

Review

A review of sustainable development of bioenergy in Africa: An outlook for the future bioenergy industry

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The paper reviews the progression in biofuels development in Africa focusing on the current situation, promising feedstock options, potential markets, environmental concerns and existing opportunities. The paper highlights the gradual development of biofuels in Africa through the first generation and the prospects of second generation lignocellulosic feedstocks which offer a better option because of the absence of competition with food security. However, it is argued that the limited uptake of these innovations is in part due to poor planning and financing arrangements. Suggestions are advanced on how some of the challenges and opportunities can be exploited including policies that can promote the development of pro-poor biofuels in order to protect the interest of local farmers while addressing environmental concerns about carbon footprint in the promotion of biofuels and preservation of biodiversity. It is also argued that the vast underutilized land in sub-Saharan African present opportunities that can be realised from the carbon markets through the clean development mechanism. The paper concludes with a call to facilitate the process of developing modalities for instituting PES including procedures of the CDM that can accommodate developing countries.

Key words: Bioenergy, biofuel, environment, markets, lignocelluloses, policy.

INTRODUCTION

Energy plays a key role in the development of nations and provides vital services and means that improve quality of life. Energy is the engine of economic progress. With the sub-Saharan Africa population of about 800 million bound to reach more than 1.2 billion by 2020, poverty cannot be effectively addressed without major improvements in the quality and magnitude of energy services. In contrast to the rest of the world, poverty in Africa is primarily a rural problem. However, subsistence livelihood can not be an acceptable norm in rural Africa; but instead an innovative technology development along the whole value chain should be the approach to move Africa out of poverty. Renewable bioenergy, particularly biofuels could help address the need for energy

expansion in the future. Capitalizing on Sub-Saharan Africa's biomass potential, bringing back the focus on agriculture, re-establishing rural pride, and at the same time address social and security issues, merits a fresh look at the bioenergy potential of Africa. According to the FAO (2009) definition, bioenergy can be categorised in three main ways as bioresources, biofuel and bio-residue. Bioenergy development is identified by two competing paradigms, which coexist within energy supply sources. The first is the traditional biomass extraction, which has been used since time immemorial to supply energy needs for domestic and industrial use. This encompasses traditional firewood and charcoal production is generally characterized as less productive and efficient without due appreciation of its economic value. It is estimated that close to 80% of African countries rely on this traditional system to meet their energy needs (NEPAD, 2005; Cotula et al., 2008). The other is the

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innovative modern approach where production of biofuels is commercially done using more efficient and environmentally friendly technologies. Typical examples of this include: bioethanol from sugarcane, sweet sorghum, or bagasse and other cellulosic agricultural residues among others, as well as biodiesel from oilseeds, palm oil and tallow (BNDES Communication Department, 2008).

Africa still remains a large consumer of traditional sources of energy mainly fuel wood and with a greater proportion of its population facing energy insecurity (ICSU, 2007). The availability and access of socially and environmentally acceptable sources of energy is still very low and disproportionate between rural and urban areas. With the exception of fuel wood, other energy sources (coal, crude oil and more recently biofuels) have been the major sources of power driving the transport and industry sectors. The quest to pursue alternative options to fossil fuel on the African continent has been triggered in part by the recent increase in global prices of crude oil and other anticipated economic, environmental benefits (Gnansounou et al., 2007, Jumbe et al., 2009). Biofuels have increasingly received attention for their potential to reduce green-house-gas (GHG) emissions, increase energy supply, open new markets for agricultural surplus (thus additional revenue for farmers), employment opportunities and local economic development opportunities in rural areas, just to mention a few (Meyer et al., 2008).

Last but not least, it would contribute to political security, making Africa less dependent on fossil oil and create local wealth and economic independence. Bioethanol and bio-diesel can be made from most arable crops. However, the generation of these feedstocks or raw materials from predominantly rain-fed agriculture for processing into biofuels face increasing risks from drought and other elements of weather. Areas with irrigation potential tend to have a better comparative advantage than those without (Cotula et al., 2008). It should be noted that the use of biofuels is often not carbon neutral because fossil fuels are used during the planting and harvesting of these crops, or natural vegetation is cleared to plant the biofuel crops, which are detrimental to natural CO₂ fixation and biodiversity. On the flip-side, if agricultural practices are undertaken in such a way that the carbon footprint is minimized and natural forests and vegetation are allowed to be re-established, biofuel production can even assist in CO₂ sequestration.

This is possible because a considerable portion of the carbohydrates produced through photosynthesis are transported through the roots to the soil microflora, whilst only the biomass above ground is used for biofuel production. It is thus crucial to understand that not all biofuel production practices are beneficial towards combating climate change, but that careful consideration should be given to the carbon footprint during the production of biofuels.

This paper presents a review of the status of biofuel use and development in Africa highlighting the current potential, technology use and development, market opportunities, environmental and sustainability issues, policy frameworks and challenges and opportunities of bioenergy industry in Africa.

