LPG as a cooking fuel option for India

Antonette D'Sa and K.V. Narasimha Murthy
International Energy Initiative, 25/5 Borebank Road, Benson Town, Bangalore 560 046, India
E-mail: ieiblr@vsnl.com

The use of clean fuels such as liquefied petroleum gas (LPG) instead of the biomass-based fuels used for cooking in India would be beneficial in several ways. However, only about 33.6 million or 17.5% of all Indian homes use LPG as their primary cooking fuel, with 90% of rural homes still dependent on some form of biomass. Hence this paper considers the possibility of enhancing the household use of LPG. From an overview of the cooking fuels used in India, it focuses on LPG, analysing the factors affecting current demand and projecting future scenarios. Salient features of the LPG supply and distribution system are also discussed. On the basis of the existing situation, barriers to increasing LPG use -- in particular, the problems regarding affordability, pricing and reliable distribution -- have been identified. In this context, experiences with the expansion of household LPG use in other countries and a programme in India have been considered. Finally, on the basis of the challenges recognised, suggestions are being made regarding the policies through which the problems can be overcome.

1. Introduction

In India, over 700 million people live in homes where biomass-based fuels are used for cooking. Such fuels have adverse impacts on those directly involved, through the concentration of particulate matter from inefficiently burnt fuels and laborious fuel collection, and on the community, through the ambient pollution from simultaneous cook-fires and land degradation in cases where fuel-wood is gathered in an unsustainable manner.

Household fuel use can be viewed along an "energy ladder", beginning with traditional biomass, and proceeding to fuel-stove combinations that are cleaner, more convenient and more efficient, but increasing in capital costs, as the ladder is ascended [OTA, 1992]. Unfortunately, while households around the world have moved to higher rungs of the ladder, as alternatives become affordable and available, many in developing countries are still dependent on fuel-wood, and some have been forced down by local fuel-wood shortage to even shrubs and grasses [UNDP et al., 2000, Ch. 3].

1.1. Why LPG?

The harmful effects of traditional fuel use on health have been proved in several regional studies. For example, a study of 58,768 individuals from 10,265 rural households of 118 villages in three north Indian states [Parikh et al., 2003] found correlation between the incidence of respiratory ailments and the use of biomass-based fuels, exacerbated by factors such as kitchen location and limited ventilation. A World Bank study of 59,000 children (aged 0-4) in the south-eastern state of Andhra Pradesh reported substantial reduction in child mortality through the use of cleaner fuels, in comparison with wood, dung, and coal [WB, 2002].

Since the tasks of collection and processing of most forms of biomass usually fall on women[1], the easier availability of alternative cooking fuels would reduce this drudgery and enable them to divert their time and energy to other pursuits. Set against this is the fact that fuel-wood scarcity is prolonging the hours spent on fuel collection by an estimated 172 million women and girls in several rural areas of India [WHO, 2000].

Further, a detailed study of household stoves in India [Smith et al., 2000], has concluded that the biomass stoves in common use burn with relatively low efficiency, while emitting products of incomplete combustion, so that a switch from these to kerosene or LPG[2] could be recommended even if biomass fuels were renewably harvested. Among the currently available "clean" cooking fuels biogas has been found to be the most efficient [Smith et al., 2000]. However, although renewable, its use is restricted by the availability of cattle. Between kerosene and LPG, the latter is preferable, on the basis of the environmental impacts of the entire fuel cycle (extraction of petroleum and natural gas, processing, transport, and distribution), and cooking [Jungbluth, 1995].

Annualised life-cycle costs (ALCCs)[3] may be used for comparison of the commonly used fuels/stoves. ALCC includes both initial costs (stove prices and any other capital costs) and operating costs, which vary with the fuel requirement (depending on the energy content of the fuel and the stove efficiency) and fuel prices. (See Appendix A for the data and calculation.) When ALCCs are compared, LPG is not as expensive an option as is usually perceived, because the larger initial investment is compensated for by the longer life of the equipment and the higher fuel efficiency.

LPG can therefore be recommended both for its higher efficiency and lower environmental impact than the alternatives, even without imputing an economic value to the avoided human labour and time saving. However, since India needs imports of both crude oil and LPG, and international sources could be adversely affected by political

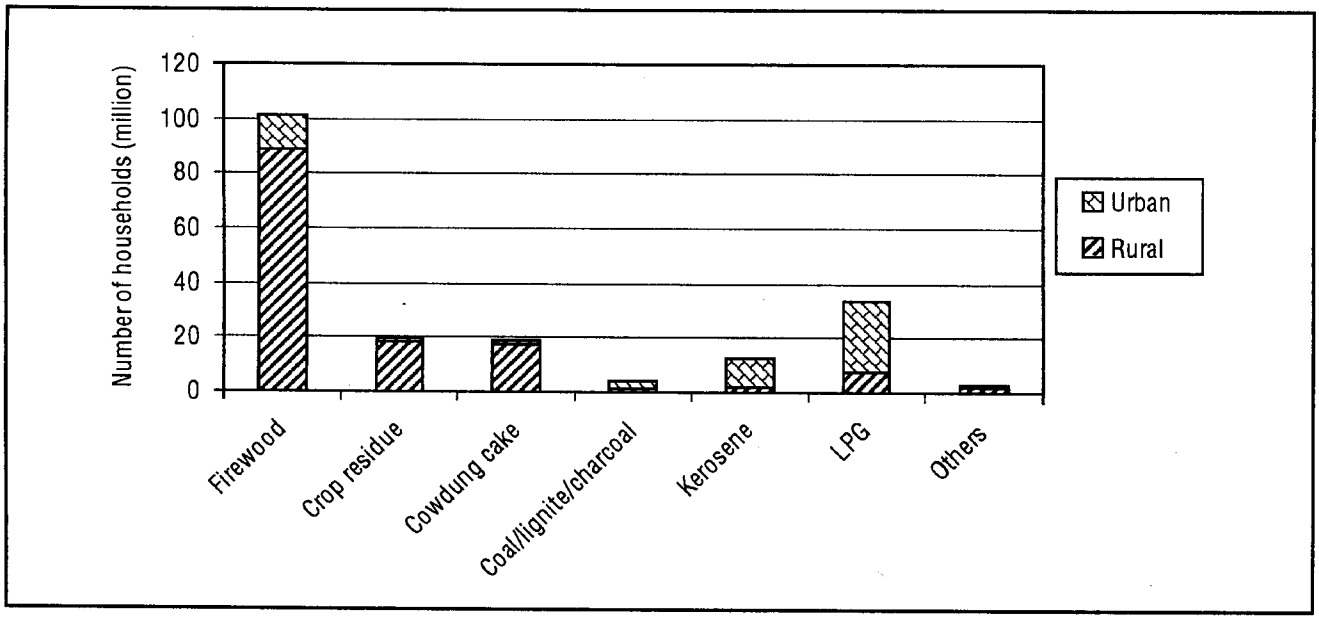


Figure 1. Indian household use of cooking fuels in 2001

problems and price volatility [Sihag et al., 2004], supplies could be insecure. It can also be argued that since LPG is derived from fossil fuels, its increased use should not be advocated.

There are other alternatives to traditional fuels. For example, one could consider processed biomass fuels already used in a few places in the country, such as producer gas, and those not yet in use, such as dimethyl ether (DME) and synthetic LPG. Renewable sources would obviously be preferable in the long term, if they were used sustainably.

Therefore, the use of LPG is being considered as a medium-term option for India, in the transition to long-term sustainable fuels[4].

1.2. Objectives of this paper

The purpose of this paper is to:

- present an overview of the domestic use of cooking fuels in India, focusing on LPG;
- derive factors affecting current domestic LPG demand and possible growth;
- list important features of the existing supply and distribution system;
- identify the challenges that are likely to be faced to the increased delivery and use of LPG;
- list experiences from elsewhere, to elicit reasons for the adoption of LPG; and
- conceptualise the policies that could help surmount the perceived challenges to increasing domestic LPG use.

2. Demand for LPG

While the worldwide annual growth rates of LPG demand averaged 3.7 % during the 1990s, India's growth was 9.5 %. Assessment of end-use demand indicates that the largest growth rates in the residential-commercial category will be in China and India; in 1985, 5 % of the world's residential-commercial LPG consumption was in these two countries, but by 2005 this share is expected to rise to more than 20 % [Purvin and Gertz, 2000]. India's dependence on LPG, at 7.8 % of its consumption of all refined petroleum products, is one of the highest in the Asia-Pacific region [MoP&NG, 2003a].

2.1. Cooking fuels used by Indian households

Sample survey estimates of household fuel use in India can be obtained[5], but the only exhaustive survey is conducted during the decennial Census of the population. Figure 1 (constructed from Census of India, 2001) shows the proportion of households using each type of cooking fuel, in rural and urban areas, respectively. In rural areas, where 72 % of the country's households reside, firewood (used by 64.10 %) is, by far, the most important fuel; other sources of biomass – crop residue (13.10 %) and cowdung (12.80 %) – are the main alternatives, so that over 90 % depend on these traditional fuels. However, in urban areas, the most commonly used fuel is LPG (47.96 %), followed by firewood (22.74 %) and kerosene (19.16 %).

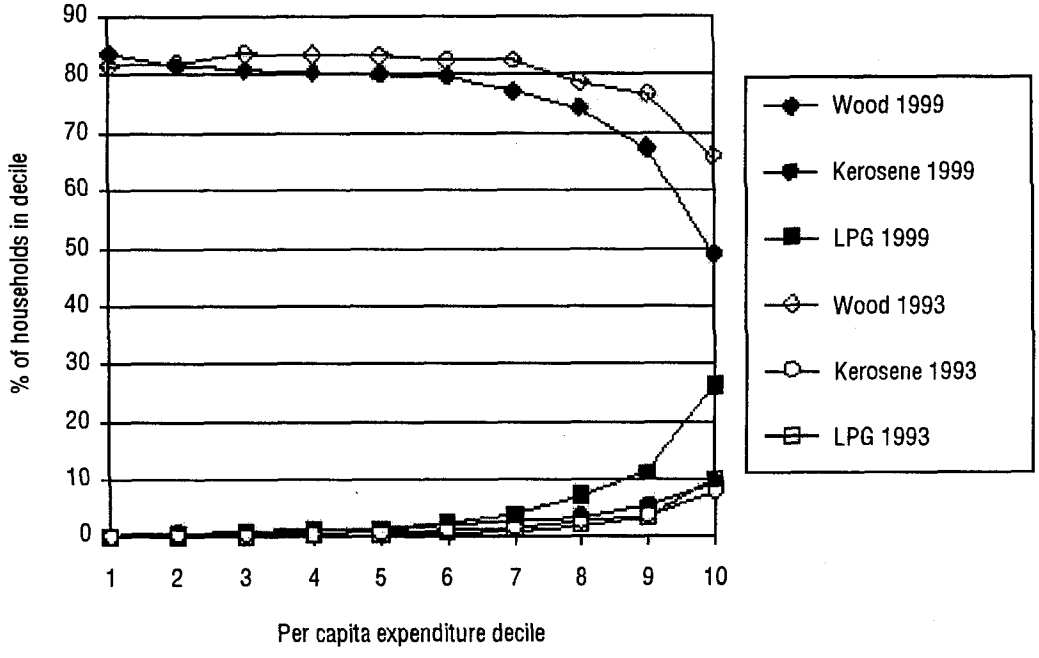
2.2. LPG use by Indian households

While analysing fuel use, we have elicited factors likely to affect the choice of LPG. The extent of LPG use has then been examined, as indicated by the number of households dependent on it and the amount of LPG used. On the basis of these parameters, future demand scenarios are being projected.

