The potential for increased use of LPG for cooking in South Africa: A rural case study

ENERGY AND DEVELOPMENT RESEARCH CENTRE

June 2003
ENERGY & DEVELOPMENT RESEARCH CENTRE
University of Cape Town

Table of contents

Acknowledgements

Several members of the Energy and Development Research Centre (EDRC) and Energy Research Institute (ERI) at the University of Cape Town contributed in the preparation of this report. From EDRC, Bill Cowan wrote Sections 1–5. Randall Spalding-Fecher wrote Section 6. Harald Winkler was chiefly responsible for initiating this study, and commented on drafts. Jean-Marc Lukamba and Ogunlade Davidson prepared initial materials. Gamieda Gierdien collected price data for LPG sales and appliance costs in different areas of the country. Pierre Mukheibir was project manager and Tim James assisted with editing and DTP. From ERI, Philip Lloyd provided access to previous and current data, and his analyses, and contributed additions to the text.

Andrew Marquard (parliamentary researcher, and EDRC PhD student) provided valuable comments and information, particularly in relation to government policy developments.

Members of the LPGas Safety Association of Southern Africa generously provided information and insights, and commented on the draft report.

The work for this report was contracted by the Lawrence Berkeley National Laboratory (USA), as part of a project titled *Supporting Economic Development through Sustainable Energy Supply and Use.*

Abbreviations and acronyms used

BEST	basic electricity support tariff
DME	Department of Minerals and Energy (South Africa)
GHG	greenhouse gas
IBLC	in bond landed cost (an import parity formula)
IDP	integrated development plan
IP	illuminating paraffin
LPG	Liquefied petroleum gas
LPGSASA	LP Gas Safety Association of Southern Africa
NMHC	non-methane hydrocarbons
PASASA	Paraffin Safety Association of South Africa
PV	photovoltaic/s
SANEA	South African National Energy Association
SAPIA	South African Petroleum Industry Association
SEED	Sustainable Energy, Environment and Development
SHS	solar home system
VAT	value-added tax
WHO	World Health Organisation
WLPGA	World LP Gas Association

1. Introduction

1.1 Main aims of the case study

The purpose of this case study is to help explore the potential for increased use of LPG (liquefied petroleum gas) for cooking in South Africa. It examines the supply, distribution and pricing of LPG and LPG appliances in South Africa, with a particular attention to how these affect access to LPG in remoter rural communities. Supply-side constraints are identified, which presently make it more difficult for low-income households to make use of this versatile clean-burning fuel. Strategies for reducing these present supply-side constraints are suggested, taking account of local conditions and experience.

From the energy-users' perspective (again focusing on lower-income and mainly rural households, in this case study) the costs and benefits of using LPG are examined, relative to other energy options for cooking. Important factors included in this comparison are the comparative money costs, labour costs, health and safety risks, and the convenience associated with using various cooking fuels, such as biomass, paraffin, LPG or electricity. Factors affecting the "acceptability" and hence market demand for LPG, including perceptions that LPG is dangerous, will be discussed – with proposals for helping community groups and individual householders to make well-informed judgements.

Two assumptions in this case study, based on other studies over many years, are that

- people who are struggling to meet their basic needs (including energy for cooking) adopt versatile coping strategies, which are price-sensitive and which change according to the prices of the options they have;
- people who are short of resources to meet their immediate living needs (like energy for cooking, paying school fees, etc) are less able to take a "long view" in their expenditure choices, and tend to choose a survival strategy which allows them to meet immediate pressing needs, even if that is going to be more costly and inefficient for them in the long run.

The ways in which such factors can affect the use of LPG will be considered, together with possible ways to improve affordable access to LPG in these circumstances.

1.2 Rationale

The most widely used cooking fuels among low-income rural households in South Africa are biomass (wood, agricultural residues, dung) and illuminating paraffin (IP). Even in electrified areas, most cooking is done using such non-electric fuels. The hazards of using paraffin are significant, with more than 100 000 cases of paraffin poisoning and some 50 000 paraffin-related fires reported annually (Biggs & Greyling 2001). By comparison with paraffin, LPG is cleaner-burning, safer, easier to control and more efficient. The problems associated with the burning of biomass include high levels of exposure to particulates and other harmful emissions, which correlate with increased risk of illnesses such as acute respiratory infections; the labour, time and sometimes physical dangers of biomass collection; and in some areas, local environmental damage from deforestation. The use of both biomass and paraffin reflects "energy poverty" in poor rural areas of South Africa. If LPG were more widely accessible, and more affordable, this could reduce energy poverty by allowing more households to use this higher-quality cooking fuel.

The most significant environmental benefits of an increased use of LPG among rural households would be a reduction in the localised air pollution associated with smoky fires or stoves. In the early 1990s the World Bank estimated that indoor air pollution was responsible for nearly 50% of the disease resulting from poor household environments in developing countries. The 1992 World Development Report described it as one of the four most critical environmental problems, globally (quoted in WHO 1996). The 2002 World Health Report of the WHO describes indoor air pollution as having a risk factor of as high as 86% in developing Africa and the percentage disability-adjusted life years [DALYs] as totalling 56% for men and 87% for women (WHO 2002: Annex 7-8).

Depending on what fuel/s it replaces, an increased use of LPG could also help to reduce greenhouse gase (GHG) emissions. For example, the CO_2-equivalent emissions of the LPG fuel-cycle are less than a third of those for electricity generated from coal (World Bank/WLPGA, 2002: 26). This case study will include an evaluation of such potential effects, based on a particular rural community situation in the Eastern Cape province.

1.3 Selecting the locale for the case study

Situations in which LPG is used (or could be used) for cooking in South Africa are widespread but quite varied. There are different circumstances in urban and rural areas, and also variations among different rural areas and urban areas in the country. LPG prices and accessibility are quite variable in these different circumstances.

We have selected a rural area for the case study, because

- the barriers against using LPG in rural areas are higher (higher distribution costs, lower income-levels, etc);
- the incentives for switching to LPG use for cooking are higher in rural areas (less widespread access to electricity, greater advantages in using LPG versus other common cooking fuels like paraffin and biomass);
- there is therefore greater scope to achieve advantages of increased LPG use in rural areas, if the higher barriers can be reduced.

A representative rural area, chosen for this case study, is in the north-eastern section of one of South Africa's poorest provinces, Eastern Cape. Set within the Alfred Nzo district municipality, there are a number of rural villages between the small towns of Matatiele and Mt Fletcher. One group of villages (Magadla) will be a focus for attention, because of previous work done there, in collaboration with village-based community groups, helping people to identify their energy needs and possible solutions.

One of the solution paths adopted by residents was to form a local energy committee, and subsequently an energy and development co-operative which operates a small community-managed "energy centre". Among other functions, this energy centre acts as a more direct and accessible local distribution outlet for fuels like paraffin and LPG. This provides a practical opportunity to investigate the potential for increased use of LPG in this area, through improvements in distribution and other possible supportive measures.

2. The supply of LPG in South Africa

This section provides an overview of LPG supply in South Africa. It includes some comparisons with LPG supply in other countries.

2.1 Volumes

Reported inland consumption of LPG in South Africa is in the order of 600 Ml or 325 000 tonnes per annum.[1] LPG production volumes are larger than this, as it is used as a fuel at refineries, and about 10% of product is exported to neighbouring countries (LPGSASA 2002). The largest proportions of South African LPG are consumed in the industrial and commercial sectors. Based on 2000 figures, Lloyd (2001a) estimated that the industrial and commercial sectors accounted for approximately 75% of the total, while the residential sector only accounts for about 25% of sales volumes. The residential share of LPG use in South Africa is a much lower percentage than in other African countries, and other developing regions. For example, the average residential share of LPG consumption in African countries is about 90%, and in Latin America about 74% (World Bank/WLPGA 2002: 84), compared with South Africa's 24% (Lloyd 2001b). The lower residential sector proportion in South Africa reflects both a higher consumption in commerce and industry as well as the fact that LPG is not very widely used here as a household fuel.

[1] Inland LPG consumption volume for 2001, as reported by the South African Petroleum Industry Association, www.mbendi.co.za/sapia/rsacons.htm. LPG density of 0.541 kg/l taken from DME, 2001: 105.

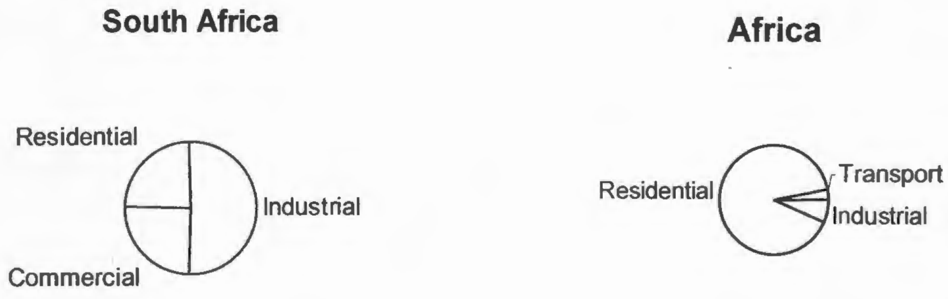


Figure 1: Approximate LPG consumption by sector, in South Africa and Africa as a whole
Source: for South Africa: Lloyd (2001b); for Africa: WLPGA/World Bank (2002: 84)

Higher-income households in South Africa predominantly use electricity for most of their domestic energy requirements. Lower-income households, whether electrified or not, typically use multiple household fuels, in combinations which depend on availability, prices, appliance ownership and other factors. The commonest liquid fuel for domestic use is IP. In terms of contained energy content, IP consumption amounts to about 30 PJ annually[2] (at around 800 million litres per annum[3]) while by comparison residential LPG consumption amounts to approximately 5 PJ annually. Hence household LPG use is almost an order of magnitude lower than residential[4] IP consumption.

Expressed as average residential LPG consumption *per capita*, South Africa can be compared with some other countries as follows:

Table 1: Per capita LPG consumption in the residential sector in selected countries
Sources: (a) WLPGA/World Bank (2002: 85); (b) Estimate based on residential consumption of 105 000 tonnes/year (LPGSASA 2002)

Country (source)	*Annual LPG consumption (kg per capita)*
Algeria *(a)*	47.8
Egypt *(a)*	36.2
India *(a)*	5.4
Kenya *(a)*	0.7
Senegal *(a)*	10.3
South Africa *(b)*	2.6
United States *(a)*	43.8

The relatively low residential use of LPG in South Africa is influenced by a number of factors which will be explored in this case study. One of these is the retail price of LPG, and LPG appliances, compared with other fuel-appliance options. This limits the affordability of LPG use for poor households. Nonetheless, the majority of residential LPG consumption is by households classified as "low income" (Lloyd 2001b) amounting to approximately 70% of total consumption within the residential sector. In recent years, it appears that the sales volumes of IP have been declining,[5] while total LPG sales volumes have been increasing at a modest rate. Figure 2 illustrates this trend, based

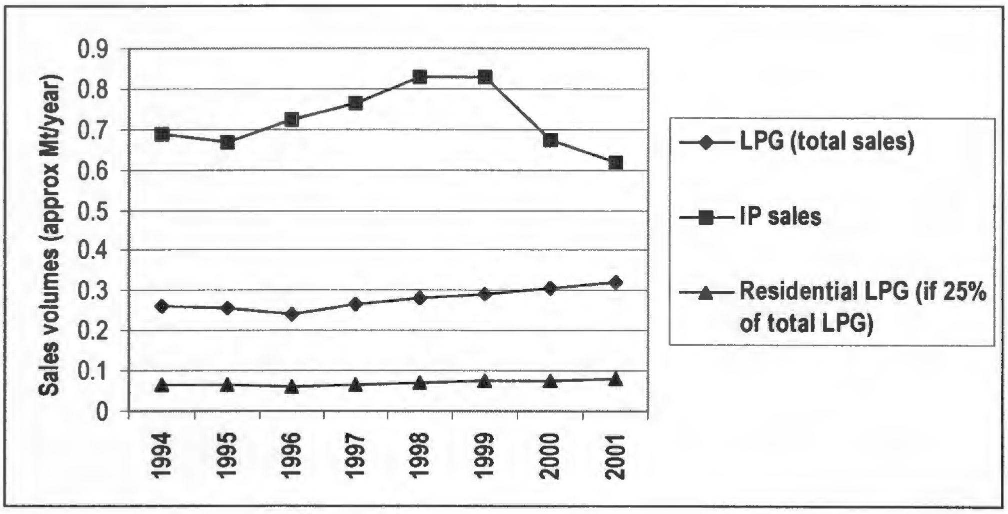
2 PJ, Petajoules: 10^{15} Joules.

3 Approximate annual paraffin sales in 2001-2 – see Figure 2.

4 It is assumed that reported IP sales are mainly to the residential sector. Total kerosene sales include jet fuel and power paraffin as well as IP. With the increase in international air traffic since South Africa's transition to democracy in 1994, the consumption of paraffin as jet fuel has risen rapidly, to a point where jet fuel kerosene consumption is approximately twice as much as the national consumption of paraffin.

5 A decision to remove VAT on paraffin led to the diversion of considerable quantities into the diesel pool, as a result of which in 2000 a dye was introduced to prevent the practice.

on published data from the South African Petroleum Industry Association, SAPIA (at www.mbendi.co.za/sapia/rsacons.htm).



Notes:

a) The estimated proportion for residential LPG sales (approximately 25% of the SAn LPG market) is based on 2001 estimations by Lloyd (2001). It is possible the residential proportion is variable over the time period shown.

b) SAPIA data in Ml per quarter have been converted and smoothed to Mt/year.

Figure 2: SAPIA trends for total sales volumes of LPG and IP, and estimated residential LPG sales

The decrease in the indicated sales volumes for IP since 1999 is quite dramatic. In part, this probably reflects an effect of South Africa's national electrification programme.[6] However, another factor may be price rises for IP. In rands, the government-quoted prices for paraffin increased by 160% between the beginning of 1999 and the end of 2001 (DME 2001: 26).[7] Given that IP is mainly used by low-income households, many of whom seek cheapest energy solutions, it is likely that these IP price rises caused poorer rural households to back-switch to using non-commercial fuels, where possible. It is less likely that the modest rise in LPG sales volumes and the rather sharp downturn in paraffin sales reflects inter-competition between these fuels, although this too could be a minor contributory factor.

Industry estimates are that the total market volume for LPG in South Africa is likely to remain fairly static between 2000 and 2005, but that there may be significant changes in sectoral shares, with industrial consumption expected to decrease and residential consumption to increase. Between 2005 and 2010, however, a growth of about 25% is expected, mainly attributable to major growth in the lower-income residential sector, moderate commercial-sector growth and stabilised industrial consumption levels (LPGSASA 2002).

Historically, the global annual growth in LPG has averaged about 4% per year in the past decade, faster than for oil products as a whole (1.3% per year, since 1990). Growth has been most rapid in the residential sector, particularly in developing countries. African LPG demand has grown by some 7% annually between 1990 and 2000, while India's residential demand has grown by about 10% p.a. and China's by more than 20% p.a. during this period (WLPGA/ World Bank 2002: 32-33).

2.2 LPG production in South Africa

In principle, LPG could be imported in bulk, as a refined product, or it can be produced locally as a by-product of oil refineries. In South Africa, LPG is produced locally. There are six refineries in

[6] An interviewed IP retailer in the case study area said that this was the main reason for declining IP sales in his stores – particularly among *larger* rural IP consumers, such as rural shop-keepers and wealthier households.

[7] Using the quoted coastal price for 20 litre cans of IP. In practice, final retail prices for IP are very variable, depending on steps in the distribution chain and the margins which distributors and retailers are able to charge.

South Africa – SAPREF (BP and Shell), GENREF (Engen), NATREF (Total/Elf), CALREF (Caltex), SASOL, and PetroSA-Mossgas. The latter two produce liquid fuels from local coal and natural gas, respectively, contributing to about 40% of South African gasoline volumes and 25% of the total liquid fuel supply, while the remainder is refined from imported crude oil.

The proportion of refinery output that is LPG can vary, according to the feedstock and the techniques used, but is typically a small fraction of total net output (e.g. 2-3% in energy terms, for crude oil refining). It is in this sense that LPG may be regarded as a by-product, dominated by the refining of major refinery outputs like petrol and diesel. To some extent, therefore, growth in LPG production is expected to be dependent on growth in demand for the major refinery fuels. However, if there are incentives for the producers to do this, the proportion of LPG could be increased through adaptations in refinery techniques. In addition, LPG flaring could be reduced. There have also been reports of significant quantities being vented to the atmosphere by SASOL, which should be potentially recoverable. The production capacity for LPG is therefore not considered a constraint for LPG market growth in the near term.

South Africa exports approximately 10% of its LPG product to neighbouring countries such as Botswana, Lesotho, Swaziland and Namibia (LPGSASA 2002).

It is interesting that for sub-Saharan Africa as a whole, the proportion of LPG obtained through international trade in the product, as opposed to production in local refineries, is low by world standards – around 5%, compared with South America at 21% and Asia at 50% (World Bank, 2001: 38). Some of the constraints on large-scale importation (by sea) include suitable port and LPG storage facilities, market size, and the significantly higher unit freight costs for shipping smaller cargoes of LPG. Nonetheless, in the South African case, some commentators have put forward the view that South Africa could obtain cheaper LPG through direct import, compared with the local refinery-gate price, as regulated by the government (Lloyd 2001a).[8] However, it appears that others within the industry are doubtful about this, for reasons such as the high costs of large storage facilities and the increased unit shipping costs if LPG were imported in smaller parcels (Marquard 2002).

2.3 LPG pricing ex-refinery

The South African refinery-gate price for LPG is regulated by government,[9] and is closely linked to the price-setting for 93-octane petrol. This in turn is based on the BFP formula (basic fuel price), which is an arms-length internationally based benchmark for the calculated costs of importing petrol (two grades) and diesel fuels to South Africa, using a basket of spot and term prices from a selection of refineries in the Mediterranean, Arab Gulf and Singapore, plus international freight, insurance and leakage charges. The BFP is updated regularly. It is intended to reflect the alternative cost if these refined products were to be imported, instead of produced/refined locally.

As a result of this mechanism, the ex-refinery LPG price in South Africa is subject to international variations in oil prices and to exchange rate fluctuations. Figure 3 shows approximate yearly-smoothed refinery-gate prices for LPG in South Africa. For comparison, some approximate yearly-smoothed international spot market prices[10] are also indicated.

8 For example, in presentations to members of the Parliamentary Portfolio Committee on Minerals and Energy.

9 This is in principle. In practice, it is said that refinery pricing and transfer-pricing for ex-refinery LPG is not effectively regulated, as it is not a "controlled product" and transactions are not monitored by government.

10 LPG spot-market prices are negotiated cargo by cargo, reflecting market conditions at the time of deal.

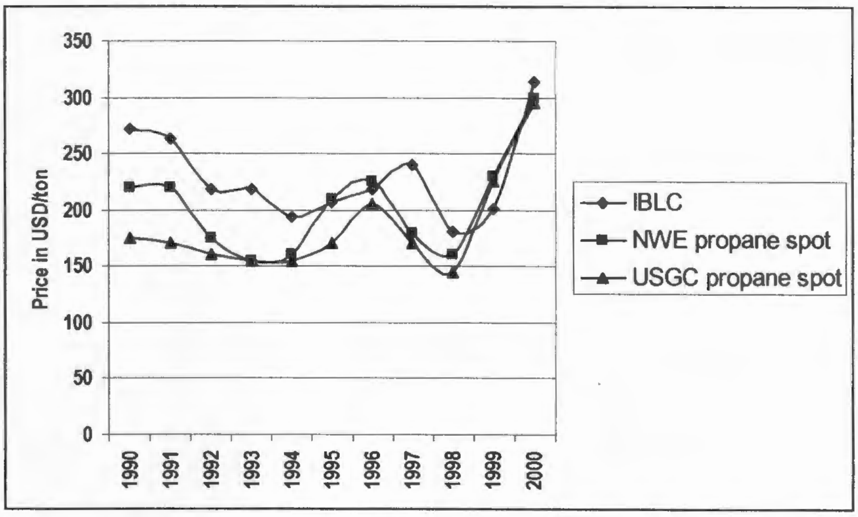


Figure 3: Approximate LPG ex-refinery prices in South Africa (BFP[11]), and selected international spot-market prices (in US$/ton, smoothed per year)

Source for SA data: Department of Minerals and Energy (2001: 9-11 and 101). Source for North-West Europe (NWE) and US Gulf Coast (USGC) spot prices: Adapted from World Bank/ WLPGA (2002: 34), drawing on Petroleum Argus and LP Gas World for propane spot prices. LPG is a variable mixture of propane and butane with a density between 0.520 and 0.535 at $-20^{0}C$, the prices of which are closely inter-linked.

The current regulated refinery-gate price for LPG in South Africa (as at September 2002) was approximately US$220/tonne or R2300/tonne. However, this does not provide a good indication of the retail price of LPG, as experienced by the variety of LPG consumers in the country. Distribution costs, and profit margins in the distribution chain, lead to a wide range of LPG costs for end-users. While retail prices for petrol and diesel are closely regulated, the wholesale and retail prices for LPG are presently unregulated although the Department of Minerals and Energy has expressed its intention to control the price. Unlike petrol, diesel and paraffin, it is presently not a "controlled product". Before looking at the prices paid by end-users, it is necessary to examine the ways in which LPG is transported and distributed.

2.4 Distribution of LPG

LPG can be delivered in bulk (in pressurised and/or refrigerated tankers) or in pressurised cylinders. Large customers (industrial and commercial) receiving bulk deliveries account for approximately 50% of the LPG market (Lloyd 2001b). Smaller customers, including households, receive or obtain LPG in various-sized cylinders, accounting for the other 50% of LPG distribution.

