THE WORLD TOWARDS BIOECONOMY, AND AFRICA TOWARDS A RESERVE FOR BIOBASED FEEDSTOCK

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ABSTRACT

Based on a review of the more recent empirical literature, we try to identify the way Africa could better participate to the global bioeconomy. The study suggests that African countries will not benefit much from the new economic order based on biological resources as the required conditions to transform its biomass feedstock potential into real market and economic opportunities are not in place yet. Without an ambitious policy, a significant and urgent investment in R&D with a strong South-South and North-South partnerships, Africa will just stay a reserve for biomass feedstock while the world will sail towards a biobased-economy. As during the past decades, Africa is likely to continue to feed the world economy with the raw and low added-value material while relying expensively on exports to meet its own needs. However, African countries could revert the trends and lead the continent towards a better economic pathway.

Keywords: Bioeconomy, biofuel, Africa, economic growth, biomass

1. Introduction

Global economic models are changing. These changes are governed by several drivers such as population growth, climate change andan increasing demand for biological goods including food and non-food biomass. Increasingly, the world economy is turning towards an economic model based on the use of biological resources. A biobased-fuel revolution is on-going. Though biomass has been used by humanity for bioenergy for millenniums, it is only in recent years that interest in bioenergy, particularly biofuels, has exploded (Verdonk et al., 2007). Production and trading volumes are already rapidly growing and are expected to increase further. Consumption of biofuels is projected to rise from 1.3 million barrels of oil equivalent per day (mboe d) in 2011 to 2.1 mboe d in 2020, and 4.1 mboe d in 2035. By 2050, biofuels is expected to meet 27% of global road-transport fuel demand, up from 3% today. But there is also a greater biomass need to feed the glowing word population. The recent financial crisis and the simultaneous price spike of the major food commodities have set food markets in forefront of largest global markets. Most of the global biomass potential lies within more tropical regions, where there is more sunlight available for photosynthesis with more lands and less need for irrigation.

Literature abounds on the global biobased economy, and some of it with a particular focus on Africa. Many experts think that this new economic direction is an opportunity for developing countries, including Africa, to boost its economic development, to alleviate poverty and end hunger (Hazell, 2013; Mosley, 2002; IEA, 2008). The development of biofuels and the increased demand for food and fuel could bring benefitAfricaand could achieve a sustainable development, increase economic opportunities in rural areas and mitigate the impact of climate change worldwide.

Others worry about the complexity of the current challenges notably the many issues related to climate change, population growth, continued increase in food and oil prices, and the growing demand for biofuel, and ask whether African countries could make the required changes to succeed in this new context (Msangi and Evans, 2013; Rosegrant et al., 2008; Ewing and Msangi, 2009). Africa is still facing significant challenges with the number of people undernourished and living in poverty. The recent rise in food prices following the increased demand for the 1st generation biofuels has caught many governments off guard and exacerbated food insecurity and poverty in Africa.

Despite the large and growing body of literature about the growing bioeconomy, there is no clear answer to the question of how Africa is going to be involved and will take advantage. Most of the existing optimist literature focuses on the biophysical potential and comparative advantage of Africa in biomass production. A comparative advantage in biomass production is not sufficient to succeed. Although developing countries are so far the major producers of agricultural primary products, developed countries account for about two-thirds of total world agricultural exports (Mohan et al. 2013). The primary reasons attributed to this low share of developing countries in world agricultural markets are their low share in world exports of agricultural processed and high value-added products. Developing countries are too dependent on exports of primary agricultural commodities with low-income elasticities of demand (Mohan et al. 2013; Nuetah et al. 2011; Diaz-Bonilla, E. and L. Reca 2000). For instance, 90% of the income from Africa's coffee, calculated as the average retail price of a pound of coffee, goes to developed countries where the bean is processed and roasted. It is also the case of other Africa's primary exports such as tea, cocoa and cotton. This deprives African countries of the income advantage that the global value chains enjoy, and also of additional opportunities for growth and creating employment in value-added industries. African agriculture has also faced many challenges with global market distortions and discriminating trade policies during the last decades, with significant implications on the competiveness of their agricultural commodities. As showed by many studies, protectionism and others markets barriers are affecting further developing countries in the coming decades.

To really succeed in the future world bioneconomy, three preliminary conditions are required. First is the ability of the country to produce, or to get access to, biomass feedstock in a cost-effective, stable and sustainable way. The second is the technical capacity to process the biomass feedstock into needed biobased commodities. The third condition is related to the ability of the country to absorb and/or sell the final biobased commodities on the global market. Although the potential of Africa in biomassproduction has been largely established, the issues of the technological capacity and the future market challenges that African countries will face in the bioeconomy have not been sufficiently studied yet.

Based on the more recent empirical literature, we try to identify the way Africa could be involved in the global bioeconomy by analyzing its ability to respond to the three perquisite conditions listed above. This allowed to identify the major challenges and required policy to let African countries get back on the way to succeed and catch up.

2. Food and energy challenges for the future world economy

2.1. Feeding a growing world population

Producing enough food to feed the growing world population in a sustainable manner is the largest challenge facing the world. Currently, the total number of undernourished people as estimated in 2010 is 925 million, higher than it was 40 years ago (FAO, 2010). Most of the undernourished people live in developing countries, namely in Africa and south Asia where the rate of malnutrition has increased over the last 20 years, although improvements have been achieved at global level (FAO, 2010).But, the world is expected to undergo significant changes with significant negative expectations on global food systems in the next decades due to the combined effect of several driving forces.

Over the next four decades, the world's population is projected to increase from 6.9 billion in 2010 to around 9.2 billion in 2050, with highest growth rates in the least developed countries (). For instance, Africa has the highest population growth rate in the world, and is expected be the most populous continent by 2050. The world's population is not only rapidly growing; it also is becoming increasingly urban as result of significant changes in demographic patterns in developing worlds. Actually, most of developing countries are in a transition stage, and their populations are increasingly changing from being mainly rural towards being urban. In the early 60s, 85% of the population of Africa lived in rural areas. But by 2030, the ratio of rural population to urban population in Africa will be equal, and after 2030 urban populations will exceed rural ones. By 2050 60% of people in Africa will be living in urban areas and 40% in rural areas (UNUP 2009). Those changes will lead to many changes in the structure of world's population. By 2050, about 70 percent of the global population will be urban, compared to 50 percent today and only one third in 1960 (FAO 2011, Chaumet et al. 2011). Moreover, developing worldis experiencing a fasting economic growth which should continue to extend over the coming decades. Over the last decade Africa experienced an average economic growth of 5% (Africa Progress Report 2014), and higher growths have also been achieved in Asia and Latin America.