2.2.1. Factors contributing to the choice of LPG

Several factors, in particular, household income, accessibility, and the prices and availability of alternative fuels, appear to determine the choice of LPG as a cooking fuel.

Using the National Sample Survey (NSS)-reported household expenditure as a proxy for household income, Figures 2a and 2b display the percentage of households dependent[6] on each cooking fuel in each expenditure decile of the sample. The graphs demonstrate that, with increasing income, households shift from fuel-wood to kerosene and then to LPG. It appears that, as incomes of households rise, their resources increase, facilitating the additional expenditure involved. Further, with increasing income, consumers can more easily make payments (or



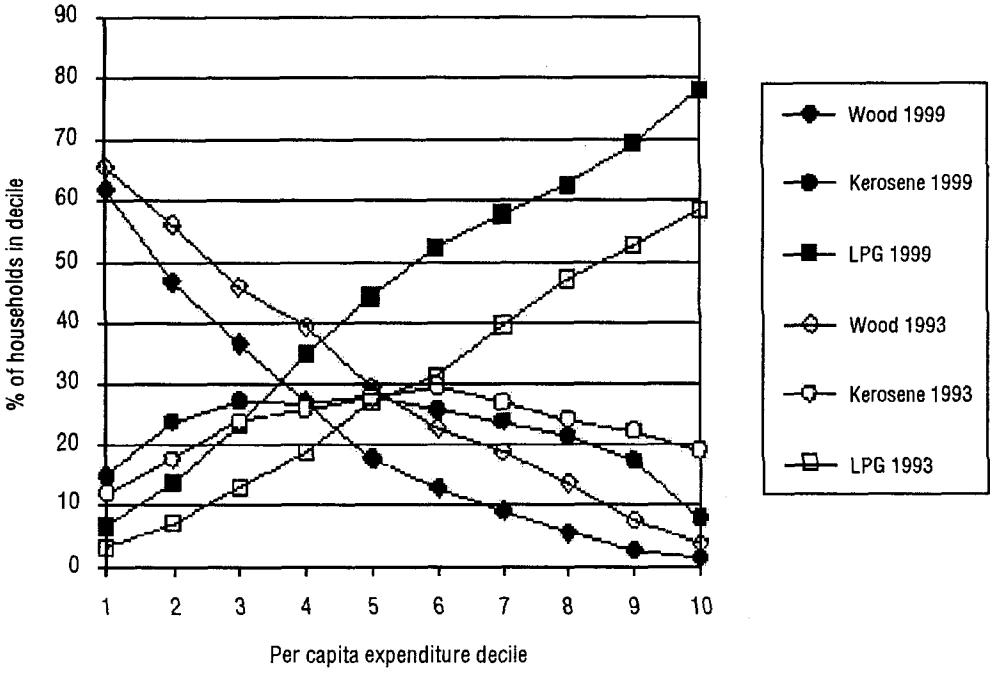


Figure 2. Use of cooking fuels varying with income in *rural* India (Figure 2a, above) and *urban* India (Figure 2b, below) (based on 1993-94 and 1999-2000 NSS data)

forgo present consumption) in return for future saving, that is, their "consumer discount rates" fall. Consequently, they can opt for higher-initial-cost options such as LPG whose fuel efficiency offers future saving in operating costs[17]. Conversely, at the lowest income levels, people persistently use unpriced biomass, because their subsistence-level existence prevents the purchase of fuel.

In addition to the ability to pay, increasing incomes lead to better education, awareness and social status; these also encourage fuel shifts, evidenced in the quick switching from wood and twigs to kerosene as a family moves from a slum to a tenement [Gupta and Köhlin, 2001]. Adoption of a "better" fuel has also been perceived as a status symbol [NIRD, 2002].

In addition to the prices of the fuel-stove package, the price of the fuel alone may be considered a determinant

of the choice of fuels. However, the increase in LPG use has not been brought about by price reduction, as LPG prices during the 1990s, administered by the central (i.e., federal) government[8], have actually risen slightly more than the corresponding consumer price index. In this context, the costs of substitute fuels have also to be considered. The fuel costs of cooking with kerosene, a fuel that usually precedes LPG along the energy ladder, slightly exceed those of LPG (indicated in Appendix A), with its price increase having been relatively higher[9]. Hence, the shifts from kerosene to LPG that have occurred indicate a positive cross-elasticity of demand, expected for a substitute. It must be noted here that the investment in the equipment for a particular energy carrier could prevent easy shifts to another that could be caused merely by small increases in the fuel prices of the current carrier. And, the alternative of unpriced biomass continues to be the predominant choice.

Apart from affordability, the availabilities of a fuel and its competitors tend to affect householders' choices, and, in so far as location determines availability, it is also a determining factor. Thus, crop residues are used even by higher-income households with farmlands, and conversely, in urban areas, several non-biomass options are used. Since kerosene is more easily transported and stored than LPG, it is used in places where LPG is not accessible.

In urban areas, there have been substantial shifts towards LPG during the last two decades. This could have been stimulated by the demonstration effect, with the acquisition of LPG "connections" (registration with a distributor who supplies cylinders and replaces them when they are empty) by a few families leading to escalating demand in the neighbourhood. To the extent of there being long waiting lists of households seeking connections, the shifts indicated in the graphs could actually be blunted by the lack of availability. This has recently been relieved by increases in the number of distributing agencies, particularly private distributors.

However, the "switch" between fuels is often found to be incomplete in both rural and urban areas [ESMAP, 2001]; many households use more than one fuel, with that used for cooking the main meal not necessarily used for supplementary meals and heating. Thus, shifts to better fuels do not completely eliminate the use of the traditional carrier. Further, although there appear to be more choices in urban areas, the gaps in and uncertainty of supply of each lead to families storing and using more than one fuel, as a risk-reduction strategy.

2.2.2. Current extent of dependence on LPG

LPG is the primary cooking fuel for 33.6 million homes, 17.5 % of the total population. This includes 7.845 million rural homes (5.67 % of the rural population) and 25.752 million urban homes (47.96 % of the urban population). LPG dependence varies from over 50 % in the (chiefly urban) Union territories (territories under greater direct control of the central government) to under 10 % in several eastern states (Table 1).

The total number of users, indicated by the number of connections[10] reported by LPG distributors (i.e., retailing

Table 1. State-wise use of LPG as fuel for cooking in 2000-01

State/Union territory	Total number of households	Households using LPG	LPG-using proportion (%)
All-India	191,963,935	33,596,798	17.5
Delhi	2,554,149	1,737,730	68.0
Chandigarh	201,878	126,146	62.5
Goa	279,216	145,453	52.1
Daman and Diu	34,342	17,304	50.4
Pondicherry	208,655	83,326	39.9
Mizoram	160,966	60,600	37.6
Punjab	4,265,156	1,435,648	33.7
Uttaranchal	1,586,321	531,076	33.5
Haryana	3,529,642	1,067,110	30.2
Maharashtra	19,063,149	5,656,425	29.7
Gujarat	9,643,989	2,746,018	28.5
Himachal Pradesh	1,240,633	348,727	28.1
Jammu and Kashmir	1,551,768	343,052	22.1
Dadra and Nagar Haveli	43,973	9,595	21.8
Manipur	397,656	86,608	21.8
Arunachal Pradesh	212,615	42,994	20.2
Andaman & Nicobar Islands	73,062	14,706	20.1
Tamil Nadu	14,173,626	2,703,970	19.1
Andhra Pradesh	16,849,857	3,200,615	19.0
Sikkim	104,738	19,718	18.8
Karnataka	10,232,133	1,874,198	18.3
Kerala	6,595,206	1,168,536	17.7
Rajasthan	9,342,294	1,437,023	15.4
Madhya Pradesh	10,919,653	1,483,947	13.6
Assam	4,935,358	652,306	13.2
Tripura	662,023	85,477	12.9
West Bengal	15,715,915	1,962,540	12.5
Lakshadweep	9,240	1,055	11.4
Uttar Pradesh	25,760,601	2,913,579	11.3
Nagaland	332,050	31,479	9.5
Meghalaya	420,246	32,520	7.7
Chhattisgarh	4,148,518	309,801	7.5
Jharkhand	4,862,590	327,624	6.7
Orissa	7,870,127	410,823	5.2
Bihar	13,982,590	529,069	3.8

Source (data): Census of India, 2001

Table 2. Trend in India's total LPG consumption, number of consumers and distributors

Years	Total (all sectors') consumption (kt)	Number of connections[1] (million)	Number of distributors
1980-81	405	3.3	1,105
1985-86	1,241	10.7	2,742
1990-91	2,415	17.0	3,930
1995-96	3,849	25.7	5,165
1996-97	4,183	29.3	5,426
1997-98	4,581	33.7	5,538
1998-99	5,041	38.1	5,648
1999-2000	6,029	47.3	6,161
2000-2001	6,613	57.9	6,477
2001-2002	7,310	63.5	7,486
2002-2003[2]	8,157	69.8	7,910

Sources (data): CMIE, 2003; MoP&NG, 2003b.

Notes

1. All consumer categories
2. Provisional data

Table 3. Domestic dependence on LPG in 2001

For the base-year (2001)	Units	Rural	Urban	Total
Census data: total number of households in the country	million	138.272	53.692	191.964
Census data: number of LPG-dependent households	million	7.845	25.752	33.597
Proportion of households using LPG	%	5.67	47.96	17.50
Assumed average annual use per household (based on derived All-India average and National Sample Survey results)	kg/year	101.4	119.3	115.1
Estimated total domestic LPG use	Mt	0.795	3.072	3.868

agencies or vendors), has increased fourfold since 1990-91 (Table 2). Categories of consumers have not been specified, but a comparison with Census of India estimates shows that in 2001, about 58 % of these connections were domestic.

