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CURRENT SITUATION OF BIOFUELS DEVELOPMENT IN SUB-SAHARAN AFRICA – POLICY, PRODUCTION AND RESEARCH

Report from an f3 project

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PREFACE

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SUMMARY

Currently there are several on-going biofuel production units and research projects in Sub-Saharan African countries. These differ in respect to countries, scales, source of raw materials (feedstock) and so forth. Thus there is a need for an overview of the on-going biofuel production, research and other related activities. The aim of this study was to give a broad overview of Sub-Saharan Africa regarding current biofuel policies, on-going and planned biofuel production, and to map research activities and actors related to biofuels in the Sub-Saharan Africa countries.

Biofuel development largely depends on the policies of the countries in the region. Several countries such as Benin, Ghana, Kenya, Mozambique, South Africa and Tanzania etc. are in the process of developing biofuel regulatory frameworks with the aim to promote sustainable development in the biofuel sector.

Some fully operational biofuel companies were identified; Ethco Ltd (Malawi), Fincha Sugar Mill (Ethiopia), Green Fuel (Zimbabwe), Kanana Sugar Cane (Sudan), Presscane Ltd (Malawi) and Royal Swaziland Sugar Corrporation. They produce bioethanol from sugar cane with various capacities ranging from 8,000 to 55,000 m^3/year. Most of them produce for both domestic and foreign markets.

Further, a number of biofuel producers are partly operational or planning for future production. Some of them produce ethanol from sugar cane, cassava and sorghum. The anticipated or actual production lies between 4,200 and 158,000 m^3/year. Others extract biodiesel from jatropha, soy beans, virgin or wasted vegetable oils with varying annual capacity between 12,000 and 288,000 m^3. Most of the firms are established in South Africa but some are also located in Angola, Mali, Mozambique and Tanzania.

The mapping of research activities was done by searching and compiling scientific publications and research developments on biofuel in Sub-Saharan African countries. The total number of publications found was 288 between 2010 and April 2013. In a countrywise search for scientific publications, South Africa (59), Nigeria (18) and Kenya (13) are listed on the top. When the biofuel scientific publications were refined with selected key words it could be noted that biodiesel has double the number of publications compared to ethanol.

The report also contains a list of institutions and universities engaged in research and development activities of biofuel and feedstocks. Also in this list, most of the institutions are located in South Africa, followed by Burkina Faso, Kenya, Ghana and Nigeria.

Future opportunities and challenges related to increased production of biofuels were also briefly discussed. Sub-Saharan Africa has been identified in many studies as having large potentials for biofuel and biofuel raw material production. But biofuel schemes need to be integrated with activities to safeguard food security and environmental performance and should result in job creation.

SAMMANFATTNING

I många länder söder om Sahara i Afrika pågår produktion och forskning om biodrivmedel. Det finns stora skillnader mellan olika länder vad gäller produktionsskala, råvaror osv. Samlad information saknas dock. Således finns det ett behov för en överblick av läget vad gäller produktionen av biodrivmedel, forskning och andra relaterade verksamheter. Syftet med denna studie var att ge en bred översikt av Afrika söder om Sahara om aktuell biodrivmedelspolitik, pågående och planerad produktion av biodrivmedel, samt att kartlägga forskning och aktörer med anknytning till biodrivmedel i dessa länder.

Utvecklingen av biodrivmedel har stark koppling till den politik som förs i länderna i regionen. Flera länder, t ex Benin, Ghana, Kenya, Mocambique, Sydafrika och Tanzania, är i färd med att utveckla mål och regelverk kring biodrivmedel, med syfte att främja en hållbar utveckling av biodrivmedel.

Några operativa företag där biodrivmedel tillverkas på kommersiell skala identifierades; Ethco Ltd (Malawi), Fincha Sugar Mill (Etiopien), Green Fuel (Zimbabwe), Kanana Sugar Cane (Sudan), Presscane Ltd (Malawi) och Royal Swaziland Sugar Corporation. De producerar bioetanol från sockerrör med kapacitet på 8 000 – 55 000 m^3/år. De flesta företag producerar för både inhemska och utländska marknader.

Dessutom finns ett antal företag som är delvis operativa eller planerar för framtida produktion, t ex etanol från sockerrör, kassava och sorghum. Den förväntade eller faktiska produktionen ligger mellan 4 200 och 158 000 m^3/år. Andra företag planerar producera biodiesel från jatropha, sojabönor, och jungfruliga och använda vegetabiliska oljor. Planerad kapacitet varierar mellan 12 000 och 288 000 m^3per år. De flesta av dessa företag som identifierats är etablerade i Sydafrika, men några är också belägna i Angola, Mali, Moçambique och Tanzania.

Kartläggningen av forskningsverksamhet innefattade en sökning and sammanställning av vetenskapliga publikationer inom biodrivmedel i Afrika söder om Sahara. Det totala antalet vetenskapliga publikationer som hittades var 288 stycken mellan 2010 och april 2013. De länder som publicerat mest var Sydafrika (59), Nigeria (18) och Kenya (13). När sökningen förfinadess med utvalda nyckelord kan det noteras att publikationerna om biodiesel var dubbelt så många som de etanolrelaterade.

Rapporten innehåller också en kartläggning av forskningsaktörer; vissa institutioner och universitet finns listade. Även denna lista toppas av Sydafrika, följt av Burkina Faso, Kenya, Ghana och Nigeria.

Framtida möjligheter och utmaningar relaterade till ökad produktion av biodrivmedel har också kortfattat diskuterats i rapporten. Afrika har i många studier identifierats ha stor potential för att prdocera biodrivmedel och biodrivmedelsråvaror. Det är dock viktigt att biodrivmedelsproduktion integreras med frågor rörande livsmedelssäkerhet, miljö och arbetstillfällen.

1 INTRODUCTION

Sub-Saharan Africa (SSA) is, geographically, the area of the continent of Africa that lies south of the Sahara with a population of 840 million (World Bank, 2011). The region comprises over 10% of the world population and is growing at a rate of 2.2% (UNAIDS and WHO, 2006). Reliance on traditional biomass energy is particularly high in Sub-Saharan Africa; about 81% of the region's population relies on biomass fuels such as wood, charcoal, crop residue and dung for cooking and heating (IEA, 2010). According to Karekezi and Majoro (2002), even oil-rich sub-Saharan African countries continue to rely on biomass energy to meet the bulk of their household energy requirements: in Nigeria, it is estimated that about 91% of the household energy needs are met by biomass.

Wood is the predominant source of biomass energy, and represents the largest single source of energy for most families in SSA. Forests which are the main sources of wood cover 26.5% of the total area in the region and the annual rate of deforestation is estimated to be 0.7% (Rumi, 2008).

Energy use in Africa is not without problems. Two of the most serious of these are a stifling dependency on imported fuels and a shortage of fuel wood, the primary fuel for the majority of African households. Compared to other nations, the energy related problems place disproportionate drain on the economy, environment, and overall well-being of the population (Boyd, 2008). Reliance on biomass (especially in the form of charcoal) also encourages land degradation. In some areas (e.g. around major cities such as Lusaka, Zambia; Nairobi, Kenya; and Dar-es-salaam, Tanzania) charcoal demand appears to contribute to degradation of the surrounding woodlands and forests (Karekezi, 2002). Traditional use of biomass also has substantial health drawbacks. The indoor air pollution from unvented biofuel cooking stoves is probably a major cause of respiratory illness in many highland areas of sub-Saharan Africa.

