerosene	61	54	76	48

[1] For definition of access to PDS kerosene, see paragraph 3.15.

3.16 The impact of access to PDS on kerosene uptake is shown in Table 3.5. Households in communities in which at least one household was purchasing PDS kerosene were far more likely to be using kerosene: in 1999–2000, in urban areas they were more than twice as likely to be using it. For all the measures examined in Table 3.5, there was an increase in rural areas and a decline in urban areas between the two time periods.

Table 3.5 Impact of Access to PDS on Kerosene Uptake (percentage of households in each category)

		1993–1994		*1999–2000*	
Households with access to PDS	*Households without access to PDS*	*Rural*	*Urban*	*Rural*	*Urban*
Using kerosene		90	80	95	75
Using PDS kerosene		73	60	80	54
	Using kerosene	62	48	87	35

3.17 Among households that reported positive consumption of kerosene there was increasing reliance on PDS kerosene in rural areas but increasing reliance on market kerosene in urban areas (see Table 3.6). Market kerosene was significantly more expensive (in urban areas, more than 2.5 times as expensive) than PDS kerosene, and yet close to one-third of urban kerosene-consuming households did not purchase any PDS kerosene. This strongly suggests that the transaction cost of purchasing PDS kerosene was high (for example, it may have been in chronic short supply at the fair price shops), or that the kerosene allotted on paper was in practice not available. Table 3.6 also shows that, when adjusted for the CPI, PDS kerosene prices did not rise as much but market kerosene prices rose more than the price of other consumer goods between the two survey periods, making PDS kerosene even more attractive in principle than market kerosene in 1999–2000.

Table 3.6 Source of Supply for Kerosene-Consuming Households

Item	*1993–94* *Rural*	*1993–94* *Urban*	*1999–2000* *Rural*	*1999–2000* *Urban*
Households using only PDS kerosene (percent)	57	55	61	46
Households using only market kerosene (percent)	28	29	20	32
Households using both market and PDS kerosene (percent)	14	15	19	22
Average PDS kerosene price paid (Rs/liter[1])	3.16	2.95	4.40	3.80
Average market kerosene price paid (Rs/liter[1])	5.48	5.51	9.24	9.70
1993–94 PDS kerosene price, adjusted for CPI (Rs/liter)			5.24	4.89
1993–94 market kerosene price, adjusted for CPI (Rs/liter)			9.09	9.14

[1] Nominal prices paid, not adjusted for interstate price differences.

3.18 Having established the patterns of kerosene uptake, the next question is to establish how much was being consumed. Table 3.7 shows the amount of kerosene consumed per month per household in each decile in rural areas, averaged across all households as well as across households reporting positive consumption of a specific type of kerosene. The monthly consumption figures are presented on a per capita as well as on a household basis. This is because while fuel requirements are expected to rise with increasing household size, there are also economies of scale in cooking and lighting—for example, one lamp can light a room whether one person or five people are trying to read.

Table 3.7 Liters of Kerosene Consumed per Month in Rural Areas, 1999–2000

Kerosene type	*PDS*	*Market*	*All[1]*	*PDS*	*Market*	*All[1]*	*PDS*	*Market*	*All[1]*	*PDS*	*Market*	*All[1]*
HH type	*All[2]*	*All[2]*	*All[2]*	*PDS[3]*	*Market[4]*	*Kero[5]*	*All[2]*	*All[2]*	*All[2]*	*PDS[3]*	*Market[4]*	*Kero[5]*
p.c. decile	*Per capita*						*Per household*					
1	0.38	0.15	0.52	0.51	0.37	0.54	2.3	0.9	3.1	3.2	2.3	3.3
2	0.43	0.17	0.60	0.55	0.42	0.61	2.5	1.0	3.5	3.2	2.5	3.6
3	0.47	0.19	0.66	0.60	0.47	0.67	2.6	1.0	3.7	3.3	2.7	3.7
4	0.50	0.21	0.71	0.63	0.50	0.72	2.7	1.2	3.9	3.5	2.8	4.0
5	0.56	0.24	0.80	0.70	0.58	0.82	2.9	1.2	4.1	3.7	3.1	4.3
6	0.60	0.25	0.85	0.75	0.65	0.87	3.0	1.3	4.3	3.9	3.3	4.4
7	0.65	0.27	0.92	0.82	0.74	0.96	3.1	1.3	4.4	4.0	3.6	4.7
8	0.70	0.31	1.0	0.88	0.85	1.1	3.2	1.4	4.6	4.1	3.8	4.8
9	0.75	0.39	1.1	0.96	1.1	1.2	3.3	1.7	4.9	4.3	4.8	5.3
10	0.82	0.47	1.3	1.1	1.5	1.5	3.0	1.8	4.8	4.4	5.5	5.5
Average	0.57	0.25	0.82	0.73	0.66	0.86	2.9	1.3	4.1	3.8	3.4	4.4

HH – household. [1] All kerosene. [2] All households. [3] Households consuming PDS kerosene. [4] Households consuming market kerosene. [5] All households that reported positive consumption of kerosene.

3.19 Per capita consumption of both PDS and market kerosene rose rapidly with increasing expenditure. Household consumption of kerosene also rose monotonically with increasing expenditure, although at a slower rate, a result of the fact that the higher expenditure households that consume more kerosene generally are smaller in size. Household consumption of PDS kerosene remained small, averaging less than 3 liters across all households and less than 4 liters even when only those households that purchase PDS kerosene were considered. Among those that reported positive consumption, the amount of market kerosene purchased exceeded that of PDS kerosene in the top two deciles. Among kerosene-consuming households, even those that consumed the largest quantity—the top decile—consumed less than 6 liters per month. This is not adequate to meet all cooking requirements. These small quantities reflect both the urban bias in kerosene allocation and the limited use of kerosene in general for household chores. For example, even when kerosene is used to "supplement" wood for cooking, it often is used mainly as a fire-starter rather than as a cooking fuel (World Bank 2002b). The small quantities of kerosene used are also indicative of the extensive use of kerosene for lighting even in electrified households, probably reflecting the low reliability of electricity supply.

3.20 The corresponding figures for urban households are given in Table 3.8. PDS kerosene consumption, both on a per capita and household basis, was higher in urban areas than rural areas except among the top three expenditure deciles. The households in the top three deciles consumed more market kerosene than PDS kerosene even when consumption was averaged across all households. Among kerosene-consuming households, kerosene consumption per household rose steadily and peaked at deciles 5–7, reaching nearly 10 liters per month, before it declined. The bottom decile consumed as much as the top decile (more than 6 liters per month), and more than the top decile in rural areas.

3.21 One of the most interesting and important findings comes from the comparison of the total amount of PDS kerosene consumed by households with the total amount allocated by the central government. Comparison for both the 50th and the 55th rounds of the NSS shows that the total amount of kerosene supplied through the PDS and consumed by households amounted to one-half of the total amount uplifted by all the states and union territories—that is to say, the leakage rate was about 50 percent. This substantial diversion of PDS kerosene, apparently to the automotive sector where kerosene is used as a substitute for diesel and to the black market for household consumption, would explain why many households rely on market kerosene despite its much higher price. Given the high leakage rate, the transaction cost of purchasing PDS kerosene would also be expected to be high, due to the consequent chronic supply shortages.

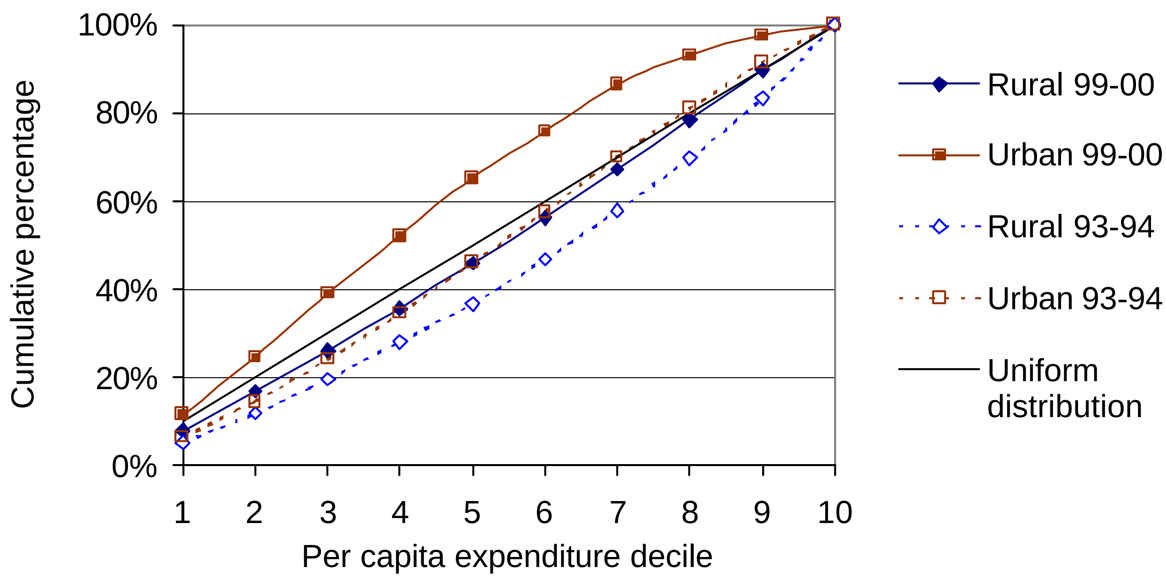
Table 3.8 Liters of Kerosene Consumed per Month in Urban Areas, 1999–2000

Kerosene type	*PDS*	*Market*	*All*[1]	*PDS*	*Market*	*All*[1]	*PDS*	*Market*	*All*[1]	*PDS*	*Market*	*All*[1]
HH type	*All*[2]	*All*[2]	*All*[2]	*PDS*[3]	*Market*[4]	*Kero*[5]	*All*[2]	*All*[2]	*All*[2]	*PDS*[3]	*Market*[4]	*Kero*[5]
P..c. decile	*Per capita*						*Per household*					
1	0.58	0.37	1.0	0.8	0.9	1.0	3.6	2.3	5.8	5.4	5.2	6.3
2	0.75	0.56	1.3	1.1	1.2	1.4	4.1	3.1	7.2	6.3	6.5	7.8
3	0.80	0.64	1.4	1.2	1.4	1.6	4.2	3.4	7.6	6.5	7.1	8.4
4	0.86	0.72	1.6	1.4	1.6	1.9	4.3	3.6	7.9	6.9	7.8	9.3
5	0.88	0.74	1.6	1.5	1.8	2.1	4.2	3.5	7.7	7.4	8.2	9.7
6	0.83	0.77	1.6	1.6	2.0	2.2	3.7	3.4	7.1	7.5	8.3	9.7
7	0.81	0.73	1.6	1.8	2.1	2.4	3.3	3.0	6.3	7.9	7.9	9.7
8	0.61	0.78	1.4	1.6	2.6	2.4	2.3	2.9	5.2	6.6	8.4	8.8
9	0.45	0.60	1.0	1.7	2.6	2.4	1.5	2.0	3.5	6.2	7.3	7.8
10	0.26	0.36	0.6	1.6	2.6	2.3	0.8	1.1	1.9	5.4	6.5	6.5
Average	0.71	0.63	1.3	1.3	1.6	1.8	3.2	2.8	6.0	6.7	7.4	8.5

HH – household. [1] All kerosene. [2] All households. [3] Households consuming PDS kerosene. [4] Households consuming market kerosene. [5] All households that reported positive consumption of kerosene.

3.22 The next important policy question is how the consumption of the PDS kerosene that reaches the intended beneficiaries (households) is in aggregate distributed among the different decile groups. To answer this question, the cumulative amount of kerosene consumed is plotted in percentages, beginning with the bottom decile, in Figure 3.8. If each decile consumed the same amount the data would fall on the line referred to as "uniform distribution" in the figure. Should the data fall below this line it would indicate that the poor consumed proportionately less than the better-off, and vice versa. Figure 3.8 shows that there was a relative shift in consumption of PDS kerosene from the rich to the worse-off in both urban and rural areas between 1993–94 and 1999–2000. Among rural households in 1999–2000, the distribution of kerosene consumption (and hence the subsidy portion that reaches households) was fairly uniform; among urban households it was skewed toward middle-income households.

Figure 3.8 Cumulative Consumption of PDS Kerosene

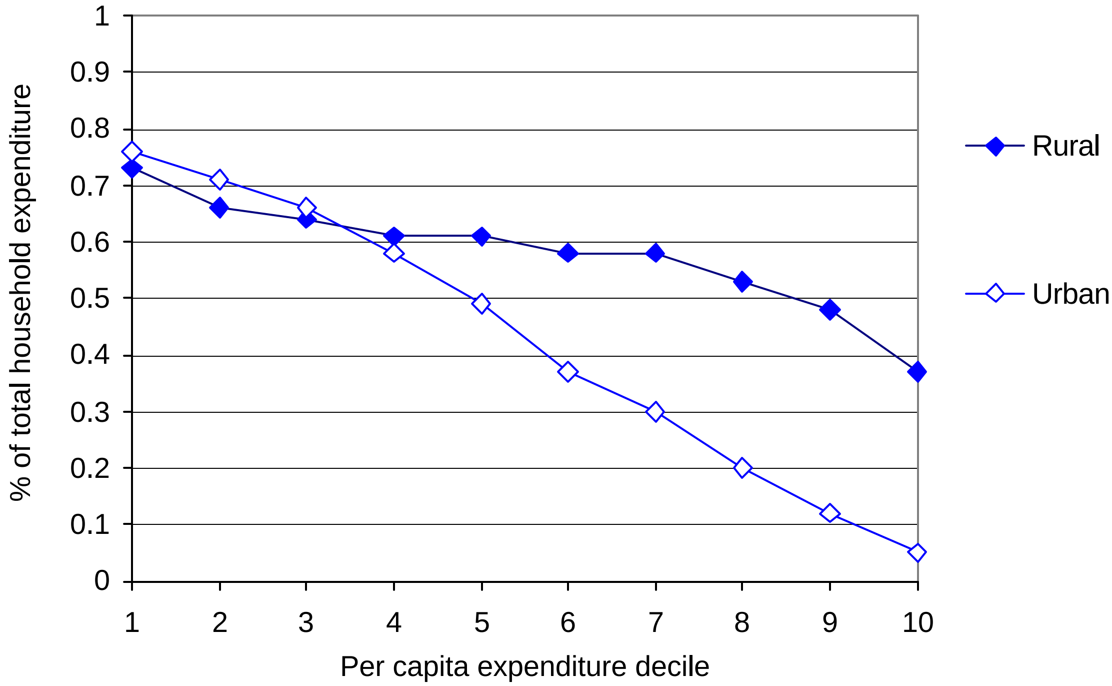


Note: To make 1993 and 1999 data comparable, expenditure deciles are based on nominal expenditures.

