Renewable Energy Strategies for Rural Africa: Is a PV-led Renewable Energy Strategy the Right Approach for Providing Modern Energy to the Rural Poor of Sub-Saharan Africa?

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Abstract

Rural areas continue to be home to majority of the population in Africa. The importance of providing modern energy to rural areas cannot therefore be overemphasised. Despite numerous efforts by Governments and donors in the region to promote solar photovoltaics for rural electrification, (almost every country in the region has had a rural electrification PV project), access to modern energy in rural Africa continues to be woefully low. In addition to being unaffordable to the rural masses, solar PV has the limitation that it can only be used for lighting and powering low-voltage appliances. This article reviews emerging trends in the rural energy sector of sub-Saharan Africa, and discusses the limitations of over-reliance on solar PV. It suggests possible options that could have greater impact on rural clean energy development. For the majority of rural households in the region, biomass fuels will continue to be the dominant fuel of choice. Efficient technologies for the use of biomass would, therefore, ensure that scarce biomass resources are effectively utilised, and reduce the negative impacts of biomass use on women and children's health. Solar thermal, windpumps, micro/pico hydropower and cleaner fuels such as kerosene and LPG, have not received adequate attention from policy makers. These energy options could significantly improve the performance of rural small and micro enterprises. This article argues that rural energy policies that emphasise a broader range of renewables that target income-generating activities are likely to yield greater benefits to the rural poor than the current policies that rely on the solar PV option.

Keywords: *rural energy; rural poor; PV;*

1. Introduction

In spite of the rapid urban growth that Africa has experienced over the last 20 years, the majority of Africans still reside in rural areas. Although this distribution is likely to change in the not-too-distant future, rural Africa continues to be home to the majority of Africans (*see brief regional profile*). This is particularly true of Sub-Saharan Africa, as shown in figure 1 (UNDP, 2000). It is estimated that 68% of inhabitants of Sub Saharan Africa reside in rural areas (World Bank, 2000a). Provision of modern energy services to this large segment of Africa's population is therefore of paramount importance.

{Insert Brief Regional Profile: SSA}

In addition, the bulk of rural inhabitants are poor, with irregular income flows.

Figure 1: Percentage of Population in Rural Areas (1998)

1.1 Energy Use in Rural Africa

Sub-Saharan Africa is the least electrified region of the world, with rural electrifications levels that are routinely below 5% (see table 1). With the bulk of the region's poor residents in dispersed rural settlements, conventional grid electrification is considered too costly for most of rural Africa. The dispersion problem is more acute in Eastern and Southern Africa where in contrast to the village settlement patterns of West Africa, the majority of rural population resides in dispersed homesteads. The transmission and distribution costs of extending grid electricity to dispersed homesteads is high, thus creating an ideal market for decentralised energy technologies that better match the dispersed nature of sub-Saharan Africa's rural population. As a result, the region is perceived to be the ideal place for the deployment of new and innovative electrification technologies that will not only be cost effective but also environmentally sound. Renewables are often recommended as the most appropriate energy technology choice for much of rural Africa.

Table 1: Percentage of Rural Households Electrified, 2001

Quantitatively, fossil fuels and conventional energy sources such as electricity play a minor role in rural energy supply demonstrated by the low electrification levels. However, the contribution of these energy forms is valuable because of their numerous productive functions. Diesel is used in small agro-processing activities such as grain milling and in rural transport. These are important rural economic activities and may often represent the only major sources of income outside the sale of agricultural produce. Similarly, electricity may be used for vehicle and agricultural equipment, repair workshops and in small-scale commercial establishments such as restaurants, shops and guesthouses. In addition, electricity is often vital for proper operation of key rural institutions such as schools, dispensaries and hospitals.

The term 'biomass energy' refers to a wide range of natural organic fuels such as wood, charcoal, agricultural residues and animal waste. As shown in table 2, in the household sector, which is the largest energy consumption sector in many African countries, rural households consume higher amounts of energy (Kgoe) than urban households. This is, due to the large amount of biomass used in rural areas.

Table 2: Per Capita Energy Consumption of Urban and Rural Households (Kgoe) – 1992

Biomass energy is the dominant energy form for most African countries. Figures for sub-Saharan African countries indicate that a high proportion of total national energy supply is derived from biomass energy. For example, biomass energy is estimated to account for 95%, 84% and 70% of the total national energy supply of Uganda, Sudan and Kenya, respectively (WEC, 1992; World Bank, 2000a).

Biomass is currently used largely in its traditional and unprocessed form. The bulk of the biomass energy is used for household cooking purposes. Other important end-uses of biomass energy in the rural areas include small-scale charcoal production, agro-processing and beer brewing.

Although there has been limited success, in a growing number of instances, substantial numbers of RETs have been disseminated in the region. Numerous improved stove programmes have been introduced in the region with positive results. Wind pumps for water pumping have been disseminated for areas with sufficient wind potential (3m/s), while pico and micro hydropower have shown potential (Karekezi and Ranja, 1997).

Conventional wisdom perceives photovoltaic (PV) energy as the most attractive renewable energy options. As the least electrified continent in the world, rural Africa is often portrayed as the most important region for the dissemination of PV technology. Consequently, many national renewable and rural energy strategies have often given priority to the dissemination of PV technology.

Almost every country in the region has had a Solar PV project. This substantial investment and emphasis on Solar PV, however, has not been matched by increased access to modern energy. This is evident in the very low rural electrification levels common in the region.

In general, energy use in rural areas can be subdivided into the following 3 categories:

- Household energy;

- Energy for Agriculture;
- Energy for Small and Micro Enterprise (SMcE).

This article examines the viability of solar PV in each of the categories mentioned above. Energy use in medium-scale and large rural enterprises such as sugar, tea and coffee estates, is not addressed by this article because of its indirect link to the rural poor.

Household Energy

The bulk of energy consumed in rural areas is used in households. Households require energy mainly for cooking, lighting and space heating. Cooking accounts for between 90 and 100% of energy consumption. The rest of the energy consumed is for lighting, provided either by woodfuel (cooking fire), kerosene lamps and candles. Space heating is required in areas with cold climates, and is often catered for by energy used for cooking (WEC/FAO, 1999).

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. Table 3 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 and LPG.

Table 3: Rural Energy Use Patterns in African Countries by End Uses

Firewood remains the most common fuel for cooking in most African countries. As shown in the following table below, Botswana, South Africa and Djibouti are exceptions in that although a substantial part of their rural populations use firewood, the use of modern fuels such as kerosene, LPG and electricity are fairly high (World Bank, 2000a).

Table 4 Fuels used for cooking in rural households for selected African countries (% of fuel used)

The predominance of firewood as the dominant source of cooking energy, despite its inefficiency and harmful impact on human health, could be attributed to its availability as a 'free' source of energy. In most cases, firewood is collected and not purchased. In some cases, factors such as taste imparted to food could cause households to shun 'improvements' such as more efficient stoves that do not satisfy their customs and preferences. For instance, in a village in Sierra Leone, households would not switch from firewood due to food tastes, safety and the wider range of cooking methods that are possible with an open fire (WEC/FAO, 1999).

