India
Household Energy, Indoor Air Pollution and Health

Report 261/02

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ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

PURPOSE

The Energy Sector Management Assistance Program (ESMAP) is a global technical assistance partnership administered by the World Bank and sponsored by bi-lateral official donors, since 1983. ESMAP's mission is to promote the role of energy in poverty reduction and economic growth in an environmentally responsible manner. Its work applies to low-income, emerging, and transition economies and contributes to the achievement of internationally agreed development goals. ESMAP interventions are knowledge products including free technical assistance, specific studies, advisory services, pilot projects, knowledge generation and dissemination, trainings, workshops and seminars, conferences and roundtables, and publications. ESMAP work is focused on four key thematic programs: energy security, renewable energy, energy-poverty and market efficiency and governance.

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Abbreviations and Acronyms

AGS additional *gram sevika*
ALRI acute lower respiratory infections
ANG *anganwadi* (child care centers)
AP Andhra Pradesh
APCPC Andhra Pradesh Civil Supplies Corp.
APL above poverty line
ARTI Appropriate Rural Technology Institute
BC Backward Caste
BPC Bharat Petroleum Corporation
BPL below poverty line
CART Classification and Regression Trees
CMEY Chief Minister's Scheme for Employment of Youth
COEH Center for Occupational and Environmental Health
COPD chronic obstructive pulmonary disease
DALY disability adjusted life years
DFID Department for International Development (UK)
DPAP Drought Prone Area Programme
DRDA District Rural Development Agency
DWCRA Development of Women and Children in Rural Areas (type of self-help group)
DWCUA Development of Women and Children in Urban Areas (type of self-help group)
GCC Girijan Cooperative Corporation
GEDA Gujarat Energy Development Agency
GOI Government of India
GOAP [State] Government of Andhra Pradesh
HDS Human Development Survey
HPC Hindustan Petroleum Corporation
ICMR Indian Council of Medical Research
IAP indoor air pollution
IHS Institute of Health Systems, Hyderabad
IPCC Intergovernmental Panel on Climate Change
IOC Indian Oil Corporation
ISI Indian Standard Institute
ITDA Integrated Tribal Development Agency
JFM Joint Forest Management
KVIC Khadi and Village Industries Commission
kg kilogram
km kilometer
LPG liquefied petroleum gas
MEF Ministry of Environment and Forests
MPHS [AP] Multi-Purpose Household Survey
NEDCAP Non-conventional Energy Development Corporation of Andhra Pradesh
NFHS National Family Health Survey
NGO non-governmental organization
NIOSH National Institute for Occupational Safety and Health
NPIC National Programme on Improved Chulhas
NSS National Sample Survey
OBC other backward class
PDS Public Distribution System
PM_{10} particulate matter less than 10 microns
RCC reinforced concrete cement
RDD Rural Development Department
REDB Rural Energy Database
Rs Indian rupees
RSPM respirable suspended particulate matter
SC Scheduled Caste
SRMC Sri Ramachandra Medical College, Chennai
TERI Tata Energy Research Institute
SEW self-employed workers
ST Scheduled Tribe
TBU technical backup unit
USAID United States Agency for International Development
VDO village development officer
VSS *Van Samrakshan Samiti* (Forest Protection Committee)
WHO World Health Organization

Currency Equivalents

(Annual Averages)

Currency Unit = India Rupee (Rs)

1998	US$1.00	Rs 41.3
1999	US$1.00	Rs 43.1
2000	US$1.00	Rs 44.9
2001	US$1.00	Rs 48.0

Fiscal Year: April 1 – March 31

Glossary

Indian society has traditionally been based on a social hierarchy associated with caste-based divisions of labor. Certain communities have historically been deprived of basic economic and other rights on the basis of their position in the social hierarchy. In an effort to right past wrongs, the Government of India has pursued policy of affirmative action since independence. In order to identify the communities that have been historically disadvantaged, communities are categorized into Scheduled Castes, Scheduled Tribes, Backward Castes, and Other Backward Classes.

Backward Castes Certain castes have been categorized as "backward" because of socio-economic and educational deprivation.

Other Backward Classes The Mandal Commission Report of the Government of India identified certain Other Backward Classes and included them in the list of the Backward Castes for the purpose of extending reservations and concessions in employment and education.

Scheduled Castes Any social group can be included in this category as per the provisions of Article 341 of the Indian Constitution. This includes any social group or community that has been socially, economically, and educationally disadvantaged because of the historical practice of "untouchability." Members of the Scheduled Castes include Hindus, Buddhists, and Sikhs.

Scheduled Tribes As per Article 342 of the Indian Constitution, communities and tribes living outside of the mainstream society are called *Scheduled Tribes*. Scheduled tribes can profess any religion. They have the least exposure to technology.

Other important terms include the following:

anganwadi childcare centers for children under the age of five

bidi locally made cigarettes

gram sevika female worker (*sevika*) in a village (*gram*)

gram panchayat village-level elected body for local self-governance

hara a stove that uses cow-dung cakes as fuel

mandal an administrative unit below the district level but above the *gram pachayat*. A mandal may comprise around 15 *gram panchayats*

mahila mandals omen's groups that operate in almost all villages in the state

pucca, kachha *Pucca* refers to durable, high-quality materials and construction techniques, such as a brick house with a tile roof. *Kachha* refers to more temporary and lower-quality materials and techniques, such as a mud house with a thatched roof.

tandoor traditional stove used for making *rotis*

Van Samrakshan Samiti Forest Protection Committee

Executive Summary

1. Household use of traditional biomass fuels—fuelwood, dung, and crop residues—is widespread in rural India. According to the 55th round of the National Sample Survey conducted in 1999–2000 covering 120,000 households, 86 percent of rural households and 24 percent of urban households relied on biomass as their primary cooking fuel. Burning biomass in traditional stoves—open-fire three-stone "stoves" or other stoves of low efficiency, and often with little ventilation—emits smoke containing large quantities of particulate matter and gaseous pollutants, with serious health consequences for the exposed population. Cooking with biomass fuels exposes household members, particularly women cooks and young children spending time around their mothers, to enhanced concentrations of harmful pollutants that are much higher than ambient air concentrations even in most polluted cities. The World Health Organization estimates that this exposure to indoor air pollution (IAP)[1] causes about 500,000 deaths and 500 million incidences of illness among women and children in India each year, which amounts to 30 percent of the global disease burden from this risk factor in the developing world and makes IAP one the top preventable health risks in India.

Study Objectives

2. This study looks into multiple social and economic dimensions of household fuel use, and attempts to explore possible solutions to mitigating IAP in a holistic manner. Specific objectives are as follows:

- Gaining a better understanding of the levels and determinants of exposure to IAP in rural households so as to guide the design of future action programs and policy research;
- Improving knowledge and creating greater awareness amongst various stakeholders of the magnitude of the health impacts from indoor air pollution and a range of mitigation measures;
- Facilitating efficient energy sector strategies and policies at the national, state, and local levels for mitigating IAP and respective damages to human health.

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1 The term "IAP" here refers to all forms of exposure by the members of a household to emissions from cooking (and heating) activities undertaken by the same household, even if cooking takes place outdoors, in the open air.

Study Design

3. Strategies for reducing the heavy toll of IAP on the health of rural families must draw on the perspectives of different sectors. This study was designed to respond to the following critical needs:

- The need to have better information on exposure levels and related health risks for population sub-groups, as well as to be able to assess the effectiveness of various interventions in reducing these risks;
- The need to find ways to deliver better energy services (both cooking fuels and methods) to rural households, including the poor;
- The need to adopt multiple mitigation strategies that would include a range of technical options and their combinations—cleaner fuels, better stoves, improved kitchen ventilation and housing type, and so on—targeted at different population groups;
- The need to involve various actors—for example, to clarify responsibilities of government departments at different levels, provide the right incentive framework and business environment for the private sector, and empower communities, especially women, to improve the ways in which daily energy needs affect their lives;
- The need to raise awareness both of the problem and of cost-effective solutions among all actors and stakeholders.

4. The study consists of four distinct components covering a wide range of IAP-related issues: (1) exposure assessment and modeling in Andhra Pradesh (AP) to obtain reliable data on the levels of exposure at the household level in rural settings and identify the key determinants of this exposure; (2) an evaluation of a capital subsidy scheme for liquefied petroleum gas (LPG) in Andhra Pradesh to assess its effectiveness in encouraging fuel switching from biomass to commercial fuels among the rural poor; (3) a review of best-performing improved-biomass-stove programs in six states of India to identify the necessary elements for successful implementation and long-term sustainability; and (4) dissemination of information and awareness-building. By approaching the IAP problem in a multi-sectoral fashion, the study strengthens the policy conclusions of individual components, and sheds additional light on both gaps and opportunities in IAP mitigation efforts.

Study Findings and Outcomes

5. The study improves the understanding of IAP exposure patterns and the impact of technical improvements and socio-economic factors at the household level. It proposes specific policy measures to increase the effectiveness of energy sector interventions, such as provision of better stoves and fuels, in addressing IAP, with particular focus on the poorest customers. Through its awareness-building campaign, undertaken in parallel with research activities, the study contributed to recognizing IAP as a major health and development issue in India and elsewhere.

Improving Knowledge of Exposure Patterns in Rural Settings

6. Despite some uncertainties about the exact magnitude of the health damage from indoor exposure to solid-fuel smoke, cumulative evidence from a growing number of indoor air pollution studies, supported by outdoor air pollution and environmental tobacco smoke studies, is sufficient to conclude that the health effects in India are very significant. There is still, however, a very limited number of quantitative assessments of exposures to biomass fuel smoke in rural households. Similarly, there is insufficient understanding on how exposure levels are distributed across different climatic zones and population groups. More work in this area would improve the accuracy of the burden-of-disease estimates and help interventions target high-exposure households.

7. The exposure assessment component of the study attempted to address these gaps. A pilot exercise was undertaken in three districts of Andhra Pradesh. Household-level surveys were conducted to obtain data on various household characteristics and behavioral factors, with the focus on secondary indicators of indoor air pollution, such as the distribution of fuel use, stove type, and ventilation conditions. To estimate exposure levels, this was followed by field monitoring to collect data on (1) ambient concentrations of respirable suspended particulate matter (RSPM) in households and (2) 24-hour activity patterns of household members. Lastly, the study included a statistical analysis of the two data sets to examine relationships between exposure levels and household characteristics, and to establish which parameters can serve as reasonable predictors of exposure.

8. The findings of this component provide much-needed quantitative confirmation that the traditional use of biomass fuels exposes all members of the family on a daily basis to levels of air pollution that well exceed available health guidelines for outdoor air quality. More importantly, the study shows that this holds true even in a warm climate like that of Southern India, where no space-heating is required and these fuels are used only for cooking. Even when cooking is done outside the house—in a separate kitchen or in the open air, a common practice of poor rural households—the resulting indoor levels of RSPM and exposure of all family members exceed health guidelines for ambient air.

9. A combination of monitoring and exposure-reconstruction techniques emphasizes, in quantitative terms, important gender and age dimensions of the IAP problem. Whereas women, in their traditional capacity as cooks, suffer from much greater average daily exposures than other family members, adult men experience the least exposure. Among non-cooks, those who are most vulnerable to the health risks of IAP—young children and elderly people—tend to experience higher levels of exposure because they spend more time indoors. This finding lends support to the results of some other studies linking household fuel use with infant and child mortality rates.

10. The study provides probably the strongest evidence yet that switching completely to cooking with clean fuels such as LPG or biogas is the best way to lower indoor exposure drastically (to the levels of outdoor air quality in a village), for all family members, including women-cooks. Families who use clean fuels sparingly and for minor cooking needs do not enjoy nearly the same benefits of exposure reduction. The policy implications of these findings, however, need to be considered in light of another component of the study: the evaluation of an

LPG promotional program in Andhra Pradesh that reveals significant challenges to the use of LPG as the main cooking fuel by rural households.

Promoting Cleaner Fuels Among the Rural Poor

11. In 1999 the State Government of Andhra Pradesh (GOAP) launched the program—the so-called Deepam Scheme—to promote the use of LPG by the poor, with the health benefits of cleaner cooking being one of the objectives. Under the scheme, the government covers the cylinder connection fee for starting LPG service to those families classified as being below the poverty line. In several respects this differs from the traditional LPG price subsidy in effect in India, which benefits mainly the well off in urban areas. First, it is a one-off subsidy, covering the capital cost rather than the operating cost. Second, only poor households are eligible. Third, the program is targeted to rural areas. Lastly, it is implemented through women self-help groups, thus linking the promotion of LPG with support for women's development and financial independence.

12. The Deepam Scheme clearly facilitated the uptake of LPG by the rural poor in Andhra Pradesh. However, this study found that biomass remains the main cooking fuel for the majority of Deepam beneficiaries, especially cash-strapped rural households who cannot afford the relatively high operating cost of the LPG service. Even with the cylinder connection fee waiver, the high costs of cylinder refills have largely confined LPG to incidental use, such as making tea or preparing meals for unexpected guests, or to when the opportunity cost of fuelwood use is substantial, such as during the monsoon season. The average consumption level of LPG found in the study was 2.9 kg per month against a minimum of 7 kg required to meet the majority of cooking needs. This consumption pattern limits the health and other social benefits of LPG uptake, as well as the potential for commercially viable LPG businesses.

13. On the positive side, the convenience introduced by even this limited use of LPG in rural AP, and especially the amount of time saved for the cooks, should not be under-estimated, even if the overall consumption of fuelwood does not decline markedly. Indeed, the Deepam beneficiaries universally cited time saved while cooking as the primary benefit of LPG use. An important achievement of the Deepam Scheme is that awareness of LPG's benefits has grown in rural areas and there seems to be a new willingness to increase the use of LPG—if a viable alternative to the high cost of refills can be found.

14. The GOAP has decided to add an additional 1.3 million connections under the Deepam Scheme at a cost of Rs 1.3 billion. In this context, an important question is whether and how a commercially viable market can be developed and sustained in rural areas. This study's findings point to several recommendations for the next stage of the Deepam Scheme or similar programs.

15. One recommendation is to allow the market to experiment with smaller cylinders. If smaller cylinders can be introduced, not only will each refill cost be lower, enabling many households to refill more regularly, but the initial cylinder deposit fee (which essentially covers the cost of cylinder manufacture) can also be lowered, reducing the barrier of upfront costs for households and/or the subsidy bill for the government. It is important to stress, however, that international experience with smaller cylinders is mixed: negative aspects include much higher cost of cylinder management and hence higher LPG price per unit, and the need for households to refill more frequently. Therefore, market forces, not government policy, should guide the size of cylinders to be made available on the market.

16. As a second recommendation, the two actions most likely to increase access to LPG in rural areas are (1) deregulating the petroleum sector at the national level and (2) creating a level playing field for all LPG distributors through promotional initiatives at the state level. Another factor, and a helpful element in any LPG marketing strategy, would be to educate people about the health benefits of cleaner household energy through awareness campaigns. Finally, subsidy programs that specifically target the poor are likely to be more effective if they focus on areas where biomass is diminishing and the implicit costs of biomass cooking are high.

Recognizing the Principal Role of Ventilation

17. The Deepam evaluation confirms that switching to clean fuels by the rural poor is a long and complex process, and that there is a need for interim solutions. More important in this context are factors other than fuel switching that could significantly reduce exposure to IAP. An examination of the household-level determinants of exposure to IAP singled-out three parameters—fuel type, kitchen configuration and/or kitchen ventilation condition—as the key predictors of household concentration levels. While keeping in mind the pilot nature of this modeling exercise and the need for further validation, there are major policy implications in the finding that kitchen ventilation and configuration turn out to be the only factors, in addition to fuel type, that significantly improve the prediction accuracy of exposure estimates .

18. There currently exist only two widely recognized exposure indicators for household environmental health, both of which are related to water quality and hygiene: *levels of access to clean water and to sanitation*. These are reported annually and separately for rural and urban areas by nearly every country and are commonly cited as measures of ill-health risk and indicators of poverty. These indicators are strikingly parallel to two possible new indicators for household air-quality-related hygiene: *levels of access to clean fuel and to ventilation*. Both indicators, although not ideal measures of true exposure and risk, have the extremely important benefit of being easily and cheaply determined by rapid surveys requiring no measurements. In both cases, they do not claim to specify what households actually do on a daily basis, but rather exemplify the *potential* represented by what is physically present—as indicated by the term *access*.

19. If validated with other data and refined models, these findings could influence the design of large-scale survey instruments, such as the Census or National Sample Survey, by introducing questions on household parameters that are the key determinants of exposure (in addition to the fuel type already used in these surveys). This would facilitate obtaining exposure estimates for population sub-groups within and across countries and states. Notably, each of the three parameters found to significantly improve the prediction accuracy of exposure estimates using household survey data are reasonably straightforward and easy to assess.

20. On the intervention side, both the analysis of exposure determinants and the evaluation of the Deepam Scheme in AP stress the importance of continued exploration of, and support for, options to alleviate the health impacts of IAP through interventions that may be more affordable and appropriate for many rural households. These interventions include simple modifications in housing design that separate kitchens from living areas and/or improve ventilation. As such, the analysis and evaluation serve as a reminder that improved biomass stoves with chimneys venting smoke outside the house remain one of the key interventions with yet-untapped potential, provided that they are well designed, installed, operated and maintained.

Tapping the Potential of Improved Stoves

21. In this light, the findings of the third study component gain additional relevance. This component was designed to identify the determinants of success for a stove program in India based on lessons from six "best practice" case studies complemented with lessons from international experience. Except for a similar program in China, the Government of India's National Programme on Improved Chulhas (NPIC) is the largest such program in the world. Overall, the performance of the program has been mixed, the main weaknesses being lack of sustainability and insufficient attention to user preferences. But because implementation approaches and achievements varied substantially across state, the findings of this evaluation provide a good basis for developing the next generation of stoves and stove programs at the state level.

22. Improved biomass stoves, with their higher fuel efficiency and better design, can potentially diminish the drudgery of collecting fuels and lower exposure to indoor air pollution for millions of rural families who cannot afford modern fuels. Although emissions from improved stoves burning solid fuels remain higher than emissions from stoves burning gaseous fuels, substantial reductions in exposure can be achieved by comparison with primitive traditional stoves. The key issue is whether stoves can be produced and disseminated in a manner that responds to the needs of women cooks and the customs and cultural preferences of all family members, addresses maintenance and repair problems, and leads to routine purchasing of improved stoves from the market.

23. Recommendations of the study are as follows:

- *Promote commercialization at the state level.* Evidence from the state of Maharashtra and international experience strongly support the goal of full commercialization of stove buying and selling. Now that the national program is being transferred to the state level, all states need to promote commercialization in order to make the use of improved stoves sustainable in the long run. The government retains a significant role in this process through a variety of instruments, such as designing incentives to private sector operators to produce, distribute and sell improved stoves; setting technical standards; and providing credit facilities for stove makers, as well as promotional support. The most successful programs worldwide involve little or no subsidy for the stove itself, but use subsidies for technical assistance and activities such as stove design, marketing, and information dissemination. Assistance with market analysis and identifying areas of highest demand is also very important. For example, the programs have a better chance to work even without—or with minimal initial—subsidies in areas of biomass shortage where people spend a considerable amount of time collecting fuel or pay cash for fuelwood supplies.
- *Strengthen the coordination function at the national level.* There also appears to be a need for a strengthened role at the national level in terms of coordinating information on stoves and capacity building activities. Some of the local technical backup units, such as the one in Maharashtra, have informally taken this role, but there is no overall group responsible for evaluating the different aspects of the program, conducting training and seminars, and in general ensuring that the information is shared among all the different programs.

- *Facilitate collaboration between designers, manufacturers, and consumers***.** The technical backup units need to be more involved with the manufacturers and consumers of the stoves—particularly women, who are the main users. This might lead to the design of models that are more durable and better adapted to consumer preferences. In many of the successful programs, the technical backup units have had a more outreach-oriented approach to stove design.
- *Develop new strategies to reach the poorest.* The most successful programs tend to work better for populations that expend cash income for stoves and can afford the expense. The needs of the poorer households appear to be either underserved or involve simple adaptations of stoves designed for more affluent rural households. In India, the increase in subsidies for the poor has not led to increased participation in the program, indicating that innovative approaches need to be developed to target these users. One possible approach is to link the promotion of better stoves (and kitchens) with housing finance. The participation of the poor in the program is also an area that could benefit from the collaboration of the technical backup units and non-governmental organizations.
- *Emphasize smoke removal and health benefits.* The emphasis in most of the improved-stove programs in India has been primarily on energy efficiency. However, users clearly consider smoke removal and cleaner kitchens among the main benefit of the stoves. These aspects of improved stoves have not been given sufficient attention in stove design and dissemination strategies. Although the technical challenges may be difficult, the development of stoves that have a long-term ability for smoke removal, in addition to being efficient and easy to use, is of paramount importance.

Facilitating Behavioral Change

24. One of the most effective strategies for mitigating IAP is to make sure rural communities know about the problem and show them what they can do about it—in other words, to raise awareness and disseminate information. This is important for other major stakeholders as well. The multi-sectoral nature of IAP requires extensive sharing of knowledge and experiences across different sectors, actors, and technical areas. Advocacy and information dissemination are necessary for mobilizing commitment and strengthening collaboration among government agencies, NGOs, and the private sector, not to mention rural communities. During this study, a significant effort has been made to disseminate information on IAP issues and raise the awareness of governmental institutions and other players inside and outside India. The study team organized several workshops, publication of newsletters, and production of a video film on IAP. This effort seems to have yielded some positive impact, contributing to growing attention to IAP. However, a critical test of whether the created momentum can be sustained lies ahead.

The Unfinished Agenda

25. A priority area for future research on IAP is to assess and document, in quantitative terms and using prudent methodologies, the actual impact of better stoves on reducing exposure—in the real field conditions of rural homes over a long period of stove functioning. This would better inform the aforementioned advocacy and awareness campaigns as well as guide the design of

cost-effective interventions. Equally useful would be the strengthening of evidence, currently available only from outdoor air pollution studies and one IAP study, on linkages between different levels of exposure to smoke and changes in the relevant health indicators.

26. The unfinished agenda for improving household energy services and housing conditions in rural India, with the corresponding improvements in health and quality of life, is enormous. The growing body of evidence of the health impacts of IAP is strong and points to a problem of alarming proportions. The remaining gaps in research should not be used as an excuse to delay action, especially if the focus of mitigation programs is on adopting low-cost measures and developing commercially viable modes of energy services delivery, in line with international best practice and the recommendations of this study. An encouraging sign is the increasing recognition by India, as well as other countries and the international community at large, that the traditional ways of using biomass fuels impose a major health risk, particularly for women and children in the developing world, and that a dedicated effort is required to address the problem.

1

Introduction: The Need for Multi-Sectoral Action

1.1. Household use of traditional biomass fuels—fuelwood, dung, and crop residues—is widespread in rural India. According to the 55th round of the National Sample Survey conducted in 1999–2000 covering 120,000 households, 86 percent of rural households and 24 percent of urban households relied on biomass as their primary cooking fuel. Burning biomass in traditional stoves (open-fire three-stone "stoves" or other stoves of low efficiency, often with little ventilation) emits smoke containing large quantities of harmful pollutants—with serious health consequences for the exposed population. Cooking with biomass fuels exposes household members, particularly women cooks and young children spending time around their mothers, to enhanced concentrations of particulate matter and gaseous pollutants. This exposure to indoor air pollution (IAP)[2] is estimated to cause about 500,000 deaths, 500 million incidences of illness and 16 million years of healthy life lost among women and children in India each year, making IAP a top preventable health risks, following malnutrition and water-borne diseases. On a global scale, India accounts for 30 percent of the disease burden from this risk factor in the developing world (see Table 1.1).

1.2. Aside from the immediate discomfort (such as eye and throat irritation) and long-term adverse health effects of exposure to smoke, cooking with biomass is time-consuming because it takes longer to get a fire going, and to clean the resulting soot from pots and pans, than cooking with liquid or gaseous fuels. Collection of biomass can take many hours every week—time that could otherwise be spent on schooling (if children are involved) or childcare and income-generating activities by adults, or even leisure. Keeping biomass dry during the monsoon season in South Asia poses an additional challenge. Given a choice, most women would prefer to cook more with liquid or gaseous fuels to avoid these problems, although traditional cooking practices and preferences may inhibit or impede a complete switch to these fuels. But the majority of the rural population, especially the poor, have no choice for two primary reasons: cleaner commercial fuels are too expensive for most rural families to afford, and distribution networks are deficient.

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2 The term "IAP" here refers to all forms of exposure by the members of a household to emissions from cooking (and heating) activities undertaken by the same household, even if cooking takes place outdoors, in the open air.

Table 1.1. Annual Disease Burden Attributable to Solid-fuel Use in the Early 1990s

Region	*Deaths*	*Illness Incidence*	*DALYs*[3]
India	496,059	448,351,369	15,954,430
China	516,475	209,727,474	9,335,387
Other Asia & Pacific Islands	210,721	306,356,582	6,599,471
Sub-Saharan Africa	429,027	350,703,204	14,323,188
Latin America	29,020	58,246,497	918,236
Mid-East and North Africa	165,761	64,150,732	5,633,022
LDC Total	**1,800,000**	**1,400,000,000**	**53,000,000**

Note: Excess significant figures have been retained to reduce rounding errors.
Source: Smith and Mehta 2000, Von Schrinding et al. 2001

1.3. Household use of energy therefore raises issues for several sectors and agencies:

- *The health sector* assesses the impact of exposure to IAP on the health of those exposed, and considers how best to respond to the public health concerns arising from this problem, particularly as it relates to child and maternal health (where the impacts of IAP are greatest) and interplay with a variety of other health risks and socio-economic factors.
- *For the environment and forestry sectors*, it is a pollution problem for the household and its neighbors, often directly linked to outdoor air pollution from household sources, and the use of wood as a household fuel may contribute to deforestation and land erosion.
- Agencies promoting the *development of women*, the most affected group, seek ways to minimize the health impacts and drudgery associated with the traditional use of biomass by giving women income-generating opportunities and financial independence.
- *The biomass and non-conventional energy sector* attempts to develop and disseminate better cooking systems based on indigenous sources of energy, such as improved biomass cookstoves or biogas appliances.
- *For the oil and gas sector* supplying commercial fuels, the availability and affordability of liquid and gaseous fuels, such as kerosene or liquefied petroleum gas (LPG), depends to a large extent on how open, competitive and efficient the sector is, and whether providers have sufficient incentives to serve rural areas and the poor.
- *For rural and economic development agencies*, the grave health impacts of traditional biomass energy are another manifestation of the poverty trap, emphasizing the need for effective programs to boost growth and cash income in rural areas.

[3] DALYs, or disability-adjusted life years, are a standard metric of the burden of disease. DALYs combine life-years lost due to premature death and fractions of years of healthy life lost as a result of illness and disability (Murray and Lopez 1996).

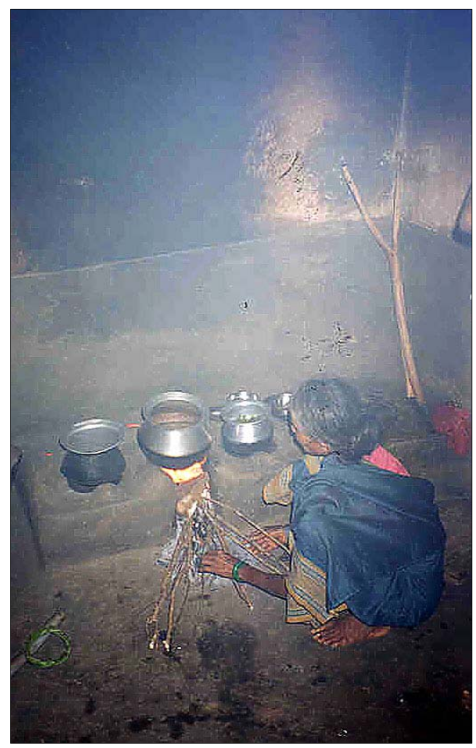
1.4. This study acknowledges multiple social and economic dimensions of household fuel use, and attempts to explore ways to mitigate IAP in a cross-sectoral fashion. More specifically, its objectives include the following:

- Gaining a better understanding of the levels and determinants of exposure to IAP in rural households, so as to guide the design of action programs and policy research;
- Facilitating efficient energy sector strategies and policies at the national, state, and local levels for mitigating IAP and respective environmental health damages;
- Improving knowledge and creating greater awareness amongst various stakeholders of the magnitude of IAP health impacts and cost-effective mitigation options across sectors.

The remainder of this chapter discusses the issues underlying the design of this study in terms of the health impacts of IAP and options for mitigating them.

Health Impact of Exposure to Biomass Fuel Smoke

1.5. Evidence of health effects associated with exposure to smoke from combustion of biomass fuels was initially provided by studies on outdoor air pollution and studies dealing with exposure to environmental tobacco smoke (ETS). Criteria documents for outdoor air pollutants published by the U.S. Environmental Protection Agency, for example, or air quality guidelines by the World Health Organization (WHO) detail the effects of many components including particulate matter, carbon monoxide, and oxides of sulfur and nitrogen. Considerable scientific understanding now exists about aerodynamic properties governing the particles' penetration and deposition in the human respiratory tract.



1.6. From an epidemiological standpoint, the earliest evidence linking biomass combustion, indoor air pollution, and respiratory health came from studies carried out in Nepal and India in the mid-1980s (Pandey 1984, Ramakrishna et al.1989, Smith et al. 1983). Since then a steady stream of studies has linked biomass combustion to several health effects, especially in women who cook with these fuels and young children (see Figure 1.1.) Strong associations between biomass fuel combustion and increased incidence of chronic bronchitis in women and acute respiratory infections in children have been documented (Ezzati 2001; Albalak et al. 1999; Armstrong and Campbell 1991; Bruce et al. 1998; Robin et al. 1996; Smith, Samet, and Romieu et al. 2000; Bruce, Perez-Pedilla, and Albalak 2000). Many recent studies have been conducted in rural Indian villages (Awasthi et al. 1996; Behera et al. 1991; Mishra and Rutherford 1997; Smith 1993; Smith and Liu 1994; Smith 1996). A recent study examined the relationship between biomass smoke exposure and acute respiratory infection in children of rural Kenyan households (Ezzati, 2001).

1.7. Table 1.2 shows relative risk[4] estimates for health outcomes that have been or are plausibly associated with exposure to smoke from solid-fuel use. There is strong evidence to support an association between solid-fuel use and acute lower respiratory infections (ALRI), chronic obstructive pulmonary disease (COPD), and lung cancer (for coal only). Although there is also epidemiological evidence to suggest an association with blindness (from cataracts), asthma, and tuberculosis, more carefully controlled studies will have to be conducted to confirm these associations. Associations with adverse pregnancy outcomes (including low birthweight and still-birth) and ischaemic[5] heart disease are biologically plausible: they have been associated with outdoor air pollution and smoking (passive and active), but have not yet been adequately explored for exposures from use of solid household fuels.

Table 1.2. Health Effects of Exposure to Smoke from Solid-fuel Use: Plausible Ranges of Relative Risk in Households Using Solid Fuel

Health Outcome	*Population Affected*	*Relative Risk*		*Evidence*
		Low	High	
Acute lower respiratory infections (ALRI)	<5 years	2.0	3.0	Strong
Asthma	Females ≥15 years	1.4	2.5	Intermediate/moderate
Blindness (cataracts)	Females ≥15 years	1.3	1.6	Intermediate/moderate
Chronic obstructive pulmonary disease (COPD)	Females ≥15 years	2.0	4.0	Strong
Lung cancer (coal only)	Females ≥15 years	3.0	5.0	Strong
Tuberculosis	Females ≥15 years	1.5	3.0	Intermediate/moderate

Note: Adapted from Smith (2000)

1.8. A comprehensive assessment of the disease burden attributable to solid-fuel use in India (which used these relative risk ratios derived from a number of studies in developing countries) has put the figure at 5–6 percent of the national burden of disease (Smith 2000, Smith and Mehta 2000). The assessment indicated that the use of solid fuel may be responsible for up to 444,000 premature deaths in children under 5 years of age, 34,000 cases of chronic respiratory disease in women under 45, and 800 cases of lung cancer. These estimates have been extremely valuable for identifying indoor air pollution and solid-fuel use as a major contributor to the national burden of disease in India. A recent World Bank study of environmental health in India that used a very different methodology for estimating the impact of solid-fuel use on health, resulted in comparable (slightly higher) estimates (Hughes, Lvovsky, and Dunleavy, 2001).

1.9. Each individual study on the impacts of indoor exposure to solid-fuel smoke has some shortcomings, and uncertainties about the exact magnitude of the health damage remain.

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4 *Relative risk* refers to the magnitude of association between exposure and disease, and indicates the likelihood of developing disease among the exposed group relative to the unexposed. A relative risk of 1 indicates that the risk is the same in the exposed and unexposed groups, i.e., there is no increased risk associated with exposure. For example, in Table 1.2, children exposed to indoor air pollution from solid-fuel use are anywhere from two to three times more likely than unexposed children to develop lower respiratory infections.

5 *Ischaemia* is a low-oxygen state usually caused by inadequate blood flow.

Nevertheless, accumulative evidence from a growing number of indoor air pollution studies, supported by outdoor air pollution and environmental tobacco smoke studies, is sufficient to conclude that the health effects in India are significant and of alarming proportion.

1.10. There are, however, two critical gaps in the available evidence. First, although exposure to fuel smoke is believed to be the key mechanism leading to a higher health risk for the users of solid fuels, virtually all epidemiological studies of indoor air pollution lack exposure information: they simply compare health risks in households using solid fuel against households that do not. Overall, data on household members' exposure to respiratory fractions of particulate matter, for which the strongest epidemiological evidence of health impacts exists in studies of outdoor air pollution, is very limited. Second, better understanding is needed of the complex linkages between a variety of possible interventions and the impact on reduction in exposure and health. One of the key challenges arises because what matters for health outcomes is not a *potential reduction* in emissions or indoor concentrations that can be achieved during laboratory testing of a technical device, but rather *actual reduction* in exposure of different family members over the lifetime of an intervention in the context of overall household energy use and choices. The design of this study takes these gaps into account.

Mitigation Options

1.11. In considering what can be done to alleviate indoor exposure to smoke from biomass fuels and the resulting health impacts, it is important to distinguish between (1) interventions that directly reduce exposure, such as changes to fuel, stoves, housing type and behavior; and (2) policies for encouraging, implementing and sustaining these changes.

Interventions

1.12. Three broad categories of interventions can help reduce the adverse effects of the use of biomass: (1) changing the source or reducing demand, (2) modifying the living environment, and (3) changing user behavior. Table 1.3 gives examples of each.

Table 1.3. Potential Interventions for Reducing Exposure to Fuel Smoke in Developing Country Homes

Source	*Living Environment*	*User Behavior*
Improved cooking devices	Improved ventilation	Reduced exposure through operation of source
Chimneyless improved biomass stoves	Hoods/fireplaces	Fuel drying
Improved stoves with chimneys	Windows/ventilation holes	Use of pot lids
Alternative fuel-cooker combinations	Kitchen design and placement of the stove	Good maintenance
Briquettes and pellets	Shelters/cooking huts	Sound operation
Charcoal	Stove at waist height	Smoke avoidance
Kerosene		Keeping children out of smoke
Gas: liquefied petroleum gas (LPG), natural gas, biogas		
Solar cookers		
Other low smoke fuels		
Electricity		
Reduced need for the fire		
Efficient housing		
Solar water heating		

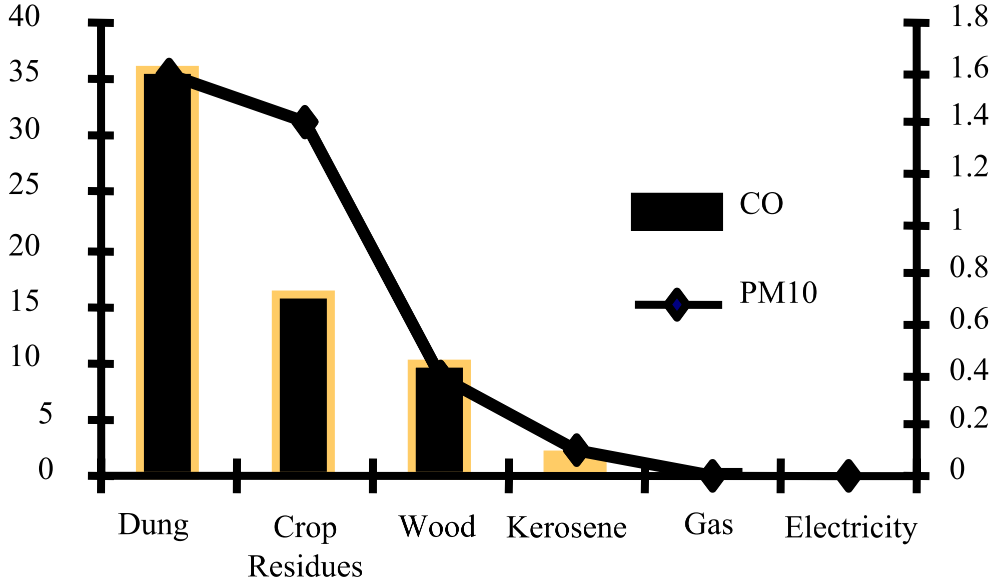
Source: Ballard-Treemeer (2000).