2.4.1 Company shares

The main oil and gas companies presently involved in the distribution of LPG are BP, Shell (Easigas), Afrox and ELF/Total. Engen's LPG distribution interests were taken over by Afrox a couple of years ago. Afrox sources its LPG from various refineries. According to data from Lloyd (2001b), Afrox dominated the market supply of LPG in cylinders to households, as shown in Table 2.

11 The BFP (previously IBLC or in bond landed cost) used here is for 93-octane petrol, at the coast. The associated regulated ex-refinery price for LPG is R74/tonne lower, at present time, reflecting the costs of butanisation which affect substitutability between LPG and petrol in the refining process. Further adjustments for inland sales are not represented here. This refinery gate price cap applies both to sales between different companies as well as transfer pricing between refining/distribution divisions of a company (RSA Government Gazette, 445(23681), 31 July 2002).

Table 2: Market shares in the supply of LPG cylinders to households
Source: Lloyd (2001b)

	Percentage market share, per category			
	BP	*Shell/Easigas*	*Afrox*	*Other*
High-income households	*23%*	*27%*	*45%*	*5%*
Low-income households	*15%*	*18%*	*45%*	*22%*

2.4.2 Cylinder sizes and ownership

Larger cylinders, which come in 9, 14, 19 and 48 kg sizes, remain the property of the supplier. Customers pay a deposit (which, however, is less than the cylinder cost, so that when these cylinders leave circulation, either because of sporadic LPG use or use of cylinders for other purposes, this represents a loss to the supply companies). Smaller cylinders are purchased by the end-user, and are refilled as required, rather than exchanged. Commonest cylinder sizes for low and middle-income households are 9 kg (leased), and the No. 7, 10 and 13 sizes (user-purchased). These latter sizes were originally denoted in pounds: the corresponding metric LPG content is 3 kg, 4.5 kg and 6 kg for the No. 7, 10 and 13 sizes respectively.

The distinction between leased and user-purchased cylinders can have potential safety implications. Company-owned cylinders are subject to thorough safety checks, as the integrity of the cylinder is a company responsibility. In principle, LPG dealers who refill user-owned cylinders are responsible for checking these cylinders as well, and are not supposed to re-fill damaged cylinders. But in some cases it is possible that this checking may not be as thorough.

The size and weight of the cylinders can be an important consideration for residential LPG users, particularly those in rural village areas where transport is a difficulty. The cylinders themselves are heavy, in order to be safe at pressure (for example, a cylinder holding 3 kg of LPG can weigh a further 4.6 kg).[12] This reduces the energy density (MJ/kg) of the cylinder-LPG combination. From this point of view, LPG can be more burdensome to transport than for instance paraffin. Further aspects relating to cylinder sizes will be discussed in Section 3 below.

2.4.3 The LPG distribution chain (for residential LPG cylinders)

The LPG distribution chain – from refineries to households – is variable in South Africa, but the two main channels can be outlined as follows.

a) Refineries sell to LPG distributors (such as Afrox) who in turn supply LPG cylinders to dealers. There may be another stage, where larger LPG dealers on-sell to smaller outlets. Depending on the situation, households may be able to purchase LPG from larger dealers or smaller outlets. The smaller outlets may be more accessible locally, but may charge an additional price margin.

b) Some oil companies producing or purchasing LPG at the various refineries are involved in more direct distribution of LPG for sale at their branded service station forecourts. They do their own cylinder filling, and deliver cylinders to service stations. They may also sell to other LPG dealers. In this more vertically-integrated model, the oil companies' LPG distribution business may be ring-fenced to some degree.

An indication of typical LPG retail price build-ups for such residential LPG cylinder sales is illustrated in Figure 4. The figures are approximate and the estimates for the price increments (indicative gross margins) at each stage of distribution are adapted from Lloyd (2001b).

[12] LPG with a higher propane content (as in South Africa) requires higher liquefication pressure than LPG with a higher butane content.

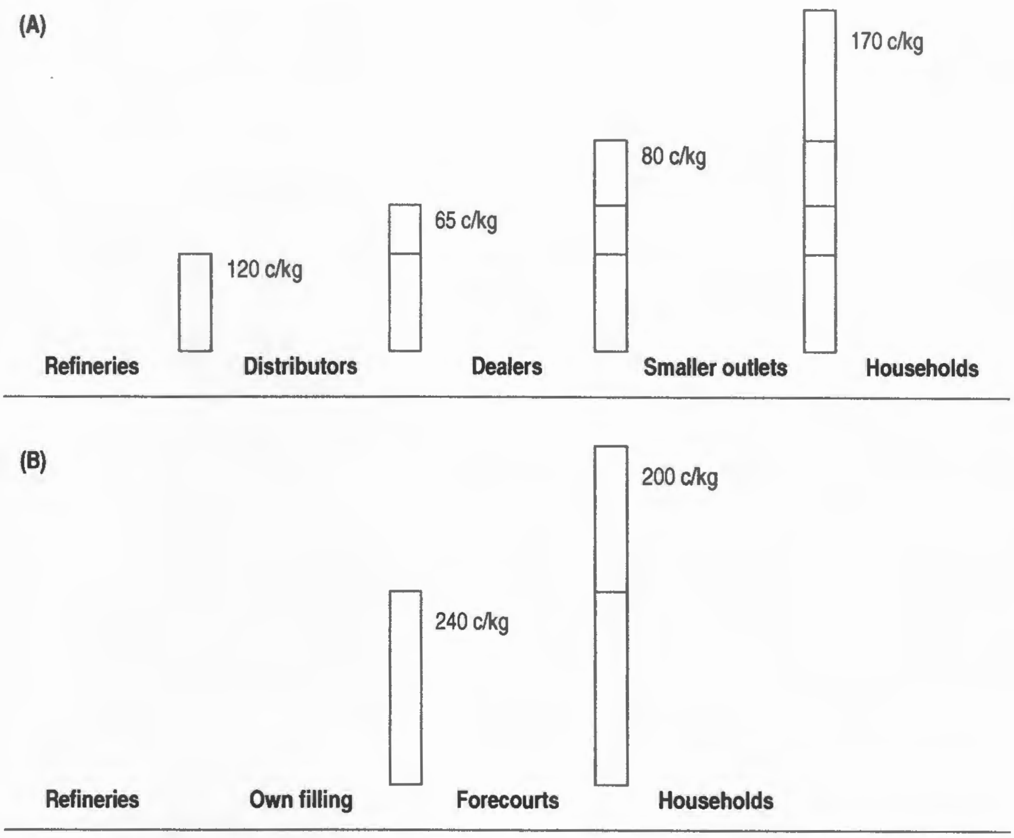


Figure 4: An indication of typical gross margins at various steps in the LPG cylinder distribution chain from refineries to households

Source: Adapted from Lloyd (2001b), with indicative gross margins in c/litre converted to c/kg

For a more specific illustration relevant to this case study, the following example indicates typical steps in the distribution chain from the refinery to a rural villager (in this example, to a household in a village near Mt Fletcher in Eastern Cape).

An example of steps in the distribution chain, to obtain LPG in an Eastern Cape village

1. Bulk delivery by road tanker from refinery in Durban to an LPG depot in Kokstad (distance about 200 km).
2. The depot refills large cylinders and delivers these to a dealer in the small market town of Matatiele (distance about 70 km).
3. The customer travels by bus from her village to Matatiele (distance about 50 km) and refills her No. 10 cylinder (which she owns herself). She uses a shopping trolley to move the cylinder from the bus rank to the LPG dealer and back.
4. The bus operators load LPG cylinders on the roof of the bus. (They charge both for the person's bus fare as well as the cylinder transport).
5. From the bus stop, her son helps to transport the cylinder home using a wheel-barrow.

In this particular illustration, the customer goes through this rather arduous refilling process once or twice a month in winter. Despite the extra costs and effort of travelling by bus to get the cylinder refilled, she judges this is cheaper in the end, because of the lower LPG prices in the town. (There can be quite fierce price competition in such rural market towns, which act as "filling stations" for surrounding rural areas – both for energy products like LPG, paraffin and candles, and for other staple commodities including food. Of course, in all these cases, the cost of transport into town and back to village areas adds a premium to the effective final price paid by villagers.)

A common comment among rural villagers in these areas is "they should bring these services closer to us". In the example given above, the distances covered by the organised supply chain and by the customer's transport give an indication of this problem:

Organised distribution	Bulk tanker transport delivery	*200 km (one way)*
	Batch cylinder delivery	*70 km (one way)*
Customer's transport	Customer's bus transport	*100 km per load*
	Walking and carrying	*some 2 km per load*

Alternatively, villagers (especially those unable to travel, for financial or other reasons) can usually make some fuel purchases locally, from small "spaza" shops. The prices are then higher, both because of the transport costs incurred by the shop-keeper in obtaining stock, and the additional mark-up to make these shops profitable. Among fuels, paraffin and candles are readily obtained from local spaza shops, as these can be sold in small quantities with little overheads, but LPG is less commonly available from local informal shops – hence price and availability are both constraints. These are facets of the commonly-expressed opinion that LPG distribution does not extend far enough into rural areas of South Africa: for individual rural customers, it is more often a case of "if you want it, come and get it" (from dealers in towns, garage forecourts, etc).

Another view, of course, is that LPG is a superior and more expensive fuel compared with paraffin, and as a result would be chosen by only a minority of somewhat wealthier rural households. This would reduce the density of demand and the viability of having LPG distribution outlets in villages.[13]

2.4.4 Options for more direct distribution of LPG to rural areas

(a) Community-managed energy centres

In recent years, a number of village communities in this Maluti-Mt Fletcher district of Eastern Cape formed energy committees, in an effort to improve their supplies and uses of energy.[14] In one cluster of villages, Magadla (between Matatiele and Mt Fletcher), the membership decided to form a co-operative. One purpose was to facilitate bulk-buying of fuels like paraffin and LPG, for local resale to households, small shops, etc.[15] Broader aims were to establish an Energy and Development Centre which would carry a range of commercial fuels and appliances as well as provide non-commercial services to assist community members: for example, safety campaigns, other information campaigns, demonstrations of improved appliances, improved techniques, etc. The scope was (and is) intended to expand beyond energy, and to include energy-related production opportunities (facilities for small business operations), a communications centre, and ways of helping to address pressing service and health issues in the area, like water and sanitation, and HIV/Aids campaigns.

This Caba-Mdeni Energy and Development Co-operative has so far succeeded in obtaining a paraffin tank and pumping equipment, receiving small-bulk deliveries from a depot in Kokstad, and in bringing down the local price of paraffin. Subsequently, batch deliveries of LPG cylinders were organised in a similar way. The Energy Centre building (which is so far unelectrified) also hosts a sewing project; and a number of other people from some of the poorest families in the village are employed part-time by the co-operative.

13 An interviewed Easigas depot manager in Kokstad opposed this view, saying that there is a vast underlying demand for LPG in rural areas of Eastern Cape, and that there are excellent business opportunities for village-based entrepreneurs (with LDVs/bakkies) to bridge the gap between LPG depots and rural customers. They would be able to charge a mark-up of about 40-50% on the depot wholesale price, and still find a strong customer base.

14 This was facilitated by the Rural SEED project (Sustainable Energy, Environment and Development), carried out by EDRC in cooperation with Danish NGOs and the local NGO, Environmental Development Agency Trust. A full-time Rural SEED Facilitator worked with communities, local government and energy service providers in this area of Eastern Cape. Another facilitator worked in areas of Limpopo Province, in the north of the country. The SEED programme was sponsored by Danish Cooperation for Environment and Development (DANCED).

15 It should be mentioned that the standard for the refilling of cylinders of domestic size (9kg and less) in rural areas allows for the use of simple liquid withdrawal systems rather than complex flow-limiting systems required in urban areas. This concession was made specifically to assist energy centres in setting up refilling stations. See SABS 087-7 2000 *The handling, storage and distribution of liquefied petroleum gas in domestic, commercial and industrial installations Part 7* Note to Section 5.2.2, Ed 2.1, SA Bureau of Standards, Pretoria

(b) Commercial energy centres and one-stop energy stores

The idea of rural energy centres, or of one-stop energy stores, has been a topic of discussion for several years in South Africa. Apart from developments in community-managed rural energy centres, there have also been initiatives by oil companies and other energy companies/consortia to establish these.

Some of the oil companies have set up retail outlets which are referred to as energy centres, because they carry a wider range of fuels and energy-related products than conventional service stations. These have been established mainly in high customer-density locations (e.g. urban and peri-urban localities).

More generally, branded service station outlets for the main liquid fuels, petrol and diesel, have been diversifying their product range (e.g. selling electricity tokens, cellphone coupons, foodstuffs), partly as a marketing strategy. This may reflect the difficulties of competing for market share in an environment where the prices of the main products, petrol and diesel, are regulated, and where these products are largely identical for each company.[16]

A further set of initiatives for supplying fuels like LPG and paraffin in rural areas revolves around solar electrification projects. Photovoltaic (PV) electrification does not cover households' important energy needs for cooking and sometimes heating. Therefore it is often thought that solar electrification should be accompanied by improved provision of thermal fuels as well, to provide a more complete energy service. For example, Eskom piloted this approach fairly successfully in a KwaZulu-Natal village area (kwaBhaza), offering a package combination of LPG for cooking and PV electricity for lighting, radio and television. On a larger scale, there is a national programme for non-grid electrification, whereby selected companies/consortia are given concession rights to provide solar home systems (SHSs) in demarcated geographic areas. The government will provide a significant subsidy per installed SHS[17], and this has attracted the interest of major companies, including several oil companies, as participants. As part of their contractual obligations, the companies awarded concession rights[18] are expected to ensure an improved provision of thermal fuels as well as PV systems. However, like the programme as a whole, progress in this aspect has tended to lag behind. The pioneering Eskom-Shell Joint Venture for solar electrification in an area of Eastern Cape, for example, is said to have neglected the provision of thermal fuels, to date. Nonetheless, at least some of the concessionaires are committed to their plans to establish one-stop rural energy stores, which will not only be marketing, installation and maintenance centres for SHSs (and hopefully other PV systems as well) but will also stock liquid fuels and a range of energy appliances.

The location of these energy stores may not be ideal for liquid fuels distribution. If the primary business is in SHSs (which tend to be fairly scattered and low density) it would make sense to locate such energy stores in a small town, serving a fairly large surrounding area, rather than within a village cluster. This might still leave villagers with transport difficulties if they wish to access LPG or paraffin from such a store.

(c) Government-initiated integrated energy centres

In recent years, the terms "integrated energy" and "integrated development" have become commonly used. "Integrated energy" has two main connotations in South Africa:

- supply and use of a *combination* of fuels, as opposed to a single focus on one energy service such as electricity;
- integrating improved energy supplies into the overall household, productive and service needs of a community.

Each of these aspects came to be highlighted in the course of South Africa's massive national electrification programme. Especially in the case of rural electrification (but also among low-income urban communities) it became increasingly evident that electricity alone was not meeting all the

[16] One refinery can provide the same fuel to several companies. The only difference between brands at different service stations may lie in proprietary additives which the companies are permitted to add individually.

[17] Currently R3500 subsidy per system, close to the capital cost of a SHS.

[18] "Concessions" is a commonly-used term, in connection with this programme for non-grid service provision, but is not a term which the government favours, as it implies too much. More exactly, the "concessionaire companies" have exclusive access to the SHS subsidy in their awarded area, for a limited time period.

energy needs of low-income households and that people were continuing to use non-electric fuels for cooking and even lighting.

There was also increasing concern that although ambitious numerical electrification targets were being met or exceeded, the benefits for people's well-being, and broader socio-economic development, were less than originally anticipated. It was hoped that improvements on this could be obtained by adopting a more integrated approach, implying

- a closer match between energy demand and supply;
- a more coordinated cross-sectoral approach;
- applying an integrated local development planning framework ("integrated development planning", IDP).

The idea of "energisation" – meaning improved provision of a bundle of fuels – became more widely used, as a target for improving energy services. An integrated sustainable rural development strategy was developed, placing emphasis on local-level empowerment and expression of demand, improved coordination between different service sectors, and the planning and accomplishment of local economic development goals within the IDP process. With regard to energy, some of the main energy strategies within the strategy (or as it has now become, the integrated sustainable rural development programme) are to

- incorporate electrification planning, and other energy planning, within a unifying IDP framework;
- promote local empowerment around energy issues;
- promote the development of integrated energy centres, which are intended to improve local access to a range of energy sources and appliances, enhance people's ability to make well-informed choices, and promote safe, healthier, efficient and more sustainable energy use in surrounding communities.

Points of relevance for the present case-study include the following:

i) The "energisation" approach is recognised as relevant in both grid-electrified, non-grid-electrified and non-electrified areas, emphasising government policy support for improving access to affordable non-electric fuels such as paraffin and LPG.

ii) The energy centre concept has policy support and active government sponsorship, indicating that successful achievements of better fuel supplies, safety awareness, etc. at rural energy centres[19] can have good opportunities for wider replication in the country.

It can be suggested that there is not yet sufficient practical experience to show how far rural energy centres and one-stop energy stores will succeed in delivering better distribution routes for fuels like LPG, on a sustainable basis, or what the relative strengths of the different models will be (community-managed, purely commercial, government-sponsored[20]). However, there appears to be sufficient momentum in the country to make it worthwhile to examine the potential for such energy centres and stores to encourage household use of LPG, which is one of the objectives of this study.

d) A "market day" approach

Given that one of the major barriers affecting the flow of goods and services into (and out of) rural areas is the high cost and limited availability of transport, it makes sense to consider a variety of options for rationalising transport costs and rendering transport services more effective. Localised energy centres/stores are one broad option, but with an emphasis on rationalising in-coming transportation costs for fuel supplies. Another option, which could be suited particularly to "deep" rural areas – where road transport costs are very severe – is to rationalise transport by operating a "market day" supply circuit, or more ambitiously, an import/export circuit, bringing goods into rural villages and transporting local products back to towns. Although this option will not be examined further in this case-study, mainly because it could be complex to achieve in South Africa, it could have a number of advantages, not limited to improved fuel supplies.

---

19 Government-sponsored integrated energy centres are not restricted to rural areas, although at present they are mostly planned to serve high-need rural areas.

20 It should be pointed out that government-sponsored IECs entail both industry co-operation and elements of community management. They can therefore be regarded as public/private/CBO partnerships.

The picture is that villages, or village clusters, would be visited on a certain day each month (or more frequent days in the month, depending on demand) to provide a range of products for sale, including energy supplies and appliances, foodstuffs, and possibly services. An obvious choice of day is "pension day", when State support payments are paid to pensioners and registered unemployed. Typically on this day both citizens and service providers gather round the payment location, and more transactions take place than during the rest of the month.

In this picture, rationalised trucking of these goods and services would reduce transportation overheads. The transport rationalisation could require

- a transporter carrying a range of products, from different supply companies (hence the complexity);
- travelling in a circuit, from one village area to another day by day, rather than having expensive to-and-fro consignments from towns to individual remote areas;
- large carrying capacity for the transporters, to enable circuit-wise distribution and economies of scale;
- mixed-load capabilities;
- time-coordination of multiple transporters, if required.

In order to contribute to sustainable development of such rural areas, it would be important that a system like this should not only reduce the costs of rural ("import") ***supplies***, but also reduce the barriers for "exporting" rural ***products*** to urban markets. At a simple level, this implies that the market-day transportation system should be able to transport local rural products back to towns. However, the marketing system for rural products ***to sell*** in towns, or nationally and internationally, is a much more complex matter than multi-product supply to rural areas. A single entrepreneur could possibly organise the sourcing and delivery of a wide range of consumer products (in the way an ***algemeene handelaar*** [Afrikaans for general dealer] operates) for sale on rural market days, but marketing a wide range of rurally-sourced products would probably require either many agencies involved, or an intermediary organisation capable of handling the collection and on-sale of multiple rural products. These are challenges.

It is possible that oil companies, in particular their distribution divisions or off-shoots, could have an advantage in venturing into a circuit-wise market day transportation initiative for rural areas. They have the infrastructure and organisation for road-transport deliveries across the country, and possibly fuel-price advantages for road haulage. In South Africa and internationally, oil companies show interest in diversification of their retail products – but as mentioned above, this is probably organised more around attracting customers to their sales outlets for main products (petrol and diesel) in the short term. A system for transporting diverse products to and from rural areas of developing countries is probably one step outside the marketing strategies of oil companies, but could possibly be encouraged by their social-responsiveness policies and government requests.

2.5 End-user LPG prices

Wholesale and retail prices for LPG are not controlled in South Africa, only the refinery-gate price. There are considerable variations in the final prices which customers pay. These depend on location, transport costs, other storage and distribution costs, the number of steps in the distribution chain, and the size of the price mark-ups at each step.

2.5.1 Sample end-user prices

A number of examples are given below. First, three supply routes for an LPG customer in the Eastern Cape village area of Magadla are examined. Then for comparison, some urban prices for re-filling or exchanging LPG cylinders are given, and also some bulk supply prices. The urban prices are from Cape Town. All prices are for October 2002, are in rands, and include VAT (at 14%). The prevailing refinery gate price for this period was approximately R2300/tonne (R2.30/kg) or US$220/tonne, according to the BFP formula. The prevailing rand/US$ exchange rate was variable but approximately R10:US$.

