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Report on biofuels in Brazil and in Africa

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Introduction

Regarding biofuels production, Brazil has several advantages due to its large territory, geographical position, solar radiation and abundant water resources. To foster the development of biofuels, the Brazilian government launched an incentive called *Brazilian National Alcohol Program.* Thus, we observed an increase of the sugarcane production (80 million Mg in 1970 to 734 million Mg in 2011), an increase of the harvested area (1.7 to 9.6 million hectares in 2006), and an increase of sugarcane yield. Nowadays, Brazil is the largest world cane producer and the main exporter of fuel ethanol. The aim of this report is to bring an overview of Brazilian biofuel programs evolution, specially, regard to **sugarcane ethanol water use** along last century till now. It is also a way to see if the Brazilian model can be extended in African countries and how they can implement the solutions.

I- Brazilian biofuel programs

The interest of ethanol is due to the **surplus of sugar** and to **the heavy burden of gasoline imports**. Thus, Brazilian government launched **the National Alcohol Program** in 1975. In 2003, the flexible-fuel vehicles (**FFV)** were launched (in Brazil, they are able to run with any fuel mix between gasohol - 18 to 25% ethanol, volume basis - and pure hydrated ethanol - 100%) and since then have been the main driving force of the domestic consumption. The FFV represents **more than 90% of the new cars sold.** Today, **both anhydrous and hydrated ethanol**s are produced in large quantities. Hydrated ethanol is used directly in FFV cars, whereas anhydrous ethanol can be used to produce gasohol. **Ethanol production** (anhydrous and hydrated) achieves **22.7 million cubic meters** in the 2011/2012 season.

Another program was launched in 2004: **the National Program of Biodiesel Production and Use** (PNPB) based on the production from different oleaginous plants (oil seeds). **Soybean is currently the single-largest source for biodiesel production** (77%) followed by animal tallow (16%) and cotton seed (4%) (ANP, 2013)
For 2013, the total Brazilian biodiesel production is forecasted at **2.8 billion liters**, assuming that **the mandatory biodiesel mixture remains unchanged at five percent**.

Ethanol production in Brazil was driven primarily by **economic factors** whereas **biodiesel production** involved at least three driving forces: ***economic***, by the influence of oil prices; ***social***, by the need to generate jobs and new opportunities for permanent settlement of families in the countryside and ***environmental*** by the production of a sustainable, renewable and friendly fuel.

1) Water use for cane production

In tropical areas, the combination of **high solar energy incidence with abundant rainfall** brings favorable conditions for bioenergy production. Besides, the availability of areas for agro-energy activities, **without reducing the farm area for food production**, highlights the Brazilian advantage regarding biofuel production. The best climate for growing sugarcane is a warm and wet climate to encourage germination and vegetative development.

The water availability plays an important role in cane production, as there is a straight correlation between **water consumption and yield**.
A way to assess the sugarcane water consumption: **the Water Productivity approach** (WP), the ratio between biomass produced per unit of evapotranspired water, to assess the amount of water used under rainfed and subsurface drip irrigation with and without nitrogen fertilization. The majority of the sugarcane plantations in Brazil are **rainfed.**
The Brazilian irrigation potential is estimated at 29 million ha, with only 10% effectively explored, including areas where irrigation can be developed and excluding areas of high ecological value. Regardless the application methods used, **sugarcane irrigation** can be divided into three groups: (1) "**salvage irrigation**", (2) "**supplementary irrigation**" and (3) "**full irrigation**".
However, this irrigation entails environmental problems such as soil salinization and fresh water resource depletion.
In Brazil, for supplementary and full irrigation, **the surface water** is the **main source for irrigation.**

2) Water use and effluent produced during industrial processes

The processing and converting of sugarcane to ethanol requires **large amounts of water**. This water is used mainly (about 87%) in four processes: *cane washing*; *juice evaporation*; *fermentation cooling* and *ethanol distillation condenser cooling*. Currently, **due to high reuse rates** that may reach 95%, the average water requirement of the sugarcane industry stays around **1.5 m3 Mg-1.**

