ALTERNATIVE DOMESTIC ENERGY OPTIONS FOR DARFUR – A REVIEW

UNEP

ProAct network
environmental partnerships for community resilience

This report was produced by ProAct as part of a project for the United Nations Environment Programme supported by UKaid from the Department for International Development.

Layout: Nikki Meith

Cover image: Smoke from the inefficient combustion of fuelwood and charcoal contributes to serious health problems, especially for women and children under five years of age.

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August 2012

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ACKNOWLEDGEMENTS

ProAct Network would like to express its thanks to the UNEP-Sudan team and Ms Mani Nair in Geneva for their support with many administrative and logistical arrangements of this project. Special thank are extended to Dr Ahmed Hood who acted as Team Leader for this work: his vast personal experience and extensive network of professional contacts were of immense help in collecting and analysing the data presented in this report. Thank also to Dr. Hassan Wardi, Dr. Osman Babiker, Daniel Wyss and Stuart Vallis for their timely and important contributions as supporting consultants to this review.

ACRONYMS AND ABBREVIATIONS

ARC	American Refugee Council
BDS	Berkeley Darfur Stove
BRRI	Building and Road Research Institute of the University of Khartoum
DAEP	Darfur Alternative Energy Project
DJAM	Darfur Joint Assessment Mission
DRC	Danish Refugee Council
ENTEC	Environmental Technology Task Force
ERI	Energy Research Institute
FAO	Food and Agriculture Organisation (of the United Nations)
FES	Fuel-efficient Stoves
FNC	Forest National Corporation
FSR	Forest Sector Review
GDAE	General Directorate for Energy Affairs
G	Gram
GJ	Giga Joule
IDP	Internally Displaced Persons
LPG	Liquefied Petroleum Gas
KCJ	Kenyan Ceramic Jiko (stove)
km	Kilometre
MJ	Mega Joule
MSW	Municipal Solid Waste
NEA	National Energy Assessment
NGO	Non-governmental organisation
PA	Practical Action
SAG	Sustainable Action Group
SDG	Sudanese Pound
SECS	Sudanese Environmental Conservation Society
SOBMC	Sudanese Organisation for Building Material and Construction
SSB	Stabilised Soil Block
SWOT	Strengths, Weaknesses, Opportunities, Threats
T	Tonne
TOE	Ton of Oil Equivalent
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNHCR	United Nations High Commissioner for Refugees
USAID	United States Agency for International Development
VBSK	Vertical Shaft Brick Kiln
WDA	Women's Development Association
WFP	World Food Programme

EXECUTIVE SUMMARY

BACKGROUND

Considerable attention has focused on domestic energy in Darfur, particularly since the start of conflict in 2003 when the visible impacts of deforestation soon became prominent around major towns such as Nyala, which attracted large number of internally displaced people (IDPs). Today, the environmental situation is even worse despite the efforts of a considerable number of international non-governmental organisations (NGOs) and government authorities to introduce more efficient technologies with a view to reducing pressure on Darfur's dwindling natural resource base. Urban populations continue to swell, creating mounting pressure on natural resources – particularly forests – in surrounding rural areas.

The Darfur Alternative Energy Project (DAEP) was one of three projects implemented by ProAct Network from December 2009 to March 2011 under the umbrella of the UNEP Sudan Integrated Environment Project (SIEP), an initiative funded by DfID. The main objective of the project was to undertake a review of the current situation, including an economic and policy analysis, with a view to identifying viable and appropriate alternative energy options that could reduce the consumption of fuelwood and charcoal and hence slow deforestation in Darfur. This review is based on extensive background research, consultations and field missions.

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.

OVERVIEW OF FINDINGS

The situation in Darfur is starkly divided between urban and rural situations. Less that 15 per cent of households in Darfur's main urban populations – El Fasher, El Geneina, Nyala and Zalengei – have access to electricity though even this is irregular on account of frequent cut-offs due to fuel supply and maintenance problems. Demand for electricity is highly suppressed. Only well-off households can afford self-generation of electricity through the use of generators. In addition to household needs, production and service sectors also suffer from this situation which affects employment and increases poverty rates. Extension of the national power grid to Darfur is unlikely to happen before 2014. Grid extension to rural areas is not feasible in the foreseeable future.

This review of the main issues pertaining to household energy use in Darfur shows the following situation:

- 80 per cent of the population live in rural areas, practicing subsistence agriculture, due to a lack of, or very minimum, energy input into agricultural activities. This leads to low production rates and consequent poverty under a subsistence economy;
- a continuing high dependence on fuelwood, most of which is unsustainably harvested and burnt on inefficient stoves. Some is transformed into charcoal but this is an equally inefficient transformation;
- biomass energy use is contributing to environmental degradation and desertification around urban areas and camps for IDPs, with a steadily increasing outward radius into the countryside;
- the humanitarian assistance package does not include energy sources for cooking. IDP households face considerable pressure and challenges to satisfy their cooking energy needs and run the risk of insecurity when collecting fuelwood;
- smoke from open cooking fires contributes to serious health problems, especially for women and children under 5 years of age;
- poor urban households spend a considerable proportion of their income to purchase fuelwood or charcoal, while rural households spend considerable time on collection, facing potential insecurity and aggression at the same time;
- petroleum products are very expensive – may reach several times the prices in Khartoum – and are sometimes scarce in Darfur due to high transport costs which, in turn, makes access to markets very difficult;
- while initial use of liquid petroleum gas (LPG) appliances has shown promise the lack of awareness of this technology and high upfront costs of LPG appliances deny access to clean cooking energy to the majority of households in El Fasher and Nyala, where the present penetration rate of LPG use is estimated at only 5 per cent of households;
- experiments and trial introductions have been undertaken with other technologies, including biogas, solar cooking, briquettes (bagasse) and pet coke. None, however, seem to have been approached in a consistent and sustained manner starting with research and consultation and following through with active technical support, monitoring and learning. This has led to most programmes being abandoned;

- the traditional brick making and, to a lesser extent, bakeries and lime kilns, are woefully inadequate in terms of energy efficiency and account for one of the major users of fuelwood. Suitable alternative technologies are available but a radical shift in approach is required to transform this sector;
- the lack of pre-planning, training, local capacity building and monitoring and evaluation, however, all stand out as clear omissions in many of the attempted fuel-related projects;
- one of the key lessons stemming from evaluations reviewed in the current work is that communities should only be offered and introduced to alternative technologies that are culturally acceptable and/or familiar. The more replicable, low cost, locally available, easy to make and culturally fitting the technology is, the higher its chance of success; and
- the energy situation in Darfur presents a non-attractive environment for investors.

FUEL-EFFICIENT STOVE PROGRAMMES

Past endeavours to introduce improved stoves and alternative fuels have shown some initial positive results in household uptake but this has invariably tailed off once a particular project or stream of donor funding ends. Important lessons need to be taken from this, especially in the approach(es) taken to introducing new stove models or alternative fuels, as well as ensuring that energy-related projects are firmly programmed into an institution's budget as well as its workplan, extending to monitoring.

Donors, NGOs and IDPs alike are eager to find a solution to the fuelwood dilemma in Darfur IDP camps – solutions which could then be extended to rural populations. Recent technical and programmatic evaluations of FES programmes conducted by USAID and ProAct have shown that while programmes implemented in Darfur have produced some positive impacts these are often not to the levels originally claimed by FES promoters. The need for alternative fuels to complement the reduction of fuelwood consumption is therefore highly recommended. In the meantime, IDPs remain susceptible to accepting alternative cooking fuels which they will use as long as they meet their cooking demand, habits, cooks fast, is convenient and, above all, is freely distributed.

In the longer term, however, the use of improved fuel-efficient stoves is likely to remain the best option for meeting household energy needs. New generation stoves should be examined and trialled before introducing them to this current context.

THE CONSTRUCTION INDUSTRY

The construction industry is flourishing in Sudan, largely in response to the need for oil-related business facilities and post-conflict development activities. Sudan is now a classic "brick country", consuming 5-10 million bricks every day and about 1-200,000 tonnes of wood per year – 3-10 per cent of the Sudanese household fuelwood consumption. As a result, the traditional brick industry is heavily contributing to national deforestation and emits gases and suspended particulate matter which affect the health of urban dwellers in particular. There is a consensus among the responsible authorities that the brick sector has to change.

Sustainability of the brick sector can only be achieved if measures are taken to improve the energy efficiency of the traditional firing method, which is currently wasting more than half of the energy through thermal losses and incomplete combustion. Several initiatives have been undertaken to improve energy efficiency and the quality of the traditional bricks, by testing alternative fuels and establishing model brick kilns and even entire factories. Most of these efforts have offered large-scale solutions and resulted in the establishment and operation of a number of large brick factories. However, a major structural change from artisanal to industrial production has not yet taken place and the vast majority of bricks sold on the Sudanese market are still produced with inefficient wood-consuming brick clamps.

The Sudanese experiences show that while the demonstration of new technologies alone may prepare the ground for a few innovative entrepreneurs it does not suffice for initiating a sustainable change of an entire sector. To promote environmental improvements in the traditional artisanal brick sector, other approaches will be required, with carefully scaled technical solutions.

ALTERNATIVE TECHNOLOGIES AND FUELS

Among the potential alternative fuels which could substitute for fuelwood, LPG and pet coke (for industrial usage) are the most promising since they may be introduced to the traditional production structure with limited investment and adaptation to the existing workflow. As clear from expenditures analysis, the use of LPG alone as a cooking fuel will not be economically sound. Thus considering its other benefits and the negative impacts of the traditional energy sources, it could be the most reasonable energy option. However, given the high energy demand of other energy consuming sectors, current production and supply capacities of both LPG and pet coke cannot meet current energy needs of the brick sector, for example.

POLICY STRUCTURES AND IMPLEMENTATION

There is a need to establish a comprehensive household energy plan to address issues related to the shortage and inefficient use of biomass and affordability of modern appliances within the National Energy Plan, now under preparation. Linked with this should be the development and application of policies and projects more closely linked to other sectors such as agriculture, forestry, water and sanitation, health, education, transportation and industry, all of which are closely tied in with energy-related issues.

Support has been expressed for a revision of the 2002 Act which called for the creation of the National Forests and Renewable Natural Resources Corporation to manage natural resources other than wildlife and water. In line with this a new Forestry Policy, as proposed by the FNC, has to be drafted. States should be more intensively involved through the inclusion of FNC policies and technical plans in their own policies.

ECONOMICS

In terms of alternative energy options, LPG looks to be the most viable option at least in the urban setting. There is potential for widespread use by the household and commercial/services sectors. A reduction of taxes and other policy constraints on LPG and other petroleum products would likely significantly enhance its use instead of woodfuel.

Should LPG be a chosen option for scaling-up, a more intensive review should be undertaken of the ongoing microfinance programme in North Darfur which allows participating households greater access to LPG. Some changes to current policies would be required for this to be sustainable in the longer term.

CONCLUSIONS

The future pattern of energy usage in Darfur, and likely other parts of Sudan, is unlikely to change a great deal unless some urgent actions are taken and sustained. Key among these is improved co-ordination between a wide range of actors, starting with government authorities in a number of environment-related sectors such as agriculture, mining and petroleum extraction, forestry, transportation and so forth, but including international and national NGOs with an interest in energy use, provincial authorities (on account of taxes), local communities and, perhaps one of the most important players missing thus far, the private sector.

An important fact that might impact any decision relating to the selection of an energy option for Darfur is the obvious link between energy resources and livelihoods, especially biomass resources. Hence, a lot of work is needed on both livelihoods and the environment, together with other factors, in order to change the current energy regimes or modes of Darfuri people.

The future energy scenario is expected to be based on a range of technologies and fuels, not on any one alone. Differences can be expected to continue between urban and rural settings, with the former coming under greater pressure due to continuing in-migration. Appropriate solutions must also, however, be found for the rural sector where people should not be penalised for resource extraction but rather encouraged to support reforestation and natural regeneration activities.

All of this calls for a carefully prepared strategic plan based on extensive consultation and agreement between both the existing and potential energy providers and users. Appropriate technologies and fuels are available today but in insufficient quantity and reliability to serve the population of Darfur alone. Fuel-efficient stoves likely offer the best long-term prospect for rural areas, while LPG and pet coke – perhaps used together at times – hold greatest prospect for urban dwellers and traditional industries. Further research and development should, however, also be encouraged and supported so that the energy sector works alongside those seeking to identify and support an environmentally friendly approach to helping households be able to cook with clean and efficient fuels in a healthier working and living environment.

1. INTRODUCTION

1.1 BACKGROUND

Domestic energy[1] has been singled out as a major concern in Darfur for a number of years, with a growing realisation that the situation is not going to improve unless there are direct, targeted and sustained interventions. No single technology or policy can resolve the current need for energy in this country: a combination of approaches is needed, including the application of tough policies coupled with broader support for alternative and more fuel-efficient technologies.

Several reasons can be attributed to the high energy demand of which the conflict and subsequent human displacement is usually cited as the main one. An estimated 50 per cent of the population – some 3.5 million people – have been directly affected by the conflict, through violence, displacement and degraded livelihoods. A subsequent high urbanisation rate has become a main feature of Darfur where the former urban/rural ratio of 20:80 has been reversed today. The high urbanisation rate, in turn, has created a huge demand for building materials, particularly red clay bricks, which are fired in inefficient kilns, further exacerbating pressure on dwindling forest resources. Other reasons for this growth in energy needs though are economic through the sale of fuelwood and charcoal, social preferences for certain types of fuel and a growing population.The high demand for fuelwood can lead to environmental degradation in areas that host internally displaced persons (IDPs), as supplies of dead wood are progressively exhausted and live trees cut in an uncontrolled manner. This is often the most visible, serious and lasting impact of informal and formal camps for displaced people. In areas already suffering from fuelwood scarcity, IDPs now have to spend significant amounts of time, money and labour securing sufficient fuel to meet their cooking fuel needs. In some instances they may be exposed to physical risk in the process.

Many projects and programmes have been attempted in Darfur and elsewhere in the country to address the growing energy divide. In the vast majority of cases reviewed as part of this study,

[1]**A NOTE ON DEFINITIONS**

Fuelwood: Firewood – not to be confused with woodfuel, which includes charcoal. The original composition of the wood is preserved.
Woodfuel: Any fuel based on wood. Normally taken to mean fuelwood and charcoal but includes all biofuels originating directly from woody biomass.

most failed as soon as project funding came to an end. Some, however, were clearly inappropriate to users as they could not satisfy their needs or cooking preferences, e.g. in the type of food being cooked. The lack of pre-planning, training, local capacity building and monitoring and evaluation, however, all stand out as clear omissions in many of the attempted projects.

Urgent and effective interventions are, however, needed not only to ensure fuel supplies but also to lay the foundation for the rehabilitation of areas degraded by deforestation. Several alternative measures are available with liquefied petroleum gas (LPG) currently seeming to have the greatest potential though this will remain restricted for some time on account of still limited production and difficulties with distribution. Despite some commendable efforts to help households acquire LPG units through microfinance, this energy source is likely to remain beyond the reach of the majority of poor households in Darfur in the medium-term.

One of the key lessons stemming from evaluations reviewed in the current work is that communities should only be offered and introduced to alternative technologies that are culturally acceptable and/or familiar. The more replicable, low cost, locally available, easy to make and culturally fitting the technology is, the higher its chance of success.

1.2 DARFUR ALTERNATIVE ENERGY PROJECT

The Darfur Alternative Energy Project (DAEP) was one of three projects implemented by ProAct Network from December 2009 to March 2011 under the umbrella of the UNEP Sudan Integrated Environment Project (SIEP), an initiative funded by DFID. The objective of the SIEP project is "improved sustainable and equitable governance, management and use of natural resources and environmental assets in conflict and post-conflict contexts in Sudan".

The main objective of the DAEP project was to identify viable and appropriate alternative energy options that could reduce the consumption of fuelwood and charcoal and hence slow deforestation in Darfur. Recognising that some alternative technologies might lend themselves to application in Darfur – if cultural and other sensitivities and preferences are addressed – the study specifically reviewed possible alternatives that have been trialled and perhaps used elsewhere to inform the introduction and eventual scale-up of such technologies across Darfur.

The project comprised a series of different thematic desk studies, field research and consultations with selected stakeholders. Outlines of four pilot projects were developed based on some of the foregoing analyses and observations. These are now expected to be further developed in collaboration with local partner organisations.

1.3 METHODOLOGY

The study involved a thorough review of the literature on Darfur's environment, its energy resources and needs, studies on household energy consumption patterns at the state level and alternative energy practices and options – those already existing in Sudan as well as elsewhere in the region. In addition to data and information on the national context, the project team consulted reports produced by various government ministries, universities and other research institutions, and project reports from various non-governmental organisations (NGOs) and UN agencies, particularly those involved in emergency operations in Darfur during the past eight years, with special emphasis on household energy interventions. In addition to household energy consumption the study also examined the energy needs of brick making and bakeries. Evaluation reports of improved cookstove programmes implemented in IDP settings were also consulted.

The above exercise permitted the production of a scoping study comprising the following reports:

- *Darfur – The Environmental Context;*
- *The Energy Sector in Darfur;* and
- *Socio-cultural Context of Household Energy in Darfur.*

In addition other reports were produced based on literature review and field missions:

- *Policy, Legal and Institutional Context of the Energy Sector in Sudan;*
- *Experience and Lessons Learned from Similar Contexts to Darfur;*
- *Darfur Alternative Energy Programme – Technologies Opportunities and Constraints;*
- *The Sudanese Brick Sector: Options for Promoting Sustainable Brick Production;* and
- *The Economics of Alternative Energy in Darfur.*

Field missions were undertaken in North, South and West Darfur where consultation workshops were organised with relevant stakeholders, including governments, UN agencies and NGOs operating in Darfur. A short field mission to Khartoum by a Brick Kiln Specialist permitted stakeholder consultations to take place as well as a visit to various brickyards using firing technologies such as traditional brick clamps, a Hoffmann Kiln and a Vertical Shaft Brick Kiln (VSBK). Field observations were quantified on a Sudan level using various reports on the energy sector and have been verified through interviews and remote sensing methods.

Towards the end of this project, four workshops were organised in 2011 at El Geneina, Zalengei, Nyala and El Fasher, with the following objectives:

- to present the preliminary findings of the DAEP scoping study to some key stakeholders;
- to collect information on current alternative energy projects;
- to discuss the findings so as to refine the final project report; and
- identify possible training and capacity building needs of stakeholders on issues relating to alternative household energy.

The outputs from the consultation workshops are contained in a separate report *DAEP Workshops in Darfur 2011*.

Direct observations and small discussion groups with woodfuel traders allowed data to be gathered on the woodfuel market chain in Darfur, specifically supply sources, sales units and prices of fuelwood and charcoal in the main markets. Separate meetings were arranged with brick makers in Darfur and Khartoum, as well as with bakers in Darfur. Discussions were also held with representatives from the Forest National Corporation (FNC) and the Food and Agricultural Organisation (FAO) in Darfur.

Although the security situation did not allow visits to happen outside the main towns and camps for IDPs, the Team Leader possessed data from previous visits to Al Salam, Abu Shauk and Zam Zam IDP camps in El Fasher, Kalma and Utash IDP camps in Nyala, the Kass IDP camps, Krinding I and II IDP camps in El Geneina and Kabkabiya IDP camps. These data were collected between 2008 and 2010 to obtain firsthand experience of how IDPs manage their fuel supplies and to learn about peoples' perceptions of alternative fuels. This involved focus group discussions with key stakeholders, including women – the main users of fuelwood, LPG and kerosene – men and community leaders (*Umdas* and *Sheiks*). Women, in particular, were asked questions on the type of fuel they use for cooking, whether they collect or purchase it, their experience with fuelwood collection, their experience with improved cookstoves, their perceptions about alternative fuels, income generating activities, woodfuel consumption and expenditure, and how they envisage switching to alternative fuels. In addition casual interviews were held with women at water points and with woodfuel retailers, fuelwood collectors and NGO staff.

1.4 PILOT PROJECT SELECTION

Based on the scoping study, experiences and lessons learned from alternative energy interventions implemented elsewhere under similar conditions to Darfur, outputs of the consultation workshops and other field visits, four pilot projects have been identified as being viable opportunities to develop and introduce in selected communities, heeding the guidance noted earlier about the need for being appropriate for local needs. The pilot projects are presented in Annex I.

2. THE CONTEXT FOR ALTERNATIVE ENERGY PROGRAMMING

2.1 SOCIAL AND ENVIRONMENTAL CONTEXT

Women are the main cooks in Darfur, the staple diet being a combination of *Asida*[2] and *Mulaah*[3]. A 2008 household survey[4] in El Fasher confirmed that *Asida* is the main staple for households: on average more than 92 per cent, 33 per cent and 69 per cent of households sampled eat *Asida* for breakfast, lunch and dinner, respectively. These figures may, however, vary according to the income level of the household as more affluent households might eat more *Kisra* and bread than *Asida.*

Fuelwood and charcoal are the main cooking fuels in Darfur. Fuelwood is almost the sole cooking fuel in rural areas, most of this being gathered by women and girls. The level of fuelwood collection in parts of Darfur has been so extreme that today, after eight years of conflict, most IDP households depend entirely on market supplies for their cooking fuel needs.

In urban areas, households use a combination of fuels, including LPG. Medium- and high- income households tend to prefer charcoal over fuelwood but the latter is still used for certain cooking tasks. Per capita consumption of fuelwood and charcoal in Darfur is shown in Figures 2.1 and 2.2, respectively.

The conflict has had many implications on energy consumption patterns, in particular cooking energy which is the most fundamental form of household energy consumption. Recent surveys[5] in some IDP camps highlight the predominant use of fuelwood over charcoal. Per capita consumption varies widely from one state to another (Figure 2.3) but the average per capita consumption is about 0.43 tonnes, close to the average value for Darfur (Figure 2.1). The absence of agricultural residues for energy conversion purposes makes limited choices for alternative biomass-based cooking fuels.

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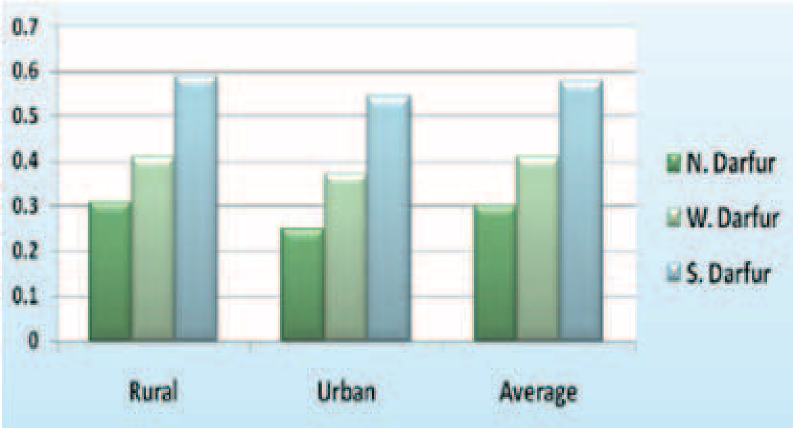
[2] *Asida* is porridge made of, preferably, millet flour. During famine or in an emergency people switch to consume sorghum and wheat flour often distributed by relief operations.

[3] *Mulaah* refers to the variety of sauces served over *Asida.* It consists of vegetables (wet/dry), meat (wet/dry), onions, oil and spices.

[4] Practical Action. 2008. Household Energy Survey.

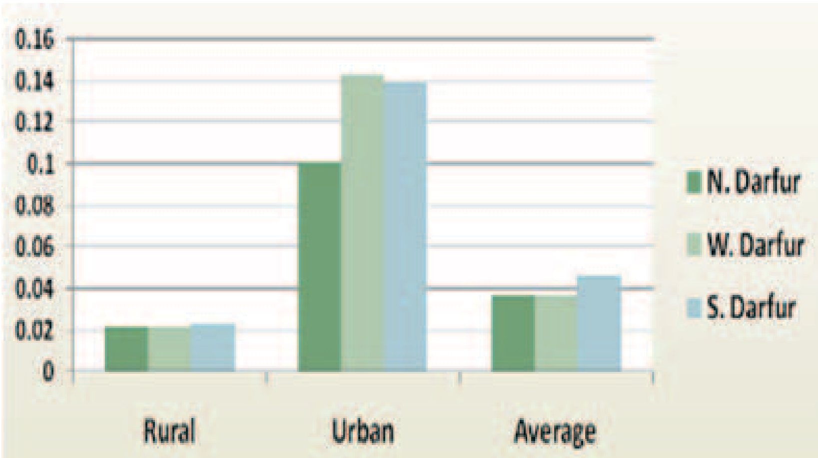
[5] USAID and UNDP FES Programme Evaluations, Interagency Livelihoods Study in El Fasher IDP camps.

Figure 2.1. Per capita fuelwood consumption (tonnes)



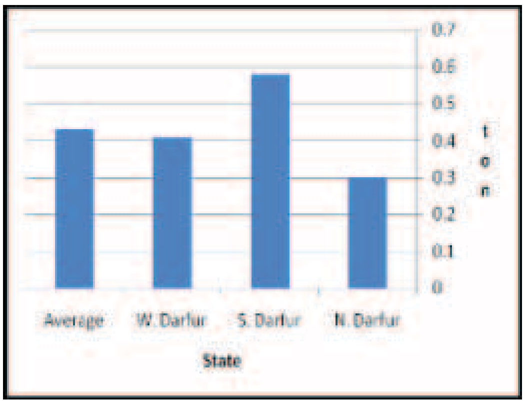
Source: Ministry of Energy and Mining, National Energy Assessment, 2001.

Figure 2.2. Per capita charcoal consumption (tonnes)



Source: Ministry of Energy and Mining, National Energy Assessment, 2001.

Figure 2.3. Per capita fuelwood consumption by IDP households in Darfur, 2005



Source: Practical Action-Sudan. Reduction of Greenhouse Gas Emissions from Households in Sudan through the Introduction of Improved Mud Soves and Fuel Switching. 2006.

2.2 A NEED FOR ALTERNATIVE TECHNOLOGIES

2.2.1 OVERVIEW

Efforts to reduce woodfuel consumption have mainly focused on the introduction of fuel-efficient stoves (FES) and solar cookers in IDP camps and LPG in urban settings. The most appropriate FES design suitable for conditions in IDP camps appears to be the mud stove design, while the main criteria for a households' choice for an alternative fuel are time savings and its suitability for satisfying different cooking tasks.

Solar cookers are widely claimed as being "unacceptable" in IDP camps due to their unsuitability for cooking common food such as *Asida*, *Kisra* and *Mulah*, all of which require rigorous stirring, personal attendance and a step-by-step addition of ingredients – activities not suited for this model of cooker. In addition, common meal times in Darfur – early morning and late evening – are not ideal for capturing solar energy[6].

2.2.2 COOKING POTS AND STOVES

The most commonly used household cooking pot is a round bottom aluminium pot, varying in diameter from 16-28cm. Virtually every household in Darfur has at least two pots of different sizes, a small one first being used for making *Mulaah* and a larger one then used for cooking *Asida*. This process takes 40-60 minutes, depending on family size.

