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RENEWABLE ENERGY RESOURCES BARRIERS IN AFRICA

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ABSTRACT
Renewable energy resource - Hydro Power in Africa is abundant and environmentally attractive. The major Hydro-Dams in Africa which combine are responsible for 70% of the continent's power supply cannot perform at more than 30% of their installed capacity, thus causing power failure that have become the rule rather than exceptions in many countries within the continent. Climate change through droughts and floods present great challenges to management of production and distribution of power supply. The paper identifies three possible climate change related barriers against hydro-dams development in Africa. These barriers could be removed by analysis and understanding of the implications of rainfall characteristics such as amount of rainfall, variations in the amount of rainfall and rainfall intensity.

KEY WORDS
Renewable Energy, Hydro Power, Rainfall Characteristics

1. Introduction

Renewable energy resource – hydro power in Africa is abundant and environmentally attractive resource, with enormous economic promise. It had been successfully used in numerous applications on commercial bases and for large scale power generation projects. Hydro-power generation involves construction of dams. In recent years, as environmental impact assessment studies have been on the increase, there has been mounting criticism that the adverse consequence of dam construction have not fully been evaluated. These undesirable consequence could in the long run drastically reduce the anticipated benefits. Various studies on dam projects suggest that they have profound negative impacts on both the environment and the local people. It is therefore important to monitor these processes of change whether negative or positive, if we are to ensure a sustainable management of our environment. There is no doubt that the coming into existence of dams in Africa over the years have altered the territorial environment of various areas they are located.

Climate change has significant regional impacts in Africa. Many factors affect renewable energy production through hydro-power dams but drought and floods are the most important in relation to vulnerability to climate change. These present great challenges to management of production and distribution of electricity power supply. Africa has abundant freshwater resources available for domestic, agricultural and industrial consumption especially Hydro-Electric Power generation but are saddled with problems. The timing and intensity of rainfall is a major determinant of runoff, flooding, groundwater recharge and also soil erosion. Flooding can lead to siltation and contamination of water. Reduced water level and erosion-induced siltation leading to false water depth is a major cause of excessive load shedding. Such problems will be exacerbated by climate change and pose major threat to the programmes of various agencies and organizations on poverty alleviation. Decimation of population and destruction of farms during release of excess water from dams/reservoirs as experienced in many parts of the continents are other challenges of climate change which must be tackled with application of data and research.

The global experiences and trends in energy demand and supply indicate the potential of renewable energy in sustainable national economic developments. Economic development can best be sustained when Renewable Energy Technologies are introduced into existing energy market mix. This reduces the overall penetration of fossil fuels in the economy thereby minimizing the consequences of Greenhouse Gas Emission. The quest for sustainable renewable energy solutions is a global agenda. For instance, Energy was an area of intensive debate at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in June 1992. In Agenda 21, chapter 9, it was agreed that current patterns of production and utilization of energy cannot be sustained, and that one of the ways of promoting sustainable development is to reduce adverse effects on the atmosphere from the energy sector. Agenda 21 identified two directions in which the energy system could evolve: i) toward more efficient production, transmission and distribution and end-use of energy, and ii) toward greater reliance on environmentally sound energy systems, particularly new and renewable sources of energy [1].

Of course, the two approaches are related. Coupled with high energy end-use efficiency, renewable source of energy through hydro-power is capable of covering a larger share of the Africa's energy needs.

Three possible, climate change related barriers against hydro-dams development in Africa are: (i) problems of erosion-induced sedimentation resulting in silting up of dams, thereby resulting in false depths, clogged turbines and high turbid water which corrode equipment. (ii) High rates of evaporation from the standing lakes with non-stationary tendencies, especially due to droughts. (iii) Poorly programmed water discharge in relation to rainfall seasonality. The paper identifies analyses and understanding the implications of rainfall characteristics such as amount of rainfall, variations in the amount of rainfall and rainfall intensity as ways of removing the barriers against Hydro-Dam Development in the continent.

