The Use of Liquified Petroleum Gas (LPG) in Sudan

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Cover image: Truck delivering gas cylinders in Khartoum

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Dr Ahmed Hassan Hood
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Executive summary

The depletion of forests in Sudan is a major challenge facing the country today. North and central states of have lost 70% of their forest cover since independence (UNEP, 2007). Recurrent droughts, desertification, over-grazing and expansion of agricultural land, as well as the collection of timber for firewood, charcoal production and other uses, are among the root causes of forest degradation. The use of biomass fuels for household energy creates significant demand for forest products and leads to further degradation of an already scarce resource.

The impacts of household reliance on wood based fuels are considerable. Poor peri-urban households spend a sizeable percentage of their income on purchasing firewood and charcoal, while rural households collect fuelwood, sometimes in insecure areas.

Biomass energy use has been shown to be highly inefficient. In households across Sudan, biomass fuels are burned in stoves that are often only 10 to 15 percent efficient, wasting heat and releasing excessive amounts of smoke. The latter contributes to serious health problems for women and for children below five years of age. Accordingly indoor air pollution measurements conducted in peri-urban households in Kassala, Eastern Sudan, showed that the level of indoor air pollution caused by wood fires is 20 times or more higher than standards specified by WHO.

In the face of these challenges, the rationale for clean and efficient energies is clear. One of the options that has emerged in Sudan is liquefied petroleum gas (LPG). Upon the onset of local production of LPG in Sudan, the Government of National Unity adopted a fuel-switching policy to increase the uptake of LPG amongst the population. The price of LPG was reduced by 50 percent and LPG appliances were exempted from import duty tax. As a result of this intervention the use of LPG, particularly by the domestic sector, increased from about 31,000 metric tonnes in 2000 to 274,000 metric tonnes in 2006. In addition there was significant uptake in use by the industrial and automotive sectors, amongst others. So as to protect supplies and ensure its policy commitment to supporting the household and services sectors with clean energy, the government removed subsidies for LPG to the country's industrial sector.

Despite the success in uptake, it is clear that the benefits of LPG have not been equally spread. Poor households in the peripheries of large towns and rural areas still have little to no access to clean energy. The consumption of LPG is largely concentrated in Khartoum state, which constituted about 75 percent of overall consumption in 2006. The other states had minor shares, with the central states of Gezira and Sinnar accounting for 14 percent together; with the remaining states consuming the rest.

As cleaner renewable energy options are still under development, LPG is presented as the short-term solution in delivering clean modern energy for household use, and particularly for cooking applications. This study concludes that there are clear benefits from the use of LPG over the existing biomass fuels that are widely used by the household sector across the country. These include improved environmental conservation and reduced deforestation, climate change mitigation, improvement in women and children health and wider socio-economic development.

This study demonstrates that LPG use in Sudan is on a slow ascendancy, due in particular to government incentives, investment by LPG companies in distribution infrastructure and dissemination efforts made by private, public and non-governmental organizations.

LPG use remains, however, concentrated in the central region of the country. This has been attributed to high population density, the high price of woodfuel, greater awareness and infrastructure development.

The study analyses a range of case studies of LPG promotion initiatives across Sudan and recognizes the following as the main barriers for the widespread national use of LPG:

1. The relatively large initial investment needed to acquire LPG appliances (cylinders and stoves);

2. The higher price of LPG compared to woodfuel prices in parts of the country;

3. The lack of infrastructure for LPG distribution;

4. A general lack of information;

5. Social and cultural issues.

Based on the best practices and lessons learnt from existing initiatives, four broad recommendations are proposed. Together these should constitute the building blocks of any strategy to scale up LPG use in Sudan. The recommendations are:

1. Public awareness and consumer education on benefits of LPG and safety precautions of LPG use;

2. Government policies and initiatives to promote LPG market development, including strategy for full application of subsidies and national price stabilization;

3. Increased focus on women as primary beneficiaries in LPG scale-up activities, including capacity building support for WDAs;

4. Development of full cost recovery microfinance options to facilitate household access to clean modern energy such as LPG.

Expanding the use of LPG in Sudan is one clear solution to help address the depletion of forest resources and the associated risks and to set Sudan on a Green Economy pathway.

1. Introduction

The forestry sector is very important in Sudan – fuelwood and charcoal constitute the main domestic energy sources, while timber is the country's primary source of construction material. The forestry sector contributes as much as 13 percent to Sudan's gross domestic product (GDP).

Sudan is confronted by a number of processes of change which significantly threaten its existing natural resource base. Increasing urbanization, which has in places been compounded by conflict related displacement, coupled with a growing population has led to significant demand in household energy needs and for construction material. Sudan's population grew from 21 million in 1981 (1981 census) to 39.2 million in 2008 (4th Census in 2008), representing a growth rate of 2.8 percent according to the Central Bureau of Statistics. This is recognized as one factor which has contributed to deforestation in Sudan. According to the UN Food and Agriculture Organization (FAO, 2006), Sudan lost more than 5,500 km^2 of forest per year between 1990 and 2000 – an annual deforestation rate of 0.77 percent. This increased to 0.84 percent between 2000 and 2005, meaning that since 1990 Sudan has lost 11.6 percent of its forest cover. UNEP (2007) meanwhile estimates that given an annual rate of loss of 1.87 percent between 1973 and 2006, 48.2 percent of forest cover has been lost in since 1973.

At the same time, climate and rainfall patterns have changed significantly. Statistics from Darfur show that there is increased variability of rainfall and an increased likelihood of drought. In Darfur, it is acknowledged that 16 of the 20 driest years on record have occurred since 1970. This pattern is in keeping with climate change models for the Sahel region and is likely to continue in the coming years.

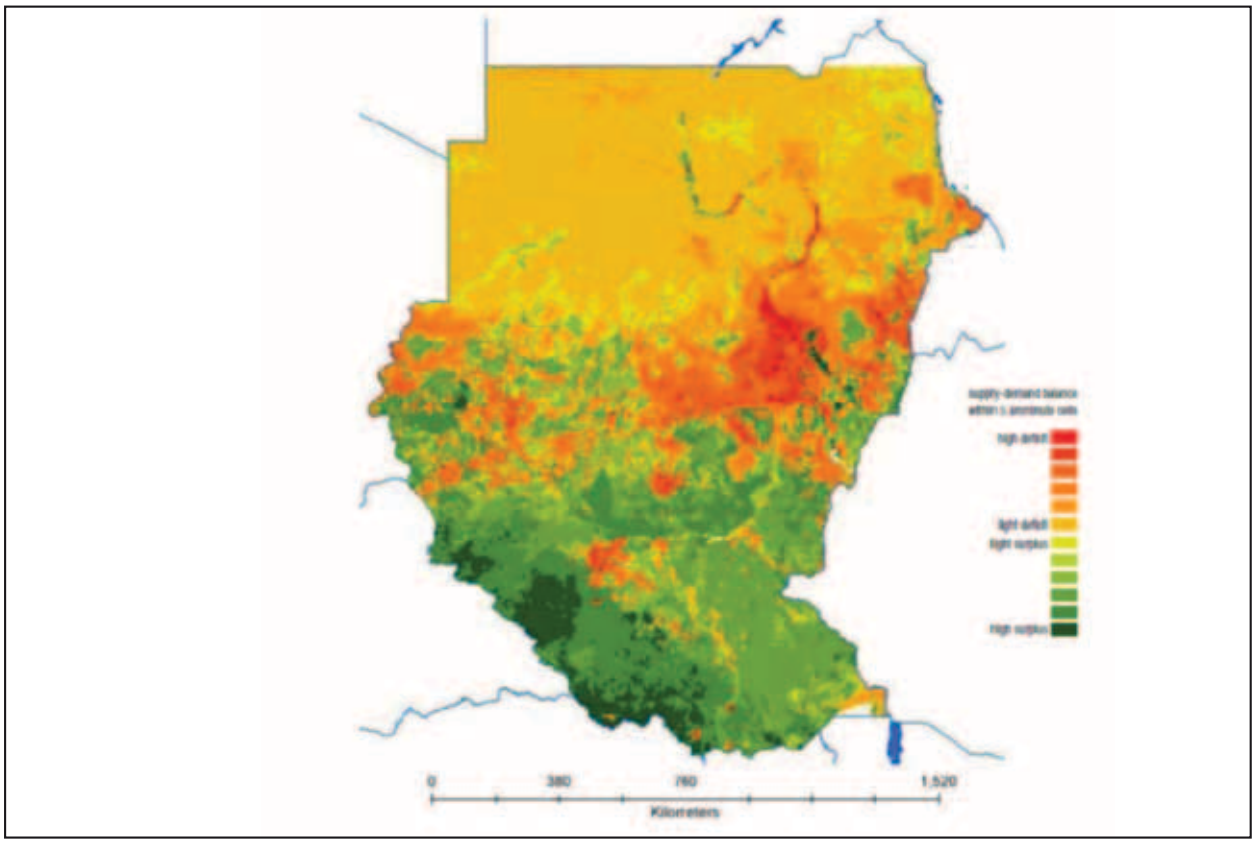
Stopping deforestation and protecting and increasing the area of land covered by forests is a necessary component for any strategy to build resilience against the consequences of climate change. Forests not only convert carbon dioxide (CO_2) into oxygen, thus slowing the pace of climate change, but they also prevent soil erosion, helping to secure agricultural productivity and combat climate change. The gum Arabic belt for example (an area of 520,000 km^2 between the latitudes of 10° and 14° north), covering one-fifth of Sudan's land surface, protects 40 percent of the country from desert encroachment.

A large increase in the consumption of forest products (mainly in Khartoum state where much of the population is concentrated), combined with the uneven distribution of resources and changing rainfall patterns, has led to serious inequalities in the supply of, and demand for, resources. The shortfall in fuelwood in some areas is clearly demonstrated by the Woodfuel Integrated Supply/Demand Overview Mapping by FAO (Figure 1.1).

The green areas in the map represent areas with a high surplus in fuelwood, while the red areas represent areas with a shortage of fuelwood. It is clear from this that the Khartoum area in particular as well as the Darfur states need to consider alternative energy sources and more efficient energy consumption, particularly in the context of the 2011 secession of South Sudan.

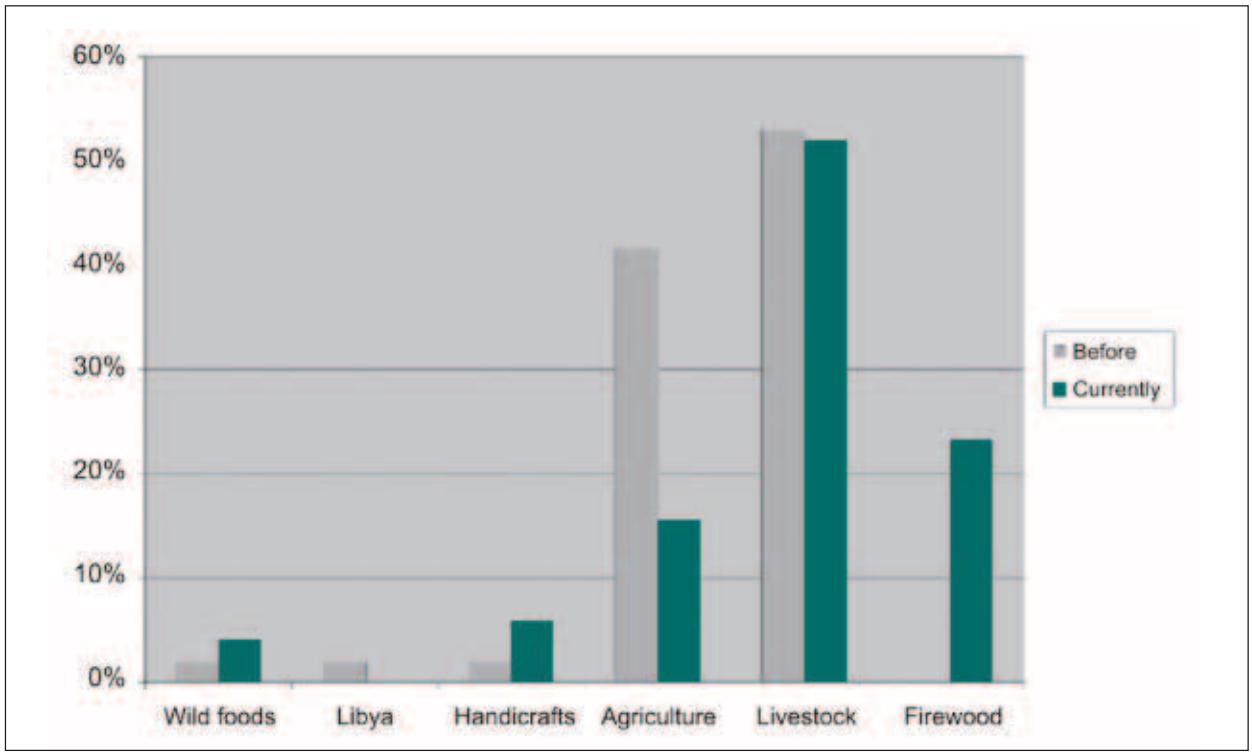
Alongside the natural and demographic factors that impact energy supply and consumption in Sudan, another contributing factor is the long period of conflict the country has experienced. This has had a particular effect on energy consumption patterns, the environment and livelihoods. With large numbers of people forced to abandon their homes, internally displaced persons (IDP) and refugee camps have become commonplace in some parts of the country. People in these camps search for firewood alongside the local population, often in situations where the conflict has cut off alternative fuel sources. This has significantly increased deforestation and wrought significant changes in livelihood patterns. For example, livestock rearing and agriculture has ceased to provide the best option and firewood collection has become more attractive (Figures 1.2). At the beginning of the conflict, collection of wood and charcoal production were only coping strategies, but now they have become viable long-term livelihood options – a seismic shift that needs to be reversed. In the event of failure to respond, conflicts over timber resources will arise,

Figure 1.1. WISDOM – East Africa. Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) Methodology.



Source: FAO (2005)

Figure 1.2. Shift in livelihood strategies (Arab Aballa in Barka Alla, North of Kutum, North Darfur)



Source: Tufts University (2009)

particularly in the north-south Sudan border regions, where economic opportunities in timber trade are high.

A switch to innovative, sustainable, clean energy sources is, therefore, urgently needed for the Sudanese people. Since the household sector is the largest energy consumer in Sudan, widespread promotion and use of clean cooking technologies is essential. Among the options for clean fuel in Sudan is Liquefied Petroleum Gas (LPG). LPG is a mixture of gaseous hydrocarbons, primarily propane and butane, derived during natural gas and oil extraction and refining. It is a clean burning fuel which emits no smoke or residual particulate matter and has relatively low pollutant emissions. It has a number of advantages over traditional wood fuels including:

- No soot, burners have a longer life and therefore maintenance is low;
- No spillage as it vaporizes at atmospheric temperature and pressure;
- Instantly controllable flame temperature;
- Avoids scaling and decarburizing of parts;
- Environmentally friendly fuel with minimal sulphur content and sulphur- free emissions;
- Very high efficiency with direct firing system instant heat for faster warm-up and cool-down;
- Can be used for a variety of applications.

LPG can be easily stored, transported and used virtually anywhere from downtown urban areas to remote rural area. These properties have made it a highly appealing global fuel option which both meets household energy needs and causes very low levels of pollution. While LPG also has potential downsides – it is highly inflammable at very low concentrations, and gas is odourless so the addition of a pungent odorant is compulsory worldwide to enable rapid detection of leakages – its use is considered significantly safer for household purposes than fuels.

The introduction of LPG in Sudan was pioneered by the Shell Petroleum Company during the 1960s. Its use was mainly limited to Khartoum, where only well-off households and a few institutions, like the University of Khartoum boarding houses, were using it. During the 1970s, other petroleum companies (Total and Agip) entered the LPG market in Sudan. Despite this, owing to the high price of (imported) LPG and the low cost of firewood and charcoal, LPG use remained restricted to Khartoum state. During the late 1980s, firewood and charcoal prices increased and this, combined with greater public awareness, saw the use of LPG expand beyond Khartoum to reach the capital cities of states in northern Sudan. However, bottlenecks in supply chains limited its use beyond well-off households that could afford to keep a stock of several cylinders.

Following the inauguration of the Khartoum refinery, which used locally produced oil, availability of LPG ceased to be an issue. The Government introduced a policy to incentivize the use of LPG by the domestic sector which attracted several institutions to engage in projects intended to scale up LPG use, particularly in the household sector, across Sudan.

This report evaluates the efforts to date to support the adoption of LPG use across the country, and looks to highlight the constraints currently blocking its widespread use.

Work on this report was undertaken on the recommendation of the Environmental Technology Task Force (ENTEC), that was set up as a collaboration between UN, donor and civil society organisations following the importance of this issue, identified during the Darfur Joint Assessment Mission (DJAM) process in 2008. ENTEC's central concern is to introduce and scale-up alternative construction and energy technologies in Darfur to reduce the current rate of deforestation and projected deforestation in the future when IDPs eventually return and reconstruction begins. The group is co-chaired by UNEP with a focus on energy and UN-Habitat with a focus on construction technologies. More information is available at www.unep.org/sudan.