2.2.3. Consumption levels

Apart from the number of LPG-using households, one needs to consider the amount of LPG used. The average use of LPG for all connections is 115 kg per year. But, for this analysis, the use by households is required. In 1999-2000, the average use in rural and urban areas was 11.3 kg per month (135.6 kg per year) and 13.3 kg per month (159.6 kg per year), respectively [NSSO, 2001]. However, the authenticity of these estimates is based on *each respondent's ability to recall and/or correctly estimate* the family's use, evidenced by the clusters around one cylinder (14.2 kg) and half a cylinder (7-8 kg) per month. There also appears to be some overestimation as compared with the distributors' estimates of sales, where available.

Regarding the rural-urban differences, the lower rural use appears to be due to the greater difficulty in obtaining refuelling, as well as the availability of biomass sources that could be used to complement the LPG supply. Further, in urban areas, LPG obtained through "domestic connections" has been known to be used for cooking in commercial establishments, for fuelling vehicles, and for small industrial units.

For an accurate estimation of domestic LPG requirement, one would need the true fuel requirement per household based on the stove efficiency and cooking time. This would require detailed computation, particularly with cooking needs varying with lifestyle patterns and regional customs. To avoid this, the assumption is being made that the average annual *consumption* per LPG connection is also equivalent to the annual *requirement* per household. This average is being adjusted for rural and urban use by *the average NSS-reported household use, i.e., 11.3 kg per* month and 13.3 kg per month, respectively. Thus, we get an annual average consumption, per LPG-using household, of 101.4 kg for rural areas and 119.3 kg for urban areas. For the reported LPG-using households in the year 2001, the total requirement would have been 0.795 million tonnes (Mt) in rural areas and 3.072 Mt in urban areas, as shown in Table 3. This represents 58.5 % of the total Indian use of 6.613 Mt reported for that year [MoP&NG, 2003b].

2.3. Estimated future requirement of LPG

If household use of LPG is to be encouraged, one would have to estimate the extent to which LPG requirement would increase. To project such scenarios, one would need to consider *the average LPG requirement per household* and the *trend (growth rate) in the number of LPG-dependent households.* Then, for a *"business-as-usual" scenario,* both the LPG requirement per household and the growth rates of households would be at current (or base-year) levels, whereas for other scenarios, one or both parameters could be altered.

The number of households using a particular fuel in a given year has been estimated from the National Sample Survey (NSS) data on the proportions of the population using specific fuels and the estimated total number of households in the country (Table 4).

From the number of LPG-using homes estimated, the current (1999-2001) average annual increase in users has been found to be 6.82 % for rural areas and 11.75 % for urban areas. These rates have been projected for a business-as-usual scenario, where the number of households and the LPG requirement have been shown at 5-year intervals till the year 2015-16[11] (Table 5). However, with the current rates of LPG adoption, even in this terminal

year, LPG would be used for cooking in only about 11.9 % of rural homes. For the country as a whole, LPG would cater for about 36.4 % of homes, with the total requirement amounting to 10.8 Mt.

Another scenario could consider increasing the rural dependence through doubling the business-as-usual growth of LPG connections from 2005-06 onwards (also shown in Table 5). Even so, only about 22 % of rural homes would be using LPG in the year 2015-16. About 43 % of all Indian homes would be included, with the total requirement amounting to 12.6 Mt.

Other enhanced-rural-growth scenarios can easily be projected; for example, a scenario where 100 % of the homes depend on LPG in the same year would result in a requirement of 27.6 Mt. However, these scenarios are unlikely to be plausible without substantial increases in household incomes[112].

Table 4. Estimated number of households using LPG in 1993-94 and 1999-2000

	Units	Rural	Urban	Total
1993-94				
Estimated total number of households	million	123.187	44.405	167.593
LPG-using proportion	%	1.80	29.70	9.19
LPG-using households	**million**	**2.217**	**13.188**	**15.406**
Kerosene-using proportion	%	1.90	22.90	7.46
Kerosene-using households	million	2.341	10.169	12.509
Firewood-using proportion	%	80.10	30.30	66.90
Firewood-using households	million	98.673	13.455	112.128
1999-00				
Estimated total number of households	million	136.009	52.255	188.264
LPG-using proportion	%	5.40	44.10	16.14
LPG-using households	**million**	**7.344**	**23.045**	**30.389**
Kerosene-using proportion	%	2.70	21.70	7.97
Kerosene-using households	million	3.672	11.339	15.012
Firewood-using proportion	%	75.40	22.20	60.63
Firewood-using households	million	102.551	11.601	114.151

Notes

The total number of households in each year was estimated by interpolating between the Census of India figures for 1991 and 2001. The proportion of total households using a particular fuel is from the National Sample Survey (NSS) in the given years.

3. Supply of LPG

The worldwide production of LPG has been increasing, and its growth rate is likely to outstrip that of most other oil products, since natural-gas processing – now the largest source of LPG – is increasing more rapidly than crude-oil processing.

3.1. Current availability of LPG in India

Indigenous production of LPG in India grew steadily during the 1990s, both from crude-oil refining and from natural-gas processing (Table 6). Imports also increased as demand exceeded indigenous production, but fell during 2000-02 owing to a surge in refinery output.

3.1.1. Indigenous production capacity

India's crude refining capacity for *all* petroleum products (in April 2002) was 116 Mt per annum (Mt/a) [MoP&NG, 2003c]. There are currently 18 refineries in operation (Figure 3)[113]. Five major refinery projects are also being implemented to add 40.5 Mt/a to refining capacity. Given the projected increases in capacity at specified refineries, one can estimate the increase in LPG production, because each refinery has its own product slate depending on the configuration of its processing units. The current LPG yield from Indian refineries is about 4.5 % of the total of all products [MoP&NG, 2003a]. LPG production from natural gas is also increasing, with new LPG extraction plants set up by the Gas Authority of India Limited [MoP&NG, 2002].

3.1.2. Imports

Imports of petroleum, oil, and lubricants (POL) had been contributing significantly to the country's import bill, particularly during the 1980s (Table 7). However,

Table 5. Scenarios for household use of LPG (2005-06 to 2015-16)

Year	Number of households using LPG (million)			Proportion of total households using LPG (%)			Consumption of LPG (Mt)		
	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total
	Scenario 1: business as usual with current growth rate								
2005-06	10.91	44.87	55.78	7.27	72.97	26.36	1.11	5.35	6.46
2010-11	15.17	63.38	78.56	9.30	90.00	33.64	1.54	7.56	9.10
2015-16	21.10	72.59	93.69	11.91	90.00	36.35	2.14	8.66	10.80
	Scenario 2: increased rural growth, with double the growth of rural users but current use per household								
2010-11	20.67	63.38	84.06	12.68	90.00	36.00	2.10	7.56	9.66
2015-16	39.17	72.59	111.76	22.12	90.00	43.36	3.97	8.66	12.63

Note

At the current rate of adoption of LPG for cooking, the *urban* dependence will reach 90 % around 2008; thereafter the growth rate of LPG-using households has been pegged at the current average household growth rate (2.75 %).

Table 6. LPG production in India (Mt)

Years	From crude oil refineries (a)	From natural gas fractionators (b)	Total indigenous production (a)+(b)	Net imports
1990-91	1.221	0.929	2.150	0.329
1995-96	1.539	1.714	3.253	0.596
1998-99	1.724	1.914	3.638	1.173
1999-2000	2.487	1.986	4.473	1.587
2000-01	4.088	2.045	6.133	0.853
2001-02	4.778	2.205	6.983	0.659
2002-03[1]	4.903	2.370	7.273	1.073

Sources (data): Ministry of Petroleum and Natural Gas [MoP&NG, 2003b,c]

Note

1. Provisional figures

Table 7. Importance of crude oil and petroleum product (POL) imports

Year	Value of imports of POL, i.e. crude oil and petroleum products (US$ million)	As a percentage of total imports (%)	As a percentage of total exports (%)
1970-71	180	8.3	8.8
1980-81	6,656	41.9	78.4
1990-91	6,028	25.0	33.2
1995-96	7,526	20.5	23.7
1996-97	10,036	25.6	30.0
1997-98	8,164	19.7	23.3
1998-99	6,433	15.4	19.1

Source: Directorate General of Commercial Intelligence and Statistics (DGCIS), Kolkata, quoted in [MoF, 2000, Table 7.2(A)]

Note

POL = Petroleum, oil and lubricants

India has recently begun exporting some petroleum products (naphtha, motor spirit, diesel and fuel oil), thereby becoming a net exporter of petroleum products; only crude oil imports continue to be essential. Since LPG has accounted for only about 1.4 % to 3.4 % of the net POL bill over the last four years, it could continue to be imported to the extent of the production deficit.

To reduce the dependence on imports, the New Exploration Licensing Policy (NELP) has been drawn up. Exploration blocks, both on land and offshore, were awarded to bidders and a large gas discovery was made in the Krishna-Godavari basin (in Andhra Pradesh). Similarly, to encourage the exploration and production of new sources of hydrocarbon resources, the coal-bed methane (CBM) policy has been formulated, through which blocks for exploration and production in this category are awarded. In addition, the Oil and Natural Gas Commission (ONGC) has identified 15 major fields for implementing improved oil recovery plans [MoP&NG, 2002].

3.1.3. Transport

LPG transport is more economical in large shipments. For example, the shipping cost per tonne of a 1,000-t shipment can work out at least 30 % more than that of a 2,000-t shipment and at least three times that for a 12,000-t shipment [WB and WLPGA, 2001]. However, the existing Indian ports with infrastructure to receive POL, although suitable for crude oil, are inadequate for LPG. In addition, owing to insufficient import facilities on the east coast, relatively more expensive inland movement is required.

LPG is moved from the point of production or import by pipelines and (rail and road) tankers to terminals, where it is stored under pressure. It is then sent as required from these terminals to petrochemical plants, bulk depots, and cylinder-filling plants. Residential users receive pressurized cylinders through the LPG distributors of petroleum companies. Even at the present level of LPG use and geographical spread, the transport infrastructure needs upgrading; increased domestic use all over the country would necessitate extensive improvement.

The railways, restricted by the availability of tank-wagons, have been hauling only about 40 % of the petroleum product freight. To overcome the tank-wagon shortage, especially for transporting LPG, an "Own your tank-wagon" scheme has been introduced, whereby a rebate in freight charges is offered on tank-wagons owned by oil companies [MoP&NG, 2003c].

Around 32 % of petroleum product transport is by pipeline. This mode is recommended for reasons of safety, operational convenience, cost, and environmental benefits. Table 8 lists the region-wise petroleum product pipeline capacities while Figure 3 indicates their locations and those of the proposed projects.