Women and children are more likely to be adversely affected by particle emissions from biofuels smoke because they spend much of their time near biomass-based cooking fires. Studies have shown that there are links between biomass combustion and respiratory illnesses in women and children (Karekezi and Ranja, 1997). Approximately 4-5 million children in developing countries die annually due to acute respiratory infections. A recent study in a rural area in Kenya found that women, who undertook most of the cooking at the household level, 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 (Schirnding, 2001).

Figure 2: Indoor Levels of Particulates Emitted from Wood in Developing Countries

The link between rural household energy use and women is one 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 (WEC/FAO, 1999).

Gender issues in energy have received attention at micro level in terms of technological interventions such as cookstoves, biogas, solar cookers, wood plantations and so on. They have are to be addressed substantially in macro level policies in most countries in the region.

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, William and Johansson 1997).

A relatively high proportion of households in rural areas of the region are female-headed: for instance 30% in South Africa (Mandhlazi, 2000), and 27% in Zambia, (Chandi, 2000). Available data indicates that the consumption of modern energy in female-headed households is lower than the consumption in male-headed households. A survey carried out in four rural areas of Zambia found that of the 174 households sampled, paraffin/kerosene was used in 18% of female headed households, compared to 82% of male headed households (Chandi, 2000). This could be attributed to the fact that male-headed households generally have higher incomes, since men provide a second source of household income. In addition, women are, in most cases, employed in the rural informal sector, where their incomes are lower and unstable.

A simple, yet not common, solar technology that could improve the health of poor women and children in rural areas is solar water disinfection. This technology uses energy from the sun to destroy pathogens in water. In Latin America, where this technology has gained significant attention, transparent bottles are filled with water and left in the sun for 6 hours. This is sufficient time to destroy 99.9% of faecal pathogens and make the water safer for drinking (Tores and Salas, 2001). The investments for this technology are negligible (mainly plastic bottles), yet its benefits could prove crucial to improving the health of the rural poor.

At the household level, electricity from PV has little impact on cooking in rural households, which is the highest end use of household energy. PV technology, therefore, does not reduce inefficient biomass energy use in rural households, which affects the health of women and children as mentioned earlier.

Kerosene is the most widely used modern energy source for lighting in rural areas. The use of kerosene normally involves relatively high costs for kerosene lamps and fuel. Firewood is another important fuel for lighting, and it does not require additional investment. For high-income rural households, electricity (either from the grid or gensets) is an option. Electricity is, however, not an important option for low-income households for lighting, due to its high up-front costs.

In the recent past, solar PV has been promoted in rural areas for meeting household lighting needs. For example in Kenya, between 1998 and 2001, the PV industry did more than US$10 million worth of business (Hankins, 2001). Assuming that most of the PV systems were sold in rural areas, this substantial amount of investment does not seem to have had a significant impact on the level of rural electrification, which is roughly 2% (Nyoike, 2000).

Table 5 Main Source of Fuel for Lighting in Rural Areas, Botswana and Uganda, 1994

In spite of high expectations and significant investment levels, the dissemination levels of PV technology in sub-Saharan Africa continue to disappoint. The expectation that millions of rural homes will install PV systems has failed to materialize.

High cost is one of the most important barriers to greater dissemination of PV technology in sub-Saharan Africa. The cost of a typical low-end PV household system is several times higher than the GNP per capita of most sub-Saharan African countries (table 6). This comparison actually underestimates the relative high cost of the PV systems because the GNP per capita figure overestimates rural incomes by including the high-income urban residents. Rural inhabitants of sub-Saharan Africa are poorer than their urban counterparts and their income flows are often less regular.

Table 6 GNP per Capita and Cost of 40-50Wp Solar PV System

Another way of looking at table 6 is to divide the cost of a typical low-power PV system by the GNP per capita. It translates the expenditure on the PV systems to an outlay of 131% to 364% of the prevailing GNP per capita. This averages to about 200% of the GNP per capita, and, if it were to be applied to the USA or a typical European country, it would translate to an expenditure of over US$50,000. This figure is equivalent to almost twice the cost of a medium range saloon vehicle. It is unlikely that anyone in the USA or Europe would be willing to make such an investment for a device that delivers some light and powers a radio and perhaps a black and white TV. On the other hand, it is quite feasible to expect a typical small-scale entrepreneur in the USA or Europe starting a business with such a sum. It is precisely for this reason that this paper argues that the most successful renewable technologies in rural Africa are likely to be the ones that can generate income and facilitate the start-up of small micro-enterprises. PV, as this paper will later demonstrate, is generally unsuitable for powering rural enterprises.

One could argue that the use of the GNP per capita figure is misleading, as it does not represent household income. The typical size of a rural household is about 6 persons. Multiplying GNP per capita by 6 should provide a more realistic figure of income. But as shown in table 7, the cost of a typical PV system is still prohibitive. It is about 22% to 61% of GNP per household. Using the above parallel, it is the equivalent of a European or American spending US$5,500 to US$20,000 for a device that provides light and powers communication devices.

Table 7: GNP per Household and Cost of 40-50Wp PV System

An even more realistic assessment would be to compare the cost of a typical PV system with estimated rural household incomes as shown in table 8. The comparison still indicates that the cost of a PV system is still too expensive for most poor rural households – it is equivalent to 100-200% of the annual income of a rural household.

Table 8: Annual Rural Household Income for Selected Sub-Saharan African Countries

For many rural households, the capital required to purchase a PV system represents a huge investment. For example, in Kenya, the typical cost of a PV system can purchase up to 3 cows, which can transform the lives of a typical rural family. Alternatively, the household may prefer to purchase 4 to 5 bicycles (more if procured on the second hand market), which can be leased and provide the family a steady stream of income. In some parts of sub-Saharan Africa, the investment of a typical PV system could build a new house for the family. Additional comparative costs of rural energy devices that could significantly improve rural household income are given in table 9.

Table 9: Comparative Costs of Solar Panels and Other Rural Energy Devices

It is often argued that the removal of duty and import taxes combined with the introduction of credit systems would make PV systems more affordable to the rural poor households. This argument would also apply to alternative application of investments. Might it be more useful to remove duties and taxes and institute credit systems on energy technologies that would generate income and create micro enterprises in rural areas?

Studies in Kenya and Namibia confirm that most poor rural households cannot afford even the low-end 18Wp PV solar systems.

This assessment is further bolstered by the fact that the largest number of installations is found in the richer African countries such as South Africa and Namibia. The GDP per capita of these two countries are 6 to 10 times higher than the typical GNP per capita of most sub-Saharan African countries (World Bank, 2001a).

1.2 Energy for Agriculture

The agricultural sector accounts for a substantial proportion of the region's GDP: over 20% in most countries (World Bank, 2000b). Agricultural commodities such as coffee, tea and tobacco often dominate the export sector of most African countries. 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.

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 policy makers in the region in terms of provision of high-grade energy services.

2. 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. 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 (FAO/ADB, 1995).

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. Table 10 estimates animate power requirements for various agricultural activities.