Those changes in the global economy will drive significant changes in global food systems. The growing and urbanized population will result in increased demand of all major foodcrops, with a shift towards high-quality, high-value and processed or packaged foods. On the other hand, changes in per capita income will be drivers of significant changes in global food demand as evidenced from both theoretical and empirical economic studies. Overall, demand for high-value foods such as meat, fish, fruits, vegetables and dairy products will increase significantly with growth of income.For instance, the apparent food consumption per person rose from around 2,500kcal/day in 1961 to over 3,000 in 2003 at global scale. Thus, between 1961 and 2000s the world's food calorie consumption was multiplied by 2.5, reaching approximately 19,000 Gkcal/day at the beginning of the 2000s (Dorin, 2011). In order to meet food demand alone and under *Business-As-Usual*scenario, e.g. in an unconstrained-climate world economy and excluding additional demand for agricultural products used in biofuel production, FAO projections suggest that by 2050 food production must increase by 70 percent globally, and by almost 100 percent in developing countries (FAO 2011). That is equivalent to an extra billion tons of cereals and 200 million tons of meat to be produced annually by 2050, compared with production between 2005 and 2007 (Bruinsma 2009). And between 2015 and 2030, about 80 percent of the additional food production will have to come from intensification in the form of yield increases and higher cropping intensities (FAO, 2003), therefore from a significant technological change of agricultural systems. But, several hundred million hectares of cropland expansion will also be required.

Yet it is clear that the world economy can no longer continue to work *as-usual*. The continuation of current trends in food and economic systems will encountermany limits. The recent IPCC's report brought up further changes in climate patterns as result of increased global warming over the next decades. The report predicts significant adverse impacts on both natural and social systems among the world's poor where climate change has already contributed to diminishing fish catch, increasing food prices, lower maize and wheat yields and increasing food insecurity. It describes tropical areas as the most vulnerable, noting that Africa and South Asia's fisheries could experience declines of 40 percent by 2050. FAO projections indicate that arable land per capita will decrease by 24%. Crop yield will drop by 2050 from 8% globally, and from 30% and 35% in Asia and Africa, respectively (FAO 2011). Agricultural water share will also decrease from 23% with also large land losses as result of increased effects of drought and desertification in arid and semi-arid areas. On the other hand, the rapid growth of urban populations at expense of rural populations will reduce agricultural labor and the ability to produce more in rural areas including in developing countries where agricultural production is mainly family-based farming which producesmore than 80 percent of the food supply. The challenge is daunting. The world economy is under pressure for greater. It needs to produce more food using less resourcesunder unfavorable demographic and climate patterns as the rural labor is decreasing, both agricultural land and water are becoming increasingly degradedand scarce, and crop yield is more and more decreasing, while food demand is significantly increasing. But, it should also face to a great energy challenge, and the increased need to produce additional foodcrops and other biobased feedstock to meet the growing and required demand for biobased energy.

2.2. Growing need for alternative energies

Over the last century, the world economymostly relied on fossil energies including petrol, natural gas and coal to support economic growth and improve people's welfare. But, since the end of the 20^{th} century, there is a growing awareness about the *unsustainabiliy* of the fossil-energy-based economy and its great accountability in the current global threat.According to the *Fifth IPPC's Assessment Report*, burning fossil fuels is by far the leading cause of the global warming and accounts for around 70% of global emissions in 2011. And, the more the world will continue to rely on fossil-energy, the worse and devastating will be the impact on the economy and people's welfare. All CO2-abatment scenarios indicate that 60 to 80% of the reductions of GHG emissions should come from changes in energy supply and use. Therefore, moving toward alternative and low-carbon energiesbecame critical.The increased price and declining availability of fossil-fuels increase as well uncertainty about the future. Without decisive action, energy-relatedGHG emissions will more than double by 2050 and increased oil demand will heighten concerns over the security of supplies (OECD/IEA, 2011).

But, sources of energy are not scarce (Azar 2005). For instance, there is enough coal in the world to meet any energy demand projections for the centuries to come. More, the solar influx to the earth carries some 100,000 times more energy per year than the current annual global anthropogenic use of fossil fuels, nuclear and hydroelectric powers combined (WEA/UNDP 2000). Significant energy supply could also be obtained from hydro, geothermal, wind and nuclear energy. Thus, the energy problem has little to do with physical scarcity (Azar 2005). The question is to choose the right energymix regarding the current issue of global warming, and what the related costs are. Some authors think that the biobased fuels are the better renewable low-carbon energysources that could play a significant role in the energetic transition (Azar 2005, Wash et al. 1996,Azar and Berndes 1999). Biofuel is cheaper than its alternative renewable energy such as solar-, hydro- and wind-power (Azar 2005; IEA 2008). This is what creates nowadays the great interest in bioenergy. Also, bioenergy is the unique renewable energy that can be provided as solid, gaseous or liquid fuel and can be used for many energy needs, such as electricity geenration, transport including in aviation, as well as heating for both industry and domestic purposes. It offers the advantage to be stored at times of low demand and providesdispatchable energy when needed (OCDE/IEA, 2011).

But, biomass-based energy is still a controversial issue. The large-scale deployment of bioenergy could create competition with existing uses of biomass such as for food and feed, or forest products, or can compete for land used for their production. The so-called 1st-generation biofuels primarily produced from food cropsarise a great concern about their ability to achieve the announced targets for fossil-oil substitution, GHG emission reductions and economic growth, in a sustainable way without competing with food production (IAE, 2008).The 2008's spike in the global food prices and the surge in food prices to record levels in early 2011 (FAO 2011), following the growing interest in bioethanol production in the USA and Latin America, support that concern (Huang et al. 2012; Bahel et al. 2012). Even the expected 2nd-generation bioenergy produced from ligno-cellulosic materials, such as cereal straw, bagasse, forest residues, and purpose-grown energy crops, are not good enough to weed out all adverse implications of bioenergy deployment on food production and food security in developing worlds.

But, it is clear that the world's interest in bioenergy production will continue to grow. The growing CO2 abatement policies could raise fossil fuel prices, and consequently could lead to higher demand and profits for the bioenergy sector.According by IAE (2008), the biofuels are driving worldwide significant interest and investments from both private and governments, and those of the 2nd-generation, expected to fully get into the global marketaround2020, will significantly contribute to reshape the global economy in the future.Biofuels provide only around 2% of total transport fuel today, but is assumed to provide 27% of world transport fuel by 2050 (OECD/IEA, 2011). Except in Africa, both developing and developed words are implementing various policies for biofuel production and use with very ambitious targets announced for the next decades. For instance, the new EU Renewable Energy Directive (RED), adopted in 2009, considerably targets biobased fuels. One of the major commitments of this directive is that by2020 renewable energy should provide 20% of the EU's total energy consumption with biofuel the most likely source (Swinbank, 2009; Kutas et al. 2007).By 2020, 1st-generation or crop-based biofuels should deliver around 6.5% of the total fuel consumption in the EU. Significant commitments and investments in bioenergy developing are also already in place in others OCDE and emerging countries. Overall,developed countries may be consuming150 kg of maize per head per year in the form of ethanol by 2020. This is similar to rates of cereal food consumption in developing countries (Rosegrant et al. 2008). But, it is important to notice that many regions and countries are promoting biofuel production not only to achieve CO_2-abatements commitments, but greatly to reduce their dependence from the fossil oil, to secure energy access for their people and to boost market opportunities for domestic producers. Loppacher and Kerr (2005), also supported by Schlegel and Kaphengst (2007),claims that "a primary motivation for the promotion of biofuels in the EU is rural economic development goals". The current rising geopoliticaltension between the West and Russia should therefore increase the commitments and investments in biofuel developing and the dependency of word's economyonbiobased resources. But, the biggest issue that arises is the ability of the world to produce and to process the required biomass to feed the growing global population and needs for bioenergy.

