UN-DESA REPORT

Final Report

Sustainable Energy Consumption in Africa

14th May 2004

Executive Summary

In comparison with other regions such as Latin America, Middle East, Europe, and North America, Africa has one of the lowest per capita consumption rates. Modern energy consumption in Africa is very low and heavily reliant on traditional biomass. Between 1995 and 2001, per capita consumption of modern energy in sub-Saharan Africa remained small and stagnant - falling slightly from an average of 138 kgs of oil equivalent (kgoe) to 126 kgoe – about 13% of the world average of 979 kgoe (IEA, 1998; IEA, 2003; World Bank, 2003a).

Many analysts use the very low levels of modern energy consumption in Africa to argue that energy consumption is, by definition, not a major issue and its environmental impact should not be of significant concern. They argue that African policy makers should be more concerned by the continued "under-consumption" of modern energy - an important indicator of high levels of poverty and under-development.

While there is some evidence supporting the aforementioned assertion, it fails to capture other important characteristics that would support the need for careful assessment of energy consumption in Africa:

- By focusing only on modern energy, one misses the serious negative impacts associated with traditional biomass energy use in Africa which range from indoor air pollution (Muchiri and Gitonga, 2000) to deforestation (World Energy Council, 1999).

- A more nuanced and differentiated assessment of energy consumption in Africa would show that certain regions (e.g. South Africa and North Africa) have experienced rapid growth in energy consumption that is somewhat similar to industrializing countries of Latin America and Asia.

- Even within sub-Saharan Africa, modern energy consumption is relatively high in urban areas due to rapidly growing demand for transport energy and electricity to power industrial and commercial enterprises.

- In the long-term (30-50 years), some African countries could experience the kind of rapid growth in energy consumption that is currently being observed in industrializing countries of Asia and Latin America resulting in significant adverse environmental impacts. In addition, sub-Saharan Africa's under-consumption of energy (leading to serious food security and health problems) should also be an issue of concern.

The key challenge facing Africa is not to increase energy consumption per se, but to ensure access to cleaner energy services, preferably through energy efficiency and renewable energy thus promoting sustainable consumption. Unlike most industrialized countries which progressed from traditional energy to unsustainable conventional energy consumption patterns and which are now struggling to move to a sustainable energy path, Africa could, in a number of sectors, leapfrog directly from current traditional energy consumption patterns to sustainable energy options. Consequently, the careful examination of energy consumption patterns and trends in Africa should be of interest to the sustainable development community.

This paper attempts to provide a differentiated assessment of energy consumption trends in the continent. Due to limited resources and time, the paper only addresses the household, agriculture and transport sectors. Follow-up studies would hopefully address other sectors such as industry and the commercial sector. Chapter 2 examines energy consumption at sub-regional levels (North Africa, Sub-Saharan Africa and South Africa) highlighting differences in consumption patterns thus presenting the case for a differentiated approach to sustainable energy consumption options. Chapter 3 reviews household energy consumption and attempts to draw out common trends through selected country case examples. Chapter 4 addresses energy use in Africa's agricultural sector. Using selected case examples, it assesses the different energy sources and technologies used in irrigation, agro-processing and agro-industrial activities.

Chapter 5 reviews energy use in the transport systems of Africa's urban areas, and associated energy consumption trends. The chapter examines the successful deployment of bus rapid transit systems in Latin America and assesses their potential for replication in African cities. In the final chapter, the paper presents a range of policy options that would assist in the promotion of sustainable energy consumption in Africa.

One of the key issues that arise from findings of the paper is the need for a differentiated approach for sustainable energy consumption in Africa. Selected options should reflect the specific characteristics of each of the three sub-regions factoring in the different consumption patterns, energy types consumed, and prevailing economic conditions. The following is a summary of the options proposed by the paper.

- *Household*
    - Improving data collection on traditional biomass use
    - Efficient energy use in the households
    - Provision of efficient biomass energy technologies
    - Sustainable and controlled tree harvesting for fuelwood or charcoal production
    - Fuel switching

- *Agriculture*
    - Improved data collection on energy use in the agriculture sector
    - Improved use of mechanical and animate energy
    - Efficient energy use
    - Wider dissemination of improved and modern biomass energy technologies
    - Greater use of other renewable energy resources and technologies

- *Transport*
    - Regulatory measures
    - Energy efficiency
    - Infrastructural development
    - Cleaner/alternative fuels and engines

The priority given to each of the above options would differ for each of the sub-regions (North Africa, sub-Saharan Africa and South Africa). This section attempts to categorise the options that would be best suited for the regions and highlighting the options that would be applicable across the continent.

	North Africa	**Sub-Saharan Africa**	**South Africa**
Household	• Efficient energy use at the household level	• Improving data collection on traditional biomass • Efficient energy use at the household level • Provision of efficient biomass energy technologies • Sustainable controlled tree harvesting for fuelwood or charcoal production • Fuel switching	• Efficient energy use at the household level
Agriculture	• Improved data collection on energy use in the agriculture sector • Efficient energy use • Greater use of other renewable energy resources and technologies	• Improved data collection on energy use in the agriculture sector • Improved use of mechanical and animate energy • Efficient energy use • Wider dissemination of improved and modern biomass energy technologies • Greater use of other renewable energy resources and technologies	• Improved data collection on energy use in the agriculture sector • Efficient energy use • Wider dissemination of improved and modern biomass energy technologies • Greater use of other renewable energy resources and technologies
Transport	• Regulatory measures • Energy efficiency • Infrastructural development • Cleaner/alternative fuels and engines	• Regulatory measures • Energy efficiency	• Regulatory measures • Energy efficiency • Infrastructural development • Cleaner/alternative fuels and engines

A rather simplistic way of identifying the most appropriate option for the continent on a whole could be to identify the options that appear to be applicable in all the sub-regions. These are:

- Efficient energy use at the household level
- Improved data collection on energy use in the agriculture sector
- Greater use of other renewable energy resources and technologies (excluding biomass) in the agriculture sector
- Regulatory measures in the transport sector

- Energy efficiency in the transport sector

In terms of institutional and policy measures that would be needed to advance the aforementioned sustainable energy options, the following set of measures could be considered:

- Setting targets, which include identifying and setting goals for the incremental contribution of sustainable energy to total national energy supply. The use of tradable sustainable energy certificates could assist in further promotion of sustainable energy options in Africa.

- Ensuring the level playing field for sustainable energy options and conventional energy forms e.g. eliminating explicit and hidden subsidies to the conventional energy industry.

- Enacting a legal and regulatory framework that facilitates the development of sustainable energy options and provides, among other incentives, access to the grid and transportation fuels market.

- Setting up regional funds for financing large scale sustainable energy investments in Africa – for example, a sustainable energy fund for Africa could be a core component of the energy initiative of the New Partnership for African Development (NEPAD).

A more elaborate set of interventions and policy options will be developed at a forthcoming UN-DESA, UNEP and Government of Morocco Regional Conference on Sustainable Consumption in Africa scheduled to be held in Morocco in May, 2004. It is the hope of the authors that the aforementioned set of options would constitute an adequate starting point for the elaboration of a comprehensive set of policy options that would be able to ensure sustainable energy consumption in Africa in the near-term as well as in the long-term future.

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Abbreviations and Acronyms

AFREPREN	African Energy Policy Research Network
AME	Agency for Energy Management
ApproTEC	Appropriate Technologies for Enterprise Creation
BRT	Bus Rapid Transit
CBO	Community Based Organisation
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CRW	Combustible Renewables and Waste
CSA	Central Statistical Authority
DoE	Department of Energy
DRC	Democratic Republic of Congo
EAAL	Energy Alternatives Africa Limited
EECG	Energy Environment, Computer and Geophysical Applications
EIU	Economist Intelligence Unit
ESES	Egyptian Solar Energy Society
ESMAP	Energy Sector Management Assistance Programme
FAO	Food and Agricultural Organisation of the United Nations
GDP	Gross Domestic Product
GEF	Global Environment Facility
GNP	Gross National Product
GTZ	Gessellschaft fur Technische Zusammernarbeit
IBT	Improved Biomass Technologies
IDE	International Development Enterprise
IEA	International Energy Agency
ISTED	Institut de Sciences et des Techniques de l'Equipement
ITDG	Intermediate Technology Development Group
LDC	Least Developed Countries
LPG	Liquefied Petroleum Gas
NCN	National Council of NGOs
NGO	Non-Governmental Organisation
NMT	Non Motorized Transport
NTL	Norconsult Tanzania Limited
NRZ	National Railways of Zimbabwe
OECD	Organisation for Economic Cooperation and Development
PV	Photovoltaic
SADC	Southern Africa Development Cooperation
SHP	Small Hydro Power
TPES	Total Primary Energy Supply
TV	Television
UBS	Uganda Bureau of Statistics
UNCHS	United Nations Centre for Human Settlements
US	United States
UTGC	Uganda Tea Growing Corporation

List of Units

%	Percent
Btu	
GWh	gigawatt hour
ha	hectare
kgoe	kilogrammes of oil equivalent
kg	kilogrammes
km	kilometres
km^2	square kilometres
kW	kilowatt
kWh	kilowatt hour
lt	litres
m/s	metres per second
Mtoe	Metric tonnes of oil equivalent
Quads	Quadrillion Btu
TOE	tonnes of oil equivalent
US$	United States dollars

1.0 Should Energy Consumption in Africa be an Issue of Concern?

In comparison with other regions such as Latin America, Middle East, Europe, and North America, Africa has one of the lowest per capita consumption rates (table 1.1).

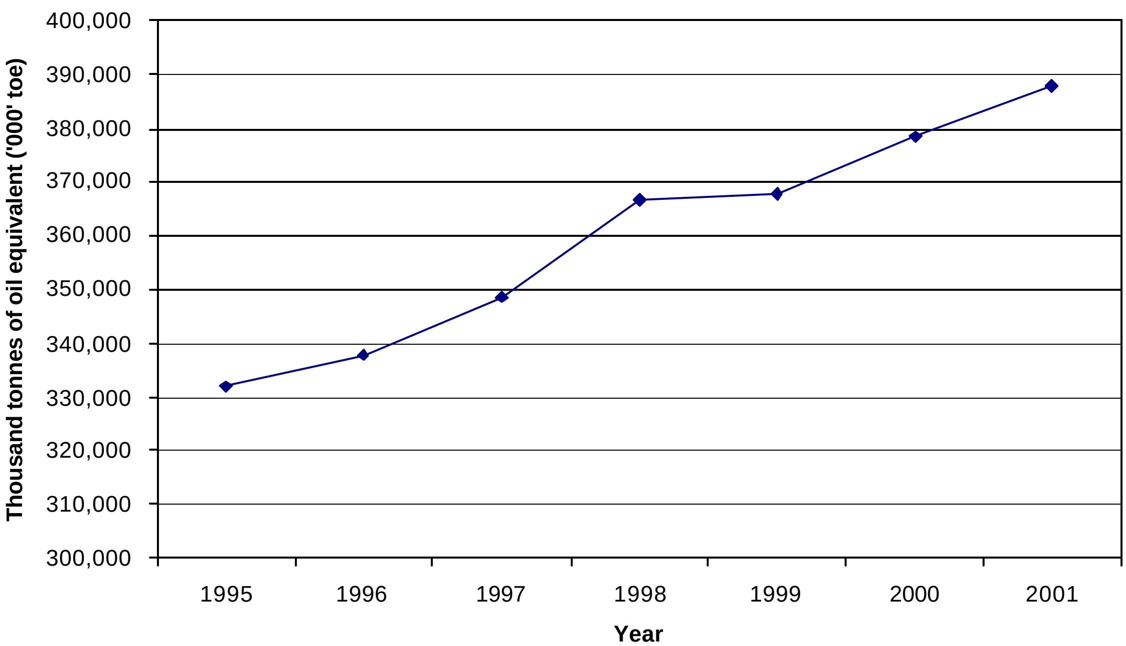
Table 1.1: Energy Consumption Rates in the World, 2001

Country/Region	TFEC*(Mtoe)	Population (Millions)	Per Capita Energy Consumption (kgoe)
Asia**	827.97	2,404.00	344.41
Africa	387.89	814.80	476.06
China***	797.08	1,278.60	623.40
Latin America and Caribbean	354.24	421.90	839.63
Non-OECD Europe	62.96	57.90	1,087.39
World	6,994.61	6,102.60	1,146.17
Middle East	279.23	168.90	1,653.23
Former USSR	628.27	289.10	2,173.19
OECD	3,656.97	1,138.50	3,212.09

*TFEC= Total Final Energy Consumption
**Asia excludes China
*** China includes the People's Republic of China and Hong Kong, China
Sources: World Bank, 2003b, IEA, 2003

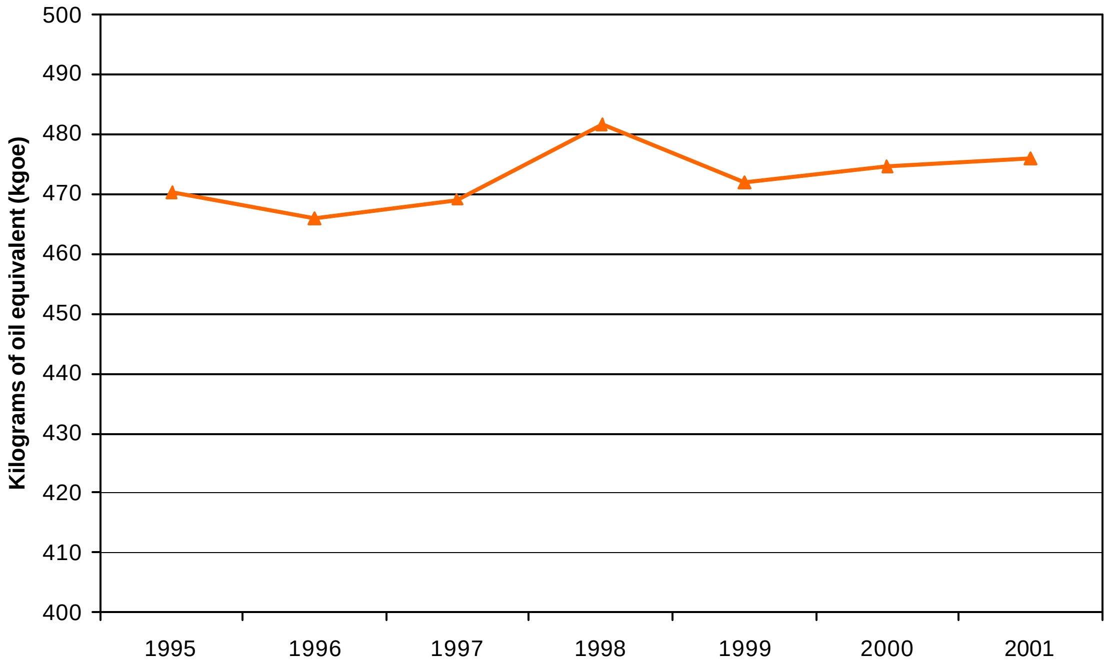
As shown in the next two graphs, total energy consumption in Africa is slowly increasing - starting at close to 330 million TOE in 1995 and rising to just below 390 million TOE in 2001. The trend on per capita basis (available trend data only available from 1994) is more erratic but the overall trend indicates stagnation.

Figure 1.1: Total Final Consumption of Energy in Africa



Source: IEA, 2003

Figure 1.2: Per Capita Energy Consumption in Africa (kgoe)

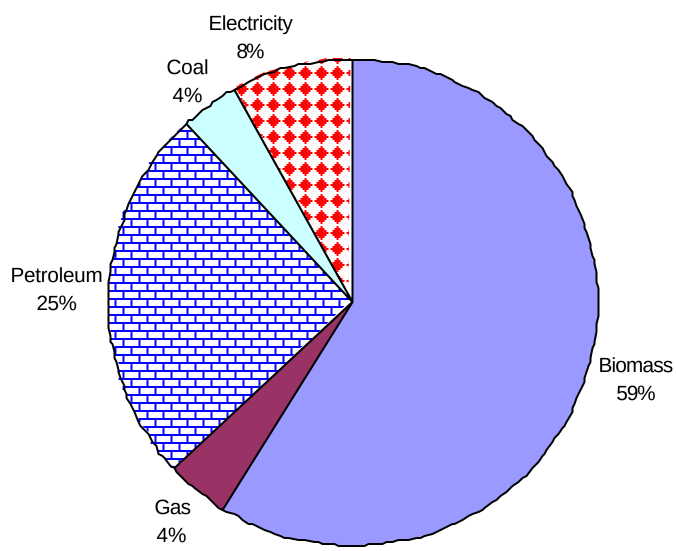


Source: IEA, 2003

The previous two graphs demonstrate the central importance of demographics as the impact of population growth appears to have a significant impact on energy consumption. A number of analysts stress that much of sub-Saharan Africa energy consumption will be largely driven by population growth (especially biomass energy consumption which is mainly used at the household level). The following figure shows energy consumption by type in Africa, illustrating the low levels of modern energy consumption and the heavy reliance on biomass.

Figure 1.3: Energy Consumption by Type in Africa (2001)

Source: IEA, 2003



Between 1995 and 2001, per capita consumption of modern energy in sub-Saharan Africa remained small and stagnant - falling slightly from an average of 138 kgs of oil equivalent (kgoe) to 126 kgoe – about 13% of the world average of 979 kgoe (IEA, 1998; IEA, 2003; World Bank, 2003a).

The low levels of modern energy consumption prevalent in sub-Saharan Africa are even more striking when one considers electricity consumption. Excluding South Africa, per capita consumption of electricity dropped from 122.8 kWh in 1990 to 112.8 kWh in 2000 – one of the lowest rates of electricity use in the world (World Bank, 2001; World Bank, 2003a). As demonstrated in table 1.2, at 22%, sub-Saharan Africa has the lowest electrification level in the world.

Table 1.2: Urban and Rural Electrification Rates (%) by region, 2000

Region	Urban	Rural	Total
North Africa	***99.3***	***79.9***	***90.3***
Sub-Saharan Africa	***51.3***	***7.5***	***22.6***
Total Africa	***63.1***	***16.9***	***34.3***
South Asia	68.2	30.1	40.8
Latin America	98.0	51.5	86.6
East Asia/China	98.5	81.0	86.9
Middle East	98.5	76.6	91.1
Development Countries	85.6	51.1	64.2
World	91.2	56.9	72.8

Source: IEA, 2002

Many analysts use the very low levels of modern energy consumption in Africa to argue that energy consumption is, by definition, not a major issue and its environmental impact should not be of significant concern. They argue that African policy makers should be more concerned by the continued "under-consumption" of modern energy - an important indicator of high levels of poverty and under-development.

While there is some evidence supporting the aforementioned assertion, it fails to capture other important characteristics that would support the need for careful assessment of energy consumption in Africa. Firstly, by focusing only on modern energy, one misses the serious negative impacts associated with traditional biomass energy use in Africa which range from indoor air pollution (Muchiri and Gitonga, 2000) to deforestation (World Energy Council, 1999). As at 1999 on a worldwide basis, 1.9 million deaths annually were blamed on rural indoor pollution while 450,000 deaths annually were attributed to urban indoor air pollution (Sheila, 1999). A significant proportion of the deaths occurred in Africa.

Secondly, as will be demonstrated later, a more nuanced and differentiated assessment of energy consumption in Africa would show that certain regions (e.g. South Africa and North Africa) have experienced rapid growth in energy consumption that is somewhat similar to industrializing countries of Latin America and Asia. Thirdly, even within sub-Saharan Africa, modern energy consumption is relatively high in urban areas due to rapidly growing demand for transport energy and electricity to power industrial and commercial enterprises. Although available data is not fully reliable, there are indications that once traditional biomass is taken account of, sub-Saharan Africa's consumption of energy increases significantly, primarily due to the inefficient way in which biomass is used.

Lastly, it is within the realm of possibilities that in the long-term (30-50 years), some African countries could experience the kind of rapid growth in energy consumption that is currently being observed in industrializing countries of Asia and Latin America resulting in significant adverse environmental impacts. In addition, sub-Saharan Africa's under-consumption of energy (leading to serious food security and health problems (discussed in the next two chapters) should also be an issue of concern.