Stoves used for burning fuelwood, charcoal and LPG are:

- fuelwood: a 3-stone open fire (Figure 2.4), the Kisra Plate (Figure 2.5), an improved mud stove (Figure 2.6), the AVI3 stove (Figure 2.7) and the Berkerley Darfur Stove (BDS) stove (Figure 2.8);

Figure 2.4. Three-stone fire (*Ladaya*)

Figure 2.5. Cooking *Kisra* (plate)

[6] Some NGOs such as Darfur Peace Development claim successful introduction of solar cookers and acceptance by households in Abushoak and Kassab IDP camps in North Darfur.

Figure 2.6. Improved mud stove

Figure 2.7. AVI3 stove

Figure 2.8. BDS (Tara) stove

Figure 2.9. Traditional metal charcoal stove

Figure 2.10. Mubkhar stove

Figure 2.11. Gas stove

- charcoal: a traditional metal stove (Figure 2.9) or the Mubkhar stove (Figure 2.10); and
- LPG: a gas cooker (Figure 2.11).

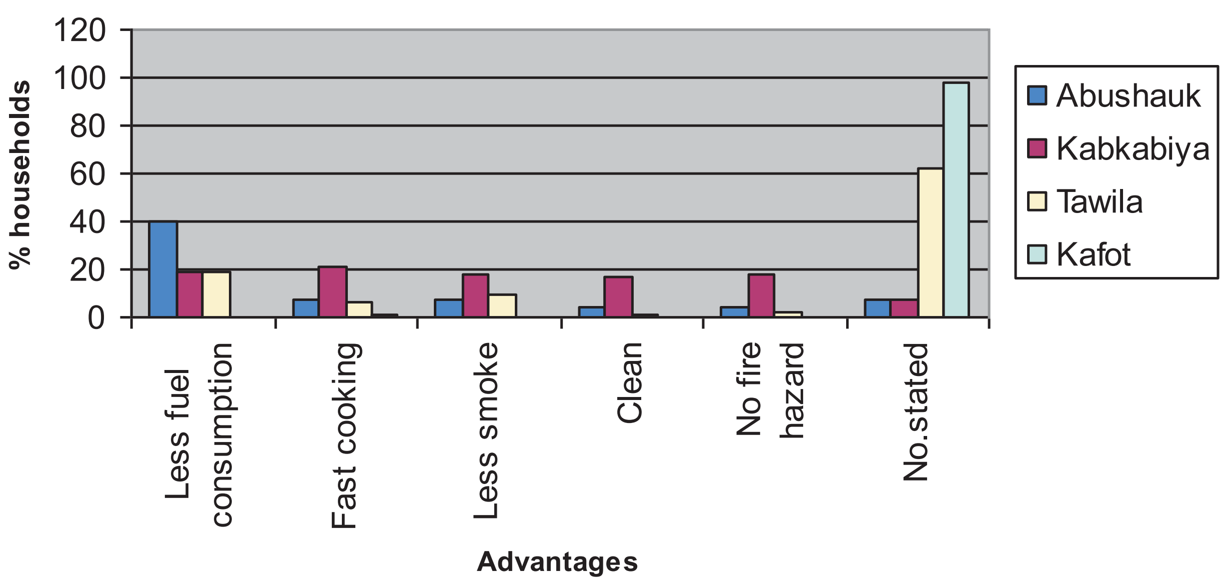
Cooking *Kisra* requires a wide, hot surface called *Saj* or a *Kisra* plate. Two types of plates are used, metal and stone, the first most common in urban areas, while rural households prefer the traditional stone plate. To obtain quality *Kisra* the plate must be evenly heated. Women claim that this can only be attained by using the 3-stone fire plate. However, well off urban households use charcoal stoves or an LPG stove specially designed for cooking *Kisra*. The BDS stove is also suitable for cooking *Kisra*.

The 3-stone fire place remains the most common stove used in Darfur. While its energy inefficiency is recognised the following characteristics are attractive for users:

- being self-made, it has no cost;
- it is suitable for all pot sizes and weights – large families, institutional cooking and social occasions;
- it is easily moved from inside a house/shelter to outdoors;
- it is suitable for cooking *Kisra* on a hot plate; and
- it is suitable for lighting.

Improved wood stoves introduced since the early stages of the conflict are more common in IDP camps where many NGOs have been responsible for their dissemination. Such stoves are made to suit a specific pot size – mainly pot size 3 – which makes them less flexible for other cooking requirements. While acceptance of such stoves has been high (Figure 2.12), the lack of a commercial approach in dissemination has meant that they are largely restricted to camps. As regards other improved stove designs, Table 2.1 summarises consumer attitudes towards FES designs disseminated in Darfur IDP camps.

Figure 2.12. Advantages of improved mud stoves as indicated by IDPs



Source: Practical Action, 2008, Household Survey in North Darfur.

Table 2.1 IDP attitudes towards improved stoves

Mud stoves	Six-brick stove	AVI3 stove	Tara stove
Saves fuelwood. Moveable. Little smoke. Clean and easy to use. White ants eat the organic material in the clay and this deteriorates the stoves. Cannot bake *Kisra*.	Conserves burning embers; good for making charcoal. Easy to re-light. Height of stove unsuitable for cooking, especially for young cooks. Too heavy to move. Consumes a lot of fuelwood. Difficult to control in windy weather. Sometimes takes a lot of time to complete cooking. The stove is ugly and hurts peoples' hands during the building process.	Fire can be easily controlled except when it is windy. Saves fuel. Conserves heat. Can be used as a charcoal stove. In windy weather the flame comes out of the stove and causes fire. If a lot of fuelwood is used, the stove will smoke. Too heavy to move. Prone to cracking, and especially sensitive to being moved if not completely dry. The durability of the stove is limited even if precautions are taken.	Easy to light. Saves fuelwood but is smoky. Hot exterior can cause burns. Unstable when stirring *Asida*. The task needs two people: one to hold the stove and the other to stir, or the cook may use her foot and a wooden stick to make the stove stable. Food cooked on this stove does not taste good. Expensive. Some prefer to use as a charcoal stove.

Source: USAID, 2008. Fuel-efficient Stove Programmes in IDP Settings. Summary Evaluation Report, Darfur, Sudan.

LPG was first introduced by the FNC during the late 1990s. However, due to several factors[7] the Gabatgas project came to standstill. At the end of production at the Al Jaili refinery, several private companies assumed LPG distribution and marketing. Government incentives on LPG[8] helped motivate households, particularly in Central Sudan, to switch from fuelwood to LPG. Its use in remote areas like Darfur, however, lagged far behind due to the high upfront cost of LPG appliances, the refilling cost and the low price of woodfuel. However, in North Darfur where woodfuel is rather scarce and expensive, LPG is more competitive, Figure 2.13.

Switching to LPG instead of woodfuel demands an investment on the part of households, namely the gas cylinder and stove both of which cost around SDG260 in El Fasher. The preferred LPG cylinder size in El Fasher as well as the IDP camps has a capacity of 12.5kg. Dissemination in El Fasher was undertaken by the Sustainable Action Group (SAG) and Practical Action (PA), the former opting for a limited – about 1,000 – and free distribution of appliances in the camps, while PA in partnership with women groups adopted a microfinance/revolving fund system[9] in order to

[7] The initial cost of gas appliances was high, there were safety problems with regards the cylinder's adapter and the refilling network was not well developed.
[8] A 2000 decree subsidised LPG by about 50 per cent and exempted LPG appliances from import duty taxes. However, the subsidised LPG price is fixed at the refinery gate price which meant that the price for refilling a cylinder varied greatly across the country.
[9] The project is funded through the Carbon Credit Fund.

enable a wider range of households to have access to the appliances and receive training on efficient and safety precautions. For an average household a 12.5kg cylinder will last for about one month and the payback period for the investment is about six months. Reasons why households in El Fasher switched to LPG instead of woodfuel are shown in Tables 2.2 and 2.3.

Figure 2.13 Energy costs (SDG/MJ) of using different cooking fuels in El Fasher

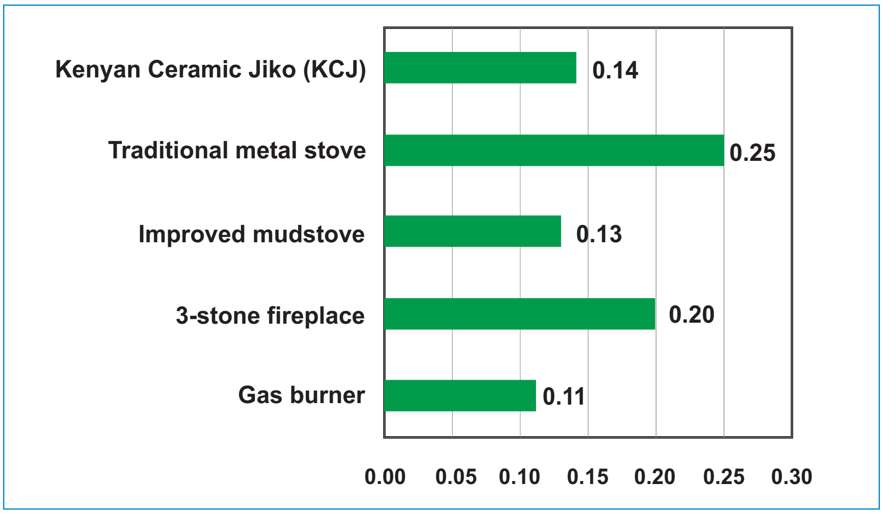


Table 2.2. Reasons that motivate household to switch to LPG

Reason for willing to buy LPG appliances	Frequency	Per cent
N.A.	54	36.7
Cooking with gas is cheaper than fuelwood and charcoal	9	6.1
Clean	2	1.4
Fast cooking – time saving	14	9.5
No smoke	1	0.7
All above answers	67	45.6
Total	147	100

Source: Practical Action, March 2008, Household energy survey, El Fasher.

Table 2.3. Disaggregated average monthly household consumption of cooking fuels in El Fasher

Reason for willing to buy LPG appliances	Frequency	Per cent
N.A.	54	36.7
Cooking with gas is cheaper than fuelwood and charcoal	9	6.1
Clean	2	1.4
Fast cooking – time saving	14	9.5
No smoke	1	0.7
All above answers	67	45.6
Total	147	100

Source: Practical Action, March 2008, Household energy survey, El Fasher.

3. ALTERNATIVE ENERGY PROGRAMMING IN DARFUR

3.1 THE INTRODUCTION OF FUEL-EFFICIENT STOVES

At the household level, fuelwood and charcoal are burnt in traditional, inefficient stoves, respectively the 3-stone fire and a charcoal metal stove. The thermal efficiency of the 3-stone fire is around 10 per cent while that of the charcoal stove is about 15 per cent. The inefficient burning of biomass fuels using such simple technologies is characterised by the incomplete combustion of the fuel. Emissions of smoke and particulate matter – the main components of indoor air pollution – are an inherent characteristic of traditional biomass stoves.

Some of the main problems and issues resulting from excessive use of biomass energy are:

- smoke from cooking fires contributes to serious health problems, especially for women and children under five years of age. According to the World Health Organisation, worldwide, indoor smoke contributes to the death of 1.6 million people every year – more than malaria;
- biomass use contributes to environmental degradation and desertification;
- poor urban households spend a considerable proportion of their income to purchase fuelwood and/or charcoal, while rural households spend considerable time collecting wood, facing hazards such as insecurity; and
- endeavours to introduce improved stoves and alternative fuels have experienced limited success due to multiple factors, discussed below.

Findings of Sudan's first energy assessment triggered the introduction of improved charcoal stoves in Sudan as early as 1985, with much of this work being pioneered by the Energy Research Institute (ERI) and CARE. By 1987, the Kenyan Ceramic Jiko[10] (KCJ), Figure 3.1, was present in

[10] The name appropriated to KCJ in Sudan is El Sorour, however, as KCJ disappeared from the market, the name persisted. Another local charcoal mud stove originally named Mubkhar has presently the name of El Sorour.

Figure 3.1. KCJ improved charcoal stove

Figure 3.2. Azza improved charcoal stove

markets. The stove is made of two different materials, – a metal cladding and ceramic liner. Its efficiency of about 26 per cent is relatively high compared to the traditional metal charcoal stove. Commercial production of KCJ took place in several parts of the country, particularly Khartoum and El Obeid, but was not sustainable as the price of these stoves was several times that of traditional ones.

A similar improved charcoal stove, the Azza (Figure 3.2) was also introduced by the FAO/FNC Fuelwood Development Project, but followed a similar fate to the KCJ.

Both FNC and FAO pioneered the introduction of FES in Darfur during the late 1980s, followed by Practical Action in the 1990s. They first concentrated on introducing Azza stoves to urban areas, with production workshops at FNC's nurseries in El Fasher and Nyala. However, by 1992 stove production came to an end mainly due to lack of funding, the low demand for the stove due to its high price and the low price of charcoal. In addition FNC/FAO introduced the *Kisra* improved mud stove, which is basically a mud stove of a rectangular shape that suits the dimensions of the *Kisra* plate.

Practical Action on the other hand disseminated an improved mud stove in rural areas of El Fasher, through partnerships with women's groups. As rural households were becoming increasingly dependent on markets for their cooking fuel supplies, adoption of the mud stove was high. Despite this success a lack of funds once again saw the project concluded.

Another traditional charcoal stove – Mubkhar (Figure 3.3) – is presently widely used in Darfur, as elsewhere in Sudan. It is made of a mixture of clay, hay/dung and metal mesh. In tests by ERI, this stove proved to be even more efficient than the El Sorour stove. It is simple to make and not being fired is very cheap (SDG1-3 in Darfur). However, it is fragile and consequently has a short life span. These shortcomings can, however, be overcome by using cement which makes the stove resistant to water, stronger and more durable. The American Refugee Council (ARC) is actively disseminating such a cement stove, Figure 3.4, in Nyala IDP camps.

The Mubkhar stove is produced all over Darfur by women potters and sold in markets alongside other pottery products.

Figure 3.3. Mubkar charcoal stove

Figure 3.4. Cement charcoal stove

In early 2004 – one year after the start of conflict – concerns about cooking fuel supplies to IDPs became prominent, which motivated donors and NGOs to embark on large FES programmes in Darfur. The improved woodstove design selected as most appropriate was the improved mud stove, Figure 3.4. The selection was very much influenced by PA's experience in disseminating the stove in rural areas of El Fasher during the early 1990s. Later, other FES designs (AVI3, BDS and a six brick stove) were also considered and disseminated in some camps, but the mud stove design remained dominant in all camps. Introduction of improved mud stoves has proven successful with a high uptake by households, but elements of sustainability are lacking.

Findings of a USAID evaluation of FES programmes in Darfur confirmed that a fuel-efficient stove is socially and culturally acceptable in this context. However, the report strongly recommended improvement of FES quality through central production in addition to commercial dissemination in order to assure sustainability. In Kabkabiya and Nyala, some IDP women already generate income from selling improved mud stoves in the market but this is of limited scale. Depending on the size of stove, it may sell from SDG8-15 in Kabkabiya.

Figure 3.5. Training IDP women to make improved mud stoves

So far, efforts undertaken to address the negative environmental impact and gender-based violence issue associated with fuelwood collection have involved several interventions, but mainly the dissemination of FES. However, it has become evident that these interventions alone cannot address such a complicated problem. Addressing cooking fuel needs in IDP camps in Darfur demands an integrated solution in terms of FES, alternative fuels and the creation of new fuel resources. The lack of planning and co-ordination among FES supporting agencies is a recognised shortcoming.

3.2 PRESENT ACTIVITIES ON ALTERNATIVE FUEL OPTIONS IN DARFUR

This review noted that few organisations are currently disseminating fuel-efficient stoves in Darfur, with no active programme in El Geneina. The former intensive work on mud stove dissemination in IDP camps at the beginning of the conflict has virtually ended, the only active organisations being the Danish Refugee Council (DRC) in Zalingei, ARC in Nyala and Oxfam America in El Fasher, most of whom are promoting woodstoves.

Oxfam America in partnership with SAG is disseminating the BDS, an all metal improved woodstove. About 9,000 stoves have been distributed in Zam Zam and Melit IDP camps as well as in the rural areas of El Fasher and Melit. Stove kits are imported from India with assembly taking place in El Fasher. Thus far stoves have been freely distributed but a marketing study is planned.

The SAFE/WFP has recently started funding FES dissemination in Darfur, focussing purely on mud stoves. It is worth noting that the adopted dissemination approach – training of trainers – for dissemination of the mud stove in Darfur is the cheapest, but did prove unsustainable. FES evaluation reports by USAID and ProAct Network highlighted the shortcomings of such an approach, particularly in terms of stove quality and sustainability. Workshop participants interviewed for this report indicated that the assumption of self-production of a mud stove by women – when their first stove is broken – is never realised. When NGOs stop dissemination and there are no stoves in the market, women revert to using a 3-stone fire.

Socio-cultural beliefs in Darfur deter women from making their own mud stoves. In Darfur, making clay products is a distinct profession of a certain cast, the Pottery Women[11], which is socially ill regarded.

A new development in the field of FES dissemination in Darfur is the involvement of universities in research and development, particularly in Nyala.

Solar cookers have received limited attention, their dissemination limited to Zalengei, El Fasher and Kutum. In the former, the University of Zalengei is involved in research, development and limited dissemination work. Both box and concentrator solar cooker types are used. Elsewhere, the DRC is distributing cardboard solar cookers in rural Zalengei while in North Darfur the NGO Darfur Peace Development is doing the same in Abushauk and Kasab IDP camps.

[11] Agricultural tools and fired clay products are respectively produced in Darfur by blacksmiths and Pottery Women, distinct ethnic casts in Darfur which are socially and culturally ill regarded by other communities.

The earlier – late 1980s – introduction of biogas technology in Darfur was a complete failure. Two biogas units installed in El Fasher never became operational on account of being installed at a secondary school and a government guesthouse, neither of which had dedicated personnel responsible for the operation and management of the units. In addition, the Ministry of Energy and Mining failed to assure adequate training, follow up and monitoring.

More recently, SAFE/WFP and World Vision International have revived the possibility of introducing biogas in Darfur. The former opted for a pilot experimental unit in El Fasher, while the latter has directly implemented two biogas units at two dairy farms in Nyala.

At this point in time it is still too early to comment on the suitability of biogas in Darfur, but experience from the above trials should help inform future decisions. One of the main challenges this technology faces, however, is the need for water which is an essential raw material for biogas. Water availability is scare and unpredictable in many rural areas, while urban centres such as El Fasher, Nyala and El Geneina also suffer from water supply problems. If enough cow dung is considered available at specific locations then the availability of water will present a real handicap for the dissemination of biogas technology.

Experience and lessons learned from ERI work on biogas technology dissemination during the 1980s and 1990s showed that acceptance, water availability, competition for cow dung by brick makers, the high cost of the digester, the availability of LPG and system management are among the main barriers to biogas technology dissemination in Sudan. In addition, biogas is most suitable for a household living within its farm where water is available, cows are most of the time kept at home and the farm absorbs the by-product, slurry, as a fertilizer. Such conditions are rarely fulfilled

Traditional forms of brick making, like traditional stoves, are woefully energy inefficient.

within the dry semi-desert climate of Darfur, though some exceptions may exist, particularly in the Jebel Marra area.

Work on the dissemination of LPG use in Darfur is mainly tackled by the private sector, where several companies are active in both El Fasher and Nyala and a single company operates in El Geneina. However, the high upfront cost of LPG appliances makes LPG only affordable and accessible by well-off households. FNC in El Geneina and Zalengei continue facilitating the refilling of its Gabagas cylinders. In El Fasher, Practical Action in partnership with the Women Development Association Network is implementing a project aiming at enabling households to access LPG appliances through microfinance. The project is funded through the Carbon Credit Fund. The credit repayment time is about one year, which enables poor households to repay the instalments at ease. Practical Action provided intensive training and capacity building in order to help people manage the microfinance system. End user training on the safety precautions and efficient use of LPG was undertaken by the Civil Defence Department. So far, more than 3,000 households are successfully using LPG appliances with no reports of accidents thus far.

The use of waste biomass materials as a cooking fuel in Darfur is rarely reported. There are, however, some exceptions such as in certain camps where households resort to using twigs, plants and millet stalks as cooking fuel. The SAFE/WFP in partnership with Kabkabiya Small Holders Charity Society is presently experimenting and testing the acceptability of fuel briquettes by households in Kabkabiya, the raw materials comprising household biomass waste, agricultural residues and animal dung. Although it is still immature to judge on the success/failure of the project, there are reports of high levels of unpleasant smoke from burning the briquettes in mud stove. In such instances, however, the efficient burning of biomass briquettes normally demands the use of a specific design of stove. Experiments conducted by the SAFE project show that, among different stoves tested, briquettes seem to burn well on the BDS.

Work on alternative building materials and techniques in Darfur is limited to the introduction of stabilised soil blocks (SSB) and cement blocks. UN-HABITAT has provided training on the production of SSBs and the construction of demonstration buildings in the three states. At the end of the project press machines were left with some NGOs and the University of Zalengei to continue dissemination of the technology. Some construction activities – mainly schools – were undertaken in Darfur using SSBs. Both UN-HABITAT and the NGOs opted for direct implementation instead of involving the private sector, an approach which negatively affected the sustainability of SSB introduction in Darfur. DRC-Zalengei reported quality problems with these SSBs, which incurred high construction costs by having to plaster the walls from the outside. The quality is very sensitive to homogenous mixing of the binder (4-5 per cent cement) and curing conditions (humidity and temperature). Any defect in one of these factors will lead to the production of low quality SSBs.

3.3 SWOT ANALYSIS OF ALTERNATIVE ENERGY FUELS

A SWOT analysis of alternative fuel programmes in Darfur was conducted with input from stakeholders in Nyala, El Fasher, El Geneina and Zalengei (Annex II). Results clearly demonstrate that two energy options – FES and LPG – received unanimous agreement between all stakeholders consulted as the best solutions to current problems of household energy in Darfur. Stakeholders indicated that the weaknesses and threats for the two technologies are surmountable or could be overcome through skills training, capacity building, awareness raising, community participation and end user training. Microfinance was unanimously agreed upon as the best means to facilitate household access to alternative cooking energy sources and technologies.

As regards the FES design, all participants only talked about improved mud stoves as it has been widely introduced in the IDP camps and is the cheapest option. FES interventions, however, excluded urban areas of Darfur as funding was directly linked with humanitarian interventions. It is, however, worth noting that other FES designs – both for fuelwood and charcoal – are available and should be considered for future trialling. These are the so called second and third generation of improved woodstoves, which are more efficient than the mud stove. Reducing smoke and greenhouse gas emissions, however, required additional design complications and increased costs.

Although SSBs are considered the best alternative and replacement for red clay bricks, their acceptability in Darfur does not appear to match perceived expectations. The unavailability of press machines in markets, the high price of cement and a lack of awareness and training are considered the main factors behind the low spread of SSB use. Involvement of the private sector, the availability of quality SSBs in the market place and awareness and skills training are the main factors to be considered to reduce the amount of wood used in the brick making industry.

3.4 BEST PRACTICE – LPG DISSEMINATION IN EL FASHER

Success with enabling poor households in Kassala State to have access to clean modern energy in the form of LPG attracted and motivated donors to fund the replication of project activities in North Darfur. Similar to the situation in Kassala, Practical Action-El Fasher is working in partnership with Women Development Associations (WDAs) in El Fasher town. Carbon Clear, a Carbon Credit Company, based in the UK is currently funding LPG dissemination in El Fasher.

The project started in December 2008, the goal being to contribute to poverty alleviation through improving the livelihoods of poor families by switching to a clean energy source – LPG – for cooking. Given the high poverty level in El Fasher, many households are denied access to LPG due to the high upfront cost of the appliances.

The project strategy is based on:

- adopting participatory project implementation while working through partnership with WDAs;
- using microcredit as the means 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 educating beneficiaries on efficient and safe use of LPG appliances;
- capacity building of partners, particularly on the principles of microfinance, including accounting and bookkeeping;
- monitoring to ensure continuous use of LPG and timely repayment of credit instalments;
- co-operation with the Civil Defence Department;

Across much of Darfur people still cook on energy inefficient stoves, despite the shortage of fuelwood and the hardship and risks that women face when gathering this resource.

- co-ordination and advocacy with stakeholders to achieve widespread dissemination of LPG in North Darfur;
- provide seed money to initiate the microfinance system, and run it on a revolving fund basis; and
- co-operation with LPG companies for supplying LPG appliances on a lease term basis.

To measure project impact, a household energy survey[12] was conducted in 2008, covering 17 residential areas. This showed that almost 58 per cent of the household sample was predominantly depending on fuelwood and charcoal for their cooking energy needs, Table 3.1. Average monthly expenditure on cooking fuel was SDG83. The same study showed that 20 per cent of households only used LPG for cooking purposes, while a considerable proportion of households – almost 10 per cent – used a cooking energy mix of fuelwood, charcoal and LPG. This is attributed to socio-cultural factors, where some households stick to cooking habits and food taste preferences.

As indicated in Table 3.2, the reasons deterring households from switching to use LPG instead of woodfuel are:

a) high upfront cost of LPG appliances;

b) high cost of refilling LPG cylinder; and

c) the use of LPG is considered dangerous.

[12] Practical Action, March 2008, Household Energy Survey, El Fasher

Table 3.1 Average monthly household cooking fuel consumption and expenditure

Total household* expenditure SDG/ month	% of total sample of 147 HHs	Fuel Combination use options	Fuel source, kg per month					
			Fuelwood		Charcoal		LPG	
			Kg	SDG	Kg	SDG	Kg	SDG
71	2.7	Only fuelwood	124.8	71				
40.6	7.5	Only charcoal			65.8	40.6		
40.8	2	Only LPG					14.6	40.8
83	57.8	Only fuelwood and charcoal	147.8	46.3	48.8	36.7		
56.3	20.4	Only LPG and charcoal			37.7	24.4	11.7	31.9
113.8	9.5	Using all three fuels	67.8	37.2	63.2	45.5	11.7	31.1

Source: Practical Action, March 2008, Household energy survey, El Fasher.

* Average household size is 7.9 persons

Table 3.2. Reasons deterring households from switching to LPG

Reason for not using LPG	Frequency	Per cent
N.A.	47	3
LPG appliance is too expensive	73	49.7
Refilling cylinder is too expensive	11	7.5
Using LPG is dangerous	9	6.1
All the above	6	4.1
Others	1	0.7
Total	147	100

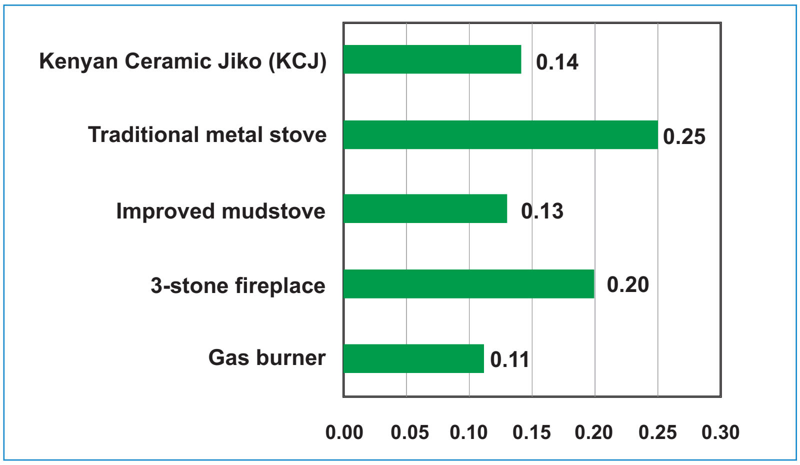
Source: Practical Action, March 2008, Household energy survey, El Fasher.