3.23 When examined in terms of the percentage of the total household budget, the kerosene subsidy that reached the households appeared to be progressive. Figure 3.9 plots the expenditure on PDS kerosene in 1999–2000 as a percentage of total household expenditure as a function of the per capita expenditure decile, averaged across all households in each decile. The share decreases monotonically in both rural and urban areas. The subsidy delivered as the share of the total household budget is in turn directly proportional to the figures shown in Figure 3.9.

3.24 The above observations indicate that the poor benefit more from the portion of the kerosene subsidy that has not been diverted to the black market than do the nonpoor. This distribution pattern is consistent with that observed in the Hyderabad study cited above, in which a kerosene subsidy, despite the problems with rationing, was found to be a more effective policy intervention for reaching poor households than were LPG or electricity subsidies. In Hyderabad, the two poorest income groups received a subsidy of close to Rs 7 million per month through this program in 1994, while the highest 20 percent of households, which used little kerosene, received only slightly more than Rs 1 million per month as a class. (The two highest income groups nonetheless were well compensated through other subsidies, as they received more than Rs 22 million per month in subsidies for electricity and LPG combined. If the kerosene subsidy leakage is taken into account, the distribution of subsidies shifts further in favor of the high-income groups.)

Figure 3.9 Expenditure on PDS Kerosene by All Households, 1999–2000 (percentage of total household expenditure)



3.23 These findings could lend support to the continuation of the kerosene subsidy in some form, but only provided that leakage can be contained. An extremely high rate of leakage, most likely to the nonpoor (such as vehicle owners), brings into serious question the cost-effectiveness of the kerosene subsidy, even should the subsidy portion that reaches households be progressive. In 1999–2000, a kerosene subsidy leakage rate of 50 percent was equivalent to a loss of Rs 40 billion (about US$1 billion), a large amount of public funds that could have been spent on high-priority social needs such as primary health, education, or employment programs.

LPG Consumption

3.25 LPG is clearly the fuel of choice for those who can afford it. By knowing how much households typically consume, it is possible to back-calculate the corresponding monthly expenditure under different price scenarios (for example, after subsidy elimination). In examining LPG uptake and consumption, it was not possible to distinguish between subsidized and market LPG because this information was not explicitly sought in the NSS questionnaire. However, private sector LPG dealers played a minor role even in 1999–2000. For all intents and purposes, the vast majority of LPG consumed by households was subsidized: the state oil companies held close to 95 percent of the LPG market at the time the 55th round of the NSS was conducted. A 14.2 kg LPG cylinder cost Rs 100.39 in rural and Rs 99.83 in urban areas in 1993–94, and Rs 185.59 on average in rural areas and Rs 175.94 in urban areas in 1999–

2000. These figures are not adjusted for interstate cost-of-living differences, and exclude the top and bottom 5 percent of the price distribution to remove outliers. Adjusted for the CPI, the 1993–94 prices would be equivalent to Rs 166.53 in rural and Rs 165.61 in urban areas in 1999–2000; in other words, LPG retail prices rose slightly more than the CPI during this period.

3.26 Consumption of LPG as a function of per capita expenditure, averaged across all households as well as across exclusively LPG-consuming households, is presented in Table 3.9 for 1999–2000. As discussed in Annex 1, these figures are may carry a significant upward bias. It is unlikely that the rural poor were consuming 8 to 10 kg of LPG per month, or that rural households on average consumed more than 11 kg per month.

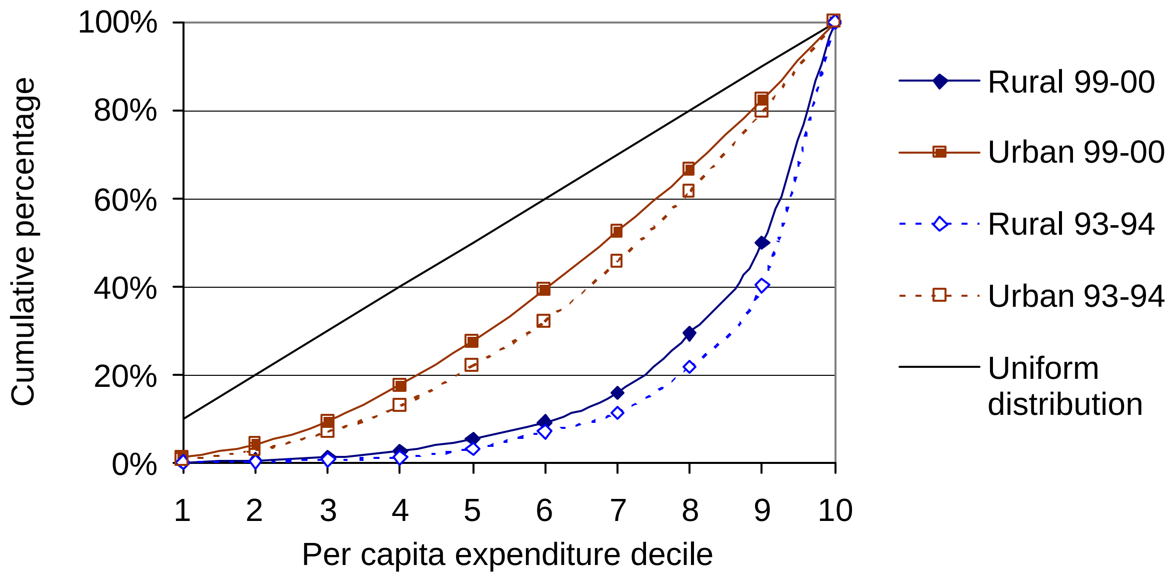
Table 3.9 Kilograms of LPG Consumed per Month, 1999–2000

	RURAL				*URBAN*			
HH type	*All*	*LPG*	*All*	*LPG*	*All*	*LPG*	*All*	*LPG*
P.c. decile	*Per capita*		*Per household*		*Per capita*		*Per household*	
1	0.00	1.9	0.0	8.3	0.1	1.6	0.8	11.8
2	0.01	1.1	0.0	9.0	0.4	2.0	1.9	12.9
3	0.01	1.6	0.1	10.5	0.6	2.0	3.2	12.7
4	0.02	1.8	0.1	10.3	0.9	2.3	4.6	13.7
5	0.03	2.1	0.2	12.8	1.2	2.4	5.9	13.5
6	0.05	1.6	0.3	10.6	1.6	2.5	6.9	13.1
7	0.09	1.7	0.5	10.9	1.9	2.7	7.8	13.2
8	0.17	1.9	0.8	11.3	2.3	3.0	8.5	13.5
9	0.32	2.0	1.4	10.9	2.7	3.3	9.2	13.2
10	0.87	2.6	3.2	11.3	3.4	3.8	10.4	13.5
Average	0.14	2.2	0.7	11.3	1.3	2.8	5.9	13.3

HH – households; All – all households; LPG – households that reported positive consumption of LPG.

3.27 Cumulative consumption of LPG for the two survey periods is shown in Figure 3.10. Compared to kerosene, the change with time in the distribution of LPG consumption was much smaller in both urban and rural areas. Among rural households in particular, the top four deciles continued to consume more than 80 percent of total household LPG demand. It is clear that the LPG subsidy accrued disproportionately to high-income households residing in urban areas.

Figure 3.10 Cumulative Consumption of LPG



Note: To make 1993 and 1999 data comparable, expenditure deciles are based on nominal expenditures.

3.28 An indication of the subsidy delivered as a percentage of the total household budget can be found in Table A1.3 (rural) and Table A1.4 (urban) in Annex 1. In rural areas, the share rose sharply with each higher decile. In urban areas, the share increased up to decile 7, after which it fell. Because no distinction was made between subsidized and market-priced LPG, the subsidy would not be strictly proportional to these figures, but the share of market LPG was small, and furthermore subsidized LPG was most readily available in large cities where the richest households live. It is clear that the LPG subsidy is regressive.

3.29 The leakage of subsidized LPG was examined by comparing the amount allocated by the central government and the actual amount consumed. The calculations showed that these two amounts were essentially identical in both 1993–94 and 1999–2000. However, given the suspected upward bias in the reported consumption of LPG, the actual differences might have been greater.

Firewood Consumption

3.30 Firewood is the most important energy source in rural India. While more households use kerosene than wood, kerosene consumption remains low on average, and rural households rely on fuels other than kerosene for the majority of their cooking needs. A large fraction of rural households, especially the rural poor, use home-grown or freely collected wood. As explained in Annex 1, this makes estimation of the quantities of wood consumed as well as their imputed values difficult. Table A1. in Annex 1 shows that close to a quarter of rural households live in communities where nobody reported purchasing firewood. This gives an indication of the extent of the absence of commercial markets for wood, a situation that is due to both the relative abundance of biomass and the low value of time, arising from a lack of income-generating opportunities. A study of LPG use in Andhra Pradesh undertaken in the previous ESMAP study (World Bank 2002a) shows that when income-generating activities are available, such as during the agricultural season, even rural households with access to free biomass shift from biomass to LPG for convenience and for the time saved.

3.31 The amounts of firewood consumed are shown in Table 3.10, averaged across all households as well as only those households that reported positive consumption of wood. Among wood-consuming households, per capita consumption increased monotonically in both rural and urban areas. Household (as opposed to per capita) consumption also rose in rural areas except in the top decile, but declined in urban areas. The rural trend is consistent with observations in other countries: as rural households become richer, their total energy consumption rises, resulting in an increase rather than a decline in wood consumption.

Table 3.10 Kilograms of Firewood Consumed per Month, 1999–2000

	RURAL				*URBAN*			
HH type	*All*	*Wood*	*All*	*Wood*	*All*	*Wood*	*All*	*Wood*
P.c. decile	*Per capita*		*Per household*		*Per capita*		*Per household*	
1	15	16	82	91	10	14	58	82
2	14	15	82	91	10	13	58	82
3	15	16	85	94	9	15	47	82
4	16	18	88	98	8	16	40	82
5	17	18	93	102	6	17	30	79
6	18	20	92	102	5	18	24	82
7	19	21	95	106	3	17	15	73
8	20	22	94	106	3	17	11	67
9	21	24	95	109	2	20	8	77
10	21	25	92	111	1	21	5	76
Average	18	20	89	103	5	15	24	80

HH – households; All – all households; Wood – households that reported positive consumption of wood.

3.32 Whether households use free or bought firewood is an important question. Where time is unconstrained (that is, valued at close to zero in monetary terms) and there is firewood to be grown or collected, it is difficult for commercial fuels to compete with firewood. The same applies to dung, which is freely available to those households with cattle. Sources of firewood, categorized by requirements for cash outlays, are shown in Table 3.11. The percentages shown are of all households, so that the sum of “free,” “cash,” and “balance” gives the percentage of households in each decile that reported positive consumption of firewood. More than one-half of rural households in every decile except decile 10 used only free firewood. On average, close to 60 percent of rural households did not pay to use wood. In contrast, in urban areas even among the bottom decile less than one-fifth used free firewood, averaging a mere 7 percent across all urban households. About 20 percent of urban and rural households alike used only purchased firewood. In urban areas close to 50 percent of the bottom decile used purchased firewood, the highest percentage of all deciles, whereas in rural areas the highest percentages of purchased firewood users were found in deciles 4 through 9. It is surprising that among those who purchased biomass, the amounts paid were essentially the same for rural and urban households, and even among the bottom 20 percent in rural areas were not markedly lower.

Table 3.11 Sources of Firewood, 1999–2000
(percentage of all households in each decile)

Per capita	*R U R A L*				*U R B A N*			
decile	*Free*	*Cash*	*Balance*	*Rs/mo*	*Free*	*Cash*	*Balance*	*Rs/mo*
1	62%	15%	13%	76	19%	47%	4%	100
2	66%	18%	6%	87	13%	41%	3%	106
3	65%	19%	6%	91	10%	36%	3%	103
4	62%	23%	6%	99	8%	28%	2%	100
5	62%	22%	6%	95	6%	21%	2%	100
6	59%	24%	6%	99	4%	16%	2%	95
7	60%	23%	6%	102	3%	12%	1%	86
8	57%	24%	7%	109	3%	7%	1%	99
9	54%	22%	7%	109	2%	4%	1%	101
10	46%	19%	6%	113	1%	2%	0%	119
Average	59%	21%	7%	99	7%	21%	2%	101

Free – only home-grown or freely collected wood; Cash – only purchased wood; Balance – combination of free and purchased, or other (unspecified) sources; Rs/mo Rs spent per month per household, adjusted for cost-of-living, on wood purchase by those who used only purchased wood.

3.33 Those who rely primarily on purchased wood are the most likely candidates for fuel switching. Those who reported using purchased wood as the primary cooking fuel were analyzed and compared to those who reported using LPG as the primary cooking fuel. The results are shown in Annex 1, Table A1.5 to Table A1.8. Although users of purchased wood were paying significant amounts, they were spending consistently less on fuel than LPG users in the same per capita expenditure decile group. Averaged across all expenditure deciles, they paid Rs 137 per month for wood, kerosene, and LPG, compared to Rs 176 per month spent by those who used LPG as the primary cooking fuel. They were also, on average, poorer than those who cooked mainly with LPG. These findings suggest that the higher cost of cooking with LPG is the major reason for not switching from purchased wood to LPG. There nonetheless were families in the poorer (lower) expenditure deciles that cooked primarily with LPG and families from richer (upper) deciles that cooked mainly with purchased wood. This suggests that factors other than price and affordability (most likely supply availability given the long waiting list for LPG at the time of the survey; other factors include customs and education) play an important role in household fuel choice.

Energy Mix

3.34 One way of understanding multiple fuel use is to list the combinations of energy sources used by households. The results for 1999–2000 are shown in Table 3.12. The top 10 energy mix patterns, which apply to about 80 percent of rural and 70 percent of urban households, are shown in order of decreasing frequency. As expected, in rural areas wood and kerosene appear in every category. Dung appears in four categories, accounting for 35 percent of rural households among the top 80 percent. LPG appears only in the 14th rank (not shown), in combination with electricity and PDS kerosene. In sharp contrast, the most dominant energy mix in urban areas is the combination of LPG and electricity, accounting for close to a quarter of all households and twice as many households as the second most common energy mix: LPG and electricity supplemented by PDS kerosene. Wood appears in only three categories, while electricity appears in all but one category.

3.35 Because kerosene can be used for both lighting and cooking, it is difficult to determine which households use kerosene only for lighting. This makes it difficult to identify dual-energy-source households: that is, those that use only one form of energy for lighting and another form for cooking. The only unambiguous cases are those that list electricity and one other fuel that cannot be used for lighting, namely wood and LPG. The only households that fall under this category are those in urban areas using LPG and electricity. There is also a group that uses only electricity. This group could be a combination of those who use electricity for cooking and those with no cooking facilities. In rural areas, the possibility that all the household categories listed in the table use both wood and kerosene for cooking cannot be excluded.