Example 1: A customer from Magadla refilling or exchanging gas cylinders from a cost-cutting furniture store in the town of Matatiele

	Refilling a No.7 cylinder (3 kg)	*Exchanging a 9 kg cylinder*
Bus fare (two ways)	R4	R4
Cylinder transport charge	R2.50	R15
LPG cost (R per cylinder)	R22	R60
LPG cost (R/kg) excluding local transport	R7.33	R6.67
LPG cost (R/kg) including transport[21]	R9.50	R8.78

Example 2: A customer from Magadla refilling or exchanging gas cylinders from a petrol station in the town of Matatiele

	Refilling a No.7 cylinder (3 kg)	*Exchanging a 9 kg cylinder*
Bus fare (two ways)	R4	R4
Cylinder transport charge	R2.50	R15
LPG cost (R per cylinder)	R22	R62.50
LPG cost (R/kg) excluding local transport	R7.33	R6.94
LPG cost (R/kg) including transport	R9.50	R9.06

Example 3: A customer from Magadla exchanging gas cylinders at the Caba-Mdeni Energy and Development Cooperative in Magadla

	Exchanging a 9 kg cylinder	*Exchanging a 19 kg cylinder*
LPG cost (R per cylinder)	R60	R124
LPG cost (R/kg)	R6.67	R6.53

Example 4: Urban LPG supply, in a middle-income Cape Town suburb

	Refilling a No.7 cylinder (3 kg)	*Exchanging a 9 kg cylinder*
LPG cost (R per cylinder)	R28	R76.85
LPG cost (R/kg)	R9.33	R8.54

Example 5: Urban LPG supply, in low-income Cape Town suburbs

	Refilling a No.7 cylinder (3 kg)	*Exchanging a 9 kg cylinder*
LPG cost (R per cylinder)	R25.45 to R28	R68.95 to R80
LPG cost (R/kg)	R8.48 to R9.33	R7.66 to R8.89

Example 6: Urban LPG supply in delivered 48 kg cylinders (commercial)

	Exchanging a 48 kg cylinder
LPG cost (R per cylinder)	R368
LPG cost (R/kg)	R7.67

Example 6: Urban LPG supply in bulk (industrial), Cape Town

LPG cost (R/kg)	R5.60

2.5.2 Comments on sample prices

Urban/rural price differences

One would expect that the *costs* of supplying LPG would be higher in a rural area, than in an urban area like Cape Town (which has a nearby local oil refinery). The transport costs of LPG distribution to retailers must be higher for the rural examples given above. Nonetheless, it is striking that the rural retail prices are lower, both for refilling and for exchanging LPG cylinders in Matatiele (which

[21] Assuming the trip is specifically for purchasing LPG. In practice, trips usually have combined purposes.

is hundreds of kilometres from refineries) than in Cape Town suburbs. Averaging the sampled retail prices shows this comparison more clearly (see Table 3).

Table 3: Averaged sample retail prices for residential LPG (October 2002)

	Refilling a 3 kg cylinder	*Exchanging a 9 kg cylinder*
A] Sampled prices in rural Matatiele area (including the Caba-Mdeni Energy Co-operative)	*7.33 R/kg*	*6.76 R/kg*
B] Prices in urban Cape Town samples	*9.05 R/kg*	*8.14 R/kg*
Urban / rural retail price differential **[(B-A)/A%]**	*23%*	*20%*

In Section 3.4 below, it will be suggested that the effective demand curves for LPG in the rural case study area may be different from LPG demand in an urban area like Cape Town. This could partly explain how rural prices could be pushed lower. However, it also seems likely that there are some limitations on LPG price competition at work. In addition, most small-cylinder LPG sales in urban areas are for recreational purposes such as barbecues or camping, in which far higher margins can be achieved than when in competition for domestic fuels.

Rural co-operative LPG prices are lowest, in the sample
Notably, the lowest retail prices for residential LPG, among all the rural and urban samples given in Section 2.5.1, are the prices quoted by the small village-based Caba-Mdeni Energy and Development Co-operative's energy centre – the outlet furthest from an oil refinery (in these examples).

In fact, the only LPG price in these samples which is lower than the prices offered by the Caba-Mdeni Co-operative is the price for bulk industrial supplies in Cape Town (R5.60 per kg). Understandably, bulk supply in areas close to a refinery should be cheaper, cutting out cylinder bottling and maintenance costs and reducing LPG transport delivery costs.

Comparing LPG and 93-octane petrol prices
As will be discussed further in Section 2.7 below, the retail energy cost (in R/MJ) for 93-octane petrol is lower than that for LPG in cylinders, at these sampled prices. Using October 2002 prices, 93-octane petrol retailed at about 0.12 R/MJ and LPG 0.13 to 0.18 R/MJ. This is despite the fact that the refinery gate price for LPG is supposed to be virtually the same as 93-octane petrol, and that petrol is subject to fuel taxes and levies making up about one-third its retail price, while LPG is not.

2.6 Availability and costs of common domestic LPG appliances

2.6.1 Types of cooking appliances

The focus of this case study is on LPG for cooking. The main LPG cooking appliances one would expect to find in lower-income rural (and urban) households are a cooking ring which is screwed directly on the top of a smaller-size LPG cylinder, and a flat two-burner cooker. LPG appliances can be designed for high gas pressure (e.g. a cooking ring connected directly to a cylinder) or for lower pressure (in which case, an in-line pressure regulator is required). Some two-plate LPG stoves in South Africa are designed to be connected to cylinders without a need for in-line pressure regulation, while others are "low pressure" appliances, requiring a pressure regulator.

Small LPG cylinders with direct stove attachments are portable, as a unit, and are probably designed mainly for the camping market. They have some limitations for general household use, such as

- relatively poor stability, especially for large pots;
- pots can slide off the cooker, e.g. when stirred or knocked;
- a single burner is a limitation on cooking practices.

A flat two-burner cooker is more stable, versatile, and easier to control, but more expensive. Other LPG cooking appliances include "skottel braais", grill plates, "potjie" cooker tops[22], full stove/ovens,

[22] "Potjie" is Afrikaans for a small pot, but it typically refers to a heavy iron pot in which stews can be made, over a fire or in this case using an LPG attachment. The pots often have three legs so that they can be set above an open fire. Such three-legged pots are very common cooking utensils in rural areas where people cook on open

and simple heavy-duty cooking burner stands. A skottel braai (*skottel* means "dish" in Afrikaans) is similar to a wok, with a large dish-shaped surface heated from underneath by gas. Food can be fried, simmered or contact-grilled on the skottel. Although this versatility is appealling in some food traditions, LPG skottel braais are fairly expensive to purchase and are likely to be fuel-inefficient. In South Africa they are used mainly for special outdoors occasions, where they allow convenient cooking of foods like sausages in a way that resembles a traditional "braaivleis" (grilling meat over a fire; a barbecue). Rural householders who want to grill meat are likely to prefer traditional methods, using real fires if possible.

Full gas ovens, usually with four cooking rings (or, in some luxury models, two gas rings and two electric plates) tend to be rather expensive in South Africa and more difficult to obtain than the smaller LPG cooking appliances. Sample prices are given in the next section. Some wealthier households choose to cook with gas rather than electricity, for reasons such as easier control of cooking temperatures. However, expensive gas ovens are likely to be unaffordable for most rural households, although it is likely that most households would value having an oven, for baking and roasting, if they could afford it [23].

There could be a demand for simple, heavy-duty gas cooking rings, which can be set on the floor and which could accommodate large pots (including the common "three-legged" pots widely used in rural areas) more safely than a camping-type LPG stove. These are available from some appliance outlets. As far as known, they are not yet readily available in rural stores.

2.6.2 Examples of prices

Table 4 provides examples of retail prices for a range of LPG cooking appliances, obtained from shops in a city (Cape Town) and a small rural town (Matatiele) in October 2002. The cost of smaller-size gas cylinders is included here, as they are integral to the appliance. Alternatively, the costs of putting down a deposit on larger LPG cylinders are also indicated in the table.

Table 4: Examples of retail prices for LPG cooking appliances and LPG cylinders (October 2002, in Cape Town and Matatiele)

	Retail prices in R, including VAT (For US$ equivalent, divide by 10)	
	Cape Town (city/suburb)	*Matatiele (rural town)*
LPG cylinders (purchase)		
No. 7 (3 kg)	180	200
No. 10 (4.5 kg)	230	265
LPG cylinder deposits		
9 kg	85	85
19 kg	85	85
48 kg	85	85
Stoves		
Camping-type screw-in cooker plate (single)	45	55
Two-ring LPG cooker (no regulator)	260	255
Skottel attachment	240	310
Four-ring stove and oven (basic)	3000	1400

fires. LPG potjie-top attachments provide a cylindrical sleeve which can accommodate a round-bottomed pot with legs. However, to cater for family cooking of staple foods, and for larger groups of people, the pots used tend to be quite large and very heavy. The camping-type potjie cooker tops would probably not be sufficiently robust to handle larger pots safely and durably.

[23] Although it is noteworthy that in a recent survey of 150 rural households, there were no ovens at all even though 93% of the homes had radios and 37% television sets (Lloyd 2003).

	Retail prices in R, including VAT (For US$ equivalent, divide by 10)	
	Cape Town (city/suburb)	*Matatiele (rural town)*
Up-market gas hob and oven	6700	n/a
Simple heavy-duty burner, single ring	90	n/a
Simple heavy-duty burner, double ring	180	n/a
Required for low-pressure appliances:		
Hosing and pressure reduction valve	120	

2.6.3 Some international comparisons

Some approximate international comparisons can be made between the sample prices for LPG cylinders and appliances, as indicated above, and quoted figures for a few other countries in Africa. The quoted figures for other countries in Africa come from a study on LPG market development in West Africa (World LP Gas Association/World Bank, 2001). The comparisons below are made in US$, which also reduces the inaccuracy of comparing 2002 South African prices with pre-2001 prices for the other countries. To increase the validity of the comparisons, the sample prices for South Africa are taken from urban areas, since "a common characteristic of all the West African markets is that LP Gas consumption is highly concentrated in and near major cities" (World Bank/WLPGA, 2002: 65).

Table 5: Approximate price comparisons for LPG cylinders and cooking appliances in South Africa and West Africa (prices in US$)[a]

Sources: SA data: see Section 2.6.2 above. Other countries: World LP Gas Association/World Bank (2001)

	South Africa	*South Africa*	*Cameroon*	*Ghana*	*Côte d'Ivoire*	*Senegal*
	3 kg cylinder + screw-on stove top	*9 kg cylinder + 2-ring stove (without regulator)*	*6 kg cylinder + burner and cooking stand*	*14.5 kg cylinder + stove[b]*	*6 kg cylinder + burner and cooking stand*	*6 kg cylinder + burner and cooking stand*
Cylinder deposit	-	9	13	-	13	10
Cylinder purchase price	20	-	-	32	-	-
Cooking appliance	5	26	15	38	23	10
Total	25	35	28	70	37	20

Notes

a. To convert to rands at current exchange rates, multiply by 10.

b. In Ghana, customers prefer to purchase a full stove/oven.

It can be seen that South African prices for common LPG cooking appliances are not unusually high, in terms of this comparison. This reflects a reasonably large and competitive market in South Africa for these LPG appliances. They are also quite widely available in supermarkets and hardware stores, at least down to the level of small rural towns.

2.7 Discussion of supply-side barriers limiting the wider use of LPG for cooking

Compared with many other countries, it can be said that the South African market for residential LPG is relatively weakly developed. In seeking answers to the main question in this case study – what is the potential for increased use of LPG for cooking in South Africa – one needs to assess

- to what extent there is a latent market demand for residential LPG, such that sales volumes could be significantly expanded if present barriers were reduced;

- to what extent the residential market for LPG is more inherently restricted in scope in South Africa.

To assess market potential, it is necessary to examine both supply- and demand-side factors. Demand-side factors will be discussed in more detail in Section 3 below, but it is also necessary to mention some of them here, as contributors to the present relatively weak market.

In broad terms, the main factors acting at the interface between supply and demand for household LPG are

- end-user *prices*, for the fuel and appliances;
- *access* to the fuel and appliances;
- *information and awareness* (market demand information for suppliers, information about the relative costs and benefits of LPG for end-users).

All of these need to be considered in comparison with other competing fuel/appliance options. Comparative costs and benefits of these different options will be examined more closely in Section 3 below, but broadly the comparisons between typical fuel/appliance combinations could be summarised as follows, in the context of rural households:

	Biomass (open fire and 3-legged pot)	*Biomass (stove with normal pots)*	*Paraffin (with wick stove)*	*LPG (with own cylinder and stove top)*	*Electricity (with two-plate stove)*
Appliance price	Low (but pot quite expensive)	High	Low; pressure stoves higher	Higher	Medium
Fuel price	Free, but if bought, variable	Generally free, but if bought, variable	Medium	Higher	Medium
Appliance availability	High (pot)	High	High	Medium	Medium
Fuel availability	Variable	Variable	High	Medium / variable	Variable but increasing
Information / awareness	Familiar	Familiar	Familiar	Less so	Less so

A few of the interesting points here, some of them rather unique to the South African situation, are:

- The costs of using electricity for cooking (for either urban or rural grid-electrified low-income households) tend to be unusually low, even without the proposed introduction of a subsidised "poverty tariff". Section 3 will show that at current prices, electricity competes favourably cost-wise against both paraffin and LPG in the case study area.
- The degree of household access to electricity, even in rural areas, is exceptionally high for an African country. More than 50% of rural households are already electrified. This also affects the expectations of people living in presently un-electrified areas. If they expect to receive grid electricity in the near future, this can reduce their initiatives to get better non-electric energy services.
- In terms of the three broad criteria above (prices, access and information/awareness) LPG does not rate better than any of the other selected fuel/appliance options, except that LPG may be available in areas where electricity is not, and also in areas where biomass is in short supply.
- Paraffin-powered households also tend to use paraffin for lighting, with simple, readily available wick lamps. LPG does not lend itself quite so readily to lighting.

These points suggest that, *at current prices,*

- LPG is unlikely to be a strong competitor against electricity for cooking, in areas where electricity is available (although the majority of people probably do not know that using electricity can be substantially cheaper);

- LPG can compete as a higher-quality but more expensive fuel for non-electrified households;
- the main competing commercial cooking fuel for non-electrified households is paraffin,[24] which is more widely available and cheaper than LPG, and is assisted by being free of taxes, particularly VAT.

It is therefore understandable that the volume sales of paraffin are much higher than household LPG, that paraffin distribution is more widespread and far-reaching, and that residential use of LPG may be considered almost a niche market in South Africa. However, this is partly a "chicken and egg" situation. Firstly, paraffin prices (although also very variable for rural households, depending on the steps in the distribution chain) are lowered by virtue of somewhat tighter government control and recently a VAT tax exemption, and by quite fierce competition at retail level, possibly wholesale level as well – reflecting the larger market size, compared with LPG. Secondly, LPG retail prices seem to be unnecessarily high in South Africa, but in a way which could reflect the higher costs and higher margins necessary to get comparable profits from selling and distributing LPG in a smaller "niche market". In other words, the customer price differential between paraffin and LPG reflects, in part, the way that these markets have been developed and also differences in government support (e.g. VAT exemption on paraffin).[25]

Government policy at present places high priorities on poverty alleviation and on promoting economic growth. With respect to LPG, current policy seems to judge that

- LPG is not a major fuel for the poor (so it does not merit special government support mechanisms on grounds of poverty-alleviation);
- measures to enhance economic growth in poor rural communities do require improvements in energy service infrastructure, but the main way of achieving this is through electrification.

Based on present conditions, including the historical development of the paraffin market and electrification in South Africa, these are reasonable judgements. Nonetheless, although LPG is unlikely to serve the energy needs of the poorest households, unless sufficiently subsidised, it remains a fuel of choice for non-electrified households able to afford the somewhat higher costs of LPG use, compared with paraffin. These households are not the poorest, but still include quite low-income households, disadvantaged by their rural location, lack of services and by the fact that they are unable to benefit from the effective subsidy on grid electricity (see Section 3.1.2 below). Secondly, while LPG is not as versatile as electricity for productive income-generating activities, it is still valuable for many commercial and agricultural purposes – for bakeries, refrigeration, heating poultry stalls, metalwork, etc. Therefore an integrated policy towards energy provision for promoting sustainable development should seek to maximise the potential benefits of affordable LPG supplies. Health and safety concerns provide a further important incentive for this, in view of the high incidence of paraffin fires and poisoning in the country, and the higher risk of respiratory diseases for people exposed to local air pollution from smoky fires and stoves.

---

24 In some parts of the country, coal is the cheapest fuel for cooking/heating purposes, but not in the case study area.

25 Although the present South African government (particularly the Ministry of Minerals and Energy) is supportive of an integrated approach to address the energy needs of the poor, two main concerns are to alleviate poverty and to encourage the growth of productive economic activities. To alleviate energy poverty, for example to help poor families with their basic energy needs for cooking and reduce the burdens and hazards of collecting and using biomass fuels, it probably makes more sense to target government efforts at price reduction for a staple fuel for the poor, paraffin. To promote the growth of productive economic activities, a challenging multi-sectoral approach is required, where improved energy provision is one of the elements. Improved LPG supplies can boost economically-productive activities in some cases, at a micro-level, but at a broader policy level there is greater hope in accelerated electrification as the main means of providing the best energy-sector input to empower rural economic development.

At present, government policy towards household LPG use could be described as fairly neutral. Unlike paraffin, LPG is subject to VAT. However, it is not subject to the suite of taxes and levies applied to transport fuel, which constitute approximately one-third of the retail prices of petrol and diesel (DME 2001: 11). Despite this difference in taxation, and despite the fact that the refinery gate price for LPG is linked to the controlled refinery gate price for 93 octane petrol, the final retail prices of LPG (in cylinders) are typically as high (in R/MJ) as the retail price of petrol. This provides an indication of higher costs and higher mark-ups in the LPG supply chain, from refinery to the customers.

Based on price data from DME (2001: 46), which in turn derives from SAPIA, Figure 5 shows price trends for petrol (Mogas), IP, LPG in 9 kg cylinders and LPG in bulk. These are coast prices, expressed in rands per gigajoule for each fuel.

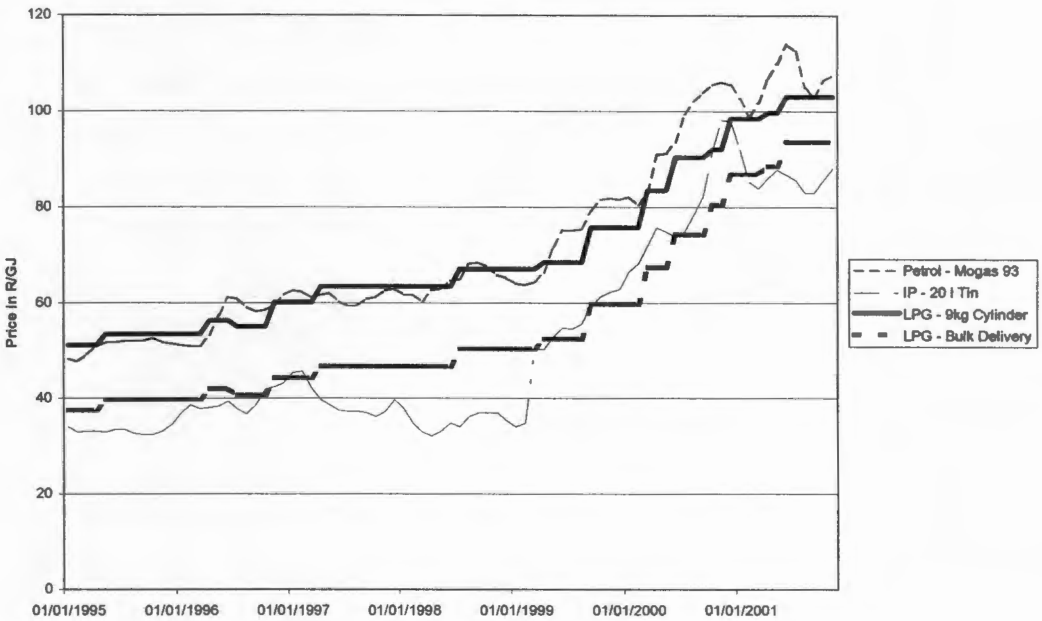


Figure 5: Comparative Coast prices in R/GJ for petrol, IP, LPG in 9 kg cylinders and LPG in bulk
Source: Prices from DME (2001: 46)

It can be seen how closely the quoted LPG (9kg cylinder) price follows the R/GJ price of 93-octane petrol. It is also notable that

- the quoted LPG prices – both for bulk supply and for 9 kg cylinders – are stepped, unlike the petrol and IP prices which are more continuously variable;
- most often, the stepped LPG price rises occur after an upturn in petrol price;
- however, unlike petrol and IP prices, the LPG price steps always go upwards (except for an isolated case in 1996).

One could question whether these points indicate some element of price-setting in the supply industry. However, it appears that the rather high LPG prices paid by end-users are affected more by margins and costs in the distribution chain, or at least that this is where there may be more ready opportunities to reduce the cost barriers.

Some reasons for high costs and/or higher mark-ups are the following:

1) Low demand density

Partcularly in rural areas of South Africa, where average income levels are low and settlements are often geographically scattered, the demand density for LPG (e.g. sales volumes per square kilometre) tends to be low. Of course, this is also affected by the price of LPG compared with other household fuels, and the ease of access.

Low demand density can increase unit transport costs for the fuel, and also act as a disincentive to establish LPG outlets closer to village areas: instead, an outlet in a rural town can "concentrate" the demand from surrounding village areas (but at the expense of customers' transport costs and inconvenience to obtain the fuel). Low demand density possibly also makes it less attractive to establish competing outlets in a locality. This could lead to higher local profit margins.

2) Steps in the distribution chain
Where several stages are involved in the distribution chain, this can lead to increased final costs, as costs will be incurred at each stage (transport, storage, stocks) and margins added. However, in general it appears that LPG distribution is more direct than is the case with paraffin, partly reflecting the need for safety controls in the handling of LPG. The other side of the coin is that rural end-users usually have to undertake the last step in the LPG distribution chain (from an outlet in a town, back to a rural village) themselves, which increases their costs.