According to Cassman and Liska (2007) several African countries will be able to substitute a large of their petroleum use because of relatively small motor fuel consumption levels and a substantial potential to increase production of biofuel crops. Liquid biofuels could also replace charcoal for household energy needs.

Sub-Saharan Africa has in many studies been identified as having large potentials for biofuel and biofuel raw material production. The region is endowed with renewable resources, which can substantially be used to produce biofuels to solve some of its problems for transport. Bioenergy systems are expected to result in the reduction or stabilization of greenhouse gas emissions, diversification of agriculture, reduction of energy imports and provision of security against the depleting conventional energy sources and increasing energy prices. The use of biofuels may therefore be an affordable solution to the region because it contributes to reducing energy dependence on oil and to increasing energy diversification and supply security (IPCC, 2007; EC, 2006; Francis et al., 2005; Ackom and Ertel, 2005).

There is however a number of challenges to consider related to biofuel expansion in SSA. In a report from UNDP (2012) it is indicated that sub-Saharan Africa is rich in land and water resources, yet hunger and starvation are widespread. Measured by agricultural production, food availability has gradually improved, but agricultural productivity remains low – much lower

than in other regions. Even where food is available, millions cannot afford it or cannot acquire it because of underdeveloped markets and weak physical infrastructure.

There are several on-going biofuel production units and research projects in Sub-Saharan African countries. These differ in respect to countries, scales, source of raw materials (feed-stock) and so forth. However there is no good overview on the on-going biofuel activities.

The aim of this study is to give a broad overview of Sub-Saharan Africa regarding current bio-fuel policies, on-going and planned biofuel production, and to map research activities and actors related to biofuels in the Sub-Saharan Africa countries. Future opportunities and challenges related to increased production of biofuels will also be briefly discussed. The report can be useful for anyone who wants to get an introduction to the current situation for biofuel develop-ment in Sub-Saharan Africa countries.

2 CURRENT BIOFUEL POLICY SITUATION

Primary policy drivers for bioenergy production in Africa include security of energy supply, a reduction of the foreign exchange burden of oil importing countries, as well as environmental benefits such as the restoration of degraded land, reduced land abandonment, and the mitigation of greenhouse gas (GHG) emissions. Furthermore the development of biofuel systems offers opportunities for investment and infrastructure improvement in agriculture with the promise to diversify agricultural production and to create additional employment and thus to stimulate socioeconomic development (Jenssen et al., 2009).

Most countries in Africa do not have policies that allow biofuels to be sold as fuel, and the lack of such policies partly accounts for their limited use, along with low fuel prices during most of the 1980s and 1990s, which discouraged biofuel production (Mitchell, 2011). The evidence available today largely indicates that biofuel sources are expensive and are less competitive as compared to fossil fuels. This poses a challenge on the speed with which biofuel technology will diffuse in Sub-Saharan Africa where financial resources are limiting (Mangoyana, 2008). However, currently several African governments are in the process of developing biofuel regulatory framework with the aim to promote a truly sustainable development of their biofuel sector (Jenssen and Rutz, 2012). This section provides an overview of on-going initiatives of selected countries.

- Benin made important development towards the development of national regulatory framework.The country adopted two decrees (Decree 360/2008 and 361/2008) on biofuel production and general conditions for installation of biofuel companies (Cocchi et al., 2009).
- The Government of Ghana published in 2009 a draft aimed to provide an institutional and regulatory framework for the promotion and development of renewable energy (Jenssen and Rutz, 2012).
- Kenyan biofuel policy is guided by the vision to increase access to energy through sustainable biofuel production and to reduce the import of fossil fuels by 25% by 2030 (Jenssen and Rutz, 2012). The Kenyan Ministry of Energy (MoE) set up a National Biofuels Committee (NBC) in 2006. In 2008 a draft Biofuel Strategy was published by the committee for comments. By 2009 a draft Bioethanol Strategy was finalised highlighting Kenya's general capacity to produce sufficient ethanol fuel from molasses to blend 10% ethanol in conventional gasoline. In April 2009, the National Biofuel Policy subcommittee was formed within the NBC to develop a combined biofuel policy including biodiesel, bioethanol, biogas and solid biomass. This policy needs to be aligned with the vision and mission of the national energy Policy (Muok et al., 2008).
- Mozambique adopted a National Biofuels Policy and Strategy (NBPS) to foster biofuel production for national consumption and export. The policy states the clear vision to establish the country's biofuels sector to contribute to energy security and socio-economically sustainable development (Government of Mozambique, 2009).
- South Africa was the first country in Africa to initiate a regulatory framework for renewable energies with the launch of a white paper in 2003 targeting 4% of a renewable

energy by 2013 (Republic of South Africa 2003). During 2009, the National Energy Regulatory of South Africa (NERSA) announced the South Africa Renewable Energy Feed in Tariff programme (REFIT) to further stimulate the renewable energy sector in South Africa. With respect to the 2006 draft strategy document, the penetration level of biofuels by 2013 was revised down from 4.5% to 2% mainly due to food security concerns (Republic of South Africa, 2007).

- In 2005, the Government of Tanzania established a Biofuel Taskforce under the lead of Ministry of Energy and Minerals. The National Biofuel Taskforce has the mandate to develop the National Biofuel Policy and to elaborate the interim Biofuel guidelines that will be used until the Biofuel Policy is fully developed. The guidelines are approved by the cabinet and that the policy is to be approved by the parliament (Maltsoglou and Khwaja, 2010).
- In Angola the parliament has approved the proposed Biofuel policy and Biofuel Strategy in 2010.
- Malawi is using a comprehensive Energy Act from 2004 to govern biofuels development. Malawi is the only country besides Brazil that has been blending ethanol with fossil fuel continuously on a national basis for more than twenty years (Aidenvironment, 2008).
- Bioenergy policy in Nigeria includes the Renewable Energy Component of the National Energy Policy (in 2003), a draft master Renewable Energy Masterplan (in 2007), as well as a pilot fuel ethanol progamme by the Nigerian National Petroleum Corporation based on cassava and sugar cane as feedstock.

There is a growing trend of using biofuel as a fuel for motor vehicles through blending with petroluem. Malawi has been blending ethanol with fossil fuels for more than twenty years. Countries like Angola, Ethiopia, Kenya, Mozambique, Nigeria, South Africa and Sudan are also stimulating biofuels and introducing blending mandates with a ratio varying from 5-10% (Lane, 2012).

According to Jenssen and Rutz (2012), it is of crucial importance to carefully integrate policies for land use, agriculture and energy and align them with policies for rural development, transport and finance. Furthermore, bioenergy development in African countries will only find its proper environmental context and agricultural scale if convergence with biodiversity, GHG emissions and water use policies is achieved.

3 CURRENT PRODUCTION OF BIOFUELS

3.1 PRINCIPAL BIOFUEL CROPS

Biofuels are produced from a variety of agricultural crops but in the Sub-Saharan Africa context so far there are few bioethanol and biodiesel crops at commercial scale. This section gives an overview of the ethanol crops sugar cane and, cassava, and the biodiesl crops jatropha and croton, which are at commercial level or heading towards that.

