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Comparative Analysis of Bioenergy Production and Consumption in Africa

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Abstract: The quest to pursue alternative options to fossil fuels on the African continent has been triggered by well-known contemporary imperatives. Biofuels are now an established alternative to fossil fuels. The increasing focus on bioenergy has been buttressed by various policies in many countries in Africa that encourage production and consumption of biofuels. With annual gross domestic product growth rates reaching 5% during the past decade, more than twice that of the 1980s and 1990s, Africa has become one of the fastest growing continents. Access to modern and sustainable energy will be critical to sustain these positive signals. Biomass is by far the most important renewable energy resource in Africa. Bioenergy represents almost 50% of the total primary energy supply for the African continent. Africa is second to Asia supplying and consuming 26% of global bioenergy. Between 2005 and 2012 there was a 22% increase in bioenergy supply in Africa. However, most of this energy is used as heat. Africa produces about 0.3% of electricity from biomass. Africa contributed 0.07% to global production of liquid biofuels in 2012. Given its vast biomass resources, there is scope for enhanced bioenergy production and consumption in Africa through increased investment in the biomass conversion sector.

Keywords: Bioenergy, Biomass, Biofuel, Consumption, Production

1. Introduction

The quest to pursue alternative options to fossil fuels on the African continent has been triggered by well-known contemporary imperatives. These in part include volatile global prices of crude oil and anticipated economic and environmental benefits [1]. Biofuels have increasingly received attention due to their vast potential to increase energy supply, offer energy independence, open new markets, and create employment opportunities, amongst several other benefits. In 2011, the share of renewable energy sources in the global gross final energy consumption (GFEC) was 18.3%, of which bioenergy was 14.3% [2]. The increasing focus on bioenergy has been buttressed by various policies in many countries in Africa that encourage growth of the biofuel sector.

It is commonplace nowadays that modern biomass and the bioenergy produced from it are providing a significant contribution to the global primary energy supply of many countries. The energy and development nexus is a strong pillar of sustainable economic development in the 21st century. For those countries wishing to achieve economic growth as well as meet the goals for sustainable development, the deployment of modern bioenergy projects and the growing international trade in biomass-based energy carriers offer potential opportunities [3]. Africa is currently experiencing strong economic growth and showing positive trends in human development indicators [4]. With annual gross domestic product (GDP) growth rates reaching 5% during the past decade, more than twice that of the 1980s and 1990s, Africa has become one of the fastest growing continents [5]. Access to modern and sustainable energy will be critical to sustain these positive signals.

According to some estimates, 47% of the population of sub-Saharan Africa (SSA) lives on less than $1.25 per day and 27% are hungry or undernourished [6]. A large number of these people depend on agriculture for livelihood. They are largely dependent on access to land and its products, which include traditional forms of bioenergy, to survive [5]. The contemporary development narrative asserts that food security and economic development in Africa can be

addressed more effectively with modern bioenergy than without it [5].

Biomass is by far the most important renewable energy resource in Africa. It is the primary energy resource for about 2.7 billion people worldwide [7]. Bioenergy plays a significant traditional role in Africa. The total primary energy demand (TPED) for Africa is predominantly determined by biomass demand, with almost half of the energy demand (47.9%) being covered by biomass and waste [4]. Biomass will continue to remain an important energy resource for Africa in the future [8].

There are many conversion technologies which can be used to convert raw biomass feedstock into disparate energy carriers. Several conversion technologies have been developed that produce a wide range of energy carriers. These range from physical (e.g. pelletisation, briquetting), thermo-chemical (e.g. pyrolysis, torrefaction), to biological technologies (e.g. anaerobic digestion). The primary services provided by the energy carriers include heat, power and use as transport fuel. A study by reference [9] concluded that Africa has potential to meet both its food and fuel needs from biomass, neither of which occurs today. Pursuant to this, Africa, and in particular SSA is currently in the process of formulating policies and developing plans to ensure that there are sustainable bioenergy programmes for economic development [10]. Food security is one of the fundamentals to be considered when implementing bioenergy policies and is more likely to be threatened by the expansion of bioenergy projects. As such, many African countries have put into practise some initiatives including characterisation of agro-ecological zones to identify land availability for food and for bioenergy production, and mandates for investors to utilise part of the allocated land for food, in order to safeguard food security [10].

