Report on the use of LPG as a domestic cooking fuel option in India

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Summary

The purpose of this study has been to examine the domestic use of liquefied petroleum gas (LPG) in India. LPG is being considered because it is one of the relatively clean and efficient cooking-fuel options currently available in the country. After estimating current and potential increases in the domestic demand for LPG, we have considered the possibility of meeting these demands, in view of several problems, and then listed policy issues that could help surmount the barriers.

Demand (Section 2)

The current (primary)[1] cooking fuel use patterns (Census of India, 2001) reveal that LPG is used by 33.6 million (or 17.5% of the total) homes. In urban areas, the most commonly used fuel is LPG (47.96%), followed by firewood (22.74%), and kerosene (19.16%). However, in rural areas, 90% of rural homes still depend on some traditional form of biomass, with firewood by far, the most important fuel (64.10%), followed by crop residues (13.10%), and cow-dung (12.80%). The use of LPG (5.67%) is now increasing in importance. Factors like income, (urban/rural) location, and the availability and price of alternatives appear to have affected the choice of fuels.

Based on estimates derived from the Census figures, the average annual rate of increase of LPG-dependent households in the 1990s' has been about 11.8% in urban and 6.8% in rural areas[2]. Corresponding to the increase in LPG dependence, the urban proportion of homes dependent on firewood and kerosene has fallen. Urban families have shifted away from these fuels to LPG, possibly because of the easier accessibility, lack of other fuel options, and more regular cash incomes.

If a business-as-usual scenario were assumed, that is if the current rates of population-derived increase in the number of homes and the above rates of adoption of LPG were projected, LPG would be used by over 90% of urban homes by the year 2008, but less than 9% of rural homes. Such growth rates could be projected to later years; however, enough data has not been obtained to gauge the adoption curves and the present positions along it, so that such projections may not be reasonable.

From the current country-wide average use per household, based on total sales, and weights for rural and urban differences (based on National Sample Survey estimates), we have found the annual LPG use to be about 101.4 kg/rural household and 119.3 kg/urban household. These estimates have been assumed for future demand estimation. (The lower rural use could be due both to difficulties in obtaining fuel refills and to the availability of biomass for back-up/supplementary use). At this level of use, the LPG required for domestic cooking would rise from about 3.87 million tonnes (mmt) in 2000-01 to 6.46 mmt in 2005-06 and 9.10 mt in 2010-11.

[1] Some households use more than one fuel; these figures pertain to the main source.
[2] There are even higher estimates of household adoption of LPG, based on point-to-point growth rates obtaining from a comparison between specific rounds of the National Sample Survey (NSS, 2001).

Apart from business-as-usual, enhanced-rural growth scenarios have been projected, but these may not be practicable, considering the number of families living at the subsistence level and unable to afford payment for fuel.

In addition, provision for other users must be included in the allocation of supply, particularly the rapidly increasing use for automobile fuelling – by consumer choice in the four-wheeler category and through a mandatory requirement in the three-wheeled auto-rickshaw segment.

Supply (Section 3)

India's indigenous production of LPG has not been able to keep pace with increasing demand. Production rose from 2.150 mmt in 1990-91 to 7.273 in 2002-03, but imports were required throughout the period. Of the total LPG supply in 2002-03, 4.903 mmt were from crude oil refineries, 2.370 mmt from natural gas, and 1.073 mmt (13% of the total) were imported. With the average yields obtaining at present at Indian refineries, LPG accounts for only 4.5% of the crude oil processed. Hence, in spite of the recent discoveries of gas and the major refinery projects being undertaken, estimates from the central Ministry of Petroleum and Natural Gas (MoP&NG) indicate a continuing shortage of LPG, at least in the near future. By the year 2006-07, indigenous LPG production would be 8.10 mmt, but total demand would be 11.48 mmt with current usage patterns and 13.40 mmt, in a higher auto-fuel[3] demand scenario. (Enhanced domestic demand scenarios, like those our study, were not published).

Regarding the cost of imports, in recent years, the LPG import bill has amounted to only 1.4%-3.4% of the net oil (POL)[4] import bill, so that this source of supply has been relied upon. However, the Asia–Pacific region has a shortage and dependence on the Middle East that may not be strategically wise.

Even when available at the main ports and scattered refineries, LPG has to be effectively transported, stored and distributed all over the country, if it has to be a viable domestic fuel. Production is concentrated in the western region; pipeline capacity and railway-tank-wagons are inadequate. There are also regional imbalances of demand and supply that have to be addressed. Improvements are being made, but considering the geographical spread of the country, the available infrastructure is still inadequate, for example, the northern region has continually been a deficit area. More importantly, although private distributors have entered the market, they have not extended services to rural areas that seem to have been left a Public Sector concern.

Challenges to effective provision of domestic LPG (Section 4)

The need for using cleaner fuels has already been established. However, numerous challenges are faced when considering the increased use of LPG; these include ensuring adequate supply and accessibility, increasing affordability, effective pricing policies, and reaching the people now dependent on collected biomass.

[3] Here, 20% of petrol (gasoline or motor spirit) would be replaced by LPG.
[4] POL = petroleum, oil, and lubricants

- **Ensuring reliable supply and accessibility –** The country needs not only additional LPG production capacity, in the face of increased demand from the domestic and auto-fuelling sectors, but also the development of adequate transportation (pipelines and rail-tank-wagons), and storage installations. There has to be a reliable distribution system running to local distributors even in rural areas, to prevent refilling inconveniences that seem to counteract the advantages of using LPG.
- **Increasing affordability –** The economically disadvantaged face the problems of high first costs of LPG (connection and equipment), and the lumpiness of relatively high refilling bills, and loans are difficult to service without financial returns from the investment.
- **Appropriate pricing policies –** These are a challenge, particularly because of the subsidies already offered. The subsidies do not reach most of the poor as they are not yet users of LPG, there is diversion of subsidised LPG from domestic to other uses, and there is also a heavy burden on the central exchequer.
- **Poverty issues –** While the use of LPG is beneficial for health and the quality of life, there is no direct impact on poverty alleviation without a link with income generation. Further, questions regarding how the inherent benefits of LPG or other clean fuels can be extended to the poor remain unanswered.

Lessons from other LPG experiences (Section 5)

Experiences in several other developing countries have been studied; the following factors appear to have helped extend the domestic use of LPG (including lower income households):

- *Lower prices of LPG* through *cross subsidies from other distillates*,
- *favourable relative prices* of LPG (in relation to competing cooking-fuels like kerosene),
- *special assistance* for LPG purchase *directed to lower income households*,
- *initial cost financing* (deferred/instalment payments for the purchase of stove and cylinder deposit),
- *smaller cylinders/bottles* to target (lower income) households through *lower periodic/incremental refuelling bills*,
- *special subsidies to these smaller cylinders/bottles* – intended for lower income groups,
- *restriction* on the supply of *competing fuels* (e.g. kerosene), and
- *dependable distribution systems*.

From the *Deepam* scheme implemented for households below the poverty line in the state of Andhra Pradesh (in south-east India), one can get some more insights. For example, although the scheme aimed at those below the poverty line, some of these dropped out from it, while 80% of those above the specified income limit managed to be included. Secondly, implementation bottlenecks -- limited choice, inability of suppliers to supply equipment on time, co-ordination problems at the local level for the supply arrangements, and irregular “commissions” for fuel refills -- contributed to dissatisfaction among the recipients.

Issues for Indian domestic fuels (Section 6)

In the context of the provision of appropriate cooking fuels, Indian decision makers would have to first consider the choice of fuels. LPG appears to be the preferred option for those able to afford the initial and refill costs. If the use of LPG were to be encouraged even for middle/low income households, there would be issues concerning appropriate pricing and financing schemes, and dependable supply and delivery.

Provision 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 of supply, effective distribution/delivery, and regulation.

- ***Pricing issues***

    - ***Choice of LPG subsidies:*** With a subsidy provided for domestic users of LPG even after the dismantling of the Administered Pricing Mechanism (APM), any decisions regarding domestic LPG provision would have to begin with pricing. Subsidy-options would also have to be decided upon – either on the initial costs of connections/stoves, or on the fuel, through funds from cross-subsidies or budgeted from the exchequer, and so on. Subsidising initial costs helps to overcome the first-cost sensitive, and seems preferable to fuel (or refill) subsidies because the latter could be diverted to other uses/users. However, first-cost subsidies leave possibilities for dropouts from those who cannot afford the fuel costs, resulting in “dead” investments.
    - ***Operating (fuel) subsidies:*** If LPG refill subsidy is to be continued, some precautions have to be taken:
        - ***rationing/quotas*** (quantitative limits) for the subsidised fuel (as with ration cards) and/or coupons (as with food stamps);
        - ***differentiated containers*** (say, smaller cylinders, and/or cylinders painted another colour) for specific purposes (as with subsidised kerosene currently being coloured blue), to prevent use by those outside the scope of the planned benefits;
        - ***use-based subsidies (as with baseline tariffs for electricity)*** with prices increasing with the level of consumption, thereby helping only the minimum-level users and restricting “subsidy capture”.
    - ***Cross subsidies from other distillates:*** This has been the Indian practice for many years, but would need to be weighed against the disadvantages of higher costs of transport (from higher priced auto-fuels).

    - ***Funding of subsidies:*** The source of funds for the subsidies would have to be one/more from among:
        - *LPG companies themselves* - through a mandate of the government, requiring the providers to sell below their costs, as in the present Indian situation, but this has to be temporary or else there could be financial disasters (as happened with the State Electricity Boards);

- *regulated cross-subsidies from one consumer category to another* - effective as long as the funding category's price elasticity is not too high as to curtail sales;
- *progressive tariffs (with the price per unit increasing with the amount consumed)*: Here, the more affluent customers who use more, pay more. This would work if the upper segment were large enough to support the lower segments and could be considered akin to cross-subsidies from higher income consumers to the others.

- ***Pricing of competing fuels:*** When evaluating the pricing of LPG, one has to consider the relative prices of these fuels, and whether or not inter-fuel shifts are desirable.
  - Reducing/removing the subsidy on kerosene could make LPG relatively cheaper, without a burden on the exchequer. (However, in the near term, or as long as homes are not electrified, subsidies to kerosene have to merit consideration because it is the source of lighting for about 43% of the population)**.**
  - 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; it can therefore be argued that LPG subsidies are not required.

- ***Direct cash benefits instead of subsidised fuel:*** There could be schemes through which LPG is priced at its full cost, but targeted households get some pre-determined compensation (as in the case of electricity for irrigation, in the state of Tamil Nadu). This would avoid careless use of the fuel, while assisting the economically disadvantaged. Such programmes would require funding from the government - with transfer payments directly to the poor, but the better the targeting, the higher the administrative costs. Also, earlier experiences with such below-BPL schemes have not been very successful.

- ***Marketing (financing and packaging) schemes:*** *Instalment payments* for the cost of connection and stove, and each fuel refill in much *smaller containers* (e.g. 2 – 5 kg, instead of the regular 14.2 kg cylinders), will reduce the "lumpiness" of successive cash outlays. (The latter option has been launched on a small scale by the three main Public Sector distributors, but needs to be extended beyond limited areas).

- ***Public awareness****:* Awareness of the adverse impacts on health of indoor pollution and the benefits of "cleaner" fuels would increase their popularity and thereby, the willingness to pay.

- ***Supply security:*** Dependable supply of LPG requires -
  - adequate and well dispersed import facilities,
  - indigenous processing plants (refineries and natural gas fractionating plants),
  - availability of storage capacities throughout the country, and
  - multi-mode transport facilities for moving LPG from alternative destinations.

- ***Dependable distribution network****:*
    - The problems of distributors -- who face unfavourable economies of scale when demand is low or dispersed, and those of consumers -- whose location precludes them from LPG use, can be addressed through extension of the distribution network beyond urban and semi-urban areas.
    - Complementary infrastructure – roads, equipment suppliers, repair services, etc. – should be built up in tandem, to facilitate the smooth operation of the system (analogous to the rationale for improving rural infrastructure along with electrification).

- ***Regulation - the government's role***: The government/regulator would have to set standards to maintain safety and avoid corruption, impose measures for ensuring that the cylinders are checked for their user-worthiness and are properly filled, and provide consumer protection. (With a large numbers of operators and poor enforcement of standards, accidents and commercial malpractice can occur).

    While the government has to be involved, at least through its policies, in helping to provide energy services to the economically disadvantaged, there has also to be a suitable environment for the private sector to cater to those who can pay for their needs. Subsidies will continue to be necessary for a while, but have to be applied with care. Development assistance/grants – from aid agencies, etc. could help only small fractions of the population; which means that the government and market forces have to handle the rest and their extent and effectiveness have to be expanded to meet current and growing needs.

Other options

There are other important alternatives to traditional cooking fuels, in particular, biomass-based fuels already in use in a few places in the country, for example, biogas (through animal dung and/or fibrous crop residues), and those not yet in use in the country, such as synthetic LPG. These have been projected, as local sources of petroleum-based products like LPG are limited, and international sources could be adversely affected by political problems and price volatility. Renewable sources would obviously be preferable, as long as they were used in a sustainable manner. Therefore, the use of LPG can be considered as a short/medium term option i.e. a transition fuel (or a complement) to sustainable fuels.

1. Introduction

1.1 Background:

Of the two billion people in the world currently dependent on biomass energy (chiefly wood, and also dung and crop residues), some 700 million are estimated to live in India alone (ESMAP, 2001). According to the Census of India, 2001, about 91% of rural and 31% of urban[5] homes depend chiefly on traditional fuels -- fuel-wood, animal and crop waste and charcoal -- for cooking.

Dependence on traditional forms of biomass adversely affects human productivity particularly when time is increasingly spent farther and farther afield for diminishing fuel-wood sources and if the health of those exposed is endangered by high concentration of particulate matter from inefficiently burnt domestic fuels. While individuals (mainly women and girls) are exposed to the injurious effects (of smoke inhalation, the emission of unburned hydrocarbons through traditional stoves, and soot deposits when washed off vessels, etc.) and also have to spend time on fuel gathering, the community as a whole is adversely affected both by the ambient pollution created by simultaneous cook-fires and through land degradation in cases where fuel-wood is gathered in an unsustainable manner[6].

While Agenda 21[7] specifically recognized the challenge of providing access for rural households to modern energy sources and called for "a rural energy transformation", efforts have focused chiefly on electricity generation. This has meant that the need for cleaner and more efficient cooking fuels has not been adequately addressed.

Trends in household fuel use can also be viewed along an "energy ladder", from simple biomass fuels -- twigs/shrubs, dung, crop waste -- at the lowest levels, to fuel-wood, charcoal, and kerosene, and finally to LPG and electricity. The fuel-stove combinations become cleaner and more efficient, but also increase in capital costs as the ladder is ascended (OTA, 1992). Therefore, as household income increases, people are able to move up the energy ladder, affording seemingly more expensive but more efficient sources of energy, if they are accessible[8].

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[5] "Urban" is defined by the Census of India as any place with a municipality, corporation, cantonment board or notified town area committee, or one satisfying the following three criteria simultaneously: (i) a minimum population of 5,000, (ii) at least 75% of the male working population engaged in non-agricultural pursuits, and (iii) a density of population of at least 400 per km^2.

[6] Actually, forests have been cleared for other reasons such as expanding settlements, roads, etc.

[7] Agenda 21 is a comprehensive plan of action of the UN Division for Sustainable Development; originally adopted at the UN Conference on Environment and Development in 1992, its implementation was reaffirmed at the World Summit on Sustainable Development in 2002.

[8] The energy ladder concept has been proven in studies of specific areas, for example, for a sample of households in the city of Bangalore India (Reddy, B.S., 1995, 1996a).

Unfortunately, while households around the world have moved to higher quality rungs of the ladder, in developing countries[9] many are still dependent on fuel-wood or have been forced down by local wood shortage to crop residues or even shrubs and grasses (UNDP, 1998). It therefore is pertinent to assess the current use of various domestic cooking fuels and the possibility of shifting to cleaner and more efficient options. One of these options is liquefied petroleum gas (LPG)[10].

However, the likelihood of enhancing supplies of LPG and a distribution network to meet increasing domestic demand have also to be considered. Juxtaposed with the household demand must be the competing demand from the automobile sector. This necessitates an assessment of the supply-side requirements – from refinery capacity to transport, bottling and distribution, and the associated constraints.

1.2 Why LPG?

Given the extensive use of firewood for cooking in India, studies have been made on emissions from biomass-based stoves, including a detailed study of greenhouse gases from small-scale combustion devices in developing countries – with special reference to household stoves (Smith *et al.*, 2000a, b). Table 1 shows the indoor concentration of health damaging pollutants from a typical wood-fired cooking stove while Table 2 indicates the default emission levels for carbon monoxide (CO), methane (CH_4), non-methane organic compounds and nitrous oxide (N_2O), through various residential fuel options.

Table 1: Indoor concentration of health-damaging pollutants from a typical wood-fired cooking stove

1 kg of wood per hour in 15ACH 40m^3 kitchen				
Carbon monoxide	**Particles**	**Benzene**	**1,3-Butadiene**	**Formaldehyde**
150 mg/m^3 (10 mg/m^3)	3.3 mg/m^3 (0.1 mg/m^3)	0.8 mg/m^3 (0.002 mg/m^3)	0.15 mg/m^3 (0.0003 mg/m^3)	0.7 mg/m^3 (0.1 mg/m^3)

The numbers in parentheses indicate typical standards set to protect health.
Source: Smith *et al.*, 2000b

[9] The term "developing countries" is usually used for lower income countries that are members of the G-77, and China.
[10] Liquefied petroleum gas consists mainly of propane (C_3H_8) and butane (C_4H_{10}). Annexe 1 contains more technical details.

Table 2: IPCC default (uncontrolled) emission factors for residential fuel combustion (g/kg)

	CO	CH_4	*TNMOC**	N_2O
Gas[1]	2.0	0.2	0.2	0.005
Oil[2]	0.9	0.4	0.2	0.030
Wood	80.0	5.0	9.0	0.060
Charcoal	200.0	6.0	3.0	0.030
Dung/agricultural wastes[3]	68.0	4.0	8.0	0.050

Source: IPCC, 1997 (quoted in Smith *et al.*, 2000b)

1. Determined using IPCC emission factors given for "Natural gas" and the net calorific value given for "LPG".
2. Determined using the IPCC emission factors given for "Oil" and the net calorific value given for "Kerosene".
3. Determined using the IPCC emission factors given for "Other Biomass and wastes" and the average of the net calorific values given for "Dung" and "Agricultural wastes".

* Total non-methane organic compounds

There have been studies correlating fuel use and personal activity patterns with health concerns, based on the use of biomass, and types of stoves, and in particular, for specific parts of the country. For example, a sample study of 58,768 individuals in 10,265 rural households in 118 villages from 18 districts in the north-Indian states of Uttar Pradesh, Himachal Pradesh and Rajasthan (Parikh, *et al*., 2003) found correlation between the incidence of respiratory ailments and the use of biomass-based fuels; the effects of health damaging pollutants through the present cooking fuels was established, although this was exacerbated by factors such as kitchen location and limited ventilation.

Among "cleaner" fuels, biogas, kerosene and LPG, the first depends on the availability of cattle, and between the latter two, LPG has been found from complete life-cycle environmental assessments (burden associated with the entire product/package) to be a preferable option. A comparison was made between kerosene and LPG (Jungbluth, 1995) in terms of the entire product/package, i.e. on the basis of the total life-cycle impact from the extraction of crude oil and natural gas, to processing in refineries and fractionating plants, product transport and distribution, and finally cooking. For a majority of the indicators, it was concluded that LPG had an ecological advantage over kerosene.

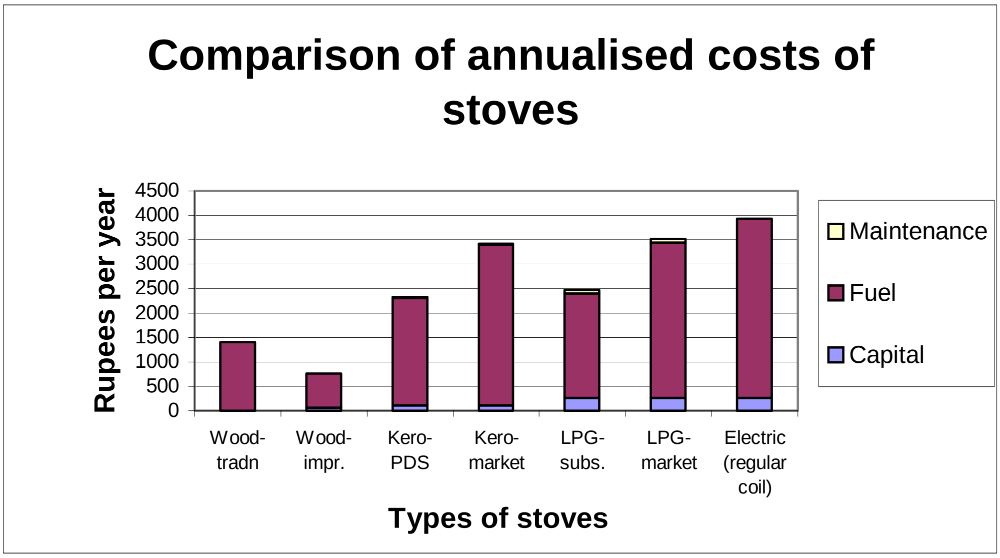
For the purpose of comparing the total costs of each alternative, we have made a comparison (in Indian Rupees) of the annualised life-cycle costs (ALCC)[11] of the commonly used stoves, at a discount rate of 12% per year. (In the case of kerosene LPG, there is a difference in the price per unit between the administered

[11] Annualised life-cycle cost = the annual equivalent value of the total costs incurred (initially and during the working life of the equipment) = [Kx(CRF) + A], where K is the capital or initial purchase cost, CRF = capital recovery factor = $i \div [1-(1+i)^{-n}]$, 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. The costs that could result from adverse health effects have not been considered.

price at which refills are purchased through the Public Sector[12] oil companies and the market price; hence two options each have been considered). These ALCCs include both the initial costs and the operating costs, the latter varying with the amount of fuel required (dependent on the energy content of the fuel and the efficiency with which it is used) and the prevailing prices of the fuel. (Annexe 3 shows the prices and efficiencies of stoves and the prices of each fuel used for the computation).