1.13. In the long run, the adverse effects of household use of traditional biomass will be eliminated by changing the type of fuel used, either to a liquid or gaseous fuel or to electricity. Conventional wisdom suggests that as development occurs, people shift up the household “energy ladder” to cleaner and more efficient fuels—and that as a result they move down the “exposure ladder,” reducing their health risk from indoor air pollution. Figure 1.2 illustrates the potential gains in limiting exposure. Although this generally holds true over the long term on a regional scale, the picture is more complex at local and household levels. For example, it has been observed that households often employ a “multiple model” of stove and energy use, whereby fuel substitution is not complete or unidirectional. Furthermore, increases in household income can lead to other changes in the household environment (such as improved roofing or a more spacious kitchen) that may affect people’s exposures to IAP in complex ways.

1.14. In India, for many years ahead, a significant number of rural households will continue to use biomass, or a combination of solid, liquid and gaseous fuels, with the consumption of solid fuels remaining high even as households adopt liquid and gaseous fuels. Therefore, many of the interventions mentioned in Table 1.3 that do not concern significant fuel switching and abandoning biomass are important, including better ways of burning fuelwood. Changing user behavior can be powerful because it need not incur any additional costs (an important consideration for the poor) while potentially yielding tangible benefits.

1.15. Before households will change their behavior in the ways listed in Table 1.3, they must be made aware both of the problem and the mitigation measures available to address it. Public awareness building can be an effective tool in encouraging and sustaining such behavioral change. A variety of stakeholders, including government ministries and agencies, NGOs and other grassroots groups, can take the lead in this area.

Figure 1.2. Emissions Along the Household Energy Ladder (grams per meal)



Source: K.R. Smith.

Policy Approach

1.16. Sector and fiscal policies influence the household choice of fuels and cooking methods. A clear example in India is the liberalization of the LPG market. When the supply was limited, very few households used LPG for cooking. The waiting list to sign up for LPG was long, sometimes lasting years. Today LPG is universally available in urban areas, with the waiting list essentially eliminated.

1.17. The creation of a level playing field in the energy sector and of an open, competitive market has been shown worldwide to increase efficiency and ultimately provide energy service to consumers at least cost. This is one of the most significant policy interventions that rightly belong to the role of the government. The deregulation in India in April 2002 of the downstream petroleum sector, which is involved in the supply of kerosene and LPG amongst other fuels, was an important step in this regard. Equally important is the situation with rural access to electricity, since kerosene, available at a subsidized price in rationed amounts, was used for lighting in one-half of rural households in 2000, markedly reducing its use as a cooking fuel.

1.18. Most government programs that promote better energy services to the rural areas and the poor involve subsidies. The Government of India's (GOI) National Programme on Improved Chulhas (NPIC), which provided improved biomass-burning cookstoves to 33 million rural households during 1984–2000, relied on heavy subsidies for the production and distribution of stoves. The GOI has also historically provided universal price subsidies for kerosene, which is rationed, and for LPG. Alternative subsidy schemes have been pilot-tested at the state level, such as kerosene coupons and a targeted capital subsidy for LPG. The main challenge in designing a subsidy instrument is to avoid inducing demand that cannot be sustained over time and does not result in creating a viable market for the services the government is trying to promote. This study pays significant attention to the role of energy policies and subsides in influencing household fuel choices.

Study Description

1.19. The study consists of four principal components: (1) exposure assessment in Andhra Pradesh (AP) to improve an understanding of the levels and determinants of exposure at the household level in rural settings; (2) a review of "best performing" improved-stove programs in six states in India to identify the necessary elements for successful implementation and long-term sustainability; (3) an evaluation of capital subsidy for LPG in Andhra Pradesh to assess its effectiveness in encouraging fuel switching from biomass to commercial fuels by the rural poor; and (4) dissemination of information and awareness-building through workshops, publication of newsletters and production of a video film.

Exposure Assessment: Evidence from Andhra Pradesh

1.20. The exposure assessment study aimed to obtain systematic information about actual exposure levels experienced by rural households in India and to identify the key parameters that affect and can possibly predict the exposure levels. The study was undertaken in three districts of Andhra Pradesh (AP) as a pilot.

1.21. To this end, household-level surveys were conducted to obtain data on various household characteristics and behavioral factors, with the focus on secondary indicators of indoor air pollution, such as the distribution of fuel use, stove type, and ventilation conditions. To estimate exposure, this was followed by field monitoring to collect data on ambient concentrations of respirable suspended particulate matter (RSPM)[6] in households and 24-hour activity patterns of household members. Lastly, the study included a statistical analysis of the two data sets to examine relationships between exposure levels and household characteristics, and to establish whether these parameters can serve as reasonable predictors of exposure.

Evaluation of a Targeted Capital Subsidy Scheme for LPG in Andhra Pradesh

1.22. In July 1999 the GOAP launched the Deepam Scheme to promote the use of LPG by the poor. Under the scheme, the government covers the cylinder connection charge of Rs 1,000 for starting LPG service for those families classified as being below the poverty line (BPL). This differs from the government's traditional LPG price subsidy in several respects. First, it is a one-off subsidy, covering the capital cost rather than the operating cost, namely the purchase of the fuel itself by giving a price subsidy. Second, only poor households are eligible for the subsidy, whereas the current LPG price subsidy in India is available to every household, and benefits mainly the well-off in urban areas. Third, the program is targeted to rural areas. Lastly, it is implemented through women self-help groups, thus linking the promotion of LPG with support for women's development and financial independence.

1.23. For this study, the team reviewed the design of the Deepam Scheme, collected primary data to assess the experience of the beneficiaries and implementing agencies, and

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6 In thus study, *RSPM* is defined as a fraction of particulate matter with a median diameter of 4 microns (µg).

attempted to quantify the impact of the scheme on the use of LPG by poor urban and rural households. The evaluation generated several recommendations for the scheme's next stage and highlighted some broader issues affecting the design of energy subsidies for the poor.

Evaluation of Selected Programs on Improved Cookstoves in Six States

1.24. Improved stoves, with their higher fuel efficiency and better design, can potentially diminish the drudgery of collecting fuels and lower exposure to indoor air pollution for millions of rural families who cannot afford modern fuels. Although emissions from improved stoves burning solid fuels remain higher than those from stoves burning gaseous fuels, substantial reductions in exposure can be achieved by comparison with the use of primitive traditional stoves. The key issue is whether stoves can be produced and disseminated in a manner that generates sustainable demand from users, responds to the needs of women cooks and the customs and cultural preferences of all family members, addresses maintenance and repair problems, and leads to routine purchasing of improved stoves on the market.

1.25. Next to a similar program in China, the NPIC is the largest improved-stove program in the world to have reached a large number of poor people in a relatively short time. Overall, the performance of the program has been mixed, the main weaknesses being the lack of sustainability and insufficient attention to user preference. Implementation approaches and achievements varied substantially across states, however, and some state programs have been more successful than others.

1.26. The purpose of this component was to identify the determinants of success for a stove program in India, based on an evaluation of the six most successful state programs, complemented with lessons from international experience. The programs for these case studies were carefully selected in consultation with the Ministry of Non-Conventional Energy Sources (MNES), the GOI, and Indian stove experts.

Building Awareness

1.27. Awareness of the adverse health impact of the traditional use of biomass, and of possible interventions, can stimulate household demand for better energy options. It also helps strengthen government commitment to addressing the problem and adopt more effective policies. All together, it accelerates the switch to alternative cooking methods and fuels. One of the objectives of this study is to assist in this process by raising awareness among all stakeholders. Knowledge sharing and awareness raising were considered particularly important in this work due to the cross-sectoral nature of the problem—which posed an additional challenge to exchanging information, creating the whole picture of impacts, critical linkages and possible solutions, and designing effective programs.

Structure of the Report

1.28. Following this introduction, Chapters 2–4 describe the design, findings, and recommendations of the three research components. Chapter 5 reports awareness building activities supported by the program and some emerging evidence of their impact. Chapter 6 summarizes conclusions and outcomes of the entire study, emphasizing the additional lessons and value added by a multi-sectoral approach.

2

Levels and Determinants of Exposure to Indoor Air Pollution: Evidence from Andhra Pradesh

2.1 In order to effectively confront the health risks of IAP, good proxy indicators of these risks, such as *population exposure*, are needed to guide and facilitate mitigation action. Diseases have multiple causes and it is often difficult, lengthy, and costly to conduct epidemiological studies that would allow discrimination of the burden of disease attributable to indoor air pollution as opposed to other factors, such as malnutrition and smoking. On the other hand, information on population exposure—a measure combining the number of people, the concentration of pollution, and the amount of time spent breathing it—can serve as an indicator of where the health risks are likely to be. Hence, developing robust methods of determining population exposure will not only improve estimates of the overall impact of indoor air pollution, but will also help better target policy interventions.

Study Rationale and Objectives

2.2 Good quantitative data on exposure is essential to assess associated health risks. Biomass combustion results in the emission of a variety of toxic pollutants including respirable particulates, carbon monoxide, sulfur-dioxide, nitrogen dioxide, formaldehyde, and benzene. Most studies point out that particulate matter is a good surrogate for overall indoor air pollution levels in households using biomass. A large number of outdoor air pollution studies provide strong epidemiological evidence linking exposure to inhalable and respirable fractions of particulate matter with the incidence of respiratory illness and death. However, there is no sufficient quantitative information for particulate matter associated with biomass combustion in rural indoor settings of developing countries. Initial studies on IAP measured concentrations of total suspended particulates and gases including CO, only during cooking windows. Determination of 24-hour averages for inhalable fractions of particulate matter (which is a better metric for exposure and health risks, and for which health-based standards exist in outdoor settings) have been thus far been attempted in very few studies. Table 2.1 lists some recent studies carried out in developing countries that compare the particulate fractions monitored, fuel types, averaging periods for monitoring, and households concentrations.

Table 2.1. Comparison of Particulate Levels as Determined in Some Recent Studies in Developing Countries

Location	*Averaging time*	*Fuel Type*	*Mean Levels Size Fraction/range (μg/m³)*
1. Gujrat, India (1983)	Cooking period/TSP	Wood	6800
2. Garhwal, India (1992)	Cooking period/TSP	Wood/Shrubs	4500 (GM)
3. Pune, India (1994)	12–24 hrs/PM10	Wood	2000 (Area)
			1100 (Personal)
4. Mozambique (1996)	Cooking period/PM10	Wood	1200
		Coal	540
		Charcoal	940
5. Rural Bolivia (1999)	6 hrs/PM 10	Dung	1830 (GM, indoor kitchens)
			280 (GM, outdoor kitchens)
6. Kenya (2000)	Daily average exposures/PM10	Wood/charcoal	1000–4800
7. Tamil Nadu, India (2000)	Cooking period/RSMP	Wood/agricultural wastes	500/2000 (personal)
	Daily average exposure/ RSPM	Wood/agricultural wastes	60–350
8. Guatemala (2001)	24-hour/ RSPM3.5	Wood	1560 (GM, traditional stove)
			250 (GM, improved stove)
			850 (GM, LPG /open fire combination)

GM = geometric mean, PM 10 = particulate matter < 10 microns, RSPM – respirable suspended particulate matter with median particle size of 4 microns, RSPM 3.5 = median particle size 3.5μm, TSP = total suspended particulates.

2.3 Studies that monitor for 24-hour concentrations and exposures are difficult to conduct and usually very resource intensive. At the same time, information on "secondary indicators" of IAP—that is, determinants of household-level exposure—is relatively easy to collect and can be incorporated as a part of ongoing national level demographic or health surveys. For example, the 1991 National Census in India collected information on fuel that aided the calculation of the national burden of disease attributable to IAP. However, there is little understanding about the different factors that affect exposure to indoor air pollution and their inter-linkages, i.e., to what extent fuel use patterns or housing characteristics predict actual household air pollution concentrations.

2.4 Improving the understanding of the relationship between household parameters that can be routinely surveyed and indoor pollution levels would be extremely valuable for generating surrogate exposure indices. Such as analysis would help researchers design better exposure indicators by elucidating, for example, which questions might be asked on a national census survey to best predict actual household pollution levels. Better estimates of exposure would, in turn, help intervention planners target the population sub-groups with the highest potential health risks due to IAP. Finally, if robust models are developed to predict indoor pollution levels using household survey parameters, this could help supply policymakers with information about the impact and, ultimately, the cost-effectiveness of interventions that alter the determinants of exposure.

2.5 In addition, although a number of studies with IAP measurements have been undertaken in Northern India, very little information on exposures in Southern India is currently available. The climatic and cultural differences between the Northern and Southern Indian regions have the potential to influence exposures significantly. There is rarely a need to heat homes in the South. Further, the restrictions on the movement of women are significantly fewer in the South. Unlike in Northern India, women in the South do not cover their faces and usually have freedom to move outside the house even in the presence of men, factors that may substantially reduce exposures. Thus, an exposure assessment study in Southern India has its own value.

2.6 With this rationale in mind, the present study was designed to collect better and more-systematic quantitative information about actual levels of exposure to indoor air pollution experienced by rural households in India; and to identify key determinants of this exposure. The study was undertaken in three districts of Andhra Pradesh (AP) and was considered a pilot for testing a methodology for predicting exposure indicators that could be applied on a larger scale.

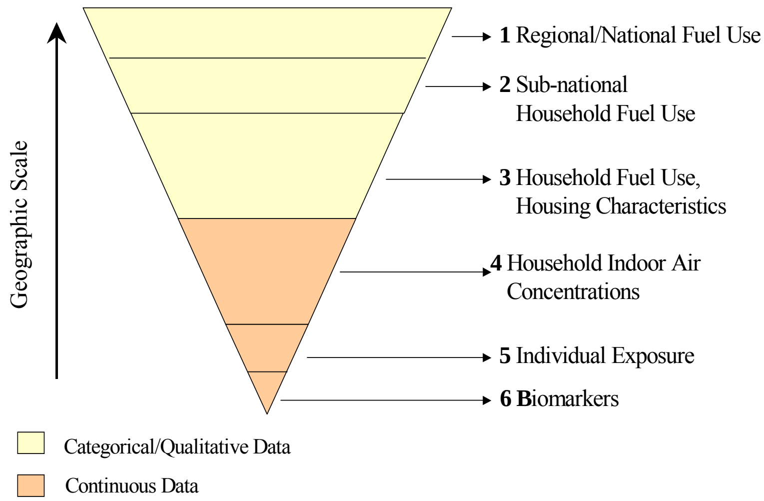
Research Design

Approach to Exposure Assessment

2.7 Exposure can be assessed in various ways, with varying degrees of accuracy, as shown in Figure 2.1. Secondary data sources, such as data on national fuel use, give some measure of potential exposure (Tier 1). However, they do not indicate how different exposure indicators are linked, i.e., to what extent fuel-use patterns in the community or households predict actual concentrations of household air pollution. Actual household surveys of fuel use (Tier 2) are more-accurate but more-expensive ways to measure exposure. Indeed, this measure has been often used as the indicator of exposure in many epidemiological studies. Even better, but more expensive, would be surveys not only of fuel use, but also household characteristics such as type of construction material, stove type, number of rooms and windows, etc., as might be part of a census or national housing survey (Tier 3). Following this, higher in cost but affording more accuracy come air pollution studies with devices set in stationary positions in the house (Tier #4). Finally, there could be studies where people actually wear devices to measure their pollution (personal) exposures or where biological fluids or tissues (biomarkers) are examined to determine how much pollution they have been exposed to (Tiers #5 and #6). In general, as the geographic scale decreases, specificity increases, availability of pre-existing or routinely collected data decreases, and the cost of original data collection increases.

2.8 As a compromise between cost and accuracy, the exposure assessment methodology in this study straddled tiers #3 and #4. Primary data on parameters such as household fuel use are available through census or other national surveys; these were used together with primary data collected on certain household-level characteristics and indoor air pollution measurements.

Figure 2.1. Tiered Exposure Assessment: Indoor Air Pollution from Solid-fuel Use



Source: K.R. Smith and S. Mehta 2000.

2.9 Broadly, the exposure assessment study included the following components:

- Household-level survey to obtain data on various household characteristics and behavioral factors that can influence the level of exposure;
- Field monitoring to collect data on 24-hour average indoor air concentrations of RSPM in the micro-environments of the same households, complemented by 24-hour time activity patterns in order to estimate exposures;
- Statistical analysis to explore linkages between secondary indicators of exposure, such as kitchen and fuel types, collected by the survey, and indoor RSPM concentrations.

2.10 This exercise was designed by the Center for Occupational and Environmental Health (COEH), University of California, Berkeley, and undertaken in partnership with two leading institutions in the field in India: Sri Ramachandra Medical College (SRMC), Chennai, and Institute of Health Systems (IHS), Hyderabad.

Developing the Household Questionnaire

2.11 Table 2.2 summarizes key household characteristics related to exposure. As a first step to designing the household survey questionnaire used in the present study, the research team reviewed all national- and state-level surveys to glean questions relevant to households, fuels, and other characteristics.[7] This effort also served to identify gaps and variables inadequately characterized in the surveys.

Table 2.2. Household Characteristics Related to Exposure

Exposure Parameters	*Measure*
Emissions	▪ Fuel-use categories and quantities ▪ Stove characteristics
Housing	▪ Housing materials ▪ Kitchen type ▪ Roof type ▪ Separate kitchen for cooking
Ventilation	▪ Number of windows/openings in kitchen ▪ Size of kitchen and living areas ▪ Chimney venting smoke outdoors
Crowding	▪ Number of people/number of rooms

2.12 The researchers found that data were available only for a few variables, such as house type and fuel type. (Annex 1 outlines the key variables present in the above-mentioned national and state surveys.) No data were available on variables likely to affect air quality levels in households, such as kitchen type and household ventilation.

2.13 On the basis of this review, the questionnaire was designed to collect primary data for two categories of information[8]:

- Information from households that parallels the information already collected by demographic surveys, including the Census and the National Family Health Survey (NFHS).
- Information for the same households on characteristics that are currently not included in demographic and health surveys but could be incorporated into future surveys if found to be predictive of indoor air pollution (see Table 2.2).

Selecting Households

2.14 The households were selected in three districts of the Telangana region of Andhra Pradesh: Nizamabad, Warangal, and Rangareddy. Since the main the objective of this exercise was to investigate affect IAP levels, it was important that the sample encompass a sufficient number of different fuel-use patterns and kitchen types. Household selection was thus done using

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7 The review included the Census of India 1991 and 2001, the AP Multi-Purpose Household Survey (MPHS), and the Human Development Survey (HDS). It also included sampled survey datasets such as the National Family Health Survey (NFHS) 1 & 2, National Sample Survey (NSS), and the Rural Energy Database (REDB), a secondary compilation of studies undertaken by TERI.

8 This survey also provided an opportunity to test whether or not this information can be effectively ascertained by questionnaire.

a purposive three-stage cluster-sampling method to ensure that each cluster of households includes a combination of kitchen types and fuel types. Clustering was necessary to efficiently use the field team's available time and pollution monitoring equipment.

2.15 The cluster-sampling scheme, which targeted 150 households in each district, proceeded as follows:

- Selection of *mandals*[9] as the first-stage sampling unit (5 from each district)
- Selection of *habitations* as the second-stage sampling unit (1 from each mandal)
- Selection of *households* as the third-stage sampling unit (about 30 from each habitation).

Selection of Mandals as the First-Stage Sampling Unit

2.16 Data on patterns of fuel use were available at the mandal level from the 1991 Census. In each of the selected districts, the research team ranked mandals in descending order according to percentage of use of clean fuels. The percentage of clean fuel use appeared to be very low (< 5 percent) in almost all mandals from each of the districts. The sampling scheme required that some households using clean fuels be included in the sample from each cluster. To ensure this requirement, all mandals whose percentage of clean fuel use was below 2 percent were excluded from the sampling frame; from the remainder, five were selected as survey mandals using probability proportionate to size criteria.

Selection of Habitations as Second-Stage Sampling Unit

2.17 Within each of the selected mandals, *habitations* were listed in descending order of population size. It was assumed that habitations having populations above 2000 were likely to yield enough households to meet each of the categories of kitchen site and fuel type as listed in the definition of clusters. Therefore, habitations having less than 2000 people were excluded from the sampling frame. From this sampling frame, one habitation was randomly selected (using a random number-generating tool in Excel) in each of the survey mandals to serve as the survey habitation.

Selection of Households as Third-Stage Sampling Unit

2.18 Previous studies have shown that within households using solid fuels (i.e., wood, dung or a combination) exposure varies according to kitchen type, whereas within households using clean (liquid and gaseous) fuels the type of kitchen has not been shown to influence exposures (Parikh et al. 2001, Balakrishnan et al 2002). Generic types of kitchen configuration commonly found in these villages include indoor kitchen with no partition, indoor kitchen with

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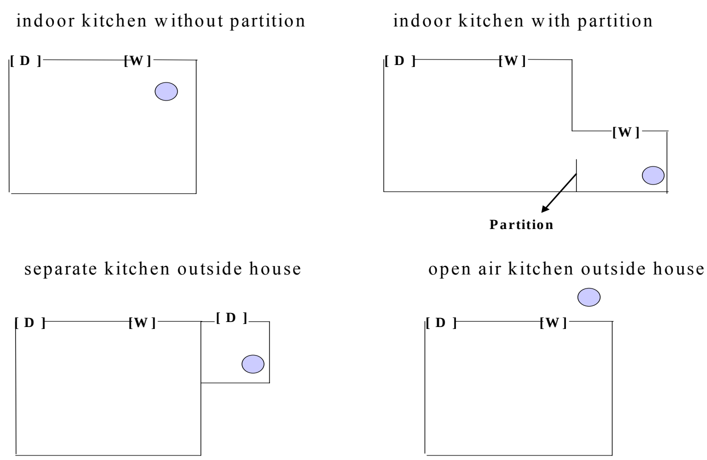
[9] A *mandal* is an administrative unit below the district level but above the *gram pachayat*. A mandal may comprise around 15 *gram panchayats*.

partition, separate outdoor kitchen, and open outdoor kitchen (i.e., open air cooking).[10] A schematic diagram of these kitchen types is given in Figure 2.2.

Figure 2.2. Sketch of Kitchen Types



Note: D = doorway, W = window opening, ◯ = stove

2.19 Therefore, the selection of households within each habitation aimed at having six households in each of the following five groups: four groups of solid fuel households, according to the four kitchen types; and a group of households using clean fuels. To select a cluster of households, the study team kept visiting every fourth household starting from the center of a habitation, until the desired criteria were reasonably satisfied. Cooking with clean fuels is negligible in rural areas, so even with a purposive sampling this category of households came out much smaller than other categories. In the end, 420 households were selected for both the household survey and monitoring, their characteristics were used exploring the determinants of pollution levels

2.20 In addition, the household survey was administered to a larger sample of 1032 households. This was done by targeting every fourth household after the three-stage cluster-sampling of households was accomplished in each habitation. The resulting sample is more representative of a typical household profile in the Telangana region and, based on the analysis of exposure determinants, provides a broader picture of prevalent exposure patterns in rural AP. The samples of 420 and 1042 households are hereafter referred to as Sample 1 and Sample 2, respectively.

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10 Separate kitchens indoors (Type 1) typically were well separated from the living areas and also usually well ventilated. Indoor kitchens without partitions (Type 2) typically had very little separation between the cooking area and the adjacent living area. Most importantly, because these households had only one indoor area that was used for cooking and all other indoor activities including sleeping, the potential for exposures was maximal in this configuration. Separate kitchens outside the house (Type 3) were somewhat difficult to define. While few households had definite walled kitchens outside the main living areas, on many occasions, they were semi-enclosed and some were connected through corridors to the rest of the house and therefore not truly outside the house. Outdoor kitchens (type 4) typically had stoves kept in the open without any enclosures or occasionally had a thatched roof on top to protect from rain, but were open on all other sides.

Profiles of Sampled Households

2.21 Separate profiles were built for the two samples of households, as summarized in Table 2.3 and briefly discussed below.

Table 2.3. Overview of Household, Fuel, and Kitchen Characteristics in the Sampled Households

Housing characteristic	*Percentage of households in each sample*	
	Sample 1 (420 households)	***Sample 2 (1032 households)***
House type (roof material)		
Grass/leaves/reeds/hatched/wood/mud/ bamboo/unburnt bricks	30.2	27.7
Tiles, slates, shingle	48.1	47.6
Metal sheets	4.0	2.3
Asbestos cement sheets	10.0	9.8
Brick stone/lime/stone	0.2	0.7
Concrete	7.4	11.7
Other material	0.0	0.2
House type (wall material)		
Grass/leaves/reeds/bamboo or thatch	2.1	1.0
Mud/dirt	76.7	70.8
Unburnt bricks	0.5	1.6
Wood	0.2	0.4
Burnt brick	19.0	23.9
Metal sheets	0.2	0.1
Stone	0.5	0.5
Cement Concrete	0.7	1.6
Other material	0.0	0.1
Kitchen type		
Indoor kitchen with partition	29.0	27.5
Indoor kitchen without partition	25.2	6.4
Separate indoor kitchen outside house	23.6	15.7
Open air kitchen	22.1	50.4
Fuel type		
Biogas	1.1	0.4
Kerosene	2.6	1.6
LPG	7.1	9.9
Wood	64.9	81.5
Mixed (dung/wood and dung)	23.3	6.6
Stove type		
Traditional stove made of three stones	18.6	21.5
Traditional stove made of three stones and plastered with mud	55.5	74.7
Traditional stove made of three stones and plastered with mud and ridges	30.0	27.7
Traditional stove made of three stones and plastered with mud with chimney	10.5	8.5
Improved stove with chimney	0.2	0.1
Kerosene stove	31.9	25.5
LPG Stove	12.4	15.2
Biogas	1.7	0.5

Socio-economic Characteristics

2.22 The socio-economic characteristics in both samples of households are similar. The majority of the villagers are either small or marginal farmers and up to 20 percent are landless. Prevalence of education is low in both samples. In approximately 23 percent of the households in both samples, household members had not even completed one year of schooling, while 49 percent and 44 percent of the households in Samples 1 and 2, respectively, had five years of schooling as the highest education level. About 23 percent and 31 percent of Sample 1 households and 26 percent and 36 percent of the Sample 2 households owned a radio and TV, respectively. In terms of smoking habit, an important compounding factor in the health impacts of fuel smoke, 43 percent and 44 percent of households in Samples 1 and 2, had at least one member smoking *bidi* (locally made cigarettes), and the prevalence of cigarette smoking was less at 6 percent in both cases. Smoking amongst women was virtually non-existent.

Housing and Kitchen Characteristics

2.23 As Table 2.3 shows, the housing characteristics in the two samples are remarkably similar. About 48 percent of the households in both samples had roofs made of tiles and slates and shingles; leaves, thatch and bamboo were used to make roofs in 30 percent of households in both categories. Cemented concrete roofs, a sign of a wealthier household, were uncommon (7 percent in Sample 1 and 11 percent in Sample 2). Most households had walls made of mud (70 percent in Sample 1 and 77 percent in Sample 2).

2.24 Not surprisingly, given the sampling design, Sample 1 and 2 households had distinct kitchen characteristics. In Sample 2, which is more representative of the prevalence of kitchen types, a much larger proportion (50 percent) of households cooked their food in the open air compared to Sample 1 (22 percent). In contrast, the number of households with an indoor kitchen without partitions was smaller (6 percent in Sample 2 versus 25 percent in Sample 1). 29 percent and 27.5 percent of the households in Samples 1 and 2, respectively, had indoor kitchens with partitions.

Fuel-use Pattern

2.25 Solid biomass fuel use dominated in all rural households of the three study districts in Andhra Pradesh (as has been repeatedly observed in many previous studies carried out in other states). Although the sample was not designed to establish prevalence of fuel types, it was clear that households using clean fuel were rare in the villages, as were households with improved stoves. A vast majority of households used wood for cooking (65 percent in Sample 1 and 81 percent in Sample 2). In addition, 23 percent of households in Sample 1 and 7 percent of households in Sample 2 used dung or a combination of dung and wood, often complemented with small amounts of kerosene for starting the fire. These households were merged into a category of “mixed fuel” users in this study. Only about 10 percent of households in both samples used clean fuels (i.e., biogas, LPG, and kerosene). Kerosene, which is supplied through the public distribution system and is mostly restricted to a quota of 3 liters per household, was mainly used for lighting and ignition of firewood.

2.26 Most households were found to use traditional stoves, that is, three stones plastered with mud (56 percent in Sample 1 and 75 percent in Sample 2). The usage of traditional stoves with chimneys was 10.5 percent in Sample 1 against 8.5 percent in Sample 2. In both samples the usage of improved stoves was negligible. Although kerosene stoves were used in 32 percent of households in Sample 1 and 25.5 percent of households in Sample 2, only 2.6 percent and 1.6 percent, respectively, indicated kerosene as the main cooking fuel. This implies, as is evident from other studies in India and elsewhere (see Chapter 3 and Masera et al. 2000), that many households are using more than one type of stove and fuel. This was usually the case with households with access to clean fuels, particularly kerosene, who often reported switching frequently to biomass fuel use. On many occasions, the study team would initiate the monitoring in a household that cited kerosene as their main cooking fuel, only to find wood having been used the subsequent morning. This reduced the number of samples taken in households that used kerosene exclusively.

Cooking Habits

2.27 Women's' cooking habits were assessed in the sample of 420 households. Typically, women who had outdoor jobs cooked two small meals over half-hour periods in the morning and evening. Women who stayed at home cooked one large meal over a period of 1.5–2 hours. Men who stayed indoors without jobs were old or suffering from various ailments. There were many variations in the kitchen configurations of the sampled households and many households reported switching the location of the stove depending on the weather and convenience. The village residents were, however, able to relate to four categories of kitchen types selected in the study, confirming that this template would comprehend most kitchen configurations found in village households.

Measuring IAP Concentrations

Methodology

2.28 The present study monitored indoor air pollution levels, using RSPM as an indicator pollutant.[11] The size-selection device (the "cyclone") used to measure RSPM is designed to mimic the size selection of the human respiratory system, that is, to reject essentially all particles larger than 10 microns (μm) and to accept essentially all smaller than 2 microns. The 50 percent cut-off occurs at about 4 microns (Vincent 1999) as opposed to sampling with a sharp cut-off at either 10 (PM 10) or 2.5 (PM 2.5) microns.[12]

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11 Respirable suspended particulate matter (RSPM) includes the fraction of inhaled aerosols that is capable of penetrating the alveolar (gas-exchange) regions of the adult lung. Because previous studies have shown that RSPM includes particles in the size range produced during the combustion of biomass fuels (i.e., <3μm), the concentration of RSPM was taken to be an appropriate surrogate for the concentration of biomass smoke.

12 Given that a large number of observations and exposure-response relationships in outdoor air pollution studies are based on PM10 (particulate matter less than 10 microns in diameter), it is useful to know a typical ration of RSPM to PM10. In this study, the ratio of RSPM to PM 10 ranged from 0.57 to 0.73 with a mean of 0.61. Although differences in measurement protocols should be kept in mind, this ratio is consistent with some other available measurements.

2.29 The monitoring study was conducted in three phases between January and May 2001. Table 2.4 shows the overall profile of the households targeted for monitoring.[13] Three types of data were collected:

- 24-hour average concentrations of RSPM at kitchen and living areas were collected from all study households using portable, battery-operated, programmable, low-volume samplers. The samplers were loaded with filters and cyclones to achieve the desired cut off for respirable particulates[14]. In addition, for roughly 10 percent of households, the team used a real-time monitoring instrument (PDRAM) to determine concentrations during cooking and non-cooking windows (see Annex 2).
- 24-hour outdoor area ambient air concentrations of RSPM were monitored at about 20 percent of the households.
- A detailed questionnaire was administered to each household to collect time-activity information as well as information on behavioral and other variables likely to influence concentrations (complimentary to the household survey described earlier).

Table 2.4. Summary Profile of Monitoring Activity

Number of Households Monitored, by Types of Kitchens	▪ Indoor kitchen with partition from living area:113 ▪ Indoor kitchen without partitions from living area: 108 ▪ Separate indoor kitchen outside the house: 96 ▪ Outdoor cooking: 95
Number of Households Monitored, by Fuel Categories[a]	▪ Mixed (wood and dung, dung only): 97 ▪ Wood: 270 ▪ Kerosene: 11 ▪ Gas (LPG/Biogas): 34
Number of Valid Measurements	▪ 385 Kitchen measurements ▪ 375 Living area measurements ▪ 28 Outdoor measurements ▪ 31 PDRAM measurements

[a] For purposes of data analysis, households were classified as mixed-fuel users (usually a combination of dung and wood, with a few households using only dung), wood users, kerosene users and gas users. Many biomass-using households used a small amount of kerosene to start the fire. Biogas and LPG users were grouped together as gas users.

Results

2.30 The results of measuring kitchen and living-area RSPM concentrations are presented here across fuel types and kitchen types.

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[13] Three of the 420 surveyed households had to be dropped due to logistical reasons. Measurements in 5 households were invalid, resulting in 412 households available for analysis.

[14] Samples were collected and analyzed according to National Institute for Occupational Safety and Health (NIOSH) Protocol 0600. Average daily concentrations of RSPM were presented in units of $\mu g/m^3$.

2.31 Table 2.5 and Figure 2.3 present the 24-hour average indoor-air RSPM concentrations in the kitchen, living, and outdoor areas for households that use wood, mixed, kerosene, and LPG fuels. 24-hour average RSPM concentrations ranged from 73 to 732 μg/m^3 in the kitchen and 75 to 362 μg/m^3 in the living areas of households using gas and solid fuel (wood or mixed-fuel) respectively. Specifically,

- Households using mixed fuels (wood and dung, or dung with small amounts of kerosene to start the fire) had the highest concentrations (732 μg/m^3 in kitchen areas), followed by wood (500 μg/m^3), kerosene (203 μg/m^3) and gas (73 μg/m^3), illustrating the "energy ladder" sequence observed in other settings.
- Mean 24-hour kitchen concentrations in solid-fuel-using households were 2.5 (wood users) to 3.5 (mixed-fuel users) times higher than those in kerosene-using households.
- Mean 24-hour kitchen concentrations in kerosene-using households were also about three times higher than those in LPG-using households (203 μg/m^3 versus 73 μg/m^3). The high RSPM levels in kerosene-using-households could stem from the households' having used wood for cooking during the monitoring period even though responding in the questionnaire that they cook with kerosene only. Alternatively, some may have cooked with biomass the previous day, resulting in residual smoke, especially in indoor kitchens without partitions.
- Gas (mostly LPG) users had the lowest concentrations in both kitchen and living areas, with no significant difference between the two. These were the only households with average indoor concentrations lower than outdoor levels (see Table 2.5).

Table 2.5. Mean 24-hour RSPM Concentrations Across Household Fuel Types (μg/m^3)

Area	*Mixed*	*Wood*	*Kerosene*	*LPG*
Kitchen	732± 88 [a]	500± 30	203± 59	73± 7
	470 [b]	340	156	61
	(83) [c]	(259)	(11)	(32)
Living room	362± 37	345± 26	289± 150	75± 7
	235	204	140	64
	(87)	(251)	(9)	(28)
Outdoors	99± 17	87± 5	d	114± 29
	87	84		103
	(8)	(16)		(4)

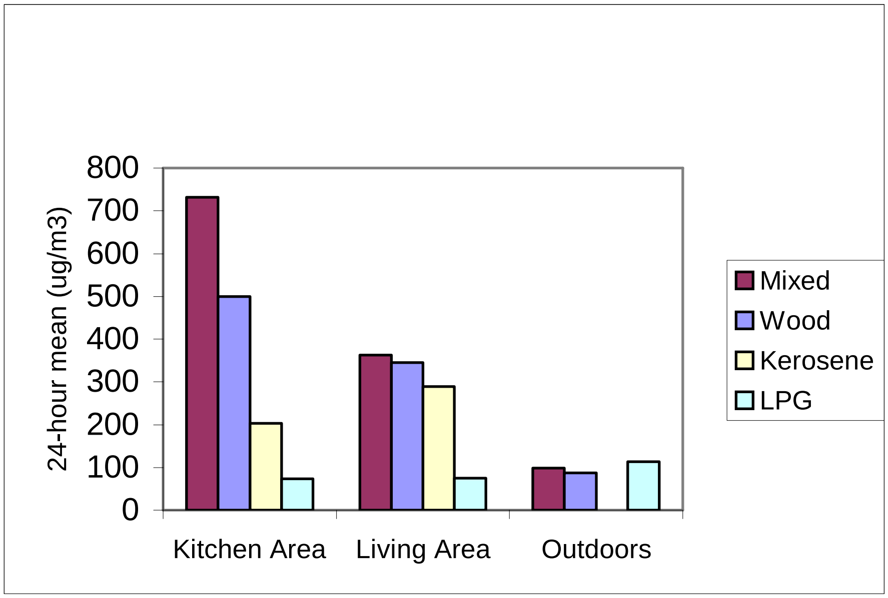
[a] Value is arithmetic mean ± standard error of the mean

[b] Value is geometric mean

[c] Value in parentheses is the sample size

[d] Given a small number of kerosene cooking households and a limited number of outdoor measurements, the latter were not taken in the former category

Figure 2.3. Mean 24-hour RSPM Concentration for Different Fuels and House Areas



2.32 Table 2.6 and Figure 2.4 presents the 24-hour average kitchen RSPM concentrations across different kitchen types. Very different patterns are observed in solid-fuel-using households (e.g., households using wood or mixed fuels) and gas-using households.