Some industry observers believe there is considerable scope to reduce the final retail price of LPG by reducing the number of stages in the distribution chain. An example approach (Lloyd 2001b) could be

- changing the design of LPG cylinders so that they are more stackable, lighter and easier to transport;
- employing a "router" distribution system where small-scale transport operators would collect centrally-filled cylinders and deliver them to a network of decentralised stockists, equipped with LPG cylinder cages, for local re-sale.

3) Extra costs of safety precautions
Representatives of the LP Gas Safety Association of Southern Africa have suggested that it would be unwise to seek price reductions in LPG, as this could lead to a compromising of the strict safety precautions presently employed (LPGSASA 2002). This implies that such safety procedures, including the checking of cylinder integrity, contribute significantly to the costs of LPG supplies. However, it has also been suggested that South African safety/quality standards should be reviewed for cost-effectiveness, and that particularly for LPG appliances it should be possible to produce much cheaper appliances with minimal safety compromises, judging by international experience (Lloyd 2001b).

4) Cylinder costs
Robust, high quality LPG cylinders are treated as a key component of LPG safety in the South African LPG cylinder distribution sector. They are heavy and designed to withstand pressure build-ups (for example, if the cylinder is exposed to heat). They are costly, and in the case of larger-size cylinders which remain the property and responsibility of the LPG suppliers represent a significant investment, which affects the economics of LPG supply. The ratio of "active" cylinders is a small fraction of the total number supplied, which raises the cost-impact of this investment, and in turn leads to higher prices for LPG supply.

There are probably several barriers which make it more difficult to change this situation, including the sunk investment in the existing inventory of larger-size cylinders,[26] and the propane/butane proportions of South African LPG, which require higher pressure than a gas of higher butane content.

At a local level, it should be possible to achieve a more efficient ratio between "active" cylinders and those leaving circulation, by means of a community-managed local distribution system.

5) Factors possibly reducing price competition
Some factors which could possibly reduce LPG price competition have already been mentioned above, such as low demand densities, which in some localities could lead to few competing suppliers. Further possibilities include

- exclusive supply contracts, so that a business selling LPG may be required to sign an agreement with the distributor that it will not sell LPG from another distributor within a certain radius, for a certain period of time;
- the fact that LPG comprises a small percentage of oil company sales, possibly reducing their incentives to devote marketing efforts to expanding their LPG volumes;

---

[26] There are said to be 3.2 million LPG cylinders in the market (9 kg and above) owned by Easigas, Afrox, BP and Total/Elf (SANEA 2002).

- the limits on competition in the main business of oil companies in South Africa, arising from the tight regulation of petrol and diesel, and the exchange of refinery products among the companies, which presumably requires the companies to act co-operatively in some respects (and this element of co-operation rather than competition may possibly extend to the LPG market as well).

A close inside knowledge of the industry would be required to judge whether these or other factors contribute in a significant way to the seemingly high price of LPG in South Africa.

3. Factors affecting demand for LPG as a cooking fuel

This section examines some of the main factors affecting the demand for LPG as a cooking fuel, with particular attention to lower-income households, and with a case-study focus on rural households in the Alfred Nzo district of Eastern Cape.

First, the comparative monetary costs of using LPG for cooking will be compared with other fuel/appliance options, from an end-user perspective. Then comparative non-monetised costs and benefits will be discussed, with a main emphasis given to health and safety aspects. Perceived barriers which hinder more widespread use of LPG will be examined, and possible ways of reducing these barriers will be suggested. Finally, some assessment will be offered regarding the relationship between demand for LPG, and LPG prices, although there is not enough evidence to address this question with any certainty.

3.1 Comparative monetary costs of using LPG for cooking

Increased use of LPG for cooking would displace the use of other fuels – either fuels which are currently used by low-income households, such as paraffin and biomass, or fuels which they might use in the future, such as electricity. This section examines the comparative costs (*monetary* costs, for end-users) of different fuel-appliance combinations, using current prices experienced in the case-study district of Eastern Cape.

3.1.1 Typical cooking fuel combinations in the case study area

In this setting, unlike some other areas of South Africa closer to coal fields, coal is little used as a household fuel. The main cooking fuels which could be displaced by LPG are paraffin, electricity (where available) and biomass.

Realistically in the near term paraffin is the most direct competitor to LPG as a cooking fuel in this locality. The majority of households in the case-study area use paraffin, although in varying amounts. Some use it for almost all their cooking needs, while others use it as a supplemental fuel and rely mainly on biomass.

Woody biomass is scarce in the area. In some places it is possible to collect firewood locally; otherwise, it needs to be purchased, or transported into the area from other localities. However, cow dung is quite widely used for cooking and heating among low-income households – including low-income electrified households.

In villages where grid electricity is already available, electricity consumption is typically restricted to lights and media appliances (radio, sometimes TV). In solar-electrified households, the use of electricity is similarly restricted. However, at present prices, grid electricity is probably a cheaper cooking option than people realise. The possible introduction of a "poverty tariff" to subsidise a certain amount of electricity provision per month for poor households would increase the affordability of using electricity for cooking.

At present, within a household, multiple fuel-use is common. The choice of fuels and their proportions in a household's energy budget can change from time to time, depending on changing prices, weather conditions, household circumstances, and the acquisition or loss/breakdown of appliances. This dynamic situation makes it hard to generalise about the proportions of households using different fuels, and the quantities used. Within the timespan of a month, a household with a small but regular monthly income (e.g. from an old-age pension) may use electricity for lights for two weeks, but not after that; some paraffin for cooking, until this too has run out; and revert to using mainly cow-dung and candles for the remainder of the month. Other monetary expenses that arise at any time can change the periods in which commercial fuels like electricity and paraffin are used. The ability to fall back on non-commercial fuels is regarded as a valuable survival strategy for low-income households.

A broad picture, based on community surveys[27] in the Magadla area, is that typical households purchase between 20 and 40 litres of paraffin per month, mainly for cooking purposes. Very poor households may use smaller quantities of paraffin (e.g. 10 litres a month) or possibly none at all. Households vary in size, with an average of 5 to 6 members. Larger households could be expected to need more cooking energy. As an estimated representative average, we will use a figure of 30 litres paraffin per month as a baseline for the cooking energy needs of an average-sized household in this area. This amounts to a contained energy content (in the paraffin) of about 300 kWh/month,[28] and assuming an efficiency of 40% for common paraffin wick stoves, a ***useful*** energy requirement of about 120 kWh/month for typical cooking requirements in this area.

This is equivalent to about 4 kWh of useful energy for cooking, per day. Obviously, families that are able to afford greater energy use may consume more than this amount, while very poor families may not be able to obtain this estimated average energy requirement for basic cooking. However, to assist cost comparisons between different fuel-mix options, we have adopted this estimate of 120 kWh useful[29] energy per month (or 4 kWh/day) as a typical basic cooking energy requirement for this area.

About 15% of households in this local area use LPG. The figures for their LPG consumption are probably not very accurate, but indicate an average consumption of about 10 to 15 kg LPG per month. This amounts to about 80 – 110 kWh useful energy per month. Households currently using LPG often use other fuels as well.

In the comparisons below, four different fuel/appliance combinations are used as "models" for typical fuel use in different categories of households in the case-study area (Examples A, B, C and D). Then two further mainly hypothetical models are given: in Example E, LPG is used for all regular cooking, and in Example F, electricity is used for all regular cooking. In each case, we assume roughly the same total requirement for useful cooking energy, 120 kWh/month, which can be met from different sources. The assumptions that are used for local prices, calorific content and conversion efficiencies are shown first in Table 6.

---

27 Household surveys carried out by members of the local energy committee, as a guide to potential local demand for paraffin and LPG. The figures may not be accurate: it is quite difficult to estimate monthly fuel use, and seasonal variations are not captured. However, for present purposes, these figures probably provide a sufficiently good indication of local energy-use patterns, in view of the fact that these can vary significantly from time to time, and from place to place.

28 Assuming a calofic content of approximately 37 MJ/litre for paraffin, this equates to approximately 10 kWh/litre.

29 In this context there is no accurate definition of "useful" energy. Broadly, it is the energy content of the fuel consumed, multiplied by the percentage efficiency in converting this fuel to a useful service, like cooking. These conversion efficiencies are uncertain and variable, as they depend on the nature of the cooking task, the state of the appliances, the way they are operated, and so on.

Table 6: Price, calorific value and efficiency assumptions used[a]

	Local price (incl. VAT) Oct. 2002		Calorific value		Conversion efficiency (to useful cooking energy)[b]
Dung	0	R	12	MJ/kg	10%
Non-commercial wood	0	R	16	MJ/kg	15%
Commercial wood	0.3	R/kg	16	MJ/kg	15%
Paraffin	2.9	R/litre	37	MJ/litre	40%
LPG	6.6	R/kg	49.5	MJ/kg	55%
Electricity	0.40	R/kWh			70%

Notes

a) See Section 3.1.2 for prices of electricity and paraffin in the case study area, and Section 2.5.1 (Example 3) for local LPG prices.

b) Calculations of quantities of useful cooking energy and corresponding unit costs are very sensitive to the conversion efficiencies which are assumed. In practice, conversion efficiencies vary according to the nature of the cooking task, the condition of appliances, ambient conditions, etc. Typical ranges in the literature are 50 – 60% for LPG cooking (e.g. World Bank/WLPGA, 2002: 26; 2002: 74; UNDP, 1997: 100) and 30 – 50% for paraffin stoves. The table uses mid-range values for these efficiencies. Fuelwood is mainly used on open fires, but these are carefully managed, so a relatively high-range efficiency is taken for cooking with fuelwood on open fires (15%).

Note: The following quantity estimates apply only to cooking energy

Example A: A typical low-income household using mainly dung, and some wood (collected by householders) as well as a small quantity of paraffin for cooking.

	Quantity		*Energy content*		*Useful energy*		*Cost*	
Dung	180	kg/month	2160	MJ	60	kWh	0	R/month
Non-commercial wood	30	kg/month	480	MJ	20	kWh	0	R/month
Paraffin	10	litres/m	370	MJ	41	kWh	29	R/month
		Totals:	3010	MJ/month	121	kWh/month	29	R/month

Example B: A moderately low-income household using commercial firewood and a limited quantity of paraffin for cooking.

	Quantity		*Energy content*		*Useful energy*		*Cost*	
Commercial wood	60	kg/month	960	MJ	40	kWh	18	R/month
Paraffin	20	litres/m	740	MJ	82	kWh	58	R/month
		Totals:	1700	MJ/month	122	kWh/month	76	R/month

Example C: A moderate income household using paraffin for all regular cooking (fuelwood only used for special occasions).

	Quantity		*Energy content*		*Useful energy*		*Cost*	
Paraffin	30	litres/m	1110	MJ	123	kWh	87	R/month
		Totals:	1110	MJ/month	123	kWh/month	87	R/month

Example D: A somewhat higher-income household using a combination of LPG and paraffin for cooking

	Quantity		*Energy content*		*Useful energy*		*Cost*	
Paraffin	13	litres/m	481	MJ	53	kWh	38	R/month
LPG	9	kg/month	446	MJ	68	kWh	59	R/month
		Totals:	927	MJ/month	122	kWh/month	97	R/month

Example E: Hypothetical case: all regular cooking done with LPG

	Quantity		*Primary energy*		*Useful energy*		*Cost*	
LPG	16	kg/month	792	MJ	121	kWh	106	R/month
		Totals:	792	MJ/month	121	kWh/month	106	R/month

Example F: Hypothetical case: all regular cooking done with electricity.

	Quantity		*Primary energy*		*Useful energy*		*Cost*	
Electricity	170	kWh/mth		kWh	120	kWh	68	R/month
		Totals:		MJ/month	119	kWh/month	68	R/month

Examples A to D above are intended to reflect typical consumption patterns among different groups of households in the case-study area (but bearing in mind that they have been normalised around an assumption that each example delivers approximately 4 kWh/day or 120 kWh/month of useful cooking energy).[30]

The proportions of households represented by Examples A to D will vary from village to village, and also over time. Furthermore, other rural districts in South Africa would show different characteristics, so it would be difficult to generalise on a larger scale beyond the case-study locality. For the purposes of this case-study analysis, the following distribution will be used.

	Model (fuels used for cooking – see above)	*Proportion of households in the area*
Example A	A typical low-income household using mainly dung, and some wood (collected by householders) as well as a small quantity of paraffin for cooking.	25%
Example B	A moderately low-income household using commercial firewood and a limited quantity of paraffin for cooking.	25%
Example C	A moderate income household using paraffin for all regular cooking (fuelwood only used for special occasions).	25%
Example D	A somewhat higher-income household using a combination of LPG and paraffin for cooking.	15%
	Exceptions (including households not using any commercial cooking fuels, and households that use electricity for all cooking)	10%

30 This normalising assumption makes it easier to examine comparative costs of fuel-switching, and to compare other factors such as GHG emissions. It is recognised that poorer households are likely to consume lesser quantities of *useful* energy than wealthier households. At the same time, it is interesting to see from the examples given that primary energy consumption is relatively greater for poorer households, as they depend more on inefficient fuel/appliance combinations. This becomes particularly important when considering externalities, such as the health risks associated with prolonged exposure to local air pollution from smoky fires and stoves, or GHG emissions.

3.1.2 Prices of other cooking fuels in the case study area

In this area, the main commercial energy sources that compete with LPG as a cooking fuel are paraffin and (where available) grid electricity. Apart from these, fuelwood supply is partly commercialised. For example, at the Caba-Mdeni Energy Centre, fuelwood can be purchased at a price of about R0.3/kg.[31] However it is difficult to treat fuelwood as a commercial cooking fuel, because there are so many localised cost variations, and because the commercial purchasing of fuelwood is often combined with non-commercial wood collection, which again varies from place to place and over time. This section will therefore focus on the local costs of paraffin and electricity, as the main commercial fuels with which LPG competes.

Paraffin prices

As with LPG prices, IP prices for end-users can vary (in place and over time). Ex-refinery prices for paraffin are regulated by government, and the product is exempted from VAT in view of the high dependence of low-income households on this fuel.

In principle, the mark-up from refinery gate to retail is also regulated by government (a cap of 33.3%), but in practice this is not readily enforceable as there are a multitude of paraffin sellers across the country. As a result of this, and the long and often complex distribution chain by which paraffin is made available to low-income rural and urban households, the actual end-cost of paraffin is quite variable.

In addition, such cost-reducing measures as the exemption from VAT are not always passed on to consumers.

In the case study area, paraffin is available from the Caba-Mdeni Energy and Development Co-operative at a price of R2.65 per litre (October 2002). This is a low price, achieved by bulk deliveries to the Co-op's tank, and low profit margins for the Co-op. Smaller outlets in other villages tend to buy from the Co-op and then add a further modest mark-up when re-selling (at prices around R2.90/litre). The latter price of R2.90/litre has been used for the cost comparisons in this case study.

By comparison, a typical supermarket price in Cape Town is approximately R5/litre for 5 litre cans of paraffin, but the volumes sold are small and the target market is usually not the domestic cooking market.

Electricity prices

There are many electricity tariffs in the country since, at present, there are many electricity distributors, notably municipalities and Eskom, the national utility. However, most rural areas are supplied directly by Eskom, which has standard nation-wide tariffs.

The most applicable set of tariffs for lower-income rural households are Eskom's "HomeLight" tariffs. They vary according to the level of supply (maximum current) that is installed. A 2.5 A supply can be obtained with no connection fee payable, and an energy cost of R0.4/kWh (including 14% VAT). A 20 A supply entails a R150 connection fee, and the same flat energy charge of R0.4/kWh. This is the tariff assumed for the cost comparisons in this case study, as a 20 A supply is sufficient for operating appliances like a two-plate electric hotplate.

The flat energy charge for these customers means that people who consume relatively small quantities per month are effectively getting a subsidised service. This is the intention of the tariff structure. At these prices, and assuming the cooking conversion efficiencies indicated in Table 6, electricity is already significantly cheaper to use than either paraffin or LPG. Despite this, electrified rural households seldom use electricity for all their cooking purposes. It is widely perceived to be more expensive than paraffin. In practice, it is difficult for a rural family to assess the comparative costs of cooking with electricity. There can also be misconceptions about the most efficient ways of cooking with electricity, such as the reported belief that electric cookers are most efficient when they are glowing red (on high power), which may be true when bringing water to the boil, but of course not during the simmering stages of cooking.

Government is considering further reductions in the cost of electricity for poor households, possibly introducing a very low energy-charge (e.g. 5 cents/kWh) for the first 50 kWh consumed per month. One proposal is that this "basic electricity support tariff" should be available to all households, on

[31] At this price, and assuming a calorific value of 16 MJ/kg and a conversion efficiency of 15%, the cost of useful energy from wood would be lower than the other fuels, around 45 cents/kWh, compared with electricity at 57 c/kWh (useful) on the HomeLight tariff.

condition they opt for a limited-current supply (e.g. 10 A maximum).[32] Qualifying households would then be self-selecting, and wealthier households requiring larger capacity supplies would not qualify.

A household using 170 kWh/month for cooking (as per Example F, Section 3.1.3 above) would pay R68 for this at current standard rates, but only R50.50 if the first 50 kWh were charged at 5 cents/kWh. The average unit energy charge would then come down to just under 30 cents/kWh.

3.1.3 Comparative energy costs for cooking in the case study area

Table 7 summarises the comparative energy costs for cooking in the case study area. The costs are based on October 2002 locality prices, as described above. The assumptions for cooking conversion efficiencies and calorific values were provided earlier (Table 6). Table 7 indicates costs per month for a cooking-energy demand of 120 kWh useful energy per month, or 4 kWh/day, and also unit energy costs per kWh of useful cooking energy, and consumed energy. The energy options included here are paraffin, LPG, electricity at the standard rate, and electricity if a "basic electricity support tariff" (BEST) would be introduced, in the manner described above.

Table 7: Summary of comparative cooking energy costs in the case study area

	Local prices of fuel		*Monthly cost for 120 kWh useful cooking energy*	*Unit energy cost of useful cooking energy*	*Unit energy cost of consumed energy*
			R/month	*R/kWh*	*R/kWh*
Paraffin	2.90	R/litre	87	0.71	0.28
LPG	6.60	R/kg	106	0.87	0.48
Electricity (standard HomeLight tariff)	0.40	R/kWh	68	0.57	0.40
Electricity (BEST + HomeLight tariff)	0.29	R/kWh at 170kWh/month	50.50	0.42	0.30

It is important to note that the costs in Table 7 reflect a situation where

- transport costs for liquid fuels have been rationalised, to a considerable extent, through bulk or batch deliveries to a local co-op;
- transport costs for obtaining electricity tokens have not been included, on the assumption that these can also be rationalised;
- the cost of purchasing and replacing cooking appliances has not been included (however, this cost is relatively low compared with energy costs, as discussed in Section 3.1.4);
- at present, only some villages in the area are grid-electrified; others (but not all households) can expect to be connected soon.

The most striking conclusion from the figures above is that liquid fuels – at present, the main commercial cooking fuels in the case study area – cannot rationally compete with grid electricity, at current prices. In the case of paraffin, this is mainly attributable to the lower efficiency of paraffin stoves compared with electric hotplates, for cooking tasks. As mentioned before, actual efficiencies are variable, and it would be useful to test and demonstrate actual efficiencies and energy costs for cooking, using different fuels, within rural communities.

In winter situations where space-heating is valuable, the overall cooking and heating efficiencies of both paraffin and LPG appliances will rise. Even so, very low-cost electricity (as envisaged in the BEST) would probably be cost-competitive for combined cooking/ heating in a well-sealed home.[33]

[32] A research study proposed an 8-Amp self-targeted current limit, as a qualification for being eligible for this subsidy (University of Cape Town 2002 *Options for a basic electricity support tariff*, Report to Eskom and Department of Minerals and Energy, Project 400903). Subsequently, arguments were put forward to increase such a current-limit to 10 Amps, in order to allow a less restricted and more beneficial combination of basic household energy services under this "electricity basic service support tariff".

[33] In the case study area, winters are severe, and bad weather can cause increased disease and loss of life. Space-heating can be considered a basic need. Fuels like paraffin and biomass require ventilation of fumes to avoid other adverse health effects, when they are used indoors. LPG has much lower particulate and noxious gas emissions, but also requires good ventilation to remove CO_2 (and CO, if there is insufficient oxygen supply). It

Nevertheless, the point must be stressed that while we have focused on cooking, the user's choice of fuel may be affected by the ability of the fuel to meet more than one need. For instance, in many coal-burning areas, the coal-burning appliance is also fed with combustible refuse, contributing to the available energy while simultaneously reducing the total refuse burden. These cross-cutting issues cannot be entirely neglected in any consideration of household energy needs.

The observations above suggest the following in the South African situation:

- In electrified rural and urban areas, the use of liquid fuels should decrease, unless there are quite significant changes in the respective prices of paraffin, LPG and electricity. If electricity remains a cheaper energy source for cooking, and if low-income households act to minimise their energy expenditures, they should switch to electricity rather than use other commercial fuels.
- Households able to use non-commercial sources of energy for some or nearly all of their energy requirements (mainly from biomass) can save money, but will probably pay another price for this in terms of labour, time and health risks.
- Non-electrified rural households (and also solar-electrified rural households) still need to use biomass, paraffin or LPG for cooking and heating, and this appears to be the main category of households for whom more affodable access to LPG could bring financial and other benefits.[34]

3.1.4 Comparative costs of appliances

Low-income households, and particularly those experiencing uncertain and fluctuating incomes and expenditures, find it difficult and risky to make capital investments. The cost of purchasing cooking appliances can be a barrier constraining people's choice of cooking energy options. For comparison, some typical appliance costs for paraffin, LPG and electric cooking appliances are given in Table 8. In the case of LPG, the cost (or deposit) for LPG cylinders is included. Prices are inclusive of VAT and dated October 2002.