The extension of pipelines may have been hindered by the high investment required; for example, Gas Authority of India Limited (GAIL)'s new 1,246-km LPG pipeline is estimated to cost Rs. 12.295 billion (US$ 273 million) [MoP&NG, 2002]. Acknowledging this, the ministry has recently approved the setting-up of an apex holding company that will co-promote specific pipeline joint venture companies (JVCs) to implement discrete sections of the grid [MoP&NG, 2003c]. The new pipelines projects yet to be fully commissioned, or under construction, are:

- the 1,246-km long GAIL pipeline between Kandla port and indigenous production units in Jamnagar (in western India) and Loni (in northern India), likely to convey 2.5 Mt/a, with receiving terminals to push LPG into the pipeline, pumping stations, boosters, and delivery terminals for supply to marketing companies [Indiainfoline, 2002];
- the 270-km long Mumbai-Manmad pipeline (in western India), with an initial capacity of 3.30 Mt/a; and
- the 380-km long Vishakhapatnam-Vijayawada pipeline (in south-eastern India), with an initial capacity of 4.00 Mt/a.

Road tankers carry the remaining nearly 30 % of petroleum product freight. Because of the insufficiency of pipeline capacity and tank-wagons, this mode is likely to continue.

Table 8. Indian petroleum product pipeline capacities (in Mt/a) in April 2002

Product	No.	Existing capacity	No.	Proposed capacity	No.	Total capacity (existing + planned)
Petrol/diesel						
West coast - inland	4	27.00	3	13.00	7	40.00
East coast - inland	3	6.70	1	1.40	4	8.10
Others	5	8.15	5	6.02	10	14.17
Total	12	41.85	9	20.42	21	62.27
LPG						
West coast - inland	1	1.70	1	0.80	2	2.50
East coast – inland	-	-	1	1.16	1	1.16
Total	1	1.70	2	1.96	3	3.66

Source: MoP&NG, 2003a

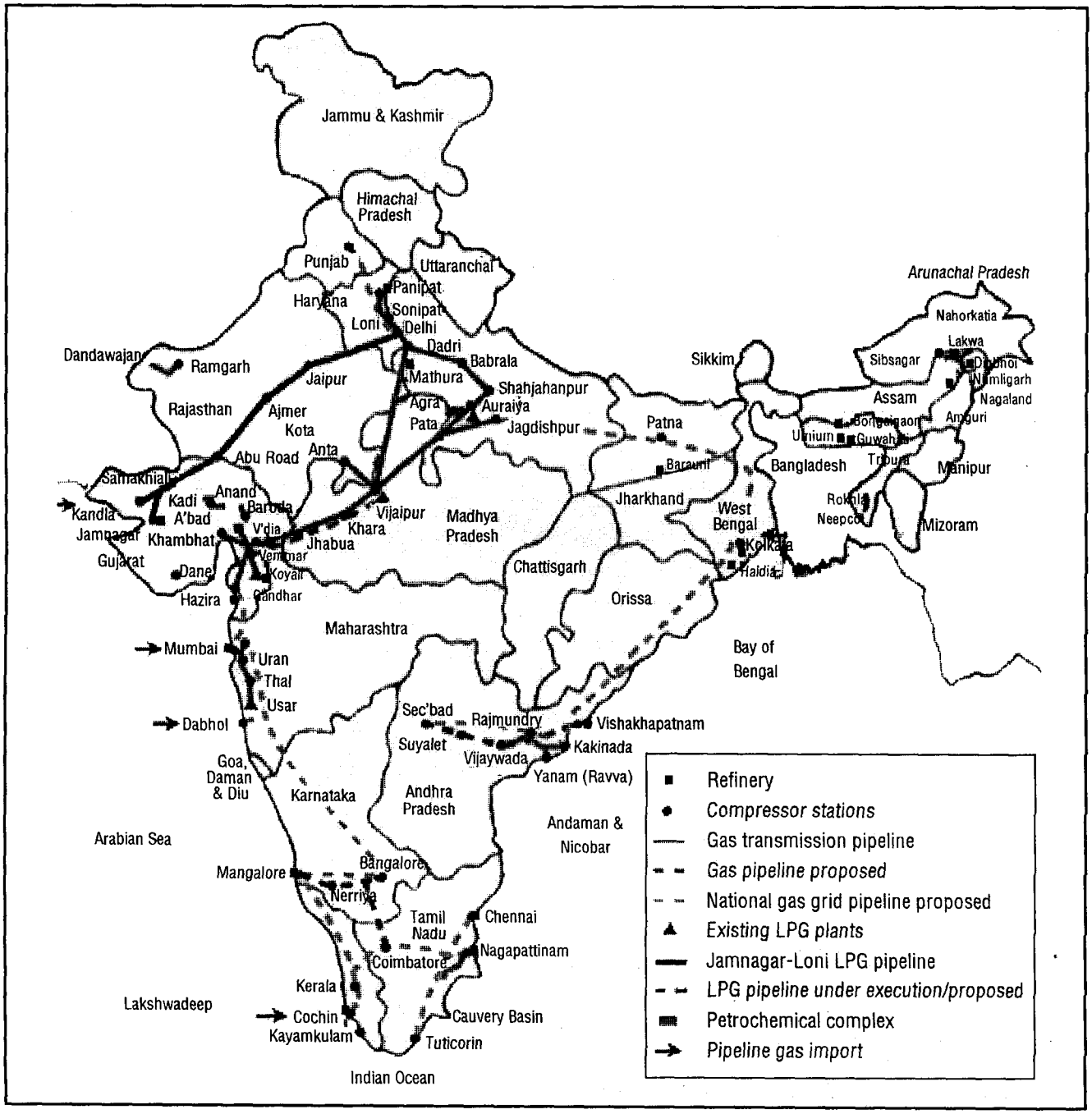


Figure 3. Petroleum refineries and pipelines (gas and LPG) in India

Currently, apart from direct import of products, limited product movement takes place between port locations, as India has only a few ports large enough to berth modern LPG tankers. Hence, the ministry is considering the option of unloading large tankers or "mother" vessels on the high seas to containers on smaller ships or "daughter" vessels [Petrowatch, 2003]; these can then berth at appropriate ports from where containers would be unloaded and stored till they can be moved to dispersed bottling plants. Southern and eastern India – with an LPG deficit and therefore dependent on imports – will benefit the most. Thus far, only Haldia (in West Bengal) and Vishakhapatnam (in Andhra Pradesh) have facilities to berth regular LPG tankers, and these cannot economically supply the southern peninsula. Through the proposed container option, the expensive option of constructing a large port is avoided and the existing smaller ports, such as Tuticorin (Tamil Nadu) and Kakinada (Andhra Pradesh), both on the south-eastern coast, can be utilised.

3.1.4. Storage and distribution infrastructure

For storage and distribution, one has to consider installations, depots, and tankage and bottling capacities. Installations are large storage points attached to refineries or to ports, serving as supply sources to locations in the region, while depots are smaller storage and distribution centres catering for the needs of a city or town.

At present, one or more of the public sector oil companies have installations in almost all major cities and port locations and depots at all district headquarters. In some areas, arrangements have been made between the companies for sharing infrastructure, in order to reduce costs. India usually has a total storage capacity of about 16 days' supply of LPG. A new 60,000-t LPG cavern-storage project in Vishakhapatnam, the first of its kind in south and south-east Asia, has also been initiated [Business Line, 2004].

LPG storage points and bottling plants have been set up near demand centres to facilitate movement of cylinders. Manual bottling and distribution in small carriers is cost-effective, hence one can ignore the economies of scale in bulk handling and distribution; however, safety and filling standards may not be as good as with automated filling plants. The initial cost of new bottling plants is about Rs. 2,600 (US$ 57.8)/t per annum (t/a) capacity, with a plant of 70,000 t/a having been built at Rs. 180 million (US$ 4 million) and another of 138,000 t/a, at Rs. 360 million (US$ 8 million) [MoP&NG, 2003c].

3.1.5. Marketing

The three main public sector oil companies, Indian Oil Corporation Limited (IOCL), Hindustan Petroleum Corporation Limited (HPCL), and Bharat Petroleum Corporation Limited (BPCL) have extensive sales networks. Of the cylinders currently being marketed by these companies, domestic consumers are provided with cylinders containing 14.2 kg, and, in a few areas, 5 kg (for low-income homes).

LPG marketing has historically been concentrated in urban and semi-urban areas; even so, there were long waiting lists for LPG connections. The entry of private LPG distribution companies has helped urban areas. Extension of supply in rural areas is being handled chiefly by public sector companies that have in recent times made some additional efforts. These include the introduction of compact 5-kg cylinders in some areas, the *rasoi ghar* (kitchen) scheme for communal use of LPG in a few villages[14], and rural mobile vehicles (RMV) for dispersed supply[15]. If supply were to be extended into rural areas on a larger scale, there would have to be more distribution agencies, as well as such schemes.

3.2. Supply-demand balances

Studies have estimated a shortage of LPG supply vis-à-vis demand of between 3.4 and 5.9 Mt by the year 2006-07 and increasing to 7.6 Mt by 2010-11 [MoP&NG, 2003a]. Given that the domestic requirement accounted for only 58.5 % in the base year 2001, enhanced domestic use would inflate the demand-supply gap even more. In addition, LPG is being increasingly used for automobile fuelling (legalised since 24 April 2001[16] and mandatory for three-wheeled auto-rickshaws in some states). This will be a competing burden.

However, the studies have not included new plants that may be constructed as a result of the recent successful exploration. The costs of new refinery capacity are high[17] and LPG constitutes a relatively small fraction of refinery output, on the basis of the current production slate. Nevertheless, increased indigenous production is likely.

With regard to actual LPG delivery to consumers, problems of regional imbalances and inadequate distribution facilities have to be addressed. The northern region, consuming about 33 % of the country's total LPG use, has been a petroleum-product-deficit area. The deficit will have to be met through increased transport from the western region via a cross-country pipeline and the completion of new refineries of 23 Mt/a capacity [Indiainfoline, 2002]. The western region uses about 30 % of the country's consumption, but if a spurt in demand does not occur, the commissioning of a new 27 Mt/a refinery [RPL, 2000] may bring about a surplus capacity. The southern region, consuming 25 % of the country's LPG use, is meeting its present requirements. The eastern region currently accounts for only about 12 % of the country's LPG consumption; its geographical spread together with the low per capita incomes in most areas have made it unattractive for distributors except in a few cities, chiefly Kolkata. Increased demand in the latter two regions would necessitate increases in cross-country transport or regional production capacity.

4. Challenges to increased domestic use of LPG

When considering the increased use of LPG for cooking, the main challenges we discern relate to the provision of equitable household access to the fuel while simultaneously ensuring viability of the production and distribution sectors. These challenges raise issues of affordability, effective pricing policies and adequate supply and distribution infrastructure.