- In solid-fuel-using households, no significant difference in concentrations was observed between indoor kitchens with partitions and those without partitions (666 µg/m^3 versus 652 µg/m^3). Kitchen area concentrations are significantly higher in indoor kitchens compared to outdoor kitchens with or without partitions (659µg/m^3 versus 436µg/m^3).
- Although outdoor cooking—the most common type of cooking in the survey households—is associated with the lowest pollution levels, the concentration levels are substantial both in the cooking area and in the living area of the house (297 µg/m^3 and 215 µg/m^3), and are well above health guidelines for outdoor air quality (the Indian standard for 24-hour average concentration for PM10 in rural outdoors is 100 µg/m^3).
- In solid-fuel-using households, living-area concentrations were highest in households having kitchens without partitions (559 µg/m^3), followed by kitchens with partitions (357 µg/m^3), separate kitchen outside (280 µg/m^3), and outdoor open-air kitchens (215 µg/m^3). Living-area concentrations in households using outdoor kitchens were much lower than those with indoor kitchens (215 µg/m^3 versus 458 µg/m^3) but about similar to households with a separate kitchen (215 µg/m^3 versus 280 µg/m^3). Thus, dispersion is able to considerably affect adjacent living-area concentrations during outdoor cooking. This could have important health implications for family members who spend time indoors during cooking.
- In gas-using households, concentrations did not vary across kitchen types.

Table 2.6. Mean 24-hour Kitchen Area RSPM Concentrations Across Kitchen Types (μg/m^3)

Area	*Type of Fuel*	*Indoor Kitchen with Partition*	*Indoor Kitchen without Partition*	*Separate Kitchen Outside the House*	*Outdoor Open Air Kitchen*	*Total*
Kitchen	Solid	666± 75[a] 428[b] (86)[c]	652± 61 465 (92)	575± 65 389 (87)	297± 35 220 (77)	556±32 368 (342)
	Gas	70± 8 60 (21)	70± 19 56 (5)	86± 20 71 (6)	d	NA
Living	Solid	357± 41 219 (84)	559± 55 377 (82)	280± 44 157 (83)	215± 19 158 (89)	350±21 211 (338)
	Gas	70± 8 60 (21)	76± 14 75 (2)	96± 22 82 (5)	d	e
Outdoor	Solid	90± 6 88 (8)	76± 8 73 (6)	105± 20 91 (7)	91± 14 89 (3)	91±6 85 (24)
	Gas	73± 18 70 (2)	d	155± 39 150 (2)	d	e

[a] Value is arithmetic mean ± standard error; [b] Value is geometric mean; [c] Value in parentheses is the sample size; [d] Sample did not contain households in this category; [e] Data are not reported.
NA = Data not available.

Figure 2.4. Kitchen and Living Area RSPM Concentrations for Different Kitchen Configurations in Solid-fuel Households in Rural AP

Note: *Solid fuel* includes wood and mixed fuels.

Estimating Exposure

2.33 Daily exposure depends not only on concentration in a particular place but also on the time that different family members typically spend during 24 hours in various household micro-environments Therefore, to estimate exposure, concentrations measurement data needs to be combined with time activity patterns. Annex 2 describes the methodology for exposure reconstruction.

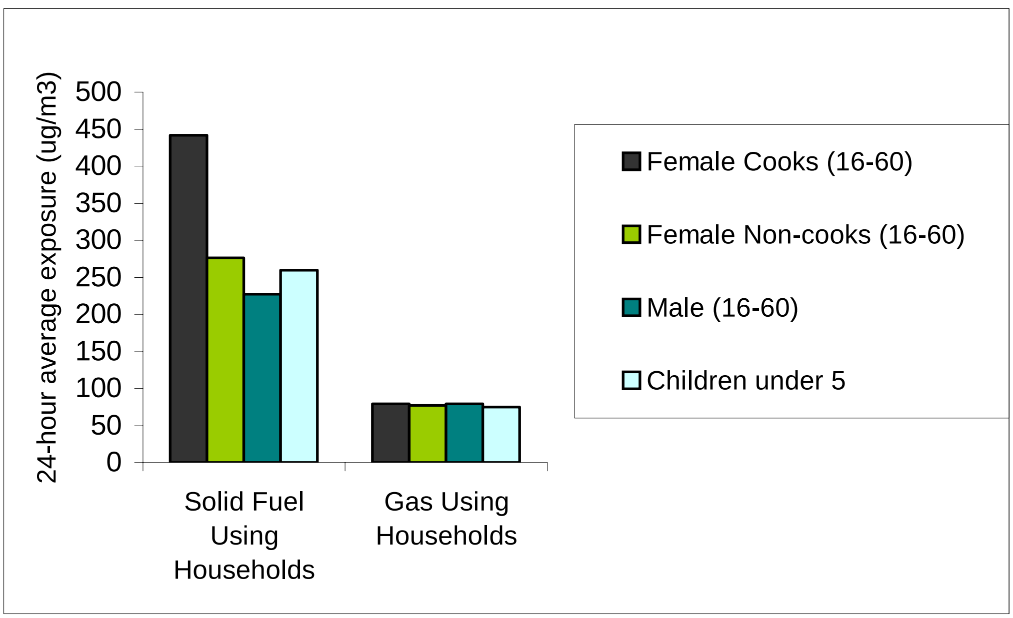
2.34 Analysis of exposure patterns revealed two principal types of differences: across fuel types, especially between solid-fuel-using versus clean-fuel-using households; and across family members, especially between female cooks and the others, emphasizing gender inequalities in the health impacts of solid-fuel users (see Table 2.7 and Figure 2.5, as well as Tables A2.2–A2.4 in Annex 2). Key results are as follows:

- Mean 24-hour average exposures were the highest in solid-fuels households using mixed fuels—573 $\mu g/m^3$ for cooks and 264 $\mu g/m^3$ for non-cooks, or about 3.5 times higher than in households using clean fuels (81 and 79 $\mu g/m^3$, respectively). Similar to concentrations, mixed-fuel households have the highest exposures, followed by wood, kerosene, and gas in that order (see Table 2.6). This suggests that average household exposures are reflected well by average concentrations.
- Amongst solid-fuel users, mean 24-hour average exposure concentrations were the highest for women cooks (447 $\mu g/m^3$) and were significantly higher than exposures for men (226 $\mu g/m^3$) and other family members. Exposures of sub-categories were not significantly different from each other among clean-fuel users.
- Among non-cooks in solid-fuel-using households, women aged 61–80 experienced the highest exposures, followed by women aged 16–60, while men aged 16–60 experienced the lowest exposures. This is presumably because older women are most likely to remain indoors and younger women (16–60) are most likely to be involved in assisting the cooks, whereas men aged 16–60 are most likely to have outdoor jobs that may lower their exposures. Men in the age group of 60–80 also experience higher exposures as compared to men between 16 and 60, perhaps also owing to a greater likelihood of remaining indoors.
- Young children (2–5) are the only group in solid-fuel-using households for which female and male exposures were similar. Their exposure was higher than for adult men.
- The exposures of cooks were not significantly different across indoor kitchen types (in agreement with the results of kitchen-concentration measurements showing little variation across indoor kitchens but higher levels than in outdoor kitchens). Since living-area concentrations differ considerably across kitchen types for solid-fuel users, it could be expected that exposures of other subcategories of household members are likely to be different across kitchen types (see Table A2.4 in Annex 2).

Table 2.7. Results for 24-hour Average Exposure Concentrations for Cooks and Non-Cooks Across Fuel Types

Type of Fuel	*Arithmetic Mean*	*N*	*Std. Error of Mean*	*Geometric Mean*
Cooks				
Mixed	573	70	65	402
Wood	403	232	25	293
Kerosene	156	8	48	121
Gas	81	28	6	72
Non-cooks				
Mixed	264	231	16	195
Wood	202	640	7	149
Kerosene	104	18	11	94
Gas	79	78	2	75

Figure 2.5. Exposure of Different Household Members: Solid Fuel Versus Gas, AP, India



Exploring Household-level Determinants of Concentrations and Exposure

2.35 Based on the data collected through household surveys and concentrations monitoring, the study extended the analysis to examine relationships between kitchen/living area concentrations and household characteristics that could plausibly be the determinants of higher exposure.

Fuel Quantity in Solid-Fuel-Using Households

2.36 As a first step, a regression analysis was undertaken to explore relationships between collected data on RSPM concentrations and a number of secondary indicators of exposure. Upon completion of monitoring, the monitoring team collected additional information on fuel quantities (by weighing) in solid-fuel-using households, as well as the duration of cooking and use of other potential sources of particulate emissions (e.g., incense coils). Fuel quantity for clean-fuel users could not be obtained because the exact amount used per meal could not be measured; thus, the analysis of the impact of fuel quantity was limited to solid-fuel users only. This complemented information collected by the household survey team on kitchen volume and windows.

2.37 Both kitchen and living area concentrations were significantly correlated (Pearson's correlation significant at $p < 0.05$) with fuel quantity amongst solid-fuel users. In addition the living-area but not the kitchen concentrations were significantly negatively correlated with the number of windows and the number of rooms. This could be explained by living room concentrations being influenced more by dispersion through windows or to other rooms as opposed to kitchen concentrations as most of the windows in the house were outside the kitchen.

2.38 Neither kitchen nor living area concentrations were correlated with kitchen volume. Concentrations were also not correlated with the number of people being cooked for and total cooking duration. Concentrations were not significantly influenced by use of kerosene lamps, incense coils, or mosquito coils; or by the presence of smokers in the house. Correlation tables and results of multiple regressions are shown in Table 2.8.

Table 2.8. Results of Correlation and Multiple Regression Analyses for Kitchen and Living Area Concentrations and Other Exposure Determinants

	Fuel Quantity	*Kitchen volume*	*Cooking duration*	*No. of people cooked for*	*No. of rooms*	*No. of windows*
24-hour average kitchen-area concentrations						
Pearson's Correlation Coefficient	0.13*	0.03	0.02	0.05	0.05	0.06
β Coefficient	0.22	0.03	0.07	0.04	0.06	0.06
24-hour average living-area concentrations						
Pearson's Correlation Coefficient	0.15*	0.06	0.08	0.12	0.13*	0.13*
β Coefficient	0.12	0.07	0.10	0.06	0.19	0.09

*p<0.05

Fuel Type and Housing Characteristics: Analysis of Variance

2.39 A more systematic statistical exercise was conducted to try to develop an exposure prediction model based on household survey information that could be routinely collected. Although this analysis included a larger number of variables, fuel quantity was omitted because of the lack of sufficient and reliable information across all fuel users.

2.40 This analysis of variance resulted in the following variables being significantly correlated with both kitchen and living area concentrations (see a detailed description in Annex 3):

- Type of cooking fuel (mixed, wood, kerosene, gas)
- Type of kitchen (4 types, as described above)
- Separate kitchen (outside the living area or not)
- Kitchen ventilation (poor, moderate, good)
- Wall type (pucca, semi-pucca, kachha)
- Floor type (pucca, semi-pucca, kachha)
- Housing type (pucca, semi-pucca, kachha)
- Stove type (traditional, improved, kerosene, gas)

2.41 Overall, differences in living-area concentrations differed across various fuel and housing characteristics in a manner similar to kitchen concentrations. There were two major differences, however. Households with semi-pucca (or intermediate-quality) floor types seemed to have the lowest living-area concentrations, followed by households with pucca and kaccha floors, respectively.[15] In addition, although living concentrations varied with kitchen type, they also varied depending on whether or not households had separate kitchens.

Modeling Concentrations

2.42 Variables significantly associated with kitchen and living areas concentrations were included in the modeling process to explore whether and how certain household characteristics could be used to predict household exposure levels (see Annex 3). Although analysis of variance indicated that there is a significant difference in concentrations within the different stove types, stove type was highly correlated with fuel type, and was therefore dropped from the analysis.[16]

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15 *Pucca* refers to durable, high-quality materials and construction techniques, such as a brick house with a tile roof. *Kachha* refers to more temporary and lower-quality materials and techniques, such as a mud house with a thatched roof.

16 It was not possible to explore differences between traditional and improved biomass stoves due to a negligible number of the latter in the sample. However, stoves with well-designed, well-installed and well-performing chimneys substantially improve kitchen ventilation, so that performance of the kitchen ventilation variable can provide some inferences about a potential impact of smokeless stoves.

2.43 The linear regression models used to predict continuous outcome variables for kitchen and living-area concentrations did not yield sufficient information for explaining the great variability in the kitchen and living-area concentrations, especially within the wood and mixed-fuel categories. Subsequently, modeling was conducted for binary concentration categories (high and low exposure households) using logistic regression, and Classification and Regression Trees (CART) techniques. All models and findings are described in Annex 3.

2.44 As a result of all modeling approaches and specifications, three variables—fuel type, kitchen type, and kitchen ventilation—were found to be good predictors of kitchen and living-area concentrations in high-concentration households. Fuel type was the best predictor of high concentrations, but not a good predictor of low concentrations. This was due to the wide range of concentrations within fuel categories. In general, low concentrations were more difficult to predict than high concentrations.

2.45 Kitchen type is a good predictor of kitchen concentrations; indoor kitchens were much more likely to have high concentrations than outdoor kitchens. For living-area concentrations, knowing the specific type of kitchen was less important than knowing whether or not the kitchen was separate from the living area.

2.46 Households with good kitchen ventilation were less likely to have high concentrations—in both kitchen and living areas—than households with moderate or poor ventilation. CART trees that utilized both kitchen type and kitchen ventilation were not better predictors than those using only one of these parameters. This suggests that it may not be necessary to collect information on both kitchen type and kitchen ventilation.

Conclusions

Research Issues and Needs

2.47 The information collected and assessed in this study helps close a substantial gap in the quantitative data available on exposures due to indoor air pollution from biomass fuels in developing countries. Specifically, this study provided, for the first time, quantitative measurements of 24-hour concentrations and exposures to RSPM for a wide cross-section of rural homes using a variety of household fuels and under various exposure conditions. To date, most studies concerning particulate measurements in households using biomass fuels have used total suspended particulates or PM10 rather than RSPM—which, because it is a better indicator of the particulate fraction that deposits in the lower airways of the lungs, is a better proxy indicator of the health risks.

2.48 Given the relatively large sample size and the limited variability in weather conditions in the study zone, it is likely that inter-household differences contributed most to the concentration and exposure profiles. Hence, the estimates from this study may provide crude surrogates for further rapid exposure- and/or health-assessment studies where monitoring may not be feasible. However, it would be prudent to exercise caution in extrapolations made from this study, since its findings are based on a sample from only three districts of a single agro-climatic zone of one state in southern India, wherein socio-cultural, housing, and climatic conditions are known to be quite different across different parts of the country. Further, the monitoring was carried out only in summer months, which may not be reflective of the time-activity pattern of household members as well as the nature of biomass fuel used for all seasons. Quantitative data collection on a regional basis would increase the level of confidence in the findings emerging from this and other similar studies.

2.49 A modeling exercise to predict RSMP concentrations based on certain easily surveyed household characteristics, which was undertaken for the first time on a pilot basis, suggests that future studies of this kind attempt to better address the high intra-household variability in the behavioral aspects of family cooking. Such variability—for example, in ways a stove has been operated—has been observed in biomass-burning households all over the world, not only season-to-season but even day-to-day. It implies that multiple-day measurements could be taken in future studies to smooth out the variability. The resulting multi-day mean concentrations levels would, presumably, be better suited to be predicted by parameters that do not change daily, such as fuel type and house structure.

Policy Implications

2.50 On the policy side, the findings of the study strengthen the basis for formulating effective interventions. The burden of environmental health is beginning to catch the attention of health policymakers in developing countries, and the morbidity and mortality associated with indoor smoke exposures and its associated economic costs are being recognized as significant. Nonetheless, better information on patterns of exposure and its key determinants is needed in order to devise appropriate mitigation policies and strategies.

2.51 A number of key linkages between exposure to indoor air pollution concentrations and household characteristics have emerged from this study. Although the degree of exposures to cooks was evident from earlier studies, the results of the present study show that the exposure to the pollutants could be significant for the other residents of the house as well. This is of particular concern for households with indoor kitchens without partitions, but even for households who cook outdoors, the 24-hour concentrations and exposures could be significant both in the cooking place and indoors, well above levels established by air quality health guidelines. The latter is an important finding from policy perspective challenging the conventional wisdom—and an excuse frequently used to ignore the problem—that cooking outdoors, as the majority of poor households do, prevents the health risks from fuel smoke.

2.52 The exposure reconstruction work allows a deeper appreciation of exposure and related health risks for different family members in rural India. Through quantitative estimates, the present study ascertains the magnitude of gender and age disparities in exposure, with women cooks being exposed to far higher concentrations than other households members, and adult men experiencing the least exposure. Women experience higher exposure than men across all age groups except for very young children under 5 years old, for whom exposure is similar. Across age groups, young children and very old people are at a greater risk of suffering the adverse consequences of exposure to indoor air pollution because they (in addition to cooks of all ages) are most likely to be inside the home while cooking is going on, and perhaps are more vulnerable.

2.53 This study strengthens the evidence that cooking with clean fuels reduces exposure substantially and, further, makes it equally low for all household members, including for women-cooks, who suffer much more than others in solid-fuel-using households. At the same time, the finding that indoor concentrations are well correlated with the quantity of solid fuel used indicates that the adoption of clean fuels will lead to a tangible reduction in exposure only if these fuels meet a substantial portion of cooking needs, meaning that biomass consumption is reduced considerably. The study, however, shows that in the reality of rural life, complete or substantial switching to clean fuels is rare, and that people continue to rely on biomass fuels—as demonstrated in many cases where kerosene was cited as the commonly used fuel, while it was used primarily for lighting a biomass-fuelled stove. As such, the study highlights the need for multiple interventions to reduce exposure and the importance of a better understanding of which parameters at the household level, apart from fuel switching, can substantially reduce concentrations of cooking smoke.

2.54 While exploratory in nature, the effort at modeling indoor air pollution concentrations provides valuable insight into the key determinants of exposures: fuel type, kitchen type, and/or kitchen ventilation. Although the predictive power of models is not impressive, the finding that primarily two easily determined factors (primary fuel type and kitchen ventilation condition) turn out to be significant in the modeling exercise invites an interesting and far-reaching parallel.

2.55 There currently exist only two widely recognized exposure indicators for household environmental health, both of which are related to water quality and hygiene: *levels of access to clean water and to sanitation*. These are reported annually and separately for rural and urban areas by nearly every country and are commonly cited as measures of ill-health risk and indicators of poverty. These indicators are strikingly parallel to two possible new indicators for household air-quality-related hygiene: *levels of access to clean fuel and to ventilation*. Both indicators, although not ideal measures of true exposure and risk, have the extremely important benefit of being easily and cheaply determined by rapid surveys requiring no measurements. In both cases, they do not claim to specify what households actually do on a daily basis, but rather exemplify the *potential* represented by what is physically present—as indicated by the term *access*.

2.56 Although further work is needed to strengthen and validate these findings, they may have major policy ramifications in terms of mitigating the health impacts of indoor air pollution, ranging from alteration in housing design to provision of cleaner fuels and better stoves that vent smoke outside the house. If validated with other data and refined models, these findings could also influence the design of large-scale survey instruments, such as the Census or National Sample Survey, by introducing questions on the key determinants of exposure (in addition to the fuel type already used by these surveys). Notably, all three of the parameters that have been found to significantly improve the prediction accuracy of exposure estimates using household survey data are reasonably straightforward and easy to assess.

3

Promoting LPG Among the Rural Poor: Lessons from the Deepam Scheme in Andhra Pradesh

3.1 As illustrated in the preceding chapter, cooking entirely with LPG can dramatically reduce exposure to harmful smoke. Furthermore, cooking with clean fuels is probably the only way to reduce exposure to similarly low levels for all household members, thus eliminating gender and age disparities in the health effects of household energy use.

3.2 The GOI has historically attempted to encourage fuel switching from biomass to cleaner commercial fuels by providing large universal price subsidies to kerosene, sold through the Public Distribution System (PDS), and LPG sold in 14.2-kilogram (kg) cylinders by dealers belonging to state-owned oil companies. However, the vast majority of LPG users are relatively well-off urban households. Price subsidy does not address one of the barriers to household fuel switching to LPG: the upfront cost associated with the start-up of LPG service. For example, a new LPG user in the state of Andhra Pradesh (AP) has to pay Rs 1,000 for "LPG connection" to receive an LPG cylinder, and must purchase an LPG stove and other accessories at an additional cost of about Rs 1,000. The combined cost of the LPG connection fee (which covers, amongst others, the cylinder production cost) and stove purchase makes it difficult for many low-income households to start using LPG as a cooking fuel.

3.3 To promote the use of LPG by the poor, particularly in under-served rural areas, the GOAP launched the so-called Deepam Scheme in July 1999. Under this scheme the GOAP pays the connection fee for women who participate in self-help groups and whose households are classified as below the poverty line (BPL). The policy objectives of the Deepam Scheme include (1) reducing drudgery among women and children from wood collection and cooking; (2) improving the health of household members by reducing exposure to cooking smoke; and (3) protecting forests from further degradation.

3.4 The Deepam Scheme differs from traditional fuel subsidies in several respects. First, it is a one-off subsidy, covering the capital cost in the form of cylinder connection fee, rather than the operating cost—the purchase of the fuel itself—by giving a price subsidy. Second, only poor households are eligible for the subsidy, whereas the current LPG price subsidy in India is available to all income levels, and benefits mainly the well-off in urban areas. Third, the program is targeted to rural areas. Lastly, it is implemented through women self-help groups, thus linking the promotion of LPG to support for women's development and financial independence. Because an examination of the scheme would provide valuable insights into the policy instruments that governments can use to promote rural access to clean fuels, an important component of the present study was to independently assess the Deepam Scheme in terms of its performance, effectiveness, sustainability, and replicability.

Design and Implementation of the Deepam Scheme

3.5 Initially designed to cover only rural households, the scheme was later expanded to include urban areas. The total number of connections approved as of early 2002 was 1.715 million, consisting of 1.30 million in rural areas and 0.41 million in urban areas, with the overall target increased from the original 1.5 million to 3.0 million. The district-wise allocations of LPG connections, as well as the actual numbers released, are given in Table A4.1, Annex 4. By March 2002, more than 1.5 million LPG connections had been released, including 1.2 million in rural areas. The majority of recipients were members of groups under the Development of Women and Children in Rural (or Urban) Areas (DWCRA and DWCUA, respectively).

Costs of Enrollment

3.6 The Deepam participants cover the following start-up costs:

- The cost of an LPG stove with an Indian Standard Institute (ISI) mark
- Rs 30 towards the purchase of rubber tubing with an ISI mark
- Rs 20 towards the dealer's administrative charge.

LPG itself is purchased by the participants at the official price set by the GOI. When the scheme was launched in July 1999, a 14.2 kg LPG cylinder refill cost Rs 160. On account of the two subsequent price hikes, the same LPG cylinder cost in the neighborhood of Rs 250 in February 2002. Four public sector oil companies—the Bharat Petroleum Corporation (BPC), the Hindustan Petroleum Corporation (HPC), IBP, and the Indian Oil Corporation (IOC)—have been involved in providing LPG to the beneficiaries. The numbers of connections allocated to the four oil companies under the scheme as well as the numbers released as of February 2002 are given in Table A 4.2, Annex 4.

3.7 In return for each LPG connection released, the GOI reduces the allocation of rationed and subsidized household kerosene to AP sold through PDS by 5 liters per month (or 60 liters a year). The GOAP has paid Rs 1.7 billion to state-owned oil companies on behalf of the beneficiaries and has committed to paying an additional Rs 1.3 billion to achieve a total of 3 million LPG connections.

3.8 During the initial phase of the Deepam Scheme, the AP State Civil Supplies Corporation (APCSC) finalized the arrangements for the procurement of stoves and their prices. The stoves were made available to beneficiaries through the District Rural Development Agencies (DRDAs) at the distribution points. Subsequently, the beneficiaries have been given freedom to choose stoves from different dealers. In particular, they are not required to purchase stoves from the dealers who supply them with LPG.

Eligibility Criteria

3.9 Only members of self-help groups satisfying certain criteria are eligible for participation in the scheme. Self-help groups in AP began to be formed in the early 1980s through the efforts of NGOs and gained strength over the years. By the 1990s, DWCRA groups became an essential aspect of rural development. Andhra Pradesh today is the forerunner of the self-help group movement in India, particularly of women: it has more than one-half of all the women self-help groups in India. There are more than 373,000 self-help groups in AP, with a total of over 5 million members. About 150,000 of these self-help groups are in rural areas.

3.10 In rural areas, to participate in the scheme, one must be a member of a self-help group that has been in existence for one year or more as of 1 June 1999 (at the time of the launching of the scheme), and that has received assistance via the DWCRA Revolving Fund, matching grants, bank loans or matching grants from other government agencies such as the Scheduled Caste Corporation, women's development corporations, and the Integrated Tribal Development Agency (ITDA). The seniority of the self-help groups is an important consideration, with preference given to older groups. Thrift groups that have not yet been included in any of the matching grant schemes are not eligible. The beneficiaries selected must be living in rural areas and must be from BPL households possessing white ration cards. However, in both rural and urban areas, women who possess no cards (white, pink or blue) are also considered on the basis of their groups' recommendations, or a below-poverty-line (BPL) certificate issued by the Mandal Revenue Officer concerned.

3.11 In urban areas, members of thrift and credit societies and DWCUA groups already in existence as of 4 February 2000 were eligible. Within each municipality, selection of different groups is based on seniority. If two groups or more were formed on the same day, selection will be based on a lottery. The BPL survey under the *Swarna Jayanthi Shahari Rozgar Yojana* (Golden Jubilee Urban Employment Scheme) forms the basis for classifying households. Rural households earning less than Rs 263 per month per capita, and urban households earning less than Rs 457 per month per capita, are classified as BPL.

3.12 The self-help groups must (1) conduct meetings on the dates fixed by the district collectors; (2) pass resolutions listing the names of the members willing to sign up for LPG connection; and (3) furnish a list of animators, motivators,[17] AGS (additional *gram sevikas*; they operate at the village level under DWCRA), and village development officers (VDOs). They must also meet a number of conditions:

- The urban beneficiaries are to surrender a portion of their share of subsidized kerosene distributed through the PDS by 5 liters per month.
- If a beneficiary does not refill the LPG cylinder for more than 90 days, the LPG connection may be withdrawn. The beneficiary is to be notified to the effect. (This condition has not been enforced, however.)

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[17] Animators and motivators are trained workers hired by DRDA on contract wages to motivate women to form self-help groups, and facilitate discussions with villagers, particularly women, on issues of concern.

- Each household is entitled to one LPG connection under the scheme. Even if two members from the same household are recommended, only one member will be selected.
- The responsibility for ensuring proper identification of the beneficiary and delivery of LPG to the correct beneficiary rests with the leader of the self-help group.
- In cases of diversion of the LPG connection to someone other than the beneficiary selected, the LPG connection will be cancelled and the BPL card withdrawn.
- Oil companies are to offer training programs for animators, motivators, and AGS in the installation and safe handling of LPG. The latter in turn are to train the beneficiaries.
- Newsletters containing all the guidelines and rules of the scheme are to be published by the departments concerned in consultation with the Department of Civil Supplies and state-level coordinators. The newsletters are to be circulated to all members of the self-help groups before the meetings to discuss the Deepam Scheme take place.

Study Methodology

3.13 The Deepam Scheme evaluation relied on primary data supplemented by secondary data, and was undertaken by the National Institute for Rural Development in Hyderabad. For primary data collection, the study team conducted focus-group discussions with 66 self-help groups as well as interviews with 134 Deepam beneficiaries between 25 May and 2 August 2001. In addition, the team held discussions held with other LPG users and non-users, oil company representatives, dealers, and government officials involved in the scheme.

3.14 The focus-group discussions by their nature concerned primarily qualitative information. Some quantitative information was collected in these group discussions as well as in individual interviews with the beneficiaries. These findings should be interpreted with caution given the small sample sizes.

Selection of Study Subjects

3.15 On the basis of discussions held with the Departments of Civil Supplies and of Rural Development, the following criteria were established for selecting six districts:

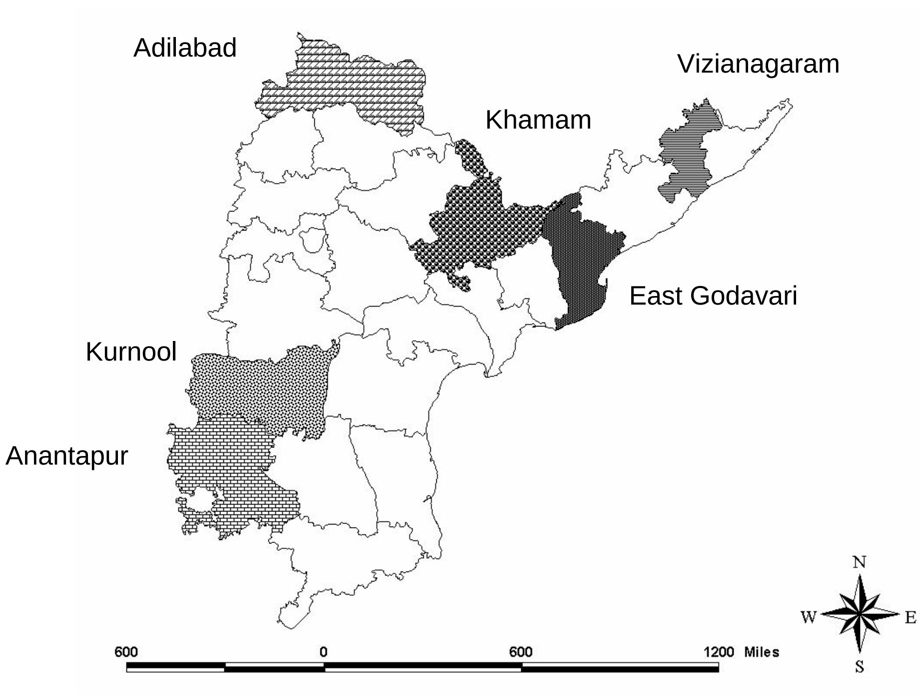
- Select two districts in each of the three regions (Telengana, Rayalaseema, and Coastal Andhra).
- Select the best- and worst-performing districts in the respective regions as a first criterion. Although DWCRA group performance is the primary criterion—because LPG distribution in rural areas is typically more difficult logistically than in urban areas, and rural households have greater access to free biomass, both factors inhibiting the use of LPG—a district with balanced performance in all the three types of target groups may also be selected.

- Avoid those districts that are known to have high political or official patronage in order to minimize biased observations.

The six districts selected for the study are shown in Figure 3.1 and described in more detail in Table A4.3 of Annex 4.

3.16 Three mandals were selected in each district, typically in consultation with the authorities concerned. Preference was given to those where supply agencies other than the oil companies (such as the Department of Civil Supplies and Girijan Cooperative Corporation) were operating. Since the logistics of LPG cylinder delivery was expected to be a major issue, villages and self-help groups within mandals and municipalities were grouped into three broad categories on the basis of distance to the closest LPG dealer: those within 5 km, those between 5 and 10 km, and those farther away than 10 km. Only those self-help groups that had been participating in the scheme for more than a year were selected in order to have a meaningful assessment of LPG consumption and experience with the scheme. Annex 4 (Tables A4.4. and A4.5) lists the villages and municipalities studied and presents the numbers of self-help groups that participated in focus-group discussions and beneficiaries who were interviewed, as well as others with whom the study team had meetings and discussions.

Figure 3.1. Districts Selected for the Study



3.17 A total of 66 DWCRA, DWCUA, and VSS (*Van Samrakshan Samiti*, or Forest Protection Committee) groups participated in the focus-group discussions. These discussions focused on the mode of implementation, sources of information, problems encountered, perceptions of benefits and disadvantages of LPG use, and suggestions for changes. In addition, 134 Deepam beneficiaries were interviewed using a semi-structured questionnaire to develop their personal profiles as well as document their experience to date. To supplement or corroborate the information collected, the team also held discussions with non-beneficiaries within self-help groups, non-self-help group members, LPG users who are not Deepam beneficiaries, local leaders, animators, ANG (*anganwadi*, child care centers for children under the age of five) workers, and various government officials and LPG supply agency representatives.

Issues Investigated

3.18 Prior to holding focus-group discussions and individual interviews, the study team visited households in villages to observe the use of LPG, housing conditions, and other factors relevant to the study. This facilitated the mobilization of participants for the focus-group discussions and identified the key issues for discussion.

3.19 Lists of questions and checklists were drafted on the basis of pilot surveys in one of the districts. The study team used the checklist for the focus-group discussions as a guide rather than a survey questionnaire, and took extensive notes during the discussions. This was done both to ensure a minimal level of uniformity across the 66 focus-group discussions and to facilitate their execution.

3.20 In the focus-group interviews, beneficiary interviews and other discussions and meetings held, the study team collected data to address the following key issues:

- The process for enrolling in the Deepam Scheme, including the selection of self-help groups, the selection of members within each group, the steps between selection and the final installment of the LPG cylinder, problems encountered, and marked differences (for example, time lag between selection and cylinder installation)
- The genuineness of Deepam beneficiaries, particularly with regard to socio-economic status indicators
- The factors affecting LPG consumption
- Mechanisms for the delivery of LPG cylinders.
- Changes resulting from the use of LPG, including the purchase of new cookware and kitchen alterations
- Perceived benefits and adverse impacts
- Suggestions for improvement.

Characteristics and Experience of Deepam Beneficiaries

3.21 Focus-group discussions provided information on the role of self-help groups in implementing the scheme as well as a broad picture of the experience of the beneficiaries. Individual interviews yielded specific information on the beneficiaries' backgrounds, experience with the scheme, and fuel consumption patterns.

Findings from Focus-group Discussions with Self-Help Groups

3.22 The Deepam Scheme guidelines specify that preference be given to older self-help groups. While self-help groups have taken root in rural areas for quite some time, they are relatively new in urban areas. In those villages where VSS have been formed, self-help groups have been formed only in recent years. Of the 66 self-help groups that participated in focus-group discussions, over one-half were older than four years, whereas those that were two years old or younger accounted for only 11 percent.

3.23 The composition and size of the self-help groups that participated in the focus-group discussions are shown in Table 3.1. Self-help groups are generally formed on the basis of social groups or occupational groups belonging to BPL families. The social groups in this study include the Scheduled Caste (SC), Scheduled Tribe (ST) and Backward Caste (BC). There are a few groups of mixed social or economic classes (i.e., families both below and above the poverty line). The size of the groups in this study varied from 11 to 55 members, with a median size of 15 and a mean size of 17. The landless accounted for about three-fourths of the members on average. Although most participating families were BPL, as identified by their white ration cards, non-white-card-holders were frequently found in the self-help groups and among the Deepam beneficiaries.

Table 3.1. Composition and Size of Self-Help Groups Studied

Category	*Adilabad*	*Anantapur*	*East Godavari*	*Khammam*	*Kurnool*	*Vizianagaram*	*Average*
Landless	13 (0)	12 (9)	12 (24)	10 (5)	13 (26)	16 (17)	13 (14)
Land-owners	4 (0)	9 (4)	1 (38)	4 (4)	3 (68)	5 (38)	4 (18)
SC	10 (0)	3 (3)	4 (23)	7 (23)	6 (34)	6 (0)	6 (13)
ST	4 (0)	1 (0)	0 (—)	1 (0)	0 (—)	8 (39)	2 (22)
BC	4 (0)	16 (8)	9 (27)	5 (12)	10 (31)	7 (21)	9 (18)
NWCH	7 (0)	4 (9)	2 (6)	3 (6)	4 (47)	9 (17)	5 (15)
Total	17 (0)	21 (7)	13 (26)	14 (17)	16 (32)	21 (21)	17 (17)

Notes: The figures in parentheses represent percentages in individual categories that are not participating in the Deepam Scheme. NWCH non–white-card-holders. — not applicable.

3.24 Judging from housing conditions, assets, and land-holding status, about one-half of the beneficiaries belonging to groups other than the SC and ST did not appear to be genuinely poor although they were white-card holders. There seemed to be more ineligible beneficiaries in urban areas, but it should be mentioned that DWCUA groups are relatively young and record-keeping and documentation is not yet well organized.

3.25 The connection-fee waiver has attracted some who are not intending to cook much on LPG to sign up; SC and ST families even regard the possession of LPG cylinders as a status symbol. The Deepam Scheme seems to have hastened the pace of formation of new groups eager to take advantage of this subsidy.

3.26 The time lapsed between the date a group was selected for participation in the Deepam Scheme and the date cylinders were delivered to homes averaged 64 days, or about 2 months, with the median being 29 days. Most of this time lag took place between selection and sanction. In some cases, there were marked differences in the number of people selected and the number of those who actually received LPG cylinders. These differences were due to mistakes in the names of people selected, incorrect names recorded on ration cards, and non-possession of white cards.

3.27 Over 80 percent of Deepam beneficiaries purchased the stove and other accessories using their own funds. The rest borrowed money from their own self-help groups; very few borrowed from other sources. Although stoves were available from district rural development agencies (DRDAs) at prices lower by about Rs 100 than elsewhere, the focus-group discussion participants indicated that they preferred to purchase from the dealers because the delivery was prompt and the quality was assured.

3.28 The Deepam Scheme stresses training in the use of LPG cylinders, and especially in their safe handling. Discussions with focus groups as well as dealers indicated that training camps were organized at the gas premises and that training was also given in the homes of all the beneficiaries during stove installation. In addition, the DRDAs have, to a limited extent, distributed pamphlets and brochures on the use of LPG. Training in the repair of LPG gas stoves was also provided to cluster-level motivators who worked with self-help groups.

3.29 Gas agencies are required to deliver refill LPG cylinders to homes to the extent possible, setting up sub-depots if necessary. The cost of cylinder delivery is built into the refill cost. However, of the 66 self-help groups, only 14 responded that as of mid-2001 they relied entirely on home delivery to obtain refill cylinders. In fact, 42 groups did not have home delivery at all.