SITUATION ANALYSIS: OVERVIEW OF BIOENERGY PRODUCTION POTENTIAL IN AFRICA

The evolution of efforts to harness the potential of biofuels on the continent dates back to early 1980s. Import substitution and energy diversification from crude oil were major drivers that spearheaded investments in biofuels. Some governments and other regional institutions commissioned studies on biofuels to understand their potential and inform strategies to maximize economic benefits without harming the environment (Gnansounou et al., 2007; Meyer et al., 2008; UEMO, 2008). Blending of ethanol with petrol programs at various rates from about 8 to 20% were commissioned to save foreign exchange in Malawi and Zimbabwe (Jumbe et al., 2009). In South Africa international political sanctions during the apartheid era were major drivers for government support in the development of synthetic fuels mainly produced from coal and generation of second-generation-biofuels (second generations bio-fuels makes use of lignin and cellulose materials such as wood and straw to make bioethanol and bio-diesel) (lignocellulosic materials) (Gnansounou et al., 2007). The biofuels industry in Africa is being developed gradually in most African countries with assistance from international agencies such as the UNDP, UNEP, UNIDO, UN-HABITAT (Darkwah et al., 2007). Some of the major biofuels that have been reported in Africa include: biogas, thermal gasification, biodiesel, bioethanol and most recently, albeit at the research and/or developmental level, the second generation biofuels devoted to total biomass conversion. For biogas, several authors have reported case studies on the biogas industry in Africa (Njoroge, 2002; Amigun et al., 2008; Brown, 2006; Karekezi, 2001). However, Darkwah et al. (2007) have cited the failure of most projects from operating efficiently and taking off as largely being due to ineffective planning and poor financing schemes.

Biodiesel technology is an emergent technology in Africa with planned large-scale productions in countries like Senegal, Ethiopia, Nigeria, Kenya, Ghana, Zambia, Liberia, Tanzania and South Africa (Zenebe, 2007; Wagdy, 2006; DME, 2006; Darkwah et al., 2007; Jumbe et al., 2009). Other governments such as those of Mali, Southern and Eastern African countries have targets in place and are initiating programmes to enable smooth take-off of the biodiesel industry (UNDESA, 2007). As for bioethanol, most plants in Africa are in Southern African

Development Community (SADC) and active participants include South Africa, Malawi, Swaziland, Mauritius and Zimbabwe. There are also substantial amounts of sugarcane and a big potential for doubling current production in the region (SADC, 2007; Salgado, 2006). Other commercial ethanol producing countries are Ethiopia and Kenya. Ethanol programmes that produce a blend of ethanol and gasoline (gasohol) for use in existing fleets of motor vehicles have been implemented in Malawi, Zimbabwe and Kenya (Amigun et al., 2008). Ethanol gel fuel, the substitute fuel for wood, charcoal, kerosene and gas, typically used in domestic cooking is among the least popular of the biofuels in Africa. Sugarcane producing countries such as Mozambique, South Africa, Angola, Uganda, Kenya, Egypt, Sudan, Tanzania, Zimbabwe, Zambia, Somalia, Congo, Ethiopia, Malawi and Mauritius have great potentials in the Ethanol gel fuel industry (Darkwah et al., 2007). Lastly, the thermal gasification and the second generation biofuels dedicated to converting biomass into gaseous energy products is not available even at the pilot plant stage in Africa yet. This technology offers the opportunity for waste-into-energy as has been accomplished in Germany, Japan and UK (Babu, 2005). Looking towards the future, a study by Smeets et al. (2007) projected that, depending on the level of advancement of agricultural technology, Africa has the largest potential for bioenergy production by 2050 in the world, which is 317 EJ per annum. This could constitute a quarter of the projected total world potential of 1,272 EJ per annum. It should be noted that Africans traditionally have been farmers living in harmony with nature.

About half of the energy used in Africa originated from biomass or agricultural residues (Amigun et al., 2006). However, for Africa to realize its potential for bioenergy production as predicted by Smeets et al. (2007), advanced agricultural technologies and practises must be employed that would involve (i) animal production primarily taking place in feedlots, (ii) very high animal feed conversion efficiencies being achieved, (iii) super-high technology for crop production used and (iv) both rainfall and irrigation water used. Although this currently may seem impossible, a focused effort to improve agricultural practices in Africa may realize this high bioenergy potential in the next forty years.

Production potential

Bioethanol production requires biomass with significant starch or sugars which is fermented through enzymatic biological processes to generate liquid biofuel (Cotula et al., 2008). The current major feedstock in the production of biofuels in the world is starchy biomass which accounts to nearly 53% of all bioethanol production. Maize, wheat, sorghum and other starchy materials are

the main starchy feedstocks used in bioethanol production. The second method uses sugarcane and sugarbeet biomass, the feedstock that is already in sugar form and the rest of the processes are the same as in starchy biomass; while the last method uses biomass from cellulosic materials such as bagasse, straw and wood biomass (BNDES Communication Department, 2008: 65). While the technology associated with the first two feedstocks (starchy biomass and sugarcane) is available and can be replicated (BNDES Communication Department, 2008: 65), maize and other starchy biomass feedstocks have a very important role in food security in the sub Saharan African. The market integration for grain cereals makes regional trade a very important factor to regional food security (Mutambatsere et al., 2007). To some extent, the use of these feedstocks (maize included) in the promotion of biofuel production makes it less attractive for most parts of Africa. On the other hand, secondary products from, for example, processing of sugar from sugarcane generates co-products like bagasse, molasses, and fibre which can be used to generate electricity and provide additional revenue if exported (Jumbe et al., 2009). Countries like Mauritius have successfully used this technology and supplied electricity to the national grid contributing up to 40% of all domestic power consumption (Deepchand, 2005). Molasses, another form of wastes from crystalline sugar production can also be used as feedstock in bioethanol production. This pathway has a very high unexploited potential in Africa. While, South Africa was in 2006 the largest producer of bioethanol from sugarcane (Figure 1A), other countries like Malawi have increased their production in recent years and have successfully used ethanol to complement the imported fuel estimated at between 80 and 90 million litres per year (Jumbe et al., 2009).

