

BIOETHANOL IN AFRICA: THE CASE FOR TECHNOLOGY TRANSFER AND SOUTH-SOUTH CO-OPERATION

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Abbreviations

AfDB	African Development Bank
BNDES	Brazilian Development Bank
BRICS	Brazil, Russia, India, China and South Africa
EMBRAPA	Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuária)
FDI	Foreign direct investment
GHG	Greenhouse gas
IBSA	India-Brazil-South Africa
IRENA	International Renewable Energy Agency
IPEA	Brazilian Institute for Applied Economic Research (Instituto de Pesquisa Econômica Aplicada)
IPP	Independent power producer
LCR	Local content requirement
m ³	Cubic metre
ODI	Overseas Development Institute
R&D	Research and development
SME	Small and medium-sized enterprise
USD	US dollar

EXECUTIVE SUMMARY

Sustainable biofuels have an important role to play in Africa's development. When biofuels such as biodiesel and bioethanol are produced and used in a sustainable way, they provide massive economic and environmental benefits. These include, for example, job creation, modern energy access, reduced pollution and climate change mitigation. They also provide a buffer against vulnerability to volatile fossil fuel prices. A solution of this kind can promote rural development by increasing the income of small farmers and improving agricultural productivity.

Why sugarcane bioethanol in Africa?

Sugarcane bioethanol is currently the most cost-effective commercial biofuel and has the highest energy balance of all commercial bioethanol. The sugarcane bioethanol production and delivery system consists of several components. These include sugarcane production, sugar processing, conversion of raw sugar to bioethanol and related by-products, research, distribution, technical and financial support services, and commercialisation and exportation (see Figure ES1). All these elements have great potential to increase the involvement of local small and medium enterprises (SMEs), brighten job prospects and growth opportunities, and improve market stability, diversity and business capabilities.

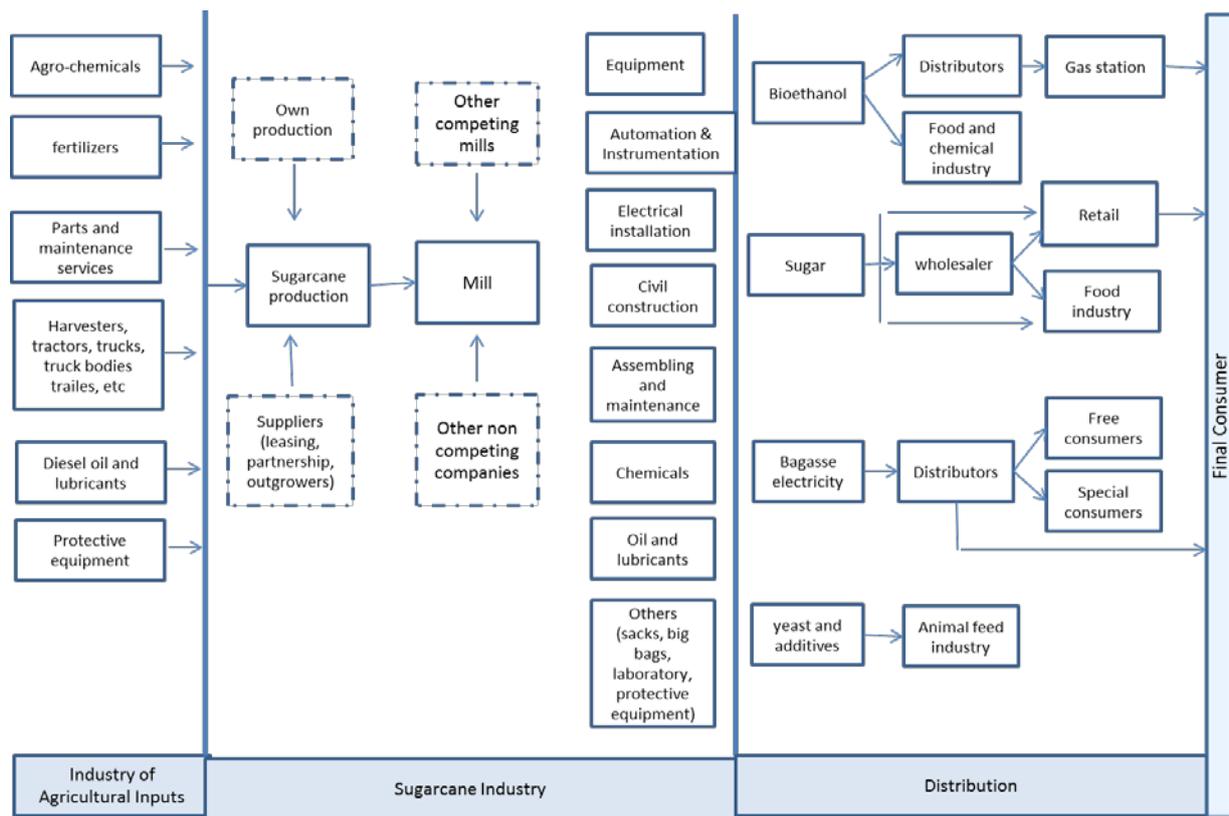
Sugarcane bioethanol production is particularly appealing to the African continent for several reasons:

- Large quantities of sugarcane available as feedstock for bioethanol production;
- Significant potential for agricultural expansion, given land-usage rates below 25% in at least 11 African countries;
- An opportunity to scale up sugar production, which is crucial for some African economies;
- Well established industries in some countries, offering opportunities to introduce bioethanol to both domestic and export markets.

The sugarcane bioethanol industry offers numerous advantages. These include increasing crop yield rates for sugarcane, small rural farmer integration into the supply chain, cogeneration opportunities using bagasse, and bioethanol use as a cooking fuel displacing traditional fuels. In addition, sugarcane bioethanol production technologies are mature and well proven compared to other feedstock options and can thus offer a real economic opportunity for many African countries.

Although the sugar and bioethanol industries are mature, opportunities are available to innovate in process optimisation and improve productivity through the efficient use of resources, including energy. At the same time, there are challenges relating to land tenure and use, food security, agricultural practices and productivity, environmental risks, infrastructure, institutional policies and fuel quality and standards for international trade. This paper presents an overview of the concerns affecting sugarcane bioethanol production in Africa and provides recommendations for resolving them.

Sugarcane bioethanol network map



(Source: Neves, 2011 and Brazilian Sugarcane Industry Association – União da Indústria de Cana-de-Açúcar, 2010)

Technology transfer to grow the industry for sugarcane bioethanol in Africa

The right policies and regulatory framework are critical to promoting the adoption of new technologies and processes taking local conditions into account. A supportive policy framework can encourage private and public investment, create a clear niche for enterprise and promote the transfer of required knowledge. Governments can also take steps to improve local capabilities and through international co-operation support bioethanol technology deployment.

However, the international transfer and adoption of technologies or new processes actually takes place at the business level. The private sector needs to be engaged in the adoption of bioethanol technologies, improve the feedstock supply chain through better logistics and existing sugarcane mills, improve practices and technologies in the agricultural and industrial phases, and promote more enterprise. Successful entrepreneurship depends on the private sector's understanding of investment opportunities in bioethanol production and of the multiple channels enabling technology adoption, such as trade, market formation, joint ventures and licensing.

Technology transfer enables the know-how and technology of technology providers to be acquired and adopted by the technology users. Technology transfer incorporates the concepts of technology dissemination within various sectors across the economy. In addition, it integrates the institutional empowerment at the national level to enhance policies that facilitate technology adoption.

For biofuels, technology transfer consists of three facets of knowledge before a market can be consolidated. These are the organisation of the feedstock supply in terms of agricultural best practices and logistics, industry equipment, services and maintenance, and market standards, incentives and targets.

The case for South-South co-operation: Potential between Brazil and Africa

Effective South-South co-operation is increasingly recognised as a tool for technology transfer. South-South co-operation refers to the exchanges of resources, technology and knowledge between developing and emerging economies. It is an important element of international co-operation, offering practical opportunities for economies in transition and developing countries to deploy low-carbon technologies, which could sustain the predicted economic boom in the continent. A good number of countries in the global South (especially South Africa, India, China and Brazil) have experienced the challenges of low-carbon technology adoption. They have worked out solutions to overcoming its challenges while growing their technical capacities.

With over 40 years of experience in bioethanol industry and market development, Brazil is a potential source of expertise across the entire bioethanol production chain. To date, Brazil is the largest bioethanol producer in the global South and the second largest in the world, having been the world's largest bioethanol exporter. Brazil thus has great potential to build capacity in African countries producing sugarcane to improve their knowledge of biofuels. This will contribute to the development of a local and sustainable biofuels industry that brings economic and environmental benefits to the African continent. Some people are concerned about whether the Brazilian experience complements the social, economic and political context in Africa. A careful assessment of African conditions and development needs is thus essential to understand and build an appropriate framework for deploying a sugarcane bioethanol industry.

There is substantial scope between Brazil and Africa for transfer of know-how, technology and for capacity-building in bioethanol. This paper identifies several realistic areas for collaboration and technology transfer between Brazil and African countries. They are outlined below:

- Improving institutional and technical capacities by supporting the design of a suitable policy framework, providing training in mapping and zoning, feasibility studies or increasing awareness.
- Engaging the private sector by strengthening research capacities, supporting the development of the supply chain or promoting opportunities for local content, among several options.
- Supporting market in key issues like distribution logistics or bioethanol quality.

1 INTRODUCTION TO TECHNOLOGY ADOPTION IN DEVELOPING COUNTRIES

The instruments and mechanisms supporting the effective adoption of technology are unique in a particular industry. They depend on the maturity of the technology, the drivers and motivation of the technology provider and the characteristics and market opportunities of the technology recipient. The design of technology adoption mechanisms also relies on the recipient country's institutional ability to promote technology diffusion and fund or attract investment for new industry or market segment development. All these factors will define the instruments, scale and breadth of the policies and incentives to be adopted, and the capacity-building and educational needs. Research and development (R&D) also plays a key role in improving knowledge and skills and expanding a country's absorptive capacity. It is thus of great relevance to technology adoption.

International co-operation is critical to encouraging the adoption and sustainable deployment of renewable energy technologies in developing countries. Emerging geopolitical configurations like the economies of Brazil, Russia, India, China and South Africa (BRICS) and new development assistance dynamics offer new pathways and opportunities for the sustainable diffusion of renewable energy technologies. South-South and triangular co-operation are building blocks in this process, through which economies in transition collaborate with developing countries, and developing countries work with mature economies.

This paper showcases South-South co-operation between Brazil and African countries to enable technology transfer and adoption related to sugarcane bioethanol production in Africa. It covers topics.

- **Chapter 2** focuses on the key factors and drivers underpinning the systematic development and implementation of the sugarcane bioethanol industry in Africa. It discusses the availability of resources for bioethanol production, and the opportunities, barriers and socioeconomic benefits of deploying a supply chain and industry for the purposes of such production. It also examines the national coherent policy framework required for market certainty and industrial development, as well as the engagement needed with the private sector. Finally, it suggests that Africa offers potential for sugarcane bioethanol industry innovation.
- **Chapter 3** concentrates on technology transfer allowing Africa to acquire bioethanol technology. It presents mechanisms for transferring technology and describes South-South co-operation in more detail. This chapter draws attention to the potential for strengthening collaboration among countries in the global South¹ to transfer and adopt technology as required for sugarcane bioethanol industry deployment.
- **Chapter 4** provides an overview of South-South co-operation specifically applied between Brazil and Africa in relation to sugarcane bioethanol. It concentrates on the Brazilian experience of establishing a dominant bioethanol supply chain, industry and market, and of co-operating on technical disciplines in the global South. This chapter identifies more than 20 potential areas for co-operation for transferring sugarcane bioethanol production technology and know-how from Brazil to Africa. They cover the private companies and technology providers as well as governmental institutions.

¹ Definition available at http://ssc.undp.org/content/dam/ssc/documents/exhibition_triangular/SSCEXPoster1.pdf

- Finally, **Chapter 5** summarises this publication's key findings. Policy makers in the global South can turn to this chapter for takeaway messages to reinforce sugarcane bioethanol adoption and to transfer the technology and knowledge required either as provider or recipient.

IRENA's mandate is to promote the widespread adoption and sustainable use of all forms of renewable energy in the pursuit of sustainable development, energy access and security, and low-carbon economic growth. Bioenergy is one form of renewable energy offering enormous potential as we move towards a sustainable energy future.

At the same time, IRENA serves its member countries as the principal platform for international co-operation on renewable energy. Several countries have thus sought assistance from IRENA to help shape their bioethanol production potential into a technology transfer and adoption framework that can help them fulfil this potential. In response to this request, IRENA presents this comprehensive and cross-disciplinary publication to support South-South co-operation for technology transfer from Brazil to Africa. Its aim is to help communicate information more broadly about technologies and experience of stimulating the sugarcane bioethanol industry.

2 SUGARCANE BIOETHANOL IN AFRICA

This chapter considers bioethanol industry development and adoption in Africa, and covers a number of areas. They relate to bioethanol industry development, local market opportunities, bioethanol production potential and challenges, institutional and technological capabilities, and the main sectors that could foster this new activity under African conditions. The sections that follow aim to explain these issues and bring clarity to the needs, drivers and scope of sugarcane bioethanol adoption in Africa.

2.1 Why bioethanol for Africa?

A number of studies,² such as the 2013 African Economic Outlook (United Nations, Economic Commission for Africa, 2013),³ point to impressive economic growth in sub-Saharan Africa. The potential for even more dramatic economic growth is yet to be fulfilled and could significantly reduce poverty across the continent. This growth will need to be driven by a structural transformation that depends on the right conditions for harnessing the continent's natural resources in a prudent way. New and effective mechanisms for improved clean technology deployment are required to realise the potential of these energy resources for Africa's economic growth. Africa has massive resources in all forms of renewable energy but limited access to modern energy forms and services. The continent shows huge potential for deploying low-carbon technologies for its long-term economic growth and social development.

The widespread and sustainable use of all forms of renewable energy resources for power generation, heating and transportation applications opens up a range of low-carbon economic growth opportunities. These result in job creation, access to modern energy services, reduced pollution, and climate change mitigation. Sustainable biofuels thus have a big role to play in Africa's development. Biofuels like biodiesel and bioethanol provide enormous economic and environmental benefits when produced and used in a sustainable way. They can reduce greenhouse gas (GHG) emissions while defending against vulnerability to volatile fossil fuel prices. They promote rural development by increasing the income of small farmers and improving agricultural productivity. This is a particularly interesting option for Africa given the huge potential arising from its bioenergy resources, low-cost labour and large agricultural sector. This is especially evident in the case of bioethanol production linked to the optimisation of the sugar value chain. Indeed, ethanol based on sugarcane is an ideal bioethanol product for Africa.

Africa has enormous biofuels potential but has not yet been able to unlock it for the purpose of economic development. Biofuels can only develop in a sustainable way once well-designed policies promoting sound market formation and certainty have been introduced. Moreover, debate continues on the role of biofuels in the global economy, especially in Africa. This is concerned with rising fossil fuel prices, climate change impacts, environmental pollution and the risk of conflict between food and energy needs (Elbehri *et al.*, 2013; Partners for Euro-African Green Energy, 2013, among others). The balance between energy, food security and land must therefore also be addressed.

² See, for example: www.imf.org/external/pubs/ft/reo/2012/afr/eng/sreo1012.pdf; www.economist.com/news/special-report/21572377-african-lives-have-already-greatly-improved-over-past-decade-says-oliver-august; www.forbes.com/2010/08/12/asia-china-africa-trade-growth-markets-economy-investment.html; http://www.mckinsey.com/insights/economic_studies/whats_driving_africas_growth; www.guardian.co.uk/global-development/2013/apr/17/imf-africa-economic-growth-surgings.

³ See www.africaneconomicoutlook.org/en/.

Although there have been a limited number of successful cases in recent years, biofuels in Africa have so far largely failed due to negative perceptions and market failures. These have been exacerbated by a lack of coherent policies, a minimal regulatory framework, and limited infrastructure and market formation. Biofuels are viewed with considerable uncertainty and attract little investment or promotion of research and innovation. Investor confidence in the sector is poor (see, for example, Jolly, 2012).

Several African countries have biofuel policies waiting for projects to unfold. Others have mandated biofuel blending targets but without the appropriate policy and regulatory structures to support such mandates. In November 2012, the African Union and the Conference of Energy Ministers of Africa endorsed the Africa Bioenergy Policy Framework and Guidelines. These had been prepared by the United Nations Economic Commission for Africa in support of the African Union Commission and the New Partnership for Africa's Development.⁴ They aim to assist African countries developing national policies and regulations for sustainable bioenergy.⁵

Bioethanol resource availability and potential in Africa

Several different crops are suited to biofuels production under African agro-climatic conditions. Biomass feedstock such as cassava, corn, sorghum, sugarcane and wheat are used to produce bioethanol,⁶ which is an ethanol fuel substitute or blender. Animal fats and vegetable oils such as palm oil, jatropha seed oil and groundnut oil are utilised for biodiesel production, a diesel substitution or blending fuel. However, the use of sugarcane and molasses for bioethanol production, and the use of jatropha for straight vegetable oil production for biodiesel, attract the most interest.

Jatropha has attracted attention because cultivation of this crop is believed to be feasible on marginal land – *i.e.* not currently used by farmers – with the potential to pay big dividends. The possibility of including smallholder farmers in the supply chain, meanwhile, suggests the crop could generate income and reduce poverty.

Sugarcane has attracted interest for two reasons. Firstly, it has well-known technology potential for bioethanol production. In addition, the well-established sugar industry could bring its learning and accumulated management experience to bioethanol production using its market penetration.

Sugarcane bioethanol is currently the most cost-effective commercial biofuel. It has the best energy balance of all commercial bioethanol feedstocks. This means it has the highest ratio of energy produced when burning bioethanol relative to the energy required in the ethanol production process. Sugarcane ethanol has an average energy balance of around 8:2, reaching 10:2 in the best cases (Coelho *et al.*, 2013). It is categorised by the US Environment Protection Agency as an 'advanced biofuel' (*i.e.* a biofuel that lowers GHG emissions by more than 50% in comparison to gasoline).⁷

⁴ The New Partnership for Africa's Development is a technical body of the African Union <http://www.nepad.org/>.

⁵ See Resolution AU/CEMA/MIN/Res. (II) at <http://www.eu-africa-infrastructure-tf.net/attachments/CEMA/resolution-on-africa-bioenergy-policy.pdf>.

⁶ 'Bioethanol' in this paper refers to ethanol used as fuel. Most ethanol produced in Africa has been for industrial and beverage use and most is aimed at the export market.

⁷ The Environment Protection Agency calculations indicate that, with a 30-year payback for indirect land use change emissions, Brazilian sugarcane bioethanol reduces GHG emissions by 61% in comparison to gasoline. The Environment Protection Agency obliges US fuel

Other potential biofuel feedstock crops include sweet sorghum and cassava for bioethanol, and croton and palm oil for biodiesel. Sweet sorghum could be used as a complementary feedstock to the existing sugar-based biofuels industry.⁸ Cassava is already produced in large quantities in some countries, such as Nigeria. However, the rapidly growing interest in biofuels across the African continent means basic research is still needed. Such research should investigate suitable crops under alternative conditions and identify best management practices and logistics in order to evaluate the opportunity costs of the feedstock and biofuel in the market. One example is a project conducted by the oil company Petromoc in Mozambique, where the production of biodiesel reached approximately 1 million litres, mainly based on coconut oil. Production ceased in 2011 due to competition in the market for fresh coconuts.