3.30 Only a one-tenth of the respondents were consuming one-half a cylinder of LPG or more a month, the amount estimated to be needed to meet the majority of cooking needs using LPG in rural areas. One-third refilled every three months, another third every three to four months, 14 percent every four to six months, and 5 percent less frequently than every six months. The refill rate was not well correlated with the distance to the closest dealership. Predictably, the most common reason given for low consumption of LPG was the high cost of switching to LPG. As already mentioned, although the scheme required that beneficiaries failing to refill at least once every 90 days forfeit the connection, this did not seem to be enforced.

3.31 LPG was found to be most extensively consumed during the monsoon season. This was for three reasons: (1) the agricultural season begins during the monsoon, making more cash available to agricultural laborers who can earn regular wages; (2) there is less time for biomass collection and cooking; (3) keeping biomass dry is difficult. The use of LPG was reported to be lowest in summer.

3.32 Questions concerning energy use indicated that wood is still used more than any other fuels for cooking, and is also the dominant fuel for heating water and other non-cooking purposes. The only exception is "other cooking," where LPG seems to have made an inroad, most likely to make tea and perform other simple tasks for which getting a fire going using wood would take up a disproportionate amount of time. After wood vand LPG, crop residues ranked third. Kerosene was used primarily for lighting in rural areas and rarely for cooking, but some urban households were relying on kerosene for cooking (see Figure 3.2).

Figure 3.2. Kerosene stove in a Hyderabad home

3.33 Four-fifths of the respondents cited clean and healthy cooking as the principal advantage of using LPG. One-half also cited time saved. Other reasons for using LPG included time made available for labor (30 percent) and the social status associated with LPG use (9 percent). Focusing on the first aspect, the cleanliness of cooking with LPG (lack of soot deposits on pots and pans, making cleanup easier) was most important (88 percent), and cited twice as many times as the absence of smoke during cooking (45 percent). In terms of economic benefits, there was a near-universal consensus that savings in cooking time represented the most significant aspect of LPG use (97 percent); this was cited twice as many times as not having to spend time collecting biomass (45 percent).

3.34 The reduction in kerosene allocation at the state level was cited as a negative feature of the Deepam Scheme (84 percent).[18] The complaint was widely expressed by urban beneficiaries who were directly affected. Other considerations included extra expenses incurred being a financial drain (33 percent) and having to pay a commission to fetch refill cylinders (10 percent). Some, presumably those who have signed up for the Deepam Scheme but have not been using LPG, referred to their participation in the scheme as a “dead investment.” More than one-half mentioned that the use of LPG was inviting envy from non-beneficiaries.

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[18] `The agreement between the GOI and the GOAP for the release of additional LPG connections for the Deepam Scheme stipulated that the state surrender 5 liters of PDS kerosene per month for each LPG connection released. The actual entitlement of kerosene under PDS, prior to Deepam, stood at 23 liters in Hyderabad City, a maximum of 10 liters in urban areas and 3 liters in rural areas. After the launching of the scheme, the GOAP initiated the following steps in respect of kerosene supply under PDS:

- Restricting the entitlement of 23 liters per card in Hyderabad city to areas considered politically sensitive according to a set of criteria; in other areas the quota is around 10 liters.
- Weeding out ineligible and fictitious cards to the tune of 0.86 million cards across the state (including of BPL and APL cards);
- Restricting the maximum entitlement to 5 liters per month among Deepam beneficiaries in urban areas.
- Strictly enforcing the rule stipulating that households with two LPC cylinders forfeit PDS kerosene allocation altogether.

3.35 Two-thirds of the respondents said that LPG was "partially" affordable. One-fifth said that LPG was affordable, but 14 percent replied that it was not affordable. Predictably, 89 percent wanted to see a reduction in the price of LPG to facilitate its greater use. In terms of the level of satisfaction with the Deepam Scheme, 97 percent were satisfied with the selection process, 77 percent were satisfied with the coverage of the scheme, and 65 percent were satisfied with the distribution arrangements. For the coverage of the scheme, 18 percent were only partially satisfied. Thirty percent of the self-help groups were only partially satisfied with the distribution arrangements.

Findings from Individual Interviews

3.36 Of the 134 interviewees, over two-thirds were SC, BC, and Other Backward Class (OBC) members. In terms of ration card-holding, 118 (88 percent) were white-card holders, 5 (4 percent) were pink card holders, and 11 (8 percent) possessed no ration cards. The breakdown of interviewees into the districts of residence and social class is given in Annex 4, Table A4.6.

3.37 The majority (117) of 134 beneficiaries interviewed lived in rural areas. Two-fifths owned land and one-half owned livestock, the most common being milch animals, followed by draught animals and sheep. (Milch animals are an obvious choice because selling milk gives income to the family and dung can be used as a source of energy.)

3.38 Housing characteristics such as roof and kitchen type can give some indication of the economic status of a household, and also affect exposure levels to IAP if a household continues to use biomass for some cooking. Among interviewees, 32 percent had thatched roofs—similar to the profile of rural households described in Chapter 2, 30 percent reinforced concrete cement (RCC), another 30 percent cement tiled, and the balance other materials of construction. (Thatched and cement tiled roofs are more common among the poor in India.)

3.39 Four types of kitchen were reported, the same as explained in Chapter 2 (see Figure 2.2). One-third of the interviewees cooked outside the house (see Annex 4, Table A4.7), either in a separate kitchen, often a small verandah, or in the open air. This can be compared with 65 percent from a larger rural survey undertaken as part of the exposure work (see Table 2.2 and Table A4.7). Remarkably, only 4 percent of the Deepam beneficiaries cooked in the open air—usually an arrangement among "the poorest"—against over 50 percent in the rural survey. Conversely, a larger proportion than in the rural survey cooked inside house with no partition between kitchen and living areas, a situation that leads to the highest exposure levels to biomass smoke for the entire family, as illustrated in Chapter 2. For these households, the benefits of a cleaner fuel are probably especially noticeable. Four-fifths of the Deepam beneficiaries interviewed cooked using traditional biomass-fed "chulha" stoves without a chimney, and one-fifth had stoves with chimneys. One-quarter of them had kerosene stoves. Similar to the findings from Chapter 2, rural households were found to use several types of stoves and fuels simultaneously.

3.40 Although no attempt was made to ask questions about income or total household cash expenditures, the study team asked a few questions about the possession of consumer durables to gauge the economic status of the household. The results—summarized in Annex 4, Table A4.8—show that close to three-quarters of the households had at least one fan, close to two-thirds had a television set (twice as much as households surveyed in the exposure work), and nearly one-half had a two-wheeler vehicle. Nineteen households (14 percent) did not possess any of the consumer durables listed in the table. There was little variation between urban and rural households. When compared to the rural survey of 1,032 households reported in Chapter 2, the profile of the Deepam beneficiaries, even when adjusted for a number of urban users (12 percent of the sample), tends to point to a larger proportion of relatively “well-off” households, indicating that the scheme reached the “border layer” of the BPL households rather than poorer families.

3.41 Most of beneficiaries learned about the Deepam Scheme from their self-help groups and local government officials. As indicated in focus-group discussions, most used their own funds to pay for the purchase of the stove and other accessories. Two-fifths lived within 5 km of an LPG distribution point. However, of those who lived within 5 km, only one-quarter had home delivery of refill cylinders. The rest had to collect the cylinders themselves, or else pay a third party for cylinder collection. The percentage of home delivery did not change significantly with increased distance to depots. The results are given in Table A4.9 in Annex 4.

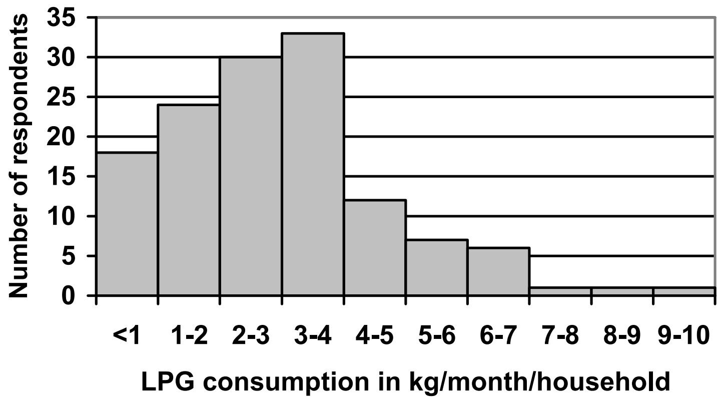
3.42 One-half of the respondents reported that they had to pay up to Rs 55 for each cylinder collection, averaging Rs 22. As expected, the total price paid, ranging from Rs 350 to Rs 300 per cylinder, typically increased with increasing distance (see Table A4.10 in Annex 4).

3.43 The refill rates reported here were considerably lower than those reported in focus-group discussions. Twenty-one households had never had a refill. On average, the respondents had had three refills, ranging from 0 to 16, since they were enrolled in the Deepam Scheme. This translates to refilling every 7 months on average, with the median being 5 months; thus both the average and the median are smaller by about 2 months than those indicated by focus groups. The difference may in part arise from the desire to appear to be using LPG more regularly in the presence of one’s peers during the focus-group discussions.

3.44 On the basis of when the cylinders were installed and the number of times refilled, LPG consumption was calculated. Average LPG consumption was estimated at 2.9 kg per household per month (see Figure 3.). These should be compared with a minimum of about 7 kg required for meeting the main cooking needs with LPG in rural areas. One-quarter of the respondents reported that they used LPG in all cooking. This consisted of one-fifth of rural respondents but over two-fifth of urban respondents. One-third said that they used LPG regularly to make tea, and one-quarter said they used LPG to cook meals for guests. At this consumption level, biomass remains the primary source of cooking for the majority of the Deepam customers. To the extent the uptake of LPG reduces fuelwood consumption, it will likely lead to a reduction in exposure (the quantity of solid fuel consumed was found to be one of the key exposure determinants; see Chapter 2). However, this reduction cannot be nearly as significant as for households cooking only with LPG, and correspondingly the health benefits of LPG uptake will be limited.

3.45 There was a marked difference between urban and rural consumption: urban households consumed on average 4.8 kg per month whereas rural households consumed 2.6 kg per month. Aside from relative lack of availability of free or cheap biomass in urban areas, the maximum monthly income levels allowed for urban and rural BPL households (Rs 457 per capita and Rs 263 per capita, respectively) in part may explain this difference, since many urban BPL households would have more disposable cash income than their rural counterparts.

Figure 3.3. Calculated LPG Consumption



3.46 These average estimates for LPG consumption in kg per month were regressed on the above potential explanatory variables. Annex 4 describes the methodology. The results, using 117 observations and excluding some outliers, are shown Table 3.2.

Table 3.2. Factors Affecting LPG Consumption (kg/month)

Variable	*Coefficient*[1]
Constant	3.37 (±0.41)
DWCRA membership (1 if member/0 otherwise)	-1.55 (±0.39)
Membership in Forest Protection Committee, VSS (1 if member/0 otherwise)	-1.35 (±0.57)
Open air cooking (1 if cooking is done in open air/0 otherwise)	-1.03 (±0.28)
Kitchen outside (1 if the kitchen is outside/0 otherwise)	-0.51 (±0.22)
Wealth index (based on the possession of a television set, washing machine, fan, two-wheeler, and "others")	0.50 (±0.10)
Home delivery of refill cylinder (1 if the refill cylinders are delivered to home/0 otherwise)	0.85 (±0.31)
Possesses no ration cards (1 if the household possesses no ration cards/0 otherwise)	1.81 (±0.80)
Delivery expenses incurred in Rs	-0.022 (±0.007)

[1] Coefficients in kg/month. The values in parentheses are standard errors.

3.47 As Table 3.2 shows, living in rural areas decreases monthly consumption. More specifically, DWCRA group members tended to consume 1.6 kg less per month, and VSS group members 1.4 kg less. For each consumer durable category that a household had, they would consume 0.5 kg more a month. Having home cylinder delivery increased consumption by 0.9 kg. This finding may suggest that arranging for cylinder delivery by a household, even if it does not cost in monetary terms, discourages consumption of LPG. On the other hand, for every Rs 10 paid for cylinder delivery, consumption decreased by 0.2 kg. Those with no ration cards (8 percent) consumed substantially more, about 1.8 kg of LPG more a month, confirming that they are not genuinely poor.

3.48 Those who cooked in the open air consumed 1 kg less per month, and those with an outside kitchen 0.5 kg less. It is worth noting, however, that because households with outside cooking have lower exposure to solid-fuel smoke (see Chapter 2), the use of less LPG does not necessarily translate to greater exposure and health risks for these (probably poorer) households.

3.49 All of the respondents cited time saved as the primary benefit of using LPG. Other benefits reported include cleaner cooking (84 percent), better for health (75 percent) and giving a status symbol (47 percent). The biggest problem cited was the additional expenses incurred in switching to LPG (89 percent), followed by inconvenience and expenses incurred in collecting refill cylinders (55 percent), having to spend money up front (17 percent), and the use of LPG being "unsafe" (13 percent).

Conclusions

3.50 Targeted capital-subsidy schemes for fuel use are rare not only in India but also in other parts of the world. As such, the Deepam Scheme is an innovative scheme meriting attention. The policy objectives of the Deepam Scheme—reducing the drudgery of biomass collection and cooking, improving health, and slowing deforestation—are highly commendable.

3.51 Achieving these objectives in a tangible manner would require substantial use of LPG as the primary fuel. This study found that for the majority of households, the incremental cost of substituting biomass with LPG was sufficiently high to deter significant switching to LPG. Instead, financial considerations have confined LPG to incidental use (such as making tea or preparing meals for unexpected guests), or to when the opportunity cost of fuelwood use is high, such as during the monsoon season.

3.52 The convenience introduced by even this limited use of LPG, and especially the amount of time saved for the cooks, should not be underestimated, even if the overall consumption of fuelwood does not decline markedly. Indeed, the beneficiaries universally cited time savings in cooking as the primary benefit of LPG use. The discussions held with beneficiaries also indicated that there are non-quantifiable benefits, the most important of which is perhaps increased self-esteem. However, with the current consumption pattern, the health and other social benefits of LPG are not fully realized.

3.53 Capital subsidies for energy service (of which the Deepam Scheme is an example) are generally acknowledged to be better than operating-cost subsidies (such as fuel subsidies or power tariff subsidies), but only if the consumers can pay for the operating costs themselves so that a viable energy market can develop. In the electricity sector, the initial connection cost is orders of magnitude higher than monthly operating costs. For example, the cost of connecting one rural household may range from US$500 to US$2,000 (ESMAP 2000), whereas the monthly operating cost may be three orders of magnitude smaller and affordable for the majority of rural customers. In such a case, a recovery charge for the cost of service start-up is usually built in electricity tariffs. The merit of capital subsidy (to cover a portion of the capital cost), which is often used in rural electrification programs, is to allow the tariff to remain affordable for rural customers, thereby making the supply of electricity in rural areas commercially viable.

3.54 In the case of LPG, the difference between the initial start-up cost and the operating cost paid for cylinder refills is considerably smaller, while the operating costs themselves are sufficiently high to represent a barrier to substantial use of LPG by low-income families. Under these circumstances, the merit of capital subsidy is not obvious. It may be argued that households who can reasonably afford the LPG refill cost of about Rs 250–300 every two months are capable of paying Rs 2,000 to start the service; it may also be argued that , for these households, other financial arrangement, such as recovery of start-up costs through the cost of refill, may be more appropriate. If and when the LPG price subsidy is withdrawn, the difference between the start-up cost and the operating cost will narrow even further.

3.55 Through waiving the connection fee, the Deepam Scheme facilitated the uptake of LPG by the poor households. However, the challenge is to sustain this effort and facilitate the development of a viable market of LPG in rural areas. Currently, the development of such markets is constrained by a limited number of rural customers and the low consumption level—an estimated average consumption of 30 kg of LPG per year. Given the dietary habits and energy needs of the target group, the consumption level might, at best, reach 60 kg per year. The fundamental issue is how to get the majority of the rural households to consume much more LPG without overstretching the state's fiscal resources.

3.56 Urban households are more willing or able than rural households to pay for LPG cylinder refills because biomass is less available (and consequently more expensive), and because cash income is probably higher and more consistent. In this regard the subsidy provided in the Deepam Scheme has been better utilized in urban areas. But the question remains as to whether the rural poor, the principal target of the Deepam Scheme, can enjoy similar benefits of LPG connection.

3.57 The experience with the Deepam Scheme has confirmed the worldwide experience with the household use of LPG. The uptake of LPG is strongly income-elastic at low income levels, so that the poor will use LPG sparingly. As long as free or cheap biomass is available, households will continue to use traditional fuels rather than LPG in the short run. The GOI plans to reduce the LPG subsidy to 15 percent in time; this will increase the end-user price of the fuel and make it more difficult for low-income households to consume LPG. The private sector has been considering the introduction of smaller (and cheaper) cylinders, but in recent years the connection-fee waiver the GOAP offers state-owned companies has reduced the rural market for private companies and discouraged them to launch a new cylinder size in AP.

3.58 If smaller cylinders can be introduced, not only will each refill cost be smaller, enabling many households to refill more regularly, but also the initial cylinder deposit fee (which essentially covers the cost of cylinder manufacture), for which the GOAP is currently paying Rs 1,000, can be lowered. Smaller cylinders may therefore yield double benefits: more regular consumption of LPG by the beneficiaries, especially in rural areas, and a lower subsidy bill for the government. It is important to stress, however, that international experience with smaller cylinders is mixed: negative aspects include much higher cost of cylinder management and hence higher LPG price on a unit basis, and the need for households to refill more frequently. Therefore, market forces, and not government policy, should guide the sizes of cylinders to be made available on the market.

3.59 Another consideration is the deregulation of the downstream petroleum sector in April 2002. One of the objectives is to create an open and competitive market with a level playing field, designed to increase efficiency in the sector and ultimately provide fuels to consumers at least cost. Differential treatment given to state-owned oil companies and private sector LPG distributors (in the form of subsidies reserved exclusively for the former) goes against the spirit of sector deregulation and its objectives. By continuing to give not only a price subsidy but also a cylinder connection fee subsidy only to the dealers for state-owned oil companies, the Deepam Scheme in its current form slows down the move towards a market-based petroleum sector that could facilitate higher LPG consumption in rural areas in the long run.

3.60 For governments wishing to promote the use of LPG by the poor, the present evaluation of the Deepam Scheme offers a number of lessons:

- Assess the economics of, and a potential market for, LPG service. The relatively high operating cost of LPG service (i.e., the cylinder refill cost) may make it difficult to develop an effective subsidy scheme for the poor that is fiscally sustainable and supports the establishment of commercially viable businesses.
- Rather than making the program universally available, consider concentrating on those areas where the availability of free or cheap biomass is diminishing. This will concentrate limited state financial resources on those poor households who are in the most difficult situation as regards meeting daily energy needs and are more likely to consume significant amounts of LPG.
- Bear in mind the importance of creating a sufficiently level playing field for all LPG distributors, including private companies, in the spirit of sector deregulation and its ultimate objective of providing better service at lowest cost.
- Publicize the health benefits of reducing exposure to indoor air pollution to increase demand for cleaner cooking. Such public education campaigns should, however, be conducted in a broader context and emphasize a number of measures, including smokeless chulhas and separate kitchens, so that households can choose from several options. The awareness-building campaign should also cover simple practices that can improve the health of household members at no additional cost, such as taking small children out of cooking areas, and ventilating cooking areas more.

3.61 The GOAP has decided to add an additional 1.3 million new connections under the Deepam Scheme at a cost of Rs 1.3 billion. In this context, an important question is whether and how a commercially viable market can be developed and sustained in rural areas. The findings of this study point to the following specific recommendations for the next stage of the Deepam Scheme:

- Allow the transfer of Deepam connections to other eligible beneficiaries in cases where the recipients find themselves incapable of purchasing refill cylinders, and afterward view the participation in the scheme, which requires the purchase of a stove and accessories, as a “dead investment.”

- Promote conditions that would allow the market to experiment with smaller cylinders. A notable impact of the Deepam Scheme is that awareness of the benefits of LPG has grown in rural areas and there seems to be a willingness to increase the use of LPG—if a viable alternative to the high cost of refills can be found.

4

What Makes a Successful Stoves Program: Lessons from Six States

4.1 The modern, efficient biomass stove can be considered an important socio-economic bridge for the millions of people in India who have access to low-cost, readily available biomass and cannot afford expensive modern fuels. The many potential benefits of improved stoves have been evident since the first discussion of the "fuelwood crisis." The fuel savings from using improved stoves reduces cash outlays, diminishes walking time to collect fuels, reduces air pollution released into the environment, and alleviates local pressure on wood resources. There has been significant effort to promote better stoves worldwide. Many of the improved stoves promoted in India since the early 1980s have chimneys to remove smoke from the household and to reduce the exposure of family members to IAP. This chapter investigates a potential of improve stove programs in India as one the principal options for alleviating indoor air pollution problems.

4.2 Since 1985, the government of India's National Programme on Improved Chulhas (NPIC)—the second largest in the world, next to a similar program in China—has introduced about 30 million improved stoves. Despite this remarkable effort, the traditional chulha stove remains the most commonly used stove for cooking (see Table 4.1). In light of the potential benefits of improved stoves, the question may be asked, Why have adoption rates been so poor in many states of India?

4.3 In the early programs it was assumed that if improved stoves were presented to people, they would be quickly adopted and the intervention would lead to self-sustaining programs. This often did not happen for several reasons. One reason was that the energy efficiencies achieved in laboratories did not translate into similar efficiency gains in rural homes. Another reason lay in an obvious failure to identify the market for improved stoves; for example, some programs introduced stoves into regions where people purchased neither their traditional stoves nor fuelwood, thus having little appreciation of efficiency gains. The health benefits of the improved stoves were not well advertised. Finally, the price of an improved stove was a significant barrier to adoption, especially in areas where there was very little cash outlay for stoves or fuel.

Table 4.1. Ownership of Cooking Stoves, by State (number per 100 households)

Type of Cooking Stove	*Andhra Pradesh*	*Himachal Pradesh*	*Maharashtra*	*Punjab*	*Rajasthan*	*West Bengal*
Wood						
Traditional chulha	114	84	124	111	125	146
Improved chulha (fixed)	6	19	6.5	10	10	2
Improved chulha (portable)	0.3	4	-	0.2	-	-
Sigri	1	2	3	2	1	-
Improved kerosene stove	18	12	26	4	7	24
Solar cooker	-	2	-	1	-	-
Biogas stove	1	0.4	1	2.3	-	4
LPG stove	4	45	2	13	1	1
Pressure cooker	3	105	-	60	4	10

Source: Operations Research Group (ORG) Household Survey (ORG 1996) completed as part of World Bank (2002) study.

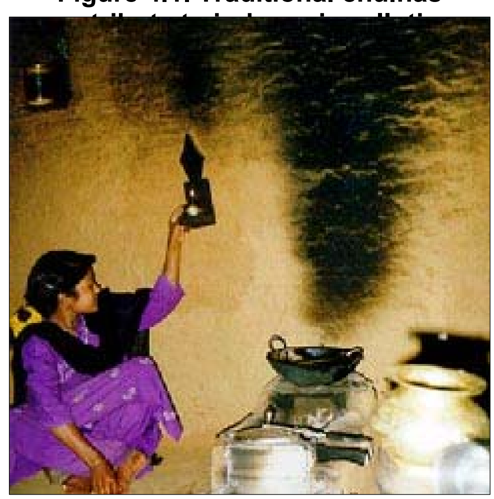
4.4 Under the umbrella of a national program, implementation approaches, performance and achievements vary substantially across states. Although there have been several evaluations of the improved-stove programs, most have concentrated on problems encountered in implementation (Natarajan 2000). Many have revealed poor stove adoption rates. What was missing, however, was a clear understanding of why some states had higher adoption rates than others and of how to implement the lessons learned from the successful components of these programs.

4.5 To fill this gap, this chapter reports the results of an evaluation exercise that examined some most successful improved-stove programs in India and compared them with the best international practice . The evaluation focused on the reasons of better performance and the ways future programs can be improved to reach a greater number of people in a sustainable manner.

Background on Stoves

4.6 Fuelwood, dung, and crop residues constitute the bulk of fuels used for cooking—over 80 percent in rural India. These traditional fuels are used in open fires and with various types of chulhas. The traditional chulha has no chimney, and consists of stones plastered with mud to form a rough cube that is one-foot square, leaving one side open to feed fuel. Smoke from the stove goes directly into the room. (See Figure 4.1). While primarily designed for fuelwood, the chulha has been adapted to burn charcoal and dung in many areas. Households often own more than one chulha, and even those that cook with LPG or kerosene use the traditional chulha.

Figure 4.1. Traditional chulhas



4.7 The main problems associated with the traditional chulha are its low efficiency and its inability to vent smoke out of a room, which causes significant levels of indoor air pollution (Parikh and Laxmi 2001; Parikh, Smith, and Laxmi 1999). The cooking efficiency of the chulha is a function of its design, the number of pots and pans placed upon it, and the type of food that is cooked. Standardized tests for estimating thermal efficiency of wood-fueled stoves indicate that traditional chulhas operate at only one-half the efficiency of standard improved stoves. Dung cakes yield even lower efficiency ratings because they have lower heat intensity, and the greater distance from the low flame to the pot or pan may result in heat loss. The low efficiency of the traditional chulha has given rise to extensive programs to improve stove efficiency and to disseminate improved models. Although such programs have made an impact, the traditional chulha still predominates in rural India.

Improved-Stove Programs in India

4.8 As early as the 1950s, India had instituted programs on improved cookstoves, biogas, and energy plantations. The early stove programs, such as the Magan chulha of 1947 and the Hyderabad Engineering Research Laboratory (HERL) chulha of 1953, focused mainly on reducing the drudgery of cooking. These stoves aimed to remove smoke from the vicinity of the cooks and reduce health hazards. They encountered limited success and thus were not disseminated widely. It was with the introduction and popularity of the Nada chulha in Haryana in 1980, and the Application of Science and Technology to Rural Areas (ASTRA) stoves in Karnataka in 1983, that hope for success of a national program grew. The local women of Nada village helped develop the Nada stoves, while the ASTRA stoves were developed by a group of scientists in the Indian Institute of Science, Bangalore.

4.9 The National Program of Improved Chulhas (NPIC) was then founded in 1983 as a series of pilot programs with the multiple goals of conserving fuel, reducing smoke emission in the cooking area, and improving health conditions. The program also aimed to reduce deforestation, to lessen the drudgery of women and children, to reduce cooking time, and to improve employment opportunities for the rural poor.

4.10 Reflecting the diversity of cooking needs and customs in India, as of early 2002 more than 100 models had been approved for dissemination by the Ministry of Non-Conventional Energy Sources (MNES). To receive approval, improved chulhas are required to have a minimum efficiency of 20 percent for fixed mud stoves and 25 percent for portable metal stoves. Under the NPIC, most of the stoves were built of mud and a few steel components, with a potential life of 2 to 5 years, depending on maintenance, and no specific requirement to reduce emissions or vent smoke outside the house. Since October 2000, however, MNES has shifted its policy towards promoting durable cement stoves with chimneys and a minimum lifespan of 5 years.

4.11 This MNES program has made a noticeable impact. During 1984–2000, as many as 33 million of these stoves had been distributed— more by far than in any other country of the world except China. The dissemination was mainly done through the government with the help of voluntary agencies, autonomous organizations, and small entrepreneurs. In a 1996 survey, improved chulhas were present in all the villages surveyed and were generally available in village markets. National evaluations indicate that 60 percent of them were in use (ESMAP

2000). These figures of course do not take into account the limited lifetime of an improved stove. Because the stoves typically lasted about 2 years, many of them are no longer part of the household inventory of appliances.

4.12 A number of studies confirm multiple benefits of improved stoves. Fuel savings were estimated to range from 19 to 23 percent, and about 70 to 80 percent of improved stoves were reported to have reduced smoke around the vicinity of the cook, a feature that women found particularly attractive. The 1996 survey showed that most villagers agreed the improved chulhas both saved fuel and, because they substantially reduced indoor air pollution, were healthier to operate than traditional stoves. Also, cooking time for such improved stoves was less than for traditional stoves. The time spent collecting fuel was about 25 percent less for women using improved chulhas (ESMAP 2002).

4.13 However, despite extensive governmental promotion efforts and widespread awareness of the program in rural areas, improved chulhas still account for less than 7 percent of the total stock of chulhas in rural areas (ESMAP 2002). Almost 60 percent of the surveyed households were not interested in changing from their present stoves.

4.14 The reasons for the program's limited success are not entirely clear. One criticism of this and other similar government programs is that they are *target-driven* rather than *need-driven*. The government uses subsidies to encourage the distribution of chulhas without paying adequate attention to consumer requirements and after-sale servicing. Stove designs might be unsuitable for cooking some dishes. Extensive subsidies deter the development of local markets, which might be more efficient in manufacturing and servicing improved stoves. Commercialization of the stoves could have been more emphasized after the initial pilot phase of the program.

4.15 Recently, the GOI decided to decentralize the stove program and transfer full implementation authority, together with funding support, to the state level. For states encountering this new responsibility, it may be useful to know the drivers of success from past experience in India, benchmarked against international best practice. It is also important to establish the areas in which the national government is best suited to play a role and should retain its involvement. These issues were examined in this evaluation and determined its design.

Study Design

4.16 Designing the research methodology for this component involved selecting and conducting case studies of stoves programs for six states in India. The programs selected for the case studies were recommended by a panel of experts assembled by MNES to be among the most successful in the country. Success of the programs was judged on their ability to achieve both a high adoption rate of improved stoves, as indicated by sales levels, and sustainability, as measured by a proportion of households purchasing or refurbishing a second or later stove. The states selected for case studies were Andhra Pradesh, West Bengal, Haryana, Gujarat, Karnataka, and Maharashtra. The evaluation was not intended to be totally representative of the each state's entire improved-stove program. The studies were carried out in selected districts chosen to reflect geographical coverage and relatively higher rates of stove penetration. Two leading institutions in the field of improved-stove research undertook the evaluations: the Tata Energy Research Institute (TERI) and Winrock International India (WII).

4.17 For each case study, research was based on user response surveys and focus-group discussions. Interviews and discussions also were held with key stakeholders, including users, non-users, stove builders, designers, and suppliers (see Table 4.2). All studies utilized similar techniques—including questionnaires for interviewing different stakeholder groups, concise checklists for focus-group discussions and a structured questionnaire for developing improved users' stove profile—so that the results could be comparable across states.

Table 4.2. Data Collection Instrument for a Typical State

Stakeholder group	*Data collection instrument*	*Sample size*
Users	Focus-group discussions	2–3 groups in each village (consisting of 8–10 persons each)
Non-users	Interviews	7–8 persons per village
Manufacturers	Interviews	2–4 interviewed
Self-Employed Workers	Focus-group discussions	2–3 per district
Implementing Agency	Interviews and Discussions	Interviews and discussions with key staff members
Technical Backup Units	Discussions	2 persons

4.18 In addition, the research included obtaining information on the pricing policies, marketing plans, means of financing, customer service, communication, monitoring and evaluation, and program development. This also helped to make the case studies comparable and to allow some comparisons between programs in different states.

4.19 The following key issues were identified for the case studies:

- *Stove pricing:* The studies examined the pricing of stoves compared to the costs to produce and market them. This included an examination of the benefits or problems of producing relatively inexpensive stoves made of local materials versus the use of higher quality components or parts that may be more expensive, and how this was related to the market for the stoves.

- *Program financing*, which can involve a delicate balance between the size and the delivery mechanism of a subsidy and the pricing of stoves to be affordable to poor households. In most internationally successful programs, the stove price does not contain a large subsidy component, but governments provide financial support (for development costs) and technical assistance to the programs.

- *Market identification* using surveys and other market assessment techniques. The use of such techniques has been an essential component of most successful programs.

- *Identification and development of stove types to be promoted in the program.* Many internationally successful programs have required an iterative process of development and test-marketing under real conditions.
- *Customer service and satisfaction.* The case studies evaluated both the impact of stoves on rural communities and the degree of consumer satisfaction with the stoves, focusing on the techniques utilized to sell and service the stoves.
- *Operational procedures.* These included the allocation of institutional responsibilities, the allocation of work, and training at the community level or for artisans.
- *Communication and promotion* between the executing agency, the stove manufacturers, and the rural beneficiary, focusing on how programs informed consumers about their service.
- *Local perception* of the stove program, including (1) whether the stoves are valued because they save energy, are convenient, or eliminate indoor air pollution, and (2) reasons why households adopt or fail to adopt the improved stoves.

Description of the Six State Programs

4.20 Table 4.3 provides an overview of the programs examined in this study component. The NPIC focuses mainly on people living below the poverty level. Although it is national in scope and level of financing, the states have differed in their approaches to implementation. In some cases, the training of self-employed workers (SEW) to be a stove entrepreneurs has been the focus of the program. In others, the emphasis has been on non-governmental organizations (NGOs). Still others have been implemented through women's self-help groups. Some states also put some of their own financial resources into the program.

Gujarat: The Rural-Development Approach

4.21 The NPIC was initiated in Gujarat in 1983–84. Up to 1988, the program was implemented by the Forest Department, after which it was transferred to the Rural Development Department. In 1994 the Department began implementing the improved-stove program at the *panchayat* level (the lowest level of government administration in India), along with many other rural development programs. There are a number of other agencies implementing the program in the state. These are the Gujarat Energy Development Agency (GEDA), the Khadi and Village Industries Commission (KVIC), the National Dairy Development Board, and the All India Women's Conference. Whereas GEDA implements the program only in Gujarat, the other three are national-level organizations that receive targets from the NPIC for the whole country, and these organizations allocate funding to the various states independently. Within Gujarat, each agency implements the national program independently of the others.[19]

[19] Improved chulhas are also disseminated in Gujarat through the *Indira Awas Yojana*, a national housing scheme wherein improved chulhas are installed in new houses. The targets for improved chulhas under this program are separate from those of the national program and are not included in the state-level targets allocated by the MNES

Table 4.3. Overview of the NPIC in Six States

State	*Type of fixed-type mud stoves frequently in use (name of model)*	*Average stove efficiency (%)*	*Districts surveyed*	*Number of stoves installed in surveyed districts (1999–2000)*	*Number of stoves installed in the state (1999–2000)*	*Cumulative total number of improved stoves installed (1995–2000)**	*Technical Backup Unit*
Andhra Pradesh	▪ 2 pot with chimney; pottery liners (Sukhad) ▪ 2 pot chimney; pottery liners (Gayathri)	20–28	Mehboobnagar	29,112	186,000	1,259,892	Regional Engineering College, Warangal
West Bengal	▪ 1 pot with chimney (Sohini Seva ▪ 1 pot coal with chimney (Kalyani) ▪ 2 pot with chimney (Sugam Seva)	18 22–40 22	Medinipur South 24 Parganas Jalpaiguri	159,076	497,589	2,093,735	Kalyani University
Haryana	▪ 1 pot with chimney (Mohini) ▪ 2 pot with chimney (Jaitan and Akash)	23 22	Panchkula Fatehbad Gurgaon	9,000	55,000	236,970	Punjab University, Chandigarh
Maharashtra	▪ 1 pot without chimney (Grihalaxmi) ▪ 2 pot with chimney (Laxmi) ▪ 2 pot without chimney (Parvati and Bhagyalaxmi)	24–28	Kolhapur Satara Sangli	10,950	95,103	788,189	Appropriate Rural Technology Institute
Gujarat	▪ 2 pot with chimney (Mamta) ▪ 1 pot without chimney (Sneha)	24	Ahmedabad Surat Dangs	16,522	99,885	397,785	MS University, Baroda
Karnataka	▪ 2 pot stove with chimney; pottery liners (Sukhad) ▪ 2 pot with chimney; pottery liners and mould (Sarale Ole)	20–29	Mysore Hassan	4,500	59,033	438,785	Karnataka State Council and Technology

* Includes both fixed and portable improved stoves.

4.22 Although several new stove models have been developed in Gujarat over the years, the most popular are the two-pot Mamta model and the chimney-less, single-pot Sneha model. The Mamta model was designed by the state technical backup unit (TBU) and approved under the NPIC in 1989.

Maharashtra: The Commercialization Approach

4.23 In Maharashtra, the NPIC is implemented by three agencies: the Rural Development and Water Conservation Department; the Maharashtra Energy Development Agency; and the KVIC. The Rural Development and Water Conservation Department (the primary implementing agency) is responsible for more than 80 percent of the state target of 120,000 stoves disseminated annually; the Maharashtra Energy Development Agency, almost 18 percent; and the KVIC, less than 2 percent. The technical backup unit for the NPIC in Maharashtra is the Appropriate Rural Technology Institute (ARTI) in Pune. The stoves are constructed by self-employed workers trained and approved by the TBU. Several models of improved chulhas were promoted within the state, depending on specific regional requirements. Notable among these are the Laxmi and Parvati chulhas.

4.24 Partly because rural people in Maharashtra have a tradition of purchasing even traditional stoves, the state has been a fertile ground for commercialization. With the support of the TBU, the program has trained potters to take the initiative in selling stoves and becoming entrepreneurs. The potters are given extensive support in the form of testing of new models developed by them and of training programs on new developments and technical designs. With the NPIC's new focus on "durable" stoves made of cement, however, the number of qualified workers has decreased from 25 to 8. This highlights the challenge of reconciling the various objectives of improved-stove programs. As one possible solution, the TBU began testing baked-mud chulhas to ascertain whether they could be approved as "durable." The market demand, combined with an innovative TBU, has put Maharashtra far ahead of many other Indian states in commercializing the improved chulhas.

Andhra Pradesh: The Energy-Agency Approach

4.25 In Andhra Pradesh, the Non-conventional Energy Development Corporation of Andhra Pradesh (NEDCAP) and the KVIC are the main agencies implementing the NPIC. The NEDCAP was created in 1969 to survey, develop, and implement renewable energy programs of state and central government; to generate electricity through renewable sources of energy such as wind and sunlight; and to conserve energy in rural areas. The agency has branches in all 23 districts of the state and a head office in Hyderabad. The KDIC is a national government-sponsored agency under the Ministry of Rural Development.