The key challenge facing Africa is not to increase energy consumption per se, but to ensure access to cleaner energy services, preferably through energy efficiency and renewable energy thus promoting sustainable consumption. Unlike most industrialized countries which progressed from traditional energy to unsustainable conventional energy consumption patterns and which are now struggling to move to a sustainable energy path, Africa could, in a number of sectors, leapfrog directly from current traditional energy consumption patterns to sustainable energy options. Consequently, the careful examination of energy consumption patterns and trends in Africa should be of interest to the sustainable development community.

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2.0 Sub-Regional Consumption of Energy in Africa

Africa's energy sector is best understood as three distinct regions (World Energy Council, 2003) – North Africa, South Africa and sub-Saharan Africa. North Africa, which is heavily reliant on oil and gas, followed by South Africa which depends on coal and the rest of sub-Saharan Africa, largely reliant on traditional biomass (which is termed as combustible renewables and wastes in table 2.1).

Table 2.1: Energy Consumption by Type in Africa (%), 2001

Region/ Country	Combustible Renewables and Waste (CRW) (%)	Petroleum Products (%)	Electricity (%)	Gas (%)	Coal (%)	Crude oil (%)
North Africa	4.06	61.51	15.08	18.01	1.31	0.03
Sub-Saharan Africa	81.18	14.51	2.87	0.99	0.45	0.00
South Africa	16.46	29.28	25.90	1.57	26.79	0.00

Source: Adapted from IEA, 2003; EIU, 2003

Reliance on traditional biomass energy is particularly high in sub-Saharan Africa, accounting in some countries for up to 95% of the total consumption. The very high figure registered for combustible renewable and waste energy consumption for sub-Saharan Africa (tables 2.1 and 2.2) is a reflection of its heavy reliance on biomass energy – primarily used at household level. As at 2001, the share of biomass consumption was 81.18% in sub-Saharan Africa, 16.46% in South Africa and 4.06% in North Africa (IEA, 2003; Ekouevi, 2001).

Table 2.2: Energy Consumption by Type in Africa ('000 toe), 2001

Region/Country	Combustible Renewables and Waste (CRW) (000'toe)	Petroleum Products ('000 toe)	Electricity ('000 toe)	Gas ('000 toe)	Coal ('000 toe)	Crude oil ('000 toe)
North Africa	3,061	46,397	11,378	13,585	990	24
Sub-Saharan Africa	164,268	29,367	5,815	2,010	901	0
South Africa	9,287	16,523	14,616	886	15,115	N/A

Source: Adapted from IEA, 2003; EIU, 2003

Although South Africa accounts for less than 10% of sub-Saharan African's population, its use of electricity is almost three times that of sub-Saharan Africa. North Africa, whose population is less than a third of sub-Saharan Africa, consumes more than one and half times the petroleum products consumed in sub-Saharan Africa (table 2.3). The differences in gas consumption are even more dramatic with the total North African consumption of gas being equivalent to over six times that of sub-Saharan Africa (table 2.2).

Table 2.3: Sub-Regional Physical, Economic and Demographic Indicators in Africa, 2001

Region	North Africa	Sub-Saharan Africa (Excluding South Africa)	South Africa
Land area ('000 km ^{2})	5,738	22,405.0	1,221.0
Total regional population (millions)	140.3	631.3	43.2
Urban population as % of regional population	52.2	33.2	57.6
Rural population as % of regional population	47.8	66.8	42.4
Modern energy consumption per capita (kgoe)	516.0	70.0	1,091.0
GNP per capita (US$)	1,668.0	300.0	2,820.0

Sources: World Bank, 2000a; World Bank, 2001; AFREPREN, 2001; World Bank, 2003a

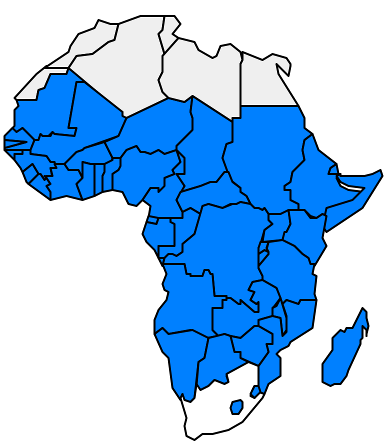


Figure 2.1: Brief Regional Profile: Africa

2.1 North Africa

As mentioned earlier, North Africa can be characterized in energy terms as an oil and gas sub-region with limited consumption of biomass. However, there are sharp differences between the five countries. In 2001, biomass equalled 5.3% of total energy consumed in Morocco and 17.0% in Tunisia (IEA, 2003; World Resources Institute, 2003b). Algeria and Egypt account for the bulk of primary natural gas consumption. In 2002, the two countries accounted for 23.3 and 19.3 Mtoe respectively, which is about 83% of Africa's total natural gas consumption (BP Statistical Review, 2003). **Algeria** is the second largest LPG exporter in the world. According to the Ministry of Energy, the country produced 9.8 million tonnes of LPG in 2003 (Sonelgaz, undated).

Energy consumption in **Egypt** has nearly tripled between 1980 and 2000 - from 0.7 quadrillion Btu (Quads) in 1980 to 2.04 Quads in 2000. Industrial demand accounted for almost half of the nation's total energy demand (46.0%) in 2001. The other half was used in transportation (25.7%), residential use (19.6%) and others (8.7%). With a decline in oil production from maturing fields, Egypt is trying to cope with a surging demand for energy. The Government is trying to discourage domestic consumption of petroleum in order to free up oil for export. One of the options it is encouraging is increased local consumption of gas (IEA, 2003; Office of Fossil Energy, 2003).

Due to major recent discoveries, natural gas is likely to be the primary growth engine of Egypt's energy sector in the foreseeable future (EIA, 2004). As at 2001, natural gas accounted for 15.8% of total energy consumption in Egypt (IEA, 2003; Michalski, 1996). In the late 1980s and early 1990s, the Egyptian Government's decision to partner with private companies and pay the world price for gas from any discovery served to encourage natural gas exploitation.

Natural gas demand has grown rapidly as thermal power plants, which account for about 65% of Egypt's total gas consumption, have switched from oil to natural gas as their primary fuel (EIA, 2004). Large industrial consumers such as petrochemical plants, a large new fertilizer plant in Suez and several major new steel projects in Alexandria, Suez and south of Aswan (Office of Fossil Energy, 2003) have also been switching to gas. Table 2.4 below presents the use of natural gas consumption in various end-use sectors in Egypt. The Government is trying to improve the availability of natural gas for residential customers by allocating service areas to several private companies (Mahmoud, 2001). Domestic natural gas consumers are to be served by several private distributors, franchises for which were awarded in late 1998 (Office of Fossil Energy, 2003).

Table 2.4: Natural Gas Consumption in Egypt by Sector

Sector	1997 (%)	2001 (%)
Industrial	94.2	92.4
Residential	1.6	7.6
Transportation	1.4	0.0
Other	2.8	0.0
Total	***100.0***	**100.0**

Source: Office of Fossil Energy, 2003; IEA, 2003

In 2001, the total amount of electricity consumed was 5,861,000 toe with industry and residential sectors as the key consuming sectors (IEA, 2003). Total electricity consumption in rural areas in Egypt was estimated at nearly 5.9 TWh (5,900 GWh) in 1994, of which about 63% was consumed by the residential and commercial sectors, about 23% by agriculture, and 13% by street lighting.

Given Egypt's almost total lack of forest land, woodfuel and other biomass represent less than 2% of total energy demand. This limited availability of biomass keeps non-commercial consumption low. Egypt's rural areas consume both commercial (kerosene, LPG and electricity) and non-commercial sources of energy (animal and plant residues) (Mahmoud, 2001).

Petroleum products are the main fuels consumed in **Morocco** (Ministere de la Communication, undated). In 1998, national commercial energy consumption was estimated at 9 million TOE. About 90% of the commercial energy consumed was imported (Berdai, 2001). In 2001, Morocco's final energy consumption was more than 8.3 Mtoe, the bulk of which was consumed by the industrial, residential and transport sectors, respectively (IEA, 2003).

Between 1971 and 2001, **Tunisia's** total energy consumption grew at an average rate of 16% (from 2.93 Mtoe in 1985 to 6.20 Mtoe in 2001). In 1997, Tunisia's Agency for Energy Management (AME) estimated that total energy consumption in Tunisia would increase from 4.3 Mtoe in 1996 to 14.2 Mtoe in 2020. As at 1996, the industrial sector was the largest energy consumer in Tunisia. However, as a result of improved living standards, the development of the service sector, and the more generalised use of heating, lighting, water heating and air-conditioning, the combined share of the service and residential sectors increased by 15.6% between 1985 and 1996 (table 2.5) while that of the industrial sector declined by 13.5% during the same period (IEA, 2003; GEF, 1998). The main source of increased energy demand was due to increased activities in the building sector. To achieve energy savings, the Tunisian Government adopted some regulatory measures such as introducing energy efficient building standards (GEF, 1998).

At the beginning of 1980, Tunisia initiated a National Energy Conservation Plan with an objective of limiting increasing energy demand, promoting the use of natural gas, and developing renewable energy. The Tunisian Agency for Energy Management was created to develop and implement the measures that would achieve the objectives of this plan (GEF, 1998).

Table 2.5: Evolution of Energy Consumption by Sector in Tunisia (1985-2020)

Share by Sector	1985 (%)	1990 (%)	1995 (%)	1996 (%)	2000 (%)	2010* (%)	2020* (%)
Industry	40.6	40.9	24.3	35.1	25.9	29.5	28.1
Transport	32.3	30.2	26.6	31.8	26.7	32.8	31.8
Residential/Tertiary	21.1	22.3	42.9	25.4	41.2	32.0	35.6
Agriculture	6.0	6.6	6.2	7.7	6.2	5.7	4.5

* estimated using an average of 5% per annum progression in energy demand between 1996 and 2020
Source: GEF, 1998; IEA, 1995; IEA, 2003

The aforementioned discussion of key features of the energy sector of selected North African countries confirms the importance of oil and gas to the sub-region. In the past, high consumption of energy in industries implied that sustainable energy consumption initiatives should primarily target the industrial sector. More recent growth in energy consumption in the transport and residential/tertiary sectors would imply that broader sustainable energy consumption initiatives that cover a wider range of sectors would be more appropriate.

2.2 Sub-Saharan Africa

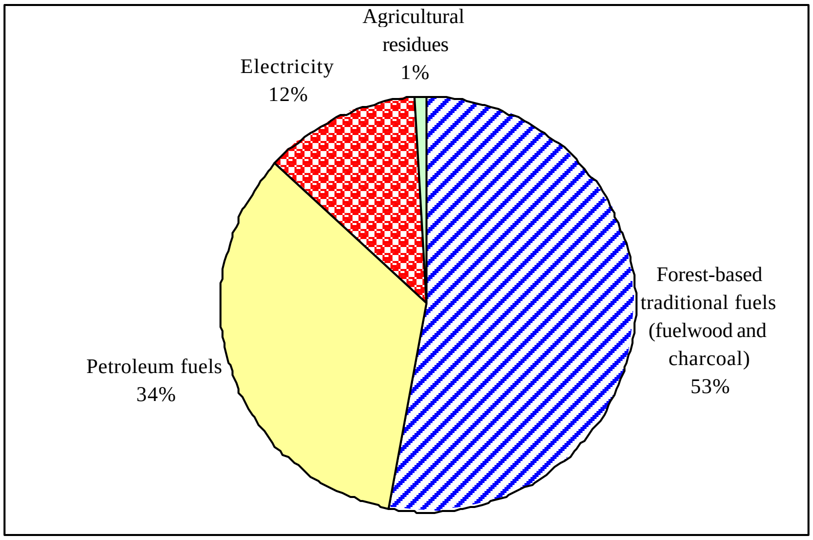
Biomass dominates energy consumption in Sub-Saharan Africa even in relatively well off countries such as Botswana and prominent oil producers such as Nigeria. **Botswana's** energy sector is characterised by both traditional and commercial energy sources, with fuelwood being the principal energy source. The key consuming sectors are residential, transport, industry and commercial, respectively (Mathangwane *et al*, 2001).

In 1994, **Nigeria** was the highest consumer for fuelwood in the West African sub-region. Fuelwood has become scarce and expensive over the years increasing the distance walked to collect fuelwood. Rapid population growth has led to forest land being converted to agricultural land to provide food and export crops. Rubber, coffee, cocoa and palm oil plantations have replaced natural forests. The increasing demand for fuelwood has caused its price to rise relatively more than the price of other fuels in the country (Akarakiri, 2002). Sources of energy for rural use in Nigeria include woodfuel, oil, gas, and coal. Petrol is used for transportation while kerosene is used for lighting and cooking. Gas is mainly used for electricity generation and fuelling electric power stations. As at 2002, gas had no significant impact on the development of the rural areas. The percent of coal consumption in the energy mix in the country was less than 0.5% (Akarakiri, 2002).

Biomass (firewood, charcoal and agricultural waste) is the predominant energy source in **Kenya** and it contributes about 78% of Kenya's final energy demand. Next in significance is petroleum which accounts for about 19% of final energy demand. Kenya's manufacturing and commercial sectors depend on petroleum while most rural households, services and small businesses depend on biomass energy (EAAL, 2003; IEA, 2003).

The major energy sources consumed in **Tanzania** (in percent) are biomass fuels (91.6%), petroleum products (6.8%) and electricity and coal (1.6%) (IEA, 2003; Kaale, 1999). In 2001, **Senegal's** final energy consumption was estimated at 2.4 million TOE - equivalent to a per capita consumption of 246 kgoe (IEA, 2003; World Bank, 2003a). The following figure presents the share of the different types of energy sources in Senegal.

Figure 2.2: Percentage Share of Energy Sources in Senegal



Source: Sokona, 2000

Biomass is the dominant source of energy in **Ghana** accounting for 65% of the total energy consumed in 2001 (IEA, 2003). Biomass energy sources in Ghana include woodfuel (firewood and charcoal), wood residues, crop residues and human/animal waste. Woodfuel is mainly used in the household sector for cooking and heat applications (Edjekumhene and Brew-Hammond, 2001).

The sub-Saharan Africa country examples discussed in the previous sections underline the importance of biomass and the household sector which largely relies on biofuels. Consequently, biomass and the household sector should be important foci for sustainable energy consumption initiatives in sub-Saharan Africa.

2.3 South Africa

South Africa's energy sector is characterised by high consumption of coal. In 1998, coal accounted for about 76% of total energy consumption (DME, 2000; IEA, 2003; World Resources Institute, 2003a). The figure dropped slightly to 69% in 1999 (see table 2.6).

Table 2.6: Energy Consumption by Source in South Africa (1999)

Energy Source	'000 mtoe	Percentage
Hydroelectric	62	0.05
Natural gas	1,518	1.30
Nuclear	3,345	2.87
Primary solid biomass (includes fuelwood)	12,466	10.70
Crude oil and natural gas liquids	17,636	15.13
Coal and coal products	81,524	69.95
Total	***116,551***	***100.00***

Source: World Resources Institute, 2003a

An increase in ownership and use of private motor vehicles and minibus taxis, and the use of heavy diesel powered road transport has resulted in the growth in consumption of liquid fuels and a decrease in coal consumption (DME, 2000). In 1996, industry (including the mining sector) was the largest energy consumers accounting for almost half of South Africa's total energy consumption. This, as shown in the following table, has not changed over the years.

Table 2.7: Energy Consumption by Sector in South Africa (1999)

Sector	'000 mtoe	Percentage
Non-energy uses	939	1.69
Agriculture	1,721	3.09
Commercial and public services	2,055	3.69
Residential	11,645	20.91
Transportation	13,578	24.38
Industry	25,748	46.24
Total	***55,686***	***100.00***

Source: World Resources Institute, 2003a

Coal and electricity provide about three quarters of total energy consumed by the industrial sector (DME, 2000; UN, 2004). Comparison of sectoral energy consumption in South Africa between 1992 and 2000 shows transport and industry energy use rising by 27% and 22%, respectively; mining and quarrying, agriculture, and commerce and public service shares falling by 15%, 18% and 25%, respectively; and, residential energy consumption remaining almost constant (DME, 2003).

Although in the past, coal and electricity use in industry were perceived as the principal targets for sustainable energy consumption initiatives, the rapid growing consumption of energy in the transport sector justifies a re-evaluation of this strategic focus. As with North Africa, it would probably be more appropriate to recommend that South Africa promotes broadly defined sustainable energy consumption initiatives that address a wider range of end-use sectors.

The next chapter examines household energy consumption in Africa using a differentiated sub-regional (North Africa, sub-Saharan Africa and South Africa) approach. Selected country case examples are used to illustrate important energy consumption trends.

3.0 Household Energy Consumption in Africa

Households require energy primarily for cooking, lighting and space conditioning[1]. In Africa, cooking often accounts for between 90 and 100% of household energy consumption because of limited space conditioning loads. Household energy consumption levels and the types of energy used depend on a variety of factors, which include the availability and costs of energy sources (World Energy Council, 1999; Karekezi and Kithyoma, 2002). Table 3.1 shows that as incomes increase, the use of modern energy becomes more prevalent in rural households. For instance, while low-income rural households rely mainly on biomass fuels for cooking, high-income households use modern fuels such as kerosene, LPG and electricity (Karekezi and Kithyoma, 2002). Among the poor, biomass resources are used in unsustainable and inefficient ways due to lack of access to information, financial resources and technology (Kammen *et al*, 2001).

Table 3.1: Rural Energy Use Patterns in African Countries by End Uses

End Use	Rural Household Income		
	Low	**Medium**	**High**
Cooking	Wood, residues, dung	Wood, residues, dung, kerosene, biogas and LPG	Wood, kerosene, biogas, LPG, coal and electricity
Lighting	Candles, kerosene, wood	Candles, kerosene, LPG and electricity	Kerosene, electricity
Space conditioning	Wood, residues and dung	Wood, residues, dung and LPG	Wood, residues, dung, coal, LPG and electricity
Other appliances	Often none	Grid or genset-based electricity and batteries	Grid or genset-based electricity and batteries

Source: AFREPREN, 1999

3.1 Energy Use in Households: A Sub-Regional Perspective

3.1.1 Household Energy Consumption in North Africa

Although LPG and kerosene are important household fuels in North Africa, biomass is still widely used in **Morocco**. As a result, there is immense pressure on woody plant cover with a deficit equivalent to about 30,000 ha annually. The bulk of the biomass consumed (almost 88%) is used for cooking and heating in the rural areas. The remaining is consumed in urban areas mainly for bakeries and public baths – hammas (Centre de Developpment des Energies Renouvalables, Maroc, undated). In response to the wood deficit problem in Morocco, woodfuel programmes focusing on fuel switching and energy efficiency were introduced. Program activities included dissemination of wood energy-saving technologies in Casablanca, promoting fuelwood-saving stoves for cooking and heating in rural zones, and encouraging LPG use (Berdai, 2001).

Morocco's rural electrification programme was launched in 1995 with the objective of electrifying 1,500 to 2,000 villages annually. The results obtained so far are tabulated below. The rural electrification programme reached 39% of the population in 1999 compared to 17% in 1994.

Table 3.2: Number of Rural Villages Electrified in Morocco

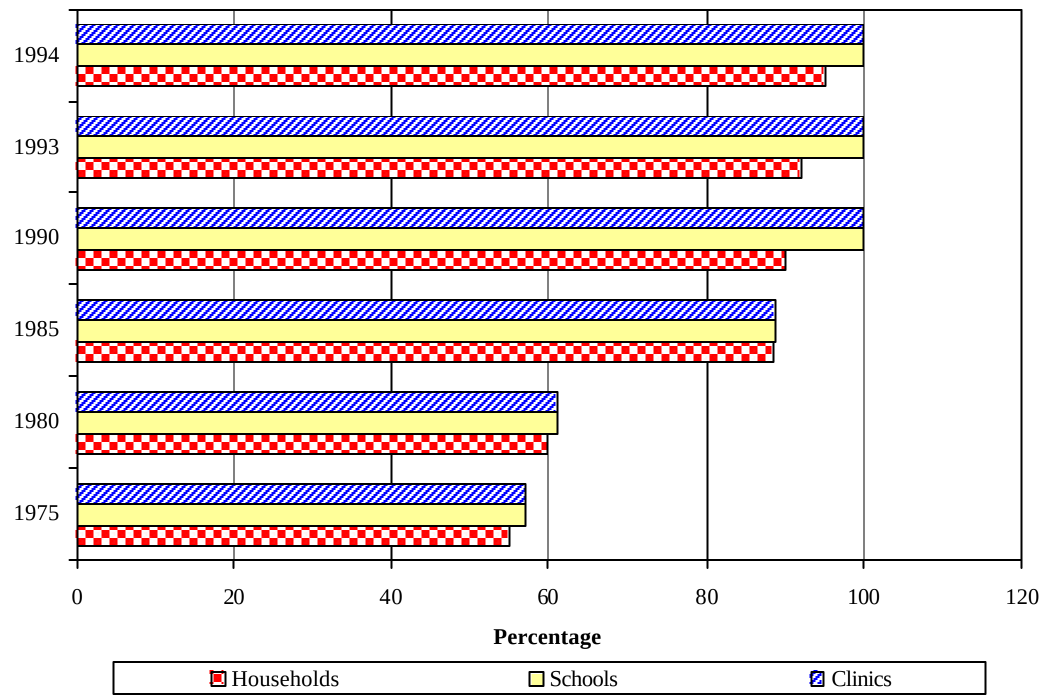
Year	1996	1997	1998	1999
No. of Villages	557	1,044	1,127	1,650

Source: Ministry of Energy and Mines

The Rural Electrification Authority in **Egypt** was established in 1971 with a mandate to electrify all areas across Egypt. Its progress in the residential sector can be seen in figure 3.1. About 400,000 domestic solar water heating units are in use in Egypt, saving 120,000 tonnes of oil annually (Office of Fossil Energy, 2003).