Notwithstanding the high refilling price of LPG cylinders (SDG35 in El Fasher), it is still much cheaper to cook with LPG than with fuelwood or charcoal. The energy cost is only SDG0.11/MJ on using LPG compared with SDG0.2 and SDG0.25 respectively for fuelwood and charcoal burned on traditional stoves, Figure 3.6. The main reasons behind this are the high price of biomass fuels with low energy density, inefficient biomass stoves and high energy density of LPG.

Based on above data, by switching to LPG households could generate considerable monetary savings, Figure 3.7: 56 per cent savings when using LPG instead of charcoal, or 45 per cent in the case of fuelwood.

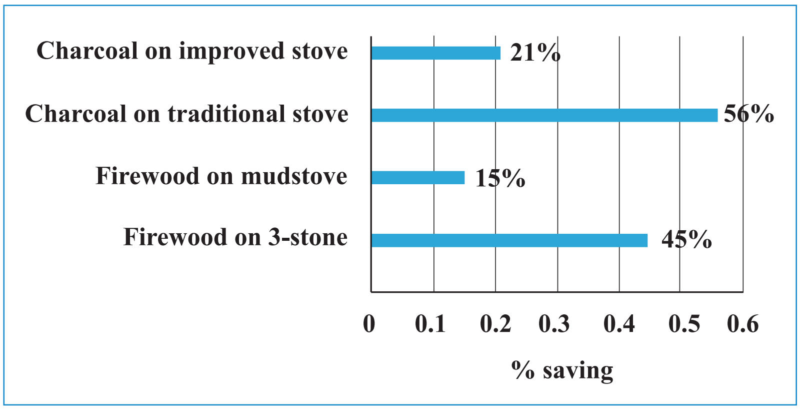
Based on baseline data, the project signed partnership agreements with the WDA-Network and two LPG companies in El Fasher. Participatory discussions with the WDAs reached an agreement on beneficiary eligibility criteria for obtaining LPG appliances through microcredit. Each WDA served as a guarantor for its members and women confirmed regular repayment of credit instalments. After training the WDAs on management and the principles of microfinance, 561 LPG appliance sets were purchased. Seven WDAs benefited from the first batch of LPG appliances. The performance of repayment of credit instalments was very good – reached an average of 95 per cent by December 2009, Table 3.3.

Figure 3.6. Energy cost (SDG/MJ) of using different cooking fuels



Source: Practical Action Consulting, Eastern Africa, 2009.

Figure 3.7. Monetary savings by switching to LPG



Source: Practical Action Consulting, Eastern Africa, 2009.

Table 3.3. Rate of repayment of credit instalments for LPG appliances, March - December 2009

Name of WDA	Number of Households	Loan (SDG)	Repayment (SDG)	Deficit (SDG)	Repayment Rate (%)
Tanmia wa Tatweer Amaraa	50	7,775	7,775	0	100
Maiarem	20	3,200	2,090	1,110	65
Market net	50	8,000	8,000	0	100
Amel	45	8,750	7,673	1,077	88
ERDN	45	8,137	7,713	424	95
Forestry families	20	3,200	3,200	0	100
Argoon	30	4,800	4,800	0	100
Total/ Average	260	43,872	41,261	2,611	95

Source: Practical Action, December 2009, Annual Project Report: Low Smoke Stoves.

While the overall repayment rate was very high, 95 per cent, there were some inevitable default repayments. From monitoring data, it became clear that some women were extremely poor and were consequently unable to repay their credit instalments or even afford to refill the cylinder. Accordingly they reverted back to using fuelwood. Given this, the project in consultation with the WDA, reviewed the credit eligibility criteria making it clear that women must have the capacity to repay the loan otherwise the appliances will 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 modern clean energy. However, within the capacity of the project, this was seen as the only option, otherwise the revolving fund would gradually diminish causing the entire scheme to collapse.

By May 2010, the total number of project beneficiaries was 2,905, more than the planned figure of 2,400 households. The number of WDAs had also increased to 27. Some 92 per cent of the beneficiaries are continuously using LPG.

Other achievements realised by the project include gaining the confidence of the LPG company, Nile Petroleum, and an ability to pay for LPG appliances on lease terms. The gas company realised that profit maximisation was in selling LPG and not in keeping the cylinders in stock.

Box 1. Improved conditions thanks to LPG

Azza Yousif is 43 years old, married with nine children. She is a member of the Tanmia wa Tatweer Women Development Association. Azza's husband works as casual labourer. Azza explained that it was her first occasion to deal with LPG when the project offered her a set in September 2008. She is very committed in paying the instalment: she completed her loans ahead of the loan period ending.

Azza explained that the LPG stove has many advantages, among them being no smoke emissions, having more time to do other activities, faster cooking times and a cleaner working environment. Furthermore, LPG as a cooking fuel is cheaper than charcoal and fuelwood. She explained that her LPG cylinder lasts for two months: this helped her save SDG3 per day which increases her ability to pay school fees. She also explained that before using LPG, she was unable to pay money for her children's school meal which meant they had to return home each day to eat before returning to school to finish their classes.

4. ALTERNATIVE DOMESTIC ENERGY TECHNOLOGY OPTIONS, OPPORTUNITIES AND CONSTRAINTS

4.1 BACKGROUND

Having access to adequate, reliable and affordable domestic cooking energy is likely to remain one of the main social, economic and, quite clearly, environmental topics in Darfur for the foreseeable future. It is imperative that solutions are found and that these are sustainable.

Many attempts have been made to introduce various alternative technologies and fuels to the region but virtually all have failed to be adopted by rural or urban households, the main users of energy, for reasons mentioned above.

This section looks at nascent technologies which are being tried in Darfur, some of which have proven successful in other similar climatic regions. It is unlikely, however, that any one solution will address the current and growing needs in Darfur and Sudan, which calls for a multifaceted and well co-ordinated approach involving a very broad spectrum of stakeholders, from the private sector, government ministries, research institutions, community groups and NGOs.

4.2 ENERGY RESOURCES IN DARFUR

For reasons of relevance only data on energy resources that could be used for household cooking purposes are examined below.

4.2.1 SOLAR ENERGY

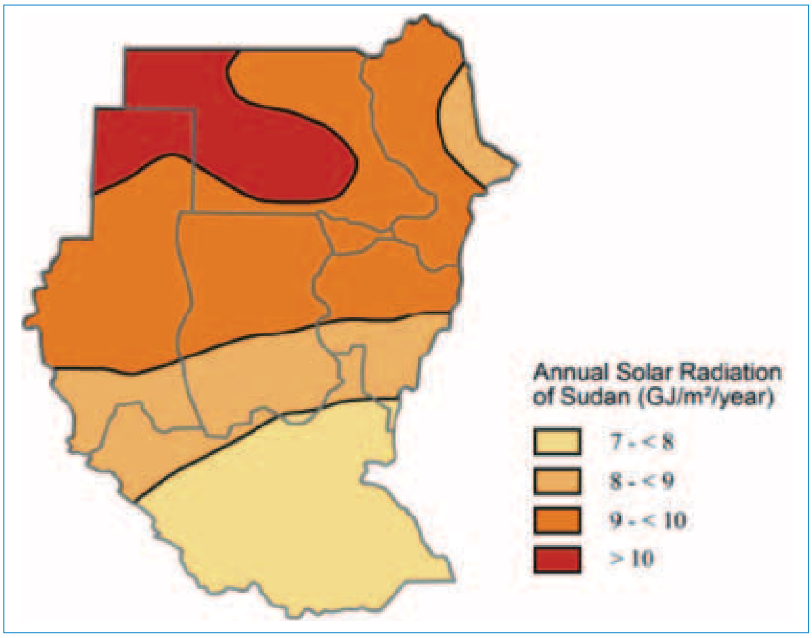
Darfur has high solar energy resource potential that could be harnessed to generate thermal and electric energy. Sunshine duration is amongst the highest worldwide ranging, on average, between 9-10 hours per day.

Solar energy intensity distribution for Sudan is shown in Figure 4.1. The annual solar radiation in Darfur generally varies between 9-10GJ/m²/year, with higher figures being recorded in northern desert areas. Solar energy radiation data for four representative stations in Darfur are shown in Table 4.1. Due to its high altitude Zalingei registered the highest values of solar radiation with a maximum of 29.5MJ/m²/day during March and April.

4.2.2 BIOMASS ENERGY

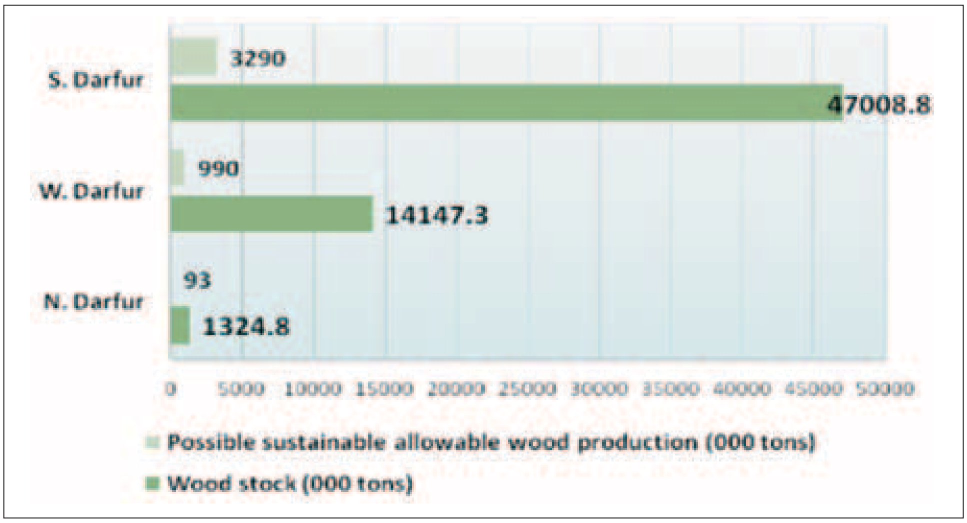
There is much discrepancy on information about woody resources in Darfur, in particular which units of conversion to use. The 2nd National Energy Assessment, Figure 4.2, indicates that the wood resources of North Darfur are relatively small compared with the other two states. This is due to

Figure 4.1. Solar energy intensity in Sudan



Source: Abdeen Mustafa Omer, 2006b.

Figure 4.2. Wood stocks in Darfur and allowable sustainable production



Source: 2nd National Energy Assessment, 2001.

Table 4.1. Average daily monthly solar radiation at four stations in Darfur, MJ/m²/day

Month	Stations (registration period: 1961-1990)			
	El Fasher	Ghazala Jawazat	Babanousa	Zalengei
January	20.71	20.52	23.5	25.1
February	23.37	22.48	26.1	27.5
March	24.7	23.36	27.7	29.5
April	25.43	23.57	28.3	29.5
May	25.1	22.53	27.4	28.9
June	23.92	21.65	26.2	27.2
July	22.45	20.47	23.7	24
August	23.03	21.23	23.8	23.1
September	23.03	21.31	25	25
October	22.76	21.39	23.6	26.3
November	21.88	21.23	22.8	26.3
December	20.58	20.35	22.3	24.9
Average/day/year	23.03	21.6	25.03	26.44
Total GJ/m²/year	8.41	7.88	9.14	9.65
Average annual daily sunshine duration (hrs)	10.2	9.1		

Source: 2nd National Energy Assessment, 2001.

the fact that North Darfur is mostly covered by desert and has been severely affected by recurrent droughts during the past four decades.

Table 4.2 shows the distribution of forest reserves in Darfur. The total area of reserved forests is 7,036,276 Fedhans[13] (64 per cent of the total), mainly concentrated in South Darfur, followed by West (39 per cent) and North Darfur. Table 4.3 shows the annual afforestation rate undertaken by the FNC in Darfur forests from 1948 to 2000. A total of 171,581 Fedhans were planted, at a rate of about 3,300 Fedhans per year. This is relatively small compared with estimated values of annually cleared forest areas.

Non-woody biomass resources, mainly in the form of agricultural residue such as millet stalks and peanut shells, are available but not generally as a source of energy due to their traditional uses as building materials and animal fodder. In addition, the conflict situation has disrupted agricultural activities and no recent data are available on levels of production.

Other biomass residues such as forest residues do not exist as not all FNC sawmills are operational. The recent conflict has prompted some illegal cutting of hardwood timber and illegal small-scale sawmills have been reported, but anecdotal evidence does not give information on the quantity of sawdust being produced.

With the high rate of urbanisation in Darfur, large quantities of municipal solid waste (MSW) are generated in major cities and towns, some of which could – if well managed – be used for energy

[13] Fedhan is equivalent to 0.42 hectares.

Table 4.2. Forest reservation status as of December 2003[14]

State	Number of Reserved Forests	Area (Fedhan)	Number of Forests under Reservation	Areas Under Reservation (Fedhan)	Total Number of Forests	Total Area of Forests (Fedhan)
North Darfur	9	16,993	49	192,269	58	209,262
West Darfur	36	498,553	36	1,811,161	72	2,309,714
South Darfur	38	3,505,701	26	1,011,599	64	4,517,300

Table 4.3. Annual afforestation in Darfur forest reserves from 1948-2000 (Fedhans)

1948-1952	53-57	58-62	63-67	68-72	73-77	78-82	83-87	88-92	93-97	1998-2000	Total
217	1,583	2,759	5,526	4,290	9,458	2,323	6,701	4,912	78,527	55,285	171,581

Source: Fatah Al Aleem Mohie El Deen, Sudan Forestry Sector Review, May 2004.

production. Most MSW constitutes about 60 per cent biomass that could be used to produce fuel briquettes. To be effective, however, the system needs good data on quantities produced, composition and present practices of collection, disposal and recycling. While the collection and disposal of MSW and accompanying environmental damage has become a concern for many municipalities, and while plans exist for better organisation of collection and dumping, municipalities lack the means to implement the plans.

As demand for cooking fuel grows and pressure increases on dwindling natural resource stocks, the need to identify viable, affordable and culturally acceptable alternatives becomes all the more important.

[14] Fatah Al Aleem Mohie El Deen, Sudan Forestry Sector Review, May 2004.

4.2.3 KEROSENE AND LIQUEFIED PETROLEUM GAS

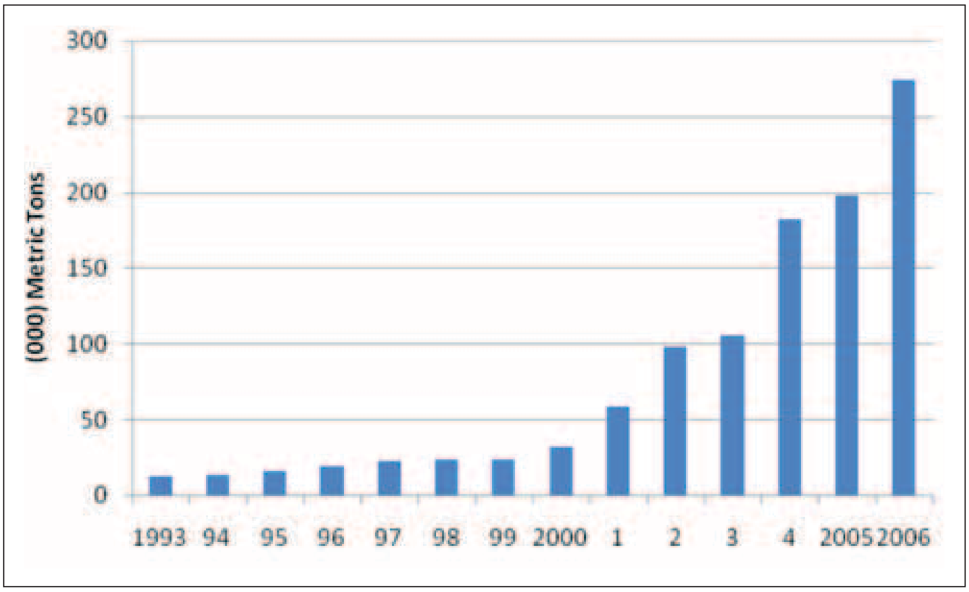
Kerosene, an important fuel for lighting and cooking in many rural households in Sub-Saharan Africa, is not abundantly available in Darfur. This is likely on account of its high sale price (SDG8 per gallon) compared with diesel (SDG7.5 per gallon). Petroleum companies in Darfur have no storage facilities for kerosene.

LPG consumption in Sudan, including Darfur, witnessed a remarkable increase during the past 10 years due to local production at the refinery at El Jaili and an accompanying government subsidy, Figure 4.3. The supply of petroleum products to Darfur is assured through road and rail transport. Rail transport is far cheaper – but irregular – than road, the latter being on average SDG2 per gallon. This is directly reflected in petroleum products prices in Darfur. It is worth noting that state governments impose taxes on petroleum products ranging from SDG0.10 (N. Darfur) to SDG0.33 (S. Darfur) per gallon. Although LPG is supposedly exempt from local state tax, El Fasher Locality does levy a tax on LPG, a consequence of which is that the cost of petroleum products in Darfur ranges from 2-3 times their equivalent in Khartoum. This has direct impact on petroleum product consumption in the region which account for less than 1 per cent of total national consumption.

The introduction of LPG to Darfur dates back to the 1980s. However, due to its high price relative to woodfuel, few households could afford to use it. At that time there were no refilling depots with cylinders being transported first from Khartoum and later, during the late 1990s, from Nyala. In 2000, the FNC launched the Sudagaz project, which provided LPG cylinders on credit to the formal sector. However, FNC lacked the necessary infrastructure, logistics and management to maintain the service. In addition, a quality defect causing major cylinder leakage was identified and many cylinders proved to be unusable.

Consumption of LPG at the household level in Darfur has, however, witnessed an increase from 2003 - 2010, mainly due to national production and a government price subsidy. At present, all four LPG companies (Nile Petroleum, Abersi Gas, Aman Gas and Iran gas) operating in Sudan are

Figure 4.3. LPG consumption from 1993 to 2006 (,000 tonnes)



Source: Practical Action, Proposal for Dissemination of LPG use in El Fasher.

operational in El Fasher and Nyala. Nile Petroleum, being the first to establish depots in Nyala and El Fasher, dominates the market. More recently Aman gas established a depot in Nyala. In 2005, monthly LPG sales in El Fasher were estimated at 37.5 tonnes, about 3,000 cylinders of 12.5kg capacity. If a family uses on average one cylinder per month then the LPG penetration rate in El Fasher is around 10 per cent. Table 4.4 shows the prices of a new LPG cylinder and its refilling cost in El Fasher.

The high upfront cost, about SDG200-260, of LPG appliances – the cylinder and gas burner – the lack of awareness and fear of LPG fire hazards deter many households from switching to LPG. However, the predominant reason is the high cost of LPG appliances and irregular supply of LPG.

Figure 4.4 shows the prices of refilling a 12.5kg cylinder in Darfur compared with rates in Khartoum and Kassala. Although there is an LPG depot in El Fasher the price is still quite prohibitive. El Geneina, with no depot currently, relies on cylinders being transported to and from Nyala for refilling.

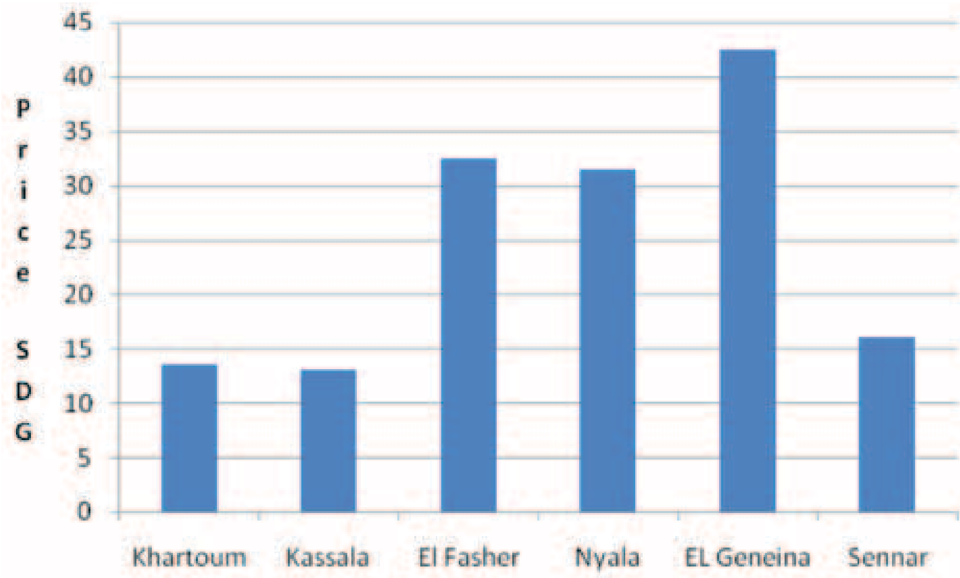
The LPG companies recognised a sharp increase in LPG consumption after the conflict started, triggered by the increased presence of NGOs and UN agencies in Darfur. In addition, awareness among households of the benefits of LPG over fuelwood is also spreading fast. Due to insecurity and

Table 4.4. Price of new LPG cylinders (12.5kg) and refilling costs

City	Price of a new filled cylinder without gas burner (SDG)	Refilling price (SDG)
El Fasher	130	30-37
Nyala	130	30-33

Source: Survey data obtained December, 2008.

Figure 4.4. Cost of a 12.5kg LPG cylinder in Sudan (SDG)



Source: Survey data obtained December, 2008.

irregular rail transport, the availability of LPG is, however, often interrupted. When this happened in 2008, prices jumped from SDG18 to SDG33.

4.3 TECHNOLOGY OPPORTUNITIES AND CONSTRAINTS

4.3.1 KEROSENE

The main disadvantages of kerosene are poisoning, skin burns and the loss of property through fire. Poisoning applies particularly to children as they are more likely to drink fluids stored in small containers such as recycled soft drinks bottles or other inappropriate containers.

In Darfur, kerosene is mostly used by households for lighting and not considered a typical fuel for cooking. In urban settings, however, it is used for cooking although to a limited extent. Overall, its low availability and high price compared to cheap fuelwood and charcoal limit its use.

In 2004, some NGOs conducted limited experiments on kerosene use in some IDP camps in Darfur. The idea was quickly abandoned on account of child safety considerations, fire hazards and low kerosene availability. More recently, starting in 2006, SAG began to distribute kerosene wick stoves in Abu Shauk and Al Salam camps. In a series of focus group discussions with women groups from the two camps in 2008, they claimed that kerosene is not at all suitable for cooking because of the following reasons:

- cooking with kerosene is more expensive than fuelwood;
- it generates too much smoke and soot, causing eye irritation and depositing soot on pots, walls and cloths;
- it has a bad smell, causing vomiting for some women and children;
- you cannot cook *Asida* since the wick stove is too small for the pot making it only suitable for making tea and other light meals; and
- the stove is not stable and the cooking pot can be easily tipped over.

Women completely rejected the kerosene stove and no woman indicated they were using it. No tests appear to have been conducted prior to distribution in order to choose an appropriate stove and corresponding fuel for the household. In addition no end-user training was conducted, similar to that with LPG appliances.

An investigation by this project of the El Fasher market revealed that kerosene is not available in commercial quantities. Petroleum companies claimed that kerosene is only used for lighting and consumption is relatively low compared with other petroleum products. Companies do not procure kerosene due to low demand and lack of storage capacity, which explains the high price of kerosene in El Fasher.

At the Khartoum refinery, kerosene production is not a priority compared with aviation fuel and diesel, which have high demand and better selling prices.

Lessons learned from kerosene use in emergency settings – for example in Nepal and Chad – do not recommend its use as a cooking fuel in IDP or refugee camps. If distributed, kerosene very often finds its way to the market and fuelwood is purchased instead. Under such conditions it would be unjustifiable to recommend the use of kerosene as a cooking fuel in Darfur.

4.3.2 SOLAR COOKERS

There are three main solar cooker models promoted for household cooking:

- panel cookers made of cardboard, which are the simplest but have a short life span. Cost varies from US$2-6 and they can cook rice in 1.5 hours;
- box ovens which can cook a meal in 2.5 hours and have a minimum cost of around US$30-45, depending on construction materials; and
- parabolic cookers. These are better built but must have a continuous sun tracking system. Cooking can be fast, 45 – 60 minutes, but they are expensive, costing about US$153.

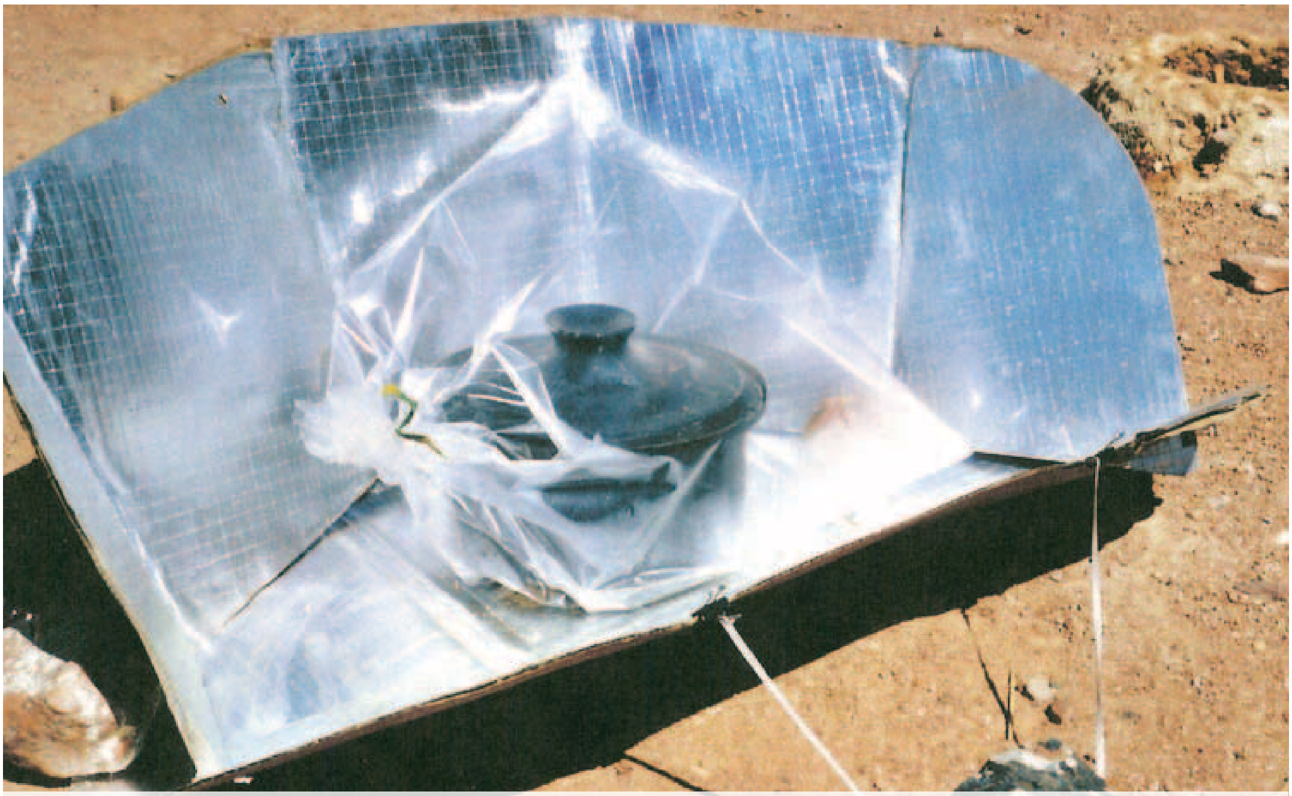
During the 1980s and early 1990s the ERI conducted considerable work on box type solar cookers, including design, local manufacture, dissemination and commercialisation. Solar cookers were a main activity of the Rural Solar Energy project implemented by ERI in Northern Kordufan from1992 - 1997. Although the project succeeded in demonstrating the adaptability of solar cooker for cooking Sudanese diets, including *Asida*, households would not apply them. Artisans trained in manufacturing the cookers could not find any market demand for the products.