The objective of this paper is to provide a comparative analysis of bioenergy supply and consumption in Africa, benchmarking on trends in other regions of the world.

2. Supply of Biomass

Biomass is projected to remain an important energy resource for Africa into the future beyond 2035 [8]. The International Energy Agency (IEA) estimates that the total final consumption of biomass/waste share for Africa will lie between 51% and 57% by 2035. The biomass potential of Africa has been a subject of numerous studies. For example, reference [4] reviewed 14 studies on biomass supply in Africa and concluded that results on African biomass potential are only very approximate and are subject to great uncertainties. The primary origins of biomass are forestry, agriculture and waste.

Forestry is a major supplier of biomass. Agriculture has a significant contribution to production of biomass after forestry in terms of energy crops, by-products and residues. Various assessments have indicated a potential for energy crops from 0 PJ/yr to 13,900 PJ/yr, between 0 PJ/yr and 5,400 PJ/yr for forestry biomass and 10 PJ/yr to 5,254 PJ/yr for residues and waste in Africa by 2020 [4]. Land holdings for forestry and agriculture for Africa and three other continents are shown in Fig. 1 and Fig. 2, respectively.

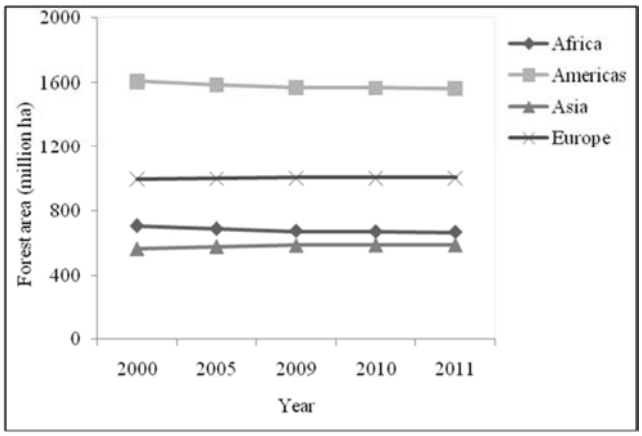

Figure 1. *Continental forest area.*

Generally, forestry products include fuel wood, charcoal, forest residues, wood industry residues and recovered wood. As of 2011, total forest area in Africa was 671 million ha. However, the forest area appears to be gradually decreasing in Africa [2], with a 5% decrease between 2000 and 2011.

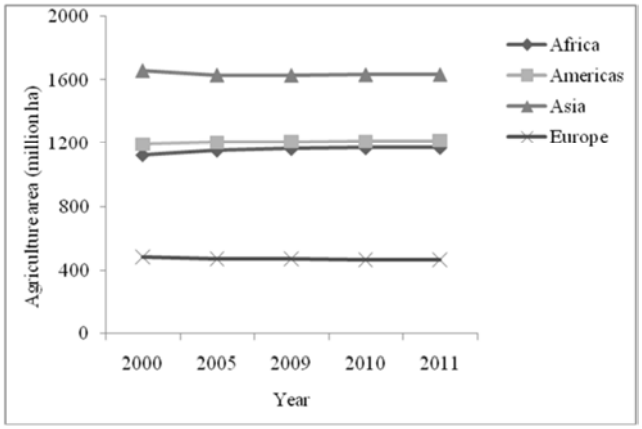

Figure 2. *Continental agricultural area.*

As shown in Figure 2, Africa has vast areas under agriculture. Agriculture supplies animal wastes, crop residues and energy crops. Energy crops, for example Jatropha, have become a common feature in African agriculture. Major crops in Africa include cassava, maize and sugarcane, all of which produce large quantities of residues.

