Bioenergy for Africa - The Quest for Energy Independence and Food Security

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Abstract: Energy is vital to sustain life activities and stability of the environment. However, dependence on fossil fuel besides creating crisis to the environment, it hugely affects human values. The deepening crisis in energy and food security in many Least Developing Countries of Africa is worsening due to poor economic conditions, crop and livestock disease epidemics, and the high incidence and impacts of HIV and other associated tropical diseases. A recent estimate indicated that more than 700 million people in the region are vulnerable to food insecurity and energy crisis. Renewable energy sources are viable options to halt the damaging effects of fossil fuel to the environment and society. Africa has great potential in biomass resources that can be used as biofuel and biofertilizer for sustainable development in this bio-energy arena. Emergency responses that focused on food aid to reduce sufferings do not provide long-term development solutions to Africa. Underutilized or poorly administered biomass resources of Africa has to be utilized and it is a requirement to introduced advanced adoptable technologies to nations and device a workable policy to support such initiatives towards implementation of the clean energy practices for household and community purposes. Besides energy security, this would leverage a wide range of income generation to the family and communities to support their livelihood. The role of biomass technologies with other renewable energy practices has not yet been fully exploited. The Africa-EU partnership is highly mandatory to mobilize resources to create cleaner, much affordable and sustainable renewable energy sources for energy and food security in Africa.

Keywords: Renewable energy, Bioenergy, DRE system, SSPS system, Low carbon energy, Waste management,; Biogenic electricity and economy.

1. Introduction

In Africa, an energy demand is concomitantly growing with an increasing of population. At present, more than three quarters of the total energy demand is met by biomass fuels directly from shrubs, firewood and animal dung. The majority of households (700 million people) in sub-Saharan Africa are vulnerable to food insecurity and energy crisis and are rely solely on traditional biomass for cooking and heating with this number projected to hit about 900 million people in 2020 if this trends continue [1]. Efforts to bring modern energy access to all – electricity and clean fuels – are far outpaced by population growth. Traditional biomass use has multiple negative impacts, most notably on respiratory health: 600,000 lives are lost each year in sub-Saharan Africa due to exposure to biomass smoke. The economic costs of high reliance of biomass for cooking are also substantial, about US$36.9 billion per year, or 2.8% of GDP, including US$29.6 billion from productive time lost gathering fuel for cooking [1]. The impacts are particularly severe for women and girls, who are typically responsible for these chores. There is a growing body of knowledge and experience about how best to achieve a shift to cleaner and safer use of biomass fuels for cooking, heating and electricity.

In Lesotho, the residential energy demand coverage reaches 88% to urban and 95% in rural areas [2]. Direct utilization of biomass such as wood and animal droppings are the most typical examples of energy recycling system with wood accounting for 70%, animal dung 25% and the remaining 5% taken by other crop residues and any other combustible materials with coal [3]. However, the cutting of shrubs and woods for fuel consumption, besides increasing the impact of greenhouse gas effect and desertification, it will eliminate diversity of indigenous and exotic tree species.

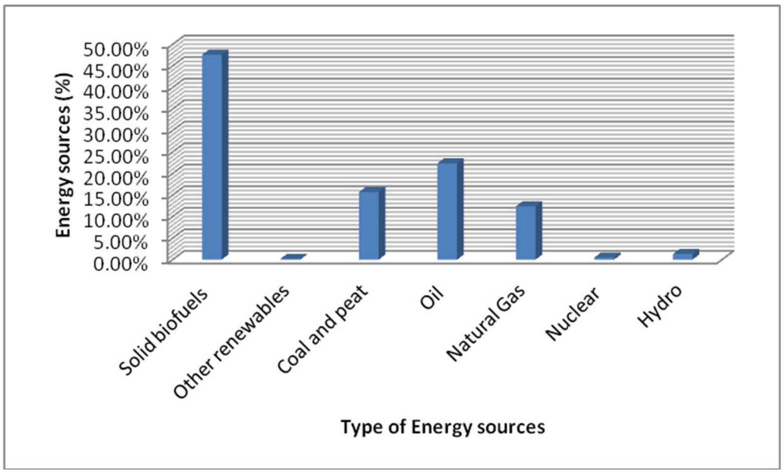

Figure 1. Energy sources type and consumption in Africa [8].

While securing energy requirements, establishment of environmentally compatible technologies that support the livelihood of the poor by sustainable use of natural resources is mandatory. Some practices involving the production of biogas from night soil and cattle manure has seen to be implemented by local NGOs

The role of biomass technologies with other renewable energy practices has not yet been fully exploited for sustainable production of energy and food security to the community. It is only at the inception and introductory level and has not reached scale levels with benefits to household livelihoods, environment and economies. There is an urgent need to ramp up these initiatives tailoring to the specific conditions in each country.