Arable land requirements in small countries

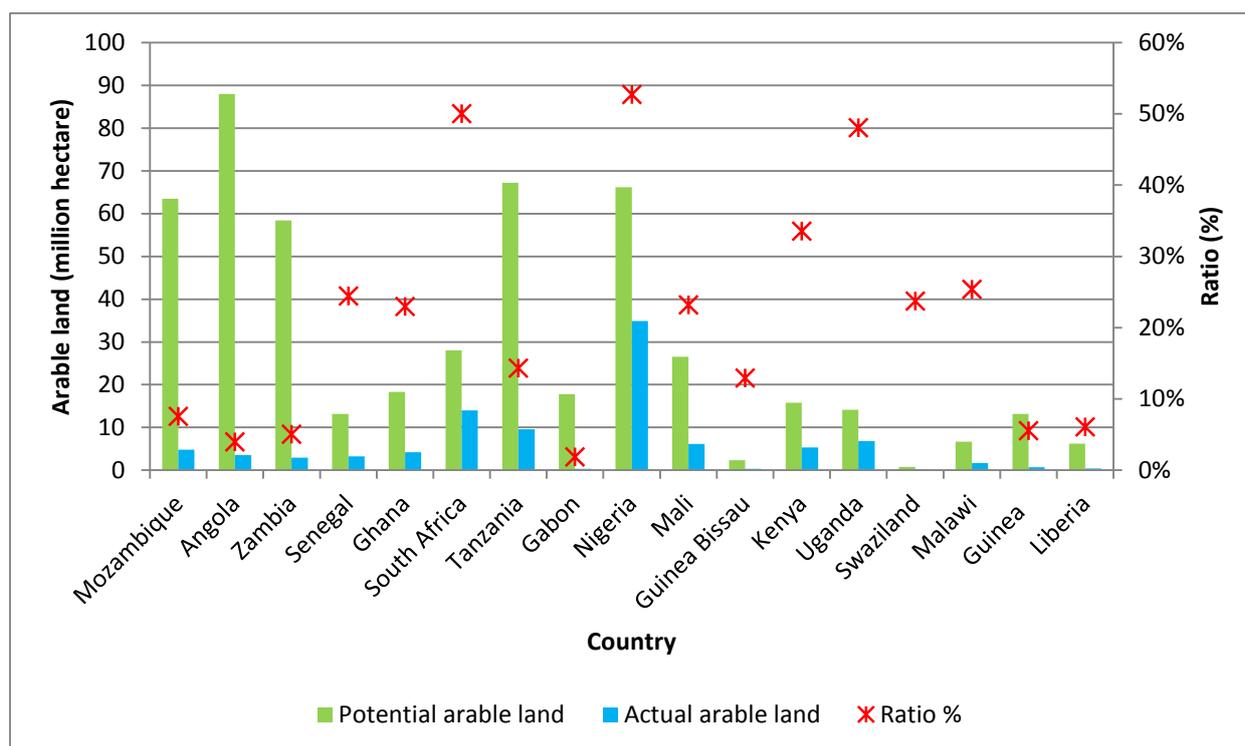
About 10,000 hectares for bioethanol production in two countries, Swaziland and Malawi, would represent 5% and 0.6% respectively of actual arable land. This fact helps assess whether bioethanol production is appropriate for small countries such as these. This actual arable land amounts to 1.2% and 0.1% of potential arable land. Both countries have sugarcane plantations of 52,000 and 23,000 hectares, corresponding to 27% and 1.3% of actual arable land respectively. They are among the lowest-cost sugar producers in the world. Assuming land requirement is not really a major concern for these small countries, producing sugarcane at a lower cost could give them some advantages if they produce bioethanol.

Figure 1 displays the actual arable land used in 17 countries against the potential arable land in sub-Saharan Africa in 2012. As the figure makes clear, 11 of the 17 countries analysed have a land use rate below 25%. This means there is significant potential for agricultural expansion. The 15,000 hectares of sugarcane used for bioethanol production in Mozambique represents 0.3% of the actual arable land in that country.

companies to use a percentage of advanced biofuel in a blend with gasoline. (<http://www.reuters.com/article/2012/09/20/us-ethanol-brazil-exports-idUSBRE88J14J20120920>).

⁸ Sweet sorghum is not suitable for refined sugar production. However, as with sugarcane, the fermentable sugars which can be extracted from sweet sorghum can be directly converted to ethanol. For more information see Swayze (2010).

Figure 1. Ratio between actual arable land and potential arable land in sub-Saharan Africa



(Source: UN Food and Agriculture Organization-Terrastat, consulted in August 2012)

Benefits across the sugarcane bioethanol value chain in Africa

The sugarcane bioethanol sector can be divided into three parts: the agricultural inputs industry; the sugar and bioethanol industry; and distribution services (Figure 2). Production in mills depends on the sugarcane supply as feedstock and the capital assets.

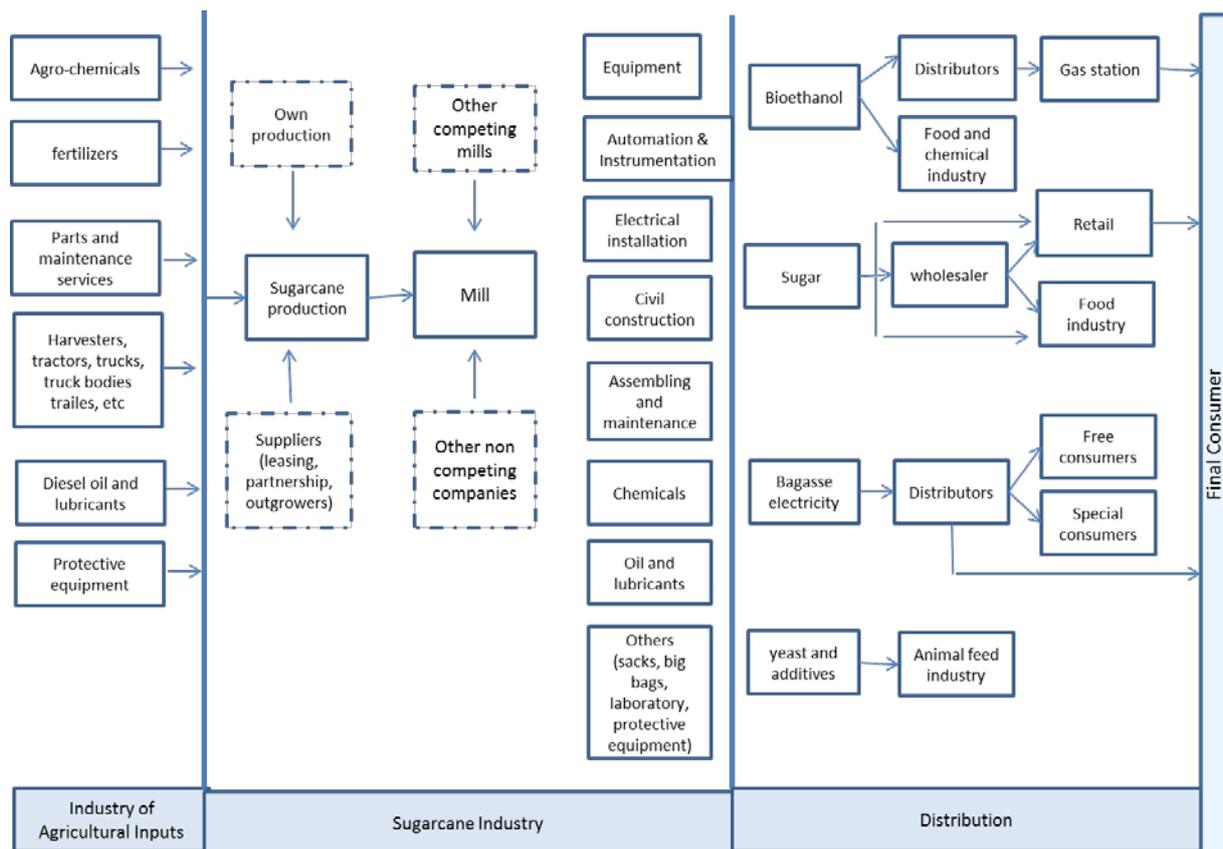
The products – bioethanol, sugar and electricity, but also fodder and chemicals – are sold to the fuel and electricity distribution companies, food industry, wholesalers, retailers and exporters. By-products are destined for use by other industries and include vinasse and cake filter which are reutilised as biofertilisers.

Biorefineries

These facilities are dedicated to the optimal use of biomass and its different components by converting them into power, fuels, materials and chemicals while maximising output. Biorefineries represent opportunities to new markets for commodity and speciality products in which production makes a low impact to the environment (Paper and Fibre Research Institute, 2012).

Africa has the potential to become a hub for biorefinery (World Economic Forum, 2010). There are a number of plans, such as the Blume Biorefinery plant in South Africa. This plant is expected to produce 19 million litres of bioethanol per year in its first stage. Its ultimate target is 160 million litres in addition to high-value agricultural products. Such outputs will have multiple applications, such as clean fuel for cooking, refrigeration or pharmaceutical products. It will power its operations with an integrated electrical cogeneration plant (Blume, 2015).

Figure 2. Sugarcane bioethanol network map



(Source: Neves (2011) and Brazilian Sugarcane Industry Association, 2010)

Developing the feedstock supply includes sugarcane harvesting and delivery. In Africa, this involves burning, cutting, loading, in-field transportation, transloading, road transportation, offloading and feeding to the mill (Watson and Purchase, 2012). Mechanisation can improve productivity and reduce costs, which is often desirable from an environmental point of view. Since manual labour offers economic advantages in the African context, mechanisation has to be evaluated according to the policy goals of the country, stage of the industry and market targets. Nevertheless, if irrigation infrastructure and mechanised harvesting are provided by the collaborating industry, the involvement of outgrowers or block farms may be feasible, as is common in Tanzania (Bauner *et al.*, 2012, p. 394).

Sugar mill operation includes the crushing season, capacity utilisation, sugar and fibre content in cane, mill extraction, boiling-house recovery, molasses and sucrose recovery, sucrose losses, sugar yield, and steam and power consumption. In Africa, as well as across different regions of the world, the overall efficiency of the sugar mill varies from the quality of cane received to the production of sugar.

The sugarcane bioethanol business thus contains several links: sugarcane production, sugar processing, bioethanol and by-products, research, distribution, technical and financial support services, commercialisation and exportation (Neves, 2011). All these links offer opportunities to increase the participation of local SMEs and increase job prospects. Understanding the sugarcane bioethanol agribusiness and the typical networks involved across the supply chain can help governments define their strategies. These need to maximise benefits to the local economy, promote the provision of goods and services by local entrepreneurs and encourage local employment and training.

The promotion of a bioethanol sector can provide entrepreneurs and local communities with more opportunities for business growth, improve entrepreneurial skills and create more stable and diverse markets. As the market for a certain technology or product assimilates into a country's development strategies, governments may wish to maximise the benefits of the emerging industry by promoting local entrepreneurship, which increases financial gains. The purpose of local content is thus to enrich the benefits of investment by fostering a local manufacturing sector and creating jobs.

Several countries have used local content requirement (LCR) to facilitate the creation of a local manufacturing industry. A consistent policy framework should be built to co-ordinate national strategies for industrial development. These strategies may incorporate support mechanisms in the context of local content. This can be understood as locally manufactured goods which comply with established standards for local services or works, financial reassurance, guarantees of market longevity and intelligent subsidies with limited lifespans. Sometimes LCRs can be included in wider government policies for promoting sustainable economic empowerment. Some countries require project developers to get involved in socioeconomic and/or enterprise development, and to promote skills development transfer targeted at local communities as part of their requests for increased local content procurement.

Policy options for local content requirement

The extent to which LCRs distort competition and affect trade depends on the way they are designed. Policies laid out in broad terms (such as stipulating a certain percentage or value of investment to be sourced locally) may offer more flexibility to investors. This contrasts with LCRs that are very specific and detail the components and parts to be sourced locally. The percentage of LCRs will also matter, of course. LCRs can influence a firm's ability or inability to optimise its supply chain. This depends on the size and attractiveness of the domestic market and the availability of local suppliers who can manufacture the required equipment and components. In many cases foreign firms will establish domestic manufacturing facilities in response to LCRs (Sugathan and Mani, 2012). However, this depends on whether the market is sufficiently great to ensure long-term prospects for new facilities.

The potential for bioethanol to promote sustainable economic empowerment and development can be realised through several options, for example:

- promoting outgrower schemes and enhancing agricultural practices; including smallholders in the downstream supply chain as suppliers of logistics, transport, brokerage or maintenance services, or using them for the production or delivery of goods such as fertilisers, parts of equipment, agrochemicals or tractors;
- requiring joint ownership and/or considering a limit on the extent of foreign ownership.

These are just few examples in a wide range of options. Their application should be evaluated in a way that does not put off potential investment by foreign companies.

2.2 Opportunities for strategic development of the sugarcane bioethanol industry

The opportunities for bioethanol production on the African continent relate to three factors. Feedstock availability is the first, accompanied by the opportunity to expand sugar production (essential in some African countries). Finally, the existence of well-established industries in some countries provides the opportunity to set up a bioethanol industry. Opportunities are available in both domestic and export markets.

The domestic market for bioethanol is attractive in many cases. This is firstly because fuel prices are high, and demand for fuel in African countries is growing rapidly. Secondly, bioethanol replaces lead, which is harmful. According to REmap 2030 (IRENA, 2015), the demand for transport fuels of Ethiopia, Kenya, Nigeria and South Africa alone will amount to more than 4,100 petajoules by 2030.⁹ Experience has illustrated the economic and social value of displacing imported oil for fuel, especially since very few countries have refineries and have to import costly refined petroleum products (Bauner *et al.*, 2012).

The sugar industry offers a good starting point for bioethanol production in Africa although the strategies and challenges behind each industry differ from each other. Annex I in this paper contains detailed information on the sugar industry market and status. The opportunity costs of producing bioethanol will depend on several factors.

First, a country with net sugar exports increasing its production for the regional/international market may find bioethanol production a strategic diversification option for sugar producers. Increased sugar production means a greater amount of molasses can be diverted to bioethanol production. As the bioethanol supply chain is consolidated, the use of sugarcane juice for bioethanol production can bring operational and economic advantages. Second, bioethanol production may not be a priority for countries whose main goal is to meet internal sugar needs (such as Uganda and the United Republic of Tanzania). Indeed this will depend on the opportunity cost of final molasses in the sugarcane industry.¹⁰ Third, the competitiveness of bioethanol in both cases will depend on policy goals as well as feedstock availability and production costs. These in turn centre around land availability, agricultural productivity, labour costs and infrastructure.

In general, the existing sugar industry is already dealing with efficiency improvements for the sugar market¹¹ as well as considering expanding bioethanol production. This will depend on sugar prices and markets as well as policy and financial incentives for bioethanol. Some steps still need to be taken to modernise and consolidate the industry to make bioethanol production profitable in Africa. However, the technologies for bioethanol production from sugarcane as opposed to other feedstocks are mature and well proven. They thus offer a real economic opportunity for many African countries.

Large-scale production has been the biggest concern affecting biofuel production in Africa. However, the continent has some advantages in terms of bioethanol production from sugarcane. First, sugarcane industries are already in place in most African countries, and bioethanol can be produced from existing molasses production. Second, the expansion of sugarcane planting areas can also result in more sugar

⁹ Excluding hydrogen and electricity and in the reference case.

¹⁰ However, depending on the scale, it is unlikely that final molasses offer a better return than bioethanol for a country importing oil.

¹¹ Some countries are clustering smallholders or establishing recovery programmes for improving sugarcane yields. The aim is to improve efficiency, reduce the costs of sugar production and achieve better access to international preferential markets. The industry is already integrating smallholders into the supply chain more efficiently and looking to improve operations, and this is considered a leapfrog step in the sustainable production of bioethanol.

production. This reduces the conflict between food and fuel, and helps the African continent to be self-sufficient in sugar. The Brazilian experience shows that sugar production increased at the same time as the sugarcane planting area. The majority of the Brazilian mills (65%) opted to have mill/distilleries with the ability to produce sugar and bioethanol (limited to a 40%-60% mix due to operational and economic interdependencies). This operational flexibility helps to stabilise the supply of sugarcane and reduces the risk of market volatility.

Other advantages of this large-scale approach include the following:

- Typically, sugarcane yields per unit of area are higher in large-scale plantations. As a consequence, their land footprint is smaller. In many cases, large-scale plantations contribute to the upgrade of regional roads, schools, hospitals and other infrastructure.
- Demand for agricultural inputs, such as fertilisers, machines and services, will increase as a result of increased dynamics in the agricultural markets. These will reduce the vulnerability of small farmers and improve the way that they produce food, thus increasing food security.
- Smallholders can be integrated into the feedstock supply chain for national/regional or international markets, thus enhancing rural economies. A number of bioethanol projects in Africa are planned, and some of these intend to include smallholders (also referred to as outgrowers) in the feedstock supply chain. The mills can support the outgrowers to help them access agricultural inputs and financial credit and loans as well as receive training and assistance in technical and logistical aspects of feedstock production.
- Bagasse cogeneration can help diversify energy supply and improve access to energy in rural areas. In most African sugar-producing countries, bagasse is only employed to meet the steam and power requirements of sugar mills. By contrast, factories with significant sugarcane production have great potential for selling surplus electricity to the grid or in some cases to nearby industries. In addition, the supply of continuous electricity from biomass can complement the intermittent or seasonal supply of hydropower or other renewables.
- When used as a cooking fuel to replace charcoal and wood use in urban and rural areas, bioethanol can be an attractive market. However, its viability will depend on its competitiveness with other ethanol markets or rival fuels.

Cooking fuel

Around 698 million people use traditional biomass fuels in Africa (POET, 2015). This figure represents a market for ethanol as a household cooking fuel estimated in 28,025 million litres per year. The estimated figures relating to the 24 million people in Africa using kerosene and 73.8 million using liquid petroleum gas are more moderate. These figures could amount to 964 million and 2,965 million litres of ethanol required per year, respectively, to meet the energy demand of household cooking fuel. Ethanol cooking gel has reached a price of 1.15 US dollars (USD) per litre in Nigeria (Green Energy Biofuels, 2014). This makes it cost-competitive against kerosene, whose current prices fluctuate around USD 1-1.55 per litre. Larger production could diminish the costs of this biofuel even further. It would then reach economies of scale and be competitive for applications other than cooking, such as vehicle fuel.

The international market has until now been the main focus for future biofuels deployment in Africa. It is also expected to become attractive because demand for bioethanol may increase since the US and EU may not be able to produce all the biofuel needed to meet their blending mandates. This could work out as a significant opportunity for African exporters, especially in the EU bioethanol market where duty-free access is available to most countries in Africa under preferential trade agreements. Sudan and Zimbabwe are examples of countries which emphasised the export market and became the main producers of bioethanol in Africa. However, both countries faced constraints due to lack of demand (see Annex VIII). Better understanding is needed of the drivers behind the opportunities and barriers affecting market access for bioethanol. This will help this emerging industry consolidate and bring larger benefits to the local economy and population.

Controversy exists over whether African countries should prioritise domestic markets or exports. In order to reduce production costs, large-scale bioethanol production is required for the international market. On the other hand, concentrating on domestic markets can reduce risk relating to price volatility and lack of external demand. If oil prices were high, the domestic market would also improve energy security in countries with high oil dependency. Some therefore argue that an incremental approach is more appropriate in most African countries. The first step is to aim for domestic markets, taking advantage of existing sugar industries, low-cost molasses for bioethanol production and the possibility of blending anhydrous bioethanol with gasoline. The next step could be a large-scale campaign for regional and international export once production conditions had improved (Rosillo-Calle *et al.*, 2012).

However, large or small-scale options are a policy choice based on a country's resources, characteristics, land potential and economic framework. Outgrowers can also be included in the agricultural component of the supply chain even if the industrial component is large-scale. Mozambique is an example of this type of large-scale approach, which is explained by a combination of the country's port facilities and a climate favouring sugarcane production. As a result, Mozambique expanded sugarcane production both to increase sugar output and promote large-scale bioethanol production for exports but also to pursue a blending mandate by 2015. This biofuel policy strikes a balance between attracting international finance for plantations and supporting smallholders. It allows them to increase agricultural productivity and thus participate and benefit from biofuels development. However, a small-scale bioethanol approach sometimes make more sense in smaller countries due to limited agricultural areas and economic diversity.