2. Energy consumption in Sudan

2.1. Overall energy consumption

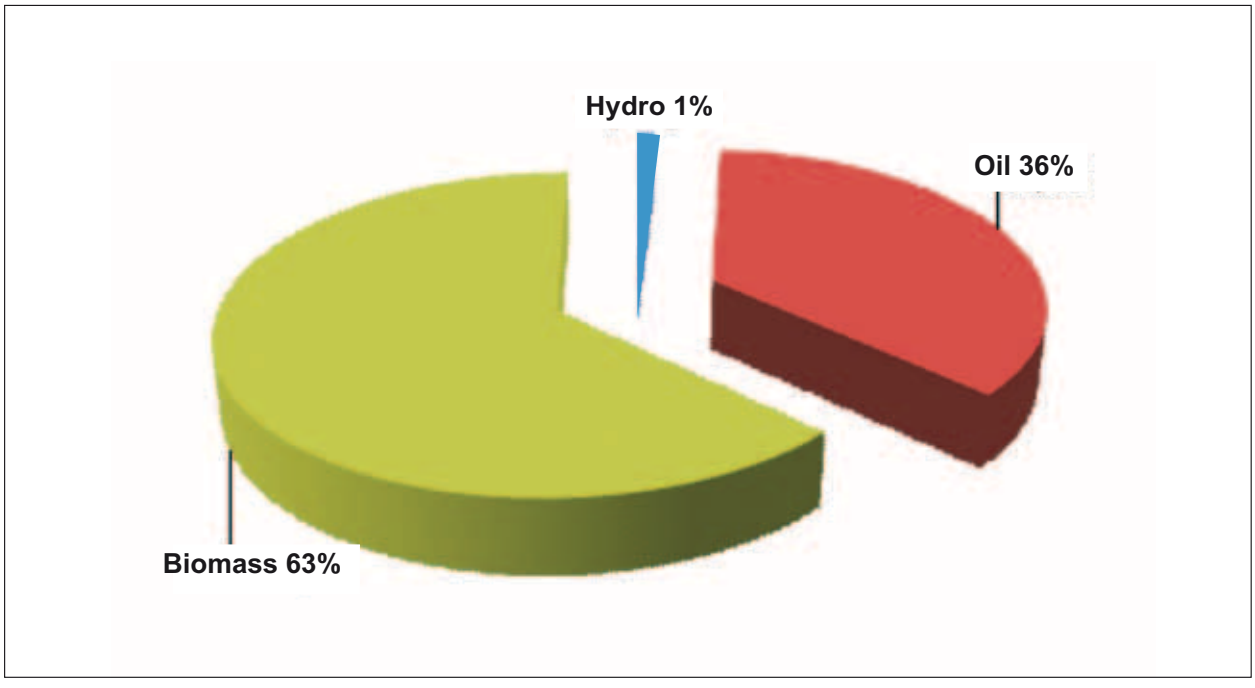
The last major national study on energy consumption in Sudan was published in 2001. Since then however, Sudan has become a major oil producer and exporter. As a result the data in the 2001 national assessment cannot be said to accurately reflect the current situation as energy consumption patterns have undergone considerable changes. In particular three major changes since the Second Energy Assessment can be noted:

- Petroleum products have become widely available from local refineries, their share in the energy market having increased from 20 percent in 2001 to 36 percent in 2009;
- Power generation (both hydro and thermal) has expanded considerably;
- LPG is produced at the Khartoum refinery and has been set aside for domestic consumption and power generation. Consequently, the biomass share in the energy market fell from 78 percent in 2001 to 63 percent in 2009. Biomass here refers to firewood, charcoal and residues from agriculture and animal waste.

The Second National Energy Assessment confirmed the findings of the First National Assessment, in 1981, that biomass is the dominant source of energy in Sudan. Its contribution to national energy consumption, however fell from 83 percent in 1981 to 78 percent in 2001 and to 63 percent in 2009. Sudan's principal energy sources are hydropower (one percent), locally produced crude petroleum (36 percent) and biomass (63 percent). (Figure 2.1) Energy from biomass mainly constitutes the burning of firewood and charcoal.

Figure 2.2 shows Sudan's national energy balance. Sudan's primary energy supply in 2008 amounted to 14,908 kilo tonnes of oil equivalent (ktoe), while energy consumption was 9,810 ktoe. This indicates a high rate of energy loss from petroleum product refining, electricity generation and distribution, petroleum products distribution, and biomass conversion (the production of charcoal).

Figure 2.1. Sources and percentages of national energy supply in Sudan, 2009



Source: Ministry of Energy and Mining (2009)

At 67 percent, the biomass conversion losses are remarkably high. This is due largely due to the characteristics of charcoal production technology – earth mound kilns, which have a theoretical efficiency of about 30 percent. Earlier research conducted by the Energy Research Institute indicated reasonable efficiency figures (of about 25 percent) for large volume (>100 m^3) earth mound kilns, which are commonly used in Sudan. (ERI, 1987)

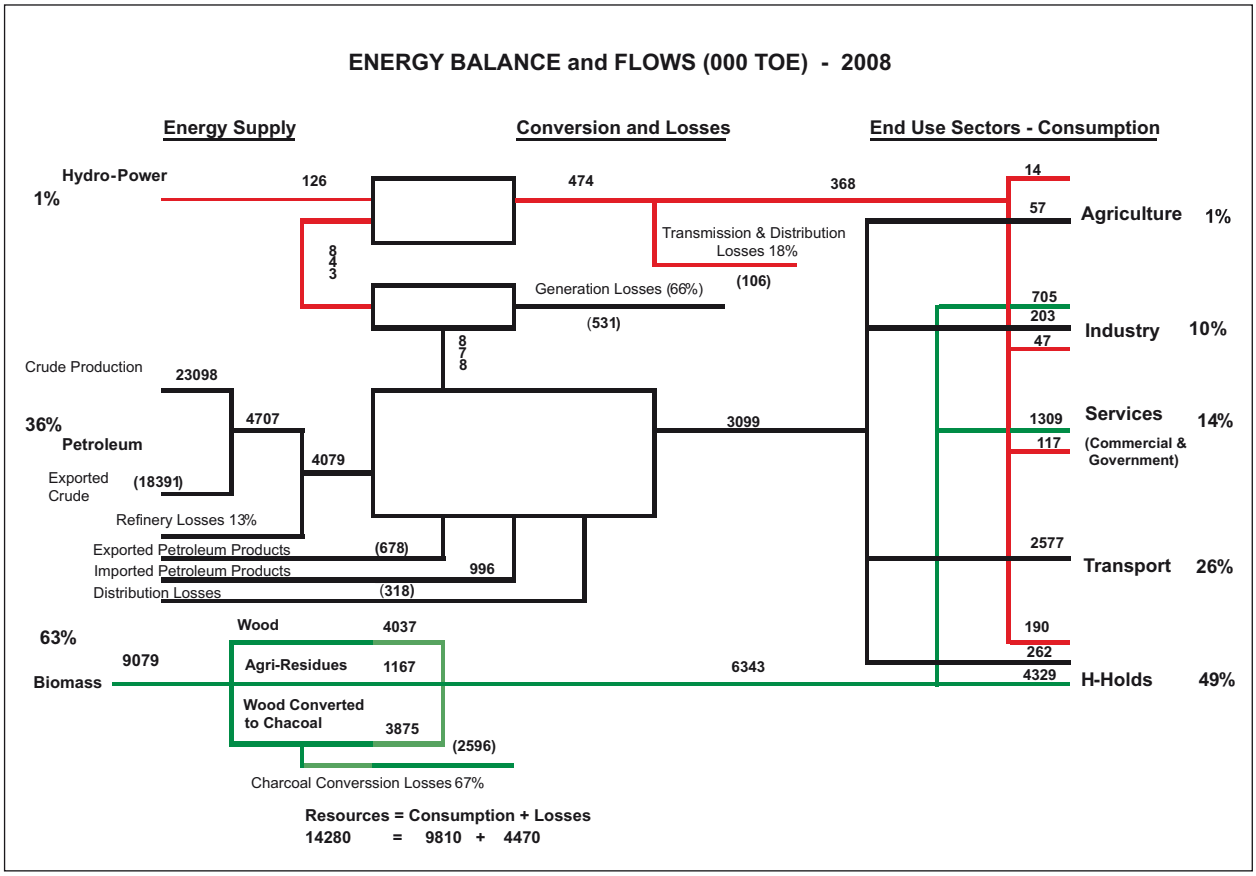
Figure 2.2 also shows energy consumption by the country's main sectors. The household sector is the dominant consumer with 49 percent in 2008, against 60 percent in 2001. This reduction is explained by the expansion in the consumption of petroleum products, mainly in the transport sector. Biomass represents 95 percent of the total energy consumed by the household sector. Of particular note is the consumption of charcoal by households in urban centres. Over the last 25 years, urbanization levels in Sudan have risen from 22.4 percent in 1985 to 45 percent in 2010. Studies have shown that a 1 percent increase in urbanization rate induced a 14 percent increase in charcoal consumption (Tanzania Association of Oil Marketing Companies, 2002).

2.2. Overall biomass energy consumption

The Second National Energy Assessment showed total consumption of biomass energy in 1999 to be about 8 million toe. This fell to 6.5 million toe in 2008. Firewood remains the dominant biomass fuel, over the years contributing 63 percent of total biomass energy consumption (Figure 2.2).

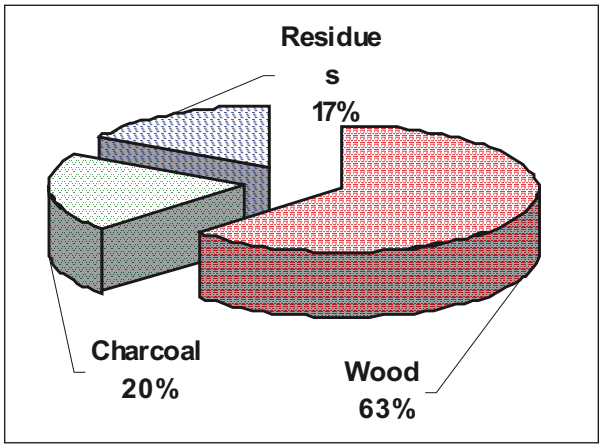
The main consuming sectors of biomass energy (Figure 2.3) are: household (68 percent), commercial/services (21 percent) and industries (11 percent). The commercial/services sector includes restaurants and schools, while the industrial sector is composed largely of brick-makers, lime-burning enterprises and oil mills.

Figure 2.2. National energy balance ('000 tonnes of oil equivalent [toe]), 2008



Source: Ministry of Energy and Mining (2009)

Figure 2.3. Composition of biomass energy consumption, 2009



Source: Ministry of Energy and Mining (2009)

The consumption of biomass energy by Sudanese states shows considerable variation dependant on the size of the population and resource availability (Table 2.1). South Darfur and Khartoum states are the major consumers of biomass energy, at 13 percent and 10 percent of total national biomass energy consumption respectively.

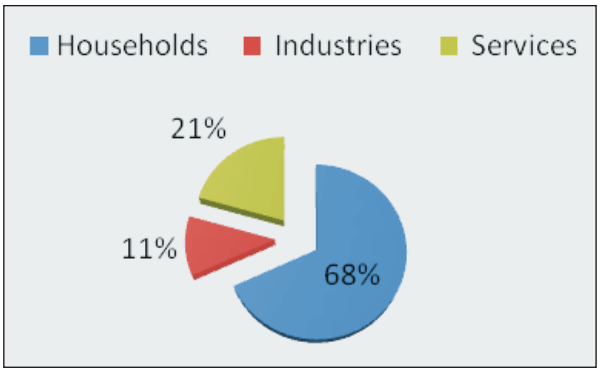
2.3. Biomass energy consumption – household sector

Household sector consumption accounts for 49 percent (2008) of total energy consumption in Sudan. Household energy consumption meanwhile – used chiefly for cooking – comes almost entirely from biomass sources which constitute 96 percent of total energy consumed by the household sector in 2001. (Figure 2.4)

Firewood and charcoal at 59 percent and 24 percent respectively, are the main fuels consumed. At more than 12 percent, biomass residues also constitute a considerable share of total household energy consumption. This is mainly in the form of cotton stalk produced in large irrigated agricultural schemes in central Sudan.

Charcoal is the main cooking fuel for urban households (used by more than 89 percent of households), while firewood is the dominant cooking fuel in rural areas (used by more than 81 percent of households). Indicatively, Khartoum state has the lowest urban consumption of firewood per capita

Figure 2.4. Consumption (%) of biomass energy by sector, 1999



Source: Ministry of Energy and Mining (2009)

Table 2.1. Biomass energy consumption in some Sudanese states ('000 toe), 2001

State	Woodfuel				Biomass residues	Total biomass	
	Charcoal	Firewood	Total	% of total country consumption		Total	% of total country consumption
North Darfur	47	274	321	5	6	326	4
West Darfur	47	306	364	5	3	357	4
South Darfur	98	834	932	14	82	1,014	13
Khartoum	286	499	785	12	8	793	10
River Nile	46	102	148	2	28	176	2
North Kordofan	98	290	388	6	49	437	5

Source: Ministry of Energy and Mining (2009)

and the highest urban charcoal consumption per capita. Similarly, the percentage of rural households using charcoal is very low in the three Darfur states compared to other states.

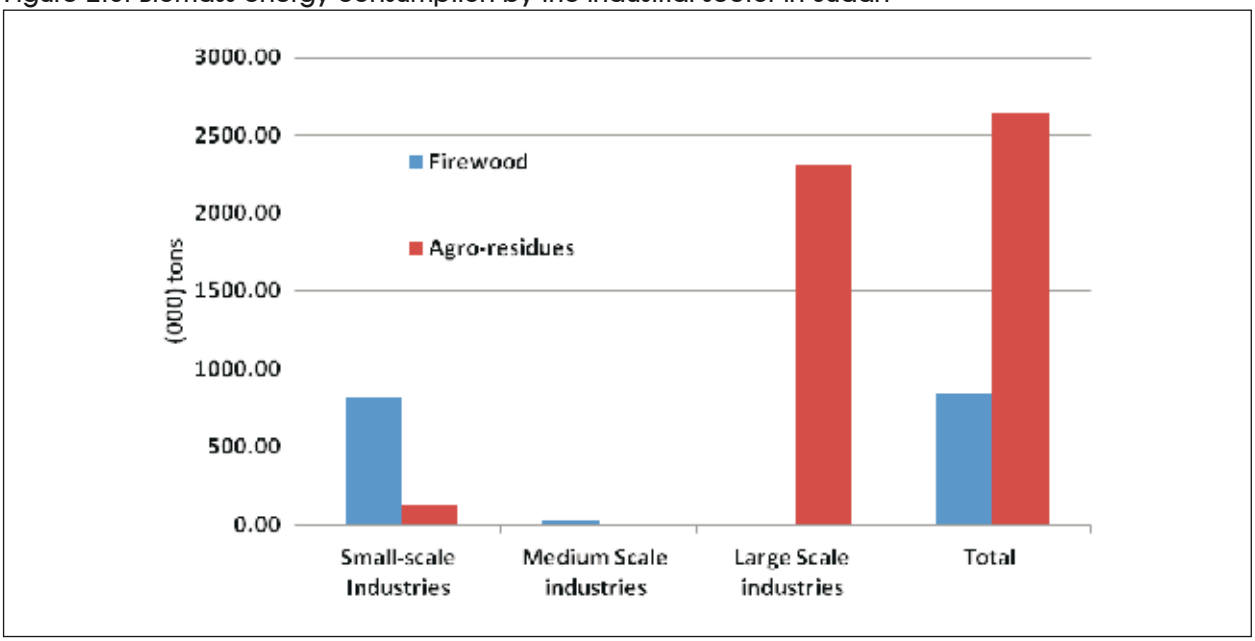
The average national per capita consumption of firewood is 0.273 tonnes (respectively 0.322 tonnes and 0.176 tonnes for rural and urban households). The national average per capita consumption of charcoal meanwhile is 0.0667 tonnes (respectively 0.0542 tonnes and 0.0913 tonnes for rural and urban households). Households often use a combination of both fuels (Table 2.2). Firewood is mostly used by both urban and rural households for cooking the main staple foods in the country: *Asida* and *Kisra*[1]. Following the 1985 drought and famines, the consumption of bread increased

Table 2.2. Households using a combination of different fuels for cooking purposes, White Nile state (%)

Type of fuel	% of consumption
LPG	3.2
Firewood	2.4
Charcoal	4.0
LPG + firewood	2.4
Charcoal + firewood	4.8
Charcoal + firewood + LPG	17.4
Charcoal + firewood + LPG + agricultural residues	61.6
Charcoal + firewood + dung + agricultural residues	4.0
Other (agriculture residues, kerosene, gasoline, dung)	5.0

Source: Mahasin (2007)

Figure 2.6. Biomass energy consumption by the industrial sector in Sudan



Source: Ministry of Energy and Mining (2001)

[1] *Asida* is the main staple food in rural areas of Sudan, particularly Darfur, a porridge made from millet flour and cooked in round aluminum pots that only fit well on the 3-stone fire place as the cooking process demands rigorous stirring) *Kisra* (mainly in Central Sudan, *Kisra* represents the main staple food, a sort of pancake cooked on a hot plate, which fits well on almost all sorts of stoves, even large size charcoal stoves (including recently LPG).No measures have been made to compare the energy consumption of cooking *Asida* and *Kisra*. The cooking of *Kisra* consumes less energy as it does not involve boiling the water.

significantly across Sudan. Bread production is now visible in almost all villages of Sudan and in remote rural areas. The availability, access and cost of fuels determine a household's choice of the energy mix for cooking.