A variety of raw materials which include agricultural wastes (plant residue, animal faeces and fish farm waste), municipal wastes, market garbage, and waste water from food and fermentation industries are used for production of biofuels either in solid or liquid forms. The sludge after this can also be used as biofertilizer to cultivate crops for family food security. The cultivation /production of grasses such as Napier, Carajas and Vetiver varieties besides being used as a feedstock for the production of biofuel, it can also benefit the communities as an animal fed and means of soil conservation. However, the role of biomass technologies with other renewable energy practices has not yet been fully exploited in Africa. According to the World Bank [4], sub-Saharan Africa will require more than $30 billion in investment to achieve universal electricity by 2030. Rural sub-Saharan Africa will require the vast amount of the funds, with more than 85% of those living in rural areas lacking access to reliable electricity [4]. Therefore, stakeholder partnership such as Africa-EU partnership is highly mandatory to mobilize resources to create cleaner, much affordable and sustainable renewable energy sources for energy and food security in Africa.

This review assesses and evaluates the biomass resources of Africa and their utilization with technological approaches for family/community energy and food security.

2. Africa's energy resources access and potential

Sub-Saharan Africa today is in the midst of a dramatic urban transition that will persist well into the 21st century. Between 2010 and 2035, the urban population is expected to more than double from approximately 298 million to 697 million. By mid-century, it is estimated that over 1 billion people will live in urban areas. While urbanization has the potential to act as an engine of economic growth and human development it also brings enormous challenges in improved waste management services. In low-income countries, in particular, rapid urban growth and community development put extraordinary pressure on limited urban resources for the provision of essential basic services such as education, health and energy provision to the public. Indeed, there is perhaps no area where the capacity to manage urban waste is more urgent and more challenging than in informal settlements.

Compared to the rest of the world, there is a general shortage of energy related information in Africa on potential of energy resources, actual installed systems and current energy uses. It is indeed difficult to compare the potential for the different energy options due to the scattered validated information [5]. This lack of information is even more apparent for renewable energies [5]. Nevertheless, available data sources are in agreement in describing a difficult situation as far as access to energy is concerned.

However, the continent possesses abundant renewable resources that could spur continued economic growth, accelerate social development and help the transition to a sustainable energy system that can provide universal energy access. The community and city council solid and liquid waste sources can be thought of high energy potential if properly managed to maintain the health of the environment and economy. In Africa, the Waste to Energy recovery is currently under way involving energy recovery technologies namely combustion of waste and anaerobic digestion in some countries, which is the best practice for the environment, health and economy. The Cows to Kilowatts project in Ibadan, where the plant generates the equivalent of 0.5MW of electricity daily and became the first plant in the world to simultaneously treat abattoir waste and provide domestic energy and organic fertilizer; and the eThekwini Landfill Gas to Electricity project in Durban, which generates 7.5MW of electricity from 2 landfill sites [(6], the BMW Company to produce 25-30% of its energy demand from animal dung and other organic wastes, South Africa [7]. The waste to biogas projects in prisons in Kissi and Homa Bay in Kenya, Bamako in Mali, and a tourist location on the beaches of Dakar for instance are some of the practices in Africa [(6]. In addition to the above, UN-Habitat is involved in the production of briquettes from the organic waste fraction of wastes as a substitute for wood charcoal, while providing a source of income for small businesses. Multifunctional Clean Energy Centres (MCECs) have been established in informal settlements in select African cities [6]. Figure 1 shows the degree of use of different energy sources in Africa.
As can be seen, from figure 1 above, the use of solid biofuels far exceeds all other sources at just over 45% with oil a fossil fuel coming second at about 20%. An emerging concern for carbon emissions fossil fuels and sustainable development has created an opportunity for renewable energy using solid and liquid community and municipal wastes on the continent.