4.1. Increasing affordability

A household's inability to pay for the costs involved in LPG use is experienced in several ways. The up-front costs of an LPG connection (deposit) and stove together[18] constitute one hurdle. Here, the household's income would affect its perception of costs, because the smaller its resources, the higher would current expenditure seem in relation to future savings. The fuel costs also undermine the use of LPG; these are high not only in relation to collectible biomass, but because larger minimum quantities usually[19] have to be bought at each refill (as compared with kerosene, charcoal, and wood).

A household's evaluation of LPG as a cooking fuel also affects its estimation of affordability, because while an improved energy carrier such as electricity leads to services such as lighting and television-viewing, enjoyed by all in the family, LPG could be seen as purely consumptive and benefiting only women. In general, improved cooking fuels do not feature high in household priorities.

It is also a fact that, at present, the poorest sections of the population cannot consider LPG even at subsidised rates. Even if financing facilities were easily available, repayment would be difficult without increased income accruing, as in the case of other energy services. While electricity for lighting facilitates longer and improved working conditions for cottage industries and service activities, leading to increased income, improved cooking fuels alone would not provide additional income[20]. So, whereas micro-credit/small loans for productive purposes are repaid even by poor households[21], through the returns they obtain, it could be difficult to repay a loan for household convenience alone. Moreover, the kerosene-electricity shift for lighting is not replicable in the case of LPG for cooking because the costs of the more efficient lighting source are lower, whereas LPG costs more than traditional carriers, unless consideration is given to reduced pollution and the resulting health benefits.

4.2. Pricing policies

Given the problem of affordability, one has to consider appropriate pricing policies. These also appear to constitute a challenge in India. Till April 1998, the Indian oil and gas industry had been controlled by the central government. Among other aspects, the pricing of petroleum products was state-determined, so that the deficit incurred on products priced lower than costs – LPG, kerosene and diesel – was compensated for by the higher-than-cost prices of the other distillates, through the administered pricing mechanism (APM). These inflows and outflows were handled by the Oil Pool Account, which was intended to be self-sufficient.

Liberalisation of the industry brought several policy changes: in 1987, private participation was allowed in joint venture refining; in 1993, parallel marketing was permitted, that is, the private sector was allowed into distribution; in 1998, phased dismantling of the APM was initiated; and in 2002, the APM was dismantled [MoP&NG, 2003c].

However, controls on the prices of 5 products (motor spirit, diesel, aviation turbine fuel, kerosene, and LPG), which contribute 70 % of the total volume, were retained. Subsidies on LPG and kerosene were continued, to help households, but were limited to 15 % and 33 %, respectively, of import parity prices. And, in the fiscal year 2002-03, these subsidies, which had previously been managed through cross-subsidies from other petroleum products using the Oil Pool Account, were for the first time included in the national budget. Obviously, this imposed a burden on the central exchequer, entailing high opportunity costs.

Further, with retail prices and subsidies for kerosene and LPG fixed for specified periods, the effects of international price spurts are borne by Indian public sector oil companies. For example, the subsidy for 2002-03 compensated for only 56 % of the loss incurred by these companies [Gupta, 2003][22]. Such a situation is obviously not sustainable.

Apart from the cost burden, subsidies, by lowering fuel prices, reduce the users' incentive to conserve fuel, and, if not reimbursed to producers, they reduce their incentive and ability to invest in new infrastructure/technology. When domestic cylinders are diverted to other purposes, for example, running vehicles, the waste is even worse.

Subsidies are justifiable – at least, as a second-best strategy – for increasing access to clean fuel for the poor, but they should be targeted at these categories of consumers. However, as the consumer pattern demonstrates, domestic LPG is used by upper-income households, and more so in urban areas, so that subsidies are garnered chiefly by the urban rich. This has been observed elsewhere too – in other Indian studies [UNDP and ESMAP, 2003] and in Africa [Sokona and Thomas, 2000]. Even if lower-income households are able to benefit from LPG through subsidies, the financial value to them is relatively small as their consumption is generally modest.

4.3. Ensuring adequate supply and distribution

If LPG were to be made available to homes, particularly in a country where 72 % live in rural areas, there would have to be not only adequate supply but extensive and reliable distribution also.

To meet the near-term demand-supply gap, imports can be resorted to in the country's present balance of payments position. However, dependence on imported petroleum may be strategically unwise because it makes the country vulnerable to spikes in the international prices of crude oil; deficits in the Asia-Pacific region are met by imports from the Middle Eastern countries, so that problems in the Persian Gulf region could lead to disruption in physical supplies and increased price risks. Hence, for supply security, indigenous production capacity would need to be increased and, since the costs of new production infrastructure – refineries and gas fractionation plants – are already high, they would be difficult to recover with the current price structure.

Regarding distribution facilities, even greater improvements are required. In many countries, pipelines are the preferred mode of petroleum product transport, but in India only around 32 % of such transport is through pipelines. Owing to non-availability of tank-wagons, 30 % of

oil product movement is undertaken by road, which is not only hazardous and polluting but also involves 15 to 20 times as much specific energy use as through pipelines, and 5 times as much as by rail[23]. The existing infrastructure at Indian ports for LPG is also inadequate, particularly on the east coast, so that inland movement is required and the costs are substantial.

Currently, vast areas of the country are located far from distribution centres. Storage and bottling facilities outside the urban centres of high demand have been limited by whatever the public sector corporations have been willing to invest. As a result, users have to pay additional charges for refuelling so that the average expenditure per LPG cylinder, indicated by NSS data, is higher in rural than in urban areas. Moreover, for small and remote markets, refills often take more than a week, so that for those without a second cylinder, there are gaps in fuel supply that necessitate a stand-by fuel. And, signing up for a second cylinder obviously increases the deposit cost, a further deterrent for lower-income households.

From the LPG dealers' point of view, the small number of purchasers and low rate of consumption in rural areas lead to poor economies of scale that along with poor road infrastructure make it difficult to establish commercially viable distribution networks.

Further, LPG delivery (as in the case of other pressurized or gaseous fuels) involves cylinder management, which necessitates more careful transport than kerosene or firewood; this, in turn, imposes additional requirements on prospective distributors.

5. Experiences of LPG programmes

Lessons could be learnt from the way household LPG use was extended in other developing countries and from regional programmes within India.

5.1. Experiences in other developing countries

5.1.1. Asia

In the Philippines, the opening of the market in 1996 encouraged several oil companies to invest there. Since 1997, more than 100 bottling plants have been built and the demand, almost entirely for the household sector, has risen by about 40 % [WB and WLPGA, 2002]. In the People's Republic of China, the shift up the energy ladder from biomass-based fuels to LPG was spurred by the restrictions on the supply of kerosene [UNDP et al., 2000, Ch. 10]. With liberalisation of the market, a number of international oil companies have established distribution and marketing operations, as joint ventures with the Chinese [WB and WLPGA, 2002]. In Indonesia, LPG for domestic use has been subsidised, but kerosene subsidies are even higher, undermining the competitiveness of LPG [WB and WLPGA, 2002].

5.1.2. West Africa

60 % of the LPG consumption in this region is concentrated in four countries – Cameroon, Côte d'Ivoire, Ghana, and Sénégal, where demand has grown significantly during the 1990s. Factors that have contributed to the increase in LPG use in the case of Sénégal, where the highest growth has been recorded, include subsidised LPG to small cylinders of 6 kg each, and also new participants in the market who have adopted aggressive marketing strategies [WB and WLPGA, 2001]. In both Sénégal and Côte d'Ivoire, price subsidies available on small cylinders have not been extended to larger bottles, emphasising the assistance to lower-income households [WLPGA and UNDP, 2002].

5.1.3. Latin America

Brazil has been successful in providing LPG to about 90 %[24] of its households. The main reason for this extent of adoption appears to be the controlled price of LPG through cross-subsidies from other petroleum products. This was proved in 2002, when deregulation led to increases in LPG prices and some lower-income rural households switched back to fuel-wood. To counteract this, an assistance programme began, providing low-income families with subsidies towards LPG purchase. In addition, smaller cylinders – of only 2 kg each – have been made available, facilitating use among lower income households [WLPGA and UNDP, 2002]. Another reason for the Brazilian success in extending LPG use is a dependable system of distribution and replacement of cylinders [UNDP et al., 2000, Ch. 10]. Brazil is said to have 26,000 such vendors serving 35 million households [Barnes and Halpern, 2000]. However, as about 81 % of Brazilian families live in urban areas [IBGE, 2001], the distribution problems found in largely rural countries would not be encountered here[25].

In Guatemala, where the LPG market is completely liberalised, instalment payment plans to cover the purchase of a suitable stove and the cylinder deposit fee are common and are helping to facilitate the adoption of this fuel by low/middle-income families.

5.1.4. Factors contributing to extension of LPG use

From the experiences summarised in this section, the following factors appear to have helped extend domestic LPG use:

- lower LPG prices through *cross-subsidies from other distillates;*
- favourable relative prices of LPG (in relation to competing fuels such as kerosene);
- special assistance for LPG purchase directed to *lower-income households;*
- initial-cost financing;
- smaller cylinders/bottles and *subsidies on these* (targeted to lower-income households);
- restriction on the supply of *competing fuels* (such as kerosene);
- dependable distribution (increased number and dispersion of storage, bottling and refuelling units); and
- more participants in the market (to facilitate regional focusing).

5.2. Experiences of an LPG programmė in India

The *Deepam* LPG scheme was launched in July 1999 in the state of Andhra Pradesh for the distribution of domestic connections to women of below-the-poverty-line (BPL)[26] families, particularly in rural areas. Each connection was accompanied by a one-off subsidy of Rs. 1,000 towards the cylinder and regulator. The scheme was

administered by the state government's Departments of Rural Development and Civil Supplies and distributed through two public sector oil companies, who were also expected to ensure training of the recipients in the use of LPG stoves. By 2002, about 1.724 million beneficiaries (including some of the urban poor) were listed, and 88 % of the urban target and 91 % of the rural target had been met [NIRD, 2002].

Several lessons can be learnt from the *Deepam* scheme. The advantages of LPG as perceived by the participants were: time saving, social status, cleaner environment, and help during the monsoons – because of more employment (implying more cash available for refuelling), more labour demand (and therefore less time for firewood collection), and the difficulty of collecting and storing biomass during the rains.