3. Biomass and technology as the major inputs in the global bioeconomy

As demonstrated above the world economy is increasingly relying on biobased feedstock to produce two major goods, namely food and energy. Biomass and technology are central in the transition to this emerging bio-based economy.

Biomass, or in some literature biobased feedstock, isany organic, *i.e.* decomposing, matter derived from plants or animals available on a renewable basis. It includes a wide range of products including wet organic wastes such as sewage sludge, animal wastes and organic liquid effluents, the organic fraction of municipal solid waste, residues from agriculture and forestry, and purpose grown energy and food crops, including perennial lingo-cellulosic plants.With the ongoing debate on biobased economy, like in this paper, biomass can be split into food and non-food feedstock. Food feedstock includesanyanimal or plant product that can serve for human feeding purpose. In contrast, biofuels refer to liquid and gaseous fuels derived from biomass. Biofuel feedstock can be obtained from non-food feedstock such as forest plantation and residues, agricultural residues, algae and herbaceous grasses, and organic wastes. But, it can also come from food feedstock including cereals, oilcrops, sugarcrops, palm oil, etc.That is actually where the major issue of competition between food production and biofuel developing comes from.Biomass feedstock is the main input in biofuel production. It accounts 45% to 70% of total production costs for the 1st-generation biofuel and 35% to 50% for the second or third generation ones (IEA, 2009).

Technology will likely be the second majorproduction factor and key driver in the transition to the worldbiobasedeconomy. Technological change is important in paving the way for transforming the energy system. The IEA's Energy Technology Roadmap 2012 (OECD/IEA 2012) highlights the pressing need to accelerate the development advanced energy technologies in order to facilitate the transition of the world towards a low-carbon economy. Spending on biofuel and other low-carbon energy technologies has risen rapidly over the last decade and is still arising significant interest from both public and private sectors (OECD/IEA 2012). The future of the world economy depends on the outcomes of significant ongoing efforts in clean energy including advanced biofuel technologies in the coming decades. According to IEA, the winner in the global bioeconomy will be therefore the country or region of the world that will succeed to establish the best technology and business model (IEA 2008).For developing worlds, technological change is not just related low-carbon energy technologies. These regions also have many issues to deal with to be able to feed the growing population and food demand. In Africa, agricultural production still remains low-input with lowest yields and productivities compared to the others regions of the world. Sub-Saharan Africa realizes only 20 percent of its potential yield.Also, only staple crops and unprocessed food commodities from rural areas could not be sufficient to meet the increased and diversified food needs of people. And a rapid modernization of production and food systems based on an increased use of new technologies and knowledge is needed to help developing countries to deal with those challenges in a sustainable manner.In sum, the best player in the rising bioeconomy will be the country or the region of the world which owns the ability to access and produce biomass, but also to transform its into biobased commodities including food and biofuel.

4. How is Africa positioned about bioeconomy requirements?

4.1. Biomass potential and production

Regarding the rising biobased global economy, many studies have been undertaken to assess the biomass potential across the world. Considering a *Business-as-usual* (BUS) and a *Climate change* (CC) scenarios, Haberl et al. (2011) studied the global biomass-based-energy potential and its distribution across 11 different regions of the world by 2050. The results of their estimates are summarized in Table 1. The global bioenergypotential in the year 2050 amounts to 105 EJ/year in absence of climate change (BUS scenario) and 152 EJ/year underclimate change. Under both scenarios, almost half of the global biomass feedstock is located in only two regions, namely Sub-Saharan Africa and Latin America including Caribbean. Each of these two regions holdsa bioenergy potential of around 24 EJ/year and 34 EJ/year under the BAS and CC scenarios, respectively. Both Northern America and South-Eastern Asia have a potential of around 26 EJ/year under BAU scenario and 57 EJ/year under CC scenario, and represent the quarter of the global potential in both scenarios. All the other regions such as Western and South Europe, Russia, Oceania and the Rest of Asia are only minor contributors. Africa therefore enjoys a great share of the world potential to produce required biomass feedstock to get the global bioeconomyfunctioning in the coming decades. But how will these biomass potentialities will be achieved world widely?

Table 1: Distribution of bioenergy potentials in the world in the year 2050 (EJ/year)

	Primary crops on cropland	Residues on cropland	Primary crops on grazingland	Total	
				BAU scenario	CC scenario[1]
Northern Africa and Western Asia	0.02	1.08	0.00	1.11	1.61
Sub-Saharan Africa	0.75	2.19	20.50	23.44	33.99
Central Asia and Russia	0.88	1.08	5.95	7.91	11.47
Eastern Asia	0.48	5.06	1.30	6.83	9.90
Southern Asia	0.65	2.09	0.00	2.94	4.24
South-Eastern Asia	1.94	2.75	6.43	11.11	16.11
Northern America	5.91	5.97	3.67	15.55	22.55
Latin America & the Caribbean	4.91	2.39	16.69	23.99	34.78
Western Europe	0.34	2.57	0.67	3.59	5.20
Eastern & South-Eastern Europe	1.85	1.91	2.58	6.34	9.19
Oceania and Australia	0.24	0.35	1.30	1.89	2.74
World	17.97	27.63	59.10	104.70	151.81

Source: Haberl et al. (2011)