[1] Space conditioning encompasses both space heating and space cooling

Figure 3.1: Rural Electrification in Egypt (%)



Source: World Energy Council, 1999

Plant residues are the most important traditional fuel in Egyptian rural households (Mahmoud, 2001). Dung cakes are used for cooking and baking. Consumption of dung cakes varies depending on animal stock in each region. Likewise, different crop residues (maize, stalks, sorghum stalks, cotton stalks and rice straw) are used for cooking, baking and heating.

The domestic market for LPG in **Algeria** is significant and consumes about 1.4 million tonnes in 2003. In areas not connected to the natural gas distribution system, the bulk of the household LPG consumption is for heating and cooking (Sonelgaz, undated).

3.1.2 Household Energy Consumption in Sub-Saharan Africa

As shown in table 3.3, firewood remains the most common cooking fuel in most of Sub-Saharan Africa (Denton, 2002; Gustafson, 2001; Misana, 2001). Space heating is required in areas with cold climates, and is often catered for by energy used for cooking. The bulk of energy consumed in rural areas is used in households (World Energy Council, 1999; Karekezi and Kithyoma, 2002).

Table 3.3: Cooking Fuels in Selected African Countries Rural Households (% of Fuel Used)

Country	Firewood	Gas, Kerosene	Charcoal	Electricity	Other
Central African Republic	100	0	0	0	0
Guinea	99	0	1	0	0
Gambia	97	1	1	0	1
Mali	97	0	0	0	2
Tanzania	96	0	3	0	0
Madagascar	94	0	5	0	0
Uganda	94	2	4	0	0
Kenya	93	2	4	0	0
Ghana	92	1	7	0.1	0.2
Burkina Faso	91	1	1	0	7
Niger	90	1	0	0	9
Cote d'Ivoire	89	1	2	0	8
Zambia	89	0	9	1	1
Botswana	86	14	0	0.03	0
Senegal	84	2	12	0	2

Source: World Bank, 2000a

In **Ethiopia**, household energy is mainly used for cooking, lighting and space conditioning. According to a household survey conducted in 1996, energy use patterns largely depend on the place of residence of a household. Table 3.4 presents a summary of the distribution of household by type of fuel used for cooking and place of residence.

Table 3.4: Distribution of Households in Ethiopia by Type of Fuel Used for Cooking and Place of Residence, 1996

Type of Cooking Fuel	Place of Residence		
	Country Level %	Urban %	Rural %
Collected firewood	65.4	17.2	74.1
Purchased firewood	8.0	44.5	1.4
Charcoal	0.7	4.3	0.1
Leaves/dung cake	17.4	7.6	19.1
Kerosene	3.0	18.9	0.2
Butane gas	0.2	1.0	0.0
Electricity	0.4	2.7	0.0
Others	5.0	3.8	5.2
Total	***100.0***	***100.0***	***100.0***

Source: Wolde-Ghiorgis, 2001; CSA, 1999

From the previous table, it is evident that firewood is widely used for cooking in both rural and urban households. The only slight difference is that urban households purchase their firewood whereas their rural counterparts collect it. The following table indicates that kerosene was the main energy source for lighting in the rural areas of Ethiopia, while in the urban areas, electricity was the main source.

Table 3.5: Percentage Distribution of Households in Ethiopia by Source of Energy for Lighting and Place of Residence - 1998

Source of Energy for Lighting	Place of Residence		
	Country Level %	Urban %	Rural %
Kerosene	73.6	26.8	81.4
Electricity (private)	5.2	31.5	0.8
Electricity (shared)	5.8	38.6	0.4
Other	15.4	3.1	17.4
Total	***100.0***	***100.0***	***100.0***

Source: CSA, 1999

The household sector is the key energy consuming sector in **Kenya**. The following table lists the fuel types consumed in the urban and rural households in Kenya.

Table 3.6: Urban and Rural Household Energy Consumption in Kenya

Fuel Type	Rural (%)	Urban (%)
Firewood	50.00	6.20
Charcoal	26.90	85.40
Kerosene	14.92	5.10
Agricultural Residues	8.11	0.20
Electricity	0.06	2.30
LPG	0.01	0.80

Source: Central Bureau of Statistics, 2003

According to Nyang (1999), the most common rural household fuel mixes in Kenya are kerosene + firewood (50%), and kerosene + charcoal + firewood (38.8%). In the urban areas, the most common fuel mixes are:

- Kerosene + charcoal (29.6%)
- Electricity + kerosene + charcoal (24.4%)
- Kerosene + charcoal + firewood (13.6%)
- Electricity + LPG + kerosene + charcoal (10.4%)

On average, rural households consume 5.2 litres of kerosene per month, while urban households consume 8.7 litres per month. The table below lists the specific uses of kerosene in Kenyan households.

Table 3.7: Kerosene Use in Kenyan Households

Type of Use	Rural (%)	Urban (%)
Tin lamps	78	38
Lanterns	80	92
Pressure Lamps	9	10
Kerosene Cookstoves (Wick Type)	76	85

Source: Nyang, 1999

Firewood is normally used in the rural areas of Kenya for cooking, space heating, lighting (in some instances), agricultural processing (curing tobacco, smoking fish, etc), and industrial activities (burning bricks, iron mongery, etc). Charcoal is mainly used for cooking and space heating, and sometimes for ironing. About 85% of Kenya's urban households use charcoal with 99.5% purchasing the charcoal. In the rural areas, 26.9% of the households use charcoal with 67% purchasing the charcoal. The remaining proportion produces their own charcoal for use and some sell the surplus. On average, a rural dweller travels 6.2 km to source charcoal while an urban resident travels 1.9 km (Central Bureau of Statistics, 2003; Nyang, 1999).

Combustible agricultural residues include both crop and animal wastes. They are normally used as substitutes to firewood in cooking. Increased firewood scarcity in Kenya is leading to greater use of agricultural residue. For instance, an estimated 70% of the rural households use agricultural residues (either on its own or combined with other fuels) for fuel while only 4% is used in the urban areas (Nyang, 1999).

In Kenyan households, electricity is used for cooking, lighting, space conditioning, ironing and powering electronics such as hair dryers, air conditioners, televisions, radios, shavers and refrigerators, among others. About 20% of Kenya's urban households have access to electricity while only 2% have access in the rural areas. LPG is mainly used for cooking. An estimated 0.01% of rural households use LPG while 0.8% of the urban households use LPG (Nyang, 1999; AFREPREN, 2003).

Meeting the basic energy needs of **Senegal's** households with fuelwood and/or charcoal has been creating problems for natural forest resources and in the immediate surroundings of human settlements. This has gradually contributed to deforestation, the increasing scarcity of traditional fuels, and contributed to desertification.

More than 85% of the population in Dar es Salaam (**Tanzania**) depend on charcoal as a source of energy for cooking. The scarcity of trees in the nearby villages has resulted in charcoal being obtained from more than 150 km (NTL, 2002). The domestic sector is the main energy consumer in Tanzania and is dominated by women (Kaale, 1999). A mini survey undertaken in selected poor urban areas of Tanzania in December 2000 indicated that the most commonly used fuels for lighting were kerosene, candles and electricity, respectively. Charcoal, kerosene, crop residues and firewood were the most commonly used fuels for cooking (Katyega *et al*, 2001).

Low capital investment in developing and sustaining the supply of biomass fuels has caused scarcity of energy to domestic and small-scale rural industries in Tanzania. One of the key assumptions made by energy planners has been that switching fuels from biomass to commercial fuels will solve the biomass fuel scarcity problem. However, energy substitution studies undertaken between 1970s and 1990s have shown that majority of biomass fuel users are not switching to commercial fuels, largely due to financial constraints. Instead, they were switching to lower cost, lower-quality biomass fuels such as cow dung and agricultural residues (Kaale, 1999).

Results of a **Botswana** study on Rural Energy Needs and Requirements undertaken in 2000 indicate that fuelwood is the main fuel for cooking followed by LPG, then kerosene and finally cowdung. For lighting, the main fuels used were kerosene, candles and then electricity. Fuelwood was once again the main fuel used for water heating, followed by LPG, kerosene and cow dung. Energy for space conditioning was provided for by fuelwood, electricity and LPG. Fuelwood was the main fuel for beer brewing and ironing. The study covered 11 villages (about 440 households), with 49 households being interviewed. From the responses, the study highlighted that a number of households had switched from other fuels to using electricity (table 3.8).

Table 3.8: Number of Households that have switched from Other Fuels to Electricity

End Use	Fuelwood	Kerosene	LPG	Coal	Other
Cooking	7	12	4	3	4
Cooling		4	1		
Lighting		12	2		

Source: Zhou, 2001

The key reasons given for switching household fuels were convenience and scarcity of other fuels. Switching was, however, partial for 44.7% of the households and complete for 55.3% of the households. Most of the households interviewed would prefer to use electricity and LPG if they could afford them (Zhou, 2001).

3.1.3 Household Energy Consumption in South Africa

Two of the most common energy applications in South African households is cooking and space heating. The following table, using data from the 1996 census, shows the different types of energy used:

Table 3.9: Number of South African Households Using Various Sources of Energy

Energy Type	Cooking	Space Heating
Unspecified	63,629	388,266
Animal dung	106,068	84,448
Gas	286,657	107,689
Coal	320,830	735,633
Kerosene	1,943,862	1,294,965
Wood	2,073,219	2,417,725
Electricity	4,265,305	4,030,849

Source: Lloyd, 2002

Although electricity plays a major role, comparatively few lower income households in South Africa use it. For poor households, wood plays a key role in rural areas, and kerosene an equally important role in urban areas. Coal use, particularly for space conditioning, is extensive nearer the mines (Lloyd, 2002; Ward, 2002). As shown in the following table, although a substantial part of South Africa's rural population use firewood for cooking, the use of modern fuels such as kerosene, LPG and electricity is, by African households, fairly high (World Bank, 2000a).

Table 3.10: Fuel Used for Cooking South Africa's Rural Households (% of Fuel Used)

Country	Firewood	Gas, Kerosene	Charcoal	Electricity	Other
South Africa	49	23	5	21	2

Source: World Bank, 2000a

The following table lists the predominant energy technologies for various household income categories in South Africa.

Table 3.11: Typical Energy Use Patterns for Different Types of Households in South Africa

	Non-Poor Households with Electricity	Poor Urban Households with Electricity	Poor Urban Households without Electricity
Cooking	Electrical appliances (hot plates, stoves, microwave ovens)	Combination appliances (electrical hot plates and flame stoves)	Coal or gas stoves. Commonly rely on kerosene cookers or flame stoves
Lighting	Electrical lighting with incandescent or fluorescent light bulbs	Electrical lights as well as kerosene lamps and candles	Kerosene lamps, incandescent bulb or candles
Space Heating	Electrical bar heaters or oil heaters (used on cold days)	Coal and kerosene heaters mostly used. Electrical heaters are sometimes used.	Kerosene stoves double up as heaters. Gas and coal heaters are also used
Heating water	Electrical geysers. Solar water heaters are becoming popular	Few geysers are installed. Stoves for water heating is more common	Kerosene and gas stoves
Fridges	Electrical refrigerators	Few refrigerators but electrical one most commonly used	Gas refrigerators are sometimes used
Media appliances	Use electricity or batteries	Use electricity or batteries	Batteries for radio and car batteries for TV

Adapted from Ward, 2002

3.2 Implications of Current Patterns of Household Energy Consumption

As mentioned at the beginning of this chapter, and as demonstrated by the selected country case examples, biomass consumption is the dominant household fuel in Sub-Saharan Africa ranging from 55% in Senegal to 92% in Tanzania (IEA, 2003). Electricity (primarily from coal-based power stations) dominates household energy consumption in South Africa and petroleum products in North Africa meet the bulk of household energy demand. With most households in South Africa and North Africa using relatively cleaner energy forms such as electricity, LPG and kerosene, the more serious household energy challenge is in sub-Saharan Africa which still relies on inefficient and environmentally unsustainable traditional biomass. The key challenges facing the household sector in sub-Saharan Africa are discussed in the next section.

3.2.1 Indoor Air Pollution

Incomplete biomass combustion leads to high concentrations of indoor air pollution. This leads to high cases of respiratory diseases such as acute respiratory infections, tuberculosis, and chronic obstructive lung disease in households. (Kammen *et al*, 2001; ESMAP, 2003; Ekouevi, 2001; Ward, 2002). At the household level, women and children are adversely affected by particulate emissions from biofuels smoke because they spend much of their time near biomass-based cooking fires. A study undertaken in rural Kenya found that women, who do most of the cooking, were exposed to twice as much particulate emission as their male counterparts, and were on the average, twice as likely to suffer from respiratory infections (Karekezi and Kithyoma, 2002; Karekezi and Ranja, 1997; Akarakiri, 2002).

3.2.2 Environmental Degradation

Biomass harvesting leads to decreased vegetation cover, erosion effects, decreased soil fertility, loss of soil moisture, and loss of biodiversity. In addition, reliance on biomass (especially in the form of charcoal) encourages land degradation. In some areas (for example around major cities such as Lusaka, Zambia; Nairobi, Kenya; and, Dar es Salaam, Tanzania) charcoal demand appears to contribute to degradation of the surrounding woodlands and forests (Kammen *et al*, 2001; Desanker and Zulu, 2001; NTL, 2002; Ekouevi, 2001). Unsustainable charcoal production practices contribute to this degradation. For example, in Tanzania, trees are cut to the ground as opposed to stumps. Thus rather than regenerating, the trees die (NTL, 2002).

In between growing seasons, agricultural residues are normally left in the field as ground cover to protect the top soil. In addition, they may be ploughed back into the soil or burnt on top of the soil both of which return nutrients to the soil. When the residues are used for fuel, they, in the long run, reduce the soil fertility and leave the soil unprotected thus prone to soil erosion (Kammen *et al*, 2001). Using animal manure as fuel takes away valuable fertilizer decreasing soil fertility and leading to lower yields. It also forces the households to rely on more expensive inorganic fertilisers (Kammen *et al*, 2001).

3.2.3 Social Burden

Firewood use in the rural and urban households in various African countries is either collected or purchased (Misana, 2001). Firewood collection in Kenya is often the responsibility of women and children. In the rural areas, 90% of the population use collected firewood in comparison to only 20% in the urban areas. In Botswana, the average distance travelled to fuelwood collection points was 6 km and the time taken was about 3.3 hours (Zhou, 2001). The average distance travelled to fetch firewood in Eritrea is 10 km and in most cases (80-90%) it is the responsibility of women and children (Semere, 2001). According to Mugisha and Klunne (2001), due to expanding sugarcane areas in Uganda, there has been a decline in fuelwood collecting areas leading to longer distances travelled to access fuelwood. Because of travelling long distances to collect firewood, women and children in rural Africa are often left with limited time for other activities resulting in low agricultural productivity and inadequate time to pursue educational opportunities.

3.3 Gender Dimension

The link between rural household energy use and women is an area that is often ignored; yet its importance cannot be overstated. The relationship between energy and women's work and well-being is evident in women's role as users of energy sources, producers of traditional biomass fuels and educators concerning the collection, management and use of fuels. In addition, women and children are the most vulnerable group in terms of energy scarcity and adverse environmental impacts associated with energy production and use (World Energy Council, 1999; ESMAP, 2003).

Women are the major users of traditional energy sources for household activities. For example, the preparation of food in most rural areas is the responsibility of women. Women have practical interest and applied expertise in the burning properties of different fuels, fire and heat management, fuel-saving techniques, and the advantages and disadvantages of different fuels and stoves. Women also purchase (or influence the purchasing patterns of) fuels, stoves and other household energy appliances. More importantly, women influence the direct and indirect energy consumption patterns of their households (Reddy et al, 1997). Since women are at the centre of household energy use in rural areas, they should be the target of sustainable energy projects. In addition, the women should be involved in actual implementation of the projects.

At the household level, women and children are adversely affected by particulate emissions from biofuels smoke leading to high cases of respiratory diseases (Kammen *et al*, 2001; ESMAP, 2003; Ekouevi, 2001; Ward, 2002). In areas where there is decreased vegetation cover, the women and children are required to walk longer distances to collect firewood. This leaves them with limited time for other activities (agricultural activities, basket weaving, pursuing educational opportunities, etc). In poor female-headed households where there is only one source of income, this aggravates the poverty situation.

Improved energy technologies could reduce the time and drudgery associated with energy procurement tasks performed by poor women, e.g. collection of fuelwood and water. Improved stoves, designed to reduce heat loss and increase combustion efficiency could significantly reduce indoor air pollution, and ensure efficient fuelwood use (Karekezi and Kithyoma, 2002; Kammen et al, 2001; Zhou, 2001; ITDG-EA, 1999; Desanker and Zulu, 2001; Akarakiri, 2002). Adopting energy efficiency measures in the household can reduce the amount of fuelwood required. This may result in a reduced fuelwood collection trips, thus freeing up some time for other activities (Bellerive Foundation, undated; Muguti *et al*, 1999). In addition, improved energy services can be a stimulus for income generating activities (IGAs) of poor women.

3.4 Response Options for Sustainable Energy Consumption

While sustainable energy consumption can be promoted in North Africa and South Africa via well known efficiency and renewables options[2] (e.g. more efficient electrical/LPG/kerosene stoves, CFLs, solar water heaters and wind), it is in the sub-Saharan Africa household sector where the consensus on the most appropriate options has yet to be reached. This section will attempt to identify the most promising options for promoting sustainable household energy consumption in sub-Saharan Africa.

Data and information on household energy consumption and biomass energy use in most sub-Saharan countries is outdated and often unreliable, which makes it difficult to plan. In comparison to the conventional energy sector, which has comprehensive 5-10 year plans, planning for household and biomass energy in most sub-Saharan African countries is often incoherent and sporadic and starved of the necessary budgetary allocation. The mobilization of additional financial and technical resources to support data collection and associated household and biomass energy planning is of priority importance (IEA, 2003).

Initiatives pertaining to inefficient and environmentally unsound traditional household biomass energy options should primarily be aimed at research and analysis as well as data collection to provide the basis for developing effective strategies for reducing reliance on traditional biomass energy options. As mentioned earlier, many sub-Saharan African countries do not have reliable databases on traditional biomass energy supply and household energy use. This makes it difficult to formulate appropriate policy and field-oriented interventions. Mechanisms for collection and documentation of data on traditional biomass supply and household energy consumption, which is regularly updated and validated, need to be instituted (IEA, 2003).

[2] There are still opportunities for promoting sustainable energy consumption in North African and South African households through increased use of solar water heaters for water heating and wind for water pumping. In addition to the aforementioned response options targeting traditional biomass consumption, sustainable building designs and insulation can promote sustainable household energy consumption by decreasing the amount of energy required for lighting and space conditioning. Houses that have natural lighting most of the time, and are insulated can reduce by almost 20% the amount of energy consumed (OECD, 2002). Another policy option would be the promotion of energy efficient use of household appliances, and standards and public awareness programs that promote energy efficient appliances and buildings. This is especially in South Africa and North Africa.