Renewable energy sources available for Africa:

wind, hydro- and biomass) that could spur continued economic growth, accelerate social development and help the transition to a sustainable energy system that can provide universal energy access.
In the world today, renewables accounted for 6.7% of global power generation. China (+20.9%) and Germany (+23.5%) recorded the largest increments in renewables in power generation. Globally, wind energy (+17.4%) remains the largest source of renewable electricity (52.2% of renewable generation), with Germany (+53.4%) recording the largest growth increment [4]. Solar power generation grew by 32.6%, with China (+69.7%), the US (+41.8%) and Japan (+58.6%) accounting for the largest increases. China overtook Germany and the US to become the world's top generator of solar energy. Global biofuels production grew by just 0.9%, well below the 10-year average of 14.3%: Brazil (+6.8%) and the US (+2.9%) accounted for essentially all of the net increase, partly offset by large declines in Indonesia (-46.9%) and Argentina (-23.9%) [4].
The total primary energy demand (TPED) for Africa is predominantly determined by biomass demand (figure 1). Sub-Saharan Africa estimated to provide more than 170 Giga watts (GW) of additional power-generation capacity, which is more than double the region's current installations through 3,200 "low-carbon" energy projects, such as combined heat-and-power, biofuels production, mass transportation, and energy efficiency [4]. Just a 0.3% of the sunlight that shines on the Sahara and Middle East deserts could supply all of Europe's energy needs [9]. The renewable energy projects potential in Africa as estimated by World Bank can provide about 170 GW worth of low-carbon energy that may require a total capital of $157 billion, but would avoid approximately 740 million tons of carbon dioxide emissions each year [4]. The support for Africa Climate Business Plan (ACBP) will increase climate resilience and develop an energy efficient and sustainable source of energy predominantly composed of biomass and waste.

Biomass feedstock:

Accessing potent feedstock has always been one of the main challenges of developing biogenic power plants in Africa. Several biomass sources can be used as feedstock for the production of flammable biogases. The following are feedstock sources for the anaerobic digester:

i. Organic crop wastes: farm leftovers and postharvest plant litter and plant debris are used as a feedstock for the bioenergy plant.
ii. Night soil: sewage water from municipal city.
iii. Animal feaces (manure) (cattle, pig and chicken…) from agricultural farms.
iv. Cultivated grasses: Vetiver, Napier and Carajass.
v. Water hyacinth, which is an invasive plant taking over Lake Naivasha, in Kenya and lake Tana, Ethiopia for instance, can be used for power generation being used as a feed stock.

Benefits of biomass from power generating plants:

Biomass power plants will not only help provide energy to those populations without access, but also will reduce the need to collect wood and burn/buy charcoal. Bioenergy products range from a simple log, to a highly refined transport fuel. Biomass can also provide thermal, electrical and mechanical energy services. Different products suit different situations and objectives. The choice of product may be affected by the quantity and cost of biomass types available; location of fuels and users; type and value of energy services required; or other co-products [10]. Highest overall efficiency is often a result of capturing more than one service e.g. in combined heat and power plants. This translates to a reduction of energy expenditure if power from the plants is cheaper. A 10% increase in biogas production could cut down deforestation by an equivalent of 9-35% [10]. Biogas power generation can also help cut down carbon emissions by displacing fossil fuel-generated power from grids. From environment and health point of view, it helps in reducing spread of pathogens and disease incidences. For agricultural purposes, the residue from the power plants is bioslurry and can provide nutrients to improve crop production being serving as organic fertilizers and soil organic modifer that has no side effects to life and environment unlike chemical fertilizers.

Investment attraction:

In order to attract large investments in renewable energy technologies, a thorough planning phase is necessary to estimate the energy share that can be supplied by renewable energy sources; compare energy costs with that of conventional solutions and to identify the most effective technologies that are adaptable to local conditions [8]. This enables countries to develop adequate policy frameworks and financing instruments, to nurture human capacity and to create the necessary infrastructure to fulfill their sustainable energy aspirations. For countries to properly analyze and plan the use of renewable energy, they need accurate and documented estimates of their renewable energy potential, as well as to identify the most suitable locations for investment and deployment in renewable energy technologies. The accuracy of this information correlates directly with the risk taken in the decision-making process. Accurate data strengthens each country's national strategy to deploy renewable energy technologies.

Regional bodies in Africa have started to recognize the opportunity and challenges to establish the Center for Renewable Energy and Energy Efficiency (ECREEE), forming strategic development pacts with several international organizations that include the European Union (EU), United Nations Development Program (UNDP) and the United Nations Food and Agricultural Organization (FAO) [11]. The renewable energy initiative that is currently running at some parts of Africa, for instance, in Lesotho, Botswana through Africa-EU partnership with govenoment, higher learning institutions and many other stakeholders is one of a kind that has to be continued in other parts of Africa.