Gurgel et al. (2008) globally studied biomass production for energy purpose and its impacts on land use by considering two scenarios including *Business-as-usual* (BAU) and "GHG Policy" scenarios, and 2050 and 2100 timeframes. "GHG Policy" scenario is based on climate change mitigation policy and biofuel targets announced by developed countries in order to take into account the global effort to control GHG emission (See,Paltsev et al. 2007). Overall, their projections, as presented in Table 2,are in line with the potential estimated by Haberl et al. (2011). Under BUS scenario, the global biomass production for energy purpose amounts to 39 and 266 EJ/year in 2050 and 2100, respectively. Almost all the production under BUS scenario will come from Africa and Latin America with a contribution of 51% and 49%, respectively, or around 100% for both in 2050. In 2100, these two regions will provide 92% of the global biomass feedstock for energy purpose under BUS assumption, with 33% from Africa and 59% from Latin America. In 2100, the USA will be the third largest world bioenergy feedstock producer with 6.4% of the global production under the BUS assumptions. Under this scenario, the world could achieve in the year 2050 around 37% of the global biomass potential estimated Haberl et al. (2011), while Africa and Latin America could achieve 81%

and 83% of their regional potentials, respectively. The contribution of other regions will be very small (~1% of world production). In GHG policy scenario, the global feedstock production will increase significantly, and will reach 134 EJ/year and 367 EJ/year in 2050 and 2100, respectively. This represents 88% of the global production potential estimated in the year 2050 by Haberl et al. (2011) under climate change scenario. The largest share of biomass production under GHG policy scenario will also come from Africa and Latin America which both will contribute to 72% of the world production in 2050, with29% and 43%for each one,respectively. As argued by several authors (Timilsina et al. 2012; Matzenberger et al., 2013), many regions of the world, such as Oceania, Europe, Russia and many others OECD countries, which would not likely produce bioenergy feedstock in absence of their own biofuel targets, will driven by their domestic biofuel targets to produce bioenergy feedstock. In contrast, the regions with any or very limit biofuel targets such as Africa and Latin America will be driven by international trade to produce biomass and/or biofuel to help ambitious target countries to achieve their ambition.

Table 2: Regional biofuel feedstock production in PCCR models (EJ/year)

	Business-as-usual scenario		**GHG Policy scenario**	
	2050	**2100**	**2050**	**2100**
United States	0	17	16	36
Australia & New Zealand	0	0	3	8
Latin America	19	157	57	193
Africa	20	87	39	101
Rest of the World	0	3	9	15
Others	0	2	10	14
Total	**39**	**266**	**134**	**367**

Source: Gurgel et al. (2008)

4.2. Technological capacity

Although owning a good potential to produce biomass feedstock is crucial in the global bioeconomy, it is not sufficient tosucceed in this new emerging economy. The technical capacity to process the biomass intohigh-value biobasedcommodities, namely biofuel and needed food, is a key factor. This ability requires an important technological transformation, and therefore significant efforts in R&D (Hertel, 2013; IAE, 2008). But, many empirical evidences showed that R&D is a long-runinvestment and its returns on the economy may take several decades (Pardey et al. 2013; Pardey and Craig, 1989; Alston et al., 2011; Alston et al., 2010; Evenson and Gollin, 2003). For instance, investments made in research 20-25 years ago in genetics, and 15-20 years ago in varietal development are just now having their impact on current corn yields in the United States(Alston et al., 2011, 2010). Others studies also indicated that both whiteandgreen revolution experienced in Asia in 1990s and the recent bioethanol revolution in Brazil have been the returns of serious and continued investments in R&D for at least three decades before (de Gorter et al., 2013; Gulati and Ganguly, 2010; Evenson and Gollin, 2003; Fan and Pardey, 1997; Huang and Rozelle,1996; Jin et al., 2002). Thus, if Africa shouldbe able to process its biomass feedstock into high-value commodities and enjoy the benefits of the worldbioeconomyin the next two decades, that should be translated into significant investments in R&D from now at least or since two decades ago. Based on these assumptions, we analyzed the trends of R&Dinvestmentsin Africa during the last decades in comparison to other regions of the world in order to analyze its ability to engage the required technological transformation to take advantage from its great potential in biological resources. We considered for this purpose two recent studies.

More recently, Pardey et al. (2013) using a long-run data analyzed public investments in agricultural R&D worldwide over the past half-century. This study shows that Africa has lost market share in public investments in agricultural R&D, declining from 10% of the world's total in 1960, to 6% in 2009, while Asia andthe Pacific region have increased from 21% in 1960 to 31% in 2009 (Fig. 1, Panel a). Besides declining market share, the amount of investments in agricultural R&D in Africa is lower than in any other region of the world (Fig. 1, Panel b). Also, research intensities in Sub-Saharan in the past two decades have been slipping unlike to Latin America and Asia (Fig.2). Particularly, the emerging countries namely Brazil, India and China have experienced a significant and constant increase in their investment in agricultural R&D throughout the past half century, and now are part of the top ten in terms of investments in agricultural R&D (Fig. 2).

Furthermore, except in Africa, R&D spending on renewable energies,including on bioenergy,has risen rapidly over the last decade in both developed and emerging countries (OECD/IEA, 2013). While geothermal and nuclear power have seen the important reductions in public R&D spending, other renewable sources, notably bioenergy, have seen significant increases in R&D funding over the last five years.Global expenditure on biofuel R&D has increased to USD 800 million in 2009 (up 57% from 2008), with much of this directed towards the development of advanced biofuels (UNEP and BNEF, 2010).In many OCDE countries, public spending in bioenergy R&D has increased more than 300-400% over the last decade (OECD/IEA, 2013).

These trends in R&D investments in Africa indicate, referring to both theoretical and empirical evidences, that a substantial technological change could not be possible in Africa as well as during the past decades and in coming ones. Therefore, Africa could not probably achievethe required technological progress to succeed in the global bioeconomy in coming decades. In contrast, Latin America, the second world's biggest feedstock producer, could be able to process a large share of its feedstock in high-valuebiobasedcommodities regarding its important investment in R&D in the last decades and its significant progress in the 1st generation biofuel technologies.