Planning for biomass and household energy development should have a decentralized component and should involve end-users. Special attention should be devoted to involving women, because they bear the burden of traditional biomass energy systems and are likely to be the greatest beneficiaries of improved household energy systems. Decentralization of rural energy planning is wise because household energy systems are based primarily on traditional biomass. Consequently, an assessment of the demand and supply flows and of desirable interventions must also occur on the same geographic scale. Through their superior knowledge of the local situation, local people—women in particular—can be integral parts of the solution (World Bank, 2003a; Karekezi and Kithyoma, 2002).

The reality of the rural energy sector is that biomass energy is bound to dominate household energy consumption. While biomass energy is often perceived in a somewhat negative light, there are attractive options for using biomass energy in a more sustainable, modern, efficient and environmentally attractive ways – discussed in the following section.

Option 1: Efficient Energy Use in the Households

The following tables demonstrate how simple energy efficiency measures can realize significant energy savings at household level thus reducing the amount of fuelwood required.

Simple Energy Saving Option	Energy Savings (%)
Using thin dry pieces of wood which burn better producing more energy than large pieces	23
Pre-soaking maize, beans and other dry foods to reduce time taken to cook thus consuming less firewood	40
Simmering	60
Using lids	20
Cutting food into small pieces	35
Having the fire burn only when you need it	18

Source: Bellerive Foundation, undated.

In addition to the above, Muguti *et al*, 1999 outlines the following ways households can reduce or save energy:

- Use thick walled containers when cooking, boiling, heating water or brewing beer. This retains the heat reducing the need to keep a good fire
- Shield open fires thus concentrating the fire on the cooking process
- On reaching boiling point, transfer cooking pot to insulated container thus reducing firewood or charcoal consumption

Option 2: Provision of Efficient Biomass Energy Technologies

Many policy analysts stress the need for aggressive dissemination of improved biomass technologies (IBTs) in sub-Saharan Africa, to mitigate the negative effects of traditional biomass energy use – particularly indoor air pollution that is linked to respiratory diseases, one the main causes of death for children under the age of five. Sub-Sahara African governments should put in place policies that support the development and dissemination of IBTs (ESMAP, 2002; Karekezi *et al*, 2002). Private sector, NGOs, CBOs and donor organisations should implement projects aimed at ensuring the rapid dissemination of these IBTs. In particular, efforts to reduce the cost of widely used IBTs such as improved cookstoves should be accelerated, so that they are within the reach of even the poorest of the poor in sub-Saharan Africa (Smith, 1991; Smith 1994; Kammen and Ezatti, 2002).

Improved rural and urban biofuel stoves, which are designed to reduce heat loss, increase combustion efficiency and attain a higher heat transfer, would be an appropriate response option. These stoves could ensure efficient utilisation of fuelwood and could significantly reduce indoor air pollution thus mitigating respiratory health problems associated with smoke emissions from stoves (Karekezi and Kithyoma, 2002; Kammen *et al*, 2001; Zhou, 2001; ITDG-EA, 1999; Desanker and Zulu, 2001; Akarakiri, 2002). With the exception of a few countries, improved stoves have continued to display low penetration rates, as shown in the following table.

Table 3.12: Current Dissemination Numbers of Improved Cookstoves in Selected African Countries

Country	No. of Improved Household Stoves Disseminated
Botswana	1,500
Malawi	3,700
Zambia	4,082
Zimbabwe	20,880
Sudan	28,000
Ethiopia	45,000
Eritrea	50,000
Uganda	52,000
Tanzania	54,000

Burkina Faso	200,000
Niger	200,000
South Africa	1,250,000
Kenya	1,450,000

Sources: AFREPREN, 2003; Karekezi and Ranja, 1997

One of the key factors that led to the high improved stoves penetration rates in Kenya was the low cost of the stoves (about US$ 2). In addition, the stove dissemination programme did not attempt to install a new production and marketing system, but instead used the same network that produced and marketed the traditional stove. The stove programme utilised both mechanised and semi-mechanised stove producers thus creating job opportunities and keeping the price of the improved stove affordable.

Box 3.1: Reducing Indoor Air Pollution in Kenya

In Kenya, the Intermediate Technology Development Group (ITDG) has helped women to develop a simple smoke hood. This has reduced smoke levels in houses by up to 80%. ITDG field staff talked to the local Maasai community to identify the social and health problems associated with smoke. They also discussed a range of solutions (windows, larger eave spaces or smoke hoods) that could be installed in the houses. The staff made house visits to identify desired positions for the windows, eave spaces and smoke hoods, and worked with each community to make models of hoods using hard manilla paper. Local blacksmiths experienced in local manufacturing techniques examined the dimensions and transferred the designs to sheet metal. The smoke hoods were manufactured and tested in site. Modifications were made and households were thereafter trained in their proper use and maintenance. To date, feedback from the communities has been positive.

Source: ITDG, 2004

It is important for improved biomass energy system development and dissemination programmes to recognize the gender- and income-differentiated impacts of biomass energy use. In particular, improved biomass energy technologies that alleviate the burden and negative health effects of traditional biomass energy on the rural poor (comprising primarily of women and children) should be promoted and given prominence in government policies (Energia, 2002). Since women are at the centre of household energy use in rural areas, they should be the target of improved biomass initiatives, and should be involved in design, planning and actual implementation of the projects.

Although consensus from decision makers on policy measures for accelerating access to IBTs is yet to be realised[3], there are a number of options that have been analysed by leading biomass energy experts and that could provide an embryonic base for broad national and regional IBTs initiatives in sub-Saharan Africa. Notable options that could be considered for implementation by policy makers in sub-Saharan Africa and respective development partners include:

- Setting targets, which include identifying and setting goals for the incremental contribution of improved biomass energy options to total national energy supply. The targets should preferably include financial commitments by sub-Saharan African governments and development partners.

- Introducing new and innovative financing mechanisms, e.g. allocating a proportion of available energy subsidies (for example levies on electricity and petroleum) to the adaptation and wide scale dissemination of improved biomass energy technologies.

Option 3: Sustainable and Controlled Tree Harvesting for Fuelwood or Charcoal Production

Given the harmful environmental impacts of charcoal production in the region, there is need to regulate the production of charcoal (Scully, 2002). Afforestation and reforestation projects should be important compoents of all charcoal production programmes. The use of improved and efficient charcoal kilns should be promoted (Karekezi and Ranja, 1997).

Planting trees within the household compound, interspersed among cultivated land can make up for loss of tree cover in natural woodlands. Currently, efforts are made to plant more trees in numerous African countries (Akarakiri, 2002). Other related options include regulating fuelwood collection within communities, and introducing forest reserves to ensure controlled fuelwood collection and tree harvesting for charcoal production (World Energy Council, 1999; Zhou, 2001; Kammen *et al*, 2001).

[3] The following are the key policy barriers to accelerating the promotion of IBTs:

- IBT targets: These were proposed at WSSD but were resisted by most African countries due to lack of comprehensive analysis of the drawbacks and benefits of the proposed targets.
- IBT levies: Economic analysis of the levies are often resisted by most Ministries of Finance as they perceive the levies as additional cost to the economy.

In Eritrea, the banning of cutting live trees for fuel; increasing coverage of tree enclosures; and, the prohibition of charcoal making have compelled increased saving of scarce fuelwood as well as substitution of traditional fuels by modern fuels (Semere and Tsighe, 2002).

Option 4: Fuel Switching

Fuel switching from biomass to kerosene, natural gas, LPG and biogas should be encouraged. However, there is a tension between the desire to move away from traditional fuel and the desire to avoid rising reliance on fossil fuels. In urban areas where alternative fuels are available, fuel switching away from biomass can be realised. Findings from two studies/surveys undertaken in 1986 and 2000 indicate a dramatic increase in urban LPG use in Botswana from 45% to 76%. This switch was largely due to the provision of an appropriate enabling environment for marketing LPG throughout the urban areas of Botswana. Elements of the enabling environment included the abundance of gas dealers which has improved the distribution of gas; the free home delivery of gas by dealers; and, housing developments incorporating gas outlets in housing designs (Afrane-Okese, 2001).

Box 3.2: Switching to LPG in Senegal

To address the problem of deforestation, environmental degradation and increasing scarcity of traditional fuels, the Senegalese Government decided to launch a 'butanization program' aimed at eventually replacing 50% of fuelwood (charcoal) consumption with LPG in major urban areas.

The first LPG cooker model that was introduced was equipped with a cylinder containing 2.75 kg of gas. Later, a larger model was introduced that was fitted with a 6 kg bottle which was better suited to the cooking habits and purchasing power of the target households. The butanization process recorded remarkable success initially due to tax breaks (exemption from customs duties on equipment connected to butane) and later subsidies awarded for this fuel in 1987.

LPG grew from less than 3,000 tonnes in 1974 to 15,000 tonnes in 1987 and nearly 100,000 tonnes in 2000, resulting in diversification of cooking fuels. Initially, LPG use was more prevalent in the upper income areas of Dakar. However, over the years, it has come into general use all over Dakar and other regions. In the major western towns of Senegal, the price of LPG is at its lowest because of low transport costs and has thus become the main cooking fuel.

The butanization program faced some constraints and the following are some of the measures implemented by the Senegalese Government to resolve the constraints:

1. The current gas stove in the market was too expensive and ill-suited to the Senegalese households' cooking habits. Better suited gas stoves had to be found. New 2.75 kg and 6 kg cookers discussed above were introduced. For both, the burner was the only imported item. The metal cooking pot support was manufactured locally.

2. There was no tax levied on this imported burner. However, this was not sufficient to maintain low income customers' interest in LPG. The Government therefore set up a pricing policy aiming at making LPG more affordable to the poor.

3. Three different price structures, which were revised quarterly, were established with the objective of taxing other petroleum products (particularly fuel oil) so that the prices of LPG could be subsidized – in effect, a cross subsidy.

The Government also pursued, concurrently with the above direct interventions, policies aimed at rationalizing wood resource management. This included measures such as raising wood cutting license fees, revision of extraction quotas, enhanced land allocation systems for charcoal production, and a gradual increase in the price of charcoal.

Source: Sokona, 2000

The next chapter examines energy consumption trends in Africa's agricultural and fisheries sector. It also attempts to analyse perceived trends in a differentiated sub-regional fashion. Data for selected country case examples provides nuanced appreciation of key energy consumption trends.

4.0 Energy Use in Africa's Agricultural and Fisheries Sectors

The agricultural and fisheries sector accounts for a substantial proportion of the region's GDP: over 30% in most countries (World Bank, 2000b). Agricultural commodities such as coffee, tea and tobacco often dominate the export sector of most African countries. In addition, the agricultural and fisheries sector employs a substantial proportion of Africa's population. Gambia's agriculture sector employs about 75% of the country's labour; generates close to 40% of the exports income and two thirds of household income. In Cote d'Ivoire, agriculture is the base of the economy employing two thirds of the economically active population. About 88% of Guinea's population is dependent on the agriculture sector (Agro Industry, 2002).

For the foreseeable future, heavy dependence on agriculture is likely to continue being the norm rather than the exception for most countries in sub-Saharan Africa. This is, however, not the case for countries with large mining and oil industries. North African countries have been registering a gradual shift away from the heavy dependence on agriculture to manufacturing and other industrial processes, but agriculture remains an important economic sector (FAO, 1995a; FAO, 1995b).

Energy is a necessity in all stages of agricultural production. The energy needs for agricultural production in rural areas range from intensive power use in transport, water lifting and pumping, land preparation, primary and seedbed cultivation, to weed control, planting, transplanting and harvesting.

There appears to be a close link between per capita commercial energy consumption in Africa and daily per capita calorie intake – a key indicator of food security (FAO, 1995b). Low per capita commercial energy consumption is almost always matched by low daily per capita calorie intake. This correlation is particularly strong in countries with less than 500 kgoe per capita modern energy consumption – the per capita figures for the majority of African countries (particularly sub-Saharan Africa) is significantly lower than the aforementioned 500 kgoe figure (FAO, 1995b). For African countries such as South Africa, with high per capita modern energy consumption, the link is much more tenuous.

In spite of abundant energy resources, available estimates of Africa's energy consumption indicate limited use of modern energy resources in the agricultural sector. The continued low consumption of modern energy is a source of concern. This could be an indication that the agricultural sector is not getting adequate attention from energy policy makers in the region in terms of provision of high-grade energy services.

Agriculture accounted for about 14% of energy consumption in Africa. To capture the diversity of energy use in the agricultural sector in Africa, we use a FAO (1995b) assessment of sectoral energy consumption of eight representative countries (Zimbabwe, Kenya, Sudan, South Africa, Ethiopia, Tanzania, Morocco and Botswana) with a combined population equivalent to a third of Africa's population.

Most of the agricultural energy data sets that are available exclude agro-processing and agro-transport which are often lumped together with energy consumption in the industrial and transport sectors, respectively. To overcome this shortfall, the aforementioned FAO (1995b) assessment used detailed Tanzanian and Zimbabwean surveys to estimate energy consumption that is attributable to agro-processing and agricultural related transport activities. The assessment concluded that agro-processing accounted for 45% of energy use in agriculture followed by on-farm agricultural activities (32%) and agriculture-related transport (23%). Agro-processing industries require large portions of mechanised energy (motive and shaft power) and process heat.

In Africa, biomass (60%), oil products (17%) and coal (16%) are the main sources of energy for the agricultural sector. Biomass provides heat for agricultural processing, oil drives both motive power and stationary processing machinery and is used for transport, while coal is used for transport (FAO, 1995b). Limited use of mechanized agricultural practices in Africa means that human labour continues to be an important source of power for agricultural activities in the continent (World Energy Council, 1999; FAO, 1995b).

Tractors are not widely used in the sub-Saharan African region. In 1994, the stock of tractors in Africa was estimated to be about 539,098 (World Resources Institute, 1998). Close to half the tractors are found in only three countries, Algeria, Egypt and South Africa. Latin America with under half the population of Africa has over a million tractors. A similar picture emerges with respect to harvesters.

Limited use of mechanized agricultural practices in Africa explains the low energy consumption of the agriculture sector. It also means that animate (human and animal) energy (inclusive of human power) continues to be an important source of power for agricultural activities in the continent. Consequently, studies of animate energy and its limitations are critical to gaining an in-depth appreciation of energy supply and use in African agriculture.

Human power, however, has limited output when compared to mechanised power sources. Humans are nevertheless flexible, skilled and can make sophisticated judgements and adjustments as they work. Animal power is used for transport, pulling implements, lifting water and in processing activities such as cane crushing and threshing (World Energy Council, 1999). However, the use of animal power is underdeveloped in much of Sub-Saharan Africa due to the prevalence of animal diseases such as trypanosomiasis. Low-power tractors can be used for pulling. With a power take-off, they can operate rotary hoes, pumps (for irrigation or crop spraying) and threshing machines.

Another important analytical question that needs to be addressed is the extent to which the energy used in the manufacture of fertilizers and pesticides should be considered. From a purely energy systems point of view, incorporation of energy used in the manufacture of fertilizers implies a much broader life-cycle approach that would sometimes go beyond national boundaries.

Another complication is energy consumption in fisheries and livestock. Although these sectors could, in strict, definitional terms, be excluded from the agricultural sector, in reality, separation of fisheries and livestock from agriculture is fraught with difficulties. For example, agriculture and livestock activities are often undertaken on the same piece of land. Similarly, fishing can be an important additional source of income for farmers. In many African countries, central Government Ministries in charge agriculture are often given the responsibility of overseeing fisheries and livestock sub-sectors. Although this paper will discuss energy use in fisheries and livestock, the analysis will largely be qualitative with limited recourse to empirical quantitative information.

The problem of collecting and assessing energy consumption in agriculture in Africa is compounded by the very limited information on the perennial tuber agriculture which predominates in wet sub-Saharan Africa and seasonal coarse grain agriculture which is important in arid sub-Saharan Africa. Biomass and animate energy are two of the most important sources of energy in both of these agricultural systems.

Energy use in agriculture differs according to the energy needs (irrigation, agricultural processing, agricultural production, etc), technologies and resources available, and the type of agricultural produce (crop, livestock, fish, etc). To counter the aforementioned absence of reliable continent-wide data on energy use in Africa's agricultural sector, the following section presents selected country case examples of energy use in agricultural production and processing and then attempts to show some important commonalities and trends.

4.1 Energy Use Patterns in Agriculture Fisheries and Livestock Sector – A Sub-Regional Perspective

4.1.1 North Africa

Almost all agriculture in **Egypt** is irrigated. The Nile Valley old lands irrigation system is a combined gravity and water lifting system. The main canal system (1st level) takes its water from head regulators which are located upstream of the Nile dams. This water is distributed along branches (2nd level) where the flow is continuous. Distributaries (3rd level) receive water according to a rotation schedule which is then pumped to irrigate the fields. Farmers use sprinkler or drip irrigation as surface irrigation has been banned in many areas. Sprinkler and drip irrigation require less water than surface irrigation (FAO, 1997a).

Libya's agricultural sector is one of the Government's top priorities. There are hopes that the Great Man Made River (GMR), a five-phase, US$ 30 billion project to pump water from underground aquifers beneath the Sahara to the Mediterranean coast, will reduce the country's water shortage, boost irrigation, and reduce its dependence on food imports. However, consensus is yet to be reached on the extent to which such large-scale water projects are sustainable in the long run. The irrigation potential in Libya is estimated at 750,000 ha. However, the development of this potential would have to rely mainly on fossil fuels. The total water managed area is approximately 470,000 ha, all equipped for full or partial control irrigation. Sprinkler irrigation is practiced on almost the entire area (FAO, 1997b).

Intensive irrigation schemes in **Tunisia** are divided into (FAO, 1997c):

- About 140,000 ha of small schemes developed individually by the farmers (70,000 households) through private investments and irrigated by open wells or by pumping of water in the wadis;

- A total of 163,000 ha of schemes with a communal irrigation network, irrigated by tube wells in the case of medium schemes (60,000 ha; 47,000 households) and by dams in the case of large schemes (103,000 ha; 24,000 households). These schemes have been developed with public investment.

Communal irrigation water distribution systems in Tunisia are generally modern. There are prefabricated canals or low-pressure pipes for surface irrigation and high-pressure pipes for sprinkler irrigation. Surface irrigation remains the most important irrigation technique. At present, about 6,000 ha are irrigated by treated wastewater, the remaining part by surface water (dams, pumping in wadis) and by groundwater (open wells, tube-wells) (FAO, 1997c). Drying of agricultural products in Tunisia is done by means of traditional industrial techniques amounting to an energy consumption of more than 1,200 TOE annually. This could be replaced by the use of solar thermal energy (European Commission, 1995).

4.1.2 Sub-Saharan Africa

Human and other animate energy continue to play a dominant role in the agricultural sector of sub-Saharan Africa. As the following country case examples will demonstrate, this has limited productivity and contributes to the sub-region's food security problem.

Although accounting for about a sixth of sub-Saharan Africa's population, the characteristics of the energy and agriculture sectors of the 10 member countries of the Southern African Development Community (Angola, Botswana, Malawi, Namibia, Mozambique, Lesotho, Tanzania, Swaziland, Zambia and Zimbabwe)[4] are representative of much of sub-Saharan Africa. Energy consumption patterns in the agricultural sector of this region are, in some respects, similar to those found in eastern or western Africa. Consequently, the region can, to some extent, be used as a proxy for the sub-region as whole. The FAO (1995b) estimates that agriculture accounts for only 5% of total energy consumption in the aforementioned 10 countries. This figure is rather low considering that agriculture dominates the economies of this region. Biomass (61%), oil products (17%) and coal (16%) are the main sources of energy for the agricultural sector. The bulk of the biomass is used to provide heat for agricultural processing. Petroleum products are used to drive both motive power and stationary processing machinery. Agriculture-related transportation is almost entirely fuelled by oil products with small contributions from coal, electricity and ethanol. The (SADC) Southern African Development Community region includes two of the three African countries (Kenya, Malawi and Zimbabwe) that have had active ethanol programs.

As illustrated in the following country case examples, small-scale food production and processing, which is a large component of agriculture in Africa, is largely dominated by women (Okorley *et al*, 2002). For example, a survey carried out in rural **Zambia** found that 92% of women engaged in agricultural activities. (Chandi, 2000) This could be linked to the relatively high proportion of households headed by females in the region, about 30% (Reddy *et al*, 1997 and Chandi, 2000).

