Rural Electrification: Energy Option Potentials of Sub-Saharan Africa

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Table of Contents

Abstract

Africa is the second largest continent in the world, yet its energy consumption is one of the lowest in the world. This is especially true for rural sub-Saharan Africa where only 8% of the population has access to electricity. Although Africa's greenhouse gas emissions are the lowest in the world, it is still prudent that the strategies for rural electrification be renewable energy sources because Africa is extremely vulnerable to climate change. Currently the most pursued renewable energy source is solar photovoltaics (PVs); however, this paper argues that hydropower and a more efficient use of biomass energy will be more successful in rural areas. The key here is remembering that rural electrification should come hand in hand with development. The solutions to rural electrification in sub-Saharan Africa must generate an increase of income and not just lighting.

1. Introduction

1.1 The African Continent Energy Situation

The paper, "Sustainable Energy in sub-Saharan Africa," written by Davidson et al describes the continent of Africa as the area equivalent to the United States of America, Europe, Australia, Brazil, and Japan combined; and, as of 2004, Africa's population was 885 million people (2006). Yet, according to Davidson et al (2006), "an African uses only one eleventh, one sixth, and one half of the energy used by a North American, a European and a Latin American, respectively" (p. 3, Figure 1). Thus, the question begged to be asked is: why does Africa have such low levels of energy use?

The facts found in the paper by Davidson et al (2006) are: 9% of the world's oil reserves, 6% of the world's coal reserves, and 7.2% of the world's natural gas reserves are found in Africa (Figure 2). However, the oil and gas reserves are found mostly in Northern

and Western Africa and not in sub-Saharan Africa, which includes Eastern and Southern Africa (Davidson et al, 2006). Still, there are significant coal reserves in South Africa and geothermal resources in East Africa (Davidson et al, 2006). Also, about 10% of the world's hydropower is found in Africa, but only 46% of Africa's hydropower potential is being used (Davidson et al, 2006). In the paper, Davidson et al (2006), states that 14% of the world's population is in Africa and 7% of the world's energy is produced in Africa, but Africans only consume 3 % of that energy and more than half of that energy is exported (Table 1,4). In fact, "the average electricity consumption is the lowest in the world; namely 515 kWh/year compared to a world average of 2326 kWh/year (Davidson et al, 2006, p. 5)

1.2 Sub-Saharan Africa versus the rest of the African Continent

It is clear then that there is a distinct difference between sub-Saharan Africa and the rest of Africa. For example, "70% of the oil consumed in Africa is used in four countries, namely, Egypt, Algeria, Libya and South Africa, and over 60% of natural gas in Algeria, Libya, Egypt and Nigeria" (Davidson et al, 2006, p. 5). South Africa is one of those exceptions in sub-Saharan Africa for it uses "93% of the coal produced on the continent" (Davidson et al, 2006, p. 5). Davidson et al (2006) makes his case very obvious that the energy consumption numbers are totally skewed for 40% of the energy in Africa is consumed by North Africa, 40% in South Africa alone, and only 20% in the whole rest of the African continent.

Sub-Saharan Africa is “heavily dependent on inefficient traditional biomass mostly for cooking in households, and it accounts for over 80% of primary energy demand” (Davidson et al, 2006, p. 5, Figure 3). According to Davidson et al (2006), only 53% of urban and 8% of rural populations in sub-Saharan Africa have access to electricity; while in North Africa, 99% of urban populations and 88% of rural populations have access to electricity (Figure 4).

1.3 The Main Questions

Why is there such a disparity between North Africa and sub-Saharan Africa in terms of access to electricity? This gap is especially apparent in rural sub-Saharan Africa. This paper will try to understand why rural sub-Saharan Africa has such low access to electricity and how can this be solved. In effect, how can we supply electricity to rural sub-Saharan Africa and is it possible for the supply of electricity to come from renewable energy sources.