2.4. Biomass energy consumption – industrial and services sector

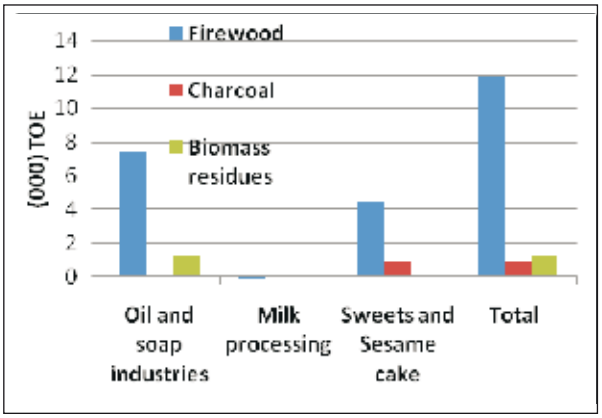
Biomass energy consumption by industry sectors is shown in Figure 2.7. The main consumer of agro-residues is the sugar industry, where bagasse (the fibrous matter that remains after sugarcane or sorghum stalks are crushed to extract their juice) is a biofuel used mainly to meet the industry's heat and power demands.

Industrial use of firewood and agricultural residues is mainly dominated by rural oil mills and soap factories (Figure 2.7), small to medium-sized concerns scattered across rural towns. Inefficiently generated heat is the main end use of these biofuels.

(i) Brickmaking Industry

The brick-making industry is distributed across Sudan, however it is particularly concentrated in central Sudan, along the Blue Nile In 1994, the industry's annual consumption of firewood amounted to 13,932,000 toe. While more up to

Figure 2.7. Biomass energy consumption by medium-sized industries ('000 toe), 1998

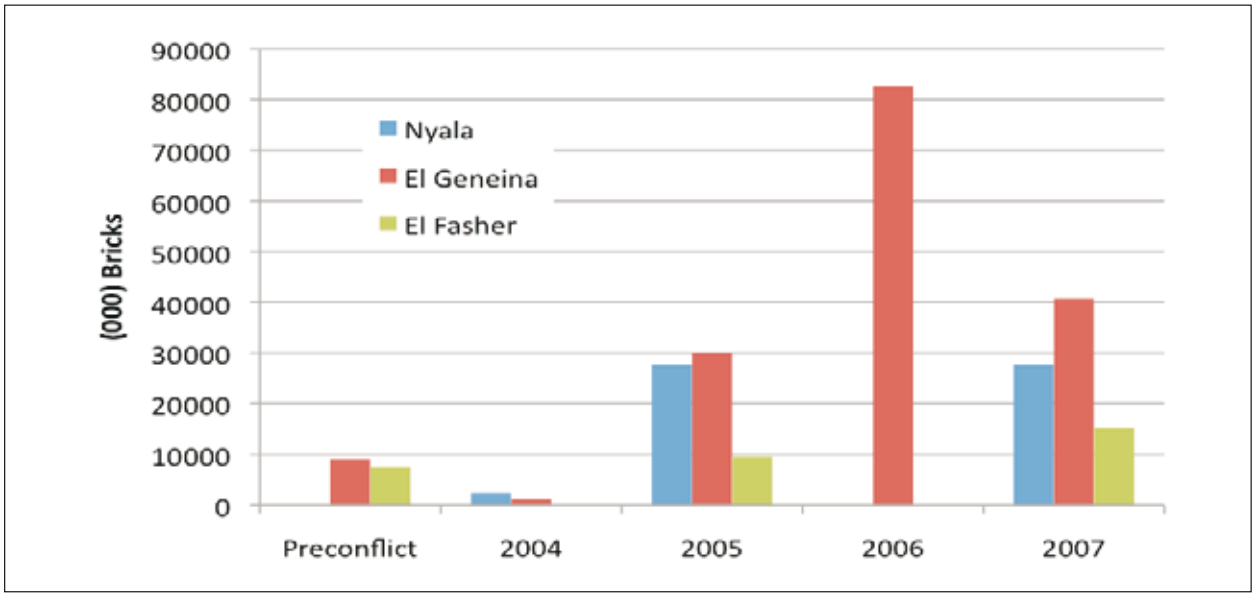


Source: Ministry of Energy and Mining (2001)

date national statistics are unavailable, it is clear that in the 15 years since then, the economic landscape of Sudan has witnessed significant change led by increased national revenue due to oil export. The building industry has flourished, prompting an increased demand for bricks. Accordingly, the production of bricks may have as much as doubled, and production has expanded to reach new areas.

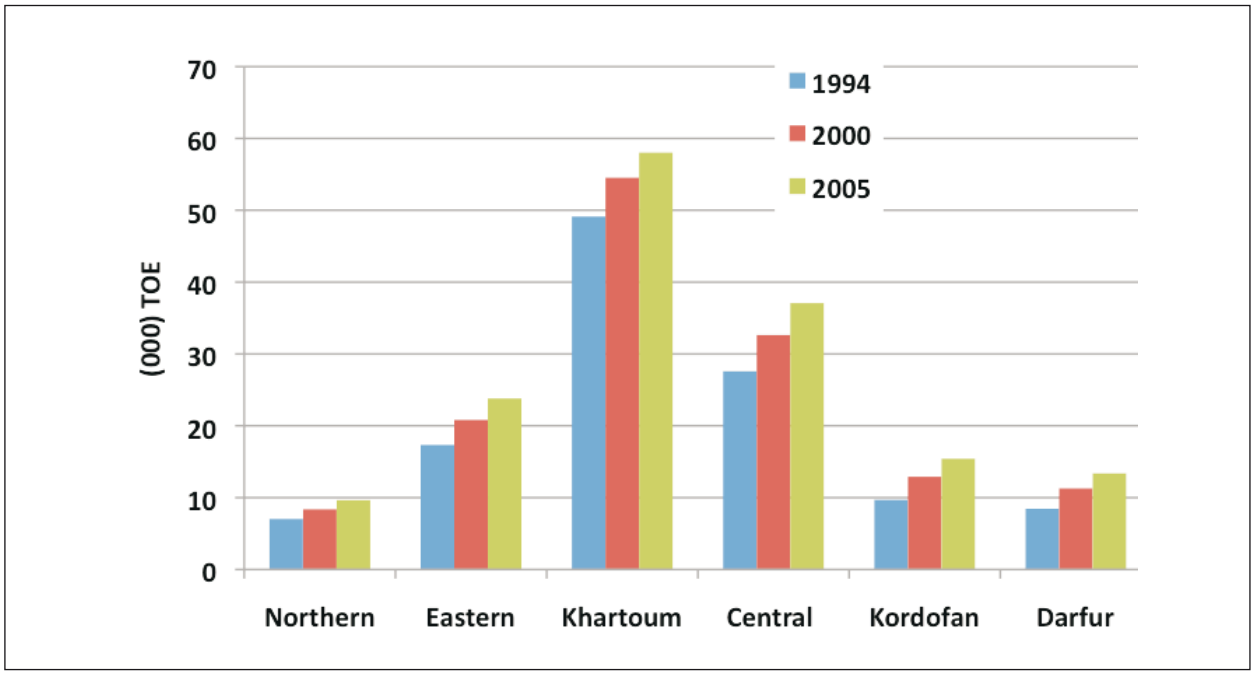
In addition, the impacts of conflict induced displacement have caused the production of bricks to increase several fold. In particular, increasing rates of urbanization through the influx of people displaced from rural areas, combined with the increased presence of the international community (UN peace-

Figure 2.8. Number of bricks produced and taxed by Forestry National Corporation (FNC) in major towns of Darfur, pre and post conflict



Source: Ministry of Energy and Mining (2001)

Figure 2.9. Regional annual firewood consumption by bakeries, 1994, 2000 and 2005 ('000 toe)



Source: Ministry of Council of Ministers (2005)

keepers and humanitarian agencies and NGOs) created significant demand drivers for construction and increased brick-making. (Figure 2.8)

(ii) Other industries

The bread-making industry is a major consumer of firewood. Since 1994 there has been a consistent increase in firewood consumption across Sudan (Figure 2.9). In 2005, firewood consumption by bakeries amounted to 15,738,000 toe, with Khartoum state and the central regions of Sudan accounting for the highest consumption levels

(iii) Commercial and services sector

Commercial and services sector consumption of biomass energy is quite considerable (Table 2.3). It is usually classified into two categories: formal (restaurants, boarding houses, schools and prisons) and informal (urban and roadside tea and food vendors).

2.5. Other sources of energy consumed by the household sector

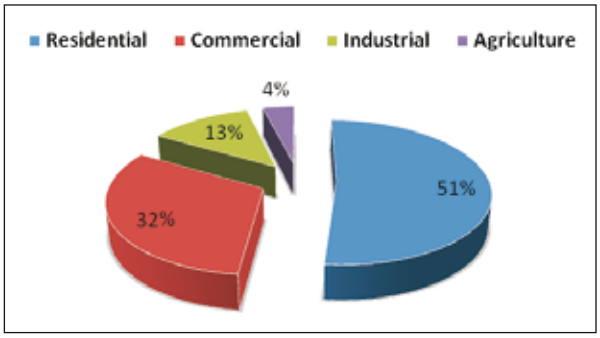
Other energy sources used in the domestic sector include electricity and petroleum products (kerosene/gasoil and LPG). Consumption of the latter, and particularly of LPG by the household sector, has increased considerably in recent years. This can be attributed both to increasing availability from local production, and to government incentives.

Table 2.3. Annual firewood and charcoal consumption by the commercial/services sector, 1999

Commercial/Services	Charcoal consumption (tonnes)	Firewood consumption (tonnes)
Formal Sector	234,640	2,477,078
Informal sector	13,925.2	10,550
Total	248,565.2	2,487,628

Source: Ministry of Energy and Mining (2001)

Figure 2.10. Share of electricity consumption by the different sectors



Source: Ministry of Energy and Mining (2009)

Kerosene/gasoil is mainly used for lighting purposes, while LPG is mainly used for cooking in urban areas.

The household sector consumes about 51 percent of total generated electric power (about 2.7 percent of total household energy consumption) (Figure 2.10). Only about 30 percent of the population enjoys this service however as the national electricity grid only covers central parts of the country. Other towns are supplied from isolated generation units, while rural areas of the country remain out of range of electricity services. The vast size of the country, coupled with distant rural settlements, have made investment in power infrastructure in rural areas prohibitive.

3. Making the case for LPG – Environmental and health impacts of high dependence on biomass energy and benefits of LPG

3.1. Environmental impacts of high dependence on biomass energy

The environmental challenges posed by the high dependence on biomass as a source of household energy are considerable in Sudan. The country has witnessed an acute reduction in forest area, which has decreased from covering 36% of the country in 1958 to 12% in 1998. (Forestry National Corporation (FNC), 1998)

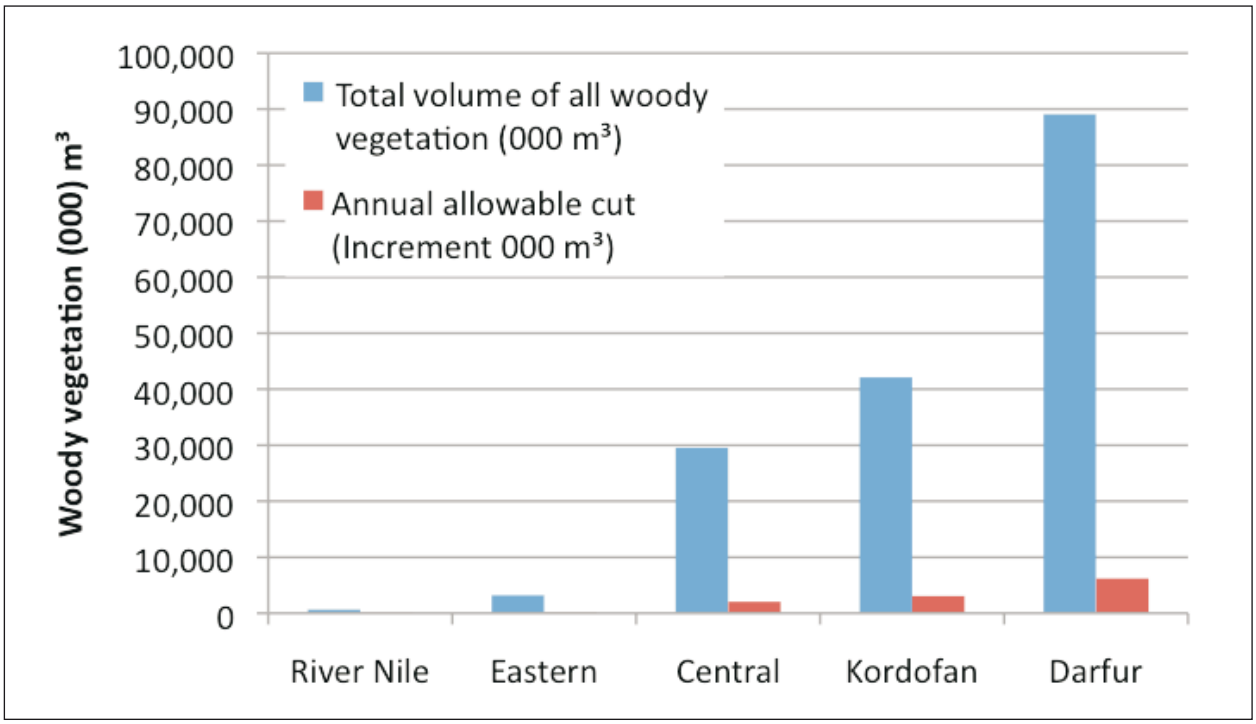
The demand for wood products is significant and far exceeds the natural regrowth rate. The annual clearance of forest area in Sudan is about 36,975 hectares. This has led to a tangible deficit between the annual consumption of forest products, 21 million m^3, and the annual growth rate and reforestation of 10 million m^3 annually. The result of such a non-sustainable exploitation of forest resources is a continuous depletion of forest area.

Table 3.1. Risks associated with forest loss and degradation

Function	Process	Implication
Climatic amelioration	Rainfall diminishes over deforested land, but not greatly	Prejudicial to agricultural and pastoral production
Soil	Unprotected soil loses fertility and/or rapidly erodes to a near-worthless condition	Highly prejudicial to agricultural production
Water catchment	Deforested slopes release water rapidly	Water loss during rains; water shortages during dry season
Habitat conservation	Heavy off-take of wood converts closed forest to open forests, and open forest to scrubland – leading to desertification	With less woodland, Sudan would lose much of its wildlife and many rare species of plants
Culture values	Traditional culture depends heavily of forest products	Medicinal herbs and wood for carving become harder to find
Subsistence	Most rural dwellers augment their food supply with forest products	Wild fruits and honey become harder to find
Civil disorder	Competition for scarce resources	Diversion of government funds to security and public order instead of development

Source: UNEP (2007)

Figure 3.1. Regional distribution of the volume of growing forest stock and annual allowable cut, 1998



Source: FNC (1998)

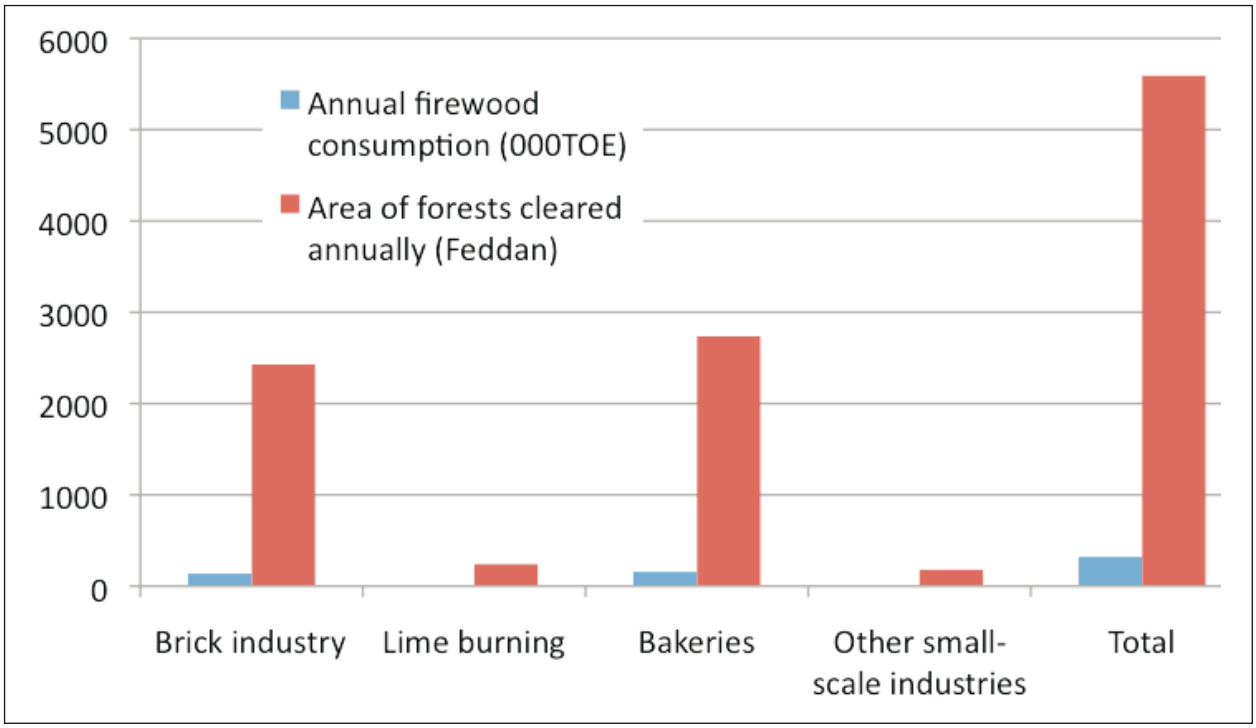
Figure 3.1 shows that the Darfur and Kordofan regions contain the bulk of remaining woody biomass stock in the Republic of Sudan. However, within these regions the distribution of remaining woody biomass stock can vary considerably – Northern Darfur and Northern Kordofan, for example are highly impacted by desert encroachment and have significantly fewer forest resources than South Darfur and South Kordofan. (FNC (1998)

Urban demand for wood products is an important driver of deforestation in less populated states. Firewood and charcoal are presently hauled over more than 1,000 km to supply major consumption areas in central Sudan (Khartoum and Central region) from as far off as South Kordofan.