2. Importance of Renewable Energy in Africa

Energy is an essential ingredient of socio-economic development and economic growth. The major objective of the energy system is to provide energy services. Energy services are the desired and useful products, processes or services that result from the use of energy, for instance, illumination, comfortable in-door climate, refrigerated storage, transportation, appropriate temperatures for cooking, materials etc. The energy chain to deliver these services begins with the collection or extraction of primary energy which is then converted into energy carriers suitable for the end-use(s). Most discussions of energy sector focus on supply-side issues. However, the energy system involves much more than what is conventionally considered the energy sector and unless the scope of discussions about energy is extended, energy efficiency will receive less attention than it deserves.

In the past, both micro and macro-economic initiatives in the Energy Sector did not place any 'premium' on climate change. But since the Rio Conference in 1992, studies on Renewable Sources of Energy and energy services (production, distribution and consumption) suggest that efforts have been stepped up to understand causes of climate change in the attempt to know and access the vulnerability of developing countries in Energy Sector (among others) so that mitigation and adaptation strategies to be adopted, for efficient delivery of Energy Services will work. In the light of the ominous signs of worst calamities in this millennium (at least during the first 25-50 years), it is important to highlight what climate has in store for the world at large and developing countries in particular which will adversely affect the renewable energy sector. The 1999 and 2002 flood disasters of Nigeria and Mozambique respectively, the 2004 and 2005 'experiences' of South East Asian countries and New Orleans in the United States of America are an indicator [2].

The Rio Accord [1] and Kyoto Protocol [3] called on nations to find more efficient system for producing, distributing and consuming energy. It placed emphasis on environmentally sound energy system with particular attention to renewable sources of energy. Renewable energy is not only 'cleaner' in relation to the environment, it can create jobs for the rural poor. For most part, renewable energy resources particularly hydroelectricity have been widely exploited in Africa. In Africa, the large hydro dams are in Egypt, Congo (Kinshasa), Sudan, Senegal, Ivory Coast, Kenya, Nigeria, Ghana and Zambia/Zimbabwe. Several African countries rely almost exclusively on hydropower for commercial electricity generation. World Commission on Dams (WCD) found that while dams have made an important and significant contribution to human development, and benefits derived from them have been considerable, in too many cases an unacceptable and often unnecessary price has been paid to secure those benefits, especially in social and environmental terms, by people displaced, by communities down stream, by taxpayers and by the natural environment. The report also found that a lack of equity in the distribution of benefits has called into question the value of many dams in meeting water and energy development needs when compared with the alternatives.

Table 1
Hydropower Generated per Hectare Inundated

Project (Country)	Final Rated Capacity (MW)	Normal Area of Reservoir (ha)	Kilowatts per hectare
Cabora Bassa (Mozambique	4,000	380,000	14
Aswan High Dam (Egypt)	2,100	40,000	5
Kariba (Zimbabwe/Zambia)	1,500	510,000	3
Akosombo (Ghana)	833	848,200	0.9
Kompienga (Burkina Faso)	14	20,000	0.7

Table 1 shows the ratio of power production per area inundated. Many hydroprojects are fraught with major environmental problems, but in the case of others, such problems could be soluble – although with much more effort than is accorded today. On the other hand, hydroprojects with large reservoirs also may have major side-benefits, such as flood control, improved water quality, and fisheries. Under certain conditions, recreation, tourism, irrigation, and navigation can be made compatible with hydropower.

Table 2
Electricity balances in Southern Africa, 1990 (GWh)

Country	Hydro generation	Oil/coal generation	Final consumption
Angola	758	84	**721**
Botswana	0	804	**725**
Lesotho	0	**0**	**151**
Malawi	581	**2**	**472**
Mozambique	165	**169**	**568**
Swaziland	211	**200**	**614**
Tanzania	1,203	**127**	**1,102**
Zambia	8,300	**20**	**6,408**
Zimbabwe	2,663	**5,583**	**8,498**
SADCC	13,881	**6,989**	**19,259**

Source: SADCC Energy Sector Tech. Adm. Unit (SADCC/TAU) 1990

Regional comparative studies of electricity balances for Southern Africa are shown in Table 2 [4]. Hydro accounts for two-thirds of the electricity produced in Southern African sub-region. Two countries – Zambia and Zimbabwe – account for nearly 80% of current electricity production, driven by large mining and industrial sector requirements respectively [5]. More than 2000 MW of SADCC total installed capacity of 7000 MW comes from a single hydro facility, Cabora Bassa, in northern Mozambique. Southern African sub-region has abundant hydro resources, with an identified potential of nearly 46,000 MW, or 215,970 GWh in firm energy. Of this potential, only 5,200 MW, providing 31,000 GWh in firm energy, is now in place (exceeding current Southern African development Community Countries (SADCC) electricity requirement of 22,800 GWh).