On the other hand, in Tanzania, only 30% of the molasses produced from sugar production are exported and used as animal feed while 70% goes to waste (GTZ, 2005; Gnansounou et al., 2007). In any case, bioethanol production of about 600 ml per annum from sugarcane bio-products are still very modest compared to more than 10 million tons of sugar produced per annum in Africa (Figure 1B). Hence, in light of current debates on the potential negative impact of increasing biofuel production to food security, sugarcane molasses offer a viable option in two main ways: firstly, it increases the revenue from sugarcane industry since the waste is treated into a usable product with higher economic value; and secondly, it is an environmentally friendly option to waste treatment. Jumbe et al. (2009) have highlighted promising energy crops for biofuels production in Sub-Sahara Africa. Looking at all the biofuel products currently available on the market, ethanol is the most promising product that can be produced from different raw materials by African countries (Table 1) with most of

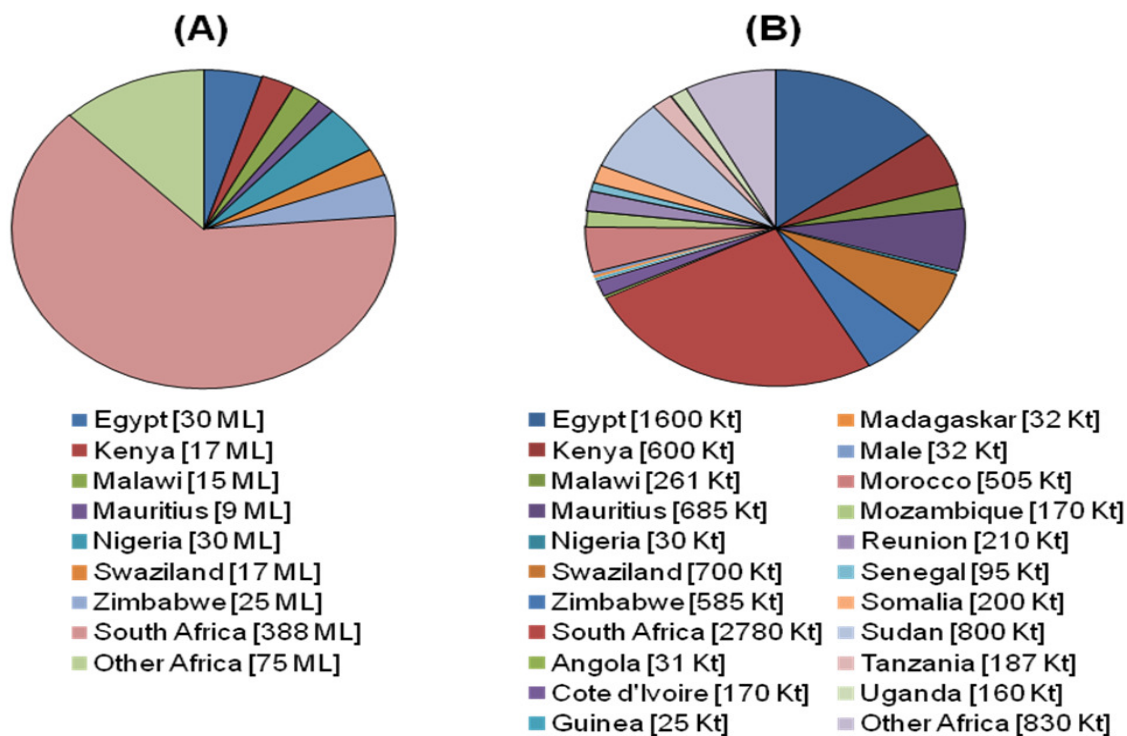


Figure 1. Comparison of ethanol production (A) in different African countries (volumes in brackets) to sugar production and (B) in different African countries (tonnes in brackets). Sources: RAF Outlook (2007) and Hassan (2008).

Table 1. Biofuels potential in selected African countries in megalitres (ML).

Country	Raw material	Biodiesel (ML)	Ethanol (ML)
Benin	Cassava	-	20
Burkina Faso	Sugarcane	-	20
Ivory Coast	Molasses	-	20
Ghana	Jatropha	50	-
Guinea Bissau	Cashew	-	10
Mali	Molasses	-	20
Malawi	Molasses	-	146
Kenya	Molasses	-	413
Ethiopia	Molasses	-	80
Niger	Jatropha	10	-
Nigeria	Sugarcane	-	70
Sudan	Molasses	-	408
Swaziland	Molasses	-	480
Senegal	Molasses	-	15
Tanzania	Molasses	-	254
Togo	Jatropha	10	-
Uganda	Molasses	-	119

Source: Jumbe et al. (2009) (adapted from Hagan (2007) and Kerekezi (2007)).

the ethanol coming from molasses. Jatropha and oil seeds are the main feedstocks for producing biodiesel

which is used to run stationary generators for electricity generation and as a diesel substitute for transportation.

Table 2. Yields of different energy crops across Africa.

Crop	Litres of oil/ per hectare	Countries grow
Palm oil	5950	Angola, DRC, Nigeria, Ghana, and Tanzania.
Soya bean	446	DRC, Malawi, Republic of South Africa, Tanzania and Ghana.
Coconut	2689	Nigeria, Ghana, Senegal, Mozambique and Tanzania.
Jatropha	1892	All countries.
Sunflower	952	Angola, Malawi, Nigeria, Ghana, Botswana, DRC, Mozambique, Republic of South Africa, Namibia, Zimbabwe, Zambia and Tanzania.
Cotton Seed	325	Angola, Malawi, Nigeria, Ghana, Mozambique, Tanzania, Zimbabwe, Zambia and Republic of South Africa.
Avocado	2638	DRC, Republic of South Africa, Tanzania, Nigeria, Ghana, and Senegal
Groundnuts	1059	Malawi, Angola, Ghana, Nigeria, DRC, Gambia, Senegal, Mozambique, Tanzania, Zimbabwe and Zambia.
Cashew nut	176	Angola, Mozambique, Tanzania, Ghana, Nigeria and Senegal.
Castor beans	1413	Angola, DRC, Tanzania, Republic of South Africa and Mozambique.