Another solar cooker project was implemented by the Sudanese Environment Conservation Society, in peri-urban Khartoum. Following demonstrations and training on their use, imported panel solar cookers, were freely distributed to households. Follow-up monitoring indicated that households were not using the solar cooker, indicating once again a negative acceptability.

Some lessons from the above two projects are that solar cookers are not acceptable by Sudanese households due to:

- solar cookers – whether imported or locally made – are very expensive;
- cooking time is very long, often several hours;
- cooking Sudanese meals demands regular mixing of the pot contents (especially for *Asida* and *Mulah*), which is not possible for some cookers, particularly the box type;
- solar cooker use demands outdoor cooking, under the sun; and
- solar cookers are not suitable for cooking early in the morning and late in the evening, typical meals times for rural inhabitants.

Many organisations, including UN agencies, tried to introduce solar cookers to the Darfur IDP camps. Different solar cooker designs were tested, particularly the panel and box type. Although most solar cookers were imported from abroad, UNIDO launched a solar cooker based on local production. In co-operation with a workshop in Khartoum an initial box cooker design was made and subjected to laboratory testing. Some Darfuri women in Khartoum were then invited to test the cooker before 10 samples were finally taken to Darfur for acceptability tests. Women in Dereig



Despite having much appeal from an environmental perspective, and particularly in a situation like Darfur where the physical conditions seem ideal, uptake of solar cookers for domestic cooking has not been a success to date. Credit: Solar Cookers International.

IDP camp were trained to use the cookers which were then left with the community for further acceptability test. The glass of a couple of cookers was known to have cracked during testing, however no further information is available on this project.

The Women's Commission study[15] on fuelwood collection and alternatives for IDPs in Darfur found that the most important feature of cooking fuel technology perceived by most women in Darfur is cooking time – the faster the better. The use of fire for cooking is also crucial. For this and a variety of other reasons, women in Darfur are very reluctant to use or even consider solar cookers.

Experience and lessons from solar cooker projects worldwide reveal controversial results. Some report successes while others completely reject the idea. Recent UNCHR experience with solar cookers in Chad – in Dafuri refugee camps – reported that refugees were successfully using solar panel cookers. However, it also indicated that a solar cooker cannot be a substitute for fuelwood but could be considered as a complementary cooking energy source in appropriate settings.

Another UNHCR experience[16] with solar cookers in Nepal showed that locally made solar box cookers costing US$30 were distributed to refugees with the intention to replace or minimise the use of kerosene which, over the years, had become very expensive. In this case the solar box cookers were very slow to cook, taking approximately 2.5 hours to cook a small pot of food, and broke frequently, particularly the glass tops. Refugees were often not repairing the cookers if they broke, casting them aside in favour of kerosene which was being freely distributed.

[15] Women's Commission, Finding Trees in the Desert: Fuelwood Collection and Alternative in Darfur.

[16] Women's Commission, 2006, Beyond Fuelwood: Alternatives and Protection Strategies for Displaced Women and Girls.

The solar box cookers were replaced by parabolic solar cookers, each costing about US$120 for the cooker and a pot. Refugee households applied for cookers but were required to pay US$2. To ease this cost, a cooker was provided to four families at a time, which created problems of time scheduling between the women.

In contrast to the box cooker, acceptance of the parabolic cooker was reported as fairly successful. The success was attributed to the fact that parabolic devices cook much more quickly than the box model – roughly 45-60 minutes for a full family meal. One litre of water will reach boiling on a parabolic cooker in 15 minutes, about the same amount of time as on a kerosene stove.

Parabolic cookers must, however, be turned every 5-10 minutes to follow the direct rays of the sun, making the cooking process somewhat labour intensive. Also, in the case of Nepal, solar cookers could only be used during certain periods of the year – 34 weeks in total. Another complementary fuel was therefore needed to fill the gap.

Although parabolic cookers seem to overcome the most common complaint regarding solar cookers – that they cook too slowly – it is still far from a perfect solution for camp situations. A main problem is the size of the cooker – the dish itself is roughly 1.5m in diameter while the full device is close to 2m high when set up on its frame. Shelters in most IDP settings are extremely crowded: in Darfur the household area is about 100m^2 or less. In Nepal the possibility of placing all cookers in a single, dedicated area in order to save space was tried, but most refugee women rejected the idea as being too inconvenient. Communal cooking has also been rejected.

In Darfur's Abu Shauk camp the community leaders, *Umdas*, indicated that one NGO introduced solar cookers to them. After demonstrations on its use, the NGO left the solar cookers for the *Umdas*' families to use. The *Umdas* reported that solar cookers were not suitable for IDPs as you cannot cook *Asida* with them. Focus group discussions with womens' groups in both Al Salam and Abu Shauk reported seeing the cookers and even attending a demonstration. For similar reasons to those outlined above, they rejected the idea of using solar cookers for cooking meals.

4.3.3 BIOMASS WASTE

The term biomass waste includes agricultural residues, sawdust, MSW and charcoal dust. As indicated above, there are no excess agricultural residues in Darfur, the main one being millet stalk which is traditionally used as building material. Peanut shells are to some extent available in Nyala and El Geneina. However, these are again traditionally used as animal feed and in brick making. Lessons learned from the experience of the Ministry of Energy and Mining during the late 1980s and early 1990s show that briquettes made from peanut shells are not suitable as a domestic cooking fuel. In addition to the need to design a special stove the product, on burning, produces smoke that irritate peoples' eyes and throats.

Apart from small-scale carpenters, there is no timber industry in Darfur. Due to insecurity FNC has no access to its sawmills in South and West Darfur. Some illegal sawmills are reported to be operational but it is unlikely that they produce enough sawdust to be used as briquetting material.

On the other hand charcoal dust is available at charcoal selling areas (*Zariba*). On agglomeration, even without grinding, and using an appropriate binder such as clay, charcoal dust could be converted into a combustible fuel very similar to charcoal, Figure 4.5. Once dry, the agglomerate could be burned on charcoal stoves. Such agglomerates burn very similar to charcoal, but for a longer time as the clay acts both as a binder and an additive that helps briquettes burns consistently for longer.

Figure 4.5. Charcoal dust agglomerate

Charcoal dust has no use and is considered a biomass waste product which can be collected freely at charcoal *Zaribas*. As each sack of charcoal contains about 10 per cent dust, the annual quantity could be considerable to sustain an entrepreneurial activity, particularly for IDP women. However, one has to consider that waste material, once converted into a valuable product, will assume a cost and will no longer be freely available.

Another waste material to consider is municipal solid waste. Some components such as paper, cartons, and straw can be converted into fuel briquettes using a simple process. The Legacy Foundation[17] briquetting process, for example, could be appropriate for converting waste biomass materials into fuel briquettes (Figures 4.6 and 4.7).

Figure 4.6. The Legacy Press

Source: Aurélien Herail, 2006.

[17] Legacy Foundation – www.legacyfound.org

Figure 4.7. Biomass briquettes produced using the Legacy Press

Source: EcoVentures International, 2007.

The SAFE/WFP project is presently experimenting with such briquettes in Kabkabiya using household waste and animal dung. The Kabkabiya Women Association (a SAFE partner) claims that briquettes generate enormous amount of unpleasant smoke. Although it is still too early to judge the effectiveness of this process it is well known that clean burning of such briquettes demands a stove specially designed for the purpose. Among those stoves so far tested by SAFE the BDS stove has proven to be the best. However, the project is not at a stage of disseminating the stove in combination with briquettes as it is too risky to disseminate two new technologies at a time.

The use of MSW as a source of household fuel demands institutional co-ordination with the relevant municipal authorities and good organisation. It is a labour intensive process which could, however, be considered as an employment opportunity. Further study on MSW composition, collection costs, transport and dumping sites is needed before taking an informed decision. Experiences and lessons learned from a similar project in Rwanda[18] show that the project could be a successful one. Other benefits would include environmental hygiene in urban settings.

4.3.4 BIOGAS – AN OVERVIEW

The anaerobic digestion of biomass waste in what is called a biogas digester produces a gas which contains 60-70 per cent methane. Gas containing more than 50 per cent methane can be burned on a conventional gas cooker. The feedstock for biogas digesters can be human waste, animal waste and organic waste such as kitchen or market waste. The amount of gas obtained from different types of biomass wastes varies, mainly depending on variables such as the type of digester being used, the amount of waste added daily, the temperature of operation and the retention time.

[18] Pete Young and Smail Khennas, 2003, Feasibility and Impact Assessment of a Proposed Project to Briquette Municipal Solid Waste for Use as a Cooking Fuel in Rwanda, Intermediate Technology Consultants (ITC).

Biogas programmes are well established in developing countries such as India, Nepal and China where different models of digesters have been developed and successfully operated. China and India alone have more than seven and three million household units in operation, respectively.

A range of biogas initiatives have been tried in Africa in the past 20 years but most have been problematic. Although many projects have failed, there is still considerable confidence in the technology. A recent initiative "Biogas for a better life – An African Initiative" has been launched in 22 African countries, including the Sahelian countries of Burkina Faso, Mali, Niger and Sudan. The project, which has partnerships with AfDB, GTZ and SNV amongst others, aims to oversee the installation of 12,000 fixed dome biogas digesters by 2014. In Kenya a new company, Sky Link Innovators, has installed over 200 biogas units for homes and institutions. The cost for a home unit is approximately US$2,000 and for an institution such as a school US$20,000. Sky Link Innovators were recently awarded a 2010 Ashden Award for its work with biogas digesters.

4.3.4.1 Biogas in Sudan

Biogas technology was first introduced to Sudan during the mid-1970s when GTZ constructed five digesters as part of a project for water hyacinth control on the White Nile River. The experiments were reported successful but were abandoned when the project ended. It did, however, motivate Sudanese research institutions such as the Faculty of Agriculture, Energy Research Institute and the National Energy Administration to embark on research on biogas technology.

The main types of biogas digesters disseminated by ERI and the General Directorate for Energy Affairs (GDEA) are the fixed dome digester, commonly called the Chinese digester (120 units each with a volume of 7-15m^3) and the floating gasholder type known as the Indian digester (80 units each with a volume of 5-13m^3). A recent modification of the Chinese fixed dome digester by the Biocon Company claims having more advantages over the traditional Chinese and Indian types.

Two biogas units (Indian type) were constructed in Darfur during the late 1980s but were never operational due to defects in construction workmanship and lack of end user training and monitoring. In 2010, the SAFE/FWP project and World Vision constructed biogas units in El Fasher and Nyala. The former is a pilot unit, while plans are underway for further dissemination, training and capacity building. In Nyala two biogas units (fixed dome) were constructed at two dairy farms. Thus far it would appear that the availability of raw materials – water and cow dung – are the main problems facing the two projects. In a semi-arid area like Darfur, water is scarce, while cow dung is often scattered on the landscape.

Biogas technology is to some extent known throughout the country, particularly in Central Sudan, mainly Khartoum, Gezira and Nile states, as more than 150 biogas digesters can be counted in households, community centres, public institutions, universities and research institutions. The end uses of biogas were quite variable but including cooking, lighting, refrigeration as well as power generation. The lead technology suppliers, who managed to develop good construction skills for various digester designs, are ERI, the GDEA and Biocon Company - a private sector company.

Although efforts by ERI and GDEA were not market driven and did not lead to the development of a sustainable market for biogas technology in Sudan, the training and capacity building formulated three teams (at ERI, GDEA and Biocon) of skilled engineers and technicians, who are still capable to further cater for any market development for biogas technology in the country.

4.3.4.2 Biogas – technical issues

The Chinese fixed dome digester is normally made out of bricks and cement. In this design the gas gathers in the top of the dome and is held in pressure by forcing sewage into the expansion chamber which will continue until the gas fills the dome and escapes through the expansion chamber. When the gas valve on top of the dome is opened the gas will flow until the digestate reaches a level when there is not enough pressure to maintain the flow of gas. The digester sewage can be dried as fertilizer or used directly for irrigation.

The Indian floating dome biogas digester differs from the above in the storage of gas as the dome is lifted by pressure from the gas. Two types of floating dome digester are currently in use in Africa, the first being a biogas digester which was invented and popularised by ARTI India is a small household unit which uses household kitchen waste as a feedstock. The capacity of the digester unit is typically 1,500 litres, and the gas holder 1,000 litres. A second model, the floating dome biogas digester, has a chamber made from cement or brick and the dome made from a single metal or plastic drum. This type of biogas digester is being used in Mali and uses cattle dung as a feedstock.

Both Indian and Chinese types of biogas digesters were disseminated in Sudan by ERI and GDEA, but most attention was given to fixed dome digesters as the floating drum digester showed a number of drawbacks including high cost, not being aesthetic and generating bad odours and attracting flies.

Lessons learned from the Sudanese biogas experience include the following:

- proper site selection is an important factor to ensure sustainability. Key issues to consider are the availability of raw materials, economic affordability, social acceptability and a realistic analysis of the energy situation taking into consideration the presence of other cooking fuel options;
- proper digester sizing: the digester volume should be properly determined to satisfy the amount of energy required and/or accommodate the amount of raw materials available;
- monitoring is essential to help users overcome difficulties and avoid problems;
- training is essential. Audiences include skilled labour and technicians required for digester construction and maintenance as well as the end users;
- in the case of community or institutional biogas digesters, it is important to determine/nominate a managerial body to take responsibility for running the installation;
- making biogas end use appliances available in the local market at reasonable prices encourages end users to diversify benefits from biogas plants;
- any marketing approach should be preceded by intense public awareness, using different information dissemination means;
- construction and operation of demonstration/pilot biogas digesters at different localities is necessary to induce customers and develop markets;
- emphasising and promoting other benefits of biogas technology e.g. organic fertilizer, hygiene and improved sanitation, time saving and so forth increase technology acceptance; and

- it is important to conduct research and development activities with the objective of reducing the cost of biogas digesters and maximise digester productivity/efficiency. Such improvements will enhance marketing biogas in Sudan.

For future prospects, the fixed dome digester looks more adaptable to the household situation. However, there is no concrete information on digester design parameters and some like the Biocon Company claim that the fixed dome digester has yet to undergo some design modifications in order to suit conditions in Sudan. In order to properly implement a national biogas programme, it is necessary to first address the technical issues and standardise the biogas digester design. Key challenges to widescale commercialisation of biogas technology in Sudan are:

- the high cost of construction materials leading to high investment requirements;
- a lack of technical capacity to install high numbers of biogas digesters;
- absence of promotional materials;
- low level of public awareness about biogas technology;
- availability of alternative cooking fuels, particularly LPG;
- guaranteed availability of waste inputs; and
- the use of slurry – a product from the process – as a fertilizer is poorly known and the other benefits of biogas have been poorly emphasised.

4.3.6 BIOFUELS

Biofuel is a renewable fuel produced from biomass derived from agricultural and forest products and wastes, MSW and sludge, agro-industrial wastes and sludge and energy crops. If produced domestically, the use of biofuels can lead to enhanced energy security through reduced dependence on oil. With an appropriately designed and managed value-chain, biofuels also lead to reduced greenhouse gas emissions.

Sudan has had long experience with the conversion of agricultural and agro-industrial residues – cotton stalks, groundnut shells and bagasse – into household and industrial fuels. Several factories were established for the production of biomass and charcoal briquettes. The process was, however, not sustainable given the low price of woodfuel. In addition, the projects were mainly donor funded and consequently came to an end when funding was exhausted.

Although Sudan has vast resources for the production of biofuels , only one ethanol factory exists and this only since June 2009. This factory, with a capacity of 200 million litres per annum, was established at the Kenana sugar factory (White Nile State), where molasses – otherwise exported – is used. The ethanol is primarily export directed as there is no foreseen plan for local use. The Kenana experience will seemingly be replicated in other existing and planned sugar factories. As molasses is already an export product the primary motive for ethanol production, at present, is increasing income through value added processing.

Experience and lessons learned from the use of ethanol in countries such as Malawi and Ethiopia show that ethanol could successfully be used as a household cooking fuel. In Malawi, for the purpose of safety, ethanol is converted into a gel fuel by adding a thickening agent. However, when ethanol prices increased due to increased international market demand and local taxes, gel fuel became uncompetitive with other cooking fuels. In Ethiopia, a Gaia project has been successful in introducing ethanol as a household fuel in refugee camps, using a specifically designed ethanol stove. Although the project initially received considerable government support, dissemination of ethanol and the stove became difficult while the local supply of ethanol stopped as the government shifted ethanol use to the transport sector, blending ethanol with petroleum products. As a consequence, the project has had to resort to importing ethanol although high international prices and demand for ethanol make supplies difficult and irregular.

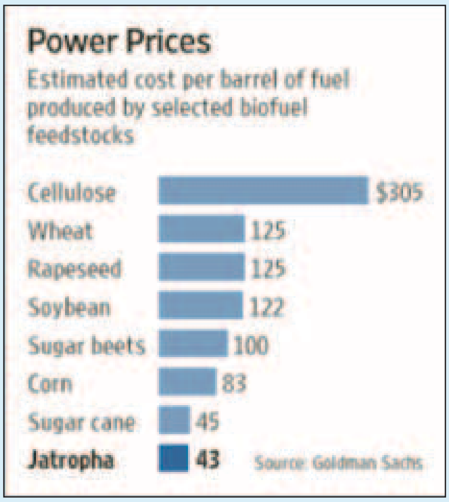
Sudan has considerable potential for ethanol production, mainly to meet high international market needs. No plans exist, however, to use ethanol at the household level or to blend it with petroleum products for the transport sector.

Case study: Biodiesel from Jatropha in Africa

Interest in the Jatropha plant in Africa is stimulated by success in India in running diesel engines on 100 per cent Jatropha biodiesel. Recently there have been trials using biofuel for aircraft. In 2008, Air New Zealand test flew a Boeing 747 using a 50:50 blend of Jet A1 airline fuel and Jatropha derived biofuel. For the test, Jatropha biodiesel was sourced in Tanzania via a company called Diligent Tanzania who buy Jatropha seeds from local farmers and then produce Jatropha oil and Jatropha fuel. The price of Jatropha-based biofuel has been estimated to be one of the lowest of all biofuels, see figure. At these prices Jatropha biofuel would be competitive with fossil fuel derived diesel without any need for subsidies.

There are currently trials and plantations of Jatropha in many African countries including the Sahelian countries of Sudan, Mali, Burkina Faso and Niger. In Sudan, Jatropha research started as early as 1972 with studies concerning the molluscicidal effect of the plant, which some people believe is an indigenous species in Sudan. In South Sudan, Jatropha is mainly used as a hedge to protect fields and crops from livestock, but recently a project has been started by the German governmental development organisation DED in Kutum, North Darfur[19].

While Jatropha has been lauded as a solution to many problems in rural development, especially in marginal lands, there are constraints such as the need for fertilizers, pesticides and irrigation in order to provide quality seeds. There is also evidence that Jatropha can be a reservoir for pests and diseases which then spread to food plants such as sorghum and peanuts.



Source: Wall Street Journal 2007.

[19] http://www.underutilized-species.org/Documents/PUBLICATIONS/jatropha_curcas_africa.pdf

5. THE BRICK MAKING SECTOR

5.1 BACKGROUND

Brick making in Sudan has a tradition of several millennia. While kiln-fired red bricks have long been used by a small elite or for buildings of special importance, rapid urbanisation in the past few decades has resulted in a dramatic increase in the demand for these bricks.

While the brick industry has increased in both size and scale it still applies the same ancient moulding and polluting firing methods from thousands of years ago. As a result, the sector has become a highly unsustainable industry, not only contributing to deforestation but also exposing millions of urban dwellers to hazardous emissions which can cause lung cancer, asthma and various other diseases. There is an urgent need to guide the traditional brick sector to more sustainable production methods.

Bricks are fired in "clamps" – temporary structures built from dry/unfired bricks – or, alternatively, in "kilns" – permanent structures, typically with a chimney. Kilns can be designed for intermittent or continuous firing and tend to be more fuel-efficient than clamps. In Africa, including Sudan, most bricks are fired in clamps using fuelwood.

Sudan has abundant brick making soils along the Nile and its tributaries or along temporary water courses (*wadis*). Brick production is seasonal and dominated by traditional entrepreneurs (about 2,000 brick enterprises) using traditional production techniques.

The Sudanese Organisation for Building Material and Construction (SOBMC) confirmed that similar to most African countries, most construction is taking place in the bigger metropolitan areas (Khartoum) and cities such as El Fasher, near the most important building materials markets. SOBMC estimates that 50 per cent of all brick kilns are operated in the Khartoum area, where an estimated 1,000 enterprises produce about two billion bricks every year. The Khartoum Brick Union counts about 5 per cent new brick enterprises every year.

In rural areas, traditional mud walling and sun dried earth blocks are the most common building materials. Since mud walls do not withstand heavy summer rains, the houses of wealthier families

The humanitarian operation in Darfur and new developments in all major cities has led to an unprecedented demand for bricks, the manufacturing of which has had severe negative impacts on the environment.

as well as certain public buildings such as mosques and schools tend to be built from fired red clay bricks which are locally produced in temporary clamps.

Small-scale brick making entrepreneurs rely heavily on wood for fuel, at least some of which is transported from several hundred kilometres away. According to Hamid (1994), brick production required 182,968 tonnes of wood annually, over half of that consumed by the industrial sector as a whole. While it requires 0.85MJ to fire 1kg of bricks, in theory, traditional clamps use 3-8MJ/kg to achieve this amount, compared with figures of 1.1-1.4MJ/kg and 0.8-1.4MJ/kg for the BTK and VSBK advanced kilns, respectively (Schilderman and Mason, 2009).

The brick sector is legally considered as a mining activity and generally falls under the law of mining. Most brick makers have official licences for mining, firing and using fuelwood and pay the respective taxes. Mining licences of certain urban brick makers in Khartoum have recently not been renewed due to urbanisation plans of the Physical Planning Authorities.

This section places a special focus on the following issues:

- the scale of current brick making facilities across Sudan;
- the main markets for different sorts of bricks being made in Sudan;
- the fuel consumed by the brick sector, with particular focus on fuelwood;
- possible alternative fuels available in Sudan for brick making; and
- alternative energy efficient brick making methods, suitable for Sudan.

Given the range and quality of data gathered from reports and interviews held in the context of this Section, the accuracy of cited figures should be treated with a little caution. Where possible, figures have been cross checked against different sources, compared with corresponding figures from other countries, and discussed with experts in order to provide best possible qualified estimations.

5.2 THE TRADITIONAL BRICK MAKING PROCESS

Soil for traditional brick making is mined in *wadis* or along riverbanks. Every year during the rainy season, the mining areas flood and fill with a new layer of mud. After clearing and levelling of the mining area – some entrepreneurs use bulldozers for this – mining and mixing crews blend the mud with older clay from lower layers, mixing it with animal dung before it is then soaked with water.

Large-scale brick factories are equipped with heavy duty clay processing and extruding machines. In the traditional system, which is mostly what exists in Sudan, after a period of 12-24 hours, the clay-dung mix is transported to moulding tables where moulders manually shape the bricks. Freshly moulded bricks are then sun-dried on a level drying area and regularly turned in order to avoid cracks and deforming through asymmetrical drying. Because of its high shrinkage rate, riverbank/*wadi* clay is particularly sensitive to fast drying. Only by mixing it with animal dung are cracks avoided.

In arid areas, where no riverbank or *wadi* clay is available, desert clay is mined for brick making. Desert clay is also the raw material favoured by the government since river banks tend to be used for agriculture or urban development. Technically, desert clays have a higher vitrification temperature and therefore require more energy for firing than riverbank clay. Bricks made with desert clay do not need to be mixed with animal dung, shrink less, are less porous and are stronger.

The traditional brick sector is almost entirely based on biomass fuel. Fuelwood is the predominant external fuel for firing the clamps while the dung component serves as an internal fuel. According to one report (Alam, 2006) 51 per cent of Sudan's industrial wood is consumed by the brick sector – 140TOE every year, which corresponds to a 1km^2 area of forest over10 days[20] or a football ground every 100 minutes. These figures are especially high as the wood-fired brick clamps used have a very low efficiency factor. Energy is lost due to the missing thermal insulation and because a considerable portion of the energy embodied in wood is not combusted and is lost as volatile matter with the exhaust gas.

Traditional brick makers fire their bricks almost exclusively with the same clamp technique, which was already used during the Nubian age when the Meroe pyramids and temples were built. Brick clamps are batches of unfired bricks piled in a specific stacking pattern which allows good air circulation and heat distribution during the firing process. A typical Sudanese clamp is about 4-5m wide, 2-3m high and of variable length, depending on the number of bricks to be fired (60,000-110,000). Once the raw bricks are piled up, the outside of the clamp is insulated with a layer of plastered fired bricks which is then removed once the firing process is complete. At the bottom of the clamp, narrow transversal fire tunnels are fed with fuel – wood or animal dung – and allow the passage of fresh air (oxygen) into the clamp.

[20] Dr Ahmed Hood

During four days of firing, fuel is fed into the clamp around the clock in order to maintain the fire at a temperature of between 750-850°C. Once this has happened the clamp is allowed to cool over a period of 6-7 days, during which time the firing crew will build another clamp nearby. This way 5-7 fire masters can operate three clamps simultaneously, producing about 100,000 bricks each week.

Irregular heat distribution within the clamp does not allow for a homogeneous quality across the clamp. As a result, different categories of bricks exist on the market:

- 1st class bricks – usually 75-80 per cent of the total – with a sellable strength, shape and typical ring, costing around SDG125/1,000 bricks;
- 2nd class bricks – usually about 5 per cent per cent which are under fired and have reduced strength, and cost around SDG80/1,000 bricks; and
- broken bricks – around 5 per cent – and over burned bricks – around 2 per cent – which cannot be sold.