Table 8: Examples of comparative costs of basic cooking appliances (October 2002)

	Stove	*Cylinder*
Paraffin wick stove	R50	
Paraffin pressure stove	R150	
LPG cooker top and No.7 cylinder	R45	R200 (purchase)
LPG 2-plate stove and 9 kg cylinder	R140 – 260	R85 (deposit)
Electric 2-plate stove	R180	

These prices indicate that the use of LPG requires a somewhat larger capital investment than the other options. Even so, the amounts are fairly low compared with annual energy costs. Using figures from Section 3.1.1, approximate comparisons are as given in Table 9.

Table 9: Examples of appliance costs as a percentage of annual energy costs

	Appliance cost (incl. LPG cylinder costs)	*Annual energy cost (see Section 3.1.1 for assumptions)*	*Appliance cost as % of annual energy cost*
Paraffin (wick stove)	R50	R1044	5%
LPG No. 7 and cooker top	R245	R1272	19%
LPG 9 kg and 2-plate cooker	R285	R1272	22%
Electric 2-plate stove	R180	R768	23%

is therefore dangerous to seal rooms where these fuels are combusted within the room space. Electric heating can allow people to increase the sealing and thermal efficiency of their rooms.

34 These are the main options in the case study area at present. In future, there may be added options, such as gel-fuels produced in nearby sugar-cane/ethanol production. Elsewhere in the country, cheap coal is cost-competitive as a heating and cooking fuel.

The low cost of paraffin wick stoves accounts for their common use among poor households, despite the fact that common models (in South Africa) are dangerous. Of 50 000 reported paraffin-related burns annually, more than 60% have been attributed to paraffin stove "explosions". These have been traced to the fact that the paraffin in the fuel tank can reach as much as 80°C while the stove is in use (PASASA 2003). Because the standard for IP sets a flash point of 43°C, the paraffin ignites spontaneously when spilled. The vigorous conflagration that results when the stove is knocked over has much of the effect of an explosion. Instantaneous energy releases of over 1MW have been measured.

The appliances above have different expected lifetimes, but reliable data for appliance lifetimes is not available. Anecdotally, paraffin wick stoves are reported to have a shorter lifetime than the other appliances shown. However, rural household surveys have also indicated many cases of electric hotplates being out of order in homes visited.

Since we do not have a firm basis for estimating appliance lifetimes, the life-cycle costs of the difference fuel-appliance combinations will not be calculated here, and instead this case study will treat the somewhat higher purchase price or deposit for an LPG cooker and cylinder as an entry barrier for low-income households wishing to switch to LPG use.

3.2 Non-monetised costs and benefits of different cooking-energy options

3.2.1 Convenience and performance

In use, LPG is a convenient cooking fuel, with instant start-up and a good range of power control. It is frequently preferred to electricity by professional cooks and in commercial cooking applications. The convenience depends, of course, on the appliance/s used. If a family can only afford a single-burner LPG cooker this can be a fairly serious limitation, making it difficult to cook with more than one pot at a time, and restricting non-pot cooking methods like grilling, roasting and baking. In this situation, LPG may only be used for some cooking tasks, while others will be performed on a fire or in parallel on a paraffin stove. For example, more rapid cooking and boiling may be done on an LPG cooker, while simmering tasks like the extended cooking of cereals, dried beans, etc. may take place in parallel on a paraffin wick stove.

Compared with cooking over an open fire, or using biomass in an *mbawula* (the IsiXhosa term for an open-topped brazier), LPG cooking has the higher convenience of easy lighting, portability, cleanliness, and not needing to constantly tend a fire (which heightens smoke exposure as well). The burden, time, physical hazards and inconvenience of collecting wood, or collecting dung and patting it into cakes to dry, are avoided if a household can switch to modern fuels like LPG, paraffin or electricity.

From the energy-user's point of view, the performance of a cooking fuel/appliance combination includes several factors. Some of these can translate into cost savings (factors increasing efficiency) while others are more to do with control and convenience, or non-monetised health, safety and environmental benefits or costs. Table 10 compares basic biomass, paraffin, LPG and electric cooking options, in forms which would be expected in a lower-income rural household, in terms of key performance factors.

Table 10: Performance comparisons for basic cooking, using dung, wood, paraffin, LPG or electricity.

		Cooking options				
Performance factor	*Impact of this factor*	*Dung in brazier*	*Open wood-fire*	*Paraffin wick stove*	*LPG, with 2-plate cooker*	*Electricity, with 2-plate cooker*
Preparation time before being ready to cook	Time, incovenience, wasteful start-up fuel consumption and increased exposure to emissions if fire preparation time is long.	Quite long – difficult to start fire in typical conditions	Can be wasteful, but skilful use can utilise early flames	Short	Short	Short
Peak power	High peak power saves time, and increases efficiency e.g. when bringing water to the boil. It allows high-temperature cooking (e.g. frying).	Poor, in typical applications	Can be high, but with low efficiency	Poor	Quite high	Quite high
Turn-down ratio	A good turn-down ratio increases efficiency during simmering phases of cooking and may be needed to avoid burning food.	Typically poor because peak power low	Moderate, with skilful fire management	Moderate to poor	Quite high, except in windy conditions	Quite high, unless hotplate has limited power settings
Ease of control	Allows for more efficient, more skilful and more convenient cooking over a range of cooking temperatures.	Poor	Requires skillsand may be difficult in varying conditions	Moderate to poor	Easy	Easy, if hotplate has continuous power settings
Speed of temperature control	As above.	Poor	Complex: fire control slow but can move pots	Rapid within limits	Rapid	Quite fast for spiral plates, slower for solid hotplates
Overall cooking efficiency (end-use only)	Reduces fuel consumption, and exposure to emissions. Higher efficiencies can imply lower fuel costs, but relative to the different fuel prices.	Very poor (e.g. 10%)	Poor (e.g. 15%)	Moderate (e.g. 30 – 45%)	Better (e.g. 45 – 60%)	Better (e.g. 60 – 75%) for end-user
Cleanliness and hygiene	Clean-burning reduces emissions, soiling of pots, and people's exposure to dirt and smoke. Dung collection can bring risks of foecal health hazards.	Very poor	Poor	Moderate	Good	Good
Harmful emissions for energy-users	Harmful (local) emissions raise the prevalence of respiratory disease, asthma, eye disease and possibly heart disease, cancer and adverse pregnancy outcomes. CO poisoning can be fatal.	Emissions are severe	Emissions are quite severe (outdoors) and severe indoors	Fumes can provoke asthma	Low noxious emissions, but CO danger if there is poor ventilation	Virtually no end-use emissions, but coal-fired electricity generation pollutes

From Table 10, it can be seen that LPG cooking scores better than biomass and paraffin cooking options, in terms of performance, convenience, and health effects (the latter are discussed further in Section 3.2.3 below). The comparison between LPG and electric cooking is more even. There are only a few non-monetised factors which favour LPG or electric cooking, from the standpoint of a lower-income rural household, and these are probably outweighed by monetary comparisons of the costs of using LPG or electricity (where available) for cooking. If electric cooking is cheaper than using LPG for cooking in the South African situation, there is little reason for low-income electrified households to choose LPG.

3.2.2 Flexibility

One of the characteristics of low-income households that make use of commercial cooking fuels (for some or all of their cooking) is the importance of flexibility. People with low incomes often switch between commercial fuels or switch their choices between commercial and non-commercial fuels according to changes in their circumstances – mainly changes in available income. For example, during the course of a month, people may cease using a commercial fuel because money has run out. Or, at times, a family may borrow a small quantity of fuel (e.g. a cupful of paraffin) from neighbours. The ability to buy or borrow fuels in small quantities is one aspect of flexibility which is important in household budgeting. This is certainly one of the advantages of paraffin, for poor households. It can usually be purchased in small quantities, if required (although small quantities typically cost more per litre, so this can be an expensive survival strategy). Paraffin use is also easier to measure and see, whereas both LPG and electricity are less tangible.

An LPG user is generally committed to a certain size of LPG cylinder (leased[35] or purchased), which restricts flexibility in the amounts of fuel which can be bought at a time. In any case, it is usually not possible to buy LPG in such small quantities as paraffin. Hence the use of LPG poses greater risks to a poor household's cash flow and ability to adjust expenditures to cope with unforeseen circumstances.

Uncertain income and expenditures tend to lead to a higher liquidity preference among poor households, meaning that it is more attractive to keep cash in hand than to make investments. In this light, a monthly purchase of say 9 kg of LPG can be thought of almost as an investment, compared with more regular purchases of small amounts of fuels such as paraffin and candles. Electricity falls inbetween the two, since electricity pre-payment cards can be obtained in quite small denominations. However, if there are transport costs involved in obtaining electricity cards, this makes intermittent purchases in small amounts less attractive.

The appliances, of course, also represent an investment, and a number of factors make the cost of appliances a common barrier, including

- households' high liquidity preference and their difficulty in making investments;
- the fact that the price of appliances like LPG cylinders and cookers tend to be somewhat higher in rural areas;
- the need to have multiple appliances if a household is pursuing a multiple fuel strategy;
- associated with this, the fact that some appliances will be used less than if a household relied exclusively on a single fuel.

In summary, a household in this situation would have higher appliance costs, and less service from the appliances. It is therefore understandable that many of the poorest rural households feel that the only affordable commercial cooking appliance for them is a cheap paraffin wick stove.

In terms of end-use flexibility, electricity is the most versatile of the commercial fuels compared here. LPG, in principle, comes next – allowing both for a wide variety of cooking methods and also other energy services like heating, lighting, ironing, refrigeration, metalwork, etc.; but only if a household possesses a corresponding range of LPG appliances. In practice, LPG is used almost exclusively for cooking, heating and refrigeration among rural households in the case study area. Paraffin is the least flexible of the three. In typical cooking appliances it is more difficult to control, and also in appliances like paraffin refrigerators, control and soot can be problems, making LPG or electricity a preferred option.

---

35 Where a customer pays a deposit to use a company-owned cylinder, it seems s/he would be able to exchange this cylinder for a different size, as a standard R85 deposit was quoted by Matatiele and Cape Town suppliers, irrespective of cylinder size. However, the sizes for company-owned cylinders are 9 kg upwards, so this system would not enable a customer to purchase LPG in smaller quantities than this.

3.2.3 Health and safety

Health and safety issues arising in household energy use must surely be a prominent concern among low-income households, and from a national perspective are a very grave concern.

Exposure to smoke from open wood and dung fires or unvented stoves is particularly severe for women and children, and occurs both while tending outdoor fires/stoves and when fires are made indoors. Indoor air pollution is recognised worldwide as a very serious environmental and health concern in developing countries. The main known health correlates of high exposure to indoor air pollution from burning dirty fuels are an increased incidence and severity of respiratory diseases. These include acute respiratory infections – pneumonia being a prominent cause of death of infants in South Africa, tuberculosis – which is epidemic, and chronic obstructive pulmonary disease. There is also evidence linking exposure to wood-smoke with eye damage, asthma and adverse pregnancy outcomes. The people most at risk are women and children. Among these, acute respiratory infections are usually considered the most important smoke-related cause of premature mortality, particularly for children, but with serious risks for adults too, especially when immunity is compromised by HIV/Aids or other factors such as malnutrition.

It must not be thought that the users are unaware of the hazards. A recent survey of 150 rural households showed that the householders were almost uniformly aware of the problems caused by the fuels, and cited coughing as a major problem that would make them seek an alternative fuel if it were available and affordable.

Health and safety hazards associated with the use of paraffin include paraffin poisoning and fires. Market research commissioned by PASASA (Biggs & Greyling 2001) has indicated more than 100 000 cases of paraffin poisoning per year, with young children at most risk, and some 50 000 paraffin-related fires.

Comparable survey data for dangers of LPG use is not available, but based on reported incidents of LPG accidents, which are collected and monitored by the LPGas Safety Association of South Africa, researchers estimate that LPG is at least an order of magnitude safer than paraffin, per MJ delivered (Lloyd 2002: 60). This is one of the main reasons behind the promotion of LPG instead of paraffin for cooking.

Electricity is a relatively safe energy carrier, if wiring is sound, and it does not cause local indoor air pollution. However, if electricity is used in combination with other smoky fuels (as is common in lower-income electrified households) the benefits of electricity's clean end-use characteristics are much reduced.

3.2.4 Environmental impacts

Indoor air pollution (and local outdoor air pollution) from smoky fires and stoves were discussed above, in relation to health impacts. Other localised environmental impacts associated with use of biomass can include

- deforestation, denudation and linked ecological problems such as damaged water catchment and soil erosion (to which fuelwood collection can contribute, although other factors are also important);
- possible damage to soil fertility, if organic matter (e.g. dung) is not returned to the soil.

GHG emissions will be analysed in Section 6, drawing attention not only to carbon dioxide emissions but also other GHG components, which appear to play a large role in the CO_2-equivalent emissions impacts of inefficient and incomplete combustion of fuels like wood and dung.

From an end-user demand-side perspective, the localised environmental effects of different fuel/appliance choices are likely to play a larger role in household decisions than global emissions considerations.

3.3 Perceived barriers affecting residential LPG demand

According to conversations with informal samples of householders in the case study district, and in surrounding areas, the main perceived barriers which limit the use of LPG are

- the expense of buying LPG fuel and appliances;
- difficulties or inconvenience in accessing LPG, for households in rural villages;
- safety concerns.

To a large extent, the factors involved here are in line with supply and demand constraints discussed in earlier sections. However, safety concerns appear to a stronger *perceived* constraint, compared with "objective" assessments about the relative health and safety dangers of LPG, paraffin, biomass and electricity.

3.3.1 Price

(a) Appliances and cylinders

It is relatively easy for rural customers to compare the *purchase prices* of LPG appliances with the prices of other appliances such as paraffin or electric cookers. For vey low-income households, the cheapest paraffin wick stoves may be the only cooking appliance they feel they can afford.

It is probably more difficult for householders to weigh up the *life-cycle costs* of purchasing, maintaining and replacing appliances. Paraffin wick stoves are likely to have a shorter lifetime, and require wick replacements, while robust LPG or electric appliances are likely to have a longer lifetime and lower maintenance cost. (However, flimsy and sometimes cheaper LPG and electric appliances may not stand up to heavy regular use well.) Such uncertainties make it more difficult to make life-cycle cost assessments. However, a more important factor here is probably the difficulty in making larger investments for households with low and/or uncertain income, as discussed in Section 3.2.2 above. Life-cycle costing is difficult to optimise for the poor.

LPG cylinders represent a similar investment cost, if purchased, which can be a perceived barrier – although they are likely to give many years of service. If LPG cylinders are obtained from supply companies on deposit, the amount is somewhat less, and in principle the deposit payed could be redeemed if a household needs to recover this amount for other urgent budgetary purposes. However, for continuous LPG use, a deposit paid on an LPG cylinder remains a significant amount of money removed from a poor household's cashflow, and this is also viewed as a barrier.

(b) LPG fuel costs

LPG is widely viewed as a more expensive fuel than paraffin. In the absence of support interventions, rural LPG users in the case study area tend to be somewhat wealthier households. This backs up the perception among lower-income households that LPG is more expensive to use than alternatives such as biomass and paraffin.

In practice, it is quite difficult for any household to make accurate assessments of the different costs of using paraffin, LPG or electricity for cooking. Fuels are often used for multiple purposes (heating, cooking, lighting, etc) making it harder to disaggregate monthly cooking costs for a particular fuel. Multiple fuels may be used for different cooking tasks, again making disaggregation more difficult. Few households would have the motive or reasonable opportunity to *make experiments* that could give them a better basis to judge the costs of their various available cooking options. For example, an electrified household might gain a better judgement of the relative energy bills from using electricity, LPG or paraffin for cooking by choosing to use just one of these fuels at a time, and comparing energy bills. This would require a household investment in three types of equivalent cooking appliances (for paraffin, LPG and electricity), and there would also be other barriers making such an experimental approach impractical or unlikely. Based on these considerations and on community workshop discussions, it seems probable that most rural householders in the case study area – and most householders anywhere in South Africa – do not have an accurate way of comparing the energy costs of various cooking options.

The perception that LPG, at current prices, is a more expensive cooking fuel than paraffin is probably correct in the case study area (based only on fuel costs, and leaving out externalities). However it is interesting to compare the perceived ranking (based on interviews with sampled households) of cooking-energy costs with the rankings suggested by this case study.

Table 11: Perceived and assessed cost-rankings of different cooking energy costs in the case study area (based only on equivalent fuel prices for households, excluding externalities)

Cost-ranking, lowest to highest	*Perceived cost-ranking*	*Assessed cost-ranking (see Table 6 for main assumptions)*
1	Biomass	Biomass
2	Paraffin	Electricity
3	LPG	Paraffin
4	Electricity	LPG

The major difference is the assessed cost advantage of electricity, at current prices.

(c) Transport costs for LPG customers
These are closely related to "access" barriers (see below). Depending on how far a village is away from a town, or another supply-point for LPG, rural LPG customers have to factor in the transport costs they incur in obtaining LPG supplies.

3.3.2 Access

Difficulties of access to LPG can vary, both in terms of how far a village is from a town (or other LPG supply point) and how far a homestead is from a transport drop-off point (such as a bus stop, or taxi route). The majority of rural villagers do not have their own motorised transport and rely on some form of public transport service, predominantly buses and mini-bus or light delivery vehicle taxis.[36] In some areas, roads may be impassable during periods of bad weather. Hilly terrain can also make it more strenuous to carry LPG cylinders to a homestead.

Apart from the costs and difficulties of travelling to an LPG supply point, there are also time and inconvenience aspects which reinforce the perception that access is a barrier. A bus trip from village to town may entail taking a morning bus in, and returning on an afternoon bus, possibly with a long period of queueing in between, as many people make their fuel purchases on days when they receive income (e.g. after pension payments).

3.3.3 Safety

Some householders in the area have reported that they would not use LPG because they think it is too dangerous (or because older members of the family think it is too dangerous). One view here is that although paraffin is also regarded as risky, if a paraffin fire occurs this is less likely to result in loss of life, whereas a gas explosion could have devastating effects.

It is not known whether there have been any direct experiences of gas explosions in the case study area.

There may be some underlying reasons why many people think "instinctively" that LPG is more dangerous. The fact that it is invisible, and perhaps also the hissing sound, may be alarming.

Based on experiences in other parts of South Africa, it appears that familiarity with LPG use can have a contagious effect, and that there can be quite different attitudes towards LPG safety from one community to another. One finds communities where LPG is widely used (supported by other factors, such as remoteness from the grid, decent LPG access and somewhat higher income levels) and others, even nearby, where hardly any households use it. If safety concerns are a collective reason for some communities avoiding LPG use, it would be useful to provide them with accurate information. One way of doing this could be to collect households' experience of using LPG, in communities where it is more widely used, and transfer this information to other communities – for example, through community video, local radio broadcasts, or exchange workshops. It is likely that people would trust and understand information expressed by other rural families to a greater extent than, say, safety awareness campaigns by a company or industry association.

[36] Some taxi services may be unwilling to transport LPG. However, buses in the case study area regularly transport LPG – larger cylinders on roof racks, smaller ones in side compartments.

3.4 Price-sensitivity of LPG demand

There is not enough evidence to construct realistic demand curves for residential LPG use, as a function of price. Unfortunately the same is true for the energy options against which LPG competes in South Africa, including electricity and paraffin. Nonetheless, it may be useful to consider possible LPG demand characteristics for different market segments, in terms of their income levels, preferences and the costs and availability of competing fuels.

3.4.1 Demand curve model

Appendix A describes a heuristic model that was constructed to explore the probable shape and sensitivity of residential demand for LPG as a cooking fuel. It compares prices of useful cooking energy for paraffin, LPG and grid electricity, using the same estimates for cooking efficiencies as presented in Table 6 earlier. The model makes the assumption that people can choose which cooking fuel they adopt, on the basis of the price per useful kWh. It does not take account of possible barriers to fuel switching such as the existing ownership of appliances, or the fact that it is difficult for customers to know accurately which cooking fuel costs least to use. However, it allows for the fact that paraffin, LPG and electricity offer different quality cooking services, and that a proportion of customers will be willing to pay a price premium for using a preferred fuel. The proportions of households willing to pay such price premiums, and the corresponding margins, are modelled as a function of income levels, with lower-income households less able to make discretionary expenditures. The maximum cooking energy bill which households are willing to pay is also modelled as a function of income levels (up to a point where the requirement for cooking energy is considered saturated). Income distributions are modelled for different situations, using a variable-parameter Weibull distribution.

An important constraint in the model is the degree of access to grid electricity. The proportion of households without grid electricity is modelled (again, with some income-dependence) for four typical settings:

- "deep rural areas" (where the majority of households do not have access to grid electricity);
- "mixed rural areas" (where a larger proportion of households have access to grid electricity, but many do not);
- "poor urban areas" (where electrification rates are quite high, overall, but a significant minority lack access to electricity or electric cooking appliances, and income levels are low);
- "mixed urban areas" (including poorer urban areas as well as higher-income areas, and with very high electrification rates for higher-income households and thus a higher overall electrification coverage, plus higher levels in the overall income distribution).

Examples of model results are provided below for a "mixed rural area", which represents conditions in the case study area, and also for a poor urban situation, intended to represent lower-income suburbs and settlements in Cape Town.

3.4.2 A rural demand curve

The modelled demand curve in Figure 7 is based on a paraffin price of R3/litre and an electricity price of 40 cents/kWh. The modelled percentage of households with access to electricity in this example varies from 30 to 60%, in different income categories (averaging 42% overall). The assumed income distribution is shown in Figure 6.