Rural areas of Kordofan State in **Sudan** face inadequate energy supplies and services when they rely primarily on fuelwood and diesel as energy sources. These fuels do not meet the local energy needs which include irrigation and mills for grinding grain. Currently, hand-milling of grain by women is a common practice (Horizon Solutions Site, 2003).

Small scale and traditional/artisinal operators in **Mali** produce dried mango products (through solar drying), mango juice and mango jam. The sun dried mango products are not for export quality and are of small volumes (Agro Industry, 2002). The local cereal processing industry in **Burkina Faso** has four different systems used by different operators:

1. Hand operated pestle and mortar: This is largely used in the rural areas for direct consumption and accounts for the largest volume of grain milled
2. Semi-artisinal method using a motorised mill: This is used to prepare grain for sale to markets at the private or community level
3. Semi-industrial using mechanised equipment and modern production techniques: These are still embryonic and not widely disseminated
4. Industrial system used in large-scale operations. These are usually undertaken by large multinational concerns

[4] New members such as Mauritius and Democratic Republic of Congo (DRC) have recently joined the Southern African Development Community (SADC)

Agricultural activities in **Botswana** are largely confined to animal farming; this is due to the arid and semi-arid climatic conditions that largely prevail in the country. The sector is dominated by traditional farming with animate power providing the bulk of the energy. Mechanised farming is mainly practised in commercial farms, which occupy 5% of the total farmland. Energy use in the sector is mainly for water lifting (for both livestock and irrigation) and crop farming, which ranges from land preparation to post harvesting activities. Diesel engines have been widely used for water pumping although a significant number of windmills have been installed throughout the country. Almost all windpumps are located in farms for watering livestock. Whenever grid power becomes available, farmers usually prefer to switch to electricity (Mogotsi, 2000). The following table lists the different technologies that are used for water lifting in Botswana.

Table 4.1: Water Lifting Technologies in Botswana

Technology	Estimated Number
Windpump	250
Diesel	5,000*
Electricity	100
Solar	>70
Biogas	5
Hand pump	45
Animal-driven pump	5

* includes domestic use
Source: Mogotsi, 2000; Mbaiwa, 2002

The two most common crop farming technologies used in Botswana are the tractor and the thresher. The tractor is used for ploughing and transportation and uses diesel. The thresher is either a manual one or one that uses diesel (Mogotsi, 2000).

A wide range of technologies and techniques are used for water collection for small-scale irrigation in **Kenya**. They include rainwater harvesting, bucket irrigation, gravity fed sprinkler and drip, treadle and pedal pumps, rope and washer, motorized pumps, windpower and construction of small earthen dams. Inexpensive and simple gravity and pump sprinkler systems for horticultural crops, and the use of the pedal pump on valley bottoms is growing fast (Purcell, 2003).

Small holders organised under the Ugandan Tea Growing Corporation (UTGC) manage a considerable portion of the tea plantations in Western **Uganda**. The European Union supports the major investments of this sector. The energy needs of the sector are electricity for running the mechanical components (fans, grinders, rolling tapes, etc), general services and the residences, and heat for weathering, fermenting and drying phases. The warm air flow is generated by wood combustion, whose supply comes from tree plantations and from natural forests. Even where the wood cutting is officially planned, there is no assurance that appropriate reafforestation plans are in place (Salis, 1996).

As at 1996, tea production in Uganda was greatly affected by the insufficient and unreliable power supply of the national grid. To maintain economic levels of production, the tea factories needed to be equipped with diesel generators in order to assure a continuous supply of electricity to the process. The cost of electricity from the utility, assuming an uninterrupted supply, was US$ 0.88 per kg of made tea, compared to US$ 2.40 per kg of made tea where diesel generators were used exclusively. Although diesel generators could provide reliable power supply, the finished product (tea) was often uncompetitively priced (Salis, 1996).

Energy use in the fisheries sector is primarily for processing activities and storage facilities. Local processing of fish in **Gambia** is both at the industrial and the artisinal level. The techniques used at the artisinal processing sub-sector, which mostly employs female labour, are salting followed by drying, and smoking –with smoking being the most common method used. The basic technologies employed include drying wooden frames, chorkor ovens, and brine basins. In **Cote d'Ivoire**, industrial processing of fish is accomplished through freezing and canning, with the bulk of the processing plants being located in Abidjan and its environs. The larger portion of aquaculture and fish farming product processing, generally by artisinal processors, is through drying, salting or smoke curing (Agro Industry, 2002).

Fish processing in **Ghana** is largely an activity dominated by women (Okorley et al, 2002). About 80% of Ghana's fish landings are processed with the remainder being consumed as fresh fish. Approximately 60% of the weight is smoke cured, 20% is sun dried and the remainder salted. By 2002, refrigeration and freezing of fish was only utilised by export industries (Agro Industry, 2002). A survey of 150 small-scale women fish processors in central Ghana indicated that only 10% of the women were in contact with the Ghanaian Government extension services. About 6% had received some training in fish processing from the extension services – most of the women got their information from other fish processors. The concerned Government agencies indicated that the key challenges facing them were inadequate personnel and finances. Other challenges included inadequate training material support, inadequate or untimely credit for fish processors, and mistrust and suspicion among group members making it difficult to form and maintain groups (Okorley et al, 2002).

Artisinal processing of fishing landings in **Senegal** is largely undertaken by women, with men assisting in fish cutting, washing and laying out. For her processing activity, each woman has a preparation and fish drying area. The equipment used includes:

- Simple wattle hurdles and trays for drying
- Washing tubs
- Various artisinal 'smoking ovens'
- Storage areas and facilities for processed products

The rudimentary nature of the fish processing equipment has resulted in high level processing losses (up to 40%) and variable quality of the processed output. Attempts have been made to introduce solar dryers and improved smoking ovens, but these have yet to be taken up in large numbers (Agro Industry, 2002).

4.1.3 South Africa

South Africa's agricultural sector is divided into established, emergent and subsistence farmers. Energy needs for each differ; for example, for cooking and space heating, established farmers use coal while subsistence farmers use fuelwood (Lithole, 1998). Wind is an important source of energy in South Africa's agricultural sector. Windmills are largely used to supply water for irrigation (very limited application), human requirements and livestock (Stassen and Holm, 1997). More than 300,000 locally manufactured wind water pumps have been installed and are used to supply water mainly for livestock (Karottki, 2001).

In many parts of KwaZulu Natal, community gardens are a major activity. The crops grown in these gardens include vegetables, corn, beans, onions, chillies, ground nuts, pumpkins, lettuce, cabbage, carrots, and potatoes. Surplus in the production of the first six vegetables are sun-dried. Solar dryers have been introduced in the community with favourable response. This is because they save time, labour, provide higher quality products and eliminate problems with rain drenching (Cawood, 2001).

4.2 Gender Analysis

As mentioned earlier, dependence on agriculture is likely to continue being the norm rather in most sub-Saharan African countries. Women play a vital role in small-scale agricultural activities in Africa's rural areas; these activities form a large component of agriculture in Africa. Women are, in most cases, heavily involved in cultivation, planting, harvesting and marketing agricultural produces. This has become a key option for the women to fight poverty and ensure food security. Policies that aim at developing the agricultural sector through providing modern energy services would need to also target women. The women would need to be involved in the implementation of the projects as they are well placed to assess the viability of proposed energy options and technologies.

In sub-Saharan Africa and parts of rural South Africa, women are heavily involved in cultivation, planting, harvesting and marketing of agricultural produce. They grow most of the family's food and grind grain and other staples by hand (Planet Wire, 2002). Their work is highly fragmented and a high value is placed on time saving, especially during peak agricultural periods (World Energy Council, 1999). In addition, inadequate mechanisation adds an additional load on the limited women's time. Modern energy options could therefore greatly enhance the productivity of women in agricultural activities.

Current food processing methods in Africa are manual, time and labour consuming. Women grind most of their grain and other staples by hand (Planet Wire, 2002; Horizon Solutions Site, 2003). The rudimentary equipment used in agro and fish processing results in high processing losses and limited productivity (Agro Industry, 2002). In areas that do not have water pumps, the women and children have to cover long distances to collect water.

Improving women's access to energy would result in positive effects such as

1. Grain grinding would be less time-consuming and labour-intensive. This would free up time for the women to pursue other gainful activities

2. Mechanized grinding equipment and improved food processing alternatives would enable the women to provide more food with less effort.

3. Pumped water used for irrigation increases yield and food security. It also reduces the woman's water collection burden

4. Solar dryers would improve the quality of agricultural produce and processed fish resulting in higher prices being fetched at the market

4.3 Response Options: Agriculture, Fisheries and Livestock Sector

One of the key implications of inefficient processing technologies and storage facilities is the high level of post harvest losses. Bad handling and non-hygienic treatment leads to about 100,000 tonnes of fish going to waste in Ghana in 1997 (Okorley *et al*, 2002). Post harvest losses due to insect infestation have resulted in reduced rice production in Sierra Leone (Bassey, 2003). This section proposes response options that will not only promote sustainable energy consumption in the agricultural and fisheries sectors of Africa, but also provide options for reducing post harvest losses and increasing productivity.

Where animal power for agricultural production and processing must be used, efficiency needs to be improved. This is through modernisation of equipment, better breeding, husbandry, feeding and veterinary care, and improved infrastructure for research, training and credit facilities (World Energy Council, 1999).

It is, however, important to underline that the paucity of data on energy in agriculture, fisheries and livestock sector presents a major challenge to the development of appropriate sustainable energy consumption strategies. Greater effort needs to be directed to the compilation of agricultural energy statistics. In addition, in the many countries where agriculture remains the pre-dominant source of employment and income and little is known about agricultural energy use patterns, systematic surveys should be considered.

The following cluster of response options can be suggested for promoting sustainable energy consumption in the agricultural, fisheries and livestock sector of Africa:

- Improved use of mechanical and animate energy
- Efficiency energy use
- Improvement and modernization of biomass energy use
- Greater use of other renewable energy resources and technologies

4.3.1 Improved Use of Available Mechanical and Animate Energy

The *MoneyMaker*, a series of manual micro-irrigation pumps developed by ApproTEC (Appropriate Technologies for Enterprise Creation), has registered encouraging success in Kenya. By February 2002, 21,788 pumps had been sold. The *MoneyMaker* has had substantial impact in terms of number of new enterprises started, new jobs created and incomes/profits increased (ApproTEC, 2001).

The portable suction pump was developed in October 1996 based on an IDE (International Development Enterprise) design from India. The pump is ideal for surface irrigation, and was originally intended for use in the Kano plains around Lake Victoria. However, this terrain was not typical of Kenya and Africa, in general. In East Africa, farmers were not used to flood and furrow irrigation, which have been practiced in India for hundreds of years. Though the pump found a market, feedback from the field indicated that there was a larger potential for a pressure pump, capable of not only drawing water to the surface but also pushing it uphill. This necessitated the design and development of a pump whose features would meet this demand; thus the development of the *Super MoneyMaker* pressure pump. Consequently, the original MoneyMaker was withdrawn from the market in February 1999 (ApproTEC, 2001; NCN, 2002; Purcell, 2003).

Figure 4.1: Super MoneyMaker Irrigation Pump

ApproTEC designed the pressure pump based on the stated needs of small-scale farmers in Africa so that it:

- Can lift water from shallow sources (river/streams/dams/lakes or hand dug wells) and irrigate more hilly lands.
- Is portable so as to move it to different plots, and for security purposes (lock it up at night).
- Is low cost ('about the cost of a bicycle').
- Is low maintenance.
- Is very durable and reliable.

Depending on the intensity of use, the pump is expected to last for 3-4 years. However, ApproTEC takes a conservative figure of 5 crop cycles (approximately 2 years) for calculating the cost/benefit ratio. ApproTEC gives a one-year guarantee (free replacement or repair) against any manufacturing defects to the farmers. The *Super MoneyMaker* can be used to irrigate up to 1 ha (2.4 acres) of land and retails in Kenya for about US$ 74.

Following a social economic impact assessment, feedback received indicated the poor could not afford the *Super MoneyMaker* pump. Consequently, a small pressure pump known as the *MoneyMaker PLUS* was designed. The cost was half that of the *Super MoneyMaker* and in the ten months it was in the market (June 2001-February 2002), 1,800 pumps had been sold (NCN, 2002; Purcell, 2003).

As a result of FAO's Special Programme for Food Security (operational in more than 60 countries), about 200 treadle pumps have been installed in **Zambia** in demonstration sites contributing to a wider adoption of the pumps. The treadle pumps are widely used for irrigation of small vegetable gardens. One of the notable benefits has been increased incomes; a rise in income of more than sixfold from US$ 125 with bucket irrigation to US$ 850-1,700 using treadle pumps. Other benefits are improved family nutrition, extended crop intensity, and sustainable use of valuable groundwater resources (AFROL News, 2003).

4.3.2 Efficient Energy Use

There is significant potential for cost-effective energy efficiency improvements in irrigation, crop curing and drying, and agro-industrial motor drives and process heating. Investing in these technological improvements would help reduce the overall costs of meeting agricultural production goals, and minimize the environmental impacts of woodfuel use and the foreign exchange and capital requirements of expanding commercial energy supply. Key areas include tobacco curing, agricultural pumpsets, and a range of agro-industries where 20% to 50% reduction in energy use, respectively, could be economic and achievable. Enhanced water provision for water pumping for irrigation would reduce the woman's water collection burden, increase crop yields and food security (Planet Wire, 2002).

4.3.3 Improvement and Modernization of Biomass Energy Use

One of the key challenges facing many African countries as well as respective development partners is the level of effort and resources that should be expended on the following two clusters of biomass energy options that can play an important role in Africa's agricultural sector, namely:

- Improved biomass energy options
- Modern biomass energy options

Improved Biomass Energy Options can contribute to more efficient and environmentally sound use of biomass energy in Africa's agricultural sector. IBTs can improve the efficiency of biomass use in traditional energy-intensive agriculture-based productive activities such as, crop drying, fish drying and local beer brewing (Reddy *et al*, 1997; Karekezi and Kithyoma, 2002).

While there is no full consensus among policy analysts and researchers, there is a growing body of evidence indicating that for low-income sub-Saharan African countries with large and very poor rural population, the accent should be on the promotion and disseminating of improved biomass energy options. This approach is likely to yield large near-term developmental benefits in terms of job generation in the small-holder agricultural sector, increased incomes for rural farmers and assist in reversing the negative environmental impacts of traditional biofuel energy use (Masera *et al*, 2003).

Modern biomass technologies have the potential of providing improved energy services to agriculture sector based on locally available biomass resources and agricultural residues[5]. Widespread use of combined heat and power generation biomass options in agriculture can address multiple social, economic and environmental issues that now constrain local development. The availability of low cost biomass power in rural areas could help provide cleaner, more efficient energy services to support agriculture, local development, promote environmental protection, provide improved domestic fuels and improve rural livelihoods. Bioenergy technologies based on sustainable biomass supply are carbon neutral and lead to net CO_2 emission reduction if used to substitute fossil fuels (IPCC, 2003; Coelho and Walter, 2003; Fischer and Schrattenholzer, 2001).

In addition, modern biomass energy technologies can contribute to better bio-waste management. For example, bagasse-based co-generation solves the problem of safe disposal of bagasse at sugar plantations (Veragoo, 2003; Deepchand, 2002).

Another advantage of modern biomass energy is its job generation potential – a very important attraction for many developing countries faced with chronic levels of unemployment and under-employment. Existing studies (Goldemberg, 2003; FAO, 2000) indicate that, in comparison to other primary energy sources, the job creation potential of modern biomass is among the highest (Table 4.2). For example, in Brazil, the annual production of 14 billion litres of ethanol from sugarcane is responsible for the creation of 462,000 direct and 1,386,000 indirect jobs in the country, corresponding to a rate of 263,000 annual jobs per MTOE generated (Goldemberg, 2003).

Table 4.2: Comparison of Job Creation – Biomass and Conventional Energy Forms

Sector	Jobs (person-years per Terawatt-hour)
Nuclear	75
Natural gas	250
Petroleum	260
Offshore oil	265
Coal	370
Wood energy	1,000
Ethanol (from sugarcane)	4,000

Source: Goldemberg, 2003

One of the main challenges facing modern biomass use is the extent to which it can compete on cost and reliability with conventional fossil fuel options - both for transportation and for electricity supply. There is, however, a growing body of assessments of national implementation programs demonstrating that modern large-scale biomass energy systems can be competitive on both economic and technical grounds. Examples include biofuels in Brazil, co-generation using a wide range of agro-residues (using wood residues, sugarcane bagasse, rice husks, etc.) in many agro-industries (IEI, 2001; Winrock, 2002).

On the other hand, smaller-scale applications of modern biomass energy technologies still faces numerous challenges particularly at the level of cost-competitiveness (although many argue that this is due to an absence of a level playing field) (IEI, 2002; Coelho and Walter, 2003). Small-scale biomass based modern biomass systems have registered encouraging levels of success in India, South East Asia and parts of Latin America (Shrestha, 2003; Pandey, 2002).

The development of modern biomass energy often requires significant capital investments and technical expertise, which may not be readily available in many developing countries. In addition, there are cases where the legal and regulatory framework in place does not support the development of modern biomass energy technologies (AFREPREN, 2001). This has been a major barrier, for example, in the co-generation of electricity for sale to the national grid by sugar companies in many countries of sub-Saharan Africa (AFREPREN, 2003).

5 One way of modernizing biomass energy use is through the use of ethanol gel to meet household energy needs. This is a liquid fuel that is composed of ethanol, water, thickening agent, colouring and flavouring agent. It has heat value of 22.3MJ/kg. Usually ethanol gel is packed in bottles and sachets for easy transportation. The fuel can suitably substitute wood, charcoal, gas and kerosene for domestic cooking in developing countries with ethanol production potential. In Zimbabwe, ethanol gel is used for camping, starting barbeque and fires and in the army. Ethanol gel is ranked third among the household energy sources in Zimbabwe, with its market value of about 113 F.CFA/kg (BTG, 2003)

The growing of the biomass energy resource can also presents several challenges. Firstly, high-input mono cropping results in the loss of biodiversity, soil fertility and land degradation, and is often accompanied by the use of fertilizers and pesticides, which could lead to pollution of underground and surface water sources. Secondly, it could lead to competition for land between food production and biomass resources (Masera *et al*, 2000).

The impact of modern biomass energy technologies on the poor is not well understood. It can complicate and compound existing competition over available biomass resources and land (Masera *et al*, 2003). Without appropriate, sensitive and equitable management, large-scale modern biomass energy development can lead to further marginalization of the rural poor. It is, however, possible that the growth and development of these technologies could lead to increased incomes for the poor (e.g. small holder sugar farmers) if a well-designed revenue sharing scheme is established. **Mauritius** provides a model case example of where a share of the benefits from large-scale co-generation plants that flow to low-income farmers have increased over time through direct policy interventions and an innovative revenue sharing mechanism (Deepchand, 2002; Karekezi *et al*, 2002b).

Although modern biomass energy technologies have not been widely disseminated in many parts of Africa, the IEA has attempted to assess the prospects of biomass-based power generation in different developing regions of the world including Africa. More comprehensive assessment that examine a wide range of modern biomass energy options (electricity, gas and fuels) are hampered by the poor quality of biomass energy data that is available.

For African countries with lower levels of poverty and higher levels of industrialization, the emphasis should probably be best placed on the encouragement of modern biomass energy technologies that can be used as levers to develop agro-industries and as a foundation for leap-frogging to cleaner biomass-based advanced fuels, electricity and gases.

The development of modern biomass energy technologies will require supportive legal and regulatory frameworks that attract investment in modern biomass energy systems. Due to the substantial amount of resources required to develop these technologies, it is important that a clear legal and regulatory framework is put in place. In addition, new and innovative ways of financing modern biomass energy projects should be pursued (Goldenmberg *et al,* 2002; Karekezi and Ranja, 1997).

In the case of ethanol production, collaboration within the sugar industry would facilitate rapid improvement of agricultural practice (to increase productivity and reduce adverse environmental impacts) and allow the capture of substantial scale benefits associated with larger and more efficient plant. Ethanol producers can fully utilise economies of scale if some form of collaboration at an international level was initiated. At moment, international trade in ethanol is constrained by various trade and non-trade related constrains. Increased trade in ethanol could provide an important impetus to the further development of the biofuel industry (Berg, 2001).