Table 3.12 Energy Mix of Rural and Urban Households, 1999–2000

Rank	*RURAL Energy mix*	*% HH*	*Cum %*	*Rs/mo*	*URBAN Energy mix*	*% HH*	*Cum %*	*Rs/mo*
1	W, PK, E	15%	15%	172	LPG, E	22%	22%	426
2	W, PK, D	14%	30%	169	PK, LPG, E	11%	33%	357
3	W, PK	12%	41%	112	PK, MK, E	7%	40%	530
4	W, PK, D, E	10%	51%	263	W, PK, E	7%	48%	222
5	W, PK, MK, D	6%	57%	200	MK, E	6%	54%	204
6	W, MK, D	5%	63%	174	MK, LPG, E	5%	59%	359
7	W, PK, MK	5%	68%	147	W, MK, E	3%	62%	215
8	W, MK	4%	72%	122	PK, E	3%	65%	165
9	W, MK, E	3%	75%	174	W, PK	3%	68%	132
10	W, PK, MK, E	2%	78%	217	E	3%	71%	68

PK – PDS kerosene; W – wood; E – electricity; MK – market kerosene; D – dung; HH – households; cum – cumulative; Rs/mo Rs spent on household energy per month per household, adjusted for interstate price differences.

Expenditures on Household Energy

3.36 The monthly household expenditure on energy and its share of the total expenditure is an important determinant of energy choice. It also gives some idea of the scope for fuel switching: for example, a household paying a lot of cash for wood out of its total energy budget is more likely to consider switching to kerosene or LPG than is one that collects free wood. Table 3.13 shows how much rural households were spending, in cash and imputed, on acquiring household energy (excluding transportation fuels), adjusted for interstate price differences. Also shown are household expenditures on energy, excluding electricity and noncash biomass, again adjusted for interstate price differences. A breakdown of energy share for kerosene, LPG, and electricity is given in Annex 1.

3.37 The strong reliance of rural households on cash-free fuels emerges clearly in the table. The percentage share of expenditures on household energy falls to 4.4 percent from 9.2 percent for the bottom decile if cash-free fuels are excluded, and the usual pattern of declining percentage share with increasing income is reversed up to decile 9. The amount of cash spent on fuels was not sufficient to switch entirely to LPG for cooking in any expenditure decile, especially given that in addition to cooking, households need fuel for heating water, and in colder regions of India, for space heating in winter. If all of the cash spent on fuels were used to purchase kerosene, taking into account the average amount of PDS kerosene purchased in each expenditure decile (see Table 3.7 for more detail), the total amount of kerosene purchased would have ranged from 9 liters in the bottom decile to 22 liters per household per month in the top decile. Since some kerosene is used for lighting, especially among the poor, switching entirely to kerosene would also not have been possible with the expenditure pattern shown in the table except among the top two decile groups.

Table 3.13 Expenditure on Household Energy among Rural Households, 1999–2000

Per capita expenditure decile	*Household energy*			*Household energy excluding electricity*				
	Rs/mo per HH	*% share*[1]	*Rs/mo p.c.*	*Rs/mo per HH*	*% share*[1]	*Rs/mo p.c.*	*Rs/mo*[2] *per HH*	*Rs/mo*[2] *p.c.*
1	117	9.2	20	110	8.7	18	46	8
2	142	8.9	24	130	8.2	22	56	10
3	150	8.5	27	135	7.7	24	60	11
4	165	8.5	30	146	7.6	27	69	13
5	172	8.4	33	150	7.3	29	69	13
6	186	8.3	37	158	7.1	31	77	15
7	195	8.3	41	161	6.9	34	78	16
8	210	8.2	46	170	6.7	37	87	19
9	232	7.8	53	180	6.2	41	97	22
10	262	6.8	71	187	5.0	51	116	31
Average	184	8.3	37	153	7.1	30	76	15

mo – month; HH – households. [1]Percentage share of total monthly household expenditure. [2] Based on cash expenditures only

3.38 Table 3.14 shows the corresponding figures for urban households. The urban poor spent close to 10 percent of their total expenditures on energy, despite fuel and electricity subsidies. As expected, reliance on cash-free fuels is markedly less than in rural areas, so that the percentage share of energy expenditures falls only to 8.4 percent from 9.5 percent even among the bottom decile when cash-free fuels are excluded from the total energy expenditure. On a cash-only basis, the pattern of declining energy share with increasing income appears only beginning with decile 5. During the survey period, a 14.2 kg cylinder of LPG—sufficient to meet the monthly cooking energy requirements of most households—cost on average Rs 186. The average cash expenditure excluding electricity purchase of Rs 150 would have purchased about 11.5 kg of LPG per month. While switching to LPG is a much stronger possibility in urban areas on the basis of household cash expenditures, as before it is important to bear in mind that households have energy requirements other than cooking, including the use of kerosene for lighting by those that are not yet electrified. If all the cash spent on fuels was used to purchase kerosene, again taking into account the average amount of PDS kerosene purchased in each expenditure decile, the total amount of kerosene would have ranged from 23 liters to 31 liters per month per household: enough for lighting, cooking, and even some water heating.

Table 3.14 Expenditure on Household Energy among Urban Households, 1999–2000

Per capita expenditure decile	*Household energy*			*Household energy excluding electricity*				
	Rs/mo per HH	*% share*[1]	*Rs/mo p.c.*	*Rs/mo per HH*	*% share*[1]	*Rs/mo p.c.*	*Rs/mo*[2] *per HH*	*Rs/mo*[2] *p.c.*
1	178	9.5	29	139	7.5	23	118	19
2	211	9.2	38	152	6.8	28	138	25
3	234	8.9	45	158	6.2	30	146	28
4	252	8.8	51	162	5.8	33	152	31
5	274	8.5	58	170	5.4	36	162	34
6	283	8.1	64	169	5.0	38	163	37
7	292	7.6	71	165	4.5	40	160	39
8	305	7.1	82	162	4.0	43	158	42
9	329	6.5	97	156	3.3	46	154	45
10	643	5.5	212	152	2.2	50	151	50
Average	299	8.0	66	159	5.1	35	150	33

mo – month; HH – households; p.c. – per capita. [1] Percentage share of total monthly household expenditure.
[2] Based on cash expenditures only

3.39 The faster decline of reliance on biomass, the much lower availability of free biomass, and the much higher cash expenditures on household fuels (excluding electricity) in urban than in rural areas all point to the much greater potential for promoting a shift to cleaner commercial fuels among urban households. At the same time, and precisely because there is much greater reliance on subsidized fuels for cooking, urban households may be affected more by subsidy elimination. This question will be examined in the next chapter.

4

Impact of Policy Alternatives on Household Fuel Consumption

4.1 As Chapter 3 has shown, households typically use a subset of the available energy sources. This study modeled household fuel use accounting for two choices made by each household: (1) the selection of energy sources and (2) the decision regarding the quantity of each energy source to consume. The first choice is made from a finite set of alternatives and can be studied using a discrete choice model. The second choice is the continuous choice of the conventional kind. Because the continuous choice flows from the discrete choice, modeling requires their interdependence to be taken into account. In this study, the first choice was modeled using multinomial logit, and the second choice using linear regression with log-log specifications correcting for the self-selection bias. Details are given in Annex 2. The model is consistent with both sequential and simultaneous decision-making with respect to the two choices.

4.2 Only kerosene, LPG, wood, and electricity were examined (dung could not be included because information on the quantity consumed was not collected). Two models were set up to test the respective model's robustness. Model 1 categorized households on the basis of combinations of energy sources used, further subdividing kerosene according to its source: PDS or market. Model 2 categorized households according to which energy sources were used for cooking and lighting (see Annex 2 for how kerosene use was estimated), not subdividing kerosene as a function of source. Because model 1 utilizes fewer assumptions, its results are taken to draw conclusions; however, the results from the two models are compared first and omitted from further consideration if the results are both statistically different from zero and differ in sign. The explanatory variables were total household expenditures, household size, fuel prices, electricity price multiplied by access, social group, occupation, kerosene quota, state kerosene allocation divided by the number of PDS-kerosene-consuming households, median cluster expenditure, the 80th percentile of PDS kerosene consumption in the first sampling units, the number of kerosene dealers, the number of LPG dealers, and statewide per capita electricity consumption for noncommercial use.

Assumptions and Policy Scenarios Tested

4.3 The results of the modeling pointed to the difficulties of analyzing household fuel use patterns. The factors that contribute to the difficulties include the following:

- ?? *Lack of quantitative information on the rationing of kerosene and LPG.* PDS kerosene is rationed, and there furthermore appears to be large-scale diversion of PDS kerosene to both the black kerosene market and the automotive diesel sector. As a result, many households in the survey did not seem able to purchase the full amounts to which they were entitled. With respect to LPG, there was also rationing in effect, taking the form of long waiting lists for the first cylinder, long turnaround time for cylinder refills, and, for some households, lack of local availability. No quantitative information is available on the actual rationing each household faced.
- ?? *Lack of information on access to free fuels*. No information was collected in the survey regarding the availability of free biomass fuel. The only information collected was the mode of fuel acquisition; no data was collected regarding the distance to the closest source of free biomass, the time it takes to travel there, or other logistical information.
- ?? *Lack of distinction between subsidized LPG and market LPG, and between black market kerosene and parallel market kerosene.* No questions were asked concerning the source of LPG or unit prices paid. Dividing expenditures by amounts did not yield results sufficiently consistent to draw conclusions about whether LPG was purchased from a public sector or private sector dealer. Similarly, it was not possible to distinguish between market kerosene and PDS kerosene diverted to the black market.
- ?? *Lack of information on disposable cash income.* Commercial fuels have to be purchased with cash, so the amount of disposable cash income is an important determinant of household fuel choice. There are no reliable data on household income in India that are linked to household energy expenditures.
- ?? *Uncertainties in the raw data*. The NSS is a general household survey and does not specifically investigate energy use. As such, the NSS questionnaire is not formulated to obtain reliable information on household energy use patterns. The monthly quantities of fuels used, especially with respect to LPG and biomass, are likely to carry large uncertainties (see Annex 1 for more detail). Estimates of imputed values of free biomass are especially problematic.
- ?? *Extrapolation outside the data range.* In trying to simulate the impact of reducing or eliminating price subsidies, the model has to operate outside the range of the available data.

4.4 As a result of the above and other limitations of the data, modeling of this nature would not be expected to yield consistent results. This was true of this study. A number of policy scenarios nonetheless were examined with the objective of assessing the effect of subsidy reduction or elimination and the corresponding mitigation measures:

- ?? increasing the prices of subsidized kerosene and LPG by varying amounts, including complete subsidy elimination
- ?? cash transfer, to the poor as well as to all households
- ?? increasing the amount of PDS kerosene quota
- ?? increasing the number of PDS kerosene dealers
- ?? increasing the number of LPG dealers
- ?? different combinations of the above scenarios

4.5 The scenario simulations tested, among others, two assumptions. The first is a set of assumptions about how the kerosene market operates, and includes the following:

- ?? Kerosene is assumed to be supply-limited because of quotas and diversion.
- ?? Rationing coupled with diversion raises the transaction cost of buying PDS kerosene.
- ?? The effective price of PDS kerosene is the sum of the retail price and its transaction cost.
- ?? Households buy market kerosene when the effective price of PDS kerosene exceeds the effective price of market kerosene (which also carries some transaction cost).
- ?? Increasing kerosene allocation to each state should help make more kerosene (PDS and black market combined, since a portion of PDS kerosene is diverted to the black market) available.
- ?? Increasing the number of kerosene dealers could also make kerosene more easily accessible by reducing the distance to the closest kerosene dealership.
- ?? Some PDS kerosene is diverted to the black market, where the price is higher than that of PDS kerosene but lower than the price that would be attained under market conditions (otherwise supply would rise to match demand). One consequence is that the parallel market for kerosene, launched in 1993, cannot develop adequately because of competition not only from PDS but also from black market kerosene.
- ?? Eliminating the kerosene subsidy (one of the policy scenarios examined) would eliminate the distinction between black market and parallel market kerosene. (Taking this elimination of distinction into account, however, is beyond the scope of this study.)
- ?? Everything else being equal, increasing the price of market kerosene (a combination of black and parallel market kerosene in this study) should make diversion to the black market even more attractive. Conversely, increasing the

price of PDS kerosene would make diversion to the black market less attractive.

The second assumption is that LPG is also supply-limited; that the transaction cost of using LPG is high for a number of households; and that increasing the number of LPG dealers—making it more easily available in principle—is one way of lowering the transaction cost (this policy simulation did not yield consistent results).

4.6 Only those results where both models gave consistent results (that is, the same signs for statistically significant results), and where the predicted trends were not immediately counterintuitive on economic grounds are considered in the rest of this report.

4.7 The policy simulation results are presented in two tables. In the first table, the impact of increasing various parameters by 10 percent and making a cash transfer of Rs 100 per month to the bottom four deciles is examined. This set of scenario simulations helped to identify which explanatory variable changes did not give reasonable results as judged on economic grounds or consistency between the two models. The scenario simulations excluded on these criteria involved increasing the kerosene quota (defined as the amount of kerosene allotted to non-LPG-using households), the number of kerosene dealers, the number of LPG dealers, the price of electricity in rural areas, the kerosene quota, the amount of kerosene allocated to each state, and the number of LPG dealers in urban areas. In the second table, the impact of reducing the kerosene subsidy by two-thirds and eliminating the LPG price subsidy is considered as the starting case for dismantling the administered pricing mechanism. This scenario is compared to seven other scenarios, including the complete elimination of the kerosene subsidy; giving Rs 100 per month to households classified as being below the poverty line (BPL) as well as to all households; eliminating the kerosene subsidy only for households above the poverty line (APL); retaining the LPG subsidy for BPL households; increasing the number of kerosene dealers; and eliminating the LPG subsidy but retaining the kerosene subsidy. The government's definition of APL and BPL for each state, on the basis of per capita expenditure, was used for this purpose.

Modeling Results

4.8 Table 4.1 shows the results of increasing the total household expenditure; increasing the kerosene allocation (defined as the mount of PDS kerosene allocated to each state divided by the number of PDS-consuming households in the state); increasing the prices of PDS kerosene, market kerosene, and LPG; and giving Rs 100 per month per household to the bottom four deciles in rural areas. Predictably, increasing the total household expenditures has the greatest impact on the consumption of LPG and electricity. However, this also increases the consumption of firewood, indicating that, given greater resources, rural households would be likely to use even more firewood. Giving Rs 100 per month to the bottom 40 percent also increases energy consumption, but to a much lesser extent. In this study, results that show percentage changes within ?1 percent are considered not statistically different from zero. On this criterion, the only statistically significant increases in energy consumption are market kerosene, firewood, and electricity. Importantly, with extra income the poor do not purchase more PDS kerosene but instead consume more market kerosene. The transaction cost of purchasing PDS kerosene seems high, if the poor are prepared to pay considerably more to buy market kerosene. Comparison of these two scenarios is not entirely consistent with the assumption of PDS kerosene being supply-limited, as richer households are seen to purchase more PDS kerosene as their household expenditures rise.