Various African countries have already designed or are in the process of designing biofuels policies. Some are trying to stimulate the creation of projects capable of leveraging the continent's competitive advantage in biofuel production. To a great extent, these policies were created as a response to European trends towards compulsory fuel blends also adopted in other developed economies. Other drivers including, for example, climate change, energy security, economic growth, poverty alleviation and the promise of rural employment have also encouraged biofuel strategies. However, people have raised concerns about land grab and food security, generating a great deal of discussion about the role of biofuels in Africa.

Some countries have recently established mandatory blending. This is expected to have a positive impact on the bioethanol industry, which is likely to expand in coming years. Biodiesel production on the African continent has faced some difficulties, and production capacity is unclear. However, some progress on bioethanol is under way.

2.3 Challenges affecting sugarcane bioethanol production expansion

Resolving the following concerns could stimulate rural development and agriculture and help transform the agricultural sector:

Land tenure and land use

Land tenure in Africa is complex, and ownership patterns vary from country to country. Most countries have a dual system for land tenure. This includes both the 'modern' *i.e* market-oriented system and a 'traditional' land tenure system in which local chiefs or elders are involved in land allocation. The two parallel systems are sometimes in conflict, especially in terms of international investment. Alternatively, they operate in an uneasy truce (Bauner *et al.*, 2012). This causes uncertainty among investors and sometimes obstructs investment plans as well as weakening the ability of the local community to properly negotiate long-term leases.

Recommendation: land laws need to be reinforced to protect local people and ensure security of land ownership while also promoting the transparent allocation of land for biofuels. Meanwhile, investors can promote sugarcane intercropping with food crops to lower the possible impacts of biofuel production.

Food security

In some African countries, governments prevented biofuels deployment due to concerns about food security. However, such restraints could reduce job opportunities in rural areas and limit the income of farmers in areas often affected by poverty (Mitchell, 2010).

Recommendation: food security can be directly resolved by increasing investment in public assets, crop-breeding research and infrastructure for more intensive food production at lower costs (Mitchell, 2010). Keeping import tariffs at a moderate level can facilitate food crop imports from neighbouring countries or markets should domestic production be reduced as a result of droughts or other factors.

Agricultural practices and productivity

The participation of outgrowers in feedstock production is viewed as a way to reduce poverty but low agricultural yields and poor agronomic practices can harm biofuels development by increasing production costs. Sugarcane harvesting and delivery can be costly. Improving the co-ordination and logistics of sugarcane, including transport rationalisation, can significantly reduce production costs.

Recommendation: integrated governmental support for smallholders will be needed to promote SMEs and restructure smallholder farmer financing. It needs to fund research into improved varieties with higher yields and resistance to pests and disease, soil and climatic adaptability, planting materials and appropriate planting procedures and harvesting methods. Improvements in the logistics of feedstock distribution by clustering smallholders may also be necessary to enhance economies of scale. Agro-ecological practices for more sustainable feedstock supply can increase the cost-efficient use of the resource. Examples of such practices include conservation tillage, seed system implementation, institutional research or extension programmes.

Environmental risks

The main environmental impacts of biofuel production relate to water consumption, water pollution, soil impacts and air pollution from some harvesting practices. Compared to many other commodity crops, pesticide use in biofuel cultivation is relatively low, and chemical application is mainly restricted to herbicides. Sugarcane cultivation requires considerable amounts of water even in areas where sugarcane

is not irrigated (Mapako, 2012). Water rights and allocation schemes in Africa are complex due to seasonal variation and there are disputes over the size of flows needed to preserve specific environmental measurements. An investor might therefore be given formal rights to use water that does not really exist in the quality or quantity needed (Bauner *et al.*, 2012).

Recommendation: environmental impact assessments are important to any decisions on biofuel projects but numerous options could be available to diminish adverse environmental impacts. One example is a more cautious project implementation plan. High conservation areas should not only be identified but carefully preserved. This can be achieved by ensuring that options are available to compensate for or reduce biodiversity loss (Maltitz and Stafford, 2011).

Infrastructure

Insufficient infrastructure commonly obstructs production and project development in Africa. This includes roads, water, fertiliser, agriculture extension services, technology development, distribution networks and market access. Once infrastructure is developed to support biofuel projects, it can also benefit other agricultural production. This can result in a win-win for both biofuels and agriculture, which will ultimately attract more investments in rural areas (Maltitz and Stafford, 2011).

Recommendation: truck transport costs are higher and port access more difficult in some countries than others. A local and national biofuel market, rather than an export market, can offer much greater economic incentives (Bauner *et al.*, 2012), which can solve infrastructure problems in the short term.

National policies and institutional capacity

Few African countries or regions have the necessary enabling environment to promote biofuel markets and/or exports. In many cases there are no laws or regulation mechanisms to protect local rights or harmonise agricultural legislation with land use and biofuel or energy policies. Similarly, the public sector lacks institutional capacity to develop effective policies while the private sector lacks the capacity to identify opportunities and implement projects.

Recommendation: strong policy instruments and government commitments, as well as relevant stakeholder communication, provide the necessary environment for biofuels development. These will guide the appropriate/necessary interventions and provide clarity for increasing private sector investment in technology development and infrastructure.

Financial incentives for ethanol production will allow the national market to move towards an economically sustainable level. Independent power producers (IPPs) also need regulatory frameworks and incentives if they are to exploit the opportunities offered by bagasse cogeneration.

International trade, fuel quality and standards

International trade in fuel ethanol is still at an early stage, and significant trade barriers have prevented the growth of this potential commodity. Global trade is affected by the absence of clear biofuels codes and classification within the harmonised system for commodities, and there is not enough clarity as to whether biofuels are industrial or agricultural goods. In addition, a number of countries, such as Japan and the US, as well as the EU, protect their domestic industry through import tariffs and subsidies to local sugar producers. The difficulties raised by certification and sustainability are another point. However, too rigorous or inappropriate requirements for the conditions of developing countries could constrain their ability to produce bioethanol (Rosillo-Calle *et al.*, 2012, p. 247).

The specification and quality of biofuels differ between producers, and efforts are under way to harmonise standards and facilitate international trade in biofuels. More information about biofuel standards can be found in Annex VII.

Recommendation: countries producing bioethanol need time to successfully develop and implement specific production processes and go through a learning curve. Discussion is needed on the adequate targets and timetables allowing developed countries to fulfil these criteria (Coelho *et al.*, 2013).

Potential African exporting countries have to consider adapting existing fuel national standards wherever appropriate. They need to create suitable frameworks to deal with international standards, evaluate trade implications and take the appropriate steps for harmonisation.

In conclusion, a regulatory framework enables domestic bioethanol market creation by putting the appropriate policy infrastructure, governance and economic incentives in place. Any government policy that ensures or encourages growth in market demand, market access and expected price will also encourage capital investment (Sugathan and Mani, 2012). Financial and credit policy guarantees, improved legal protection for joint ventures and adequate contractual assurance for project stakeholders also reduces the perception of risk and stimulate private sector technology transfer. In addition, an enabling regulatory framework also supports capacity-building.

Incentives and/or support for education and training in bioethanol and the power sector, as well as by collaborative R&D, achieve this aim. One example is research on improvements to sugarcane varieties. The objectives are to build competence and human capital, as well as to facilitate technology diffusion. They can be met through bilateral/trilateral technical co-operation agreements, training and education abroad, knowledge-sharing and lesson learning. Strengthening national research institutions and creating an environment for supporting university research consortia and public-private R&D partnerships will also help expand local knowledge along the bioethanol value chain.

2.4 Policies favourable to sugarcane bioethanol production

Sugarcane cultivation and bioethanol production are mature technologies, and the scope for technology adoption is related to **lessons learned** and **transfer of know-how**. This will allow policy makers in Africa to identify the right policies, incentives and market conditions to build the environment attracting investment and promoting further adoption and diffusion of bioethanol production technologies. The actual technology is therefore important, but it is only one aspect of technology adoption.

The main role of governments in adopting a new 'mature' technology in the market is to design appropriate policies. These need to help enhance existing industrial activities and in this way raise the level of capabilities to increase competitiveness or foster new industrial activity that would otherwise not be pursued (Byrne *et al.*, 2012, p.127-128). The **implementation of the right policies and regulatory framework** is essential to providing the right environment for the adoption of a new technology/process. It needs to attract investment, encourage private and public investment, create a clear niche for SMEs and promote the transfer of know-how needed by the private sector at the business level. This helps them adapt the technology, procedures and products to local conditions. Annex VI displays a detailed framework for promoting a bioethanol industry.

Governments should also contribute to **improving local capabilities**. Ancillary policies for building adequate skilled and trained personnel, improving R&D capacity and promoting local knowledge are required to develop a robust bioethanol industry and increase the potential for technology adoption. A country's absorptive capacity can be improved through policies for creating a national or regional innovation system. These include policies for property rights, licensing contracts and royalties. Such policies would encourage both R&D and knowledge transfer from academia and public research institutions to local firms.

National governments can use **international co-operation** to provide effective support for enabling bioethanol technology adoption activities through appropriate mechanisms. Examples include co-operative research agreements, technical co-operation agreements, co-production agreements, education, training and capacity-building directed towards the public and private sector. Knowledge institutions must be incentivised, and their co-operation in R&D with international partners must be reinforced, while training abroad and research co-operation must be promoted. This fosters the 'soft' component of local capacity and narrows the technological gap between foreign and local firms.

Policy and production status

Biofuels policies have been discussed in seven African countries (Angola, Ethiopia, Mali, Mozambique, South Africa, Uganda and Zambia), and mandatory blending requirements have been introduced in Ethiopia, Mozambique and Zambia. Other countries, like Kenya and Malawi, have implemented a blending mandate but no formal biofuels policy. Sudan and Zimbabwe provide an interesting case study since neither had a formal biofuels policy nor blending mandate despite being major bioethanol producers in Africa. Both countries have mainly targeted the export market, but they experienced a lack of demand in 2012. This shows the potentially important role played by a mandatory blending framework in consolidating the bioethanol industry. Annex VIII describes the main issues and initiatives related to bioethanol production in those countries.

2.5 Private sector engagement

Government policies can provide the most important framework for the introduction of a new technology or product in the marketplace. Sharing knowledge at the international level is a fundamental component of capacity-building in local institutions, agencies, potential investors and the local private sector skills needed for governments map out strategies, design and implement an effective plan. However, the international transfer and adoption of technologies or new processes actually takes place at the business level. Several types of technology adoption activities affect **private sector engagement and development**. These include improving and increasing the capacity of farms and outgrowers for feedstock management alongside the logistics of existing sugarcane mills to build a better feedstock supply chain. They include the introduction of better practices and technologies in the agricultural and industrial phase, as well as in the local private sector, to promote the creation of SMEs where possible.

In the private sector, an understanding of the opportunity to invest in bioethanol production by existing mills in Africa can form the basis for domestic entrepreneurship and international collaboration. At this level, technology is adopted through a number of channels such as trade, investment, joint ventures and licences. However, technology adoption and knowledge absorption are often subject to the overall macroeconomic and governance environment.

This influences the willingness of entrepreneurs to take risks in new technologies or processes and the cultivation of advanced skills and literacy needed to implement and adapt the new technology or process. Beyond trade, foreign direct investment (FDI) can be an important way to adopt technology (Sugathan and Mani, 2012).

The conditions for successful partnerships and technology integration through private sector relationships include strengthening collaborative mechanisms, minimising transaction costs and nurturing trust and credibility in joint ventures and public-private partnerships (IRENA, 2013b).

2.6 Bioethanol innovation requirements: research, technology development and market formation

Some institutions across the African continent have already been conducting research into a wide range of aspects of sugarcane production. Most of these research programmes are financed by the planting community or the sugarcane industry in different ways. The Cane Research Institutes in Mauritius and South Africa are active in providing varieties and 'fuzz' (seeds) to African countries or private companies under special contracts. This involves royalty payments when varieties achieve commercial status. Breeding and selection programmes can also be found in Kenya, Egypt, Morocco, Sudan and Zimbabwe (Ramdoyal *et al.*, 2012).

These breeding programmes and development of African varieties mainly aim to raise sucrose content, which increases sugar production per hectare. Research should also be considered into a wide range of concerns in the industry. Examples include yield, pest and disease, and resistance to drought and frost. The profitability of bioenergy from sugarcane could equal that of sugar if research in this area was improved and increased, and if international/regional research co-operation were promoted.

Cane yield varies widely depending on geographical location, husbandry, soil fertility, water availability and irrigation. Many African countries cultivate old varieties, particularly those countries with no breeding programmes. This practice has a direct impact on productivity. The potential to increase productivity in African countries through improved varieties or genetic improvements is therefore excellent (Ramdoyal *et al.*, 2012). Improving agronomic practices is also important, especially when existing small farmers are included in the supply chain and milling companies control the provision of these services to outgrowers. This is commonplace across Africa.

Given the maturity of the sugar-making process, opportunities for novel technology developments are limited, and some African sugar producers lack sufficient financial capacity to invest in new technologies. However, there is potential to innovate in process optimisation, particularly in relation to productivity improvements. This can be achieved through efficient energy and resources use, the design of equipment (Seebaluck and Sobhanbabu, 2012) and application of vinasse for 'ferti-irrigation.'

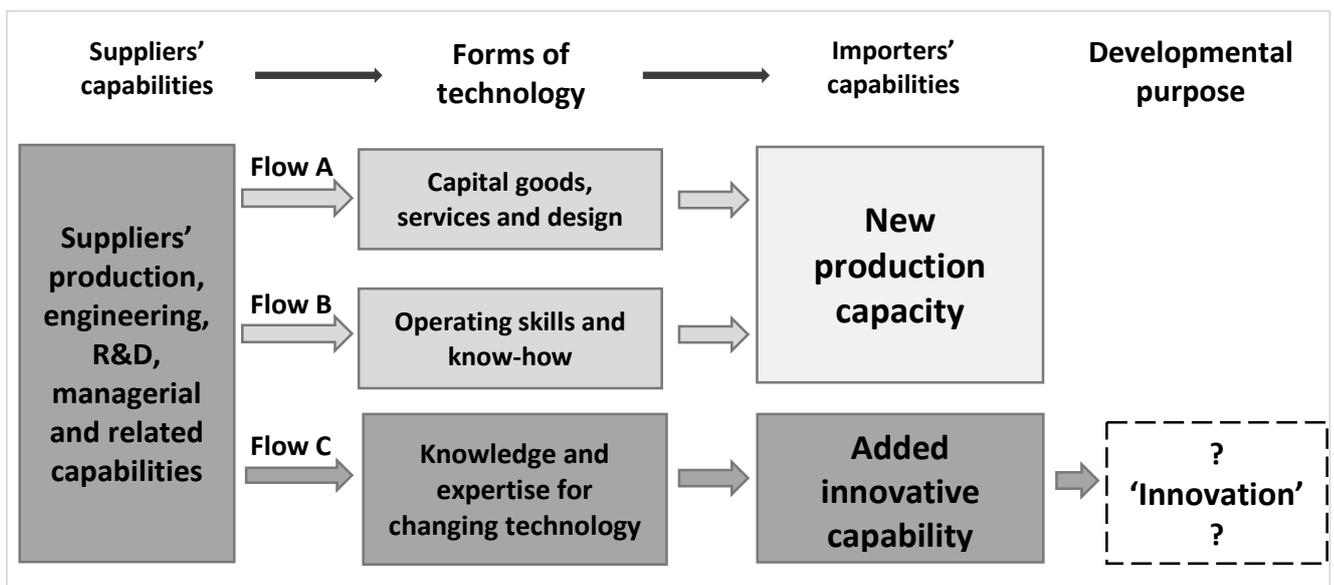
Bagasse cogeneration offers the possibility of selling electricity surplus to the grid by installing high-efficiency cogeneration systems. This technology is conventional in the power industry worldwide. The basic knowledge is related to: (a) optimising the fibre content of bagasse through breeding programmes (b) the efficiency of the sugar and bioethanol production processing unit because more efficient technologies tend to be less energy-intensive (c) the efficiency of thermal energy conversion to electricity and steam generation, and power plant operation, which is also affected by grid connection and electricity market operation.

3 SUGARCANE BIOETHANOL TECHNOLOGY TRANSFER AND ACQUISITION IN AFRICA

Technology transfer is defined in various ways depending on how the technology is used and in what context. It can be defined as the movement of resources, innovative technical equipment, novel technology, procedures and specific skills from the technology providers' setting to technology users or recipients to accelerate technology penetration (Mansfield, 1975).

Bell (2012) has described the content of technology transfer at the level of firms, as well as the capabilities required, as shown in Figure 3. Here, Flow A refers to the hardware, as well as the managerial and engineering services needed to implement technology transfer. Flow B consists of operational procedures, equipment information and training required to run and maintain such hardware. Flows A and B contribute to improving the firm's and economy's production capacity. However, these flows do not necessarily contribute to developing the skills required to create new technologies. Flow C represents the elements improving the skills for creating new technology, or business ability to identify the added value of new information and integrate it into their commercial operations. This includes the absorptive capacity to adopt and adapt new technologies – referred to as the 'software' (Byrne *et al.*, 2012).

Figure 3. Content of technology transfer and capabilities required



(Source: Bell, 2012)

Biofuels technology transfer consists of three types of knowledge before a consolidated market can be achieved. These include the organisation of **feedstock supply** (agriculture, best practices, logistics), **industry** (equipment, services, maintenance) and **market** (standards, incentives, targets). This needs to be recognised to implement an innovative process and ensure efficient technology transfer. From the viewpoint of the innovation chain, bioethanol production is already a mature commercial technology. Technology transfer is therefore focused on improving and adapting the technology, and building a regulatory environment.

This usually involves the transfer of know-how for the following purposes:

- a) Policies and economic incentives for creating the market.
- b) Improving feedstock production and management, and better logistical practices for supply. This includes technologies for harvesting, transporting, storing and processing, as well as R&D for improving feedstock varieties and soil conditions.
- c) Better practices and technologies for industrial processes, including training to enhance local expertise for the development, deployment and diffusion of these technologies in future.
- d) Improvement of institutional arrangements to allow better market access for the bioethanol, sugar or electricity produced.
- e) Business models or financing structures, and the creation of capacity and knowledge for project design, installation, system integration and maintenance.
- f) Wider understanding of the potential impacts of the entire bioethanol supply chain on society and the environment.

In the **African context**, an enabling environment is critical to increase awareness and improve access to technical and commercial information. It also creates a supportive complementary organisational and policy context for attracting investment in new technologies or procedures, and develops domestic capacities to assimilate and adapt the knowledge transferred. In this way, it promotes the much-needed market pull for technology implementation.

Most African countries lack the institutional capacity for better understanding technology and market opportunities, including the availability of finances. Political instability accentuates this problem in some countries. However, once countries take responsibility for increasing governance and leadership, and reducing political instability, strategic bilateral and multilateral technological co-operation may follow. This can help promote technology transfer and build the capacity needed at the institutional level. Bioethanol production involves many stakeholders from diverse sectors and is a complex programme with many facets, so its successful implementation is accompanied by wide range of considerations. This includes awareness and capacity-building among political and administrative leaders as well as education and training for a broad spectrum of stakeholders. Examples include government departments, farmers, participants in the agricultural and electricity sectors, funding and financial institutions, the sugarcane industry and related industries like petroleum, automobile, industry associations and R&D institutions.

Policy makers in Africa need to be aware that governments and the private sector play different roles in domestic technology transfer as well as in international co-operation and international technology transfer. They should also be aware that particular industries or industrial segments are affected by technology transfer in their own way. This also depends on technology maturity and market demand. Market demand is the main driver for bioethanol because the technology is already mature. Once that demand is created, the private sector plays a critical role in promoting and diffusing bioethanol technology to African countries. Strategic alliances between national governments in Africa and countries that own the appropriate bioethanol technology knowledge and skills are an important way to communicate information and provide technical exchange. They help build capacity on the institutional side as well as in the bioethanol agro-industry by using and adapting existing technologies and procedures, thus lowering start-up costs.