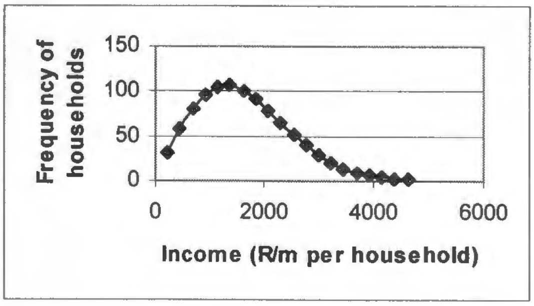


Figure 6: Rural income distribution for this example

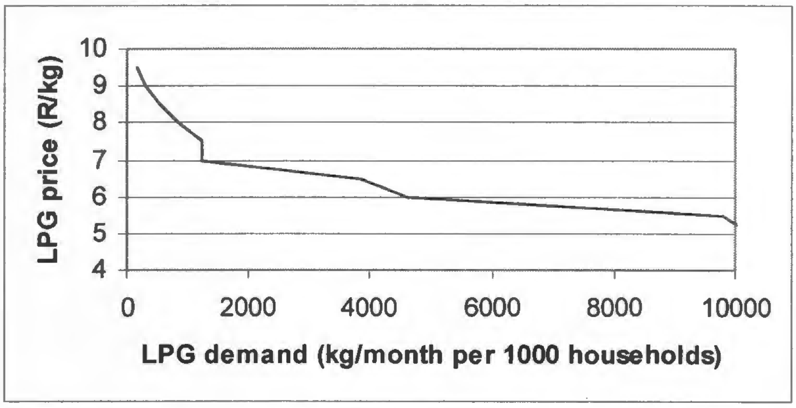


Figure 7: Modelled LPG demand curve for a mixed rural area.

It can be seen that, on the model assumptions employed in this example, the aggregate demand for LPG is very sensitive to LPG price, with larger numbers of households opting for LPG as a cooking fuel as the price falls. This reflects mainly a choice for LPG rather than paraffin in *non-electrified areas*, if the energy costs of using LPG are comparable with or lower than the costs of using paraffin. The demand is very price-elastic, for LPG prices below R7/kg, first attracting increasing numbers of somewhat wealthier households (willing to pay a 20% premium to use LPG rather than paraffin, according to the model's assumptions) and then at lower prices attracting larger numbers of non-electrified paraffin users who are less able/willing to pay such a premium.

However, in the LPG price range shown in Figure 7, there is not much competition between LPG and grid electricity at 40 cents/kWh. Only a minority of households with access to grid electricity would be expected to opt for LPG, based on useful cooking energy costs.

At prices higher than R7/kg, the model predicts restricted LPG use by a small number of wealthier households in this situation. Notably, an LPG supplier retailing at higher costs in this market would gain lower revenues, because the inelastic portion of LPG demand is small compared with the larger volumes of sales that could be expected at lower prices.

3.4.3 An urban demand curve

By comparison, Figure 9 shows a modelled demand curve for residential LGP for a relatively low-income urban area. The average assumed electrification rate in this case is 85%, and the assumed income distribution is as shown in Figure 8. Other model parameters are the same as in the rural example above. Note that the model is only intended to apply to LPG for regular cooking purposes and does not cover other applications like space heating, or portable cooking applications (e.g. for camping, barbecues and other outdoor functions).

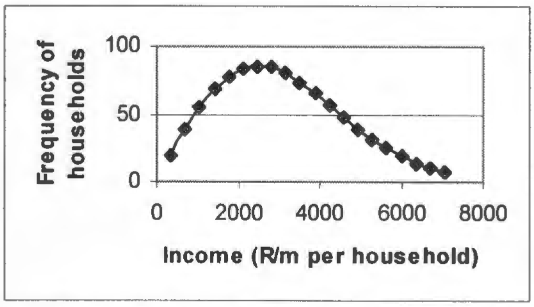


Figure 8: Urban income distribution for this example

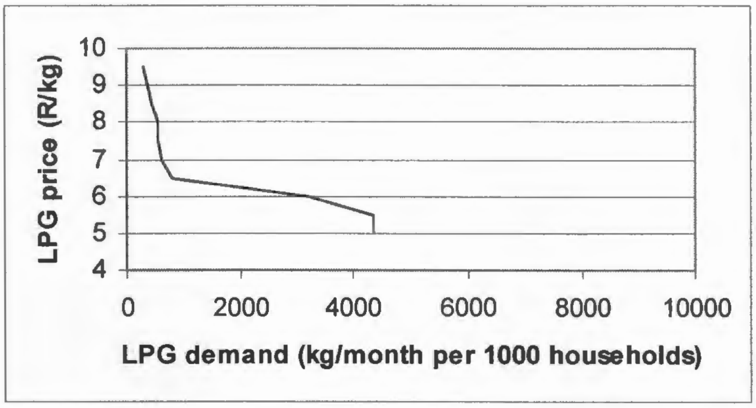


Figure 9: Modelled LPG demand curve for a low-income urban area

In this case, it can be seen that the model predicts that there would be a minority price-inelastic demand for LPG at prices above about R6.50/kg. At prices below this, another category of customers could be expected to switch to LPG – mainly those without electricity, who are willing to pay a premium to use LPG. If LPG prices dropped further, e.g. below R6/kg, most households without electricity should consider LPG, together with a minority of other (wealthier) households that prefer to use LPG rather than electricity for cooking. At the prevailing electricity price of 40 cents/kWh, assumed in this example (and currently applicable in practice), and based on the efficiency assumptions indicated in Table 6, the LPG price would have to drop to even lower levels (e.g. R4.40/kg) in order to openly compete with electricity, in terms of the costs for useful cooking energy. These levels are not shown in Figure 9, but Section 3.4.5 below discusses the sensitivity of LPG demand to electricity prices in such a setting.

Surveyed retail prices for LPG in low-income suburbs of Cape Town were in the order of R8.30/kg (October 2002), which would fall in the inelastic high-gradient section of the modelled demand curve. Once LPG prices rise to this inelastic demand zone, revenues from LPG sales can be maximised by raising the price above a competitive level, as discussed below.

3.4.4 Discussion

The two examples of modelled LPG demand curves show a number of features worth comment.

i) The larger aggregate demand (per 1000 households) in the rural example directly reflects the lower levels of electrification in that example, compared with the urban case.

ii) Among households identified as not having access to grid electricity, paraffin is the competing fuel in this model. Even at high LPG prices, a minority of households are assumed to be willing to pay a significant premium for using LPG rather than paraffin (wealthier households). At lower LPG prices, LPG becomes more attractive than paraffin for an increasing proportion of other households (lower income) that are assumed to be less willing or able to pay a significant price premium.

iii) The modelled features of the demand curves are of course sensitive to the assumptions and variables employed in these examples, including the prices of paraffin and grid electricity, conversion efficiencies and, in the case of premiums, what percentage of households are willing to pay a premium and if so how much. (See Appendix A.)

iv) A striking difference between the modelled rural and urban demand curves lies in their different shapes. Because of higher electrification levels, the urban demand curve has a more pronounced section – for LPG prices above R6.50/kg – which is steep and relatively insensitive to price. In order to get onto the flatter section of this curve, prices would need to be less than R6.50/kg. In contrast, the rural demand curve is very price-elastic at these levels.

v) The sampled (Cape Town) urban LPG prices, in the order of R8.30/kg, would clearly fall on the inelastic section of the modelled urban demand curve. If there are barriers to competition, and suppliers are able to set prices to some extent, they could maximise their revenues by maintaining higher prices, on this inelastic section of the demand curve.

vi) On the other hand, if the suppliers were able to get onto the flatter section of the curve (e.g. at prices around R6/kg) they could achieve higher revenues by the increased volumes. Whether this would increase their profits, however, depends on the change in margins that would be needed to achieve the lower price. In addition, there may be supply-side barriers which work against lower prices.

vii) One should also bear in mind that, particularly in urban areas, the low-income LPG cooking market is just one segment of the market for LPG in cylinders to households. Other segments such as the camping and leisure market, and discretionary use of LPG for gas fireplaces, for instance, are expected to be quite price inelastic. In combination, this woud increase the profit incentives to maintain higher prices. Maintaining higher prices, however, presumably requires some effective restrictions on price competition among suppliers.

viii) In the rural case, the modelled demand curve shows that maximum revenues, and almost certainly maximum profits, would be achieved by going for high sales volumes. The curve is so price elastic that even if lower margins are needed to achieved higher volumes, this is still likely to lead to higher overall profits. It is understandable in such a situation that LPG suppliers would compete to achieve lower prices and higher volumes.

ix) Nonetheless, the model indicates that the relatively low cost of electricity (at current prices) remains a constraint that should be expected to restrict the demand for household LPG. This constraint would be reinforced if a basic electricity support tariff is introduced, bringing down even further the average R/kWh costs of using electricity, for households using this tariff.

3.4.5 Sensitivity of residential LPG demand to electricity prices

Figure 10 models demand curves for LPG (for cooking, among lower-income households) at different electricity price levels. In order to illustrate the price competition between LPG and electricity more clearly, this example uses model parameters for a "poor urban area" (as in Figure 9), where there is relatively high access to electricity (85% overall).

The three electricity prices in this example are 30, 40 and 50 cents/kWh. 40 cents/kWh is a typical prevailing price at present. 30 cents/kWh would be an average price if a basic electricity support tariff is introduced, as described in Section 3.1.2, for a household consuming about 170 kWh/month.

As noted earlier, the model for residential LPG demand only targets the use of LPG for regular cooking purposes, and is based on an assumption that households would choose the cooking-energy option with lowest useful energy costs (apart from a proportion of households willing to pay a price premium for preferred cooking fuels). The assumptions for the calorific values and useful cooking conversion efficiencies of paraffin, LPG and electric cooking options are important in making such cost comparisons (see Table 6).

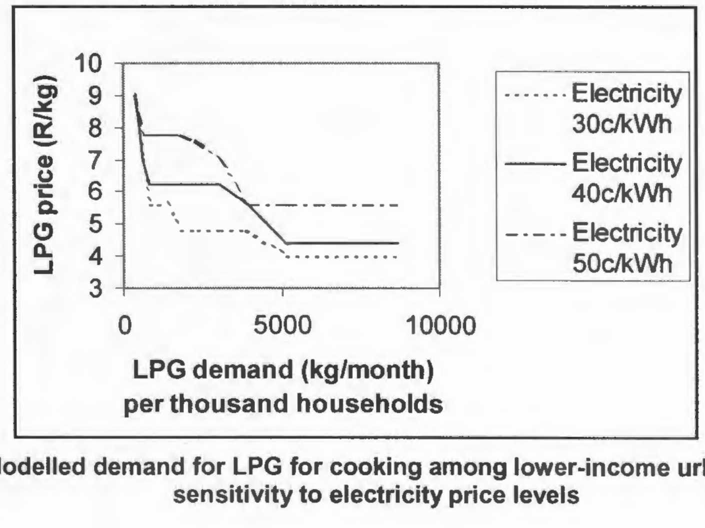


Figure 10: Modelled demand for LPG for cooking among lower-income urban households: sensitivity to electricity price levels

Essentially, this comparison indicates that large numbers of electricity users would only be expected to switch to LPG if LPG were cheaper than about R4/kg (with electricity at 30 cents/kWh), R4.40/kg (electricity 40 cents/kWh) or R5.60/kg (electricity at 50 cents/kWh).

Current LPG prices for household cylinders in Cape Town are roughly twice these indicated amounts. Both a significant reduction in LPG price and an increase in electricity prices would probably be needed to make LPG financially more attractive than electricity for cooking.

4. Energy sector linkages

An increased use of LPG for cooking would have an impact on other energy carriers currently in use. This section briefly examines some of these linkages.

4.1 Displacement of paraffin and biomass

One of the hoped-for effects would be a reduction in the use of paraffin and biomass. The motives for displacing paraffin lie mainly in the health and safety risks associated with domestic use of paraffin in South Africa. (It is important to note that fuel substitution is not the only way of reducing paraffin poisoning and fires, and that paraffin safety measures and awareness campaigns as promoted by PASASA will remain vitally important.) One of the main reasons for seeking a reduction in biomass use for cooking is the health damaging effects of exposure to smoke. Again, it is important to recognise that fuel substitution is not the only way of reducing such smoke exposure, and that other strategies such as promotion of vented stoves or awareness campaigns to highlight the dangers of smoke exposure should be conducted as well.

Where biomass is used on a non-commercial basis, it is likely that poorest households will continue to use it for some or most of their cooking and heating needs. One could at most expect a partial shift to LPG, assuming LPG use could be made more affordable, among such households. Households using *commercialised* biomass for their regular cooking would be more likely to shift to affordable LPG. However, if a primary motive to make LPG more affordable is to achieve a significant reduction in the smoke hazards and other burdens of biomass use, this would probably require **strong** support measures including fuel-price subsidies, backed by policy, in order to reach the lowest-income households who bear the highest risks.

Displacement of paraffin could have commercial impacts on some companies and dealers who are involved in the distribution and sales of paraffin and paraffin appliances. Other companies and dealers who trade in both LPG and paraffin (which of course includes the supplying oil companies) would presumably gain from increased LPG sales while losing on domestic paraffin volumes, with little net effect unless the profit margins are very different.

4.2 Links with electrification

There are a number of inter-linkages between increased domestic LPG use and the direction of South Africa's electrification programme.

Firstly, at current prices (and even more so, if a subsidised electricity "poverty tariff" is introduced) there would be little incentive for a low-income household to use LPG for cooking, rather than electricity. At some future time, South African electricity prices will probably need to rise, when the effects of the country's excess generation capacity run out, but until then and as long as the delivery of affordable electricity is considered a key social goal in the government's energy policies, there will be efforts to keep electricity prices low. This would be a constraint on increased use of LPG for cooking. At the same time, electric cooking carries the same (or better) *local* environmental benefits for households, compared with LPG, although of course coal-fired electricity has high emissions at point of generation. A strong policy and set of measures to reduce the local environmental and health hazards of indoor (and local outdoor) pollution from dirty use of biomass fuels could reasonably focus on making electricity more affordable for cooking in areas where grid electricity is available, and making LPG more affordable for households living in off-grid areas.

However, before discussing the use of LPG for off-grid households, it is relevant to consider some tensions between different objectives in South Africa's electrification programme. One policy objective is to achieve virtually universal *access* to electricity in the country, both through expansive grid electrification and a parallel non-grid electrification drive. Another is to make electricity consumption *affordable* for the poor. Cheap electricity ought to imply an increased use of electricity for cooking (unless there are very low current limits imposed, and not in the case of solar electrification) and the introduction of a poverty tariff would surely bolster this – bringing real energy advantages to the poor. However, an increased use of electricity for cooking could have a significant impact on electricity demand profiles, particularly in low-income settlements where there is little diversity of electric loads. Load factors could be severely affected by simultaneuous peak cooking loads. This would raise the kVA capacity required (in distribution lines, transformers, etc.) and could raise the costs of the electricity supply. Conversely, a key element in the success of South Africa's rapid rural electrification has been the ability to *bring down* average electricity supply costs, year by year. This has partly been achieved through providing lower-capacity supplies (or designing systems for a lower average After-Diversity Maximum Demand); and increasingly, as Eskom tries to electrify settlements further away from the existing network, a "weak grid" approach is considered attractive – designing systems for very low after-diversity maximum demands. An assumption here is that most lower-income rural households will *not* be using electricity for cooking, as at present, and will instead continue to use biomass, paraffin, or preferably LPG for this purpose. If instead large numbers of households switch to electric cooking, larger capacity requirements will increase the electrification costs and reduce the speed at which remoter communities can be electrified. In the process, social equity would be compromised, even if the parallel non-grid electrification programme proceeds successfully.

In the particular South African context of high expectations and rapid delivery of rural grid electrification, it is possible that the lower social benefits of non-grid electrification will become increasingly politicised, particularly if people perceive that their more basic energy needs for cooking are not being addressed in an improved way.[37]

There are still some uncertainties about the future success of the non-grid electrification programme (with attached government subsidies, to attract the interest of major companies and utilities to take part). At present, even with a government subsidy of R3500 per installed Solar Home System, the monthly payments expected from SHS users are more than R50/month.[38] This is more than most rural grid-electrified low-income households spend on electricity per month, while the potential energy service from small solar systems is less than from a grid supply. Rural customers tend to be acutely aware of such differences, and as long as electricity provision is perceived as a basic service "provided by the government" they are likely to be less understanding about the underlying differences in supply costs.

In any event, in those areas where grid electricity is not available – whether the alternative solar electricity option is widely adopted or not – these households clearly would not have the option of subsidised grid electricity for cooking. It is suggested that:

- with current pricing structures, such off-grid communities would probably constitute the main potential market for increased use of LPG for cooking;
- in the special case of areas where subsidised solar electrification is taking place, it may be particularly important to provide improved, affordable access to a high-quality cooking fuel like LPG,[39] so that people can see the benefits of an improved integrated energy package. Without this, perceptions towards solar electrification may remain or become negative.

With quite different pricing structures (e.g. cost-reflective prices for electricity,[40] even for low-income consumers,[41] and competitive, efficient industry-pricing for LPG, brought down further by

---

37 In presentations to the Parliamentary Portfolio Committee on Minerals and Energy, rural representatives from some of the non-grid "concession areas" complained that, although solar electrification brought some benefits, "every day our women are still struggling" [to collect fuel for cooking].

38 The government, however, has proposed a further monthly subsidy for these SHS users, which could bring down their monthly payments below R20.

39 Substantial improvements in the safety of paraffin use and the quality of appliances could qualify it as a high-quality cooking fuel. Gaseous, liquid or gel fuels derived from biomass could also qualify (e.g. biogas, ethanol, ethanol-cellulose gel), with benefits of drawing on renewable resources.

40 Presumably cost-reflective prices should include externalities, such as GHG emissions in electicity generation, as well as long-term accounting for the lower costs of coal in South Africa attributable partly to historical resource-rights issues.

41 Low-income electricity consumers are restricted in the amount of electricity they can afford, and their monthly consumption rates tend to be low. The cost of supplying their electricity includes capital costs of electricity distribution, reticulation, installing meters, etc.; the monthly service costs (e.g. for system maintenance) which are fairly independent of electricity consumption levels; and the energy costs of providing the kWh consumed.

targeted government subsidies) there could be a wider potential rural and urban market for increased use of LPG for cooking and heating, including both electrified and unelectrified homes. However, given the government's commitment to grid electrification, the scale of investments already made, the desire for these electrification investments to "bear fruit" for the poor, and the identification of paraffin as the most staple alternative commercial cooking fuel for the poor, and despite the dangers of paraffin use in South Africa, it seems quite unlikely that policy-makers would support such a large strategy adjustment. It seems more realistic to focus attention on measures that could be taken to improve access to affordable LPG-use in non-electrified (and partly electrified) communities.[42]

5. Possible measures to reduce the barriers restricting LPG use for cooking

For the purpose of this case study, a limited set of measures will be considered, revolving around improved distribution, access to LPG fuel, cylinders and appliances, and end-user awareness campaigns, in the context of local rural energy centres, such as the one operated by the Caba-Mdeni Energy and Development Co-operative. This set assumes that the prices at which LPG can be delivered to the energy centres remain similar to the current LPG prices paid by the Caba-Mdeni Energy and Development Co-operative.

After discussing the measures proposed, estimates will be given for the start-up costs of establishing five such energy centres and establishing their LPG operations. Then a scenario for the impact of more affordable and accessible LPG on households' use of cooking fuels in the case study area will be put forward. In Section 6, this scenario will be used to investigate possible environmental impacts, both from the perspective of GHG emissions and of reductions in indoor air pollution.

The measures proposed below focus on reducing immediate barriers to LPG use in the case study area. They do not include more wide-ranging measures, on a national level, which might be necessary to achieve more significant reductions in LPG supply prices.

5.1 Proposed measures for improved access, through energy centres

5.1.1 Achievable price reductions and improved access

The Caba-Mdeni Energy Centre has already demonstrated that it can sell LPG at a lower cost than rural customers would otherwise pay. The current LPG price for local customers is between 6.53 and 6.67 R/kg for exchanged cylinders. This compares favourably with current urban (Cape Town) prices of around 8.30 R/kg for exchanged domestic cylinders and 9 R/kg for refilling cylinders. The Energy Centre's cost reductions are attributable to batch deliveries of cylinders, and modest profit margins. At the same time, the Energy Centre has made physical access to LPG cylinders easier for the local surrounding communities. It is quite likely that further price advantages could be achieved, as the scale of LPG sales increases, but for the present analysis that will not be assumed. Further measures to reduce barriers could include those given immediately below.

Making smaller-size cylinders readily available

This would benefit people who live fairly close to the Energy Centre, but who do not have ready access to motorised transport (or whose homes are difficult to access by road, making local light delivery vehicle deliveries impractical). Smaller size cylinders are easier to carry. A further advantage is that they would allow poorer families to buy LPG in smaller quantities. The smallest common LPG cylinder contains 1.5 kg of gas, which could presumably be refilled for about R10. For households with better access to transport, larger cylinders have the convenience of less frequent

For consumers who consume few kWh per month, the energy supply cost is low, but the other cost factors then become a larger proportion of total costs. South Africa's "HomeLight" tariff charges a flat R/kWh energy charge. People with low monthly kWh consumption are effectively subsidised, as their total payments are insufficient to cover the capital and service costs of their electricity supply. In a cost-reflective system, low consumers would have to pay more for each kWh they consume, compared with wealthier high-consumption customers.

42 It would appear that most developing countries where rapidly expanding use of LPG has taken place probably do not have such widespread access to price-competitive grid electricity as South Africa.

replacement, so an Energy Centre should ideally be able to supply or refill a wide range of cylinder sizes, serving different households' needs and resources.