Africa clearly needs energy development. Not one of the Millennium Development Goals is attainable without greater energy development. On the aspect of alleviating energy poverty, electricity and other modern energy services would bring enormous benefits for health, education and livelihood to the majority of Africa's population, which is rural and based in small-scale agriculture.

3. Barriers to Renewable Energy Resources

Climate change has significant regional impacts in Africa. The historical climate record for Africa shows warming of approximately 0.7^0C over the continent during the 20^{th} century, a decrease in rainfall over large portions of the Sahel, and an increase in rainfall in east central Africa [6]. Climate change scenarios for Africa, based on results from several general circulation models using data collated by the Intergovernmental Panel on Climate Change (IPCC) Data Distribution Centre (DDC), indicate future warming across Africa ranging from 0.2^0C per decade to more than 0.5^0C per decade. This warming is greatest over the interior of semi-arid margins of the Sahara and central southern Africa.

The most recent expert assessment of science of climate change confirm that human activity has influenced the global climate change over the past century and is projected to have potentially significant impacts on global climate over this century [7]. Higher greenhouse gas concentrations would increase global average temperatures over the 1990 to 2100 period by 1.4^0C to 5.8^0C, according to climate models. The rate of warming over the next century would very likely be greater than any temperature change experienced over the past 10,000 years. This warming would increase summer mid-latitude continental drying and the associated drought risk.

Climate change is altering hydrological cycle, meaning that historical data is no longer a reliable predictor of future hydrological patterns. Many sub-Saharan countries are already over-dependent on hydropower for their electricity, and many areas have experienced increasing crippling droughts that have sidelined hydropower production. For example, the Intergovernmental Panel on Climate Change reports that in the Nile Basin, there has been a reduction in runoff of 20% between 1972 and 1987, corresponding to a general decrease in precipitation in the tributary of basins calculated. In recent years there have been significant interruptions in hydropower generation as a result of severe drought. Building more large hydropower projects will only intensify African nations' vulnerability to climate change. Renewable, decentralized energy will give Africans greater independence to energy access and help diversify the energy portfolio of African countries.

Many factors affect renewable energy production through hydro-power dams but drought and floods are the most important in relation to vulnerability to climate change. These present great challenges to management of production and distribution of electricity power supply. Africa has abundant freshwater resources available for domestic, agricultural and industrial consumption especially Hydro-Electric Power generation but are saddled with problems. The major Hydro-Dams in Africa which combine are responsible for 70% of the continent's power supply cannot perform at more than 30% of their installed capacity, thus causing power failure that have become the rule rather than exceptions in many countries within the continent.

The timing and intensity of rainfall is a major determinant of runoff, flooding, groundwater recharge and also soil erosion. Flooding can lead to siltation and contamination of water with human, soil, animal waste, and agricultural chemicals. Reduced water level and erosion-induced siltation leading to false water depth is a major cause of excessive load shedding leading to blackouts. Such problems will be exacerbated by climate change and pose major threat to the programmes of various agencies and organizations on poverty alleviation. Decimation of population and destruction of farms during release of excess water from dams/reservoirs as experienced in many parts of the continents are other challenges of climate change which must be tackled with application of data and research.

Three possible, climate change related barriers against hydro-dams development in Africa are: (i) problems of erosion-induced sedimentation resulting in silting up of dams, thereby resulting in false depths, clogged turbines and high turbid water which corrode equipment. (ii) High rates of evaporation from the standing lakes with non-stationary tendencies, especially due to droughts. (iii) Poorly programmed water discharge in relation to rainfall seasonality. These barriers could be removed by analysis and understanding of the implications of rainfall characteristics such as amount of rainfall, variations in the amount and intensity of rainfall.

4. Case Study

Three dams namely Kainji, Jebba and Shiroro Hydro-Dams in the Niger-Benue Basin of Nigeria are used as case study.