Table 4.1 Impact of a 10 Percent Increase in Energy Consumption in Rural Areas

Energy	*Total household expenditure*	*Rs 100 to bottom 40%*	*Price of LPG*	*Price of PDS kerosene*	*Price of market kerosene*	*Kerosene allocation*
Total kerosene	2.4	0.7	0.0	-1.6	-0.1	2.9
PDS kerosene	1.3	0.5	0.1	-2.0	0.7	0.6
Market kerosene	5.3	1.3	0.0	-0.5	-1.9	8.6
LPG	16	0.6	-7.4	0.5	0.8	0.9
Firewood	2.9	1.0	0.1	-0.2	-0.2	-3.6
Electricity	9.0	1.1	-0.1	0.7	-0.4	-3.7

Note: Percentage change relative to the base (1999–2000 actual) case

4.9 Increasing the price of LPG has the expected result of decreasing LPG consumption, but has no other impact. Increasing the price of PDS kerosene decreases the consumption of PDS kerosene. The impact of increasing the price of PDS kerosene is complicated to work out because of several considerations: it may or may not lower the transaction cost of procuring PDS kerosene, it lowers the effective income of households by reducing the amount of subsidy received, it makes diversion less attractive (thereby making more PDS kerosene available for household use), and as a result of lower diversion, the amount of black market kerosene available may be decreased. In the above result, price elasticity is seen to dominate.

4.10 Increasing the price of market kerosene should make diversion to the black market even more attractive, reducing the availability of PDS kerosene for purchase by households and increasing supply on the black market. The impact on diversion to the automotive sector is not clear unless the price of market kerosene is linked to the price of diesel, in which case diversion to the automotive sector also becomes more attractive. The model result gives a fall in the consumption of market kerosene and no statistically significant change in the consumption of any other energy source. The fact that higher retail prices of PDS and market kerosene lead to a decline in the consumption of both fuels suggests that the transaction cost effect is weaker than the direct price effects.

4.11 Increasing the allocation of PDS kerosene gives a somewhat surprising result. Everything else, including diversion, being the same, increasing kerosene allocation by 10 percent should result in a 10 percent increase in the consumption of PDS kerosene. In fact, the increase is statistically insignificant, indicating a near 100 percent leakage. If the numerically obtained figure of 0.6 percent (which is not statistically different from zero) is used to compute diversion, it still amounts to a leakage rate of 94 percent. While leakage may increase with increasing allocation, such a high leakage rate is unlikely and further points to problems encountered when trying to model household energy use in the face of so many uncertainties and limitations.

4.12 Table 4.2 shows the impact of reducing the kerosene subsidy by two-thirds and eliminating the LPG subsidy (under the scenario named "reduced subsidy"), and several variations on this reference case. Predictably, the reduced subsidy case has a larger impact on the consumption of PDS kerosene and LPG than on other energy sources. Eliminating the kerosene subsidy altogether (case A) further reduces PDS kerosene consumption. Eliminating the kerosene subsidy only for APL households and reducing it by two-thirds for BPL households (case B) has a comparable effect to that of case A. Keeping the same prices as in case A but giving Rs 100 per month to BPL families (case C) has little impact: there is a slight increase in the consumption of all energy sources relative to case A but the increase is very small compared to the difference with the base case. Giving Rs 100 per month to all households (case D) has a larger impact than case C, with more LPG and market kerosene being purchased. As expected, eliminating the LPG subsidy only for APL households in case E is no different from case A, because BPL families do not typically use LPG. Eliminating the kerosene subsidy but retaining the LPG subsidy actually increases LPG consumption, suggesting that higher-income rural households would switch from kerosene to LPG. If the kerosene subsidy is retained and the LPG subsidy is eliminated, the opposite happens: kerosene consumption remains the same as the base case and LPG consumption falls markedly.

4.13 The model outputs shown in Table 4.2 contain some problematic results. First, wood consumption in most cases is seen to fall. It is unlikely that rural areas, where about 60 percent of all households use free biomass, would see a fall in the consumption of firewood when the prices of kerosene and LPG are doubled. On the contrary, those households using kerosene and LPG for cooking would be expected to cut back on the consumption of kerosene and LPG and use more firewood. Both models gave results with the same sign, but this suggests that modeling is not robust with respect to firewood consumption. Second, electricity consumption increases in response to higher kerosene and LPG prices. This would not be expected on two accounts: (a) electricity is cheaper than kerosene for lighting, so whenever power is available, households prefer to use electricity if they are connected; and (b) households that are connected turn to kerosene primarily when electricity is not available due to power outages. Subsidy reductions are also equivalent to income reduction, with the result that through the income effect households may be expected to use less electricity. The output of the discrete choice model in fact shows that the number of households connected to electricity falls in the reduced subsidy case, but those who remain connected use more. This is difficult to explain, and suggests that the model is not robust with respect to electricity consumption.

Table 4.2 Percentage Change in Energy Consumption in Rural Areas

Energy	*RS*	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*A*	*B*	*C*	*D*	*E*	*F*	*G*
	Relative to the base (1999–2000 actual) case								*Relative to RS*						
Total kerosene	-11	-15	-14	-14	-13	-15	-15	0.2	-3.8	-3.1	-3.4	-2.4	-3.8	-4.0	13
PDS kerosene	-14	-18	-17	-18	-17	-18	-18	0.3	-4.7	-3.8	-4.5	-3.9	-4.8	-5.0	16
Market kerosene	-4.1	-5.7	-5.6	-5.0	-3.2	-5.7	-5.8	0.1	-1.7	-1.5	-0.9	1.0	-1.7	-1.8	4.5
LPG	-33	-32	-32	-32	-29	-32	5.7	-36	1.4	1.4	1.7	5.8	1.7	57	-4.1
Firewood	-0.9	-1.3	-1.2	-0.7	0.3	-1.3	-1.6	0.3	-0.4	-0.3	0.2	1.2	-0.4	-0.8	1.3
Electricity	4.8	6.3	6.2	6.8	10	6.3	6.7	-0.4	1.5	1.3	2.0	5.1	1.5	1.9	-4.9

RS (reduced subsidy) – PDS kerosene price increases by Rs 4 per liter and LPG cylinder price increases by Rs 124
A – PDS kerosene price increases by Rs 6 per liter and LPG cylinder price increases by Rs 124
B – PDS kerosene price increases by Rs 4 per liter for BPL, Rs 6 per liter for APL, and LPG cylinder price increases by Rs 124 for all households
C – Same as A but Rs 100 per month is given to BPL households
D – Same as A but Rs 100 per month is given to all households
E – PDS kerosene price increases by Rs 6 per liter for all households and LPG cylinder price by Rs 124, only for APL households
F – PDS kerosene price increases by Rs 6 per liter and LPG subsidy is retained in full
G – PDS kerosene subsidy is retained in full and LPG cylinder price increases by Rs 124

4.14 The corresponding tables for urban areas are shown in Table 4.3 and Table 4.4. In these tables, the scenarios reported are not the same as those for rural areas because different scenarios had to be excluded based on the two criteria discussed in paragraph 4.6. Comparison of Table 4.1 with Table 4.3 immediately points to marked differences between urban and rural households. Increasing the total household expenditure by 10 percent reduces kerosene and firewood consumption in urban areas; in contrast, their consumption in rural areas rises. Giving Rs 100 per month to the bottom four expenditure deciles gave no statistically significant changes. Increasing the price of LPG and the electricity tariff has the expected effect of reducing the consumption of these two energy sources. As in rural areas, increasing the price of PDS kerosene decreases its consumption, but increasing the price of market kerosene has no impact. Increasing the number of PDS kerosene dealers increases the consumption of PDS kerosene markedly and somewhat decreases firewood consumption, suggesting that this is one way of reducing the transaction cost of buying PDS kerosene. Assuming that PDS kerosene is diverted to the black market, one explanation for the increase in the consumption of market kerosene is that the lower transaction cost of obtaining PDS kerosene leads to greater diversion to the black market. It is not clear why electricity consumption should fall, given that the primary use of kerosene in urban areas is for cooking: using more kerosene to cook should not have an impact on electricity consumption. As before, the model may not be robust with respect to electricity consumption.

Table 4.3 Impact of a 10 Percent Increase in Energy Consumption in Urban Areas

Energy	*Total household expenditure*	*Rs 100 to bottom 40%*	*LPG price*	*Electricity price*	*PDS kerosene price*	*Market kerosene price*	*PDS kerosene dealers*
Total kerosene	-1.0	0.3	0.1	-0.5	-1.7	0.2	4.3
PDS kerosene	-1.2	0.0	0.2	-0.3	-2.4	0.8	6.1
Market kerosene	-0.7	0.8	0.1	-0.8	-0.8	-0.5	2.2
LPG	7.4	0.8	-8.1	0.4	0.8	-0.3	-0.5
Firewood	-2.0	0.2	0.1	-0.6	0.5	0.1	-1.0
Electricity	8.1	0.9	-0.3	-5.3	-0.1	-0.3	-2.8

Note: Percentage change relative to the base (1999–2000 actual) case

Table 4.4 Percentage Change in Energy Consumption in Urban Areas

Energy	*RS*	*A*	*B*	*C*	*D*	*E*	*G*	*H*	*A*	*B*	*C*	*D*	*E*	*G*	*H*
	Relative to the base case								*Relative to RS*						
Total kerosene	-14	-19	-18	-19	-19	-19	0.8	-9.8	-6.2	-4.9	-6.0	-6.1	-6.3	4.8	17
PDS kerosene	-19	-26	-24	-26	-26	-26	0.9	-14	-8.5	-6.6	-8.5	-8.8	-8.5	6.4	25
Market kerosene	-7	-11	-10	-11	-10	-11	0.6	-4.7	-3.8	-3.0	-3.3	-3.2	-3.8	3.0	8.7
LPG	-36	-35	-35	-34	-33	-33	-40	-36	2.0	1.7	2.3	4.1	3.6	-0.3	-6.2
Firewood	4.3	5.7	5.1	6.0	5.6	5.7	0.3	3.8	1.3	0.7	1.6	1.2	1.3	-0.5	-3.9
Electricity	-2.1	-2.1	-2.1	-1.7	0.1	-2.1	-1.4	-5.3	0.0	0.0	0.5	2.3	0.1	-3.2	0.7

RS (reduced subsidy) – PDS kerosene price increases by Rs 4 per liter and LPG cylinder price increases by Rs 124

A –PDS kerosene price increases by Rs 6 per liter and LPG cylinder price increases by Rs 124

B – PDS kerosene price increases by Rs 4 per liter for BPL, Rs 6 per liter for APL, and LPG cylinder price increases by Rs 124 for all households

C – Same as A but Rs 100 per month is given to BPL households

D – Same as A but Rs 100 per month is given to all households

E – PDS kerosene price increases by Rs 6 per liter for all households and LPG cylinder price by Rs 124 only for APL households

G – PDS kerosene subsidy is retained in full and LPG cylinder price increases by Rs 124

H – Same as RS, and in addition the number of PDS kerosene dealers is increased by 10 percent

4.15 Comparison of Table 4.2 and Table 4.4 shows that in the reduced subsidy scenario and in cases A–E, the fall in the consumption of PDS kerosene, market kerosene, and LPG is greater, and the increase in the consumption of wood much greater, in urban areas than in rural areas. The patterns with respect to kerosene and LPG may reflect the fact that a significantly greater proportion of households use kerosene and LPG in urban areas, and those users who are not well off respond more to price increases. Although the fall in wood consumption in rural areas with subsidy reduction seems questionable, it is possible that wood consumption rises more in urban areas because of the greater reliance in these areas on kerosene and LPG for cooking, for which wood is a substitute. Comparison of case A and case C shows that the poor would not spend the extra Rs 100 per month on the purchase of fuel—a finding similar to that for rural households.

4.16 The only difference between the reduced subsidy scenario and case B is that in the latter APL households pay an extra Rs 2 per liter for PDS kerosene. Urban APL households respond to this additional price increase by increasing LPG consumption at the expense of kerosene. Comparison of case C and case D shows that APL households may spend a little of the extra Rs 100 on LPG, but not on kerosene. APL households would, however, use more electricity. Case H suggests that the effect of reducing the kerosene subsidy could be partially compensated by increasing the number of PDS kerosene dealers, although LPG consumption falls slightly.

4.17 The key findings of the modeling exercise can be summarized as follows:

- ?? Increasing the prices of kerosene and LPG (by reducing subsidies) causes a greater reduction in the use of PDS kerosene, market kerosene, and LPG in urban areas than in rural areas, probably on account of the greater use of kerosene and LPG for cooking by low- and middle-income households in urban areas.
- ?? With respect to possible compensatory measures, a cash transfer to the poor of Rs 100 per household per month did not much change fuel selection. Using cleaner fuels apparently is not a top priority of poor households, especially not of those that have access to free or cheap biomass.
- ?? Increasing everyone’s income by 10 percent resulted in an increase in the consumption of every energy source in rural areas, but a drop in the use of firewood and kerosene (in favor of LPG) in urban areas.
- ?? If PDS kerosene is to be preserved, increasing the number of PDS kerosene dealers may be one way of lowering the transaction cost of buying PDS kerosene and of reducing leakage.

The hypothesis that the use of LPG may be limited by supply constraints, in addition to income and price considerations, could not be tested adequately because increasing the number of LPG dealers gave inconclusive results.

5

Conclusions and Recommendations

5.1 The foregoing chapters have described the status of the kerosene and LPG markets in India, rural and urban household fuel use patterns as reported in the NSS, and estimates of the impact of phasing down kerosene and LPG subsidies and of a handful of mitigation measures. This chapter compares the findings with those from other countries, and considers the implications given the international price trends of these two fuels in recent years and the market structure in India.

Evidence from International Experience

5.2 It is useful to look to the experience of other countries that have attempted to promote household use of hydrocarbon-based fuels. The standard approach is to change relative fuel prices by fiscal means. Worldwide, a number of countries, particularly oil producing countries, have had zero or negative taxes on kerosene and other fuels such as diesel and LPG. Countries that subsidize LPG include Côte d'Ivoire, Ecuador, India, Senegal, and Venezuela. LPG subsidies, however, typically benefit middle- and higher-income families in urban areas, and hence are not pro-poor. Some countries have made efforts to make LPG subsidies more pro-poor. For example, Côte d'Ivoire and Senegal have specifically targeted their subsidies at smaller cylinders to make each refill more affordable, promoting the use of 6 kg and smaller cylinders as opposed to the more commonly used 12.5 kg cylinder. However, despite the subsidy (about 25 percent, as of December 1999) making unit costs lower for cylinders smaller than 12.5 kg, consumers in Côte d'Ivoire have not switched to 6 kg cylinders: in 1999, less than 10 percent of LPG was sold in the subsidized 6 kg bottles. In Senegal, 2.75 kg and 6 kg cylinders have historically been heavily cross-subsidized by larger cylinders, and LPG has become the principal cooking fuel for many urban households. However, the urban poor still find (subsidized) LPG expensive, using instead charcoal, which is cheaper and can be purchased daily. The government of Senegal is now in the process of phasing out its LPG subsidy entirely because of its high fiscal cost.