Table 10: Human Power Consumption for Various Farming Activities

An important view to consider when estimating the amount of human energy available for agricultural activities in rural areas is the amount of calories contained in food intake. In many countries in the region, daily per capita calorie supply is below 2,000 Calories (2.32 kWh), as compared to 2,200 Calories (2.55 kWh), which is the recommended daily average calorie intake (The National Energy Foundation, 1995). The average per capita calorie intake figure includes urban and higher income groups. Realistically, for low-income rural inhabitants in sub-Saharan Africa, the daily calorie intake is significantly less than 2000 calories. The daily per capita calorie intake needs to be used with caution because it includes allocations for children, who may not be fully involved in agricultural activities.

It would appear that the daily per capita calorie intake in rural areas is insufficient for a full day's agricultural work (Table 10). If one factors in the debilitating impacts of frequent food shortages, famine, disease, drought and floods, it is most likely that few in rural sub-Saharan Africa have access to adequate calorie intake.

Women play a vital role in agricultural activities in rural areas of many countries in the region. 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% as stated earlier (Reddy, Williams and Johansson, 1997 and Chandi, 2000). Women are heavily involved in cultivation, planting harvesting and marketing of agricultural produce. Their work is highly fragmented and a high value is placed on time saving, especially during peak agricultural periods (WEC/FAO, 1999). Modern energy would therefore go a long way in enhancing the productivity of women in agricultural activities.

An analysis of rural transport activities in Tanzania revealed that women spend more time than men in both agricultural and household related transport activities (Figure 2). Women were found to spend 70% of their time on transport. Assuming that they are walking, this translates to 1170 Calories used only for walking (Balbach, 2000). Given an average Calorie intake of 2000 (which, as mentioned earlier, is likely to be an underestimate), and the other activities that women must perform, it appears that women are overburdened. The heavy reliance on women in labour combined with low calorie intake may explain the low and declining levels of agricultural productivity in much of sub-Saharan Africa. The increased use of modern energy in rural areas could relieve this burden on women.

Figure 3: Rural Transport Activities by Males and Females, Tanzania, 1987

Another important source of power found in most rural areas of the region is animal traction. Cattle and donkeys provide transport, pull implements, lift water and are used in processing activities such as cane crushing and threshing. In contrast to much of Asia, use of animal power is underdeveloped in much of sub-Saharan Africa. Reasons for this state of affairs vary, the most common being the prevalence of animal diseases such as trypanosomiasis.

Semi-mechanized technologies include basic hand tools (hoes, slashers), semi-mechanized hand tools (hand-driven threshers) and animal drawn tools (ox-ploughs). Reliance on hand tools has generally been the norm throughout the region (FAO, 1995), with limited use of semi-mechanised hand tools and animal drawn tools. Mechanized technologies such as tractors are not widely used in the region. The stock of tractors in Africa was estimated to be about 540,000 in 1994. Over half the tractors were in three countries, Algeria, Egypt and South Africa. This is less than half the total number used in Latin America, which stood at 1,214,093 tractors in 1994, (WRI, 1998).

A number of renewable energy technologies have demonstrated an encouraging level of success in meeting the demand for energy for agriculture in rural Africa.

Table 11 Renewable Energy Technologies Applications in Agriculture

In particular, the following technologies have shown promise (Karekezi and Ranja, 1997):

- Small hydro plants for shaft power and electricity generation
- Biogas plans which provide sludge for use as fertiliser
- Solar crop dryers

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 12, 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 12: Wind Energy Potentials and Number of Wind Pumps in Selected Countries

In the agricultural sector, electricity from PV is 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. These average US$21/Wp (McNelis et al, 1992), and are unattainable for the rural poor.

Table 13 shows the cost of various solar PV pumping sets.

Table 13: Costs of PV Pumping Systems

3. Energy Use in Small and Micro Rural Enterprises

A wide range of small and micro enterprises (SMcE) exists in rural areas. In this article, the term 'small and micro-scale enterprises' refers to entities that largely rely on family/household members with limited use of non-household members. Most of these enterprises are based in the informal sector, and can be categorised into commercial/service enterprises and production enterprises. Commercial/ service enterprises include small shops, beer halls and battery recharging centres. Production enterprises are largely agro-based, and include saw milling, grain milling and pottery making.

The range of small and micro-enterprises in different rural areas of the region share similar characteristics (e.g. reliance on family labour). However the types could vary depending on cultural and socio-economic conditions. Table 14 presents an inventory of rural micro-enterprises in three eastern and southern African countries.

Table 14: Examples of Rural Income Generating Activities

Biomass consumption is still dominant in many small and micro rural enterprises. Examples of enterprises that largely rely on biomass include beer brewing, fish smoking, baking and tobacco curing. For example, tobacco curing uses 23 percent of total fuelwood consumption in Malawi (Kgathi and Mlotshwa, 1997), while beer brewing consumes 25% of total fuelwood annually in Zambia. Lighting, motive and shaft power needs are invariably met using modern energy sources, for example, electricity from the grid or from gensets, kerosene or solar PV.

The estimated power requirements for small industries in rural areas are significantly higher than those of typical rural households. As shown in table 17, these range from 2,000w (power mills) to 163,000w (oil mills), (WEC, 1992).

Diesel generators are preferred for applications requiring 3 kWp and above. Micro and Pico hydropower is also used to provide motive and shaft power in some countries. Wind pumps and wind generators can be instrumental in the provision of energy to small and micro enterprises. Table 15 shows the typical uses of different sizes of wind generators. The dissemination of wind turbines in the sub-Saharan African region has, however, been very limited. This is partly attributable to low wind speeds and high costs (Karekezi and Ranja, 1997).

Table 15: Typical Applications of Wind Generators

Table 16: Renewable Energy Technologies for Small and Micro Rural Enterprises

Women participate in a large number of rural enterprises. In a study carried out by ZERO on 'Energy and Sustainable Rural Industries', women were found to be major players in rural micro-enterprises. The Zimbabwe study found that although the majority of micro-enterprises tended to have a mixture of men and women, 89% of the bakeries were owned and managed by women. Beer brewing was generally regarded as a female activity, and 95% of the brewing enterprises were owned and managed by women.

Unlike the above two activities, the ZERO study found that brick making was male-dominated. This is especially true where brick making is undertaken as an income generating activity. Where bricks were being moulded for domestic use, women dominated (ZERO, 1998). More mechanised technologies for brick making could result in higher productivity and better quality. Brick making for domestic use (female-dominated) is largely characterised by more manual techniques, which increase drudgery and slow down the production process.

Table 17: Gender Distribution in Rural Industries in Zimbabwe, 1998

Most of the income-generating activities that women participate in are fuel intensive, and largely biomass based. Examples include food-processing industries, manufacturing activities and numerous service-sector activities. In addition, most home-based industries depend on biomass fuels. This has direct impact on the participation of women in these income-generating activities, since biomass energy prices and availability affect the viability of their rural businesses.

Table 18 Sample Energy-intensive, Small-scale Enterprises Operated by Women

PV is useful for providing better lighting, for SMcE's run by women in rural areas such as weaving. PV technologies has little impact on energy intensive rural SMcEs such as beer brewing. Beer brewing is the highest source of income for women in rural Botswana and the main source of income in Mkushi District and Northern Province of Zambia (McCall, 2001). Other technologies such as solar drying and improved biofuel stoves could provide useful alternatives for poor rural women enterprises.