As Figure 1 indicates, the life-cycle costs increase from ordinary fuel-wood stoves to LPG and electricity stoves. It is important to note that the constituents of total life-cycle cost vary, with fuel comprising a much higher proportion in the case of the less efficient options like fuel wood and conversely the stove (capital) cost contributing much more to the higher-efficiency options like LPG. Therefore, a larger investment made in the present for acquiring a more efficient carrier system[13] is compensated for by the long-term saving in fuel costs.

Figure 1:



This is based on the authors' computation, using market prices/subsidies prevailing in the year 2003 (as shown in Annexe 3).

LPG can therefore be recommended both for its higher efficiency and lower environmental impact than the alternatives. The human labour avoided and time saving achieved through convenient cooking fuels have not been imputed with a value, but need to be considered too.

There are other alternatives to traditional cooking fuels. Renewable sources would obviously be preferable, as long as they were used in a sustainable[14] manner. In particular, biogas (through animal dung and/or fibrous crop residues)

[12] A company is termed "Public Sector" when the government owns a 51% or greater shareholding in the organisation.
[13] In addition to the cost of the LPG stove, one has to pay for the initial LPG "connection".
[14] We use the internationally accepted definition of sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs".

has been found to be the most efficient among the currently available "clean" cooking fuels (Smith, *et al*., 2000). But the use of biogas is restricted by the availability of cattle. New renewable options not yet in use the country, such as di-methyl ether (DME), methanol, and synthetic LPG (syn-LPG) have also to be considered.

Since LPG is a petroleum-based fuel, it can be argued that increased use of this fuel should not be advocated; local sources of petroleum-based products are limited, and international sources are adversely affected by political problems and price volatility. On the contrary, it should also be considered that people in developing countries, particularly in the lower income categories should be allowed the choice of such a fuel, because their contribution to greenhouse gas (GHG) emissions has been miniscule and constraints should therefore not be imposed on them in the name of climate change. A poor person in India is said to emit only 50 to 60 kg of carbon, compared to the world average of 1,100 kg and 5,000 kg in the USA (Parikh and Denton, 2002).

Therefore, the use of LPG is being considered as a short/medium term option i.e. a transition fuel (or a complement) to biomass-based fuels.

1.3 Objectives of this study:

The purpose of this study is to examine:

1. the domestic use of cooking fuels in India, particularly that of LPG
2. the growth in domestic use of LPG in India particularly -
    a. in continuation of the recent trend,
    b. in excess of the trend,
3. the requirements – in terms of supply and distribution – to meet the increased demand for LPG (in 2),
4. the challenges that are likely to be faced (for the implementation of 2 and 3),
5. experiences elsewhere, from which lessons could be learnt, and
6. the policies that could help surmount the barriers (in 4).

1.4 Methodology

The method followed for the subsequent sections is briefly being described below.

Demand estimation:

Current requirement -

As data are not available in the form required, some computation has to be done (using assumptions where required) to obtain estimates of the relevant variables.

The service-based energy-use of any category of users for any period can be described as the product of two variables, namely, (1) the total *number of users* (an indicator of the *spread* of, or access to, that energy source), and (2) the energy *requirement for each user* during that period (an indicator of the *magnitude* of energy required to enjoy the service derived from that energy source).

For (1) *the number of households using LPG for cooking*, there are several numbers available, namely, the decennial Census of India (2001) and various estimates based on the aggregate number of domestic connections served by the main Public Sector Undertakings in the petroleum sector. The Census information is being considered the most reliable and hence the *year 2000-01 is being taken as the base year* for the estimation.

For (2), the average LPG requirement per household, we are dividing the estimated total annual use by "domestic" connections, by the estimated number of such domestic connections (through all the public sector and private distributors)[15]. This is not strictly correct because "domestic" LPG is known to be diverted to automobiles and even small industries and commercial establishments. This can be taken as a proxy for the "requirement per home", because the actual requirement for cooking based on the food cooked at each meal and the number of meals for which LPG was the cooking fuel (in cases where more than one fuel is used), are difficult to obtain for the country as a whole.

For the base-year, the **total LPG use** $\mathbf{M_1}$ is therefore the product of $\mathbf{n_1}$, the **number of households using LPG**, and $\mathbf{m_1}$, the **average annual use per household** (as a proxy for the strict requirement based on actual heat used for a specified level of cooking). Then:

$\mathbf{n_1}$	**x**	$\mathbf{m_1}$	$\mathbf{= M_1}$
[number of households		[specific annual fuel use]	[total LPG requirement]
(say, *in thousands*)		(*kg per household*)	(*thousand kg or tonnes*)

[15] As the question of privatisation of (or government "dis-investment" from) Public Sector undertakings is currently being debated, oil corporations have not been forthcoming about details.

It is important to avoid the "per capita" consumption figures usually published, as these represent total use divided by the total number of homes in the *entire* population and are therefore incorrect when applied only to LPG-using homes.

Estimates of future requirement -

In this case, future use of a particular fuel, is estimated on the basis of the base-year data.

Given the base-year number of LPG-dependent households and the average use, the total LPG requirement $\mathbf{M_k}$ in any future year $\mathbf{k}$ can be estimated according to the expected rates of change (growth rates) $\mathbf{g_n}$ and $\mathbf{g_m}$, of the number of users $\mathbf{n_1}$, and their average annual fuel use[16] $\mathbf{m_1}$, respectively,
i.e., $\mathbf{n_k \times m_k = M_k}$,
where

$$\mathbf{n_k = n_1 \times (1 + g_n)^{k-1}}$$

and $\mathbf{m_k = m_1 \times (1 + g_m)^{k-1}}$

These growth rates $\mathbf{g_n}$ and $\mathbf{g_m}$, could be based on past trends or on new growth rates, $\mathbf{g'_n}$ and $\mathbf{g'_m}$, depending on the policies likely to be implemented. For example, if cleaner more efficient fuel use is to be encouraged in the domestic sector, an increased growth rates of household LPG connections would be called for, so that $\mathbf{g'_n} > \mathbf{g_n}$. (These rates of growth of consumers could vary over the period considered).

Similarly, the average fuel use per consumer could also be expected to be either constant, or change (increase/decrease). A focus on improved efficiency of energy, say, through improved stoves, if possible, would result in lower fuel use per household for the same level of energy service, i.e. $\mathbf{m'_k} < \mathbf{m_k}$. Even with stove-efficiency constant, there could be changes in the average use because of the level of services derived, for instance, where people shift from a complementary/back-up fuel to using it for all their cooking/heating needs, the requirement per household would increase, i.e. $\mathbf{m'_k} > \mathbf{m_k}$.

Simplifying the required steps from the above generalisation, one could consider only two options for each variable -- number of households and fuel use per household – in future scenarios:
The number of households would change over time either:
according to the current (business-as-usual) annual rate of growth $\mathbf{g_n}$, (leading to $\mathbf{n_k}$), or
a new suggested rate of growth $\mathbf{g'_n}$ (leading to $\mathbf{n_k}$).
The unit use per household, could:
continue at the current level, i.e. $\mathbf{m_k} = \mathbf{m_1}$ without any change (i.e. $\mathbf{g_m}$=0), or
change by some determined amount to $\mathbf{m'_k}$.

[16] Ideally, at any point of time, one would have to consider, not merely an average fuel use per consumer for the entire population, but several consumer segments, each with a particular usage pattern.

Hence, as shown in Figure 2, there are four possible outcomes: business-as usual ($\mathbf{n_k.m_k}$), user-development-focused ($\mathbf{n'_k.m_k}$), use-intensity-altered ($\mathbf{n_k.m'_k}$), and combined user and intensity altered ($\mathbf{n'_k.m'_k}$).

Figure 2: Range of demand scenarios

Focus on consumer-population

End-use (per consumer) orientation

	Current growth rate	***New growth rate***
Current Unit Use	**business-as-usual** $\mathbf{n_k.m_k}$	**user-development-focused** $\mathbf{n'_k.m_k}$
New Unit Use	**use-intensity-altered** $\mathbf{n_k.m'_k}$	**user-& intensity-altered** $\mathbf{n'_k.m'_k}$

Even without strictly working out *growth rates* in relation to a base-year, one can consider scenarios with different *proportions* of the expected population dependent on LPG for their main cooking requirements; one could also consider a restriction (ceiling) on the dependence on LPG.

Supply assessment:

When assessing the possibility of meeting the requirement, one has to consider both the quantity of LPG needs and the system for effective domestic delivery.

Quantity

Current production and the proposed refinery increases and production pattern will give the estimated in-country supply; this includes production both directly from natural gas and from distillation yield at refineries. To these one must add imports; here there are problems of the country's debt burden from the import bill, depending on the international prices and currency exchange rates, and also on the political situation.

Infrastructure

Supply to the consumer has to be analysed further, considering other necessities of transport, bottling and distribution infrastructure, as well as the regional bottlenecks and other problems. Marketing facilities must also be considered. In the absence of corporation/company specific details (not revealed for strategic reasons), an overall picture is being presented.

Challenges:

There are obvious problems regarding increased LPG use, particularly with regard to *accessibility* – particularly in rural areas, *affordability* – of the initial costs and fuel, and *availability* – in terms of the supply, transport, storage and distribution network. These have to be looked at systematically, so that a solution can be suggested to tackle each challenge.

Other experiences:

The experiences with (i) the expansion of LPG use in other countries and (ii) LPG programmes in India are also being used to derive factors that would either help or inhibit the successful implementation of LPG use programmes.

Suggested:

Finally, based on the situation described in the demand and supply sections, the barriers to enhanced supply, and the lessons that could be learnt, suggestions are being made regarding the policies through which the problems encountered can be overcome.

2. Demand for LPG

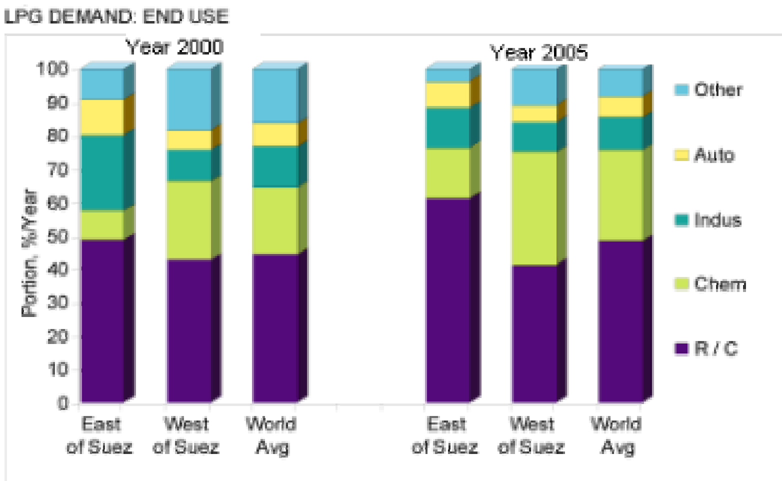
While the worldwide average growth rate for LPG demand was about 3.7% per year during the 1990s, this varied between about 2% in Western Europe and 3% in North America and about 6% in Asia (Purvin and Gertz, 2000). In particular, China exhibited an average annual growth of over 19% and India, 9.5%. It is estimated that India's annual growth will be over 11% between 1999 and 2005. In addition, 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[17] (MoPN&G, 2003b).

Worldwide, the end-use demand for LPG has been as shown in Figure 3. However, while half of all LPG used East of the Suez was consumed by the residential-commercial sector in 1985, this use is expected to increase to about 60% by the year 2005 (Purvin and Gertz, 2000). Growth of the residential-commercial sector LPG demand is also expected to vary from region to region, varying from a barely positive growth rate in Europe to over 5% for Asia during 1999-2005. The largest growth rates in this category will be in China and India; in 1985, 5% of the total world residential-commercial LPG consumption was in these two countries, but by 2005, this consumption will rise to more than 20% of

[17] Conversely, India's dependence on petrol (gasoline or motor spirit) is one of the lowest in the region.

the world total. This would result in a deficit in the Asia Pacific region, further necessitating imports from the Middle-east.

Figure 3: World-wide end-use demand for LPG - in the year 2000 and estimates for the year 2005



Source: Purvin and Gertz, 2000
R/C = residential and/or commercial

2.1 Domestic use of cooking fuels in India

Several estimates of household use of cooking fuels in India have been obtained (for example, IIFM, 1999; Malhotra, *et al.*, 2001; Natarajan, 1990; NSSO, 1992). However, the most exhaustive information appears to be from the recent decennial Census of the Indian population (Census of India, 2001). Figures 4a and b (constructed from this information) show the proportion of households using each type of cooking fuel, in urban and rural areas, respectively. In urban areas, the most commonly used fuel is LPG (47.96%), followed by firewood (22.74%) and kerosene (19.16%), with much lower dependence on other fuels. In the rural areas, in contrast, firewood is, by far, the most important fuel (64.10%). Other sources of biomass – crop residue (13.10%) and cow-dung (12.80%), are so far the main alternatives, although LPG (5.67%) is now increasing in importance. However, 72% of the country's households live in rural areas. Thus, the countrywide picture, shown in Figure 4c, indicates that traditional biomass (firewood, crop waste, and dung) constitutes the main source of cooking fuels.

Figure 4a: Indian urban household dependence on various cooking fuels in 2001 (the figures indicate the proportion of all urban households using a particular fuel)

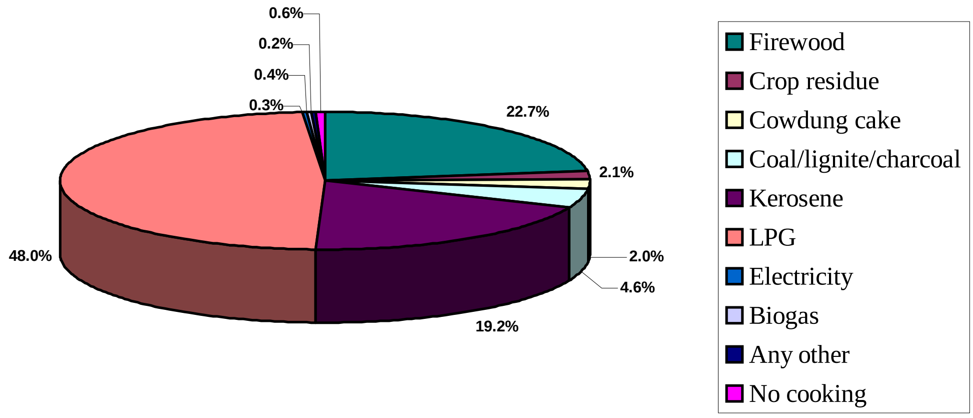


Figure 4b: Indian rural household dependence on various cooking fuels in 2001 (the figures indicate the proportion of all rural households using a particular fuel)

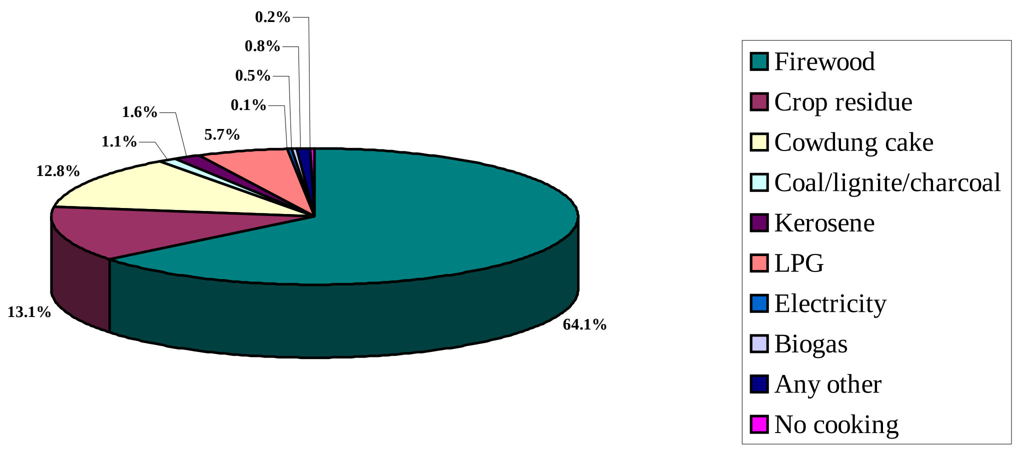
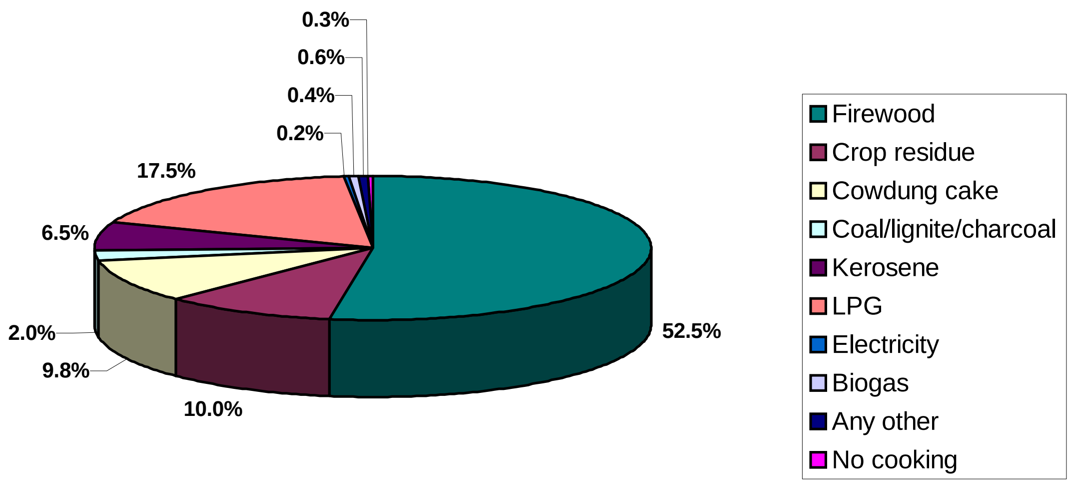


Figure 4c: All India household dependence on various cooking fuels in 2001



2.2 Estimated domestic requirement of LPG

2.2.1 Extent of dependence on LPG

The Census reveals that in the year 2001, there were 33.6 million or 17.5% of the households in the country using LPG as their primary cooking fuel. These comprised 7.845 million homes (or 5.67 % of the population) in rural areas and 25.752 million (or 47.96 % of the population) in urban areas. From the information on individual states and union territories in the country, as shown in Table 3, the dependence varied from over 50% in the (chiefly urban) union territories to under 15% in the eastern states.

Table 3: State-wise use of LPG as fuel for cooking in the year 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 & 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 & Kashmir	1,551,768	343,052	22.1
Dadra & 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: Census of India, 2001

Several factors such as household income, location, and availability and prices of alternatives, appear to affect the choice of or dependence on LPG.

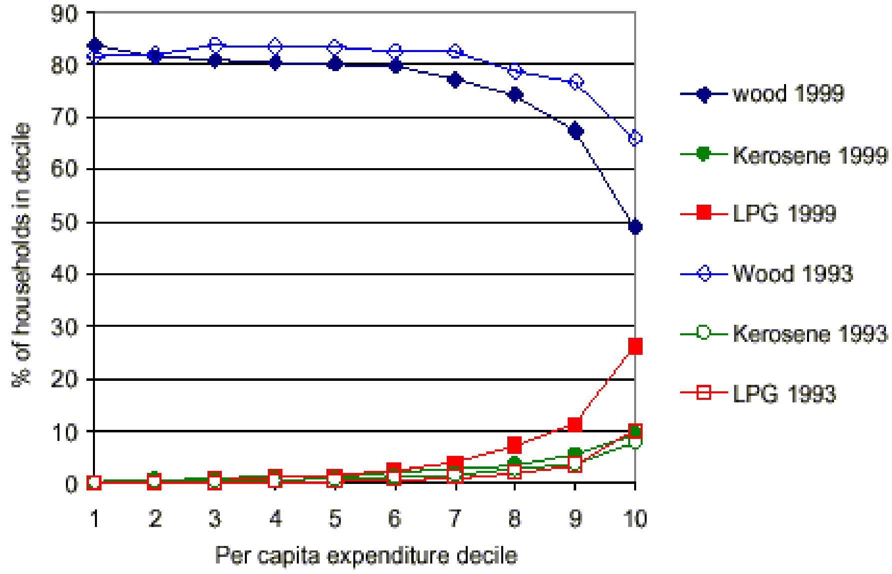
Household income

It is expected that the dependence on LPG would increase with the income/expenditure level of the household, as income has been found to be an important variable in the choice of household items. This has been proven by the periodic National Sample Survey (NSS), conducted by the Government of India[18], that elicits household expenditure on a variety of items. Using the reported household expenditure as a proxy for household income, the expenditure on each commodity/category of commodities, can be analysed according to household income levels.