2. The Case for Renewable Energy Sources

According to Davidson et al (2006):

> The energy challenges in sub-Saharan Africa are many and greatly impact on the overall performance of the region’s social and economic indicators. The relatively poor health and education indicators of the region can be greatly enhanced with the provision of improved modern energy services. Increased availability of, and access to electricity for health facilities can lead to better health care. Modern educational

facilities are largely dependent on the provision of modern energy services, which can facilitate improved student performance.

It is understandable then that the low access to electricity is one of the main reasons why sub-Saharan Africa is behind most other third world regions.

There are many reasons why the rural areas in sub-Saharan Africa have had trouble accessing electricity. These reasons include low population density in the rural areas, the seclusion of the small villages in the rural areas from the grid, and high costs of production, transmission, and distribution of electricity (Davidson et al, 2006). Other reasons stated by Davidson et al (2006) include the low energy demand due to minimal levels of industrialization and small amounts of money allocated to the energy sector due to a strong reliance on external financing. The World Bank estimates that a total investment of $18 billion would be enough to fund the entire energy sector in sub-Saharan Africa, $5 billion from utility and domestic sources, $3 billion from the World Bank, and $10 billion from the private sector (Turkson et al, 2001).

The solutions to the above problems can be found when there is a joint development towards a viable energy sector by all stakeholders: public sector, private sector, non-governmental institutions, and international bodies (Davidson eat al, 2006). The key here is the need for highly skilled African manpower/womanpower and the building of infrastructure between countries and sub-regions to maximize efficiency because there is such an uneven distribution of resources (Davidson et al, 2006).

2.1 Climate Change and the African Energy Situation

The African continent only contributes 3% of the world's greenhouse gas emissions, nevertheless, it will be and is the most affected by climate change (Davidson et al, 2006). According to the World Bank Group (1998), climate change increases the likelihood of intense droughts, floods, changes to growing seasons, water supply, and food security, which in a third world country is highly problematic when dealing with a population that is fighting for basic survival. Studies done by the World Bank Group (1998) have projected a worst case scenario for Africa by the end of the next century when these variables are in place: high population growth, high economic growth, high energy demand, high use of fossil fuels, high deforestation rates, and high rates of burning vegetation. If these variables are all in place in the near future, Africa will be emitting high amounts of greenhouse gases into the atmosphere.

It is important to remember that even though current greenhouse gas emissions are negligible this might not be so in the near future. Since Africa is within the development process and making choices of what energy sources to use, they might as well choose renewable energy sources. Especially since deforestation is the main source of greenhouse gas emissions in Africa and of course one of the primary causes of deforestation is the burning of wood for fuel (EIA, 2003). Biomass fuel, wood or charcoal, is highly inefficient as well and when used indoors has adverse emissions that can cause severe health

problems; in sub-Saharan Africa alone, it is estimated that 393,000 people died in 2002 due to inhaling the pollution from biomass fuels (Davidson et al, 2006).

So not only are the traditional biomass fuels inefficient, but they are dangerous to one's health when burnt indoors, and they cause deforestation. Central Africa has one of the largest rain forests in the world which serves as a carbon sink, captures carbon dioxide from the atmosphere, and in turn decreases world levels of greenhouse gases (EIA, 2003). Deforestation also leads to desertification, which is described as the loss of soil fertility, which is a huge problem when most people are relying on the crops they are growing to eat (EIA, 2003).

Consequently, it makes sense to make the solutions to the energy problem in sub-Saharan Africa renewable energy sources, however, not at the cost of development, which is a fine line. The most successful projects so far in rural electrification have included wind, geothermal, and solar power. The fundamental point here is that the projects should be small scale and in turn inexpensive. Sub-Saharan African villages are widely dispersed and thus it is an ideal market for decentralized energy technologies (Karekezi et al, 2003).