Another origin of biomass is the wastes sector. Wastes are mainly municipal wastes from households and industry. Sewage sludge and municipal solid waste are common feedstocks for energy production. Europe and the Americas dominate the statistics for the use of municipal waste for energy production. The Organisation for Economic Co-operation and Development (OECD) countries produce almost half of the world's waste, while Africa and South Asia regions produce the least waste [11]. Waste generation in SSA is approximately 62 million tonnes per year. Per capita

waste generation is generally low in this region, but spans a wide range, from 0.09 to 3.0 kg per person per day, with an average of 0.65 kg/capita/day [11].

3. Experience with Bioenergy in Africa

Efforts to harness the potential of biofuels on the continent escalated as far back as the early 80s. Several countries and regional institutions commissioned studies on biofuels to understand their potential and inform strategies to maximize economic benefits without harming the environment [1, 12]. In 1990, Africa's primary energy consumption had reached 16 EJ, less than 5% of the global energy demand, of which bioenergy provided 60% [5]. By 2010, its primary energy consumption had risen to 28 EJ, slightly more than 5% of the global demand, with bioenergy providing about half of this for the continent as a whole [4]. It is projected that in Africa by 2020, between 41 EJ and 410 EJ of energy could be derived from bioenergy, with an upper estimate comparable to current global primary energy consumption (GEPC) [13]. Generally, bioenergy represents almost 50% of the total primary energy supply (TPES) for the African continent and more than 60% of the SSA TPES.

Biomass has been the main source of energy for many people in Africa both in rural and urban areas. For SSA (excluding South Africa), over 80% of the total energy supply for heating, cooking, and processing of agricultural produce is derived from biomass such as fuel wood and agricultural residues [5]. Bioenergy systems in Africa can be disaggregated into two systems. The first is the traditional biomass system which has been used since time immemorial to supply energy needs for domestic and industrial uses. This system encompasses mainly traditional firewood and charcoal production. It is estimated that 52% of the developing world and close to 80% of African countries rely on this traditional system to meet their energy needs [14]. Traditional biomass resources are cheaply available to the local communities in the developing world.

The challenges with the traditional biomass system have been documented. Cooking using open fires is highly energy inefficient and also poses a major public health problem. An estimated 4,000 Africans die prematurely every day from household smoke pollution [15, 16]. Demand for wood for cooking, particularly when converted to charcoal to sell in urban markets, can exceed supply; resulting in environmental degradation in addition to serious health impacts [15, 16]. By contrast, the other system is the modern bioenergy system which involves using higher efficiency technologies to produce biofuels. This system has the potential to boost the agricultural sector and stimulate socio-economic development through investment and infrastructure improvement [10]. Typical examples of morden energy system include liquid biofuels (bioethanol from sugarcane, biodiesel from oilseeds), biogas from anaerobic digestion of organic matter and torrefaction products. Nowadays, African countries are concentrating on liquid biofuels as a bioenergy development strategy for transport fuel and for improving rural energy supplies [10]. There is still a back log in terms of improvement of the economic viability and sustainability of the modern bioenergy system [5]. Therefore many countries in Africa are now adopting policies promoting generation and consumption of bioenergy, and have initiated several modern bioenergy programmes. For example, there is a National Biogas Programme in Zimbabwe aimed to install 7,400 biogas digesters between 2013 and 2017 [17]. Currently, at least 400 digesters with technical feasibility of 5,000 m^3 are installed in Zimbabwe [18].

4. Bioenergy Supply and Consumption

4.1. Mix of the Biomass Sector

The biomass sector can be broken down into three categories. Solid biomass comprises mainly wood, forestry and agricultural waste and municipal solid waste. Gaseous biomass is manly biogas from anaerobic digestion in landfills, sewage treatment plants or digesters. Biogas can be upgraded to biomethane. Liquid biomass includes vegetable oils, bioethanol and biodiesel amongst others.

4.2. Total Primary Energy Supply and Total Final Energy Consumption

Using statistics from IEA [19], the bioenergy TPES and total final energy consumption (TFEC) can be computed. Disaggregated by region, the TPES and TFEC for bioenergy are presented in Table 1 for the year 2012.