The most recent information obtained is from the NSS 55th round pertaining to the year 1999-2000. Figures 5a and b, based on NSS data (for 1993-94 and 1999-2000), show the percentage of households dependent on each type of cooking fuel in each expenditure decile of the sample.

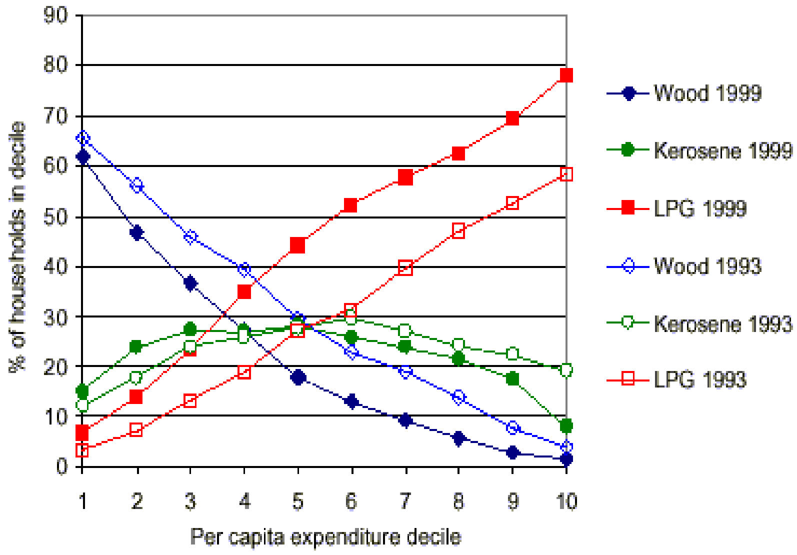
[18] The National Sample Survey Organisation (NSSO) is under the Ministry of Statistics and Programme Implementation of the Government of India. Details about the Survey are included in Annexe 5, part 6.

Figure 5a: Historical progression of primary cooking fuel choice in *rural* India (Comparison of 1993-94 and 1999-2000 NSS data)



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

Figure 5b: Historical progression of primary cooking fuel choice in *urban* India (comparison of 1993-94 and 1999-2000 NSS data)



The graphs indicate that as one proceeds upwards along the expenditure (income) deciles, households shift to "better" (cleaner and more efficient) fuels. Obviously, the top deciles consume a disproportionately higher share of these better carriers than the poor. This could be because, as incomes rise, the households' capital resources also increase, so that they can more easily incur the initial costs of more expensive energy carriers like LPG (for the stove, connection). Further, with increasing income, the *consumer discount rate* falls as consumers more easily forego present consumption in return for future earning.

In other words, with lower consumer discount rates, future saving[19] would have relatively higher present values, so that seemingly more expensive options like LPG would be more attractive. Studies on household energy use, for example, a study on Bangalore city (Reddy, B.S., 1996), have verified this.

Comparative prices of fuels

The use of each cooking fuel, as with commodities, is influenced by the prevailing prices. As such, wherever fuel can be "freely" collected, it is the preferred option, hence the high proportion of firewood (usually twigs, etc.) use in rural areas. Where firewood is not collectible, the next available option is used. Kerosene is usually the first modern fuel to be used, because the administered price, when obtained through the Public Distribution System, is relatively low.

Availability

The availability of a particular type of fuel has a strong influence on the householders' choices; obviously, apart from the prices, the ease with which substitutes or competing fuels can be obtained, would affect the amount of the fuel used. For example, kerosene is more easily transported and stored than LPG, and therefore easier to obtain. The following Section, dealing with the amount of LPG used, indicates a lower average use of LPG in rural than in urban areas; this could be the result of greater difficulty in obtaining refuelling (cylinder replacements) as also the availability of biomass sources that could be used to complement the supply of LPG. The distribution system is obviously more developed in urban areas, thereby affecting availability. As Figures 5a and b indicate, the decline in the graph of homes using any fuel is balanced by increases in those using the available alternatives.

Location

As shown in Figure 5a on rural areas, the use of firewood is persistently high except in the highest three deciles where it is partially replaced by LPG, whereas in Figure 5b on urban areas, both purchased wood and kerosene are increasingly replaced by LPG as one proceeds up the income ladder.

The demand for LPG has historically been higher in the urban areas, probably because the higher costs of refills vis-à-vis other fuels necessitates higher cash incomes and also because the absence/shortage of biomass forces a dependence on other fuels. Moreover, LPG is more easily available in urban areas, as discussed above. However, the "switch" between fuels is often found to be incomplete, as many households use more than one fuel, partly because of differences between the tasks undertaken – the main meal versus supplementary or additional heating. Further, although there appear to be more choices (wood, kerosene, LPG, electricity), the gaps in and uncertainty of supply of each lead to dependence on more than one source, with families storing and using more than one fuel simultaneously as a risk mitigation strategy.

[19] The present value of any saving S, derived k years from the present, at discount rate i% per year $= S \div (1+i)^k$

In contrast, in rural areas, the continued availability of some type of biomass -- branches, twigs, fronds, grasses, crop field waste, -- even if further away from home, has not pushed households to other options. But here too, shifts to better fuels do not eliminate the use of a traditional carrier, as users distinguish between cooking of the main meals and other uses such as water heating.

Social factors

In addition to ability to pay, increasing incomes and education also lead to awareness of the adverse impacts of indoor pollution associated with each fuel evidenced in the quick switching from wood and twigs to kerosene as a family moves from a slum to a tenement (Gupta and Kohlin, 2001). Adoption of a "better" fuel has also been perceived as a status symbol (NIRD, 2002).

Historical progression

There have been perceptible shifts between over time away from fuelwood and kerosene and towards LPG. As shown in the Figure 4 series above, the shifts are evident even between the six-year period 1994-2000. In particular, during the last two decades, the demand for LPG as a convenient fuel for cooking has been increasing, to the extent of there being waiting lists of households seeking "connections" (implying access to one/two cylinders of LPG at a time) from distributing agencies. Thus the shifts shown in the Figures could have been blunted by the lack of availability. The increasing demand for LPG has provided a consumer base for private distributors who have been permitted into the market in 1996.

However, it must be noted that the use of LPG through domestic connections may not have been only for household use but also for cooking in commercial establishments (hotels, etc.), for fuelling vehicles, and for small industrial units.

2.2.2 Consumption levels

The estimated total number of consumers – domestic and others -- and their corresponding use of LPG are shown in Table 4.

Table 4: Increase in India's total LPG consumption and the number of consumers and distributors

Years	**Total (all sectors') consumption ('000 tonnes)**	**Number of consumers (millions)**	**Number of distributors (actual)**
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
99-2000	6,029	47.3	6,161
2000-01	6,613	57.9	6,477
2001-02	7,310	63.5	7,486
2002-03*	8,157	69.8	7,910

** indicates provisional data*

Sources of data: CMIE, 2003; MoP&NG, 2003c.

Given the total consumption of LPG and the number of connections, as shown in Table 4, the average annual use of LPG per connection works out to about 115 kg.

The NSS results can be used to verify this. Details from the 55th round (1999-2000) on the reported average monthly household consumption of LPG (shown in Table 5) indicate a cluster around 14.2 kilograms (one regular cylinder) per month and another cluster around 7-8 kg (half a cylinder) per month; these are equivalent to 170 kg and 85 kg per year, respectively. The averages from the entire sample survey for rural and urban households were 11.3 kg per month (135.6 kg/year) and 13.3 kg per month (159.6 kg/year), respectively.

Table 5: Reported monthly household consumption of LPG, 1999-2000
(Figures in parentheses indicate the percentage of households using LPG in the sample)

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

Source of data: NSS 55th Round

The corresponding nominal monthly expenditure on LPG and proportion of the household's expenses are listed in Tables 6a and 6b for rural and urban households, respectively.

Table 6a: Nominal monthly expenditure on LPG as primary cooking fuel in *rural* India, (NSS) 1999-2000

Expenditure decile	Amount spent (Rupees)	Proportion of expenses (%)
1	53	4.8
2	91	3.9
3	84	3.9
4	102	4.9
5	138	5.5
6	141	4.8
7	137	4.8
8	152	4.4
9	148	4.1
10	153	3.3

Table 6b: Monthly expenditure on LPG as primary cooking fuel in *urban* India, (NSS) 1999-2000

Expenditure decile	Amount spent (Rupees)	Proportion of expenses (%)
1	137	5.9
2	147	5.5
3	156	5.6
4	162	4.9
5	163	4.4
6	163	4.1
7	165	3.8
8	160	3.3
9	163	3.0
10	162	2.1

However, the authenticity of these estimates is based on each respondent's ability to recall and/or correctly estimate the family's purchases and use of the relevant commodity and there appears to be overestimation as compared with the distributors' estimates of sales, where available. The amount of LPG used for cooking may also be overestimated because domestic buyers have been known to use their quota for other purposes such as running cars. In this context, the LPG use in rural areas can reasonably be considered lower than that in urban areas because it is less likely that it is used for other services.

For future estimation of domestic LPG requirement, therefore, one needs the true fuel requirement per household, based on efficiency of LPG-stoves and cooking needs. However, cooking needs vary between families, in terms of lifestyle patterns and the type of food cooked (depending on regional customs). And, as indicated above, overestimation also occurs.

Hence, the assumption is being made that the average annual *consumption*[20] per connection is equivalent to the annual *requirement* per household, but this single average is being weighted between rural and urban areas in the ratio of the average NSS-reported household use, i.e. 11.3 kg per month and 13.3 kg per month, and the number of Census-reported LPG-dependent households -- 7.845 million and 25.752 million, in rural and urban areas, respectively. Correspondingly, *the aggregate annual average of 115.12 kg is being disaggregated into 101.4 kg for rural areas and 119.3 kg for urban areas*. Then, for the average LPG requirement per household, as a first approximation for the base year 2001, we are using these estimates of average LPG use per household in rural and urban areas. Therefore, for the reported LPG-using households, the total requirement would be 0.795 million metric tonnes (mmt) in rural areas and 3.072 mmt in urban areas, as shown in Table 7. Further this represents 58.5% of the total use of 6.613 mmt of LPG reported (MoP&NG, 2003) for that year.

Table 7: Domestic dependence on LPG in the year 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	mmt	0.795	3.072	3.868

2.3 Estimated future requirement of LPG

As explained in the methodology, *for the estimation of future domestic LPG demand*, one needs to consider *the average LPG requirement per household*, and the *projected increases (growth rates) for the number of LPG-dependent households*.

The average LPG requirement per household was estimated in Section 2.2.2 above. Growth rates would depend on the scenario envisaged.

For *a "business-as-usual" scenario*, the average requirement per household is assumed to be the same as that in the base year and the projected increases in the number of LPG-dependent households depend on the current rate of growth of LPG-using households (or that obtaining in the recent past,

[20] To obtain the average consumption per household, it is important to compute the average obtaining among *only the LPG-using households of the population*; if the amount used in the domestic sector were divided by the total households in the population, the "average" for the country would be unrealistically low.

depending on accurate data availability). These growth rates have been estimated as follows:

(1) The total number of households in the country, in rural and urban areas, in any particular year, has to be estimated by interpolating between the decennial Census figures. Then, with the National Sample Survey (NSS) proportions of the population using a particular fuel, and the estimated total number of households, the relevant number of households using the fuel in that year can be obtained. Thus, the number of LPG-using households for the NSS years 1993-94 and 1999-2000 was estimated. These numbers are shown in Table 8.

Table 8: Estimated number of households using LPG in the years 1993-94 and 1999-2000

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

Please note:
(a) The total number of households in each year was estimated by interpolating between the Census figures for 1991 and 2001.
(b) The *proportion* of households using each fuel in rural and urban areas is from the National Sample Survey (NSS) in the given years.

(2) From the number of LPG-using homes so estimated[21], the current (1999-2001) average annual increase in users has been derived. These annual growth rates of 6.82% for rural areas and 11.75% for urban areas are being used for the business-as-usual scenario.

Table 9 shows a business-as usual scenario, with the number of households and the LPG requirement at 5-year intervals. Here, one must note that projecting

[21] As a means of verifying these estimates, the same method was used to estimate the number of kerosene-using households, because apart from new households, the increase in LPG using-households would involve a fuel shift from households that paid for another fuel. In addition, those purchasing firewood also incur costs that could stimulate a changeover to the LPG option.

the current increase in the number of LPG-using households would take the urban dependence on LPG to around 90% of the projected number of households by the year 2008. If one envisages that the urban dependence will not exceed 90%, the rate of increase of households could, after that point, be reduced to the expected population-determined increase of households (2.75% per year)[22]. Actually, enough data has not been obtained to gauge the adoption curves and the relative positions along it, so that annual-growth-rate based projections may not be reasonable. However, with the current rates of LPG adoption, even in the year 2015-16, LPG would be used for cooking in only about 11.9% of rural homes. For the country as a whole, LPG would account for about 36.4% of homes, with the total requirement amounting to 10.8 mmt.

Table 9: Business-as-usual scenario - Projected domestic LPG requirement based on current growth rates and use per household

	units	**Rural**	**Urban**	**Total**
2000-01 (base year):				
Number of LPG-dependent households	million	7.845	25.752	33.597
Growth rates projected	**%/year**	**6.82**	**11.75**	
2005-06:				
Estimated total number of households	millions	150.164	61.493	211.657
Estimated LPG-using households	millions	10.910	44.873	55.783
=> Proportion of total households	%	7.27	72.97	26.36
=> Estimated domestic LPG use	mmt	1.106	5.354	6.460
2010-11:				
Estimated total number of households	millions	163.080	70.426	233.506
Estimated LPG-using households	millions	15.171	63.384	78.555
=> Proportion* of total households	%	9.30	90.00	33.64
=> Estimated domestic LPG use	mmt	1.538	7.562	9.100
2015-16:				
Estimated total number of households	millions	177.106	80.658	257.764
Estimated LPG-using households	millions	21.098	72.592	93.69
=> Proportion* of total households	%	11.91	90.00	36.35
=> Estimated domestic LPG use	mmt	2.139	8.661	10.799

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

As an alternative, one could consider *a scenario in which the rural dependence is increased* through doubling of the rate of increase of LPG-connections from 2005-06 onwards. Even in this scenario, LPG would be used for cooking in only about 22% of rural homes in the year 2015-16. For the country as a whole, LPG would account for about 43% of homes, with the total requirement amounting to 12.6 mmt. Other rural-enhanced-growth scenarios can

[22] This was the average annual increase in the number of households in urban areas between 1991 and 2001; the corresponding rate for rural households was 1.66%. As a first approximation, these rates are being projected for the estimation of the total number of households in the scenarios till 2016.

be projected, but these would not be practicable without substantial increases in household incomes.

Table 10: Scenario 2: Projected domestic LPG requirement based on increased rural dependence but current use per household

	units	**Rural**	**Urban**	**Total**
2000-01 (base year):				
Number of LPG-dependent households	million	7.845	25.752	33.597
Growth rates projected	**%/year**	**13.63**	**11.75**	
2005-06:				
Estimated total number of households	millions	150.164	61.493	211.657
Estimated LPG-using households	millions	10.910	44.873	55.783
=> Proportion* of total households	%	7.27	72.97	26.36
=> Estimated domestic LPG use	mmt	1.106	5.354	6.460
2010-11:				
Estimated total number of households	millions	163.080	70.426	233.506
Estimated LPG-using households	millions	20.671	63.384	84.055
=> Proportion* of total households	%	12.68	90.00	36.00
=> Estimated domestic LPG use	mmt	2.095	7.562	9.658
2015-16:				
Estimated total number of households	millions	177.106	80.658	257.764
Estimated LPG-using households	millions	39.167	72.592	111.760
=> Proportion* of total households	%	22.12	90.00	43.36
=> Estimated domestic LPG use	mmt	3.970	8.661	12.631

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

3. Supply of LPG

Worldwide, the supplies of LPG are growing to meet demand. In 1985, world supply was approximately 114 million tonnes; this is expected to increase to 240 million tonnes in 2005 (Purvin and Gertz, 2000), from enhanced processing of natural gas and rising oil-refinery throughput. The growth in production of LPG will probably 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. Rising natural gas production will add to the amount of gas that is processed and boost the supply of propane and butane. As markets develop, reduced flaring of natural gas in many countries will also boost LPG supply; Saudi Arabia and Nigeria, that flare gas the most, both plan to phase out the practice (WB & WLPGA, 2002).

3.1 Current availability of LPG in India

Production of LPG in India grew steadily during the 1990s, both from crude oil refining and from increased natural gas processing (Table 11). Imports also increased during the 1990s' as demand outstripped indigenous production, but fell during 2000-02 due to the surge in Indian refinery output.

Table 11: LPG Production in India (in million tonnes or mmt)

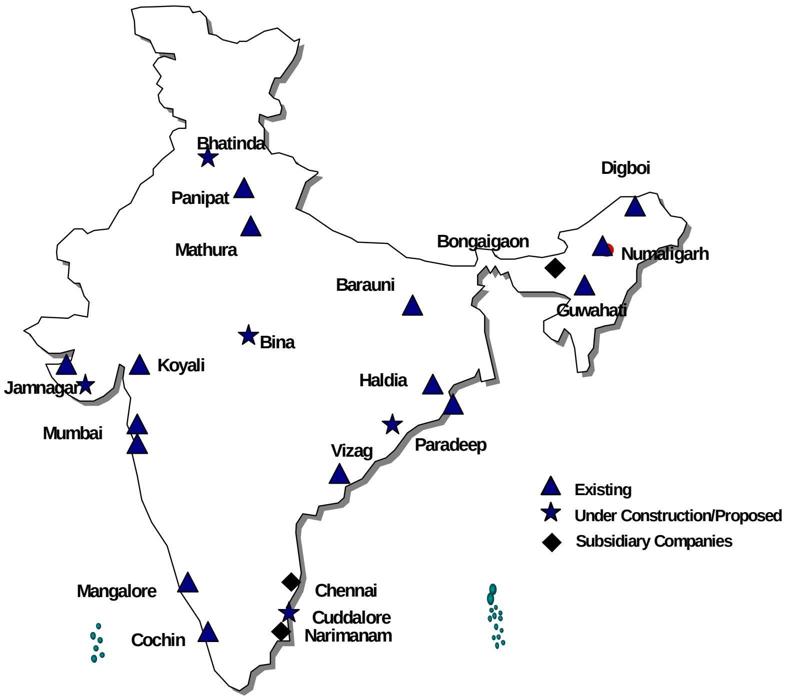
Years	From crude oil refineries (a)	From natural gas fractionators (b)	Total indigenous production (a)+(b)	Net imports
1990-91	1.221	0.929	2.150	0.329
1995-96	1.539	1.714	3.253	0.596
1998-99	1.724	1.914	3.638	1.173
99-2000	2.487	1.986	4.473	1.587
2000-01	4.088	2.045	6.133	0.853
2001-02	4.778	2.205	6.983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

* indicates the Ministry's provisional figures
Source: MoP&NG, 2003a,c; also www.indialpg.com

3.1.1 In-country refining capacity

India's total refining capacity for *all* petroleum products (as on 1.4.2002) was 116.07 million metric tonnes per annum (mmtpa) (MoP&NG, 2003a). As shown in Figure 6, there are currently 18 refineries in operation in the country (16 in Public Sector, one in joint sector, and one in private sector). Of the 16 Public Sector refineries, seven are owned by Indian Oil Corporation Limited (IOCL), two by Chennai Petroleum Corporation Limited (a subsidiary of IOCL), two by Hindustan Petroleum Corporation Limited (HPCL) and one each by Bharat Petroleum Corporation Limited (BPCL), Kochi Refineries Limited (KRL) (a subsidiary of BPCL), Bongaigaon Refinery & Petrochemicals Limited (BRPL) (a subsidiary of IOCL), Numaligarh Refineries Limited (NRL) (a subsidiary of BPCL) and Oil and Natural Gas Corporation Limited (ONGC). There is one refinery Mangalore Refinery & Petrochemicals Limited (MRPL) in the joint sector, (operated by HPCL), and one refinery in the private sector, at Jamnagar (in the western state of Gujarat) belonging to Reliance Petroleum Limited (RPL).

Figure 6: Petroleum refineries in India



Indian Oil Corporation Limited (IOCL) owns and operates seven refineries in the country -- at Digboi, Guwahati, Barauni, (all the north east), Haldia (in the east), Mathura and Panipat (in the north), and Gujarat (in the west) with a combined installed capacity of 38.15 mmtpa; these achieved a total crude throughput of 33.76 mmt (million metric tonnes) during 2001-2002. In addition, its two subsidiaries, Chennai Petroleum Corporation Ltd. (with two refineries in south India) and Bongaigaon Refinery and Petrochemicals Ltd. (with one refinery in the north east), add another 9.35 mmtpa to its refining capacity.

The two refineries of the Hindustan Petroleum Corporation Limited (HPCL) -- one on the west coast (in Mumbai) with a capacity of 5.5 mmtpa and the other on the east coast (Visakhapatnam) with the capacity of 7.5 mmtpa -- produce a wide variety of petroleum products. During the year 2001-02, these achieved a combined crude throughput of 12.33 mmt. The Corporation also operates Mangalore Refinery & Petrochemicals Limited, with a capacity of 9 mmtpa.