3. The Argument against Solar Photovoltaics (PVs)

3.1 Three Categories of Energy use in Rural Areas

As said by, Price Waterhouse Cooper (2004), in "Sub-Saharan Africa's Energy Conundrum," the region has some of the world's largest water systems such as the Nile, the Congo, the Niger, the Volta, and the Zambezi. Although hydroelectricity is widely used in most of the countries, this resource remains barely exploited (Price Waterhouse Cooper, 2004). For example, Price Waterhouse Cooper estimates that Cameroon has a hydro-potential of about 115, 000 MW and as of now only has less than 800 MW in use. In addition, the Democratic Republic of Congo has some of the highest hydropower potential in Africa (Table 5). The hydro-potential is about 1,400 TWh per year, which is technically sufficient to meet the electricity consumption of all of sub-Saharan Africa, less than 100 TWh per year (Price Waterhouse Cooper, 2004).

This paper will argue that micro-/pico-hydropower, wind power, and cleaner fuels such as kerosene and LPG are the renewable energy sources for sub-Saharan Africa's rural electrification problem and not solar photovoltaics (PVs). According to Karekezi et al (2003), even though every country in sub-Saharan Africa has had a Solar PV project, there has been no significant increase in access to modern energy. First of all, rural areas have three categories of energy use: household energy, agricultural energy, and energy for small/micro enterprises (Karekezi et al, 2003).

3.2 Household Energy

Most of the energy consumed in the rural areas of sub-Saharan Africa is used for cooking and the rest of the energy is used for lightening (Karekezi et al, 2003). The problem as stated by Karekezi et al (2003) is that:

> 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.

PV was advertised in sub-Saharan Africa to meet household lighting needs, but the "cost of a typical low-end PV household system is several times higher than the GNP per capita of most sub-Saharan countries (Karekezi et al, 2003, p. 1074, Table 2). As a result, it would make perfect sense that firewood is the main source of energy for cooking in poor rural areas because it is free even though it is inefficient.

3.3 Agricultural Energy

First of all the agricultural sector in rural areas of sub-Saharan Africa contributes roughly 20% of the countries GDP (Karekezi et al, 2003). In turn, the agricultural production energy needed for transportation, water lifting and pumping, land preparation, seed cultivation, weed control, planting, transplanting, and harvesting is highly critical in communities that depend on it for survival and income (Karekezi et al, 2003). Electricity from PV can be used for water pumping, but cannot be used efficiently for human labor and animal traction, which is the most important source of energy for rural agriculture in sub-Saharan Africa (Karekezi et al, 2003). According to Karekezi et al (2003), a number of energy technologies have shown success in the agricultural sector: small hydro-plants for shaft power and electricity generation and wind energy for water pumping to irrigate.

3.4 Energy for small/micro Enterprises

Small/micro enterprises in sub-Saharan Africa include beer brewing, fish smoking, pottery, weaving, and grain milling, which are done mostly by household members; the energy needed is significantly higher than in the household for cooking and lighting (Karekezi et al, 2003). PV technology is simply not the best option for these rural areas when it comes to agro-processing activities for agro-processing activities require a minimum output above 1000 Wp; a PV system of this magnitude is too expensive for most rural people in sub-Saharan Africa.

3.5 Development versus Rural Electrification

Karekezi et al (2003) makes it clear that PV technology is truly not the solution for the sub-Saharan rural electrification problem for it is too expensive and mostly useful for lightening, which leaves out cooking and the power needed to run agricultural infrastructure. Karekezi et al (2003) brings up another important point that PV technology is reliant on imported parts; “promoting a technology such as PV with high import content in countries facing a massive fall in export earning is not good macro-economic practice” (p. 1080).

Now, the development question is brought into the discussion. Is rural electrification truly what African’s need? May it not be smarter to provide rural Africans with technologies that increase their incomes, as suggested by Karekezi et al (2003)? For

example, biomass energy is most likely going to be continued to be of use so it would make sense to increase its efficiency and decrease its environmental impacts (Karekezi et al, 2003). This can be done with woodstoves that are designed to increase efficiency, reduce respiratory health problems, and reduce wood consumption (Karekezi et al, 2003).