5.3 Worldwide experience shows that it is extremely difficult to use subsidies to induce the poor to switch to kerosene or LPG for cooking. The task is virtually impossible where free biomass is available and time is unconstrained because of the absence of income-generating opportunities. Only when biomass becomes a commodity traded for cash, typically in urban and peri-urban areas, do the poor begin to consider alternative fuel options. Even so, the poor find fuels that can be purchased on a daily basis, such as kerosene or charcoal, more affordable than LPG, which can be purchased only one cylinder at a time. Add to this the higher start-up cost of LPG and its higher price relative to kerosene or charcoal, and LPG is out of reach for the poor.

5.4 Kerosene merits special consideration because it is used for lighting by the poor. Absent a reliable source of electricity, making kerosene available and affordable to poor nonelectrified households has been considered important by many governments. However, no developing country government has been able to develop a successful kerosene subsidy scheme to set an example to follow. Subsidies need to be sizable to induce the poor to take up kerosene, but a large kerosene price subsidy leads to both massive leakage and lack of fiscal sustainability. A coupon scheme, which in principle can allow better targeting and be effective for some goods, does not seem to prevent or significantly reduce kerosene leakage as illustrated by the experience of Nepal. In another example, kerosene was heavily subsidized in Peru from the 1950s until 1991, when the subsidy was withdrawn. During this period, kerosene became the cooking fuel of choice among many households. Subsidized kerosene was not rationed, and a substantial amount was diverted to the automotive diesel sector or was smuggled out of the country. As in India, petroleum product subsidies in Peru amounted to billions of dollars by the late 1980s, eventually leading the government to withdraw the subsidy and liberalize the market. Today, significant private sector participation has made LPG available at competitive prices in large and medium-size cities, with the result that LPG has become the fuel of choice.

5.5 The findings of this study are broadly consistent with those of a series of studies conducted in mainly rural Mexico (Masera and others 2000), (. The researchers found that the exclusive use of fuelwood for cooking tended to be concentrated among low-income households. When households began using LPG, in rural areas they almost never abandoned fuelwood, such that nearly all households that were using LPG were multiple-fuel users. Furthermore, mixed fuel (fuelwood and LPG) users tended to consume more overall energy than fuelwood-only users. As a result, the fuelwood savings from adopting LPG, which ranged from 0 to 35 percent, were much smaller than would have been expected if fuel substitution alone had occurred.

5.6 In the Mexican study (Masera and others 2000), surprising results were found when smoke was measured during cooking. Ambient concentrations of particles smaller than 7 microns were measured around the cook. (In terms of health impact, the smaller the particle the more damaging it is. Particles smaller than 7 microns are therefore suitable for estimating the adverse impact of indoor air pollution on public health.) The average particulate concentration did not decrease consistently as income rose. In fact, the average concentration among the lowest-income households was 450 ? g/m³, but this rose to 845 ? g/m³ among the most affluent households where the highest proportion of LPG usage was found. While these findings need to be interpreted with caution because of the small sample size, they nevertheless illustrate the point that air pollution levels do not necessarily decrease monotonically with increasing wealth or by the simple expedient of adopting LPG. The researchers offered several possible explanations for these household pollution measurements results. For example, as income rises the kitchen area is more frequently separated within the house, and some affluent households also will remodel the kitchen, using materials that do not permit as much air flow: for example, replacing wooden walls with cement walls.

5.7 In some countries, governments do not subsidize LPG directly but use moral suasion to prevent retail prices from rising too high. One consequence of setting an arbitrary price ceiling that is unrelated to the international price is that such a move discourages investment in importation infrastructure by constraining the ability to recoup that investment, resulting in LPG supply shortages. This points to the importance of allowing market-determined prices to test consumer willingness to pay and of allowing market forces to equilibrate supply and demand.

5.8 Some governments also require all LPG distributors to supply a certain fraction of their total sale to "remote areas." This tends to result in an inefficient and costly distribution system, because it is difficult for any one firm to take advantage of economies of scale. If supply to remote areas is a legitimate concern, it may be better to introduce a bidding process whereby a time-bound exclusive right to supply a remote area is given to one (or two) supplier(s) according to performance-based criteria, rather than to require every LPG distributor to supply a mandatory percentage of their product to these areas.

5.9 Reducing the start-up cost is another way of easing the transition to petroleum, and especially gaseous, fuels. The Government of Senegal began its LPG promotion program by removing all import duties on 2.75 kg LPG cylinders and on the cookers designed for these cylinders. In Guatemala, LPG dealers offer installment plans for the cylinder deposit fee and stove purchase. While it actually increases the total payment for start-up, this payment scheme helps households with cash constraints to take up LPG.

5.10 With respect to reducing the start-up cost, the Deepam scheme launched by the State Government of Andhra Pradesh (GoAP) in July 1999 offers some useful insights. Under this scheme, the GoAP agreed to cover the cylinder connection fee of Rs 1,000 for 3 million women from BPL households who are members of self-help groups. The scheme covers only LPG sold by state oil companies. The Deepam scheme differs from the central government's LPG subsidy in several respects. First, it is a one-off subsidy, covering the connection fee rather than the fuel purchase. Second, it is a targeted subsidy scheme for which only BPL households are eligible. Third, the program especially concentrates on rural areas, with the majority of recipients selected from these areas. Last, it is implemented through women self-help groups which have helped their members to overcome the upfront cost barrier of LPG uptake by providing credit for the purchase of LPG stoves and accessories (amounting to some Rs 1,000).

5.11 A review of the Deepam scheme conducted in 2001–02 (Rajakutty and others 2002) for the previous ESMAP study found that the Deepam Scheme had successfully facilitated the uptake of LPG by the rural poor in Andhra Pradesh, with 1.7 million connections released by February 2002. However, the review also found that biomass remained the main cooking fuel for most Deepam beneficiaries, and especially for the cash-strapped rural households that could not easily afford the relatively high cost of LPG refills. While in principle microcredit schemes may help with LPG purchase, and while self-help groups are ideally suited for microcredits, the groups under the Deepam scheme did not consider this a priority (this is consistent with the general observation that microcredit schemes are most effective when used for production rather than consumption). Among such rural households LPG use was confined to incidental use, such as for making tea or preparing meals for unexpected guests. LPG was most extensively consumed during the monsoon season, which coincides with the beginning of the agricultural season: at this time more cash is available to agricultural laborers, who earn regular wages during this period; less labor is available as a result for firewood collection; and keeping biomass dry is difficult. On average only 2.6 kg of LPG per month per household was consumed by rural Deepam beneficiaries, which is not nearly enough to meet their cooking requirements. The limited use of LPG diminishes the health and other social benefits of LPG uptake as well as the potential for establishing commercially viable LPG markets catering to these poorer households.

5.12 Predictably, LPG consumption was higher among urban households that had higher cash income and limited access to cheap biomass. To facilitate the uptake of LPG, it is important that the targeted beneficiaries can afford regular refills and that they regard this expense as a priority. Those who are too poor to buy LPG regularly may be tempted to take advantage of the cylinder subsidy, but make limited use of it. Overall, the Deepam scheme facilitated the uptake of LPG but failed to encourage substantial and sustainable use by its intended primary beneficiaries, the rural poor, raising questions about its effectiveness.

5.13 In summary, a review of international experience points to two important observations. First, no good example of an effective subsidy scheme for LPG or kerosene has been found. Subsidies to reduce the price of these fuels commonly have resulted in significant leakage and/or mistargeting; the Deepam scheme furthermore has highlighted the limitations of encouraging the poor to use LPG with the help of targeted capital subsidy. Second, the approach that emerges as most sustainable in the long run for the purposes of expanding access and improving the quality of service is to create an open and competitive market with clearly defined and well-enforced rules and regulations for all participants.

5.14 The use of natural gas as a household fuel is limited in India, although its use can potentially expand in the future given recent large gas discoveries. Establishing a distribution system for households is expensive, but it is worth considering the many advantages of natural gas. Aside from electricity, natural gas is the cleanest commercially viable household fuel. Its greatest drawback is the fact that it is primarily viable only for urban and peri-urban areas, because laying down distribution networks to rural areas would in most cases be prohibitively costly. It nonetheless can serve a useful purpose by supplying a large number of urban households; and with growing urbanization, the percentage of the population that can be served by natural gas will increase. Where indigenous sources of natural gas exist, as in some parts of India, it can be far cheaper than LPG or kerosene. Except where electricity is specifically required, it is perhaps the only fuel that can meet all the energy needs of the urban poor, including heating. Targeted subsidies are also easier to construct, because it is more difficult to "divert" natural gas piped to the household than it is to divert kerosene or LPG. The simplest approach would be to structure the tariff so that there is a small first block, enough to meet the cooking and limited amount of heating needs of poor households, at a (low) "lifeline rate." This first block could be cross-subsidized by higher blocks so that the scheme entails no government subsidies. Analysis of household use of natural gas in Pakistan indicates that a reasonable first block can cover about 25 to 30 percent of all consumers and those who consume less than the first block limit consume only about 5 percent of the total gas sale to households.

Summary of Observed Fuel Use Patterns and Impacts of Policy Alternatives

5.15 The findings of this study are broadly consistent with observations made in other countries. The majority of households in rural areas and many urban households use multiple energy sources for cooking and lighting. In 1999–2000, the use among the urban poor of LPG and kerosene as primary cooking fuels was found to be limited, and among the rural poor to be essentially nonexistent. Kerosene was used as the primary lighting fuel by the majority of rural households.

5.16 The price subsidy for LPG accrues disproportionately to the urban rich, and is difficult to justify on equity grounds. The kerosene subsidy is subject to massive leakage, with as much as half of the subsidized kerosene being diverted to the black market and to other sectors such as transport. In 1999–2000, this leakage amounted to Rs 40 billion (about US$ 1 billion) of public funds that did not reach the intended beneficiaries. The kerosene subsidy that actually reaches households benefits the poor more than the nonpoor, but given the level of diversion the cost-effectiveness of the subsidy is low.

5.17 Nationally, three-quarters of all households were using biomass in 1999–2000. In rural areas this level of usage had remained virtually unchanged since 1993–94, with more than 90 percent of rural households using wood, dung, or both. Mirroring the findings in other countries, wood consumption by rural households rose with increasing income, so that boosting income alone would not help to reduce wood use. Close to 60 percent of all rural households were using cash-free wood in 1999–2000. In short, supply conditions in rural areas favor biomass because of the low labor costs in such areas and the ready availability of fuel. This suggests that it would be difficult to design a fiscally sustainable pricing policy that would promote fuel switching from biomass to petroleum fuels in rural areas.

5.18 In contrast, over the same period in urban areas biomass use declined markedly and kerosene consumption also fell, largely in favor of LPG. In 1999–2000, one-third of all urban households were still using biomass, but the proportion of households relying on cash-free wood was 7 percent, considerably less than the corresponding figure in rural areas. About one-fifth of urban households, including one-third to one-half of the urban poor, were paying on average Rs 100 per month to purchase wood. With continuing urbanization and the increasing scarcity of biomass, wood prices are likely to rise, obliging this group of households to pay more for their fuel and potentially driving them to use modern fuels. This suggests that targeted interventions are likely to meet with greater success in urban and peri-urban areas than in rural areas. Growing urbanization in India also means that those households that are potential candidates for fuel switching will increase as a percentage of the total population.

5.19 In 2002–03, the Ministry of Finance initially provided Rs 45 billion for kerosene and LPG price subsidies. Because of the rising international oil price this proved to be inadequate, and the actual subsidy figure was more than Rs 100 billion, of which the government agreed to pay Rs 63 billion (Business Standard 2003a). Clearly, this situation is not sustainable. Given the enormous sum of public funds involved, coupled with a remarkably high leakage (about half) of the PDS kerosene subsidy and a highly regressive distribution of the LPG subsidy, it is worth seeking alternative uses of this money that from the point of view of increasing public welfare generate higher returns, such as, for example, improving and expanding the provision of basic health care and education, or improving the supply of safe water and sanitation. The subsidy figure of Rs 63 billion for fiscal 2002–03 was the same order of magnitude as the entire central government's spending on education (the Central Plan allocation for education was Rs 62 billion, of which Rs 43 billion was set aside for primary education (The Tribune 2003)), and was markedly higher than the Rs 4 billion allocated for rural employment programs (The Hindu 2002).

5.20 Phasing down subsidies will diminish the ability of the urban poor and low- and middle-income households to use LPG or kerosene as their primary cooking fuels. It is, however, difficult to overlook the problems associated with the current subsidies. There are other means to help these households. Promoting the uptake of LPG and kerosene is a challenge that needs to be addressed, but not necessarily through a government-funded fuel subsidy (see the recommendation section below).

5.21 In the case of lighting, those without connection or a reliable electricity supply have little choice but to continue using kerosene. The amount of kerosene used for lighting is about 4 to 5 liters a month. If the kerosene subsidy were to be eliminated altogether, it could lead to a price increase of Rs 7 per liter (at the international oil price as of February 2003, when oil prices were high). This would translate to an incremental cost of Rs 28 to 35 per month per household, or about an additional 2 percent as a share of the total expenditure of a BPL household. Assuming a world crude oil price that is more representative of historical averages, the impact would be smaller. It is not obvious that this modest amount justifies the current subsidy, half of which is diverted to nonintended users. In the longer term, this issue is expected to be addressed by the improving access to and better quality of electricity services.

5.22 Cash transfer to the poor to compensate for subsidy phase-down or elimination, normally a sensible policy on account of the freedom of choice it gives to recipients, does not seem suitable for promoting a shift in cooking fuel use toward hydrocarbons. Limited modeling, consistent with international evidence, indicates that the urban poor and all rural households conversely may use more wood if a modest amount of cash is given to them.

5.23 Generally, no effective subsidy mechanism for kerosene or LPG seems to exist. Neither analysis of consumer energy choice in India nor international experience points to any viable subsidy scheme for these petroleum fuels. This is because both kerosene and LPG have attractive alternative uses by the nonpoor (such as vehicle owners), while the poor have other cash expenditure needs that they consider a higher priority than conversion to modern cooking fuels when traditional biomass is widely available. LPG in particular is strongly favored by the rich as a cooking fuel. Any subsidy for these fuels, regardless of its design, therefore is subject to significant leakage, mistargeting, or both. In addition, unlike water, electricity, or natural gas networks, access to which is predicated on the larger community choosing to establish the necessary supply infrastructure, with the decision often taken by the government, the distribution of kerosene and even LPG relies on the individual household's decision and its ability and willingness to pay for the start-up (stove and cylinder) and operating (fuel) costs. The ratio of operating to start-up costs furthermore is much higher for kerosene and LPG than it is for water, electricity, or natural gas, thus limiting the effectiveness of subsidizing the start-up costs for the poor, as illustrated by the Deepam scheme. All these factors compound the difficulties of designing a subsidy to facilitate a shift to kerosene or LPG by low-income households.