4.1 Basic Characteristics Features

The Kainji Hydro-Dam is the most important of the three with respect to Hydro-Power Generation Potentials and it is in situation along the course of River Niger as it enters Niger State. Major tributaries of River Niger which feed into the Dam are rivers Sokoto Ka, Zamfara and Malendo. Most of the rivers are perennial.

The Jebba Hydro-Dam, also built on the River Niger upstream of Jebba town takes advantage of the large peneplain before the sudden drop in the river course for massive build-up of water that almost becomes a 'river-fall'. It is however bordered by an escarpment with degraded bare slopes to the northwest running down (south) to Jebba town which limits its spatial extent and constitutes excessive siltation into the large and expansive Dam. The major tributary of River Niger south of Kainji that feed into the Jebba Hydro-dam is River Kontagora. This river flows through overworked arable farmland which due to overgrazing have become bare soils. The sediment-potential of the Jebba Dam is traceable to the washing of top soils into River Kontagora which, in turn, empties same into River Niger.

The case of Shiroro Hydro-Dam is different. Built on River Kaduna at about 40 km northeast of Minna, the Capital of Niger State, the competing uses of the river upstream and the level of effluent released from industrial activities account for the turbid flow [8]. In recent years, due to persistent droughts, surrounding wooded savanna has deteriorated into shrubs with scanty Baobab-type trees. The Dam, which is usually shallow but occupying large land area is unprotected from the 'Elements' of weather. However, because Kaduna River and its tributaries take their origin from Jos Plateau, there is ample 'inflow' into Shiroro dam which unfortunately could become too much when rainfall is usually too heavy.

4.2 Removal of barriers using rainfall characteristics

An analysis and understanding of rainfall characteristics such as amount of rainfall, variations in the amount and intensity of rainfall and their derived parameters are employed in solution of hydro dams problems.

4.3 The amount of rainfall

The total amount of areal rainfall gives an estimate of the total amount of water that is naturally recycled annually. The demand for this amount of water varies from the requirement of soil moisture and groundwater storage, surface storage in ponds, lakes and streams to that for evaporation back into the atmosphere. Part of the water required to replenish the groundwater storage usually returns to surface storage by way of seepage as baseflow. The outcome of this intervention is creation of some imbalance within the system in favour of one or more, of the natural dispensation channel. However, man's intervention is normally limited to the inception of surface and groundwater storages which are the developable components.

Estimates of the various components of natural water budget in Kainji, Jebba and Shiroro hydro-dams area give conservative estimate of the coefficient of AET as 66% of the total Annual rainfall [9]. It is thus clear that developable components: discharge and net retention coefficient are very important.

As Olofin [9] found, discharge which is an important component for large-scale water development projects, is very low in the zone. Specifically, the Rima (5.8%) and the Yobe (3.3%) provide the average estimate of discharge coefficient for the zone because they drain up to 75% of the area. Headstreams of these two river systems that flow over crystalline structures have higher coefficients (e.g., Jama'are, 26% and Kano, 17%) of discharge with low coefficients (8% and 17%) of net retention. The headstreams flowing over unconsolidated sediments in the Chad and Sokoto depressions as well as the main rivers show high coefficients (over 25%) of net retention.

The implication of this natural water budget in the zone include the fact that the development of groundwater (through wells and boreholes) is to be preferred to surface water development in many parts of the zone such as Lower Sokoto, Rima, Lower Hadejia and Yobe systems. However, surface water development is feasible in some section of the region such as Upper Sokoto and Upper Hadejia (Kano and Jama'are) systems that have similar geoenvironmental conditions as the Niger.

4.4 Variations in the amount of rainfall

In a dry or drought year, the AET can be more than 80% of a smaller amount of rainfall. What is more, the AET is satisfied first before there is effective discharge or retention. Of the two residual components, it is the discharge (runoff) that is affected more seriously under drought conditions. For example in Gurara river basin, the runoff was about 18.8% of the rainfall in a wet year, but only 0.8% in extreme drought year. Conversely, seepage (an index of retention) was 14.5% in a wet year but 10.3%

in an extreme year of drought. It is obvious that surface flow may cease completely under severe drought conditions to render surface water development impossible. Under such conditions, existing surface water projects and natural surface water storages are also adversely affected. For example, the 1972/73 and 1983/84 droughts resulted in the drying up of many wells, boreholes, ponds and lakes in the zone. Similarly, Lake Alo (near Maiduguri) and Lake Kalmalo (near Sokoto) dried up within few months of 1984 dry season, partially because of 1983 drought, and partially because of damming of the flowing streams [10; 11].