As discussed above, micro-/pico-hydropower is abundant in sub-Saharan Africa and unlike PV technologies is capable of powering agricultural tools. The biggest benefit of micro-/pico-hydropower is that it can be used for energy generation, irrigation, and water supply (Karekezi et al, 2003). Karekezi et al (2003) says it most eloquently with this quote in reference to micro-/pico-hydropower: “It is ideal for rural areas where grid connections do not reach… the increased provision of motive/shaft power in rural areas will improve the production processes of small/micro enterprise, leading to higher outputs and increased productivity” (pp. 1081-1082)

4. Conclusions

Sub-Saharan Africa has such low levels of energy use because of how widely spread out the villages are in the rural areas, which makes it very difficult to connect these people up to the grid. Those living in rural areas live off the land and need energy to supply themselves with food, most of which they eat themselves and some of which they sell to generate a small income. Therefore most of the agricultural processes they execute are to produce food for their own consumption and the rest is for small enterprises that sell

goods to generate a modest income. Thus the need for energy is mostly based upon the powering of tools and cooking.

The rural areas will most likely always use biomass energy for cooking because it is cheaper than other technologies. So it makes sense to increase the efficiency of biomass energy with better burning techniques, like more efficient woodstoves. The key to biomass energy is finding a way to make it more efficient, more environmentally friendly, and less damaging to the respiratory system. While, the energy needed in the agricultural sector is best supplied through hydropower because of the abundance of water systems in sub-Saharan Africa, the reliability of the technology, and the multiple uses of the technology.

Renewable energy technologies are generally not cost effective for third world regions like sub-Saharan Africa. However, as the world market changes and climate change becomes more of a global issue, the prices will come down. It is important to emphasize that the long term energy solutions to rural electrification in sub-Saharan Africa are renewable energy sources. Even though renewable energy technologies are more expensive, they are more effective because they target needs of each individual in all the various households and businesses.

The key here is not electrification, but development. The technologies must be cost effective, so more efficient uses of biomass energy and cleaner fuels like LPG and kerosene are still viable energy sources as long as they are enabling communities to tackle development issues. The renewable energy sources are also viable as long as they are

tackling the cost effective dilemma and providing income developing strategies for rural farmers.

The supply of modern energy to rural sub-Saharan Africa cannot be discussed without the issues of development. Rural sub-Saharan Africa is home to some of the poorest people in the world and rural electrification is only beneficially when it increases their industrial output and income levels. It is clear that there is not one solution to which renewable energy source is the most successful in rural areas. The key is that the renewable energy source be the best fit, for example, “if a rural farmer happens to reside near a river or stream, pico-/micro-hydro might be appropriate” (Karekezi et al, 2003, p. 1083).

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6. List of Tables

Table 1: Final Energy Consumption in Sub-Saharan Africa (million TOE)

	Industry	Transport	Residential	Total
Solid Fuels	3.8	0.2	1.2	5.2
Petroleum Products	12.5	21.1	11.9	45.5
Gas	4.7	-	0.02	4.7
Electricity	1.9	-	1.3	3.2
Total Conventional Energy	22.9	21.3	14.5	58.7
Biomass	3	-	93	96
General Total	25.9	21.3	107.5	154.7

Source: ADB, Energy Sector Policy, 1994

Table 2: Household Energy Expenditure as a Percentage of Income, per Sub-Region

Sub-Region	Energy Expenditure (% of income)
East Africa	12.7
Southern Africa	11.9
West/Central Africa	14.06
North Africa	7.9

Source: ADB - Household Energy Consumption Patterns, 1996

Table 4: Primary Energy Production in Sub-Saharan Africa (million TOE)

	Oil and its derivatives	Natural Gas	Coal	Hydro-electricity	Total
North Africa	163	53	0.3	0.7	217
Sub-Saharan Africa	140	3.5	4.5	3.9	152
Total	303	56.5	4.8	4.6	369

Source: ADB - Energy Sector Policy, 1994.

Table 5: Estimates of Primary Energy Supplies (%) in Representative Countries of each Sub-Region.