The burning of non-renewable woodfuel is also responsible for emissions of greenhouse gases, including as CO_2, CH_4, CO, N_2O and NO_x. Given that the household sector is responsible for consuming 68% of total biomass consumption in Sudan, it is clear that this sector is an important source of greenhouse gas emissions as it uses non-renewable woodfuel burned in inefficient stoves. However, some studies (Ministry of Energy and Mining,1983) claim that households in the rural areas use renewable wood as they usually collect fallen branches and other deadwood. In contrast urban households primarily depend on fuel purchased from the market. In general, commercial fuelwood is collected by organized, well-equipped traders who undertake large-scale tree felling to obtain bulk quantities of fuel which is then transported to urban areas. By clearing large forest areas annually without replanting trees, the harvesting of fuel for the urban markets contributes to environmental degradation.

The industrial sector also contributes to the depletion of forest resources (Figure 3.2). Bakeries and brickmakers are the main consumers of firewood in the industrial sector. Both industries employ traditional production processes characterized by using inefficient wood burning techniques. The brickmaking industry is considered highly polluting in nature and energy intensive. Such highly polluting industries are a major health hazard for not only the workers but also for the surrounding populations. This is particularly the case in Khartoum State, where brickmaking yards along the Blue and main River Niles are becoming enclosed within the residential areas. Smoke from the brick kilns accompanied by a strong odour has become an inherent feature of many residential areas of Khartoum. The burning of cow dung contained in the bricks is the main source of the odour.

Figure 3.2. Annual fuelwood consumption by traditional industries and forest area cleared to meet the demand



Source: Ministry of Council of Ministers (2005)

The inefficient burning of biomass fuels emits harmful greenhouse gases which usually are referred to as products of incomplete combustion (PIC). These are considered to be significantly larger contributors to global warming than CO_2 and include methane (CH_4), nitrous Oxide (N_2O), carbon monoxide (CO) and non-methane hydrocarbons (NMHC). (COMPETE, 2009).

The burning of fuelwood is considered to be among the highest contributors of PIC's amongst other sources of domestic fuel. Due to incomplete combustion of fuelwood anywhere between 10 and 20% of released carbon is PIC.

Modern cooking fuels emit far less PIC than fuelwoods which, due to incomplete combustion, release 10 and 20% of released carbon as PIC. LPG on the other hand is far more efficient, with a release rate of 2.3%.(COMPETE, 2009) Even where biomass is harvested sustainably, the fuelwood would not be carbon neutral due to its incomplete combustion. The situation is further exacerbated when fuelwood is inefficiently burned on traditional stoves, as is the case in Sudan.

3.2. Health impacts

Cooking and heating with solid fuels, such as dung, wood, agricultural residues, charcoal and coal, remains the most widespread traditional source of indoor air pollution exposure globally. Indoor smoke contains a range of health-damaging pollutants, such as small particles and CO, and particulate pollution levels may be 20 times higher than accepted guideline values (WHO 2004). Indeed, indoor air pollution has been identified as being responsible for 2.7 percent of the global burden of disease (WHO, 2009).Nearly 2 million people die every year from household air pollution; 44 percent from childhood lower respiratory infections (LRI), 54 percent from chronic obstructive pulmonary disease and 2 percent from lung cancer. (WHO 2011) It has been found that children exposed to indoor air pollution from household solid fuel use have a 2.3-fold higher risk of LRI, while women exposed to such indoor air pollution have a 3.2-fold higher risk of COPD (Goldemberg, J. *et al.*, 2004).

People cook with solid fuels at least once a day in around half of the world's households (Desai et al., 2004). In rural areas of developing countries,

Table 3.2. Annual premature death and disability associated with indoor air pollution in Sudan

Premature deaths attributable to use of fuelwood and charcoal for cooking	Disability-adjusted life years attributable to use of fuelwood and charcoal	Share of total national burden of disease attributable to use of fuelwood and charcoal
4,400	79,000	0.7%

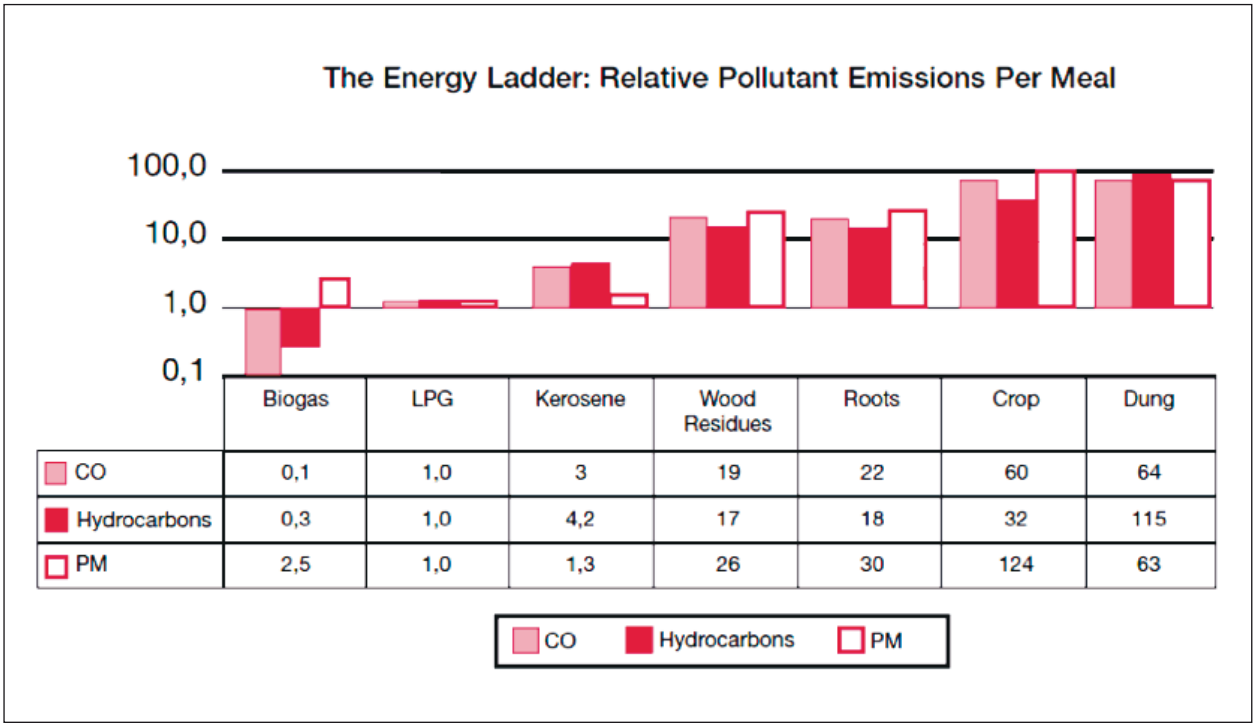
Source: IEA (2008)

the prevalence of solid fuel use is even higher. In Sudan, more than 70 percent of households use solid fuels as their primary household cooking fuel (SHHS, 2006). Combustion of solid fuels on inefficient stoves in poor ventilation conditions results in large exposure to indoor air pollution, particularly for women and young children, who spend the greater part of their time at home.

In Sudan premature deaths attributable to the use of fuelwood and charcoal for cooking are estimated at 4,400 per year, while disability-adjusted life years attributable to their use are estimated at 79,900 per year (IEA 2008). The share of total national burden of disease attributable to the use of fuelwood and charcoal is estimated at 0.7 percent (see Table 3.3). Monitoring of indoor air pollution in poor households in Eastern Sudan, meanwhile, showed that concentrations of CO and particulate matter were 20 times the WHO standard of 50 $\mu g/m^3$ (Practical Action, 2006).

Figure 3.3 shows the emission of pollutants of different household fuels per cooked meal. As concerns the relative emissions per meal, LPG use is second lowest for both carbon monoxide and hydrocarbons, and lowest for particulate matter.

Figure 3.3. Health-damaging pollutants per unit energy delivered: ratio of emissions to LPG



	Biogas	LPG	Kerosene	Wood Residues	Roots	Crop	Dung
CO	0,1	1,0	3	19	22	60	64
Hydrocarbons	0,3	1,0	4,2	17	18	32	115
PM	2,5	1,0	1,3	26	30	124	63

Smith, K.R et al. (2005)

3.3. Environmental and health benefits of LPG to households

LPG, a mixture of gaseous hydrocarbons produced from natural gas and oil extraction as well as oil refining, has three physical properties that are particularly relevant to its carbon footprint:

i. In comparison to most hydrocarbons, LPG has a low carbon to hydrogen ratio, which means that it generates lower amounts of CO_2 per amount of heat produced.

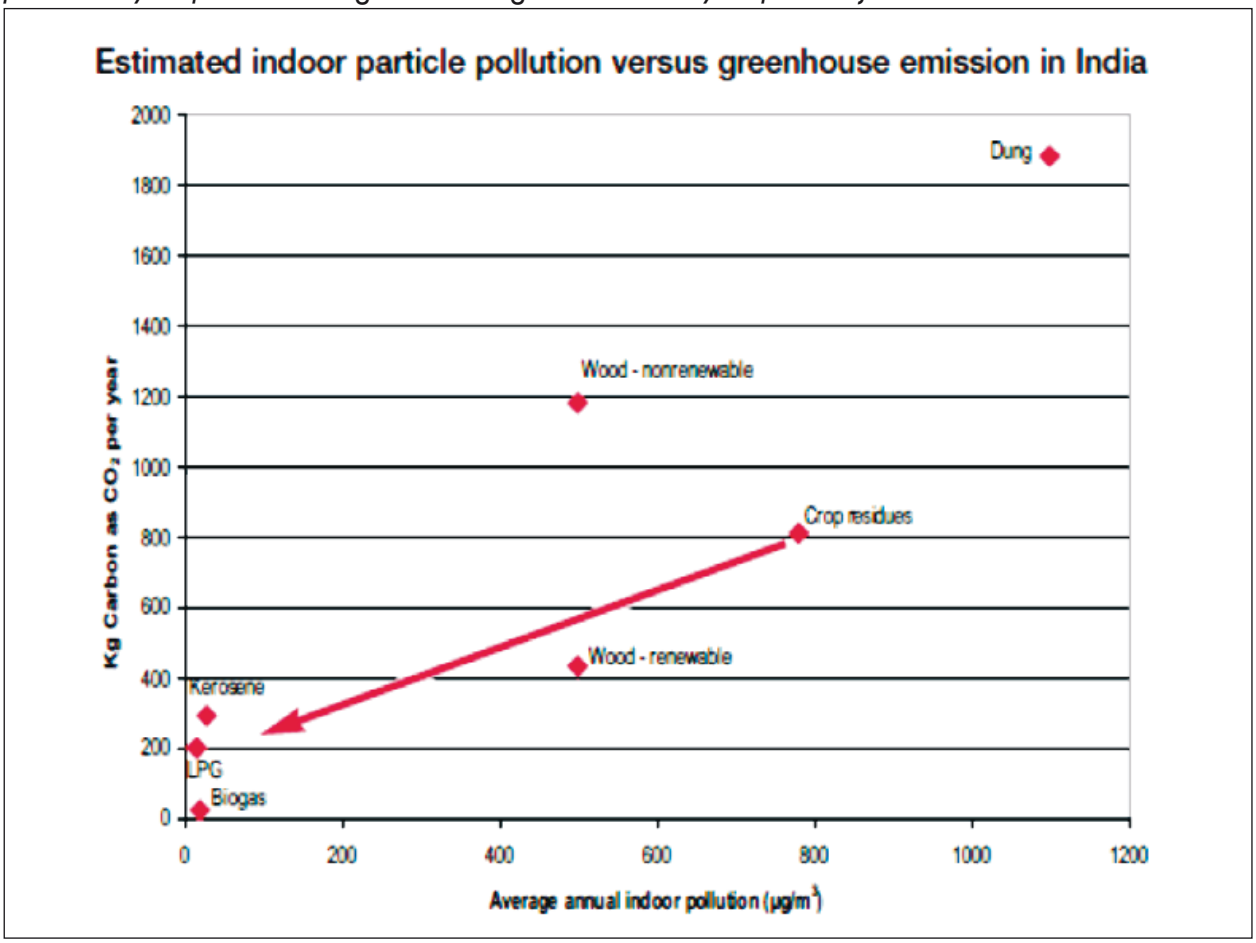
ii. While there is a degree of natural variation in heating values due to the specific proportions of butane and propane within a particular sample of LPG, it nevertheless has a comparably high heating value, meaning it contains more energy per kg than most competing fuels.

iii. According to the IPCC, LPG is not a greenhouse gas, meaning it is assigned a global warming potential factor of zero. The IPCC lists the global warming potential factor of CO_2 as 1 and C_4 as 25 (IPCC, 2007).

In studies carried out in India, it was shown that the burning of LPG emits far less greenhouse gases compared to other fossil fuels and non-renewable biomass fuels. Cooking with LPG at the household level emits 126 g/MJ CO_2 and 0.002 g/MJ N_2O, while for the same amount of energy wood fuel emits respectively 305g and 0.018 g of CO_2 and N_2O. Hence, the burning of LPG produces far less greenhouse gases compared to non-renewable wood (Figure 3.4).

In addition, LPG provides a safe alternative to traditional for household cooking. As highlighted

Figure 3.4. Co-benefits for climate and health of changes in household fuels in India
(For comparison, the health-based standard for particle air pollution is about 50 µg/m3. The arrow illustrates a shift from crop residues to LPG for one household, which would decrease indoor air pollution by 95 percent and greenhouse gas emissions by 75 percent)



Source: Kirk R. Smith et al. (2005)

Table 3.3. Airborne emissions for household cooking, India (g/MJ delivered energy)

Fuel	CO_2	N_2O
LPG	126	0.002
Biogas	144	0.002
Kerosene	138	0.002
Wood fuel	305	0.018
Crop residues	565	0.028
Charcoal	710	0.018
Dung cake	876	0.022

Source: UNDP/World LP Gas Association (2003)

in Table 3.3 above, LPG emissions of the main noxious gases are the lowest of all other cooking fuels including biogas.

As a low carbon and particulate energy able to replace less clean sources, LPG can contribute to improving quality of life by helping to reduce the social cost of energy use on the Sudanese population.

Due to its characteristics LPG provides a useful tool for national policy makers and international actors. LPG is portable, multi-purpose and has a high volume-to-energy yield ratio. As a result it can rapidly be introduced in the aftermath of natural disasters and humanitarian crises where local availability of energy for heating, cooking or power generation is required.

LPG can also play an important role in economic and social development as it allows for activity and development to take place throughout Sudan, even in remote areas characterized by low population density. In rural areas without reliable access to petroleum products, LPG serves as a reliable back-up to renewable energy sources, thereby facilitating decentralized energy production and accelerating the proliferation of renewable technology.

4. Sudan's energy policy

4.1. Key stakeholders in the energy sector

A number of national institutions in Sudan have mandates related to the energy sector. These are summarised in Table 4.1 below. The main stakeholders responsible for policy making as concerns LPG are the Ministry of Petroleum and the FNC.

Over the past 10 years, the energy sector has seen several changes with the creation of new ministries, and shifts of functions between existing ministries. As an example, the Ministry of Energy and Mining was split in two ministries (Oil and Electricity), regrouped into one ministry and then again in 2010 split into three ministries (Oil, Mining and Electricity). Similarly, the FNC, which was formerly under the Ministry of Agriculture, is now under the Ministry of Environment, Forestry and Physical Development.

In addition to the agencies listed above, the following bodies are also responsible for regulatory activities relevant to the sector.

- **General Administration for Environment and Safety**: This regulatory body within the petroleum sector deals with environmental issues in the oil fields (explorations, refineries, transportation activities and legislations).

Table 4.1. Institutional structure of the energy sector in Sudan

Function	Key Institution
Policy and Planning	Ministry of Petroleum (General Directorate of Energy Affairs) Ministry of Electricity and Dams Forests National Corporation (Ministry of Environment, Forestry and Physical Development) Ministry of Finance and National Economy National Council for Strategic Plan
Energy Supply	Sudan Petroleum Corporation (Ministry of Petroleum) Pipeline Companies and Transport (Ministry of Petroleum) Khartoum Refinery (Ministry of Petroleum) Petroleum Exploration Companies National Electricity Corporation (Ministry of Electricity and Dams), now divided into several companies Forests National Corporation Private sector companies and enterprises
Training, Research and Development	Energy Research Institute, ERI, – National Centre for Research, Ministry of Science and Technology Forestry Research Institute Khartoum University and the Sudan University for Science and Technology – Ministry of High Education Sudan Academy for Science and Technology – Ministry of Science and Technology General Directorate of Energy Affairs (responsible for undertaking National Energy Assessments, planning, and policy)
Energy/ Environment	Higher Council for Environment and Natural Resources – Ministry of Environment, Forests and Physical Development
Protection/ security	Civil Defence Department – Ministry of interior Affairs

Source: Own table

- **FNC**: Responsible for non-commercial fuel i.e. wood fuel resources.