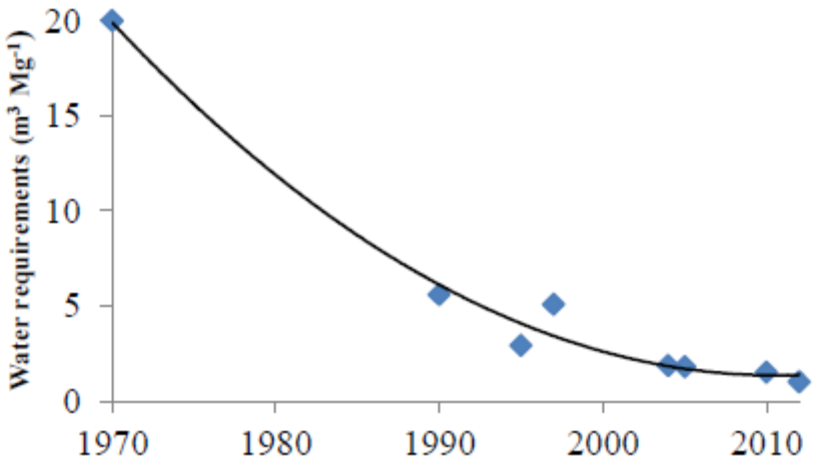


Figure 1: Evolution of sugarcane industry water requirements in Brazil

Besides, the industrial production of sugar and ethanol generates **large amounts of waste** with **impacts on the aquatic systems**, with the **vinasse** the most important waste. Now, the vinasse is recycled back to the sugarcane fields as **organic fertilizer.** The application of vinasse as a fertilizer adds a **significant amount of organic matter** to the soil and modifies the physical soil conditions, such as the infiltration capacity, water retention, formation of aggregates and the reduced susceptibility to erosion. The vinasse application is now **restricted**.

3) Deterioration of aquatic systems

Soil erosion from sugarcane may vary dramatically depending on many factors, such as the slope, the annual rainfall, the management and the harvesting system. **Vinasse discharge** in open water systems has disastrous effects on the **water quality**, due to the high temperature, **BOD** and **salt content level.**

II- Brazilian model in biogas

1) Production of biogas

Brazil has a large potential for biogas production, but today the biogas sector contributes only a very small part of the total renewable energy produced. The **production of electricity** from biomass corresponds to **8.5%** in the Brazilian electric grid. In Brazil there are 22 biogas power plants connected to the electric grid. The majority of biogas plants are installed on agricultural properties, processing residues, and at landfills.

Pig manure is especially interesting since it is available in large quantities. Indeed, Brazil produces three point three million tons of pork meat. In addition to pig manure, there are an increasing number of **households with sanitation services** which create an increased potential to produce biogas in **waste water treatment plants** (WWTP). A final important source for biogas production is **landfills.**

Plant type	Number of plants	Energy production (GWh/year)*
Sewage sludge	5	42
Biowaste	1	1
Agriculture	8	10
Industrial	2	248
Landfills	6	637
Total	**22**	**697**

* = Produced energy as electricity excluding efficiency losses.

<u>**Table 1**</u>: Status of biogas production used for electricity production in Brazil (values from 2013)

2) Utilization of biogas

The main part of the biogas is used for **electricity and heat production**, while biogas use as a **vehicle fuel** is rare. The biogas upgrading units for biomethane production and gas supply stations are available from experimental projects.

Utilisation type	GWh
Electricity	697
Heat	17*
Vehicle fuel	n.d.
Flare	n.d.

* Data collected with the cooperatives of western of Parana

Table 2: Utilization of biogas in Brazil (Values from 2013)

Biogas in Brazil has been developing strongly based on the use of organic waste produced in agriculture, urban areas and industries.