Distributed Renewable energy systems:

The impending deregulated environment facing the electric utilities in the twenty first century is both a challenge and an opportunity for a variety of technologies and operating scenarios. Distributed renewable energy systems generate clean, renewable electricity on site, where that energy will be used. The term distributed generation distinguishes these systems from the large, centralized power plants that provide the vast majority of the nation's power. Distributed renewable energy systems can take many forms, including geothermal systems, micro-hydroelectric systems, solar panels, wind turbines, and biomass [12], [13]. There are many programs and policies that can either help or hinder the adoption and integration of distributed energy systems. Municipal solid waste (MSW) and natural waste, such as sewage sludge, food waste and animal manure will decompose and discharge methane-containing gas that can be collected and used as fuel in gas turbines or micro turbines to produce electricity as a distributed energy resource. A distributed energy resource is not limited to the generation of electricity but may also include a device to store distributed energy (DE) [14]. Distributed energy storage systems (DESS) applications include several types of battery, pumped hydro, compressed air, and thermal energy storage [15]. Access to energy storage for commercial applications is easily accessible through programs such as Energy Storage as a Service (ESaaS) [15].

Sustainable service and product system:

Service is an action or an activity which can be offered by a party to another party, which is basically intangible and can not affect any ownership. This conventional services marketing definition only draws little attention to the element of sustainability. However, starting in the 1980s and especially growing since the 1992 Rio Earth Summit stakeholders and customers likewise increasingly considered the environmental and social consequences of the products they bought [16]. The consumer green movement imposed tremendous pressure on both businesses and governments to reduce the environmental impact of their production and consumption, leading to an increasing demand for developing concepts for a more sustainable future. These early ideas later on developed from cleaner and greener improvements to processes and products and new products and services-mixes [17]. In the current smart business concept, companies have started reviewing their organizational performance by adding environmental quality and social benefits to economic prosperity as part of their business evaluation process and adopting green services and products to reach ever-increasing environmentally aware consumers [18]. To this effect, the concept of sustainable product-service systems has emerged recently, and is distinct from the ideas of cleaner production, eco-design and design for the environment [16]. The concept goes beyond the environmental optimization of products and processes and requires radical and creative thinking to reduce environmental impacts by a factor of between 4 and 20 times while maintaining an acceptable quality of service. Sustainable product-services consider alternative socio-technical systems that can provide the essential end-use function, such as warmth or mobility, that an existing product offers. Four types are outlined—result services; shared utilization services; product-life extension services; and demand side management. Sustainable product-service systems attempt to create designs that are sustainable in terms of environmental burden and resource use, whilst developing product concepts as parts of sustainable whole systems that provide a service or function to meet essential needs [16].

Policy issues and legislation:

In Africa, policies crafted on the use of "nature's capital" (air, water, and sun) has to be diverted to the use of "nature's income" (waste (solid/liquid), and biomass…)) for the production of bioenergy-electricity. For instance, a proposed mission statement for Lesotho's renewable energy policy is framed to manage and develop water and land resources for diversified economically sound and sustainable irrigation and drainage systems. As land is owned by the people in Lesotho, it is allocated by and through the traditional structure of chieftainship. Until very recently, when new forms of land holding were introduced, there was little legal (as opposed to customary) security for the tenants [19]. For irrigation and renewable energy projects this has had major consequences, as the high fixed costs of providing the systems are only justifiable when the benefits can be shared between many recipients. The existing framework of land tenure is not likely to change rapidly and thus any effective irrigation and renewable energy scheme would in the short to medium term have to work within it. New policy documents has to be framed on the bases of bioenergy projects development for better management [20].

Challenges:

New bioenergy sources including biohydrogen, microbial fuel cells, bioethanol, and biodiesel production are ideal options in the future for fulfilling ever-increasing energy demands. However, the technology gap between research and industrial application still exists. The field of bioenergy is interdisciplinary, requiring the knowledge of biologists, chemists, physicists, and engineers. Exploring the current trends and future prospects for biofuels will be valuable for identifying new options to circumvent problems that exist in bioenergy applications.

3. Conclusion and recommendation

Without access to energy, Africa's growth will be stifled and, investing in energy solutions for the continent is an absolute necessity. Renewable Energy in Africa is a huge opportunity to allow for a better standard of living for a large part of current and future population in Africa. However, it should be pointed out that much of the knowledge has be transferred swiftly to research and technology partners in Africa in collaboration and co-operation with the wide range of existing research and university infrastructure. It is only if such activities can be deployed in research, prototyping and demonstration that would accelerate the uptake of renewable energy in Africa. Strategies for fostering international collaboration in using its biomass resources are required to tap resource to maximize its development while minimizing its impact to the environment. In summary, many of these initiatives are providing benefits in terms of low-carbon energy generation, reuse of waste, effective land use and reduced deforestation if funding organizations, government and other implementing agents are working hand in hand together.

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