- **Higher Council for Environment and Natural Resources**: Operating within the Ministry of Environment, HCENR is charged with regulatory issues in environmental matters, including those related to energy.

4.1.1 Ministry of Petroleum

The Ministry of Petroleum consists of a number of corporations and companies, the main ones being:

- The Sudanese Petroleum Corporation which is responsible for exploring, producing, refining, transporting, marketing, financing, planning, arranging licenses, supervision and the development of new legislation. This corporation is composed of several departments, each responsible for specific mandate within the wider petroleum sector.

- Controlling more than 50 per cent of the market, the Nile Petroleum Company is considered to be the sole arm for the Ministry of Petroleum with the mandate of distributing and marketing petroleum products. The Company is responsible of supplying petroleum products to important strategic sectors like electricity stations, sugar factories, irrigated and mechanical agricultural sectors, irrigation institutes, roads and bridges, service sectors, security and the various development projects in progress.

4.1.2 Civil Defence

While Civil Defence has no engagement on biomass fuels production and use, the department establishes safety measures for the storage, transportation, handling and end use facilities of petroleum products. Actors in the sector must obtain a license from Sudan Civil Defence prior to establishing any petroleum product service facility.

4.1.3 Public corporations

The energy sector is dominated by three public corporations: the FNC, Sudanese Petroleum Corporation (SPC) and the National Electricity Corporation (NEC).

NEC: The NEC is responsible for electricity generation, transmission and distribution in Sudan. One of NEC's objectives is to diversify its electricity supply options through greater use of renewable energy.

SPC: The SPC is responsible for petroleum exploration, production, refining, transportation, marketing, financing, planning, arranging licenses, supervision and new legislation. SPC is composed of several departments, each responsible for specific mandate within the wider petroleum sector.

The Nile Petroleum Company, (NPC) operating under the Ministry of Petroleum, is responsible for marketing petroleum products. The NPC has an integrated system of storage and delivery from its main depots in Al-Jaili, Al-Shajara, Port Sudan and Wad Medani. The NPC is responsible of supplying petroleum products to a number of sectors including: Electricity Stations, Sugar Factories, Irrigated and Mechanical Agricultural Sectors, Irrigation Institutes, Roads and Bridges, Service Sectors, Security and various development projects. In addition to its major depots, ten regional depots (Port Sudan, Medani, Atbara, Sennar, Kassala, Gedarif, Rabak, Al-Fasher, Nyala, Dongola and Al-Obeid) are distributed across Sudan to deliver gas cylinders.

In conformity with the government's directives at naturalizing LPG services as an alternative for charcoal and wood as a source of domestic energy, the NPC distributes gas tanks for bakeries free of charge, and provides the delivery service from its main depots to assist in providing clean and healthy bread for the public. This comes through commercial agreements and coordination with the major companies working in the marketing and distribution of wheat flour such as Sayga and Wheata Companies.

FNC: The FNC is empowered to exercise technical supervision over all forests throughout the country and entitled to issuing directives or take measures for protection and management of reserved and unreserved forests across the country. At the federal level, FNC is the sole agency responsible of managing the forestry sector. Through its state offices, FNC manages the production, supply and marketing of firewood and charcoal all over the country.

In the early 1990s, the FNC launched its Gabatgaz Project which aimed at facilitating households'

Brick kilns on the banks of the Blue Nile, in El Gezira state. The brick-making industry is a major market for fuelwood.

accessibility to LPG and its appliances. This is discussed in detail below at section 5.1)

4.1.4 Civil society organizations

A number of NGOs concerned with environmental conservation, food security and livelihoods have implemented LPG promotion projects in different parts of the country. These include:

- Practical Action in Eastern Sudan, PA, (Kassala and Gedaref States)
- Sudanese Environment Conservation Society, SECS, (Khartoum State)
- Plan Sudan (Kassala State)
- Sustainable Action Group (IDP camps in North Darfur)

These initiatives are discussed in greater detail in Section 5 below.

4.2. Energy policy

The Ministry of Petroleum has the responsibility for formulating and implementing the energy policies in the country. The government formulates its energy policies by using a participatory process between relevant ministries and stakeholders for each policy field e.g. oil, electricity. The national energy policy sets the direction for the development of the energy sector in order to meet national development goals in a sustainable manner. Through its General Directorate of Energy Affairs, the Ministry of Energy and Mining is responsible for:

- Conducting National Energy Assessments;
- Formulating and implementing the strategic national energy planning issues;
- Promoting and disseminating renewable energy technologies; and
- Conducting studies for conservation and environmental impacts issues.

The First National Energy Assessment (1981) was the first policy endeavour towards understanding and planning the energy sector in Sudan. The main output was the first National Energy Plan, 1983, which placed significant emphasis on the environmental crisis facing the country given the high dependence on biomass energy. The main policy directives were:

- Improving the efficiency of biomass fuels conversion, particularly in the household sector
- Development of alternative fuels, mainly targeting the conversion of biomass residues into convenient fuels for the household sector
- Creation of new biomass resources – tree plantations, and maximum use of available resources, particularly woody biomass resulting from mechanized farms clearing operations
- Development and dissemination of renewable energy technologies use, particularly solar energy

In the wake of the National Energy Plan, several projects were launched with international support aimed at realizing the above policy objectives. However, by the end of 1992 almost all of these projects had come to a standstill, largely due to lack of funding.

The Second National Energy Assessment (2001) did not formulate a National Energy Plan. Oil production and export had created new priorities in the energy sector and all efforts were directed towards more exploration with the objective of increasing oil production and export. Following the inauguration of two oil refineries at Al Obeid and Khartoum, the country became energy self-sufficient, and an exporter of petroleum products.

Given the changing energy environment, a revised energy policy was articulated. The energy policy within the overall development policy (as articulated by the National Strategic Plan) is as follows (NCSP, 2006):

- To provide an adequate and reliable supply of energy from local resources to support sustainable development.
- To conserve the environment through efficient and optimal utilization of local resources, especially forests, and to promote tree planting activities. The solution of the energy problem should not be at the cost of deterioration of natural resources.
- To conserve all energy types so as to generate the highest economic value for energy and minimize the cost to the economy.
- To develop the energy sector institutions to ensure coordination between consumers and producers.
- To develop and promote local and/ or adapted energy technologies particularly in the field of renewable energy resources.
- To train qualified and adequate staff at all levels to facilitate the development of energy sector.

The government energy policy has the following objectives for the energy sector, with emphasis on energy security through:

- Efficient energy supply in an environmentally sustainable manner at feasible but socially acceptable prices;
- De-monopolization and liberalization of the energy market;
- Fostering competition in the energy market where possible through privatization;
- Establishing a regulatory framework; and
- Addressing market and institutional failures to promote energy efficiency and renewable energy resources and to protect the environment.

In realization of the above policy the prices of petroleum products were subsidised at levels below prevailing international prices. Indicatively, at the inauguration of the Khartoum refinery in 2001, the price of LPG for domestic consumption was reduced by 50 percent and has remained fixed since. In addition, LPG equipment was exempted from import duty tax.

4.3. Government subsidies for LPG

As one of its components, the 2001 National Energy Policy sought to encourage the widespread use of LPG by the household sector. This was done through:

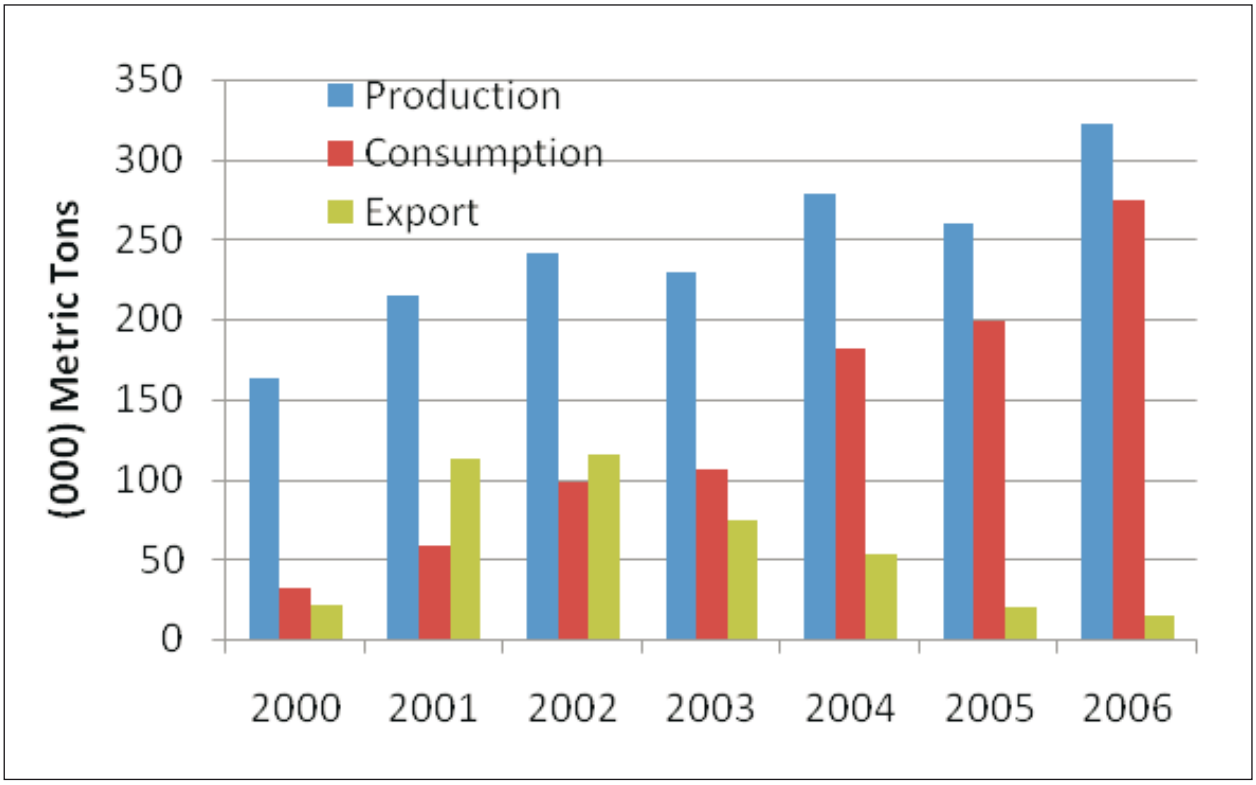
- Reduction of LPG price by 50 percent at refinery gate;
- Exemption of LPG equipment from import duty tax (although VAT applied);
- Commitment for consistent and sustainable supply of LPG for the domestic consumption;
- Measures to ensure LPG price stability.

The government subsidy scheme for LPG did not however involve any awareness campaign or promotional activity in order to further encourage households to switch to LPG use instead of woodfuel. In addition, LPG subsidies are maintained only for the household and commercial/services sectors, and for bakeries, which together have been identified as key biofuel users in need of intervention.

Promotion efforts to achieve widespread use of LPG by the household sector were mainly directed towards facilitating households' access to LPG appliances (cylinders and gas burners). The main target was the formal sector, where institutions were directed to facilitate employees' access to LPG appliances. Institutions purchased the LPG equipment and employees repaid the cost through monthly installments from their salaries.

As a consequence of the above policy and dissemination efforts the consumption of LPG increased tremendously (Figures 4.1). The low price of LPG relative to other petroleum products attracted other sectors, including the automobile and industrial sectors, to switch to LPG use instead of gasoline and fuel oil. However, faced with a steady growth of LPG consumption by the domestic sector, the government banned distribution for the automobile sector, and stopped new authorizations for the industrial sector (2008). In addition, industries which had already converted to LPG use were subject to pay a premium price of SDG 1,000 per tonne. For the household sector, the price was maintained at SDG 960 per tonne. Export of LPG was also

Figure 4.1. Development of LPG production, consumption and export, 2000-2006 ('000 mt)



Source: Ministry of Energy and Mining, SPC- website

reduced significantly. (Figures 4.1). However, the local consumption of LPG sharply increased from 31,977 tonnes in 2000 to 274,397 tonnes in 2006, Figure 5.2.

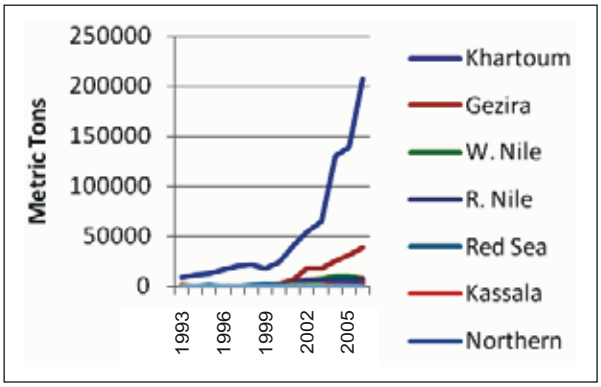
Due to the high upfront costs of LPG appliances, refilling cost and lack of awareness in many parts of the country, the consumption of LPG is mainly concentrated in Khartoum State, which accounts for over 70 percent of total use. (Figure 4.2), followed by the Gezira, Nile and Kassala States. In these states the penetration of LPG use was also facilitated by proximity to a major supplier of LPG (the Al Gaily Refinery) and the existence of good transport infrastructure, coupled with high local prices of fuelwood.

The government has sought to fix the price of LPG and regulated LPG refilling prices in Khartoum State. There is however poor adherence to these regulations, and of the suppliers, only the NPC applies the fixed price of SDG 12.0 for 12.5 kg cylinder at its petrol stations in Khartoum State. For other suppliers in Khartoum the price has been noted to vary between SDG 12 and 15.

For the other states, sales prices are determined by transport costs and availability. Given the state of roads, there is significant variation in LPG consumer prices across the different states (Figure 4.3). The highest refilling price of LPG is noted in Darfur, where transport by either rail or road tankers is very expensive, due to long hauling distance and insecurity.

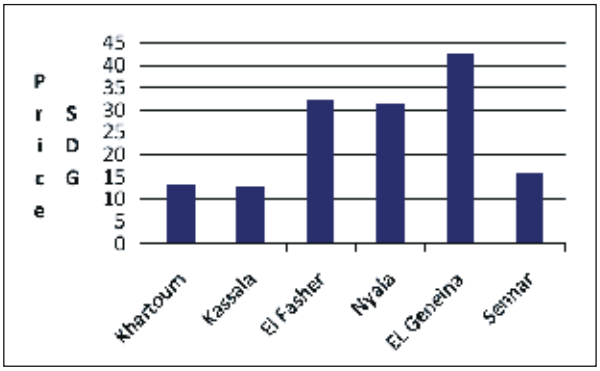
The uptake of LPG across the country is in some cases hindered by taxes levied by various states governments and localities on LPG. This points to a weakness in policy coordination between the central and states governments as regards the dissemination of LPG use. These taxes may serve to make fuelwood much cheaper than LPG in these states, and keep the majority of households using biomass fuels.

Figure 4.2. LPG consumption in Sudanese states, 1993-2006



Source: Ministry of Energy and Mining Website, Oil Statistics Book (n.d.)

Figure 4.3. Variation in 12.5 kg LPG cylinder refilling price in different cities and towns in Sudan



Source: Practical Action (2008a)

Khartoum Locality LPG Initiative

In 2005, the Khartoum Locality (Environment Department) issued a decree requiring the commercial and services sectors to switch from firewood and charcoal to LPG. To encourage uptake, the Locality threatened to ban the entry of firewood and charcoal into Khartoum State. Concurrently, the Khartoum State Social Fund was directed to facilitate household access to LPG equipment through microfinance loans. This endeavour was however unsuccessful due to a number of defaults on the repayment of loans.

As the prices of firewood and charcoal soared, the response of the commercial and services, sector in Khartoum was very positive and almost all restaurants switched to LPG use in place of firewood and charcoal. The Civil Defence Department (Ministry of Interior) put in place safety regulations and an awareness program to allay fears over the possible safety risks of LPG appliances. This initiative can be credited as supporting the significantly increased consumption of LPG in Khartoum (figure 4.2).

4.4. A preliminary analysis of relevant policy issues

At the federal level there are a number of government departments with mandates relating to LPG. These include the Ministry of Energy, the State Petroleum Administration, the Civil Defence, the Ministry of Finance and the FNC. These actors have a say as to the extent to which LPG replaces woodfuel as a source of energy, pricing levels for LPG, and whether to allow the importing of LPG to keep pace with local demand. A preliminary review of federal policy relating to LPG in Northern Sudan indicates that it has not been consistent and that it has not yet prioritised increasing and stabilising the supply of LPG.

State level policies have also had an impact on the uptake of LPG, particularly through fees and taxes. As described in section 5.6 below, firewood traders in Khartoum attribute a large part of the rise in firewood prices to increasing taxes imposed at the state level. This directly helps the substitution of LPG for firewood. Some state governments have taken more significant measures to reduce the use of firewood. For example, Khartoum State passed an Act to stop the use of charcoal and firewood in the commercial and services sector, although this does not appear to have been fully implemented.

In the absence of clear policy implementation on LPG there are cases of contradictory measures being taken at federal and at state levels. For example, at federal level taxes were removed from domestic appliances which use LPG, but various state governments (e.g. the Northern State) have then taken their own initiative in levying taxes on the transport of LPG.