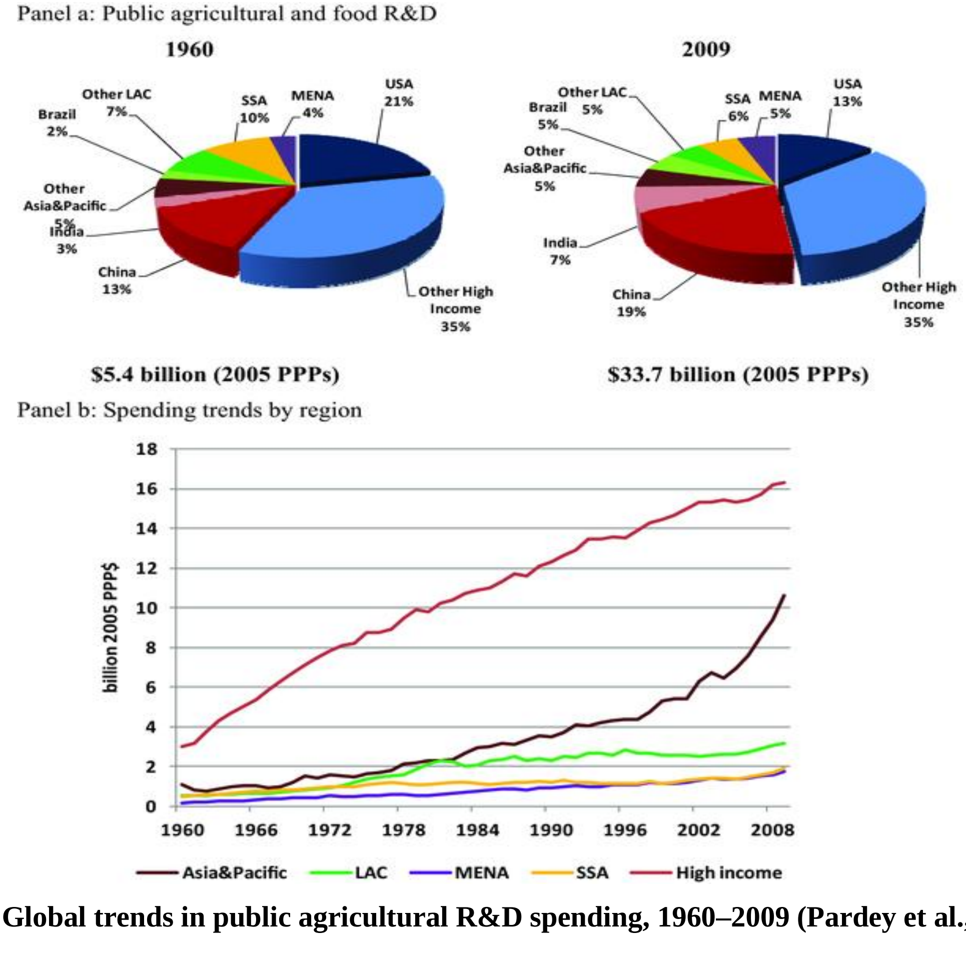

Fig 1: Global trends in public agricultural R&D spending, 1960–2009 (Pardey et al., 2013)

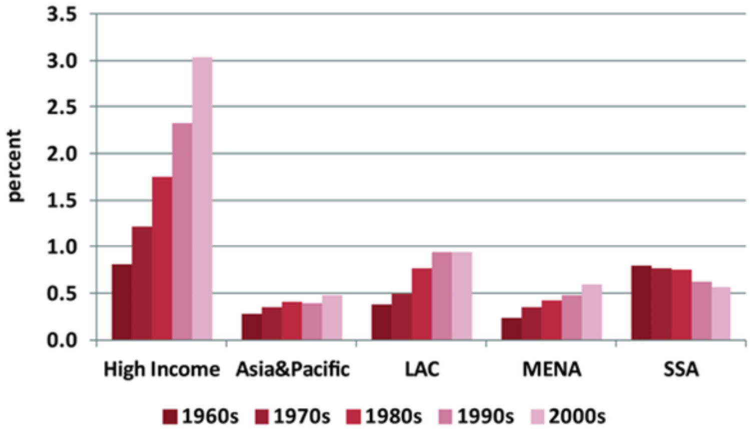

Fig.2: Agricultural research intensities by region and income class, 1960-2009 (Pardey et al. 2013).

Many other studies support these evidences (Alene, 2010; Rezek et al. 2011). Alene (2010) and Huang et al. (2010) studied the correlation between investment in R&D and agricultural growth rate in Africa and China, respectively.Alene (2010) showed that African agriculture has experienced little technical progress from 1979 to 2004. While China's agriculture experienced an average annual growth ranging between around3-7% over 1970 to 2005, African agricultural productivity ranged between-0.9% to 1.4% over the same period asa result of a low technical progress due to a lowinvestment in R&D (Table 4). Alene (2010) arguedthat the agricultural productivity growth experienced in Africa after the mid-1980s was led by the strong growth in R&D spending of about 2% per year in the 1970s, while the low productivity growth experienced in the 2000s was led by the stagnation of R&D spending in the 1980s and early 1990s. So, the decrease in R&D investment and intensity noted in Africa in the last two decades (see, Pardey et al., 2013) will certainlylead to a low technological progress and agricultural growth in the next decades. Therefore, Africa could likely not achieve the required technological transformation to succeed in the global economy despite its great ability in biomass production.

Table 4: Annual agricultural growth rate in Africa and China, 1970-2005

Africa[1]			China[2]	
Periods	**Annual agricultural growth (%)**	**Technological progress (%)**	**Periods**	**Annual agricultural growth (%)**
1970-1980	-0.9	-1.1	1970-1978	2.7
1981-1990	1.4	1.5	1979-1984	7.1
1991-2004	0.5	0.0	1985-1995	4.0
-	-	-	1996-2005	3.6
1970-2004	**0.3**	**0.1**	**1970-2005**	**4.4**

[1]Source: Alene (2010)
[2]Source: Huang et al. (2010)

4.3. Food and biofuel trade

Timilsina et al. (2012) under two scenarios based on the announced biofuel targets. The first scenario considers the implementation of announced targets (AT) while the second scenario (ET) considers a doubling of the AT keeping the timing unchanged. Even if the estimates target very near horizon, 2020, it provides some relevant insights to appreciate biofuels production and trade worldwide and Africa share in the global biofuel market as well. Also, by considering the scenario of a doubling of announced targets (ET), the authors bring their analysis close to what could be happening in the long-run with the increase of biofueldemand. The results of these estimates are presented in Table 5. The world total biofuel production will increase by 38.8 and 92.1 US$ billion in 2020 under AT and ET scenarios, respectively. While the developed countries hold a small potential for producing biomass feedstock (see section 2.1), they could become the largest biofuel producers in the future. Around 25.4 and 67.7 US$ billion, or 65% and 74%, of the total world increase in biofuel production in the next decades will come from developed countries under AT and ET scenarios, respectively. In middle and low-income countries, the increase in biofuel production is estimated at US$ 13.4 billion under the AT scenario and US$ 24.4 billion under the ET scenario, or 35% and 26% of the global increase, respectively. Latin America, including Brazil, will only count for around half of the total biofuel production in middle and low-income countries under AT scenario, and for 36% under ET scenario. Under both scenarios, the contribution from Africa to the global biofuel production is nil.

Table 5 also presents the trade patterns of the global biofuel market in 2020 under both AT and ET scenarios. Theglobal biofuel market will be dominated by developed countries those exports and imports will increase significantly. Manycountries, non-biomass feedstock producers, in developed regions, namely France, Spain, Germany, the United Kingdom, and other European countries, will become biofuel exporters and will contribute significantly to the global biofuel market. Some middle and low-income countries, such as Brazil, India, China, Argentina, will also experience an increase of their share in global biofuel markets. But, Africa will be completely absent in the global biofuel market. The large biomass feedstock produced in Africa will likely be imported by non-feedstock producers in developed regions to meet their domestic biofuel targets and to contribute to the global biofuel markets.These projections are similar to those made in the recent publication of the IEA Bioenergy Task 40 (See, Matzenberger et al., 2013), and show that African countries will be just a biomass feedstock supplier in the global bioeconomy.