4.26 The TBU at Regional Engineering College in Warangal is mainly responsible for providing technical support and training to the various stakeholders (such as self-employed workers and users) involved in the NPIC. It is also involved in the design and development of audio-visual publicity material in the local language. There were quite a few models introduced under the NPIC, starting with the Sahayoga stove model disseminated in the mid-1980s. The technical developments were considerably influenced by national program policies. For instance, the chimneyless stoves developed and disseminated in Andhra Pradesh were discontinued after the national program quit providing a subsidy for chimneyless stoves in the year 2000.

4.27 The number of portable cookstoves being disseminated in Andhra Pradesh is quite high. These cookstoves are provided under the various housing schemes of the state, such as Indira Awaz Yojana, a rural housing scheme. The government has made it mandatory to install an improved stove in all new houses being constructed under these schemes. The housing boards purchase the portable improved stoves directly from NEDCAP and distribute them to the beneficiaries. The improved chulhas are not being disseminated through entrepreneurs in Andhra Pradesh because the incentives being provided to the self-employed workers are very low.

Haryana: The Role of Women

4.28 The Department of Women and Child Development manages the stove program in Haryana. The Department handles the NPIC as a women-to-women program, and implements it through its network of over 7000 *mahila mandals*—women's groups that operate in almost all villages in the state. The chulhas are made by self-employed village women trained in chulha construction. The TBU is an important stakeholder in the improved-chulha program; for Haryana, it is the Energy Research Centre at the Punjab University.

4.29 Work on improved stoves in Haryana started in 1980 when the Nada chulha was developed under a Ford Foundation program in the village of Nada. It was simply a traditional two-pot chulha with a chimney attached. As the demand for this chulha grew, it became clear that an organizational structure needed to be developed for training of potters and chulha owners. In 1983, the Swedish International Development Agency provided funds for training local women, having deemed them best suited to transfer a new technology to other women. During the first years, the users of the Nada chulha had to pay only for chimneys and dampers. Thus, from the very beginning of the program in Haryana, its was based on the importance of women users in the actual making of the chulha and their involvement at every stage of design and development.

4.30 Initially, the users appreciated the Nada chulhas. However, over time the dampers were perceived as unnecessary inconveniences and were often removed by the users, which affected stove efficiency. In light of this, the Energy Research Centre developed damper-less chulhas, called the Jaitan model, of which more than 150,000 have been constructed. For larger families, the high-powered Akash model chulha was designed. While the Jaitan model can cook food for up to 8 persons, the Akash is more suited for families of 8–15 people. A further improvement was the incorporation of a grate at the bottom of the firebox, which increased combustion

efficiency. For smaller and poorer families, the Mohini model was designed to occupy a smaller space.

4.31 Both family size and traditional cooking customs had a significant influence on the technical development of the improved stoves introduced in the state. In Haryana milk is an important food. The indigenous system for storing milk in the absence of refrigeration involves keeping the milk simmering throughout the day on a stove called a *hara*, which uses cow-dung cakes as fuel (see Figure 4.2). The traditional hara is thermally inefficient and extremely polluting. In order to meet the requirement of simmering large quantities of milk throughout the day, the Sohini model was developed and later modified by the technical backup unit to fulfill users needs. The technical backup unit also modified the design of the traditional *tandoor*, a typical stove used in the region for making rotis. All of these innovations in stove design reflect the extensive interaction between women and the stove designers, a tradition that was started early in the program and brought encouraging results.

Karnataka: Involvement and Cooperation of Several Key Players

4.32 The dissemination of improved stoves in Karnataka was begun in 1980 by the Karnataka State Council for Science and Technology in coordination with the Centre for Application of Science and Technology. In 1993 the Centre, which serves as the TBU, designed the Sarale ole stove, which was a simple, modified version of the Astra ole. The model is a clay fixed stove based on a ceramic mold, with two-pot opening, and has a provision to feed fuel into the stove from the front or the side. It remains the main model of stoves that are produced and distributed in Karnataka.

4.33 The NPIC has been implemented through the rural energy wing of the Department of Rural Development and Panchayat Raj. As in other states, the program is also implemented through rural housing schemes, including the Indira Awaz Yojana and Swacha Grama schemes. The Department of Rural Development and Panchayat Raj sets the targets for the stoves, and then the responsibility of implementing the program is passed down to the local officials. However, it is the self-employed workers who are most actively involved in the promotion of improved stoves in the state. Once certified, the self-employed potter can construct the stove for a consumer, and then receive a fee for the service from both the consumer and the government. This is all done in coordination with NGOs active in stove dissemination. The Karnataka program, therefore, features a good level of cooperation among different levels of government, potters, and NGOs.

West Bengal: Empowering Non-Governmental Organizations

4.34 The main feature of the improved-stove program in West Bengal is that it is almost entirely implemented through local NGOs. The program is being executed by the Social Welfare Department and the West Bengal Renewable Energy Development Agency in 18 districts of West Bengal through a network of over 150 NGOs. The KVIC also administers a program in 10 districts in the state. The use of NGOs for implementing the program began in the early 1990s and grew consistently. The TBU provides support for stove development, potter training, and entrepreneurship development. One of the KVIC's interesting innovations is that they require at least one village in each program block to be fully covered by the improved-stoves program, which means that 100 percent of families in the village have an improved chulha.

4.35 In many parts of West Bengal, coal is available and many households use it for cooking, so stove designers had to take this into consideration. This, plus dissatisfaction with some of the previous stove models, spurred the TBU to develop the Kalyani stove, which has a 40 percent energy efficiency rating with coal as the main fuel. This model is now widely accepted in areas where coal is easily available. More recently, the TBU has been very active in developing the durable stoves that last 5 years or more. Although the responsibility of stove design is formally with the TBU, some of the NGOs have r become involved in designing and submitting stoves for approval to the unit.

Comparative Assessment of State Stove Programs

4.36 The strengths and weaknesses of each states' implementation of the NPIC are summarized in Annex 5. The following comparative assessment yields valuable lessons in terms of institutional structure, commercialization, design issues, and subsidies.

Commercialization of Stoves

4.37 The goal of the most successful stove programs is the full commercialization of the buying and selling of stoves. However, it is not practical to expect the private sector, usually small entrepreneurs, to bear all of the costs of stove de should be to support the process of commercialization. Th ways. Governments or donors can assist in the formulatio sector operators to produce, distribute, and sell improved form of providing technical standards, better access to rav makers, and promotional support.

4.38 For India, the commercialization of improved cookstoves has been active mainly in one state. At the initiative of the technical backup unit established in Maharashtra, the Appropriate Rural Technology Institute (the aforementioned ARTI) developed a program to train entrepreneurs in the design, manufacture, and sale of stoves. These rural entrepreneurs now sell their products in the open market and through the NPIC, with annual sales of Rs 100,000. Some 25 entrepreneurs operate in Maharashtra, most of whom have obtained loans from local cooperatives. With modest investments, the stove entrepreneurs have earned reasonable profits and are keen to expand their businesses. (See Figure 4.3.)

4.39 ARTI has developed several innovative approaches to commercialization that are now being applied elsewhere in the country. These include the use of easy-to-assemble portable molds for making improved chulhas, setting up an entrepreneurship development program for stove makers, and training them in the installation of community chulhas. The ARTI approach promotes improved chulha technology as an income-generating opportunity for rural potters. Rural householders find that potters' claims are more convincing than those of government officials or even NGOs. The construction and sale of stoves are left up to the potters, who are most familiar with their markets and thus can apply appropriate sales techniques (Hanbar 1993; Karve 1993; Karve 1999).

4.40 Independently, the ARTI program has adopted several techniques recognized as best practices in the development of improved-biomass-stove programs worldwide. For example, in China, the world's largest program is successfully using standardized stove inserts to lower costs and ensure the quality of improved stoves. The close association and even suggested inputs of stove retailers are found important in all well-performing programs. The program involves an interface with customers when designing the stoves, a critical success factor. The grant funds ARTI receives are used to support stove testing, artisan training, and other activities not directly involved with the retailing of stoves, which is also consistent with best practices. What further makes the ARTI program a success is that government and NGO involvement is limited to areas where they can contribute most, such as research and development of improved stoves, demonstration and dissemination of molds (not the stoves themselves), training of potters, and information dissemination. There is a need for all the states to promote commercialization in order to make the use of improved stoves sustainable in the long run.

Stove Design Issues

4.41 The NPIC has recognized that good stove design and development is essential. It has assigned this task to technical backup units that serve each state program. However, this study reveals that, after many years of stove development by these technical backup units, users either still have some complaints about the improved stoves or make modifications to stove designs to improve usability. The users are not particularly concerned about the stoves having to conform with technical specifications; rather, their primary interest is a smoke-free kitchen and adequate heat generation in the firebox that suits their cooking needs. (See Figure 4.4.)

Figure 4.4. An improved cookstove in use

4.42 The case studies identified several problem areas. In some Karnataka households, users lengthened chimneys by attaching spare broken pipes to allow the prescribed 10-foot chimneys to actually exit the roofs of their houses. In addition, some households with thatched roofs removed their chimneys during rainy season to avoid leakages inside the house through the roof hole made for the chimney. The Gujjar community in Haryana preferred to increase the size of the firebox so that large rotis could be baked inside the box. In some households, the chimney outlet was inside the house itself as people were unwilling to make a hole in their roofs to allow the chimney to pass through. In

Gujarat, the size of the firebox was enlarged to fit bigger pieces of wood for burning. People also complained that the tiles of their roof broke when the chimney was cleaned or that the chimney mouth needs to be bigger. All of these problems taken together mean that the stoves were not properly designed for the actual conditions under which they were going to be used.

4.43 People still using traditional chulhas gave the following reasons for not adopting improved stoves:

- In houses with thatched roofs, the installation of stove chimneys causes leaks during rainy weather.
- They cannot afford a one-time payment for the stove.
- The home lacks the space to install an improved stove
- The self-employed workers had to postpone stove installation due to unavailable chimneys.

4.44 In Maharashtra, changing the pothole size and removal of the grate are common modifications made by users. However, unlike other states, the custom is to make the potholes smaller. Women removed the grate because of the difficulty of removing the hot ash from under the grate, and the lack of space to accommodate large pieces of wood. In Maharashtra, a majority of the households belonging to one district stopped using their stoves because the gap between the end of the chimney and tin roofs had not been sealed properly, resulting in leakages during rainy weather. In West Bengal, the diameter of the tunnel to facilitate the flow of heat to the second pothole was increased. Also, the diameter of the chimney was increased from 3 to 4 inches to facilitate cleaning and smoke elimination. In Andhra Pradesh, people changed the pothole size, removed grates and raised the height of pothole to be able to see the flame while cooking. This leads to more fuel being used and smoke that does pass through the chimney. Some households complained that the pottery liners cracked, and others felt that their improved stoves use more fuel.

4.45 Complicating matters even further is that, as mentioned earlier, subsidies are now being made available only for "durable" improved stoves with chimneys. The fireboxes of the new models are made of either cement mortar, pottery liner, or steel sheet. However, incentives may be needed to help people make the transition to a more expensive stove. Although many users are willing to pay for durable stoves, poorer users may not be able to afford the higher user contribution necessary for the more expensive stoves. Some NGOs feel that the current mud stoves should be continued, with a gradual phase-out, until acceptance of the durable model is established.

4.46 Thus, the most common modifications made by users in various states include altering the pothole size, removing the grate, changing the size of the firebox, and modifying the chimney. All of these modifications can lead to greater smoke inside the home and also can lead to a reduction of energy efficiency of the stoves.

Interaction between Stove Users, Builders, and Designers

4.47 The best stove programs in the world are the result of significant interaction between stove users, builders, and designers. The variety of cooking customs and preferences combined with stove design, engineering, and production issues make it possible to have literally hundreds of improved stove designs. Stoves must not only be useful and easy to use; they must also must meet certain engineering standards for removal of smoke and conservation of energy. High energy efficiency or smoke removal in the laboratory may not translate into similar levels of efficiency and smoke removal in the home if the stoves are not easy and practical to use.

4.48 Good engineering should be matched with the effective involvement of stove manufacturers and users before a program can be successful. In some successful programs in both China and Africa, there has been extensive consumer testing and marketing before programs achieved success. In Rwanda, several different types of charcoal stoves were given to consumers for determining which was most suitable to their cooking needs (ESMAP 1991). After selecting the most suitable stove, this stove was again modified to better serve the stove users. In China, the initial programs involved custom-made stoves, which had a propensity to break down early and often. As a consequence, later designs were based on durable components manufactured in factories, so the assembly in the household was made easier and the stove was more reliable (Smith 1993; Smith, Huang, and Qiu 1993).

4.49 In India, for most states covered by this study, interaction is fairly minimal between users, self-employed workers, NGOs, and the technical backup units. The NPIC early on perceived (rightly) that the technical backup units were an essential part of the program, and gave them responsibility for quality control, stove testing, and stove design. However, with the exception of Maharashtra and to a certain extent Haryana noted above, there have been significant problems in getting the units to interact in a significant and satisfactory way with the producers and users of the stoves.

4.50 One outcome of this lack of interaction is that in some cases consumer priorities have been less important than the technical efficiencies of the stoves. The extensive efforts in Haryana to modify stoves to fit local eating customs and preferences have already been detailed. An interesting finding in terms of stove design priorities is that the users of the improved stoves actually rank the removal of cooking smoke from the household as a higher priority than energy savings (see Table 4.4). This can have significant implications for the design of a program.

Table 4.4. Ranking of Perceived Benefits of Improved Stoves

	Ranking of Perceived Benefits of Improved Stoves				
State	*Better Health (less eye problem coughing)*	*Cleaner kitchen due to less soot*	*Faster Cooking*	*Fuel Savings*	*Smoke Removal*
Andhra Pradesh	2	4	1	3	4
West Bengal	2	5	3	4	1
Gujarat	5	4	3	2	1
Karnataka	5	4	3	2	1
Maharashtra	5	4	3	1	2
Haryana	5	2	4	3	1

Note: 1 is the highest rank and 5 is the lowest rank.

4.51 The stove users interact mainly with the self-employed workers and consider them to be the informal stove designers. The Karnataka survey revealed that only six percent of the users had participated in a user-training program organized by the technical backup unit, even though training users was one of their responsibilities. Although the technical backup units have conducted surveys to assess the working status of stoves, the surveys generally do not take into account issues relating to stove design and efficiency. They are concerned mainly with determining whether or not a household has adopted or still uses an improved stove.

4.52 The interaction between stove builders and the technical backup units often is limited to sporadic state-level meetings, capacity-building programs, and feedback surveys. In most of the states surveyed, the self-employed workers used their own ingenuity to make modifications while producing the stove, mainly because of a lack of contact with the technical backup unit. In West Bengal, a low level of interaction between the technical backup unit and non-governmental organizations is highlighted by stove development efforts undertaken by them. The NGOs collaborated with the state implementing agencies rather than the technical backup units. In Haryana and Maharashtra, the self-employed workers and the Gram Sevikas have modified the stoves in response to the needs of families.

4.53 Thus, there generally is no uniform policy with regard to the responsibility of the technical backup unit in approving or supporting modifications of stoves by NGOs or self-employed workers. Also, although training users is part of the responsibility of the technical backup units, generally there do not seem to be sufficient funds to complete this task. The effect of these problems on the quality of the stoves is the covered in the next section.

Quality Control Issues

4.54 Most successful international programs on improved stoves have a system in place to ensure the quality of the stoves. In many countries this is accomplished through the central production of stoves. This may be a solution for the improved charcoal stoves used mainly in urban areas, as all-metal stoves can be produced and sold in the marketplace along with other consumer goods. However, it is more of a challenge in countries like India in which households have stoves built into their houses. Such stoves require custom installation, and during this process the dimension of the stoves can be altered in many ways, reducing the effectiveness of the stoves. As indicated, this problem was solved in China by producing all of the major critical stove components (including the firebox) in small factories, and then assembling the stoves in the home.

4.55 Quality control also has been of great concern to the NPIC from the very beginning of the program. Until recently, the major stove being promoted in India has been the mud chulha. Early on, the India program experienced the same problems as experienced in China: the size and the dimensions of the stoves were often altered in the process of custom installation, making them lose efficiency. Also, as indicated above, the users of the stoves often made alterations to them after installation. Until recently the India program stayed with the production of the chulha in the home, but turned to standardized ceramic molds and inserts to keep the stove dimensions according to specification.

4.56 The problems that were discovered in the case studies involved a combination of material and institutional issues. First, although the national program permits only self-employed workers certified by the technical backup units to construct and install the improved chulhas, uncertified workers often build and install the stoves, leading to defective construction and early problems with the stoves. Second, stove parts are supposed to be purchased from suppliers approved by the technical backup unit. In reality, however, many stove makers purchase inferior materials from the marketplace. Third, in some programs, the self-employed workers are expected to provide one year of service after installing a stove. In many cases this was not practical, so the workers would install the stoves and then any problems would go unresolved except by the user.

4.57 Many of these problems could be avoided with greater use of standardized parts and more interaction between those responsible for the stoves program. For many of the problems cited above, it would have been quite simple to design stoves that would take user preferences into consideration so that they do not have to make changes to the stoves. In addition, many of the quality problems stem from the target nature of the program, in which users are not purchasing the stove themselves from a variety of different models. The consequence is that they get something that is not quite right for them and then modify it accordingly. The use of more standardized parts in the stove also can be important for lowering costs and improving quality control. With a few factories producing parts, the process of quality control becomes somewhat easier. The parts can also be designed so that they can endure the local means of transporting them to the households.

The Role of Subsidies

4.58 The international experience of stove programs is that although subsidies are usually involved, they are not a sufficient condition of a program's success. Many international donor-funded programs involve very heavy subsidies for the stove itself. This may not be much of a problem for small programs, as the subsidies are limited in geographical scope. However, problems arise when the programs become large or national in scope. When donors or governments are involved in directing subsidies to selected program participants, the programs often go awry because of problems associated with the choice of program beneficiaries.

4.59 The most successful programs involve little or no subsidy for the stove itself, and use of subsidies is for technical assistance and activities such as stove design, marketing, and information dissemination about the stoves. The distortions caused by providing subsidies for the stove do not appear to be worth their meager benefits.

4.60 In successful stove programs around the world, governments have mainly subsidized technical support and assistance for determining where demand is the strongest. In China and Sri Lanka, the lower cost of supply in centralized production of components has lowered overall stove costs, allowing the purchase of stove by local people lacking significant cash resources and suffer from having to spend a considerable amount of time on collecting fuel.

4.61 In India, the program subsidizes technical support, stove dissemination, and the cost of the stove itself. The large stove subsidies in the program have ensured distribution of stoves, but not necessarily their sustained use or demand. In the six states surveyed, the unit cost of a fixed-type mud improved stove varies from Rs 110 to 190, while the central subsidy accounts for 50 percent of the stove cost (see Table 4.5). However, the use and maintenance of stoves have been poor among the households getting the highly subsidized stoves. In some parts of Maharashtra the poorest households received the highest subsidies under the national program, but unfortunately their improved stoves fell into disuse due to poor maintenance and lack of appreciation by the poor households. In Haryana, many users declared that they would only continue to use the improved stove as long as it lasts, and then they would revert back to their traditional stove. The duration of most improved stoves distributed under the national program is very short, on average 2–3 years, so the benefits from such programs are very few.

Table 4.5. NPIC Subsidy Structure

State	*Type of Stove*	*Unit Cost of Stove* (1) *(Rs)*	*Central Subsidy (Rs)*	*Subsidy Given by District Administration (Rs)*	*Beneficiary Contribution* (2) *(Rs)*	*Contribution of Beneficiary (%)*
Andhra Pradesh	2 pot (mud)	148	70	63	15	10
	2 pot (mud)	135	70	0	65	48
	Sukhad (cement)	190	100	0	90	47
Haryana	1 pot cement	130	100	10	20	15
Maharashtra	2 pot (mud precast)	180	70	0	110	61
	1 & 2 pot cement	220	110	0	110	50
Gujarat	2 pot mud	110	60	25	25	23
	1 & 2 pot cement	280	110	145	25	9
West Bengal	1 pot mud	150	60	0	90	60
	2 pot mud	180	70	0	110	61
	1 pot cement	240	100	0	140	58
Karnataka	2 pot mud	140–190	70	23	43–93	31–49

1. This includes charges for material of the stove and stove construction charges of Rs 20–30 paid to the SEW.
2. Beneficiary contribution gets reduced by Rs 10–20 further to the figures in this column whenever the beneficiary arranges for the stove material, such as mud or cement.

4.62 The attractiveness of improved stoves to rural people also differs according to local shortages or surpluses of wood or other fuels. People value stoves more in those areas where there is wood scarcity. This is because the time saved in collection fuel is much greater in regions with scarcity of biomass fuels. These are the areas where people spend a considerable amount of time collecting fuel, have already had to move down the energy ladder to straw and dung, or pay cash for fuelwood supplies. In such areas, the programs have a better chance to work even without—or with minimal initial—subsidies. For instance, such a program has been relatively successful in Maharashtra, where people typically purchase their traditional stoves and it is not uncommon for households to pay for wood fuels.

4.63 In addition, people are generally unaware of the significant long-term health benefits of venting smoke from the kitchen. Women cooks are aware of the short-term irritation to their eyes and the difficulty in inhaling smoke, but they do not appreciate the substantial health benefits to young children and the whole family of keeping the kitchen and home free of smoke. Making them aware could increase demand for improved stoves and reduce the need for financial incentives.

4.64 There is a perception that providing subsidies in the form of government contracts, grants, and technical assistance to universities, private firms, and non-governmental organizations is not a good practice because it does not target the users themselves. In fact, the strategy of supporting the development of new products is likely to bring the benefits of better stoves—including both improved health and a reduction in the drudgery of fuel collection to a larger number of consumers.

Lessons from International Experience

4.65 The international programs for improved stoves can provide some insights into the successes and problems in the national India program. Some comparisons between the India programs and the international experience are presented in Table 4.6. The states in this study have been judged to have achieved a degree of success based on existing stove usage and sustainability of the program. Taken together, the practices of all of the states combined make an important contribution to the understanding the factors that could lead to a more successful program.

4.66 The role of the TBUs can be revised because in most programs it is too isolated from the people producing and using the stoves. The TBUs are responsible for developing new stove designs, testing and quality standards for stoves, and development of strategies on the basis of interaction with stove users, stove makers, and implementing agencies. The technical backup units also can be responsible for conducting training courses for entrepreneurs, with the goal of supporting the commercial development of the improved stoves program. The technical backup units of Maharashtra and Haryana are fulfilling many of these functions, but greater assistance is needed to expand their role in the program.

Table 4.6. NPIC Characteristics Compared to International Experience

International Practices	*NPIC Practices*
Approach is need-based	Target approach, stress on number of villages to be covered rather than households. Demand for stoves is not taken into consideration.
Minimal subsidy for the stove from government or donors	Subsidy on stove accounts for the largest share (50%) of government support. Users in periurban areas are willing to pay greater amounts subject to guarantee on stove quality
Maximum support for R&D, production and distribution of stoves, credit, capacity building and publicity awareness	Program funds technical backup units, but does not adequately support R&D, with no such support extended to NGOs. Support for capacity and awareness generation is also inadequate.
Close interaction among the designers, producers and users of stoves	Interaction between producer and user is adequate, but is negligible between designer and producer/user.
Dependence on centralized production of stove	For fixed stoves, there is no scope of centralized

and stove parts to enable out-reach to larger number of people due to lower cost of supply	production as these are built at user's homes. Mass production of stove parts (chimney, cowl, etc) is undertaken by private manufacturer. No mass production of the firebox.
Onus on producers and designers to meet needs of consumers	Consumer needs met by self-employed workers/NGOs through changes in stove design with low inputs from designers.
Long-term funding	Long-term target-based funding by government, routed through nodal agencies and disbursed through NGOs for implementation.

4.67 The implementing agencies in most programs can make greater use of non-governmental organizations and women's associations in the dissemination of stoves. Many of the programs that have been successful in dissemination of stoves involve non-governmental organizations or women's groups that are either wholly or partially responsible for the dissemination efforts. It also appears that with the involvement of NGOs, women's and stove-users' issues receive greater consideration than in other programs. The program in West Bengal has been successful mainly because of the involvement of NGOs in the process of implementing the program, and the program in Haryana used existing government programs that deal with women's issues.

4.68 The most successful international programs target the subsidies towards the commercialization of the stoves rather than providing the user with extensive subsides. The idea is to stimulate entrepreneurs to build the stoves and to create a real market for them. The role of subsidies in India's program is mixed. On the one hand, in the successful programs subsidies have encouraged possible stove owners to purchase them. However, the problems are many. Once purchased, there are no follow-up subsidies for spare parts and maintenance. Because some stoves only last 6 months to 2 years, they need replacement; however, the programs do not have any type of stove replacement policy. Thus, the subsidy can be phased out for the end users of the stove. Subsidies can be used to support the development of the capability of the TBUs, quality control facilities for testing stoves, monitoring surveys for discerning stove functionality and opinions of users concerning the stoves, and training and education regarding subjects such as stove design, indoor air pollution, and energy efficiency. However, this should be done in a way that integrates the design, construction, and convenience of the stoves for users.

4.69 The best international programs have developed stove programs in the regions with the greatest needs to conserve energy. For the most part, the regions have significant biomass shortages and emerging markets in the sale of fuelwood. In addition, the experiences in West Bengal indicate that concentrating efforts on specific regions tends to be more successful than spreading the programs thinly over all of the state. Therefore, one of the successes seems to be in the selection of villages for program participation on the basis of such factors as biomass shortage and concern for the health impact of traditional stoves. The programs would further benefit from campaigns to inform rural people about the health problems associated with indoor smoke, interest in clean kitchens by users, and a cooperative local government or administrative unit. Such programs could be run collaboratively by the administrative units and NGOs involved.

The spreading out of resources on too many locations seems to dilute the effects of most programs.

4.70 The availability of components and component parts appears to be a weakness in most of the programs in India. Both producers and users complained about the availability and quality of the stove components. There needs to be greater coordination to make the development of high-quality, and if possible inexpensive, stove components a central part of the state programs, as in best international programs. This requires a greater interaction between the technical backup units and the component makers.

4.71 The case studies reveal that although most of the states integrated several of the best practices for improved-stove programs, few have all of the components necessary for widespread success. There are many ways to implement programs, but it would be wise to incorporate as many of the success factors in the programs as needed to achieve a critical mass.

Conclusions

4.72 The improved-stove program in India is the second largest program in the world. While the overall performance of the program has fallen short of the standard set by the best international practices, there was a significant positive impact achieved through the program in a number of locations. A comparative assessment of six of the most successful state implementations of the NPIC allows us to draw useful lessons.

4.73 ***Commercialization at the state level***. Evidence from the state of Maharashtra and international experience strongly support the goal of full commercialization of stove buying and selling. The main role of government should be to support the process of commercialization, which can be done through a variety of ways: designing incentives to private sector operators to produce, distributing and selling improved stoves, setting technical standards, and providing credit facilities for stove makers, as well as promotional support. The most successful programs worldwide involve little or no subsidy for the stove itself, but use subsidies for technical assistance and activities such as stove design, marketing, and information dissemination about the stoves. Assisting with market analysis and identifying areas of highest demand is also very important. For example, the programs have a better chance to work even without—or with minimal initial—subsidies in areas of biomass shortage where people spend a considerable amount of time collecting fuel or pay cash for fuelwood supplies. Now that the national program is being transferred to the state level, there is a need for all states to promote commercialization in order to make the use of improved stoves sustainable in the long run.

4.74 ***Coordination function at the national level***. There also seems to be a need for a strengthened role of the national level in terms of coordination of information on stoves and capacity-building activities. Some of the local technical backup units, such as the one in Maharashtra, have informally taken this role, but there does not seem to be any overall group responsible for evaluating the different aspects of the program, conducting training and seminars, and in general ensuring that the information is shared among all of the different programs.

4.75 ***Collaboration between design, manufacturers, and consumers***. Technical assistance for improved stoves needs to be reoriented so that the technical backup units are more involved with the manufactures and consumers of the stoves—particularly women, who are the main users. This might include the design of models that are more durable and better adapted to consumer preferences. In many of the successful programs, the technical backup units have had a more outreach-oriented approach to stove design.

4.76 ***Need for new strategies to reach the poorest***. The most successful programs tend to work better for populations that expend cash income for stoves and can afford the expense. The needs of the poorer households appear to be either underserved or involve simple adaptations of stoves designed for more affluent rural households. In India, the increase in subsidies for the poor has not led to increased participation in the program, indicating that innovative approaches need to be developed to target these users. One possible approach is to combine the promotion of better stoves (and healthier kitchens) with housing finance and other programs. The participation of the poor in the program is an area that could benefit from the collaboration of the technical backup units and non-governmental organizations.

4.77 ***Emphasizing smoke removal and heath benefits***. The emphasis in most of the improved-stove programs in India has been more on energy efficiency than on indoor air pollution. At the same time, users clearly consider smoke removal and cleaner kitchen among the main benefit of the stoves. These aspects of improved stoves have not been given sufficient attention in stove design and dissemination strategies. Although the technical challenges may be difficult, the development of stoves that have a long-term ability to vent smoke outside the house, in addition to being efficient and easy to use, is of paramount importance.

4.78 ***Building on positive lessons***. Despite drawbacks, efforts to implement the NIPC have achieved a great deal in a number of states. Nevertheless, the unfinished agenda for improving household energy services for the rural poor in India, with the respective improvement in health and quality of life, is enormous. Lessons learned from this assessment are largely consistent with those from successful programs in other countries. This record should provide a strong basis for developing the next generation of stoves and improving program implementation at the state level.

5

Advocacy and Awareness Raising

5.1 Developing and implementing national, state, and local action programs to address the problem of IAP requires a variety of intervention measures across several sectors as well as involvement of all major stakeholders—the state and national governments, NGOs, the private sector, and rural communities.

5.2 One of the most important roles that the government can play in addressing IAP is to raise rural families' awareness of the health impacts of traditional household energy and of specific ways to mitigate them. For this to happen, government agencies should be fully sensitized to and informed of the issues. Although several research institutions and NGOs in India have carried out good work to describe the nature of the problem through documentation and exposure assessment studies, communication and dissemination of this information have been limited. This highlights the need for effective advocacy efforts.

5.3 Additional challenges arise from the multi-sectoral nature of IAP and the lack of sharing of knowledge and experiences across different sectors, actors, and technical areas. Advocacy and information dissemination activities are critical for closing this gap and strengthening collaboration among health, energy, environment, housing, and rural development agencies.

Objectives of the Advocacy Component

5.4 In addition to the three research components of the ESMAP study "India: Household Energy, Air Pollution and Health" described in the previous chapters, the study team embarked on a coordinated advocacy strategy through sponsoring multiple activities designed to inform key decision makers and stakeholders of the nature and extent of the problems and effective measures to address them. The main approach was to create public fora for a range of actors involved in IAP-related issues to interact and share experiences. The advocacy component had the following specific objectives:

- Improve knowledge and foster greater awareness among government officials, NGOs, communities, and other stakeholders.

- Encourage participants to interact and thereby catalyze new dialogues and incipient partnerships that will be sustained beyond the program.
- Bring wider national and international experience and lessons to bear when designing approaches and mitigation measures to address the problem.
- Strengthen commitments to specific mitigation measures among various players, including donors, to facilitate future action programs.

5.5 Through this component, the World Bank, ESMAP, and committed partners—government, non-government, and academic institutions within and outside India—played a valuable role in supporting and facilitating the collection of information and disseminating it to key audiences. This increased the overall level of attention to IAP and the understanding of main issues and solutions.

Advocacy and Awareness-Raising Activities

5.6 The advocacy effort covered (1) collecting, analyzing, and disseminating information on IAP-related issues, including newsletters and video materials; and (2) sponsoring a series of seminars and workshops, both to discuss study findings and to encourage broader exchange of knowledge and lessons learned. This section describes the specific activities undertaken.

Stakeholder Consultation Workshops

5.7 On March 27, 2000, the World Bank study team organized a launch workshop in New Delhi to identify the key issues involved in addressing IAP in India. The workshop was attended by 36 participants from government agencies, research institutions, private sector marketers and NGOs representing the health, environment, rural development, and energy sectors. This forum provided directions for policy research components of the study and created strong local ownership of the program.

5.8 As the study neared completion, three subsequent workshops were organized to discuss separate program components with key stakeholders. Workshops on improved stoves, exposure assessment, and the Deepam Scheme were held on 15 November, 2001; 15 January, 2002; and 20 February, 2002, respectively. The National Institute of Rural Development in Hyderabad hosted the Deepam workshop; the other workshops took place in New Delhi. These workshops made a valuable contribution to, and facilitated consensus on, study conclusions and recommendations.

Regional Dissemination Workshop

5.9 A regional workshop on Household Energy, Indoor Air Pollution and Health was held on 9–10 May 2002 in New Delhi. This was organized by the World Bank and Tata Energy Research Institute (TERI) in partnership with a number of government agencies, such as the Planning Commission, the Ministry of Non-Conventional Energy Sources (MNES), the Ministry of Environment and Forests (MEF), and the Indian Council of Medical Research (ICMR). The event was co-sponsored by the World Health Organization, the United States Agency for International Development (USAID), the United Kingdom Department for International

Development (DFID), and the Shell Foundation, indicating that an increasing number of donors are considering IAP to be an important health- and poverty-related issue. More than 150 participants from 15 countries attended, including government officials from health, environment, energy, and rural development agencies; practitioners (representing NGOs, the private sector, and community groups); policy analysts and researchers; and representatives of various donor agencies and leading international experts.

5. 10 The workshop disseminated the results and recommendations of this study to this important audience. Furthermore, it provided a large forum in which to exchange information on recent developments, programs, successes, and challenges in India and other developing countries of Asia. This exchange improved knowledge of specific mitigation measures, strengthened commitment among various players, and facilitated future action programs.

5.11 The workshop covered a range of IAP-related issues in a holistic, multi-sectoral fashion. Topics discussed included exposure assessment and health impacts, promotion of cleaner fuels, provision of better stoves and housing, global co-benefits of addressing IAP, and the role of rural communities and women. Recommendations of the workshop that reinforce findings of this study and place them in a broader context by highlighting other dimensions of the IAP problem are given in Annex 6.

Facilitating Global Knowledge and Networking

Support to International Conferences on IAP

5.12 In October and November 2000, two major international conferences were held in India to address issues closely related to indoor air pollution: the International Conference on Environmental and Occupational Respiratory Diseases (in Lucknow) and the International Conference on Biomass-based Fuels and Cooking Systems (in Pune). The events involved top medical experts, researchers, stove technologists and policy makers. This component of the study co-sponsored both events, bringing additional Indian experts and Bank staff, who contributed to the discussions and recommendations.

The IAP Newsletter

5.13 A bimonthly newsletter titled *Indoor Air Pollution: Energy and Health for the Poor* was produced and distributed—in print and electronically—to over 80 institutions in India and to an international network of researchers and institutions. Eight issues of the newsletter have been published on the following topics:

- The health effects of IAP
- Reports from two international conferences held in India on issues related to IAP
- Women and energy
- Household energy and poverty
- Review of India’s National Programme on Improved Stoves
- The evaluation of the Deepam Scheme in Andhra Pradesh

- Assessment of exposure to IAP and its determinants in Andhra Pradesh
- The report of the Regional Workshop on Household Energy, Indoor Air Pollution and Health

5.14 National and international audiences have found this IAP newsletter very useful. The distribution list has grown over time as requests to be included in the mailing list have come from various corners. Many subscribers have expressed the need to sustain such an effort beyond completion of this study.

Distance Learning Training Module and Video on IAP

5.15 In collaboration with the World Bank Institute—a training branch of the World Bank Group that is developing a distance-learning training course on air quality management in Asia under the Clean Air-Asia Initiative—the study team produced a videotaped training module on IAP. This was the first time that IAP issues had been added to the training course, which had traditionally focused on urban air quality. The training module is designed for government officials, technocrats, and policy makers, and covers a broad range of issues, including health effects of IAP, mitigation options, and policy barriers. In addition, a short video on IAP for a broader audience has been made.

Building Partnerships to Address IAP

Sharing Experience With China

5.16 In February 2002, several members of the study team participated in a workshop in China, organized by the Ministry of Health, to help design an intervention study to assess the exposure and health impact of improved stoves. The team's contributions were based on findings and lessons learned from this study in India.

Working with a Multi-Sectoral Steering Committee

5.17 For this multidisciplinary program, a Steering Committee was formed comprising government officials from several organizations that deal with various aspects of IAP. These included the Planning Commission (GOI), the Ministry of Non-Conventional Energy Sources (GOI), the Ministry of Environment and Forests (GOI), the Indian Council of Medical Research, the Oil Coordination Committee[20] of the Ministry of Petroleum and Natural Gas (GOI), the Department of Civil Supplies (GOAP), the Department of Environment Forest Science and Technology (GOAP), and the Andhra Pradesh Pollution Control Board. The committee served as a resource for technical consultation on various program areas (such as improved stoves, health aspects, and petroleum sector policies) and provided useful guidance whenever required. The committee also facilitated partnerships with various government departments and agencies in support of the advocacy efforts.

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20 The Oil Coordination Committee was dissolved in early 2002.

Impact: Evidence of New Thinking

5.18 During the course of the study, a number of positive developments in the field of indoor air pollution have been observed. Although these developments have resulted from many trends and initiatives, the synergy among various players and efforts is indeed encouraging to note.