Table 1. *Comparing total primary energy supply and total final energy consumption for bioenergy in selected regions of the world in 2012 (EJ).*

	Total primary energy supply	% of world total	Total final energy consumption	% of world total
World	56.1	-	46.5	-
Africa	14.8	26.4	12.3	26.5
Asia	24.3	43.3	22.4	48.2
OECD	11.2	20	7.6	16.3
Non-OECD Americas	4.9	8.7	3.6	7.7
Rest of the world	0.9	1.6	0.6	1.3

Source [19]

It can be seen from Table 1 that Asia supplies and consumes almost half of the global bioenergy. However, about 9 EJ of TPES in Asia (24.3 EJ) were contributed by China in 2012. Most of the bioenergy in Asia is used as heat [2]. Africa is second to Asia supplying and consuming 26% of global bioenergy. As stated earlier, the dominant bioenergy system in Africa is the traditional biomass system.

A trend analysis shows the bioenergy supply and

consumption dynamics over time. Fig. 3 shows trends in bioenergy TPES from 2005 to 2012.

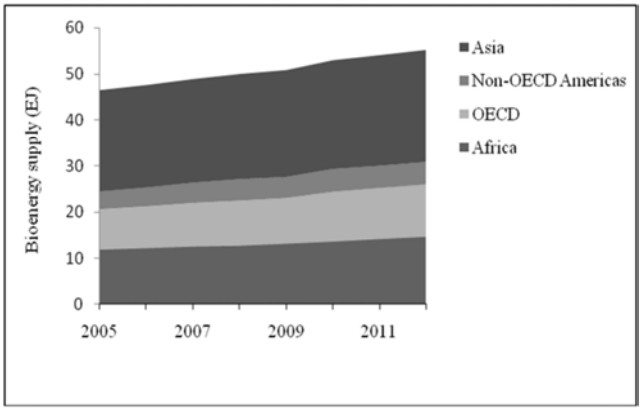

Figure 3. *Bioenergy supply in different regions of the world.*

The trends in bioenergy supply (Fig. 3) show a gradual increase between 2005 and 2012 in all the regions. Between 2005 and 2012 there was a 22% increase in bioenergy supply in Africa and 11% in Asia. Non-OECD Americas and OECD countries had increases of 31% and 24%, respectively. Comparatively, from 2000 till 2011 the global primary energy supply increased by 30% and the highest absolute increase among renewable energy supply (27%) was reached by bioenergy [2]. It is therefore apparent that bioenergy is and will continue to be a major component of the global energy mix.

4.3. Gross Final Energy Consumption for Bioenergy

The major end uses for energy are heat, transport and electricity. The main end use of bioenergy globally is heat, comprising 92% of GFEC in 2011 [2]. What is apparent is the dominant use of bioenergy in Africa and Asia as heat, with negligible uses for transport and electricity. The GFEC for Africa and Asia in 2011 was 100% and 98% as heat, respectively. The distribution of GFEC of bioenergy per end use for 2011 is shown in Fig. 4.

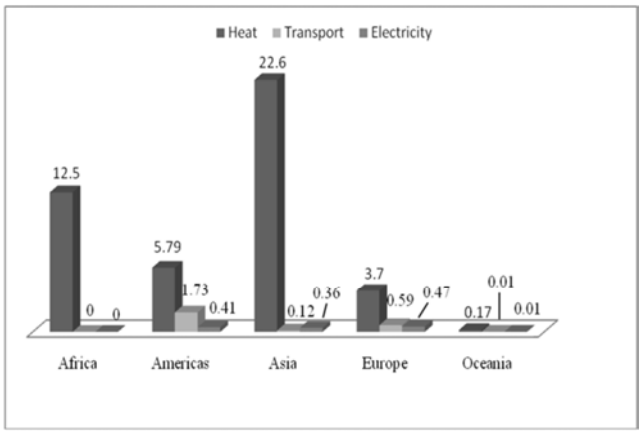

Figure 4. *Gross final energy consumption for bioenergy for 2011 (EJ): Source [2].*