Even for food commodities, some projections indicate that the continent will still remain in 2050 a net importer of major food commodities. Considering two scenario, *Business-As-Usual* and *Bioeconomy* scenarios by 2050, IFPRI IMPACT projections indicates that net cereal and meat exports should continue to increase significantly in Latin America and Caribbean, Europe and Central Asia, as a result of higher agricultural productivity and technological progress. But, South Asia and Sub-Saharan Africa will remain net importers of meat and many major staple food including rice, maize, sorghum and millet. Under the bioeconomy scenario, Sub-Saharan Africa will be the largest net food importers in 2050 with around 202 billion and 21 billion tons of net imports of cereals and meat, respectively (Table 6).

Table 5: Changes in biofuel production and trade in 2020

	Increase in biofuel production in 2020				Change in biofuel trade (%) in 2020			
	AT		ET		Imports		Exports	
	US$ billion	%	US$ billion	%	AT	ET	AT	ET
World total	**38.8**	**100.0**	**92.1**	**100.0**	**258.7**	**520.7**	**258.7**	**520.7**
High-income	**25.4**	**65.5**	**67.7**	**73.5**	**310.9**	**794.2**	**370.6**	**934.7**
Canada	0.2	0.5	0.8	0.9	65.5	249.1	0.3	0.5
United States	0.2	0.5	0.8	0.9	0.6	2.3	38.3	163.4
France	7.7	19.8	19.8	21.5	153.8	564.8	486.1	1,204.7
Germany	3.3	8.5	11.1	12.1	78.9	303.2	873.5	2,220.7

Italy	2.7	7.0	7	7.6	319.7	820.0	0.0	0.0
Spain	2.8	7.2	7.3	7.9	362.1	909.6	375.9	1,017.7
United Kingdom	2.7	7.0	6.1	6.6	1,042.4	2,556.6	472.7	1,096.3
Rest of UE and EFTA	5.7	14.7	14.5	15.7	637.2	1,527.9	82.7	332.3
Middle and Low income	**13.4**	**34.5**	**24.4**	**26.5**	**203.6**	**232.6**	**181.1**	**234.1**
Asia	**6.9**	**17.8**	**15.9**	**17.3**	**-**	**-**	**-**	**-**
China	2.2	5.7	8.7	9.4	0.0	0.0	25.9	79.5
Indonesia	0.3	0.8	1.4	1.5	0.0	0.0	1.7	4.9
Thailand	0.4	1.0	1.3	1.4	0.0	0.0	-39.0	-77.4
India	3.9	10.1	3.9	4.2	420.3	425.8	0.0	0.0
Rest of Asia	0.1	0.3	0.6	0.7	-	-	-	-
Latin America & Caribbean	**6.4**	**16.5**	**8.7**	**9.4**	**-**	**-**	**-**	**-**
Argentina	0.1	0.3	0.6	0.7	0.0	0.0	1.5	26.5
Brazil	6.3	16.2	7.9	8.6	0.0	0.0	198.5	250.6
Rest of Latin America	0.0	0.0	0.2	0.2	0.0	46.2	0.0	0.0
Africa	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

5. Who will produce biomass feedstock in Africa?

In previous sections we showed that Africa will be the largest world's biomass feedstock producer in the coming decades, but probably not a big player in the global bioeconomy. This underlines the concern about who will produce biomass feedstock in Africa as the recent initiatives to produce feedstock and/orbiofuefin Africa have failedand ruined many small farmers. In most parts of Africa where governments and the private sector have experienced feedstock production with smallholder farmers, the result has been disappointingbecause of the failures in the design of national biofuel programs, absence of extension support to the farmers, poor quality planting material, uncertain market prospects, low technological capacity and no insurance (Hazell andEvans, 2011;Msangi and Evans, 2013). The risks associated to biofuel production have been mostly transferred to smallfarmers who are already facing many other adverse and challenging conditions. Smallholdershave turned suspicious of energy-crops and expectingfrom them to go back to feedstock production is likely to be difficultin the coming decades.

Biomass production in Africa is likely to be driven by foreign companies and investments. The land acquisitionisaccelerating across the continent. Deininger and Byerlee (2011) documented land acquisitions projects in African countries from 2004 to 2009 (Table 6). Over a five year period, from 2004 to 2009, 1,075 projects of large land acquisitions have been performed in only five African countries. The total amount of land acquired and under acquisition in these five countries over five years has been estimated to exceed 10million ha. In the entire continent, demand for land acquisition in 2009 alone amountto almost 40 million hectares. Land acquisition projects target more agricultural suitable lands and more rainy and countries or with a better water potential (Vermeulen and Cotula, 2010; Arndt et al., 2010; Saturnino et al. 2011). A large share of the land acquired and under acquisition isled by foreign companies. Foreign investments account for about three-fourths of the total land acquired (Vermeulen and Cotula, 2010; Sulle and Nelson 2009). Most are led by biofuel companies looking for better climate conditions, land, water and cheaper labor to producebiomass and/or biofuel to feed the growing demand in developed countries. Many others multinationals driven by the recent financial crisis and the simultaneous price spike of the major food commodities such as maize, rice,barley, wheat, vegetables and meat, are also acquiring significant suitable agricultural lands for large commercialized farms in Africa. For instance,Saudi Star, a Saudi company owned by the King of the Kingdom of Saudi Arabia, acquired 500,000 hectares of land in the region of Gambela in Ethiopia where it produces high-quality potato and rice (Der Kote, 2013). Others large commercialized farms owned by Saudi, Indian, Chinese and European companies are also noticed in the country. In many cases, those large land acquisitions have been followed by the expulsion of local people from who all right on the land has been snatched (Der Kote, 2013; Cotula et al. 2009). Thus, while many millions of people, mostly children and women, are currently threaten by a severe and chronic hunger and malnutrition in the Horn of Africa, the staple crops produced on the fertile lands in Western part of Ethiopia, are exported to Europe and Saudi Arabiawith the indication "*Made in Saudi Arabia*". More recently, e.g. in may 2014,Oxfam with many other humanitarian organizationswarned for urgent actions to prevent a catastrophic food crisis in Somalia where more than three million people suffer of a severe and deathly hunger and malnutrition.

Table 6: Extent of land acquisition in selected African countries, 2004-2009

Country	Number of projects	Area (1,000 ha)
Ethiopia	406	1,190
Liberia	17	1,602
Mozambique	405	2,670
Nigeria	115	793
Sudan	132	3,965
Total	**1,075**	**10,220**

Source: Deininger and Byerlee (2011)

Overall, Africa is becoming a reserve for biomass feedstock for the growing global bioeconomy. The way Africa will be involved in thenew world economy order will not be different from the way it has been involved in during the last decades, where developed countries share around 90% of the world exports of roasted coffee,60% of cocoa powder, while almost all raw coffee, cocoa and tea is produced in developing countries with the largest share in Africa (Nuetah, 2011).The current scheme could be worse than in the past. During the last decades raw agricultural materials were produced by smallfarmers in Africa. With the current scheme, biomass feedstock production in Africa willbe directly governing by foreign companies.Therefore, after missing the green revolution, Africa is still on the way to loose from the biobasedrevolution.