5.24 Given the merit qualities of cleaner household energy, the social benefits (health and time savings for women and children) of partial fuel switching, whereby wood continues to be used and only partially substituted by kerosene or LPG, need to be better understood. For example, the health benefits of smoke-free indoor air that could be realized through the full abandonment of traditional biomass fuel use are likely to be compromised by partial fuel switching, but the effects of different combinations of fuels and stove technologies are little understood. Benefits from time savings, however, are more broadly in line with the amount of biomass used, and accrue to women even with partial fuel switching (time savings were the most significant benefit cited by the Deepam beneficiaries). Furthermore, to the extent partial fuel switching is the first step toward full fuel switching and may accelerate the latter, it may warrant efforts to promote it even if the immediate social benefits are limited.

Recommendations

5.25 **There is a strong case for phasing out the LPG price subsidy.** Aside from equity considerations, subsidy phase-down and eventual elimination would remove an important obstacle to the development of a vigorous LPG market: the unequal treatment given to private versus public sector LPG marketers. Creating a market environment in which fair, healthy, and transparent competition flourishes is the most effective way to enhance efficiency and to pass the efficiency gains to consumers, and thus to expand the supply and availability of LPG. What is important is the introduction of full competition on a level playing field: international experience demonstrates abundantly that nothing forces the oil industry to innovate, increase efficiency, improve corporate governance, and increase quality of service as much as intense and relentless competitive pressures. At a minimum, such a market environment should help to make more LPG available to those households that are able and willing to pay to switch to LPG. A competitive market also would encourage market innovations and experimentation with different schemes to help low-income households to take up LPG, such as the marketing of smaller cylinders and the introduction of installment plans for the purchase of the LPG cylinder and stove—or even LPG refills if a commercially viable scheme can be designed.

5.26 **Despite some equity concerns, there is a strong case against the policy of universal price subsidy on rationed PDS kerosene**. Kerosene is too close a substitute for automotive diesel to maintain an effective price subsidy. (In some parts of North America, kerosene and diesel are in fact identical in chemical composition and differ only in labeling.) In India, the dual system of kerosene marketing further exacerbates leakage. Subsidy removal would end rationing and supply shortages and would give greater incentives to private marketers of kerosene to establish dealerships in areas where there is demand

5.27 The conclusions of this study therefore lend support to the announcement by the Ministry of Finance in June 2003 that the LPG and kerosene subsidies will be phased down in three years and eliminated by April 2006 (Business Standard 2003d). It should also be noted that there are ways to ease the impact of subsidy phase-down on consumers. Given the subsidy framework in India, subsidy phase-down would be easier for the government when international prices are low, when the subsidy element is small and the impact on households of the phase-down correspondingly small. When international prices are falling, by maintaining end-user prices constant the government may be able to effectively shrink the subsidy component to the point where its removal results in little or no price increase. The three-year period proposed by the Ministry of Finance gives, in principle, sufficient opportunities to implement this approach and eliminate subsidies in a smooth manner, avoiding large price shocks for consumers.

5.28 **There is a clear need to identify options other than LPG and kerosene subsidies to promote cleaner household energy, inside and outside the petroleum sector, that are effective and viable.** The prospects for fuel switching by households and for effective government interventions are distinctly different for urban and rural areas. Access to free or cheap biomass fuel and the availability of income-generating opportunities for those spending time on biomass collection and cooking are critical factors in determining consumer choice. These factors more strongly favor a shift to petroleum fuels in urban than in rural areas. To the extent biomass is traded for cash or has clear opportunity costs in rural areas (such as during harvesting or during the monsoon season), it also influences fuel choice, but on a much smaller scale both in terms of the percentage of households affected and in terms of the relative share of commercial fuels in the total household energy mix. The following are some possible solutions and approaches taking account of these urban/rural differences.

?? **For LPG and kerosene, the best way to promote access and uptake in the long run is to liberalize the downstream petroleum market.** To this end, a necessary step is to phase out subsidies which cause market distortions, impede new entry and competition, and slow down the development of efficient markets.

?? **An important role of the government is to establish and enforce adequate technical and safety standards, and ensure consumer protection**, especially against under-filling of LPG cylinders. This merits special attention in the early days of rapid LPG market development, as international experience suggests that in a market with a large number of operators and little enforcement, accidents and commercial malpractice can become common.

?? **There are significant opportunities to facilitate a shift away from traditional biomass to clean fuels in urban and peri-urban areas, including among the poor.**

- Urban and peri-urban households would be among the primary beneficiaries of a fully liberalized, competitive market for LPG and kerosene, which would increase uptake among those who are able to pay.
- There is scope for expanding the market for these fuels through the use of incentives for low-middle-income households. Neither kerosene nor LPG is likely to become the primary cooking fuel of the poor. There are, however, households that are higher on the income ladder that would consider switching to LPG if they could afford the cylinder connection fee. Market-based schemes to help these households pay for the start-up cost of LPG could be effective. Importantly, these schemes are more likely to be implemented in a competitive market.
- For those poorer urban and peri-urban households that cannot afford LPG or kerosene but purchase wood for cash, improved (cleaner and more efficient) biomass stoves and fuels (such as biomass waste briquette technologies) may be a cheaper attractive option.
- In the long term, promoting the use of natural gas in cities with gas pipelines merits consideration, particularly in view of the recent gas discoveries in eastern India. Establishing a distribution network for households is expensive. Nevertheless, natural gas is well suited for a targeted subsidy: diversion is difficult and there is the option of cross-subsidizing a small first block (lifeline tariff) by higher blocks. The gas tariff structure should be carefully designed to allow the urban poor to use natural gas to meet most of their household energy needs without unduly subsidizing middle- and upper-income households.

?? **Rural areas are more difficult to deal with and require a concerted multi-sectoral approach over a long period of time.**

- Establishing an open and competitive market of petroleum fuels would help, even though to a smaller extent than in urban areas.

- Fostering economic growth, employment opportunities (particularly for women), and rural infrastructure development, important in and of themselves, have the collateral benefits of also facilitating fuel switching.
- Accelerating the viable expansion of rural electrification is of special importance, because it would both reduce the need for kerosene for lighting and has been found in a number of countries to be strongly correlated with the uptake of clean fuels for cooking.
- Given that biomass will continue to remain the main practical option for rural India in the foreseeable future, the promotion of cleaner biomass-based household energy products, such as biomass briquettes, biogas, improved stoves, and other appliances, needs to be given greater attention. To be sustainable, however, solutions to the rural household energy problem should be demand-driven and commercially oriented. In particular, it is important to determine what types of biomass-based and other clean energy technologies are likely to work for different economic circumstances and household preferences. Any technological alternatives to free or cheap traditional biomass will be widely adopted only if the incremental costs are affordable and are outweighed by tangible nonmonetary benefits valued by the user.
- In facilitating a long-term shift to clean household fuels and other energy technologies, it is important to identify and target areas where the likelihood of achieving a switch is higher. These include areas that have limited free biomass, so that many households must purchase wood for cash; that have electrified houses; and that have sufficient income-generating opportunities for households to be able to purchase commercial energy products and services on a regular basis.

5.29 **Raising public awareness about the health costs of traditional energy would further facilitate the uptake of clean fuels**. One of the most important and effective roles that the government could perform is to educate the public about the health impacts of traditional household energy, the benefits of using cleaner fuels, and the benefits of other options, such as the use of more efficient stoves. In the early stage of consumer education, the government may even consider providing seed money for the research and development of more efficient, more durable stoves. Public awareness of the adverse impact of indoor air pollution could encourage households to reduce their exposure to smoke emissions and could encourage those who can afford, such as higher-income households in rural areas, to switch out of traditional biomass, to seriously consider switching to kerosene or LPG, or to switch to biomass-based clean technologies for cooking.

Annex 1: Analysis of National Sample Survey Data

A1.1 The sample for the 50th round of the National Sample Survey consisted of 115,394 households in 11,601 first sampling units (FSUs). The total number of households represented by the survey was 177.9 million. The rural sample consisted of 69,225 households, representing a total of 132.2 million households. The corresponding figures for the urban sample were 46,169 and 45.7 million, respectively.

A1.2 The 55th round sampled 120,309 households in 10,104 FSUs, representing a total of 188.7 million households. The rural sample consisted of 71,385 households, representing 137.4 million households. The corresponding figures for the urban sample were 48,924 and 51.4 million, respectively.

A1.3 The design of the NSS changed in 1999–2000 in ways that make it difficult to compare its results with those from the previous years. Historically, the NSS used 30-day recall for all consumption items. This changed with the survey in 1994–95 and the subsequent surveys carried out until 1998. For these surveys, the NSS administered two different consumption schedules to two independent subsamples of households. One used the traditional 30-day recall, and the other used multiple recall periods, depending on the consumption item: 7 days for food; 30 days for high-frequency nonfood, including fuels; and 365 days for low-frequency nonfood, such as durables, clothing, footwear, and educational and institutional medical expenditures. The 1999–2000 NSS included additional changes. In this round, food consumption was obtained by both 7-day and 30-day recall for the same set of households. The numbers for the mean of food consumption from the 1999–2000 NSS round were far more similar than those in the four previous experimental rounds in which different households were given different recall schedules. Spending on low-frequency nonfood consumption items was obtained using only a 365-day recall period. The only item for which there was continuity was high-frequency nonfood, for which 30-day recall was used.

A1.4 The above changes in the 55th round led to the conflicting findings that the poverty rate decreased by about 10 percentage points between 1993–94 and 1999–2000 if food expenditures were based on 30-day recall, but increased between 1994–95 and 1999–2000 if they were based on 7-day recall (Datt and Ravallion 2002). Deaton (2003) attempted to adjust the 55th round poverty estimates to make them comparable with earlier official estimates. Correcting for this lack of comparability involved making two key assumptions: (a) that the 1999–2000 results for the common 30-day recall period were unaffected by the change in survey design; and (b) that there was no change in the distribution of total consumption, conditional on consumption of the common-recall goods, so that the distribution could be inferred from the 1993–94 round. These adjustments led to the revised finding that the poverty rate fell by 8 percent, rather than 10 percent, between 1993–94 and 1999–2000.

A1.5 The incomparability of the data sets is a serious concern for assessing poverty trends over time. For the purpose of this work, however, it affects only the descriptive statistics comparing the trend between 1993–94 and 1999–2000, and largely the distribution of households among the 10 expenditure deciles. Given the large measurement uncertainties associated with expenditures on fuels, as described below, adjusting total expenditures would be expected to have essentially no impact on the conclusions drawn. Therefore, no adjustments were made to the data in this study.

Information Collected

A1.6 In the absence of reliable information on household income, total expenditures were taken as a proxy for income. Total expenditures consisted of consumption items, durable goods purchased in the past 365 days and converted to monthly equivalent expenditures by multiplying by 30/365, and housing or land rentals. While an imputed value for nonrented housing in urban areas was estimated, this was not used in calculating the total monthly household expenditure. Housing that was not rented carried no value, which could seriously underestimate the expenses in rural areas, making rural households appear poorer compared to their urban counterparts. This needs to be borne in mind when interpreting results aggregated nationally. Total expenditures were adjusted for interstate price differences.

A1.7 Households were divided into 10 groups, each containing the same number of households unless indicated otherwise, ranked in order of increasing per capita expenditure (total household expenditures adjusted by the cost-of-living index and divided by the household size). Decile 1 corresponds to the bottom 10 percent, decile 10 to the top 10 percent. Because poor households are larger in size, the lower deciles have more people than upper deciles. In one case, the population was divided into 10 groups, each containing the same number of individuals rather than households. This was to help assess the number of people who live in houses using different fuel types. Households were typically divided into urban and rural areas before analysis. In these cases, the per capita expenditure in each per decile is higher in urban areas than in rural areas. When households are analyzed across the country, the top decile is dominated by urban households and the bottom decile by rural households. Population and expenditure statistics for deciles in which each decile group contains the same number of households (as opposed to individuals) are shown in Table A1.1. The lower expenditures in any given decile in rural areas compared to urban areas, and the population of lower deciles by rural households and of higher deciles by urban households, when deciles are taken nationally, emerge clearly in the table.

Table A1.1 Population and Expenditure Statistics, 1999–2000

Per capita expenditure decile	*Range (Rs per capita)*	*Median (Rs per capita)*	*Mean (Rs per capita)*	*Househol d size*	*Number of people in rural*	*Number of people in urban*
Rural 1	0-277	234	224	6.0	81,379,553	N.A.
2	278–332	293	292	5.8	78,859,202	N.A.
3	333–380	339	339	5.5	74,933,194	N.A.
4	381–429	382	382	5.5	74,735,782	N.A.
5	430–482	426	426	5.2	70,490,802	N.A.
6	483–543	477	477	5.1	68,446,685	N.A.
7	544–624	535	536	4.8	65,111,421	N.A.
8	625–737	617	618	4.5	61,833,333	N.A.
9	738–949	745	752	4.4	59,040,219	N.A.
10	more than 949	1,069	1,252	3.7	50,330,351	N.A.
Urban 1	0–345	285	274	6.1	N.A.	31,337,821
2	346–431	380	379	5.5	N.A.	28,041,782
3	432–515	459	459	5.3	N.A.	26,686,662
4	516–607	542	542	5.0	N.A.	25,230,062
5	608–710	635	637	4.8	N.A.	24,258,426
6	711–837	748	749	4.4	N.A.	22,561,648
7	838–1,003	888	889	4.1	N.A.	20,872,650
8	1,004–1,238	1,075	1,078	3.7	N.A.	18,996,742
9	1,239–1,653	1,367	1,380	3.4	N.A.	17,340,678
10	more than 1,653	2,115	2,594	3.0	N.A.	15,489,932
National 1	0–310	246	236	6.0	108,000,000	3,682,252
2	311–382	316	315	5.7	98,916,620	7,485,666
3	383–449	372	372	5.6	94,109,185	9,887,355
4	450–521	425	426	5.3	85,163,537	13,411,174
5	522–607	485	486	5.1	78,603,170	16,206,361
6	608–715	555	557	4.9	69,845,223	21,527,664
7	716–868	651	653	4.7	59,705,859	27,324,158
8	869–1,107	794	798	4.5	48,379,132	35,001,557
9	1,108–1,579	1,052	1,065	4.1	30,371,880	45,573,948
10	more than 1,579	1,757	2,161	3.4	12,031,104	50,716,268

N.A. = not applicable

A1.8 The survey asked for the "primary" sources of energy for cooking and lighting. It collected information on the consumption of coke, firewood and chips, electricity, dung, kerosene sold through the PDS, kerosene from sources other than PDS, matches, coal, LPG, charcoal, candles, gobar gas, and other fuels. The quantities were not recorded for dung, gobar gas, and other fuels. The values in rupees were recorded for all of the above items. Sources were categorized according to (1) only purchase, (2) only home-grown stock, (3) both purchase and home-grown stock, (4) only free collection, and (5) others.