III- Biofuels in Africa

1) Presentation of biofuels

Currently, the most biofuels used for the transport sector are bioethanol and biodiesel which are liquid biofuels. There is also straight vegetable oil (SVO). In Africa, the **large-scale production of liquid biofuels** to substitute for imported fossil fuels **is just beginning.** The big problem is the **lack of biofuel policies** but it is changing with the high fuel prices.

a) Production

Biofuels are produced from any **biomass or animal fat** but actually only from a few of these products (feedstocks).
The condition is that the **concentration** of sugar, starches, or fats in the feedstock must be **high enough**.
There are two situations: the biomass produced per hectare is very high (the case of sugarcane); the concentration of sugar, starches, or oils is very high per unit (the case with many oilseeds, such as jatropha).

b) Technology

First-generation technology: referred to the production of biofuels from food crops

Examples: producing ethanol from sugar crops (sugarcane or sweet sorghum); producing biodiesel from animal fats or vegetable oils.

The process for producing ethanol is the ***fermentation*** of sugars and **depends of the feedstock** (difference between sugar crops and starchy crops).

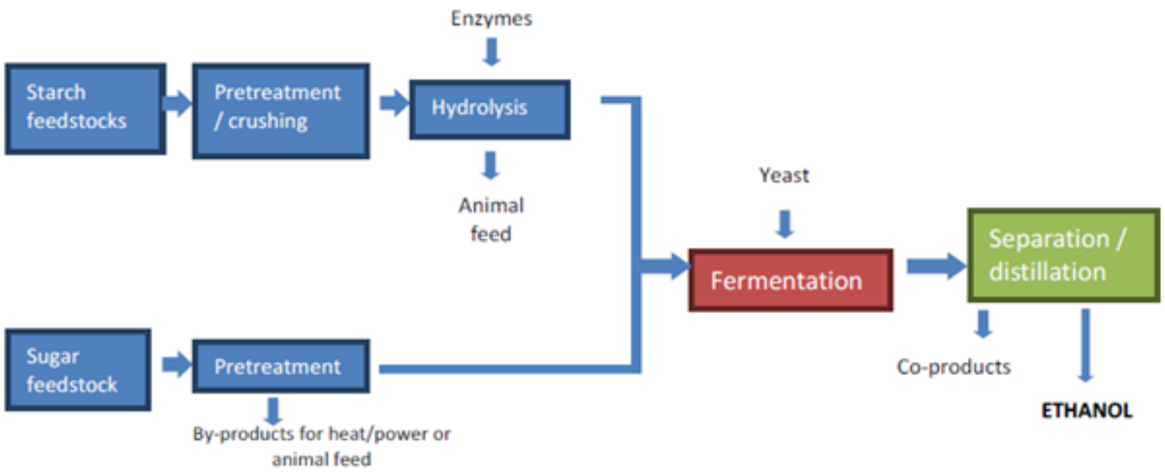


Figure 2: Conversion route for sugar and starch feedstocks for ethanol

The process for producing biodiesel from animal fats or vegetable oils is called ***transesterification*** (the fat or oil is mixed with alcohol and a catalyst to produce biodiesel). But the problem is that the quality of the biodiesel is linked to the kind of plants. (ex: automated plants where quality is no longer a problem)

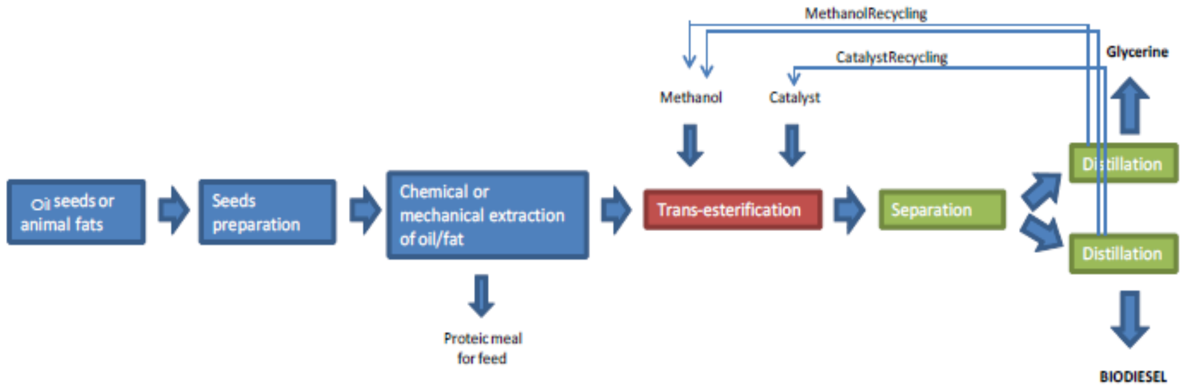


Figure 3: Conversion route for oilseeds and animal fats to biodiesel

Now two countries have a lot of experience in **biofuel production efficiency**: Brazil and the USA.
Examples: In the USA, there are new processing techniques that reduced input requirements