As demand for LPG has started to outstrip supply in Northern Sudan (and Khartoum in particular) the government has prioritised certain users of LPG (households, restaurants and bakeries) over others (the use of LPG for vehicles and for brick kilns.) Despite these measures many stakeholders in the LPG industry believe that imports will be necessary to keep pace with rising demand. Whether this option will be acceptable for the national stakeholders remains to be seen.

The basic price structure for LPG is determined by the SPC which sets the price at the refinery gate, applying a subsidy of approximately 50 percent. As such, in July 2009 the price of LPG in Sudan was $250/mt compared with the average world price of around $530/mt. The transport costs from the refinery to distribution points around Sudan are also supposed to be determined by government. In practice, however, there is sometimes considerable local variation in the price that different LPG distributors charge. The findings of this report suggest that further research is needed to fully understand the dynamics of LPG pricing policy and practice in Sudan.

4.5. Conclusion

In combination with proactive government policies aimed at encouraging the use of LPG by the household sector, a number of LPG stakeholders have played complementary roles in promoting widespread uptake of LPG across the country. It is clear however that due to challenges in pricing and policy coherence, the target of a real reduction in the use of biomass in the household sector require further effort. One possible solution may lie in the creation of an LPG Forum where stakeholders could streamline their, consolidate achievements to date and prepare a joint strategy and plan to achieve maximum substitution of LPG for woodfuel in the domestic.

5. Efforts to substitute LPG for biomass fuels

A number of initiatives have been undertaken to encourage the use of LPG in place of traditional biomass fuels. These build on recognition of the opportunities it presents in addressing both household health and in arresting deforestation due to household energy demand.

5.1. Sudagaz/FNC project

In a joint partnership with Sudagaz Alamarty, the FNC launched the Gabat Gas project in 2002, aimed at facilitating households' accessibility to LPG and LPG based appliances.

Under the partnership Sudagaz imported LPG cylinders from abroad. Through its offices across Sudan, the FNC ensured that these were widely distribution throughout the States.

In total 88,521 LPG cylinders were distributed across the country in 2002. The refilling of cylinders was conducted by the FNC. However, as FNC lacked the necessary infrastructure and logistics for managing the refilling process, the project faced considerable constraints. These included (Mahasin, 2007):

- High initial cost of gas appliances;
- Safety concerns over gas leakage due to the cylinder's adapter;
- Underdeveloped LPG distribution and refilling network;
- Micro credit refund failure due to lack of clear implementation system and proper collateral means.

As a number of private actors emerged to take advantage of LPG subsidies, the Gabatagas project stopped. The new LPG companies were authorized to refill its cylinders for existing consumers.

Although the Gabatgaz project witnessed lot of drawbacks, it can be lauded for encouraged private sector investments in LPG distribution and marketing. In addition following the project several NGOs adopted the dissemination of LPG instead of improved stoves within their food security and livelihoods interventions, particularly in urban areas.

5.2. Practical action – Kassala/El Fasher

Practical Action's LPG use promotion projects in Kassala and North Darfur have aimed to facilitate access to clean modern cooking energy for poor households. The primary goal of the project is to improve the health conditions of women and children below five years age, through a reduction of smoke emitted by inefficient biomass fuel stoves.

5.2.1. Kassala

Hood et al. (2004) report on the experience in Kassala. Practical Action initiated the first indoor air pollution monitoring in Sudan, monitoring household indoor air pollution levels over a period of 24 hours. Thirty poor households from a semi-urban residential area (Wau Nour, Kassala) voluntarily participated in the research. Firewood purchased from the market, was the dominant cooking fuel, and usually took a significant share of the daily household expenditure. Cooking took place on traditional inefficient three stone stoves.

The monitoring of indoor air pollution revealed high levels of particulate matter and CO. During the research phase, the project enabled 167 households to switch to cooking with LPG. The use of LPG led to a reduction in indoor air pollution levels by more than 80 percent (Table 5.1). A scaling up strategy was developed focussing on Women Development Associations (WDA) and incorporating project partners and stakeholders. The scaling up phase started in May 2004 and since then significant achievements have been realized – over 3000 households switched to LPG use instead of biomass fuels.

The Practical Action project carried our energy saving and conservation calculations, concluding that cooking with LPG costs much less than using biomass fuels. It was shown that a household in

Table 5.1. Comparison between the levels of particulate matter and carbon monoxide as measured before and after switching to LPG

Pollutant	24-hour means:	
	Pre-intervention (n=30)	Post-intervention (n=30)
	Round 1 (wet season)	Round 3 (wet season)
Respirable PM µg/m^3)	980	160
CO kitchen (ppm)	12.9	3.1
CO woman (ppm)	6.3	1.9

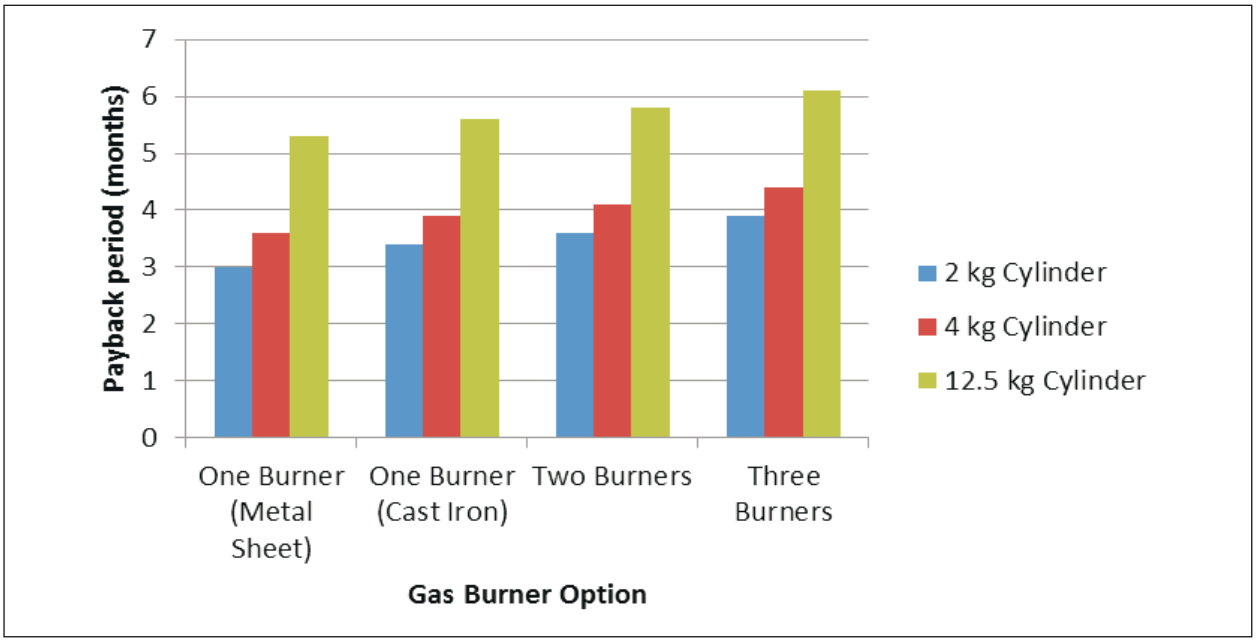
Source: Hood, A., et al (2004)

Kassala could repay the cost of LPG appliances over a period of six months (Figure 5.1). Accordingly, the idea of using a revolving fund system was presented to the WDA, which already had experience with a revolving fund system used for funding income-generating activities. The WDAs are registered charity organizations, have accounts with the Credit and Social Development Bank and are registered for receiving formal credits. On their acceptance of the idea, the project provided seed funding to initiate the microcredit system. The WDA was trained and its capacity built to procure LPG appliances and to manage the microcredit system. The households repaid their loans through lease term instalments.

The strategy for scaling up LPG use in Kassala, particularly in poor residential areas, was based on the following components:

- Supporting and capacity building of WDA's as the primary local partners;
- Provision of seed funding for the revolving fund system;
- Awareness raising and training of women on the advantages of LPG over biomass fuels;
- Training women on safety precautions and efficient use of LPG;

Figure 5.1. Payback periods (months) for the different LPG cylinders and appliance combination options



Source: Hood (2004)

- Close cooperation with relevant stakeholders and partners. These included: Ministry of Health; Civil Defence Department; LPG Companies; and NGOs;

- Convincing LPG companies to provide LPG cylinders on credit to WDA.

The main lessons drawn from this project are summarized in Hood et al. (2004) and expanded on below.

- For poor communities the acceptability of new ideas and technologies to alleviate poverty is linked to addressing their needs and priorities;

- Participatory approaches and awareness-raising are the best methods to reach, organize, and understand the needs and priorities of poor communities, and to guarantee their involvement in project activities. It is an approach that leads to sustainability;

- Women organizations (WDAs) are the most appropriate and interlocutors for the widespread dissemination of LPG use in the domestic sector in Sudan. However, training and capacity building of WDAs are essential for ensuring successful outcomes;

- The revolving fund system is the development of a traditional funding system in Sudan (Sandug). It solves the problem of poor communities' access to services and income-generating activities, and is an empowerment tool, particularly for women, which leads to an improvement in their livelihoods;

- Involving partners and stakeholders at early stages of the project is a key element of project success and sustainability;

- In poor households, smoke from burning firewood is not the sole source of indoor air pollution. Traditional kerosene wick lamps and candles also contribute to indoor air pollution;

- For poor households accessibility to LPG appliances does not guarantee consistent use of LPG. Poor households may not be able to afford the refilling cost of an LPG cylinder;

- Close monitoring of the microfinance system is essential to ensure the sustainability of LPG funding initiatives.

Over a period of three years the Practical Action project enabled more than 3000 households in Kassala State to switch from the use of firewood to LPG. As the WDA have branches in rural towns and villages, the project activities expanded to cover all of Kassala State. The successful participatory project implementation approach adopted by Practical Action produced enabled the WDA to sustainably run the project after the withdrawal of Practical Action.

5.2.2. El Fasher – North Darfur

Following its successful experience in Kassala, Practical Action has looked to replicate its LPG initiative in El Fasher. The project started in December 2008 and seeks to facilitate poor families' sustainable access to and use of LPG for cooking.

The project strategy is based on the following components:

- Adopting a participatory project implementation approach while working through partnership with Women Development Associations, (WDAs), in North Darfur;

- Use microcredit to facilitate poor households' access to LPG;

- Raising public awareness about the negative environmental and health impacts of burning fuelwood on inefficient stoves;

- Training and education of beneficiaries on efficient and safe use of LPG appliances;

- Capacity building of partners. This includes the training of WDA-Net (Women Development Association Network in North Darfur) and WDA's on microfinance, accounting, bookkeeping;

- Monitoring to ensure continuous use of LPG and timely repayment of credit instalments;

- Cooperation with Civil Defence Department for training and raising awareness on safety issues of LPG use;

Selling point of LPG cylinders. The high upfront cost of LPG appliances and the cost of refilling LPG cylinders are reasons cited by households for hindering the uptake of LPG in Darfur.

- Coordination and advocacy with view of influencing stakeholders to joint efforts with the project to achieve widespread dissemination of LPG use in North Darfur;
- Provide seed money to initiate the microfinance system, then run it on a revolving fund basis;
- Close cooperation with LPG companies for supplying LPG appliances on a lease term basis.

For the purpose of measuring the projects impact, a household energy survey was conducted by Practical Action in El Fasher, 2008, covering 17 residential areas. It showed that 57.8 percent of households were predominantly dependant on firewood and charcoal for satisfying their cooking energy needs (see Table 5.3). Their average monthly expenditure on cooking fuel was SDG 83.0.

The same study showed that 20.4 percent of the households only use LPG for cooking purposes, while 9.5 percent of households use a cooking energy mix (firewood, charcoal and LPG).

The continued use of biomass fuels can be attributed to traditional cooking methods and taste preference. Some local staple foods, including *Asida* and *Kisra* are more conveniently prepared on the 3-stone fire place. It should be noted here that there are no LPG stoves designed specifically for cooking *Kisra*.

It is clear therefore that in North Darfur the dynamics of new fuel and stove adoption and use does not follow the correlation between household affluence and modern fuels that is often seen elsewhere. Other factors (including awareness and cultural preference) greatly influence the decision to switch to using clean modern fuel at the household level. The situation in El Fasher is representative of this phenomenon, with well-off households using multiple fuels to satisfy their cooking energy needs.

Given the high rate of poverty in El Fasher, the main barrier to household access to LPG is the high upfront cost of LPG appliances. As indicated in Table 5.3 below, this, along with the high cost of

Table 5.2. Average monthly household consumption of cooking fuels in El Fasher, and expenditure, 2008

Total household* expenditure SDG/month	% of total sample of 147 HHs	Fuel combination use options	Fuel source (kg per month)					
			Firewood		Charcoal		LPG	
			Kg	SDG	Kg	SDG	Kg	SDG
71.0	2.7	Only using firewood	124.8	71.0				
40.6	7.5	Only using charcoal			65.8	40.6		
40.8	2.0	Only using LPG					14.6	40.8
83.0	57.8	Only using firewood and charcoal	147.8	46.3	48.8	36.7		
56.3	20.4	Only using LPG and charcoal			37.7	24.4	11.7	31.9
113.8	9.5	Using three fuels (firewood + charcoal + LPG)	67.8	37.2	63.2	45.5	11.7	31.1

** Average household size is 7.9 persons*
Source: Practical Action (2008)

refilling LPG cylinders (12.5 kg), and perceptions that the use of LPG is dangerous are the three main reasons deterring households from switching from fuelwood to LPG

Due to the high prices of biomass based fuels in north Darfur, it much cheaper to cook with LPG than with firewood or charcoal. This is notwithstanding the high refilling price of LPG cylinders in El Fasher, which at SDG 35 are more than twice as expensive as those in Khartoum. As shown in figure 5.2, the useful energy cost of using LPG is only SDG 0.11 compared to SDG 0.2 and 0.25 respectively for firewood and charcoal on traditional stoves (3-stone fireplace and traditional metal charcoal stove). The main reasons behind these figures are the high price of biomass fuels with low energy density; inefficient biomass stoves; and the high energy density of LPG.

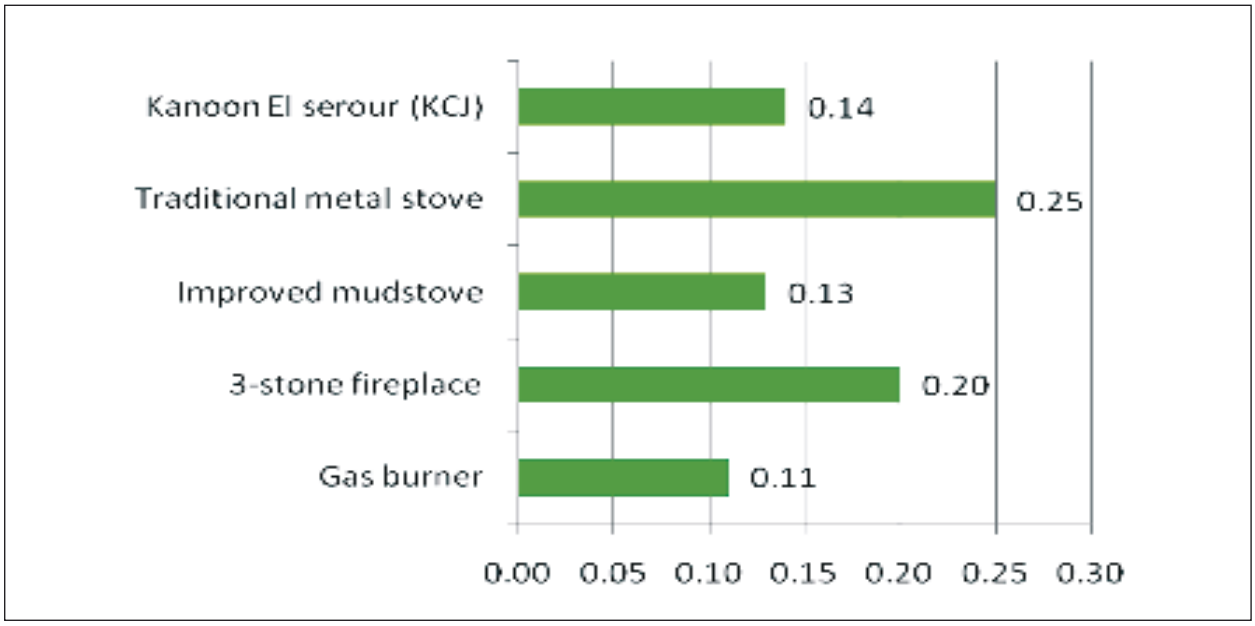
Based on this data, it was found that switching to LPG use in place of firewood and charcoal could generate considerable monetary savings for

Table 5.3. Reasons that deter households from switching to LPG use in El Fasher

Reason for not using LPG	Frequency	%
N.A.	47	32.0
LPG appliances are too expensive -cannot afford it	73	49.7
Refilling cylinder is too expensive – cannot spare money	11	7.5
Using LPG is dangerous	9	6.1
All above answers	6	4.1
Others	1	0.7
Total	**147**	**100.0**

Source: Practical Action (2008)

Figure 5.2. Useful energy costs (SDG/MJ) of using different cooking fuels in El Fasher



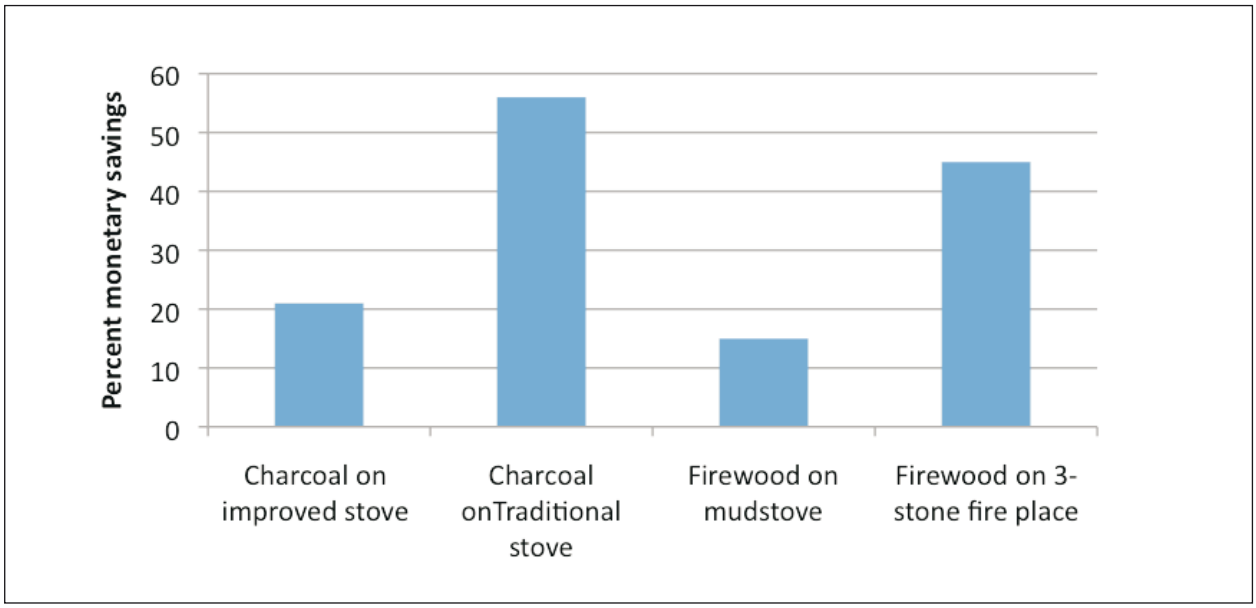
Source: Practical Action (2009)

household in El Fasher. As highlighted in Figure 5.3 below these include 56 percent savings when LPG replaced charcoal, and 45 percent saving when replacing firewood to LPG use.