6. Some hope

The outlook of Africa in the growing global bioeconomy is pessimistic. Africa should awake and realize its best to reverse the trends and catch up. Africa enjoys some great comparative advantages through its large potential biobased feedstock. Actually, the largest non-cropped and non-protected suitable lands for biomass production in the world are located in Africa which holds around 42% of the world's total (Deininger and Byerlee 2011). Also, there is room to increase crop yields from smallholders in Africa which currently realizes only 20% of its potential yield. If Africa managed to obtain only 80% of the potential yield across the continent, it could quadruple its maize production (Deininger and Byerlee, 2011). At current yields, this would be equivalent to an extra production of 90 million ha, more than the entire area suitable to extend maize production, globally. The bioeconomy brings to Africa a good opportunity to reshape its contribution to the global economy and trade. During the past decades and until now, agricultural exports from Africa were mostly based on some primary food and raw commodities such as coffee, cocoa, cotton, banana, tea, and groundnuts which the real prices have fallen significantly over the past decade (Sexton et al. 2007; Nuetah et al., 2011;Mohan et al. 2013; Oxfam 2001). The global trade of cacao and coffee isshrunken and is characterized by market imperfection (Sexton et al. 2007) with low-elasticity of demand (Bergtold et al. 2004). More than three-fourths of the global market of coffee and cacao are governed by a few firms in Europe and USA. This makes their markets less competitive. But, biofuel market is assumed to be more diversified and competitive, as it will be governed bythousands of companies and firms with many national and international mechanisms around the world (IAE, 2011). Also, as energy, biofuel demand is more elastic and is, with its price, growing significantly. It could therefore become a new additional export product, more competitive than the primary food commodities. Biofuels also offer to African countries to reduce energy poverty across the continent to increase the competiveness of agricultural sectors by boosting agricultural processing and establishing high-value added value chains.

Furthermore, most of the lingo-cellulosic feedstocksused for 2nde generation biofuels production are tropical raw materials and species that were already present in smallholder farming systems. In many parts of Sub-Saharan Africa, including in arid and semi-arid areas, smallholder farmers are using agro-forestry system integrating many of the 2nde generation feedstock such as *jatropha*, *jojoba*, *eucalyptus* and *acacia*, to combat desertification and erosion, and to restore marginal lands. Small farmer’s interest in these lingo-cellulosic feedstocks will increase if they are aware that they could gain additional income by intensifying the use of these species. Similarly, in Southern Africa where *robinia*and *poplars* trees, otherspotential woody biofuel feedstock, are considered like invasive plants and induce important lost resources and income for famers. In other parts such as forest and equatorial regions, there are significant woody and forest residues and by-products that could sustainability constitutean important feedstock source for biofuel production.

Africa displays a significant lag in R&D and in mastering biobased technologies but there is still an opportunity for Africa to catch up this technological lag. Although R&D is a long-term type of investment which could take around three to four decades before producing returns on the economy, Africa can reduce significantly this time by taking advantage from existing knowledge and technologies developed in Asia, America or Europe. Emerging countries namely Brazil, China and India achieved significant progress in biobased and agricultural technologies. For example, Indonesiadeveloped important knowledge and technologies in *jatropha*-based fuel. Other countries such as the United States, Brazil, Canada and many European countries are also setting up technologies and pilot projects in sugarcane and forest and crop residue biobased fuels. All this represents an important opportunity for Africa to overcome its late biomass-based technologies. In addition, most R&D activities in Africa are an adaptive research based on knowledge or technology developed elsewhere. Some showed that the return lag of the adaptive research is shorter and can be around one decade and a half(Alene, 2010; Schimmelpfennig et al, 2000). But, overcoming this challenge requires a strong political commitment with serious efforts to face to the new challenges that the world bioeconomy is bringing for the developing world, and especially for Africa.

7. Challenges and policy implications

African countries display little interest in domestic biofuel production and use. Even if African countries are not directly involved to Greenhouse gas mitigation, they should be aware thatout of the challenge of mitigation,bioeconomycomes with some opportunities and challenges. Many regions of the world are involving in biofuel production not only to achieve their mitigation commitments, but to build on development opportunities. Regarding the current efforts and forces in place, it is clear that the ongoing dynamic for establishing a global economic model based on biological resources is irreversible, at least over the next few decades. Biobased commodities, namely high-value foods and biofuel, are likely to play a strong role in the new emerging economic order. Africa may not make a choice for domestic biofuel production and use, as the continent owns abundant potential in other alternatives renewable energies. But, within an increasing-openedworld economy, Africa will have little choice. Led and forced by the international investments and global market, rural areas in Africa will be transformed into large commercialized plantations for producing both food and biofuel feedstock to feed the glowing demand in developed and emerging countries. African governments have to be aware of those evidences and engage required actions to take advantage from the new world biomass-basedeconomyto boost the economic development of the continent, to reshape African contribution in the global food and agricultural commodities, and to cope with the issues of food security and poverty. Defining their own biofuel targets for domestic production and use according to their local needs and capacities, with possibility for exports, is an option and maybe the best. If domestic biofuel production is not a choice, then,protecting small farmers from the opportunist large land acquisition and implementing an ambitious policy for agricultural transformation through increased use of family-farming-based technologies and value-chain approach should be the more noble option. But, hiding out the issues of food security and poverty to reject domestic biofuel production, while providing significant facilities for foreign companies, acquiring large lands for biomass feedstock production in Africa, is a serious risk and error.

Whatever the choice, pro- or cons-biofuel, African agriculture needs a significant technological transformationin order to be able to valorize its comparative advantage and become competitive in the global bioeconomy. A substantial effort is needed in order to catch up the lag in agricultural and biobased technologies across the continent.This should require a substantial investment in R&D and technological cooperation and transfer. Currently, governments should meet the NEPAD’s agreement under the Comprehensive African Agricultural Development Plan (CAADP) by allocating at least 10% of the total government expenditure to agriculture. An effective implementation of this plan will play a significant role in accelerating African involving in the global bioeconomy. If African countries were to achieve the CAADP’s targets then most countries would achieve 80-90% of the required spending to achieve a significant agricultural transformation in Africa (Diao et al. 2008).But in long-run, the share of agricultural expenditure in the total public spending should be more important regarding to the role of agriculture in African economy and the news issues of the global bioeconomy. To be useful, a large share of agricultural expenditure should be devoted to R&D with a specific focus on biological technologies more oriented towards small farmers. Africa has experienced a rapid economic growth over the past decade driven by sectors such as mining and petroleum that have little effect on rural areas, where the majority of Africa’s poor live (Africa Progress Report 2014).Therefore, Africa’s recent growth has not done nearly as much as it should to reduce poverty and hunger, or improve people welfare. Well oriented, the recent economic surplus could lead to relevant investments in key sectors, and therefore to a real pro-poor and inclusive economic transformation. Agriculture must be at the heart that transformation. This also requires well-designed social welfare programmes to protect vulnerable households from shocks, set in place national and regional food reserves and insure minimum prices and wages to small farmers.