A1.9 Where items were not paid for in cash, imputed values were assigned. In the case of fuels, two main categories that required the assigning of imputed values were dung and firewood. The values were solicited from respondents by enumerators, so that there is a large element of subjective judgment. Where there is a well-established market for firewood, as would be the case in many peri-urban and urban areas, the imputed values are more likely to reflect the market value of firewood in the community. For biomass-rich areas without commercial wood markets nearby, imputed values should ideally reflect the value of time involved in biomass collection. It is not clear, and in fact unlikely, that the respondents tried to estimate the cash equivalent value of the time spent on fuel collection.

A1.10 Table A1.2 lists the percentage of households in each per capita expenditure decile that resided in FSUs in which no household reported (1) or (3) as described in paragraph A1.8 as the source of firewood—that is, where nobody reported purchasing firewood. Also shown in the table are the imputed values reported by these households as well as those households that relied only on cash-free firewood but lived in FSUs in which at least one household reported purchasing firewood. About one-quarter of rural households lived in villages (FSUs) where nobody reported purchasing firewood, whereas in rural areas only a very small percentage of households lived in FSUs where nobody purchased wood.

A1.11 In principle, a household will buy wood on the market if the cost of collection exceeds the sum of the market price and the cost of transporting the wood from the market to the house. To the extent that the cost of transporting wood (or any other fuel, for that matter) from the market to the house is not included, the market price underestimates the actual cost to the household of using a specific fuel. If the sum of the cost of collection and the cost of transporting wood to the market is lower than the market price, then the household may collect wood for sale. For wood-selling households, the market price of wood reflects the value of wood. Even if a household resides next to an abundant source of firewood that can be gathered at little cost, and the market price of wood is relatively high, if it is costly to transport wood to the market (on account of distance or bad road conditions), the household will not collect wood for sale. For those households that are neither selling nor buying firewood, the market price may overestimate the cost and value of firewood, in some cases by a large margin.

Table A1.2 Households Living in FSUs where Nobody Reported Firewood Purchase, 1999–2000

Per capita expenditure decile	*RURAL*			*URBAN*		
	% of households	*Rs / mo*[1]	*Rs / mo*[2]	*% of households*	*Rs / mo*[1]	*Rs / mo*[2]
1	28%	74	75	4%	60	84
2	25%	82	81	4%	65	92
3	24%	86	84	4%	75	85
4	23%	92	91	4%	59	91
5	21%	92	96	3%	70	104
6	21%	92	99	4%	66	96
7	22%	98	99	3%	61	91
8	22%	99	103	3%	90	89
9	22%	99	105	2%	67	96
10	20%	108	103	2%	71	83
Average	23%	91	93	4%	66	90

[1] Imputed value of cash-free firewood in rupees per month per household, averaged across those who lived in FSUs where no household reported purchasing firewood. [2] Imputed value of cash-free firewood in rupees per month per household, averaged across all households that reported using only home-grown or freely collected firewood and that lived in FSUs where at least one household reported purchasing firewood.

A1.12 Similarly, the actual cost to a household of using kerosene and LPG includes additional expenses incurred in bringing the fuel to the house. Home delivery of LPG refill cylinders, required in principle for those that live within a certain distance of the dealership, was unreliable and often did not happen, especially in peri-urban and rural areas, so that consumers would have had to make their own arrangements for cylinder collection, such as paying a third party to do the work. It is not clear to what extent the full cost of kerosene and LPG use was captured in the survey. To the extent that respondents were not asked to estimate the value of the time spent on the purchase of commercial fuels, the expenditures reported underestimate the actual cost.

A1.13 Expenditures on kerosene, LPG, and electricity as a percentage share of the total household expenditure are shown in Table A1.3 and Table A1.4 for rural and urban households, respectively. Among users, LPG accounts for the largest share of household expenditures, except in the top 30 percent of urban households where electricity expenditures exceed those for LPG. Averaged across all households, electricity had the largest share in urban areas irrespective of expenditure decile. Kerosene dominated for the bottom half in rural areas, consistent with the reliance of lower-income rural households on kerosene as the primary energy source for lighting.

Table A1.3 Expenditure on Energy by Rural Households, 1999–2000 (percentage of total household expenditure)

	Users only			*All households*		
p.c. decile	*Kerosene*	*LPG*	*Electricity*	*Kerosene*	*LPG*	*Electricity*
1	1.3	6.8	2.6	1.3	0.0	0.5
2	1.2	4.3	2.4	1.2	0.0	0.7
3	1.2	5.6	2.3	1.1	0.0	0.8
4	1.2	6.3	2.4	1.1	0.1	0.9
5	1.2	5.4	2.5	1.1	0.1	1.0
6	1.1	4.6	2.5	1.1	0.1	1.2
7	1.1	4.5	2.6	1.1	0.2	1.3
8	1.1	4.2	2.5	1.1	0.3	1.5
9	1.1	3.8	2.5	1.0	0.5	1.6
10	1.0	3.0	2.4	0.9	0.8	1.8
Average	1.1	3.6	2.5	1.1	0.2	1.1

Table A1.4 Expenditure on Energy by Urban Households, 1999–2000 (percentage of total household expenditure)

	Users only			*All households*		
p.c. decile	*Kerosene*	*LPG*	*Electricity*	*Kerosene*	*LPG*	*Electricity*
1	2.2	7.2	4.1	2.0	0.5	2.2
2	2.5	7.3	3.9	2.3	1.1	2.7
3	2.3	6.1	4.0	2.1	1.5	3.1
4	2.6	5.5	4.0	2.2	1.8	3.3
5	2.5	5.1	3.9	2.0	2.2	3.4
6	2.5	4.5	4.0	1.8	2.4	3.5
7	2.3	4.1	3.9	1.5	2.5	3.5
8	2.4	3.7	3.9	1.4	2.3	3.4
9	2.0	3.2	3.9	0.9	2.2	3.5
10	1.4	2.2	3.9	0.4	1.7	3.5
Average	2.3	4.1	3.9	1.7	1.8	3.2

A1.14 One interesting question is how much households that use purchased wood as their primary cooking fuel spend compared to those that use LPG as their primary cooking fuel. Table A1.5 and Table A1.6 take only those households that reported using cash wood as the primary cooking fuel (those that recorded (1), cash wood only, as their source of wood, and excluding those that reported both purchased and home-grown wood) and those that reported LPG for rural and urban areas, respectively. Figure A1.1 shows the distribution of these households across the expenditure deciles. It is clear that in terms of percentages, those households that used purchased wood typically paid more for kerosene, LPG, and wood than did those that used LPG, in both rural and urban areas.

Table A1.5 Expenditure on Cash Wood or LPG as Primary Cooking Fuel in Rural India, 1999–2000 (percentage of total household expenditure)

P.c.	*Cash wood as primary fuel*					*LPG as primary fuel*				
Decile	*Kerosene*	*LPG*	*Wood*	*Total*[1]	*Electricity*	*Kerosene*	*LPG*	*Wood*	*Total*[1]	*Electricity*
1	1.4	0.0	6.1	7.5	0.8	0.8	4.8	1.8	7.4	2.0
2	1.2	0.0	5.7	7.0	1.0	0.8	3.9	0.0	4.7	2.3
3	1.2	0.0	5.6	6.8	1.0	0.8	3.9	0.7	5.3	2.6
4	1.1	0.0	5.3	6.4	1.1	0.7	4.9	0.4	5.9	2.7
5	1.2	0.0	5.1	6.2	1.3	0.7	5.5	0.4	6.6	2.7
6	1.2	0.0	4.9	6.1	1.5	0.6	4.8	0.2	5.6	3.2
7	1.1	0.0	4.9	6.0	1.5	0.7	4.8	0.2	5.7	3.1
8	1.1	0.0	4.9	6.0	1.5	0.5	4.4	0.3	5.2	2.6
9	1.1	0.1	4.4	5.5	1.7	0.6	4.1	0.2	4.9	2.7
10	0.9	0.1	3.8	4.8	1.7	0.3	3.3	0.1	3.7	2.5
Total	1.2	0.0	5.1	6.2	1.3	0.5	3.9	0.2	4.5	2.6

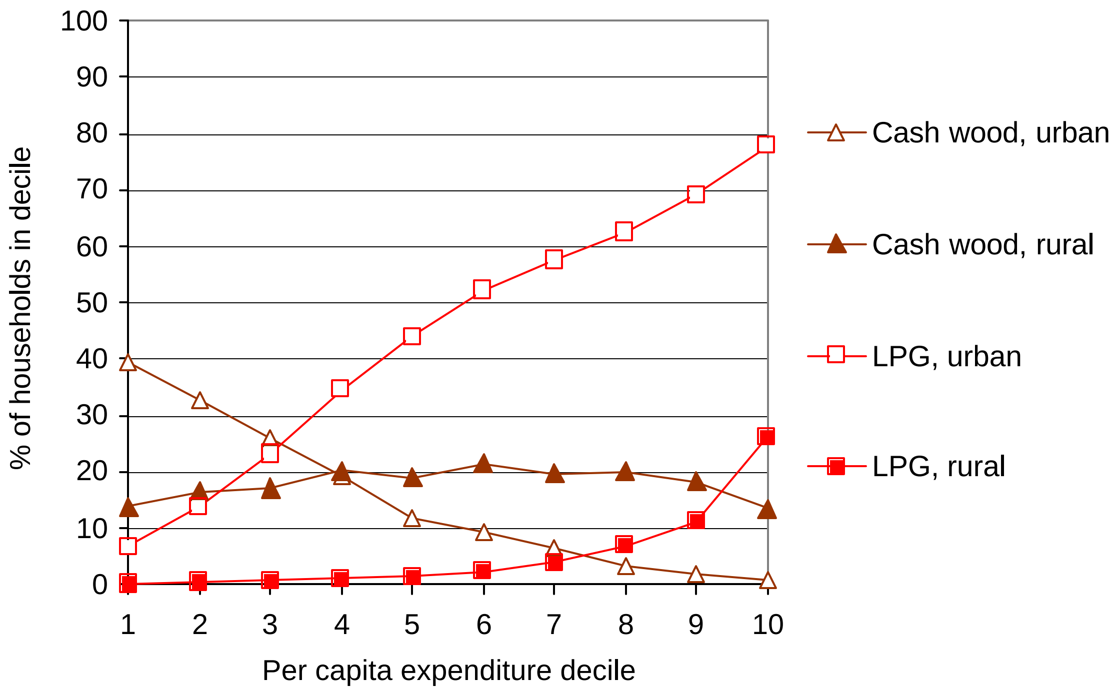
[1] Sum of kerosene, LPG, and wood.

Table A1.6 Expenditure on Cash Wood or LPG as Primary Cooking Fuel in Urban India, 1999–2000 (percentage of total household expenditure)

P.c.	*Cash wood as primary fuel*					*LPG as primary fuel*				
Decile	*Kerosene*	*LPG*	*Wood*	*Total*[1]	*Electricity*	*Kerosene*	*LPG*	*Wood*	*Total*[1]	*Electricity*
1	1.4	0.0	5.8	7.2	1.8	0.8	5.9	0.4	7.1	3.9
2	1.2	0.0	5.4	6.6	2.1	0.7	5.5	0.3	6.5	3.5
3	1.3	0.0	4.9	6.2	2.3	0.6	5.6	0.2	6.3	3.5
4	1.2	0.0	4.7	5.9	2.3	0.5	4.9	0.1	5.6	3.7
5	1.1	0.0	4.8	5.9	2.3	0.4	4.4	0.1	5.0	3.7
6	1.2	0.1	4.3	5.6	2.3	0.4	4.1	0.1	4.5	3.6
7	1.4	0.0	4.3	5.7	2.1	0.3	3.8	0.1	4.1	3.7
8	1.0	0.1	3.8	4.8	2.0	0.3	3.3	0.0	3.6	3.7
9	0.9	0.1	3.7	4.7	1.8	0.2	3.0	0.0	3.2	3.7
10	1.4	0.1	2.8	4.2	0.9	0.1	2.1	0.0	2.2	3.8
Total	1.3	0.0	5.1	6.4	2.1	0.3	3.7	0.1	4.1	3.7

[1] Sum of kerosene, LPG, and wood.

Figure A1.1 Percentage of Households Using Cash Wood or LPG as Primary Cooking Fuel, 1999–2000



A1.15 To answer if this is because wood is expensive in some parts of India, including rural areas, Table A1.7 and Table A1.8 show how much these households paid in nominal terms on average in each expenditure decile. It becomes immediately clear that those households that used LPG as the primary cooking fuel paid more in cash, and that the reverse trend observed with the percentage share is on account of wood-users being poorer in each decile group. That is to say, those who purchase wood do so because using wood is cheaper given their specific total household budget. The per capita expenditure ranking hides the fact that the total household expenditure is a function of the household size in any decile group, and because of economies of scale in a number of household economic activities such as housing, cooking, and lighting, both per capita and household expenditures should be standardized for proper comparison. In each per capita expenditure decile, those who used purchased wood as the primary cooking fuel had a smaller household size. When households are compared at the same per capita and household expenditures, those who cooked with purchased wood were found to be paying less, both as a percentage share of the total household budget and in rupees, than those who cooked with LPG. What is more difficult to explain is the fact that this trend is observed in each expenditure decile. One important point to bear in mind is that more than 13 million households were on the waiting list for LPG at the time of the survey. In addition to personal preferences and fuel availability, possible explanations include the weak correlation between cash income on one hand and expenditures, including imputed values and excluding many durable goods and real estate, recording and recall errors during the survey, and unrecorded transaction costs of different fuel use, on the other.

Table A1.7 Nominal Monthly Expenditure on Cash Wood or LPG as Primary Cooking Fuel in Rural India, 1999–2000 (rupees)

P.c.	*Cash wood as primary fuel*					*LPG as primary fuel*				
Decile	*Kerosene*	*LPG*	*Wood*	*Total*[1]	*Electricity*	*Kerosene*	*LPG*	*Wood*	*Total*[1]	*Electricity*
1	18	0	79	97	11	8	53	22	84	21
2	19	0	91	110	16	17	91	0	107	51
3	20	0	96	116	18	15	84	9	108	50
4	21	0	105	127	22	14	102	6	123	54
5	22	0	102	124	28	18	138	13	168	69
6	25	0	104	130	34	19	141	5	165	91
7	25	1	111	136	35	18	137	7	162	92
8	26	1	115	143	39	19	152	9	180	91
9	27	3	117	147	48	20	148	10	178	103
10	27	6	132	165	59	16	153	7	176	123
Total	23	1	105	130	31	17	147	8	173	107

[1] Sum of kerosene, LPG, and wood. The expenditures are not adjusted for cost-of-living differences.