Sugarcane

Sugarcane is a perennial grass that grows in tropical and subtropical areas up to 1600 meters above sea level (FAO, 2013a). Sugarcane is currently the highest yielding crop in terms of energy per hectare. The Brazilian ethanol yield per hectare amounts to 5,800 liters (Fresco, 2006). Africa has a much lower sugarcane yield of some 4,000 liters of ethanol per hectare. Sugarcane is mostly produced in large-scale plantations. About 10-20% of sugarcane in Sub-Saharan Africa is produced by smallholders or outgrowers with plots ranging from one to ten hectares (Johnson and Rosillo-Calle, 2007). In the Sub-Saharan region of Africa, thirty-seven countries produced sugarcane in 2006. South Africa accounted for 27% of production. Other large producers (by African standards) are Sudan, Kenya, Swaziland, Zimbabwe and Mauritius (FAO-STAT, 2013). In Central and East Africa 22 sugar factories that use sugar cane as a raw material are available; however there is no detailed information on how many of the factories produce ethanol (Sugartech, 2013).Those equipped with distilleries vary considerably in ethanol production due to various reasons.

Cassava

Cassava is a perennial woody shrub that grows in tropical climates up to 1.000 meters altitude. Its roots can be dug up between six and twenty-four months after planting and are rich in starch. The crop is mainly used as a staple for poor farmers around the world, but is also exported as animal feed. The crop is resilient to poor environmental conditions, such as low rainfall (FAO, 2013b). As a biofuel crop, cassava has the advantage that the root can remain in the ground for months without deterioration, allowing for carefully planned and continuous harvest schemes. Once it is harvested, cassava needs to be processed within two to three days (Clay, 2004). This means that cassava can be grown at considerable distance from the ethanol plant, and be harvested when needed. The roots are not as voluminous as sugarcane or sorghum stalks and cassava is therefore easier and cheaper to transport. A hectare of cassava can produce up to 5,400 liters of ethanol. Based on the current average cassava production in Africa, ethanol production would be around 1,750 liters per hectare. This is because the bulk of the African production is done at very low efficiency by small family farmers. Cassava is mostly intercropped with other food crops. Farmers hardly use fertilizers and pesticides to stimulate production, as they cannot afford them. If the crop is given more attention, yields could double or triple in Africa (FAO, 2013b).

Nigeria is responsible for 18% of world cassava production. Other important cassava-producing countries in Africa are Congo and Mozambique. There is also large potential for growing cassava in Benin and Ghana (Kuiper et al., 2007).

Jatropha

Jatropha Curcas is a perennial plant that can grow in tropical, sub-tropical and semi-arid regions at altitudes of up to 500 meters. Its lifecycle is between thirty to fifty years. It takes three to five years before the tree produces yields, but after that harvesting is possible every six to twelve months (EDCO, 2006). Jatropha is drought-resistant and can grow in areas where annual rainfall is as low as 300 mm and on poor soils. However, at poor soils and low rainfall, the production of seeds is limited. Rainfall patterns of 1,200 mm and the use of fertilizers on poor soils are more appropriate (UN-Energy, 2007).

According to Kenyan farmers, both large- and small-scale, Jatropha's yield potential as a cash crop depends on the successful development of the agronomy needed to domesticate what is essentially a semi-wild plant, as well as the creation of a market that ensures farmers can sell their seeds at a reasonable price (Endelevu Energy et al., 2009). Estimates of the productivity of jatropha vary greatly and are based on a limited number of actual field experiences. Generally, pure plant oil yield varies between 400 liters and 2,200 liters per hectare (Aidenvironment, 2008).

Various jatropha projects have failed due to insufficient revenues or meeting farmer resistance to being dependent on one processing plant. However, there are new investments in jatropha plantations around the world (Euler and Gorriz, 2004; Grain, 2007). In Ghana, Mali, Tanzania and Mozambique some jatropha plantations exist and pilot projects to produce biofuels from jatropha are being implemented (Aidenvironment, (2008).

In Mali, a project to generate electricity from jatropha has recently started (MBSA, 2013). Another project in Mali aims at setting up several biodiesel plants with a combined capacity of 55,000 liters per year. They should be supplied through an extensive network of smallholders (Mable Fuels, 2013). In South Africa, different biodiesel plants are under construction that should be supplied with jatropha seeds. Large-scale plantations have been set up within South Africa to provide some of the supply to these plants, with the rest to be imported from neighboring countries (Embassy of the Netherlands, 2007).

Croton

Croton megalocarpus (Haya name: muhihi) is an indigenous tree growing in seven East African countries and it grows in semi-arid climates on marginal lands and produces 25-50 kg of seeds annually with 32% oil content. Croton tree has the feedstock characteristics to produce a commercial grade biofuel. The Croton tree has been used for centuries by rural East Africans for lighting, heating and cooking. At the beginning, three years after planting the yield is relatively small. The Croton tree reaches maturity after 10-12 years. According to Africa Biofuel in East Africa (ABEA) a mature tree can produce as much as 120 liters of oil annually. Other major benefits from using this indigenous non-edible oil seed for biofuel feedstock include the non-invasive nature of this indigenous species. Empirical evidence exists to demonstrate that Croton biofuel can replace petroleum diesel for use in simple engines, generators, and for cogeneration of electricity (Africabiofuel, 2013a).

It has recently been shown in Kenya that Croton nuts, such as those from Croton megalocarpus, are a more economical source of biofuel than Jatropha. In Kenya, Jatropha requires as much as 20,000 litres of water to make a litre of biofuel, while Croton trees grow wild and yield about 35

litres of oil per kilo of nuts. Croton trees are planted as a windbreak in Kenya and its use as a source of biofuel may benefit rural economies there. As arable land is under population pressure, people have been cutting down the windbreaks to expand farmland. This new use may save the windbreaks which should help fight desertification (Wikipedia, 2013).

3.2 BIOFUEL PRODUCERS

Main biofuel producers are presented in Tables 1-3. The tables are divided according to classifications based on whether the company is fully operational (Table 1) or under planning and partly operational (Table 2). There are also companies where their activities remain unclear due to lack of up to date information or they have decided to switch to another farm activity (Table 3). Certain companies have not yet reached commercial scale production, however, as part of the investment focus is devoted to research in order to improve yield during production. Further information regarding the status of companies is also included in text following the order in the tables. The biofuel companies were identified via web searches, and much information about South Africa was col-lected from a recent IEA-report (van Zyl and Prior, 2013).

Table 1. Biofuel production facilities in Sub-Saharan Africa, classification 1 - fully operational

Company	Type of biofuel and raw material	Location	Capacity (m^3/yr)	Market	Website
ETHCO Ltd.	Ethanol, sugar cane	Dwangwa, Malawi	30,000	Domestic and foreign	www.ethanolmalawi.com
FSM, ESF	Ethanol, sugar cane	Finchaa, Ethiopia	8,000	Domestic	Na
Green Fuel	Ethanol, sugar cane	Zimbabwe		Domestic and foreign	www.greenfuel.co.zw
KSC	Ethanol, sugar cane	Kanana, Sudan	55,000	Domestic and foreign	Na
Presscane Ltd.	Ethanol, sugar cane	Blantyre, Malawi		Domestic and foreign	www.presscorp.com
RSSC	Ethanol, sugar cane	Simunye and Mhlume, Swaziland	32,000	Domestic and foreign	www.rssc.co.sz

ETHCO Ltd. (Malawi) Ethanol Company Limited commissioned in 1982, has produced well over a quarter billion litres of ethanol (ETHCO Ltd., 2013).

FSM, Finchaa Sugar Mill and **ESF, Ethiopia Sugar Factories,** (Ethiopia): In 2008, Ethiopia had four sugar factories (Methara, Wonji, Finchaa and Tendaho) and Finchaa sugar mill produced about eight million liters of ethanol per year. According to Ministry of Mines and Energy, in 2013 the country will produce over 130 million liters of ethanol from three sugar factories. Ethiopia has a large, government owned industry, which produces about 115,000 tons of molasses per annum as by-product (Yewondwossen, 2008). At present the country is expanding additional sugar cane plantation sites on 6000 hectares of land in Southern Omo. The plantations are

intended to serve the six Omo Kuraz Sugar factories (Tekleberhan, 2012). The number of sugar factories in Ethiopia will be 10 in shortly few years.