The high percentage of animal dung inside the clay makes the bricks extremely porous and light. The high porosity and the relatively low burning temperature achieved considerably limits the compressive strength of traditional bricks (according to BRRI, 3N/mm^2) compared with a brick from South Asia (10-20 N/mm^2).

Most brisk making in Sudan continues in the traditional, labour intense and energy inefficient manner. Resistance to change will stem mainly from a financial perspective for those controlling the brick making sector.

5.3 ENVIRONMENTAL IMPACT

Open brick clamps are known for being the most energy wasting and polluting brick firing method, due to their modest thermal insulation and low combustion efficiency. Additional energy is lost in the atmosphere during the cooling process. Every such clamp wastes the thermal energy embodied in 100 tonnes of nearly 1,000°C of hot clay which newer, permanently fired kiln technologies, recycle to preheat unfired bricks. This re-use of cooling energy in modern brick kilns significantly reduces the overall fuel consumption of the firing process.

Energy consumption is particularly high in zones where low quality wood meets soil with a high sand and low organic content and a high vitrification temperature. In such areas, long intensive firing is required to reach the high temperature (up to nearly 1,000°C) and kiln firing consumes 5-10 times more wood than under Nile bank conditions.[21] With the consumption of more than 100,000 tonnes of fuelwood every year, brick kilns consume 3-10 per cent of the country's forests. The high energy consumption also generates considerable volumes of greenhouse gases (carbon dioxide and black carbon) and a high quantity of suspended particulate matter which is a serious health hazard for brick makers and people living nearby.

5.4 THE ECONOMY OF TRADITIONAL BRICK MAKING

5.4.1 PRODUCTION OUTPUT, SALES PRICE AND TURNOVER

An average brick maker produces 1-3,000,000 bricks per year, during a period or eight months, generating an annual turnover of some SDG2-300,000, approximately US$100,000. Rural brick makers operating smaller units and producing on demand only would have a lower turnover.

Brick production in this manner does not require any hardware investment since there are no permanent structures. The only upfront investment is the yearly rent – approximately SDG10,000 per entrepreneur and the levelling of the land by bulldozer, or by hand in rural areas, plus operational capital for fuel.

Sales prices vary from region to region and by season, depending on availability and demand. Industrially produced high quality bricks – as are used in Europe for example – can be sold for around five times the price of a locally produced brick[22].

5.4.2 PRODUCTION COSTS AND PROFIT MARGIN

The production costs and profit margins in the brick sector vary considerably across the country, according to different business sizes, settings and management capacities of the owners, and changes throughout the course of the year. Comparing detailed production cost figures is therefore not useful if the production setting and targeted market segments are not identical. However, in order to appraise potential economic dynamics which may go along with changes in the fuel supply, it is

[21] Report by Dr. Mohamed Hussein
[22] Price quoted by BRRI

recommended that the ratios between the fuel costs, the profit margin and the rest of the production costs are analysed.

The sale of bricks is based on their quality, however, the average brick price is approximately SDG125/1,000 bricks.

The average profit margin in brick kilns producing for the urban market is estimated at 20 per cent (SDG20/1,000 bricks). Profit margins in rural settings are more difficult to estimate since many operate on demand only, which affects the supply costs as well as the sales price.

Fuel costs in peri-urban areas are between 30-40 per cent higher (SDG30) out of which SDG15 is for fuelwood. In arid zones, where a high percentage of desert clay is fired and energy intensive fuelwood is scarce, the energy need and the related costs are considerably higher.

Remaining production costs – labour, tools, land lease and taxes – are between 60-70 per cent of the total production costs and are considerably lower in remote, arid zones. Of recent interest was the rise in labour costs around the timing of the South Sudan referendum as many men returned to South Sudan to vote or to repatriate.

Compared with the brick sector in other countries, the non-fuel costs are rather high, despite no hardware maintenance costs being incurred. Labour costs are one of the most important cost factors in Sudanese brick making process so it is surprising that brick makers have not yet experimented with mechanising certain work intensive tasks, since reducing labour costs would have the biggest impact on the profit of their business[24]. One reason for this may be the relatively low profit margin, which makes a stable production and permanent brick quality the most critical elements in the traditional brick business. Only small changes on the quality and the resulting sales price might cause the business to decline, at least temporarily.

Table 5.1. The Economics of Brick Making (SDG)

Costs per 1,000 bricks	Clamp Kiln (wood fired)			Hoffmann Kiln			
	Dec-Jan	Feb-July	Average (%)	Fuel Oil fired		Pet Coke fired[23]	
Fuelwood	15	16	26-30	60	10%	15	2%
Cow dung	15	16					
Moulding	50	35	60				
(Un-) Loading - firing	20	20					
Land lease	5	5					
Total production costs	105	90	80-85				
Sales price	125	110	100	600	100%	1,100	100%
Profit margin	20	20	15-20	Phasing brick	Large hollow brick		

[23] Figures from the kiln manager appear rather optimistically low regarding the fuel consumption.
[24] The only brick makers exploring new production method are those directly threatened by urban development projects.

Hoffmann kilns are already in use in Sudan but if broader agreement between these factories and traditional brick making families can be established, brick factories may become valuable partners in the process of industrial change.

5.5 POTENTIAL ALTERNATIVE FUELS FOR BRICK MAKING

Deforestation, caused and accelerated by the traditional brick sector, is without a doubt one of the most urgent environmental concerns regarding the Sudanese building material sector. Finding alternative fuels is therefore one of the key priorities cited in Sudan's environment policies. Beside fuelwood, various alternative energy sources have been tested or are currently being used by other industries, some of which are reviewed below.

Fuel Oil is used by most large-scale brick factories. While the fire is ignited by fuelwood the actual firing process is fuelled with oil stored in tanks and distributed through an internal system of pipes with a mobile firing unit sprinkling the fuel from the top of the kiln.

Fuel oil is locally produced at the El Obeid refinery and exclusively used for power generation. The refinery capacity does not match the demand for fuel oil and imports are necessary to fill the gap, particularly by private sector industries.

Waste engine oil from the many international organisations present in Darfur could provide at least a temporary fuel oil substitute in this region.

Plastic waste such as rubber tyres are reported to be partially used as fuel in a Bull's Trench Kiln. Due to their toxic emissions, however, they are not suitable as an alternative fuel.

Bagasse blocks were first tested in a brick clamp in the late 1980s by FNC/FAO, Practical Action and others using bagasse compressed into blocks by using the same equipment for stabilised soil blocks. In these trials, bagasse was only used as a supplement to fuelwood.

The blocks were initially produced by a refugee co-operative to supply cooking fuel to refugee households in eastern Sudan. Bagasse blocks were mainly produced at the new Halfa Sugar factory until production stopped when the co-operative was dissolved – use of fuel in households was rejected due to the high emission of smoke which had an unpleasant odour. According to one Sudanese energy expert[25], no other agricultural high energy waste is available in sufficient quantity to be considered as a direct fuel for the brick sector.

Liquid petroleum gas has been used for brick firing on an experimental basis only. In co-operation with the Ministry of Petroleum and the gas supply company AMAN, SOBMC conducted several tests on LPG firing in traditional brick kilns in Khartoum. Similar experiences have been made by the University of Kordofan in 2009[26], in Kassala by Practical Action as well as in Nyala. Although the operation tuning has not yet been completed, promising results have been achieved regarding fuel costs. SOBMC reported a fuel consumption of 5g LPG per traditional brick, three times less than a fuelwood brick fired in a clamp. Consequently, LPG may be an economic alternative fuel, even without its current subsidies. However, on a technical level, the firing method and kiln design needs further tuning in order to achieve a comparable breakage rate as with woodfuel fired clamps (15 per cent instead of 25 per cent during the LPG experimentation). The main problems were caused by the gas torches which increased the gas draft, causing uneven distribution of heat. Due to a lack of funding, the tests have now been interrupted but the SOBMC and BRRI are interested in continuing experiments. Since the clamp structure seems to need serious modification to suit LPG firing, alternative brick kiln technologies would also need to be tested with regards their suitability for LPG firing.

Although LPG is currently considered the best alternative to fuelwood in general, there is currently not sufficient domestic LGP available to cover the needs of households and industry if the present growth in consumption continues. As a result, Sudan might resort to importing LPG and heavily subsidise it to make it affordable for average income level households. If LPG was to be used for firing bricks, a political decision would be required, favouring the supply of non-subsidised LPG to the urban brick making sector instead of supplying it highly subsidised to households.

Petroleum coke (Pet Coke) is a residue product from oil refineries which are refining the oil with delayed coking units. It is locally produced at the Al Jaili refinery. The energy price (SDG6/GJ ex refinery) is more than three times lower than that for LPG (SDG21/MJ). Pet coke is therefore a potential alternative to gas firing, at least from an economic and operational point of view, since it is easy to store and to handle.

Currently two Hoffmann Kiln brickyards are firing pet coke with very positive results. The fuel costs are low and no visible or smelly gases are emitted. Pet coke has also been tested in traditional clamps but was discontinued due to excessive emissions of black smoke and low quality bricks. Unlike the Hoffmann Kiln, the brick clamps combust pet coke in an inefficient manner, which results in the emission of potentially toxic gases. Better results may be achieved by firing pet coke in

[25] Dr Ahmed Hood.

[26] Sheikh Eldin Amin Hussein: University of Kordofan. Testing LPG for Brick Clamp Firing in 2009. Report in Arabic available at FNC.

Table 5.2. Overview of Fuel Types

	General fuel data			Brick firing data						
	Calorific value	Fuel price	Energy price	Fuel consumption	Fuel costs		Energy consumption		Soil properties	
Data on fuel mixes										
Fuel type	GJ/t_{fuel}	SDG/t_{fuel}	SDG/GJ	Kg_{fuel}/t_{brick}	SDG/t_{brick}		GJ/t_{brick}		Soil/Vitification temp.	Kiln type
Fuel wood/	17	330	20	50	18	32	0.9	1.4	Blue Nile Clay/ 750-800°C	Clamp
Cow dung	7	218	31	64	14		0.5			
Test: LPG/	46	960	20	5	5	19	0.2	0.7	Blue Nile Clay/750-800°C	Clamp
Cow dung	7	218	31	64	14		0.5			
Single fuel data										
Fuel wood	17	330	20							
Cow dung	7	140	18	No data or no experiences on single fuel firing						
LPG	46	960	21							
Fuel Oil	42	400	10	53*	21		2.17*		Clay mix 875°C	Hoffmann
Pet Coke	34	260	7	11*	3		0.4*		Desert clay 900°C	Hoffmann
Charcoal	28									
Coal	28	Not available		No data/experience on single fuel firing						
Cotton stalk	21									

** Figures stated by the respective kiln managers: for a final comparison, detailed analyses may be required.*

VSBKs which offer the best possible fuel combustion and reduce smoke emissions of, for example, coal by up to 80 per cent.

The Sudanese oil refinery produces 500 tonnes of pet coke per day, an amount which is set to double if the installation of a second coker unit goes ahead. While an important quantity of the pet coke is now exported, two 55MW power plants which have recently been commissioned by the National Energy Corporation may absorb up to 3/4 (750-800t/day) of the future pet coke production. Remaining pet coke of 100-250t/day would be available for industries such as the two Hoffman kilns and in cement plants.

Since the traditional brick sector requires a daily energy equivalent to about 200 tonnes of pet coke, what remains of the national production alone may not cover the brick sector's current energy needs, as long as energy wasting brick clamps are the predominant firing method. By introducing energy efficient low emission kilns, however, pet coke may be a suitable fuel-alternative, especially for the urban brick sector which will likely also have to be modernised for reasons of public health.

[27] Power plants may use a variable fuel blend of 50 per cent oil or LPG and 50 per cent Pet Coke. In this case sufficient energy may be left for the entire brick sector.

6. INSTITUTIONAL, LEGAL AND POLICY ISSUES

6.1 INTRODUCTION

The energy crisis and resultant oil exploration in Sudan during the 1970s prompted the necessity for a proper energy institution and policy. Created in 1978, one of the first tasks of the Ministry of Energy and Mining was to produce an energy policy. The first National Energy Assessment was conducted from 1981-1983 and showed that energy consumption in Sudan was characterised by high dependence – about 80 per cent – on biomass energy, primarily fuelwood, charcoal and agricultural residues. The resulting draft National Energy Plan was, however, never ratified.

A second such Assessment was conducted from 1999-2001, again confirming the dominance of biomass fuels (78 per cent) in the energy balance, 69 per cent of this being fuelwood and charcoal. At the time, the household sector consumed about 60 per cent of the country's total energy consumption and 72 per cent of total biomass energy.

Fuelwood and charcoal are presently transported more than 1,000km to supply major consumption markets in Central Sudan. Poor urban households spend a considerable proportion of their income on woodfuel while rural households spend a great deal of time collecting fuelwood, exposing themselves to security risks at the same time.

Key issues which the energy sector faces and which need to be addressed by policies and practices are:

- inefficient production and use of biomass energy ;
- low public awareness about the efficiency and potency of markets for renewable energy technologies;
- underdeveloped markets for renewable technologies equipment and services because of high initial investment costs and lack of financial capacity to cover this;

- lack of mechanisms to monitor standards and ensure quality control of renewable energy technologies;
- inadequate financing mechanisms and other incentives to facilitate investment, communication, promotion and dissemination of renewable energy technologies; and
- incomplete data on the potential of indigenous renewable energy sources such as geothermal, solar, wind, mini and micro hydro resources.

6.2. SUDAN'S ENERGY POLICY

6.2.1 GENERAL

The 1981 National Energy Assessment represented the first policy endeavour towards understanding and planning the energy sector in Sudan. The resulting National Energy Plan in 1983[28] placed considerable emphasis on the environmental crisis facing the country due to high dependence on biomass energy. The main policy directives from this plan were the need to:

- improve the efficiency of biomass fuels conversion, particularly in the household sector;
- develop alternative fuels, mainly targeting the conversion of biomass residues into convenient fuels for the household sector;
- create new biomass resources such as plantations and maximise the use of available resources, particularly woody biomass resulting from mechanised farm clearing operations[29]; and
- develop and disseminate renewable energy technologies, particularly solar energy.

The second National Energy Assessment[30] was conducted from 1999 to 2001 but no plan was formulated at the end of this period. Oil production and export were adding new dimensions to the energy sector and all efforts were directed towards exploration with the objective of increasing oil production and export. A 2007 National Strategic Plan[31], however, outlined the need to:

- provide an adequate and reliable supply of energy from local resources to support sustainable development;
- conserve the environment through efficient and optimal utilisation 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;

[28] The first National Energy Plan was never officially ratified by the government due to political instability during the 1980s. However, it remained the sole energy policy guiding the government policy.
[29] The Mechanised Farming Corporation allocates vast areas of forest land for clearance and conversion for mechanised farming, mainly for sorghum, sesame and sunflower cultivation. The FNC ensures that charcoal producers are allowed to make use of such forest lands for charcoal production.
[30] The National Energy Assessment is a 10-year programme undertaken by the Ministry of Energy and Mining, with the objective of updating data and information on energy and drawing up future plans. The first energy assessment was conducted in 1981-1983, followed by a second in 1999-2001.
[31] The National Strategic Plan is a five year development plan for Sudan, co-ordinated by the National Strategic Council. The last was formulated in 2007 and covers the period 2007-2011.

- conserve all energy types so as to generate the highest economic value for energy and minimise the cost to the economy;
- develop the energy sector institutions to ensure co-ordination between consumers and producers;
- develop and promote local and/or adapted energy technologies, particularly in the field of renewable energy resources; and
- train qualified and adequate staff at all levels to facilitate the development of the energy sector.

This energy policy placed particular emphasis on energy security through:

- efficient energy supply in an environmentally sustainable manner at realistic but socially acceptable prices;
- de-monopolisation and liberalisation of the energy market;
- fostering competition in the energy market, where possible through privatisation;
- establishment of a regulatory framework; and
- addressing market and institutional failures to promote energy efficiency and renewable energy resources and to protect the environment.

6.2.2 SPECIFIC POLICIES FOR THE HOUSEHOLD SECTOR

A specific objective of the energy policy was to "provide affordable energy services for households and community-based services including water supply and sanitation, health, education, public lighting and communication in order to improve the social welfare of the rural population". The following goals are applicable to the present context:

- to achieve a sustainable level of energy security for low income households so as to reduce poverty at the household level;
- to improve efficiency in the use of biomass resources, recognising that biomass will remain a dominant source of energy, especially in the rural areas, for the foreseeable future;
- specifically target the provision of energy to productive activities such as home-based industries in order to directly raise household incomes; and
- to sensitise women on energy sources and technology choices in order to reduce the labour and health burdens associated with biomass energy use.

The above was to have been achieved through the following strategies:

- household and community energy services were to be a priority in the poverty eradication programme;
- a comprehensive Household Energy Plan was to have been established to address issues related to shortages and inefficient use of biomass and affordability of modern appliances;

- energy services were to be created;
- household energy policies and projects were to be linked more closely to other sectors such as agriculture, forestry, water and sanitation, health, education and industry;
- emphasis was to be given to implementing energy conservation measures in institutional buildings and government departments; and
- incentives were to be created to make electricity and other modern fuels more easily accessible in rural areas.

6.2.3 PETROLEUM SECTOR POLICY

The overall oil sector policy, goals and objective are:

- intensify oil exploration and development processes in all productive areas and any other new potential ones in Sudan;
- develop all existing oil fields to increase domestic crude oil production;
- expand existing oil refinery capacity to satisfy future products demand and planned exports excess from different products to the international market;
- expand pipelines for crude oil and petroleum products to neighbouring countries where there is technical and economic feasibility;
- expand other means for transporting crude and/or petroleum products to satisfy the required development needs;
- expand stock capacities for both crude and petroleum products to satisfy changing conditions expected due to an increase in demand and exports for both crude and petroleum products;
- satisfy the petrochemical industry and enlarge the participation of the private sector; and
- develop local human resources working in the industry.

6.2.4 ELECTRICITY SECTOR POLICY

The 2004 electricity law abolished the monopoly of the power sector by the National Energy Corporation and provided provision for private sector interventions through the following policies:

- electricity generation expansion – both hydro and thermal to satisfy both power and energy demand;
- expansion of the power grid to include all of the country;
- find loans and grants from regional and international institutions;
- attract foreign investors to expand and build new power generation using an independent power producer system;

- encourage local and foreign investors to become involved in power generation, transmission, distribution and services;
- make maximum use from hydropower resources to satisfy future demands for all economic and services sectors; and
- start the development of connections with neighbouring countries such as Egypt and Ethiopia.

6.2.5 RENEWABLE ENERGY SECTOR POLICY AND STRATEGIES

- Exploit the potential of renewable energy resources.
- Promote the provision of an adequate and sustainable supply from appropriate alternative fuels, i.e. switching from biomass.
- Implement action programmes aimed at reducing Sudan's dependence on biomass and other conventional fuels.
- Improve the efficiency of biomass use, in particular traditional stoves.
- Develop and promote energy efficient processes and products using refined fuels to replace biomass.
- Identify and exploit the commercial potential of renewable energy sources for community benefits. Such sources will include wind energy applications for electricity generation and water pumping, as well as solar applications.
- Assess the potential and conduct feasibility studies to develop geothermal and mini-hydro schemes for electricity generation.
- Develop international co-operation to transfer research and technical know-how and track latest technological developments.
- Develop a database of the geographic potential and climatic conditions conducive to renewable energy exploitation.
- Stimulate and co-ordinate international co-operation, particularly with respect to the transfer of technology.
- Offer various training programmes for technicians in the energy sector.
- Conduct and promote research on energy conservation methods.

In 2005, a UNDP/GEF solar photovoltaic barrier removal project sponsored the formulation of a Renewable Energy Master Plan, while in 2008, with the assistance of the Dutch Ministry of Foreign Co-operation the Ministry of Energy and Mining, a Strategic Options Plan was made for renewable energy in North and South Sudan. No action was taken to implement the recommendations from either study.

6.2.6 FOREST POLICY AND LEGISLATION IN THE NORTH

The first phase in the development of northern Sudan's forest policy culminated in the Forest Sector Review (FSR) in 1986, the equivalent of a national forest programme. Often noted as a six-year project, the FSR focused on strengthening central and regional public institutions and introducing incentives to engage the private sector in the conservation of energy and woodfuel. Resource constraints during the 1980s resulted in a prioritisation of activities which involved less capital and yielded maximum benefits in the short-term. Later interventions would concentrate on longer term development.

Using the FSR as a basis for national policy development, the Minister of Agriculture and Natural Resources approved the Statement of Forest Policy (1986). In accordance with this Statement and because of the need to restructure the forestry administration to carry out new responsibilities, the government passed the Forests Act in 1989, the same year it established Linking National Forest Programmes to Poverty Reduction Strategies: Sudan the Forests National Corporation – a service-oriented parastatal body which reports to the Minister of Agriculture and Forestry. This Act provides for private forest ownership, community ownership and forest reserves to be managed by institutions, in addition to national and regional reserves. All forest reserves are under the technical supervision of the FNC.

In 2002, the Forests and Renewable Natural Resources Act replaced the 1989 Forests Act, providing a framework for the management and protection of forests and renewable natural resources, including pastures, rangelands and aspects of agricultural land use. The 2002 Act calls for the creation of the National Forests and Renewable Natural Resources Corporation to manage natural resources other than wildlife and water. However, it has not yet been established. In the interim, the FNC is performing the functions stipulated in the legislation including the management of federal forest reserves. States manage state forest reserves, in accordance with FNC policies and technical plans.

Weak capacity and a lack of resources, among other difficulties, have hindered enforcement of both the 1989 and 2002 acts. Significant changes have, however, taken place since the FSR was developed and recent events are shaping future direction. The FNC, for example, has proposed to draft a new Forestry Policy, amend the Forest Act, update the FSR and review its own functions with a view to adjusting to the changing institutional landscape.

With the above background, the main forestry sector policy objectives are:

- to decrease the abuse of forestry resources using appropriate sustainable practices;
- to plot a national map for land use planning to upgrade natural resources to cover 25 per cent of the country and to be controlled by the technical department in this co-operation;
- continuous observations of forest conditions and human needs;
- protect forests from natural and human danger such as fires;
- to make use of public and traditional knowledge for maintaining, developing and managing the forest sector;

- to upgrade education levels and research in this field to international levels;
- promote sustainable forest management to control and increase forest productivity;
- protect natural resources from deforestation;
- develop a co-operative approach between different sectors;
- encourage local communities and natural resource users to play a lead role in rehabilitation programmes; and
- be fully responsible for international agreements related to environmental protection and natural resources management.

6.2.7 ENVIRONMENT POLICY

Sudan is richly endowed with natural resources such as oil, forests, agricultural lands and fisheries. However, the potential for transforming this natural wealth into broad-based economic development has not been realised. Sudan's history of conflict combined with poor use and management of natural resources has created a range of critical environmental challenges, in terms of:

- land degradation and desertification;
- deforestation;
- water scarcity and pollution; and
- natural disasters and climate change.

Sudan's institutional structure for environmental governance is very weak in light of the environmental challenges outlined above. An Environmental Framework Act (2001) and sector legislation with environmental components exist as well as a federal structure for environmental governance (Ministry of Environment, Forests and Physical Development). There is, however, considerable scope for improvement of legislation and institutional mandates but it is even more important to address the lack of enforcement of existing environmental legislation. While this lack of enforcement is partly linked to a shortage of funds and staff at key institutions it also reflects the low priority given to environmental management.

Matters relating to the exploitation of natural resources had been incorporated in the responsibilities and terms of reference of different central government departments. Each department has been given responsibility for the management of a single resource, i.e. forestry, wildlife, rangelands, water, agriculture and land. The gradual processes of decentralisation and devolution of power seems to had have very little impact on this basic set up as the sector-based legislation, professional practice and traditions continued. With the advent of the Comprehensive Peace Agreement and the Darfur Peace Agreement some new developments were noted where land commissions were formed both at the central level as well as one for each of South Sudan and Darfur.

The general feature of natural resources management in Sudan remains the lack of co-ordination between different ministries and departments. There is a duplication of responsibility between federal and state institutions. To address this, a National Plan for Environmental Management in post-conflict Sudan was prepared in 2007, but little has so far been done to implement the plan.

6.3 KEY INSTITUTIONS AND STAKEHOLDERS

Table 6.1 shows the mandate of the main institutions active within the energy sector. During the past 10 years, the sector has witnessed several changes in terms of the creation or abolishment of new ministries and institutions' affiliation to the different ministries. For example, in 2010, the Ministry of Energy and Mining was split in three – Oil, Mining and Electricity.

Likewise, the FNC, which was for long time under the Ministry of Agriculture and Forests, was also in 2010 affiliated to the Ministry of Environment, Forests and Physical Development. As a consequence of such changes the General Directorate for Energy Affairs, which acts as a co-ordinating body between the different energy sector institutions and stakeholders, lost its power over the other sectors and its main role of planning and policy formulation has witnessed considerable decline.

Table 6.1. Institutional Functions Relating to the Energy Sector in Sudan

FUNCTION	KEY INSTITUTION
Policy and Planning	Ministry of Oil (General Directorate for Energy Affairs) Ministry of Electricity and Dams National Forests Corporation (Ministry of Environment) Ministry of Finance and National Economy National Council for Strategic Plan
Energy Supply	Sudan Petroleum Corporation (Ministry of Oil) Pipeline Companies and Transport (Ministry of Oil) Khartoum Refinery (Ministry of Oil) Petroleum Exploration Companies National Electricity Corporation (Ministry of Electricity and Dams) – now divided into several companies Forest National Corporation Private sector companies and enterprises
Training, Research and Development	Energy Research Institute National Centre for Research – Ministry of Science and Technology Forestry Research Institute – Agricultural Research Corporation – Ministry of Agriculture 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

The table below shows stakeholders in the energy sector are institutionally diverse and affiliated to different ministries – at federal level. At the state level both the FNC and the National Electricity Corporation exist as autonomous departments, however, there is a department within each State Ministry Finance that manages and regulates affairs related to petroleum products.

The institutional diversity of the energy sector necessitated the creation of a national policy and co-ordination body, the General Directorate for Energy Affairs, within the Ministry of Energy and Mining. Its main functions are to:

- transform the state's strategies and policies in the energy sector into detailed studies and plans for orientation of the energy sector and to formulate the general guidelines for the state;
- formulate national and state energy plans;
- set up priorities for energy investment programmes in addition to the assessment, updating and follow-up of their implementation;
- supply decision-makers on all levels in the ministry with information, analysis and various alternatives, to help make sound decisions;
- undertake the preparation of studies concerning the determination of the expected demand on energy from different sources;
- formulate economic feasibility and evaluation studies of commercial and renewable energy sources in the country; and
- establish an effective and integrated system for keeping and maintaining information related to this sector.

The government formulates its energy policies through a participatory process between relevant ministries and stakeholders for each policy field e.g. oil or 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. Further details of some of the main institutions are provided below.

6.3.1 MINISTRY OF PETROLEUM

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

- the Sudan 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 a specific mandate within the wider petroleum sector; and
- 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.