Table A1.8 Nominal Monthly Expenditure on Cash Wood or LPG as Primary Cooking Fuel in Urban India, 1999–2000 (rupees)

P.c.	*Cash wood as primary fuel*					*LPG as primary fuel*				
Decile	*Kerosene*	*LPG*	*Wood*	*Total*[1]	*Electricity*	*Kerosene*	*LPG*	*Wood*	*Total*[1]	*Electricity*
1	24	1	107	132	37	20	137	10	167	93
2	27	0	119	147	49	20	147	9	175	96
3	30	1	120	151	61	18	156	6	180	112
4	29	1	120	150	65	18	162	5	185	129
5	31	0	133	164	69	16	163	5	183	142
6	32	2	120	153	71	14	163	4	181	153
7	31	2	106	139	58	13	165	3	181	169
8	34	4	122	160	60	12	160	2	173	189
9	30	5	129	164	69	8	163	2	173	219
10	60	11	141	212	43	6	162	2	170	345
Total	28	1	117	146	54	28	1	117	146	54

[1] Sum of kerosene, LPG, and wood. The expenditures are not adjusted for cost-of-living differences.

A1.16 It is difficult to obtain accurate data on the consumption of fuels using a household survey unless the questionnaire is carefully designed for this purpose. One source of error, aside from recall errors, is the tendency of households to report their last purchase rather than how much they consume in a month. One way of reducing this error is to ask two or more sets of questions that can be used to check the internal consistency of the answers provided. For example, one question can ask about the quantity consumed in the last 30 days, and another can ask how much was purchased the time before last and how long the purchased fuel lasted. This was unfortunately not done in the NSS, which is not a household energy survey. Table A1.9 shows the distribution of answers given for LPG. That there is "bunching" around 1 cylinder may indicate that there is an upward bias. This interpretation is further supported by the average quantity of LPG consumed by rural households, and especially the rural poor. Among rural LPG users, even the bottom two deciles reported consuming close to 9 kg a month, which is much higher than average rural household consumption figures reported by the LPG marketing departments of the state oil companies. It appears therefore that LPG consumption figures carry an upward bias.

Table A1.9 Reported Monthly Household Consumption of LPG, 1999–2000 (percentage of LPG-consuming households)

Quantity in kg/month	*Rural*	*Urban*	*National*
up to 2	4%	3%	4%
2–4	5%	1%	2%
4–6	7%	3%	4%
6–7	6%	3%	4%
7–8	14%	8%	10%
8–9	1%	1%	1%
9–10	8%	9%	9%
10–11	3%	3%	3%
11–12	2%	3%	2%
12–13	1%	1%	1%
13–14.2	6%	6%	6%
14.2	31%	42%	39%
14.2–15	6%	6%	6%
15–16	2%	2%	2%
16–18	1%	2%	2%
18–20	1%	1%	1%
20–25	1%	3%	2%
25–30	1%	2%	2%
30 or more	0%	1%	1%

A1.17 In the case of wood, the quantities reported consumed are probably more accurate for those who purchase wood regularly. For those that use freely collected or home-grown wood, it is not clear how accurate are their estimates of wood consumed.

A1.18 For dung, questions were not asked about quantities consumed, presumably because of the difficulties involved in estimating them. The respondents were asked about the value of the dung consumed, but in the absence of a market for dung, it is not clear how these imputed values were estimated. The percentage of those who purchased dung was small in rural areas (16 percent), but in urban areas 54 percent reported paying for dung.

Annex 2: Modeling

A2.1 For modeling household energy consumption in this study, a discrete choice analysis and a continuous choice model conditional on the discrete choices were used. Urban and rural households were modeled separately. A household's decision-making consists of choosing energy sources and how much of each to consume. For energy choice, households are divided into different energy mix groups using multinomial logit. The multinomial logit model is for data in which the response is a set of choices and is measured on a nominal scale. A set of coefficients $ß_{ik}$ are estimated corresponding to each outcome category,

$$Pro_{i,n} = \exp \sum_k \beta_{ik} X_{ikn} / \sum_j \exp(\sum_k \beta_{jk} X_{jkn})$$

where $Pro_{i,n}$ is the probability of household *n* choosing energy mix *i*, and X_{ikn} represents the value of the characteristic *k* for household *n* and the energy mix option *i*.

A2.2 After allocating each household to a specific energy mix group, the quantity of each fuel consumed is modeled using conditional demand equations, where the effect of an independent variable is conditional on the household choosing among different energy mix alternatives. Estimation of the conditional demand by ordinary least squares gives inconsistent coefficient estimates because the choice of energy mix and its use are endogenous. Consistent estimates can be obtained by means of instrumental variables or by correcting for the self-selection bias. In this study, the latter approach was used. The aggregate demand for each fuel is obtained as a weighted average of the choice probabilities and conditional demands.

A2.3 For defining energy mix categories, households were not categorized according to their primary cooking and lighting energy sources. This is because different combinations of energy sources were used by households with the same primary energy sources for cooking and lighting. Instead, energy mixes were defined as follows for two separate models, hereafter called model 1 and model 2.

A2.4 Only firewood, PDS kerosene, market kerosene, LPG, and electricity are explicitly considered in modeling because these are the most commonly used energy sources. Dung use, although common in rural areas, is not modeled because there is no information on the quantity consumed. Model 1 specifies the choice set based on the combination of these five energy sources. Model 2 does not distinguish between PDS and market kerosene but distinguishes energy sources on the basis of their use in cooking and lighting. For cooking, the fuels considered are firewood, kerosene, and LPG. For lighting, kerosene and electricity are considered.

A2.5 Model 2 splits household kerosene consumption into its use in cooking and lighting. Because the survey questionnaire does not provide information on how kerosene was used by each household, assumptions have to be made so that kerosene can be assigned to cooking or lighting. In principle, the two models can be integrated so that kerosene can be traced to both its source (PDS or market) and its use (cooking or lighting). In practice, this would lead to many cases and increase the number of parameters to be estimated in the multinomial logit. Although the sample size of the NSS is large, the computational burden increases with the number of alternatives and often the maximum likelihood algorithms fail to converge. No model encompassing all the possible combinations was set up.

Assigning Kerosene to Lighting and Cooking

A2.6 For the purpose of assigning kerosene to lighting and cooking in model 2, those households that reported positive consumption of kerosene were classified into five groups:

?? households whose primary lighting code was kerosene and primary cooking code was *not* kerosene

?? households whose primary lighting code was kerosene and primary cooking code was *also* kerosene

?? households whose primary lighting code was electricity and primary cooking code was *not* kerosene

?? households whose primary lighting code was electricity and primary cooking code was *also* kerosene

?? households that did not fall into any of the above categories

A2.7 Table A2.1 shows the distribution of households among the five categories and the monthly consumption of kerosene per household, averaged in each category. The following assumptions were made in allocating kerosene to lighting and cooking. In the first category, the average monthly household consumption of kerosene was nearly 4 liters in rural areas and 5 liters in urban areas. As kerosene was the primary lighting fuel but not the primary cooking fuel, it is reasonable to assign the entire kerosene consumption to lighting. In the second category, kerosene was used for both lighting and cooking. The differences in consumption between the first and second categories of 6 liters in rural areas and 10 in urban were assigned to cooking. In the third and fourth categories, electricity was the primary lighting source. In the third category, kerosene was not the primary fuel for lighting or cooking, and so could be regarded as a supplementary fuel. Because rural households tend to use kerosene mostly for lighting and urban households use kerosene more for cooking, kerosene consumption in rural areas was assigned entirely to lighting and in urban areas to cooking. Comparison of the third and fourth categories gives an increase in monthly kerosene consumption of nearly 10 liters in rural areas and close to 13 liters in urban areas. For rural households in category 4, this additional demand for kerosene was assigned to cooking. That is to say, even when electricity was the primary lighting and kerosene the cooking code, not all the kerosene was assigned to cooking. In contrast, all kerosene consumption among category 4 urban households was assigned to cooking. For the last category, which includes only a few households, kerosene was considered a supplementary fuel and was assigned in rural areas to lighting and in urban areas to cooking.

Table A2.1 Monthly Kerosene Consumption per Household, 1999–2000

			RURAL		*URBAN*	
Category	*Primary cooking fuel*	*Primary lighting source*	*Liters per month*	*% Households*	*Liters per month*	*% Households*
1	Not kerosene	Kerosene	3.9	50	5.0	8.7
2	Kerosene	Kerosene	10.0	0.3	15.2	1.5
3	Not kerosene	Electricity	3.9	46	3.1	69
4	Kerosene	Electricity	13.5	2.4	15.9	20
5	Other combinations		3.7	1.2	4.9	0.9

Energy Choice Categories

A2.8 Model 1 looks only at the choice of energy sources and not at their intended purposes. The following top six combinations, accounting for 80 percent of all rural households, were examined. Households that also used dung were included in each category: for example, a household using PDS kerosene, firewood, and dung was included in the first category listed below, of households that used PDS kerosene and firewood.

?? PDS kerosene and firewood (26 percent of rural households)

?? PDS kerosene, firewood, and electricity (25 percent)

?? PDS kerosene, market kerosene, and firewood (12 percent)

?? market kerosene and firewood (10 percent)

?? market kerosene, firewood, and electricity (5.3 percent)

?? LPG and electricity (1.5 percent)

The eight leading combinations, accounting for 70 percent of urban households examined in model 1, were:

?? LPG and electricity (21 percent of urban households)

?? PDS kerosene, LPG, and electricity (12 percent)

?? PDS kerosene, firewood, and electricity (10 percent)

?? PDS kerosene, market kerosene, and electricity (7.7 percent)

?? market kerosene and electricity (6.7 percent)

?? market kerosene, LPG, and electricity, (4.9 percent)

?? PDS kerosene and firewood, (4.4 percent)

?? market kerosene and firewood (3.3 percent)

A2.9 Model 2, in contrast, divided households on the basis of the energy sources used for cooking and lighting. The four leading combinations, accounting for 87 percent of all rural households examined in model 2, were:

- ?? firewood for cooking; kerosene for lighting (47 percent of rural households)
- ?? firewood for cooking; electricity and kerosene for lighting (34 percent)
- ?? LPG, kerosene, or both for cooking; electricity and kerosene for lighting (6.2 percent)
- ?? LPG, kerosene, or both for cooking; kerosene for lighting (1 percent)

The seven leading combinations, accounting for 84 percent of all urban households examined in model 2, were:

- ?? LPG for cooking; electricity for lighting, (22 percent of urban households)
- ?? kerosene for cooking; electricity for lighting (18 percent)
- ?? LPG and kerosene for cooking; electricity for lighting (18 percent)
- ?? kerosene and firewood for cooking; electricity for lighting (17 percent)
- ?? firewood for cooking; kerosene for lighting (7.2 percent)
- ?? LPG, kerosene, or both for cooking; kerosene for lighting (1.6 percent)
- ?? firewood for cooking; electricity for lighting (1 percent)

Explanatory Variables

A2.10 For both models, the explanatory variables given in Table A2.2 were used. In the discrete choice model in the first stage of modeling, all the variables were included. For conditional demand equations in the second stage, two criteria were used for retaining variables. A variable was retained if the variable was of policy significance or needed on theoretical grounds, or if retaining the variable increased the adjusted R-squared (that is, the absolute value of the t-statistic associated with the coefficient is greater than unity).

Table A2.2 Independent Variables Used in Regression Analysis

Variable	*Description*
Total expenditure	Total monthly household expenditure, adjusted for interstate price differences
Firewood price	Household-specific expenditure (cash or imputed, in rupees) on firewood, divided by kilograms consumed, adjusted for interstate price differences; or if the household does not consume firewood, the mean price paid in the FSU, district, or region (whichever is the smallest unit for which data exist)
PDS kerosene price	Household-specific expenditure on PDS kerosene, divided by liters purchased, adjusted for inter-state price differences; or if the household does not consume firewood, the mean price paid in the FSU, district, or region (whichever is the smallest unit for which data exist)

Variable	*Description*
Market kerosene price	Household-specific expenditure on market kerosene, divided by liters purchased, adjusted for interstate price differences; or if the household does not consume firewood, the mean price paid in the FSU, district, or region (whichever is the smallest unit for which data exist)
LPG price	Household-specific expenditure on LPG, divided by kilograms purchased, adjusted for interstate price differences; or if the household does not consume firewood, the mean price paid in the FSU, district, or region (whichever is the smallest unit for which data exist)
Electricity access and price	Multiple of a dummy variable taking on 1 if at least one household in the FSU reports using electricity, 0 otherwise, and the price of electricity obtained by dividing household-specific expenditure on electricity by quantity consumed for each household, adjusted for interstate price differences; or if the household does not consume firewood, the mean price paid in the FSU, district, or region (whichever is the smallest unit for which data exist)
Household size	Number of people in the household
Social group	1/0 dummy for four categories: scheduled tribe, scheduled caste, other backward classes, and others
Occupation	1/0 dummy for the activity from which the household derives more than 50 percent of its income. The five categories in rural areas are self-employment in nonagriculture, agricultural labor, other labor, self-employment in agriculture, and others. The four categories in urban areas are self-employment, regular wage/salary, casual labor, and others
Kerosene quota	The amount of kerosene in liters per month to which a household with no LPG connection is entitled
Kerosene allocation	Amount of PDS kerosene allocated to each state, divided by the number of PDS-consuming households in the state
Median cluster expenditure	Median monthly household expenditure in the FSU
Access to kerosene quota	80th percentile of PDS kerosene in liters purchased by households in the FSU
Kerosene dealers per area	Number of PDS kerosene dealers in the state, divided by the surface area of the state in square kilometers (km^2)
Kerosene dealers per household	Number of PDS kerosene dealers in the state, divided by the number of households in the state
LPG dealers per area	Number of LPG dealers for state oil companies in the state, divided by the surface area of the state in square kilometers (km^2)
LPG dealers per household	Number of LPG dealers for state oil companies in the state, divided by the number of households in the state
Per capita electricity consumption	Per capita consumption of electricity for noncommercial use in the state

A2.11 In addition, the impact of education on fuel use was examined briefly. Information was collected in the survey on the education of the head of the household and the spouse. However, due to missing entries about 12,000 observations each in rural and urban areas were lost, accounting for about 20 percent and 27 percent, respectively, of the total sample. As an alternative approach, education variables were defined as dummies for the maximum level of any member in the household. Three dummies were used for a maximal education level of primary, secondary, and post-secondary. The omitted category was below-primary. Defining the education variables in this way avoided losing any observations.

A2.12 Model 1 was run with the above education dummies in addition to the explanatory variables shown in Table A2.2. For urban households there were essentially no differences in the results, except in the case where total household expenditures were increased by 10 percent. In that scenario, including education dummies increased overall LPG consumption and decreased firewood consumption markedly. In rural areas, there were more cases with marked differences, all of which related to consumption of LPG, which increased except for the scenario in which the price of LPG was increased by 10 percent. Among the scenarios that were retained according to the criteria defined in paragraph 4.2 of Chapter 4, including the education dummies increased overall LPG consumption markedly when the total household expenditures were increased by 10 percent, and decreased LPG consumption when the price of LPG was increased by 10 percent.

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