Governments in Africa should also be able to evaluate the possibilities and constraints of promoting local content in the bioethanol supply chain. Much attention is given to the inclusion of small-scale farmers, who offer natural advantages in the African context, but opportunities are also available to include small-scale contractors in the downstream supply chain. SMEs can be encouraged to participate in other areas of the supply chain such as services, transportation and marketing. Another possibility is equipment manufacturing. However, the capability to recognise business opportunities along the supply chain needs to be built alongside the capability to adapt technologies and procedures according to local conditions. Improving such local capacities requires time and appropriate policies.

Experience shows the relationship between the steps needed to develop a sustainable bioethanol industry and the drivers for technology transfer can be understood in the African context. Table 1 shows some of the best practices identified.

Table 1. Considerations underlying best practice encouraging bioethanol technology transfer

Government considerations for encouraging bioethanol technology transfer	
Empowerment of institutional capacity	<ul style="list-style-type: none"> • Potential of different feedstock options in the country and their competitiveness. • Current opportunity for sugarcane bioethanol in the country or region. • Technical solutions adopted during the agricultural and industrial phase of bioethanol/sugar production for reducing environment impacts. • Bioethanol production competitiveness for domestic and export market (regional, international). • Incentives promoting the bioethanol production (<i>e.g.</i> tax breaks, blending mandates). • Land use footprint for bioethanol production to meet (1) domestic market (2) international market, and the potential land for industry expansion at the national level. • Planning tools like agro-ecological zoning, mapping and zoning, which address capacity-building. • Environmental planning. • Local water management issues and potential. • Policies and regulatory framework for promoting the bioethanol industry. • Viable options for local content and potential policies increasing local skills and employment and enhancing benefits for local people. • Education, training and capacity-building needs of farms, local entrepreneurs, petrol companies, financial institutions and the wide range of stakeholders involved in the bioethanol sector. • Policies to include bagasse cogeneration in IPP projects, access to the grid and level of tariffs.

Private sector considerations for engaging in bioethanol technology transfer	
Increase farm, outgrower, local private sector and existing sugarcane mill awareness, absorptive capacity and general capabilities	<ul style="list-style-type: none"> Technologies and best management in agriculture and logistics taking African conditions into account. Opportunity for including smallholders/outgrowers in the feedstock supply chain and contracting schemes. Sugarcane logistics improvement, including transport rationalisation and outgrower clusters. Contracts/schemes for supplying feedstock between outgrowers and mills, and security of feedstock. Credit access and finance mechanisms for bioethanol; finance availability to small farmers and industry. Integration of new distilleries with traditional sugar mills. Assessment of bioethanol from sugarcane competitiveness and markets in African context. Better industrial processes, practices and technologies.
Support research: breeding, genetics, physiology and biotechnology/collaborative research	<ul style="list-style-type: none"> Improving varieties of sugarcane – multipurpose varieties for bioethanol, sugar and electricity. Improving soil conditions.
Increase capacity	<ul style="list-style-type: none"> Finance sector to understand feedstock procurement risk and mechanisms for risk mitigation. Capacity-building and training for engineering, business modelling, project design, installation, system integration, operation and maintenance.

Bioethanol technology transfer stakeholder considerations for establishing a market and commercialising products	
Institutional support	<ul style="list-style-type: none"> Support the creation of regulatory body for monitoring bioethanol/fuel market, quality and standards. Help identify the best operational models for blending bioethanol with gasoline and for distribution. Mechanisms for price parity between hydrous bioethanol and gasoline (if hydrous bioethanol is on the agenda).
Capacity-building	<ul style="list-style-type: none"> Monitoring quality and standards of bioethanol to the final consumer (national or international). Blending anhydrous bioethanol with gasoline. Logistics of bioethanol distribution to final consumers.

Table 2. Technology transfer mechanisms for knowledge flow and bilateral trade

	Mechanisms	Characteristics
Group 1 (public sector)	Publications	Open literature (such as papers and articles, academic books, scientific magazines and journals) and trade literature to transmit and share knowledge.
	Exchange of professional experiences	Personnel mobility programmes, field visits and professional migration.
	Public and open events	Forums, symposiums, seminars, lectures and conferences.
Group 2 (private sector)	Services and goods trade	Purchase of knowledge and technology unavailable in the country of the acquirer.
	FDI	International route for international technical know-how, technological product or technology transfer via spin-off enterprises or joint ventures.
	Licensing agreements	Contractual/legal criteria for the use of technological goods and intellectual property rights, such as trademarks, patents or copyrights.
	Grants and co-operative agreements	Contracts for collaboration between institutions of a different type, (e.g. universities, private and public research entities or non-governmental agencies) and collaborative R&D initiatives.
Group 3 (knowledge-specific)	Sharing knowledge/building competence	Sharing lessons and comprehensive capacity-building to promote technology diffusion, institutional empowerment and capacity, including human capacity development (training, education etc.); private development, public-private partnership incentives; business technological capability expansion; government, institutional and financial sector capacity-building to remove barriers to market development; industry association support; robust intellectual property protection; encouragement of collaborative research to reinforce R&D institutes in recipient countries.

Source: Groups 1 and 2 are from Rogers *et al.* (2001); Urama *et al.* (2012); Group 3 was devised by IRENA

3.1 Technology transfer strategies

A sample of technology transfer mechanisms is presented in Table 2. These illustrate knowledge flows and schemes amongst countries and between technology providers and users. The mechanisms in Groups 1 and 2 have influenced technology transfer and innovation between the global North and South in recent years and still function as traditional technology transfer mechanisms between businesses.

Technology transfer is not only about the acquisition of know-how and technology between technology providers and technology users at the level of the firm. In addition, technology transfer incorporates technology diffusion within sectors and the whole economy, as well as the institutional empowerment required at the national level to enhance policies facilitating technology transfer (Group 3). Technology transfer thus also integrates learning on technology replication and use, capacity improvement to adapt technology to local conditions, and the nexus between firms and the institutional context of policies, laws and regulations. At the business level, this broad technology transfer perspective represents a wide range of steps for improving the capability of a recipient company or organisation. This includes the capability for technology acquisition as well as the assimilation of skills and the capacity for technology absorption. This means technology transfer also includes the acquisition of technical proficiency in using imported technology and applying such skills to create and develop more technology.

Technology can be transferred internationally through a number of channels. FDI is the principal mode of technology transfer. It often involves international joint venture partnerships, with the foreign firm making an international direct investment in the partnership coupled with a domestic investment by a local firm. FDI is a particularly common strategic choice in service industries because of the importance of face-to-face contact for service exchanges. Companies often also enter into international licensing agreements. This can work in stand-alone mode allowing the company to enter and serve a foreign market (Brewer and Falke, 2012). Another option is the turnkey project, which is undertaken by a developer until it is ready to start operation. At that point, the project is sold to a buyer

The size of a market in a particular country, the skills of its labour force and the existence of competitors may also determine the mode of transfer. Larger markets may induce a business to transfer the technology within its own organisation instead of licensing. In such cases, the firm may choose to internalise the technology and prefer greenfield investments, mergers and acquisitions, joint ventures and franchising (United Nations Economic Commission for Africa, 2010). Smaller markets may not be sufficiently attractive to induce technology owners to invest abroad. In such cases, the local private sector may be willing to invest and purchase a technology from abroad or obtain a licence. Usually, buyers receive the knowledge needed to operate and maintain technology from the technology provider. Alternatively, the local government or international co-operation agency furnishes them with the knowledge needed to operate the technology adequately.

3.2 The case for South-South co-operation

South-South co-operation describes the exchange of knowledge, resources and technology between developing economies. An important element of international collaboration, it offers workable opportunities for countries with economies in transition pursuing sustainable development and economic growth either through individual or joint efforts (UN Development Programme, 2012). Thus, South-South co-operation provides a framework for collaboration and shared learning for development in various subject areas and sectors between countries of the global South. South-South co-operation relations are often characterised by inclusive and horizontal partnerships and networks based on equity, trust and mutual learning.

Countries with similar challenges can share similar solutions, building on their common development pathways. This is the rationale for such development co-operation. It means countries that have already devised solutions can share their expertise and lessons. Due to similarities in history, political and socioeconomic challenges, the countries of the South can share common concerns and build partnerships. These can promote innovation beneficial to achieving common solutions for poverty reduction, industrial development and economic growth. Such co-operation enables trade and investment flows for mutual economic and political benefit between the countries involved. The concept of South-South co-operation includes the government-driven model of collaboration between countries of the South. It also connects up with the various stakeholders in the private sector, universities, civil society and R&D centres. South-South co-operation can be bilateral or trilateral.¹² Trilateral programmes are increasingly viewed as an effective new approach for delivering OECD country development assistance.

On 12 September 1978 in Buenos Aires, Argentina, the UN Conference on Technical Co-operation among Developing Countries adopted the Buenos Aires Plan of Action.¹³ Although South-South co-operation had been taking place before then through bilateral arrangements, the Buenos Aires Plan of Action marked its formal beginning. Ever since, the UN has continued to endorse the importance of South-South co-operation as a key mechanism for development (UN, 2012; UN Conference on Trade and Development, 2012). In a communication highlighting the UN Day for South-South Co-operation on 12 September 2012, UN Secretary General Ban Ki-Moon said: “The countries of the South are building new models of development co-operation that emphasise mutual benefit and solidarity as well as cost-effectiveness.”¹⁴

Since 2009, countries of the global South have reinforced economic agreements and political bonds, resulting into greater integration. In recent years, the background and outlook of South-South co-operation has altered with the emergence of a new global economic balance and geopolitics including the G20, BRICS and India-Brazil-South Africa (IBSA) country groups. The African Union’s drive for regional integration in Africa supporting intra-continental trade¹⁵ and African economic structural transformation will offer an increasing role for South-South co-operation between African countries themselves. This will be supported by increasing co-operation with the existing regional economic commissions in Africa.

However, the potential for maximising the benefits of South-South co-operation – such as raising capacity, institutional network promotion and the exchange of technological solutions – is still unfulfilled. Enhancing resources like new support mechanisms or innovative funding, as well as improving co-ordination, is thus considered essential. It will amplify positive results and establish partnerships to encompass economic and social challenges at the local, regional and global level.

¹² Trilateral or triangular co-operation typically consists of a tripartite partnership consisting of a northern provider of financial/or technical assistance, a southern provider of technical assistance and a southern recipient country.

¹³ <http://ssc.undp.org/content/dam/ssc/documents/Key%20Policy%20Documents/Buenos%20Aires%20Plan%20of%20Action.pdf>;

¹⁴ http://ssc.undp.org/content/ssc/news/articles/2012/marking_south-south_co-operation_un_officials_call_for.html;

¹⁵ See <http://ti.au.int/en/sites/default/files/Decision%20-%20English.pdf>.

4 SOUTH-SOUTH CO-OPERATION BETWEEN BRAZIL AND AFRICA

South-South and triangular co-operation to deploy low-carbon technologies for Africa's sustainable development is key to ensuring that the predicted economic growth will actually materialise and be maintained in the long term. A good number of countries in the global South (especially the BRICS group) have been through the difficulties and development pathways of most African countries. They have created solutions to some of their development challenges as well as the technical capacity to grow.

The problems confronted by Brazil in the past are similar to those currently affecting countries in the South. This means the solutions collected in the innovative Brazilian policies could help other developing countries. What is more, Brazil is considered a favourable co-operation partner due to its cultural and socioeconomic affinities with the South. The next section discusses Brazilian experiences in bioethanol industry development, as well as in South-South co-operation.

4.1 Brazil's bioethanol technology experience

With more than 40 years of experience in the development of the bioethanol industry and market, Brazil has the opportunity to be a source of expertise across the entire bioethanol production chain. Brazil offers valuable lessons on developing a biofuels market in a developing country. The lessons learned after almost 40 years' experience of bioethanol industry, and a biodiesel programme of around a decade, show that strong government involvement is needed. This brings a new energy source to the point where the industry consolidates, and costs reduce along the supply chain.

To date, Brazil is the largest bioethanol producer in the global South and the second in the world, having been the world's largest exporter of bioethanol.¹⁶ Before reaching this position, bioethanol production in Brazil had been forged by incrementally building institutional capacity and infrastructure in the agro-industry to address environmental impact. The institutional capacity and infrastructure show an exemplary path of progressive increases in productivity accompanied by environmental initiatives to recycle water or reduce its consumption, for example (Brazilian Development Bank – BNDES, 2008). Brazil's biofuels experience dates back around four decades and was driven mainly by the oil crises experienced during the 1970s and 1980s. Renewable energy policies and strategies ensued to reduce dependence on imported fossil fuels.

The Brazilian ethanol industry began in the 1930s. However, national policies for promoting the use and production of fuel ethanol were only introduced in 1975 as a response to the international oil crisis. At that time, the Brazilian government's main motivation in launching its National Alcohol Programme (Pro-Alcool) centred around the country's dependency on oil importation as reflected in the national balance of payments. The programme set a blending mandate for mixing anhydrous bioethanol in gasoline consumed and introduced economic incentives to the agro-industry in the form of low interest rates. This resulted in sugarcane production growth, new distilleries and the expansion and modernisation of existing sugar mills to produce bioethanol. The programme also enabled government control on the sales and distribution of ethanol within the national territory.

¹⁶ See, for example, <http://www.americasquarterly.org/content/rise-ethanol-brazil>; <http://www.nature.com/news/growth-of-ethanol-fuel-stalls-in-brazil-1.11900>.

After the second oil crisis (1979), there were also efforts to introduce hydrous ethanol by providing a stimulus for cars powered by hydrous bioethanol.¹⁷ Several incentives were provided to guarantee price parity between bioethanol and sugar and to guarantee a final price for end-consumers compared to gasoline prices (hydrous ethanol reached 64.5% of the gasoline price¹⁸). These were enough to guarantee the competitiveness of hydrous bioethanol. As a result, hydrous alcohol powered 80% of vehicles manufactured in Brazil by 1980.

Co-ordination between farmers, sugarcane mills, financiers and the automobile industry was critical to overcoming technical scepticism about large-scale anhydrous ethanol blending in gasoline and vehicles driven by pure hydrous bioethanol (Goldemberg, 2008). The initial blend of anhydrous bioethanol and gasoline was 12% by volume. Later, this increased to 18% and then to 20%-25%. Demand for bioethanol grew rapidly. However, bioethanol production became unattractive after 1987, and Pro-Alcool entered a stagnation phase due to deficiencies in public resources to subsidise the programme. This resulted in shortages in ethanol supply, and a shift toward sugar exports. At the same time, this undermined the confidence of bioethanol consumers in Brazil, leading to a reduction in sales of vehicles powered with hydrous ethanol. This fell from 85% of new car sales in 1985 to 11.4% in 1990.

At the beginning of the 1990s, the national government took administrative measures. In 1991-1999, the sugarcane bioethanol sector experienced a transition towards free market pricing, incremental subsidy cessation and reduced governmental intervention in bioethanol price fixing. Once direct subsidies for anhydrous and hydrous bioethanol production had stopped, a differential tax on hydrous bioethanol and bioethanol-powered vehicles was introduced.

The aim was to maintain parity between hydrous bioethanol and gasoline. However, bioethanol is traded freely between producers and distributors so this parity also depends on market conditions and sugar prices, particularly in international markets. Other indirect measures also incentivised bioethanol use. Table 3 presents an overview of the incentives adopted along the Brazilian journey to a bioethanol market.

¹⁷The National Research Centre for Aviation and Space researched alloys which avoid hydrous bioethanol corrosion of fuel tanks and engines powered with gasoline.

¹⁸ Bioethanol has a higher octane number than gasoline although it has 67% of the energy content of gasoline per unit of volume. Bioethanol can therefore be used in engines which have higher compression ratios (12:1) than those used with gasoline (typically 8:1). This means engines containing bioethanol are 15% more efficient, which can balance the lower energy content of bioethanol. For every kilometre driven, 20% more bioethanol would be required than gasoline (Goldemberg, 2008).

Table 3. Incentives promoting the bioethanol market

Pro-Alcool programme incentives	Other incentives
Mandatory blend of gasoline with anhydrous bioethanol (progressively increased to 25%)	Mandatory blend of gasoline with anhydrous bioethanol and government definition of the content of anhydrous bioethanol in gasoline (20%-25%)
Hydrous bioethanol price guarantee (maximum 65% of gasoline)	Tax reduction on hydrous bioethanol; 1%-13% for state tax and 95% for federal tax (Contribution for Intervention in Economic Domain) ¹⁹
Competitive prices guaranteed to bioethanol producers, even when international sugar prices were more attractive (competition subsidy)	Tax reduction (maximum 7%) for flex-fuel vehicles and hydrous bioethanol-powered vehicles
Tax reduction of 5% on hydrous bioethanol-powered vehicles	Indirect measures
Subsidised loans for bioethanol producers to improve production capacity	A requirement that all government entities purchase 100% hydrous bioethanol-fuelled vehicles
Mandatory sales of bioethanol at fuel stations	R&D programmes for bioethanol development
Price and supply guarantee through governmental control of fuel stocks	

Source: Brazilian Foundation for Sustainable Development²⁰ (2006), BNDES (2008), Moreira (2009)

The flex-fuel technology, introduced in 2003, was critical to increasing hydrous ethanol demand and allowed consumers to choose the mix between gasoline and hydrous ethanol. This flex-fuel technology is equipped with sensors which can systematically detect the bioethanol proportion in the fuel. The electronic control of the engine is then self-calibrated to operate under the best conditions. If the fuel mix does not include hydrous bioethanol, the electronic control calibrates the engine to operate only with gasoline. The driver cannot detect the calibration since the process is immediate and the driver cannot detect it (Goldemberg, 2008). The engine can therefore work with different blends of hydrous bioethanol and gasoline (from 0%-100%).²¹ Between 2003 and 2010, the consumption of hydrous bioethanol increased 19% per year on average, reaching 27.3 billion litres in 2010. Brazilian bioethanol is cost-competitive with fossil gasoline and already replaces a significant proportion of domestic road transport fuel. More detailed trends and figures on sugarcane bioethanol in Brazil are listed in Annex II.

Brazil benefits from two other key success factors complementing the networks built to develop the bioethanol market in Brazil (farmers, sugarcane mills, financiers and automobile industry). One is the vast geographic area covered by service stations. The other is policy maker and fuel distribution company support to meet this coverage. These stations sell hydrous bioethanol and blends with gasoline. The required infrastructure was originally set up with the Pro-Alcool programme and only completed gradually. In Brazil, fuel distribution companies assess the fuel (gasoline, anhydrous and hydrous bioethanol), carry out the blending (anhydrous bioethanol with gasoline) and ensure the quality of the product they deliver (BNDES, 2008). These companies alongside government willingness to deploy the bioethanol infrastructure played a key part in the Brazilian experience.

Sugarcane bioethanol is a mature commercial process in Brazil but there is still room for reducing production costs. Important technological and scientific advances in the agro-industry lay behind the success of the Pro-Alcool programme. Some examples of these advances are presented in Annex IV.

¹⁹ Contribuição e Intervenção no Domínio Econômico.

²⁰ Fundação Brasileira para o Desenvolvimento Sustentável

²¹ In Brazil, gasoline already contains 20%-25% of anhydrous bioethanol.

4.2 Overview of Brazilian South-South co-operation

Under the principles of South-South co-operation, Brazil rejects the label of ‘donor’ or ‘aid provider’ and prefers to be considered a horizontal partner pursuing mutual benefits between peers. The Brazilian Co-operation Agency (Agência Brasileira de Co-operação) is responsible for managing all negotiation, approval and international co-operation monitoring in Brazil. Brazilian co-operation consists of four components: humanitarian assistance, scholarships, technical co-operation and contribution to multilateral institutions. Technical co-operation is typically provided through conventional stand-alone projects under bilateral or trilateral co-operation. Brazil is one of the world’s top participants in triangular co-operation, and the Brazilian Co-operation Agency manages a growing number of projects under this modality. More ambitious endeavours have recently taken the approach of ‘groundwork’ projects, a term used to describe projects conceived under a longer-term, larger-scale, more fund-intensive and complex perspective (Overseas Development Institute – ODI, 2010a). Annex III presents a snapshot of Brazilian technical co-operation.