Sub-Regions	Representative Countries	Oil	Coal	Gas	Biomass	Hydro Electricity
West Africa	Nigeria	27	0.4	12.6	59	1
	Ghana	21	-	-	69	10
East Africa	Kenya	21	1	-	70	8
	Ethiopia	8	-	-	90	2
South Africa	Zimbabwe	10	50	-	25	15
	Botswana	17	-	-	73	4
Central Africa	Cameroon	19	-	-	67	14
	Chad	33	-	-	77	-
Average					62.5	

Source: Compiled and computed from AEP (1994/1995) and UNEP (1990).

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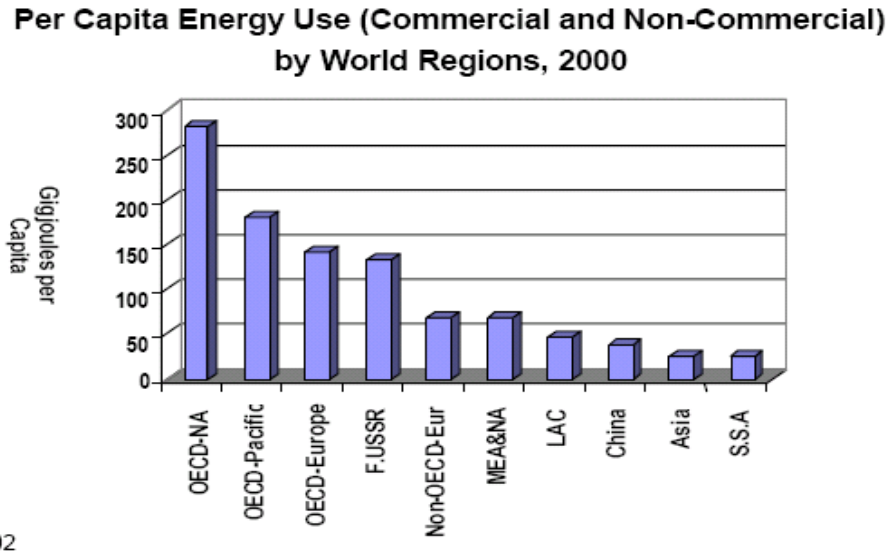
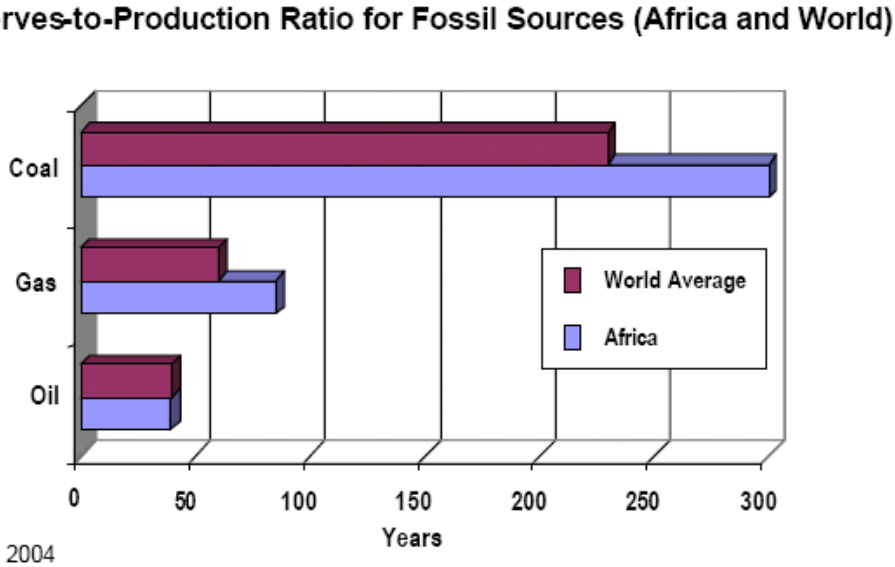
7. List of Figures