Green Fuel (Zimbabwe) is a large-scale ethanol producing factory in Africa, manufacturing anhydrous ethanol from sugarcane and supplying Zimbabwe, the region and beyond, with a clean, efficient, renewable fuel source. The company produces high quality anhydrous ethanol with less than 0.04% water content. Green Fuel is committed to following sustainable environmental policies as set out in EU Guidelines published in June 2010. (Greenfuel, 2013).

KSC, Kanana Sugar Company (Sudan) at the moment has reached 55,000 m^3 and Sudan is the biggest anhydrous ethanol exporter in Africa after South Africa and the biggest exporter to the Middle East. The company is planning to increase ethanol production by about 5-fold (Hussein, 2012).

Presscane Ltd (Malawi) is an ethanol distillery which is a subsidiary of the conglomerate Press Corporation Limited and began operations in June 2004. The plant is located in Chikwawa on the east bank of the Shire River and employs 112 Malawians including management. The main products of the distillery are fuel ethanol also known as anhydrous alcohol (AA 99.8% v/v) and industrial alcohol (rectified spirit 96.5% v/v). The high quality of the ethanol is possible due to the new molecular sieve dehydration (MSDH) technology installed in the distillery. The molasses are a waste material (effluent) for the Illovo Sugar Mill whose environmental disposal issues have been solved by the establishment of PressCane Limited. The fuel ethanol is blended with petrol in the ratio 10% ethanol to 90% petrol by the petroleum companies such as BP Malawi, TOTAL Malawi and CHEVRON Malawi. Fuel blending in Malawi was precipitated by the energy crisis in the early 1970s. The surplus ethanol, after national blending requirements have been met, is exported thus generating foreign currency for Malawi (Press Corporation Limited, 2013).

RSSC, Royal Swaziland Sugar Corporation is owned by several hundred shareholders. The corporation manages approximately 17,000 hectares of irrigated sugar cane on two estates leased from the Swazi Nation and manages a further 5 000 hectares on behalf of third parties, delivering approximately 2.3 million tonnes of cane per season to the corporation's two sugar mills. These two mills currently crush cane at a combined throughput of 700 tonnes per hour, producing approximately 430,000 tonnes of sugar per season. RSSC also operates a sugar refinery, situated at the Mhlume mill, which produces 150,000 tonnes of refined sugar, and a 32 million litre capacity ethanol plant, which is situated adjacent to the Simunye mill (Royal Swaziland Sugar Corporation, 2013).

Table 2. Biofuel production facilities in Sub-Saharan Africa, classification 2 - under planning or partly operational

Company	Type of biofuel and raw material	Location	Capacity (m^3/yr)	Comment	Website
Arengo	Ethanol (Sorghum)	Cradock, South Africa	90,000	Licence granted	na*
Basfour 3528	Biodiesel (waste vegetable oil)	Berlin, South Africa	50,000	Licence granted	http://www.ctafrica.co.za/
Biocom	Ethanol, sugar cane	Cacuso, Angola	60,000		http://www.biocom-angola.com/
Biogreen	Biodiesel, virgin and wasted oil Algae oil	Cape Town, South Africa	na*		www.biogreen.co.za
E10 Petroleum Africa OC	Ethanol	Germiston, South Africa	4,200	Licence granted	http://www.e10petroleum.co.za/
EcoEnergy	Ethanol, sugar cane	Bagamoy, Tanzania	8-15,000		www.ecoenergy.co.tz
Exol oil refinery	Biodiesel (waste vegetable oil)	Krugersdorp, South Africa	12,000	Licence granted	na*
First In Spec Biofuel	Vegetable oil (virgin and wasted)	South Africa	na*		www.fisbiofuels.co.za
KSLC /Illovo	Ethanol and beverage alcohol, sugar cane	Kidatu, Tanzania	na*		www.illovosugar.co.za
Mabele Fuels	Ethanol (Sorghum)	Bothaville, South Africa	158,000	Licene issued	http://www.mabelefuels.com/
MFC	Oil, tree oil seed, Jatropha	Garalo, Mali	na*		www.malifolkecenter.org/
NDZiLO	Ethanol, casava	Dondo, Mozambique	1440		na*
RNRF (Rainbow Nation Renewable Fuesls Ltd.)	Biodiesel, soy beans	Port Elizabet, South Africa	288,000	Licence issued	www.rnrf.co.za
Ubuhle Renewable Energy	Ethanol (Sugarcane)	Jozini, South Africa	50,000	Licence granted	na*

** na-not available/could not find (May 2013)*

Arengo is a joint venture between the Industrial Development Corporation (IDC), Sugar Beet SA and the Central Energy Fund and was formed to develop and manage the ethanol plant. Following an application by Arengo 316, land had been re-zoned at Cradock to develop an industrial park that would include the proposed plant. The company's annual sorghum grain feedstock will be about 230,000 tons and it expects to acquire a minimum of 30% of the grain volumes from local farmers (Radebe, 2012).

Basfour 3528 (Pty) Ltd - Biodiesel is manufactured from used vegetable and soya oil. The plant is located in Berlin, Eastern Cape, South Africa. The current biodiesel production capacity is 75 million Litres per annum with plans to ramp-up. The company is in discussions with the Provincial Agriculture Department and private farming co-operatives to secure a sustainable supply of canola/Soya feedstock - products which are the basis of one of the major agricultural projects within the Eastern Cape - from these rural farming communities (Clean Tech Africa, 2013).

Biocom, Angola Bioenergy Company is currently Angola's only sugar and ethanol-producing company. Biocom, a partnership between Sonangol, Damer and Odebrecht, is created in 2006; it covers 30,000 hectares in Cacuso, Malange, 1,450 hectares of which are already covered with sugarcane. When the project reaches its maturity, Biocom will be capable of producing 250,000 tonnes of sugar per year and 250,000 liters of ethanol per day, which may be used as fuel and also to blend with petrol. In the near future, Biocom's sugarcane will cover 25,000 hectares. Angola's sugar market demand exceeds 400,000 tonnes per year (Faus and Faus, 2012).

Biogreen diesel (South Africa) produces biodiesel from both virgin and waste oil. Biogreen expands use of waste oil to biodiesel operation into all the major centres across the country through providing expertise and equipment to regions. It also explores algae as a viable third generation feedstock (Biogreen, 2013).

e10 Petroleum Africa CC was granted a licence in the year 2009. It is involved in wholesales, imports and manufacturing. It has sites and logistics in Gauteng, to retail filling stations in Free State, Mpumalanga, North West and Limpopo. It has over 35 privately owned and operated branded filling stations and owns over 120 underground tanks. It has its own depots, trucks and maintenance services available to the network (e10 Petroleum, 2013).