While they may be useful for lighting in rural small and micro enterprises, typical solar PV systems (40Wp to 100Wp) cannot meet the energy requirements of rural SMcE's, which are 100 to 1000 times higher. PV technology is unsuitable for agro-processing activities that often represent the most attractive options for generating incomes in rural areas. Agro-processing activities require equipment with a minimum power output of well above 1000Wp. A PV system of this size is often too costly for most rural homes. Consequently, PV is limited to low-power applications such as lighting and communication (powering radios and black and white TVs).

Table 19 Power Requirements for Agro-processing and Power Outputs of Small Scale PV Systems

Rural SMcEs have benefited from lighting provided by PV electrification. Other benefits of PV electricity include cooling, grinding and battery charging. Process heat and shaft/motive power needs for SMcEs, however, cannot be met by solar PV in an economical fashion. In addition, the installation costs of solar PV for lighting far outweigh the benefits. For example, the cost of a 1.3kWp solar PV array is equal to the installed costs of between two and five 5kW-diesel generators. Although their running costs are much higher, each of these generators could provide power for a wide range of uses such as water pumping, irrigation, milling, lighting and entertainment (Hislop, 1992). These extra uses are an important source of income in rural areas, and can cover the running costs of diesel generators, while providing surplus income for the enterprises. The major drawback of diesel sets however, is the use of a polluting fossil fuel.

4. The Case for a Diversified Renewable Energy Strategy

Biomass energy use will continue to dominate rural energy statistics in the region for the foreseeable future. Consequently, increased biomass energy use in rural households and small and medium enterprises is likely to continue to be the norm rather than the exception. Human power and animal traction will also continue to dominate rural agricultural processes. Since biomass is currently used in its traditional and unprocessed form using inefficient technologies, the low level of modern energy penetration in rural areas of the region is likely to persist unless appropriate interventions are introduced.

Conventional wisdom on how to increase modern energy use in rural sub-Saharan Africa often perceives solar PV as the most attractive option. It is argued that PV is ideal for the dispersed rural households and enterprises of Africa and is, in the long-term, a cheaper option than grid-based electricity. Many national renewable and rural energy strategies give priority to the dissemination of PV technology.

As a result, substantial financing in the form of grants and credit has been provided to various initiatives disseminating PV technologies in rural Africa. Experience to date, has, however, been below expectations. For instance, the UNDP/GEF project in Zimbabwe, with funding of US$7 million, installed just over 10,000 systems over six years (Hankins, 2001; Mulugetta et al, 2000). However, it is not clear how many of the systems are still operational. Despite the substantial growth of companies in the PV sector caused by the project (from a handful to 60 by late 1997), only 15 companies existed by the year 2000. In addition, affluent rural household purchased most of the systems, since over 80% of rural population could not afford the smallest systems even at the cheapest rates. Stringent requirements for loan applications excluded the majority of the rural population from qualifying (Mulugetta, et al 2000, Mapako, 2001). In another study on the viability of PV in Manicaland, Zimbabwe, 65% of the rural population could not afford to pay for solar service fee (the lowest cost possible for providing PV-based electricity), while 91.5% could not afford a credit scheme, (Cloin, 1998).

The less visible but equally important drawback of PV technology is its high reliance on imported components. Well over 50% of the cost of PV technology consists of the panel and solar battery, which are often imported and as a result, the potential of PV technology in job creation is severely reduced.

The high import content of PV technology adds an additional load to the foreign exchange reserves of sub-Saharan African countries which are often miniscule and perennially close to exhaustion. With diminishing revenue from unprocessed commodities, the export earnings of most countries have been on a downward trend with little prospect of better world prices in the foreseeable future. For example, sub-Saharan African countries that largely rely on coffee as their main export have seen world prices of coffee fall by two thirds in the last few years. Promoting a technology such as PV with high import content in countries facing a massive fall in export earnings is not good macro-economic practice.

It is therefore evident that future renewable energy strategies in sub-Saharan Africa should de-emphasise PV and give greater prominence to a wider range of renewables that offer more attractive opportunities for income generation and job creation.

One of the key drivers to the interest in disseminating PV technology in sub-Saharan Africa is the pre-occupation with electricity. External observers and experts react with a great deal of concern when shown data indicating that in a typical sub-Saharan African country, less than 5% of the rural population have access to electricity. Since most of the experts come from countries with almost universal electricity access, the thought of any form of development without electricity is perceived as unthinkable. Consequently, numerous electrification programmes have been launched in the region.

In the near to medium term future, greater emphasis on electrification of rural households is unlikely to succeed and would not address the needs of the rural poor in sub-Saharan Africa. What are urgently needed are technologies that can quickly increase incomes to the rural poor in sub-Saharan Africa. Energy technologies that are primarily designed to generate electricity are unlikely to be best candidates primarily for reasons of cost. The following technologies offer a greater range of income generation benefits at relatively low cost:

- Low cost efficient hand tools and animal drawn implements, which would increase the agricultural productivity of rural Africa
- Low cost but more efficient biomass-based combustion technologies (e.g. improved cookstoves, efficient charcoal kilns, brick making kilns, fish smokers, tea dryers and wood dryers).
- Pico and micro hydro for shaft power that can be used to process agricultural produce and increase its value
- Ram pumps for irrigation, which increase agricultural outputs thus generating income to the rural farmer
- Solar dryers that can lower post-harvest losses and enable the rural farmer to market his produce when prices are higher
- Solar water pasteurizers that provide clean potable water and reduce water

borne diseases, which translates to increased availability of labour and thus increases agricultural output and income.

In the near term, the implementation of the following recommendations will greatly assist the dissemination of improved energy technology to the rural poor in sub-Saharan Africa.

4.1 Recommendation 1: Emphasis should be on provision of efficient biomass energy technologies and appliances.

The reality of the rural energy sector is that biomass energy use is bound to continue being dominant. While biomass energy is often perceived in a somewhat negative light, there are attractive opportunities for using biomass energy in a more modern, efficient and environmentally attractive ways.

At the household level, improved rural woodstoves, which are designed to reduce heat loss, increase combustion efficiency and attain a higher heat transfer, would be appropriate for dissemination. However, despite these obvious benefits, improved rural stoves have continued to display low penetration rates when compared to urban stoves, as shown in table below. Increased dissemination of these stoves in rural areas of the region therefore needs to be aggressively pursued.

Other benefits that could accrue from increased use of improved biomass technologies include the alleviation of the burden placed on women in fuel collection, freeing up more time for women to engage in other activities, especially income generating activities. The production and dissemination of improved stoves in rural areas is likely to benefit women. An example is the Maendeleo stove, which was produced and disseminated in Kenya under the Women and Energy Project. Mass production of the stoves was mainly achieved through women's groups, demonstrating that women would benefit directly from similar initiatives (Karekezi and Ranja, 1997).

Additionally, the provision of more efficient stoves can reduce respiratory health problems associated with smoke emission from biofuel stoves.

Table 20 Improved Stoves Dissemination

Improved institutional stoves have also been disseminated in several countries within eastern and southern Africa, and would be ideal for rural institutions such as schools and hospitals. These stoves are designed to reduce running expenditure for institutions through reduced wood-fuel consumption (Karekezi and Ranja, 1997).