and improved process yields: **energy-saving technologies** such as the **reuse of liquefaction** and **scarification energy** for removing water from ethanol in the distillation column. It leads to 70% decline in the thermal and electrical energy used to produce ethanol.

<u>Second-generation technology</u>: Using different processes and a wide array of feedstocks (agricultural residue, timber waste, fast-growing grasses or trees)

The advantages are a reduction in GHG emissions and in land-use requirements, and less completion for land, food, fiber, and water. The problem is that currently this technology is **not used commercially**.

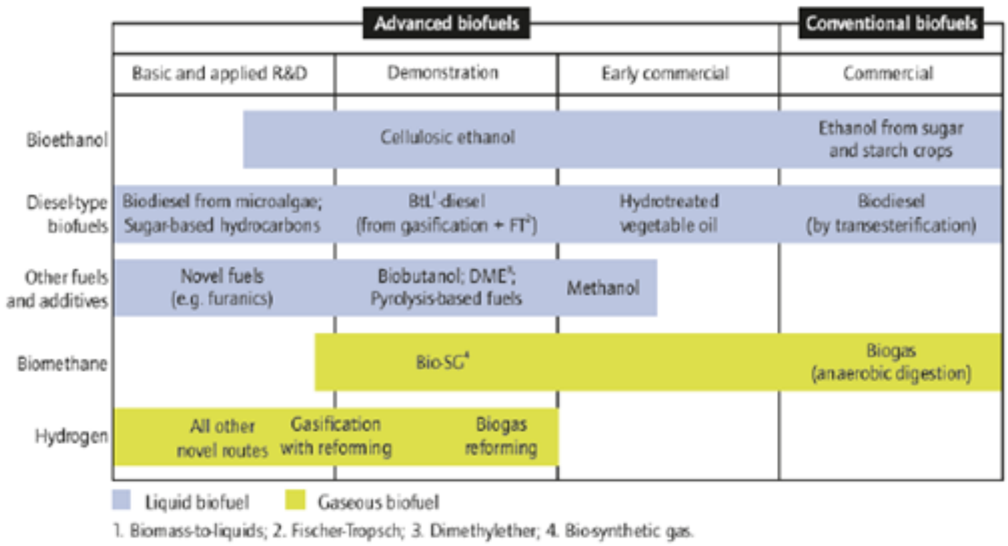
There are two different processing routes to produce biofuels from **lignocellulosic feedstocks:**

- Biochemical enzyme hydrolysis
- Thermochemical biomass to liquid
- Others …

The transition to integrated first and second-generation biofuel production will be **the key in the future** (first-generation production paths appear to offer natural transition to second-generation production).

<u>Example:</u> Sugarcane ethanol with the sugarcane residue (bagasse) as feedstock for the second-generation technology.

Third-generation technology: still at the R&D stage (advanced biofuels from algae)



Source: IEA 2011

Figure 4: Development status of common Second-generation biofuels and associated conversion technology

2) Feedstock for biofuels in Africa

The feedstocks which receive the greatest interests are **sugarcane or molasses** to produce ethanol and **jatropha** to produce biodiesel or to be used as SVO. Other promising feedstocks are harnessed such as **cassava and sweet sorghum** to produce ethanol, **oil palm** to produce biodiesel and **croton** to be used as SVO.
Sugarcane and molasses are considered as the **lowest-cost feedstocks** for biofuel production (primary feedstocks used in Brazil ethanol program).
The low-cost sugar-producing countries are Malawi, Swaziland, Zambia, Zimbabwe, and Mozambique.