EcoEnergy (Tanzania) aims to produce sugar and renewable energy in a sustainable manner and runs the Bagamoyo Project. The Bagamoyo Project comprises a total of approximately 11,000 ha of sugar cane plantations, where 7,800 ha will be on the site of the project and approximately 3,000 ha of outgrower land (developed over a six year time period), which will be outside of the site. A demonstration farm of 200 ha with drip irrigation has been operational since 2007 with excellent yields. A sugar cane processing facility will be established on the estate. The facility is also designed and prepared for a flexible production of ethanol/sugar plus co-generation of electric power. As Tanzania has a large structural domestic sugar shortage, the Bagamoyo project will maximise sugar production. It is anticipated that the project will produce approximately 125,000 tonnes of sugar for sale to the domestic market, 8-15 million litres of ethanol primarily for the domestic market, and 100,000 MWh/year for delivery to the Tanzanian national electricity grid. It is anticipated that up to 300,000 tonnes of sugar cane, or approximately 30% of all supply will be sourced through an outgrowers' programme by 2018. Construction of the project is planned to be initiated in the third quarter of 2012 estimating a 26 months

construction period for the processing plant and for the first 4000 ha of sugar cane estate. The production of sugar, power and ethanol is planned to start in the third quarter of 2014 (EcoEnergy, 2013).

Exol oil refinery: In South Africa reprocessing used oil into industrial fuel is commercially attractive. Exol Pty Ltd, part of the Exol Group, also buy significant volumes of used oil from environmentally approved collectors and using simple process techniques produce an industrial grade furnace fuel. The reprocessed product is sold as a substitute for heavy fuel oil that is derived from crude oil. According to ROSE environmental compliance audits (2005), Exol Oil Refinery has successfully met the stringent environmental and legal requirements in ensuring excellent operational conformance (ROSE Foundation HOUSE, 2013).

First In Spec Biofuels Ltd produces commercial biodiesel from waste vegetable oil (WVO) that conforms to local and international specifications required by the major fuel companies to be blended with fossil fuel. First In Spec Biofuel is a member of South African Biofuel Association (First In Spec Biofuels Ltd, 2013).

KSCL, Kilombero Sugar Company Limited, according to Lazaro (2007), has been awarded US$ 299,780 to install a distillation plant for ethanol production using waste molasses. The general manager of KSCL told Business Week in Dar es Salaam that Tanzania's growing energy demands needed to be supplemented by alternative energy. The company produces ethanol and beverage alcohol. According to Africa Sugar Digest (2012) report Illovo Sugar received approval on their environmental impact assessment to build a USD 45 million distillery at its Tanzanian subsidiary, Kilombero Sugar. The distillery will produce 12 million litres per year of beverage alcohol and its construction started in 2011 (Chullén, 2012).

Mabele Fuels is a company founded in 2005 and resolves to build a bio-ethanol-from-sorghum plant in Bothaville in the Free State Province, South Africa. Mabele Fuels has chosen grain sorghum specifically to meet the requirements and as a result of its potential to promote comercially successful emerging farmers. The Free State and Mpumalanga Provinces are the largest contributors to the area planted to sorghum and sorghum production. The company will be facilitating the domestic production of fuel-grade ethanol, with a capacity to produce 153 million liters of fuel-grade bioethanol per year and is expected to come online in the second quarte of 2014 (Mabele Fuels, 2013).

MFC, Mali-Folke Center, initiated its first large scale jatropha project (in 2006) to provide power to a village of 10 000 people in the village of Garalo, in southern Mali. This project is carried out in cooperation with ACCESS (an innovative Malian energy service provision company), SHGW (Netherlands), Stichting DOEN (Netherlands), and AMADER (Agence Malienne pour le Developpement de l'Energie Domestique et de l'Electrification Rural - Mali's rural electrification agency). The project has installed 300 kW of power in the village. MFC has been actively working on the promotion of the jatropha plant since activities began in 1999. A range of projects have been executed, focusing on different aspects of jatropha production and use, from plantations, use as a living hedge, soap making, multi-functional platforms, jatropha as diesel substitute for transportation, etc (MFC, 2013).

NDZiLO's (Mozambique) ethanol plant in the province of Dondo has a capacity to supply two million liters of cassava-based ethanol. The cassava will be grown by local farmers using a crop

rotation system. NDZiLO was founded in partnership with CleanStar Ventures and Novozymes to provide an improved cooking solution for the people of the urban centers of Mozambique (where the price of charcoal has tripled in the past 3 years). The ethanol is intended to be used as fuel for cooking. The ethanol burns cleaner than charcoal – which means that houses and lungs stay cleaner, and deforestation is reduced. The plant will produce around 30,000 liters of fuel per week at full capacity, which will be transported to Maputo on a weekly basis. Right now the plant is at 25% capacity, due to the fact that the marketing and operations teams that sell the stoves and fuel need to ramp up demand. Around 500 stoves are currently in use in the market with another 2,200 pre-orders in place. According to CleanStar, Mozambique wants farmers to grow the cassava using a permaculture style arrangement: for each hectare one strip should be cassava, one legume and one cereal like maize. The whole hectare is then surrounded by agroforest to reduce water runoff and increase shade (which reduces the need for irrigation). (Boynton, 2012).

RNRF Ltd, Rainbow Nation Renewable Fuels is a South African soy-based biodiesel producing company (RNRF Ltd.) and is a member of Biofuels Group Pty. Ltd. The group also incorporates National Biodiesel Pty.Ltd. in Australia, National Biofuels group Trading Operations as well as the research and development company Algae Energy Pty.Ltd. (RNRF, 2013).

Ubuhle Renewable Energy is one of the potential biofuel producers and licence has been granted to produce ethanol from sugar cane. The Sugar Cane Development Project aims at establishing an agriprocessing business cluster on the Makhathini Flats comprising sugar cane farming, a fuel ethanol distillery with electricity co-generation and/or sugar milling. The project will be implemented in a phased manner, with the envisaged initial investment being sugar cane farming on 8,220 ha net irrigated area not currently under cane farming and 1,200 ha currently being farmed to sugar cane, a fuel ethanol distillery and electricity cogeneration. Ultimately phase 2 could take the area under sugar cane to some 15,000 ha. The full-scale capital investment is envisaged to expand the fuel ethanol production or include raw sugar production (Makhathini Sugar Cane Project, 2012). The Muragappa Group from India has partnered with Ubuhle Renewable Energy and Makhathini Agricultural Development Co-operative to set up a production plant at Jozini (SABC, 2012).

Table 3. Biofuel production facilities in Sub-Saharan Africa, classification 3 - companies where activities remain unclear or companies that have decided to switch to another farm activities

Company	Type of biofuel and raw material	Location	Capacity (m^3/yr)	Comment	Website
Agroils	Oil, tree oil seed, Jatropha	Florence, Italy	110,000		www.agroils.com
Crown Agro-Allied Industries	Ethanol, cassava	Ikole, Ekiti State, Nigeria	48,000		
Phyto Energy	Biodeisel (canola, rape)	Port Elizabeth, South Africa	>500,000	Initial stage of licence application	
ABEA Ltd.	Oil, tree oil seed, Croton	Dar es Salaam, Tanzania Nairobi, Kenya	186,000		www.africabiofuel.com
ScanFuel	Oil, tree oil seed, Jatropha	Stavanger, Norway	240,000	Name changed to ScanFarm Ghana Ltd	

Agroils is an Italian bioenergy consultancy company that aims to produce 100,000 tonnes of biofuel from jatropha plant in 2018 in Africa and Brazil where it works together with local farmers. Agroils started projects to grow jatropha to make biofuels in Marocco, Ghana, Senegal, Cameroon and Brazil in 2008. The projects included a 200-hectare field in a desert in Marocco and 10,000 hectares in Ghana and areas would grow if the initial projects were a success. The company manager indicated that biodiesel made from jatropha would be used mostly locally and a Cameroon railway is one of the potential clients (Reuters, 2009).