Long-term energy training programmes designed to develop a critical mass of locally trained manpower with the requisite technical, economic and social-cultural skills are needed. Many of the engineering and technical courses that are currently taught at universities and colleges in African countries provide little exposure to biomass energy technologies. Both capacity and demand for local analytical expertise to provide comprehensive evaluations of available biomass energy resources and options for utilizing them are needed. Non-partisan groups, such as NGOs and independent research institutes and networks are well placed to perform such studies (IEI, 2001; Karekezi and Ranja, 1997).

As in the case of IBTs (Improved Biomass Technologies), there is no general consensus on what policy options would accelerate the use of modern biomass technologies but the following options could provide an initial menu for action:

- Setting targets, which include identifying and setting goals for the incremental contribution of agro-based modern biomass energy to total national energy supply. The use of tradable renewable energy certificates could assist in further promotion of modern biomass energy technologies use in the agriculture sector in Africa.

- Ensuring the level playing field for modern biomass and conventional energy forms produced by agro industries, e.g. setting prices that are attractive to investors in the modern biomass energy sector.

- Enacting a legal and regulatory framework that allows for the development of modern biomass energy by agro industries, and provides, among other incentives, access to the grid and transport fuel market.

- Setting up regional funds for financing large scale biomass energy technologies in Africa's agricultural sector.

4.3.4 Greater Use of Other Renewable Energy Resources and Technologies

Renewable energy technologies use could be promoted to meet the demand for energy for agriculture in rural Africa and to increase productivity. In particular, the following technologies have shown promise (Karekezi and Ranja, 1997).

- Small hydro plants for shaft power which can be used to process agricultural produce
- Biogas plans which provide sludge for use as fertiliser
- Solar crop/fish dryers
- Wind pumps for irrigation

One technology that could have considerable impact in the region's agricultural sector is wind energy for water pumping, for irrigation. Most countries in the region have wind energy potentials that are sufficient for water pumping (3m/s). Wind pumping for water lifting could have a significant impact on agricultural productivity in rural areas of the region. Positive results have already been registered in the Ala Plains of **Eritrea**, where this technology is in use (Habtetsion and Zemenfes, 2001). However, as shown in the table 4.3, this potential has not been exploited fully in most countries (Karekezi and Ranja, 1997), mainly due to the high initial costs (US$10,000).

Table 4.3: Wind Energy Potentials and Number of Wind Pumps in Selected African Countries

Country	Potential (m/s)	Number of Wind Pumps
South Africa	7.2-9.7	300,000
Namibia	8.0	30,000
Kenya	3.0	360
Botswana	3.0	250
Zambia	2.5	100
Tanzania	3.0	58
Mozambique	0.7-2.6	50
Uganda	4.0	13
Sudan	3.0	12
Burundi	2.5	1
Cape Verde	9-10	-
Lesotho	5.0	-
Seychelles	3.62-6.34	-

Source: Karekezi and Ranja, 1997

An effort could be made to reduce the capital costs of these wind pumps. Local assembly of the wind pumps could be one such initiative. In **Kenya**, the manufacture of wind pumps is now an established industry. Wind powered water pumps have led to increased agricultural production and improved water supply in the rural areas (Harries, 2002). Local windpump manufacturing has also been successful in **South Africa** and **Namibia** Other initiatives to help reduce the costs would be government subsidies or tax exemption for all wind pump installations and appropriate financing mechanisms.

A total of 20 windpumps have been locally manufactured in **Egypt** with the aim of introducing water-pumping windmills for meeting water supply needs for farmers for irrigation and drinking water. Wind pumping becomes more attractive in agriculture when it is combined with drip irrigation. This is suitable for large areas in desert zones of western and eastern Egypt which are possible to cultivate but are isolated from the electric grid (ESES, 2000).

The Naima Commune is a residential and agricultural commune in the semi-arid region in North Eastern **Morocco** whose water supply was pumped by a diesel pump. Although the installation of the pumps was subsidised by the Moroccan Government, the maintenance and fuel were financed by the community. Limited financial resources led to reduced pumping of water and inadequate water resources (Fairman, 1999).

In 1989, through USAID's assistance and with local support from Morocco's Centre de Developpement des Energies Renouvelables (CDER), two 10 kW wind turbines were installed in the commune. The pumps yielded three times the water supplied by the diesel powered pumps. This amount of water was greater than the commune's demand, allowing them to sell water to other communes for extra revenue. The extra revenue was then be used to finance the maintenance cost of the wind pumps. In addition, the installation of the wind water pumps reduced time wasted hauling water from distant tanks and sources, and increased the education level and economic status of the village. The success of the project has prompted other villages to replace their diesel pumps (Fairman, 1999).

An example of the impact of pumped water on women's time is the case of PV water pumping in KwaZulu, **South Africa**. About 46 households in the Sondela community, situated in KwaZulu about 40 km south of Pietermaritzburg, have garden plots. Before the purchase of the PV powered water pump, the women faced the long and tedious job of collecting water directly from the river. The time saved by the pump has resulted in more work being done in the garden with resulting higher food yields and hence incomes. It also has the beneficial effect of releasing the women to enable other money earning industries such as basket weaving to expand (Sinclair, 1990).

Pico- and micro-hydro power could be used in the agriculture sector for irrigation, milling, grinding and providing shaft power for crop processing. Although not in Africa, Nepal (it has development indicators that are roughly similar to sub-Saharan African countries, and therefore provides useful lessons for the region), is one of the countries in the developing world that has achieved substantial small hydropower development. A key factor in the success of small hydropower in Nepal is the instrumental role the Nepalese government has played in the promotion of small hydropower. In 1984, it sanctioned privately instituted small hydro projects under 100 kW, eliminated licensing requirements and granted approval for charging unrestricted tariffs. This led to active private sector involvement in SHP development, as well as increased dissemination of the technology.

Solar dryers can be used to reduce post-harvest losses and enable the farmers to secure off-season high returns. For example, the key food crop grown in Sierra Leone is rice. However, production regularly falls short of self-sufficiency level due to insect infestation and spoilage. Improvements in drying and storing systems are required to accommodate any increased production and reduce post harvest losses. Solar drying is one option that could be explored (Bassey, 2003).

Braguy *et a*l, 2003 (see box 4.1) illustrates how women involved in fish processing in Sao Tome were trained on improved fish salting methods and fish drying using the solar dryers. As a result, the fish harvested could be dried for a longer period. The salted and dried fish was of a higher quality fetching high prices in the market.

Box 4.1: Solar Fish Drying in Sao Tome

A large number of Sao Tome's beaches are distant from the capital city. Due to the irregular transport, the fish caught has to be stored in the beaches for a long period. Women processors generally salt and dry the fish. Before 2001, the method used was laying out the fish on horizontal racks about one metre from the ground. This was to avoid contact with the sand and on the ground. The racks made of a wooden frame with a cover from bamboo or small branches, or a palm leaves or twig mat covered with a fishing net.

This method led to large quantities of post-catch loses. In addition, the quality of the fish sold was poor thus fetching low prices in the market. Other disadvantages of this method included: dust contamination, insect infestation, exposure to harmful human and animal handling, the fish had to be brought inside each time it rained and each evening to avoid night dew and its consequences (mould). As a result of this, the Angolares community, with support from the Sustainable Fisheries Livelihoods Programme (SFLP), resolved to investigate ways of improving fish drying techniques. Marapa, a local NGO, helped the community build two experimental collective solar dryers. The dryers looked like small tents set up one metre above the ground, and were built by the processors themselves using locally available materials – only the mosquito netting and the polythene sheets are purchased.

To aid in the transition from the traditional method to an improved one, the women who undertook fish drying were given training in fish salting and drying methods. The training covered:

- The process from gutting to washing before salting
- Laying fish out in the salting tray to turning the fish on the racks
- Improved hygiene and storage of the fish

By 2003, positive results had been registered. About a third of the solar dryers implemented are in use throughout the year. The fish can be dried for periods longer than the traditional method could (four weeks compared to 3-8 days using the traditional method), and any unsold fish could be salted and dried. In addition, the use of solar dryers resulted in higher profits for the fisheries community. Their salted and dried fish is of better quality and consequently fetching a higher price (20% higher) in the market.

Source: Braguy et al, 2003

Box 4.2: Solar Fish Drying in Nigeria

Fish drying is a common practice in the Lake Kainji area, north of Nigeria. The traditional method used was simply to spread out the fish on mats or on the ground to be dried by the sun. The quality of fish dried this way reduces due to dust, insects, sand and stones. To improve the situation, the National Institute for Freshwater Fisheries Research (NIFFR) and GTZ undertook research on solar drying of fish. After the trial period, based on their observations and facts in the field, the community and the scientists worked to improve the initial model. The key adaptations were using locally available material such as wood instead of metal, and rocks covered with locally made black dye material instead of black polythene sheets.

Due to the role played by the community in developing the dryer, it was easily accepted and adopted. Solar drying increased profits. The increased quality of the fish made it easier to sell it and at a higher price. In addition, the use of solar dryers helped reduced pressure on the environment by reducing the demand for firewood for smoking fish.

Source: Braguy et al, 2003

In the agricultural sector, electricity from PV can be useful for lighting, water pumping, refrigeration and grinding. It cannot, however, cost-effectively replace the use of human labour and animal traction, which is the major source of energy for rural agriculture. Solar PV water pumping for irrigation has been disseminated in several countries in the region. However, this technology has not registered widespread success, mainly due to the high costs of installation. The following are some potential uses of PV in aquaculture and fishing (Campen *et al*, 2000):

1. Aeration of water: This increases oxygen levels contributing significantly to productivity. PV can be used for small applications while PV/diesel hybrid systems could be used for higher energy consuming applications.

2. On-shore refrigeration of fish and ice making in unelectrified fishing communities. PV refrigerators, however, are still not cost competitive with gas and kerosene alternatives. Developments in low-energy consuming compressors and improved insulation techniques for smaller sized refrigerators (household size) can bring cost-competitive PV refrigeration within reach.

3. Lighting for fishing both as light for fishermen and as underwater light for attracting fish. This use improves safety and increases yields.

5.0 Energy and Urban Transport in Africa

A steadily growing population requires appropriate means of transport, which implies increased energy use in the transportation sector. Since the late 1980s, the urban transport sector in African cities has changed dramatically. Of particular note is the gradual disappearance of large public transport companies partly as a result of privatisation and withdrawal of the state from the transport sector, and partly as a result of the rise of the ubiquitous small transit urban transport sector.

Rapid population growth, uncontrolled urban expansion, unsustained economic growth, increased energy consumption and increased motorization all translate into serious air pollution problems in cities throughout the African continent. In addition, the number of vehicles in African cities has continued to increase raising concern over their impact on urban air quality (Molina and Mario, 2003). Table 5.1 presents a summary of the total number of vehicles in selected African economies.

Table 5.1: Increasing Trends in the Total Number of Vehicles in Selected African Countries, 1992-2001

Country	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Botswana	90,544	101,031	109,510	116,242	93,836	99,161	114,015	131,796	139,322	150,574
Ethiopia	73,362	76,196	73,741	88,985	93,511	102,883	105,850		128,000	
Kenya	386,058	398,056	416,132	438,356	467,020	496,913	528,631	556,623	576,759	
Mauritius	153,500	166,200	178,800	188,600	198,000	208,000	219,900	230,900	239,700	248,700
South Africa	5,391,291	5,414,200	5,499,812	5,587,400	5,690,091	5,760,885	5,850,566	5,954,949	6,049,964	
Uganda	53,045	58,669	72,506	96,262	126,214	150,495	176,164	186,244	189,105	
Zambia	129,150	135,608	142,322	150,000	154,500	159,135	163,910	172,688	173,897	179,109
Zimbabwe	423,551	448,066	475,167	522,682	575,342	632,886	721,227	739,543	899,199	

Sources: AFREPREN, 2003; CSO, 2002; Baguant, 2002

As shown in table 5.1, the total number of vehicles in South Africa is larger than all the other sub-Saharan African countries listed. Although the authors are yet to secure reliable numbers for North Africa, one would expect a similar picture with Egypt recording the largest number of vehicles. The number of passenger cars in Africa is more than the number of other units of motorised means of transportation. In South Africa, of the estimated 6 million registered vehicles in 2001, about 4 million were passenger motor cars

Demand for petroleum products accounts for a significant proportion of Africa's export earnings. Road transport is the main user of petroleum and diesel. This is attributed to increased number of vehicles and the relatively large road infrastructure that facilitates motor vehicle use in contrast to rail whose infrastructure has not grown significantly.

From the previous table, the energy consumption in the transport sector is likely to be of greater concern in South Africa and North Africa. Nonetheless, the transport sectors in urban areas of Africa share the following important commonalties:

- In almost all African countries, co-ordination and policy planning for the formal transport structure is weak, often leading to conflicting objectives, overlapping responsibilities and duplication of activities.
- Partly as a result of a weak formal transport sector and rapidly growing transportation requirements, an informal transport sector has emerged to meet growing transport needs.
- With the rapid rise in motorization in urban areas, African cities are beginning to experience serious traffic congestion and pollution problems that plague many Latin America and Asian cities.

As discussed in previous chapters, the following section on energy consumption trends in the transport sector is organised on a sub-regional basis. Country case examples provide additional insights on key trends

5.1 Energy Consumption Trends in the Transport Sector

5.1.1 North Africa

Algerian cities have similar characteristics with countries in the Latin America and Asia, i.e. rapid urban growth with increasingly marked imbalance between stagnating city centres and under-equipped, fast growing fringe areas. Algeria’s public transport service is inadequate and nearly always saturated. Depending on the cities, 60-62% of the trips are on foot while about 20% are by public transport. With the growing increase in private transport, taxis have come to play a greater role in the Algerian transport system. Although liberalisation of the transport sector increased supply of public transport, it also created negative effects owing to a lack of regulation by the public authorities. Despite the emergence of the private sector, Algeria still suffers from a severely deficient public transport system. The ongoing construction of the rail transit system is plagued by delays that rules out any possibility of opening the service for several years to come (ISTED, 1999).

Energy consumption in Algeria's transportation sector is quite high with more than 7 million tonnes of petroleum products (mainly gasoline and diesel oil) being consumed in 2001. Consumption levels of diesel oil and unleaded gasoline are experiencing sharp increases as a result of the growth of vehicles running on diesel and unleaded gasoline (Sonatrach Annual Report, 2002).

Morocco's transport sector was liberalised in 1986 boosting private sector involvement. However, the private sector, over the years, has faced serious problems. The vehicle fleet is becoming obsolete and the operators do not meet their obligations (payment of a fee to the transport authorities for the operation of services of their lines). The introduction of a surface rail transit system in Casablanca was mooted in 1999 (ISTED, 1999). Urban transport services in Tunis, the capital of **Tunisia**, are provided by bus services (75%) and light rail transit (20%). The private sector is marginal (ISTED, 1999).

5.1.2 Sub-Saharan Africa

Statistics indicate that road transport is the dominant mode of transportation in Africa. In **Sierra Leone** and **Ethiopia**, 95% and 90% respectively of all transport is by road. Passenger cars are the most predominant form of motorized transport in most African countries

In **Zimbabwe**, despite the deregulation of the transport sector in the 1990s, commuters continue to face hardships as fares continue to rise. The service offered is erratic, unsafe and unreliable. In addition, it is worsened by deteriorating infrastructure which results in, among other problems, poor turn around times and localised pollution. Poor access to services such as maintenance and spare parts has increased the inefficiency of this sector. The transport sector is a major consumer of energy accounting for 14% of total energy consumption, or 66% of all liquid fuels consumption. Zimbabwe does not have its own oil resources and relies on imported oil; this puts an enormous burden on the foreign exchange requirements (IEA, 2003; Batidzirai, 1999).

The transport sector in **Botswana** is the major consumer of petroleum products in Botswana with more than 90% of the petroleum being used on road transport. Consumption of petroleum on road transport is mostly by urban transport, where the largest concentration of motor vehicle is (Zhou, 2002). The urban transport system in Gaborone is characterised by large passenger fleets which congest the city particularly at peak hours. The high per capita incomes for Botswana have resulted in vehicle ownership beginning to exceed the road capacity. This is largely responsible for the rapidly increasing petroleum consumption in the country (Zhou, 1999). City Authorities in Gaborone have been preoccupied with addressing the problems of traffic congestion, road safety and improving access to transport services by commuters. In an attempt to improve traffic flow and road safety, roads with restricted access were introduced. However, the City Authorities do not have an elaborate plan to address the environmental problems associated with energy-related vehicle emissions (Zhou, 1999).

The recent civil disturbances in **Cote d'Ivoire** is likely to have led to significant changes to the country's transport sector but due to continued instability, the requisite data is not available. A significant proportion of Cote d'Ivoire's population is in the north of the country, while the south provides most of the employment opportunities. Consequently, the heaviest demand for transport is from the peripheral districts in the north towards the central districts in the South. SOTRA, a national bus service company, was set up to meet this demand. Abidjan's transport sector gradually evolved to consist of the following components (Adolehoume and Bonnafous, 2001):

- SOTRA, a semi public company
- Minibus services (*gbakas*) operated by private transport operators on an informal basis. These were vehicles with 14-32 seats. 18-seaters were the most common vehicles.
- City taxis commonly referred to as '*woro-woros*'. These were private cars with four seats
- Private metered taxis

Between 1988 and 1999, SOTRA faced increasing financial and structural difficulties such as excess staff, management problems and unpaid government subsidies. These rendered it unable to meet transport demand and as a result its market share dropped from 47% in 1988 to 27% in 1998. During the same period, the *gbakas* doubled their market share while the *woro-woros* increased from 16% to 27% (Adolehoume and Bonnafous, 2001). Due to recent disturbances, current data on transport energy in Cote d'Ivoire is not available.

Inland transport is the lifeline of the Mauritian economy. Substantial investment took place in the **Mauritius** transport sector resulting in improvement in the road network, port and airport facilities. However, the level of investment did not keep pace with the demand. The public transport has several deficiencies and can no longer respond to the needs of the day (Baguant and Bunjun, 2002). Key problems included congestion, quality deficiencies in the bus system, parking problems, lack of pavements for pedestrians throughout the country, failure to consistently implement traffic management measures, and limited attention paid to road maintenance.

Non-motorized transportation is common in rural areas of Africa and largely consists of walking, bicycles, including cycle-rickshaws (found mainly in **Madagascar**) and animal-drawn carts and carriages. Studies on urban transportation indicate that walking is still a common mode of transportation in a number of African cities. According to Davidson (1992), it accounts for 60% of urban transport in Bamako, **Mali**. In Kampala, **Uganda**, the majority of trips are made by either non-motorized transport or public transport. It is estimated that up to 40% of all person trips are either by walking or by bicycle. In **Zimbabwe**, walking is the most common mode of transportation accounting for slightly more than 80% of the trips (Otiti, 1997; Batidzirai, 2002)

The economic and environmental benefits associated with non-motorized transportation are well known but there are some limitations to their use. Important constraints include topography, weather, security, carrying capacity, road safety risks and social norms. In many African cities, cyclists are expected to use the same road as motorists, with no dedicated lanes. Consequently, cycling is dangerous in many African cities.

Two independent studies conducted by the World Bank (1992) and Cervero (2000) reveal that governments often discriminate fiscally against non-motorized transport. In Africa, the diminishing stock of bicycles is partly a consequence of high taxation on imports (which treats bicycles as a luxury). Currently in **South Africa**, bicycles are not manufactured and are imported and taxed heavily while private vehicles are manufactured locally and face lower taxes. Although the ownership of a bicycle may substantially reduce the real costs to the very poor of moving both passengers and freight, typically, persons who are very poor cannot raise the capital to purchase a bicycle. Mark-ups on border prices have ranged between 200-500% in **Ethiopia**, **Ghana** and **Tanzania**. In 2002, a bicycle cost an average per capita income of four and a half months in Tanzania and eight months in **Uganda** (ITDP, 2002).

Generally, non-motorized facilities are largely inexistent or unplanned for in many African cities. A study on urban transport in Harare, **Zimbabwe**, reveals that infrastructure for safe walking is limited and pedestrians and cyclists are the most endangered road users in the city. In Kampala, **Uganda**, it is indicated that other than a few footpaths adjacent to some roads, particularly in the Central Business district, there are no specific facilities for non-motorized transport in Kampala. Slow moving bicycles and wheelbarrows are forced to mix with faster motorized traffic in normal traffic lanes. In some instances, footpaths are in very poor conditions, forcing pedestrians to walk on traffic lanes posing risks and slowing traffic further (KUS: Transport, 1993; Otiti, 1997; Batidzirai, 2002).