Here a list of all the characteristics of the feedstocks used in Africa showing their advantages:

- Sugarcane : **High yields of biomass** per hectare, **easy process** (sugars fermented directly into ethanol), bagasse for powering the factory, easy progression-path to second-generation technology (since it is already transported to the factory as part of the sugar production process)

- Molasses: **Cheaper feedstock** than sugarcane juice because it has low opportunity costs in Africa and has high sugar content.

- Jatropha: **Not a food crop** well suited for biodiesel production, use as an SVO, used as a fertilizer thanks to the high concentration of nitrogen in the press cake, grow in degraded land. The problem is that yields are low and it entails high labor costs.

- Sweet sorghum: Providing human food from the grain and animal fodder from the leaves. Can be grown in dry or semiarid tropics as a rain-fed crop in areas with more than 700 ml of rainfall. It requires **less fertilizer, water, and labor than sugarcane** and is **planted from seeds that require less labor than planting sugarcane cuttings**. Advantage of mechanized sowing and harvesting. The drawback is that **the ethanol yield per ton of feedstock** for grain sorghum is **lower** than sugarcane. But it is **cost competitive** with sugarcane for ethanol production.

Interest: Used to **supplement** sugarcane.

- African oil palm: Grow in tropical parts of Africa (West Africa). Low cost production than soybean oil. It could become the **low-cost feedstock** for biodiesel in Africa. The major problem is the **environmental impact** with the clearing of tropical forests and **sustainability criteria** of importing countries met. Besides, **the oil palm fruit yields are low** compared to those of Southeast Asia. Largest African producers: Cameroon, Cote d'Ivoire, Ghana, Nigeria.

- Cassava: Potential of **low-cost feedstock** for ethanol production in Africa. **Better suited to smallholder production** than sugarcane. Drought tolerant can grow on marginal soils and **continuous harvesting** due to the absence of maturation of the crops.
  Higher yields (especially in Nigeria the first producer). The problem comes from the need to use a mix of plantation and outgrower production for the ethanol production

- Croton: Cake not toxic like jatropha and can be used as feed. **Less labor intensive** than harvesting jatropha. The problem is that the crop is unproven as biofuel. But potential in remote areas such as Tanzania, where importing diesel is expensive because of high transport costs.

3) Yields of biofuels per hectare

It is a **criterion** to assess biofuel feedstocks. According to this criterion, **sugarcane, oil palm and cassava** rank highest among crops that could be used in Africa.

4) By-products of biofuel production

Biofuel production results in large quantities of **by-products that can add economic value** or **become waste** that must be disposed. However, in African countries, domestic economies won't support the profitable use of these by-products.

Examples of by-products

- **Sugar crops** produce by-products such as **bagasse.** Bagasse is burned to **power the factory** and can be used to produce **surplus electricity**. It is also used in the manufacture of particleboard for construction.
- **Starchy crops** produce residues that can be **used in feed** (used as animal or poultry feed for instance).
- **Carbon dioxide** is also a by-product of ethanol production during the fermentation stage.
- **Cogeneration of electricity** for sale to the power grid is an important by-product of ethanol production from sugar. It can be an additional source of revenue for the producers, rural power supplies. It's the case in Mauritius. But the capital cost of equipment is high.
- **Glycerol** is a by-product of the transesterification process that produces biodiesel. Once refined, glycerol can be used in food products, cosmetics, toiletries, toothpaste, explosives, drugs, animal feed, plasticizers, emulsifiers and tobacco. Only, a matter came from the dumping into waterways and fields in the USA due to the surge of biodiesel production since the discharges are hazardous to fish and birds and can alter existing soil nutrients.
- **Press cake** is the second major by-product of biodiesel or SVO and comes from the extraction of oil from the oilseed. Can be used for animal feed, fertilizer and other purposes (it depends of the feedstock).

5) Consumption

One of the potentially substantial uses of **ethanol** in African countries is for **home-cooking fuel** (gel fuel) as an alternative to charcoal or kerosene. The advantages of ethanol are a reduction of the pressure on forests and a health benefits by reducing indoor air pollution

a) Biofuels as transport fuel

The main demand for biofuels is for use as liquid transport fuels:

- As fuel enhancers
- As fossil fuel substitute
- To satisfy government use mandates or environmental regulations

The demand for fuel enhancers depend on the age and technology of the vehicle fleet.