It will be suggested below that the Co-op should lease or own the LPG cylinders (and possibly appliances as well). In this case, the following are proposed:

- Cookers should not be screw top, but rather connected by hose (with regulators), even when small LPG cylinders are used. The reasons are greater safety (better stability, especially when cooking in large pots)[43] and the freedom to use a range of cylinder sizes with such cookers.
- Customers served by the Co-op should be able to exchange one cylinder for another of a different size, according to the quantity of LPG they wish to purchase at a given time. Otherwise, their flexibility in budgeting energy expenditures would be reduced (as discussed in Section 3.2.2 above).

Collective co-operative ownership/leasing of the local cylinder stock could make this feasible.

Co-operative ownership and leasing of cylinders

The cost of purchasing smaller cylinders, or of paying a deposit for leasing larger ones, is considered an entry barrier for low-income households. Further, as indicated above, individual ownership or leasing of a cylinder of a particular size can reduce the flexibility of amounts of LPG purchased. It is therefore proposed that the co-op could pay for the deposits on larger cylinders, and the purchase price of a stock of smaller cylinders.

Larger cylinders which are the property of the gas distributor company are already effectively subsidised by the companies, and wasteage (cylinders leaving circulation) is a loss factor which presumably contributes to higher LPG supply prices. Community-managed responsibility for monitoring cylinder circulation could probably reduce this wasteage to a high degree. In return, it may be possible to negotiate lower LPG supply prices on this ground.

In view of the environmental advantages of using LPG for cooking, rather than paraffin, biomass, or coal-fired electricity, and the considerable health and safety advantages of LPG compared with paraffin or biomass, it is proposed that the costs for an Energy Centre to obtain and maintain a stock of cylinders should be subsidised. The maintenance costs would include training costs in safety and inspection of cylinders.

Local sale (or leasing) of suitable LPG appliances

Although a simple screw-on LPG cooker top is quite cheap, it is not entirely suitable for regular family cooking. Heavy-duty burners which can hold large pots more safely, and flat stove tops, could be preferable. These are not always readily available for rural households, and can cost more (R80 – R200 and above). A co-operative Energy Centre may be able to reduce costs by bulk wholesale buying of suitable appliances.

Even so, these LPG cooking-appliance costs are likely to remain an entry barrier for low-income households, and a case could be made for further measures to reduce this barrier. Possibilities here include

- low interest micro-finance to assist householders purchase LPG appliances;
- a leasing option that allows householders to use appliances supplied and owned by the co-op (similar in effect, except that ownership does not pass to the household, and there are some possible efficiency gains by pooling stock management, maintenance and safety inspections).

Again, in view of environmental, health and safety advantages of LPG, this case study proposes a subsidy element to reduce the entry barriers of accessing suitable LPG cooking appliances.

To increase the benefits and attractions of switching to LPG, it would also be a good idea for a rural energy centre to source and stock a range of other (non-cooking) energy appliances, like LPG irons,

[43] There may be other safety improvements in separating the cylinder from the cooker appliance. One way that LPG accidents can occur in electrified homes is when LPG is used as a back-up in cases of electricity power failures (which are more common in rural areas). The LPG cylinder-cooker may be placed on top of the electric stove for this purpose. When electric power comes back on, there can be a danger of LPG explosion if the electric stove had not been switched off. More generally, larger-size cylinders are supposed to be installed in cages outside a building, for enhanced safety. It should not be overly difficult to encourage this precaution for cylinders of any size, if appliances are of a type connected by hose. Energy Centre staff could provide a cage-building and installation service.

which are difficult to obtain, and provide information about access to more costly LPG appliances, like oven/stoves and refrigerators. The latter are likely to be affordable only for a minority of households within the supply radius of a rural energy centre, and it is more likely that appliance retailers in a rural town would have a competitive edge in such sales sectors.

5.1.2 Awareness campaigns

It is proposed that local awareness campaigns (backed up with participatory demonstrations and workshops) would be useful to help householders make well-informed choices about their household energy practices and options. The main topics would include

- better information and community demonstrations about the comparative money costs of different energy-use options, particularly for cooking and heating;
- better information about the health and safety risks of different energy-use options;
- practical information and training about ways of economising in energy use (saving money or getting superior services more efficiently) and of avoiding health and safety hazards.

The objectives here could be considered mainly public welfare benefits, and on this ground this case study proposes that the costs of such awareness campaigns should be subsidised, although it is important to recognise that local people have an interest and willingness to participate.

5.1.3 Operational and management training for energy centre staff

At present, the main line of commercial business for a community-managed rural energy centre (represented in this study by the Caba-Mdeni Energy Centre) lies in selling liquid fuels locally at a competitive price, as a result of more efficient distribution routes and reducing profit margins. These activities need to be well managed, in order to be sustainable. The low profit margins increase the need for careful management. As the scale of operations expand, leading members of the Caba-Mdeni Energy and Development Co-operative see a need for further training in business management, administration and book-keeping. There is also a need for good training in operational safety procedures, when dealing with inherently dangerous fuels like paraffin and LPG. The costs of safety training are usually contributed by fuel supply companies, or their related industry associations, such as PASASA and LPGSASA. Specific business training for establishing an outlet for a product like paraffin or LPG can be provided by the major oil companies, but it seems this is difficult to organise. More general business training for multi-product rural enterprises like energy centres seems hard to obtain, and at present this must be regarded as a major barrier.

There are strong government incentives to try and reduce this barrier towards rural enterprise, and there are also significant contributions from private-sector companies, mainly within their framework of social responsibility programmes. There are also NGO and donor-funded efforts to help support the development of rural business skills, but altogether it still seems difficult for an organisation like the Caba-Mdeni Co-op to obtain any of these kinds of support. The most appropriate route for rural business-development support is probably *via* local government (in this case, the Alfred Nzo district municipality). Municipalities like this could usefully channel national government finance into training support for the business operations of rural enterprises.

5.2 Cost estimates for establishing energy centres and their LPG operations

Based on experience gained during the establishment of the Caba-Mdeni Energy and Development Co-operative's Energy Centre, the following incremental cost elements are estimated for establishing five such centres in the Alfred Nzo district:

- organisational set-up assistance;
- training;
- equipment and facilities;
- subsidy on a stock of LPG cylinders;
- subsidy on a stock of LPG cookers;
- communications, awareness and marketing campaigns;
- technical and mnagement support for the project.

Although the process of establishing new co-operatives and energy centres would be expected to take some time – we assume a period of two years, during which a full-time faciltator works with the community organisations, in partnership with local government, DME and industry participants – the cost elements above are treated as "start-up" costs. It is assumed that after this period, the energy centres' running costs (including maintenance of stocks) will be covered by their profit margins on fuel sales. In Table 12, services which are expected to be provided as part of an agency's normal operations are indicated as "inclusive" and are not treated as part of the incremental costs of the project.

Table 12: Estimated incremental costs for establishing five community-managed rural energy centres in the Alfred Nzo district

Cost element	*Service supplier*	*Unit cost per Energy Centre (R)*	*Cost for 5 energy centres (R)*
Organisational set-up assistance			
Assistance by:	Local government		inclusive
	Existing Energy Centre staff	10 000	50 000
	Full-time facilitator in the district		700 000[a]
	DME regional staff		inclusive
Training			
Co-operatives	National co-operatives association	5 000	25 000
Business training	Local NGO	20 000	100 000
Safety training	Companies / industry associations		inclusive
Energy awareness	Facilitator		inclusive
Equipment and facilities			
Tanks and LPG cages	Fuel supply companies		inclusive
Premises	Partial project subsidy	30 000	150 000
Telecommunications	Project subsidy	10 000	50 000
LPG subsidy elements			
Deposits on 500 cylinders per EC	Project subsidy	42 500	212 500
Stock of 500 cookers per EC	Project subsidy	90 000	450 000
Communications, awareness and marketing campaigns	Project subsidy		100 000
Technical and management support	Project management		500 000 *(a)*
	TOTALS	**467 500**	**2 337 500**

Note:

a) Over two years, including salary, transport and operating costs.

If it is further assumed that each energy centre would serve 500 households (i.e. a total of 2500 households for the project as a whole) the figures above lead to a unit cost of R935 per household.

5.3 A fuel-switch scenario

A base-case model for fuel use patterns in the case study district was suggested in Section 3.1.1 above, and is summarised again in Table 13.[44] This table puts forward a scenario for how baseline fuel-use patterns (for cooking) could change, as a consequence of the greater affordability, ease of access and community knowledge of LPG.

Table 13: Base-case assumptions and a project intervention scenario for cooking energy-use patterns in the case study localities

Household type	*Model (fuels used for cooking – see Section 3.1.1)*	*Proportion of households in the case study localities*	
		Base-case	*Project scenario*
A	A typical low-income household using mainly dung, and some wood (collected by householders) as well as a small quantity of paraffin for cooking.	25%	10%
B	A moderately low-income household using commercial firewood and a limited quantity of paraffin for cooking.	25%	15%
C	A moderate income household using paraffin for all regular cooking (fuelwood only used for special occasions).	25%	10%
D	A somewhat higher-income household using a combination of LPG and paraffin for cooking.	15%	0%
E	A household using LPG for all cooking.	5%	60%
F	A household using electricity for all cooking.	5%	5%

This "project scenario" is of course only an estimate of possible impacts on fuel use changes. It is based on the following reasoning and assumptions:

- Poorest households depending mainly on non-commercial fuels (type A) are likely to find it more difficult to switch to the use of commercial fuels.
- However, they are the most at risk from exposure to smoky cooking practices, particularly householders using dung, so a pro-active assessment is estimated: 25% of households in this category in the base case decline to 10% as a result of the project intervention support (this is optimistic).
- Type B households are also constrained by income. Their use of a combination of firewood and paraffin remains cheaper (though unhealthier) compared with LPG. The base case percentage of households in this category, 25%, is assumed to decline to 15%.
- A significant proportion of type C households are considered likely to move to LPG use, if the price differential between paraffin and LPG is reduced and access to LPG fuel and appliances is improved. We assume the base case proportion of 25% declines to 10% in this household category.
- People currently using a mix of paraffin and LPG should have a strong incentive to move to LPG, if the dangers of paraffin use and comparative costs are well communicated, and the local barriers to LPG use are significantly reduced (type D households).
- This project scenario assumes, as a result of the above, that 60% of households might end up using LPG for essentially all their cooking needs (type E). However, this contains a further important assumption, which will be location-specific, and this is that the majority of households in the case study areas do not have access to grid electricity.

[44] Slight changes have been made to facilitate the GHG emissions analysis in Section 6. The 10% of households classified as "exceptions" in Section 3.1.1. have been allocated to household categories E and F for the base case.

With regard to this last point, earlier energy cost estimates (Section 3.1.3) indicated that at current prices, grid electricity should be cheaper than other commercial fuels for cooking,[45] and even more so if a subsidised Basic Electricity Support Tariff is introduced; and that there are few incentives for rural households to use LPG rather than electricity for cooking, where grid electricity is available.

An alternative scenario for grid-electrified rural areas could therefore be considered, where a large proportion of households currently using non-electric commercial fuels would switch to the use of grid electricity for cooking. Although the focus of this present case study is on the potential for increased use of LPG for cooking, the questions around increased use of electricity for cooking by the rural and urban poor is probably of greater national importance in the present policy and pricing environment.

6. Environmental assessment

6.1 GHG emissions assessment

6.1.1 Impact of GHG emissions

The basic approach to estimating GHG impacts of changes in residential energy use is first to assess the changes in energy use of different fuels, and then use the emissions factors for these fuels to estimate net GHG emissions impacts (Sathaye & Meyers 1995; Halsnaes et al. 1998; Spalding-Fecher et al. 2002). This is complicated in rural areas by the fact that many households use biomass, which, even when renewably harvested, has significant non-CO_2 GHG emissions. The emissions factors for non-CO_2 gases from biomass burning are more uncertain than those for CO_2 and also than those for fossil fuel combustion non-CO_2 emissions (IPCC 1996; Smith et al. 2000). Several recent studies have surveyed the literature to provide estimates, including for different stove-fuel technology combinations (Streets & Waldhoff 1999; Bhattacharya et al. 2000; Smith et al. 2000). We use the assumptions from Smith et al (2000) because they are recent, specific to stove technology, and reflect similar conditions to those that are expected in rural South Africa.

Table 14 shows the emissions factors used for our four fuel types. Note that for all but the last pollutant, emissions are given as grams pollutant per MJ of useful energy (i.e. energy delivered into the cooking pot). For total suspended particulates, the emissions factor is grams carbon in TSP per kilogram fuel input. We return to the non-GHGes in the next section.

Table 14: Emissions factors used in this case study (g/MJ useful energy)
Source: Smith et al (2000)

	CO_2	CH_4	N_2O	CO	NMHC[a]	TSP[b]
Fuel wood –open fire	503	3.44	0.065	23.7	3.53	1.97
Dung – metal stove	929	5.16	0.279	44.9	17.0	1.61
Paraffin – wick	140	0.0134	0.00366	0.819	0.689	0.449
LPG – gas ring	126	0.00203	0.00598	0.608	0.764	0.514

Notes
a) NMHC: non-methane hydrocarbons
b) Units are g-C TSP per kg fuel input.

For biomass fuels, these emissions factors are somewhat different than IPCC default factors, which do not take into account how the fuels are used. The methane emissions factors used here are lower for wood, LPG, and paraffin, but somewhat higher for dung. For nitrous oxide, the factors used here for dung are significantly higher than the IPCC default values, as are those for LPG. This is based on the fuel and appliance specific testing done for the Smith et al (2000) study, which also matched similar detailed studies done for other regions.

[45] Except commercial fuelwood, if prices are as low as 30 cents/kg, as quoted for the Caba-Mdeni Energy Centre. Even at this price, however, a subsidised basic electricity service tariff would come out slightly cheaper, per unit of useful cooking energy, according to assumptions referred to in Section 3.1.3.

Table 15: Emissions factors used in this case study and IPCC emissions factors (g/kg fuel input)
Source: Adapted from Smith et al (2000) using different stove efficiencies

	CH_4	N_2O	CO	NMHC
Wood (eucalyp-3 rock)	2.5	0.06	53	7.1
Wood-IPCC	5	0.06	80	9
Dung (trad mud)	6.2	0.33	54	20
Dung -IPCC[a]	4	0.05	68	8
Paraffin (wick)	0.25	0.067	15	13
Oil-IPCC[b]	0.4	0.03	0.9	0.2
LPG (ring)	0.055	0.16	17	21
Gas-IPCC[c]	0.2	0.005	2	0.2

Notes
a. IPCC emissions factors given for large scale use of "other biomass and wastes" and average net calorific values given for "dung" and "agricultural waste".
b. IPCC emissions factors given for "oil" and net calorific value given for "other kerosene".
c. IPCC emissions factors given for "natural gas" and net calorific value given for "LPG".

For electricity emissions factors, we use the draft rules for small scale CDM projects which say that for projects that produce or displace grid electricity, the emissions factor can be based on (a) weighted average of the plants forming the operating margin, (b) an average of the weighted average operating and build margins or (c) weighted average of plants corresponding to dispatch data (see Kartha et al. 2002, for more explanation of the methodology for the first two). For South Africa, the operating margin would be 917 g CO_2/kWh, while the average of operating and build margins would be 949 g/kWh (Bosi & Laurence 2002). The project developer would obviously prefer the higher baseline, and so we use the combined margin in this case study. We have not included non-CO_2 emissions for electricity, because their contribution is so small.[46] Including rural transmission and distribution losses of 20% (Spalding-Fecher 2002a) gives an emissions factor of 1.19 kg CO_2 per kWh delivered to the home.

Based on the fuel consumption patterns, appliance efficiencies, and emissions factors for the fuel-appliance combinations, Table 16 shows the total annual emissions from each household type. Of course, in the homes using all electricity for cooking (type F), indoor emissions will be zero, although there will be emissions from the power stations of all of these pollutants. We have therefore included the carbon dioxide emissions from Eskom power stations for type F homes.

Table 16: Annual emissions by household type (kg/year)

Household type	*A*	*B*	*C*	*D*	*E*	*F*
CO_2	3146	1470	734	690	657	2461
CH_4	14.3	1.85	0.070	0.0366	0.0106	n/a
N_2O	0.752	0.0591	0.0191	0.0259	0.0313	n/a
CO	137	41.2	4.28	3.66	3.18	n/a
NMHC	47.9	7.50	3.60	3.82	4.00	n/a
TSP[a]	4.23	1.50	0.128	0.112	0.099	n/a

Note
a. Kg of carbon in TSP form, not total weight of TSP

To convert the GHG emissions into carbon dioxide equivalents, we use Global Warming Potentials, which reflect the contribution of the gases to radiative forcing of the atmosphere relative to carbon dioxide (See Table 17) (IPCC 2001). The IPCC does not give default emissions factors for carbon monoxide and non-methane hydrocarbons in the Third Assessment Report, but these were included in earlier assessments and are used here (IPCC 1990). Only the first three gases are included in the Kyoto Protocol, and therefore these are the only gases eligible for carbon credits under the CDM.

46 Eskom N_2O emissions in 2001 were 2.154 kt, or 638 kt CO_2 equivalent (Eskom 2001). On net production of 186 590 GWh, this is 3 g CO_2 equivalent per kWh, or one third of one percent of CO_2 emissions.

We therefore calculated two versions of total GHG emissions – a "Kyoto Protocol" basket and a "full GHG" basket. We assume that the biomass fuels are carbon dioxide neutral, since the carbon dioxide is taken up by regrowth. There is a great deal of uncertainty in South Africa about land use changes and the sustainability of biomass use, however, with the national inventories suggesting increasing forest cover due to commercial forestry expansion while other studies point to local fuel wood scarcity (Scholes & Van der Merwe 1995; Spalding-Fecher 2002c). The results for the household types are shown in Table 18.

Table 17: Global warming potentials used in this study

Source: CO_2, CH_4, N_2O (IPCC 2001); CO, NMHC (Smith et al. 2000)

CO_2	CH_4	N_2O	CO	NMHC
1	23	296	1.9	4.1

Table 18: GHG emissions by household type (kg CO_2 equivalent/year)

	A	B	C	D	E	F
Kyoto Protocol gases	800	551	741	699	666	2461
Full GHGs	1256	660	764	722	688	2461

As Table 18 shows, including the additional gases makes a significant difference in households that rely heavily on dung and wood, but only small changes for households using commercial fuels. In fact, households that use only LPG (type E) would have higher emissions that those using wood and paraffin if we only consider Kyoto Protocol gases, while emissions would be almost equal if the full basket is considered.

The implications of the different household emissions levels are that, for the project to generate carbon revenue, it as important to shift homes using dung to LPG as it is to shift those using large amounts of paraffin. The baseline and project case are defined by the share of households with different fuel use patterns. Table 19 shows the share of households for each fuel use pattern in the baseline and project cases. The project intervention would shift all of those homes using a mix of paraffin and LPG to using only LPG. For the other household types, we assume that some households will still use fuels other than LPG after the intervention, depending on social-economic circumstances and social/cultural preferences. Tables 20 and 22 show the resulting GHG and indoor air emissions, respectively. The columns headed "project" assume a total sample size of 2500 households in the project area.

Table 19: Share of households by fuel use pattern

	A	B	C	D	E	F
Baseline	25%	25%	25%	15%	5%	5%
Project case	10%	15%	10%	0%	60%	5%

Table 20: Weighted average emissions per household and for project

	Per H/H (kg/yr)	Project (tonnes/yr)
Kyoto Protocol basket		
Baseline	784	1 961
Project case	759	1 899
Avoided emissions	25	62
Full basket		
Baseline	936	2 340
Project case	837	2 093
Avoided emissions	99	247

As Table 20 shows, the GHG impacts of the project, if we only include the Kyoto Protocol gases, are quite small – only a 3% reduction in emissions. This is because many of the households were using renewable energy sources for cooking (and so moving to LPG increases carbon emissions), many households continue to use fuels other than LPG, and also because the efficiencies of paraffin and LPG stoves (the main shift in commercial energy) are not dramatically different. If we include the additional GHGes, the project intervention leads to an 11% reduction in household emissions.

6.1.2 Possibility of carbon financing

The LPG intervention has been presented here as a potential project based emissions trading initiative, which could receive funding through the Clean Development Mechanism under the Kyoto Protocol or through other bilateral and multilateral carbon financing channels (Spalding-Fecher 2002b). The question for the project developers, however, would be whether the potential carbon revenue would more than offset the additional costs of preparing a project proposal and monitoring changes in emissions.

One of the first challenges with the project is that it will result in higher energy expenditures for the community, even though it would also substantially improve the cooking service households receive. Table 21 shows the weighted average energy expenditures for the baseline and project cases, which increases by more than a quarter.

Table 21: Weighted average energy expenditure

	Per H/H (R/yr)	*Project (R m/yr)*
Baseline	848	2.1
Project case	1 076	2.7
Change in costs	228	0.6

Could some of this increase in energy costs be offset by carbon revenue? It would seem quite unlikely. With the reduction of emissions of only 62 tonnes of CO_2 equivalent per year, as given in Table 20, and carbon prices in the range of \$1 to \$5/tCO_2 (Natsource 2000; Bailie et al. 2001; Spalding-Fecher 2002a), this amounts to only R620 to R3100 additional revenue for the project! Even if the CDM investor only put in the upfront costs of the intervention of R2.3 million (see Section 5.2) and received all of the carbon credits for 21 years,[47] this would amount to an investor price of \$175 per tonne of CO_2, which is clearly well above the range of any carbon investor. For these reasons, we have not taken project-based emissions trading assessment any further for this case study.