Source: Raemaekers (2001) and Jumbe et al. (2009).

Although many countries grow *Jatropha* (Togo, Ghana and Niger have large *Jatropha* farms), there may also be a variation in yield production across the countries depending on varieties and/or species, soil and climatic conditions, susceptibility to diseases and technologies used in oil extraction. Overall, palm has the highest oil yields per hectare compared to any other energy crop. Palm is commonly grown in Angola, the Democratic Republic of Congo (DRC), Nigeria, Ghana and Tanzania. Other crops used in different countries include: sunflower, soya bean, coconut, cotton seed, avocado, ground nuts, castor beans and cashew (Table 2). Lately, a number of governments on the continent have made strides in positioning themselves to harness the potential benefit of biofuels (Jumbe et al., 2009). This has led to increased investments in biofuel promotion programmes where there is potential of biofuels (Jumbe et al., 2009).

In Uganda, the government is responsible for facilitating the development of the biofuels sector through policies and regulations, the provision of incentives, extension services, information and market infrastructure. In some West African countries including Mali, Benin, Burkina Faso, Ivory Coast, Guinea Bissau, Niger, Senegal and Togo, there are a number of biofuel projects where the local communities are involved (UEMOA, 2008). In Tanzania, a number of multinational companies, non-governmental organizations (NGOs) and smallholder farmers are implementing a number of projects aimed at increasing the supply of liquid biofuels (Martin et al., 2009). The companies include Prokon, Wilma, SEKAB and Diligent from the United States of America, United

Kingdom, the Netherlands and Germany, respectively (Jumbe et al., 2009). Other organizations such as farming for energy for better livelihoods in Southern Africa (FELISA) from Belgium have formed joint ventures with local entrepreneurs to produce biofuels. With support from the Southern Africa Development Community (SADC), program for biomass energy conservation (PROBEC), "solid biofuels" is implementing biomass programs in order to improve the supply and use of solid biofuels for improved rural livelihoods. Local NGOs Kakute and Tanzania Traditional Energy Development and Environment Organization (TaTEDO) are implementing a number of activities in rural areas involving local communities including the promotion of biofuels through awareness creation, technological support for processing of oil from *Jatropha* and sunflower to run multifunctional platforms.

There are also other biofuels initiatives in Senegal, Mozambique, Mauritius, Ghana and recently Egypt, Zambia, Nigeria, South Africa and Ethiopia.

NEXT GENERATION TECHNOLOGIES FOR TOTAL BIOMASS CONVERSION

Lignocellulose is globally recognised as the preferred biomass for the production of a variety of fuels and sustainable chemicals and fuels industry with significant benefits in agricultural development. Lignocellulose represents the most wide-spread and abundant source of carbon in nature and is the only source that could provide

a sufficient amount of feedstock to satisfy the world's energy and chemicals needs in a renewable manner (Lynd et al., 2003; Marrison and Larson, 1996). Besides the lignocellulose produced as agricultural wastes in the grain-based industries, Southern Africa also has strong biomass-based industries in sugar production and the paper-and-pulp industry, thereby providing widespread availability of this renewable resource. Lignocellulose can be converted to fuels and chemicals by a combination of biological and thermo-chemical processing. Biological processing involves the hydrolysis of cellulose and hemicellulose into fermentable sugars for use in fermentation processes, while typical thermo-chemical treatment involves gasification, combustion or pyrolysis to convert lignocellulose into high-value energy or chemical products (Lynd et al., 2003). The preference for lignocellulose as a future resource for biofuels (ethanol) production stems from its widespread availability, lower cost per energy-unit than starch, and overwhelmingly positive energy balance that is superior to starch (Lynd et al., 2003; van Zyl et al., 2011). However, the major technical barrier to the biochemical conversion of the cellulose and hemicellulose components of lignocellulose is the recalcitrance of lignocellulose to biological degradation, which affects downstream product yields and overall economics (Lynd et al., 2003). Hence, current lignocellulose-to-bioethanol processes are not deemed economically viable without government subsidies, thus requiring low-cost substrates, such as agricultural bio-wastes available locally, as well as technological developments to reduce processing costs.

In addition, while methods for lignocellulose pre-treatment/fractionation are available, these have not been optimized for local substrates and novel African bio-energy crops. Notwithstanding, research, for example, in the development of yeast strains capable of producing a cocktail of cellulase and hemicellulase enzymes required for lignocellulose hydrolysis is on-going (van Zyl et al., 2007).