4.5 Rainfall intensity

It has been stated that storm intensities, usually greater than 75mm/hr occur frequently at the onset/cessation periods of the rainy season, while intensities of over 30mm/hr are quite common. Infiltration capacity is low in most headstream areas (about 25mm/hr) where the surface material is rich in clay particles. This combination results in large runoffs and flash flooding in these headstream areas. Thus, streams have a high carrying capacity, with large sediment yields and concentrations. Most of the sediments generated in the headstreams become bed-load deposits in the lower courses of rivers. The implications of this mode of operation of water resources development include reservoir siltation, the development of dead streams, damage to water treatment equipment, expensive water treatment procedure and other utilization problems. Sedimentation of reservoirs and natural lakes constitute the most serious problem of water management in Nigeria.

4.6 Rainfall intensity as factor of erosion-induced sedimentation potentials in the three hydro-dams

Rainfall intensity data for 25 years were collected from 15 stations within the study area. Tested statistical techniques were used to obtain five Precipitation Intensity qualities namely: One-Hour Duration Fall; Weighted Rainfall Intensity for Normalised One-Hour Fall; Weighted Maximum Fall Intensity for Long-Duration fall; Rainfall Intensity for Near-Zero Time duration Fall and Percentage Probability of 50-min/30-min Fall (Flash – Flood Condition).

All the five parameters indicate the Kainji Hydro-Dam site as highly prone to high intensity fall. Both actual and estimated one-hour fall exceed 50 mm in Kainji Lake basin suggesting that erodibility of topsoils will be high while inflow of turbid water into the dam is a serious threat to the quality of water available for both aquatic life development and efficiency level of power production equipment.

Expected Lightest rainfall from Long-duration falls show Kainji Basin as receiving 80 mm or more while near-zero Time Duration Fall could be as high as 40 mm or more. Thus, the percentage probability of Kainji Hydro-Dam Site having Flash-Flood is between 70 and 110% during any particular rainy season. This condition is known as the 50-mm/30-min Fall.

Compared with Kainji, Jebba and Shiroro Hydro-Dam Sites are relatively ‘stable’ with respect to erosion-induced sedimentation. This is because all five parameters defined above for Kainji are ‘weak’ in the two sites. The tendency for Flash Flood at Jebba Dam is about 60% while it is 50% at Shiroro. But the value of 30-35 mm for Near-Zero Time Duration Fall at both locations suggest that with bare soils, a lot of sediments will end up in these dams especially during the Onset and Cessation periods of the rains when rain showers are sporadic and short-lived just as either the dry season is at its peak (onset) or harvesting of open farmlands is nearing completion when soils are bare and topsoils ‘loose’.

5. Conclusion

Coupled with high energy end-use efficiency, renewable source of energy through hydro-power is capable of covering a larger share of the Africa’s energy needs. It is obvious from the discussions that most Hydro-Dams in Africa are prone to erosion and Flash-Floods. Kainji Dam for example is one of the worst and it is necessary to redesign it in order to reduce its level of liability to the nation. Environmentally well designed hydro dams can be preferable to alternatives (coal, nuclear) and most environmental costs can be prevented, thus making hydro renewable and sustainable.

It is opined that, for development of hydro power on international river, the different basin states should not pursue diverse projects, rather, the ultimate goal should be that of harnessing the water resources of the river for the socio-economic growth of the peoples and nations of the region through the increasing use of the river basin management approach. This will involve the setting up of a suitable management team of experts and administrators to pursue a comprehensive or integrated planning and management for attainment of broader regional prosperity. If this is done, the future of Africa promises great improvement in power generation, domestic and industrial water supplies, irrigation, for livestock, for waste disposal, for fishing, for recreation and for navigation.

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