During the year 2001-02, the Bharat Petroleum Corporation Limited (BPCL) refinery at Mumbai achieved a throughput of 8.77 mmt; the throughput achieved between April and December 2002 was 6.50 mmt.

Further, to keep pace with increasing consumption, 5 major refinery projects are being implemented to add 40.5 mmtpa to refining capacity. Of these, the construction of a 9 mmtpa refinery at Paradeep (a port in the eastern state of Orissa) was commenced in May 2000 and that of another 9 mmtpa refinery at Bhatinda (Punjab, north India) in June 2000. The first cross-country LPG pipeline with a carrying capacity of 1.7 mmtpa and a total length of 1,270 km has also been commenced. However, the costs of even expansion of refinery capacity are high, with a recent addition of only 3 mmtpa estimated at Rs 23,603.8 million (US$ 524.5 million) (MoP&NG, 2002, Section 3.4.4).

Given projected increases in capacity at specified refineries, one can estimate the increase in LPG production through these refineries, because each refinery has its own product slate/pattern depending on the configuration of its processing units and it is not technically feasible to change the product slate substantially. Table 12 gives the average refinery yields of Indian refineries. The LPG yield from Indian refineries is about 4.5% of the total distillates.

Table 12: Average refinery yields of Indian refineries (based on 2001-02 production)

Product	**Percentage *by weight* of crude oil processed**
LPG	4.5
Naphtha	8.6
Petrol	9.1
ATF/Kerosene	11.5
Diesel	37.5
Lubes	0.6
FO/LSHS	11.5
Bitumen	2.4
Others	6.8
Fuel & Loss	7.5
Total	**100.0**

Source: Petroleum Planning & Analysis Cell (PPAC), MoP&NG, 2003b

Apart from the production at oil refineries, LPG is extracted from natural gas (as was indicated in Table 11). This is currently the source of almost a half of the LPG produced in the country. LPG is now being extracted from natural gas at Duliajan and Lakwa in Assam (in the north-east), Bijaipur in Madhya Pradesh (central India), Hazira and Vaghodia in Gujarat, and Uran and Ussar in Maharashtra (all in the west), Pata in Uttar Pradesh (in the north) and Nagapattinam in Tamil Nadu (in the south). In addition, a new plant is being set up at Gandhar in Gujarat by the Gas Authority of India Limited (GAIL) and this will have the processing capacity of 0.207 mmtpa (MoP&NG, 2002).

Ideally, this study should project estimates of future supply of LPG from the various potential sources described so far. However, these estimates would be subject to several assumptions, as the plans of the main firms dealing with the supply of LPG (and other petroleum products) are not providing information on the basis of which such estimates could be drawn. This appears to be mainly due to the fact that structural changes in the sector are on the anvil, particularly dis-investment of governmental holding in these undertakings.

3.1.2 Imports

Import of crude oil was made duty-free with effect from 1st April 2001. Further, the Government decided in May 2001 to allow public sector oil companies to exercise the option to import their crude oil requirement directly, under the "actual user licensing policy" or through the largest Public Sector Undertaking (IOCL).

In order to improve oil security, the oil companies made efforts towards diversification of crude oil sourcing during 2002-03. IOCL had term contracts with the national oil companies of Saudi Arabia, Kuwait, Abu Dhabi, Malaysia, Libya & Nigeria. In addition, IOCL had a term contract with the national oil company of Iran for supply of crude oil to MRPL. The remaining requirement was procured through tenders. BPCL entered into term contracts with the national companies of Kuwait, Saudi Arabia, Malaysia and Abu Dhabi to import crude oil for its Mumbai refinery and KRL. Besides this, BPCL purchased crude oil of Yemen, Egypt and some West African countries, on tender basis. BPCL is also in the process of developing other sources of crude oil from countries like Angola and Libya. For its Mumbai and Visakhapatnam refineries, HPCL entered into term contracts during 2002-03 with the national oil companies of Saudi Arabia, Abu Dhabi and Libya.

Import bill

Imports of petroleum products (petroleum, oil and lubricants or POL, in export-import parlance) have constituted a significant proportion of the country's import bill over the years, contributing to the country's unfavourable balance of payments. As shown in Table 13, crude oil and petroleum product imports have accounted for over 40% of the value of imports, although this contribution has fallen to 15-20% of the total import bill. This "energy-debt nexus" has largely been ignored, with discussions on the debt crises focussing on terms of repayment rather than the role that prominent imports such as energy have played in accentuating the problem (C.R.Reddy, *et al*., 1992).

Table 13: 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 Table 7.2(A), Economic Survey: 1999-2000, (MoF, 2000)
POL = Petroleum, oil and lubricants

However, thus far, LPG has not contributed greatly to the total crude oil and petroleum product (POL) import bill. LPG accounted for between about 1.4% and 3.4% of the *net* POL bill over the last four years ('99 –'03)[23]. (During the last three years, India has been exporting petroleum products like naphtha, motor spirit, diesel and fuel oil, so that we are now net exporters of petroleum products as a whole; however, the increasing imports of crude oil contribute to the growing net import bill). Hence, it can be proposed that India import LPG to the extent of the deficit of requirement over indigenous production.

Further, for LPG, in particular, there can be price differences on the basis of the size of shipments that influence the landed costs; the larger the shipment, the lower the cost per unit. For example, in West African markets, the shipping cost of a 1,000 tonne shipment is at least 30% more on a per tonne basis than a 2,000 tonne shipment and at least three times the cost per tonne of a 12,000 tonne shipment (WB&WLPGA, 2001).

Ports

IOCL is a promoter of Petronet LNG Limited (PLL) along with the Oil and Natural Gas Commission (ONGC), Bharat Petroleum Corporation Limited (BPCL) and Gas Authority of India Limited (GAIL). PLL is putting up terminals at Dahej in Gujarat and Kochi in Kerala. The LPG import/export facility of the joint venture Indian Oil Petronas Pvt. Ltd. at Haldia has been commissioned and is terminalling LPG for public sector companies.

The existing infrastructure to receive imported crude oil and LPG are given in Table 14. Although adequate for crude oil, the infrastructure at Indian ports for LPG is inadequate to meet demand and is also not well dispersed. Over 75 per cent of indigenous LPG production comes from the sources located north of Goa, and half the LPG import infrastructure is also located in that region. Due to inadequate import facilities on the east coast, inland movement is required and the costs are substantial.

Table 14: Import facilities for petrol/diesel and LPG

(in mmtpa)

Port	**Crude oil**	**LPG**
Kandla	-	1.00
Vadinar/Sikka	48.60	0.10
Mumbai including JNPT	6.90	0.20
Ratnagiri	-	0.20
Goa	-	-
Mangalore	9.60	0.60*
Kochi	7.60	-

[23] The US$ was equivalent to about Rs 46 - 48, during the period.

Chennai	6.30	-
Tuticorin	0.80	0.20
Vizag	7.40	0.25
Paradeep	-	-
Haldia	9.10	0.60
Total	**96.30**	**3.15**

*Can receive 1mmtpa by special measures

Source: Petroleum Planning & Analysis Cell (PPAC), MoP&NG, 2003b

Efforts for increasing supply

To reduce the dependence on oil imports, the New Exploration Licensing Policy (NELP) has been drawn up. Through this policy, exploration blocks, both on land and offshore were awarded to bidders. A large gas discovery (named Annapurna) 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 this policy blocks for exploration and production in this category have also been awarded. In addition, the Oil and Natural Gas Commission (ONGC) has identified 15 major fields for implementing improved oil recovery plans.

3.1.3 Transport

LPG is moved from the point of production or import by pipelines, barges, and rail and road tankers, to terminals, where it is stored under pressure. From the terminals, it is transported as required to petrochemical plants, bulk depots or cylinder filling plants; large users are supplied in bulk, while residential and small commercial users receive pressurized cylinders through the distribution agents of petroleum companies.

Considering the geographical spread of the country, the infrastructure for movement of petroleum products is inadequate for handling the growing volume of petroleum products. Pipelines are limited. Due to non-availability of tank-wagons, oil movement is undertaken by road, which is not only hazardous and polluting but also involves 15 to 20 times the specific energy use as through pipelines and 5 times the energy use by rail[24]. In a country where oil is being imported, expenditure on movement of POL products by road thus has been an additional drain on foreign exchange. The actual losses due to road/rail transportation are also 3 to 5 times higher than through pipelines.

Rail:

The Railways have been an important means of transportation, but the limiting factor has been the availability of tank-wagons. Notwithstanding this fact, more than 40% of the petroleum product transport is by rail. The available details are listed in Table 15.

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[24] The average diesel used by trucks per tonne km of freight hauled in India has been 0.0341 litres, whereas by rail it has been 0.0069 litres (Plan. Com., GoI, 1991)

Table 15: Estimated movement of petroleum products through the Railways

Year	Freight hauled by rail (million tonnes)	Total (million tonnes)	Proportion (%)
1989-90	24.6	54.1	45.50
1990-91	25.1	55.0	45.60
1991-92	26.2	57.0	46.00
1992-93	26.5	59.0	44.90
1993-94	26.1	60.8	42.90
1994-95	28.6	65.4	43.70
1995-96	29.3	72.5	40.40

Source: MoP&NG, 2003a

The rail share of total petroleum product transport may, however, fall in the years to come due to withdrawal of budgetary support. To overcome the shortage of tank-wagons, especially for transportation of LPG, oil companies have been financing railways under the "Own your tank-wagon scheme". The Railways offer a rebate in freight with respect to products moved through tank-wagons owned by oil companies. Since the depreciation on tank-wagons is compensated for under the administered pricing mechanism (APM)[25], oil companies surrender the rebate so received to the Oil Coordination Committee (OCC).

Pipelines:

Internationally, transport of products by pipelines is preferred to other modes of transport for reasons of safety, operational convenience and environmental benefits. In most cases, pipeline transport is also cheaper than rail and road transport, but in India, only around 32% of petroleum product transport is through pipelines. However, it is estimated that the share of pipelines in product transportation may touch around 45% in a few years (MoP&NG, 2003a). The region-wise petroleum product pipeline capacities in the country are listed in Table 16.

Table 16: Indian petroleum product pipeline capacities (in mmtpa), as on 1st 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

[25] The APM is explained in Annexe 4.

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: Petroleum Planning & Analysis Cell (PPAC), MoP&NG, 2003b

To match the post Administered Pricing Mechanism (APM) scenario, the Ministry of Petroleum and Natural Gas (MoP&NG) has issued guidelines[26] for laying petroleum product pipelines. The new guidelines for grant of right of user (ROU) for petroleum products do not contemplate any restrictions or conditions for grant of ROU for crude oil. Product pipelines have been categorised as follows:

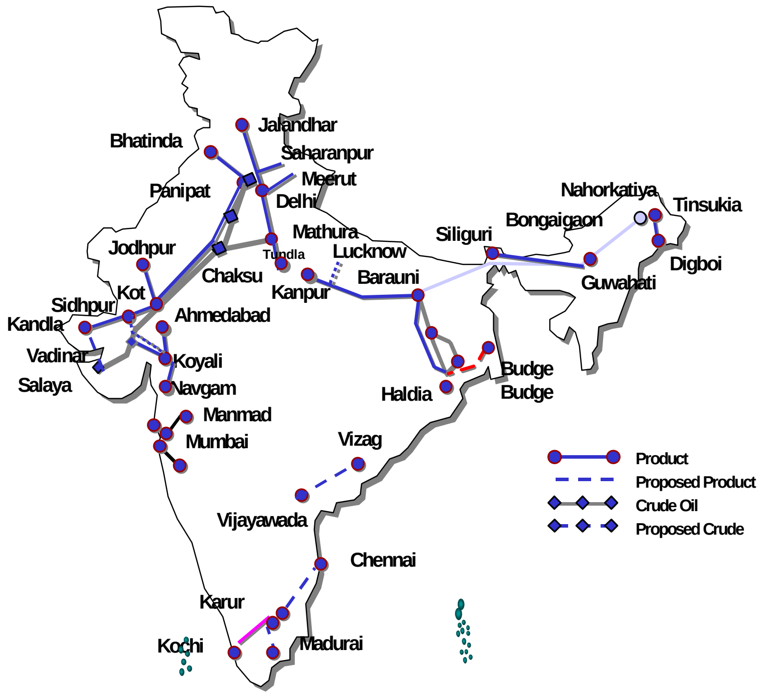
(i) Pipelines originating from refineries, whether coastal or inland, till a distance of 300 kilometres from the refinery,
(ii) pipelines dedicated to supplying product to particular consumer, originating either from a refinery or from the oil company's terminal, and
(iii) pipelines originating from ports and pipelines originating from refineries exceeding 300 km in length, other than those specified in (i) & (ii) above.
As per the guidelines, companies and investors will have complete freedom in respect of the pipelines originating from refineries or meant for captive use of companies for which ROU will be unconditional.
However, for pipelines exceeding 300 km in length and those originating from a port location, grant of ROU will be subject to fulfilment of certain conditions[27].

Figure 7 indicates the location of crude oil and product pipelines in India. Indian Oil Corporation Limited (IOCL) has the country's largest network, with a combined length of 6,523 kms and a capacity of 43.45 mmtpa. IOCL's pipelines carried 40.36 mmt during 2001-2002. Petronet India Limited (PIL) a private

[26] Vide notification F.No. P-20012/5/99-PP dated 20.11.2002
[27] Some of these conditions are:
- Oil companies/investors interested in laying a product pipeline originating from a refinery or a port would be required to publish the proposal inviting other interested companies to take capacity in the pipeline.
- Any oil company interested in sharing the capacity of the pipeline, will be able to do so on mutually agreed commercial terms and conditions. The proposer would then provide capacity for such interested party also.
- The proposer company applying for the grant of ROU in land would need to provide at least 25% extra capacity for others.
- The pipeline will be owned and operated by the proposer company.
- The pipeline tariff will be subject to the control orders or the regulations that may be issued by the Government under the appropriate law in force.

company, has so far implemented the Vadinar - Kandla pipeline and the Kochi - Kurur pipeline projects. The Mangalore – Bangalore pipeline project (in the state of Karnataka) is at an advanced stage of implementation.

Figure 7: Petroleum and product pipelines in India



The new pipelines projects yet to be fully commissioned, or still under construction, are:

- Kandla port (Jamnagar in western India) and indigenous production units in Jamnagar, to Loni (in Uttar Pradesh in northern India), 1,246 km long and likely to convey 2.5 mmtpa,
- Mumbai - Manmad pipeline, by Bharat Petroleum Corporation Ltd. (BPCL), covering 270 km with an initial capacity of 3.30 mmtpa,
- Vizag - Vijayawada pipeline, by Hindustan Petroleum Corporation Ltd. (HPCL), covering 380 km, with an initial capacity of 4.00 mmtpa, expected to be commissioned by mid–1999.

However, the investment required may have hindered pipeline expansion, for example, Gas Authority of India Limited (GAIL)'s 1,246 km LPG pipeline from Kandla to Loni is estimated to cost Rs 12.295 billion (US$ 273 million), including a foreign exchange component of Rs 3.867 billion. Acknowledging the importance of creation of a pipeline grid, the Ministry of Petroleum & Natural Gas (MoP&NG) of the Government of India has recently approved the setting up of an apex holding company[28] which will co-promote specific pipeline joint venture companies (JVCs) to implement discrete sections of the grid.

***Port traffic*:**

Currently, limited product movements take place between port locations. Oil companies, at the direction of the Oil Coordination Committee (OCC), have taken on charter-hire 27 tankers from shipping companies with an aggregate tonnage of 0.638mn (MoP&NG, 2003a). In addition, the direct import of products is also handled at port locations.

Road:

Nearly 30% of the total transport of petroleum products is by road. Unless urgent measures are taken to improve the pipeline and rail infrastructure, road will continue to be one of the key modes of transport.

3.1.4 Storage and distribution infrastructure

For storage and distribution, one has to consider installations, depots, bottling and tankage capacity. Installations are large storage points attached to refineries or to ports, serving as supply sources to locations in the region, while depots are small storage and distribution centres that generally cater to the needs of a city or town. At present, oil companies have installations in almost all major cities and port locations and depots at all district headquarters.

Tankage

India usually has total storage capacity of about 16 days' supply of LPG, as shown in Table 17. Details on tankage of the industry are available for 1995 when the total tankage (all products') capacity stood at 10.75 mmt.

Table 17: Fuel storage capacity (effective tankage) in the country

(in number of days requirement)

Product name	**Marketing terminals/ tankage**	**Refinery tankage**	**Total tankage**
Petrol	47	17	64
Diesel	36	12	48
LPG[a]	10	6	16

[a] Total storage for domestic and auto-fuel LPG

Source: Petroleum Planning & Analysis Cell (PPAC), MoP&NG, 2003b

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[28] The holding company will be a non-governmental company in which the main public sector companies IOCL, BPCL, and HPCL will hold 16% each and IBP will hold 2%. The remaining 50% will be offered to private sector oil companies and financial institutions. The holding company shall subscribe to 26% of equity in each of the JVCs, 48% shall be offered to the public and the remaining 26% shall be subscribed to by oil PSUs, financial institutions and private sector oil companies.

The Ministry of Petroleum and Natural Gas (MoP&NG) intends construction of an additional 530,000 tonnes capacity. For example, HPCL has construction in progress for additional product tankage and allied facilities at Pedapalli, Hassan and Irumpanam, in southern India.

A 60,000 tonne LPG cavern-storage project has just been initiated in Vishakapatnam (in the state of Andhra Pradesh). A joint venture between HPCL and the French company Total SA, it is being described as the safest method of storing hydrocarbons (Business Line, 2004b). It will also help feed the southeastern part of the country.

Containers

To meet the growing demand for LPG, the country is looking at quicker ways of distributing imports. LPG is usually imported in large tankers and unloaded into onshore storage tanks at ports. However, as India has only a few ports large enough to berth modern LPG tankers, there remains the problem of conveying LPG from theses few ports to the bottling plants at various locations.

Hence, the Ministry is considering the following option: Large tankers or "mother" vessels will bring around 30,000 tonnes to the high seas and unload their cargo into containers on smaller ships or "daughter" vessels of 14,000 tonnes each (*Petrowatch*, 2003). These smaller vessels will then berth at ports that are too small for the main carriers. The containers would then be unloaded and stored at parking yards till they can be moved to bottling plants on especially designed trucks.

Southern and eastern India – with an LPG deficit and therefore dependent on imports – will benefit the most. Thus far, only Haldia (in West Bengal in eastern India) and Vishakapatnam (in Andhra Pradesh, south-eastern India) have facilities to berth regular LPG tankers, and these cannot economically supply the southern peninsula region. Through this proposed container option, the expensive option of constructing a large port along the southern part of the peninsula 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. The risk will also be lower as transfer from mother to daughter vessels will take place further from the shore.

LPG bottling plants

Four types of cylinders/bottles are currently being marketed by the Public Sector Oil Companies – Indian Oil Company (IOCL), Hindustan Petroleum Company (HPCL) and Bharat Petroleum Company (BPCL): the 14.2 kilograms (kg), 19 kg, 47.5 kg and recently, 5 kg, each[29]. While the 19 and 47.5 kg cylinders

[29] Each LPG cylinder marketed by the public and the private sectors is supposed to carry its complete details including serial number, tare and gross weight, water capacity, ISI approval monogram, test dates, manufacturer's identification and year of manufacture. The cylinders have to be manufactured only by the approved manufacturers, under the supervision of BIS inspectors

are meant for industrial and commercial customers, domestic consumers are provided with the 14.2 kg cylinders and now 5 kg for low-income urban, as well as semi-urban and rural homes.

Special facilities are needed to pack LPG in cylinders and LPG bottling plants have been set up near the markets to facilitate the return of empty cylinders and re-fuelling. It may be noted that manual bottling and distribution in small carriers is cost-effective in developing countries, hence one can ignore the economies of scale in bulk handling and distribution. However, safety standards and reliability 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) per tonne per annum (tpa) capacity, with a plant of 70,000 tpa having been built at Rs 180 million (US$ 4 million) (MoP&NG, 2003, Section 3.7.2) and another of 138,000 tpa, at Rs 360 million (US$ 8 million) (MoP&NG, 2003, Section 4.2.2.1).

Regional distribution

Some regional distribution activities are worth noting.

The northern region:

GAIL has commenced work on a mega-project for laying a 1,264 km LPG pipeline with a capacity to carry 2.5 mmtpa; the pipeline would run from Jamnagar (in western India) to Loni (near Delhi) with receiving terminals to push LPG into the pipeline, pumping stations, and boosters and delivery terminals for supply to the marketing companies (Indiainfoline, 2002).

The western region:

There are arrangements between the organisations IOCL, HPCL and BPCL for sharing infrastructure like depots, terminals and bottling plants. For instance, HPCL is expanding its facilities at Loni so that BPCL does not have to invest in a new plant of its own there and BPCL is sharing its facilities at Manmad with HPCL.

The southern region:

Private players – Sri Shakthi, Caltex-SPIC and Mobil -- have a strong foothold in the distribution market in the region, possibly due to inadequate supply from the existing organisations. However, HPCL has a unique 60,000 million tonne underground cavern storage facility at Vishakapatnam.