INTEGRATED PRODUCTION OF BIOFUELS AND HIGH-VALUE CHEMICALS IN A BIOREFINERY

Food and first generation biofuels are already produced from sugar, starch and oil-rich food crops. When second generation technologies come to fruition, the appropriate entry point could be the use of agricultural and forestry residues. This would allow the roll-out of the necessary technologies and establishing biofuels value chains. Simultaneously, agronomists and environmentalists can assist in identifying energy crops and how to utilise intruder plants in a cost-effective way. The economics of the conversion of starch, sugar, lignocellulosics and vegetable oil raw materials into biofuels can be improved by the integration of various processing technologies in a

single production plant, or "biorefinery", based on the conditions in a particular local industry and region (Lynd et al., 2003; Hatti-Kaul, 2010). Such a biorefinery is built on the example of an oil refinery where a range of fuel and high-value chemical products is produced from crude oil to achieve optimal profitability. In the case of biofuels production, such an integration of processing is of particular importance due to the current dependence of commercial undertakings on government incentives. In most countries, including the USA, government incentives, subsidies and regulations are essential to keeping the biofuels industry commercially viable.

Biorefineries represent a technological solution that can substantially improve economic feasibility, especially considering the highly volatile nature of agricultural raw material costs and market prices for transportation fuels due to exposure to international economic and political pressures. It is likely that the future global market for biofuels will be exposed to similar volatility as the current crude oil markets, with substantial economic impacts for the industry internally and externally.

BIOENERGY MARKETS AND OPPORTUNITIES FOR AFRICA

Biofuel energy markets in general are at an infancy stage but undergoing developmental phase which will bring suppliers and consumers together (FAO, 2008). The end use of the biofuels is split into two major categories: namely solvent and transport market. The outlook of market potential for biofuels in Africa is varied with Sub-Saharan Africa having the most potential and North Africa having the least potential. The potential value of biofuels for Sub-Saharan Africa by 2010 to 2013 as estimated by global growth consultancy Frost and Sullivan in the Africa Review of Business Technology, March 2008 was between US\$ 1.54bn to US\$ 1.83. However, if the next generation technologies unlock the potential of converting all cellulosic biomass, the potential value could be significantly higher. Figure 2 compares the potential biofuels production from agricultural and forestry residues, invasive plants and energy crops in South Africa, in relation to the current fossil fuel and the Industrial Biofuels Strategy's target for 400 ML/annum. In this case, when considering the use of only 50-70% of this plant biomass with second generation biochemical and thermo-chemical technologies, South Africa could very well exchange the bulk of its current liquid fossil fuel usage (currently 21.2 BL/annum) with renewable biofuels (van Zyl et al., 2011). On the demand side, there are a number of factors which are stimulating domestic demand on the continent. Most African governments are implementing lead phase out programs in gasoline. This creates new demand/opportunity for ethanol to replace lead in ethanol-petrol blending programs.

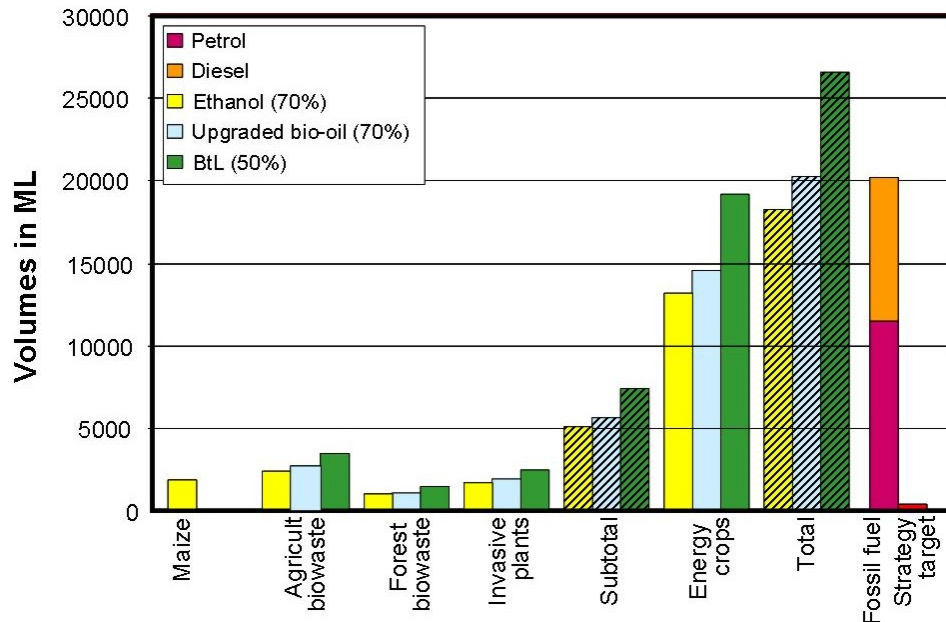


Figure 2. Potential biofuels production from lignocellulosic biomass (assuming only 50 to 70% was utilized) when advance second generation biochemical and thermo-chemical technologies are available. Optimal biofuels yields estimated when the appropriate technologies are available, include (i) biochemical processing of maize-to-ethanol = 460 L/ton or lignocellulosic-to-ethanol = 280 L/ton (only polysaccharide fraction); and (ii) thermo-chemical upgrade of bio-oils from fast pyrolysis = 310 L/ton and thermo-chemical biomass-to-liquid (BtL) = 570 L/ton. Source: (van Zyl et al., 2011).