Crown Agro-Allied Industries Limited has concluded plans to build an integrated cassava ethanol fuel refinery in Ikole, Ekiti State, in Nigeria at an estimated cost of $110m. The project is an integrated comprising a 10,000 hectare cassava farm, 200,000 litres per day fuel ethanol refinery, 60 tonnes per day carbon dioxide plant, and a waste treatment bio-gas plant for the production fertiliser. The cassava farm that will feed the factory will take between 18–24 months to be established because it will be the largest cassava farm in the world (The Bioenergy Site, 2009a).

PhytoEnergy SA plans to produce biofuels from canola on 500,000 hectares in the Eastern Cape Province. The project envisages local production of biodiesel for export to Europe to satisfy European statutory biodiesel requirements of the future. The biodiesel refinery will be constructed in the East London Industrial Development Zone and were planned to be completed by 2011. PhytoEnergy SA and its Black Economic Empowerment partner are responsible for the capital layout at a cost of about R3.5 billion ($0.42bn). PhytoEnergy SA forms part of the Euro-

pean PhytoEnergy Group with projects in India and the Ukraine. The group is also negotiating with various German and South African financial institutions to acquire further funding. Long-term supply agreements have been secured in Europe (The Bioenergy Site, 2009b).

ABEA Ltd, Africa BioFuel and Emission Reduction (East Africa) Ltd, completed more than 11 years of research and development to determine that Croton megalocarpus (Cmeg), a local, indigenous tree growing in seven East African countries. The company's main purpose is bringing an existing natural resource to the commercial renewable energy market, first in Africa, then to South and North America. Africa Biofuel and Emission Reduction Company (East Africa) Ltd. is an East African operating company of Euphorb US Ltd. Expected production at maturity level of the company is 186,000 m^3 yearly (Africabiofuel, 2013b).

Scanfuel AS has acquired 400,000 hectares of land in the Asante Akim North Municipality of the Ashanti Region in Ghana to plant Jatropha for large scale biodiesel production for export. It is noted to be the largest Jatropha plantation in Ghana (Dogbevi, 2010). The company planned to produce 240,000 m^3 yearly by 2015 in Ghana (Roelf, 2008). According to the inter-views conducted in Ghana, its production of jatropha seeds never reached commercial quantities thus the company switched towards cultivation of maize and soybean for human consumption (Preuss, 2012).

4 MAPPING OF RESEARCH ACTIVITIES

In this chapter we give an overview of scientific publications, research and development of biofuels in Sub-Saharan Africa.

4.1 SCIENTIFIC PUBLICATIONS

A search was done for scientific publications in Web of Knowledge for biofuels in SSA countries between the years 1998 and 2012. The word "biofuel*" was wtitten in the topic field and the Sub-Saharan countries (52 as listed by UNSTATS, 2013) in the address field. It can clearly be seen that the number of publications has increased over the years (Figure 1).

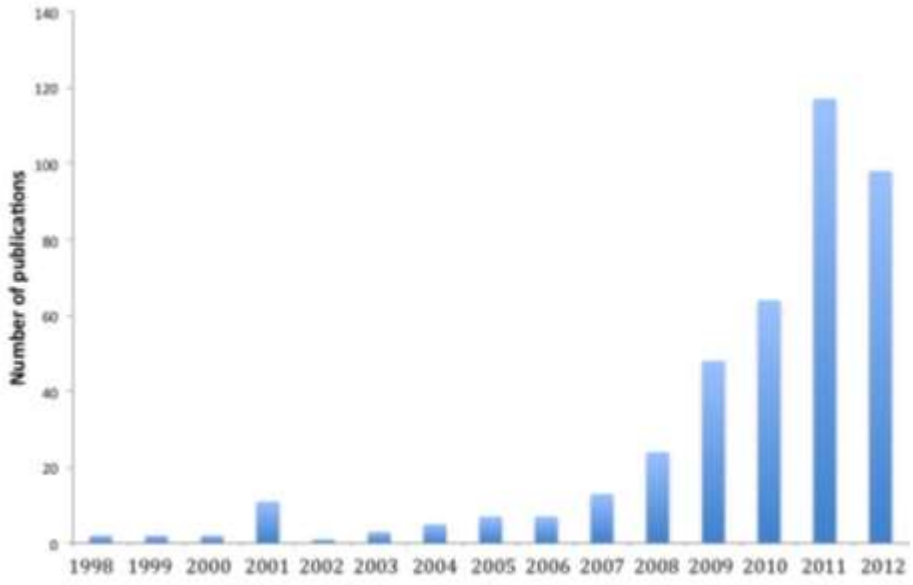

Figure 1. Number of publications in Web of Knowledge on the topic "biofuels" by Sub-Saharan Africa countries. In the search, the word "biofuel*" was written in the topic field and the Sub-Saharan countries (52 as listed by UNSTATS, 2013) separated by "OR" in the address field.

Another search was done on the 18th of April 2013 for scientific publications in Web of Knowledge, using the word "biofuel*" in topic and the Sub-Saharan countries (52 as listed by UNSTATS, 2013) separated by "OR" in the address field. The publication date was limited to papers pub-lished between 2010 and 2013. This yielded 288 results (Figure 2).

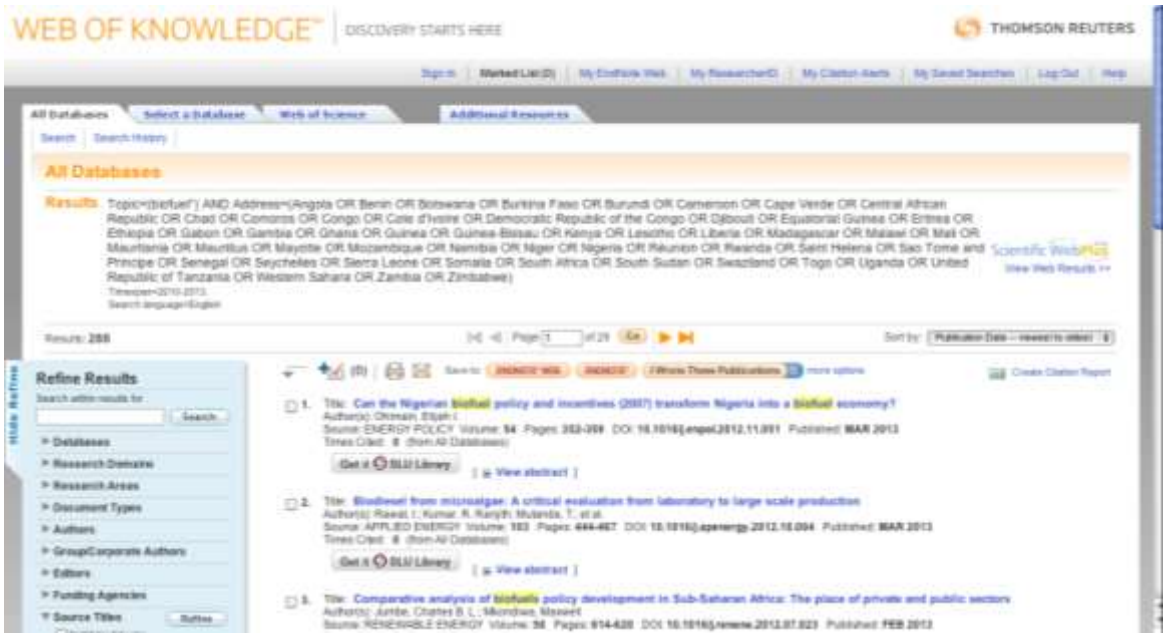

Figure 2. Screen dump of search results in Web of Knowledge

The results were then listed by country, the main publishing countries for the defined search is shown in Table 4.