Rail Transport - In **Zimbabwe**, rail transport is the most economic transportation mode for medium and long distance bulk goods traffic, carrying about 14 million tonnes per year or 90% of such traffic. It is expected that the traffic will increase by an average of 3.5% per annum. The National Railways of Zimbabwe (NRZ) is the largest parastatal in Zimbabwe (employing about 20,000 people) with a turnover representing 6% of the GDP (Batidzirai, 2002). In line with the Zimbabwe Government's policy for reducing the import bill, the National Railways of Zimbabwe has decided to electrify parts of its network using the locally-generated electricity.

The Zimbabwean case appears to be the exception in the region rather than the rule. The railway sub-sector has over the years experienced reduced traffic. This has been attributed to staff inefficiency, insufficient rolling stock, breakdown of machinery and operational problems (New African, 1996) while the African Railway Union cites lack of revenue, poor productivity, ageing rolling stock and overstaffing. In **Uganda**, for instance, the number of passenger traffic stood at over 180,000 passengers in 1990. This figure fell steadily through the 90s and stood at 27,000 passengers in 1996. Freight traffic, however, doubled over the same period. In **Botswana**, the number of passenger traffic fell steadily from 619,000 in 1996 to 336,100 in 1999. Freight traffic, however, increased by about 40% over the same period (EIU, 2002).

5.1.3 South Africa

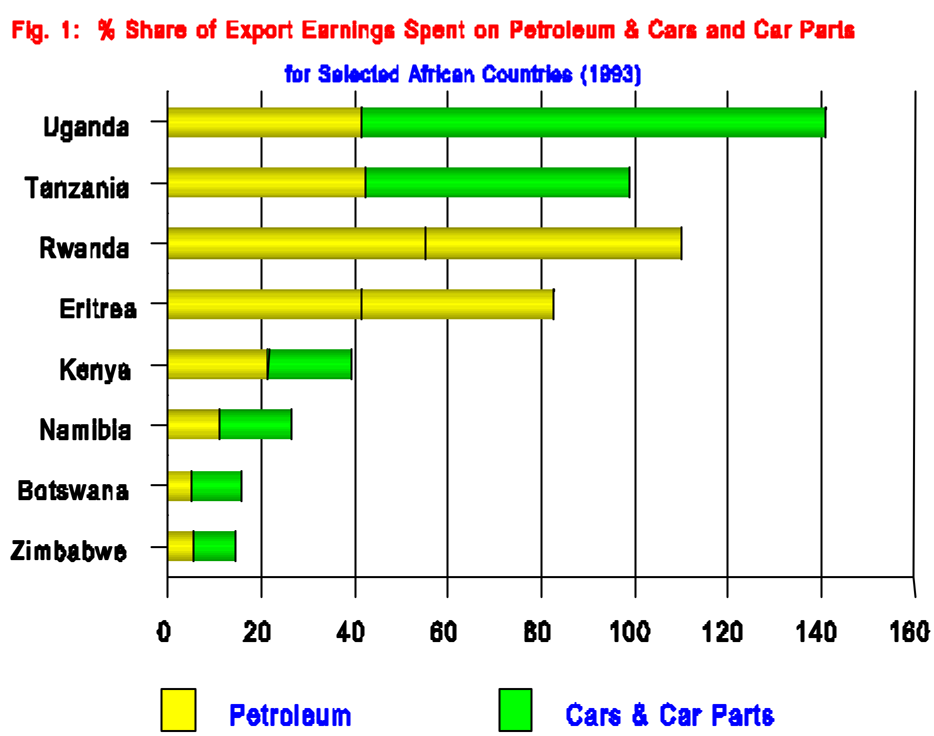
In South Africa, transport accounts for 29% of total energy consumed and 28% of total carbon emissions. Urban air pollution is worsening with the increase in vehicles on the road (Ward, 2002). In 1998, the sector consumed 27% of the country's final energy consumption, of which petroleum products accounted for 97%, electricity 3% and coal 0.2% (Howells, 1998). By the same year, South Africa's transport system was characterised by serious problems such as 10,000 road fatalities annually, declining rail and bus ridership, limited investment in maintaining the road system, large number of people having to commute long distances and spend a higher proportion of their income on transport, and overloading by road haulers (Saint-Laurent, 1998). Car ownership and use is growing rapidly in South Africa. A stock of about 6.0 million cars existed in 2000; this was double what the GNP per capita would suggest when compared to similar countries.

5.2 Social, Environmental and Economic Impacts

Transportation brings people and goods to people, returning enormous benefits to economies. However, transportation also brings significant undesirable energy related side effects or externalities, particularly in the urban areas and on the global environment. These include:

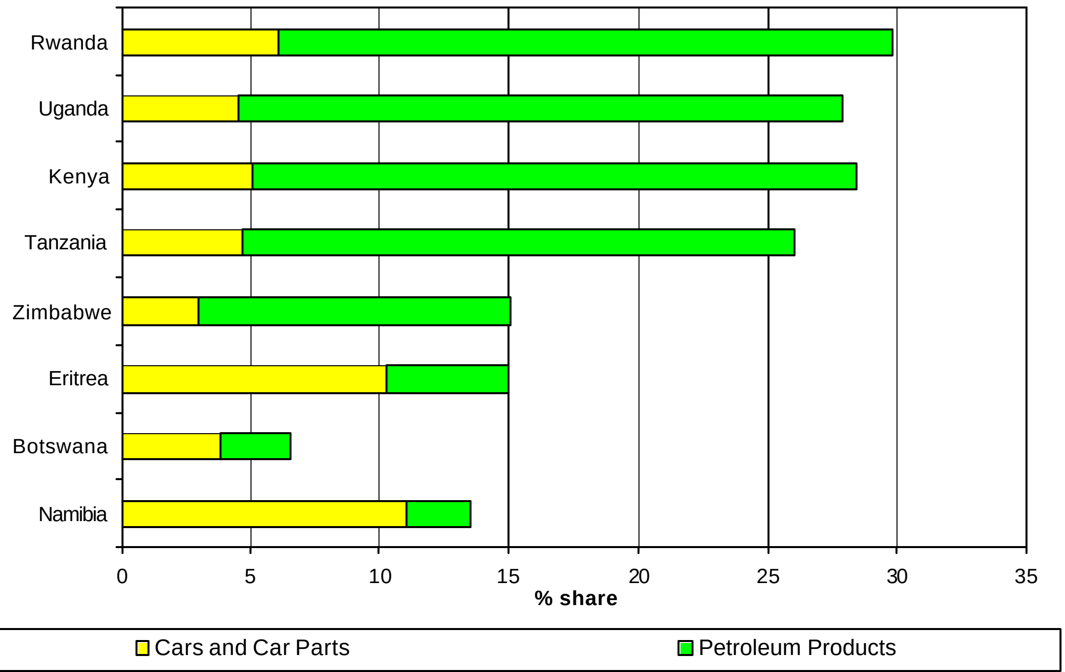
Increased Imports of Fossil fuels
Heavy reliance on fossil fuel places a huge burden on limited financial resources of poor African countries (Kammen *et al*, 2001). A review of 1996 and 1997 Economic Intelligence Unit reports reveals the following startling statistics on the expenditure on petroleum and cars & car parts as a share of export earnings in selected African countries (Fig.1). Eritrea, Rwanda, Tanzania and Uganda spend over 50% of their total exports earnings on importation of vehicles and petroleum fuel. The bulk of the imported petroleum is used in the transport sector. In Uganda's case, the vehicle and fuel bill exceeded the total foreign exchange earnings in 1993.

Figure 5.1: Percentage Share of Export Earnings Spent on Petroleum & Cars and Car Parts



More recent figures indicate a less startling picture but the cost to national economies due to reliance on motor vehicles is still high (see next chart). As the majority of motor vehicles are passenger cars, a transition to mass transit systems would yield enormous benefits to the region.

Figure 5.2: Percentage Share of Export Earnings Spent on Petroleum Products, Cars and Car Parts, 2000



Source: World Bank, 2003a; www.un/internationaltradestatistics, 2002

Inadequate Infrastructure Resulting in Traffic Congestion Which Leads to Greater Fuel Use

Despite the rise in transport demand and the crucial role of the sector, most African countries do not have adequate road and rail infrastructure. According to the World Bank, (2003), the proportion of paved roads in the region averages 25% and is generally below 30% in individual countries except in Mauritius where almost the whole (97%) network is paved.

Poor Vehicle and Road Maintenance Which Increases Fuel Consumption

In addition to expanding the transport networks and services, one of the greatest transportation challenges in Africa today is the maintenance crisis. A road inventory conducted by GTZ in Cameroon and Ghana (1996) reveals that over 30% of the paved roads in the countries are in poor to very poor condition. Consensus among transportation experts (World Bank, 1996:3 and GTZ, 1996:186) is that for every dollar of essential maintenance postponed increases the costs (including the cost of procuring fuel) of operating a vehicle in the current period by about 3 US dollars. Postponed maintenance also increases the costs incurred by road agencies in the long run. Over the two-decade period of 1964-1984, the World Bank reports that US$ 45 billion worth of road infrastructure assets was lost in eighty-five developing countries (many of them African countries) because of inadequate maintenance.

Air Pollution

Almost all motorized transportation today involves the combustion of fossil fuels, which transforms energy into motion. This combustion is the reaction of the hydrogen and carbon present in the fuels with oxygen in the air to produce water vapour and carbon dioxide. Carbon dioxide is the principal gas responsible for the greenhouse effect. The more energy consumed, the more carbon dioxide emitted. Particulate matter is one of the most critical transport-sector pollutant for most African and developing countries. The causes of pollutant emissions can be summarised as follows: motor vehicles are being used too often, and they are not 'clean' enough (Gorham, 2002). Other common causes of vehicular pollution include fuel adulteration, use of improper lubricants, overloading of vehicles, alteration of engines, driver behaviour, and poor vehicle maintenance (Karekezi et al, 2003). Lead from transport fuels reduces the IQ of children by 4.25 points (Musa, 2003). Egypt is the only leaded-gasoline free country in Africa, followed by South Africa which is now 80% lead free (Kituyi, 2003). Tanzania and Uganda both launched the use of unleaded fuel in November 2003.

5.3 Response Options for the Transport Sector

To address the previously discussed undesirable side effects of energy use in the African transport sector, this paper proposes the following options:

- Regulatory measures
- Energy efficiency measures
- Infrastructural development measures
- Cleaner/alternative fuels and engines

Typical options under each of the main categories above are presented in the following table.

Regulatory Measures	**Energy Efficiency Measures**	**Infrastructural Development**	**Cleaner/Alternative Fuels and Engines**
• Regulatory measures such as speed limits; vehicle inspections; emissions and fuel quality standards enforcement; vehicle make restrictions to encourage fleet standardization; vehicle taxation regimes; delisting of old and inefficient vehicles; and, fuel pricing • Traffic management e.g. parking codes; coordinated traffic lights; dedicated bus lanes; bus stops	• Vehicle efficiency improvements such as enhanced vehicle maintenance; increased fuel use efficiency; and, streamlining of vehicle body design.	• Improved road maintenance • Better urban planning • Non-motorized transport • Mass transit systems (buses, trains, rail) • Enhanced telecommunications and postal services	• Removal of lead • Ethanol • Natural gas and LNG • Catalytic Converters • Electric vehicles

Regulatory Measures

This includes elimination of leaded gasoline fuel, more efficient engines, catalytic converters, elimination and/or cleaning up of high-mileage gross polluting vehicles as well as replacement of two-stroke by four-stroke motorcycles (Karekezi *et al*, 2003). In addition, improvements in the specification of available fuels can reduce emissions. Regulatory and fiscal means can be used to promote cleaner fuels and technologies by encouraging changes in vehicle design and performance characteristics and in the type of fuel used (Gorham, 2002). Removing subsidies and increasing fuel taxation can help reduce fuel consumption in the transport sector (UNCHS, 2003).

Improved operational efficiency of the transport modes through better road system management and regulation can also reduce transport fuel use. Better traffic management ensures smooth traffic flow thus reducing energy use and associated vehicle emissions from intense stop/go operation vehicles (UNCHS, 2003).There is urgent need to reverse the urban road decay now occurring in many African countries. One of the key reasons for this decay are the absence of clarity concerning which institutions have jurisdiction over urban road development and maintenance, as well as inadequate funding (Karekezi *et al*, 2003). It is more cost-effective to improve the capacity of the existing roads by more efficient traffic management than it is to build new roads (Baguant and Bunjun, 2002).

Energy Efficiency

Vehicle maintenance is an important option as poorly maintained diesel engines in trucks and buses are a major source of particulates in the atmosphere. However, this is only the visible component of vehicle emissions; invisible gases such as carbon monoxide, nitrous oxide and ozone, together with lead in petrol, also pose a threat to human health (Baguant and Bunjun, 2002).

Regular vehicle maintenance would help reduce per kilometre emissions of pollutants. Although emission and fuel efficiency performance deteriorate with age, good maintenance practices can greatly reduce the rate of this deterioration.

Infrastructure Development

Better land use management can reduce transport energy consumption by streamlining the integration of urban settlements and transportation systems. It underlines the need for coordinated and integrated planning of land use and for development of urban transport infrastructure (Karekezi *et al*, 2003).

An important option is promoting integrated development of different elements of transport system from walking and cycling to rapid bus and rail transit, such that they complement each other. Substituting travel by car with public transport, non-motorised modes or cleaner fuel two-wheelers will often result in reduction in energy use and emissions, as will the use of carpools (Gorham, 2002). Increased use of public transport systems combined with better traffic management can enhance the effectiveness of urban transport systems while reducing air pollution (Karekezi *et al*, 2003).

The trial public transport system in Tunis, **Tunisia** is unique as it is the only city in the Maghreb region that has developed a light rail transit system (or modern tramw ay), which in 1997 included four main lines over some 42km. The success of the system encouraged the authorities to study and plan further regional railway infrastructure to keep up with urbanization and demand trends.

Cost effective public transport programs such as bus rapid transit (BRT) potentially have large benefits on climate change (Karekezi et al, 2003). Although outside Africa, the example of **Brazil's** Curitiba BRT system is an example of effective urban planning. Curitiba opted to use buses as its primary means of transport as they were most effective and have been the choice of transport in the past (Horizon International, 2000).

Another option is non-motorised transport (NMT) which is more affordable to the poor, has zero emissions, and reduces consumption of fossil fuels. Currently, most African cities lack continuous and secure NMT infrastructure. The needs and priorities of pedestrians and cyclists rarely feature in urban transport policy, and road funding statues and procedures do not make significant allocations for NMT investments. Greater attention to non-motorized transport can improve the efficiency of the urban transportation system and reduce local air pollutants (UNCHS, 2003; Karekezi *et al*, 2003; Baguant and Bunjun, 2002). There is data indicating an increase in the use of NMT in selected industrialized countries. This data could be used to convince sceptical African policy makers of the benefits of NMT both in urban planning and sustainable transport energy consumption.

Although arrangements to provide relatively poor people with credit for non-motorized transport are rare, several schemes have been successful. In Burkina Faso and Zimbabwe, these have been associated with Government-financed integrated rural development programs (World Bank, 1996).

Cleaner/Alternative Fuels and Engines

This includes elimination of leaded gasoline fuel, more efficient engines, catalytic converters, and the use of alternative fuels such as natural gas, ethanol, rape-seed fuel or electricity as a substitute or to complement petroleum fuels. These measures reduce local and regional pollutants as well as mitigate GHG emissions. In a bid to reduce domestic consumption of the already-declining stock of petroleum, public buses in Cairo (**Egypt**) have switched to running on compressed natural gas (CNG). There is a pilot program for taxis to run on CNG. Some 20,000 taxis in Cairo have been modified to run on CNG as part of the program. To support this project, 17 CNG service stations are supporting the project (Office of Fossil Energy, 2003). Consumption of LPG as a motor vehicle fuel in **Algeria** has been growing. Between 2001 and 2002, LPG consumption increased by about 17% (from 217,000 tonnes to 253,000 tonnes). There are 286 petrol stations equipped with motor vehicle LPG facilities and about 2,400 conversion-to-LPG centres. In the very long term, electricity and hydrogen could be attractive options for powering vehicles in parts of Africa (most likely South Africa and the Maghreb region).

6.0 Prioritizing Response Options

One of the key issues that arise from findings of the preceding chapters is the need for a differentiated approach for sustainable energy consumption in Africa. Selected options should reflect the specific characteristics of each of the three sub-regions factoring in the different consumption patterns, energy types consumed, and prevailing economic conditions. The following is a summary of the options proposed by the paper.

- *Household*
    - Improving data collection on traditional biomass use
    - Efficient energy use in the households [6]
    - Provision of efficient biomass energy technologies
    - Sustainable and controlled tree harvesting for fuelwood or charcoal production
    - Fuel switching

- *Agriculture*
    - Improved data collection on energy use in the agriculture sector
    - Improved use of available mechanical and animate energy
    - Efficient energy use
    - Improvement and modernization of biomass energy use (IBTs)
    - Greater use of other renewable energy resources and technologies

- *Transport*
    - Regulatory measures
    - Energy efficiency
    - Infrastructural development
    - Cleaner/alternative fuels and engines

The priority given to each of the above options would differ for each of the sub-regions (North Africa, sub-Saharan Africa and South Africa). This section attempts to categorise the options that would be best suited for the regions and highlighting the options that would be applicable across the continent.

Response Options for Promoting Sustainable Energy Consumption in Africa			
	North Africa	**Sub-Saharan Africa**	**South Africa**
Household	• Efficient energy use at the household level	• Improving data collection on traditional biomass • Efficient energy use at the household level • Provision of efficient biomass energy technologies • Sustainable controlled tree harvesting for fuelwood or charcoal production • Fuel switching	• Efficient energy use at the household level
Agriculture	• Improved data collection on energy use in the agriculture sector • Efficient energy use • Greater use of other renewable energy resources and technologies	• Improved data collection on energy use in the agriculture sector • Improved use of available mechanical and animate energy • Efficient energy use • Improvement and modernization of biomass energy use (IBTs) • Greater use of other renewable energy resources and technologies	• Improved data collection on energy use in the agriculture sector • Efficient energy use • Improvement and modernization of biomass energy use (IBTs) • Greater use of other renewable energy resources and technologies

[6] *This includes energy efficient household appliances (fridges, cookers, washing machines, etc) as well as standards and public awareness programmes that promote energy efficient appliances and buildings. This is especially appropriate for North Africa and South Africa*

Response Options for Promoting Sustainable Energy Consumption in Africa			
	North Africa	**Sub-Saharan Africa**	**South Africa**
Transport	• Regulatory measures • Energy efficiency • Infrastructural development • Cleaner/alternative fuels and engines	• Regulatory measures • Energy efficiency	• Regulatory measures • Energy efficiency • Infrastructural development • Cleaner/alternative fuels and engines

A rather simplistic way of identifying the most appropriate option for the continent on a whole could be to identify the options that appear to be applicable in all the sub-regions. These are:

- Efficient energy use at the household level
- Improved data collection on energy use in the agriculture sector
- Greater use of other renewable energy resources and technologies (excluding biomass) in the agriculture sector
- Regulatory measures in the transport sector
- Energy efficiency in the transport sector

In terms of institutional and policy measures that would be needed to advance the aforementioned sustainable energy options, the following set of measures could be considered:

- Setting targets, which include identifying and setting goals for the incremental contribution of sustainable energy to total national energy supply. The use of tradable sustainable energy certificates could assist in further promotion of sustainable energy options in Africa.

- Ensuring the level playing field for sustainable energy options and conventional energy forms e.g. eliminating explicit and hidden subsidies to the conventional energy industry.

- Enacting a legal and regulatory framework that facilitates the development of sustainable energy options and provides, among other incentives, access to the grid and transportation fuels market.

- Setting up regional funds for financing large scale sustainable energy investments in Africa – for example, a sustainable energy fund for Africa could be a core component of the energy initiative of the New Partnership for African Development (NEPAD).