6.2 Indoor air pollution impact

Indoor air pollution caused by smoke and pollutants from wood, other poor quality biomass, and in some regions coal, is one of the leading health threats worldwide. According to the World Health Organisation, indoor smoke from solid fuels is the fourth highest contributor to the overall burden of disease (WHO 2002). It is responsible for roughly 4% of the total life years lost (adjusting for disability) in the developing world, after underweight births, unsafe sex and unsafe water, sanitation and hygiene (ibid.). In South Africa, the number two cause of death among children is acute respiratory infection (von Schirnding et al. 1991). Much of this is directly related to indoor air pollution as a risk factor (Van Horen 1996). A study by Terblanche et al (1993), for example, found indoor total suspended particulate levels in homes using wood and coal for space heating to be 3 to 8 times above acceptable health guidelines (i.e. WHO guidelines), while a third of homes had indoor sulphur dioxide levels 2 to 10 times above safe levels. For paraffin using households, however, the main risks are from poisoning of infants who accidentally ingest paraffin stored in cold drink bottles, and burns from fires caused by paraffin stoves (Spalding-Fecher et al. 2000). A major new study commissioned by the Paraffin Safety Association of South Africa (PASASA) provides the most comprehensive estimates of the number of paraffin poisonings and burns to date (Biggs & Greyling 2001). The number of cases for both, based on a national survey, are significantly higher than earlier

[47] This is the maximum crediting period for CDM projects, although the baseline would be revised twice during this time.

estimates – 53 000 cases of poisoning and 50 000 burns, as opposed to 16 000 and 8 000, respectively.

In contrast to the modest reductions in GHG emissions, the project intervention would cut indoor air pollution emissions in half in most cases, as shown in Table 22. While linking this to changes in ambient air quality indoors and illness incidence is beyond the scope of this report, we would expect significant reductions in adverse health impacts. Using the most recent external costs estimates for household fuels (see Appendix B), the weighted average reduction in household external costs from fuels (wood, dung,[48] and paraffin) would be roughly R450 per year. This assessment is not complete, however, since it does not include any external costs for household-level impacts of LPG or electricity due to lack of data. Nevertheless, it gives an indication of the significant local benefits from the shift towards LPG, assuming that safety issues are adequately addressed.

Table 22: Weighted average indoor air pollution emissions per household and for project

Baseline	*Per H/H (kg/yr)*	*Project (tonnes/yr)*	*% reduction*
– CO	46	116	
– NMHC	16	39	
– TSP	1.21	3.02	
Project case			
– CO	22	55	*53*
– NMHC	9	22	*44*
– TSP	0.57	1.43	*53*

[48] We have set the external cost of dung equal to that for fuelwood, which is conservative given the much higher levels of pollutants from dung smoke.

Appendix A: Heuristic model for household LPG demand curves

General description

The intention is to model household LPG demand for cooking energy, as a function of LPG price, for varying contexts in South Africa. The model concentrates on the comparative prices, availability and preferences for alternative/competing domestic cooking fuels such as paraffin, LPG and electricity. The model is designed to apply to batches of households (e.g. 1000 households at a time) within a certain locality or context, for example in

- "deep rural areas" (where the majority of households do not have access to grid electricity);
- "mixed rural areas" (where a larger proportion of households have access to grid electricity, but many do not);
- "poor urban areas" (where electrification rates are quite high, overall, but a significant minority lack access to elelectricity or electric cooking appliances, and income levels are low);
- "mixed urban areas" (including poorer urban areas as well as higher-income areas, and with very high electrification rates for higher-income households and thus a higher overall electrification coverage, plus higher levels in the overall income distribution).

Each of these situations (or others which can be added) can be characterised in terms of

- income distributions for households in the area;
- prevailing retail pricès (or what-if prices) for the main competing cooking fuels in the area;
- degree and distribution of access to grid electricity in the area.

The model is based on the broad assumption of households choosing to use the cooking fuel which delivers the useful cooking-energy service at lowest cost. This assumption ignores some barriers which would make it difficult for households to achieve this, such as lack of information about comparative costs. It also does not try to factor in appliance costs, and the resistance to fuel switching which can result from existing appliance ownership and reluctance to buy new appliances. However, it recognises that the quality of cooking-energy service is different for paraffin, LPG and electricity – for example, paraffin may be more dangerous, LPG easier to control, etc., and tries to account for such differences in service quality by postulating that some households will be willing to pay a price premium for using higher-quality cooking fuels.

The proportion of households willing to pay such a price-premium for higher-quality services is modelled as a function of their discretionary budget for meeting cooking energy expenses. This in turn is a function of income distributions in an area and available options.

For a batch of households in a particular situation, the model estimates the number of households (per income category) that would choose to use LPG for cooking, rather than alternative cooking fuels, and if so their probable LPG consumption in kg/month. For the entire sample situation, the estimated LPG consumption is aggregated. The total LPG consumption for this batch is a function of LPG price (and any other factors in the model which can be altered to conduct sensitivity analyses). For a given set of situational assumptions, LPG demand curves as a function of LPG price are obtained by using a spreadsheet data table which calculates aggregate LPG demand (kg/month per 1000 households) for different LPG retail prices (R/kg).

Brief description of sub-models (with references to worksheets)

The parameters for the model are entered in the main worksheet, "*Model*" and the main results are presented in the same worksheet. Other worksheets perform calculations and/or contain model data such as access-to-electricity data.

Size of batch considered

The number of households considered as a batch can be enetered. For examples in this case study, batch size was 1000 households per situation.

Local situation income distribution
This can be modelled using a Weibull distribution, or data can be used where income distributions are known (worksheet: *"Weibull income distribution"*).

The Weibull frequency distribution is given by

frequency (x) = (alpha / beta **exp** alpha) * x **exp** (alpha – 1) * e **exp** (– (x / beta) **exp** alpha)

The alpha and beta parameters can be varied to change the shape and scale of the distribution. The median income can be set as well. The resulting frequency distribution is displayed in worksheet *"Model"*.

Values used for the examples presented in Section 3.4 were

	alpha	*beta*	*median R/month per household*
Mixed rural area	2	8	1 500
Poor urban area	2	10	3 000

Prices of competing fuels
These are entered in *"Model"*. For the examples in Sections 3.4.2 and 3.4.3 the paraffin price was set at R3/litre and the electricity price at 40 cents/kWh (incl. VAT). Setting the LPG price does not affect the demand curve calculations, because a data table runs through a range of LPG prices (this range settable inside the data table) in *"Model"*.

To conduct sensitivity analyses on varying fuel price combinations (e.g. varying electricity prices) separate demand curve data must be obtained for each set electricity price and then transferred (*paste-special-values*) to the worksheet *"Sensitivity"*.

Access to electricity sub-models
Different levels of access to grid electricity are modelled in worksheet *"Electricity access"*. These are indexed to income levels. Different profiles are entered for deep rural areas, mixed rural areas, poor urban areas and mixed urban areas. Other profiles can be entered. Which sub-model is used depends on specifying the sub-model number in *"Model"*. Data used for the examples in Sections 3.4.2 and 3.4.3 were:

	Model number				
	1	*2*	*3*	*4*	*5*
	Deep rural	*Mixed rural*	*Poor urban*	*Mixed urban*	*Other*
Income index	*% households with access to grid electricity*				
1 (low)	0%	30%	70%	70%	0%
2	0%	30%	70%	70%	0%
3	0%	30%	70%	70%	0%
4	0%	30%	70%	80%	0%
5	0%	30%	70%	80%	0%
6	0%	30%	70%	80%	0%
7	0%	40%	80%	80%	0%
8	0%	40%	80%	90%	0%
9	0%	40%	80%	90%	0%
10	0%	40%	90%	90%	0%
11	0%	40%	90%	90%	0%
12	0%	40%	90%	95%	100%
13	0%	40%	95%	95%	100%
14	0%	50%	95%	95%	100%
15	0%	50%	95%	95%	100%
16	0%	50%	95%	95%	100%
17	0%	50%	95%	99%	100%
18	0%	60%	95%	99%	100%
19	0%	60%	95%	99%	100%
20	0%	60%	95%	99%	100%
Average %	0%	42%	85%	88%	45%

The relation between household income and maximum chosen cooking-energy expenditure
It is assumed that poorest households are only able to spend a smaller proportion of their income on commercial energy, because they are so constrained in meeting other expenses. The effect of this assumption is that they are excluded from commercial energy use, or only consume small quantities of commercial energy. Moderately poor households (within these income distributions) may spend a higher percentage. Higher-income households are *able* to spend a higher percentage but are unlikely to, as they have other discretionary ways of spending money. A triangular function is used to relate maximum household energy expenditure to income levels. For the examples in Section 3.4 the income level breakpoints and corresponding percentages of income were:

Income category	***% of income willing to spend on cooking energy (max)***	***Definition of income category (per household)***
Very poor	5%	less than R600/month
Moderately poor	12%	midpoint: R2500/month
Rich	10%	more than R4000/month

Depending on their ability to pay inadequately, adequately or excessively for cooking energy (at prevailing prices and subject to minimum and maximum constraints described below) households are divided into three "choice groups":

1. Households that cannot afford all their minimum cooking requirements using any of these fuels
2. Households that can afford full commercial cooking, using least cost option
3. Households that can afford any cooking option

These choice indices affect the application of factors like price premiums described below.

Minimum and maximum kWh constraints for useful cooking energy
For the examples in Section 3.4, the minimum useful energy requirement for full cooking was set at 120 kWh/month and the saturation level at 300 kWh/month.

Assumptions for price premiums which different groups of households are willing to pay for different fuel choices
These can be set in *"Model"*. The parameters are for the inter-fuel price premium a household may be willing to pay, depending on the choice group (see above), and within each of these choice groups, the percentage of households for whom this premium is considered applicable.

Parameters used in the examples in Section 3.4 were

		Income-related choice group		
	Fuel switch	*1*	*2*	*3*
Price premium	LPG/para	0%	20%	50%
	LPG/elec	0%	5%	30%
% of households to whom premium choice applies	LPG/para	0%	50%	50%
	LPG/elec	0%	10%	10%

Appendix B: External costs of household fuels

***Extract from: Spalding-Fecher, R, submitted. Health benefits of electrification in developing countries: a quantitative assessment in South Africa.* Environment and Development Economics.**

Before estimating the change in fuel use patterns, we need to assess the unit health costs of the household fuels that will be avoided. The unit cost assumptions used in this study are presented in Table 2. Unit costs were derived by dividing the total external cost estimates with the total consumption of a given fuel in the household sector (DME 2002). For morbidity from indoor air pollution from wood and coal, the approach was to use the same dose-response functions and assumptions about hospitalisation days and mortality rates as Van Horen (Van Horen 1996), but to update the opportunity costs. As mentioned above, all direct medical costs were confirmed and brought up to 2001 Rands. For lost work days, we used average wages in the private economy (NPI 2001), adjusted for the fact the African and Coloured workers – those most likely to be exposed to wood and coal smoke – are only paid 37% of the average wage (SSA 2000).

Similarly, for morbidity from paraffin poisoning of children and paraffin fire-related burns, the medical costs were updated to current costs. More importantly, a major new study commissioned by the Paraffin Safety Association of South Africa (PASASA) provides the most comprehensive estimates of the number of paraffin poisonings and burns to date (Biggs & Greyling 2001). The number of cases for both, based on a national survey, are significantly higher than Van Horen's work – 53,000 cases of poisoning and 50,000 burns, as opposed to earlier estimates of 16,000 and 8,000, respectively. The paraffin study also provides a breakdown of the treatment regimes for burns and poisonings, the share of cases admitted to hospital, and length of stay. The PASASA study also reports fires and burns causes by other energy sources, which from previous research is likely to be candles. Morbidity costs for candle burns assume two thirds of the 'other energy' fires are candles, a quarter of those lead to hospital admission (considerably less than for paraffin burns), and that the hospital stay is half the length of time for paraffin burns.

For mortality valuations for all fuels, we use the 1998 ExternE values for VOLY from air pollution, which range from 60,340 ECU to 234,000 ECU (1995 ECUs), depending on the discount rate and type of mortality (Mayerhofer et al. 1997). South Africa's GDP per capita was 14% of that of the European Union in 2000 (World Bank 2000). Converting the European values into Rands, adjusting for relative GDP, and inflating to 2001 Rands, we have mortality values of 70,000 to 230,000 Rands. Note that this is an order of magnitude lower than the latest VOSL values, which would be almost 3 million Rands.

There are two separate issues with fuel wood scarcity and how it is valued. The first is the social cost of local fuel wood scarcity – namely the opportunity cost of the time that poor rural women must spend gathering fuel wood, often from further and further away from their homes. It could be argued that, given the high unemployment levels in South Africa (SA Reserve Bank 2000), the opportunity cost of labour is very low – even lower than average wages for the employed. In rural South Africa, however, where many of the males are migrant workers in urban areas, leaving behind women to do agricultural and other productive work, the time of women is generally fully utilised. It is therefore reasonable to use a typical rural wage as a proxy for the value of labour. The total costs are estimated by combining the hours of time spent gathering wood from Van Horen, an estimate of the current wages for the self-employed (SALDRU 1993; SARB 2002), and the number of rural households (NER 2000).

The second issue with fuel wood is whether electrification will reduce pressure on overall biomass resources – particularly deforestation caused by overuse of fuel wood resources (Hassan & Hertzler 1988). The situation in South Africa, however, is complex. While there is significant evidence of local fuel wood scarcity, the most recent analysis of overall biomass resources suggests these are increasing rather than decreasing. Scarcity in one area, in other words, may be offset by increasing resources in another area. South Africa's draft National Communication to the climate change convention, for example, reports that South Africa is a net sink for carbon in terms of land use changes (RSA 2001). This is, however, based primarily on the increase in plantation forestry in South Africa, rather than a detailed assessment of biomass resources available to local communities. Moreover, as discussed in Section 4.2, the evidence of significant declines in rural fuel wood consumption after electrification is also fairly weak (Davis 1998). For these reasons, avoided overall deforestation and loss of carbon is not considered within the external cost valuation presented in this study.

Table B.1: External costs assumptions for household fuels (2001 rands/GJ)

	Low	*Central*	*High*
Wood indoor air pollution	3.4	15.2	40.1
Social costs of wood scarcity	3.8	8.6	13.4
Total wood	***7.2***	***23.8***	***53.6***
Paraffin poisoning	6.0	20.8	61.1
Paraffin bums	13.0	50.5	110.0
Total paraffin	**19.0**	**71.3**	**171.1**
Coal indoor air pollution	2.7	6.1	10.7
Candle burns	13.3	69.1	163.3

References

Bailie, A, Bernow, S, Dougherty, W, Lazarus, M & Kartha, S 2001. The American Way to the Kyoto Protocol: An economic analysis to reduce carbon pollution. A study for the World Wildlife Fund. Boston, Tellus Institute.

Bhattacharya, S, Abdul Salam, P & Sharma, M 2000. Emissions from biomass energy use in some selected Asian countries. *Energy* 25 (2): 169-188.

Biggs, R & Greyling, A 2001. Project energy. Report for the Paraffin Safety Association of Southern Africa. Cape Town, Markinor.

Bosi, M & Laurence, A 2002. Road-testing baselines for GHG mitigation projects in the electric power sector. Paris, International Energy Agency & Organisation for Economic Co-operation and Development.

Davis, M 1998. Rural household energy consumption: the effects of access to electricity-evidence from South Africa. *Energy Policy* 26 (3): 207-217.

DME (Department of Minerals and Energy) 2001. DME statistics: South African National Energy Database: energy prices – November 2001. Pretoria, DME.

DME (Department of Minerals and Energy) 2002. South Africa National Energy Balance 2000. Pretoria, DME. Received 6 June.

Eskom 2001. Annual Report 2001: Embracing sustainable development. Sandton, Eskom. www.eskom.co.za.

Halsnaes, K, Callaway, J M & Meyer, H J 1998. Economics of GHG limitations: Methodological guidelines. Roskilde, Denmark, UNEP Collaborating Centre on Energy and Environment.

Hassan, R & Hertzler, G 1988. Deforestation from the overexploitation of wood resources as a cooking fuel. A dynamic approach to pricing energy resources in Sudan. *Energy Economics*: 163-168. April.

IPCC (Intergovernmental Panel on Climate Change) 1990. Climate change: The IPCC scientific assessment. Cambridge, Cambridge University Press.

IPCC (Intergovernmental Panel on Climate Change) 1996. Revised 1996 guidelines for national GHG inventories. Paris, Organisation for Economic Co-operation and Development.

IPCC (Intergovernmental Panel on Climate Change) 2001. Climate Change 2001: The scientific basis. Contribution of Working Group I to the Third Assessment Report. Cambridge, Cambridge University Press for Intergovernmental Panel on Climate Change.

Kartha, S, Lazarus, M & Bosi, M 2002. Practical Baseline Recommendations for GHG Mitigation Projects in the Electric Power Sector. OECD and IEA Information Paper. With M Bosi. Paris, Organisation for Economic Co-operation and Development/International Energy Agency.

Lloyd P J D, 2001a. Energy Research Institute, University of Cape Town, personal communication.

Lloyd, P J D, 2001b. Household fuels – prices, and health and safety issues. Presentation to the Parliamentary Portfolio Committee on Minerals and Energy, September 2001. Energy Research Institute, University of Cape Town.

Lloyd, P J D, 2002. The safety of paraffin and LPG appliances for domestic use. *Journal of Energy in Southern Africa 13 (2): 56-61.*

Lloyd P J D, 2003. Energy Research Institute, University of Cape Town, personal communication.

LPGSASA (LP Gas Safety Association of Southern Africa), 2002. Personal communication.

Marquard, A, 2002. Energy & Development Research Centre, personal communication.

Mayerhofer, P, Krewitt, W & Friedrich, R 1997. Extention of the accounting framework: final report. Stuttgart, Institute of Energy Economics and Rational Use of Energy. December.

Natsource 2000. Review and analysis of the emerging international GHG market: Executive Summary. New York, Natsource LLC.

NER (National Electricity Regulator) 2000. Lighting up South Africa 2000. Johannesburg, NER.

NPI (National Productivity Institute) 2001. Productivity statistics 2001: productivity releases value. Pretoria, National Productivity Institute.

PASASA (Paraffin Safety Association of SA) 2003, *Paraffin Stove Safety*, PASASA.

RSA (Republic of South Africa) 2001. South Africa: Initial National Communication under the United Nations Framework Convention on Climate Change. Draft 4 January 2001. Pretoria.

SA Reserve Bank 2000. Quarterly Bulletin. Johannesburg, South African Reserve Bank. March.

SALDRU (South African Labour and Development Research Unit) 1993. Project for statistics on living standards and development. Cape Town, University of Cape Town.

SANEA (South African National Energy Association) 2002. *Newsletter*, September 2002.

SARB (South African Reserve Bank) 2002. Quarterly Bulletin March 2002. Pretoria.

SAPIA (South African Ptroleum Industry Association) 2002. Annual Report, 2001, www.mbendi.co.za/sapia/rsacons.htm.

Sathaye, J & Meyers, S 1995. *GHG mitigation assessment: a guidebook.* Dordrecht, Kluwer.

Scholes, R J & Van der Merwe, M R 1995. South African GHG inventory. Pretoria, CSIR.

Smith, K R, Uma, R, Kishore, V, Junfeng, Z, Joshi, V & Khalil, M 2000. Greenhouse implications of household stoves: an analysis for India. *Annual review of energy and environment* 25: 741-763.

Spalding-Fecher, R 2002a. Can carbon credits make solar home system projects more viable? *Journal of Energy in Southern Africa* 13 (3): 79-85. August.

Spalding-Fecher, R (Ed) 2002b. *The CDM Guidebook: the Clean Development Mechanism of the Kyoto Protocol – a guide for project developers in Southern Africa.* Contributors: R Berold, G S Hodes, W R Makundi, S Raubenheimer, H Rukato, R Spalding-Fecher, S Thorne and L Tyani. Cape Town, Energy & Development Research Centre, University of Cape Town.

Spalding-Fecher, R 2002c. Energy sustainability indicators for South Africa. Cape Town, Energy & Development Research Centre, University of Cape Town.

Spalding-Fecher, R, Clark, A, Davis, M & Simmonds, G 2002. The economics of energy efficiency for the poor – a South African case study. *Energy: The International Journal* 27 (12): 1099-1117. December.

Spalding-Fecher, R, Williams, A & Van Horen, C 2000. Energy and environment in South Africa: charting a course to sustainability. *Energy for Sustainable Development* 4 (4): 8-17. December.

SSA (Statistics South Africa) 2000. Mean and minimum wages. Pretoria, Statistics South Africa.

Streets, D G & Waldhoff, S T 1999. Greenhouse-gas emissions from biofuel combustion in Asia. *Energy* 24 (10): 841-855.

Terblanche, A P S, Nel, C & Opperman, L 1993. Helath and safety aspects of domestic fuels: phase II. Pretoria, National Energy Council.

UNDP 1997. Energy after Rio: prospects and challenges. New York, United Nations Development Programme.

Van Horen, C 1996. The cost of power: externalities in South Africa's energy sector. Doctoral dissertation Thesis. School of Economics. Cape Town, University of Cape Town.

Von Schirnding, Y E R, Yach, D & Klein, M 1991. Acute respiratory infections as an important cause of childhood deaths in South Africa. *South African Medical Journal* 80 (2).

WHO (World Health Organisation) 1996. Factsheet N109, March 1996, www.who-int/inf-fs/en/fact109.htm.

WHO (World Health Organisation) 2002. World Health Report. Chapter 4. Quantifying Selected Major Risks to Health. Geneva, October. www.who.int/whr/2002/chapter4/en/.

World Bank 2000. *World Development Report 2000/2001*. Oxford, Oxford University Press.

WLPGA (World LP Gas Association) / World Bank 2001. West Africa LP Gas market development study. Paris, World LP Gas Association.

WLPGA (World LP Gas Association) / World Bank 2002. The role of LP Gas in meeting the goals of sustainable development. Paris, World LP Gas Association.