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 $\mu g/m^3$ 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 ($\mu g/m^3$).

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 $\mu g/m^3$, and often lower than 50 $\mu g/m^3$. 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 mg/m^3 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

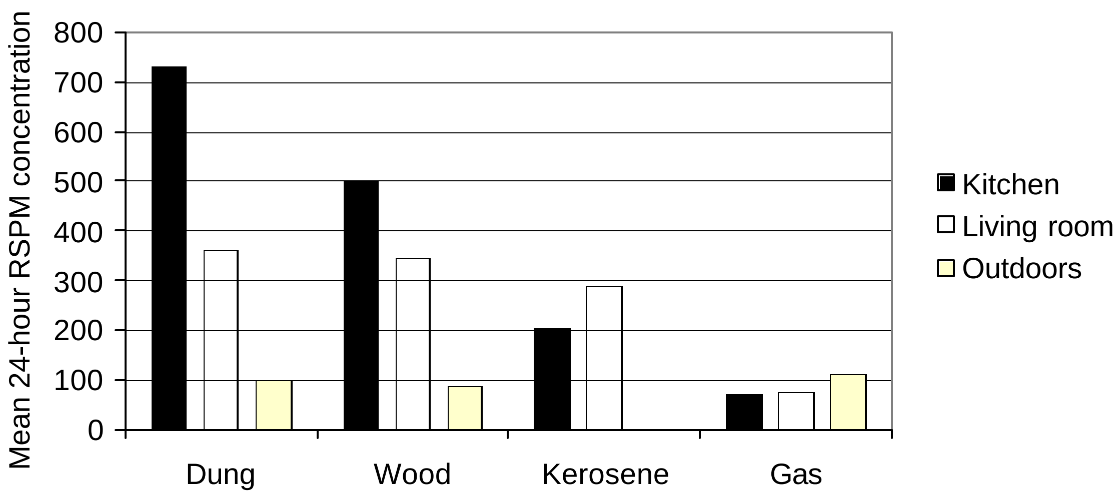
1.7 An exposure assessment study carried out in the state of Andhra Pradesh gives a good overview of the effects of ambient concentrations of small particles and varying exposure levels on different members of households using different fuels (World Bank 2002). In this study, concentrations of respirable 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 $\mu g/m^3$ in the United Kingdom (to be achieved by end-2004) and 150 $\mu g/m^3$ in the United States, and to the 24-hour $PM_{2.5}$ standard of 65 $\mu g/m^3$ in the United States.[2]

Figure 1.1 RSPM Concentrations by Fuel Type ($\mu g/m^3$)



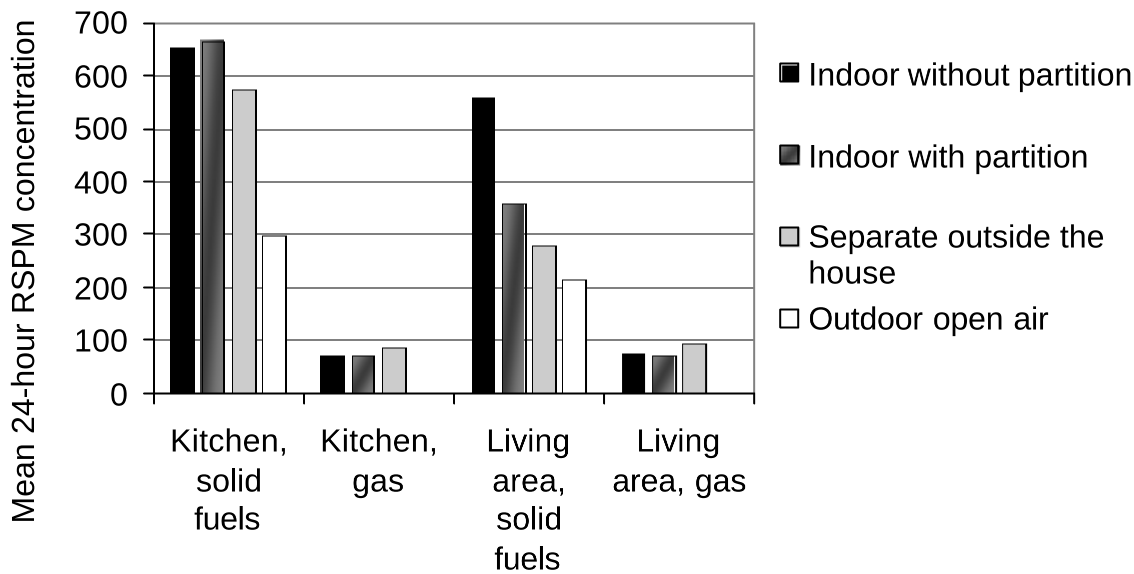
Note: Dung refers to households using dung and wood, or dung with small amounts of kerosene to start the fire.

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.

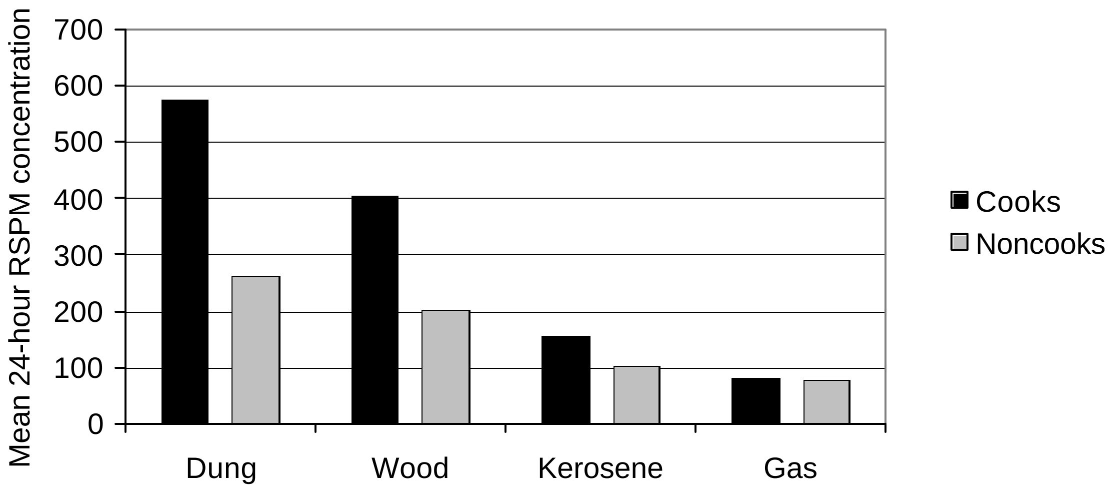
emissions from solid fuel use, lowered ambient concentrations, but these concentrations nonetheless remained alarmingly high where cooking was taking place, averaging 300 μg/m³. Outdoor cooking next to the house also led to high indoor concentrations, averaging more than 200 μg/m³. The impact on gas-using 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 (mg/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 (mg/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.