From Fig. 4, Europe and the Americas used 0.59 and 1.73 EJ of bioenergy for transport, respectively. This translates to about 12% and 22% of their total bioenergy consumption, respectively. It is clear from Fig. 4 that the predominant end use of bioenergy in Africa is heat. The predominant end use of bioenergy as heat in Africa can be ascribed to the preponderance of the traditional biomass system. In Africa, a total of 657 million people (80% of the population) rely on the traditional use of biomass for cooking [8]. Given the scenarios in Fig. 4, it is prudent that Africa must diversify the use of bioenergy into transport and electricity generation. In order for this to happen, more advanced biofuels need to be produced in Africa using existing conversion technologies. This requires the production of liquid and gaseous biofuels.

4.4. Biomass to Electricity

Worldwide about 1.3 billion people live without access to electricity. Nearly 97% of those without access to electricity live in SSA and developing Asia [20]. Access to electricity in SSA is about 26% and falls to less than 1% in the rural areas [21]. The largest populations without electricity in Africa are in Nigeria, Ethiopia, and Democratic Republic of Congo [17]. SSA has a per capita electricity output of 490 kWh, almost thirty times less than that of North America [19]. This makes increasing access to electricity by people in Africa a priority development issue. Reference [21] estimated a power generation potential of about 5,000 MW and 10,000 MW by using 30% of residues generated during agro-processing and 10% of forest residues from the wood processing industry in SSA, respectively.

The global production of electricity from biomass has more than doubled during a period between 2000 and 2011 from 170 to 422 TWh [2]. In 2012, biomass accounted for 1.4% of global electricity production [22]. A study of 12 countries in SSA [22] showed that biomass accounted for 0.3% on the structure of electricity production in 2012. The total electricity production from biomass was 1.4 TWh in the selected African countries. Notable was a flat trend in production of electricity from biomass at this level of 1.4 TWh between 2009 and 2012. In North Africa, that region's electricity mix had negligible contribution from biomass. In the same year, global electricity production from biomass was 326 TWh. Comparatively, 140.7 TWh were produced from biomass in Europe in 2012 [22]. This represented a 32% increase between 2009 and 2012 in Europe.

The trend is that the contribution of biomass to the global electricity mix is increasing. As such there must be concerted efforts in Africa to produce more electricity from biomass. At the global level, both liquid biomass and biogas contribute to the share of electricity produced from biomass. However, most biomass-derived electricity comes from solid biomass (71.3%) and biogas (17.8%) [22]. Generally, liquid biomass is used for transportation and marginally for producing electricity. In Africa it is mainly solid biomass that is used for producing electricity, yet biogas is widely used for that purpose in Europe.

Lessons for Africa can be derived from Western Europe and North America who are the main producers of electricity from

biomass. These regions have well developed biomass electricity conversion sectors. Western Europe is the main producer of electricity from biomass at 38.5% of global production and North America at 22.7% of global production [22].

4.5. Biomass to Liquid Biofuels

The United States and Brazil are the world's largest producers and consumers of liquid biofuels. The IEA has projected that biofuels will meet 8% of the world road transport fuel by 2035, up from 3% in 2009 [8]. Using their central scenario, reference [20] projected that use of biofuels will more than triple to 4.6 mb/d by 2040. By 2040, SSA's economy is projected to quadruple in size, the population nearly doubles and energy demand grows by around 80% [20]. These dynamics call for increased production and consumption of biofuels in Africa.

The major liquid biofuels are biodiesel and bioethanol. Using IEA statistics [23], about 110 billion litres of biofuels were produced in 2012. Africa contributed 0.07% to the global production of biofuels in 2012. Production levels of bioethanol and biodiesel in Africa in 2012 were 0.036 and 0.04 billion litres, respectively. Comparatively in the same year, North America, South America and Europe produced 52.7, 24.9 and 4 billion litres of bioethanol and 67.7, 103.8 and 170.9 billion litres of biodiesel, respectively. The trends in production of bioethanol are given in Fig. 5.