Current developments on the WTO Doha negotiations present another challenge to the preferential agreements enjoyed by ACP countries on sugar markets in EU. There is pressure to remove distortions on the market which will affect the preferential sugar export prices offered by European markets. Thus, the use of sugar for biofuels production can provide an opportunity to absorb the loss in tradable volumes of sugar. On the supply side, it is argued that Africa has the potential to meet the demand created by the lead phase out policy from domestic production. A modest shift from sugarcane production can meet the new demand for ethanol. For some countries especially in SADC region this demand can be met solely by molasses from sugar production, (co-products) (Jumbe, 2009). In North Africa, the potential of biofuels is narrow due to climatic factors which limit agriculture production (mainly desert land). Simulations of the effect of projected 2015 US and EU biofuels mandates on increasing crop cover suggest that North Africa and Middle East combined will be very small (0.018%). However, these countries are expected to experience significant welfare losses from lower prices offered for their crude oil. The terms of trade effect of up to US\$ -11,727 million are expected and are the highest globally (Taheripour et al, 2009). In West Africa, a study commissioned by UEMOA member states recognizes that biofuels could have a significant contribution to

energy supply in the region; suggesting that sustainable production of the biofuel can have the potential benefits from increased energy sources, employment opportunities and incomes.

In 2006, a market opportunity study for biofuels in the same region indicated that locally produced anhydrous ethanol favourably competed with petrol (UEMOA, 2008). In SADC, sugarcane production, an important feedstock for bioethanol production is growing steadily (2.5%). Most of this potential in biofuels for the region is in domestic markets especially in transport sector (blending programs). This has been attributed to the contribution from rehabilitation programs in post-conflict countries (Angola and Mozambique). The region has great potential to produce and meet the growing demand for lead phase out programs in fuel for transport. Current figures for cultivated land (6%) are very low and suggest that availability of land may not be a constraint to increasing production of biomass for fuel production (Gnansounou et al., 2007).

POLICY AND INSTITUTIONAL FRAMEWORK FOR BIOENERGY INDUSTRY DEVELOPMENT

Political commitment and support for the development of the necessary regulatory instruments for advancement of

bioenergy is very important. The cooperation and interaction of all relevant stakeholders including civil society, private sector can lead to the development of conducive policy instruments that can foster significant growth in biofuels development. These policies guide the placement of appropriate/necessary government intervention facilities and also project the vision of the nation. This does not only benefit the national agenda but also appeals to the outside world including foreign investors, donors and the international community. Other benefits of a good policy environment include; increased private sector investment in technology development and infrastructure. At macroeconomic level, experiences from countries already advanced in renewable energy development (biofuels inclusive) has shown that good policies have some common characteristics which include; policies that are predictable and consistent over time, civil society buy-in and support, clear niche for small and medium entrepreneurs' benefits, policy coherence, private and public investment, transparent governance and political will to implement these policies (BNDES Communication Department, 2008: 236). Government incentives where these policies exist have taken different forms like: capital subsidies, grants or rebates, investment or other tax credits, public competitive bidding for contracts, public investment loans or financing, energy sales tax (VAT, excise) reduction just to mention some.

In biofuels, policies and regulatory frameworks have centred on the first generation of commercially viable biofuels. The major reason why nearly all existing policies are on first generation biofuels worldwide is because of advancement in research for these first generation biofuels and that technology was available for practical application. Research in second generation biofuels is still going on and there are hurdles to be overcome to make the technology efficient and economically viable. As the technology becomes readily available and commercially viable the second generation biofuels sector is expected to grow (BNDES Communication Department, 2008: 236; WH Van Zyl, 2009). In future, the existing policies are likely to extend to other second generation biofuels because of the sector's associated expansion and growth (UEMOA, 2008). From a rural development perspective, at the microeconomic level, bio-fuel policy development must aim at contributing to the larger developmental goals but not at the expense of more pertinent issues like food and social security. There are a number of socioeconomic parameters that need to inform the development processes like; the need to maximise benefits and land tenure security, environmental considerations, domestic production especially in rural areas that promote resilience, accessibility to soft loans and guarantees, collective marketing for economies of scale to be realized, etc (UEMOA, 2008). Specifically on land tenure, decisions on land use for biofuels are usually made by governments without consulting farmers (IFAD,

2008).

In most cases these lands are allocated to big corporations with export-oriented biofuel crops. Thus, biofuel development could, without appropriate policy guidelines, increase pressure on land to the disadvantage of poor rural people. However, secure access to land tenure is a much broader issue in most developing countries that generally affects agricultural production and so biofuels are not its main driver. Setting of deliberate funding mechanisms is also important in supporting development of renewable energy policies. These take forms like committed public expenditures, levies on traditional sources of energy, collaboration or co-financing with private sector and development partners. Mauritius presents a very interesting success story of bagasse based cogeneration of domestic power supplied to the national grid. This is an example of public and private partnership in action. This was supported through deliberate government incentives which included; tax breaks, removal of export duty and foreign exchange controls for investment in bagasse electricity generation. This was done over a period of nine years through four different policies (The sugar Industry Efficiency Act (1988), Bagasse energy development programme (1991), abolition of sugar export duty (1994) and removal of foreign exchange controls (1995) (Deepchand, 2005; UEMOA, 2008). This process especially with the first policy provided for the participation of small and medium scale producers (UEMOA, 2008).

A number of governments in Africa have made some progress in coming up with definitive policy strategies on renewable energy (Amigun et al., 2006). These policy instruments are mostly embedded within the energy policies for the countries but wide disparities exist. Some of these strategies, where renewable energy policies exist, have been formed to some extent by commissioned relevant studies on the potential of alternatives to crude oil (solar, wind energy and biofuels) (UEMOA, 2008). While the potential of biofuels debate is increasingly becoming important in different platforms of economic development, most African countries have lagged behind on development of specific strategies on biofuels. A recent study which reviewed poverty reduction strategies for 17 Sub Saharan African (SSA) countries indicated that only two countries had clear policies on biofuels (Jumbe et al., 2009). Lack of specific biofuel policies is one of the obstacles affecting the development of biofuels in Africa (Amigun et al., 2006). Some countries are in the process of reviewing existing energy policies while others are in the process of incorporating new policies (Gnansounou et al., 2007). Some countries like South Africa and Mauritius have taken keen interest in taking up ambitious projects to support renewable energy through provision of appropriate policies. In the 2007 biofuels industry strategy paper for South Africa, the government planned to invest US\$ 437 million in partnership with

private sector (commercial maize farmers) to build 8 ethanol plants. The target was to achieve 2% market penetration of biofuels into the transport sector by 2013. However, the implementation structures for these policies are another source of confusion with some pieces of mandates scattered in different departments falling under different ministries (Amigun et al., 2006). Not only does this slow progress but it affects advancement of innovative ideas because the processes are not streamlined.