The Brazilian approach to South-South co-operation is based on strategies already implemented at home. They include the capital and technology-intensive approach to commercial agribusiness, and a more inclusive approach to agricultural growth through land reform and smallholder agriculture. There are some concerns as to whether these two approaches are complementary given the social, economic and political dimension in Africa. However, careful assessment of their suitability to African conditions and development needs could provide an appropriate mix of subsistence, commercial, smallholder and larger farm agriculture in Africa. Brazilian engagement in Africa opens up significant opportunities because its technology and expertise provide a good match for the African economic and institutional development stage and climate.

Brazil’s current South-South co-operation with Africa provides an interesting opportunity for African countries involved in sugarcane production. It could help them develop the institutional capacities for designing consistent biofuels policies, and the regulatory framework required to facilitate private and public investments to bring new energy sources to market. Based on knowledge-sharing and skills transfer, the Brazilian style of co-operation could considerably improve the institutional capacity of African countries. This would be achieved by raising awareness and spreading information about the technology between different institutional stakeholders for the development of a bioethanol industry. This could make a significant contribution given the limited experience of effective South-South co-operation in biofuels between African countries.

Brazil has the potential to play a key role in establishing an international bioethanol market and turning it into a commodity while transferring technology to African countries which could produce it locally (South African Institute of International Affairs, 2009). There are thus widespread opportunities for Brazil to build capacity in African countries, and for African countries producing sugarcane to improve their knowledge of biofuels. This would contribute to the development of a local and sustainable biofuels industry generating an economic and environmental payback.

The bioethanol programme in Brazil has yielded many environmental, political and socioeconomic benefits. These include the development of the agricultural and industrial sectors along with increased employment, indirect macroeconomic advantages and increased energy security. However, there have also been problems and concerns related to the environment, labour conditions, price volatility and market instability.

Valuable lessons have been drawn from these experiences in a developing country setting. These can help African countries make the leapfrog needed to adapt technology and processes to their local conditions.

South-South co-operation in bioethanol technology transfer from Brazil to Africa is unlikely to include massive investment in bioethanol plants around the continent – or not at first. Although traditional Brazilian companies like Odebrecht and Petrobras have been engaged in existing initiatives in Angola and Mozambique, Brazil has enough agricultural area to expand sugarcane cultivation to meet demand in its domestic bioethanol market. Sugarcane mill owners thus generally avoid direct investment outside Brazil. However, there are significant opportunities for transferring knowledge and expertise and building capacity as part of South-South technical co-operation.

There are also opportunities for stimulating international investment or creating a common fund that could be channelled into development priorities in Africa. This could function either through microfinance institutions, R&D support or direct investment in fixed assets and working capital (equity funds). From the Brazilian government's point of view, turning bioethanol into a commodity is good strategy. Helping create the right political and institutional environment to attract global investment in Africa through horizontal partnerships is a possible way to achieve this objective. However, Brazilian co-operation with Africa to some extent encompasses the expansion of commercial ties with the continent through agricultural machinery and equipment export.

4.3 Potential areas for collaboration between Brazil and Africa

Africa has massive bioenergy resource potential, and sustainable biofuels could play an important role in meeting Africa's energy needs. In addition, Brazil is forming a leading bioethanol market following its long experience in making the fuel. These factors demonstrate a push-pull effect in favour of South-South and triangular co-operation between Brazil and Africa on the sustainable development and deployment of bioethanol in the continent. Moreover, Brazil has strong historical and natural ties with Africa.

Operating and integrating a bioethanol market offers many technology transfer possibilities from Brazil to Africa across the entire bioethanol production chain. Brazilian expertise can build the institutional capacity to design suitable policies and understand the market conditions for bankable investments and appropriate technology pricing. This would contribute to promoting technical co-operation projects aiming to build capacity and train different stakeholders, especially in feedstock production, and to evaluate potential business models.

The use, operation and maintenance of the technology, including feedstock planting, logistics and industrial management, is more related to the private sector. Private companies can form partnerships with national governments or use international technology transfer to improve local capacity by training outgrowers and employing local expertise. Improvements in the industrial and management domains can be replicated without difficulty. Sugarcane production is trickier because differences in soil and climate create new variables according to individual region. Table 4 below outlines some potential co-operation areas. This list is not intended to be exhaustive but a start towards consolidating information and providing guidance on the main possibilities for technology transfer.

Some Brazilian South-South co-operation initiatives with African countries have already made a start on these matters. For example, the Pro-Renova project promotes capacity-building through training courses and awareness of different planning tools like mapping and zoning, agro-ecological zoning and public policies and incentives introducing biofuels into the market. The Getulio Vargas Foundation provides another example through its feasibility studies. These map out agro-ecological zones in selected countries and evaluate the potential for different crops (energy and food). They quantify the resources and recommend potential investments. Annex V surveys other South-South co-operation activities between Brazil and African countries.

Table 4. Potential areas for collaboration and technology transfer between Brazil and African countries

Topic	Description	Scope
Governmental enabling environment		
Raise awareness of bioethanol opportunities and challenges among different stakeholders	Lesson-learning through the Brazilian experience on regulatory framework, biofuels feedstock options, biofuels competitiveness, sugarcane production and best management practices, technical solutions in the bioethanol supply chain, potential markets and competitiveness, finance etc.	Knowledge-sharing (diffusion of Brazilian know-how), seminars/workshops/training tours.
Train in mapping and zoning	Planning tools to identify areas for environment protection, agricultural expansion and crop suitability. Allow the agricultural expansion.	
Train in agro-ecological zoning	Planning tool for development projects. This is carried out according to type of crop (such as sugarcane) and includes an analysis of the most suitable area for sugarcane expansion considering factors like environment impact, water resources and socioeconomic strategies.	
Support design of suitable regulatory framework and policies for bioethanol	Mandatory targets and incentives for bioethanol – creating the right environment/market incentives. Including harmonisation with agriculture and energy regulations (for bagasse cogeneration).	Knowledge-sharing/diffusion of Brazilian know-how through seminars, workshops or training courses); bilateral/trilateral technical co-operation agreements supporting laws designed according to recipient country – project specific.

Feasibility studies	<p>Use of Brazilian expertise to identify the potential of biofuels and food production projects. The study evaluates the possible project, including land availability (mapping and zoning), land suitability for different crops, project design, investment costs and competitiveness.</p> <p>The study offer a tool for policy makers to decide the policy and developmental goals for the country in the agriculture/bioenergy development.</p>	Bilateral/trilateral technical co-operation; this can also create knowledge (capacity-building) if local people are involved in the preparation of the study.
Technology/private sector engagement and development		
Strengthen research capacity for agricultural development, including energy and food crops	Collaborative research projects between Brazilian and African academic institutions (such as the Africa-Brazil agricultural innovation marketplace).	Knowledge-sharing: capacity-building/diffusing Brazilian know-how.
Support feedstock research and productivity	Support research for improving varieties of sugarcane, best practices in feedstock production and improvement of soil conditions.	Capacity-building: education and training (scholarship programmes/collaborative research); bilateral/trilateral technical co-operation agreements; directly between private sector and/or industry associations.
Support development of sugarcane supply chain	Increase farm, outgrower and sugarcane mill capacity for best agricultural practices and logistics in the sugarcane supply chain.	
Support for identifying better contract schemes	Contract schemes between outgrowers and the sugarcane industry; contracts for small-scale services such as transport; purchase contracts; contractual assurance.	Bilateral/trilateral technical co-operation agreement; directly between private sector and/or industry associations.
Technologies for industrial phase	Best practices and technologies for the industrial process; integration of distilleries with traditional sugar mills.	Knowledge-sharing: capacity-building/diffusing Brazilian know-how; bilateral/trilateral technical co-operation agreement; directly between private sector and/or industry associations.

Opportunities for SMEs and local content	Capacity-building to promote local entrepreneurship.	Bilateral/trilateral technical co-operation agreement; directly between private sector and/or industry association.
Train in engineering, project development, finance	Capacity-building for design of project, finance analysis, business plan, market and risks analysis, development of executive projects.	Capacity-building: education and training (scholarship programmes); bilateral/trilateral technical co-operation agreement; directly between private sector and/or industry associations.
Train in installation, operation and maintenance	Capacity-building for industry.	
Feedstock adaptability – sugarcane	Development of multipurpose varieties for bioethanol/sugar/electricity adapted to African soil and climate conditions.	Joint ventures, FDI or trade and licence of sugarcane varieties; promotion of joint research with international/national institutes.
Feedstock production	Best management agricultural practices; improved machinery for agricultural purposes.	Joint ventures or FDI; promotion of training and capacity-building with international/national institutes.
Harvesting and transport logistics	Outgrower clustering; improvement of logistics, rationalisation of transport equipment.	
Industrial process	Improved efficiency of the process for bioethanol/sugar production; method/cost analysis for collecting straw for electricity generation; ferti-irrigation methods (with vinasse).	Joint ventures, FDI, trade and licence of procedures or equipment.
Cogeneration of electricity	Equipment such as higher-pressure boilers; mini-grid design and engineering, grid connection issues, bagasse management.	Jointly with industry association, governments/international co-operation.
Training/capacity-building	Technical training for local staff (engineering, project development, finance, operation and maintenance); brokerage activities with domestic stakeholders.	Jointly with governments/international co-operation, industry associations.

Products and markets		
Institutional support for bioethanol market access	Support creation of a regulatory body to monitor quality and standards; support in identifying best operational model for blending anhydrous bioethanol with gasoline support in designing best model for distribution.	Knowledge-sharing: capacity-building/diffusing Brazilian know-how; bilateral/trilateral technical co-operation agreement.
Capacity-building in bioethanol quality and distribution logistics	Training in mixing anhydrous ethanol with gasoline logistics support for distribution/storage; monitoring quality and standards of bioethanol.	Capacity-building (petrol companies and the bioethanol industry): bilateral/trilateral technical co-operation agreement; directly between private sector and/or industry associations.
Current ancillary activities from Brazil supporting technology transfer		
Build competence and human capital	Increase local capacities to support development activities at the country level. An example is UNILAB, which is offering courses in agronomy, energy engineering, public management and public administration/good governance for Portuguese-speaking countries. Another is SENAI. ²²	Capacity-building: education and training (scholarship programmes).
Financial support	Co-operation to support the creation of funds for investing in African development projects.	Initiatives: special fund managed by BNDES and African Development Bank (AfDB); BTG Pactual private equity fund.

²² The training is carried out by the Brazilian National Service for Industrial Apprenticeship (Serviço Nacional de Aprendizagem Industrial) (SENAI). SENAI runs vocational training to promote industrialisation and foster youth employment policies. Founded in 1942, the organisation supports industrial development in Brazil. Its mission is to establish partnerships between the public sector and key Brazilian engineering and infrastructure companies, and promote industrial education and capacity. Through the Brazilian Co-operation Agency, SENAI is involved in several South-South technical co-operation projects (IPEA, 2011).

5 CONCLUSION

Bioethanol production from sugarcane is a mature technology from the point of view of feedstock production, conversion technology and its use in vehicles. Its integration into Africa offers a number of advantages. The most significant of these is the lower economic risk in developing the bioethanol supply chain due to the existing sugarcane crop and market across the continent. This favours a “learning by doing” process due to the greater likelihood of successful implementation, allowing different stakeholders to improve technical and institutional capacity. This in turn will allow policy makers and the private sector to improve evaluations of other energy crop opportunities, linkages between energy markets and agriculture, and other factors affecting the wider sustainable bioenergy strategy.

Existing capacity from sugar industry in Africa ready to be used. Several African countries are sugarcane producers. This opens up an attractive opportunity to start bioethanol production from molasses as a first step and evaluate the possibility of expansion at the country level. Assessments need to cover scale, target markets and social, environmental and economic safeguards. The large or small-scale approach should be evaluated at the country-level according to the country’s characteristics and land availability. Large-scale projects draw investors more easily and also facilitate technology transfer through FDI or joint ventures. However, some small countries benefit from a small-scale approach provided they can be competitive in sugarcane production and integrated a regional market/development approach. Governments will need to be heavily involved in creating the market and adopting the right parameters and pathways to develop a sustainable bioethanol strategy. They will need to help both local entrepreneurs increase their ability to participate in the supply chain as well as the private sector achieve competitiveness in bioethanol production.

National bioethanol production strategy should match national background and goals. The pathways and strategies towards a bioethanol industry and market need to distinguish between individual country characteristics. Is the country both a sugar and oil importer? Is it a sugar exporter or a country producing oil? Countries that import both sugar and oil, for example, could optimise sugar and bioethanol production from the outset. In addition, there is a tremendous diversity in the socioeconomic and political context and between the institutional and technological capabilities. The role of the public and private sector may therefore differ alongside technology transfer needs. For example, countries with high sugarcane production and/or outgrowers in the supply chain and/or lower-cost sugar producers have particular pathways. This diverges from countries which still need to provide solutions to agricultural productivity, infrastructure and labour for the sugarcane sector. In addition, land availability, national tenure systems and domestic oil prices also influence the pathway to bioethanol production.

Detailed cost/benefit analysis should be conducted on a local basis. The meaning of ‘large’ and ‘small-scale’ in the African context needs to be considered, and the land footprint from bioethanol production measured against the potential benefits from the industry. For example, several studies have reported on the risk to land availability and the conflict between food, fuel and animal feed. However, the exact area necessary for bioethanol production should be better analysed. The costs, benefits and risks are always rather site-specific. Specific locations need to be identified for a proper analysis of the potential risks/benefits to the local population and the possible interventions to minimise the risks of a large or small-scale approach.

Regional integration can make the most of shared resources and experiences. Most African countries are too small in economic terms to have their own research, technical capacity and full infrastructure for bioethanol programmes. This means a regional approach could be desirable in some cases. Regional collaboration for technology adoption/development can help integrate the region and facilitate a regional market thereafter. Greater integration is already visible via regional trade agreements in Southern Africa and East Africa benefiting the trade of sugar regionally. In addition, research institutions for sugarcane exist (for example, Mauritius Sugarcane Industry Research Institute, South African Sugarcane Research Institute or Zimbabwe Sugar Association Experiment Station) to concentrate on the development of multipurpose varieties for the region.

South-South co-operation can create a win-win scenario for Africa and Brazil. Brazil is a key partner for bioethanol technology transfer not only as a result of its well-known expertise in bioethanol production. It also experiences similar climate and soil conditions and has generated knowledge of the development of its agricultural sector. Historical and cultural affinities allow Brazil to better understand the pathways to a new industry in Africa and the common economic challenges developing countries face when constructing local industries. The current approach and strategy of Brazil's South-South co-operation provides African countries with an interesting opportunity. It could help them increase their institutional capacity for promoting a bioethanol industry and encourage closer technical co-operation, opening up broader solutions through a perspective of the 'South' by the 'South.' IRENA, furthermore, can help countries in their efforts to accelerate technology deployment.

The analysis in this paper is summarised in Table 5. These key findings should be refined according to the capacities and needs of each country. The technology-transfer opportunities can be pursued to foster co-operation between Brazil and African countries, and support deployment. IRENA can also evaluate other renewable energy technologies for its member countries. It can also link donor and recipient countries, as well as technology providers and users.

Table 5. Bioethanol opportunities in Africa

<p>Stage of technology</p>	<ul style="list-style-type: none"> • The industrial process for bioethanol production is already a mature commercial technology (off-patent), and technology transfer activity is directed more at improving and adapting the technology/procedures along the supply chain, including feedstock management.
<p>Evaluating the opportunity – why the technology make sense</p>	<ul style="list-style-type: none"> • Various countries in Africa are sugarcane producers and operating in the sugar industry. A first approach is to take relatively small steps to produce bioethanol from molasses. With the consolidation of the market/industry, the economics of diverting some sugarcane juice for bioethanol can be assessed. • Increasing sugarcane production can help countries importing sugar to be self-sufficient in sugar and bioethanol production, adding value to the economy. • Domestic market opportunities: Average gasoline prices in some of these countries are as high as USD 1.20 per litre. E10 blending will reduce oil imports and increase energy security. • International market opportunities due to GHG mitigation policies. This can make sense depending on the national’s biofuels strategy and trade-off criteria. • Potential for generating surplus electricity using bagasse. This can provide better energy services by electrifying rural areas without costly grid expansion. • Possibility of involving smallholders in the supply chain (including downstream).
<p>Analysis of potential: resource and local conditions</p>	<ul style="list-style-type: none"> • Sugarcane is already marketed and is very well known on the continent. A feedstock supply chain already exists, and some countries have outgrower schemes. • Good productivity in some countries. • Sub-Saharan African is part of the tropical belt: A warm climate suitable for sugarcane. These countries enjoy comparative advantages in the production of sugarcane bioethanol. • Sugarcane is known to have the best energy balance of all bioethanol feedstocks. • Environmental and social challenges: Water and land availability; conflict food v. fuel. The land footprint for bioethanol production and land potential of individual countries need to be better understood through mapping and zoning.

Sectors involved	<ul style="list-style-type: none"> • Energy (electricity, fuel production and distribution) • Agriculture (food production, land availability) • Environment; science and technology; trade and industry
Policy support and incentives	<ul style="list-style-type: none"> • Sugarcane and bioethanol is a mature technology: the policy approach is to create the market, attract the private sector and support capacity-building along the supply chain to improve technology absorption.
Development of the industry	<ul style="list-style-type: none"> • The strategy for developing the industry should consider: Analysis of land footprint, and mapping and zoning to identify areas suitable for sugarcane in line with the current existing sugarcane industry. It should evaluate industry adaptation for bioethanol, as well as costs and market opportunities according to country characteristics and resource potential. It needs to assess the regulatory framework covering the energy/biofuel sectors, agriculture, electricity and include land use patterns, food security, land use rights and environmental safeguards. • Private sector support to increase technological capabilities for improved sugarcane varieties, logistics of supply, education and training. • Evaluate policies and strategy for helping smallholders produce feedstock but also the downstream supply chain. • Support market access.
Drivers for technology adoption in Africa	<ul style="list-style-type: none"> • Bioethanol industry is still in its infancy on the African continent. There is a lack of institutional capacity for creating a consistent market and framework for promoting the new bioethanol industry. Improvements are needed in the diffusion of technology and opportunities under different decision-makers and the private sector. • Create the right policy environment for attracting private sector. • Better understanding of environmental and social risks and challenges for designing suitable policies and applying appropriate tools and analysis. • Increase absorptive capacity and general capabilities of farms and outgrowers, private sector and finance institutions. • Improve varieties of sugarcane – multipurpose varieties for bioethanol, sugar and electricity. • Capacity-building and training of different stakeholders.