The eastern region:

This has so far been a region of relatively low demand, so that distribution facilities are not increasing as in the other regions.

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and are painted with a signal red colour; those from BPCL have a yellow ring around the bung, those from HPCL a blue ring, and those from IOCL are fully red.

3.1.5 Marketing

In answer to demand, LPG marketing has historically been confined largely to urban and semi-urban areas. Until recently there have been long waiting lists for LPG "connections", in spite of the extensive network of sales points.

With the entry of private LPG distribution companies, the situation in urban areas has eased considerably. The Petroleum Ministry of the Central Government (MoP&NG) is also loosening its permissible marketing rules and has proposed that private refiners be allowed to sell directly to bulk consumers after meeting the demands of Public Sector companies that sell to domestic users (Business Line, 2004a).

Tables 18 and 19 indicate the most recently available number of LPG distributors and consumers served by Public and private companies, all over the country. In recent years there have been noticeable attempts by Public Sector companies to increase their supply to rural areas, but the tables do not distinguish between urban and rural areas.

Table 18: Current state-wise distributors as on 1.4.2003

States	Number of distributors
Andhra Pradesh	711
Arunachal Pradesh	28
Assam	212
Bihar	231
Chhatisgarh	94
Delhi	307
Goa	48
Gujarat	508
Haryana	256
Himachal Pradesh	97
Jammu & Kashmir	138
Jharkhand	106
Karnataka	455
Kerala	318
Madhya Pradesh	420
Maharashtra	908
Manipur	26
Meghalaya	30
Mizoram	23
Nagaland	22
Orissa	150
Punjab	400
Rajasthan	392
Sikkim	3
Tamil Nadu	510
Tripura	26
Uttar Pradesh	914
Uttaranchal	126

West Bengal	402
Union Territories	
Andaman & Nicobar	2
Chandigarh	30
Dadra & Nagar Haveli	1
Daman & Diu	2
Lakshadweep	2
Pondicherry	12
TOTAL	7,910

Table 19: Current state-wise consumers as on 1.4.2003

States	**Number of consumers (in thousands)**
Andhra Pradesh	7504
Arunachal Pradesh	88
Assam	1247
Bihar	1564
Chhatisgarh	623
Delhi	3443
Goa	325
Gujarat	4115
Haryana	2315
Himachal Pradesh	929
Jammu & Kashmir	995
Jharkhand	674
Karnataka	3688
Kerala	3514
Madhya Pradesh	2809
Maharashtra	9362
Manipur	163
Meghalaya	72
Mizoram	141
Nagaland	90
Orissa	934
Punjab	3299
Rajasthan	2779
Sikkim	69
Tamil Nadu	6592
Tripura	164
Uttar Pradesh	7077
Uttaranchal	1154
West Bengal	3547
Union Territories	
Andaman & Nicobar	32
Chandigarh	279
Dadra & Nagar Haveli	20
Daman & Diu	22
Lakshadweep	3

Pondicherry	173
TOTAL	69,805

Source: MoP&NG, 2003c

Public sector marketing network and schemes

IOCL has an extensive network of over 22,000 sales points backed for supplies by 182 bulk storage points, and 78 LPG bottling plants. During the year 2002, IOCL has launched compact 5 kg cylinders for the benefit of the people in rural and hilly areas.

During the year 2001-02, HPCL commissioned 178 retail outlets and 210 LPG distributorships and released 17.42 lakh new LPG connections. HPCL has also introduced 5 kg cylinders in the states of Punjab, Uttar Pradesh and Jammu & Kashmir, in the month of August '02. One LPG bottling plant of 44-mmtpa capacity at Kota, Rajasthan, and capacity augmentation of six existing plants (at Kondapally, Mysore, Palghat, Gummudipundi, Unnao, and Jamshedpur) by a total of 138 mmtpa, have been completed during 2002-'03 (till September '02). Construction work for the augmentation of an additional four LPG bottling plants by a total capacity of 142 mmtpa is in progress and scheduled to be completed during 2003.

HPCL now has a scheme called *rasoi ghar* (kitchen) for communal use of LPG stoves in villages. Individual households would not have to invest on stoves or pay a connection deposit, as with personal connections, but would have only to pay for the use of the fuel and the facility, on the basis of the duration of usage. In order to identify all the factors that can influence the effective operation of HPCL's *rasoi ghar* and to develop a viable model, a pilot project was taken up at village Agwan, Tal Palghar, in Thane district (Maharashtra state). Accordingly, the idea of a community kitchen was mooted to the *panchayat* of the village. The pilot project was commissioned on 17.8.2002. Till November 2002, 49 community kitchens had been established in various parts of the country.

During the year 2001-02, BPCL commissioned 140 new retail outlets, 17 kerosene dealerships and 313 new LPG distributorships, and released 15.68 lakh new LPG connections. In August 2002, BPCL has launched 5 kg cylinders at 33 selected rural markets in the State of Andhra Pradesh, Karnataka, Tamil Nadu, Punjab, Rajasthan, Maharashtra, Gujarat, Madhya Pradesh, & West Bengal.

BPCL's brand of LPG called *Bharatgas*, now has an online customer service B2C (Business to Consumer) initiative in order to provide a direct channel for Bharatgas customers to interact with BPCL. The online facility of booking Bharatgas cylinders is currently available in the cities of Kolkata, Chennai, Mumbai, Thane District, NCR Delhi (including Noida, Ghaziabad, Hapur, Meerut and Sardana) Hyderabad/Secunderabad, Bangalore, Pune, Jaipur, Alwar, Dausa, Bharatpur, Sikar, Lucknow and Nasik covering 5.2 million Bharatgas customers.

In order to reach far-flung rural customers, BPCL had introduced the Rural Mobile Vehicle (RMV), in 1999, in the state of Punjab. Encouraged by this novel method of reaching rural customers, BPCL has introduced 20 RMVs during the year 2002-03.

Costs of LPG

Estimates of costs (Indiainfoline, 2002) show an import price varying between Rs 15/kg and Rs 17/kg (including freight charges that also vary between Rs 1.50/kg and Rs 3.00/kg, depending on volumes) so that, with port and terminal charges, the cost would be Rs 21/kg to Rs 23/kg. The ex-refinery cost is estimated to be Rs 17.50/kg. The costs of bottling as well as transport costs and the distribution margin would have to be added to this.

If supply were to be extended into rural areas on a larger scale, there would have to be more distribution agencies/vendors. Brazil is said to have 26,000 such vendors serving 35 million households (Barnes and Halpern, 2000). In contrast, India has only about 12,000 distributors (WB&WLPGA, 2002), serving about 33.3 million -- 7.8 million in rural areas and 25.8 million in urban areas (Census of India, 2001). This is not intended to imply that the number of distributing agencies is the reason for inadequate rural penetration, but a successful distribution system would require many more rural-based market players.

In the context of increasing LPG infrastructure in the form of cylinder filling capacity, road tankers, storage tanks and cylinders, estimates of international costs are as follows:

Table 20: LPG Infrastructure Costs

Item	**Capacity**	**Cost**
Additional cylinder filling capacity at an existing facility	100 fills/day @ 12.5kg each	US$ 2,500 – US$ 3,500
Small LPG road tanker	6 – 7 tonnes	US$ 60,000 – US$ 70,000
Storage tank (at end-user site)	1 tonne	US$ 1,000 – US$ 2,000
LPG cylinder (e.g. for residential Consumers)	12.5 kg	US$ 15 – US$ 20
LPG cylinder (e.g. for smaller Residential consumers)	6 kg	US$ 10 – US$ 15

Source: WLPGA, 2002.

In view of estimates of meeting future storage and distribution requirements, more details regarding increases in bottling capacity, tankage, and so on, are required. These have not been obtained for the reasons already explained, but efforts will continue to be made to complete this aspect of the analysis.

3.2 Supply-demand balances

3.2.1 Regional balances

The possible problems of zone-/region-wise imbalances between supply and demand are being discussed below.

The northern region, consisting of the states of Jammu and Kashmir, Himachal Pradesh, Haryana, Punjab, Delhi, Chandigarh, Uttaranchal, Uttar Pradesh and Madhya Pradesh, consumes about 1.94 mmtpa or 33% of the country's total LPG use.

This has been a petroleum product deficit area (Indiainfoline, 2002). The Indian Oil Corporation (IOCL)'s Mathura and Panipat refineries together contribute about 0.5 mmtpa, and Gas Authority of India Limited (GAIL) supplies LPG from its gas fractioning plants at Auraiya (0.3 mmtpa) and Vijaypur (0.4 mmtpa), with the balance met from the western region (including imports). However, it is expected that the situation will be remedied in future through increased transport from the western region via a cross-country pipeline and also with the completion of new refineries. Hindustan Petroleum Corporation (HPCL) is setting up a 9 mmtpa refinery at Bhatinda, while Bharat Petroleum Corporation (BPCL) is due to construct a 7 mmtpa refinery at Bina and another 7 mmtpa refinery in Lucknow.

The western region, comprising Rajasthan, Gujarat, Maharashtra and Goa, uses about 1.77 mmtpa or 30% of the country's consumption. However, this region may have a surplus capacity with the commissioning of Reliance Petrochemical Limited (RPL)'s 27mmtpa refinery, apart from the existing refineries of the three main corporations, IOCL, HPCL and BPCL (Indiainfoline, 2002).

The southern region that includes Karnataka, Kerala, Andhra Pradesh and Tamil Nadu, consumes about 1.47 mmtpa (or 25% of the country's LPG use). The public sector companies HPCL, Cochin Refineries Limited (CRL), Madras Refineries Limited (MRL), and Mangalore Refineries and Petroleum Limited (MRPL) together supply about 0.8 mmtpa. This total will increase with MRPL's expanded capacity (6 mmtpa) and the proposed expansion of HPCL's Vishakapatnam refinery (by 3 mmtpa). The private Nagarjuna Oil Corporation has recently commissioned a 6 mmtpa refinery.

The eastern region comprises the states of Bihar, Jharkand, West Bengal, Orissa, Chattisgarh, Sikkim, Assam, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Tripura and Mizoram. It currently accounts for only about 0.67 mmtpa or 12% of the country's LPG consumption. This requirement is met mostly through the refineries of the IOCL, although the port facilities of Haldia (in West Bengal) are used for imports. At present, the geographical spread together with the low per capita incomes in most areas make it unattractive except in the few cities (chiefly Kolkata).

3.2.2 Sensitivity to demand scenarios

As indicated in several studies (some of which are quoted below), the current shortage of LPG supply vis-à-vis demand is likely to worsen. The estimated LPG shortage varies between 3.4 and 5.9 mmt by the year 2006-07 and increases to 7.6 mmt by 2010-11.

In addition, LPG is being increasingly used for auto fuel use (legalised since 24th April 2001)[30]. This will be a competing source of demand on the already insufficient supply, as indicated in the Ministry's Scenario 2, shown in Table 21(a).

Table 21(a): LPG demand-supply balance, with special reference to auto-fuels in India, projected till 2007

(in million tonnes)

Year	Demand		Supply	Surplus/(Deficit)	
	Scenario 1*	Scenario 2**		Scenario 1	Scenario 2
2002-03	8.42	8.42	7.60	(0.82)	(0.82)
2004-05	9.89	10.77	8.02	(1.87)	(2.75)
2006-07	11.48	13.40	8.10	(3.38)	(5.88)

* considers the current pattern of use of automobile fuels

** considers substitution of 10% petrol demand by LPG by 2004-05, and 20% by 2006-07

Source of data: MoP&NG, 2003b.

Table 21(b):LPG demand-supply balance in India projected till 2007

(in million tonnes)

Year	Demand	Supply	(Deficit)
2003-04	9.528	7.989	(1.539)
2004-05	10.310	8.823	(1.487)
2005-06	11.123	8.749	(2.374)
2006-07	11.966	8.635	(3.331)

Source of data: Business Line, 2003b.

Table 21(c): LPG demand-supply balance in India projected till 2010-11

(in million tonnes)

Year	Demand	Supply	Gap between demand and supply	Additional capacity	Import required
2006-07	10.2	4.7	5.5	2.1	3.4
2010-11	12.3	4.7	7.6	4.2	3.4

Source: Extract from Sundarajan Committee report on "Hydrocarbon Perspective-2010 AD"

The estimates in our study deal with only the domestic demand, but even the business-as-usual domestic requirement of 9.1 mmt and 10.8 mmt in the years 2010-11 and 2015-16, could exceed indigenous supply. Given that the domestic requirement accounted for only 58.5% in the base year 2001 and the use of LPG for fuelling cars and auto-rickshaws has been increasing rapidly, the total demand-supply gap would be even higher.

[30] LPG use for automobiles is not only legal, but even mandatory for use in some cases (e.g. auto-rickshaws in certain parts of the country).

3.2.3 Estimated increases in supply to meet projected requirements

The supply estimates listed thus far have not considered the recent results of new exploration and the proposals of increasing LPG production by both private and public sector organisations. If these proposals fructify, increased delivery to currently under-supplied areas could be possible.

The costs of new refinery capacity are high[31]. For instance, the total investment for the 27 million metric tonnes per annum (mmtpa) plant at Jamnagar, (in the state of Gujarat, in western India) was reported to be US$ 6 billion[32] (Rs 288 billion in 2002), and LPG constitutes a relatively small fraction of potential refinery output (as shown in Table 12).

Supply increases have to be derived from such enhanced refinery capacity, natural gas fractionators, or imports. In the last case, dependence on international markets may not be strategically wise as the necessity of importing petroleum products has makes the country vulnerable to increases in the international prices of crude oil and its products (and any fall in the value of the rupee vis-à-vis other currencies).

4. Challenges to effective provision of domestic LPG

The need for using cleaner fuels has already been established. However, numerous challenges are faced when considering the increased use of LPG; these range from ensuring adequate supply and accessibility, to increasing affordability, effective pricing policies, and reaching the people now dependent on un-priced biomass.

4.1 Ensuring adequate supply and accessibility

Adequacy of supply is obviously related to the magnitude of demand. But, in addition, ensuring the availability and accessibility all over the country requires not only adequate refining capacity and/or imports but also the development of adequate storage installations and transport systems, a reliable distribution system, and the avoidance of infrastructure bottlenecks. Storage and bottling facilities outside the urban centres of high demand have been limited by whatever the Public Sector Undertakings (PSUs) have been willing to invest.

Supply issues:

[31] These are not disclosed by oil companies for strategic reasons; only the costs of a few projects indicated in other contexts are mentioned in reports or news items.
[32] This plant of Reliance Petroleum Limited boasts the world's largest polypropylene complex (0.6 mmtpa), largest fluid catalytic cracking unit, delayed coking plant and paraxylene complex (1.4 mmtpa), and also estimates its cost at 30-40% lower on a per-tonne basis, than recent refineries built in Asia (RPL, 2000).

- ***Present supply shortage***: As indicated in Tables 21(a) to (c), LPG is in short supply even at the present requirement. Growing domestic consumption would lead to an ever-increasing imbalance.
- ***Competing demands***: There are likely to be further problems of supply if LPG is used increasingly for automobile fuelling – both because of four-wheelers (private vehicles and taxis) being converted and due to mandatory norms requiring the use of LPG, as in the case of three-wheelers (auto-rickshaws).
- ***Indigenous production:*** The costs of new production infrastructure -- refinery capacity and gas fractionation, and bottling units – are already high (as indicated in Section 3.1) and would be difficult to recover with the current price structure.
- ***Imports***: More importantly, the Asia Pacific region will have a sizeable deficit in the supply of LPG that would have to be met by importing from the middle-eastern countries, any interruption in the Arab Gulf region may lead to disruption in physical supplies and price risks.

Distribution/delivery issues:

- ***Infrastructure:*** The existing infrastructure at Indian ports for LPG is inadequate to meet present demand. Also, over 75 per cent of indigenous LPG production is from the western region, and half the LPG import infrastructure is also located there. Due to inadequate import facilities on the east coast, inland movement is required and the costs are substantial. Internationally, pipelines are the preferred mode of transport, but in India only around 32% of such transport is through pipelines. Due 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 the specific energy use as through pipelines and 5 times the energy use by rail.
- ***Consumer problems:*** Currently, vast (rural) areas of the country are located far from distribution centres, so that users have to pay for the extra costs of cylinder supply. 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, requiring a standby fuel also. (And, signing up for a second cylinder obviously increases the deposit cost, precluding lower income households from investing).
- ***Distributor problems:*** For LPG dealers considering rural markets, the small number of purchasers and low rate of consumption (and refills) lead to poor economies of scale, that, along with poor road infrastructure make it difficult to establish commercially viable distribution networks.
- ***Safety:*** LPG delivery (as in the case of other pressurised or gaseous fuels) involves cylinder management; this necessitates more careful transport than kerosene or firewood that in turn imposes additional requirements on prospective dealers.

4.2 Increasing affordability

A lack of awareness about the effects on health and the relative thermal efficiency of alternative fuels could hinder people from making the effort to obtain cleaner and more efficient fuels, even without financial hurdles. However, the problem of affordability affects the households' decision in several ways.

- ***Relatively high initial cost***: An LPG "connection" (deposit for the pressurised cylinder/canister) and stove constitute a large upfront cost (when compared with the equipment for other fuels), so that some who could afford the fuel cannot make the initial investment.
- ***Household perception of future saving***: Total annual cost = annual fuel expenses + annualised equipment costs. With the poor using higher discount rates, future savings (if any) would be less valuable than current expenditure.
- ***Larger minimum quantities of LPG*** usually[33] have to be bought at each refill (as compared to kerosene, charcoal and wood), undermining the use of LPG in low-income households.
- ***Repayment difficulties:*** Whereas micro-credit programmes and loans for productive purposes are repaid even by poor households, particularly by women (*Grameen Shakti* in Bangladesh, SEWA in India, Vietnam Women's Union), through the returns they obtain, it could be ***difficult to repay a loan for household convenience alone***. (Improved lighting systems contribute to longer hours and improved working conditions for household industries like tailoring and basket-making and service industries like TV repair shops, the profits from which can be used to service the loans; but improved cooking conditions may not warrant payment). People pay for some conveniences; beyond this level, there needs to be some productive outcome to justify the expenses.
- The ***kerosene->electricity shift for lighting is not replicable*** because the costs of the former are higher than for the improved (more efficacious lighting); here, LPG can be more expensive when the total (equipment + fuel) cost is added, unless consideration is given for reduced pollution and the resulting health effects.
- Currently, the ***poorest sections of the population*** who do not "pay" for fuel because they depend on whatever they can collect, cannot even consider it.

4.3 Pricing policies

Appropriate pricing policies also appear to constitute a challenge in India. Till April 1998, the Indian oil & gas industry had been under state control vide the Administered Pricing Mechanism. (Annexure 4 has more details). The production pattern, capital expenditure and pricing of petroleum products were all determined by the state. The deficit incurred on products priced lower than costs – LPG, kerosene and diesel – was compensated for by the higher-than cost prices of motor spirit (gasoline), aviation turbine fuel, naphtha, fuel oil, etc. These inflows and outflows were handled by the Oil Pool Account that was self-sufficient, so that no government support was necessary.

[33] New cylinders of 5 kg or less are not available in most places.

Liberalisation is supposed to have taken root in the petroleum sector with several policy changes: in 1987, private participation was allowed in joint venture refining, in 1993, parallel marketing was allowed for LPG and kerosene, to attract the private sector into distribution and thereby increase the availability of the products, in 1998, phased dismantling of the Administered Pricing Mechanism (APM) was initiated and in 2002, the APM was dismantled. When decontrol measures were initiated, retention pricing for refineries was abolished. But controls on the prices of 5 products (motor spirit, diesel, aviation turbine fuel, kerosene, and LPG) that contribute 70% of the volumes, were retained, while subsidies on LPG and kerosene were limited to 15% and 33% of import parity prices. (Tariffs on crude and petroleum products were reduced to 0-5% and 15% respectively).

The kerosene and LPG segments still enjoy subsidies; these subsidies were scheduled to be reduced substantially by the time of downstream petroleum sector deregulation in April 2002. However, what happened was that in the fiscal year (April to March) 2002-03, these subsidies that had previously been managed through cross-subsidies from other petroleum products using the Oil Pool Account, were for the first time made explicit in the national Budget. The Ministry of Finance allocated Rs 45 billion (approximately US$ 1 billion in December 2003) for LPG and kerosene; due to the rising international prices, the actual subsidy worked out to Rs 100 billion, of which the Government paid Rs 63 billion (Business Standard, 2003). With the retail prices fixed[34], and the costs higher than expected, there was a shortfall that had to be met by the four main state oil companies[35]. For example, based on the international price of US$ 230/tonne (April 2003), the cost of LPG is Rs 80/cylinder higher than the permitted retail price to the domestic sector, but the subsidy provides only 56% (Rs 45.17) of it (Gupta, 2003).

There appear to be several problems, particularly with the subsidy system:

- ***Heavy burden on the exchequer*** – The fuel subsidy imposes high opportunity costs. For example, the (central) government's total bill for subsidies to kerosene and LPG together for the year 2002-03 (Rs 63 billion) was similar to the Central Plan allocation for education (Rs 62 billion), of which only Rs 43 billion was set aside for primary education in that year! (The Tribune, 2003) And, the amount allocated for rural employment programmes was only Rs 4 billion (The Hindu, 2002).