A strong partnership with both public and private sectors in developed and emerging countries is also required to benefit from their significant advancement in biofuel and bio-genetic technologies and value-chain, rather than providing institutional support for foreign companies seeking acquiring land for feedstock production in Africa.

But, it is supposed that Africa will face many issues and conflicts with both developed and emerging countries under bioeconomy. Widely in the developed world and also in emerging countries, governments are providing significant support to their farmers and private sector in terms of subsidies, tax reduction, tax on fossil oil, and others domesticsupports in order to encourage and to make local biofuel competitive. For instance, China’s levels of subsidies to the sector as grown from USD 115 million in 2006, towards an anticipated USD 1.2 billion by 2020 (GSI, 2008). Also, the import barriers including import tariffs and tariff rate import quotas defined in the U.S. and the EU biofuel policies have made Brazilian bioethanol less competitive in American and European markets (Kojima et al. 2007). Erixon (2009, 2013) indicates that EU’s renewable energy directive go into opposition to WTO rules and obligationsto keep markets open and not discriminate against foreign producers and non-European biofuels. A number authors expect significant clashes with WTO regarding to biofuel markets in the future (Swinbank 2009; De Vera 2008; Loppacher Kerr 2005; Kojima et al. 2007). In 2011 and more recently in 2013, Argentina requested consultations with the EU under WTO concerning certain EU Member States' measures related to the importation and marketing of biofuels into the EU, as well as the incentives granted to the biofuel industry. The EU is currently negotiating Free Trade Agreements with countries that take the view that EU policy on biofuels is protectionist, discriminatory and hurt the trading rights of their producers.

In the last decades, these distortions and trade barriers in the global market have seriously harmed small farmers in Africa and reducedsignificantly the African share in the global agricultural market (Nuetah et al., 2011; Sexton et al. 2007; Oxfam, 2001). As a result, some think that Africa should develop its share of the regional market, improve its infrastructure and design a biofuel policy based on local needs in order to process most of their feedstock and consume their biofuel production domestically (de Goter et al., 2013). That could allow African countries to benefit from their biofuel production such as replacing oil and reducing foreign exchange payments, improving energy access including rural areas, increase crop processing, speeding economic growth and reducing poverty. However as there is also a significant market potential in developed world, they should strengthen their position in the trade negotiation,not only through multilateral negotiationunderthe WTO, but greatly through the bilateral trade agreements in order to establish specific advantage and market for their products. The existing trade agreements with developed countries such as ACP-EU Economic Partnership Agreements and AGOA (Africa Growth and Opportunity Act) with US constitute a strengththat should be enhanced by incorporating new products and exploring new specific market facilities. A specific interest should be paid to South-South cooperation including with the emerging countries such as Brazil, China, India, and Argentina. Models established in China and Brazil could be a viable way to promote bioenergy electricity generation in developing countries with high energy demand growth rates and high availability of biomass.

But, great vigilance is needed for African countries. More recently, Carlos Lopez, the Executive Secretary of UN Economic Commission for Africa, claimed that the ACP-EU trade agreement under discussion is unfair and non-transparent and does not consider what Africa is supposed to become in the next two or three decades. This trade agreement under discussion since early 2000 might not be consistent nowadays regarding the new driven forces of the world economy, the increased entrance of biomass into international trade agreements, and the new economic, trade and energy policies in force in the EU and under the WTO. For instance, the issues of biofuel production and trade were not dealt with at the beginning of the consultations on the new ACP-EU trade agreement.

Africa just endorsed the 2020's strategy of the Africa-EU Renewable Energy Cooperation Programme (RECP) in the framework of the next step of the Africa-EU Energy Partnership (AEEP) for energy security and sustainable energy services in Africa. But, while EU is increasingly turning its renewable energy policy towards bioenergy, the new Africa-EU energy partnership is greatly encouraging the development of non-biobased renewable energies in Africa, namely solar-, hydro- and windpower. The RECP 2020's strategy, indeed, anticipates a strong political and technical cooperation between Africa and Europe in order to insure modern and sustainable energy services for at least an additional 100 million Africans through the development of additional 10,000 megawatts of hydropower, 5,000 megawatts of wind-energy and 500 megawatts of solar (RECP 2020's strategy 2014; AEEP HLM Bulletin 2014). Even though the documents also indicate the developing of other renewable energies including biofuels, there isn't any target and time frame with a real ambition to promote biomass-based fuel in Africa through the ongoing energy partnership between Africa and EU. Africa is blessed with abundant renewable energy resources with a vast potential in hydropower, solar, wind, geothermal as well as biomass energy. And no one can reject the importance of solar-, hydro- or windpower in the efforts to reduce energy poverty in Africa and insure social development and sustainable energy services. But, biofuel is currently the cheapest (Azar, 2005) and the only renewable energy that can be easily used in key economic sectors, such as transport and industry, which also represent the major sectors of fossil fuel consumption in African countries. According to the EU's Renewable Energy Directive, 10% of total fuel consumption in all forms of transport in EU by 2020 should come from biofuel[1] (Swinbank, 2009; Schlegel and Kaphengst 2007; Pacini et al. 2013), with larger for decades after.So, one should ask why EU, despite its low ability in biomass production, is developing a big ambition in biofuel production, while it advises and support African countries to orient their renewable energy policy toward only non-biobased renewable energies. Even if this concern may arise many controversial responses, it is clear that if African countries show, as all other regions of the world, a large ambitious for domestic biofuel production and use, it will be very challenging for European countries and many others emerging and developed countries to meet their biofuel targets. This therefore seems like a new form of the so-called "*économie de traite"* greatly criticized during the past decades as the major factor of the underdevelopment of Africa. Africa should therefore show a great vigilance and evidenced-based decision in the framework of ongoing negotiations on trade, energy and technical cooperation as well as on climate. If needed, it should request a revision of the existing agreements according the new emerging issues.

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[1] The initial directive proposal submitted to European Parliament indicated a mandatory 10% biofuel target for the transport sector by 2020. But, during the decision-making process undertaken between the European Parliament and the Council, the term biofuels was replaced by renewable energy in transport (Pacini et al 2013). However, it is well known that this target will be achieved with biofuels which are the more renewable energy targeted in transport sector. The change, from 10% biofuel to 10% renewable energy target, adopted in the final text by European Parliament was based on perceived risks related to increased biofuels production such as impact on food supply, competition for land and water, indirect land use change, as well as conditions in agricultural areas in developing countries (Pacini et al. 2013).

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