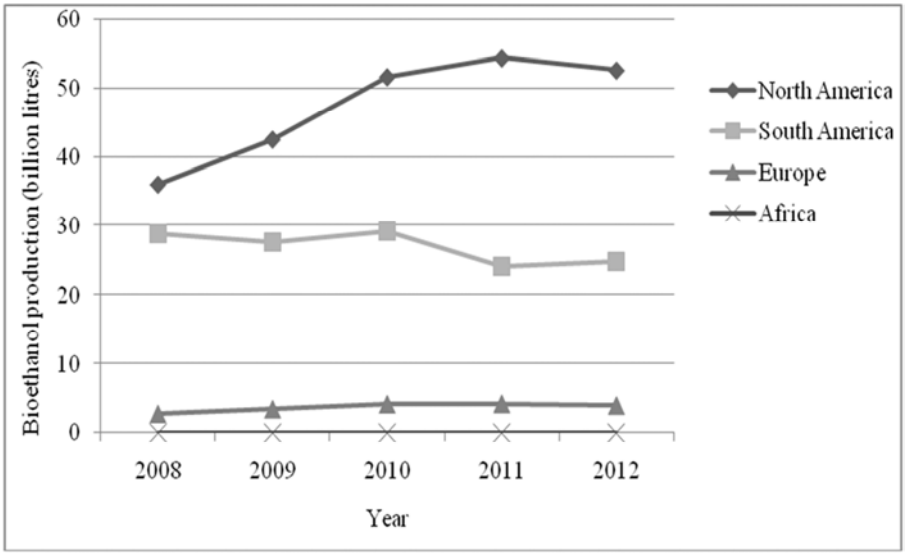

Figure 5. *Trends in bioethanol production in Africa and three other regions.*

The dominance of North America in bioethanol production in recent times is evident in Fig. 5. Production levels of bioethanol in Africa lag way behind the Americas and Europe. It is worth noting that some African countries now have mandatory blending levels for bioethanol and gasoline. An example is Zimbabwe. This is an enabler for enhanced production of bioethanol. For biodiesel the trends are shown in Fig. 6. Again Africa lags way behind the other regions. However, the dominance of Europe in biodiesel production is quite evident.

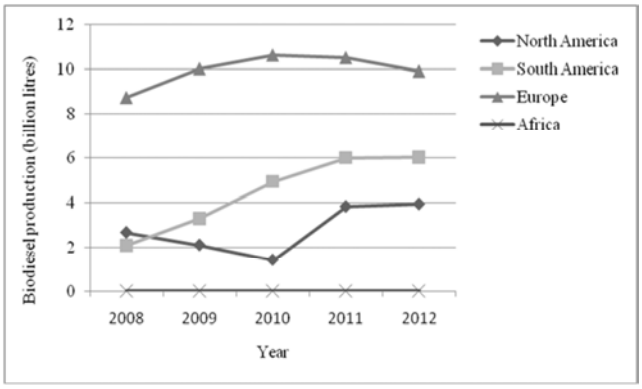

Figure 6. *Trends in biodiesel production in Africa and three other regions.*

It is quite clear from both Fig. 5 and Fig. 6 that Africa is lagging behind the major biofuel production regions of the world. The biofuel production levels in Africa cannot be measured on the same scale with the Americas and Europe. Consequently, Africa needs to invest more in biofuel production.

5. Conclusion

There are many economic and environmental benefits in using biofuels. In fact, the dominant narrative in contemporary times is to optimise production and consumption and of carbon-neutral fuels. That biofuels are a substitute of fossil fuels and that their demand will continue to rise into the foreseeable future is not disputable. The existence of modern biomass conversion technologies is an enabler that must be used to optimise production of bioenergy in Africa. Indeed, Africa is richly endowed with vast biomass resources, which unfortunately are not matched with high levels of biofuels production. For the enhanced supply and consumption of bioenergy, Africa must escalate its investment in the biomass conversion sector. The potential for this to happen exist and benchmarking with the leading biofuels regions is a sure approach to increasing the role of

biofuels in the energy mix in Africa.

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