Changes on the Ground

5.19 Within the Government of India, the following developments should be noted:

- The Ministry of Non-conventional Energy Sources has initiated a research study, the first of its kind in India, to evaluate the exposure and health impacts of a new generation of durable improved stoves, with the aim of making health benefits the cornerstone of a marketing strategy for improved stoves. The study covers five regions in India and its implementation will involve several GOI technical back-up units.
- For the first time, IAP has found a place in the Tenth Five Year Plan of the Government of India. The Indian Council of Medical Research was instrumental in lobbying for this change and has included IAP-related awareness raising efforts in its maternal and child health programs.
- The Ministry of Environment and Forests has included IAP issues in the activities of its Environmental Health Cell.

Influencing the Donor Community

5.20 Within the World Bank and the overall ESMAP program, IAP has received increased attention. Three Bank sectoral strategies—energy, environment, and public health—now consider IAP a priority issue. Several new initiatives in different parts of the world (e.g., China, Guatemala, Mongolia) are underway, and ESMAP supported the international Indoor Air 2002 Conference. The World Health Organization, in a paper for the EU Macroeconomic Commission on Health, called for concerted multi-sectoral action to mitigate the health impacts of IAP from the use of solid fuels. Bilateral donors, such as USAID and DFID, are also paying greater attention to this problem. One of the indications of growing interest and commitment from the donor community was strong support from various donor agencies to the regional workshop on Household Energy, Indoor Air Pollution and Health in New Delhi. Together, these activities are expected to create a solid basis for addressing IAP in a sustained manner over the long term.

6

Conclusions

6.1 Indoor air pollution is a multi-dimensional problem, and strategies to reduce its heavy toll on the health of rural families should integrate knowledge and perspectives from different sectors. By approaching the IAP problem in a multi-sectoral fashion and integrating the findings of individual components, the study strengthens its policy conclusions and sheds additional light on both gaps and opportunities in IAP mitigation efforts. Specifically, it responds to the following set of needs:

- The need to have better information on exposure levels and related health risks for population sub-groups, as well as to be able to assess the effectiveness of various interventions in reducing these;
- The need to find ways to deliver better energy services (both cooking fuels and methods) to rural households, including the poor;
- The need to adopt multiple mitigation strategies that would include a range of technical options and their combinations—cleaner fuels, better stoves, improved kitchen ventilation and housing type, and so on—targeted at different population groups;
- The need to involve various actors—for example, to clarify the responsibilities of government departments at different levels, to provide the right incentive framework and business environment for the private sector, and to empower communities, especially women, to improve the ways in which daily energy needs affect their lives;
- The need to raise awareness of the problem and of cost-effective solutions among all actors and stakeholders.

Strengthened Evidence of Exposure Patterns in Rural Settings

6.2 The findings of this study's exposure assessment component, conducted in the state of Andhra Pradesh, strengthen the evidence that the traditional use of biomass fuels for household daily needs exposes all members of the family to levels of air pollution (measured by 24-hour mean of RSPM) that well exceed health guidelines available for outdoor air quality. Importantly, the study shows that this holds true even (1) in a warm climate like that of Southern India, where no heating is required and these fuels are used only for cooking, and (2) when cooking is done outside the house, in a separate kitchen or in the open air, as is common in poor rural households.

6.3 The study ascertains in quantitative terms that women, in their traditional capacity as cooks, suffer from much greater exposures than other family members, whereas adult men experience the least exposure, emphasizing an important gender dimension of the IAP problem. Among non-cooks, those who are most vulnerable to the health risks of IAP—young children and elderly people—tend to experience higher levels of exposure because they spend more time indoors. This finding lends support to the results of some other studies linking household fuel use with infant and child mortality rates.

Challenges to Promoting Cleaner Fuels Among the Rural Poor

6.4 The study provides probably the strongest evidence yet that switching completely to cooking with clean fuels, such as LPG or biogas, is the best way to improve indoor air quality in rural homes and reduce exposure for all family members, including women-cooks (see Figure 6.1). However, families using multiple fuels that resort to clean fuels sparingly and for minor cooking needs do not enjoy anywhere near the same benefits of exposure reduction. At the same time, evaluation of an LPG promotional program in Andhra Pradesh, the Deepam Scheme, highlights significant challenges to the use of LPG as the primary cooking fuel by the majority of rural households.

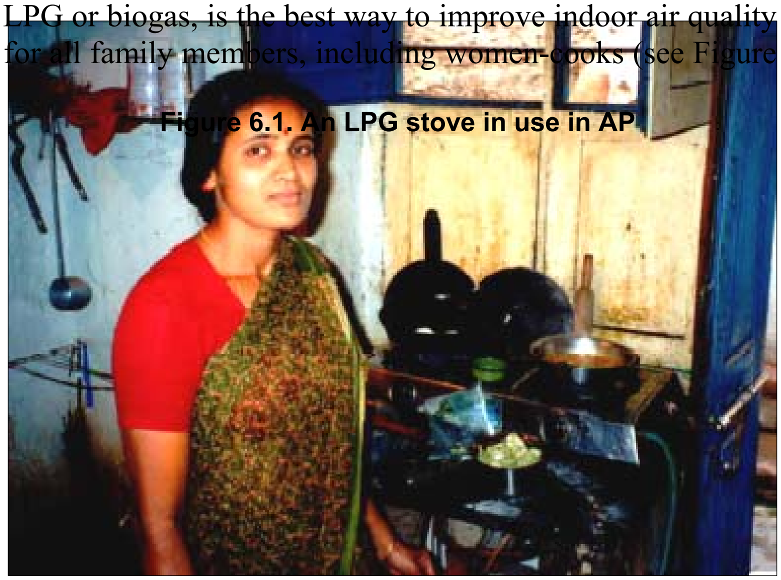
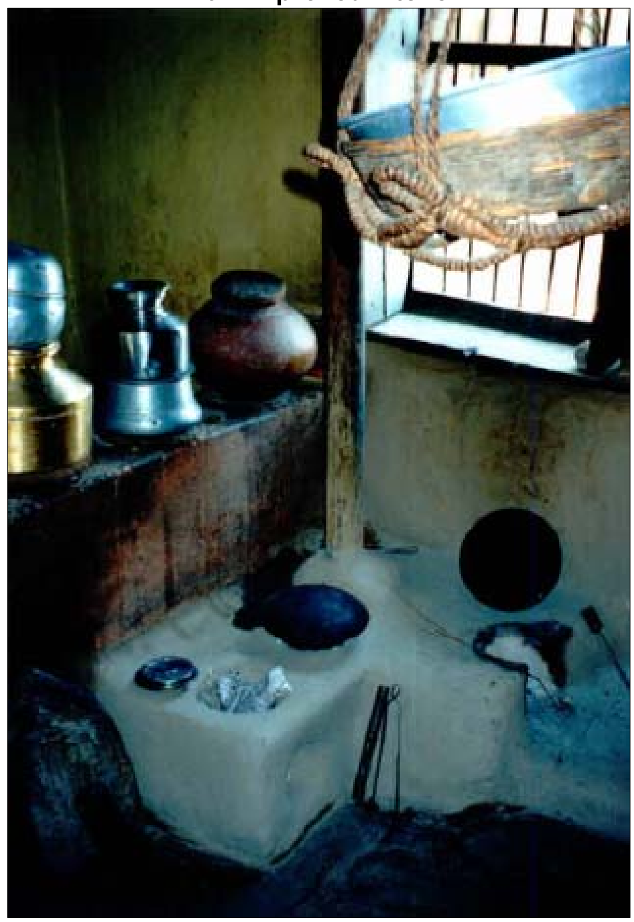


Figure 6.1. An LPG stove in use in AP

6.5 The economics of LPG service, with its relatively high operating cost, impede the design of an effective subsidy scheme targeted to the poor. Price subsidy is not sustainable from the fiscal perspective and almost entirely benefits better-off urban customers. Means-tested capital subsidy, such as the GOAP connection-fee waiver for BPL families, addresses both these problems. However, it does not take away the barrier of high cost of cylinder refills, which makes substantial use of LPG prohibitive for poor households. The development of LPG market in rural areas is thus constrained by significant incremental costs of switching to LPG from biomass cooking while the majority of rural households are cash-strapped.

6.6 The two actions that will facilitate increasing access to LPG in rural areas are (1) deregulating the petroleum sector at the national level and (2) creating a level playing field for all LPG distributors in promotional initiatives at the state level. Another factor, and a helpful element in any LPG marketing strategy, could be to educate people about the health benefits of cleaner household energy through awareness campaigns. LPG promotional programs that specifically target the poor are likely to be more effective if they focus on areas where biomass is diminishing and the implicit costs of biomass cooking are high.

Figure 6.2. An improved stove in an improved kitchen



The Important Role of Ventilation

6.7 This study's exposure-assessment component identified means other than fuel switching to significantly reduce exposure to IAP. An extensive investigation of the household-level determinants of exposure in rural Andhra Pradesh singled out three parameters—fuel type, kitchen configuration, and/or kitchen ventilation condition—as the key predictors of household concentration levels. While keeping in mind a pilot nature of this modeling exercise and the need for further validation, there are major policy implications in the finding that kitchen ventilation and configuration turn out to be the principal factors, in addition to fuel type, that significantly affect the levels of exposure (see Figure 6.2).

6.8 There currently exist only two widely recognized exposure indicators for household environmental health, both of which are related to water quality and hygiene: *levels of access to clean water and to sanitation*. These are reported annually and separately for rural and urban areas by nearly every country and are commonly cited as measures of ill-health risk and indicators of poverty. These indicators are strikingly parallel to two possible new indicators for household air-quality-related hygiene: *levels of access to clean fuel and to ventilation*. Both indicators, although not ideal measures of true exposure and risk, have the extremely important benefit of being easily and cheaply determined by rapid surveys requiring no measurements. In both cases, they do not claim to specify what households actually do on a daily basis, but rather exemplify the *potential* represented by what is physically present—as indicated by the term *access*.

6.9 If validated with other data and refined models in future studies, these findings could also influence the design of large-scale survey instruments, such as the Census or National Sample Survey, by introducing questions on the key determinants of exposure (in addition to the fuel type already used by these surveys), with a view to obtaining exposure estimates for population sub-groups.

6.10 On the intervention side, findings from the analysis of exposure determinants, combined with the evaluation of the Deepam Scheme, stress the importance of continuing to explore and support mitigation options that may be more affordable and appropriate for many rural households, such as simple modifications in housing design that separate kitchen from living areas and/or improve ventilation conditions. As such, both study components serve as a reminder that improved biomass stoves with chimneys venting smoke outside the house remain one of the key interventions with yet-untapped potential, provided that they are well designed, installed, operated, and maintained.

Tapping the Potential of Improved Stoves

6.11 In this light, this study's evaluation of the NPIC's implementation in six Indian states gains additional relevance. While the overall performance of the NPIC fell short of international best practice, these states' programs fared better than most others in India and achieved some good results. The lessons learned from the evaluation are largely consistent with those learned from successful programs in other countries. This record provides a good basis for developing the next generation of stoves and the next stages of implementing the stove programs at the state level.

6.12 One important conclusion is the continuing need for new strategies to reach the poorest. The most successful programs around the world have achieved full commercialization. Now that the national program is being transferred to the state level, there is a need and an opportunity to promote commercialization in order to make the use of improved stoves sustainable in the long run. However, commercial programs tend to work better for populations that expend cash income for stoves and can afford the expense. The needs of the poorer households appear to be either underserved or involve simple adaptations of stoves designed for more affluent rural households. In India, the increase in subsidies for the poor has not led to increased participation in the program, indicating the need for innovative approaches to target these users.

6.13 Another critical lesson is that more attention should be given to smoke removal in stove design and dissemination (marketing) strategies, complemented with publicizing the health benefits of reduced smoke. This conclusion is based not only on the evidence of the health effects of IAP from a panel of international studies, but also on the perceptions of improved-stove users in rural India who attached highest values to smoke removal and cleanliness. So far, the emphasis in most of the improved-stove programs in India and worldwide has been on energy efficiency rather than on indoor air pollution. With this new evidence of health impacts and user preferences, the development of stoves that have a long term ability to vent smoke outside the house—in addition to being efficient, easy to use and adapted to user needs—is of paramount importance.

Facilitating Behavioral Change

6.14 One of the most effective strategies for mitigating IAP is to make sure rural communities know about the problem and show them what they can do about it—in other words, to raise awareness and disseminate information. This is important for other major stakeholders as well. The multi-sectoral nature of IAP requires extensive sharing of knowledge and experiences across different sectors, actors, and technical areas. Advocacy and information dissemination are necessary for mobilizing commitment and strengthening collaboration among government agencies, NGOs, and the private sector, not to mention rural communities. During this study, a significant effort has been made to disseminate information on IAP issues and raise the awareness of governmental institutions and other players inside and outside India. The study team organized several workshops, publication of newsletters, and production of a video film on IAP. This effort seems to have yielded some positive impact, contributing to growing attention to IAP. However, a critical test of whether the created momentum can be sustained lies ahead.

Combining Research and Action

6.15 A priority area for future research on IAP, which could better inform these advocacy and awareness campaigns as well as guide the design of cost-effective interventions, is to assess and document, in quantitative terms and using prudent methodologies, the actual impact of better stoves on reducing exposure in the real field conditions of rural homes over a long-term period of stove functioning. Equally important would be to strengthen evidence, currently available only from outdoor air pollution studies and one IAP study in Kenya, on linkages between different levels of exposure to smoke and changes in the relevant health indicators.

6.16 The unfinished agenda for improving household energy services and housing conditions in rural India, with the respective improvement in health and the quality of life, is enormous. The growing body of evidence of the health impacts of IAP is strong and points to a problem of alarming proportion. The remaining gaps in research should not be used as an excuse to delay actions, especially if the focus in mitigation programs is given to adopting low-cost measures and developing commercially viable modes of energy services delivery, in line with international best practice and the recommendations of this study. An encouraging sign is an increasing recognition by India, as well as other countries and the international community at large, that the traditional ways of using biomass fuels impose a major health risk, particularly for women and children in the developing world, and that a dedicated effort is required to address the problem.

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Annex 1. Overview of IAP-Related Questions in State and National Surveys

Table A1.1. List of Key Variables Available from Current National and State Level Surveys

Source	*Year of Administration*	*How Often*	*Questions on Fuel Used For Cooking/Lighting*	*Codes*	*Questions on Housing Characteristics*	*Codes*
Census 1991 House-list Schedule	1991	Every 10 years	Q.19 Type of fuel used for cooking.	1. Cow-dung cakes, 2.Electricity, 3.Coal/coke/lignite, 4.Charcoal, 5. Cooking gas, 6. Wood, 7.Biogas, 8. Kerosene, 9.Others	Predominant construction material of the census house. Q.4. Wall Q.5. Roof Q.6. Floor	Wall (Q.4) 1.Grass / leaves /etc 2. Mud, 3. Unburnt brick, 4. Wood, 5. Burnt-brick 6. GI Sheets / Metal sheets, 7. Stone, 8. Cement concrete, 9. Ekra, 10. Other Roof(Q.5)1.Grass/leaves/reeds/Unburnt brick / bamboo, 2.Tiles / slate, 3.Corrugated iron, zinc or other metal sheets, 4. Asbestos sheets, 5. Brick / sand and lime, 6.Stone, 7. RCC/RBC, 8.Others Floor (Q.6) 1. Mud, 2. Wood/ planks, 3. Bamboo/logs 4. Brick, stone, lime,5. Cement, 6. Mosaic / tiles, 7. Others
Census 2001 House-list Schedule	2001	Every 10 years	Q. 22 Source of light. Q. 27 Fuels used for cooking	Q. 22. 1. Electricity, 2.Kerosene, 3. Solar,4. Other oil, 5. Any other, 6. No light Q. 27. 1. Firewood 2. Crop residues 3. Cow dung cake 4. Coal/lignite/charcoal 5. Kerosene, 6. LPG 7. Electricity, 8. Biogas 9. Any other, 0. No cooking	Predominant construction material of the floor, wall, and roof of the census house. Q.4 Floor Q.5 Wall Q 6. Roof Q.26. Kitchen within the house Q.17. Number of dwelling rooms within the households (Record 0.1.2.3...)	Floor (Q. 4) 1. Mud, 2. Wood / bamboo, 3. Brick, 4. Stone, 5. Cement 6.Mosaic floor / tiles, 7.Any other. Wall (Q.5) 1. Grass/ thatch Bamboo etc, 2. Plastic / polythene, 3. Mud / unburnt brick, 4. Wood, 5. GI Metal / asbestos sheets, 6. Burnt brick, 7. Stone, 8. Concrete, 9. Any other. Roof(Q.6) 1. Grass / thatch Bamboo/wood/mud, 2. Plastic / polythene, 3. Tiles, 4. Slate 5. GI / metal / asbestos sheets, 6. Brick, 7. Stone, 8. Concrete, 9. Any other. Q.26. 1. Yes, 2. No, 3. Cooking in open, 4. No cooking.

Source	*Year of Administration*	*How Often*	*Questions on Fuel Used For Cooking/Lighting*	*Codes*	*Questions on Housing Characteristics*	*Codes*
NFHS 1 (National Family Health Survey)	1992–1993	-	Q.30.What type of fuel does your household mainly use for cooking? Q.27.What is the main source of lighting for your household.?	Q.30. 01.Wood, 02. Cow-dung cakes, 03. Coal/coke/ lignite, 04. Charcoal, 05. Kerosene, 06. Electricity, 07.Liquid Petroleum gas, 08. Biogas, 09. Other specify Q.27. 1. Electricity, 2. Kerosene, 3. Gas, 4. Oil, 5. Others	Q.28.How many rooms are there in your household? Q.29.Do you have a separate room which is used as a kitchen? Q.31. Type of house Roof__Wall__Floor__	Q.28. No of rooms__ Q.29. 1. Yes, 2. No Q30. 1. Pucca, 2. Kacha, 3. Semi-pucca
NFHS 2 (National Family Health Survey)	1998–1999	-	Q.37.What type of fuel does your household commonly use for cooking? Q.38.What other types of fuel does your household commonly use for cooking or heating.? Q.34.What is the main source of lighting for your household.?	Q.37. 01.Wood, 02. Crop residues, 03. Dung cakes, 04. Coal/coke/lignite, 05. Charcoal, 06. Kerosene, 07. Electricity, 08. Liquid petroleum gas, 09. Biogas, 96. Other specify Q.38. A. Wood, Bicorn residues, C. Dung cakes, D. Coal/coke/lignite, E. Charcoal, F. Kerosene, G. Electricity, H. Liquid petroleum gas, I. Biogas, X. Other specify, Y. No other types. Q.34. 1. Electricity,2. Kerosene,3. Gas, 4. Oil , 6. Other	Q.35. How many rooms are there in your household. Q.36. Do you have a separate room which is used as a kitchen? Q.49. Type of house. Roof__ Wall__ Floor__	Q.35. No. of rooms __ Q.36. Yes. 1, No. 2 Q.49. 1. Pucca, 2. Semi-pucca, 3. Kacha
NSS (Household Energy Survey)	50th round 1993–1994	5 years (Quinquennially)	Block 3, Item 11. Primary source of energy for cooking. Block3, Item 12. Primary source of energy for lighting 5.1(460-479) Cash and purchase of fuels & lights during the last 30 days.	Item 11, 01. Coke, coal 02. Firewood and chips. 03. LPG, 04.Gas, 05. Dung cake, 06. Charcoal, 07. Kerosene, 08. Electricity, 09. Others, 10. No cooking arrangements Item 12, 1. Kerosene, 2. Other oil, 3. Gas, 4. Candle, 5. Electricity , 6. No lighting arrangement, 9. Others.		
Multi Purpose Household Survey (MPHS)	1995	-	-	-	Q 4. Type of shelter	Q 4. Pucca- Kacha
Human Development Survey (HDS)	2000 January (Janmabhoomi Program)	-	Q. 45. Main source of cooking	Q.45. 1. LPG, 2. Kerosene, 3. Coal, 4. Electricity, 5.Biogas, 6. Fuel wood, 7. Other.	Q.9. Type of house	Q.9. 1. RCC, 2. Tiles, 3. Asbestos sheets

Annex 2. Assessing Exposure: Methodology and Results

Exposure Reconstruction Models

A2.1 Exposures to indoor air pollution are estimated using two methods, both relying on the same time-activity data: (1) 24-hour area measurements and (2) relative ratios of the 24-hour averages to the cooking and non-cooking window concentrations, respectively, calculated by real-time (PDRAM) monitoring in a few households. Accordingly, two models of exposure were constructed. The first (Model 1) used average 24-hour concentrations at the kitchen/living/outdoor locations, applied it to the total time spent by each individual member at these locations during the preceding 24 hours (obtained from time-activity records), and calculated the average 24-hour exposure.

$$\text{Average 24-hour exposure (Model 1)} = \frac{K1*T1+L1*T2+O1*T3}{T1+T2+T3}$$

Where K1= 24-hour average concentration in kitchen (Loc.1)
T1= Total time spent in kitchen
L1= 24-hour average concentration in living area (Loc.2)
T2= Total time spent in living area
O1= 24-hour average concentration outdoors (Loc. 3)
T3= Total time spent outdoors
and T1+T2+T3= 24

A2.2 Since the 24-hour average concentrations determined gravimetrically does not yield information on relative concentrations during cooking and non- cooking times this model did not address the contributions originating from differences between cooking and non-cooking concentrations. For example, a cook may spend 3 hrs in kitchen while cooking (and thereby experience much higher concentrations) while another member may spend 3 hrs at the same location during a non-cooking window but yet the contributions to 24 exposures from this location will remain the same for the two individuals, in Model 1.

A2.3 In order to refine this calculation, PDRAM records were used to determine relative ratios of 24-hour concentrations to concentrations during cooking and non-cooking windows (see Table A2.1). Although the size fractions monitored by the PDRAM (<10μm) and the gravimetric cyclones (50 percent cut off of 4 μm) are somewhat different and so is the analytical technique (light scattering versus gramimetric), it was assumed that the ratios would be comparable. The 24-hour average concentrations for each location were thus split into concentrations during cooking and non-cooking periods. Since detailed time- activity records had information not only where an individual was present but also when, it was possible to split the total times at each location (from Model 1) into times spent at the location during cooking/non-cooking periods. Thus Model 2 was constructed using the following formula:

$$\text{Average 24-hour exposure (Model 2)} = \frac{K1a*T1a+K1b*T1b+L1a*T2a+L1b*T2b+O1*T3}{T1a+T1b+T2a+T2b+T3}$$

Where K1a= Average concentration in kitchen (location1) during cooking periods

T1a= Total time spent in kitchen during cooking periods
K1b= Average concentration in kitchen (location1) during non-cooking periods

T1b= Total time spent in kitchen during non-cooking periods
L1a= Average concentration in living area (location 2) during cooking periods
T2a= Total time spent in living area during cooking periods
L1b= Average concentration in living area (location 2) during non-cooking periods
T2b= Total time spent in living area during non-cooking periods
O1= 24-hour average concentration outdoors (location 3)
T3= Total time spent outdoors

and T1a+T1b+T2a+T2b+T3= 24

A2.4 Outdoor concentrations were not adjusted in Model 2 as PDRAM measurements were not taken outdoors, and it was assumed that the differences in outdoor concentrations between cooking and non-cooking windows is not significant. The exposure calculations have been thus performed on a case-by-case basis, using individual time- activity records together with the particular micro-environmental concentration information collected in the concerned household.

Table A2.1. Ratios of 24-Hour Average Concentrations in Kitchen and Living Areas Relative to Concentrations in These Areas During Cooking/Non-Cooking Windows

		Cooking periods		*Non-cooking periods*	
Type of Fuel	*Type of Kitchen*	*Kitchen Area*	*Living Area*	*Kitchen Area*	*Living Area*
Solid fuels	Indoor kitchens w/ partitions	3.87	1.42	0.57	0.89
	Indoor kitchens w/o partitions	5.24	2.96	0.28	0.60
	Outdoor kitchens w/ partitions	3.87	1.34	0.52	0.81
	Outdoor cooking	4.22	3.40	0.75	0.74
Clean fuels (Gas users only)	Indoor kitchens w/ partitions	1.37	1.35	0.94	0.93
	Indoor kitchens w/o partitions	1.64	2.12	0.90	0.74
	Outdoor kitchens w/ partitions	1.99	1.79	0.83	0.82

Utility of Real-Time (PDRAM) Measurements

A2.5 The PDRAM monitor was mainly used for generating real time monitoring data, which would allow the determination of ratios of 24-hour averages to average concentrations during cooking and non-cooking windows. Also, comparison of 24-hour averages obtained using the PDRAM instrument with those obtained gravimetrically would produce additional information on the relative ratios of these size fractions in biomass smoke. Ratios obtained from PDRAM data are listed in Table A2.1.

Methodology for Recording Time-Activity

A2.6 Time- activity records were obtained from members of the households, which included women cooks, women not involved in cooking, children, and men. Time-activity records were not collected from infants below the age of 2. Records were obtained on the basis of a 24-hour recall that detailed the type, location and duration (including start and stop times) of each activity carried out. In about 10 percent of the households, independent field assistants were used to assess the bias in time activity recalls. The monitoring data (obtained from the gravimetric analyses) provided 24-hour average area concentrations for three microenvironments viz. kitchen, living area and outdoors. These concentrations were used with real time measurements (described above) to compute the ratio of 24-hour averages to average concentrations during cooking and non-cooking windows. Using area concentrations at each microenvironment together with the total duration spent at each location during cooking/non-cooking windows gave the 24-hour exposures.

A2.7 Model 1 predicts lower exposures than Model 2 for both cooks and non-cooks amongst solid-fuel users. The difference is most pronounced for cooks as their exposures are underestimated by not addressing cooking window concentrations. Although Models 1 and 2 are different in absolute values, the trends amongst sub-categories of household members are similar as determined after analyses using both model values. Hence, results of comparisons across fuel and kitchen types are presented in the main text and below using only Model 2.

Results of Exposure Assessment

A2.8 Tables A2.2 through A2.4 detail 24-hour exposure concentrations across different family members, solid versus clean-fuel-using households, and various kitchen configurations.

Table A2.2. 24-Hour Average Exposures for Household Sub-Groups in Solid-Fuel-Using Households

Sub-groups	*Arithmetic Mean*	*N*	*Standard Error of Mean*	*Geometric Mean*
COOKS				
Female (6–15)	467	11	159	293
Female (16–60)	442	267	26	318
Female (61–80)	431	19	117	282
NON COOKS				
Female (2–5)	254	23	67	151
Female (6–15)	237	162	14	185
Female (16–60)	276	106	27	191
Female (61–80)	337	26	57	232
Male (2–5)	268	33	47	178
Male (6–15)	227	163	15	167
Male (16–60)	148	278	5	128
Male (61–80)	260	62	40	165

Table A2.3. 24-hour Average Exposures for Household Sub-Groups in Gas-using Households

Sub-groups	*Arithmetic Mean*	*N*	*Standard Error of Mean*	*Geometric Mean*
COOKS				
Female (6–15)	79	1	8	79
Female (16–60)	79	25	7	70
Female (61–80)	103	2	42	93
NON COOKS				
Female (2–5)	69	1	.	69
Female (6–15)	77	9	7	74
Female (16–60)	72	10	8	66
Male (2–5)	77	9	7	73
Male (6–15)	82	10	6	79
Male (16–60)	79	32	3	76
Male (61–80)	88	7	18	77

Table A2.4. 24-hour Exposures for Cooks and Non-Cooks in Solid-Fuel-Using Households Across Kitchen Configurations

Type of Kitchen	*Mean*	*N*	*Standard Error of Mean*	*Geometric Mean*
COOKS				
Indoor Kitchens				
Indoor kitchen with partitions	520	76	56	368
Indoor kitchen without partitions	540	73	50	408
Outdoor kitchens				
Outdoor kitchen with partitions	439	83	52	304
Outdoor cooking	259	70	23	212
NON COOKS				
Indoor Kitchens				
Indoor kitchen with partitions	264	232	17	185
Indoor kitchen without partitions	280	155	17	223
Outdoor Kitchens				
Outdoor kitchen with partitions	178	264	11	133
Outdoor cooking	175	220	10	137

Annex 3. Development of a Methodology for Predicting Exposure

A3.1 This annex summarizes the outcomes of an extensive modeling exercise to predict kitchen and living areas concentrations in rural households on the basis of information that is relatively easy to obtain through household surveys.

Modeling

Linear Regression

A3.2 Initially, a linear regression model was used to predict quantitative exposures on the basis of fuel use and housing characteristics. Linear regression is a modeling technique used to describe the relationship between a dependent (outcome) variable and a set of independent (predictor or explanatory) variables. Since both kitchen and living concentrations are approximately lognormally distributed (Figures A3.1-4), loglinear regression models were used.

Modeling with Categories of Concentration

A3.3 Linear regression models were created using continuous-outcome variables for kitchen and living-area concentrations. However, because there was so much variability in the kitchen and living-area concentrations, especially within the wood and mixed-fuel categories, an overall linear regression model did not yield much information. Subsequently, modeling was conducted using binary concentration categories and applying logistic regression and classification and regression trees (CART) techniques.

Model Inputs

Continuous Dependent Variables

Kitchen Concentrations

A3.4 Table A3.1 summarizes the kitchen concentrations. Kitchen concentrations are approximately lognormally distributed. See Figures A3.1 and A3.2.

Table A3.1. Summary of Kitchen Concentrations

	Kitchen Concentration RSPM ($\mu g/m^3$)	*ln (Kitchen Concentration) RSPM ($\mu g/m^3$)*
N	385	385
Geometric Mean	310	5.64
Mean	506	5.74
Minimum	17.9	2.89
Maximum	4000	8.29
Std. Error of Mean	29.5	.005

Figure A3.1. Kitchen Concentration in µg/m³

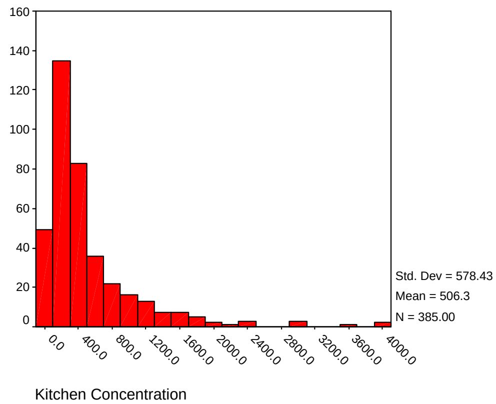
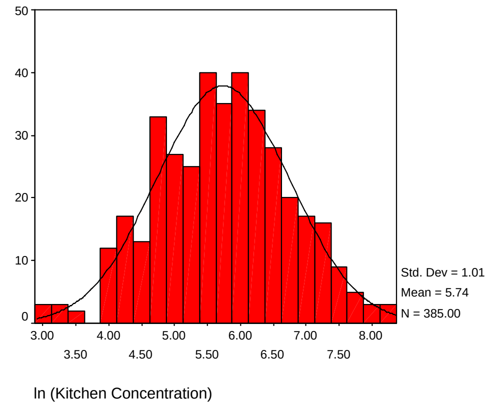


Figure A3.2. ln (Kitchen Concentration) in µg/m³



Living-area Concentrations

A3.5 Table A3.2 summarizes living-area concentrations. As with kitchen concentrations, living-area concentrations are approximately lognormally distributed. See Figures A3.3 and A3.4.

Table A3.2. Summary of Living-area Concentrations

	Kitchen Concentration RSPM (µg/m³)	*ln (Kitchen Concentration) RSPM (µg/m³)*
N	375	375
Geometric Mean	191.8703	5.1517
Mean	328.371	5.2568
Minimum	12.2	2.5
Maximum	2739.09	7.92
Std. Error of Mean	20.4128	5.36E-02

Figure A3.3. Living-Area Concentration in µg/m³

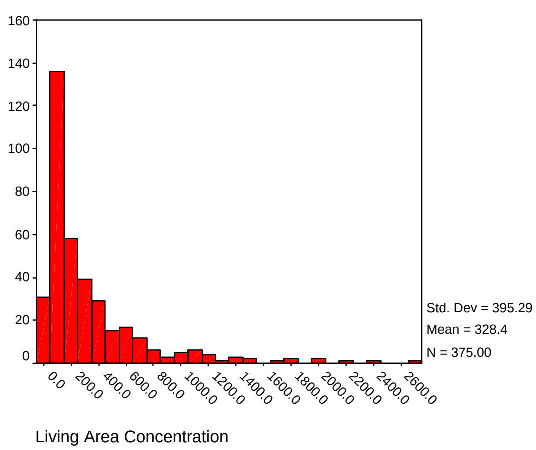
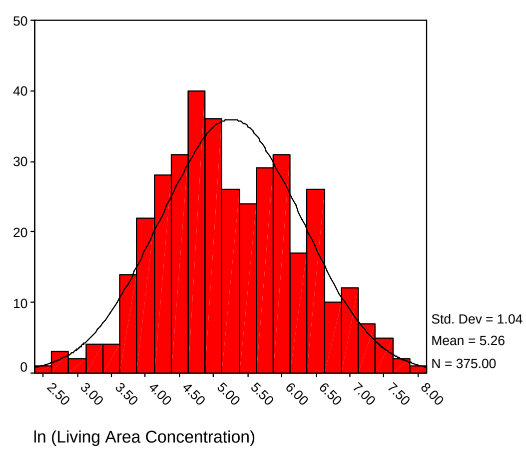


Figure A3.4. ln (Living-area Concentration) in µg/m³



Binary Dependent Variables

A3.6 Although using binary concentration categories results in a loss of statistical power, it increases the practical application and interpretation of the models created. In order to create binary concentration categories, we had to define a cut-off between high and low concentrations. There is no universal or completely objective way to determine what constitute a "high" concentration under these circumstances. There is no epidemiological evidence to suggest a cut-off point, for example, since the epidemiological literature is based on qualitative categories of exposure, such as the type of fuel used for cooking, whether or not children are indoors during cooking, or whether or not children are carried on the backs while cooking is taking place. At the same time, because there may be a flattening of the exposure/response curve at higher concentration levels, it is not possible to extrapolate from studies conducted in developed countries with much lower concentrations. Indeed, the most recent WHO air quality guidelines specify that the health impacts slope for PM_{10} (RSPM is a significant proportion of PM_{10}, which includes all particles less than 10 μm in diameter) should not be extrapolated beyond 150 $\mu g/m^3$ (WHO 1999). Even under the conservative assumption that RSPM is 50 percent of PM10, only 30 households in this study would have average kitchen concentrations below 150 $\mu g/m^3$.

A3.7 In the absence of a clear approach, we had to make a judgment as to where the cut-off should be made. We decided to start with a value close to the geometric mean of the kitchen and living-area concentrations and thus 300 $\mu g/m^3$ was used as the cut-off point for kitchen concentrations, and 200 $\mu g/m^3$ was used as the cut-off point for living-area concentrations. All households at or above these cut-offs were considered "high" concentration households. This allowed us to have relatively even numbers of high- and low-concentration households, thus improving the statistical stability of the model. We also conducted a sensitivity analysis to evaluate changes if other cut-off points were chosen.

Independent Variables

Table A3.3. Analysis of Variance: ln (Kitchen Concentration)

			ln (Kitchen Concentration)	
		n	*Mean*	*Std. Dev.*
Fuel Category**				
	Wood	259	-1.08	0.88
	Mixed	83	-0.75	0.94
	Kerosene	11	-1.86	0.69
	Gas	32	-2.78	0.63
Kitchen Type**				
	Indoor with partition	110	-1.26	1.19
	Indoor without partition	104	-0.92	0.95
	Separate indoor kitchen outside the house	94	-1.07	0.98
	Open air kitchen outside the house	77	-1.51	0.72
Separate Kitchen				
	No	177	-1.18	0.91
	Yes	208	-1.17	1.09
Roof Type				
	Pucca[1]	264	-1.23	1.05
	Kaccha[2]	121	-1.04	0.91
Wall Type**				
	Pucca[1]	81	-1.42	0.95
	Semi-pucca	69	-1.39	1.08
	Kaccha[2]	235	-1.02	0.99
Floor Type**				
	Pucca[1]	143	-1.43	1.08
	Semi-pucca	16	-1.66	1.20
	Kaccha[2]	226	-0.97	0.91
Housing Type**				
	Pucca[1]	38	-1.63	1.00
	Semi-pucca	276	-1.20	1.02
	Kaccha[2]	71	-0.82	0.88
Main Stove**				
	Traditional #1	319	-0.99	0.88
	Traditional #2	4	-1.68	1.40
	Improved	21	-1.13	1.15
	Kerosene	9	-1.73	0.79
	LPG	26	-2.73	0.62
	Biogas	6	-3.03	0.63
Kitchen Ventilation**				
	Poor	102	-0.75	0.90
	Moderate	151	-1.16	1.05
	Good	55	-1.51	1.14

*F-statistic for one-way Anova significant at $p<0.05$ level

**F-statistic for one-way Anova significant at $p<0.001$ level

[1]*Pucca* refers to more durable higher quality materials and construction techniques, e.g., a brick house with a tile roof.

[2]*Kachha* refers to more temporary and lower quality materials and techniques, e.g., a mud house with a thatched roof.