A more elaborate set of interventions and policy options will be developed at a forthcoming UN-DESA, UNEP and Government of Morocco Regional Conference on Sustainable Consumption in Africa scheduled to be held in Morocco in May, 2004. It is the hope of the authors that the aforementioned set of options would constitute an adequate starting point for the elaboration of a comprehensive set of policy options that would be able to ensure sustainable energy consumption in Africa in the near-term as well as in the long-term future.

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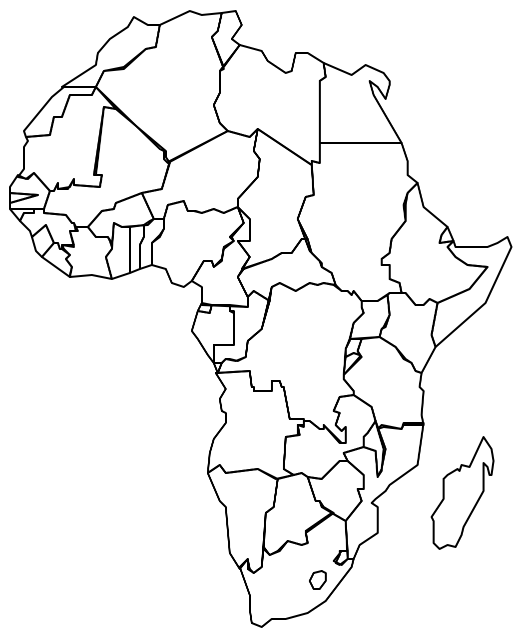
8.0 Appendices

Appendix 1: Socio-Economic Data and Information

Africa has 32 of the 49 least developed countries (LDCs) in the world (UNCTAD; 2002). As pointed out by the World Bank, the GDP per capita in the continent is low, typically less than US$ 746.3 in 2001 for 27 of the states classified by the World Bank as low-income economies (World Bank, 2003a).

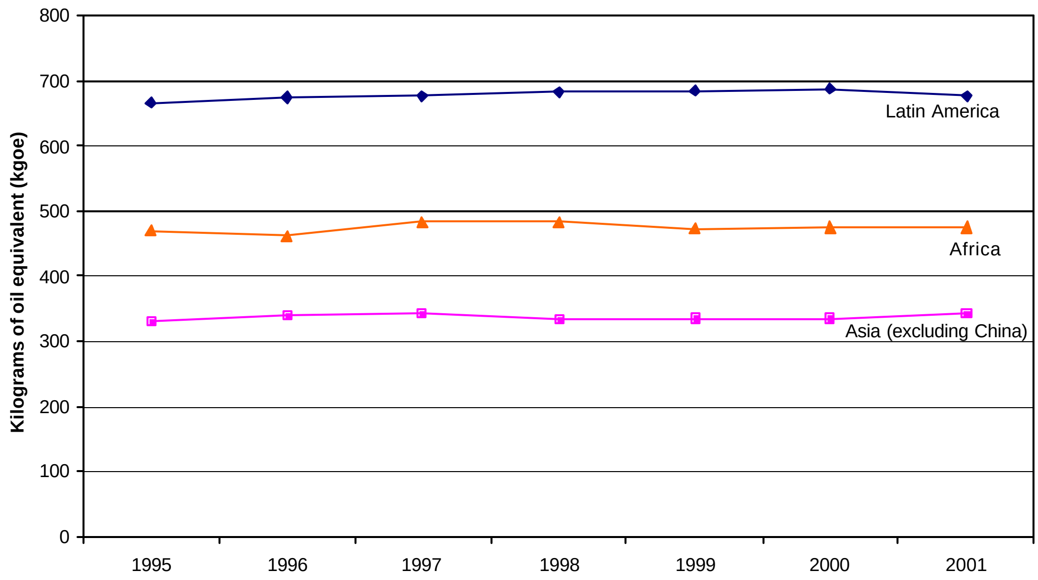
Figure 8.1: Brief African Profile



Africa: Selected Indicators
Land area ('000 km ^{2}): 29,364 **Total number of independent countries:** 53 (2001) **Total number of LDCs countries:** 32 (2002) **Total continental population (millions):** 814.80 (2001) **Urban population as % of total population:** 37.8 (2001) **Rural population as % of total population:** 62.2 (2001) **Average population growth rate (%):** 2.1(2001) **Population Density (people/km ^{2}):** 27 (2001) **GDP (million US$):** 608,094 (2001) **GDP Growth Rate (%):** 3.4 (2001) **GNP per Capita (US$):** 664 (2001) **Energy Sources:** Coal, combustible renewables and waste (CWR), electricity, gas, petroleum products **Total Primary Energy Supply (mtoe):** 514.33 (2001) **Total final consumption (mtoe)**: 387.89 (2001) **Modern Energy Consumption per capita (kgoe):** 200.74 (2001) **Total final consumption per capita (kgoe)**: 476.06 (2001) **Electricity Generation (GWh):** 464,006 (2001) **Total Electricity consumption (GWh):** 418,470 (2001) **Electricity Consumption per Capita (kWh):** 513.57 (2001)

According to the World Bank (2003a: 5, 6), Africa's population stood at 814.8 million in mid 2001. Africa's population was estimated at 744 million in 1995 (World Resources Institute, 1994) denoting a growth rate of 9.5% in 6 years.

Figure 8.2: Per Capita Energy Consumption in Africa and Other Developing Regions (kgoe)



Source: IEA, 2003

Table 8.1: Physical Demographic and Socio-economic Background for Eastern and Southern Africa, 2001

	Land Area (km^2)	National population (millions)	Urban Population as % of total population	Rural Population as % of total population	GDP (millions of US$)	GDP Growth Rate (%)	GNP per Capita (US$)
Botswana	581,730	1.70	49.40	51.60	7,000	10.58	3,100
Eritrea	124,320	4.23	19.10	80.90	612	-3.62	160
Ethiopia	1,100,000	65.40	15.90	84.10	7,933	6.47	100
Kenya	580,000	30.70	34.30	65.70	9,993	1.18	350
Malawi	118,484	11.30	15.10	84.90	1,714	-1.44	160
South Africa	1,860	43.20	57.60	43.40	175,901	3.13	2,820
Tanzania	883,749	34.55	33.20	66.80	6,784	5.69	270
Uganda	197,097	22.79	14.50	85.50	8,086	4.63	260
Zambia	753,000	10.38	39.80	60.20	4,166	5.23	320
Zimbabwe	391,000	12.82	36.00	64.00	7,460	-10.41	480

Source: AFREPREN, 2003

Table 8.2: Income and Poverty Levels in Eastern and Southern Africa: Population Living Below the Poverty Line.

Country	Year of Study	Rural (%)	Urban (%)	National (%)
Ethiopia	2000	45.0	37.0	44.2
Kenya	1992	46.4	29.3	42.0
Madagascar	1999	76.7	52.1	71.3
Malawi	1998	66.5	54.9	65.3
Mozambique	1997	71.3	62.0	69.4
Tanzania	1993	49.7	24.4	41.6
Zambia	1998	83.1	56.0	72.9
Zimbabwe	1996	48.0	7.9	34.9

Source: World Bank, 2003b

Appendix 2: Energy Production and Consumption Data

Table 8.3: Energy Production by Type in Africa, 2001

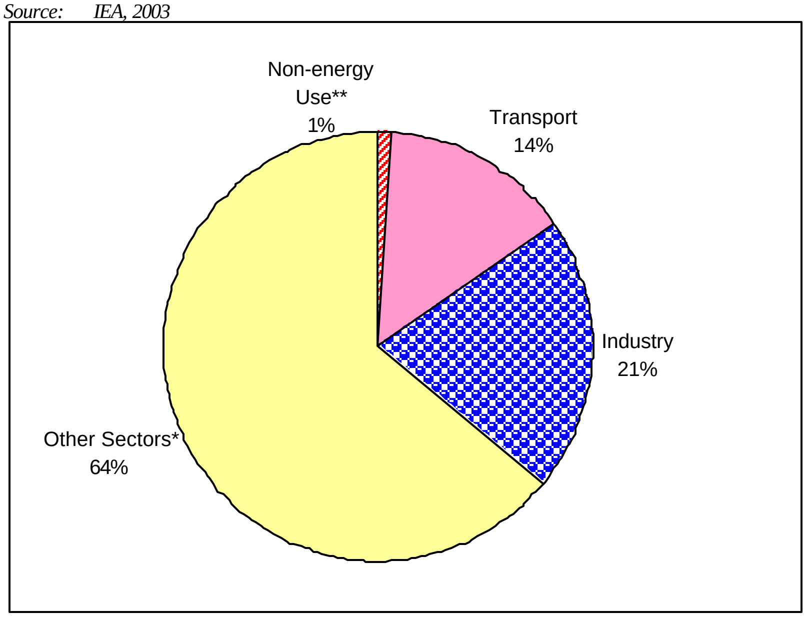
Type	Amount (Mtoe)	Percentage
Solar/wind/tide	0.02	0.002
Geothermal	0.42	0.041
Nuclear	2.79	0.273
Hydro	6.70	0.654
Gas	117.06	11.434
Petroleum Products	126.08	12.315
Coal	131.24	12.820
Combustible renewables* and waste	250.63	24.481
Crude Oil	388.82	37.980
Total	***1,023.76***	***100.000***

* Combustible renewables are mainly fuelwood, charcoal and agro-residues
Source: IEA, 2003

Table 8.4: Energy Consumption by Sector in Africa, 2001

Sector	Amount (Mtoe)	Percentage
Non-energy Use**	4.51	1.19
Transport	53.01	14.01
Industry	79.02	20.88
Other Sectors*	241.93	63.92
Total	***378.47***	***100.00***

Source: IEA, 2003



* Other sectors include agriculture, commercial and public services and residential
** Non energy use covers the use of other petroleum products such as white spirit, kerosene, waxes, lubricants and bitumen. It also includes non-energy use of coal. It assumes that the use of each of these products is exclusively non-energy.
Source: IEA, 2003

Table 8.5: Consumption of Firewood, Kerosene and Electricity in Zimbabwe in 1988

	Firewood (kg/day)	Kerosene (lt/week)	Electricity (kWh/month)
Rural	15.5	0.6	-
Urban	5.6	2.5	282.7
National	15.0	0.8	461.2

- : Data not available

Source: Nyang, 1999

Table 8.6: Fuelwood Consumption in Malawi: 1983-1985 in Million m^3 (Solid Roundwood)

Wood Using Category	1983	1984	1985
Rural households	5.10	5.40	5.54
Urban households	0.90	0.92	0.98
Tobacco industry	2.00	2.10	2.14
Other industries	0.50	0.51	0.52
Total	***8.50***	***8.93***	***9.18***

Source: MFNR, 1986

Table 8.7: Energy Consumption by Sector in Regional Africa ('000 toe), 2001

Region/Country	Industrial (000'toe)	Transport ('000 toe)	Other Sectors ('000 toe)[1]	Non-Energy uses ('000 toe)[2]
North Africa	26,421	18,903	27,608	2,504
Sub-Saharan Africa	24,432	18,944	158,281	1,395
South Africa	26,023	13,593	16,256	556
North Africa				
Algeria	3,836	3,201	8,982	386
Egypt	15,456	8,661	7,970	1,529
Libya	3,231	4,470	2,861	216
Morocco	2,243	919	5,007	204
Tunisia	1,655	1,652	2,788	169
Sub Saharan Africa				
Angola	847	916	4,642	189
Benin	67	350	1,336	N/A
Cameroon	1,018	694	4,336	30
Congo	41	188	448	14
Cote d'Ivoire	278	427	3,452	32
Democratic Republic of Congo	3,032	283	10,919	46
Ethiopia	315	657	17,443	36
Eritrea	19	93	500	8
Gabon	321	285	891	41
Ghana	911	1,070	4,296	60
Kenya	1,187	1,246	8,551	54
Mozambique	913	302	5,273	8
Namibia	62	452	609	6
Nigeria	9,268	8,412	67,212	600
Senegal	469	524	1,424	19
Sudan	2,180	1,300	5,482	119
Tanzania	1,268	582	10,582	15
Togo	99	118	766	65
Zambia	1,157	302	3,595	29
Zimbabwe	980	743	6,524	24
South Africa				
South Africa	26,023	13,593	16,256	556

N/A : Data not available

1. Other sectors comprise of Agriculture, Communication and Publication Servi ces, Residential and other non specified uses

2. Non energy uses chiefly constitute electricity generation.

Source: IEA, 2003

Table 8.8: Energy Consumption by Sector ('000 toe) in Eritrea, 1998

Fuel/unit	Household	Industry	Public/commercial	Transport	Total 1998
Electricity	4.900	5.500	2.680	-	13.090
LPG	0.653	-	0.171	-	0.824
Gasoline	-		2.150	13.880	16.030
Kerosene	18.890	0.030	2.270	-	21.190
Jet fuel	-	-	-	6.870	6.870
Diesel	-	0.950	46.620	56.000	103.540
Light fuel oil	-	10.810	30.710	-	41.520
Bunker,	-	-	-	0.950	0.950
Bitumen	-		2.860		2.860
Lubricants	-	0.150	0.420	2.020	2.590
Firewood	800.500	-	30.180	-	830.680
Charcoal	70.690	-	2.610	-	73.30
Dung	261.470	-	3.900		265.370
Agricultural residue	87.270	-	3.520	-	90.790

\- : Data not available

Source: AFREPREN, 2001; Semere, 2001

Table 8.9: Electricity Consumption by Sector in Egypt (1975-1994)

GWh	1975	1980	1985	1990	1993	1994
Residential	2,468.2	3,461.0	8,080.9	1,262.5	13,382.0	14,719.9
Agricultural	670.0	796.6	1,188.1	1,366.7	1,602.2	1,939.4
Industrial	6,661.4	14,171.8	22,188.8	39,840.9	32,939.8	33,168.7

Source: World Energy Council, 1999-2003

Table 8.10: Energy Consumption by Type in Regional Africa ('000 toe), 2001

Region/Country	Combustible Renewables and Waste (CRW) (000'toe)	Petroleum Products ('000 toe)	Electricity ('000 toe)	Gas ('000 toe)	Coal ('000 toe)	Crude oil ('000 toe)
North Africa						
Algeria	76	8,763	1,691	5,768	82	24
Egypt	1,331	20,728	5,863	5,305	389	N/A
Libya	143	6,953	1,846	1,835	N/A	N/A
Morocco	443	6,252	1,157	37	483	N/A
Tunisia	1,068	3,701	821	640	36	N/A
Sub Saharan Africa						
Angola	4,276	1,776	110	433	N/A	N/A
Benin	1,170	547	36	N/A	N/A	N/A
Cameroon	4,862	988	226	N/A	N/A	N/A
Congo	414	255	23	N/A	N/A	N/A
Cote d'Ivoire	2,716	749	266	458	N/A	N/A
Democratic Republic of Congo	2,821	555	200	N/A	175	N/A
Eritrea	422	181	17	N/A	N/A	N/A
Ethiopia	17,186	1,142	124	N/A	N/A	N/A
Gabon	942	505	90	N/A	N/A	N/A
Ghana	4,100	1,653	584	N/A	N/A	N/A
Kenya	8,620	2,069	309	N/A	41	N/A
Mozambique	5,644	438	413	N/A	N/A	N/A
Namibia	176	746	206	N/A	N/A	N/A
Nigeria	72,024	11,423	919	1,119	6	N/A
Senegal	1,347	981	109	N/A	N/A	N/A
Sudan	6,785	2,111	185	N/A	N/A	N/A
Tanzania	11,406	846	173	N/A	22	N/A
Togo	701	303	44	N/A	N/A	N/A
Uganda	9,000	460	380	N/A	N/A	N/A
Zambia	3,981	522	506	N/A	73	N/A
Zimbabwe	5,675	1,117	895	N/A	584	N/A
South Africa						
South Africa	9,287	16,523	14,616	886	15,115	N/A

N/A : Data not available

Source: IEA, 2003; EIU, 2003

Appendix 3: Additional Household Energy Consumption Data

Table 8.11: Household Fuel Consumption by Sub-region - 1992 (%)

Sub-region	Electricity		LPG/N.G		Kerosene		Fuel-wood		Charcoal		Residues		Coal	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
East Africa	19.6	0.7	7.8	1.7	3.4	6.3	16.8	84.8	52.4	2.8	N.A	3.7	N.A	N.A
Southern Africa	34.5	2.9	5.3	0.2	5.3	2.8	40.4	81.3	14.0	12.7	N.A	0.4	0.2	N.A
West/Central Africa	14.0	3.2	11.0	1.6	9.1	6.7	39.8	76.4	24.8	11.5	1.3	0.5	N.A	N.A
North Africa	22.0	12.2	65.5	30.0	6.3	17.8	4.8	16.2	1.8	5.0	0.0	19.2	N.A	N.A

N.A : Data not available

ADB, 1996

Table 8.12: Urban and Rural Household Energy Consumption in Ethiopia

Energy Sources	Rural (%)	Urban (%)
Fuelwood and charcoal	82.2	74.7
Dung	9.8	7.8
Agricultural residues	8.4	6.3
Kerosene	0.0	7.6
LPG	0.0	0.6
Electricity	0.6	3.0

Source: GTZ, 1998

Table 8.13: Estimated Percentage of Rural Household Income Spend on Energy in Ethiopia

Percentage of Monthly Income Spend on Energy By Income Bracket	60-90	91-180	181-240	241-360	361-420	>420
Woodfuel (56.78 Birr/cum)& agricultural wastes	a	a	a	2.5	2.9	3
Charcoal (21Birr/small sack)	b	b	b	2	2.5	3.5
Kerosene (2.85 Birr/litre)	3.8	4.2	4.1	2.9	2.9	2
Electricity (0.42 Birr/kWh)	c	c	4	4.2	4.3	5
Matches (0.35 Birr/box)	0.2	0.15	0.1	0.05	0.04	0.03
Candles (6 Birr/pack of 8)	d	d	1.4	1	0.75	0.7
Dry Cells (1.9 Birr/pc)	e	1.8	1.2	0.4	0.3	0.3
Total Estimate (%)**	4.3	6.2	10.8	12.1	13.2	13.4

Source: Wolde-Ghiorgis, 2001.

Notes:

a. Rural people with the lowest incomes are still totally dependent on gathered fuel wood, twigs, branches, agricultural wastes and dung. Other than for cooking purposes, agricultural wastes and cattle are also used fro preheating and boiling purposes.

b. Again rural people on the lowest income scale do not use charcoal.

c. Rural electrification has been reaching slowly those areas with relatively higher incomes and minimum scales of urbanization.

d. Candles have mostly been made from locally available wax in many rural areas. For lighting purposes, most rural households depend on kerosene lamps.

e. The use of dry cells is associated with torches and small radios, which are not yet commonly used by the largest and lowest income groups in the rural areas.

** The total estimates appear to be too high for the relatively higher income groups.

Table 8.14: Estimated Percentage of Rural Household Income Spend on Energy in Zambia

Income Group (Monthly)	Energy Form	Cost (US$)	Energy Percentage of Household Income (%)
Low Income Between US$ 31 – 62	Woodfuel Kerosene	1.00	2.7
High Income Above US$ 248	Electricity Electricity	12.40 52.50	5.0 21.2
	Charcoal Candles Kerosene	9.99	4.0

Source: Mbewe, 2001

Table 8.15: Energy Expenditure as Percentage of Total Household Income - 1992 (By Sub-Region)

Sub-Region	Energy Expenditure (as % of income)
East Africa	12.70
Southern Africa	11.90
West/Central Africa	14.06
North Africa	7.90

Source: ADB, 1996

Future potential for natural gas consumption in residential (household) and commercial sectors in Nigeria will strongly depend on the development of transportation and distribution infrastructure in the country. The eventual rate of penetration will also depend on the price of natural gas in the market relative to prices of LPG and kerosene and consumer ability to afford end-use equipment (Dayo and Adegbulugbe, 1988).

Table 8.16: Percentage Share of Energy Sources in Senegal

Energy Type	Percentage Share (%)
Forest-based traditional fuels (fuelwood and charcoal)	53
Petroleum fuels	34
Electricity	12
Agricultural residues	1

Source: Sokona, 2000

Table 8.17: Rural Electrification in Egypt (%)

	1975	1980	1985	1990	1993	1994
Households	55.0	60.0	88.5	90.0	92.0	95.0
Schools	57.0	61.1	88.6	100.0	100.0	100.0
Clinics	57.0	61.1	88.6	100.0	100.0	100.0

Source: World Energy Council, 1999