At small and micro enterprise level, biomass energy is an attractive fuel for small-scale industrial boilers found in many rural agro-industries. In addition, there are technologies that can improve the efficiency of biomass in traditional energy-intensive rural productive activities such as charcoal production, crop drying, fish drying and beer brewing.

4.2 Recommendation 2: Provision of modern energy (process heat, motive or shaft power) to SMcEs and agricultural sector can be enhanced by liberalisation of both distribution and tariff setting.

Numerous micro-enterprises exist in rural areas of the region. Most of these are energy intensive. For example, beer brewing, baking and agro-processing industries require large portions of mechanised energy (motive and shaft power) and process heat in rural areas. As mentioned earlier, process heat requirements are currently met using biomass, and solar PV would not be an economical option. Other options for providing mechanical power therefore need to be emphasised.

A technology that appears to be promising in terms of motive/shaft power provision is pico and micro hydropower (PMcH). PMcH, unlike other sources of energy, has the great advantage of multiple uses: energy generation, irrigation and water supply. In addition, PMcH is a very reliable technology that has a solid track record. It is ideal for rural areas where grid connections do not reach, and has demonstrated important contributions to rural industrial growth in many countries (Karekezi and Ranja, 1997).

While this technology seems promising, the results of many of the initiatives in the region have been disappointing largely because of the unexpected complexity of developing, selecting and implementing these options (Karekezi and Ranja, 1997). The table below shows the amount of small hydropower (larger than pico and micro) harnessed to date in selected African countries.

Table 21 Small Hydro Power Utilisation in the Region

Nepal is one of the countries in the developing world that has achieved substantial small hydropower development. Although not in Africa, Nepal has development indicators that are roughly similar to sub-Saharan African countries, and therefore provides useful lessons on PMcH development, for the sub-Saharan African region.

In Nepal, the harnessing of waterpower is not a new phenomenon: traditional water wells for agro-processing have been in use for centuries in the rural areas, with the first modern hydropower installed in 1993. (SHP News, 3, 1994). Small hydro turbine and electrification schemes have been found to be viable options for meeting the energy needs of the rural population in remote areas of Nepal (SHP News, 3, 1994). To date the country has about 25,000 operational small hydro units (Karekezi and Ranja, 1997).

The Nepalese government has been instrumental in the promotion of small hydropower. In 1984, it sanctioned privately instituted small hydro projects under 100kW, eliminated licensing requirements and granted approval for charging unrestricted tariffs. This has led to active private sector involvement in SHP development, as well as increased dissemination of the technology.

Micro-hydro systems provide direct drive which can be used for milling, grinding and to generate electricity. In Nepal, the revenue generated by the provision of a milling service provides the owner with a profit, which can be supplemented, in an increasing number of cases, by the sale of electricity for lighting at night (Hislop, 1992).

The case of Nepal provides a good example of what legislation can achieve in terms of increasing access of modern energy in rural areas. In Uganda, legislation was passed in 1999 that generation of electricity below 500kW does not require a licence. It is expected that in the long run this will positively impact the dissemination of modern energy to households, SMcEs and the agricultural sector in rural Uganda.

The increased provision of motive/shaft power in rural areas will improve the production processes of SMcEs, leading to higher outputs and increased productivity. It will also reduce the use of human power in the agricultural sector. This will lead to increased mechanisation, resulting in the following benefits:

- Increased productivity of agricultural labour by performing agricultural tasks in the shortest possible time and overcoming barriers in critical operations; and,
- Improved quality of agricultural work and reduced drudgery (FAO, 1995)

Other attractive technology options that could play a major role in providing mechanical power in rural areas if backed by appropriate legislation include biomass gasifiers, wind generators, wind pumps and efficient diesel/petrol generating sets.

4.3 Recommendation 3: Modern energy dissemination in rural areas should target small and micro enterprises and agriculture.

Available data from country studies in the AFREPREN research programme (2000-2002) indicates that the majority of energy initiatives by governments and utilities in rural areas are largely aimed at the welfare needs of the target population. These include lighting for homes, schools and hospitals using solar PV. Given the high costs involved in implementation of PV technologies, most of these rural sectors cannot afford to pay for the PV systems. Government and donors are in most cases forced to provide large subsidies to make the systems affordable to rural communities.

After installation of the systems is complete, government and donors are rarely available to provide the technical support required in maintaining the systems. There is also a lack of ownership of the systems, since the community pay minimal charges for installation. These factors compounded over a long period of time result in complete breakdown of the systems, and eventually the majority of systems are abandoned.

One possible solution to this problem would be to target income-generating activities in rural areas, especially those in the SMcE and agricultural sectors, when disseminating modern energy in rural areas. There is evidence in the region indicating that this approach has led to the successful dissemination of energy technologies in rural areas. SMcEs and the agricultural activities have higher turnovers than households. For example, the rural household per capita income in Botswana was USD168 in 1998 (Ministry of Finance and Development Planning, Botswana, 1995). This is quite low when compared to the turnover for rural SMcEs as shown in the table below.

Table 22: Turnover of Typical Small and Medium Rural Enterprises in Botswana (US$).

This seems to indicate that SMcEs and the agricultural sector would be able to purchase modern energy technologies if favourable and affordable financing mechanisms were put in place. In addition, since SMcEs and agricultural activities have relatively more stable cash flows, they would be able to afford maintenance of the modern energy systems, therefore leading to sustainability of the systems.

4.4 Recommendation 4: Modern energy technology projects in rural areas should target women, while providing them opportunities for income generation, in order to achieve greater impact

Women dominate rural energy use at the household level. In the agricultural sector and in rural SMcEs, women also play a crucial role and provide a substantial proportion of the human power required for these activities. Available data however indicates that women are rarely the target of most modern energy technology projects in rural areas. This may be one of the reasons why these projects have not met expectations.

Targeting modern energy technology projects at women would go a long way in easing the burden placed on women in rural areas. At the household level, the provision of modern energy could directly address the negative health impacts on women and children associated with inefficient use of biomass, as well as reduce the time taken in collecting firewood.

As mentioned earlier, most of the SMcEs operated by women are energy intensive and largely biomass-based. Modern energy technologies directly targeted at female-owned/managed rural SMcEs would reduce the negative effects on health associated with inefficient biomass use, and increase productivity. This would lead to increased incomes for women, enhancing their living standards directly.

An example of where this approach has worked is the Upesi Stove Project in Western Kenya. The ‘Women and Energy Project’ of the Ministry of Energy in Kenya initially spearheaded the production and dissemination of the Upesi stove. The project had the overall objective of improving the living conditions of Kenya’s rural population by reducing fuelwood requirements and improving fuelwood availability (Muriithi, 1995).

Given the difficulty faced in disseminating the Maendeleo Stove in rural areas, the Intermediate Technology Development Group (ITDG) renamed the stove ‘upesi’, and promoted its commercial production in west Kenya. ITDG focussed on benefits to the producers and the development of a commercial market for the stoves.