Fig.1



Source: IEA,2002

Fig.2



Source: Davidson, 2004

Fig.3

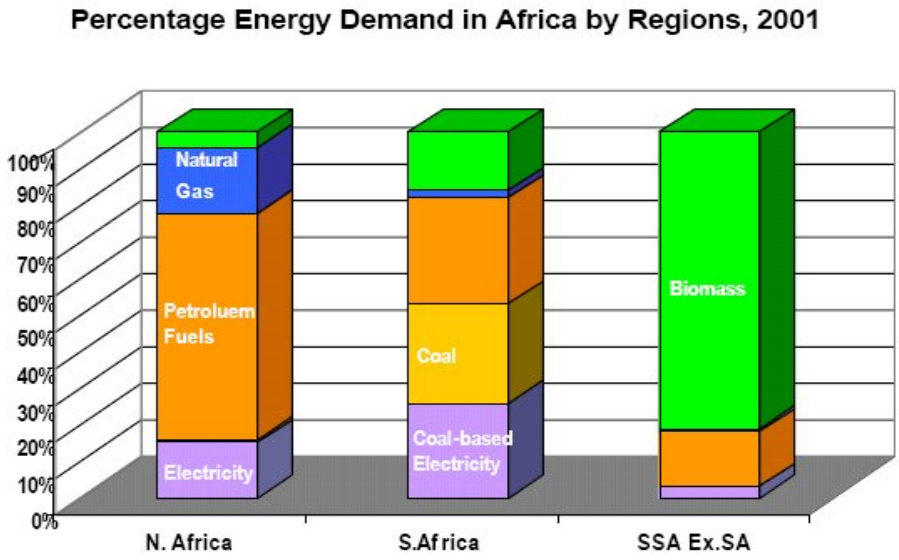


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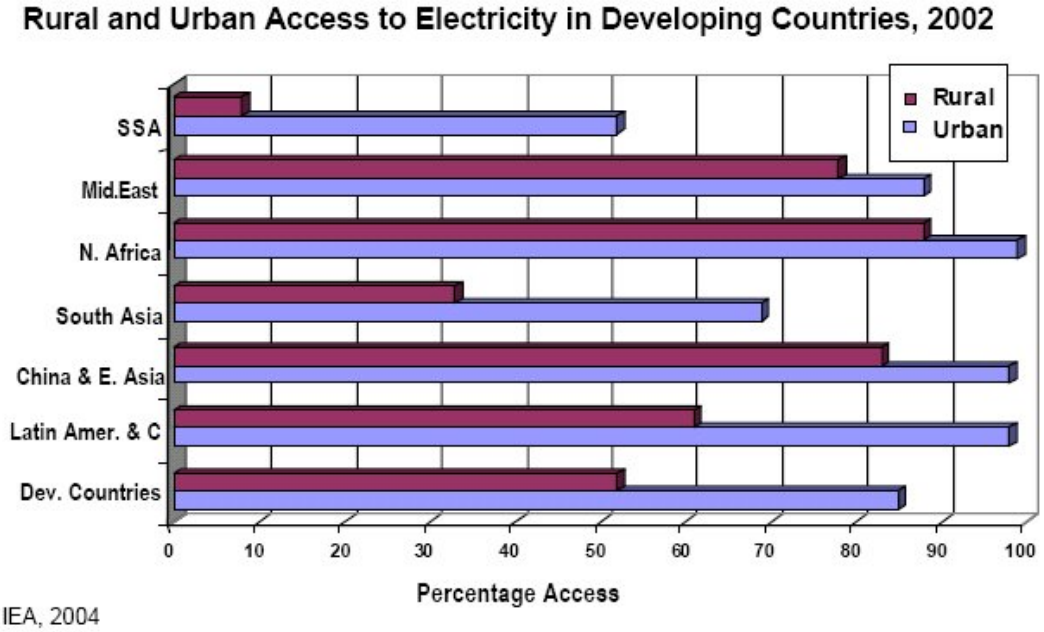
Fig.4



Source: IEA, 2004

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