- ***Subsidies for fuel reduce the incentive for efficient use*** – By lowering end-use prices, they reduce the users' incentive to conserve or use energy more efficiently, and if not reimbursed to producers, they reduce their incentive and ability to invest in new infrastructure/technology.

[34] Prices were raised on 16th June 2004, since this report was prepared.

[35] An additional problem has recently arisen. The Finance Ministry has proposed that private LPG distributors be given the same subsidy for domestic sales as the Public sector companies (Business Line, 2004a), but the retail price restriction for them has not been specified, which is likely to lead to further problems.

- ***Misuse of subsidies*** **–** Even though subsidies for refills are provided for domestic connections, domestic cylinders are often diverted to running vehicles. The average use calculated on the basis of the total quantity of LPG in some areas, divided by the number of domestic connections works out to over 200kg per connection per year; this is too high for cooking and indicates an obvious diversion to other uses.

- ***Subsidies to LPG users for fuel purchase not justifiable*** **–** The usual justification for subsidies (sunrise industry protection, increased employment, access for the poor, redistribution of income, etc.) cannot apply in general, but only to specific categories of consumers. (Perhaps one could justify subsidies for increased access to a "cleaner" fuel or avoidance of other inefficient/polluting fuel options?)

- ***Subsidies garnered chiefly by the urban rich*** - This is obvious from the residential descriptions of consumers and also from specific studies. It has been estimated that three-quarters of the LPG subsidy went to urban households in 1999-2000, four-fifths of whom were in the top half of the population, expenditure-wise[36]. For example, a study of a sample of homes in the city of Hyderabad indicated that 90% of the urban rich were utilising the subsidy meant for domestic LPG (UNDP&ESMAP, 2003). Even if lower-income households are able to benefit from LPG through subsidies, the relative financial value to them is relatively small as their consumption is generally modest.

4.4 Poverty issues

The requirements of those who survive on collected ("free") biomass do not appear to be addressed by providing LPG even at the present subsidised rates. In particular:

- ***Would improved cooking fuel options have any impact on poverty alleviation?*** There is not much empirical evidence to convincingly demonstrate the linkage between specific *energy strategies* and *poverty reduction* (as opposed to *merely widening access*); these are available in other sectors such as health (Cecelski, 2000). LPG and other modern fuels would be more efficient (in terms of heat delivered from input) and also more environmentally benign in comparison with traditional biomass-based stoves; they would also enable labour and time saving, freeing people for more productive pursuits, *if* these were available. However, without direct linkages to income-generation, there is no obvious affect on reducing poverty.

- ***Would improved cooking fuels benefit the poor less than the others?*** It has been observed in the past that rural electrification has benefited people

[36] In economic parlance, this is the problem of "inclusion".

with higher income rather than lower income[37]. The explanation seems straightforward as only those with sufficient resources for the initial investment in the connection and the energy-using equipment will be in a position to benefit from electricity or any energy supply (Jechoutek, 1992).

The same is likely to be observed with modern sources of fuel for cooking such as LPG, where the poorest households are unable to afford even the subsidised rates. Thus far, the "middle" and "upper" classes on the income ladder have benefited the most, and, on the energy ladder, kerosene is being replaced by LPG, but not "free" biomass. It seems unlikely that the poor would leapfrog the lower rungs of the ladder unless "free" biomass is no longer available, hence the drudgery of fuel collection and traditional stove tending for the poorest has not been reduced.

- ***Other cooking fuel options?*** For the poorest people who cannot afford (to purchase) LPG (or any other fuels), there obviously need to be options like more efficient biomass-based stoves, but appropriate strategies for this that are not being discussed in this report.

5. Experiences of LPG programmes

When considering the increased domestic use of LPG in India, lessons could be learnt from the way LPG use was enhanced in other developing countries and from regional programmes within India.

5.1 Experiences in other developing countries:

Brazil: In Brazil, although LPG distribution had begun with private entrepreneurship, the entire production and import system was taken over by Petrobrás, the state-owned national oil company in 1955. From 1975, LPG prices have been cross-subsidised by higher gasoline and diesel prices. In addition, the supply and distribution facilities were suitably enhanced. However, since liberalisation of the sector in the 1990s, several international oil companies have entered the market. Retail prices of LPG have been deregulated progressively since 1998, although the Federal Government has retained its control over the wholesale price at which Petrobrás sells LPG from its refineries, processing plants and import terminals.

Brazil has been successful in providing LPG to about 90%[38] 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 de-regulation 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

[37] These include Munasinghe, 1987; Cecelski, 1990; Jechoutek, 1992; Foley, 1990; Barnes, 1998.
[38] This was computed, as a proportion of the total 46 million households (WRI, 2002) in Brazil.

(WLPGA and UNDP, 2002). Another important reason for Brazilian success in replacing domestic fuel-wood use with LPG even in relatively remote areas is a very dependable system of distribution and replacement of cylinders (UNDP, *et al*., 2000, Chapter 10). However, as about 81% of Brazilian families reside in urban areas (IBGE, 2001), the distribution problems in largely rural countries would not be encountered.

Guatemala: In this Central American country, where the LPG market is completely liberalized, 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.

Indonesia: LPG for domestic use has been subsidised, but kerosene subsidies are even higher, which undermines the competitiveness of LPG (WB&WLPGA, 2002).

West African region: 60% of the LPG consumption in this region is concentrated in four countries -- Cameroon, Côte d'Ivoire, Ghana, and Senegal, where demand has grown significantly during the 1990s. (The use of LPG in the other countries of the region is considerably lower). Factors that have contributed to the increase in demand in the case of Senegal, where the highest growth has been recorded, include subsidised LPG to small cylinders[39] (of 6 kg each), helpful for low-income households, and also new participants in the market who have adopted aggressive marketing strategies (WB&WLPGA, 2002). In both Senegal and Côte d'Ivoire, price subsidies available to small cylinders have not been extended to larger bottles, emphasizing the assistance to lower income households (WLPGA & UNDP, 2002).

Vietnam: Market liberalisation including lifting of price controls in the early 1990s'[40] resulted in a number of private distributors entering the LPG market. Around 75% of sales are to the household sector.

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 demand, almost entirely for the household sector, has risen by about 40% (WB&WLPGA, 2002).

China: In the People's Republic of China, the shift up the energy ladder from biomass-based fuels to LPG was spurred on by the restrictions on the supply of kerosene (UNDP *et al*., 2000, Chapter 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&WLPGA, 2002).

Factors contributing to extension of LPG use:

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[39] Retail prices ranged (in 2000) from US$ 336/tonne to US$ 652/tonne.
[40] Price ceilings were reintroduced temporarily between June 1999 and March 2001 in response to a surge in import costs (WLPGA, 2002).

From the experiences summarised in this Section, the following factors appear to have helped extend the domestic use of LPG (including lower income households):

- *Lower prices of LPG* through *cross subsidies from other distillates*, (particularly gasoline),
- *favourable relative prices* of LPG (in relation to competing fuels like kerosene)
- *initial cost financing* (instalment payments for the purchase of stove and cylinder deposit),
- *smaller cylinders/bottles* to target (lower income) households through *lower periodic/incremental refuelling bills*
- *special subsidies to these smaller cylinders/bottles* – intended for lower income groups
- *restriction* on the supply of *competing fuels* (e.g. kerosene)
- *dependable distribution* (reliable and more storage, bottling and refuelling units)

5.2 Experiences of an LPG programme in India

An important scheme implemented for the expansion of domestic LPG use has been the *Deepam LPG scheme* in the state of Andhra Pradesh. This project was launched on the 9th July 1999 for the distribution of domestic connections to women of below the poverty line (BPL)[41] families in the rural areas of the state. Each connection was accompanied by a one-off subsidy to the extent of the initial cost, to overcome the barrier to fuel switching. It was meant to reduce dependence on firewood, reduce the drudgery of collection of/cooking on firewood, reduce pollution and improve the health of women. Salient features of this scheme are:

- The scheme was administered by the State government Departments of Rural Development and Civil Supplies and distributed through Public Sector Oil Companies (Bharat Petroleum and Hindustan Petroleum).
- The High Court directed that the scheme be confined only to “white-cardholders” (i.e. those below Rs 11,000/year/family).
- The Department of Rural Development identified the beneficiaries; a target of 1.154 million spread over 22 districts was indicated. Later, the numbers were increased so that by 2002 about 1.724 beneficiaries (including some of the urban poor) were listed.
- The lists were given to the LPG dealers of the oil companies, who were also expected to ensure training of the allottees in the use of LPG stoves.
- The Department of Civil Supplies provided a one-time deposit of Rs 1,000/connection towards the cylinder and regulator.
- Results in terms of the number of connections allotted: till March 2002, 88% of the urban target and 91% of the rural target had been met (NIRD, 2002).

Several lessons can be learnt from *Deepam*:

[41] The Poverty Line is defined in terms of the cost of a certain basket of goods, in particular, a specified level of calorie intake per capita in urban and rural areas in each state.

- The scheme *was not very efficacious*, because although all white-card holders participated, over 80% of non-white card-holders in the region also did[42]!
- 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 (including dowry to daughters), and being lent (!) to civil servants in local areas (NIRD, 2002).
- Factors affecting the refill rate were: distance from distribution points, and the season i.e., there is higher demand during the monsoons.
- *(Participants') perceived advantages of LPG were*: timesaving, social status, cleaner environment, and help during the monsoons. LPG was found useful chiefly during the rainy season because of more employment (implying more cash available for refuelling), more labour demand (and therefore less time for firewood collection) and moisture making collection and preservation of biomass difficult. (The scheme itself was considered attractive because of the initial fee waiver).
- However, the *perceived disadvantages were*: implementation bottlenecks, reduction in kerosene quota (in municipal areas), high refill costs (including illegal commissions) of refills, and unwanted envy of non-beneficiaries. *Implementation bottlenecks* within the scheme that contributed to dissatisfaction included: limited choice, inability of suppliers to supply stoves and accessories on time, co-ordination problems at the local level for the supply arrangements, and irregularities with beneficiaries also having to incur Rs 5 – 30 extra, per cylinder, for collection/delivery.
- Suggestions from local self help groups (SHGs) for improvement include: credit for refills and reduction in cylinder size (reducing cash outflow per refill although the cost/kg would increase).
- Most importantly, *the fuel use pattern of Deepam beneficiaries has not changed as much as intended*: Wood remains the dominant fuel (for the main meals), while LPG is used for additional cooking (tea, guests, etc.); crop residues the third most important source, and kerosene the fourth -- used for igniting the fire or in urban areas. LPG (average) use in these areas = 3kg/family/month and does not increase with the number of family members and/or wage earners.

(In addition, Annexe 5 has information on the National improved stove programme in India).

6. Issues for Indian domestic cooking fuels

In the context of the provision of appropriate cooking fuels, Indian decision makers would have to first consider the choice of fuels. If the use of LPG were to be encouraged, these would be issues concerning the provision/ delivery of LPG. For the longer term, alternative fuels would also have to be considered.

[42] Further, some "white-card holders" do not appear to be BPL, but that is a separate issue.

6.1 Choice of fuels

The advantages of LPG over the traditional biomass-based fuels are numerous – reduced pollution and thereby improved health, reduced/avoided deforestation and ecological damage, improved efficiency and reduced cooking time, and reduced fuel collection time and effort. However, factors like the beneficial (or reduction of harmful) effects on health are not being quantified or even included in the households' consideration (as it appears in the survey of households of the Deepam scheme). Hence, that it would need some intervention or public awareness drive to insert the "clean" fuel factor into the reckoning. Only obvious cause-effect sequences like polluted water causing illnesses push people to pay for alternatives (IEI, 2003).

Another phenomenon to be considered is that many households both in rural and in urban areas use multiple energy sources for cooking. In these cases, the social benefits of shifting to cleaner fuels in terms of improved health and time saving accrue only partially, to the extent of the shift. The effects in these cases have not been studied, but, in so far as a partial shift is a step towards a complete shift, efforts to promote such action would be justified.

If the goal is to address the difficulty of obtaining fuel in rural areas where biomass supply is getting scarce, then LPG promotion remains a worthwhile strategy; further, with reduced demand for biomass from those able to shift to another fuel, those still dependent on biomass for economic reasons, would be helped.

However, the 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 issues of urban air quality, etc, in Mexico, as well as Brazil, China, and India. As LPG infrastructure can be more quickly deployed and because LPG would be an improvement over wood and coal, opportunities for increased LPG use were perceived.

6.2 Providing LPG

In view of the problems faced in the country (in Section 4) and the experiences elsewhere (in Section 5), the following issues would have to be considered when drawing up policies for the provision/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 of supply, effective distribution/delivery, and regulation.

Demand issues

6.2.1 Pricing

6.2.1.1 LPG subsidies

When discussing the pricing of LPG in India, the most important issue is that of the prevailing subsidies. Market forces are being recommended in most sectors nowadays, but these affect affordability of LPG among lower income households. If subsidies could be justified for this purpose, policy makers need to consider several specific issues regarding the choice of subsidies and their funding.

- ***Choice of LPG subsidies***: Choices have to be made from among the many subsidy-options – either on the *initial costs* of connections/stoves, or on the *fuel*, and either *cross-subsidies* or *budgeted from the exchequer*. In particular, the following aspects should be considered:

    - ***Initial (first-cost) subsidies –*** *Subsidising initial costs seem preferable to fuel (or refill) subsidies* because the latter could encourage inefficient use or could be diverted to other uses/users. A one-off fee-waiver on the connection/stove makes sense when the barrier to adoption is the high initial cost. However, first-cost subsidies leave possibilities for dropouts from those who cannot afford the fuel costs, resulting in "dead" investments, as noted in the case of the *Deepam* scheme in the state of Andhra Pradesh.

    - ***Operating (fuel) subsidies –*** If LPG refill subsidy is to be continued, some precautions have to be taken:

        - There could be ***rationing/quotas*** (quantitative limits) for the subsidised fuel (as with ration cards) and/or coupons (as with food stamps).[43]
        - There could be ***differentiated containers*** (say, smaller cylinders, and/or cylinders painted another colour) for specific purposes (as with subsidised kerosene currently being coloured blue), to prevent use by those outside the scope of the planned benefits.
        - Subsidies could be ***use-based (as with baseline tariffs for electricity)*** with prices increasing with the level of consumption, rather than across-the-board reduction in price that results in "subsidy capture" (WEC, 2001) by wealthier sections of the population.

    - ***Cross subsidies from other distillates –*** This has been the Indian practice for many years, but would need to be weighed against the disadvantages of higher costs of transport.

- ***Evaluation of subsidies:*** Even when justified for social/environmental benefits, subsidies should be appropriate. Before introduction, subsidies should be evaluated in terms of *efficiency* (cost-benefit analysis of welfare gained versus the distorting effects and the costs of the subsidy), *efficacy* (*targeting* success in reaching those for whom it is intended, avoiding errors of inclusion of those who should not be benefited and exclusion of those who should), and *cost-effectiveness* (i.e. *administrative costs* should not be prohibitive) (WB, 2000).

[43] There could also be time-limits (sunset clauses) for such subsidies, but this may not be practicable as it is often politically infeasible to remove such benefits.

- ***Funding of subsidies:*** The source of funds for the subsidies would have to be one/more from among -
  - LPG companies themselves, through a mandate of the government, requiring the providers to sell below their costs, as in the present Indian situation, but this has to be temporary or else there could be financial disasters (as happened with the State Electricity Boards);
  - regulated cross-subsidies from one consumer category to another - effective as long as the funding category's price elasticity is not too high as to curtail sales;
  - progressive tariffs with the price per unit increasing with the amount consumed: the more affluent customers who use more, pay more, but this would need the upper segment to be large enough to support the lower segments and could be considered akin to cross-subsidies from higher income consumers to the others.

6.2.1.2 Pricing of competing fuels

When evaluating the pricing of LPG, ***one has to consider the relative prices of these fuels and whether or not inter-fuel shifts are desirable***.

- ***Subsidies to kerosene***: Reducing/removing the subsidy on kerosene could make LPG relatively cheaper, without a burden on the exchequer. Thus far, subsidies have been higher for kerosene than for LPG; in 1998 when the APM dismantling was initiated, LPG subsidy was about 32% while the kerosene subsidy was more than 50% (MoP&NG, 2003a). However, in the near term, or *as long as homes are not electrified, subsidy to kerosene has to merit consideration* because it is the source of lighting for about 43% of the population (according to the household data from the Census of India, 2001).

- ***Relative efficiencies:*** 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[44] (as was shown in Figure 1).

6.2.1.3 Direct cash benefits instead of subsidised fuel

There could be schemes through which LPG is priced at its full cost, but targeted households get some pre-determined compensation. This would avoid careless use of the fuel (and may also be an incentive for fuel efficiency), while assisting the economically disadvantaged. Such programmes would require funding from the government - with transfer payments directly to the poor, but the better the targeting, the higher the administrative costs, and experiences with BPL schemes have shown that those not entitled manage to get themselves included.

[44] With lighting improvement, payments for the improved source (electricity) are less than those for the earlier source (kerosene lamps) because of the much greater efficacy of electric lighting.

6.2.2 Marketing (financing and packaging) schemes

There are several marketing schemes 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 much ***smaller containers*** (e.g. 2 – 5 kg, instead of the regular 14.2 kg cylinders), will reduce the "lumpiness" of successive cash outlays. The latter option has been launched by the Public Sector companies but needs to be extended beyond limited areas.

6.2.3 Public awareness

Awareness of the adverse impacts on health of indoor pollution and the benefits of "cleaner" fuels would increase their popularity and thereby the willingness to pay.

Supply issues

6.2.4 Supply security

Supply security implies uninterrupted availability of LPG. Since various deficiencies exist in the present system, we require:

- adequate and well dispersed import facilities,
- well dispersed indigenous LPG processing plants (refineries and natural gas fractionating plants),
- storage capacities throughout the country, and
- multi-mode transport facilities for moving LPG from alternative destinations.

6.2.5 Dependable distribution network

The LPG distribution network also needs to be improved – or else bottlenecks hamper the delivery flow:

- Distributors face unfavourable economies of scale when the demand is low or dispersed. The problems of consumers whose location precludes them from enjoying the facility have to be addressed through extension of the distribution network beyond urban and semi-urban areas.
- There should be complementary infrastructure – roads, equipment suppliers, repair services, etc. – built in tandem, to facilitate the smooth operation of the system. This would be analogous to the rationale for improving rural infrastructure along with electrification.

6.2.6 Regulation

The government's roles in setting standards to maintain safety and avoid corruption are essential. In Brazil, the LPG industry and the government had to introduce a code of practice in 1996 to improve the quality of service and safety of the system particularly with respect to the standard of the cylinders.

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 (distributors) and poor enforcement of standards, accidents and commercial malpractice can occur.

Currently, the UNDP and the World LPG Association (WLPGA) have a partnership/initiative called the LPG Challenge to address concrete barriers to meeting the thermal energy needs of rural and peri-urban populations through the expanded use of LPG (UNDP, 2002)[45]. Additional factors identified through the project could be included.

The government has to be involved, at least through its policies, in helping to provide energy services to the economically disadvantaged. But there has also to be a suitable environment for the private sector to cater to those who can pay for their needs. Subsidies will continue to be necessary for a while, but have to be applied with care. Development assistance/grants – from aid agencies, etc. could help only small fractions of the population; which means that the government and market forces have to handle the rest and their extent and effectiveness have to be expanded to meet current and growing needs.

6.3 Non-conventional alternatives

It is important to reiterate that LPG is a fossil-based fuel and as such cannot be considered a sustainable source in the long term; it is being recommended as a part of the transition to renewable energy sources such as modern biomass-based fuels, till such times as these technologies become affordable, accessible, available and acceptable. Some of these biomass-based fuel options are listed below:

Biogas from animal waste: In areas where cattle are kept extensively (for example for dairying), biogas (CH_4 and CO_2, in the ratio 3:2) can be generated from cattle dung, if adequate amounts can be supplied daily to the digester. India's largest biogas plant has been running since April 1987 in the village of Methan (Sidhpur *tehsil*, Patan district, in the state of Gujarat); the plant, consisting of eight digesters, has a total capacity of 630 m^3, and caters to the main cooking fuel requirements of 320 families (Jamwal, 2003). However, the supply of dung by villagers to the plant has been found to be inadequate to meet the village cooking needs in many other villages; in fact, it has not been enough even for running a dual-fuel (biogas-diesel) generation plant for the electricity and water-pumping needs of the village (IEI, 2003). Family-size biogas plants are operating successfully and constitute a feasible option (wherever the cattle owned are adequate). About 3.482 million family-size biogas plants have been constructed in the country (MNES, 2003), of which an

[45] UNDP has initiated pilot projects in different regions. Specific targets will have two basic categories – affordability and availability. UNDP hopes to undertake this partnership in not less than 10 countries.

estimated 80% are operating successfully (AFPRO-CHF, 1997). The efficiency of biogas stoves has been found to be higher than other available alternatives (Smith, *et al*., 2000).

Other options:

Gasification: Where adequate crop residues are available from the crops cultivated in the area, crop-residue can be gasified to produce carbon monoxide and hydrogen, combustible gases that could be used for cooking or for power generation, (Mukunda *et al*., check, 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).