Table 4. Scientific publications in Web of Knowledge on the topic biofuels from Sub-Saharan Africa, main or co-author, between 2010 and April 2013

Country	Number of publications
South Africa	59
Nigeria	18
Kenya	13
Burkina Faso	8
Botswana	4
Ghana	4
Mozambique	4
Zimbabwe	4
Other SSA countries	170
Sum	288

Many SSA countries published only 1 or 2 scientific papers during the selected period, which is the reason for the majority of publications ending up in the category "other SSA countries".

It should be noted that this search perhaps does not give a full picture of scientific publications. Many African universities probably publish in open access journals due to the high subscription fees for the traditional scientific journals. Publication in open access journals is an increasing phenomenon, not only for developing countries. However, the search engines provided in open access databases are less advanced (see e.g. Directory of Open Access Journals, DOAJ) and do not allow for article search by country, neither does Google Scholar which is another large search engine including both traditional and open access journals.

The publications are found in a large variety of scientific journals, both international, African orientted and a few domestic. The main scientific journal was Biomass & Bioenergy (19 publications), Energy Policy (11 publications) and African Journal of Biotechnology (10 publications). Of the 288 hits, 248 publications were listed as articles, 24 as reviews, 20 as meetings (conference proceedings) and 7 as books. The publications are in Web of Knowledge also listed in different research areas, see Table 5.

Table 5. Scientific publications on the topic biofuels between 2010 and April 2013 in Web of Knowledge by Sub-Saharan African countries, listed by different research areas. (N.B. Some publications are listed in more than one area, and not all areas are included in the table.)

Research area	Number of publications
Energy fuels	218
Agriculture	146
Environmental science ecology	114
Plant science	58
Instruments and instrumentations	57
Biotechnology & applied microbiology	55
Business economics	56
Forestry	36

Searching for certain keywords within the results can further refine the selection, to highlight the topics of the papers (Table 6).

Table 6. Scientific publications on the topic "biofuels" between 2010 and April 2013 in Web of Knowledge by Sub-Saharan African countries, refined with selected keywords

Keyword	Number of publications
ethanol	61
biodiesel	112
jatropha	43
sugarcane OR sugar cane	22
cassava	13
croton	6
soy*	13
alg*	19

It can be concluded that the number of publications from SSA-countries on the topic "biofuels" has increased during the last years. From the literature review we can also see that most SSA-countries produced only 1-2 publications during the last 3 years, only a handful of countries produced more and South Africa has by far the largest number of publications. We can also see that there are more publications on biodiesel and biodiesel feedstock than on ethanol.

4.2 R&D ACTORS IN SUB-SAHARAN AFRICA

It is difficult to give a full overview of actors involved in research and development of biofuels in SSA-countries. Research actors can be found by studying the scientific publications in detail. As previously mentioned, the publications are scattered all over SSA, most countries producing 1-2 papers during 2010-2013. It is therefore not feasible to list all universities or research bodies having published papers on biofuels. It can, however, be mentioned that Stellenbosch University published 25 of the 59 publications from South Africa, implying that it is one of the main publishing institutions in scientific journals on biofuels in SSA.

Most of the information in Table 7 was found by performing web searches. During the searches we used combinations of the following words: biofuel, biofuels, Africa, research, development, project R&D. This lead to a number of homepages, giving information about specific projects, but often also links further to partners, other projects and to other organisations in the field. It is important to note that this list is far from complete. As can be seen, most of the search results came from South Africa. This can be because the homepages and information on internet is more developed in this country.

There are also researchers in a number of other countries cooperating with SSA countries on biofuels. For the EU there are some European policies that traditionally set the overall framework for cooperation with Africa, e.g. the Cotonou Agreement between the EU and 77 ACP

(African, Caribbean and Pacific Group of States) which came into operation in 2003 and is due to last for 20 years, and the Trade, Development and Cooperation Agreement (TDCA) with South Africa (EU, 2009). African countries have also participated in European Research Framework Programmes (FP). Those with more than 10 participations each in FP6 (2002-2006) were: Benin (11), Burkina Faso (21), Cameroon (11), Ethiopia (16), Ghana (19), Kenya (46), Mali (18), Mozambique (11), Niger (15), Senegal (37), Tanzania (29), Uganda (27) and Zambia (12) (EC, 2013). The numbers include all sorts of research not only on biofuels.

Table 7. Some identified research and development actors in Sub-Saharan Africa

Institution	Country/region	Main activity	Website
CEF	Southern Africa	Central Energy Fund (CEF). Research and consultancy, mainly fossil fuels but also biofuels	http://www.cef.org.za, and http://www.cefgroup.co.za
ARL	Nigeria	African Research Laboratories (ARL), research on e.g. ethanol from cassava	http://africanlabs.org/
EBEA	East Africa	R&D, focus biofuel from croton tree	http://www.africabiofuel.com
Kwame Nkrumah Univ. of Science and Technology	Ghana	Research includes development of biofuels as alternative energy sources	http://energycenter.knust.edu.gh/pages/
Univ. of Pretoria	South Africa	Research on biofuels from Moringa biofuel tree (2004)	http://web.up.ac.za
SABA	Southern Africa	Southern Africa Bioenergy Association (SABA), membership association for bioenergy companies	http://www.saba.za.org/index.html
SANERI	South Africa	South Africa's National Energy Research Institute	http://reee.sacities.net/resources/saneri.htm
PISCES	Kenya	Policy Innovation Systems for Clean Energy Security (PISCES). 5 year initiative funded by the UK's Department for International Development	www.pisces.or.ke/node/1
NEPAD	African Union	Planning and coordinating technical body of the African Union	http://nepad.org/climatechangeandsustainabledevelopment/energy
GBEP	Global	Global Bioenergy Partnership	http://www.globalbioenergy.org/
Stellenbosch University	South Africa	Several departments do research on biofuels, e.g. dep of process engineering, chemical engineering, dep of microbiology, centre for Renewable & Sustainable Energy Studies	http://www.sun.ac.za/university/
CSIR	South Africa	Council for Scientific and Industrial Research (CSIR)	http://www.csir.co.za/
Durban University of Technology	South Africa	Research on algae, Institute for Water and Wastewater Technology	http://www.dut.ac.za/iwwt
CIRAD	Burkina Faso	Agricultural development	http://www.cirad.bf/
World Agroforestry Centre (ICRAF)	East, west, south and central Africa	Research, agroforestry	http://www.worldagroforestry.org/
Bioenergy Africa	South Africa	Consultancy, R&D	www.bio-africa.com
Pangea	Based in Brussels	Bioenergy companies membership association and developmental campaigner	www.pangealink.org

4.3 WEBSITES WITH OVERVIEWS OF BIOFUEL RESEARCH PROJECTS

Information about R&D projects is perishable. We have therefore chosen to also include a number of websites that gather and update information about research and development of biofuels in SSA-countries (Table 8).

Table 8. Some websites with information about research projects of biofuels in Sub-Saharan Africa.