<p>Scope/instrument for technology transfer</p>	<ul style="list-style-type: none"> • Knowledge-sharing: Transfer of know-how and lessons • Capacity-building • Collaborative research • Bilateral/trilateral technical co-operation agreements • Training and education
<p>Opportunities for technology transfer</p>	<ul style="list-style-type: none"> • South-South co-operation approach from Brazil to Africa: African countries can use the Brazilian experience and try to foster the opportunities offered by Brazil and expand co-operation (see Table 11). • Need for support mechanisms and funding to expand co-operation.
<p>South-South co-operation areas between Brazil and Africa</p>	<ul style="list-style-type: none"> • Increasing awareness of bioethanol opportunities and challenges between stakeholders • Supporting design of suitable regulatory framework and policies • Feasibility studies • Strengthening research capacity for agriculture development, including energy and food crops • Researching feedstock and productivity • further developing the sugarcane supply chain • Identifying more appropriate contract schemes • Integrating technologies for the industrial phase • Training in mapping and agro-ecological zoning, engineering, project development and finance, and in operations and maintenance • Adapting feedstock and feedstock production • Harvesting and improving transport logistics

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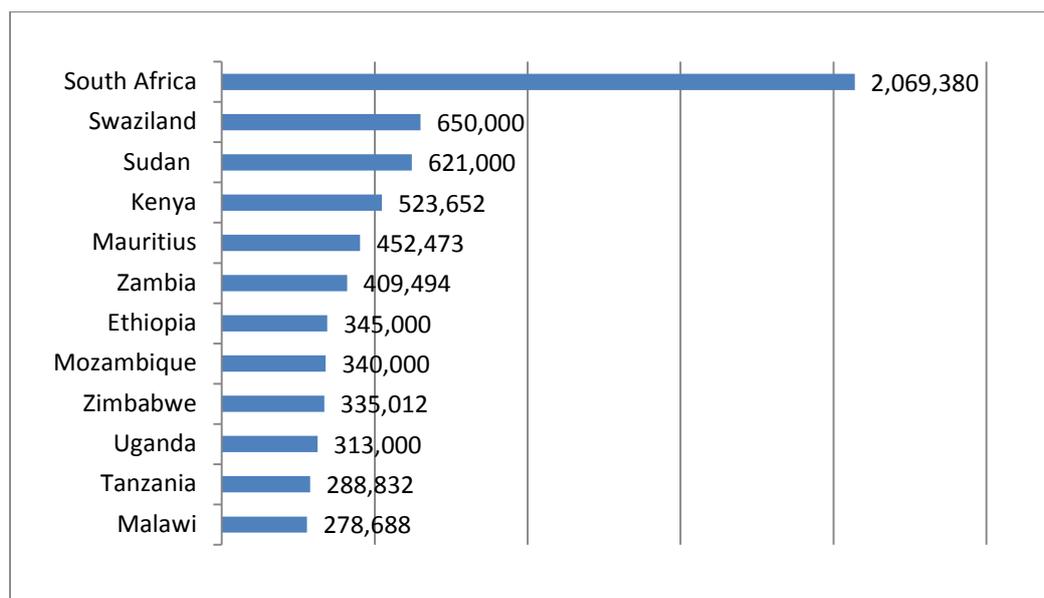
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ANNEX I: SUGAR INDUSTRY IN AFRICA — MARKET AND STATUS

According to Jolly (2012), the sugar industry in Africa covers a large spectrum of socioeconomic conditions and ownership structures. These range from irrigated beet sugar production in North Africa to rain-fed and irrigated sugarcane in the sub-Saharan region. There are corporate-owned sugarcane plantations and extensive small-grower schemes, large modern factories and small older plants. Refineries range from finalised produced extensions to raw cane sugar factories and large stand-alone refinery units in Algeria, Egypt and Nigeria.

Figure 4. Key sugar producers (by tonnage) in sub-Saharan Africa in 2010



Source: UN Food and Agriculture Organization database

Key sugar producers in sub-Saharan Africa are shown in Figure 4. In 2010, South Africa was the largest producer, followed by Swaziland, Sudan and Kenya. In that year, 37 countries in sub-Saharan Africa produced sugar from sugarcane, with an output of 8 million tonnes from approximately 1.5 million hectares under cultivation.²³ However, this represented only 5% of global production. Sugar imports in the region accounted for approximately 60% of the total sugar produced in sub-Saharan Africa in 2011. Yet consumption had been growing at a rate of 3.8% annually, and local industry needed to meet increasing demand. Table 6 shows that sub-Saharan African sugar production has remained almost constant over the last decade. It experienced a slight growth of 7% in 2008-2012, especially in Ethiopia, Mozambique, Sudan, Uganda, the United Republic of Tanzania, and Zambia.

²³If Egypt and Morocco are included, total sugar production from sugarcane in Africa accounted for 10.1 million tonnes in 2010. However, both countries produce the majority of their sugar output from irrigated beet.

Table 6. Centrifugal sugar production, supply and distribution ('000 tonnes)

Sub-Saharan Africa

	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17		
South Africa	Opening stocks			227	79	100	158	162	189	460	424	306
	Total sugar production			2,350	2,265	1,985	1,897	2,020	2,435	2,192	1,684	1,660
	Total imports			137	105	138	193	218	599	506	485	500
	Total supply			2,714	2,449	2,223	2,248	2,400	3,223	3,158	2,593	2466
	Total exports			1,230	754	400	271	356	868	772	320	320
	Total use			1,405	1,595	1,665	1,815	1,855	1,895	1,962	1967	1967
	Closing stocks			79	100	158	162	189	460	424	306	179
Other sub-Saharan Africa	Opening stocks			2,024	1,947	1,759	1,704	1,656	1,729	1,766	1,930	1,977
	Total sugar production			5,412	5,420	5,591	5,787	5,965	6,018	6,114	6,189	5,962
	Total imports			4,272	5,115	5,486	5,285	6,161	6,040	6,897	7,188	7,236
	Total supply			11,708	12,482	12,836	12,776	13,782	13,787	14,777	15,307	15,175
	Total exports			1,647	1,284	1,327	1,428	1,762	2,011	2,270	2,198	1,985
	Total use			8,114	9,439	9,805	9,692	10,291	10,010	10,577	11,132	11,232
	Closing stocks			1,947	1,759	1,704	1,656	1,729	1,766	1,930	1,977	1,958
Total sub-Saharan Africa	Opening stocks			2,251	2,026	1,859	1,862	1,818	1,918	2,226	2,354	2,283
	Total sugar production			7,762	7,685	7,576	7,684	7,985	8,453	8,306	7,873	7,622
	Total imports			4,409	5,220	5,624	5,478	6,379	6,639	7,403	7,673	7,736
	Total supply			14,422	14,931	15,059	15,024	16,182	17,010	17,935	17,900	17,641
	Total exports			2,877	2,038	1,727	1,699	2,118	2,879	3,042	2,518	2,305
	Total use			9,519	11,034	11,470	11,507	12,146	11,905	12,539	13,099	13,199
	Closing stocks			2,026	1,859	1,862	1,818	1,918	2,226	2,354	2,283	2,137

Source: United States Department of Agriculture, 2016

Malawi, Swaziland and Zimbabwe are among the most cost-competitive sugar producers globally. Companies based in South Africa tend to take a share of equity in or acquire many mills in other countries. They motivated largely by the following factors: South Africa does not have Least Developed Country status, which prevents access to preferential sugar markets. It has higher production costs and limited land availability, which prevents the growth of the sugarcane industry in South Africa. According to Innes (2010), private ownership is common in Southern Africa. Outside South Africa, the ownership structure is usually 'miller-cum-planter.' This means the mill grows a significant amount of its cane requirements on its own land and purchases the remainder from both large and small-scale outgrowers.

The key drivers of sugar production and exports in sub-Saharan Africa are related to regional prices. Some Least Developed Countries have access to preferential EU and US sugar markets, which typically offer higher prices than the world market. However, some sugar-producing countries enjoy sales into high-priced regional markets that offer 'natural price' protection due to their remoteness and distance from key ports. Other sugar-producing countries have to deal with restricted access to export markets because they are landlocked and a long way from coastal ports. This in turn means export markets are less attractive, especially since regional trade agreements²⁴ are broadening the integration of African markets. However, lower-cost producers using efficient seaports tend to continue to focus on the EU market, which with increased market access is still lucrative.

In short, these issues are encouraging the sugar industries to reduce production costs and consolidate production to enhance their competitiveness in the increasing regional and international marketplace (Jolly, 2010).

²⁴South Africa Customs Union, Southern African Development Community, East African Community, Common Market for Eastern and Southern Africa.

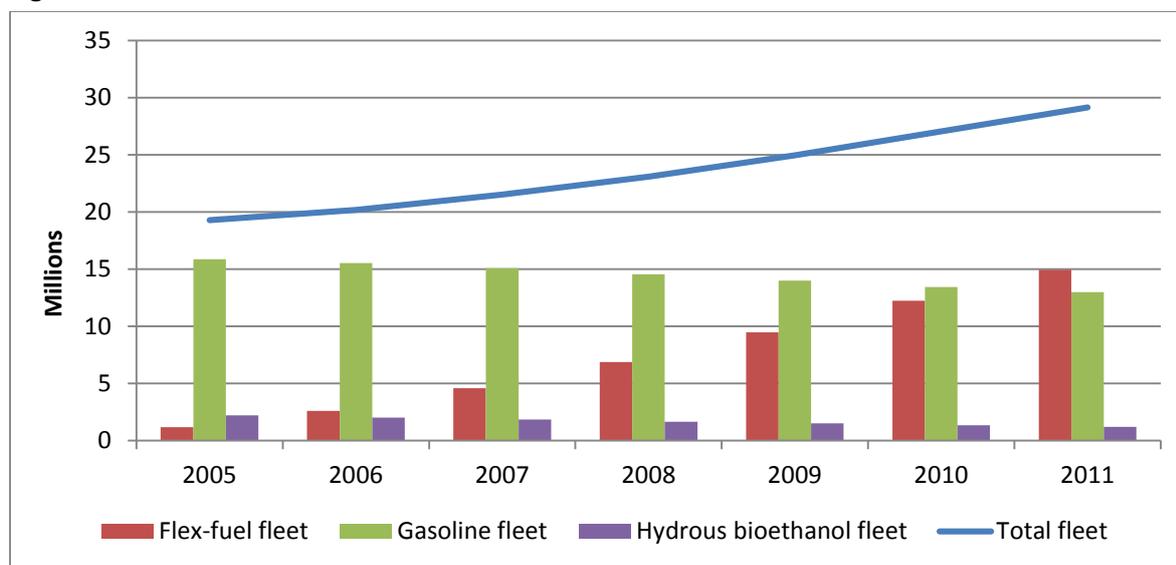
ANNEX II: BIOETHANOL IN BRAZIL: TRENDS AND FIGURES

In Brazil, sugarcane supply chain and payment is based on the value of the sugar and bioethanol in international and domestic markets.²⁵ “This system rewards higher productivity and allows farmers to share the rewards, and the risks, of the value chain with sugarcane millers. The system has proved to be more effective than a minimum price guaranteed by the government” (Mitchell, 2010, p. 56).

Most sugarcane mills in Brazil are complex mill/distilleries, and production of both bioethanol and sugar is limited to a 40:60 ratio. Based on the cost-effectiveness of demand, price and other market factors, mills are able to arbitrarily operate the production (BNDES, 2008). This agro-industry could make a significant adaptation to its technology to overcome a number of operational problems relating to the utilisation of molasses and low-value sugar by-product as a feedstock for higher-value bioethanol (Leyow, 2011).

Flex-fuel technology²⁶ accounted for 88% of the car fleet sold in Brazil. This technology allows the consumer a free choice of fuels, depending on the pump price (hydrous bioethanol becomes competitive when it reaches 70% of the price of gasoline). Figure 5 shows the share of flex-fuel vehicles in the total Brazilian fleet in 2012. In that year, production costs were around USD 0.40-0.55 per litre of bioethanol (2012 data), including raw materials, operation, maintenance and investment. This corresponds to petrol prices of around USD 57-78 per equivalent barrel.

Figure 5. Total vehicle fleet sales



Based on: Brazilian Sugarcane Industry Association (2012)

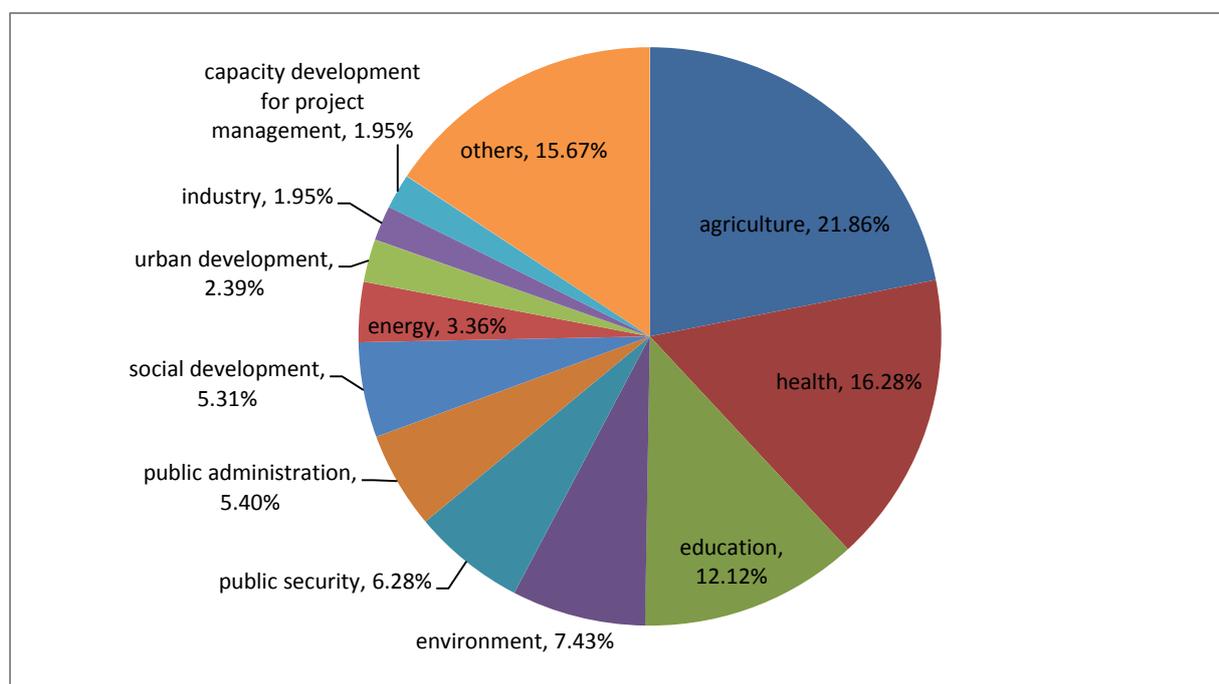
²⁵A special scheme guarantees the equalisation of sugarcane prices across the entire production chain. This means sugarcane is purchased on the basis of its sugar content, and the sales and economics of bioethanol and sugar in international and domestic end-user markets define the prices (BNDES, 2008). This model is co-ordinated by a council of sugarcane producers involving representatives of private institutions in the bioethanol industry.

²⁶ Flex-fuel vehicles in the US and EU run at a maximum E85, unlike those in Brazil. According to the US Department of Energy, E85 is a blend of gasoline and 51%-83% bioethanol by volume. The blend varies between summer and winter and it is limited to 83% bioethanol to ensure that vehicles will start in cold weather.

ANNEX III: SNAPSHOT OF BRAZILIAN TECHNICAL CO-OPERATION

About half the technical co-operation provided by Brazil in the past decade was related to agriculture, health and education (Figure 6). However, it runs a broad portfolio of activities, such as professional training in industrial development, environmental and water concerns, public administration and policies, food safety programmes, energy or solid residues management. Biofuels are included in the list of co-operation activities. Negotiations have taken place with countries in which Brazilian know-how and techniques can be assimilated at a low cost and with a high success potential (Brazilian Co-operation Agency, 2011).

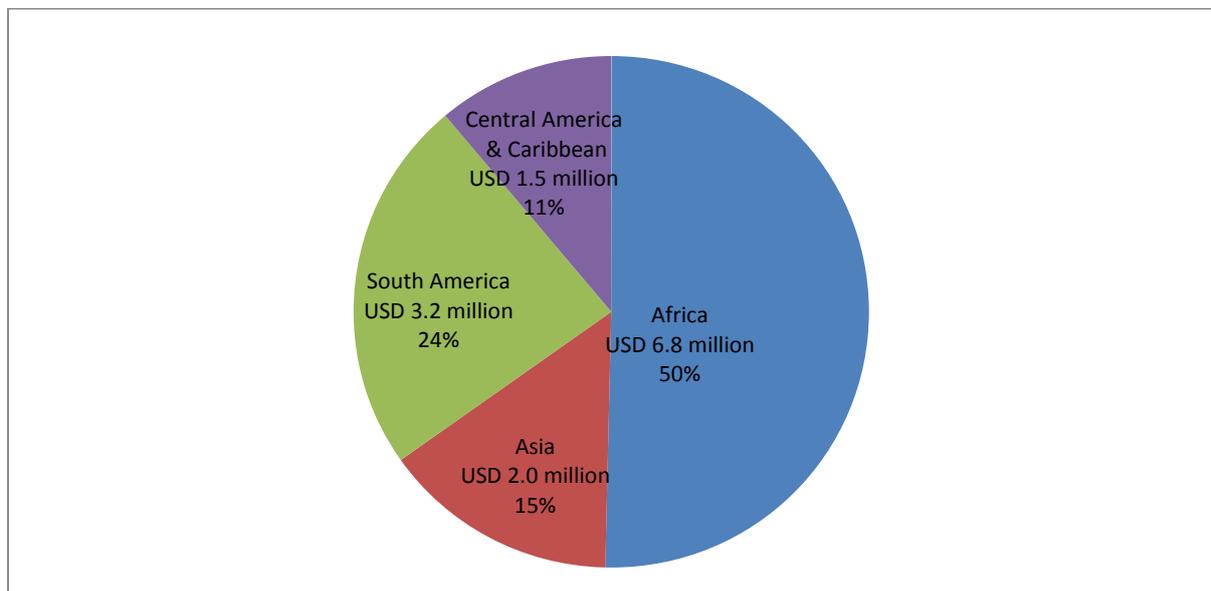
Figure 6. Total co-operation activities per segment, 2003-2010



Source: Brazilian Co-operation Agency (2011)

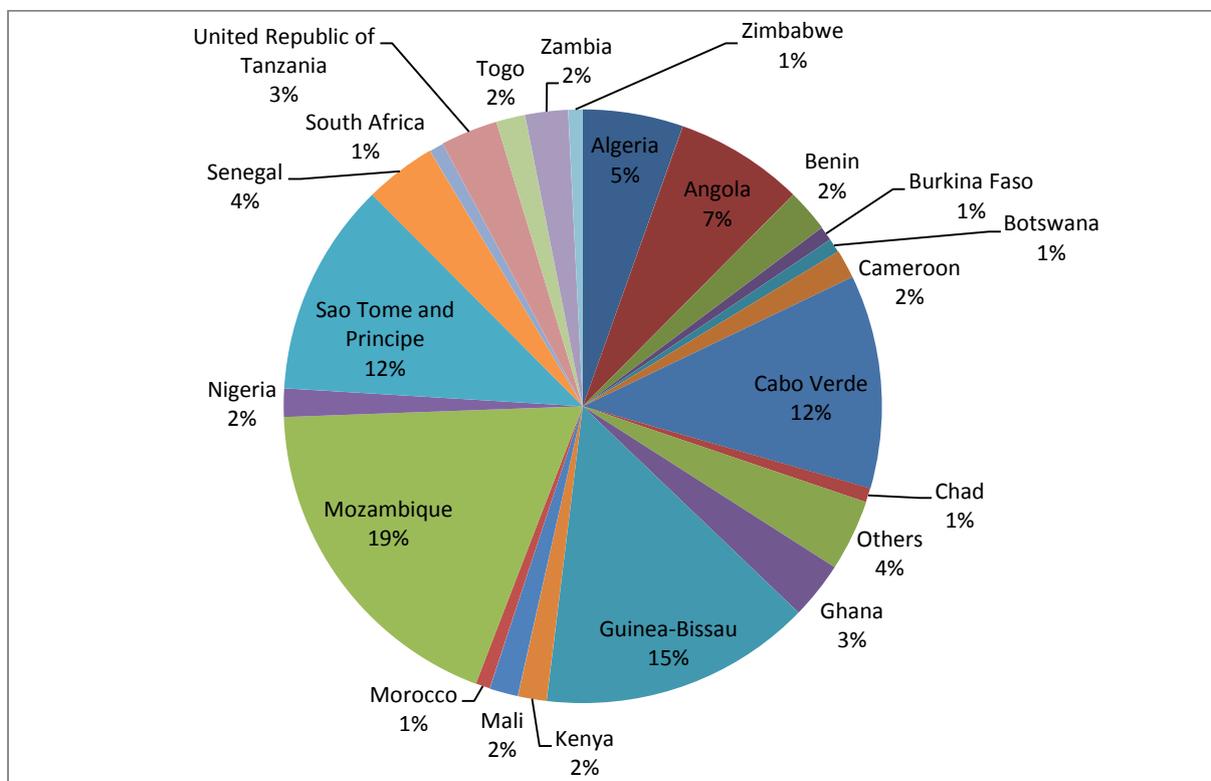
Brazil has targeted African countries in particular for technical co-operation, especially Portuguese-speaking countries, over the past decade (Figures 7 and 8). Although Angola, Cabo Verde, Guinea-Bissau, Mozambique and Sao Tome and Principe accounted for 65% of projects, Brazilian co-operation also includes other African countries. In 2009, 128 projects were in progress in Africa, mostly in agriculture, health and education (Figure 9).