6.3.2 GENERAL DIRECTORATE FOR ENERGY AFFAIRS

The National Energy Administration was established in the Ministry of Energy and Mining in 1980 to set up policies and strategies for the energy sector to collect data on sources, supplies and consumption rates of energy and to develop a national plan for energy use. The NEA's name was later changed to the General Directorate for Energy Affairs (GDEA) and it became affiliated with Sudan Petroleum Company. Recently this ministry was split into three – the Ministry of Petroleum, the Ministry of Electricity and Dams and the Ministry of Mines.

As a consequence of such changes the GDEA, which had acted as a co-ordinating body between the different energy sector institutions and stakeholders, has lost its power over the other sectors and its main role of planning and policy formulation has witnessed considerable decline.

The main functions of the Policies and Energy Planning Department on Energy Policies are as to:

- transform the state's strategies and policies in the energy sector into detailed studies and plans for orientation of the energy sector and formulating general guidelines for the state;
- formulate national and state energy plans;
- set up priority energy investment programmes in addition to the assessment, up-dating and follow-up on their implementation;
- supply decision-makers in the ministry with information, analysis and various alternatives to help decision making;
- undertake the preparation of studies concerning the determination of the expected demand on energy from different sources;
- formulate economic feasibility and evaluation studies of commercial and renewable energy sources; and
- establish an effective and integrated system for keeping and maintaining information related to this sector.

6.3.3 FOREST NATIONAL CORPORATION

Formerly under the administration of the Ministry of Agriculture, the FNC is today affiliated to the Ministry of Environment, Forests and Physical Development. It is empowered to exercise technical supervision over all forests throughout the country and entitled to issue directives or take measures to protect and manage reserved and unreserved forests.

6.3.4 ENERGY RESEARCH INSTITUTE

The ERI, under the Ministry of Science and Technology, undertakes research and development, promotes renewable energy technologies and strengthens – in co-operation with academic institutions – capacity to adapt and use these technologies.

6.3.5 MINISTRY OF FINANCE

Although this ministry oversees the implementation of Sudan's development objectives in terms of sustainable energy supply at affordable cost to all the citizens, it is very keen to keep its mandate within the budgetary limits. To this end the ministry imposes taxes on the different energy sources, both upstream (production) and downstream (consumption). However, the general policy is to increase taxation on fuelwood products in order to discourage urban households from using them. On the other hand, LPG is subsidised (50 per cent) to encourage households to switch to using this product.

6.3.6 CIVIL DEFENCE DEPARTMENT

While it has almost no intervention on biomass fuel production or use, the Civil Defence Department establishes safety measures for the storage, transportation, handling and end use facilities of petroleum products. Different actors in this sector have to get a license from the Civil Defence prior to establishing any petroleum product service facility.

6.3.7 CIVIL SOCIETY ORGANISATIONS

A number of NGOs concerned with environmental conservation, food security and livelihoods have promoted and helped implement LPG use in different parts of the country, namely:

- Practical Action in eastern Sudan – Kassala and Gedaref states and North Darfur;
- Sudanese Environment Conservation Society – Khartoum State;
- Plan Sudan – Kassala State; and
- Sustainable Action Group – IDP camps in North Darfur.

Practical Action's LPG projects in eastern Sudan and North Darfur are intended to facilitate poor household access to clean modern cooking energy. The project's goal is to improve the health conditions of women and children below the age of five by reducing smoke emitted from inefficient biomass fuel stoves. The promotion strategy is based on partnership and project ownership by women associations and adopting microfinance to enable poor households' access to LPG appliances. Close co-operation and collaboration with LPG companies – Nile Petroleum – further enhanced and consolidated project activities and are helping ensure its sustainability.

The Sudanese Environmental Conservation Society (SECS) implemented a small and limited LPG use promotion activity in a rural area of Khartoum State, the Al Gumouya area. Besides raising awareness of the benefits of LPG, SECS introduced a microfinance system in order to enable poor households' access to LPG appliances. This activity was a small component of a larger project which took place in 2000-2001 but no records were found to enable further comments on project success and lessons learned.

Plan Sudan worked on LPG use promotion in the rural parts of Kassala state. LPG cylinders were freely distributed to the households. However, as the women were not directly involved in the project and given the lack of LPG refilling facilities in rural areas, several households ended-up selling the LPG cylinders.

6.3.8 BROAD SECTOR INSTITUTIONAL ISSUES

The broad energy sector issues are as follows:

- inadequate facilities to monitor the sector and carry out appropriate research and development due to understaffing in key areas and budgetary constraints;
- lack of appropriate curricula in energy studies at institutions of higher learning;
- inefficient supply and use of energy resources;
- inadequate co-ordination and information sharing among the various projects, government institutions and the private sector;
- inadequate information on energy supply and demand as well as the country's resource potential; and
- lack of appropriate mechanisms to enable modern and efficient energy services to be accessed by rural populations.

6.4 POLICY IMPLEMENTATION

6.4.1 IMPROVED STOVES

The introduction of improved cook stoves and related conservation measures to the Sudanese household energy sector was pioneered by ERI and FNC, with support from FAO and other donors during the 1980s and 1990s. These included improved charcoal stoves and, to a limited extent, fuelwood burning stoves. Both ERI and FNC trained a number of artisans who produced and distributed the improved stoves for a short period. The overall impact of these initiatives has, however, been quite limited.

The Darfur conflict revived work on FES dissemination in the IDP camps although the focus has only been on improved woodstoves, particularly the mud stove design. Recent evaluation reports on FES programmes revealed major shortcomings in programmatic issues and a lack of sustainability.

6.4.2 CREATION OF NEW COOKING FUEL RESOURCES

By the mid-1980s an intensive programme was launched aimed at producing alternative household cooking fuels from agricultural residues – cotton stalks, peanut shells and bagasse. Conversion approaches of direct briquetting and carbonisation combined with briquetting were tested. The main target was to reduce woodfuel consumption in the high consumption areas in Central Sudan. Several briquetting factories were established in Gazera Scheme, Rahad Scheme, New Halfa Scheme and El Nuhud in northern Kordofan. However, all factories witnessed a complete failure due to uncompetitive product prices with fuelwood and charcoal.

6.4.3 LIQUEFIED PETROLEUM GAS

In 1994 the FNC conducted the National Survey of Forest Products Consumption in northern Sudan. This survey revealed that the household sector consumed about 88 per cent of the woodfuel. Given previous failures with the improved stoves and biomass briquetting projects, the FNC opted for a new strategy based on household fuel switching from woofuel to LPG – the Gabatgaz project. More than 88,000 LPG cylinders were distributed to households in northern Sudan. However, due to inadequate supply and distribution network this project also came to standstill.

On the wake of local production of LPG in 2001 and announced government incentives – a 50 per cent subsidy on LPG refining costs and exemption of LPG appliances from import duty taxes – and learning from FNC experience the private sector tackled LPG distribution, mainly targeting the household sector. Fuel switching to LPG proved to reduce indoor air pollution by 80 per cent, especially particulate matter and carbon monoxide. Poor households, however, still have no access to clean energy due to high upfront cost or initial investment in the gas cylinder and gas burner. This is being aggravated by the recent general increases in the prices of LPG as well as the appliances.

Concerned by the environmental degradation taking place in Sudan the Council of Ministers formed a Technical Committee in 2005 to study possible alternative fuel substitutes for woodfuel used by traditional industries, households and services sectors. The Committee recommended programmes that encourage the substitution of LPG for biomass fuels, particularly for the household sector. However, the Council of Ministers did not react to the recommendations of the study.

The main actors involved in policy-making with regards energy in general and LPG in particular are the Ministry of Petroleum, the FNC and the Ministry of Finance. Other environment-concerned organisations have also played a critical role in influencing government policy towards the adoption of LPG as a substitute for fuelwood.

State level policies have also had an impact on the use and scale-up of LPG use, particularly through fees and taxes. Fuelwood traders in Khartoum and some other states attribute a large part of the rise in fuelwood prices to increased taxes imposed at the state level. This directly affects the economics of household cooking in favour of substituting LPG for woodfuel. Some state governments have taken more drastic measures to reduce the use of woodfuel: Khartoum State, for example, passed an Act in 2002 to stop the use of charcoal and fuelwood in the commercial and services sectors.

The government's policy of subsidising LPG and its appliances is supported by FNC's management of forest resources and taxation in order to curb the demand for woodfuel and enforce the adoption of LPG. In addition, FNC launched its nationwide Gabatgaz project which, despite experiencing drawbacks, encouraged the private sector to invest in LPG distribution and marketing. In addition several NGOs, within their food security and livelihoods interventions, adopted the dissemination of LPG instead of improved stoves, particularly in urban areas.

Notwithstanding the large LPG distribution network developed by the Nile Petroleum Company and other LPG companies, covering most northern states, the penetration of LPG use in others is still very low: at the national level only 6 per cent of households have access to LPG. This is attributed to the high cost of LPG itself and the up-front cost of LPG appliances.

6.4.4 SOLAR ENERGY

While considerable effort has been invested since the late 1970s on the development, adaptation and dissemination of renewable energy technologies, and in particular to address energy supply problems in rural areas, there are no concrete government policies or strategy to harness such energy sources. Supported by a number of donor agencies, ERI implemented a number of projects aiming at testing, adapting and demonstrating solar photovoltaic systems and solar thermal appliances – cookers, water heaters, distillers, dryers and cold stores for agricultural products. At present solar cookers are commercially produced by one national enterprise which includes the solar box as well as solar reflector cookers.

The ERI implemented a rural solar energy development project in northern Kordofan during the 1990s, with support from UNDP and OPEC. Based on the lessons learned from that project, photovoltaic technology is now identified as an ideal energy option for addressing electrical energy problems in rural Sudan. A solar photovoltaic assembly factory was established in Khartoum by ERI while the Ministry of Energy, in co-operation with GEF and UNDP, implemented a barrier removal photovoltaic project (2000-2006) which established a microfinance credit system to enable households in peri-urban and rural areas to have access to photovoltaic systems. In addition a legislative decree was issued by the National Assembly in 2004 according to which solar photovoltaic systems – excluding batteries – are exempt from all customs and other taxes.

6.4.5 BIOGAS

The main government institutions involved in biogas development and dissemination in Sudan are the ERI and the GDEA. The ERI deals mainly with research, development and demonstration while the GDEA handles the promotion and commercialisation aspects of biogas technology. ERI has concentrated its work on the Indian type of biogas digesters, though later worked on the Chinese fixed digester, while GDEA has promoted the Chinese or modified Chinese biogas digester.

Due to the high cost of biogas units and other factors related to social considerations and availability of raw materials, the GDEA concentrated dissemination and promotion campaigns on public institutions like prisons, military camps and schools. The cost of units constructed under GDEA responsibility was mainly shouldered by the Ministry of Energy and Mining. However, some institutions made in-cost contributions, albeit small compared with GDEA contributions.

At present neither ERI nor GDEA have activities on biogas dissemination due to a lack of funding. A private company, Biocon, has recently engaged in the construction of institutional biogas digesters.

6.4.6 OTHER INITIATIVES

Central government and some states, especially Khartoum State, are highly concerned about the environmental damage caused by the traditional brick making industry. Government has opted to encourage the use of cement blocks as an alternative for fired clay bricks. Cement blocks have been widely accepted by the construction industry and their production is flourishing.

7. THE ECONOMICS OF ALTERNATIVE ENERGY IN DARFUR

7.1 BACKGROUND

The majority of households now have to purchase their cooking fuels from markets. As a direct consequence, fuelwood harvesting, the production of charcoal, transport and trade have become attractive employment opportunities and sources of livelihoods for a considerable proportion of the population of Darfur. Woodfuel, in particular, constitutes a major source of income for rural households residing within reasonable distances of main cities and towns.

Darfur consumes about 21 per cent of the national biomass energy consumption (Table 7.1), which is almost proportionate to the population percentage. The use of agricultural residues as a source of household energy is very low, the main crop residue being millet stalks which are mainly used as a building material.

In 2001, the national annual consumption of fuelwood and charcoal by households amounted to approximately eight and two million tonnes, respectively. Urban households use more charcoal compared with rural ones. The national per capita consumption of fuelwood and charcoal are 0.273

Table 7.1. Biomass Energy Consumption in Darfur States (,000 TOE)

State	Woodfuel				Biomass residues	Total Biomass	
	Charcoal (,000 toe)	Fuelwood (,000 toe)	Total (,000 toe)	% of total country consumption		Total (,000 toe)	% from total country consumption
North	47	274	321	5	6	327	4
West	47	306	353	5	3	356	4
South	98	834	932	14	82	1,014	13
Total	192	1,414	1,606	24	91	1,697	21

Source: 2nd National Energy Assessment, 2001.

tonnes and 0.067 tonnes, respectively. Per capita consumption of fuelwood in Darfur is rather high, compared with the national figure, explained by the fact that more than 80 per cent of the population live in rural areas.

Fuelwood is freely collected in rural areas and its supply to urban centres constitutes an important livelihood source for rural dwellers. However, some rural areas in North Darfur, particularly around El Fasher, depend heavily on fuelwood purchase from the market due to an already depleted forest cover. While both South and West Darfur are currently self-sufficient in fuelwood supply the North is reliant on imports from South Darfur.

Insecurity has exacerbated the problem of fuelwood supply in Darfur, particularly in and around IDP camps as humanitarian assistance programmes do not include an energy supply option. As a consequence, areas around the camps are now completely deforested, adding a new dimension to the environmental degradation process already taking place in the region.

7.2 THE WOODFUEL MARKET

7.2.1 COLLECTION AND TRADE

Immediate supply distances for fuelwood are now in the range of 50-70km, with people working individually to either collect wood or make charcoal, delivering them to urban markets by donkey carts. At greater distances, people tend to work in groups who then sell on-site to woodfuel traders, who transport it on trucks and lorries to larger markets, particularly El Fasher, Nyala and El Geneina.

Armed groups control the forests, in addition to multiple checkpoints along the road. Fuelwood collectors can only access forests after paying tax to both of the above (Box 2). Deliveries from South Darfur to North Darfur undergo the same procedures. A lorry has to pay about SDG300 to access a forest area. With time, some sort of relationship is generally established between the different groups and only newcomers to the business face problems if they refuse to pay.

Box 2. IDPS collecting fuelwood as livelihood activity

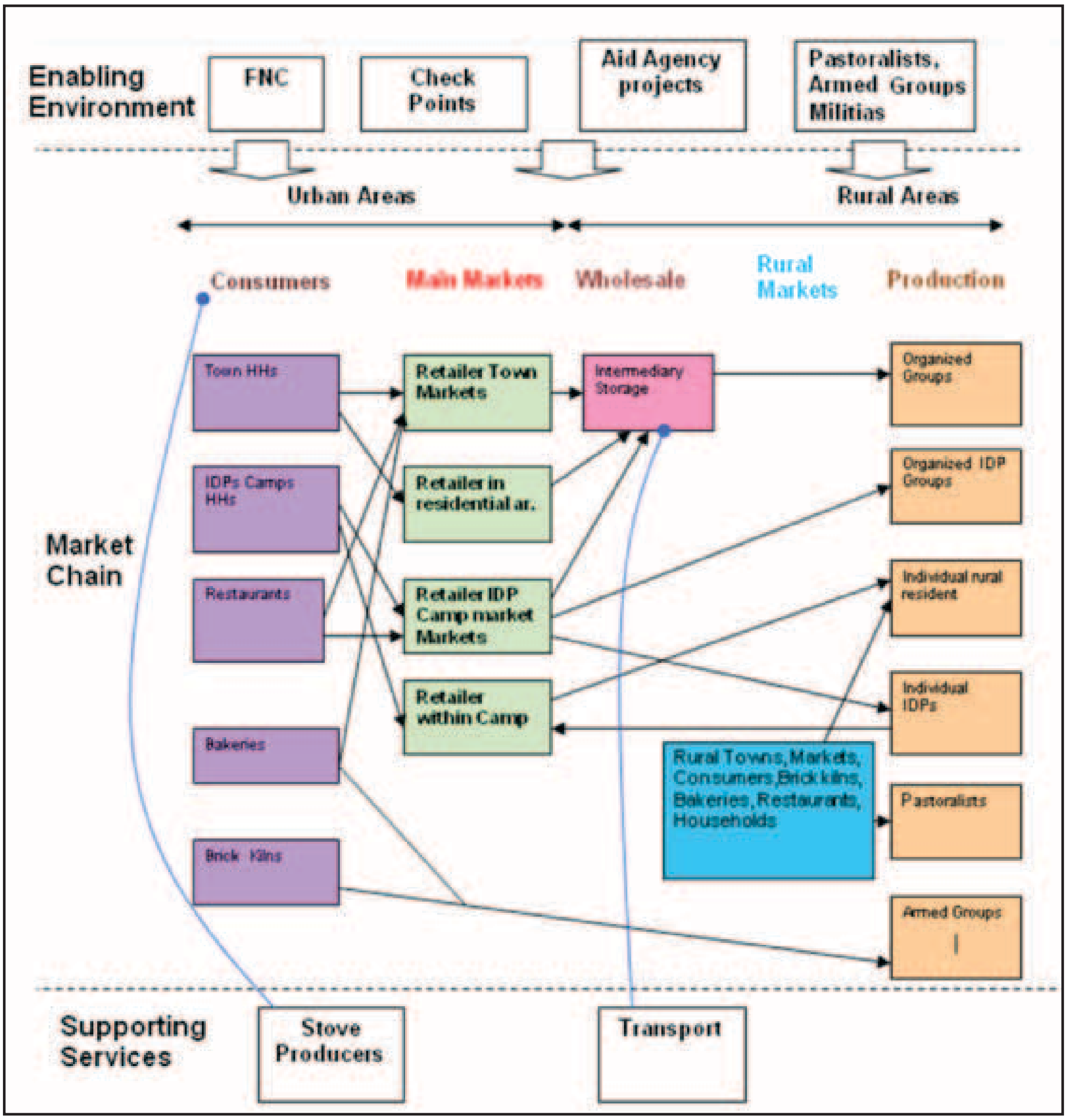
Two horse carts owners interviewed admitted to collecting fuelwood some 70-100km north of El Fasher. The return trip takes 7-8 days. Each cart owner has to take 12 jerry cans of water for himself and the horse, food, sorghum for the horse and some cash for the armed groups and checkpoints.

Depending on the distance and number of armed groups, a fuelwood collector could pay up to six times before reaching El Fasher, where the last government check point is located. Payment to armed groups is a must otherwise there is risk of harassment, loss of the horse or even loss of life in case of resistance. Rates practiced by the armed groups are SDG5 for a donkey cart and SDG10 for a horse cart. A horse cart of wood is sold at Abu Shauk camp market for SDG180.

Figure 7.1 shows the market chain for fuelwood and charcoal in Darfur. The market enabling factors are mainly in terms of insecurity where collectors and transporters are subject to harassment, loss of property or even life in the case of resistance. New players in the business include armed groups, militias and pastoralists who today control areas from where the original inhabitants have been evicted (UNEP, 2008). The role played by the FNC is drastically reduced to the boundaries of capital towns. Large scale traders store fuelwood and charcoal in the peripheral areas of major cities as well as in IDP camps from where fuelwood and charcoal are distributed on animal carts to the main markets.

Similar market structures exist in the rural areas, mainly the headquarters of Localities. The main suppliers are IDPs, rural residents and pastoralists. Some charcoal traders also collect charcoal from the rural markets and transport it to larger markets in El Fasher, Nyala and El Geneina.

Figure 7.1. Fuelwood and Charcoal Market Chain in Darfur



Source: Hood, 2008.

The FNC tax and royalty on woodfuel is shown in Table 7.2. This method of wood stumpage is based on average volumes of trucks commonly used in transporting wood but it allows room for entrepreneurs to overload trucks. On some occasions, a lorry may be unloaded close to town with the offloaded wood being transported or smuggled to markets in small batches.

Table 7.3 presents data on how rural dwellers around El Geneina make a living from selling fuelwood: generated income could result in about SDG204 per month. If an opportunity cost of the person's time (two days) is subtracted from this total, the net profit is convincing to those who practice this activity as a mode of living.

Table 7.2. Taxes and Royalties on Woodfuel Collected by the FNC

Unit	Tax, SDG	Volume/weight
Fuelwood lorry load (Comer)	100	7m^3 (3 tonnes)
Fuelwood lorry load (Thames)	140	14-20m^3 (7 tonnes)
Fuelwood lorry load (Nissan)	280	20m^3 (12 tonnes)
Fuelwood camel load	4	
Fuelwood donkey load	2	25-30kg
Charcoal, sack	10	30-35kg

Source: Alternative fuel study, RI, 2005.

Table 7.3. Returns per Month from Fuelwood Trade

Item	Average/Description
Time spent on collection	1 day
Trips per week	3
Distance from town	25-30km
Time spent on transport	1 day
Means of transport	Donkey load
Selling price	SDG17

Source: Semi-structured Interviews, DAEP Field Survey, 2011.

7.2.2 THE PRICE OF WOODFUEL

Insecurity has had a negative impact on the supply of woodfuel to many cities and towns in Darfur, one consequence of which has been significantly high costs for both fuelwood and charcoal. Tables 7.4 and 7.5 show, respectively, the prices of fuelwood and charcoal in the main towns in Darfur. For example, the price of a sack of charcoal increased from SDG12 in 2002, before the conflict, to SDG37 in 2011, an increase of 208 per cent. The resulting impacts on the livelihoods of poor households have been considerable.

Table 7.4. Cost of Fuelwood in Darfur Markets

Unit	Weight (kg)	Price (SDG)	Price/kg (SDG)
Zalingei			
Large bundle (*Rubta*)	7	2	0.29
Small bundle	3	1	0.33
El Geneina			
Large bundle (*Kulega*)	4	2	0.5
Small bundle	2.25	1	0.44
Nyala			
Large bundle (*Kulega*)	7.5	2	0.27
Small bundle	3.5	2	0.57
El Fasher			
Large bundle	7	2	0.29
Small bundle	3	1	0.33
Average			0.38

Source: Semi-structured Interviews, DAEP Field Survey, 2011.

Table 7.5. Cost of Charcoal in Darfur Markets

Unit	Weight (kg)	Price (SDG)	Price/Kg (SDG)
Zalingei			
Large sack	35	21	0.6
Small sack	7	5	0.71
El Geneina			
Large sack	37	25	0.68
Small sack	7.5	6	0.8
Nyala			
Large sack	38	20	0.53
Small sack	8	5	0.63
El Fasher			
Large sack	35	37	1.1
Small sack	7	7	1.0
Average			0.76

Source: Semi-structured Interviews, DAEP Field Survey, 2011.

7.3 THE LPG MARKET

7.3.1 LPG TRADE

The supply of petroleum products to Darfur is assured by road (North and West Darfur) and rail (South Darfur) transport, the latter being far cheaper. The cost of road transport is on average SDG2 per gallon. This is directly reflected in petroleum products sale prices in the three states (Table 3.6). It is worth noting that state governments impose taxes on petroleum products ranging from SDG0.10 (North Darfur) to SDG0.30 (South Darfur) per gallon. While LPG is exempted from local state tax, El Fasher locality levies tax on LPG.

The introduction of LPG to the region dates back to the 1980s. However, due to its high price relevant to cheap woodfuel few households could afford to use it. At the time there were no refilling depots and cylinders had to be transported from Khartoum and later, during the late 1990s, Nyala. In 2000, the FNC launched its Sudagaz project which provided LPG cylinders on credit to the formal sector. However, FNC lacked the necessary infrastructure, logistics and management to maintain the service. In addition, a quality defect causing major leakage was identified and many cylinders proved to be unusable, remaining idle with their owners. This is the main reason behind the very low annual consumption of LPG in Darfur – less than 0.1 per cent of the national consumption in 2006.

LPG consumption by the household sector in Darfur has, however, witnessed a great increase during the past five years, mainly due to national production and an encouraging government policy. At present, several LPG companies are operational in Darfur with Nile Petroleum dominating the market. The monthly LPG sale in El Fasher was estimated at 37.5 tonne in 2006, about 3,000 cylinders of 12.5kg capacity. If a family consumes on average 12.5kg LPG per month then the LPG penetration rate in El Fasher is around 10 per cent. LPG users in El Fasher are mainly government officials and staff of NGOs and UN organisations.

7.3.2 THE PRICE OF LPG

The cost of petroleum products in Darfur ranges from 2-3 times its equivalent price in Khartoum. This has had a direct impact on petroleum product consumption in the region, amounting to less than 1 per cent of the total national consumption figure. Petroleum products, particularly gasoline and gas oil, are extensively used by the transport sector with some gas oil also being used for pumping water. The high prices of petroleum products generally prohibit their use as an input in productive activities. Table 7.6 shows the prices of a new LPG cylinder and its refilling cost in El Fasher.

Table 7.6. LPG Appliance Refilling Costs Darfur (12.5kg cylinder)

Location	Appliances* price	Refilling price	Duration	Unit Cost	
				SDG/Kg	SDG/Day
Zalingei	200	55	30 – 45	4.4	1.5
El Geneina	180	50	30 – 40	4	1.4
Nyala	200	35	30 – 40	2.8	1.0
El Fasher	210	40	30 - 40	3.2	1.1
Average		45	36	3.6	1.3

* Appliances include a combination of 12.5kg cylinder and gas stove with three burners, the preferred set by households.

7.4 HOUSEHOLD EXPENDITURE ON COOKING FUELS

Households, particularly in urban settings, may often not depend entirely on one source of cooking fuel, the actual choice being influenced by household income levels and socio-economic status. This also reflects that some households have a preference to cook certain foods with certain fuels and/or because some stoves are not adaptable to cooking certain foods.

Although the cooking fuel consumption level might vary from one area to another and between rural, urban and IDP settings, average estimation figures for Darfur have been established based on a combination of cooking fuels, Table 7.7. Calculations exclude the cost of stoves and LPG appliances.

Table 7.7. Household Expenditure on Energy Sources in Darfur

Fuel combination	Daily expenditures		Monthly expenditure (SDG)
	Kg	SDG	
Fuelwood only	10	3.8	114
Fuelwood and charcoal	7.5kg + 1.8kg	4.22	126.6
Charcoal only	3	2.28	68.4
LPG and charcoal	LPG + 1.2kg	2.4	72
LPG only	LPG	1.5	45
Fuelwood and LPG	LPG + 7kg + 1kg	4.96	148.8

Source: Semi-structured Interviews, DAEP Field Survey, 2011

According to these data, the combination of fuelwood and charcoal is the highest monthly expenditure as a source of cooking energy at the household level. LPG is the least expensive cooking fuel, especially in the urban settings.