One of the suggestions that have been proposed as fundamental in the "bio-energy revolution" has been the organization of smallholder farmers and producers in order to facilitate their access to markets and enable them to commercially interact with large private entities engaged in the energy markets (IFAD, 2008).

IMPACT OF BIOENERGY PRODUCTION ON THE ENVIRONMENT

According to the intergovernmental panel on climate change (IPCC), agricultural production and access to food in many regions may be severely compromised by climate variability and change. The area suitable for agriculture, the length of growing seasons and the yield potential of some mainly arid areas are expected to decrease. The adverse impacts of mitigation measures being taken under the Kyoto Protocol such as carbon sinks, the expansion of mono-crop plantations for biofuels (for example palm oil, soya, sugar cane and jatropha) have been associated with undermining small-scale traditional livelihoods of indigenous peoples and practices (for example rotational agriculture, pastoralism, hunting and gathering) which usually have higher biodiversity as opposed to the monocrops. In dry areas, the growing of fast growing biofuel crops will naturally be associated with the competition for water between food and fuel crops thus may become the overriding issue in the fuels vs. food debate. Improvement in crop productivity as well as the shift from high water-use bio-fuel crops (such as sugarcane) to drought-tolerant crops (such as sweet sorghum) and *Jatropha* can be used as options to address the issue of water scarcity. Despite what it is often said about growing biofuel crops on dry and marginal lands, irrigation in low-rainfall ecologies is required for optimal yields. This may have the undesirable water salinity problem in many regions (IFAD, 2008).

The processing of energy crops into biofuels also requires water and, though new conversion plants offer options for controlling water pollution, existing processing facilities can discharge organically contaminated effluent (IFAD, 2008). All agrochemical runoff and sediments are problematic, but these problems apply as much to food crops as they do to biofuel crops. In the EU, measures to

control indiscriminate land use changes are underway with the proposal to institute a policy to ban imports of biofuels derived from crops grown on forestlands, wetlands or grasslands (WWF, 2006). Thus, such policies may be necessary as part of the policy legislation on countries developing biofuels to address indiscriminate expansion of land use changes. On GHG emissions from biofuel crops, the jury is still out whether biofuels decrease or increase the emissions. Hence, it will be important to appraise the entire energy chain when comparing options and it is equally important to analyse the production and emissions based on best practices, including innovative ways to manage crops and soils, such as zero-tillage approaches; and also examine forestry management that includes judicious forest use without burning and other activities that generate high emissions (IFAD, 2008).

Lastly, the introduction of some biofuel species needs to be done following proper studies on their eco-biology in order to institute measures that can help to manage in a way that avoids invasiveness.

CHALLENGES AND OPPORTUNITIES SURROUNDING THE BIOENERGY INDUSTRY IN AFRICA

Unfavourable weather conditions have recently affected food security in most of the regions on the continent. Developing countries which cannot feed themselves have had to battle with the paradox of fighting hunger versus promotion of biofuels in the same space. Fears have been on the potential effect of substitution of food crops for feedstock in land allocation. However, this theory does not hold where land is not a constraint to increased production like in most countries marked with potential for biofuels in SADC and UEMOA regions (UEMOA, 2008). Thus, biofuels presented opportunities for the small farmers and governments need to develop and implement certain pro-poor policies. In this regard, international organizations need to understand how to optimize the "biofuel revolution" to make it truly pro-poor. The type of approach that should be taken is to look at biofuel production not in prime land, but in marginal land, and look at crops that can avoid the food-versus-fuel issue (IFAD, 2008). Large scale production of biofuels is likely to cause an increase in input costs for livestock production. The effect comes from the likely increased conversion of pastureland to cropland with the incentive of higher returns from land put to biofuels. Biofuel mandates from EU and US projections for 2015 are anticipated to cause an increase in global crop cover by 7.09 million hectares of which 3.06 million is from sub-Saharan Africa alone (Taheripour et al., 2009).

There is another debate on increased biofuel promotion and land tenure issues. It is argued that the current land

tenure in some countries is likely to favour foreign investors at the expense of local inhabitants. The concept of "idle", "under utilized", "marginal" land has faced a number of criticisms. One school of thought argues that this basis does not take into account the loss of livelihoods from these areas in forms of grazing area, gathering of wild fruits, thatch grass etc. In aspects of control of land, the general notion that government assumes the overall control of land in enacted agreements with foreign investors has received criticism of lack of regulation on the ground. This, in the process, fails to protect the livelihood interests of the people on the ground. Additionally, there are fears that government local tenure laws may lack legal enforcements. What is missing in some of the presented arguments is a clear assessment of the extent to which two equally competing priorities can co-exist. Without that picture, the argument is not different from arguments against any other agriculture expansion program (Cotula et al., 2008). Global prices of food stuffs are likely to increase and alter trade patterns for coarse grain, oilseed, and crude and refined vegetable oils and livestock products. The US alone, a major exporter of coarse grain, is expected to reduce net export of coarse grain by \$495.1 million and increase the net export of oilseeds by \$960.6 million (Taheripour et al., 2009). In this era of globalization these shifts are likely to have an impact on the African economies.