Women were the main implementers of the project by ITDG, and 19 women's groups were trained on the manufacture of the stove. To date, a total of 10 women's groups are recognised as producers of the stove. This has had a positive impact on the recognition of women's status in the society, as well as control over household budgets.

The project developed a participatory approach to ensure that the producer groups controlled the extent of their involvement in the project and the nature and pace of their training. The aim is to ensure that only the most motivated and best-organised groups continue with the training and production. This competitive aspect has impacted positively on the quantity as well as the quality of stoves produced.
Overall, the project has achieved significant results. The annual production is over 12,000 Upesi stoves and 2,500 liners for the Kenya Ceramic Jiko. The total profit generated by the production of the stoves is estimated to be between 217,500 Kenya shilling (US$ 2,788) and 397, 500 Kenya Shillings (US$ 5,096) (Khennas et al, 1995). The project provided the opportunity for women to engage in income generating activities, and has undoubtedly improved their livelihood and welfare.

In the agricultural sector where women provide most of the human labour, provision of modern energy would lead to increased productivity and reduce the drudgery associated with agricultural work. Increased agricultural productivity may be one way of resolving the issue of insufficient calorie intake prevalent in rural households.

5. Conclusion

A renewable energy strategy that relies on a wider range of renewable technologies can ensure that the poor select the technology that best fits their comparative advantage as well as their incomes. For example, if a rural farmer is near a river or stream, pico/micro hydro might be appropriate. If the farmer happens to reside near a ready supply of wood from planted forests or near a sawmill with plenty of wood waster available, biofuels technologies might be best. In conclusion, sub-Saharan African countries need to develop renewable energy technology strategies that rely on a diverse set of technologies that are not confined to PV and that reflect their national natural endowment profiles, and incomes of the poor, who constitute the majority of sub-Saharan Africa inhabitants.

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Table 1 Rural Electrification in selected Sub-Saharan African

Country	**% of Population living below the poverty line (majority of whom reside in rural areas)**	**% Of Electrified Rural Households**
Ethiopia	76.4	0.20
Malawi	54.0	0.32
Mozambique	78.4	0.66
Uganda	55.0	0.72
Tanzania	51.1	1.00
Zambia	86.0	2.00
Kenya	47.0	2.00
Eritrea	n.a.	2.1
Botswana	33.0	2.09
Zimbabwe	41.0	18.00

Source: AFREPREN, 2000

Table 2 Per Capita Energy Consumption of Urban and Rural Households (Kgoe) – 1992

Country	Urban	Rural
Kenya	60	220
Zimbabwe	150	300
Botswana	166	390
Zambia	180	200
Senegal	120	170

Source: African Development Bank, 1996

Table 3 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 and biogas	Wood, kerosene, biogas, LPG and coal
Lighting	Candles, kerosene (Sometimes none)	Candles, kerosene	Kerosene, electricity
Space heating	Wood, residues and dung	Wood, residues and dung	Wood, residues, dung and coal
Other appliances	None	Grid or genset-based electricity and batteries	Grid or genset-based electricity and batteries

Source: AFREPREN, 1999

Table 4 Fuels used for cooking in rural households for selected African countries (% 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	85.73	14.1	0	0.03	0
Senegal	84	2	12	0	2
South Africa	49	23	5	21	2
Djibouti	*44*	*48*	*5*	*1*	*2*

Source: World Bank, 2000a.

Table 5 Main Source of fuel for lighting in rural areas, Botswana and Uganda, 1994

Type of fuel	**% Of households using**	
	Botswana	**Uganda**
Paraffin/Kerosene	75.76	85.77
Wood/Charcoal	11.26	11.37
Candle	8.65	-
Electricity	2.68	1.5
Gas	1	0.13
Others	0.64	1.23

Source: Central Statistical Office, Botswana, 1995; Statistics Department, Ministry of Finance and Economic Planning, Uganda, 1995

Table 6 GNP per Capita and cost of 40-50 Wp Solar PV System

Country	GNP per capita (1999)	Estimated Cost of Solar PV System (40-50 Wp) US $	% of estimated cost of Solar PV System per GNP per capita
Zambia	330	1200	363.63
Uganda	310	1037	334.52
Eritrea	200	600	300.00
Kenya	350	620	177.14
Lesotho	570	1000	175.44
Zimbabwe	610	800	131.15

Source: World Bank, 2001; AFREPREN, 2001; Kijek et al, 1994

Table 7 GNP Per Household and cost of 40-50 Wp PV System

Country	GNP per capita (1999)	Estimated Household income (GNP *6)	Estimated Cost of Solar PV System (40-50 Wp) US $	% of estimated cost of the PV system per estimated household income
Zambia	330	1,980	1200	60.61
Uganda	310	1,860	1037	55.75
Eritrea	200	1,200	600	50.00
Kenya	350	2,100	620	29.52
Lesotho	570	3,420	1000	29.24
Zimbabwe	610	3,660	800	21.86

Source: World Bank, 2001; AFREPREN, 2001; Kijek et al, 1994

Table 8 Annual Rural Household Incomes for Selected Countries

Country	Annual Rural Household Income (US$ in year 2000)
Eritrea	372
Ethiopia	528
Zambia	768

Source: AFREPREN, 2001

Table 9 Comparative Costs of Solar Panels and other Rural Energy Devices

Prices of Solar PV Panels in Kenya in 2001	
Sizes of Panels	**Cost of panel only (in US$)**
40W	210
50W	261
60W	350
110W	529
120W	580
Comparative Costs	
Improved Firewood Stove	2
Kerosene Stove	5
Solar dryer	10
300W micro hydropower generator	30
Manual grinder	56
Manual Water pump	63
Animal-Drawn Cart	70
Animal-drawn plough	100
Sewing Machine	115

Source: AFREPREN, 2001

Table 10 Human Power Consumption for Various Farming Activities

Activity	**Gross power needed (Watts)**	**KWh consumed (Assume 7hour working day)**
Clearing bush and scrub	400-600	2.8-4.2
Felling trees	600	4.2
Hoeing	300-500	2.1-3.5
Ridging, deep digging	400-1000	2.8-7.0
Planting	200-300	1.4-2.1
Ploughing with animal drought	350-550	2.45-3.850

Source: WEC/FAO, 1999 and National Energy Foundation, 1995

Table 11 Renewable Energy Technologies Applications in Agriculture

RET	**Selected Agricultural Process**
Photovoltaic Technologies	Pumping, lighting, cooling, crop processing
Solar water heaters	Dairy processing and heat energy for poultry
Wind pumps	Irrigation, crop processing
Biogas plants	Production of fertiliser
Bio-fuel cookstoves	Milk pasteurisation, heat energy for poultry, crop drying, crop processing

Source: AFREPREN, 1999

Table 12 Wind Energy Potentials and Number of Wind Pumps in Selected Countries

Country	Potential (m/s)	Number of Wind Pumps
South Africa	7.2-9.7	280,000
Namibia	-	30,000
Kenya	3.0	360
Botswana	3.0	250
Zambia	2.5	100
Tanzania	-	58
Uganda	4.0	13
Sudan	3.0	12
Burundi	2.5	1
Cape Verde	9-10	-
Lesotho	5.0	-
Seychelles	3.62-6.34	-
Mozambique	0.7-2.6	-