However, the scheme was not very efficient, because although most BPL families participated, over 80 % of non-BPL families in the region also did. The retention rate was down to 85 % in less than three years, in a sample of 52 villages and 18 municipal wards, because of cylinders having been given away to relatives, and being lent (!) to local civil servants [NIRD, 2002]. The perceived disadvantages included implementation bottlenecks, high refill costs (including illegal commissions of Rs. 5-30 extra, per cylinder, for collection/delivery), and reduction in the permitted kerosene quota (in municipal areas). The implementation bottlenecks included limited choice, inability of suppliers to supply stoves and accessories when required, and local co-ordination problems. Suggestions from local self-help groups for improvement included loans toward refills and reduction in cylinder size (reducing the cash outflow per refill, although the cost/kg would increase).

Most importantly, *the scheme failed to influence the fuel-use pattern of Deepam beneficiaries substantially* because wood remained the dominant fuel (for the main meals), while LPG was used only for supplementary cooking. Crop residues constituted the third most important source, and kerosene the fourth.

6. Policy issues for domestic cooking fuels in India

Discussion regarding the provision of clean cooking fuels to all homes would have to begin with the choice of appropriate fuels. If the use of LPG were to be encouraged, there would then be issues concerning the pricing and delivery of LPG. For the longer term, alternative options would have to be considered, including the integration of fuel programmes with those of economic growth and development.

6.1. Choice of LPG among clean fuels?

The advantages of LPG over traditional biomass-based fuels are numerous – reduced pollution and thereby improved health, higher efficiency and therefore less cooking time, reduced fuel collection time and effort, and avoided deforestation (in some areas). What is more, if the relative costs of LPG vis-à-vis other fuels were reckoned after accounting for their calorific values and the efficiencies of the related stoves, LPG would not seem as expensive. However, it appears that such factors as the beneficial effects on health are not being quantified or even included in the households' consideration, evident in the survey of *Deepam* recipients. Only the obvious cause-effect sequences such as polluted water causing illnesses appear to force people to pay for alternatives [IEI, 2003]. Hence, it would need public awareness drives to introduce the "clean fuel" factor into the reckoning.

Another phenomenon to be considered is the use of more than one fuel for cooking. In such cases, the social benefits of shifting to cleaner fuels accrue only partially, but in so far as a partial shift is a step towards a complete shift, efforts to promote such action would be beneficial.

However, the inter-fuel comparison need not necessarily be only with traditional fuels. A study was made [CBA Energy Institute, 1996] chiefly for the comparison of LPG with natural gas, but also for other issues such as urban air quality in Mexico, in comparison with Brazil, China, and India. As LPG infrastructure can be more quickly deployed than that of natural gas, and because LPG would be an improvement over wood and coal, opportunities for increased use were perceived.

If the goal were to address the availability of fuel in rural areas where biomass supply is getting scarce, it may be difficult to accomplish with the poorest households. However, LPG promotion remains a worthwhile strategy for those higher on the income ladder. Further, with reduced demand from those able to progress to another fuel, the others still dependent on biomass for economic reasons would be helped.

6.2. Providing LPG

In view of the challenges to increasing the domestic use of LPG, the following issues would have to be considered when drawing up policies for the delivery of LPG. On the demand side, one would have to consider pricing (in particular, the question of subsidies), financing options, and public awareness, and on the supply side, security, effective distribution, and regulation[27].

6.2.1. Demand issues

6.2.1.1. Pricing

When discussing the pricing of LPG in India, the most important issue is how the existing subsidies may be dealt with. It may be recommended that subsidies be reduced/removed, but these would make LPG even less affordable to lower-income households. If subsidies could be justified for this reason, policy-makers need to consider several specific issues regarding the types of subsidies and their funding.

Choices have to be made from among the subsidy options for LPG – either on the *initial costs* of connections/stoves, or on the *fuel,* and either *cross-subsidies from other distillates* or those *budgeted from the exchequer.* Subsidising initial costs (i.e., a one-off reduction) seems preferable to fuel (or refill) subsidies because the latter could encourage inefficient use or diversion to other uses/users. However, first-cost subsidies leave possibilities for dropouts from those who cannot afford the fuel costs, resulting in "dead" investments.

If operating or fuel subsidies were to be continued,

some precautions would have to be taken. There could be *rationing/quotas* (quantitative limits) for the subsidised fuel (similar to the ration cards for grain through the government's public distribution system, PDS) and/or *coupons* (as with food stamps)[28]. Alternatively, subsidies could be restricted to *differentiated containers* (say, smaller cylinders, and/or cylinders painted another colour). Subsidies also need to be *use-based,* with the subsidy decreasing with the level of consumption (as with electricity tariffs), rather than across-the-board, because the latter results in "subsidy capture" by wealthier sections of the population [WEC, 2001].

Financing of subsidies would also have to be worked out. Regulated *cross-subsidies from other distillates* have been the norm in India and elsewhere, but would need to be weighed against the disadvantages of higher costs of other services (for example, transport). In recent times, Indian public sector oil corporations have been required to sell domestic LPG at below-cost prices without commensurate subsidy, but this could be financially disastrous (as in the case of the state electricity boards). *Progressive tariffs,* with the price per unit increasing with the amount consumed, would probably be the best option, because the more affluent customers could pay for higher use; this would be akin to cross-subsidies from higher-income consumers to the others and would need the upper segment to be large enough to support the lower segments.

Even when justifiable for social/environmental benefits, before introducing subsidies, there needs to be evaluation of *efficiency* (i.e. cost-benefit analysis of welfare gain versus the cost burden and any distortion effects), *efficacy* (i.e., success in *targeting* those for whom it is intended, including those who should benefit and excluding those who should not), and *cost-effectiveness* (i.e., *administrative costs* should not be prohibitive) [WB, 2000].

When evaluating the pricing of LPG, one has to consider *the relative prices of alternative fuels,* as these could effect inter-fuel shifts. For example, reducing/removing the subsidy on kerosene would make LPG relatively cheaper, without a burden on the exchequer. Thus far, as already indicated, subsidies have been higher for kerosene than for LPG. But as long as homes are not electrified, subsidy to kerosene has to merit consideration because it is currently the source of lighting for about 43 % of the country's population.

6.2.1.2. Non-pricing schemes

There could be schemes through which LPG is priced at near/full cost, but targeted households get some predetermined compensation. This would avoid careless use of subsidised fuel (and may also be an incentive for fuel efficiency), while assisting the economically disadvantaged. However, programmes involving direct payments have to be carefully implemented, and the better the targeting, the higher the administrative costs. Also, experiences with BPL schemes have shown that those not entitled manage to be included and, even where correctly targeted, the payment received may not be used for cleaner fuels.

6.2.1.3. Marketing

There are several promotional campaigns that encourage the purchase of consumer durables by lowering the amount of each cash outflow. Similar methods could be used to help lower-income households in the case of LPG. *Instalment payments* for the cost of connection and stove and each fuel refill in *smaller containers* (e.g., 2-5 kg, instead of the regular 14.2-kg cylinders) would reduce the "lumpiness" of successive cash outflows. The latter option has been launched by the public sector companies but needs to be extended beyond limited areas.

In addition, public awareness campaigns on the impacts of indoor pollution and the benefits of cleaner fuels could increase their popularity and thereby the willingness to pay.

6.2.2. Supply issues

6.2.2.1. Supply security

Uninterrupted availability of LPG would require that there be adequate supplies from indigenous sources and/or reliable sources of imports. In addition, as the International Energy Agency has emphasised, appropriate transport and logistics are required in order to meet the growing oil demand [IEA, 2004].

6.2.2.2. Dependable distribution network

Multi-mode transport facilities, particularly pipelines, are required for moving LPG to and from alternative destinations. The LPG distribution network also needs to be improved through the development of geographically dispersed storage installations and depots, in order that bottlenecks be avoided. Extension of the distribution infrastructure would help to address the problems of consumers whose location currently precludes their using LPG and those of distributors who face unfavourable economies of scale. There should be also complementary infrastructure – roads, equipment suppliers, and complementary services – in tandem, to facilitate the smooth operation of the system. This would be analogous to the rationale for improving rural infrastructure along with electrification.

6.2.2.3. Regulation

The government's role in setting standards to maintain safety and avoid corruption is essential. Measures for ensuring that the cylinders are checked for their user-worthiness and are properly filled have to be in force. Consumer protection has to be provided, particularly as with a large number of operators and poor enforcement of standards, accidents and commercial malpractice can occur.

6.2.2.4. Alternatives for automobile fuelling

Instead of LPG for automobile fuelling, compressed natural gas (CNG) can be used, as indicated in the Auto-Fuel Policy [MoP&NG, 2003a]. However, the feasibility of dispensing CNG all around the country would be contingent not merely on the availability of natural gas but on pipeline links being established.

6.3. Alternative cooking fuels

It is important to reiterate that as LPG is fossil-fuel-based, it may not be considered a sustainable source in the long term; it is being recommended as a part of the transition to improved biomass-based fuels. Some of these alternatives

include the following.

- Biogas from animal waste. In areas where households keep cattle, biogas can be generated from cattle dung, if adequate amounts can be supplied daily to the digester. About 3.482 million family-size biogas plants have been constructed in the country [MNES, 2003], of which an estimated 60-80 % are operating successfully [AFPRO-CHF, 1997]. India's largest community biogas plant with a total capacity of 630 m^3 has been running since April 1987 in the village of Methan (Sidhpur *tehsil,* Patan district, in the state of Gujarat); it caters for the main cooking requirements of 320 families [Jamwal, 2003]. Other village/institutional plants have also been constructed, but the success of such community plants is contingent on the delivery of dung by the individual households and effective local management [IEI, 2003].
- Producer gas. Where adequate crop residues are available from cultivated land in the area, these can be gasified to generate producer gas that could be used for cooking or for power generation [Mukunda et al., 1993; Henderick and Williams, 2000; Shyam, 2002]. Even where crop residues are not normally available, plantations can be started on fallow/degraded lands (to avoid competing with agriculture) for biomass generation [Larson and Kartha, 2000]. However, one concern is that as producer gas contains carbon monoxide, leaks would be dangerous.
- New options. Advanced technologies make it possible to produce synthetic fuels such as synthetic liquid petroleum gas [Larson and Jin, 1999] and dimethyl ether (DME) from biomass; being clean and non-toxic, they are well suited to cooking. These technologies are not currently available in the field, but could be, with adequate market interest and development effort.

6.4. Poverty alleviation

LPG (like other clean fuels), being more efficient (in terms of heat delivered from input) and also more environmentally benign in comparison with traditional biomass-based stoves, would enable labour reduction as well as better health for those involved. This would obviously improve the quality of life. Further, the time saving would free people for more productive pursuits, if these were available. However, without direct linkages to income generation, there is no obvious effect on reducing poverty[29].