Figure 7. Technical co-operation projects by world region (USD million and %), 2009



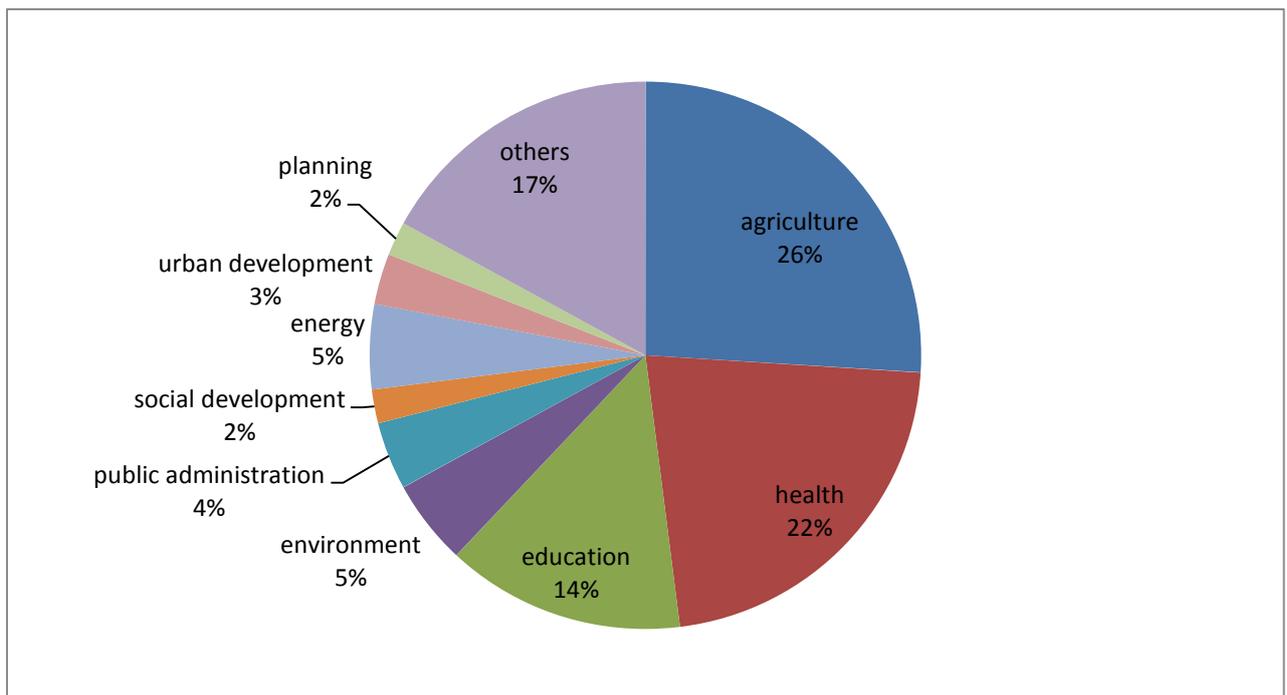
Source: Brazilian Co-operation Agency (2011)

Figure 8. Co-operation activities in Africa by country (%), 2011



Source: Brazilian Co-operation Agency (2011)

Figure 9. African co-operation activities by segment, 2003-2010



Source: Brazilian Co-operation Agency (2011)

ANNEX IV: ADVANCES IN AGRO-INDUSTRIAL USES OF ETHANOL IN BRAZIL

Although sugarcane bioethanol has become a mature commercial process in Brazil, producing clean micro-organisms for fermentation or improved steam economy to increase surplus power generation may further lower production costs. New research and applications have been inspired by the success of flex-fuel vehicles in Brazil. For instance, a new and similar flex-fuel technology for motorcycles allows bioethanol and gasoline to be blended in any proportion.²⁷ A bioethanol-powered bus undergoing tests, and a bioethanol-fuelled agriculture monoplane has been in use since 2004 by Brazilian aviation company Embraer. Some examples of advances in agro-industrial uses of ethanol are presented below (sources: BNDES (2008), Mitchell (2010), Johnson and Seebaluck (2012), and open sources online):

- During the last 35 years, improved breeding techniques have adapted varieties to droughts and pests and various climate and soil conditions relating to shorter production cycles. Such adaptation achieved productivity gains of 1.4% and 1.6% respectively in agriculture and agro-industry. The gains resulted in a 3.1% rate of cumulative average annual growth in the per-hectare yield of bioethanol. Process advances included new grinding techniques and fermentation improvements to produce larger amounts of bioethanol faster by utilising different enzymes and micro-organisms. Various Brazilian biotechnology institutions have researched the identification and production of clones with the shortest maturation, better disease resilience and higher sucrose and biomass content etc.
- The consumption of traditional fertilisers could be considered relatively low in Brazil because vinasse (a by-product of the sugar industry) is recycled through a process called 'ferti-irrigation.' Fertiliser costs to agriculture are significant. This encourages the adoption of new practices and technologies which decrease lime and fertiliser use. Vinasse, a corrosive liquid by-product of ethanol distillation, can cause environmental damage if dumped in rivers. Its composition fluctuates with the mixture of bioethanol and sugar produced. Vinasse can be mixed with residues of the industrial process such as the filter cake, water and ash from boilers, and then applied to the soil as a fertiliser. Techniques are under examination to diminish the amount of vinasse per litre of bioethanol produced from 10-12 litres to 8-9 litres.
- Water is used in several processes in the conversion of sugarcane into bioethanol, especially for cleaning and in cooling systems, multi-jet/barometric condensers and other equipment. Typical water consumption is about 0.92 cubic metres (m³) per tonne of cane, based on 5.07 m³ per tonne of cane collected, and a discharge of 4.15 m³ per tonne of cane. The total water consumed was reduced by recycling water used in some circuits and modifications in processes like dry washing and mechanical cutting to reduce water use for cane washing. Research has been conducted to further reduce average water consumption per tonne of sugarcane processed.
- Biological techniques for controlling the most common sugarcane pests have reduced the use of pesticides in Brazil. For example, biological control makes use of predators or parasites to accurately manage agricultural pests while maintaining a low impact on the environment. Provided that this technique does not involve the application of chemical pesticides, biological techniques can also create economic savings by replacing traditional pesticides.

²⁷ 12% of the motorcycle fleet uses flex-fuel technology (Brazilian Sugarcane Industry Association database).

- The agro-ecological zoning tool adopted by the government provided sustainable territorial planning and allowed the harmonious production of food and fuel. It enabled the identification of land use options and the definition of zones with potential for agricultural expansion. This was achieved by considering different crops based on a diagnosis of natural and socio-economic resources. It could also create scenarios for planning sustainable land use in harmony with biodiversity and conservation objectives.

Tropical agricultural revolution: research in science and technology

The transformation of Brazil's central *Cerrado* savannah belt into the world's most important soybean production region is one of the country's main successes in the agricultural sector. The same soil conditions are found in many parts of Africa, such as the Guinea savannah. Consistent research in tropical agricultural science and technology has brought about an agricultural revolution. Over the last 30 years, Brazil has reversed its status from a net food importer to a net food exporter. Brazil is also a world expert in biofuels, with extensive experience of the sugarcane supply chain. Technological and scientific development in this field have led to higher economic value and energy balance per hectare.

ANNEX V: BIOFUELS COLLABORATION BETWEEN BRAZIL AND AFRICA

South-South co-operation

Estimates suggest that Brazil channelled around USD 1 billion per year in 2010 into development assistance in addition to its contributions to multilateral development agencies. Technical co-operation amounted to about USD 480 million (Table 7). According to a survey conducted by the Brazilian Institute for Applied Economic Research (Instituto de Pesquisa Econômica Aplicada) (IPEA), these figures would represent an increase in comparison to the sum disbursed by Brazil in previous years. In 2005-2009, this amounted to USD 1.72 billion, or USD 430 million per year.

Table 7. Brazilian expenditure on South-South co-operation in 2010

Modalities	USD million
Technical co-operation	480
Brazilian Co-operation Agency budget	30
Expertise provided by Brazilian technical co-operation institutions	450
Humanitarian assistance	650
Peace-keeping mission to Haiti	350
UN World Food Programme	300
Total	1 130

Source: (ODI, 2010); (Brazilian Co-operation Agency, 2010)

Programmes like 'Family Farming,' 'Zero Hunger' or schemes to increase electricity access to rural population have generated abundant knowledge of smallholder farmer development and poverty reduction (Goldemberg *et al.*, 2004; Goldemberg *et al.*, 2013). Brazil's experiences and skills can be shared to contribute to tackling development challenges such as food security as well as developing agriculture and the agro-industry as a whole, including biofuels. These areas could be of common interest to African countries.

The Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuária) (EMBRAPA) is a public institution which has played a crucial role in the agricultural path and success of Brazil. The institution has generated and recommended more than 9,000 technologies for Brazilian agriculture, reduced production costs and helped Brazil to increase food supply while conserving natural resources and the environment (IPEA, 2011, p. 51). A number of research projects were undertaken to improve soil and crop management. They rendered previous wastelands suitable for commercial activity by reducing levels of acidity with lime and using technologies such as nitrogen biological fixation. These both reduce the need for fertilisers. Furthermore, EMBRAPA has researched genetic engineering to obtain plant tolerance to drought and disease and resistance to insects (Galerani *et al.*, 2007).

As a result of such R&D in the agricultural sector, Brazil's farm production increased from USD 16 billion to USD 72 billion in 1996-2006 (The Economist, 2010). The opening of an EMBRAPA office in Accra, Ghana in 2006 was a major step towards integrating with African partners. The office was established to co-ordinate projects more closely with EMBRAPA's African partners and more effectively promote know-how and technology transfer across Africa. This would contribute to the continent's agricultural development.

Table 8 presents bilateral and triangular ‘groundwork projects’ in which EMBRAPA has been engaged. Groundwork projects are specially designed for local biome and economic conditions, and adapted to local needs through the continued participation of local stakeholder along the different stages of project development. Table 9 lists the activities in which the Brazilian government has co-operated with various national institutions to share knowledge.

Table 8. Groundwork projects under Brazilian co-operation with Africa

Groundwork projects	Description	Institution/countries
Cotton-4 2008	This project consists of an experimental cotton station in Mali which also benefits Benin, Burkina Faso and Chad. Its aim is to contribute to developing a domestic cotton industry in these countries. Nine Brazilian cotton varieties developed by EMBRAPA are being tested and adapted in Mali. Despite difficulties relating to infrastructure, communication and labour, cotton yields increased from 1,000 kilogrammes to 3,000 kilogrammes per hectare in 2009.	EMBRAPA/ Mali, Benin, Burkina Faso and Chad
Agriculture innovation/Mozambique 2010	This project has five target areas of innovation i) research capacity of the Agricultural Research Institute of Mozambique ii) seed system iii) territorial management iv) information and monitoring v) communication.	EMBRAPA/ Agricultural Research Institute of Mozambique/ USAID
Nacala corridor/Mozambique design phase	The objective of this project is to support agricultural development in the Nacala corridor by improving research capacity and knowledge transfer. This project intends to achieve the transformation of the Nacala corridor to a more productive agricultural area like the <i>Cerrado</i> in Brazil. It aims to increase competitiveness while developing agriculture locally and regionally in a sustainable and environmentally friendly manner.	EMBRAPA/ Getulio Vargas Foundation/Ag riculture Ministry of Mozambique/J apan International Co-operation Agency
Food security Mozambique design phase	This project aims to build capacity in horticulture and reinforce the distribution of its products to secure food and ensure nutrition at the same time as supporting agricultural family businesses. This project takes place in the context of the Global Initiative for Food Security and Nutrition.	No data
Rice culture development projects 2010 Senegal	This project seeks to improve Senegal’s rice production by transferring technology for a more self-sufficient productive system. Some tasks include mechanising the production chain, capacity-building and training local technicians, and researching rice varieties for irrigation, high and medium elevations.	EMBRAPA/Sen egalese Institute for Agricultural Research

Source: IPEA (2011), Brazilian Co-operation Agency (2010)

Table 9. Brazilian co-operation activities with Africa – platform for knowledge-sharing

Activities	Description	Institutions
Africa Brazil Agricultural Innovation Marketplace	This project was launched in 2010 and its goal is to reinforce South-South transfer of technology and knowledge between Brazil and Africa, and encourage dialogue between them on agricultural policy. It is based on co-operative R&D initiatives between Brazilian and African academic or research institutions, as well as investments in agricultural R&D.	EMBRAPA, Forum for Agricultural Research in Africa, UK Department for International Development, International Fund for Agricultural Development, World Bank and agricultural research centres in Africa
Brazil-Africa Dialogue on Food Security	An initiative aimed at creating a framework for co-operation based on dialogue and support of national strategies in nutrition, rural development and food security.	Foreign Affairs Office, Brazil
Africa-Brazil Health Research Network	A network set up in 2010 to share research and experience between institutions in Africa and Brazil. Its goal is to identify small to medium-sized collaborative projects on tropical diseases and later to develop large-scale projects to submit to international funding.	Ministry of Health, Oswaldo Cruz Foundation (Fundação Oswaldo Cruz), Brazil, partnership with Institute of Hygiene and Tropical Medicine, Portugal
UNILAB (University Luso-Afro-Brazilian Integration)	Launched in 2011, UNILAB, located in Fortaleza, Ceará, Brazil, aims to integrate Brazil with African Portuguese-speaking countries. Half its students are expected to come from these countries, and the university's focus will be to strengthen social, economic and cultural ties between partner countries.	Ministry of Education, Brazil
IBSA Dialogue Forum	Launched in 2003, IBSA is a tripartite India-Brazil-South Africa dialogue forum. It provides a platform for discussions on co-operation in agriculture, education and culture, energy, science and technology, trade, transport and defence. IBSA also aims to increase trade opportunities between the three countries. It aims to facilitate the trilateral exchange of information, technologies and skills to complement each other's strengths, including a biofuel technology transfer forum.	High-level governmental group from each country

Source: AfDB (2011), IBSA website, UNILAB website, Almeida *et al.* (2010), IPEA (2011)

One of the main knowledge-sharing co-operation programmes was the 'Pro-Renova.' It was launched in 2009 and involved five ministries: Foreign Affairs, Energy, Agriculture, Science and Technology, and Industrial Development. Its main focus was to build capacity in African countries and promote seminars and short-term courses. At least 18 countries participated as presented in Table 10. Bioethanol was the main focus but other bioenergy sources such as biodiesel and agricultural waste were also covered.

Table 10. Knowledge-sharing co-operation programme on biofuels

Activity	Countries/institutions
Seminars: agro-ecological zoning tool for designing public policies for sustainable biofuels production	Angola, Botswana, Mozambique, South Africa, United Republic of Tanzania, Zambia, Zimbabwe
Seminars: public policies for biofuels	Benin, Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Senegal and Togo (Economic Community of West African States – ECOWAS countries)
Seminars: public policies for biofuels	Ethiopia, Kenya, Mozambique, Sudan, Uganda and United Republic of Tanzania

Source: Rebuá (2012)

Brazil's interest in co-operating with African countries on biofuels also resulted in several bilateral agreements. For example, it supported the development of a regulatory framework for the biofuel sector with Mozambique, Botswana and the United Republic of Tanzania. It provided technical co-operation to Nigeria for training Nigeria's petrol company to mix anhydrous bioethanol with gasoline.

Other important steps have been taken on biofuels. Feasibility studies were conducted in Central America²⁸ and Africa in a trilateral co-operation initiative with the US and EU. Senegal was the first country in Africa to benefit, followed by Guinea-Bissau and Mozambique. Other studies were done, as shown in Table 11.

Table 11. Biofuels feasibility studies completed or in progress

Country	Description
Senegal, Guinea-Bissau²⁹	Triangular co-operation – Africa-Brazil-US – to encourage and conduct joint work on biofuels use and production in countries with emerging economies (central America and Africa)
Kenya, Mozambique¹⁰	Triangular co-operation – Africa-Brazil-EU – to promote the use of bioenergy and bioelectricity production in Africa
Guinea, Liberia and Zambia¹⁰	To be conducted on a bilateral basis
Benin, Burkina Faso, Cote d'Ivoire, Mali, Niger and Togo	ECOWAS-Brazil agreement on technical co-operation and the completion of bioenergy feasibility studies, taking into consideration the approach made by studies in Senegal and Guinea-Bissau

Source: Rebuá (2012), BNDES (2012)³⁰

²⁸In Central America, the countries included in the partnership are the Dominican Republic, El Salvador, Guatemala, Haiti, Jamaica and Saint Kitts and Nevis.

²⁹ Carried out by Brazil's Getulio Vargas Foundation.

³⁰ http://www.bndes.gov.br/SiteBNDES/bndes/bndes_pt/Institucional/Sala_de_Imprensa/Noticias/2012/energia/20120503_africa.html.

These feasibility studies analysed the agriculture potential of sugarcane bioethanol but also included other energy crops for bioethanol, biodiesel and bioelectricity as well as food crops. They included three stages: 1) an analysis of land suitability by creating maps with agro-climatic zones, edaphic zones and agro-ecological zones 2) an evaluation of production capability, identifying potential crops and possible food and biofuels projects 3) recommendations for investment, highlighting some questions related to regulatory needs, infrastructure and environmental issues. This was based on social, economic and geographical considerations.

Commercial bonds between Brazil and Africa

Brazil's exports to Africa rose from USD 2.4 billion in 2002 to USD 12.2 billion in 2011, and total trade (imports and exports) increased from USD 4.3 billion to USD 27.6 billion over the same period (Ortiz, 2012). In November 2011, an 'African Group' led by Brazil's Trade and Industry Ministry was created to increase ties with Africa. This resulted in the creation of a special fund, announced in May 2012, to finance projects for development in Africa jointly with multilateral lenders. Managed by BNDES and AfDB, the objective of the fund is to mobilise technical solutions and development expertise available in the South to support African countries. BTG Pactual, a private bank, also launched a USD 1 billion risk capital private equity fund to invest in Africa. These initiatives were intended to support Brazilian projects in the region, including agriculture, agro-business, infrastructure and energy.

Within the private sector, companies have also sought to form strategic alliances with African partners to build new business and markets by transferring know-how through FDI and joint ventures, and by creating more employment (AfDB, 2011).

ANNEX VI: FRAMEWORK FOR PROMOTING A BIOETHANOL INDUSTRY

Figure 10 shows the overall framework for promoting a bioethanol industry. It comprises three aspects of organisation and planning to support the adoption and adaptation of the technology: (1) an enabling government environment for attracting the private sector, promoting technology diffusion and increasing absorptive capacity (2) technology/private sector engagement to support the adoption of the best practices and technologies according to existing market opportunities (3) to build the right structure and capacity required to ensure product access to markets.

This **first package** consists of creating the institutional environment to promote technology adoption. This includes creating incentives to invest in and adopt technologies through laws and regulations. It usually requires the development of investment delivery mechanisms and building the capacity of different institutional actors, as well as awareness-raising and provision of technology information.