Name	Description	Web address
CORDIS	EU research project database	http://cordis.europa.eu
CAAST-Net	A Network for the Coordination and Advancement of Sub-Saharan Africa-EU Science & Technology Cooperation	http://www.caast-net.org/
COMPETE	Competence Platform on Energy Crop and Agroforestry Systems for Arid and Semi-arid Ecosystems- Africa	http://www.compete-bioafrica.net/index.html
UNEP	The United Nations Environment Programme's African Rural Energy Enterprise Development Programme	http://www.areed.org/
CTA	Information on key ACP-EU programmes and events from Brussels relevant to agriculture and rural development in ACP countries	http://brussels.cta.int/
BIA	Research project with focus on Jatropha	www.bioenergyinafrica.net/
Partners for Africa	Project supported by the European Commission's Sixth Framework Programme with the aim to bring together partners in renewable energy	http://www.partners4africa.org

5 FUTURE CHALLENGES AND OPPORTUNITIES

As the previous chapters point out, there is much on-going activity in the biofuel area, both in production, research & development and policy. However, it is also important to note that the development of biofuels in SSA is not without dispute. There is ongoing debate and research as to what extent biofuels is an opportunity or a threat to development in Africa. Although it is not the main purpose of this report, we find it important to give a very short introduction to some of the challenges and opportunities for biofuel development in SSA countries. To produce knowledge of how to realise benefits and synergies, and to overcome challenges and avoid risks, will be an important task for biofuel research and development in SSA in the years to come.

Some issues raised by sceptics to biofuel development are:

- There are hundreds of millions of undernourished people in Africa. Agricultural land should be used to produce food. Although it is widely recognized that most food insecurity is caused by poverty and associated public policy failures, rather than actual food shortages, there is a need to increase food production in Africa, and biofuels compete for agricultural land.
- In many countries in Africa, large parts of the rural population do not have formal right to the land where they live and grow their food. They risk losing their livelihoods if formal landowners allow biofuel development on the land.
- Biofuel production can cause food prices to increase, which can increase poverty.
- Biofuel production uses water and can put stress on already limited water resources.
- Biofuel production can cause soil degradation and soil eroision.
- Biofuel development mainly brings profit to foreign companies (Oxfam, 2012).
- The promise of biofuel production as a driver for change might not hold, as in the case in Tanzania where virtually all companies that engaged in biofuel production since 2005 have either gone bankrupt or left, all employees laid off and the community unable to access the now idle land (van Teeffelen, 2013).
- There is a risk that biofuel development actually causes higher greenhouse gas emissions, if agriculture moves into previously forested areas.

Those who stress the opportunities with biofuel development bring up the following issues:

- *Energy security:* Availability of energy is the fundamental for intensifying agriculture, industrial development and pro-poor growth. Locally produced liquid biofuel could lead to national and local benefits such as reduced pressure on forests for woodfuel, reduced dependency oil imports and limited exposure to volatile international prices. Locally produced bioenergy can provide energy for local agriculture, industrial and household uses (UN-Energy, 2007).
- *Employment:* Adoption of clean energy technologies contributes among other things to creation of industries (large, as well as small and medium size enterprises) with conse-

quent job creation and promotes rural development. Thus clean energy plays a significant role in economic growth, security of supply, employment and well-being (Actionaid, 2008).

- *Income opportunity for farmers*: To farmers, biomass for biofuel is just another cash crop, no different in principle from other cash crops. It is an opportunity to diversify and get another cash income (SCC, 2008). Also, if biofuel production causes food prices to rise, those farmers who have a net export of products from their farm will get better paid for their products. So called outgrower contracts is another opportunity of income, in which farmers grow crops under contract to large-scale enterprises in exchange for various price guarantees, inputs, and services, e.g. free seeds and training (German et al., 2011).

- *Investment in infrastructure:* Investments in biofuel can also bring about investment in general infrastructure such as roads, which give wider benefit to communities and local business (SCC, 2008).

- *Investments in agriculture*: The introduction of modern agricultural practices due to biofuel production can have an overall positive effect on agriculture and have positive impact on food production.

There is a potential that biofuels can contribute to development in the Sub-Saharan countries. Some of the greatest gains are likely when traditional biomass practices are integrated into bioenergy schemes in ways that both support local farmers and produce ethanol or biodiesel for local consumption and regional sale (Engström, 2009).

Sustainability criteria covering a wide range of issues are by many actors seen as a meaningful way forward. The Roundtable for Sustainable Biofuels, which is a multi-stakeholder organisation, has listed 12 principles, which they consider necessary to ensure sustainable production of biofuels (RSB, 2010). The principles, under which detailed critera are specified, are:

1. Legality: Biofuel operations shall follow all applicable laws and regulations.

2. Planning, Monitoring and Continuous Improvement: Sustainable biofuel operations shall be planned, implemented, and continuously improved through an open, transparent, and consultative impact assessment and management process and an economic viability analysis.

3. Greenhouse Gas Emissions: Biofuels shall contribute to climate change mitigation by significantly reducing lifecycle GHG emissions as compared to fossil fuels.

4. Human and Labor Rights: Biofuel operations shall not violate human rights or labor rights, and shall promote decent work and the well-being of workers.

5. Rural and Social Development. In regions of poverty, biofuel operations shall contribute to the social and economic development of local, rural and indigenous people and communities.

6. Local Food Security: Biofuel operations shall ensure the human right to adequate food and improve food security in food insecure regions.

7. Conservation: Biofuel operations shall avoid negative impacts on biodiversity, ecosystems, and conservation values.

8. Soil: Biofuel operations shall implement practices that seek to reverse soil degradation and/or maintain soil health.

9. Water: Biofuel operations shall maintain or enhance the quality and quantity of surface and ground water resources, and respect prior formal or customary water rights.

10. Air: Air pollution from biofuel operations shall be minimized along the supply chain.

11. Use of Technology, Inputs, and Management of Waste: The use of technologies in biofuel operations shall seek to maximize production efficiency and social and environmental performance, and minimize the risk of damages to the environment and people.

12. Land Rights: Biofuel operations shall respect land rights and land use rights.

Modern biofuels in relation to current bioenergy use

Wood fuel is the largest energy source in Africa. Wood fuel consumption is a major contributor to total wood removal, and contributes to greenhouse gas emissions. Wood fuel use is therefore a major local and global environmental issue in Africa, and should be fully integrated into forestry planning and environmental protection processes (Amous, 1999).

Charcoal is a dominant energy source for urban households. Charcoal is generally unsustainably harvested from woodlands within quite long distances of urban markets. Rapid urbanisation, poverty and high population growth rates are driving the growth in the use of charcoal in urban cities and periurban areas. This leads to a gradual degradation of forest resources. Therefore the traditional production of charcoal puts significant pressure on the environment (VENRO et al., 2009).

More efficient charcoal production, innovative fuel switch programmes, and market development of efficient charcoal stoves are some of the toolkits for addressing the environmental pressure stemming from charcoal production and use. Sustainable bioenergy production – whether in the form of modern energy carriers such as transport fuels or electricity, or in traditional energy forms such as fuel wood and their more efficient use – can reduce energy poverty, contribute to rural development and avoid the negative impacts (health, deforestation, time etc.) of the current energy system.

6 CONCLUSIONS

The mapping of biofuel policies, current and planned production, scientific publications and R&D actors shows that there is an increasing activity in SSA countires on biofuels. The activities differ in respect to countries, scales, sources of raw materials (feedstock) and so forth. Even though the identified operational plants produce ethanol, many companies plan to produce biodiesel and much of the research is targeted towards biodiesel.

However, the accesilibility of information is troublesome which makes it difficult to draw accurate conclusions. Some production companies do not have a homepage or the homepage is not updated.

South Africa sticks out among the SSA countries; there are many planned production facilities as well as a great deal of scientific publications and the information is available on many homepages. University of Stellenbosch is one of the largest producers of scientific papers on biofuels in SSA with a broad variety of research topics.

It seems that SSA holds a large potential for biofuel and biofuel raw material production, and that there will be substantial development in the coming years. However, biofuel schemes need to be integrated with activities to safeguard food security and environmental performance should result in job creation.

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