Table A3.4. Analysis of Variance: In (Living-Area Concentration)

			ln (Living-Area Concentration)	
		n	*Mean*	*Std. Dev.*
Fuel Category**				
	wood	251	-1.59	1.02
	mixed	87	-1.45	0.98
	kerosene	9	-1.96	1.19
	gas	28	-2.74	0.62
Kitchen Type**				
	indoor with partition	108	-1.81	1.09
	indoor without partition	89	-1.03	1.00
	separate indoor kitchen outside the house	89	-1.89	1.00
	open air kitchen outside the house	89	-1.84	0.79
Separate Kitchen**				
	no	175	-1.44	1.00
	yes	200	-1.84	1.04
Roof Type				
	pucca	254	-1.67	1.07
	kachha	121	-1.62	0.97
Wall Type*				
	pucca	76	-1.99	1.06
	semi-pucca	66	-1.66	0.95
	kachha	233	-1.54	1.03
Floor Type*				
	pucca	131	-1.81	1.07
	semi-pucca	17	-2.20	1.20
	kachha	227	-1.52	0.99
Housing Type*				
	pucca	36	-2.12	1.17
	semi-pucca	266	-1.61	1.02
	kachha	73	-1.56	1.00
Main Stove**				
	traditional #1	318	-1.53	0.98
	traditional #2	3	-1.50	1.17
	improved	20	-2.01	1.27
	kerosene	6	-2.09	1.47
	LPG	22	-2.66	0.65
	biogas	6	-3.05	0.38
Kitchen Ventilation**				
	poor	94	-1.22	1.01
	moderate	136	-1.65	1.04
	good	55	-2.04	1.18

*F-statistic for one-way Anova significant at $p<0.05$ level

**F-statistic for one-way Anova significant at $p<0.001$ level

A3.8 Table A3.5 shows the variables included in the modeling process. Note that only variables shown to be significantly associated with higher concentrations were selected. Kitchen volume and roof type were not associated with kitchen or living-area concentrations. In addition, the following continuous variables were found to be associated with kitchen and living-area concentrations in univariate regression analyses, and were included in the modeling process: 1) time the main cook spends cooking and 2) number of kitchen openings. Although analysis of variance indicated that there is a significant difference in concentrations within the different stove types, stove type is highly correlated with fuel type, and was therefore dropped from the analysis.

Table A3.5. Variables Included in the Modeling Process

Variable name	*Description*	*Values*
Kitch	Kitchen concentration	Continuous variable
Lnkitch	Kitchen concentration	Continuous variable
Living	Living-area concentration	Continuous variable
Lnliving	Living-area concentration	Continuous variable
K300	Kitchen concentration (categorical)	0 = low
		1 = high
L200	Living-area concentration (categorical)	0 = low
		1 = high
fuel type	Cooking fuel	1 = wood
		2 = mixed fuel
		3 = kerosene or gas*
kitch2	Kitchen type	1 = indoor with partition
		2 = indoor without partition
		3 = separate indoor kitchen outside the house
		4 = open air kitchen outside the house*
kitsep	Separate kitchen	0 = no separate kitchen
		1 = separate kitchen*
kitvent3	Kitchen ventilation	1 = poor
		2 = moderate
		3 = good*
maintime	Time main cook spends cooking	Continuous variable
wallb	Wall type	0 = kachha
		1 = pucca
floorb	Floor type	0 = kachha
		1 = pucca
kitopenc	Number of kitchen openings	0 = 0
		1 = 1
		2 = >1

*Reference category

Results

Linear Regression

A3.9 Linear regression models were used to assess which household characteristics are associated with high concentrations of RSPM. All models use log-transformed values for kitchen and living-area concentrations. Univariate linear regression with an exclusion criterion of $p>0.25$ was used to select independent variables eligible for inclusion in the model. Stepwise selection was used to arrive at the most parsimonious model.

Table A3.6. Final Linear Regression Model for Kitchen Concentrations

Final model Adjusted $R^2 = 0.323$

Household Characteristic	*Coefficient*	*Standard Error of Coefficient*	*P>|t|*
Fuel type			
Wood	1.54	0.147	0.000
Mixed	1.86	0.165	0.000
Kerosene or Gas*			
Kitchen Type			
Indoor kitchen with partition	0.430	0.165	0.010
Indoor kitchen without partition	0.596	0.174	0.001
Separate indoor kitchen outside the house	0.424	0.158	0.008
Outdoor kitchen*			
Ventilation			
Poor	0.323	0.147	0.027
Moderate	0.132	0.132	0.322
Good*			
Constant	-3.13	0.172	0.000

*reference category

A3.10 An interaction occurs when the impact of one risk factor on the outcome variable of interest varies according to the value of another variable. For example, in this study, there was a possibility that kitchen types could impact kitchen concentrations differently depending on the type of fuel being used. Two-way analysis of variance was used to screen for the possibility of interactions between the predictor variables. In addition, all possible two-way interactions between the predictor variables were assessed. No evidence of interaction was found.

Kitchen Concentrations

A3.11 Table A3.6 shows the final model for kitchen concentrations. This model includes 3 parameters: fuel type, kitchen type, and kitchen ventilation. This model has an R^2 of 0.323, suggesting that the model explains about 32 percent of the variation in kitchen concentration.

A3.12 Part of the task of this modeling exercise was to evaluate not only the best fitting model, but also to assess the capability of the best fitting model compared to simpler models. In other words, how much better does the best model, that includes information on fuel type, kitchen type, and ventilation, perform compared to models that only include information on fuel type? Table A3.7 shows the R^2 for regression models with fewer parameters. Including information on kitchen type and kitchen ventilation clearly improves the explanatory power of the model. Including information on both kitchen type and kitchen ventilation, however, does not result in much improvement compared to adding only one of these parameters.

Table A3.7. Kitchen Concentration Models with Different Parameters

Parameters Included in the Model	*Adjusted R^2*
fuel type	0.245
fuel type + kitchen type	0.313
fuel type + kitchen ventilation	0.307
fuel type + kitchen type + kitchen ventilation	0.323

Living-area Concentration

A3.13 Table A3.8 shows the final model for living-area concentrations. This model includes the same 3 parameters as the kitchen concentration model: fuel type, kitchen type, and kitchen ventilation. This model has a lower R^2 of 0.198, however. In other words, less variation in living area is explained by the model compared to kitchen concentration. This is not surprising, since living-area concentrations are generally more distally related to solid-fuel use in the kitchen. Even in cases where the kitchen and living area are in the same room (type 1 kitchen), measurements for living-area concentration were taken in the main living space, i.e., away from the hearth. It is interesting to note that the same parameters that influence kitchen concentrations influence living-area concentrations. In particular, poor kitchen ventilation not only affects kitchen concentrations, but affects living-area concentrations in the same manner. In other words, improvements in kitchen ventilation do not occur at the expense of living room concentrations.

Table A3.8. Final Linear Regression Model for Living-Area Concentrations

Final model: Adjusted $R^2 = 0.198$

Household Characteristic	*Coefficient*	*Standard Error of Coefficient*	*P>|t|*
Fuel type			
Wood	0.893	0.179	0.000
Mixed	1.100	0.196	0.000
Kerosene or Gas*			
Kitchen Type			
Indoor kitchen with partition	0.041	0.186	0.826
Indoor kitchen without partition	0.648	0.197	0.001
Separate indoor kitchen outside the house	-0.140	0.175	0.425
Outdoor kitchen*			
Ventilation			
Poor	0.385	0.170	0.024
Moderate	0.183	0.153	0.230
Good*			
Constant	-2.80	0.202	0.000

*reference category

A3.14 Table A3.9 shows the R^2 for the living-area concentration models using different parameters. Adding information on kitchen type and kitchen ventilation more than doubles the prediction capability of the model. If only one parameter is to be added to fuel type, however, kitchen type adds more to the model that kitchen ventilation.

Table A3.9. Living-Area Concentration Models with Different Parameters

Parameters Included in the Model	*Adjusted R^2*
Fuel type	0.081
Fuel type + kitchen type	0.192
Fuel type + kitchen ventilation	0.134
Fuel type + kitchen type + kitchen ventilation	0.198

A3.15 In summary, three variables were found to predict kitchen and living-area concentrations: fuel type, kitchen type, and kitchen ventilation. Linear regression techniques had little predictive power, however. The best model for kitchen concentration could only explain around 32 percent of the variance in concentrations. This is partially due to the fact that the data consist of continuous outcome variables and mostly categorical or qualitative predictor variables.

Logistic Regression

A3.16 The coefficients in a logistic regression model are not easy to interpret, as the outcome is binary. Therefore, results are discussed in the form of odds ratios, which are simply the antilogs of the coefficients in a logistic regression model. Odds ratios represent the ratio of the odds of having the characteristic of interest among high-concentration households to that among low-concentration households. Each variable has a reference category, which is the baseline with respect to which the odds ratios for all other categories are defined. An odds ratio of 1 indicates that households with the characteristic of interest have no greater or lower risk of having a high concentration compared to those in the reference category. Odds ratios above 1 indicate an increased risk, and odds ratios below one indicate a decreased risk.

A3.17 Univariate logistic regression with an exclusion criterion of $p>0.25$ was used to select independent variables eligible for inclusion in the model. Stepwise selection was used to arrive at the most parsimonious model.

Kitchen Concentrations

A3.18 Three variables were found to be significantly associated with high kitchen concentrations: fuel type, kitchen type, and kitchen ventilation. The model predicts about 88 percent of high-concentration households and nearly 53 percent of low-concentration households correctly, for an overall prediction accuracy of around 71 percent.

Fuel type

A3.19 Kerosene and LPG using households were used as the reference category for fuel type Compared to these households, mixed-fuel households were at a 68 times greater risk of having high kitchen concentrations. Wood-using households had a risk of high kitchen concentration that is 28 times that of kerosene and LPG using households.

Kitchen Type

A3.20 Outdoor open-air kitchens were used as the reference category for kitchen type. Indoor kitchens without partitions had the highest risk of having high kitchen concentrations, followed by households with separate indoor kitchens outside the house, and then households with indoor kitchens with partitions.

Kitchen Ventilation

A3.21 Households assessed to have poor ventilation had more than a two-fold risk of having high kitchen concentrations compared to households with good ventilation. Households with moderate ventilation had a slightly elevated risk, but this risk was not statistically significant. See Table A3.10.

Table A3.10. Predictors of High Kitchen Concentrations: Logistic Regression Analysis

Household Characteristic	*Odds Ratio (OR)*	*95% CI*†
Fuel Type		
Wood	28.2	(6.5, 121.6)
Mixed	62.8	(13.6, 289.8)
Kerosene or LPG	1.0 *	-
Kitchen Type		
Indoor kitchen with partition	3.4	(1.4, 8.2)
Indoor kitchen without partition	4.6	(1.8, 11.6)
Separate indoor kitchen outside the house	4.1	(1.8, 9.6)
Outdoor kitchen	1.0 *	-
Ventilation		
Poor	2.3	(1.0, 5.0)
Moderate	1.1	(0.5, 2.3)
Good	1.0 *	-

*Reference Category

† 95% Confidence Interval (CI) for the Odds Ratio. CI refers to the computed interval with a 95% probability that the true value of the OR lies within. For example, the point estimate for the OR for wood fuel is 28.2, but this is the estimate within a range of uncertainty ranging from 6.5 to 121.6.

Living-area Concentrations

A3.22 A subtle difference between predicting kitchen and living-area concentrations is the way in which kitchen type affects concentrations. Testing using kitchen type and separate kitchen indicated that information on whether or not a household has a separate kitchen is more meaningful and more informing when predicting living-area concentrations. The modeling for living-area concentration was conducted in two ways:

1. Modeling under the assumption that kitchen concentrations are known. Here, information on kitchen concentrations is included in the model.
2. Modeling under the assumption that kitchen concentrations are unknown. Here, no information on kitchen concentrations is included in the model.

A3.23 The first model would also give information as to the additional value of doing more than just one pollution measurement per household. If kitchen concentrations, combined with survey results, predict living-area concentrations sufficiently well, much time and money could potentially be saved in field surveys.

Modeling When Kitchen Concentrations Are Known

A3.24 In the model that included information on kitchen concentration, four variables were significantly associated with high living-area concentrations: kitchen concentration, fuel type, kitchen type, and ventilation. This model was able to identify 73 percent of high-concentration and 63 percent of low-concentration households, for an overall prediction accuracy of 67 percent. See Table A3.11.

Table A3.11. Predictors of High Living-Area Concentrations: Logistic Regression Analysis When Kitchen Concentration is Known

Household Characteristic	*Odds Ratio (OR)*	*95% CI*†
Kitchen Concentration		
Low	1.0 *	-
High	3.1	(1.9, 5.2)
Fuel type		
Wood	3.5	(1.1, 11.4)
Mixed	5.0	(1.4, 17.7)
Kerosene or LPG	1.0 *	-
Kitchen Type		
No Separate Kitchen	1.0 *	-
Separate Kitchen	0.33	(0.20, 0.57)
Ventilation		
Poor	3.5	(1.8, 6.7)
Moderate	2.5	(1.3, 4.6)
Good	1.0 *	-

*Reference Category

† 95% Confidence Interval for the Odds Ratio

Kitchen Concentration

A3.25 Households with low kitchen concentrations (< 300 µg/m3) were used as the reference category. Households with high kitchen concentrations have over a three-fold greater risk of having high living-area concentrations.

Fuel Type

A3.26 The reference category consisted of all households using kerosene or LPG for cooking. Households cooking with mixed fuels were at greatest risk of having living-area concentrations, with over five times the risk compared to kerosene or LPG using households. Households using wood had a risk 3.5 times greater than their kerosene or LPG using counterparts.

Kitchen Type

A3.27 Households without a separate kitchen were used as the reference category here. Households with a separate kitchen have, on average, lower living-area concentrations. Households with separate kitchens have a 33-percent lower risk of high living-area concentrations compared to households without separate kitchens. In other words, households without separate kitchens have a threefold-higher risk of high living-area concentrations.

Ventilation

A3.28 Compared to households with good kitchen ventilation, households with moderate kitchen ventilation have more than double the risk of high living-area concentrations. Households with poor kitchen ventilation have over 3.5 times the risk of high living-area concentrations. This finding is notable, in that it suggests that good kitchen ventilation is not achieved at the expense of air quality in the rest of the household. Since households with separate kitchens are at lower risk of high living concentrations, the direction of the effect of kitchen ventilation on living-area concentrations was not certain. If kitchen ventilation were achieved by shifting air pollution to the living area of households, then decreasing kitchen concentrations through improved ventilation might not affect average household exposures at all. That better kitchen ventilation is associated with decreased kitchen and living-area concentrations suggests that improved kitchen ventilation could actually be associated with a decrease in the overall exposure of household members.

Modeling When Kitchen Concentrations Are Unknown

A3.29 When information on kitchen concentrations was not included in the model, the predictive value of the model decreased somewhat. Around 61 percent and 67 percent of high and low living-area concentration households were classified correctly, with nearly 64 percent of households classified accurately overall. In the absence of information on kitchen concentrations, the influence of the other variables (fuel type, kitchen type, and ventilation) increased, but the overall model remained the same. See Table A3.12.

Fuel Type

A3.30 Households cooking with mixed fuels have nearly ten times the risk of high living-area concentrations of kerosene or LPG using households. Households using wood have more than five-and-a-half times greater risk of high living concentrations.

Table A3.12. Predictors of High Living-Area Concentrations: Logistic Regression Analysis When Kitchen Concentration is Unknown

Household Characteristic	*Odds Ratio (OR)*	*95% CI*[†]
Fuel Type		
Wood	5.7	(1.9, 17.6)
Mixed	9.9	(3.0, 32.4)
Kerosene or LPG	1.0 *	-
Kitchen Type		
No Separate Kitchen	1.0 *	-
Separate Kitchen	0.34	(0.20, 0.56)
Ventilation		
Poor	4.6	(2.5, 8.5)
Moderate	2.9	(1.6, 5.1)
Good	1.0 *	-

*Reference Category

[†] 95% Confidence Interval for the Odds Ratio

Kitchen Type

A3.31 Here too, households with a separate kitchen have, on average, lower living-area concentrations. Households with separate kitchens have around a 34 percent lower risk of high living-area concentrations compared to households without separate kitchens. This translates into households without separate kitchens having a three fold higher risk of high living-area concentrations.

Ventilation

A3.32 Better kitchen ventilation is associated with decreased living-area concentrations. Households with moderate kitchen ventilation have nearly three times the risk of households with good ventilation, and households with poor ventilation have over four-and-a-half times the risk.

Classification and Regression Trees (CART)

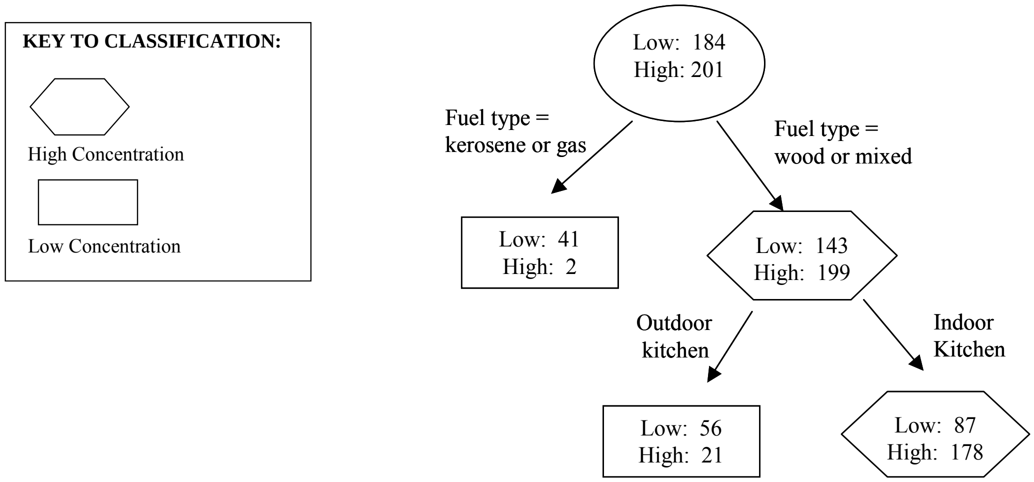
A3.33 After allowing CART to select what it determined to be the "optimal" tree, several different trees were produced, using different combinations of the predictor variables, in order to determine which tree(s) had the best ability to predict high- and low-concentration households.

Kitchen Concentrations

A3.34 CART produces several different classification trees, and then determines the "optimal" tree, i.e., the tree that classifies most accurately with a minimal amount of complexity. After allowing CART to select what it determined to be the "optimal" tree, several different trees were produced, using different combinations of the predictor variables, in order to determine which tree(s) had the best ability to predict high- and low-concentration households.

A3.35 The optimum tree generated by CART included two parameters: fuel type and kitchen type. In this model, households were first split on the basis of fuel type; all households using kerosene or LPG were classified as low-concentration households. Next, households using wood or mixed fuel are further split by kitchen type; all households with outdoor kitchens are classified as low-concentration households.

Figure A3.5. Optimal Tree for Kitchen Concentrations



A3.36 Fuel type predicted high-concentration households well, but did very poorly in predicting low-concentration households. Using fuel type alone, with no further splitting, nearly all high-concentration households were identified, but only 20 percent of low-concentration households were identified accurately. Using fuel type alone would thus be useful in a context where all households using wood or mixed fuels had high kitchen concentrations. In reality, however, there are a wide range of household concentrations within wood and mixed fuel types. Hence, a model that only takes fuel type into account will identify the clean-fuel-using households, but does not tell us why some solid-fuel-using households are able to sustain low kitchen concentrations. Splitting the wood- and mixed-fuel-using households by kitchen type resulted in a small loss of prediction accuracy in high-concentration households, but a significant improvement in the prediction of low-concentration households, with 89 percent and 53 percent of high- and low-concentration households identified accurately.

A3.37 This suggests that there are important household characteristics other than fuel type influencing kitchen concentration. In fact, kitchen type was not the only parameter found to greatly improve the ability to identify low-concentration households. Although the optimal tree as determined by the CART program used fuel type and kitchen type, an examination of the other trees generated by CART indicated that kitchen ventilation minimizes misclassification of low-concentration households as well as kitchen type. After splitting by fuel type, splitting by either kitchen type or kitchen ventilation results in nearly the same improvement in classification. Table A3.13 shows how the number of parameters utilized in the different trees generated by CART affects the prediction accuracy for low- and high-concentration households.

Table A3.13. Prediction Accuracy of CART Models Predicting Kitchen Concentration

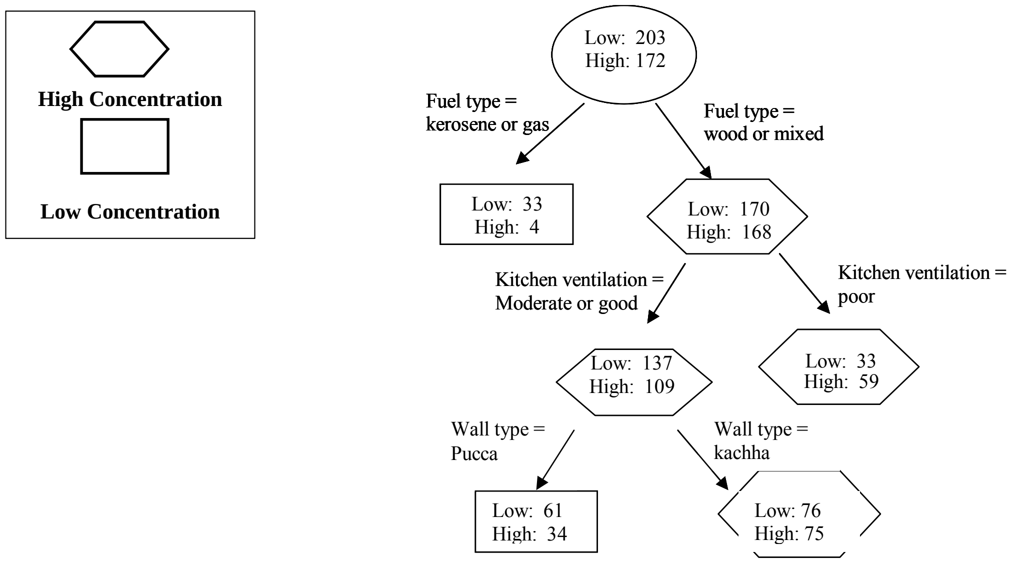
	% Predicted Accurately	
Parameters Utilized by CART	*Low Concentration*	*High Concentration*
Fuel type	22%	99%
Kitchen type	30%	90%
Kitchen ventilation	46%	78%
fuel type + kitchen type	53%	89%
fuel type + kitchen ventilation	55%	86%
fuel type + kitchen type + kitchen ventilation	52%	93%

A3.38 The tree that utilized both kitchen type and kitchen ventilation did not predict much better than the trees that used only one of these parameters. This suggests that it is not necessary to collect information on both kitchen type and kitchen ventilation. In future work, the decision whether to collect information on kitchen type or ventilation will be dependent on the study location. Kitchen types vary from region to region, thus the classifications used here may not be applicable to other locations. Likewise, depending on the amount of variation in kitchen and housing types, differences in kitchen ventilation may or may not be easily assessed by surveyors. In future studies, observations made during the initial site visit should make it relatively easy to decide which parameter to use.

Living-Area Concentrations

A3.39 The optimum tree generated by CART included three parameters: fuel type, kitchen ventilation, and wall type. In this model, as with the model for kitchen concentrations, households were first split on the basis of fuel type; all households using kerosene or LPG were classified as low-concentration households. Next, households using wood or mixed fuel were further split by kitchen ventilation; households with poor kitchen concentration were classified as high-concentration households. Households with moderate or good kitchen ventilation were split by wall type; households with pucca walls were classified as low-concentration households, and households with kachha walls were classified as high-concentration households.

Figure A3.6. Optimal Tree for Living-area Concentrations



A3.40 Another tree generated by CART, that utilized information on fuel type, kitchen ventilation, wall type, and roof type, was better at predicting low concentrations, but slightly worse at predicting high concentrations.

A3.41 Once again, after allowing CART to select what it determined to be the "optimal" tree, other trees were produced, using different combinations of the predictor variables, in order to determine which tree(s) had the best ability to predict high- and low-concentration households. Here, the parameters found to be significant in the logistic regression models for living-area concentration were used. Results were similar to the results of the kitchen models, although prediction accuracy was much less overall. Fuel type alone was a very good predictor of high concentrations, but very poor at predicting low concentrations. Once fuel type was included in the model, adding information on either kitchen type (separate or not) and kitchen ventilation had nearly the same effect, although using kitchen ventilation predicted a few more high-concentration and a few less low-concentration households accurately. When information on both kitchen type and kitchen ventilation was included, the model predicted low-concentration households much better, but prediction accuracy of high-concentration households declined. Once again, collecting information on both kitchen type and kitchen ventilation seems to be unnecessary. See Table A3.14.

Table A3.14. Prediction Accuracy of CART Models Predicting Living-Area Concentration

	% Predicted Accurately	
Parameters Utilized by CART	*Low Concentration*	*High Concentration*
Fuel type + kitchen ventilation + wall type	46%	78%
Fuel type + kitchen ventilation + wall type + roof type	58%	70%
Fuel type	16%	98%
Separate kitchen	62%	57%
kitchen ventilation	83%	35%
fuel type + separate kitchen	51%	72%
fuel type + kitchen ventilation	46%	79%
fuel type + separate kitchen + kitchen ventilation	71%	58%

Summary

Kitchen Concentrations

A3.42 Fuel type is the best predictor of high concentrations, but not a very good predictor of low concentrations. This is due to the wide range of concentrations within fuel categories. Kitchen type is also an important predictor; indoor kitchens are much more likely to have high concentrations than outdoor kitchens. Households with good kitchen ventilation are much less likely to have high concentrations than households with moderate or poor ventilation.

Living-Area Concentrations

A3.43 Fuel type is the best predictor of high living-area concentrations. This is true both in the presence and absence of information on kitchen concentration. For living-area concentrations, knowing the specific type of kitchen is less important than knowing whether or not the kitchen is separate from the living area. Information on kitchen ventilation is consistent with the results of the kitchen concentration models; wood or mixed-fuel households with good kitchen ventilation are likely to have lower living-area concentrations. This suggests that improvements in kitchen ventilation do not occur at the expense of air quality in the living area.

How Does Changing the Cut-off Point Affect Prediction?

A3.44 We conducted a sensitivity analysis to evaluate how changing the cut-off affects prediction accuracy. The optimum tree was used to identify high- and low-concentration households using different cut-off points, from 300 $\mu g/m^3$ to 850 $\mu g/m^3$ (approximately one standard deviation above the geometric mean). The sensitivity analysis was only done in one direction, i.e., we did not assess cut-off points below 300 $\mu g/m^3$, as a lowering of the cut-off point below 300 $\mu g/m^3$ would put a majority of the households into the high-concentration category. In other words, since the model has been developed to predict high-concentration households, classifying most of the households as "high-concentration" would defeat the purpose of the exercise. Changing the cut-off did not seem to affect the prediction accuracy of high-concentration households. Prediction accuracy of low-concentration households increased as the cut-off decreased. For example, 53 percent of low-concentration households were identified correctly using a 300 μg/m^3 cut-off, compared with only 37 percent of households using a cut-off of 700 μg/m^3. See Table A3.15.

Table A3.15. Effect of Concentration Cut-off on Prediction Accuracy

	% Predicted Accurately	
Concentration Cut-off	*Class 0*	*Class 1*
kitchen RSPM = 300 μg/m^3	53%	89%
kitchen RSPM = 400 μg/m^3	47%	91%
kitchen RSPM = 500 μg/m^3	41%	92%
kitchen RSPM = 600 μg/m^3	39%	92%
kitchen RSPM = 700 μg/m^3	37%	92%
kitchen RSPM = 850 μg/m^3	36%	92%

Consistency and Stability

A3.45 Results were consistent across linear regression, logistic regression, and CART models. In other words, the same variables were found to be important in all models. Although this does not guarantee the validity of the model, it does provide some reassurance about the robustness of the parameters used in the modeling exercise.

A3.46 In the CART model, bootstrap aggregation (bagging) was used to determine how much the results might have changed if another random sample had been used. The results of 50 resamplings of the data were averaged. If the results of the different samplings were different, suggesting instability, then the averaging would yield more accurate predictions. If the separate analyses are very similar to each other, the trees exhibit would stability and the averaging will not harm or improve the predictions. Averaging the results of the resampled data did not improve prediction accuracy, suggesting that the model is quite stable.

Annex 4. Deepam Scheme Evaluation

Implementation Status

A4.1 As of February 2002, a total of 1.53 million connections had been released under the Deepam Scheme, consisting of 1.19 million in rural areas and 0.34 million in urban areas. The district-wise distribution of LPG cylinders to Deepam beneficiaries is shown in Table A4.1. The connections allocated to the four state-owned oil companies and the actual numbers released as of February 2002 are shown in Table A4.2.

Table A4.1. Distribution of LPG Cylinders to Deepam Beneficiaries as of 9 March 2002, by District

District	*Rural*		*Urban*		*% Target achieved*		*Ranking*	
	Allocated	Released	Allocated	Released	Rural	Urban	Rural	Urban
Telangana								
Nalgonda	64,280	57,650	6,719	5,869	90	87	16	12
Medak	48,658	41,142	6,964	6,259	85	90	19	11
Khammam	48,258	43,736	8,020	6,441	91	80	13	16
Mahaboobnagar	74,846	54,795	8,409	8,199	73	98	22	8
Nizamabad	42,176	45,470	7,784	8,705	108	112	2	3
Karimnagar	65,749	59,027	12,140	9,152	90	75	15	20
Adilabad	56,536	63,789	10,710	13,928	113	130	1	2
Warangal	70,303	63,350	11,829	19,076	90	161	14	1
Ranga Reddy	47,483	50,000	40,857	29,633	105	73	3	21
Hyderabad	—	—	101,500	76,941	—	76	—	19
Coastal Andhra								
Srikakulam	40,902	39,594	6,597	6,977	97	106	7	6
Prakasam	60,024	50,439	6,003	4,846	84	81	20	15
Nellore	55,911	48,906	7,608	5,288	87	70	17	23
Vizianagaram	38,360	33,106	7,437	7,197	86	97	18	9
West Godavari	57,913	53,586	14,976	12,608	93	84	10	14
Krishna	79,232	78,737	13,648	14,344	99	105	4	4
Visakhapatnam	62,422	61,188	21,442	20,256	98	94	5	10
Guntur	73,622	71,900	22,243	23,342	98	105	6	5
East Godavari	77,547	74,776	33,225	33,838	96	102	9	7
Rayalaseema								
Chittoor	66,318	61,328	25,515	22,194	92	87	11	13
Anantapur	68,827	62,557	15,364	12,262	91	80	12	17
Kurnool	56,459	54,585	15,240	10,731	97	70	8	22
Cuddapah	48,534	36,505	6,270	4,869	75	78	21	18
Grand Total	1,304,360	1,206,166	410,500	362,955				

— not applicable.

Table A4.2. New LPG Connections Released by the Oil Companies in the Deepam Scheme as of February 2002

	Rural		Urban		Total	
Company	*Allocated*	*Released*	*Allocated*	*Released*	*Allocated*	*Released*
IOC	506,022	450,252	155,221	121,771	661,243	572,023
HPC	537,859	492,967	177,573	154,008	715,432	646,975
BPC	258,387	245,565	77,706	63,738	336,093	309,303
IBP	2,113	1,434	0	0	2,113	1,434
Total	1,304,381	1,190,218	410,500	339,517	1,714,881	1,529,735

Selection of Study Subjects

A4.2 The six districts selected, are tabulated in Table A4.3. Three mandals were selected in each district typically in consultation with the authorities concerned. Preference was given to those where supply agencies other than the oil companies (such as the Department of Civil Supplies and Girijan Cooperative Corporation) were operating. Since the logistics of LPG cylinder delivery was expected to be a major issue, villages and self-help groups within mandals and municipalities were grouped into three broad categories on the basis of the distance to the closest LPG dealer: those within 5 kilometers (km), those between 5 and 10 km, and those farther away from 10 km. Only those self-help groups that had been participating in the scheme for more than a year were selected in order to have a meaningful assessment of LPG consumption and experience with the scheme. A list of villages and municipalities studied is presented in Table A4.4. The numbers of self-help groups that participated in focus-group discussions and beneficiaries interviewed, as well as others with whom the study team had meetings and discussions are given in Table A4.5.

Table A4.3. Districts Selected for the Study

Region	*Highest Performance*	*Lowest Performance*	*Remarks*
Telengana	Adilabad	Khammam	Although Warangal is the highest performer, it has high municipal connections.
Coastal Andhra	East Godavari	Visianagaram	
Rayalaseema	Anantapur	Kurnool	Although Chittor is a high performer, it has political patronage. Cuddapha has done extremely poorly and may not be representative[1].

[1]For various reasons the uptake of the Deepam Scheme in Cuddapah is the lowest in the state as well as within the Rayalaseema region. Officials suggested that this district is highly faction-ridden and may not be a representative district for the study.

Table A4.4. Villages and Municipalities Examined in This Study

District	*Mandals*	*Villages*	*Municipalities*
Adilabad	Tallamadugu	Sunkidi Kodad Kothur	Nirmal Bhagyanagar Ward Adilabad Ward 7
	Sarangapur	Jam Chincholi Dhani	
	Indervally Utnoor (VSS)	Galiyabai Tanda Rampur (B) Pulimadugu	
Anantapur	Gooty	Chethanapalli Issarallpally Chattanapally	Gooty Ananthapur
	Bathanapally	Suryachaandrapuram Potlamarri Anatahsagaram	
	Puttaparthi	Jagarajupally Guvvaguntapally Kapalabanda	
Khammam	Khammam	Nayudupeta Thallampadu Venkatayapalem	Khammam Palavancha
	Vemsur	Dudipudi Bhimavaaram Kondigalta	
	Palavancha	Thoggudem Pullaigudem Vanambilli	
Vizianagaram	Poosapatirega	Kandivalasa Karada Chinthapalli	Bobbili Salur
	Bobbili	Karadi Piridi	
	Gummalakshmi Puram (VSS)	Rella Glpuram Dhulikuppa	
East Godavari	Peddapuram	Kattamurruchinnabrahmadevaram Marlava	Rajahmundry
	Tallrevu	Thoorpeta Neelapally Chollangi	
	Allavaram	Komaragiripatnam Allvaram Bodasarru	
Kurnool	Orvakal	Orvakal Kannamadakala Nannoor	Adoni Farooq nagar (Ward) Ambedkar nagar

District	*Mandals*	*Villages*	*Municipalities*
	Asperi	Benegedi Chigili Chirumandoddi	(Ward)
	Nandyal	Chabolu Chakirevula Pandurangapuram	

Note: A ward is a sub-division of a municipality.

Table A4.5. Number of Group Discussions and Interviews

District	*Mandals*	*DWCRA*	*VSS*	*DWCUA*	*Non-Users*	*Private Users*	*Beneficiaries*	*Gas Agencies*
Adilabad	Tallamadugu	3	0	0	3	2	6	1 (IOC, HPC)
	Sarangapur	3	0	0	3	4	6	0
	Indervally Utnoor	0	0	3	0	0	6	0
	Adilabad (U)	0	1	0	6	3	2	1 (IOC)
	Nirmal (U)	0	1	0	6	3	2	1 (HPC)
Sub-total		6	2	3	18	12	22	3
Anantapur	Gooty	3	0	0	2	1	6	1 (IOC)
	Bathanapally	2	0	1	2	2	6	0
	Puttaparthi	3	0	0	2	1	6	1 (HPC)
	Gooty (U)	0	1	0	2	2	2	1 (BPC)
	Ananthapur (U)	0	1	0	2	1	3	0
Sub-total		8	2	1	10	7	23	3
Khammam	Khammam	3	0	0	2	2	6	1 (IOC)
	Vemsur	3	0	0	2	2	6	0
	Palavancha	3	0	0	2	2	6	1 (HPC)
	Khammam (U)	0	1	0	2	2	2	1 (HPC)
	Palavancha (U)	0	1	0	2	2	2	0
Sub-total		9	2	0	10	10	22	3
Vizianagaram	Poosapatirega	3	0	0	2	3	6	1 (IOC)
	Bobbili	3	0	0	2	3	6	1 (HPC)
	Gummalakshmi Puram	0	0	3	2	0	6	1 (IOC)
	Bobbili (U)	0	1	0	2	2	2	0
	Salur (U)	0	1	0	2	2	3	0
Sub-total		6	2	3	10	10	23	3

District	Mandals	DWCRA	VSS	DWCUA	Non-Users	Private Users	Beneficiaries	Gas Agencies
East Godavari	Peddapuram	3	0	0	2	3	6	1 (HPC)
	Tallarevu	3	0	0	2	3	6	0
	Allavaram	3	0	0	2	3	6	1 (BPC)
	Rajahmundri (U)	0	2	0	2	2	4	1 (IOC)
Sub-total		9	2	0	8	11	22	3
Kurnool	Orvakal	3	0	0	2	2	6	1 (IOC)
	Asperi	3	0	0	2	2	6	1 (IOC)
	Nandyal	3	0	1	2	2	8	1 (HPC)
	Adoni	0	0	1	0	0	2	0
Sub-total		9	0	2	6	6	22	3
Total		47	10	9	62	56	134	18

Notes: U urban; IOC Indian Oil Corporation; HPC Hindustan Petroleum Corporation; BPC Bharat Petroleum Corporation.

Characteristics of the Deepam beneficiaries: Individual interviews

A4.3 The following tables illustrate the profile of the Deepam beneficiaries obtained from 134 individual interviews.