Source: Karekezi and Ranja, 1997

Table 13 Costs of PV Pumping Systems

Motor pump/ configuration	Output (m^3/day) @ $kWhm^2$/day insolation	Head (m)	Solar Array (Wp)	System price (US$ free on board)
Submerged borehole	40	20	1200	16,000 - 18,000
Motor pump	25	20	800	10,000 – 12,000
Surface motor/submerged pump	60	7	840	9,000 – 12,000
Reciprocating positive displacement pump	6	100	1200	16, 000 – 19,000
Floating motor	100	3	530	8,000
Pumpset	10	3	85	3,000
Surface suction pump	40	4	350	6,000

Source: Hislop, 1992

Table 14 Examples of Rural Income Generating Activities

Country	**Examples of Rural Income Generating Activities**
Ethiopia	Pottery, weaving, dairy processing, local beer brewing, leather treatment, grain milling, small scale mining, edible oil processing, bakeries, guest houses, shops, candle wax manufacture, honey processing, mechanical and electrical repair workshops
Zambia	Pottery, weaving, dairy processing, local beer brewing, grain milling, small scale mining, edible oil processing, bakeries, guest houses, shops, candle wax manufacture, welding, tinsmiths, soap making, mechanical and electrical repair workshops
Zimbabwe	Pottery, weaving, dairy processing, local beer brewing, grain milling, small scale mining, edible oil processing, bakeries, guest houses, shops, candle wax manufacture, welding, battery charging, tinsmiths, blacksmiths, soap making, mechanical and electrical repair workshops

Source: AFREPREN, 2000

Table 15 Typical Applications of Wind Generators

Rotor diameter (m)	**Typical rated power in 12m/s wind**	**Typical use**
1	50W	Battery charging for lighting and communications in remote locations
2	1kW	Multi-battery charging and communications
6	10kW	Heating and multi-electrical uses, probably with some battery storage
14	50kW	Stand-alone electricity generation for communities (small villages)
20	100kW	Grid connection, export and sale of output to grid company

Source: Karekezi and Ranja, 1997

Table 16 Renewable Energy Technologies for Small and Micro Rural Enterprises

	Production Enterprises	**Commercial & service Enterprises**
Solar drying	Processing of tobacco, timber, coffee, tea	
Solar water heaters	Crop processing	Clinics, schools
Animal-driven vehicles	Transport	Transport, Water pumping
Cookstoves		Food kiosks, food preparation for clinics, hospitals and schools
Photovoltaics	Dairy Processing	Electrification of small shops, bars, food kiosks, and powering of mobile communication devices

Source: Adopted from Best, 1992

Table 17 Gender Distribution in Rural Industries in Zimbabwe, 1998

Industry	**Female**	**Male**
Bakeries	89%	11%
Beer Brewing	95%	5%
Brick making	23%	77%

Source: ZERO, 1998

Table 18 Sample Energy-Intensive, Small-Scale Enterprises Operated by Women

Enterprise	Comment
Beer Brewing	25% of fuelwood used in Ouagadougou; main source of income for 54% of women surveyed in Tanzanian village/1kg wood/ 1 litre beer
Rice cooking	15-20% of firewood in some districts of Bangladesh
Bakeries	Wood is 25% of bread production costs in Kenya; 80% in Peru 0.8-1.5kg wood/1kg of bread
Fish smoking	40,000 tonnes of wood/year in Mopti, Mali; 1.5-12kg wood/kg smoked fish; fuel is 40% of processing costs
Palm oil processing	Extremely arduous, requires lifting and moving heavy containers of liquid; 0.43 kg wood/1 litre oil; 55% of income of female-headed households in Cameroon
Cassava Processing	Women in 2 Nigerian districts earned $171/year each; 1kg wood/4kg cassava
Hotels, restaurants, guest houses, tea shops	816,865 tonnes wood annually in Nepal
Food preparation and processing	13% of total household income in Nepal; 48% of mothers in Dangbe district in Ghana engaged; 49% of women in one village in Burkina Faso
Pottery making	Men and women both have distinctive roles in different processes
Soap making	Fuel is high percentage of production

Source: Reddy, Williams and Johansson, 1997

Table 189 Power Requirements for Agro-Processing and Power Output of Small Scale PV system

Agro-Processing Needs	Average effective mechanical power of small industries (watts)	Power Output of Typical small scale PV system
Rice mills/groundnut shellers	14,000	
Flour mills	73,000	18Wp to 40Wp
Cotton gin mills	33,000	
Saw mills	13,000	
Power mills	2,200	
Oil mills	163,000	

Source: Best, 1992

Table 19 Improved Stoves Dissemination

Country	Number of improves stoves disseminated in rural areas
Kenya	180,000
Ethiopia	22,000
Zimbabwe	20880
Lesotho	1,380
Sudan	800

Source: Karekezi and Ranja, 1997

Table 20 Small Hydro Power Utilisation in the Region

Country	Harnessed (Small) (MW)
Uganda*	0.50
Mauritius	6.70
Kenya	6.28
Burundi	5.17
Somalia	4.60
Zambia	4.50
Tanzania	4.00
Lesotho	3.54
Malawi	1.52
Botswana	1.00
Rwanda	1.00
South Africa	0.40
Swaziland	0.30
Mozambique	0.10

Source: Source: Karekezi and Ranja, 1997
* Other stations of total capacity 6.81MW are not operational

Table 21 Turnover of typical small and medium rural enterprises (US$) Botswana

Size of Enterprise	Average annual turnover (US$)
Micro Enterprise (1-3 employees)	1,666
Small Enterprise (4-10 employees)	10,339
Medium sized Enterprises (>10 employees)	39,311

Source: Mogotsi, 2001

Captions to Figures

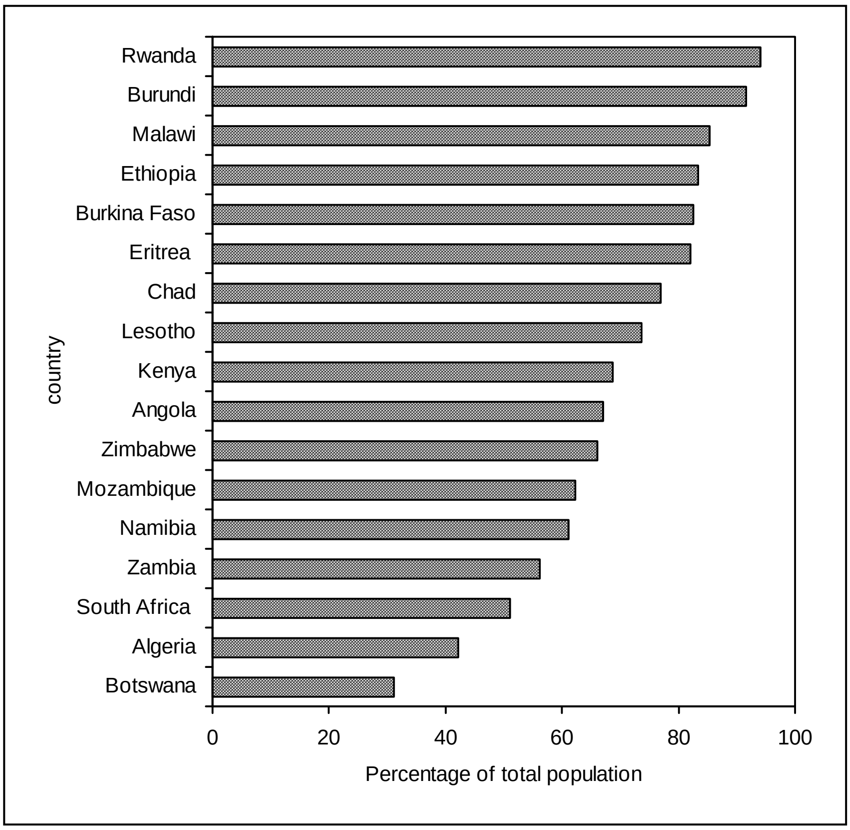


Figure 1 Percentage of population in rural areas (1998)