Following the baseline study the Practical Action project signed partnership agreements with the WDA-Net and two LPG companies in El Fasher. The agreement with WDAs included beneficiary eligibility criteria for obtaining LPG appliances through microcredit, with each WDA to serve as a guarantor for loans to its members.

On the basis of these agreements, the initial seed money for the revolving fund was used to purchase a first batch of 561 LPG appliances sets for the benefit of seven WDAs. The repayment of credit instalments from this batch was very good, reach-

Figure 5.3. Monetary savings (%) on switching from firewood and charcoal to LPG in El Fasher



Source: Practical Action Consulting (2009)

ing an average of 95 percent by December 2009 (Table 5.4).

Despite the high average repayment rate, there were some cases of non-payment – including for example within the Maiarem Women Association which defaulted on 35% of its total loan. Household poverty was cited as the main reason for defaults, with some women being unable to afford the repayment of the loan or for the refilling of the cylinder. Accordingly they resorted back to using firewood for cooking fuel.

Following this finding the credit eligibility criteria was revised to ensure that borrowers could pay for LPG appliances. This included stipulations that LPG appliances would be withdrawn within three consecutive months of default repayment. Changing the beneficiary eligibility criteria has to some extent denied the poorest households from access to LPG. However, within the context of the project, it was decided that this was the only option to ensure access to credit for the WDA's and project sustainability.

By May 2010, the total number of project beneficiaries reached 2,905 – more than the planned target of 2400 households, and the number of WDAs being supported increased to 27. WDAs from rural El Fasher, and from as far off as Kooma Garadayat (80 km from El Fasher) and Kabkabiya (150 km from El Fasher) were engaged with the project. The repayment of credit instalments is very high, and 92 percent of the beneficiaries are continuously using LPG.

Other achievements of the project include building a strong relationship with NPC, resulting in full lease arrangements for payment for LPG appliances. Practical Action and the WDAs are now well known and trusted chartered organizations in El Fasher. As a result of this the number of beneficiaries per batch has increased significantly.

5.3. Sustainable Action Group (SAG) – Abu Shouk and El Salam IDP camps in El Fasher

Due to the scarcity of forest resources and insecurity in Darfur, particularly around El Fasher, IDPs face difficulties in meeting their cooking energy needs. As a consequence humanitarian organizations are undertaking efforts to help IDPs through energy conservation measures and alternative fuels. Among others a local NGO – the Sustainable Action Group (SAG) – launched a free distribution initiative of 12.5

Table 5.4. Rate of repayment of credit instalments, first batch of LPG appliances

First Beneficiary Batch Loan Duration: March 09 – December 09						
SN	**Name of WDA**	**Number of households**	**Loan (SDG)**	**Repayment (SDG)**	**Deficit (SDG)**	**Repayment rate (%)**
1	Tanmia wa Tatweer Amaraa	50	7,775	7,775	0	100
2	Maiarem	20	3,200	2,090	1,110	65
3	Market net	50	8,000	8,000	0	100
4	Amel	45	8,750	7,673	1077	88
5	ERDN	45	8,137	7,713	424	95
6	Forestry families	20	3,200	3,200	0	100
7	Argoon	30	4,800	4,800	0	100
Total/Average		260	43,872	41,261	2,611	95

Source: Practical Action (2009)

kg LPG cylinders to 1200 households in Abu Shauk and Al Salam IDP camps in El Fasher.

In consultation with the traditional leaders (Umdas) SAG agreed on a distribution criteria for LPG appliances. This essentially focused on the capacity of the household to refill the cylinder in El Fasher (about SDG 37 including transport). As a result LPG appliances were mainly distributed to Umdas, Sheikhs and some relatively well-off households.

All LPG users in the two IDP camps unanimously cited the advantages and benefits of LPG over firewood, as follows:

- Using LPG (on average SDG 35 per month) is cheaper than firewood (minimum SDG 60 per month);
- Cooking with LPG is fast – time saving (preparing *Asida* on firewood fire takes minimum one hour, while using LPG it takes 30 to 45 minutes);
- There is no smoke, ash, or soot – the house and clothes remain clean;
- It is healthier and there is no eye irritation and coughing;
- Children get to school in time and meals are prepared in a short time;
- When there are guests at home, hot drinks are served in a short time
- LPG reduces water consumption. Cooking pots are clean as there is no soot deposit.

Monitoring undertaken by SAG staff indicated that the LPG adoption rate by beneficiaries was very high. Although no specific figure is mentioned, SAG staff highlighted that some men who received LPG cylinders on behalf of their wives sold them. With regards to LPG accidents, SAG staff noted that only one accident was reported during the three-year period. It was however a small accident which was quickly contained by the household members without causing any damage.

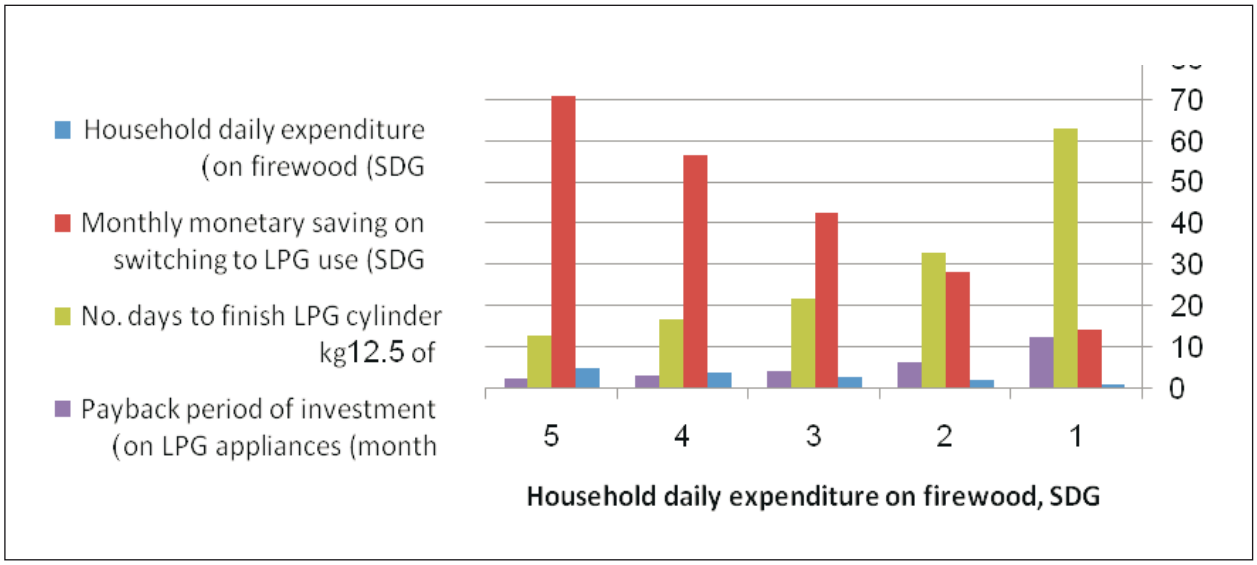
Switching to LPG use instead of firewood requires a significant initial investment by households in cooking appliances, namely the gas cylinder and gas burner. The preferred LPG cylinder size in El Fasher as well as in the IDP camps is the 12.5 kg capacity. The market price of the cylinder and one gas burner is currently about SDG 432 (2012) in El Fasher. However, Practical Action Smoke project has especial deal with Nile Petroleum Company at a price of SDG 330. On switching to LPG use, Figure 5.4 shows the monthly monetary saving, number of days to consume a 12.5kg LPG cylinder and the payback period for different households which are spending between 1 SDG and 5 SDG daily on firewood.

As households in Al Salam and Abu Shauk indicated, a minimum daily expenditure of 2 SDG on buying firewood justifies switching to LPG use, saving households about 28 SDG every month. An LPG cylinder lasts for about one month and the payback period is about 6 months. Depending on family size and daily expenditure on firewood, the payback period for investment on LPG appliances ranges between 2.5 to 6.3 months. However, within the IDP camp context, very few households could afford investing 180 SDG to purchase the LPG appliances.

Lessons learned from the SAG LPG experience in Abu Shauk and Al Salam IDP camps, as confirmed by the staff, are:

- LPG is the best alternative cooking fuel option for IDPs in Abu Shauk and Al Salam IDP camps
- In contrast to the general statement that LPG is a hazardous and dangerous fuel for IDP settings, the limited experience demonstrated that adequate training of beneficiaries on correct use and safety precautions helped to avoid accidents.
- The introduction of LPG raised IDPs awareness and encouraged a considerable number of well-off IDP households to switch to LPG use through direct purchase from the market
- The unavailability of LPG refilling services within the camp discouraged some households from refilling their empty LPG cylinders. If an LPG refilling service is made available within the camp boundary, small size cylinders (4, and 6 kg) could replace the 12.5 kg cylinder thereby increasing the number of beneficiaries several fold.

Figure 5.4. Household daily expenditure on firewood and corresponding monthly monetary savings on switching to LPG use



Source: Practical Action Consulting (2009)

5.4. Sudanese Organization for Building Materials and Construction (SOBMC)

The Sudanese Organization for Building Materials and Construction (SOBMC) has tried to encourage the brickmaking industry, particularly in Khartoum, to switch to LPG use instead of firewood. Without giving much attention to technical considerations regarding brick kiln design, SOBMC conducted intensive experimental work on clamp kiln firing using LPG. Some slight modifications were introduced to the clamp kiln (covering the top of the kiln and introducing a side chimney) in order to reduce the heat loss that occurs through flue gas created by high draught which is caused by gas burners.

Although SOBMC claimed to successfully convert clamp kiln to LPG firing, it did not succeed in convincing brickmaking entrepreneurs to adopt the new fuel. The later claimed that there were non-financial benefits in switching to LPG use, and that additional investment would be necessary to acquire an LPG tank and burners.

SOBMC reported the results in Table 5.5 below. These represent the best results that have been achieved so far through clamp kiln firing with LP gas. The high percentage of first class bricks is an indication of successful firing. Brickmaking entrepreneurs however have noted that LP gas firing of clamp kiln does not produce results that are significantly better than wood firing (as regards the percentage of first class bricks) and thereby results in none or very little financial saving.

Similarly, Practical Action's effort to introduce LPG as substitute for firewood in brickmaking in Kassala did not yield encouraging results. The main reasons identified for this were: 1) LPG supply problems where only cylinders of 25 Kg capacity were available; and 2) the clamp kiln proved unsuitable for LPG firing.

5.5. Green Bakery Project, Sayga

In the private sector, Sayga Flour Mills have launched a corporate social responsibility initiative aimed at both supporting the baking industry, and improving the environment.

The Green Bakery Project supports traditional bakeries by replacing woodfuel with a clean, safe, cost-effective, and environmentally-friendly gas burner system. In addition the project plants trees near the vicinity of bakeries that adopt the burner system, and ensures that appropriate conservation and watering arrangements are made.

The goals of the project include:

- An efficient and cost-effective operational system which aims to reduce fuel costs by more than 40 percent.
- High standards of occupational health conditions and work environment by eliminating pollution resulting from wood burning.
- Shifting the baking industry to becoming more environmentally sustainable.

The Sayga LPG initiative is directly linked to the Company's promotion campaign for its products, notably flour. In a similar manner, other companies in the industry have increasingly started promoting their products by providing LPG equipment to bakeries.

LPG Companies freely provide fuel tanks (2 to 4 tonnes) to the bakeries for the purpose so as to ensure that the gas supply comes through them. In areas where there is no tanker service, the bakeries are given with 45 kg cylinders (4 cylinders connected in series).

LPG use by the bakeries is mainly concentrated in the central part of the country, where LPG competes with high prices of firewood. In other areas, for example Darfur, the high price of LPG renders its use in the bakeries unfeasible.

5.6. Other initiatives

Some other efforts that have been undertaken to disseminate the widespread use of LPG bear note.

In 2000 the Sudanese Environmental Conservation Society (SECS) implemented a small LPG use promotion activity in a rural area of Khartoum State. Innovatively, the project included a microfinance system to support household access to LPG appliances. Unfortunately due to a lack of records on the project, it was not possible to evaluate its results.

Table 5.5. Results of clamp kilns fired with LP Gas

Kiln No.	Quantity of bricks ('000)	Quantity of LPG used (kg)	LPG use rate kg/1,000 bricks	First class bricks (%)
1	120	540	4.5	86
2	117	657	5.6	83
3	70	436	6.2	74
4	73	400	5.5	88
5	113	518	4.6	72
6	109.5	676	6.3	83
7	114	550	4.8	88
8	52	330	6.3	89
Average			5.5	

Source: SOBMC (2006)

Another LPG use promotion effort was undertaken by the Credit and Savings Bank (2007). The main objective of the project was the reduction/elimination of charcoal use by women tea makers in Khartoum State, while increasing their income. On contract from the bank, a sustainable tea making stall was designed and manufactured by the Sudan University of Science and Technology. It consisted of a working table, shade and drawers containing an LPG cylinder and gas burner. The stall was initially distributed to tea makers on a credit basis, with lease term repayments. The endeavour however was short lived. As roadside tea making is an informal activity, tea makers were liable to being removed by local authorities and having their stalls confiscated.

The NGO Plan Sudan has worked on LPG use promotion in rural areas of Kassala. Under the project LPG cylinders were freely distributed to the households. However, the effectiveness of the project was hampered by lack of buy in due to a lack of direct participation by women.

6. Findings, conclusion and recommendations

Following the commencement of local production of LPG at Al Jaili Refinery in 2000, and as a result of government incentives aimed at encouraging households to switch to LPG use instead of fuelwood, there has been a significant net up-take of LPG use in Sudan. As a result, a number of private sector companies have emerged to address the increasing demand for LPG.

It is clear also that LPG use has a number of benefits over the conventional biomass energy sources which are widely used in the countries household sector. These include improved environmental conservation and reduced deforestation, climate change mitigation, improvement in women and children health and wider socio-economic development.

The findings of this study indicate however that notwithstanding government incentives and the expansion of the LPG distribution network, and the clear benefits of LPG use, the penetration of LPG use across households Sudan as a whole is still very low at about 6 percent. It is clear that the use of LPG remains concentrated largely in the central region of the country, and that it is still very low in remote areas of the country and even in the peripheries of major towns in central Sudan. Given the analysis considered above five main barriers to the widespread use of LPG in Sudan can be identified:

- Relative large investment in LPG appliances (cylinder and stove);
- Price competitiveness of LPG against low prices of woodfuel;
- Lack of infrastructure for LPG distribution;
- Lack of information;
- Socio-cultural issues.

These are elaborated on below. What is clear is that further national and local interventions are necessary to build on the successes with LPG up-take to date, and to improve coverage to address the identified barriers. These should form the basis for a national LPG Scale-up strategy, which is discussed in greater detail in section 6.2 below.

6.1. Barriers to widespread use of LPG

6.1.1. High upfront cost of LPG appliances and new technology

Practical Action's experience as well as that of LPG programs in other African countries has demonstrated that the price of LPG appliances (almost ten times the refilling cost of the LPG cylinder in Sudan) is the main constraint hindering poor households' access to LPG. Even where the long term savings from a switch to LPG for fuel are significant, poor households find it very difficult to justify the initial investment.