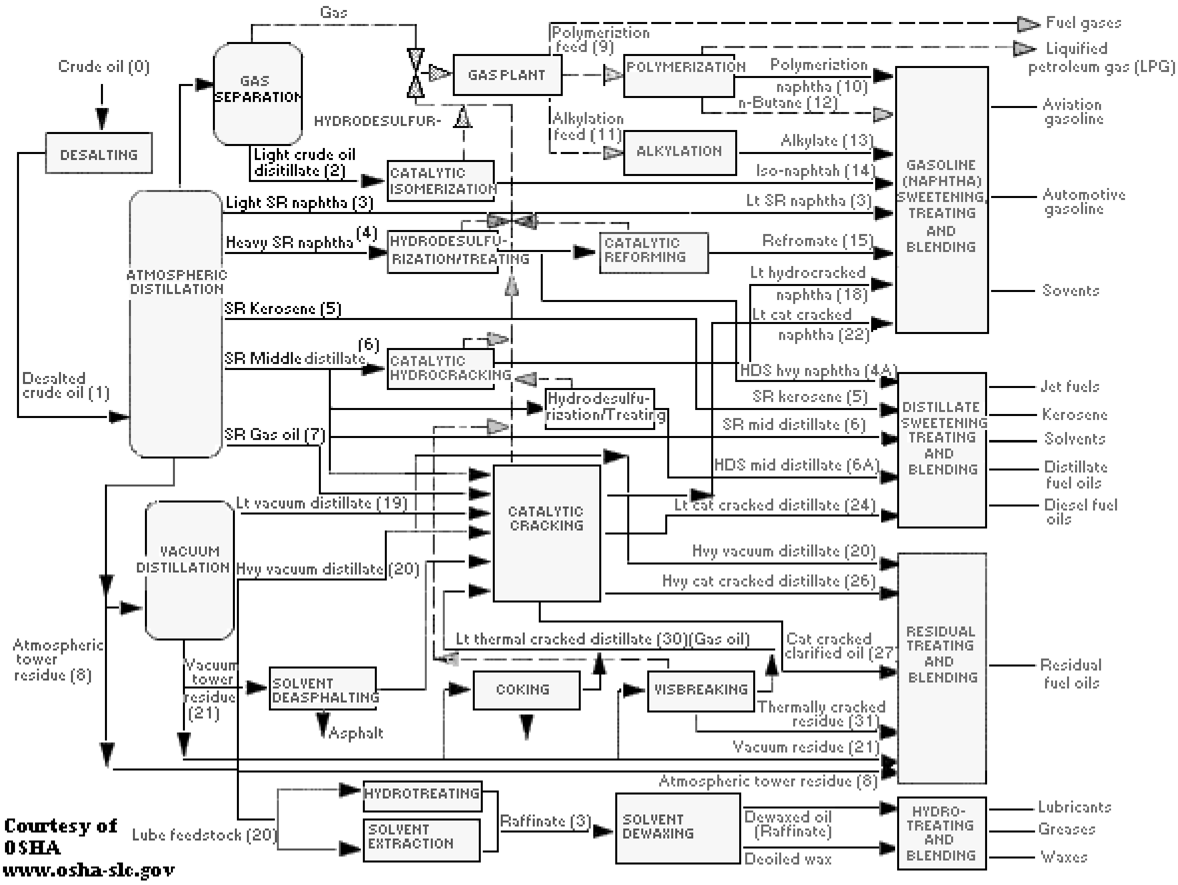
New options (not yet field-tested in India): The amount of household cooking fuel that could be produced from the biomass assigned for the purpose depends on the particular fuel considered and the conversion technologies employed; possibilities include ethanol, di-methyl ether (DME), and synthetic LPG, but these have yet to be tried in India.

In general, the country's strategies of fostering economic growth and employment opportunities need to be focused on and accelerated because they would bring in the collateral benefits of the use of better domestic fuels.

Annexe 1:
Technical details of LPG

LPG consists of hydrocarbons that are gaseous at normal atmospheric pressure, but can be condensed to the liquid state at normal temperature, by the application of moderate pressure. LPG is derived from two sources: from the processing of natural gas streams produced either alone or in association with crude oil, and from crude oil refining. Worldwide, natural gas processing currently accounts for roughly 60% of total marketed LPG supply and crude oil refining for the remaining 40% (WB&WLPGA, 2002).

Figure 8: Crude oil refining process



Distillation is the first step in the processing of crude oil and it takes place in a tall steel tower called a fractionation column. The inside of the column is divided at intervals by horizontal trays. The insulated column is kept very hot at the bottom, but as different hydrocarbons boil at different temperatures, the temperature gradually reduces towards the top, so that each tray is a little cooler than the one below.

The crude oil needs to be heated up before entering the fractionation column and this is done at first in a series of heat exchangers where heat is taken from other process streams that require cooling before being sent to rundown. Heat is also exchanged against condensing streams from the main column. Typically, the crude will be heated up in this way up to a temperature of 200 - 280 ^{0}C, before entering a furnace.

As the raw crude oil arriving contains quite a bit of water and salt, it is normally sent for salt removing first, in a piece of equipment called a desalter. Upstream from the desalter, the crude is mixed with a water stream, typically about 4 - 6% on feed. Intense mixing takes place over a mixing valve and (optionally) as static mixer. The desalter, a large liquid full vessel, uses an electric field to separate the crude from the water droplets. It operates best at 120 - 150 ^{0}C, hence it is conveniently placed somewhere in the middle of the preheat train.

A part of the salts contained in the crude oil, particularly magnesium chloride, are hydrolysable at temperatures above 120 ^{0}C. Upon hydrolysis, the chlorides get converted into hydrochloric acid, which will find its way to the distillation column's overhead where it will corrode the overhead condensers. A good performing desalter can remove about 90% of the salt in raw crude.

Downstream from the desalter, crude is further heated up with heat exchangers, and starts vaporising, which will increase the system pressure drop. At about 170 -200 ^{0}C, the crude will enter a 'pre-flashvessel', operating at about 2 - 5 bar, where the vapours are separated from the remaining liquid. Vapours are directly sent to the fractionation column, and by doing so, the hydraulic load on the remainder of the crude preheat train and furnace is reduced (smaller piping and pumps).

Just upstream the preflash vessel, a small caustic stream is mixed with the crude, in order to neutralise any hydrochloric acid formed by hydrolysis. The sodium chloride formed will leave the fractionation column via the bottom residue stream. The dosing rate of caustic is adjusted based on chloride measurements in the overhead vessel (typically 10 - 20 ppm).

At about 200 - 280 ^{0}C the crude enters the furnace where it is heated up further to about 330 -370 ^{0}C. The furnace outlet stream is sent directly to the fractionation column. Here, it is separated into a number of fractions, each having a particular boiling range.

At 350 ^{0}C, and about 1 bar, most of the fractions in the crude oil vaporise and rise up the column through perforations in the trays, losing heat as they rise. When each fraction reaches the tray where the temperature is just below its own boiling point, it condenses and changes back into liquid phase. A continuous liquid phase is flowing by gravity through 'downcomers' from tray to tray downwards. In this way, the different fractions are gradually separated from each other on the trays of the fractionation column. The heaviest fractions condense on the lower trays and the lighter fractions condense on the trays higher up in the column. At different elevations in the column, with special trays called draw-off trays, fractions can be drawn out on gravity through pipes, for further processing in the refinery.

At the top of the column, vapours leave through a pipe and are routed to an overhead condenser, typically cooled by air fin-fans. At the outlet of the overhead condensers, at temperature about 40 ^{0}C, a mixture of gas, and liquid naphtha exists, which is falling into an overhead accumulator. Gases are routed to a compressor for further recovery of LPG, while the liquids (gasoline) are pumped to a hydrotreater unit for sulphur removal.

A fractionation column needs a flow of condensing liquid downwards in order to provide a driving force for separation between light and heavy fractions. At the top of the column this liquid flow is provided by pumping a stream back from the overhead accumulator into the column. Unfortunately, a lot of the heat provided by the furnace to vaporise hydrocarbons is lost against ambient air in the overhead fin-fan coolers. A clever way of preventing this heat lost of condensing hydrocarbons is done via the circulating refluxes of the column. In a circulating reflux, a hot side draw-off from the column is pumped through a series of heat exchangers (against crude for instance), where the stream is cooled down. The cool stream is sent back into the column at a higher elevation, where it is been brought in contact with hotter rising vapours. This provides an internal condensing mechanism inside the column, in a similar way as the top reflux does which is sent back from the overhead accumulator. The main objective of a circulating reflux therefore is to recover heat from condensing vapours. A fractionating column will have several (typically three) of such refluxes, each providing sufficient liquid flow down the corresponding section of the column. An additional advantage of having circulating refluxes is that it will reduce the vapour load when going upwards in the column. This provided the opportunity to have a smaller column diameter for top sections of the tower. Such a reduction in diameter is called a 'swage'.

The lightest side draw-off from the fractionating column is a fraction called kerosene, boiling in the range 160 - 280 ^{0}C, which falls down through a pipe into a smaller column called 'side-stripper'. The purpose of the side stripper is to remove very light hydrocarbons by using steam injection or an external heater called 'reboiler'. The stripping steam rate, or reboiled duty is controlled such as to meet the flashpoint specification of the product. Similarly to the atmospheric column, the side stripper has fractionating trays for providing contact between vapour and liquid. The vapours produced from the top of the side stripper are routed back via pipe into the fractionating column.

The second and third (optional) side draw-offs from the main fractionating column are gas oil fractions, boiling in the range 200 - 400 ^{0}C, which are ultimately used for blending the final diesel product. Similar as with the kerosene product, the gas oil fractions (light and heavy gas oil) are first sent to a side stripper before being routed to further treating units.

At the bottom of the fractionation column a heavy, brown/black coloured fraction called residue is drawn off. In order to strip all light hydrocarbons from this fraction properly, the bottom section of the column is equipped with a set of stripping trays, which are operated by injecting some stripping steam (1 - 3% on bottom product) into the bottom of the column.

LPG produced from straight distillation consists of "saturated" hydrocarbons, i.e. propane and butane, whereas LPG produced by both cracking and reforming processes has, in addition to hydrocarbons, some quantities of unsaturated hydrocarbons also (i.e. propylene and butylene). There is also moisture and some impurities (such as sulphur compounds) that -are removed by suitable treatment at the refinery. LPG burns cleanly, producing no particulate matter, with low emissions of CO, unburned hydrocarbons and NO_x, and less CO_2 than most other fossil fuels and less than unsustainable biomass. The exact composition of LPG can vary but it usually consists predominantly of propane (C_3H_8) and butane (C_4H_{10}), with a small proportion of propylene (C_3H_6) and butylene (C_4H_8). Commercial LPG also contains traces of lighter hydrocarbons like ethane (C_2H_6) and ethylene (C_2H_4) and heavier hydrocarbons like pentane (C_5H_{12}). LPG marketed in India conforms to Indian Standard Specification IS-4576.

Table 22: Properties of LPG

	Propane	**Butane**
Chemical formula	C_3H_8	C_4H_{10}
Liquid Density	0.505	0.575
Gas Density	1.5	1.95
Ratio Gas/liquid	274	230
Atm. Boiling ptc.	-42	-2
Specific heat liquid	0.60 Btu/deg.	0.58 Btu/deg
Latent heat Vaporization	358 kj/kg.	372 kj/kg
Flammability limit	2.2 - 9.5%	1.8 - 8.5%
Auto temp ign	470ºC	410ºC
Mole Weight	44.10 kg/k/mole	58.12
Freezing Point	-187.7ºC	-138.4
Critical temp	96.7ºC	152.1ºC
Critical Press	42.5 bar	38.0 bar
Litres/tonne	1965-2019	1723-1760
Octane number	<100	92
Relative density of liquid	537-543	406-431
Maximum flame temperature	1980	1990
Ratio of gas volume to liquid volume	274	233
Soluble in water	Slight	Slight
Colour	Colourless	Colourless

Normally used as gas, LPG is stored and transported as liquid under pressure for convenience and ease of handling; liquid LPG evaporates to produce about 270 times its volume of gas. This facilitates storage and transportation in relatively small containers. In addition, unlike traditional fuels and other liquid fuels, LPG has an indefinite shelf life, not deteriorating over time. (Adapted from Cheresources, 2002)

LPG at about 45.5GJ/tonne, has a higher energy content than the fuels currently in use for cooking – kerosene (43.2 GJ/tonne), fuel-wood (about 15 GJ/tonne), crop residues (13 – 14 GJ/tonne) and dung (12.5 – 13 GJ/tonne). In addition, the higher efficiency of LPG stoves (about 65%) as compared with traditional stoves (about

15%) and even "improved" models of biomass-based stoves (up to 45%), makes the relative efficiency considerable.

Annexe 2:
Fuel Analysis

Solid fuels and kerosene were analysed for carbon, ash, sulphur, nitrogen and hydrogen content using standard methods (BIS 1987). For LPG, the energy content was given by Bharat Petroleum Company Ltd. (BPCL). The chemical composition, moisture content and net (low heating value) energy of the fuels are given in Table 23, using the method described below.

Table 23: Fuel chemical composition, moisture content, and net energy

Fuel	*Moisture content (%)*	*Net Energy (kJ/kg)*	**Carbon**	**Nitrogen**	**Ash**	**H_2**	**Sulfur**
LPG	-	45837	86.0				
Biogas	-	17707 (kJ/M^3)[1]	39.6			6.5	
Kerosene	-	43116	84.3	0.02	0.0	14.2	0.04
Eucalyptus	6.1	15333	45.4	0.14	0.4	6.4	0.02
Acacia	6.5	15099	41.8	0.35	2.89	6.3	0.01
Root fuel	5.7	15480	51.8	1.18	7.0	4.5	0.08
Charcoal	1.7	25715	80.0	0.69	7.4	1.8	0.06
Char-briquette	7.2	15928	50.3	0.25	40.0	3.2	0.05
Mustard straw	5.9	16531	42.1	0.36	2.7	6.3	0.01
Rice straw	8.8	13027	38.1	0.40	15.6	6.2	0.05
Dung cake	7.3	11763	33.4	0.90	52.2	3.9	0.07

[1] standard temperature and pressure

Basis of calculation:

Moisture content (wet basis): To determine the moisture content of any fuel it is necessary that it should be of small particle size. The wood was sawed to make sawdust in such a way that the whole area, including cell wall, was included. About five pieces of the fuel samples taken from different places were sawed and the sawdust obtained were mixed properly and used for moisture content measurement. These steps were all carried out in triplicate.

A known quantity of sample was taken in a crucible and kept in an oven maintained at 105 $_o$C till the weight stabilizes. The weight loss was measured and the moisture content of the sample was estimated as follows.

$$\% \text{ Moisture Content (M.C.)} = (W_1 - W_f)/ (W_1 - W_c) * 100$$

W_1 = initial weight of sample
W_f = final weight of sample
W_c = weight of crucible

Calorific value: Calorific value (energy content) of a fuel was determined by calorimetry.
Benzoic acid was used to standardize the bomb calorimeter. One gram of sample was taken in a crucible and made into a pallet and the initial weight was noted. It was placed in the bomb, which was pressurized to 18 atm of oxygen. The bomb was placed in a vessel containing a measured quantity of water. The ignition circuit was connected and the water temperature noted. After ignition the temperature rise was noted every minute till a constant temperature was recorded. The pressure was released and the length of unburned fuse wire was measured. The calorific value was calculated as:

$$((t_c \text{ x } w) - (m+n))/\text{weight of sample(g)} = \text{kj/kg} = H_w$$

t_c = temperature rise (C)
w = apparent heat capacity by benzoic acid (J)
m = calorific value of thread (J)
n = calorific value of Nichrome ignition wire (J)

The apparent heat capacity by benzoic acid (w), calorific value of thread (m), and the calorific value of Nichrome ignition wire were provided by the instrument supplier.

Annexe 3:
A comparison of the annualised costs of cook-stoves (in India)

	<-------------------- all at 12% discount rate				---------------------------->		
	wood/crop waste		**<-- kerosene ---->**		**<--------- LPG --------->**		**Elect.**
	trad.	**improved**	**PDS fuel**	**mket fuel**	**subsidised fuel**	**market fuel**	
STOVE PRICE (a) (Rs)	10	150	400	400	1800	1800	1500
USEFUL LIFE OF EACH STOVE (years)	3	3	5	5	15	15	10
DEPOSIT OR ONE-TIME PAYMENT (Rs)					750	750	
INTEREST (discount) RATES (%)	12	12	12	12	12	12	12
CAPITAL RECOVERY FACTOR	0.416	0.416	0.277	0.277	0.147	0.147	0.177
ANNUALISED CAPITAL COST (b) (Rs)	4.16	62.45	110.96	110.96	264.28	264.28	265.48
ENERGY CONTENT OF THE FUEL (MJ per kg, litre, or kWh)	15	15	35	35	45.5	45.5	3.6
EFFICIENCY OF STOVE (c)	15%	30%	45%	45%	60%	60%	71%
ANNUAL FUEL USAGE (litres/yr., kg/yr., kWh/yr.) (d)	1395	698	199	199	115	115	1223
PRICE OF FUEL (Rs/litre, Rs/kg, Rs/kWh) (e)	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 assumed nil (Rs)	0.00	0.00	25.00	25.00	75.00	75.00	0.00
=> TOTAL ANNUALISED COSTS PER STOVE (Rs)	1,399	760	2,329	3,425	2,469	3,519	3,935

Please note:
US$ = Rs 45 (November 2003)

(a) Stove prices refer to the market prices prevailing in Bangalore.
(b) Annualised cost = cost x capital recovery factor (CRF), where CRF = $i/\{(1+ 1/i)\}^n$; discount rate (i) here is assumed = 12%
(c) The efficiencies of stoves are from "Bioenergy: Direct Applications in Cooking" by G.S.Dutt and N.H.Ravindranath, (Table 10, p.676) in Renewable Energy, 1993 and from NCAER's "Energy Demand in Greater Bombay", 1975, quoted in TEDDY, 1996-97.
(d) 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:
$(\text{MJ/kg x efficiency x kg/year})_{LPG}$ / $(\text{MJ/kg x efficiency})_{other}$ = $(\text{kg/year})_{other}$
(e) Market-level fuel prices are also from Bangalore;
subsidised prices of kerosene through the PDS (public distribution system) through which specified amounts of fuel per household are provided, are limited to 24 litres per family per year for regular card holders and 120 litres per “green card” holder.

Annexe 4:
India's Administered Pricing Mechanism (APM) for the Petroleum Sector
(based on information from MoP&NG, 2003a)

Evolution of APM

Till 1939, there were no controls whatsoever on the pricing of petroleum products. Between 1939 and 1948, the oil companies themselves maintained pool accounts for major products without any intervention by the government. In 1948, an attempt was made to regulate prices through Valued Stock account procedure. Under this procedure, realisation of oil companies was restricted to the import parity price of finished goods (with Ras Tanura as the basing point), plus excise duties/ local taxes/ dealer margins and agreed marketing margins of each of the refineries. Any excess realization was surrendered to the Government. The Shantilal Shah committee, set up in 1969, did not favour the import parity price being set as a benchmark for domestic pricing as domestic refining capacity had significantly increased by then. In 1976, the Oil Pricing Committee (OPC) recommended the discontinuance of the import parity principle on the following grounds:

- About 90% of the total demand of POL products were met by indigenous production and no major shortfall was anticipated.
- Prices of finished products and crude oil did not necessarily move in tandem.
- Import parity did not take into account inter-refinery differences in terms of product pattern, type of crude used, location and scale of operation.
- The structure of West Asian product prices, which was the basis of determining prices in India, did not necessarily reflect the cost pattern and operations of Indian refineries.

The OPC therefore suggested that the domestic cost of production should be the determining factor for pricing of petroleum products.

The Administered Pricing Mechanism (APM) in existence until 1998, was evolved on the recommendation of the OPC and came into existence on December 16, 1977. The smooth implementation of APM was possible, as by then, all the foreign oil companies were acquired by the Government of India.

Rationale for APM

One of the important drawbacks of the import parity pricing was that the indigenous cost of production was totally overlooked while determining producer prices. This issue was addressed through Retention Pricing Mechanism, by which refiners were allowed to "retain" out of the sale proceeds,

- Cost of crude
- Refining cost and
- Reasonable return on investment.

The same mechanism was extended to marketing & distribution companies as well. The Government of India also fixed the pricing of finished products and the returns of oil companies were de-linked from the price at which the goods were finally sold. With the administration of pricing of products by the government, the retention mechanism also came to be known as the Administered Pricing Mechanism or APM.

The scheme was administered under the aegis of the Ministry of Petroleum & Natural Gas through its executive wing "Oil Co-ordination Committee" (OCC) with its secretariat at New Delhi.

Objectives of APM

- To optimise the utilisation of refining and marketing infrastructure by treating the facilities of all the oil companies as common industry infrastructure, the access of which would be available to all the oil companies by hospitality arrangements, thus eliminating wasteful duplication of investment.
- To make available all products at uniform price ex-all refineries so as to minimise cross-haulage of products & associated energy costs.
- To ensure continuous availability of products/ crude to refiners by recognising import needs wherever there are deficits in indigenous production.
- To ensure that the returns to oil companies are reasonable, in line with operational efficiencies as also generation of sufficient resources to enable industry to set up facilities to meet the growing needs.
- To ensure stable prices by insulating domestic market from the volatility of prices in the international market.
- To achieve socio-economic objectives of the Government by ensuring availability of certain products at subsidized rates for weaker sections of the society and priority sectors in the industry through cross-subsidization of products.