Further, just as rural electrification has been of benefit to people with higher income, because only those with sufficient resources for the initial investment are in a position to benefit from electricity [Jechoutek, 1992], the same is likely to be observed with modern sources of fuel for cooking such as LPG. The "middle" and "upper" classes on the income ladder have moved up the energy ladder, with fuel-wood, charcoal, and kerosene being replaced by LPG, but it seems unlikely that the poor would leapfrog the lower rungs of the ladder. However, if innovative financing schemes can provide adequate leverage to overcome the income barrier, then the benefits of improved cooking fuels could be extended down the income ladder, and the resulting impacts on human development indices through shorter hours of work and improved health would justify the additional administrative and financing costs.

The government has to be involved, at least through its policies, in helping to provide energy services to the economically disadvantaged. Subsidies will continue to be necessary for a while, but have to be applied with care. But there has also to be a suitable environment for the private sector to cater for those who can pay for their needs. Simultaneously, there should be viable expansion of rural electrification, because the expenditure on LPG and other clean fuels for cooking could be balanced by that on the kerosene requirement for lighting.

In general, the country's strategies of fostering development, economic growth, and employment opportunities need to be focused on and accelerated. Only then could there be major changes in household expenditure patterns that would in turn bring in the collateral benefits of clean cooking fuels. ■

Notes

1. Even in recent times, the procurement and processing of fuel-wood and dung (chopping branches and twigs, or forming dung-cakes) has been found to be done by women, while for crop residues, both men and women are involved in the collection and transport [Dutta, 2002; Mahapatra, 2002].
2. LPG consists mainly of propane (C_3H_8) and butane (C_4H_{10}).
3. Annualised life-cycle cost (ALCC) = the annual equivalent of the total costs incurred (initially and during the working life of the equipment) = [K×(CRF) + A], where K is the capital or initial purchase cost, CRF = capital recovery factor = $i/[1-(1+i)^{-n}]$, with i = interest or discount rate/year and n = operating life of the equipment (in years), and A is the average annual operating cost = the sum of fuel and maintenance costs. No value has been imputed to adverse health/environmental impacts, if any.
4. The World Energy Assessment had considered LPG for the near (< 5 years) term [UNDP et al., 2000, Ch. 10, p. 380].
5. A domestic fuel survey conducted by the National Council for Applied Economic Research revealed fuel-use patterns, particularly with respect to kerosene [NCAER, 1985]. The National Sample Survey Organisation (NSSO) of the Government of India conducts annual sample surveys; the most recent data obtained pertains to the 55th Round conducted in 1999-2000 [NSSO, 2001].
6. Only the primary fuel has been indicated in cases where households use more than one fuel.
7. Studies on household energy use, for example, a study on Bangalore city [Reddy, 1996], have verified this conclusion.
8. The administered pricing mechanism (APM) is being discussed in Section 4.2; the prices of both kerosene (for limited purchase) and LPG are subsidised.
9. With 1993-94 = 100, the LPG price index rose to 284.0 in 2002-03, while that of kerosene rose to 359.7 (Office of the Economic Advisor, Ministry of Industry, quoted in [MoP&NG, 2003b]).
10. This implies access to one or two cylinders of LPG at a time.
11. Ideally, fuel-adoption curves should be drawn and the region's current position along it ascertained, so that annual growth rates are not constant, but correspond to the shape of the curves.
12. Challenges to increased household use of LPG are discussed in Section 4.
13. 16 of these are in the public sector, that is, with at least 51 % government shareholding.
14. In HPCL's *rasoi ghar* scheme, individual households do not have to invest on stoves or pay a connection deposit, but have only to pay for the use of the fuel and the facility, on the basis of the duration of use.
15. BPCL had introduced an RMV in 1999, in the state of Punjab [MoP&NG, 2003c]. Encouraged by its reception, it introduced several more.
16. Private cars and taxis are also being run on LPG instead of petrol (motor spirit or gasoline).
17. These are not disclosed by oil companies; the costs of only a few projects indicated in other contexts are mentioned. For example, a recent addition of only 3 Mt/a is estimated at Rs. 23.6038 billion (US$ 524.5 million) [MoP&NG, 2003c].
18. The "connection" charge is about Rs. 750 through public sector companies, while the

basic stove price varies between Rs. 800 and Rs. 2,000, so that the package costs Rs. 1,550 to Rs. 2,750 (US$ 34 to 61).

19. New cylinders of 5 kg or less are not available in most places.
20. There would be increased income if the time saved by women on fuel procurement could be diverted to productive activities.
21. This has been proved in several cases, for example, Grameen Shakti in Bangladesh, Self-Employed Women's Association (SEWA) in India, and Vietnam Women's Union.
22. The new government is continuing the subsidy arrangement for kerosene and LPG till 2007. But, although an increase in retail prices has been permitted (on 16 June 2004), a gap between revenue and costs of Rs. 90 billion (US$ 2 billion) is expected for the year 2004-05. Of this, the Government is providing only Rs. 35 billion (39 %), indicated in the annual budget presented by the Finance Minister on 8 July 2004.
23. The average fuel (diesel) consumption by trucks, per tonne-km of freight hauled, has been 0.0341 litres (l), whereas by rail it has been 0.0069 l [PC, 1991].
24. This was computed as a proportion of the total 46 million households [WRI, 2002] in Brazil.
25. For other information on the Brazilian experience, see [Lucon et al., 2004] (in this issue).
26. The "poverty line" is defined in terms of the cost of a specified level of calorie intake per capita, in urban and rural areas, in each state.
27. Currently, the UNDP and the World LPG Association (WLPGA) have an initiative called the LPG Challenge to address the barriers to meeting the heat energy needs of rural and peri-urban populations through the expanded use of LPG [UNDP, 2002]. For other information on the UNDP initiative, see [McDade, 2004] (in this issue).
28. There could also be time-limits for such subsidies, but this may not be practicable as it is often politically infeasible to remove such benefits.
29. There is not much empirical evidence to convincingly demonstrate the linkage between better fuel use and poverty reduction (as opposed to merely widening access); such evidence is available in other sectors such as health [Cecelski, 2000].

References

Action for Food Production, Canadian Hunger Foundation (AFPRO-CHF), 1997. *Biogas: the Indian NGO Experience*, Action for Food Production, Canadian Hunger Foundation and Tata Energy Research Institute, New Delhi.

Barnes, D.F., and Halpern, J., 2000. "The Role of energy subsidies", in *Energy Services for the World's Poor*, ESMAP Energy and Development Report.

Business Line, 2004. "*Minister to lay foundation stone for LPG cavern storage project*", *Business Line*, (bureau report, New Delhi) Bangalore, 19 February, p. 5.

CBA Energy Institute, 1996. *LPG Markets in Mexico: Analysis, Issues and Cross-National Comparisons*, a CBA Energy Institute White Paper, prepared by M.M. Foss, F. García, G.T. Westbrook and J. Campos, CBA Energy Institute, University of Houston, Houston, Texas, available at www.uh.edu/energyinstitute/pdf/lpgsum.pdf.

Cecelski, E., 2000. "Enabling equitable access to rural electrification: current thinking and major activities in energy, poverty and gender", briefing paper for a Brainstorming Meeting on Asia Alternative Energy Policy and Project Development Support: *Emphasis on Poverty Alleviation and Women*, Asia Technical Unit for Alternative Energy (ASTAE), The World Bank, Washington, DC, 26-27 January, available at www.sms.utwente.nl/energia/download/resources/current_thinking_energypovertygenderz.pdf

Census of India, 2001. *Houses, Household Amenities and Assets: India, States and Union Territories – 2001 Census*, Office of the Registrar General, Census of India, Government of India, New Delhi, available at www.censusindia.net

Centre for Monitoring Indian Economy (CMIE), 2003. *Energy*, Centre for Monitoring Indian Economy, Mumbai, May.

Dutt, G.S., and Ravindranath, N.H., 1993. "Bioenergy: direct applications in cooking", in Johansson, T.B., Kelly, H., Reddy, A.K.N., and Williams, R.H., (Eds.), *Renewable Energy: Sources for Fuels and Electricity*, Island Press, pp. 653-698.

Dutta, S., 2002. Presentation at Mainstreaming Gender in Energy – ENERGIA Regional Consultation to establish a national gender and energy network in India, 7 December, available at www.energia.org/resources/papers/soma_pres_wshop_india.pdf.

Energy Sector Management Assistance Program (ESMAP), 2001. "Household energy and poverty", in *Indoor Air Pollution – Energy and Health for the Poor*, Issue No. 4, World Bank Energy Sector Management Assistance Program, May.

Gupta, G., and Köhlin, G., 2001. *Options and Choices of Domestic Fuel in Urban Households: the Case Study of Kolkata, India*, available at www.handels.gu.se/econ/EnvironmentalEconomicsUnit/fuelpapers.pdf

Gupta, U., 2003. "Few gains from notional decontrol", *Business Line*, 5 July 2003, Bangalore, p. 8.

Henderick, P., and Williams, R.H., 2000. "Trigeneration in a northern Chinese village using crop residues", *Energy for Sustainable Development*, IV(3), pp. 26-42.

Instituto Brasileiro de Geografia e Estatísticas (IBGE), 2001. *Demographic Census 2000 – Results of the Universe*, Instituto Brasileiro de Geografia e Estatísticas, available at www.ibge.gov.br

International Energy Agency (IEA), 2004. *Oil Market Report*, International Energy Agency, Paris, 12 May, available at www.omrpublic.iea.org/currentissues/full.pdf

International Energy Initiative (IEI), 2003. *Report on IEI's Rural Electricity and Water Supply Utility (REWSU) Project with Special Reference to the Utility at Mavinakere*, prepared by K.V. Narasimha Murthy, B.T. Chandru, and Antonette D'Sa, October, available at www.iei-asia.org/IEIBLR-REWSUReport.pdf

Indiainfoline, 2002. Information on the oil and gas industry, available at www.indiainfoline.com

Jamwal, N., 2003. "Full circle: India's largest biogas plant produces more than just cooking gas", *Down to Earth*, March 15, p. 42.

Jechoutek, K.G., 1992. "Selection and economic viability of rural electrification projects", in Saunier, G. (Ed.), *Rural Electrification Guidebook for Asia and Pacific*, Asian Institute of Technology, Bangkok.

Jungbluth, N., 1995. *Restricted Life-cycle Assessment for the Use of Liquefied Petroleum Gas and Kerosene as Cooking Fuels in India*, thesis submitted to the University of Berlin, December, available at www.esu-services/download/DA-India.pdf.

Larson, E.D., and Jin, H., 1999. "Biomass conversion to Fischer-Tropsch liquids: preliminary energy balances", in Overend, R.P., and Chornet, E., (Eds.), *Biomass - a Growth Opportunity in Green Energy and Value-added Products: Proceedings of the 4th Biomass Conference of the Americas*, Vol. 1, Elsevier Science, Oxford, UK, pp. 843-853.