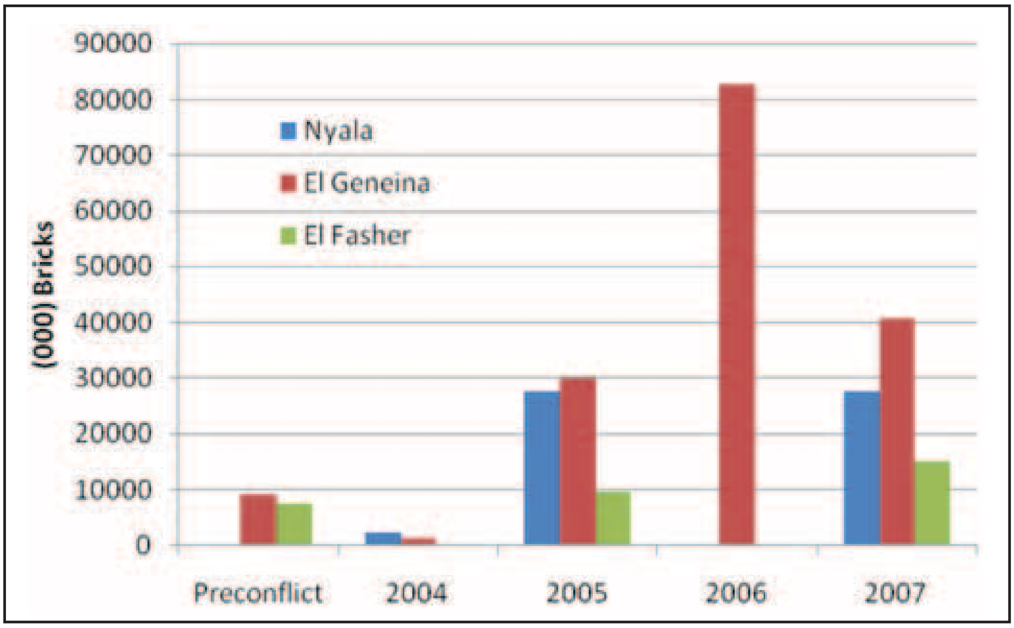
7.5 FUEL COSTS IN TRADITIONAL INDUSTRIES

Darfur boasts only a limited industrial sector, mainly small-scale vegetable oil mills in Nyala, El Fasher, El Geneina and El Lieit. While such mills use fuelwood to generate the necessary heat for processing no data are available on energy consumption rates.

Other industries in Darfur that consume considerable amounts of energy in terms of fuelwood are the brick making industry (see Section 5), bakeries and lime burning kilns.

A major increase in brick making has been observed around the main IDP camps and many urban centres as the construction industry witnessed a major boom (Figure 7.2). A UNEP (2008) report showed that Zalingei had only 10 kilns during the pre-conflict period but that figure had risen to more than 200 by 2008. A similar trend appears to have taken place in El Fasher which formerly had only 90 and now has more than 500 kilns. Thus, the annual consumption of fuelwood for this purpose is likely to be far higher than that reported above.

Figure 7.2. Number of bricks produced and taxed by FNC in Darfur, Pre- and Post-conflict



Source: UNEP - Destitution, Distortion and Deforestation - The Impact of Conflict on the Timber and Woodfuel Trade in Darfur, November 2008.

Table 7.8 provides estimates of the number of clamp kilns based on interviews in the three states. Kils vary considerably in size, starting from two tunnels and increasing to 14 tunnels .

The main kiln operations are loading, stacking, firing and unloading. According to a study on traditional brick making in Sudan (Alam, 2008), the number of workers in any brick making industry largely depends on the number of tables per production unit, the number of workers per table and the number of workers required to fire the kiln. Thus, a range of 4-20 persons could be employed per kiln depending on its size. However, some large kilns could employ more than 20 persons especially in loading and unloading operations.

Table 7.8. Brick Kilns in Surveyed Areas in Darfur

Item	Nyala	El Fasher	El Geneina	Zalingei
Estimated number of kilns	More than 800	More than 500	More than 600	More than 300
Workers per kiln	4-10 (small kiln) 12-20 (large kiln)	4-12 (small kiln) 15-20 (large kiln)	15-70	4-6 (small kiln) 12-20 (large kiln)
Wood consumed per kiln		4-6m^3 (small kiln) 50-90m^3 (large kiln)		6-8m^3 (small kiln) 70-90m^3 (large kiln)

Source: Stakeholder Interviews, DAEP Field Survey, February 2011.

Regarding the consumption of wood for firing the kilns, it is very high, especially for larger kilns. Interviews with kilns owners revealed a strong preference towards the use of green wood which has had and will continue to have a serious impact on the environment.

Table 7.9 shows a detailed production cost analysis, selling prices and net profits per 1,000 bricks for a typical brick making business in Darfur. The net profit from this business is about SDG28 per 1,000 bricks or about 25 per cent of the total production cost. The total labour cost constitutes about 45 per cent of the total production, which is justified by the inherent labour intensive characteristic of traditional brick making in Sudan. Fuelwood costs represents about 12 per cent of the total cost of 1,000 bricks.

The bakery sector is another important consumer of fuelwood in Darfur. Table 7.10 shows estimates of bakeries in Darfur, the number of employees and the wood consumed per bakery. The table shows slight variations between the four sites in terms of number of workers and wood consumed for each bakery, but their approximate total number per town fluctuates depending on the population size and degree of urbanisation.

Table 7.9. Production Cost Analysis for Brick Production in Darfur (per 1,000 bricks)

Item	SDG/1,000 brick	% of total cost
Land rent	11	9.8
Land preparation	0.75	0.7
Tools	0.90	0.8
Water	20	17.9
Animal dung	7	6.2
Fuelwood cost	13.5	12
Brick moulding (labour)	25	22.3
Brick loading	7.28	6.5
Labour cost for firing	2.4	2.1
Preparation for drying	4	3.5
Brick unloading	5	4.5
Supervision cost	1.5	1.3
FNC royalties	10	8.9
Local royalties	1	0.9
Zakat [34]	2.9	2.6
Total production cost	112.23	100
Selling price	140	
Profit per 1,000 bricks	27.77	24.74

[34] Zakat is an Islamic tax levied on assets and business.

Table 7.11 presents a production cost analysis for a bakery. Fuelwood comprises almost 6 per cent of the total cost, which is relatively low compared with the costs of flour and labour, respectively almost 70 per cent and 18 per cent. The net profit from one sack is thus economically justifiable.

These calculations are based on a small bakery, where two sacks per round are usually baked. The profit per round is about SDG109. In a large bakery, the number of sacks baked per round is about 14 sacks yielding, in this case, a profit of about SDG763. Each round lasts for eight hours with many bakeries working two, and sometimes three, rounds per day.

Table 7.10. Bakeries in the Surveyed Areas in Darfur

Item	Nyala	El Fasher	El Geneina	Zalingei
Estimated number. of bakeries	More than 200	More than 60	More than 50	More than 50
Workers per bakery	5-10 workers	5-10 workers	5-10 workers	5-10 workers
Wood consumed per bakery	0.5m³ per day (small bakery) - 1m³ per day (large bakery)			

Source: Stakeholder Interviews, DAEP Field Survey, February 2011.

Table 7.11. Budget Analysis for a Bakery in Darfur

Item	SDG/One Sack of Flour	% of total cost
Purchase price of flour (50kg)	145	69.71
Bakery rent	8.3	3.99
Fuelwood	12	5.77
Water	1	0.48
Labour	38	18.27
Other costs	3.7	1.78
Total production cost	208	100
Bread produced from one sack	1,050	
Total sales (1,050 x SDG0.25)	262.5	
Profit per sack of flour	54.5	26.2

Source: Stakeholder Interviews, DAEP Field Survey, February 2011.

8. KEY RECOMMENDATIONS

The prominent feature of the energy sector in Sudan today is the lack of co-ordination, planning and monitoring between a number of key actors, beginning with those ministries and departments responsible for the management of a specific sector or resource, but also including the NGO community which has been largely responsible for the introduction of fuel-efficient stoves thus far. Missing also from the equation is the consistent presence of the private sector and academic institutions.

What this has resulted in is a large number of failed uptake of alternative technologies and energies, largely accounted by inadequate planning and the end of specific energy-related projects and associated funding. More fundamentally, however, insufficient effort would seem to have been given to first understanding and then addressing cultural and social preferences for domestic energies, which is an essential starting point if one is attempting to introduce supplementary alternative energies intended to diminish the impact on a particular fuel such as fuelwood or charcoal.

The following priority recommendations are proposed on the basis of findings from this review. To address these in more detail it is suggested that a national, or at least Darfur-wide, workshop is convened with all key actors, co-ordinated perhaps by the Energy and Mining Committee of the National Assembly with technical and logistical support of UNEP and representatives from the NGO and civil society communities. The following recommendations are intended for presentation at this workshop with a view to emerging with practical and accepted actions and agreed roles and responsibilities to take these further.

GENERAL

- The energy sector in Darfur is in serious need of support and diversification if further environmental degradation, most notable deforestation, is to be arrested. Urgent and co-ordinated action is required by all key stakeholders, from community representatives to government authorities. As a first step to address this, a dedicated workshop is proposed to review the situation and plan for future actions, with identified interested actors.

- Public awareness needs to be heightened on the negative environmental and health impacts of unsustainable and inefficient use of biomass fuels, particularly amongst women, in order to motivate and encourage households to switch to cleaner cooking fuels. For this to be effective, however, awareness raising must be done in conjunction with actions recommended below.

- While major emphasis seems to be heading towards promoting alternative fuels and technologies, better management of existing natural resources – particularly forests – should not be overlooked. This would have a multiple impact on improved ecosystem management, habitat restoration and the opportunity for sustainably harvesting some such resources in due course, some of which can be used in support of construction and fuel provisioning, both for direct provisioning as well as income generation.

- Key to the broader uptake of alternative energies such as LPG in urban and peri-urban settings is livelihood diversification and income generating activities apart from subsistence agriculture and livestock production. The introduction of environmentally friendly livelihood diversification activities should be developed in parallel in rural communities, given that these will on occasion at least be different.

ALTERNATIVE ENERGIES AND TECHNOLOGIES

- Liquid petroleum gas would appear be the most viable option to substitute for woodfuel in the urban household sector in Darfur. It may also find application in brick and lime kilns and bakeries. In order for this to become a sustainable and viable alternative, however, a strategic review of this sector – from production to delivery and availability – needs to be undertaken, with accompanying updated socio-economic analyses.

- At the household level women shoulder the responsibilities of fuel collection and cooking. Therefore, a gender perspective must be mainstreamed into planning and policy-making related to alternative cooking options and choices in order to ensure that the concerns and needs of both men and women are taken into account. The socio-cultural dimension factors affecting the choice of cooking fuels also has to be carefully studied and considered in the design of cooking stoves.

- Households adopting modern, clean fuels will continue to use woodfuel to satisfy their specific cooking tasks. In such cases, options to increase the efficiency of woodfuel consumption merit careful attention. One alternative that has proved promising in Darfur is improved cooking stoves designed to meet user needs. Attention needs to be given, however, to cultural and social issues linked with stove manufacture, distribution and maintenance.

- End user education on fuel-efficient use techniques and efficient use of alternative fuels and FES is crucial in order to realise the environmental and health objectives of such an intervention. Women should have greater access to information and accompanying support, where needed, to enable them to learn about and decide on the suitability of modern energy services to satisfy or fulfill their cooking needs.

- Central production of FES would help assure the quality of stoves and sustainability of the intervention. This, however, will have implications such as access, cost and how stoves are going to be distributed and resultant programmes monitored.

- Poor households can be expected to face difficulties with accessing modern energy services, including FES. More effort is needed to enable this sector of society access to credit such as microfinance. From experience, this is best realised through partnerships and supported training with women groups and organisations.
- Women groups and organisations have to be trained in literacy, accounting, bookkeeping and management, have their their capacity built and be empowered in order to ensure the sustainability of alternative cooking fuels interventions.
- Improved and consistent research, monitoring and evaluation of ongoing interventions is essential to better understand the dynamics and soicio-cultural cultural aspects of cooking fuel switching in Darfur.
- The hand-out mentality for distributing free stoves to households should end. Households need to demonstrate their interest in and commitment to using alternative technologies and fuels as long as cultural and social issues have been properly addressed.

BRICK MAKING

- Support the planning authorities' brickyard relocation activities in order to find solutions for desert clay firing with alternative fuels which are acceptable for the relocated entrepreneurs as well as for the planning authorities. A win-win situation may be possible.
- Resume research and development on LPG fuel-firing for brick clamps with more active involvement of the Brick Maker's Union and punctual support by selected experts.
- Make the VSBK at the BRRI site operational and experiment with pet coke and LPG fuel firing with desert clays.
- Develop supply options for alternative fuels jointly with brick makers and fuel suppliers.
- Monitor the overall building material sector and new companies manufacturing new products such as ceramics and soil stabilised blocks.
- Develop a promotion programme – policy, technical and financial support – based on findings from the activities listed above.

POLICY STRUCTURES AND IMPLEMENTATION

- Establish a comprehensive household energy plan to address issues related to the shortage and inefficient use of biomass and affordability of modern appliances within the National Energy Plan, now under preparation. This could be part of the CDM Programme of Activities proposed by the FNC.

- Develop and apply policies and projects more closely linked to other sectors such as agriculture, forestry, water and sanitation, health, education, transportation and industry, all of which are closely tied in with energy-related issues.

- Revise the 2002 Act which called for the creation of the National Forests and Renewable Natural Resources Corporation to manage natural resources other than wildlife and water. In line with this a new Forestry Policy, as proposed by the FNC, has to be drafted. States should be more intensively involved through the inclusion of FNC policies and technical plans in their own policies.

- Strengthen policy to encourage broader LPG use using microfinance credit to facilitate access to clean energy by poor households, particularly in urban areas of Darfur.

ECONOMICS

- In terms of alternative energy options, LPG looks to be the most viable option at least in the urban setting. There is potential for widespread use by the household and commercial/services sectors. A reduction of taxes and other policy constraints on LPG and other petroleum products would likely significantly enhance its use instead of woodfuel.

- Based on existing experience form North Darfur, review the possibility of scaling-up and rolling out a closely co-ordinated and monitored microfinance programme to facilitate stakeholders – households and entrepreneurs – greater access to alternative fuels such as LPG and efficient woodfuel burning technologies.

9. SELECTED REFERENCES

Alam, S. A. (2006). Use of biomass fuels in the brick making industries of Sudan: Implications for deforestation and greenhouse gas emission, M.Sc. thesis, University of Helsinki, Finland.

Bromwich, B. 2008. Environmental Degradation and Conflict in Darfur: Implications for Peace and Recovery. Humanitarian Exchange Magazine, Issue 39.

El Deen, Fatah Al Aleem Mohie. 2004. Forestry Sector Review Sudan: Revision of National Forest Policy, Legislation and Institutional Reorganisation Project (TCP/SUD/2903).

FAO. 2010. WISDOM Darfur: Land Cover Mapping and Wood Energy Analysis of Darfur's IDP Regions. Final Report, Land and Water Division.

Hamed, Ibrahim Rahamtalla. 2007. Forest Policy, Legal and Institutional Framework Information Report, FNC, Sudan.

Hamid, Mohamed Hussein. Wood Use in the Brick Making Industry in Sudan. Forest Products Consumption Survey: Topic Specific Study Report No. 04, FNC/FAO, Khartoum, February 1994.

Hood A. H., Ahmed, A. O. and Ausheik, A. A. 2004. Dissemination of Smoke Reduction.

Interventions in Sudan. World Urban Forum Workshop, Barcelona.

Kevane, M. Gray, L. 2008. Darfur: rainfall and conflict, Environmental Research Letters, 3. 10pp.

Leroy, M. 2006. Environment and Conflict in Africa – Reflections on Darfur. University for Peace, Africa Programme Addis Ababa, Ethiopia.

National Council for Strategic Planning. 2007. The Five-Year Plan (2007-2011) – Situation Analysis, Challenges, Key Result Areas and Strategic Objectives, Cross-Cutting Issues, Sector Priorities and Strategies and Plan Implementation, Council of Ministers, Khartoum, Sudan.

Omer, Abdeen Mustafa. 2007. Renewable Energy Resources for Electricity Generation in Sudan, Renewable and Sustainable Energy Reviews Volume 11, Issue 7.

Practical Action Consulting, Eastern Africa. 2009. Study on Alternative Fuels to Promote Improved Natural Resource Management, and Improved Access to Sustainable Fuels in Darfur, Sudan.

Practical Action Sudan. 2006. Reduction of Greenhouse Gas Emissions from Households in Sudan through the Introduction of Improved Mud Stoves and Fuel Switching.

Practical Action Sudan. 2008. Household Energy Survey in El Fasher – North Darfur.

ProAct Network. 2008. Assessing the Effectiveness of Fuel-efficient Stove Programming – A Darfur-wide Review. www.proactnetwork.org.

Robinson, J. 2006. Bio-ethanol as a Household Cooking Fuel: A Mini Pilot Study of the SuperBlu Stove in Peri-urban Malawi. Loughborough University, UK.

Salih, Amira Awad M. 2000. Forestry Outlook Study for Africa – Sudan. Ministry of Agriculture and Forests, FNC/FAO.

Schilderman, T. and Mason, K. 2009. Using Residues as Fuel in Small-scale Brick Making, Proceedings of the 11th International Conference on Non-conventional Materials and Technologies, 6-9 September 2009, Bath, UK.

Suliman, Kabbashi M. 2010. Factors Affecting the Choice of Households' Primary Cooking Fuel in Sudan. University of Khartoum, Department of Economics, Research report presented to the Economic Research Forum, Egypt, Cairo.

UNEP. 2008. Destitution, Distortion and Deforestation – The Impact of Conflict on the Timber and Woodfuel Trade in Darfur.

USAID. 2008. Fuel-efficient Stove Programmes in IDP Settings: Summary Evaluation Report Darfur, Sudan.

USAID. 2010. Biomass Briquetting in Sudan: A Feasibility Study. Women's Refugee Commission.

ANNEX I. PILOT PROJECTS

1. BRICK MAKING

The brick making industry is expanding at a very high rate around the major towns in Darfur. Alternative building materials to replace fired clay bricks and wood used in hut construction reside in the development and promotion of woodless construction and SSB technologies. The endeavours of UN HABITAT, Mercy Corps, CRS and Practical Action to introduce SSB and woodless construction technologies in Darfur have to be consolidated and lessons learned and good practices used for scaling up. The introduction of improved brick firing technologies is too demanding both in terms of technology, alternative fuel and investment. The traditional entrepreneurial nature of brick production is unlikely to accept or adopt any changes in the near future. The adoption of alternative building materials and technologies has a better chance of success as long as the end user prices are below that of fired clay bricks.

This project proposal on improved kiln firing of red clay bricks places emphasis on Khartoum. Work will be carried out on experimenting and training in the use of a vertical shaft kils, presently available at the BRRI brick yard at Soba.

A particular focus on Darfur will concentrate on commercial applications of SSBs through partnership with the private sector, UN agencies and international NGOs.

Intervention Option I (Minimum intervention with fuel focus)

Impact

Sudanese bricks are increasingly fired without the use of fuel wood.

Outcomes

A reliable alternative fuel supply is available for traditional Sudanese brick makers. Solutions for adapting traditional brickyards and firing methods are anchored within the Sudanese brick sector.

Approach

Linking the interest of brick makers, fuel suppliers, service providers and government institutions in order to develop and promote economically viable solutions for firing bricks with alternative fuels.

Timeframe

PHASE 1 (two years): Economically viable solutions for brick firing with alternative fuels are developed and piloted.

PHASE 2 (two years): New technical and entrepreneurial solutions are anchored among the avant-garde of the traditional brick makers, fuel suppliers and equipment manufacturers.

Key actors

- Relevant government and multilateral institutions (e.g. Ministry of Petroleum, FNC, UNEP).
- Brick Makers' Union (selected innovative entrepreneurs).
- BRRI.
- Fuel suppliers (e.g. AMAN, Nile Petroleum).
- Equipment suppliers, such as gas torches.
- SOBMC.
- Banks and carbon traders.

Intervention

PHASE 1

- The first rainy season, joint interest established between the Brick Makers' Union, BRRI, the Ministry of Petroleum, the Ministry of Environment, UNEP and fuel suppliers. A project steering committee is established, which appoints the members of a Technical Working Group, consisting of selected brick makers, fuel suppliers and expert engineers.
- During the first brick season, the working group re-launches the experimentation on brick firing with LPG and petroleum coke in traditional brick clamps, which was interrupted some time ago. Suitable green brick production and firing methods are identified ensuring a high output quality.
- After the first results are achieved, fuel supply options and, if necessary, fuel processing options are identified for scaling up for mass supply and are tested for calculating future fuel prices for brick makers.
- Simultaneously, the "low hanging" energy efficiency measures are tested, e.g. the VSBK at the BRRI site is made operational and test-fired with alternative fuel for comparing the clamps overall fuel consumption with an energy efficient kiln technology.
- During the 2nd rainy season, selected pilot entrepreneurs are identified for applying LPG or Pet Coke firing procedures in their brick yards on a commercial basis. The necessary equipment is installed and the respective entrepreneurs and labour are trained by the Technical Working Group.
- During the second brick season these pilot entrepreneurs fine tune the new workflow and production in order to optimise the profitability of the new production method. Jointly with the equipment suppliers, cost/efficient technical firing devices are developed in order to ensure stable production, while keeping the upfront investment and maintenance costs as low as possible.
- Simultaneously a model business plan is established for brick makers and financing options are identified, to enable traditional entrepreneurs with limited financial capital to invest in the shift to new fuels.
- On the fuel supply side, the fuel distribution company will optimise its supply mode in order to offer a stable fuel supply to a growing number of brick maker customers.

PHASE 2

- The economic and environmental performance of the new fuel and related firing methods is analysed in light of the latest development in the energy and construction sector and environmental priorities.
- Based on the review's findings, a strategy for mass dissemination of the new fuel and firing method is developed, targeting the avant-garde brick makers.
- Support packages may be offered, containing some loan for the upfront investment, as well as trainings and technical support during the first brick season. Some legal or tax advantage may further incite entrepreneurs to shift to the new fuel(s).
- The most promising of the tested energy efficiency measures are further adapted and optimised and pilot-tested on a full scale.
- A potential follow-up phase may be designed to accelerate the brick sector's shift to alternative fuel and energy efficient environmentally friendly brick making methods.

Budget requirements

PHASE 1: US$2-400,000/year.

PHASE 2: US$2-300,000/year, depending on the financial participation of the private sector.

Advantages

Relatively low costs due to the narrow focus on alternative fuel firing only. Since the existing brick making structures remain unchanged the new technology's inhibition threshold for the traditional brick makers will be lower than for a new kiln technology.

Disadvantages

The narrow focus on the fuel issue neglects other burning issues of the brick sector, such as air pollution, health hazards and the destruction of fertile soil or urban zones. Such a focused intervention may contribute to resolving the deforestation issue but it still leaves the entire sector in a still highly unsustainable state.

Opportunities

An increasing number of urban brickyards will have to move off the banks of the Nile. Since the new production sites will require considerable adjustments in the production procedure these brick makers may be particularly open to pilot new fuels and firing methods.

Risks

A focus on fuel only may lead to some quick and visible results, but hinder further improvements of the numerous other problematic aspects of the traditional brick production. Entrepreneurs who have put efforts and means into changing to other fuels may have to wait a long time before investing in energy efficiency or tackling hazardous emissions.

Intervention Option II (Comprehensive intervention on all environmental aspects of brick making)

Impact:

Sudanese brick makers increasingly adopt sustainable production methods

Outcomes

Attractive alternatives are available to wood-fired brick clamps and become anchored within the Sudanese brick sector.

Approach

Linking the interest of brick makers, fuel suppliers, service providers and governmental institutions in order to develop and promote economically viable solutions for energy-efficient and low emitting brick yards, which can be operated off the Nile riverbanks.

Timeframe:

PHASE 1 (two years): Alternative solutions for environment-friendly brick making are tested with a pilot brickyard off the Nile river bank established and test-fired.

PHASE 2 (two years): A pilot brickyard is fine-tuned and its supply and operation optimised for maximising its environmental and economic performance.

PHASE 3 (two years): New technical and entrepreneurial solutions are anchored among the avant-garde of the traditional brick makers, fuel and equipment suppliers.

Key actors:

- Relevant governmental and multilateral institutions (Ministry of Petroleum, FNC and UNEP, for example).
- Brick Makers' Union (selected innovative entrepreneurs).
- Fuel suppliers – AMAN and Nile Oil, for example.
- BRRI and SOBMC.
- International technology suppliers, e.g. from the VSBK expert pool in Nepal.
- Equipment suppliers.
- Banks and carbon traders.

Intervention

PHASE 1

- During the first rainy season, joint interests between the Brick Makers' Union, the Ministry of Petroleum, the Ministry of Environment and UNEP, as well as fuel suppliers, are identified. A project steering committee is established, which appoints the members of a Technical Working Group, consisting of selected brick makers, fuel suppliers and expert-engineers from Sudan and abroad.

- With the first brick season, alternative firing technologies (such as the VSBK at the BRRI site) are made operational and test-fired with alternative fuels (Pet Coke, LPG) to compare the clamps' overall fuel consumption with energy efficient kiln technologies.
- After first results are achieved, the most promising of the tested energy efficiency measures are further adapted and optimised.
- Sustainable model brickyard designs and workflow schemes for the governmental brickyard relocation site are developed and the economic viability simulated.
- During the second rainy season, a pioneer entrepreneur is selected who will later operate the model brickyard on a commercial basis. Material suppliers are identified, the construction design finalised and the fuel and raw material supply contracts agreed.
- By the end of the second brick season, the model brickyard is established, respective entrepreneurs and labour are trained, initial production finalised and the operational mode for stable production documented.

PHASE 2

- During the third brick season the pilot entrepreneur, supported by the Technical Working Group, fine tunes the workflow and supply in order to optimise the profitability of the new brickyards. Jointly with the equipment suppliers, cost-efficiency of the technical solutions are optimised in order to ensure stable production and to keep the upfront investment and maintenance costs as low as possible.
- Simultaneously, a business plan and financing options are identified, to enable brick makers with limited financial capital to invest in the shift to the new production method.
- On the fuel supply side, the fuel distribution company will optimise its supply mode in order to offer stable fuel supply to a growing number of brick maker customers.
- During the fourth brick season, additional kilns are established for a second generation of pilot entrepreneurs, allowing joint R&D for further optimisation of the kiln operation and negotiating better service provision and supply contracts, than for the pioneer entrepreneur.

PHASE 3

- The economic and environmental performance of the new brickyards is analysed in light of the latest developments in the energy and construction sector as well as environmental priorities.
- Based on the review's findings, a strategy for mass dissemination of the brick making methods is developed, targeting brick makers who are relocated off the riverbanks.
- Support packages may be offered, containing some loan for the upfront investment, as well as trainings and technical support during the first brick season. Some legal or tax advantage may further incite entrepreneurs to shift to new fuel(s).
- A potential follow-up phase may be designed to accelerate the brick sector's shift to alternative fuel and energy-efficient environmentally friendly brick making methods.

Budget requirements

PHASES 1 and 2: US$3-400,000/year; PHASE 3: US$2-300,000/year, depending on available synergies with other environmental programmes.

Advantages

This initiative would offer a comprehensive, sustainable alternative to dislocated brick makers, which also address issues such as energy inefficiency, air pollution and related health hazard issues as well as destruction of fertile soil.

Disadvantages

The introduction of sustainable brick making solutions requires a longer commitment from the government, donors and the private sector.

Opportunities

An increasing number of urban brickyards will have to move off the Nile banks to desert clay areas. Traditional brick clamps are even more energy inefficient if they have to fire desert clays. Consequently, environment-friendly brick firing methods may be particularly attractive for relocated brick makers, especially since it is likely that with the new clay and firing methods improvements to the currently very low brick quality may be possible.