Functioning of APM

The basic principles on which the edifice of APM was built can be summarised thus:

- Raw materials were made available at a pre-determined fixed price at the manufacturing point (Delivered Cost of Crude) on a sustained & continuous basis to refiners. Similarly, finished products were made available to marketing companies at pre-determined prices (Ex-refinery prices).
- Refining/ conversion/ marketing costs were reimbursed as per certain pre-determined criteria.
- Compensation for investments in fixed assets and working capital was given as per laid down norms.
- Rewards and penalties were built into the system to encourage efficiency.

Retention price

The oil companies were reimbursed in addition to the cost of crude oil
- Operating costs
- Return on capital employed

The Oil Coordination Committee (OCC) undertook a cost updating study of each of the oil companies, once every Pricing Period of three years. The first year in the pricing period was called the base year. The exercise was normally undertaken in the middle of the pricing period and completed at the end of the pricing period. The costs incurred during the said period, including projections for the pricing cycle, were collated for each of the oil companies and ad-hoc margins were worked out first and thereafter replaced by final margins. It may be noted that not all costs were reimbursed and the expert committee of OCC moderated the actual costs. The margins for the pricing period were worked out by pro-rating the aggregate costs over the standard throughput/ sales volumes as per the sales plan entitlement (SPE) to arrive at operating cost per unit. The operating cost so arrived would be static during the pricing period excepting for permitted escalations which were considered for reimbursement on the merits of each case (e.g., increases in salaries/wages on account of long term settlements, increases in the direct variable costs such as chemicals, catalysts, utilities, etc.).

The companies were also eligible for a return on their total capital employed, consisting of average net fixed assets and normative working capital.

APM for refineries

Standards were laid down for each refinery with respect to throughput, product pattern, fuel and losses. The standard throughput was fixed after taking into account the crude availability, the primary/ secondary/ offsite facilities, intake capacity and other technical factors. For a new refinery, the standard was 60% of the installed capacity in the first year of operation and 90% in the second year of operation.

Based on the aggregate operating cost (OC) and return on capital employed (ROCE) standards so set, the OC and ROCE per unit of crude throughput was worked out for each of the refineries, for the relevant pricing period.

The Delivered Cost of Crude (DCC) for imported crude was worked out for each of the refineries, on the basis of pooled free-on-board (FOB) cost of crude, freight, insurance, ocean loss, wharfage/other landing charges and customs duty.

The difference between the landed cost of crude and the DCC could be claimed from the Pool account, subject to the following restrictions.

- Actual cost of insurance was limited to a maximum premia based on free particular average clause including war risk premia.
- Ocean loss for imported crude was taken as 0.5% of the bill of lading quantity, 0.2%/ 0.3% of Bombay High custody transfer quantity by West Coast / East Coast refineries. Variation in actual quantity of losses vis-à-vis the norms would benefit or adversely affect the refineries.

The retention price per tonne of crude for each of the refineries was thereafter worked out by cumulating the DCC, the operating cost (OC) and the ROCE.

While working out the operating cost, the following amounts were reduced as the same was recovered from the marketing companies separately in addition to the ex-refinery prices.

- Rs 50/tonne of LPG filled in bulk.

- Rs 200/tonne of LPG filled in packed cylinders.

The total amount of reduction was worked out by multiplying the aforementioned rates with the standards set for the pricing period.

The retention price per tonne of crude so computed was then pro-rated over various products, as laid down in the standard product pattern through a set of indices laid down by OCC. While calculating the retention prices of the products, the cost of fuel and loss was spread over all the products, based on indices developed after taking note of the current supply & demand position. These were the prevailing international prices of various petroleum products, need to encourage production of deficit products and conversely to discourage production of surplus products, and other factors affecting the distribution and allocation efficiency. The role of the indices was limited to determination of the product prices of refineries; this had little bearing on the final consumer prices.

APM for marketing and distribution – with reference to LPG

Marketing of petroleum products is done by oil companies through a network of storage and distribution facilities which include installations, depots, LPG bottling plants, airfield stations (AFS), retail pump outlets (RPOs) and sales offices spread across the country.

Operating costs till ex-storage level:

Under APM, the operating costs to be reimbursed up to the ex-storage level were broken up as:

- Installation cost
- Distribution cost
- Administration cost

The installation & distribution cost were disaggregated into common costs and specific costs.

Specific costs represented the cost of product losses incurred at the installation and distribution stage and were determined as per the given norms. For example, for LPG, distribution losses of 0.25% were permissible. Specific costs were computed by multiplying the aforementioned percentage to the sum of ex-refinery price and excise duty of each product. Specific costs were uniform for all the oil companies and therefore if a company was able to reduce its incidence of loss, it would gain. On the contrary, if its losses were more than the norm, it would lose.

All operating costs other than specific costs were categorized as common costs. Since the common costs were bound to be different from one company to another, the actual reimbursement would differ from one company to another. The allowable costs for the pricing period were collated and the total cost was pro-rated over volumes to arrive at a per kilolitre (kl) cost or per metric tonne (mt) cost.

In line with the procedure for the return on capital employed at the refinery stage, the return on capital employed up to the ex-storage stage was worked out. Capital employed to the extent of net worth would earn 12% post-tax return and balance if any would be treated as deemed borrowings on which the weighted average cost of borrowings would be given.

The marketing margin at the ex-storage point would thus include the installation, distribution (both specific & common), and administration costs and the return on capital employed and this would be the retention margin per selling unit. The weighted average marketing margin of all the oil companies was computed and included in the selling price, and the oil companies would adjust the differential between the retention margin and the marketing margin included in the selling price in the Pool account.

LPG filling, cylinder compensation & LPG pricing

Packed LPG is being marketed in cylinders of several sizes - 14.2 kg, 19 kg and 50 kg from the Public Sector Units (PSUs) and 12 kg and 17 kg from private sector distributors. While 14.2 kg cylinders are supplied for domestic consumers only, the others are for non-domestic consumers. The selling prices of LPG for domestic consumption are subsidised, but for other uses the selling price is determined on an import parity basis.

For each refinery, standard LPG filling norms were set. For all fillings up to the standard, each refinery would be entitled to a uniform filling margin of Rs 200 per mt for packed LPG and Rs 50/ mt for LPG sold in bulk. If LPG filling exceeded the standard, the refineries were eligible to retain Rs 50/ mt of incremental LPG packed and the balance amount of Rs 150/ mt was surrendered to Pool account. There is no penalty however for not filling up to the standard.

As stated earlier, the filling margin recovered on LPG was deducted from the refining cost while computing retention margins, and the amount so deducted was restricted to the standard. Thus the additional margin of Rs 50 per mt would accrue as an incentive for the refining companies.

In respect of bottling plants other than refineries, operating cost excluding depreciation was reimbursed uniformly on the basis of industry average cost. Depreciation cost and return on capital employed were computed for each of the refineries and the retention margin was worked out for each of the oil companies by aggregating the operating cost, depreciation cost and return on capital employed. The weighted average filling margin of refining & marketing companies was built into the selling price and the difference between the margin recovered through the selling price and the retention margin would be adjusted in the Pool account. With respect to sales effected out of the bottling done by refining companies, the difference between the margin recovered through the selling price and the margin paid to refining companies was surrendered to Pool a/c. Thus, marketing companies whose operating cost other than depreciation were below the industry average were bound to gain and those whose costs were above the industry average would lose.

In addition to the filling margin, marketing companies were entitled to a uniform marketing margin of Rs 640/ mt of LPG packed, recovered through selling price, to cover the following expenses:

- Depreciation on LPG cylinders/ regulators: Rs 252/ mt
- Return on Net investment in cylinder/ regulators: Rs 196/ mt (Net investment meaning actual procurement cost minus deposits received from consumers)
- Repairs & maintenance: Rs 192/ mt

The depreciation included in the marketing margin represented 1/15th of cylinder cost/ regulators, while 100% depreciation for cylinder/ regulator was charged off in the accounts. To compensate oil companies for this depreciation cost, companies were permitted to claim the differential between procurement cost, depreciation & return element included in the marketing margin from the pool a/c. Each new enrolment would bring in a deposit (of Rs 900, Rs 1,500 and Rs 2,000, for 14.2, 19 kg and 50 kg cylinder, respectively) and Rs 100 (per pressure regulator). Also, 100% of the cost of cylinders qualified for depreciation under the Income-Tax rules, hence actual cash inflow to the oil companies for every new enrolment was nearly 2.35 times the actual cash outflow. For example, for every Re 1 invested in a cylinder, Re 1 from the Pool a/c towards depreciation, approximately Re 1 from consumers in the form of deposits, and Re 0.35 being the tax saving on account of depreciation. Since the depreciation cost reimbursed was treated as an income, the net cash flow after reducing the impact on such income was twice that of the investment. In respect of replacements, as no deposit was received, the cash inflow was equal to the cash outflow. Thus the LPG business was the most lucrative among the APM products, both in terms of profit and cash generation.

To ensure uniform pricing, the commission payable to the distributors is determined by the Government of India. The formula for calculation of distributor's commission as on April 1, of every year is the same as applicable to other (petrol/diesel) dealers, except for the slabs and factors which were, for 14.2 kg domestic (pkd) cylinders:

- Slab I - till 3000 refills per month: factor = 0.31
- Slab II - beyond 3000 refills per month: factor = 0.33

No such bifurcation regarding slabs was made for 19 kg and 50 kg refills. Unlike the case of petrol and diesel, distributor commission is not revised with changes in administered prices.

For LPG supplied at centres other than refinery points, notional rail freight (NRF) applicable for bulk LPG was recovered through the selling price from the nearest refinery to the bottling plant located in the upcountry centre. The difference between the actual freight and NRF could be claimed by the oil companies from the Pool a/c. Even if the product were supplied from a point other than the contiguous refinery point, the difference in transportation charges could also be claimed from the Pool a/c.

Surcharges

In addition to claims/ surrenders that are self-balancing, oil companies were entitled to several other claims like crude oil price differential, imported product price differential, differential freight etc. The oil pool had to generate funds to meet these claims and the same was done through levy of surcharges such as Cost & Freight surcharge, Freight surcharge pool surcharge, Retail pump outlet surcharge and State surcharge.

Product price adjustment

In addition to these surcharges, the Government of India tried to achieve its objective of ensuring availability of certain products at subsidised rates for weaker sections of the society and priority sectors in the industry through cross-subsidisation of products. The cross subsidisation was done through product price adjustment (PPA) by which a higher PPA was recovered from products which were expected to bear the loading and a lower or a negative PPA was recovered from the price of products which were to be subsidised. Kerosene and LPG supplied to domestic consumers and naphtha, and fuel oil supplied to fertilizer units were subsidised through a lower / negative PPA. The bulk of this subsidy was borne by petrol (motor spirit), aviation turbine fuel (domestic airlines), LPG (other than domestic), and naphtha, and fuel oil supplied to industries other than fertilizer.

Standard LPG filling norms

For all refineries, the filling quantity was fixed. Any quantity filled in excess of standard would entitle the refineries for an additional amount of Rs 50/ mt that would be a straight addition to contribution margins. No penalty was applied for filling below the standard.

For all marketing bottling plants, the cost reimbursement was uniform based on industry average. Therefore companies whose operating cost was lower than the industry average were bound to gain and companies whose operating cost was higher were bound to lose, to the extent of differential cost. It may also be noted that as regards marketing plants, no standards were set and the actual contribution was a multiple of actual quantity filled and the per unit retention margins. Hence, there was a tremendous incentive for LPG filling at these plants. The additional contribution, earned by filling marketing bottling plants, was significantly higher than Rs 50/mt for additional filling in refinery bottling plants.

Summary of the APM

The Administered Price Mechanism (APM) was thus based on a retention or cost-plus formula, whereby oil companies were allowed to recover their operating costs and earn a post-tax return on net assets. The Central government's Oil Co-ordination Committee (OCC) controlled the prices of each product; it also computed an ex-refinery price applicable across the country. For each distributor, a margin was calculated, based on actual operating costs and a return on assets, this margin being added to the ex-refinery price to reach the gross selling price. The price would then be adjusted according to the subsidy set by the OCC, to arrive at the final selling price (including an excise duty set by the Government); the OCC adjusted prices and subsidies about once a year.

The Oil Industry Pool Account mechanism was used to subsidise and cross-subsidies certain oil products; financial inflows from collection of surcharges on the sale of some products were meant to offset the outflows for compensating for the shortfall in revenue on other products. The Pool Account was meant to be in balance over the long run without budgetary support from the Central Government. However, during the 1990s the Pool Account fell into deficit when adjustments failed to keep pace with changes in import prices; this led to shortfalls in disbursements to the oil companies.

Dismantling of the APM

While the APM ensured a degree of price stability, it failed to provide adequate incentive for companies to minimise their costs and use capital efficiently. In addition, Pool Account deficits undermined the public distributors' ability to invest in distribution infrastructure.

In 1998 the (Central) Government initiated a phased dismantling of the APM, to bring prices in India in line with international prices (but inclusive of duties); refinery-gate prices, including that if LPG, were set at the level if import prices. LPG subsidy was reduced from 68% to 33% at the beginning of 2001-02. In March 2002, the APM was dismantled, with all major products decontrolled and the Pool Account wound up. However, subsidies for kerosene and LPG will continue (while being reduced in a phased manner) at least till March 2005. The Government is financing this subsidy directly.

Current (2003-04) status of LPG subsidies

The Finance Ministry has provided (Public Sector Unit) oil firms a subsidy on LPG cylinders for domestic use, at Rs 67.75 per cylinder during 2002-03, and will provide Rs 45.17 per cylinder during 2003-04; the subsidy per cylinder is likely to drop to Rs 22.58 during 2004-05. This subsidy was not earlier available to private LPG marketing companies, but from the year 2003-04 is likely to be given to them too. However, there remains a difference between the cost and the retail price per cylinder, even after taking into account the subsidy. To counter this, the central Government has put together an intricate system of cross-subsidisation by which retailing firms and LPG producers share the under-recoveries in the case of Public Sector Units; thus far, this mechanism has not been made available to private companies.

Gas pricing

Till the 1970s', gas prices were based on the recommendations given by expert committees. In the early 1970s', gas prices were set on a negotiated basis, resulting in different gas prices for different consumer segments. In the mid 70s', the price of natural gas was determined by the producers themselves, based on the thermal equivalence of substitute fuels and the opportunity cost to the consumer.

In 1986, a decision was taken by the Government of India to fix uniform prices for natural gas on a year-to- year basis. This policy was followed till 1991. From January 1, 1992, the prices of natural gas were fixed for a period of four years. This pricing was based on the recommendation of the Kelkar Committee, set up by the Government to examine natural gas prices.

Post December 1995, the consumer price for non-North-East areas was fixed by the Government at Rs 1,850/tcm (exclusive of royalty @ 10 per cent and class tax varying from 0 to 19 per cent), for a calorific value of 9,000 kilocalories. The corresponding figure for North East India was Rs 1,000/tcm with a provision for further discounts. In January 1996, the Government appointed a Committee under the chairmanship of Mr T.L.Sankar to review the pricing of natural gas. Based on the recommendations of this Committee, Government fixed a price band of 2,150 Rs/tcm as the lower limit and 2,850 Rs/tcm as the ceiling for the consumer price. Producer Price actually payable to the producer (ONGC) was pre-determined at an amount lower than the consumer price so that the difference between the Consumer Price and Producer Price could be credited to a Gas Pool Account. This Account was established in order to encourage the development of the gas industry in India by partly compensating exploration and development companies for the low margins received in the development and sale of gas, at prices fixed by the government.

In addition to the price as fixed above, royalty, taxes, duties and other statutory levies on the production and sale of natural gas are payable by the consumers. The royalty on gas, as fixed under the Oilfields Development Act, is 10 per cent of the wellhead price. For privately operated fields, the royalty is fixed on the negotiated wellhead prices. There is no cess on natural gas (unlike crude oil) although a cess could be levied under the law. There is no excise duty on natural gas or on crude oil, as these are minerals, although excise duty is charged on petroleum products. A sales tax is leviable at state rates if the sale is within the state or at the central rate of 4 percent for inter-state sales. The sales tax rates vary from state to state ranging from zero to 22 per cent. It may be noted that Gas Authority of India Limited (GAIL) does not get a margin on merchant sales; it is allowed a return only on its investment in the pipeline. In order to encourage investment in the exploration of oil and gas, the Government has allowed contractors freedom to market oil and gas produced under New Exploraton Licencing Policy (NELP). Accordingly, oil and gas produced under NELP blocks are not covered under the Administered Gas Pricing Mechanism and the producers are free to market gas at the market-determined prices.

On July 23, 2003, a Group of Ministers, represented by producer and user Ministries, met and recommended that:

- natural gas prices be increased on an ad-hoc basis with immediate effect, as the prices have remained static since October 1999;

- a Tariff Committee be appointed to study the cost structure of ONGC and OIL, and suggest a reasonable price, within six months, for the period till complete deregulation of the gas prices is brought about;
- the price of gas be raised from 2,850 Rs/tcm to Rs 3,200/tcm, a rise of 12.28 per cent;
- the gas produced by the joint venture of Tapti and Panna-Mukta of about 8 MSCMD be sold by GAIL/producer at market-determined price; however, 1 MSCMD of gas from Ravva joint venture field in Krishna-Godavari basin could be taken by GAIL and adjustment for the higher cost made as per the existing arrangement;
- the Gas Pool Account be limited to Rs 1 billion per annum as per the actual requirement of compensation for concessional gas prices in the northeast region and other purposes;
- gas produced by ONGC and OIL from new gas fields be sold at a price determined in terms of NELP contracts, to provide a level-playing field between these oil sector PSUs and other players;
- the price of gas for northeastern region be pegged at 60 per cent of the revised price for general consumers;[46]

The gas transportation charges along the HBJ pipeline system were fixed at 1,150 Rs/tcm with effect from October 1, 1997 based on the recommendations of the Sankar Committee.

GAIL also uses natural gas internally, as a fuel for operating the compressors required to ensure desired pressure of gas in the HBJ pipeline system. There are a total of six compressors stations along the HBJ system of which two compressors were commissioned after October 1, 1997. Further, two compressor stations at Jhabua and Hazira were augmented after October 1, 1997. As a result, the total quantum of natural gas used internally as fuel by GAIL has increased. Simultaneously, the gas price has also increased from the level considered during HBJ tariff fixation by Sankar Committee. Therefore, the cost of transportation has been raised to 1,160 Rs/tcm. At the meeting of Committee of Secretaries (CoS) in May 2003, ministry of Petroleum and Natural Gas (MoP&NG) had suggested that the gas prices be increased from Rs 2,850/tcm to Rs 3850/tcm whereas the Ministry of Power and Department of Fertilisers indicated Rs 3250/tcm as their acceptable price for gas. On July 23, 2003, Group of Minister (GoM), represented by producer and user Ministries met and recommended an increase in natural gas prices of Rs 350/tcm. They have also suggested that the Gas Pool Account to be limited to Rs 1 billion per annum as per the actual requirement of compensation for concessional gas price in northeast region and other purposes. However, MoP&NG is yet to take a decision on these recommendations.

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[46] At present, the consumer price for general consumers is 2,850 Rs/tcm whereas for north-eastern consumers the corresponding price is 1,700 Rs/tcm which works out to be 60 percent of the general consumer prices. The difference between the producer price and the consumer price in the northeastern region may be reimbursed to OIL from the Gas Pool Account as is being done under the existing arrangement.

Annexe 5:
Lessons from India's improved stove programme

Lessons could also be learnt from India's national improved stove (*chulha*) programme.

In 1984-85, the Ministry of Non-Conventional Energy Sources (MNES) of the Union Government of India had initiated the national programme on improved *chulhas*[47] (NPIC) for the promotion of research and dissemination of improved chulhas among biomass-using households. Till April 2002, when this programme was disbanded, about 34 million improved chulhas had been installed in homes Mahapatra, 2003) in 23 States and 5 Union Territories of the country. The programme had two components: R&D and target fulfilment. While the R&D component was handled at the state level by independent government or academic bodies, the targets were to be met by agencies of the state government primarily as a welfare activity (Hanbar and Karve, 2002). The lessons that could be learnt from the programme and the assessments particularly by the National Council for Applied Economic Research (NCAER):

- Participation of the users is essential. Lack of perception of improvements resulted in few wanting the improved stoves. A study of 9,867 chulha owners (who acquired the stoves between 1996 and 2001) and 1,979 non-owners in 24 states, revealed that only 38.8% demanded them, while the rest had to be persuaded by implementing agencies.
- Target installation numbers can be distorted by corruption. (In some places stoves were shown to be working when they were never installed).
- Training cannot be ignored. The NCAER study reported an average of only 27.2% of households receiving training, with some regions having no training at all. There were better results where states took an interest.
- Maintenance after installation is also essential. Around 89% of users did not know whom to contact when repairs were needed and only 17% reported the availability of adequate hardware in nearby markets.
- Standards have to be maintained. The promised fuel efficiency was not experienced with 35% complaining that cooking time was longer. The NCAER report found that although women had been instrumental in taking the decision to install the new stove, their disillusionment adversely affected the continued use of the stoves; only 16.6% showed willingness to reinstall the chulha, if broken. However, when offered a new version with longer life, no smoke and less fuel, 87% were very keen.
- There are categories of users who have more than one stove; the chulha is used for cooking regular meals and a "superior" fuel – LPG or kerosene - for quick additions.

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[47] *Chulha* = stove

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