Larson, E.D., and Kartha, S., 2000. "Expanding roles for modernised biomass energy", *Energy for Sustainable Development*, IV(3), pp. 15-25, October.

Lucon, O., Coelho, S.T., and Goldemberg, J., 2004. "LPG in Brazil: lessons and challenges", *Energy for Sustainable Development*, VIII(3), September (this issue).

Mahapatra, R., 2002. "Phulmai's walk", *Down to Earth*, December 15, 2002, pp. 25-34.

McDade, S., "Fueling development: the role of LPG in poverty reduction and growth", *Energy for Sustainable Development*, VIII(3), September (this issue).

Ministry of Finance (MoF), 2000. *Economic Survey: 1999-2000*, Ministry of Finance (Economics Division), Government of India, New Delhi.

Ministry of Non-Conventional Energy Sources (MNES), 2003. "Cumulative achievements of renewable energy programmes in India – 31st March 2003", Ministry of Non-Conventional Energy Sources, Government of India, available at www.mnes.nic.in/ach1.htm

Ministry of Petroleum and Natural Gas (MoP&NG), 2002. *Natural Gas*, Ministry of Petroleum and Natural Gas, Government of India, available at http://petroleum.nic.in/ngbody.htm

Ministry of Petroleum and Natural Gas (MoP&NG), 2003a. "Availability, demand and security of supply of autofuels", Chapter 7 of *Auto Fuel Policy Report*, Petroleum Planning and Analysis Cell (PPAC), Ministry of Petroleum and Natural Gas, Government of India, available at www.petroleum.nic.in/ch_7.pdf

Ministry of Petroleum and Natural Gas (MoP&NG), 2003b. *Petroleum Statistics*, Petroleum Planning and Analysis Cell (PPAC), Ministry of Petroleum and Natural Gas, Government of India, available at www.petroleum.nic.in/Petstat.pdf

Ministry of Petroleum and Natural Gas (MoP&NG), 2003c. *Annual Report for the Year 2002-03*, Ministry of Petroleum and Natural Gas, Government of India, available at www.petroleum.nic.in/annrep2003.pdf

Mukunda, H.S., Dasappa, S., and Shrinivasa, U., 1993. "Open-top wood gasifiers", in Johansson, T.B., Kelly, H., Reddy, A.K.N., and Williams, R.H., (Eds.), *Renewable Energy: Sources for Fuels and Electricity*, Island Press, pp. 699-728.

National Council for Applied Economic Research (NCAER), 1985. *Domestic Fuel Survey with Special Reference to Kerosene*, Vols. I and II, National Council for Applied Economic Research, New Delhi.

National Institute of Rural Development (NIRD), 2002. Presentation of the *Salient Findings of the Evaluation of the Deepam Scheme in Andhra Pradesh*, NIRD-World Bank Research Study Team, available at www.worldbank.org/wbi/cleanair/caiasia/topics/iap/20workshop/iap_documents/Rajakutty.pdf

National Sample Survey Organisation (NSSO), 2001. National Sample Survey, 55th Round: July 1999-June 2000, National Sample Survey Organisation, Ministry of Statistics and Programme Implementation, Government of India, New Delhi.

Office of Technology Assessment (OTA), 1992. *Fueling Development: Energy Technologies for Developing Countries*, Office of Technology Assessment, OTA-E516, Washington, DC.

Parikh, J., Biswas, H., and Karmakar, S., 2003. "Cooking with biofuels: risk factors affecting health impact on rural women", Special Article in *Economic and Political Weekly*, Vol. XXXVIII, No. 26, June 28-July 4, pp. 2681-2692.

Petrowatch, 2003. Vol. 7 Issue 15, 8 October.

Planning Commission, Government of India (PC), 1991. *Sectoral Energy Demand in India*, Government of India in cooperation with the Economic and Social Commission for Asia and the Pacific, the UNDP and the Government of France, Regional Energy Development Programme (RAS/86/136), August.

Purvin and Gertz (A. Chandra, R. Gist, K. Otto and C. Whitley), 2000. "Continued LPG demand growth changes historical trade patterns", *Oil & Gas Journal*, 26 June, available

at www.purvingertz.com/ogj062600.html

Reddy, B.S., 1996. "Consumer discount rates and energy carrier choices in urban households", *International Journal of Energy Research*, Vol. 20, pp. 187-195.

Reliance Petroleum Limited (RPL), 2000. *Dikhana Hai*, Reliance Petroleum Limited, available at www.indianmarketwatch.com/uploaded-files/research/rpl.htm

Shyam, M., 2002. "Agro-residue-based renewable energy technologies for rural development", *Energy for Sustainable Development*, VI(2), pp. 37-42.

Sihag, A.R., Chatterji, S., and Khetan, A., 2004. "Vulnerability of the Indian economy to tensions in the Middle East: impacts and responses", *Pacific and Asian Journal of Energy*, 12(1), pp. 7-22.

Sokona, Y., and Thomas, J-P., 2000. "Widening access to rural energy services in Africa: looking to the future", ENDA-TM, Dakar, Sénégal, available at www.enda.sn/energie/accessener.htm

Smith, K.R., Uma, R., Kishore, V.V.N., Lata, K., Joshi, V., Zhang, J., Khalil, M.A.K., 2000. "Greenhouse implications of household stoves: an analysis for India", *Annual Review of Energy and Environment*, 25, pp. 741-763.

Tata Energy Research Institute (TERI), 1996. *TERI Energy Data Directory and Yearbook (TEDDY) 1996/97*, Tata Energy Research Institute, New Delhi.

United Nations Development Programme (UNDP), United Nations Department of Economic and Social Affairs (UNDESA), and World Energy Council (WEC), 2000. *World Energy Assessment: Energy and the Challenge of Sustainability*, United Nations Development Programme, United Nations Department of Economic and Social Affairs, and World Energy Council, September.

United Nations Development Programme (UNDP), 2002. *The LPG Challenge – Discussion Paper*, UNDP Sustainable Energy Programme, available at www.undp.org/seed/eap.

United Nations Development Programme (UNDP) and Energy Sector Management Assistance Programme (ESMAP), 2003. *India: Access of the Poor to Clean Household Fuels*, United Nations Development Programme and the World Bank Energy Sector Management Assistance Programme, July, available at www.wbnl0018.worldbank.org/esmap/site.nsf/files/263-03+India.pdf

World Bank (WB), 2000. *Energy Services for the World's Poor: Energy and Development Report 2000*, World Bank, available at www.worldbank.org/html/fpd/esmap/energy-report2000

World Bank (WB), 2002. "The health benefits of clean fuels in India: a case study of Andhra Pradesh", prepared by G. Hughes, M. Dunleavy and K. Lvovsky, World Bank, January, available at www.worldbank.org/wbi/cleanair/global/topics/topic_documents/rural_energy_and_health.pdf

World Bank (WB) and World LP Gas Association (WLPGA), 2001. *West Africa LPG Market Development Study*, World Bank and World LP Gas Association, available at www.worldgas.com/mainpages/publications/publications.php.

World Bank (WB) and World LP Gas Association (WLPGA), 2002. *The Role of LP Gas in Meeting the Goals of Sustainable Development*, World Bank and World LP Gas Association, Paris, January, available at www.worldgas.com/mainpages/publications/publications.php.

World Energy Council (WEC), 2001. *Pricing Energy in Developing Countries*, World Energy Council, London, June, available at www.worldenergy.org/wec.geis/global/downloads/pedc/PEDC.pdf

World Health Organisation (WHO), 2000. "Chapter 5: Health problems related to work and environment, Part I – Women's health status", in *Women of South-East Asia: A Health Profile*, World Health Organisation, available at www.whosea.org/women/ch5_1.htm

World LP Gas Association and United Nations Development Programme (WLPGA and UNDP), 2002. *The LP Gas Rural Energy Challenge – Draft Concept Paper*, World LP Gas Association and United Nations Development Programme, available at http://www.undp.org/wec-geis/wssd/lpgchallenge.pdf

World Resources Institute (WRI), 2002. *Brazil: the Structure of Poverty*, available at www.povertyprofit.wri.org/pdfs/hammond_brazil_profile_xls.pdf

Appendix A. A comparison of the annualised costs of cook-stoves (in India)

	All at 10 % discount rate						
	Wood/crop waste		Kerosene		LPG		Electric
	Traditional	Improved	PDS fuel	Market fuel	Subsidised fuel	Market fuel	
Stove price[1] (Rs.)[2]	10	150	400	400	1,250	1,250	1500
Useful life of each stove (years)	3	3	5	5	15	15	10
Deposit or one-time payment (Rs.)					750	1,150	
Capital recovery factor	0.402	0.402	0.264	0.264	0.131	0.131	0.163
Annualised capital cost[3] (Rs.)	4.02	60.32	105.52	105.52	164.34	164.34	244.12
Energy content of the fuel (MJ per kg, litre (l), or kWh)	15	15	35	35	45.5	45.5	3.6
Efficiency of stove[4]	15 %	30 %	45 %	45 %	60 %	60 %	71 %
Annual fuel usage (l/a, kg/a, kWh/a)[5]	1,395	698	199	199	115	115	1,223
Price of fuel (Rs./l, Rs./kg, Rs./kWh)[6]	1.00	1.00	11.00	16.50	18.52	27.65	3.00
Annual fuel cost (Rs.)	1,395	698	2,193	3,289	2,130	3,179	3,669
Annual maintenance expenses (Rs.)	0.00	0.00	25.00	25.00	75.00	75.00	0.00
Total annualised costs per stove (Rs.)	1,399	758	2,323	3,420	2,344	3,394	3,913

Notes

1. Stove prices refer to the market prices prevailing in Karnataka state.
2. 1 US$ = Rs. 45 (2004).
3. Annualised cost = cost × capital recovery factor (CRF), where CRF = $i/\{1-(1+i)^{-n}\}$; i = discount rate
4. The efficiencies of stoves are from [Dutt and Ravindranath, 1993, Table 10, p. 676] and from NCAER's "Energy demand in Greater Bombay", 1975 (quoted in [TERI, 1996]).
5. The annual fuel usage was entered for LPG connections (= average usage per connection according to the oil companies' sales figures) and that of the other fuels was derived thus: $(MJ/kg \times efficiency \times kg/year)_{LPG} / (MJ/kg \times efficiency)_{other} = (kg/year)_{other}$.
6. Market fuel prices are also from Karnataka and applicable till 15 June 2004. In the case of kerosene and LPG, there are differences between the administered (subsidised) price per unit and that obtaining in the market, hence two options each have been considered. The PDS (public distribution system) is supposed to provide specified amounts of subsidised kerosene per household, limited to 24 l per family per year for regular card-holders and 120 l per lower-income holder.