With the BRRI, Sudan has a very skilled research unit which can play a key role in finding appropriate sustainable solutions for the traditional brick makers. Furthermore, BRRI has already an energy efficient small scale unit (VSBK) established, which can be made operational for experimentation with relatively short time and limited means.

Risks

The shift from brick clamp production to small-scale industrial production requires a change of the entrepreneur's mindset and a considerable managerial effort. Especially during the pilot phase the support of the entrepreneurs must be well measured in order to keep them active as the project owner, while avoiding frustrations from initial setbacks.

Intervention Option III (Intervention at the overall building material level)

Impact:

Sudanese construction firms and housing clients increasingly use environment-friendly build materials.

Outcomes

The environmental impact of different building materials in Sudan is known and measures are established that favouring the production of the most sustainable sector.

Approach

Enabling and inciting entrepreneurs to produce environment-friendly building material and to increase their market share within the overall building material market.

Timeframe

PHASE 1 (two years): Assessment, environmental impact measuring and identifying and deciding on promotion measures.

PHASE 2 (two years): Establishing capacity building offers and quality control measures.

PHASE3 (two years): Developing and testing financing mechanisms, incentives and policy and marketing measures that promote clean building materials.

PHASE 4 (four years): Application of promotion measures and periodic evaluation and adjustment.

Key actors:

- Relevant governmental and multilateral institutions.
- Alternative building material technology providers.
- Policy experts.
- Vocational training institutions.
- Quality control institutions such as laboratories.
- Building material association – selected innovative entrepreneurs.
- BRRI and SOBMC.
- Banks and carbon traders.

Intervention

PHASE 1

- Assessment of the Sudanese building material market, the manufacturers and the environmental impact of the different building materials, including their application, durability using, for example, SBAM methodology.
- Assess and map key stakeholders and the most relevant markets – urban, peri-urban and rural.
- Establish a group of relevant stakeholders from governmental institutions, the building material sector and the client groups, supported by independent sector experts and establishing a project governing body.
- Identify barriers to environmentally friendly building material production.
- Design measures to promote the most sustainable materials.

PHASE 2

- Identify vocational education and business developing institutes who may host specific training programmes for environmental building material production.
- Develop training and capacity building offers for selected key stakeholders.
- Test and adjust training offers.
- Launch a policy dialogue with relevant governmental institutions to establish quality standards and of an environmental legal framework for existing and alternative building materials.

- Establish quality control mechanisms for clients and building material manufacturers to building trust in new products.

PHASE 3

- Launch an awareness raising programme for building material manufacturers.
- Launch the full scale training programme on alternative products and production methods.
- Develop and test business support packages for entrepreneurs willing to start environmentally friendly building material production.
- Review the initial reception of these measures among key stakeholders and adjust the policy strategy accordingly.
- Based on the review's findings, a strategy for mass dissemination of environment-friendly building products are developed.

PHASE 4

- Review the real achieved improvements regarding the environmental impacts of different building materials before launching governmental support measures.
- Implement policy level support measures, such as tax advantages.
- Launch marketing campaigns.
- Periodic review on the effectiveness of the measures.

Budget requirements

PHASES 1 and 2: US$ 3-400,000/year; PHASES 3 and 4: US$ 2-300,000/year, depending on the active (free of cost) participation of the respective ministries in policy development and promotional measures such as training and quality control.

Advantages

Offers sustainable alternative solutions to the construction sector and housing clients, which also takes into account alternative building materials.

Disadvantages

Past experiences, e.g. with cement blocks, has shown that existing brick makers are not eager to adopt alternative building materials. New products are produced by new entrepreneurs. Consequently new products will have not only have to penetrate the building material market but also have to push out well established traditional brick makers who can be expected to actively defend their business. As experience elsewhere has shown, such market push-outs are very slow and often fail if they are not accompanied by a very strong policy framework.

Opportunities

Industrially produced SSBs – as has been announced in Khartoum – may be an opportunity for a successful penetration in the metropolitan building material market. Medium- to large-scale production units are in a better position to assure quality during the highly sensitive initial phase of market penetration and have the means for active marketing and self-defence against counter-marketing of competitors. Another opportunity is the increasingly popular hollow clay blocks, which can be fired with considerably less energy and substitute traditional bricks without losing the red, popular, brick appearance.

Risks

Building material clients used to be even more conservative than the brick sector itself. Punctual setbacks (e.g. on the quality of SSB, as experienced in the past) would affect the reputation and trust in a new building material and may eliminate years of promotional efforts. Furthermore, the required policy measures are difficult to implement against often massive lobbying through building material manufacturers.

2. STABILISED SOIL BLOCKS

PILOT PROJECT PROPOSAL	
Title	Quality improvement and scale-up of SBB use in Greater Darfur
Goal/Overall Objective	Replacement of fired clay bricks through more widespread use of SSBs in Darfur.
Outputs	1. Improved public awareness of the negative environmental impacts of fired bricks. 2. Entrepreneurs produce SSBs instead of fired clay bricks. 3. SSBs are available in markets at a competitive price with red clay bricks. 4. States' authorities and development programmes are adopting SSBs as the basic building material for the public utilities and development projects. 5. High reduction in wood use by the brick making industry. 6. Reduced greenhouse gas emissions, climate change mitigation and environment conservation.
Critical need/gap/ urgent issue the project addresses/resolves	The conflict in Darfur has prompted high demand for housing which, in turn, has boosted the construction industry. Fired clay bricks are the main building material used for construction, mostly produced by traditional entrepreneurs using inefficient firing techniques. Woodfuel is unsustainably harvested and the brick industry is one of the contributory factors to ongoing environment degradation. UN HABITAT and some NGOs have introduced SSB in Darfur – several schools were built using SSB. However, technology uptake by the private sector did not take place. SSB press machines are not available in the market and those procured by UN HABITAT are mostly kept in stores. Increased local production of cement has led to a decrease in consumer price which should make the production of SSB more feasible and competitive.
Strategy	The scale-up of SSB use in Darfur depends on its recognition by public authorities, donors and development practitioners as the best alternative building material suitable for widespread use in Darfur. Building contractors should be trained and machine presses made available in the market. Besides providing training and capacity building for entrepreneurs, the project will work towards advocacy and influencing different stakeholders towards the adoption of SSBs as the best alternative building material in Darfur. The project will assist the private sector towards availing SSB press machines in the market. In addition technical assistance for skills training will be provided to ensure the production of high quality SSBs.
Implementing Partner(s)	UN HABITAT
Additional Stakeholders	Public authorities, UN agencies, NGOs, bricks producers association and building contractors.
Area	Darfur.
Beneficiaries	Brick makers and building contractors, as well as the population of Darfur.
Duration	5 years.
Budget	Approximately US$3 million.

3. FUEL-EFFICIENT STOVES

PILOT PROJECT PROPOSAL	
Title	Dissemination of fuel-efficient stoves in Darfur.
Goal/Overall Objective	To reduce the consumption of woodfuel use as a cooking fuel in the household sector in Darfur.
Outputs	1. Households are prepared to address the negative health and environmental impact of unsustainable harvest and burning of woodfuel on inefficient stoves. 2. Fuel-efficient stoves are commercially available in markets and are widely and consistently used by households. 3. Reduced household indoor air pollution leading to improved health of women and children. 4. Improved living conditions. 5. Reduced greenhouse gas emissions, climate change mitigation and environment conservation.
Critical need/gap/ urgent issue the project addresses/ resolves	Woodfuel is the dominant cooking fuel in Darfur, both in urban and rural settings. Fuelwood is the preferred fuel in rural areas while urban households prefer to use charcoal. Woodfuel is, however, unsustainably harvested, while charcoal is produced using inefficient traditional techniques (15-20 per cent efficiency) in small-scale earth mound kilns. At the household level, woodfuel is burnt on inefficient stoves (10-15 per cent efficiency). The dissemination of fuel-efficient stoves as part of humanitarian interventions has only focused on IDP camps. The conflict in Darfur has prompted a high degree of urbanisation and additional population concentrations in IDPs camps around major towns. Tree cover has now completely disappeared around these towns and IDP camps and accessing cooking fuel is a major concern. Due to insecurity and scarcity of wood resources women and girls were subjecting themselves to drudgery, security risks, harassment, rape and loss of life. Since the past few years the majority of households in Darfur obtain their cooking fuel needs from the markets. Expenditure on cooking fuel could reach over 30 per cent of household income. In the IDP camps a considerable proportion of households exchange a good share of their food rations for cooking fuel. Technical and programmatic evaluations of the fuel-efficient programmes in Darfur's IDP programmes have shown great shortcomings, particularly in terms of FES quality and non-sustainability. Programmes being implemented under the humanitarian context have greatly neglected the above issues and are additionally characterised by poor co-ordination between both donors and implementing agencies. The main FES design disseminated in the IDP camps is the improved mud stove, a simple design made of locally available cheap materials. Many women have been trained on its manufacture. Today, however, six years after the start of mudstove dissemination IDP camps most households have resorted back to using the 3-stone fire place. This is attributed to the fact that the main international NGOs working on free distribution of FES are no longer present in these camps. There are no FES in the markets nor are trained women willing to produce the mud stove due to socio-cultural factors. With climate change concerns, FES design has received considerable attention during the last decade. New second and third generation stoves involve both high combustion and heat transfer efficiencies. In addition FES programmes are now liable for cleaner development mechanism and carbon credit funding. Within the energy sector the mitigation of climate changes impacts has necessitated the adoption of integrated approaches, namely conservation, the use of alternative energy sources and the creation of new forest resources. A sustained introduction of FES in Darfur will complement both the introduction of LPG as well as work of forest resources management. The high upfront cost of LPG appliances and lack of distribution in the rural areas will handicap rural households from switching to LPG use. Under such circumstance FES remains the sole option for dissemination in the rural areas of Darfur.

Strategy	The first step of this project is to investigate which FES designs are suitable for Darfur. There is no need for the project to re-invent the wheel, but to save time, money and efforts by examining the widely available FES designs. Second and third generation FES designs are to be considered. The dissemination approach for the FES should be commercially oriented in order to avail quality stoves and ensure sustainability. The social outreach component of the project will concentrate on awareness raising, training beneficiaries and facilitate households' access through introduction of microfinance credit. Work in partnership with women groups and CBOs will further enhance the project reaching its target beneficiaries – women.
Implementing Partner(s)	Practical Action, NRC, CDA, SAG, SAFE/WFP, ProAct and many other NGOs with practical experience on FES dissemination in Darfur.
Additional Stakeholders	FNC, WFP and FAO.
Area	Three Darfur States.
Beneficiaries	The population of Darfur is about 7.5 million persons, however, about 4 million persons or about 600,000 are rural households would be the primary beneficiaries of FES. In addition poor urban and IDP households will also directly benefit from FES. Secondary beneficiaries are urban households who opt for fuel stacking due to socio-cultural norms that allow them to continue cooking certain foods with woodfuel.
Duration	5 years.
Budget	US$5 million. FES projects are becoming more liable to clean development mechanisms and carbon credit funding. Under such circumstances the project will finance project initiation and procedural costs until revenues from selling saved CO_2 emissions can take over.

4. SCALE-UP OF LPG USE IN DARFUR

PILOT PROJECT PROPOSAL	
Title	Scale-up of LPG use in Greater Darfur
Goal/ Overall Objective	Improve the livelihoods of poor families and poverty alleviation through switching to a clean cooking energy source, LPG, a move that would have positive consequences for the environment.
Outputs	1. Decreased use of woodfuel use as a source of cooking fuel in Greater Darfur region. 2. increased use of LPG by households in Darfur. 3. Reduced indoor air pollution. 4. Improved health of women and children. 5. Reduced greenhouse gas emissions, climate change mitigation and environment conservation.
Critical need/gap/ urgent issue the project addresses/ resolves	Woodfuel is the dominant cooking fuel in Darfur, both in urban and rural settings. Fuelwood is predominantly used in the rural areas while urban households have a tendency to prefer charcoal over fuelwood. Woodfuel is unsustainably harvested, while charcoal is produced using inefficient traditional techniques (15 to 20 per cent efficiency) in small-scale earth mound kilns. At the household level woodfuel is burnt on inefficient stoves (10 to 15 per cent efficiency). The dissemination of fuel-efficient stoves as part of humanitarian interventions has thus far only covered IDP camps. The conflict in Darfur has prompted a high urbanisation rate and created population concentrations in IDPs camps around the major towns. Tree cover has now completely disappeared around towns and IDP camps. Access to cooking fuel is a major concern in Darfur. Due to insecurity and scarcity of wood resources women and girls subject themselves to drudgery, security risks, harassment, rape and loss of life while collecting fuelwood. In recent years the majority of households in Darfur resource their cooking fuel needs from markets. Expenditure on cooking fuel may reach over 30 per cent of household income. In the IDP camps a considerable proportion of households exchange a good share of their food rations for cooking fuel. Notwithstanding the scarcity of alternative cooking fuels in Darfur, however, LPG, is a modern, clean cooking fuel and is reasonably available in major towns (El Fasher, Nyala and el Geneina). Several LPG companies have established major depots in Nyala and there is currently one in El Fasher. Government policy encourages households to switch to LPG use instead of woodfuel. This is achieved through price subsidy and regulation as well as exemption of LPG appliances from import customs. Still, however, some households in Darfur have difficulties to access LPG due to high upfront cost of LPG appliances and refilling cost of cylinders. The recent government endeavour to control the LPG refilling price through the establishment of major depots and refilling price regulation, will contribute towards enabling households in Darfur to switch to LPG use. However, the high upfront cost of LPG appliances and awareness will remain major factors deterring households in Darfur from switching to LPG use. Lessons learned from good practices by Practical Action have demonstrated that working in partnership with women groups, introducing microfinance and raising awareness, capacity building and training women on LPG use and safety precautions is an effective means to facilitate households' switching to use LPG instead of woodfuel.
Strategy	Based on Practical Actions experience the project will adopt the strategy of partnership with women groups, built their capacity, introduce microfinance and train the women on efficient use of LPG and safety precautions. Project stakeholders (local authorities, Ministry of health, FNC and Civil Defense department and LPG companies) will be approached and consulted at the early stages of the project in order to ensure their support and participation in different stages of project implementation. Besides funding the capacity building, training and awareness raising components, the project will avail seed money for the start up of the microfinance system. The microfinance system will develop into a revolving fund system where households will have access to LPG in batches, based on successful repayment of credit installments.

Implementing Partner(s)	UN HABITAT
Additional Stakeholders	Public authorities, UN agencies, NGOs, brick producers association and building contractors.
Area	Darfur.
Beneficiaries	Brick makers and building contractors, as well as the population of Darfur.
Duration	5 years.
Budget	Approximately US$3 million.

ANNEX II. SWOT ANALYSIS OF ALTERNATIVE COOKING FUELS IN DARFUR

FUEL-EFFICIENT STOVES (MAINLY THE MUDSTOVE)	
Strengths	**Weaknesses**
Locally available and accessible manufacturing materials – clay and animal dung. Easy to manufacture, use and maintain. It uses less wood compared with the 3-stone stove. Reduces women's' movements to collect fuelwood – protection. No fire hazards or burns. Less smoke compared with 3-stone stove. Improves the health of women and children. Saves time and money and mitigate climate change. Traditionally and culturally acceptable. Fast cooking compared with 3-stone stove. Can be self-made and maintained. Close, or very similar, to the traditional 3-stone stove. Strong enough for cooking *Asida*.	Lack of knowledge in rural areas. Fragile and breaks easily. Heavy and difficult to move from one place to another. Sensitive to water/moisture. Cannot handle more than one pot size. Not available in the market. Low household awareness about stove use. Only disseminated in IDP camps. Lack of monitoring and evaluation. Lack of adequate co-ordination between organisations working on FES dissemination. Only suitable for burning wood but could be adapted to burn charcoal. Production difficult during rainy season – long drying time.
Opportunities	**Threats**
Suits socio-cultural cooking habits. Acceptable by the local community. Already familiar to the people in Darfur. Replicable to any community. Income generation activity source for entrepreneurs and/or pottery women. International climate change agenda and availability of funds. Several NGOs and CBOs are still active and continue working on FES (e.g. DRC in Zalengei) while others are planning to resume activities. Some NGOs (Oxfam America) are disseminating other FES designs, e.g. the BDS Funding available (WFP). Other funding sources are possible, e.g. CDM, carbon credits and donors. Encouraged by the government. Ongoing research and development – universities (cement could be used instead of animal dung – University of Nyala) as well as University of Zalengei. Existence of humanitarian actors – dissemination.	Socio-cultural aspects as regards self-manufacturing – women are sensitive or not willing to make the mud stove themselves; pottery is a specialisation of certain ethnic group. Not competitive with advanced technologies e.g. LPG and solar cookers. Health – diseases during production, e.g. meningitis from animal dung. Availability of alternatives.

LIQUIFIED PETROLEUM GAS	
Strengths	**Weaknesses**
Fast cooking (saves time). Easy to use and control the fire while using it. Environmentally friendly - Reduce the consumption of fuelwood and charcoal and consequently reduces pressure on dwindling forest resources. Saves money compared to wood and charcoal. Readily available in the market – private sector companies. There is no waste of energy – high efficiency. Flexibility and multifunctional/multipurpose (lighting, fridge, electricity). Not exhausting like other energy sources during use (instantaneous start up). Once you have the cylinder you just fill it when it is finished. Clean – no smoke No negative heath impacts. You can cook with several pots at a time when owning multi-burners cooker. Cost effectiveness – cheap (cost per useful energy).	Dangerous when it is not properly handled and used. It needs end user education and training to use it correctly and safely. It is a bit expensive compared to other cooking energy sources. There is always tendency of supply hick-ups during rainy season. High upfront cost of LPG appliances – make unaffordable by all HHs, particularly the poor ones. No LPG depot in West Darfur. Refilling cost is too expensive. It can stop in the middle of cooking. Few distribution agencies (refilling shops) in residential areas. Low awareness of households of the use of LPG. Not available in the rural areas - Lack of proper storage – depot and refilling shops - poor distribution network. Availability – irregular supply.
Opportunities	**Threats**
Readily available in the market. Best alternative compared to other sources of cooking energy. Consumer willingness to switch to LPG. Locally produced – in Khartoum – and With the perspective of local oil production in Darfur there are higher chances of price reduction in the future. FNC experience with Gabatgaz gas distributed LPG cylinders in Zalengei. There is one centre for LPG refilling in Zaleng. There is possibility of private sector and NGOs participation in the dissemination of LPG use in the area. Supported by many actors – government, UN, NGOs… Government subsidy. Possible funding – CDM or carbon credits. Microfinance funding. Possible refilling price regulation (case of Nyala).	It is hazardous if not handled and used properly. Irregular supply to Darfur – often scarcity problems. Lack of adequate/regular supply may result in deterring HHs from switching/using LPG . It depends on oil. Storage and transport risks – explosion. Sustainability of supply (access). Risk of explosion. Transportation problems – due to insecurity. Distribution network – coverage. If subsidy stopped.

SOLAR COOKERS	
Strengths	**Weaknesses**
Availability of free renewable energy source – solar radiation. Easy to work with. No negative environmental and health impacts – environment friendly – No greenhouse gas emissions – climate change. No gases emission (smoke, fumes or greenhouse gas emissions). Availability during the day, whenever the sun is shining. No operational/running costs. Zero ignition time as with biomass fuels.	High initial cost. Impractical for food preparation. Time consuming – long cooking time. Inconvenient with meal times in Darfur, particularly in rural areas. Low awareness about it. Limited pilot projects in area or past experience. Solar radiation is intermittent – only available during the day. Solar radiation is variable during the day and seasonally. It is difficult to use solar cookers under certain conditions – cloudy days. Solar cooker needs continuous attendance for orientation – follow the sun movement. Solar energy storage is expensive. Does not match the socio-cultural traditions and cooking habits in Darfur. No access during early morning and night and during rainy season (clouds). Cook exposed to sun radiation – only outdoor cooking. Not durable (cardboard type). Not suitable for cooking *Asida*. Not available in the local markets.
Opportunities	**Threats**
Rich availability of solar energy – long sun shining hours. Availability of many stakeholders. Existence of some lessons within Darfur that might encourage solar energy uses – lighting. The rising international concerns about the environment – possible funding (CDM, carbon credits). Existing experience with Help Age, DRC and DPD NGOs – cardboard cookers. Sun shines most of the year (average > 10 hrs). Can be manufactured locally. Potential available funding. R & D within Darfur - There are several successful experiments undertaken in the area – University of Zalengei.	Lack of sustainability due to high cost. Lack of acceptance by the households in IDP camps. Higher acceptance to other energy alternatives. Reflected solar radiation which is harmful to the eyes. Some types of solar cookers are easy to damage (low acceptance). Some types are not easy to move (not portable).

BIOGAS	
Strengths	**Weaknesses**
Local availability of raw materials (biomass wastes and water). Local availability of construction materials – but cement may be very expensive. By product (slurry) can be used as fertilizer. Culturally acceptable. Environment friendly. Health and hygiene benefits. Easy to manage. Environment friendly – very little greenhouse gas emissions Can be made locally (parts locally available). Availability of local experience in Sudan (ERI) and one private company . Creation of local employment – entrepreneurs for construction of biogas digesters. Cooks faster – time saving. Can be used for other household energy needs – light, heat, fridge, electricity. Biofertilizer – increased agricultural productivity Improves household hygiene – no flies or bad odours.	Upfront cost – high for households. Requires a lot of water. Requires proper training and management. Works best in a closed environment – anaerobic conditions. Biogas cannot be stored. Involve intensive follow up. Hard to transport once installed – fixed. Biochemical reaction dependent on several factors that affects the rate of gas production. At start takes three weeks to produce gas. Very limited zero grazing in Darfur affects the availability of animal dung. Lack of population awareness about potentials of biogas.
Opportunities	**Threats**
Vigorous environmental destruction – need to reduce fuelwood and charcoal consumption. Increasing cost of both fuelwood and charcoal. Government policy for environment protection. Experience in Sudan – ERI. Proven for community cooking – elsewhere. International support – potentials for funding (CDM and carbon credit funding). International experience and support (Project: Biogas for better Life in Africa – Dutch government).	Cultural beliefs/norms. Water availability (summer time). Acceptability issues – culture. Low rate of skills transfer. Raw materials availability around towns – competition with other uses (brick making and pottery). Free grazing of livestock in rural areas. Water – semi dry region, where drinking water is a problem. Green biomass wastes at the household level, if available, is often used to feed animals and chickens.

BIOMASS BRIQUETTES	
Strengths	**Weaknesses**
Local materials are available. Low cost/free. Collection safety and easy. Easy to make. Saves money. Environment friendly. Can replace fuelwood and charcoal.	A lot of smoke when burning. Take time to dry. Limited experience in Darfu. Briquettes need special stove for burning. New product for households.
Opportunities	**Threats**
A mixing machine can be used instead of hand mixing. It is still at pilot stage – subject to improvements. Briquettes are accepted by the communities.	A lot of smoke while burning – may deter households from using it. Drying and storage problems – easily/attractive attacked by termites. Very sensitive to moisture and termites. Hand mixing of ingredients, particularly animal dung, might not be acceptable by households.

BRICK MAKING	
Strengths	**Weaknesses**
Environmentally friendly. Simple technology, but needs training. Needs less time for construction – less building cost. Reduce wood consumption by traditional buildings. Very strong and durable. Fast construction of buildings. Low cost of building compared to red clay bricks. It production demand less water compared to red clay bricks. Raw materials are available locally, however cement is very expensive in Darfur. Building has good aesthetic appearance – no plastering.	SSB production Presses are not available in the market and are expensive. SSB production demands intensive labour training. Trained labour is not available. People are not convinced to use it. SSB is not commercially available in the market as opposed to red bricks. SSB production demands long curing time (21 days). Manual SSB press has very production rate (about 400 bricks per day).
Opportunities	**Threats**
Implemented projects, mainly schools. Relative availability of raw materials (mainly soil). UN-HABITAT, NGOS and others are ready to provide machines and conduct training. Several NGOs are implementing SSB projects (schools) in Darfur. There are several demonstrations in Darfur – schools and government. Buildings. Availability of local materials for cement production (limestone, volcanic ash and clay). The price of cement is presently going down. SSB production represents a good source of income generation. Can be used in recovery and return projects – quality buildings.	New technology – needs further experimentation. Reduce employment in the red bricks production sector. Quality – bad quality SSB might deter people from accepting it. Socio-cultural factors. SSB quality is sensitive to homogenous mixing of binder (5 per cent cement) and curing (humidity and heat). Need trained masons. Red brick makers (entrepreneurs and labour) risk to lose employment and income. Affordability of cement by poor households.

ANNEX III. CURRENT ALTERNATIVE ENERGY ACTIVITIES IN DARFUR BY UN AGENCIES AND NGOS

ALTERNATIVE ENERGY	EL GENEINA	ZALENGEI	NYALA	EL FASHER
Fuel-efficient stoves	No organisation is currently active in dissemination of FES. But several NGOs – HAI and others – are planning such an activity	DRC in Abata, Wadi Salih (mud stove and KCJ)	FNC: mud stove, Kisra Stove and KCJ	SAG: BDS + mud stove with fund from SAFE / WFP
		University of Zalengei (mainly R & D)	University of Nyala: Cement charcoal stove design (R & D)	WADAN: mud stove with fund from SAFE / WFP
		School feeding & Nutrition Department	ARC: mud stoves and cement stoves (charcoal)	KSCS: mud stove with fund from SAFE / WFP
		FNC	WFP: SAFE project extending to Nyala and Greida	Plan Sudan : BDS stove
			UNDP: Kiln for pottery making (livelihoods activity)	DRA: planning to start very soon funding from SAFE/WFP
			FAO: mainly supporting partners: like ARS; GFO (mud stove in rural IDP camps); ZOA (production and institution)	
			NOCD - FES Group in Kass	
Solar Cooker	NONE	Ministry of Agriculture: R&D and testing	ZOA solar energy lighting: HOPO-hospital	DPD in Abushauk and Kutum
		U. of Zalengei: R & D	NONE	Solar PV for water pumping
		DRC: Dissemination		
Liquefied Petroleum Gas	Private Sector	FNC supporting refilling	FNC supporting refilling	Practical Action with WDAN
		Private Sector	Private Sector	Private Sector
			Tearfund	WFP - limited
Waste materials (briquetting)	NONE	Jebel Marra Development Project	NONE	SAFE/WFP - KSCS, WADAN, SAG (briquettes from HH waste, agri. Residues, animal dung)
Biogas	NONE	NONE	World Vision – two pilot units	SAFE/WFP - pilot
Soil stabilised blocks	Tearfund	DRC building schools with SSB	UNHABITAT	Practical Action
	CRS [35]	U of Zalengei – Community Development College works on SSBs	GPO	ERDN
	CDA - Proposal		NOCD	PAI (UNICEF)

[35] CRS did not attend the workshop as it was not operational at the time.

ProAct network | environmental partnerships for community resilience

ProAct Network
Avenue Alfred-Cortot 7D
1260 Nyon
Switzerland

Tel: +41 22 362 5384
Fax: +41 22 362 5385
E-mail: info@proactnetwork.org
Web: www.proactnetwork.org