Source: UNDP, 2000

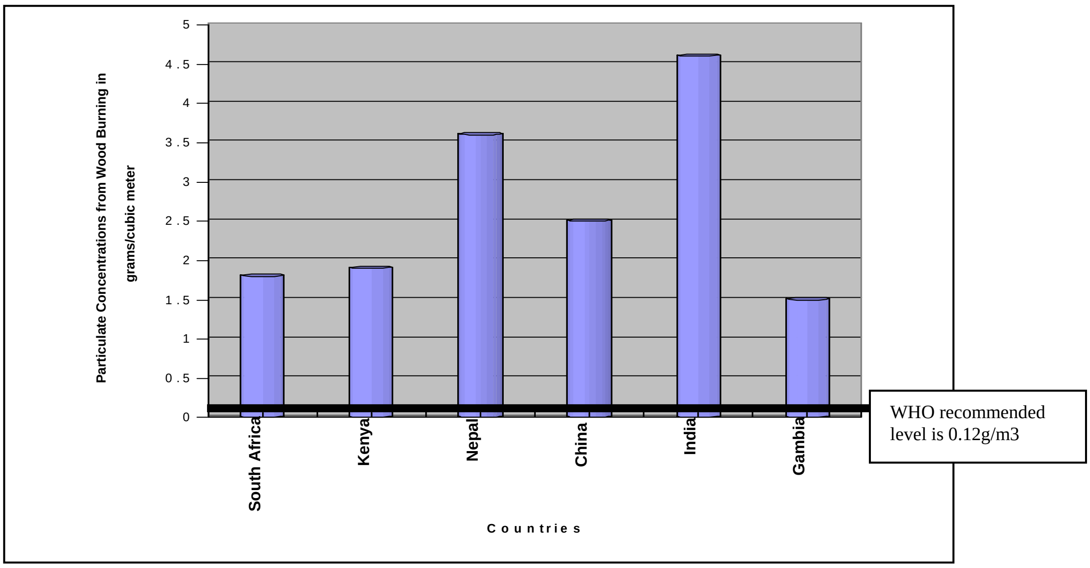


Figure 2 Indoor Levels of Particulates Emitted from Wood in Developing Countries

Source: Karekezi et al, 1995

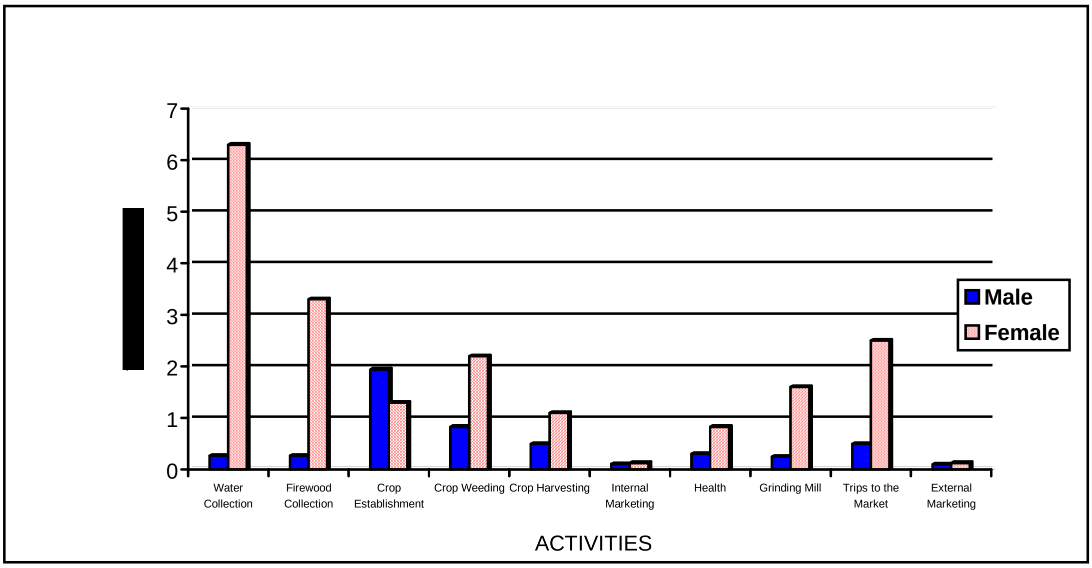
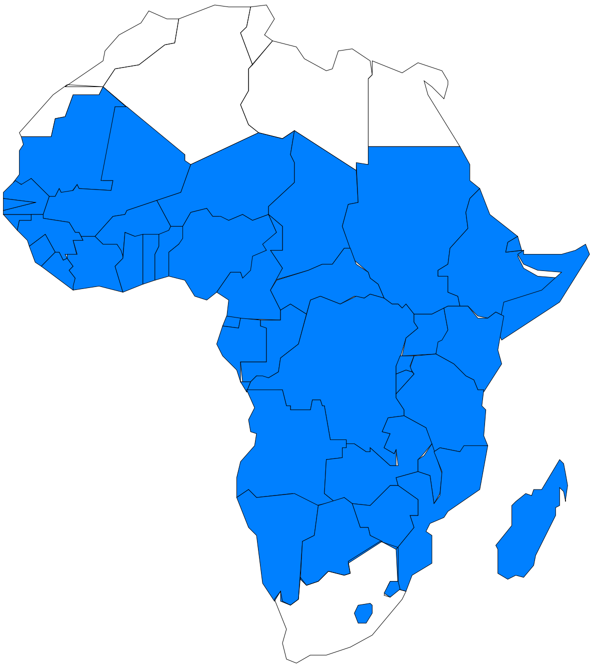


Figure 3 Rural Transport Activities by Males and Females, Tanzania, 1987

Source: Reddy, Williams and Johansson, 1997

Brief Regional Profile



Sub-Saharan Africa (excluding South Africa): Selected Indicators
• **Population (million):** 600.8 (1999) • **Area (km^2):** 22,407,000 • **GNP per Capita (US$):** 306 (1999) • **Modern Energy Consumption per Capita (kgoe):** 355 (1997) • **Rural Population (million):** 420.7 (1999) • **Rural Population Growth Rate (%):** 3.0 (Average 1990-1995) • **Biomass Contribution to total energy consumption (%):** (40-90)

Sources: World Bank (2000); World Bank (2001); AFREPREN (2001)