Table A4.6. Social Class Stratification of Individuals Interviewed, by District

District	SC	ST	BC/OBC	Others	Total
Adilabad	5	5	12	1	21
Anantapur	6	0	4	12	24
East Godavari	7	2	9	4	22
Khammam	9	0	8	5	22
Kurnool	5	2	8	9	22
Vizianagaram	9	1	10	1	23
Total	41 (31%)	10 (8%)	51 (38%)	32 (24%)	134 (100%)

Table A4.7. Type of Kitchen

District	Outside the house	Open air	Inside with no partition	Inside, with partition
Adilabad	1	1	16	3
Anantapur	4	0	5	14
East Godavari	16	0	4	2
Khammam	12	1	8	1
Kurnool	2	0	4	16
Vizianagaram	2	3	10	8
Total	37 (28%)	5 (4%)	47 (35%)	44 (33%)

Table A4.8. Possession of Consumer Durables (number of households)

District	*Television*	*Washing machine*	*Fan*	*Two-wheeler*	*Others*
Adilabad	15	0	18	9	8
Anantapur	15	0	18	6	0
East Godavari	10	3	13	15	0
Khammam	15	0	17	1	1
Kurnool	16	0	16	17	1
Vizianagaram	14	0	15	15	5
Total	85	3	97	63	15

Table A4.9. Cylinder Delivery Mode

	0 to 5 km			*5 to 10 km*			*More than 10 km*		
District	*Home*	*Self*	*Comm.*	*Home*	*Self*	*Comm.*	*Home*	*Self*	*Comm.*
Adilabad	5	3	0	2	4	0	0	7	0
Anantapur	2	1	1	0	6	0	2	5	4
East Godavari	0	8	2	2	4	0	2	4	0
Khammam	5	3	0	3	2	0	3	5	0
Kurnool	2	8	0	0	5	0	2	3	0
Vizianagaram	0	12	0	1	8	0	0	1	0
Total	14	35	3	8	29	0	9	25	4

Note: The distances are up to 5 km, greater than 5 but equal to or less than 10 km, and greater than 10 km. Home is free home delivery; self is a member of the household collecting the cylinder; comm. is delivery by paying a commission to a third party.

Table A4.10. Cost of Cylinder Refill (Rs)

District	*0 to 5 km*	*5 to 10 km*	*More than 10 km*
Adilabad	271	293	299
Anantapur	286	284	293
East Godavari	245	250	250
Khammam	263	282	272
Kurnool	265	269	273
Vizianagaram	251	254	270
Average	261	272	278

Note: The distances are to the nearest LPG distribution point and the same as those in Table A4.9

A4.4 **Calculation of LPG consumption**. One simplifying assumption used in this calculation is that the last refill has been half used up. For those who have had a number of refills, this will not affect the estimate markedly, but for those who have had only one or two refills, or never had one, this could over- or under-estimate LPG consumption considerably. Indeed, there were 21 households which had never had a refill. On average, the respondents had had three refills, ranging from 0 to 16, since they were enrolled in the Deepam Scheme. This translates to refilling every 7 months on average, with the median being 5 months. The refill rates reported here are considerably lower than those reported in focus-group discussions where both the average and the median were smaller than by about 2 months. The difference may in part arise from wanting to appear to be utilizing LPG more regularly in the presence of one's peers during the focus-group discussions

A4.5 An upper and lower bound on LPG consumption can be calculated by assuming that all of the LPG from the last refill had been used, and none had been used, respectively. In this way, high, mid and low estimates may be computed, depending on the assumption made about the consumption of the last cylinder refill. The data collected in the individual interviews give the three estimates for average LPG consumption as 3.4, 2.9 and 2.4 kg per month per household. The three estimates for urban households are 5.3, 4.8 and 4.3 kg per month per household, and the corresponding figures for rural households are 3.1, 2.6 and 2.4.

A4.6 **Modeling explanatory variables**. Taking the above correlations as a starting point, mid-estimates for LPG consumption in kg per month were regressed on the above potential explanatory variables. The regressions were run in EViews. The model was constructed using White heteroskedasticity-consistent standard errors and covariances to allow for possible non-constancy of variance in the error terms arising from equation misspecification. The dependent variables were entered in linear form. Residuals were obtained and the Jarque-Bera statistic was computed. The Jarque-Bera statistic is a measure of skewness and kurtosis, with a normal distribution giving a Jarque-Bera statistic of zero. This was checked to see if the residuals were normally distributed as a test of equation mis-specification. Two observations with very high LPG consumption were found to lead to high Jarque-Bera statistics. When they were omitted, the Jarque-Bera statistic fell markedly.

A4.7 The models were initially fitted with all main effects, and then insignificant terms were successively deleted until the model contained only those independent variables that were statistically significant using a two-sided significance test of size 5 percent. (A 5-percent test is one such that the null hypothesis—that is, the identified variable has no additional effect on LPG consumption—would be rejected in 5 percent of tests even if it were true.) Two-sided tests were used because there did not seem to be a basis for predetermining the sign of the expected impact of various parameters examined. Because step-wise deletion does not guarantee the inclusion of all the relevant independent variables, the rejected variables were added back individually and also in groups at the last stage to see if their t-statistics increased.

Annex 5. Strengths and Weaknesses of Improved-Stove Programs in Six States

Gujarat

Success Factors:

The GOAP's commitment to and participation in the promotion and implementation of the program in financial terms is one of main factors responsible for the success of the program.

The program is targeted to those families below the poverty line that need it the most.

The program is integrated with a housing program, where the stove comes with a house. Two agencies implement the program in the state: the Rural Development Department (RDD) and the Gujarat Energy Development Agency (GEDA). The RDD's strategy is to concentrate the dissemination of stoves in smaller populations, especially BPL households. GEDA implements the program through NGOs, which match implementation to local requirements. The multi-agency approach in stove dissemination helps the program reach more rural people.

Weaknesses:

The emphasis of the program in the state is more on installation of stoves, rather than on following up the beneficiaries to ensure its continued use and effectiveness. Ensuring functionality, quality control and awareness generation are lacking to a large extent, especially in the case of RDD.

The state government funds given to GEDA for stove implementation are routed through the RDD, which is also an implementing agency and in fact handles a lesser target than GEDA. This affects the efficiency and performance of GEDA as it is dependent on another agency for flow of funds for smooth implementation. The customers contribute only to labor costs of stoves (Rs 10) and all other costs are subsidized. Providing the stoves virtually free of cost to the beneficiaries tends to work against the program in the long run as the beneficiaries lack the sense of ownership and contribution required for regular and sustained use.

Quality control is not good in the program, as it is the responsibility of the self-employed workers who make the stoves. Unlike in Maharashtra and Haryana, where the GOAP identifies and certifies stove component suppliers, there is no such identification of quality control procedures undertaken in Gujarat.

SEWs and NGOs find the transition to the cement stoves from mud stoves to be difficult as they have to tackle new methods of production (e.g., centralized production) and technology issues.

Maharashtra

***Success factors**:*

The state program is implemented through a decentralized local government administrative system, which helps to ensure that targets for stove dissemination are met. At the state level, the implementing agencies include the Rural Development and Water Conservation (80 percent), the Maharashtra. Energy Development Agency (18 percent), and the Khadi Village and Industries Commission (2 percent). The combined efforts of multiple implementing agencies ensure greater program effectiveness in rural areas.

The Technical Backup Unit is closely involved with both the stove users and manufacturers. It has made valuable contributions to the program not only in technology development but also in terms of conceptualizing and developing training courses for various stakeholders, including entrepreneurs. Stove entrepreneurs develop new designs and have them approved by the TBU.

The program is focused on a commercialization strategy, with some caveats. There is already an existing tradition of stove construction and selling by potters in the state and purchase of stoves by rural people, which results in a high overall preparedness of the beneficiaries towards commercialization.

Subsidies are given for the stove, and in some districts stoves are given free to the backward communities. The partial subsidy program has worked satisfactorily, but the free stoves have been problematic as it does not ensure regular maintenance and sustained use.

Weaknesses:

Large subsidies tend to devalue the perception of the stove, as the improved stove is used for as long as it lasts and then the household reverts to the traditional stove. The existing tradition of rural people buying stoves in the state should be used as an advantage to target subsidies to poor households only rather than implementing a uniform policy for subsidies to households across all income levels.

Greater allocation of resources is required for technical assistance and training rather than for stove subsidies. The role of the TBU in obtaining regular feedback from the users and designing new models based on the feedback needs to be strengthened.

Coverage of the program is very small at 120,000 stoves per year and the average life of a mud stove is 1.5 to 2 years.

Quality control is very poor in the program. There is pressure by the field implementation staff to meet targets, and untrained entrepreneurs often build the stoves.

There is no mechanism to ensure that stove producers buy parts from approved vendors. Also, this leads to stove vendors cutting corners to develop stoves, which lowers stove quality.

Andhra Pradesh

Success Factors:

The nodal agencies (NEDCAP and KVIC) and the CDAs have cooperated well in the program. They conduct 100 percent verification that stoves have been properly installed in homes. They follow a whole village approach, reaching most of the households in particular villages, rather than trying to reach all villages.

Stoves are installed in the homes of "opinion leaders" to demonstrate their benefits.

The TBU maintains contact with Nodal agency, and does testing and certification of stoves. It does not deal directly with users, but has been active in developing some new stove designs.

Weaknesses:

There is a lack of after sales service and maintenance.

The monitoring surveys only evaluate functionality. They do not monitor users satisfaction.

The subsidy for the stoves is 50 percent of stove costs. This is the main factor in stove adoption, but it seems users are willing to pay more.

The stove parts are not of very good quality. The stove liners tend to crack after 6 months of use. The parts are not available, so the user cannot fix an improved stove. Thus, there is a problem for consumers in fixing their stoves, because they cannot get the parts.

Stove program needs to be directed towards commercialization of improves stoves, and providing incentives for the entrepreneurs, self-employed workers, and potters.

Haryana

Program is successful in that it meets its targets and has a well-defined implementation strategy.

Success Factors:

The program does not try to cover the whole state, but targets selected villages where it is anticipated that the stoves will be appreciated and where there is local political acceptance of the program.

The program is implemented through one government agency and through well established women's organizations. The Department of Women and Child Development utilize Mahila Mandals (women's group) to identify households for the adoption of the stoves. This is done mainly through their network of members.

The technical backup unit is responsible for stoves designs and improving the stoves. They have done this quite well, but have had a fairly narrow mandate. It appears that because of the cold weather people want their stoves to provide heat in addition to the cooking function. Also, the TBU has not taken into consideration that some families do not want the chimneys to go through their roofs. In other states they have developed designs to vent the smoke through the walls of the house because of this concern.

The most common reaction of consumers to the stoves was that it reduces kitchen smoke.

Weaknesses:

The self-employed workers are only involved in the program for producing stoves for the families. They get paid mainly for stove installation, and are not involved in trying to meet consumers' needs by testing out other designs. Thus, with the exception of producing the stoves, they appear to have very little input into the program.

The program is very rigid, probably a result of the heavy subsidies given for the stoves. Consumers say they would not buy an improved stove unless they were provided with a subsidy. There also was some concern that the subsidy actually devalues the consumer perception of the improved stove.

Consumers were altering the stoves that were installed in their households. This would tend to indicate that the technical backup unit, although it had a monitoring unit, was acting rather independently from the consumers and the producers.

The consumer reaction that the stoves are mainly appreciated for their reducing in cooking to indicate that they do not appreciate the main feature for which the stove were designed—energy efficiency. Thus, the implication is that there is a mismatch between the consumer preference and the design of the stove, which probably explains the reluctance of consumers to pay for the full cost of the stoves.

Karnataka

Success Factors:

With the involvement of SEWs and NGOs the focus in Karnataka is to install improved stoves in more number of households in a particular village rather than the number of villages covered.

The program involves panchayat leaders and anganwadi workers to a large extent for purposes of motivation and awareness generation.

Initiatives have been made by the Technical Backup Unit to develop moulds and template for construction of stoves. This has clear advantages in terms of production of standardized and better quality stoves. The dependence on skill masons is also reduced.

The program is amalgamated with other development activities such as housing schemes

Weaknesses:

The program is working only as far subsidies are extended to people. Subsidies on the stoves vary from 50 to 70 percent.

Monitoring and after sales service of improved stoves is weak. There is inadequate technical staff to conduct evaluation exercises. Moreover, these surveys need to better designed to obtain information on stove efficiency other than just functional status of stoves.

There is little interaction between those who design, construct and use the stoves. Several households were found where users had fixed to enhance the length of the chimney or chimneys were removed in houses with thatched roofs to avoid leakages during rains.

People are not willing to purchase the same type of stoves again mainly due to non-availability of stove parts locally and lack of skilled masons to build the stove.

West Bengal

Success Factors:

Main credit for the high penetration of improved stoves is the extensive village level dissemination by NGOs. Over 150 NGOs are involved in stove dissemination which has resulted in an outreach covering the whole state. The NGOs concentrate on covering maximum number of households in village, rather than covering maximum number of villages.

Active participation of village-level institutions is facilitated by the NGOs, which lends credibility to the program. NGOs involve the Panchayat members, rural development project officers, and school teachers are in motivating the target users and undertaking monitoring and evaluation of stoves.

Frequent interaction between the NGOs and the nodal agencies is a positive feature of the program.

The main marketing strategy of the NGOs is to install improved stoves in the houses of prominent members of the community for a demonstration effect.

Although the TBU was involved in some innovative design, for the most part they were not very consumer oriented. The NGOs even began to develop some stoves closer to the needs of consumers.

There is some flexibility in pricing the stoves. Price is kept the same in communities, but can vary between regions. This helps with the incentives of the producers to participate in the program.

Weaknesses:

The programs goes only so far as the subsidies for the stoves. The users pay only about 40 percent of the cost of the stove. There was an attempt by an NGO to start a program that would not have subsidies, but it was stopped because of pressure from the panchayats.

The NGOs involved in the program are not provided with any support for administrative expenses. They are not provided with funds to have publicity campaigns.

Problems are involved in the transition to the durable stoves.

There is negligible interaction between designer and the producer and the user. But there is interaction between the producer and users. Users are totally unaware of the input of the TBU in the design of the stove.

Reflecting the lack of interaction between the TBU and the user, the stoves have actually been redesigned by the local producers to meet the needs of the consumers. There is no quality control checking mechanism to see of this is a help or a hindrance to the efficiency of the stove.

Feedback surveys only take into consideration the functional status of the stoves and not their technical performance, such as reductions in energy consumption.

Annex 6. Recommendations of the Regional Workshop on Household Energy, Indoor Air Pollution and Health, Delhi, May 9–10, 2002

A. General/Cross-cutting themes

1. Take immediate action

1.1 While there are research gaps and uncertainties about the exact levels of exposure and specific health outcomes, there is sufficient evidence that the health impacts of traditional household energy use are significant enough to justify immediate action. Economic development and poverty reduction are among the key factors for improvements in household energy use, environment, and related health effects; however, the links are complex, multidirectional and with significant time lags at the household level. Thus, certain measures to prevent the death of young children and improve the health of rural women can and should be undertaken before a change in the economic status will trigger better health indicators. Furthermore, better health, especially of women and children, is not only an outcome but also a critical input in economic growth and poverty eradication; thus, addressing the health impacts of household energy and Indoor Air Pollution (IAP) should be an integral part of poverty eradication efforts now.

2. Support a range of mitigation options in a holistic manner

2.1 Switching completely to cooking with clean fuels, such as LPG or biogas or electricity, is the most certain way to lower exposure dramatically to indoor air pollution. However, the incremental costs of switching to modern and superior fuels are prohibitive for many rural households. Further, rural markets of commercial fuels are not developed. For example, in India, the economics of LPG service, with its relatively high operating cost, is not favorable to the rural poor who cannot afford to pay for refilling a LPG cylinder every month or two.

2.2 Improved biomass stoves (and cleaner biomass-based fuels) will thus continue to be an option for reducing exposure, for a large majority of the rural poor. In those counties, where coal stoves are extensively used for heating, such as China and Mongolia, improved coal stoves (and a better, processed coal) are an important option to improve the health impacts of household energy use.

2.3 Improvements in cooking and heating technology need to be complemented with simple housing improvements, such as kitchen configuration and ventilation conditions, which could be among most cost-effective measures to reduce exposure. Facilitating behavioral changes among women, children and other household members offers another opportunity to reduce exposure and alleviate the associated health impacts. Improving the status of women can be one of the most effective interventions to promote markets for better stoves and other household energy use services.

2.4 An effective IAP mitigation strategy should include all these options and attempt to match specific interventions (and/or their combinations) with the right segments of the market. Such a strategy should also take into account the multi-dimensional nature of household energy use and promote synergy among a variety of possible benefits, such as health, gender development, and impacts on the local and global environment.

3. Integrate IAP and related issues into sectoral policies and programs

3.1 A central challenge is to facilitate integration of IAP issues in health, energy, infrastructure and rural development programs. For example, it is important to integrate indoor air pollution into existing women (maternal) and child health programs as well as to address IAP in other home-related health programs (e.g., hygiene, water and sanitation). There are already some examples of successful household energy initiatives integrating IAP with projects and programs on agriculture, forestry, nutrition, family planning, and the promotion of women.

3.2 National energy policies and planning should include specific household energy goals as well as recognition of the importance of gender-sensitive participation process in formulating household energy programs. These need to be reflected in institutional frameworks for integrated stakeholder participation in household energy policy at the national, regional and local levels, that bring together a variety of energy and development stakeholders, including women's organizations.

4. Combine market-based approaches with effective government interventions

4.1 The government has an important role in guiding and facilitating actions that alleviate the problem of indoor air pollution. To ensure a sustained effect of mitigation measures, there is a need to promote market mechanisms for distribution of improved stoves and commercial fuels. Programs that disseminate improved stoves (i.e., biomass stoves having higher efficiency and lower emissions), on a commercial basis, with proper certification and quality control by government agencies, enjoy greater financial sustainability and better respond to user demand, including the production of more durable stoves. Similarly, a liberalized market for commercial fuels with a level playing field for all operators with proper regulations would lower cost and increase quality and availability of service to consumers. Therefore, government interventions should be re-oriented towards creating a sound regulatory framework and incentive structure that works with, not against, the market.

4.5 One critical area for government interventions is the design of innovative incentives and mechanisms to deliver better energy services (and housing) to the poorest customers. For example, there is evidence from India that large subsidies on stoves do not ensure increased and sustained use of improved stoves, nor result in greater participation by the poor in stove programs. LPG price subsidy is heavily biased towards more affluent urban households and results in diversion of subsidized domestic LPG to the automotive and commercial sectors. There is a clear need for developing new, more effective strategies to reach the poorest complementing market-based approaches to service delivery.

4.6 Among other areas for government intervention highlighted by this workshop are:

- Facilitating attention to the health dimension in programs that disseminate improved cooking stoves and cleaner fuels (as well as programs that provide other rural infrastructure services, such as housing, water and sanitation, etc.);
- Establishing quality assurance program for services and products delivered by private operators;
- Considering innovative financing schemes that combine housing finance with improved kitchen and/or stove design;
- Actively supporting research and development (R&D) in several multidisciplinary areas related to IAP that are critical for designing more effective programs and interventions (see specific recommendations below).

5. Increase public awareness

5.1 One of the most important elements of a strategy to mitigate IAP is to facilitate behavioral change, including greater demand for cleaner cooking. This requires awareness raising amongst rural families about the health impacts of traditional household energy and providing specific information on the range and effectiveness of mitigation options. Various methods – from including IAP issues in basic hygiene education by primary schools and health centers to mass media – should be utilized. Improving knowledge of the IAP problem and possible solutions among all major stakeholders, including the medical community, is as important.

5.2 The awareness campaigns should provide a balanced overview of a number of options, pointing to the associated costs and benefits. Specifically, it could include the following topics:

- Different fuel options
- Cleaner use of biomass (improved stoves, as well as improved biomass-based fuels)
- Pollutant emissions from different stove types using the same fuel (for example kerosene wick stoves are polluting but pressurized kerosene stoves which gasify kerosene are considerably cleaner) and different fuels (for example, gaseous fuels versus liquid versus solid)
- Incremental costs and benefits, including health impacts and other social benefits, of cleaner options (LPG versus kerosene and wood, kerosene versus wood, wood versus other biomass, improved biomass stoves versus traditional stoves, etc.).

6. Facilitate involvement of communities and users, especially women

6.1 Effective implementation of household energy programs requires extensive involvement of end-users from the design stage to implementation. No central scheme – whether at the national or the state or provincial level – can do justice to *what communities and individuals really need and want.* Women are the mainstay of household energy programs and it is therefore important to empower women to make choices and influence household decisions regarding the use of fuels. Activities to target women for training, capacity and skill building to use and maintain better stoves (using improved biomass, kerosene or gas), as well as for awareness raising of the detrimental impacts of traditional energy, should be strengthened. Innovative financing schemes (e.g., micro-credit) should be also explored support local entrepreneurs, both female and male, as well as communities in the manufacturing and dissemination of stoves and other suitable technologies.

7. Coordinate and expand support by the donor agencies

7.1 Given the multisectoral nature of IAP, there are different sectoral avenues for addressing the problem and providing external support. Within the World Bank, IAP has received increased attention, reinforced by a sharpened focus on poverty reduction and commitment to achieving Millennium Development Goals. IAP is considered a priority issue from the perspective of three different sectors – energy, public health, and environment. A joint UNDP/World Bank Energy Sector Management Assistance Programmer (ESMAP) has supported several initiatives in different parts of the world (e.g., India, China, Mongolia, Guatemala, Kenya, Sub-Saharan Africa) that are completed or underway. A number of rural projects promote sustainable use of biomass and improved stoves, and there are attempts to include IAP issues in health sector projects. WHO considers IAP a top priority in its two programs: air quality and health, and child health. Further, there is a growing interest and commitment from other donor agencies, such as the WHO, USAID, DFID, Shell Foundation, etc.

7.2 Nonetheless, the donor assistance allocated to IAP and household energy remains miniscule compared the amount spent on other rural energy programs such as, for example, promotion of photovoltaics for rural electrification. While there are a number of reasons for this, one is undoubtedly related to the low status of cooking and of women in the energy sector. To maintain the momentum of these new initiatives and achieve maximum benefits from the activities by various agencies, there is a need for a more coordinated effort. The workshop pointed to the importance of establishing a common agenda for the near- to medium term which could serve as the basis for effective partnerships that are built on comparative advantages of different donor agencies. A work group with representatives of a number of agencies to guide and facilitate the process is one option to consider.

B. Improved Stoves, Cleaner Homes, Healthy Villages

8. Promote commercialization of improved stoves and low-polluting solid fuels

8.1 Evidence from international experience as well as the state of Maharashtra in India strongly supports commercialization as a critical factor for promoting sustainability of improved stoves, one of the key IAP mitigation option. The government should facilitate and support the process of commercialization in a variety of ways, such as:

- designing financial incentives and providing training to private entrepreneurs;
- setting technical standards and establishing credit facilities to stoves makers;

- providing promotional support.

8.2 There are a number of areas where promotional support is needed:

- Commercialization of stoves will be successful only if takes into account flexibility in design, production and marketing of stoves to meet local needs (i.e., find out what people want and market stoves according to user preferences); thus, good market analysis is a possible area for government support.
- Stove programs should also integrate behavioral factors and communication methodologies, with some government support to these activities.
- Another critical lesson is the need for giving more attention to smoke removal (cleanliness of kitchen, pots and pans) in stove design that is accompanied by other measures (ventilation, chimneys, hoods) in the marketing of stoves complemented with publicizing the health benefits of reduced smoke.
- Commercial programs work better for populations that expend cash income for the stoves and can afford the expense, so that special efforts are needed to reach the poorest customers (see below).

8.3 Alternative and less polluting biomass fuels (e.g. charcoal) can be an important IAP mitigation option and a valuable employment opportunity in rural areas. These fuel options should be also promoted on a commercial basis. In cold countries, such as China and Mongolia, where coal is the primary fuel used in improved stoves, strategies to commercialize improved coal stoves, along with low-polluting coal fuels (briquettes, smokeless coal) for household use should be promoted.

9. Develop innovative ways of service delivery to the poor

9.1 Commercialized stove programs are the only way to develop a sustainable market of improved stoves that customer are willing to use, but this may leave out the poorest families. At the same time, there is evidence that large stove subsidies do not ensure increased and sustained use of stoves, as the poor do not value a product that is given to them almost free of cost. This type of subsidies, therefore, should be avoided to the extent possible. One possibility is to retain targeted financial support for stoves to the poorest families only (with a clear and broadly accepted identification of eligible beneficiaries); however, it must be accompanied by operation and maintenance support and delivered in a manner that does not undermine commercial viability and sustainability of the service.

9.2 In principle, a more effective form of government support is to direct subsidies towards technical assistance and activities such as stove design, marketing and quality control facilities, testing of stoves, monitoring and evaluation, and information dissemination. While this type of support benefits all customers, it could also include financial incentives and other types of assistance (such as training) to transferring stove design and technology to CBO/NGOs, self-help groups, communities, entrepreneurs, and other “grassroots” groups. Such initiatives would contribute not only to a greater penetration of improved stoves among the poor, but also to broader anti-poverty efforts.

10. Combine the dissemination of stoves with interventions to improve housing design and alter behavior

10.1 For a program to reduce indoor air pollution effectively and ensure better health and cleaner homes, improved stoves should be combined with better house design. Kitchen ventilation was found to an important determinant of exposure to IAP in India. In western Kenya, a combination of interventions, such as smoke hoods and ventilation space, were more effective in reducing the concentration of pollutants (particulates and carbon monoxide) in rural homes than stoves alone. Thus, it is important to consider and design innovative programs and financing schemes that would combine housing finance with improved kitchen and/or stove design. In addition, there is a need to promote appropriate behavior changes among the household members, particularly women and children, that can help to reduce their exposure to indoor air pollution and alleviate adverse health impacts.

11. Support research and development for improved stoves

11.1 Research and development needs were identified in the following areas:

- Design stoves with exposure reduction as the explicit and main objective, in addition to fuel efficiency objective
- Better stoves for space heating and/or drying food items (to address the needs of tribal and other households using stoves for a number of economic activities);
- Agro-waste/multi-fuel stoves
- New materials, including locally available materials, for stove design
- Apply lessons from water-supply and sanitation experience on community-based approaches to stoves programs
- Piloting of financing mechanisms to local entrepreneurs
- Assessment of exposure and health impacts of improved stoves
- Research of "software" rather just "hardware" issues (e.g. cooking practices, diet, behavior etc.)

C. Moving Up the Energy Ladder: Kerosene and LPG

12. Promote fair, transparent and competitive market of petroleum fuels

12.1 There is a need to create an open and competitive LPG and kerosene market with a level playing field for all operators. This would increase efficiency in the sector, ensure higher quality of service, provide fuels to the consumers at lower cost, and potentially facilitate higher LPG consumption in rural areas. Differential treatment of state-owned versus private oil companies for subsidy and taxation slows down the move towards a market-based approach. A market-based approach should be encouraged for innovative financing schemes, distribution setups, improved distribution network, and different size cylinders. Here, the role of government should be to intervene only when there are clear market failures.

13. Experiment with small size LPG cylinders through a market approach

13.1 Small size cylinders could enable poorer households to purchase LPG more regularly, especially in rural areas where households have less reliable cash income. Small size cylinders would also lower the subsidy bill for the government if it decides to subsidize cylinder connection. However, international experience with small size cylinders is mixed: negative aspects include much higher cost of cylinder management and hence higher LPG price on a unit weight basis, and the need for households to fill more frequently. Therefore market forces, and not government policy, should guide the sizes of cylinders to be made available in the market. The government should not subsidize small size cylinders or else it will be diverted illegally even more. One option for reducing the cost of supply is the “cash-and-carry” sale of LPG in small size cylinders in grocery stores.

14. Examine the effectiveness of alternative subsidy schemes for kerosene

14.1 Better provision of low-cost kerosene for use by the poor should receive more attention given: (a) the ease of distribution and delivery compared to LPG; (b) its importance as an energy source for lighting in rural areas; and (c) its potential as an intermediate fuel between biomass and LPG. Points for further consideration for the purpose of mitigating IAP include different subsidy delivery mechanisms to reduce the currently high level of diversion to the automotive sector and more work on kerosene stove design to lower emissions.

15. Re-evaluate the need and delivery mechanism for LPG subsidy

15.1 A number of countries provide a universal price subsidy for domestic LPG. In India, this amounted to US$1 billion in the last fiscal year. But this subsidy does not help the poor, especially those in rural areas. Studies show that 80-90 percent of the subsidy is channeled to the better off urban residents, who can afford LPG without the subsidy. It would make sense to phase out the universal price subsidy in a time-bound manner. If a subsidy is to be retained, it needs to be targeted, and means other than price subsidy should be considered. To minimize the cost of beneficiary identification, existing systems (e.g., white cards in India identifying households below poverty line) could be utilized and, if necessary, improved upon. It is also recommended that attempts to design an alternative targeted subsidy take into account the lessons of evaluating the Deepam Scheme in Andhra Pradesh that highlights the challenges of promoting the use of LPG among the rural poor in low-income countries.

D. Addressing IAP through gender and community development

16. Address the needs of rural communities in IAP/household energy programs

16.1 To be effective in reducing IAP, household energy programs should address the range of livelihood and poverty needs of both women and men. Men, for example, may desire well-cooked, on-time meals; a healthy family; and lower costs for fuel and health care. Women on the other hand may look for reductions in their workload stress in the energy system, improvements in kitchen hygiene and lighting convenience, and biomass fuel supply. In poor households, energy and time use for consumption and production are closely inter-related: food and beverages may be prepared for family use as well as sale; fuelwood may be collected for cooking and higher quality fuels sold; etc. Increasing opportunities for women to earn income outside of the household may be the only way to reduce use of fuelwood collected with unpaid family labor. Programs to improve household energy services and mitigate IAP need to address these aspects, by providing opportunities for income-earning for women, as well as for men, in stove-building, in tree nurseries, and other activities.

17. Empower women to make household fuel choices

17.1 For the rural poor, the more dominant economic decision-making power and preferences of men play a significant role in fuel use choices at the household level, while women continue to bear the burden of collecting fuel wood and use it for cooking, thus exposing themselves to highest levels of indoor air pollution. (This was demonstrated by a number of studies including the recent one in Andhra Pradesh, India). It is therefore important to ensure mechanisms that allow both women and men to make choices and influence household decisions regarding the use of fuels. Creating self-help groups and ensuring income-generation opportunities for women as part of household energy projects are some proven approaches here.

17.2 In the Indian stoves program, there is evidence that the program fared better in areas (such as Haryana) where women were involved in stove making and dissemination. Stove programs and, in the broader context, energy programs should effectively involve women. Some of the areas include:

- Management and implementation of community-based energy programs.
- Data collection, as surveyors and data analysts.
- Capacity building in operation and maintenance of stoves and other household pr community energy devices, such as repair and maintenance of biogas plants and solar lanterns etc. This will also help in the sustainability of the household energy programs by bridging the gap of “after sale” services in the rural areas.
- Education on the negative health impacts of use of solid fuels and possible solutions.

18. Research the role of gender in energy programs

18.1 While proven methodologies for gender analysis are widely available and used in many development sectors, only a few studies of IAP have used gender analysis.[21] More case

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21 Gender analysis is the basic tool that should be used at all stages for understanding gender differences in IAP/household energy. This means looking at differences between men and women in e.g. division of labor, intra-household distribution of subsistence resources, access to productive resources and assets, income-earning opportunities, and participation in decision-making in the household energy sector. Gender analysis can be used to increase the effectiveness of household energy interventions at the policy level (policy support for household energy and for gender-sensitive participation), at the institutional level (gender balance and expertise, disaggregation of data by gender, and how gender is defined), and at the implementation level, both for stove producers (gender balance in training and perceived benefits) and for stove users (inputs to stove design, benefits perceptions, stove purchase, and use in small businesses, by men and women).

studies and impact studies are needed to better understand the relationship between women's status and the value of women's unpaid labor, and appropriate IAP interventions. Further adaptation of gender analysis to the household energy sector is also needed. While there is often a perceived link between gender-sensitive participation and successful household energy projects, this link and related impacts have not been well-documented to have a clear and practical answer under which conditions does gender "make a difference" in project success.

18.2 The barriers and constraints faced by men and women due to various factors, such as cultural habits and traditions, in adopting certain technologies have been largely ignored. Thus, studies that improve our understanding of the socio-economic impacts of technology will make a valuable contribution to designing effective household energy programs. Issues such as energy-use patterns, the effect of IAP on health, and the benefits of saved time should be addressed in these studies. More systematic exchange of information on the lessons and success stories of energy programs in various countries could be also undertaken.

E. Exposure and Health Research

19. Increase support to priority areas of immediate policy relevance

19.1 While research gaps should not be used as an excuse to delay actions, there are some critical areas where better knowledge is needed to help design effective interventions. Given that household fuel related IAP research was significantly under-funded in the past, these priority areas warrant increased level of support by developing countries' governments and international donor agencies.

20. Develop rapid and robust methods for exposure assessment

20.1 Although it is health risks that drive policy concern, collecting data on health endpoints is costly and time-consuming. Data on exposures are easier to gather and can be used as a proxy indicator of likely levels of indoor air pollution. However, while exposure is a reasonably good surrogate for making health predictions at the population level, more work is needed to determine the linkages between exposure and health at an individual level in health research studies.

20.2 Exposure assessment studies can also help to reveal crucial household parameters that predict indoor air pollution levels. One recent study in Andhra Pradesh, India, identified three parameters that were highly predictive of these levels, namely, fuel type, kitchen type, and/or kitchen ventilation. Similar studies in other geographic areas need to be done to identify and validate key determinants of exposure. These factors can then be added to large-scale surveillance instruments such as censuses and surveys. These existing surveillance systems, if well designed, are useful for making predictions of household levels of exposure on a population level and may even prove fruitful for ecological analyses in epidemiological studies.

20.3 Overall, there is a need for developing appropriate exposure assessment methods to address three objectives:

- Estimating exposure to indoor air pollution for national/state/regional level monitoring of exposure levels and health risks,

- Assessing impact of interventions on reduction in exposure levels and health risks for cost-effectiveness analyses, and
- Use in health studies to strengthen links between exposure levels in rural settings and health end-points (see below).

20.4 The workshop also pointed to the need of exposure research in the following areas:

- Variations and characteristics of exposure to IAP in settings though cooking vs. cooking and heating
- Assessment of how activity patterns affect exposure.
- IAP source apportionment and assessment of IAP's impact as a portion of total air pollution exposure (indoor and outdoor).

21. Research the link between health and IAP

21.1 While there seems to be sufficient evidence on the linkages between IAP and acute respiratory infection, stronger evidence through additional research is needed in the following areas:

- Association of IAP with such health outcomes as tuberculosis, asthma, and infant mortality
- Contribution of IAP to the overall burden of disease, including the confounding effects of IAP on other risk factors such as malnutrition, tuberculosis, or diarrhea or major diastase causes of infant mortality
- Exposure-response studies aimed at clarifying how much reduction in exposure is needed to reach a target health level
- Specific health effects related to use of coal including the effects of exposure to fluoride, arsenic, and different pathways of exposure
- Linkages with ambient air pollution and its health effects e.g. asthma
- Impact of interactions with environmental tobacco smoke
- Impact of exposures from possible alternative energy sources such as bedroom mosquito coils, volatile compounds from dung burning and toxic trace constituents from burning industrial materials
- Impacts of biological agents and varying pollutant mixtures (bio marker based research)
- Impact of behaviors, beliefs, cultures, literacy on health outcomes
- Economic impacts of the health burden due to IAP.

22. Strengthen intervention and operational research

22.1 Operations and intervention research is needed in the following areas:

- Operations research on the effectiveness of IEC (information, education, and communication) activities, e.g., the use of mass media
- Intervention research to evaluate exposure reduction and health benefits (effectiveness) of various mitigation strategies involving behavioral and/or technological changes. For instance, in some settings behavioral change may produce substantial impact, which may alleviate the need for technological improvement.
- Policy-relevant research focusing on economic, institutional, regulatory, socio-cultural feasibility of IAP–related interventions to and improved health, in addition to mere technical feasibility.

F. Integrating the local and global benefits of IAP mitigation

23. Attach priority to local health benefits

23.1 Given the magnitude of the health impacts, household energy strategies should be driven by local health benefits.

24. Explore synergies to develop win-win strategies

24.1 At the same time, it is useful to identify “local-global” win-win solutions, such as more efficient coal stoves or stoves with high combustion efficiency and using processed (gaseous) biomass, i.e., biogas and producer gas. One new area to explore is black carbon emission from traditional biomass cookstoves. At present, there is uncertainty about black carbon emission from cookstoves and their contribution to greenhouse gas (GHG) emissions, with some studies showing greater GHG impact of traditional energy compared to modern household fuels. There is a need to strengthen research in the area of black carbon emission from cookstoves and life cycle analysis of alternative fuels, such as biogas or LPG. Common models could be developed for standardization of the data generated and strengthening conclusions.

24.2 It is further recommended that the Intergovernmental Panel on Climate Change (IPCC) considers creating a sub-committee to explore the co-benefits of various interventions in terms of global warming and local health benefits, including (but certainly not limited to) household energy options.

25. Assess and tap opportunities for international “climate change” financing

25.1 “Win-win” strategies could help developing countries mobilize additional international financing for the benefits of global environment and local users. Accordingly, assistance should be provided to local institutions to develop capacity to use existing financial mechanisms, such as GEF, the Prototype Carbon Fund (PCF), or bi-lateral resources. For example, the Bank helped Mongolia to prepare a project where GEF is supporting market development for more efficient coal stoves, which are also expected to reduce exposure and improve health of the users. GEF also supported some activities involving biogas and gaseous biomass.

25.2 The potential for support by these financial mechanisms of improved stoves using traditional biomass has not yet been explored. A research on black carbon emissions from traditional biomass energy can, in principle, open a window for such support; however, it is unlikely to become a priority area for institutions, like GEF, tasked with supporting most effective and far-reaching measures to protect “global commons.” Thus, attempts to explore and obtain such international financing should ensure that transaction costs are not excessive relative to possible financial support and that attention of local institutions is not diverted from the main local health and development issues. This points to the need for new donor initiatives that will better reconcile global environmental agenda with community development needs.