Efforts that have been based on the free distribution of LPG appliances to overcome this problem have rarely been successful. Plan-Sudan's experience in Kassala State showed that LPG cylinders provided for free were often later sold by households. It is generally recognized that poor households very often undervalue the socio-economic benefits of free donations. This implies the necessity of imposing a cost on LPG appliances. As shown by the success of Practical Actions interventions in Kassala and El Fasher, supporting WDA's with access to lease arrangements is a useful method to ensure access of LPG for poor households.

6.1.2. Price competiveness of woodfuel

Almost all households in the urban areas of Northern Sudan obtain their cooking fuel supplies from the market. The prices of traditional biomass fuels relative to LPG, whenever available, are an important determinant factor in households' decision to switch to LPG use.

The price of different biomass fuels varies to a great extent between urban and rural areas and across national borders due to transportation costs, availability of resources, national policy, and market-

driven demand. Experience shows that if direct and significant economic incentives to encourage demand for LPG are not properly implemented, there is a clear pattern where traditional options remain much cheaper and therefore more widely used than LPG. Indicatively even though in certain areas the price of LPG per unit of energy delivered may be cheaper than that delivered by traditional fuels, households might be dissuaded to adopt use due to the high recurrent filling cost of LPG. Smaller size cylinders are often proposed as a means to address this constraint; however, in practice households unanimously rejected the small size cylinders for reasons of frequent refilling (Hood, A., *et al.*, 2004).

In the case of rural areas with direct access to woodfuel it is much harder to make a compelling case for the uptake of LPG on the basis of price. Low prices of charcoal and firewood result from the fact that both of these fuels are derived from a natural forest resource that can be exploited with little or no direct cost to producers or consumers. As long as the price of clean cooking fuel remains uncompetitive vis-a-vis traditional fuel it will be difficult for it to gain widespread use. Indicatively, where cost-effective alternatives to traditional fuel have been offered, they have gained a significant share of the market. For example, the widespread use of LPG in Senegal and Brazil resulted from government actions that removed all taxes on LPG combined with price subsidy.

Despite the success of Senegal's LPG program, the use of fuel subsidies to incentivise fuel switching does not provide a simple solution to the problem of price competitiveness. The primary beneficiaries of such subsidies tend to be wealthy and middle class urban households. The desired effect of the subsidy is often lost on the urban poor, who, with little disposable income, find it more affordable to purchase fuelwood on a day-to-day basis. Poor households tend to prefer fuel that can be purchased in small, discrete quantities (e.g. charcoal, firewood) to that which requires the purchase of a larger unit of fuel (e.g. a cylinder of LPG). For example, lessons learned from Practical Action's LPG project in Kassala revealed that poor households switch back to using firewood and charcoal whenever they do not have enough money for refilling the LPG cylinder. As a result, in the long run poor households may actually spend more money by purchasing traditional fuels each day instead of purchasing larger quantities of clean cooking fuels.

Conversely, fuel subsidies can even have a negative effect on the urban poor. A study of kerosene subsidies in several African nations (Schlag, N. and Zuzarte, F. 2008) found that the urban poor would actually benefit from their removal. This is because they continue to purchase traditional fuels which are taxed to fund the kerosene subsidy. Thus, before any subsidy is introduced there should be careful consideration of how all stakeholders might be affected. Nonetheless, Senegal's success with subsidies still provides a promising example of how such a policy can change fuel consumption patterns.

The case of rural areas deserves special attention as the pattern of energy use is very different to that in urban areas. Forest resources may be abundant allowing free collection of firewood and charcoal produce. In addition the supply of firewood and charcoal to urban markets is a basic livelihood activity for a considerable proportion of the rural population, particularly during the dry season. In consequence widespread use of LPG might produce a negative impact on the rural economy. For example, in Kassala, as a result of the intervention of Practical Action the price of charcoal fell, negatively influencing the income of rural population which depended largely on charcoal supply to the urban population in Kassala.

6.1.3. Lack of adequate infrastructure

As a result of government LPG subsidies, the consumer price of LPG for the household sector is fixed, but only at ex-refinery gate price. In addition, the refilling price for Khartoum State consumers is also fixed at SDG 12 for a 12.5 kg capacity cylinder.

Despite this however, there are consumer price disparities across the country (Figure 4.3 above). Due to lack of adequate transport infrastructure the consumer price of LPG, in many places largely depends on the state of roads, and the distance from the main depots at Al Jaili and Al Shagara. Even within Khartoum State there is some variation (SDG 12 to 16 per 12.5 kg cylinder) in LPG refilling price despite the fixed price.

In recent years the LPG distribution network has witnessed remarkable improvements. There are

Tea maker in Khartoum market preparing tea using an LPG cylinder. LPG provides a more environmentally friendly alternative to the use of charcoal in tea making.

now about 12 LPG storage depots in the capitals of twelve Northern States of Sudan. Even then however, there are still price disparities between the State capitals and Khartoum and between the State capitals and rural areas. For example in White Nile State, the refilling price of 12.5 kg capacity cylinder is SDG 16 in Kosti and Rabak, while in the southern parts of the State it reaches up to SDG 30.

For Darfur and southern Sudan the refilling price of LPG is further exacerbated by the lack of paved roads and prevalence of insecurity. The price of a 12.5 kg capacity cylinder varies between SDG 30-35 (in Nyala and El Fasher) and SDG 50 in Al Geneina and Kutum, for example. The rail transport, if adequately operated, could have improved access and therefore the price, however only road tankers are used which – depending on the security situation and the rainy season – often results in supply shortages leading to scarcity and further increases in LPG price.

The situation in Nyala is indicative of the challenges facing LPG supply. In 2010 the price of a gas cylinder rose from SDG 30 to SDG 50 as a result of serious shortages and black market availability. So as to correct the prices the Sudanese government intervened in 2011 to set up a strategic stock of LPG in the town, to supply distributors in the event of unavailability of cylinders. As a result the price of a cylinder fell to SDG 25.

6.1.4. Lack of information

Public awareness, and particularly women's awareness, about the benefits of LPG is a crucial factor that could further increase the widespread use of clean cooking fuels. As it stands there is generally a lack of information flow between producers, consumers and intermediary organizations. In addition, there is significant gap in information as regards household energy consumption patterns. The last national energy assessment was conducted in the years 1999/2000. In addition, over the past 15 years there has been increased awareness of issues

LPG stove for cooking Kisra developed by artisans in Khartoum. Despite attempts to adapt LPG appliances to cook local dishes, most households still prefer firewood and charcoal for cooking Asida and Kisra'

related to the impacts of forest degradation and the negative health impacts of high dependence on solid biomass fuels, including the identification of indoor air pollution as one of the main cause of morbidity and mortality among women and children below 5 years age.

At the same time, consumers have little access to information about their energy options. There is a lack of awareness among the public on a number of levels: first, many consumers are not aware of the available alternatives and do not have a clear understanding of what their purchasing options are. Second, those consumers who know their options are often ignorant of the effects of their consumption choices. Because they do not understand the consequences of their use of traditional fuels — specifically, the health and environmental effects — they continue to use them in spite of the benefits of a transition to clean alternatives. This makes encouraging a shift to clean alternatives a difficult task. Thus, public awareness and consumer education would play an important role in encouraging a transition to clean cooking fuels (Schlag, N. and Zuzarte, F. 2008).

6.1.5. Social and cultural issues

In addition to the factors discussed above there are a number of minor social and cultural issues that reinforce the dependence on traditional fuels. Food taste is a minor constraint identified mostly by elderly women. In addition, the preferred food preparation method for the main national staples – *Asida* and *Kisra* is difficult to replicate on an LPG stove. These are usually prepared in round bottom aluminum pots and hot plate, which do not easily fit on the LPG burner. This has been identified as a reason that many affluent households still use firewood and charcoal for cooking *Asida* and *Kisra*, while using LPG for other cooking tasks.

Some households claim that cooking with LPG is inadequate as it does not allow enough time for the food to cook slowly. However, this claim is incongruous with the inherent advantage of LPG fire being controllable as opposed to wood and

charcoal fires, which are harder to control. Biomass Stoves are hardly controllable at minimum power without regular attendance. As a result a long time is spent by those preparing food sitting on a stool in front of cooking pots.

Another constraint is based on traditional household structures where household decision making authority often rests with men. This is often the case when women are not employed and the supply of household needs, including cooking fuel, is the responsibility of the man. For example, when Plan-Sudan freely distributed LPG cylinders to households in rural areas of Kassala, the household interlocutors were men as per tradition in Eastern Sudan. LPG cylinders were delivered to the men, without the knowledge of the women, and as a result a number of LPG cylinders found their way to the market. Similar cases happened in Abu Shouk IDP camp in El Fasher. In the later case the men decided that LPG was too dangerous for use and likely to lead to fire and explosion hazards for the family members. As a consequence they either sold the LPG cylinders or otherwise hid them from display, requiring that they be present when the cylinders were being used.

6.2. Recommendations

Having identified the major impediments to the full uptake on LPG in Sudan, four broad recommendations aimed at scaling up the use of LPG can be put forward. These are based on lessons learnt and best practices ascertained from existing initiatives.

1. Development of full cost recovery microfinance options to facilitate household access to clean modern energy such as LPG.

It is clear from the lessons of existing initiatives that both full price and free LPG appliances have met with poor up take. So as to overcome the high initial cost of LPG units, a lease term microcredit system for acquiring LPG appliances is essential. Creditors should look to support initiatives focused on WDA's and other groups that have a proven record of guaranteeing repayments.

2. Increased focus on women as primary beneficiaries in LPG scale-up activities, including capacity building support for Womens Development Associations (WDAs).

Working through women organizations is the ideal outreach approach to scale-up LPG use within the household sector as women constitute the main beneficiaries from their use. In the experience of this author, it is generally stated that switching to LPG use is becoming the ambition of almost all Sudanese women, particularly when accessibility is rendered or facilitated.

Training women's organisations and WDAs on management of the lease term microcredit system, and in monitoring will ensure that repayment of loan instalments are timely will help to ensure continuous delivery of LPG appliances to newly registered households.

3. Government policies and initiatives to promote LPG market development, including strategy for full application of subsidies and national price stabilization.

Existing government policies to enhance LPG uptake across the country are laudable. However there is still scope for further action through innovative policy frameworks and financing mechanisms. Possible government interventions in this regard may include;

- Development of legislation, regulations and standards that organize and govern the LPG market and assure public safety as well as consumer safety and protection.
- Monitoring LPG sale prices to ensure the LPG agents are not imposing excessive retail prices
- Expansion of LPG distribution network – depots and retail/refilling shops
- Further removal of taxes on LPG appliances, for example VAT
- Set standards for LPG stoves, cylinders and accessories
- Undertake policy and regulatory framework measures attractive to prospective energy and financial investors, and to users
- Encourage and support private sector and NGOs involved in the dissemination of LPG use, particularly among households and other sectors that are major consumers of firewood and charcoal

Fixed tea making stand (hidden are the two LPG cylinders).

4. Public awareness and consumer education on benefits of LPG, and safety precautions of LPG use.

Public awareness activities must have two components. The first involves awareness campaigns aimed at highlighting both the negative health and environmental impacts of inefficient use of fuelwood. This must be augmented with clear messages on the benefits of LPG use, including monetary savings, health improvement, time saving, and cleanliness.

The second involves comprehensive training modules on the correct methods of using LPG and on safety precautions of LPG use. In this regard the Civil Defence department of the Ministry of Interior is recognized as an important counterpart. With the Practical Action initiative, close cooperation with the Civil Defence department in educating women on the correct use and safety precautions greatly helped to convince hesitating women to switch to LPG use.

Annex 1. List of tables

Annex 2. List of figures

Annex 3. Acronyms and abbreviations

ALRI	Acute lower respiratory infection
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
DJAM	Darfur Joint Assessment Mission
ENTEC	Environmental Technology Task Force
ERI	Energy Research Institute
FAO	Food and Agriculture Organization of the United Nations
FNC	Forest National Corporation
GHG	Greenhouse gas
g/MJ	Gram per mega joule
IDP	Internally Displaced Person
km	Kilometres
ktoe	Kilotonne of oil equivalent
LPG	Liquefied Petroleum Gas
MDG	Millennium Development Goal
Mt	Mega tonne
N_2O	Nitrous oxide
NEC	National Electricity Corporation
NMHC	Non-methane hydrocarbons
NO	Nitrogen monoxide
NO_x	Mono-nitrogen oxides
PIC	Products of incomplete combustion
SPC	Sudanese Petroleum Corporation
SAG	Sustainable Action Group
SDG	Sudanese Pound (Geneih)
SECS	Sudanese Environment Conservation Society
SOBMC	Sudanese Organization for Building Materials and Construction
NEC	National Electricity Corporation
toe	Tonne of oil equivalent
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
WDA	Women Development Association
WHO	World Health Organization
VAT	Value Added Tax

Woodfuel: Woodfuels refer to all types of biofuels originating directly or indirectly from woody biomass, including fuelwood, charcoal and black liquor.

Fuelwood: Fuelwood refers to woodfuel where the original composition of the wood is preserved.

Annex 4. LPG consumption in the Sudanese states (1993-2006)

State	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Khartoum	8981	11312	13275	16633	19760	20838	17946	23703	39574	54326	64997	130141	138584	207421
Gezira	444	686	678	895	342	428	1178	2358	6199	18249	17968	24952	31261	39022
W. Nile	0	0	0	54	0	42	363	628	1898	6332	6645	8944	9464	6656
R. Nile	107	124	28	43	492	284	722	1350	3199	5820	5345	5491	5968	7032
Red Sea	913	342	1403	717	742	1249	2222	1859	2494	2845	2749	3163	3765	4037
Kassala	1621	588	581	590	550	685	706	862	2113	4085	2922	3295	3421	4031
Northern	23	61	18	237	562	22	148	781	1912	3730	2656	3425	3159	2788
N. Kordofan	56	84	132	211	110	157	254	207	797	1679	1153	1672	1877	2502
B. Nile	0	0	0	28	0	0	9	194	539	697	566	275	185	151
S. Darfur	0	0	0	0	0	0	154	20	107	103	288	670	575	686
N. Darfur	0	0	0	0	0	0	3	6	35	43	83	25	97	2
S. Kordofan	0	0	0	0	45	0	0	9	43	30	31	14	22	9
All Southern	0	0	0	0	0	0	0	0	0	0	0	0	37	60
Total	12145	13197	16115	19408	22603	23705	23705	31977	58910	97939	105403	182067	198415	274397

Source: Ministry of Energy and Mining / Sudan Petroleum Corporation – Oil Statistics Book (n.d.)

Annex 5. Summary of advantages and disadvantages of LPG

Characteristic	LPG compared to Biomass as cooking Fuel	Kerosene compared to LPG as cooking Fuel
Ease of use for household cooking	LPG is much easier to light, control, and store than biomass. However, it has to be bought in fairly large amounts.	Kerosene is easier to control and light than biomass, but not as easy as LPG. It can be bought and stored in small quantities.
Safety	LPG poses some safety concerns in local transport and use. Government attention is required to reduce risks. As it is stored in sealed containers and generally contains odorants to warn of leaks, household risks are low.	Kerosene poses safety concerns in its use and storage, including child poisonings, household fires and burns, whereas safety concerns for LPG stem from leaky appliances to which odorants are added to warn of leaks.
Ease of local transport	Local LPG transport requires the use of low-pressure cylinders, which are heavy for a woman to handle at refilling time.	Kerosene does not require pressure vessels for transport or storage.
Health damaging air pollution	LPG reliably produces much lower air pollution emissions for all classes of pollutants.	Kerosene pollution levels are lower than biomass, but are not as low nor produced as reliably with LPG.
Greenhouse pollutants	Although always a net emitter, LPG emits far less than poorly combusted and/or non renewably harvested biomass.	Kerosene produces somewhat more GHGs than LPG.
Dependence on centralized networks	LPG is a product of the sometimes unstable and unpredictable global petroleum fuel cycle, but locally is independent of pipelines. Local reliability requires smooth operation of rail or road supply chains on a national and local level.	Kerosene is also a product of the international global petroleum fuel cycle and is independent of pipelines. Like LPG, it also requires smooth operation of national and local supply chains. Unlike LPG, however, its production competes with other middle distillates, such as diesel.
Impact on women's time	Less reliance on local harvesting of biomass can be positive, negative, or neutral depending on local conditions, such as value of women's time and alternatives available.	Kerosene may require somewhat more cleaning in kitchens than LPG and, perhaps, more care to keep children safe from burns.
Impact on demand for children's time	Less need to harvest biomass can release time (for example, allowing children to attend school).	
Local ecosystem	Less pressure on local biomass resources may reduce deforestation and soil degradation rates and increase availability of biomass wastes for crop enhancement in some regions.	
Daily cost at household level	LPG is generally more expensive in rural areas even where biomass fuels are purchased but is sometimes cheaper in peri urban areas. Where biomass is gathered, LPG costs (excluding opportunity costs from time spent gathering) are usually substantially more expensive.	Kerosene is often somewhat cheaper than LPG, but prices vary according to a number of local factors. In the long run, the prices of both fuels are closely linked to the international price of crude oil.
Capital cost at household level	LPG stoves and cylinders are much more expensive than many traditional biomass stoves although not too different in cost from advanced biomass stoves (with chimneys, grates, baffles, dampers and good insulation).	Kerosene stoves cost less than LPG stoves, but cheap ones can be dangerous and can be short-lived. Fuel storage costs are minimal.
Impact on balance of payments	Most countries import a substantial portion of their petroleum fuels and thus increases in either LPG or kerosene use would put pressure on their balance of payments, assuming all other demands remained unchanged.	

Source: Smith et al. (2005)

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