Two aspects of the climate change regime are of significance to small farmers in developing countries: opportunities for carbon sequestration and funding for mitigation action; and the possibility of new funding for adaptation (IFAD, 2008; FARA, 2008). On carbon market and small-scale farmers, it has been suggested that ways need to be found to link small-scale farmers to the global carbon market, but without creating bureaucracies or additional burdens for them. In addition, clear indicators must be established for bringing carbon into the soil and providing payments to poor farmers for such environmental services. Thus, networks of national farmers' organizations and international federations of agricultural producers can play an important role. Options for financing activities that address the reduction of the carbon foot print are much broader and are emerging rapidly (IFAD, 2008; FARA, 2008). The growing market for carbon for projects and activities, through both the clean development mechanism (CDM) and voluntary markets, demonstrates that the sequestration of carbon could offer opportunities for smallholder agriculturalists to gain from the mitigation potential of the agriculture sector. However, in the global carbon market the participation of developing countries, particularly the poorest communities within them, has been extremely challenging, because the modalities and procedures of the CDM in particular are complex and present many barriers to participation. One of the problems cited is the detailed set

of standards for CDM verification, which results in high transaction costs for CDM certification, and this excludes small-scale projects. Lastly, while there has been concerns on the local environment that biofuel cultivation, refining, combustion and transport may result in significant environmental problems that are likely to become more acute as biofuels production and trade expand, others (IFAD, 2008) believe that biofuel cultivation can have positive impacts in rural areas where poor people have limited options to meet their energy needs.

Fuelwood is usually their primary household energy source but its harvesting is usually unsustainable and can contribute to deforestation. On the other hand, burning animal dung another important energy source can cause serious health problems (IFAD, 2008). Hence, substituting biofuels for fuelwood and dung can increase energy efficiency and decrease health risks. At the same time, biofuel cultivation, if combined with appropriate technologies, can open the door to sustainable, low-cost, off-grid electricity generation, with the added benefits of reducing women's domestic chores and increasing opportunity for rural industry and employment (IFAD, 2008).

SUMMARY AND CONCLUSIONS

Africa still remains a large consumer of traditional sources of energy mainly fuel wood and with a greater population facing unsustainable energy supply (ICSU, 2007). Biofuels (bioethanol and/or biodiesel) have increasingly received attention for their potential as a renewable substitution as well as an energy diversification from crude oil. Indeed, in some cases it has been touted as one of the means of addressing some of the MDGs (FAO, 2005). While promising energy crops for biofuels production in SSA have been highlighted, there may also be a variation in yield production across the countries depending on varieties and/or species, soil and climatic conditions and technologies used in oil extraction (Table 2). This hence, calls for the need for more research and development with new promising biofuel crops and technologies. The outlook of market potential for biofuels in Africa is varied with Sub-Saharan Africa having the most potential and North Africa having the least potential. The potential value of biofuels for Sub-Saharan Africa by 2010 to 2013 as estimated by Frost and Sullivan (African Review of Business and Technology, 2008) is between US\$ 1.54bn to US\$ 1.83. This is in good stead as most African governments are implementing lead phase out programs in gasoline. This also creates new demand/opportunity for ethanol to replace lead in ethanol-petrol blending programs; and in SADC region this demand can be met solely by molasses from sugar production- co-products. There is still a need to conduct detailed market analysis studies in order to

establish the real market potential along the value market chain in order to justify the full scaling up of the biofuel development.

A number of governments in Africa have made some progress in coming up with definitive policy strategies on renewable energy but wide disparities exist (Jumbe et al., 2009). Where these policies exist, Government incentives have taken different forms like; capital subsidies, grants or rebates, investment or other tax credits, public competitive bidding for contracts, public investment loans or financing, energy sales tax (VAT, excise) reduction etc. From a rural development perspective, at the micro-economic level, bio-fuel policy development must aim at contributing to the larger developmental goals but not at the expense of more pertinent issue like food and social security. Specifically on land tenure, decisions on land use for biofuels are usually made by governments without consulting farmers (IFAD, 2008); but there is need for the policies to have appropriate policy guidelines they do not necessarily increase pressure on land to the disadvantage of poor rural people by ensuring secure land tenure. A number of environmental concerns have been highlighted mostly emanating from the mitigation measures being promoted under the Kyoto Protocol such as the possible use of biofuels as carbon sinks. Thus, the expansion of mono-crop plantations for biofuels have been associated with undermining small-scale traditional livelihoods of indigenous peoples which usually have higher biodiversity, competition for water in rain fed agriculture and the possibility of introducing alien invasive species. In addition, the processing of energy crops into biofuels may also in some cases discharge organically contaminated effluent (IFAD, 2008). Thus policies need to deliberately address these issues through some regulatory frameworks on biofuel cropping that will address sustainability issues through for example some certification standards such as ISO and other related standards.

Notwithstanding, the challenges highlighted in this paper, biofuels may present opportunities for the small farmers provided governments develop and implement certain pro-poor policies with international organizations playing a leading role on the need to understand how to optimize the "biofuel revolution" to make it truly pro-poor. Additionally, the linkage of small-scale farmers to the global carbon market through PES is an opportunity; but there is clear need to facilitate this process by developing modalities and procedures of the CDM that can accommodate the developing countries due to the high transaction costs usually associated with certification.

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