In this package, the first approach (A) is to identify the type of biofuel crop/feedstock best suited at the country level and how much land can be allocated to its cultivation. The main tool for such analysis, which will support the subsequent planning phase, is a biofuel-crop-feasibility analysis. This includes mapping and zoning the potential land to produce biofuel crops and food crops. Mapping and zoning should provide information on the different soil and climate conditions, and available water resources to make appropriate choices about which crop to grow in which area. It should help identify priority areas for environmental preservation. It offers a key primary source of technical support to both overall agricultural production strategies and the sustainable development of a given large area or region. Once a country has the potential to develop new areas or expand existing sugarcane plantations, policy makers should start the planning phase. This consists of defining the development goals and evaluating the opportunities for bioethanol production, the opportunities in domestic and exports markets, possible trade-offs and action to address private investment.

The next step is to introduce policies for creating the market according to the development priorities and goals shaped during the planning phase. The domestic market for anhydrous bioethanol can be attractive. It has the advantage of increasing energy security given that the sugarcane industry and accompanying infrastructure are more organised in countries with a sugarcane production tradition. Enabling a consistent **energy/bioethanol policy** (B) and establishing a blending mandate will allow investors to understand the size of the market. It will provide long-term security for the investment as well as background to evaluate the need for incentives (pricing, taxing and tariff policies) and bioethanol competitiveness in the short to medium term. Export can be a desirable country strategy but if that is the option taken the bioethanol policy should include safeguards to guarantee some of the benefits are distributed into the local community.

Any significant increase in bioethanol production in African countries will require additional sugarcane cultivation. The main constraint to bioethanol production is linked to the availability and subsequent development of suitable agricultural areas since the installation of sugarcane distilleries does not create technical problems (Leal, 2012, p 131). Agro-ecological zoning, as used in Brazil, is an interesting tool available during this phase. It complements mapping and zoning, and provides socioeconomic, strategic and political support information to decision-makers on land use options when developing projects. Agro-ecological zoning involves a spatial assessment of a region's land potential for a given crop or product. This becomes a basis for planning sustainable land use in harmony with biodiversity and conservation objectives (Strapasson *et al.*, 2012).

The energy/bioethanol policy can include a national programme aiming to provide financial support to initiatives designed to boost the agricultural and bioenergy sector. A policy of this type can also define phases of market implementation (pilot, operational, expansion and consolidation) as with Mozambique. It can allow systematic evaluation, and the accompanying learning process can provide valuable inputs for the next development phase. Once a country has gained a comparative advantage in bioethanol feedstock production and manufacturing, an important aspect of this phase is to regulate the bioethanol standards and quality for the final market. This is achieved by establishing fuel norms and monitoring and regulatory agencies.

Policies to address **agricultural development (C)**, should consider **land use patterns, food security and land use rights (D)**. **Environment policies (E)** should also be in place to avoid potential negative impacts from agricultural/industrial activity but also to protect high conservation value areas. Land laws in Africa may need to be strengthened to protect local people, and land allocation should be transparent, involve all stakeholders and provide just compensation (Mitchell, 2010, p. xxiv). Concerns have been raised about the adverse socioeconomic impacts of large-scale feedstock plantations, especially in terms of existing livelihoods. Mechanisms to improve local skills and employment and ensure job opportunities for local people should be therefore be reinforced. Other institutional mechanisms can be adopted to enhance the benefits of large-scale projects. One example is joint ownership through FDI with petrol companies once the project is set up. Another is investment of a percentage of profits to build and finance infrastructure in with social concern impacts such as schools or hospitals (Maltitz and Stafford, 2011). To maximise sustainability, all these institutional mechanisms have to be evaluated and adopted when drafting policy and legislation (normally under local content policies F). They will rely on the country's policy goals and the characteristics of country-level entrepreneurship.

Food/fuel conflicts can be reduced by employing the mapping and zoning tool, defining land allocation and also by intensifying agricultural practices to reinforce the farming sector. Policy constraints that could have a negative effect on national food security must be analysed in order to modify policies adequately. This should be carried out regardless of biofuel development although the organisation of the biofuel/crop supply chain will probably support some of these assessments.

Direct government support to the **agricultural sector(C)** is crucial in stimulating food production. This is because it can create policies to stimulate R&D in agriculture, reform legislation on land and provide subsidies. At the same time, government support can maintain a favourable macroeconomic environment that avoids high taxes on agriculture (Maltitz and Stafford, 2011).

The bioethanol supply chain can provide opportunities for small-scale farmers. Policy makers and planners, therefore, need to identify, on the basis of country characteristics, how and to what extent outgrowers can contribute and be included in the supply chain. Some sugar industries in Africa already source part of their sugarcane from outgrowers and are clustering them to improve supply logistics and economies of scale. Brazil has an interesting contracting model based on final bioethanol and sugar prices, which can provide a fair share of the profits. From the industry point of view, including outgrowers in the supply chain can be beneficial. This is because industry will not need to deal with large tracts of land, and the market will evolve favourably, especially under certification schemes. Mills will be working more closely with small farmers, and this adds another advantage to this model from the point of view of capability and skills improvement. It will enable better access to facilities like government credits and loans, as well as better technical and logistical assistance to ensure the industry obtains adequate feedstock quality and supply.

The **electricity sector (G)** will also be important to address, especially in relation to the sugarcane industry. Regulations and incentives will be needed to accelerate the introduction of surplus electricity produced from bagasse into the grid. Electricity generation to the grid under IPP schemes is not the natural end-product of a sugar/ethanol plant. This means owners need to be made aware of its potential, as well as the various operation schemes, grid connection patterns and standards. Information on state-of-the-art biomass-based technologies, such as improved combustion in traditional boilers, condensing extraction steam turbines and high-pressure boilers, should also be communicated. Policies and regulation development may also be needed. These may cover IPP policies, electricity tariff levels, grid access and infrastructure including grid expansion or the construction of mini-grids to increase energy access.

The involvement of other ministries/sectors related to science and technology, trade and industrial development could make a difference. This would provide ancillary policies to strengthen R&D capacities and reduce bureaucratic barriers to FDI and trade.

The second package is more related to operations at the corporate level and comprises feedstock production and supply (G) and industry (J). However, feedstock production can also be related to governmental matters when the country is interested in including outgrowers in the supply chain. Even in sugarcane production, where crops are already grown and marketed, policies addressing training on best management agricultural practices (H), transport logistics (I) and access to credit, will be critical. These will improve productivity and guarantee the success of smallholder participation.

Feedstock cultivation is the main cost in biofuels production. For sugarcane it represents around two-thirds of costs. Competitiveness, therefore, must be achieved during this phase. Research into traditional breeding, genetics, physiology and biotechnology should be supported to enable the expansion of sugarcane cultivation under a wide range of soil and climatic conditions.

The **third package** consists of support for market access (K) for bioethanol and also for the surplus electricity generated from bagasse. Support does not mean creating a regulatory framework (as is envisaged in the first package). Instead, it means providing the institutional support for establishing regulatory bodies and creating the knowledge needed to monitor bioethanol quality and standards according to national and international market goals. This includes training petrol companies to mix anhydrous bioethanol with gasoline, building capacity in monitoring and regulatory agencies. For hydrous bioethanol, it means building knowledge of how to operate bioethanol distribution and logistics to consumers. For bagasse cogeneration, support means capacity-building for operating and dispatching electricity under the regulatory and operational framework of the country's power sector.

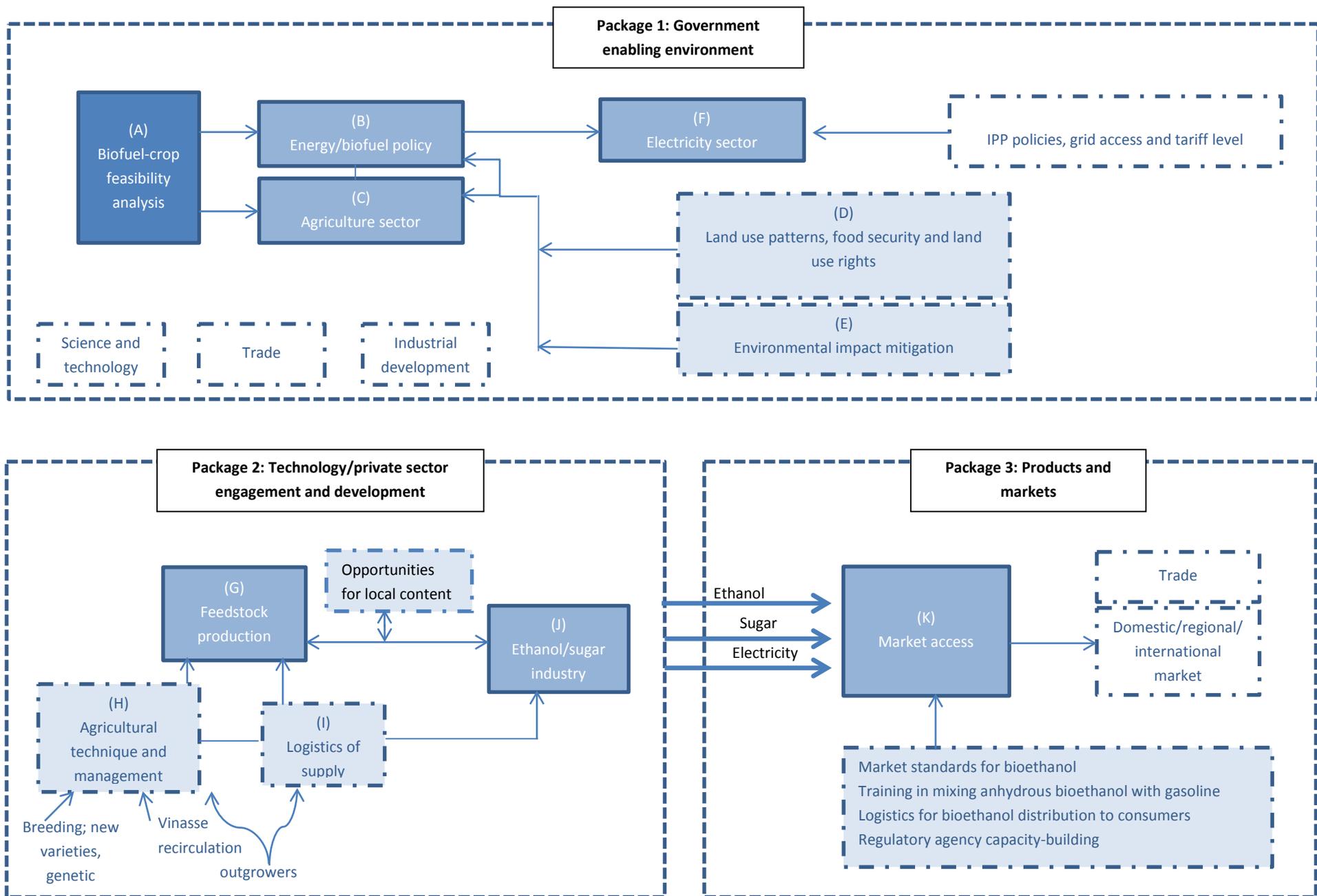


Figure 10. Framework to accelerate the implementation of a sustainable bioethanol industry

ANNEX VII: BIOFUEL STANDARDS

Biofuel producers have been using different standards over time reflecting different feedstock and vehicle requirements. However, with the prospect of international trade growth, the need to harmonise biofuel specifications emerged. In 2006, a tripartite taskforce was formed between Brazil, the EU and US to develop compatible biofuels-related standards. The taskforce produced the White Paper on Internationally Compatible Biofuel Standards,³¹ which would eventually lead to steps countries should take to harmonise and make existing standards more compatible (Tripartite Task Force Brazil, European Union and United States of America, 2007).

An expert working group was established from Brazil, the EU and US plus China, India and South Africa to review standards for ethanol and biodiesel and promote worldwide compatibility. A report was then delivered identifying 16 specifications for ethanol and 24 for biodiesel. According to the report, nine of the 16 ethanol specifications and six of the 24 biodiesel specifications could be considered aligned, and the others 'in alignment' in the short term – with one exception. It also pointed out that existing specifications created no obstacles to ethanol global trade. However, the report recognised that Brazilian and US exporters seeking to enter European markets would have to carry out additional drying and testing. It suggested a solution to bridge differences between countries. This would mean blending different types of biodiesel to come up with a final product which complies with regional specifications on quality and emissions.

The main differences between different ethanol supplies lies in the water content. This level varies because of differences in gasoline distribution and in the permitted concentrations of ethanol in gasoline. While the EU sets the lowest maximum threshold at 0.24% by volume, the highest limit in the US amounts to 1.0% by volume. Brazilian specifications do not include a maximum content of water so that levels reach up to 0.4 % by volume based on 99.6% by volume of minimum total alcohol content. Biodiesel specifications vary more than ethanol. This is due to different feedstock characteristics, current diesel fuel standards, differences in diesel engines used in each region and varying regulations for emissions applying to different engine types. (Tripartite Task Force Brazil, European Union and United States of America, 2007).

³¹ See http://www.nist.gov/public_affairs/releases/upload/biofuels_report.pdf.

ANNEX VIII: STATUS OF BIOETHANOL DEVELOPMENT IN SELECTED AFRICAN COUNTRIES

Angola

The Parliament of Angola approved a law in March 2010 calling for bioethanol and biodiesel to be blended with fossil fuels although it did not specify how much or set deadlines (Biofuels Watch, 2010). The law also established that international companies investing in biofuels should sell part of the biofuel produced to Sonangol (State Oil Company of Angola) and enable the availability of water and medical services to locals. In addition, the law stated that only marginal land can be dedicated to biofuels production.

Ethiopia

Ethiopia issued a Biofuels Development and Utilisation Strategy in 2007 reflecting the main principles of the Ethiopian policy on land tenure (Secretariat of the Roundtable on Sustainable Biofuels, 2012). Such strategy seemed to close key gaps for the sustainable development of biofuels. The country introduced an E5 mandatory blend in 2010, increasing it to E10 in March 2011. Between 2008 and 2012 around 32.8 million litres of fuel ethanol was produced, saving around USD 25 million by blending anhydrous bioethanol with gasoline is planning to produce 128 million litres per year. The Biofuels Strategy also discussed the imports of flex-fuel vehicles, the implementation of guidelines for replacing kerosene for cooking, a boost to ethanol cookstove manufacturing and market formation to export bioethanol.

Kenya

Kenya has been considering biofuels since 2004 when a National Biofuel Committee was established primarily only focused on devising a biodiesel strategy. In 2009, a bioethanol strategy was formulated, and a National Biofuel Strategy was drafted in 2010. The national strategy included report mapping and zoning for various suitable feedstocks to address the sustainability of biofuels production in the country. Some prospects for bioethanol production emerged at the end of 2011 through the preferential trade terms on sugar agreed with other producers within the Common Market for Eastern and Southern Africa.

Malawi

Malawi launched a regulation under the Malawi Energy Authority for E10 mandatory blending. The goal of the regulation was to consolidate the blending programme which had taken place since 1982. Historically, fuel bioethanol was produced according to the size of the potable and industrial ethanol market, and the blending percentage was established according to market needs.

Mali

Mali was the location for some small-scale jatropha projects, and a biofuel strategy was launched in 2009. There has been a large greenfield project (financed by AfDB) for sugarcane called the Markala project. It is 70% owned by Illovo Sugar, a South African company.

Mauritius

Mauritius has interesting experience in promoting cogeneration from bagasse. This has been achieved over a continuous period since 1985 by offering tax-free revenues for bagasse and electricity, capital allowance on investment, export duty rebate on bagasse savings and pricing policies. The country has been the largest African, Caribbean and Pacific sugar exporter, selling around 90% of its production to the EU, and has therefore been significantly affected by EU sugar reform. This made the industry invest in restructuring the sector to improve economies of scale by implementing a ten-year action plan to centralise production at four mills and by clustering smallholder farmers. On August 2010, the Minister of Finance approved a policy to encourage local value addition in the form of E10 fuel and favour the production of anhydrous bioethanol by levying an environmental fee on exports of molasses from 2012.

Mozambique

The Mozambique government conducted an evaluation of biofuels in 2007. The focus was on environmental, technical and socioeconomic feasibility including regulation, mapping, zoning and crop selection over 11 million hectares of land suitable for biofuels production. Its emphasis was on coconut palm, jatropha, sorghum and sugarcane. On March 2009, the government approved the National Biofuels Policy and Strategy (Resolution No. 22/2009) setting up a framework for the future deployment of a biofuels industry. It included a strategy to combat poverty, promote energy and food security, and establish social and environmental parameters for biofuels production and use. In June 2011, the executive issued a decree regulating nationwide biofuel blends of E10 and B3 by 2015 (Netherlands Agency, 2014). A Memorandum of Understanding was signed with Brazil to promote co-operation and technical exchanges, and a feasibility study for sustainable production of biofuels is now under way.

Nigeria

The Nigerian Biofuel Policy and Incentives was released in 2007 (Ohimain, 2013). The Nigerian National Petroleum Corporation signed a Memorandum of Understanding with Brazilian oil company Petrobras for the transfer of bioethanol production and market expertise (LatinPetroleum, 2007). The Nigerian National Petroleum Corporation goal was to develop a bioethanol industry based on sugarcane and cassava for E10 national blending and exporting. Biodiesel production would focus on palm oil and jatropha. The government offered a number of incentives to stimulate Nigeria's biofuel industry, and a 60,000 hectare pilot project for bioethanol production was proposed.

South Africa

South Africa introduced its Biofuels Industrial Strategy in 2007. This included a target of 2% penetration within five years for biodiesel made from soybean, sunflower or canola or bioethanol from sugar beet or sugarcane. However, no mandates were introduced. The strategy also included strong socioeconomic objectives aimed at stimulating rural development and reducing poverty. In addition, it recommended investment in R&D to develop second generation biofuels because the country has relatively little land availability. Regulations on the Mandatory Blending of Biofuels with Petrol and Diesel are currently enacted (OECD/International Energy Agency-IRENA Joint Policies and Measures Database, 2016a).

United Republic of Tanzania

The United Republic of Tanzania published its Guidelines for Sustainable Liquid Biofuels Development³² in 2011. By that year, the country had four main sugar mills, all of which had plans for investment and expansion. However, priority was given to sugar production (the country was a net importer) and better efficiency by clustering smallholder farms to improve agricultural practices and logistics management.

Zambia

Zambia began debating a biofuels policy in 2006 with the creation of the Energy Regulation Commission. By the end of 2008, the commission had set biofuel standards although the government has not managed to address the lack of clarity on its export focus or domestic energy provision. Through the Sixth National Development Plan, the Ministry of Energy and Water Development announced a strategy in which the government would purchase all bioethanol produced and setting blending ratios of up to 10% bioethanol. Producers could also sell bioethanol to users as long as it complied with the standards and specifications. Zambia Sugar reached an export figure of 10% of production to the EU under preferential sugar agreements while 50% was consumed in Zambia and the remainder exported to other African countries. In 2010, an agreement with the Zambia government led to an expansion of the existing sugarcane area.

Zimbabwe

Zimbabwe adopted ethanol petrol blending regulations (OECD/International Energy Agency-IRENA Joint Policies and Measures Database, 2016b). Two mills, known as Triangle Sugar and Hippo Valley, were owned by South African agribusiness company Tongaat Hulett. A recovery programme was in place to improve cane yields and re-establish cane lands in order to restore the 600,000 tonnes annual installed capacity for sugar production.³³ In 2010, the Triangle mill resumed ethanol production after refurbishing its ethanol plant with a capacity of 27 million litres per year. The government of Zimbabwe also initiated the Chisumbanje sugar/bioethanol project based on 10,000 hectares of sugarcane under irrigation. This was a joint venture between Green Fuel company, Agricultural and Rural Development Authority, and Macdom investment. In March 2012, Green Fuel halted production because it was running out of storage space. It had stocks of 10 million litres of fuel ethanol although it has sold only 2 million litres since October 2011. Some oil companies were only selling E10 at a few of their filling stations, and this too was a problem.

³²

http://www.tzdpd.or.tz/fileadmin/documents/dpg_internal/dpg_working_groups_clusters/cluster_1/Energy_and_Minerals/Key_Documents/Strategy/Liquid_Biofuel_Strategy.pdf.

³³In 2010 sugar production was 335,000 tonnes per year.



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