The demand for biofuels as fossil fuel substitutes depends on the price of biofuels relative to the price of fossil fuels.
From the Brazilian experience, it has shown that ethanol blends of up to **26%** ethanol with gasoline can be used in convential vehicles without modification.

Consumption mandates could specify the share of liquid transport fuels that must come from renewable energy.

b) The effect of biofuels on food crop prices

The effect of biofuels on food crop prices **depends on the feedstock** used to produce the biofuels.
Besides, biofuel mandates can greatly affect global food crop prices when they are raised quickly or established at high levels.

c) Greehouse gas emissions, carbon credits and biofuels

There are possibilities to get carbon credits and thus to mitigate the climate change.

Example: Wastewater treatment at an ethanol plant in Phillipines (the project avoids the emission of methane from the **ethanol plant's wastewater treatment system** for vinasse, the wastewater effluent of ethanol plants.

6) Technology transfer and capacity development

Technology transfer and capacity development are by-products of investment activities in developing countries. Technology transfer is considered as very important because it should bring developmental benefits of foreign investment. We have several types of technology transfer:

- Technology to design, construct and operate a biofuels conversion plant.
- Agricultural technology for farming (large and small scale) and producing biofuels feedstock.
- Technology and know-how to deal with local and international markets including building up the necessary infrastructure (rural roads, silos, harbours).
- Technology to measure the results; for example Paraguay has an obligatory blending with biofuels but does not control this regulation so that consequently the biofuels blending regulation exists on the paper only.

The 1st generation biofuels technology is long off-patents and therefore the intellectual property rights do not play an important role any longer and do not hamper technology transfer. The 2nd generation biofuels are much more complex and even if the technology is not so difficult to understand, the application is very expensive in respect to the investment as well as concerning the running cost (enzymes). The intellectual property rights for the 2^{nd} generation biofuels play an important role with many registered patents.
Given the status of the technology and investment requirements to establish processing plants, it is according to UNEP **unlikely that second generation biofuels production can be achieved in developing countries in the coming decade.**

However, the potential development of second generation biofuels in African countries could be approached via the **biofuel feedstock production**. Investment in feedstock production could offer an option for developing countries to profit from the growing biomass market for second-generation biofuels production outside their borders, provided that long distance transport infrastructure is suitably developed.

7) Recommendations

a) Instruments for implementing bioenergy policies

➢ Guidelines and standards

The International Sustainability and Carbon Certification System developed the first internationally recognized certification system for biomass. More recently, the work of FAO/GBEP can serve as model.

➢ Awareness

In most African countries, resources, such as agro-processing residues and urban waste, are not recognized as sources of energy, but rather burned in open fields as a way to avoid disposal costs. The small amount of bioenergy that is mobilized or available at household level is wasted through inefficient consumption devices such as the traditional kilns and inadequate behaviour.

b) Implementation strategies

Africa is home to substantial bioenergy resources and potentials, though the resources are mostly under developed (agri-processing and household wastes) or poorly used (inefficient energy conversion process and poor cooking devices). There is urgent need to formulate policies that can mobilize resources and stakeholders to make a proper use of the resources to the benefit of humans and the ecosystems. The following recommendations at country level are proposed:

Assess national biomass resources through the:
- Adoption of coherent biomass assessment approach
- Application of sustainability criteria
- Consideration of cross-country effects

Implement national bioenergy policies taking into consideration:

- Policy impact on actual market and industry development; foods, gender, environment, biodiversity
- Cost-effectiveness of bioenergy strategy and support schemes
- Efficiency of administrative procedures
- Information and integration of stakeholders
- Quality standards and qualification of key actors

Monitor national bioenergy markets and policies by applying:

- Effective approach to market monitoring
- Effective approach to policy performance measurement
- Effective approach to sustainability guarantee with a proper reward and penalty system.

Conclusion

Biofuels can be produced from a wide variety of crops but sugarcane and molasses to produce ethanol and jatropha to produce biodiesel are attracting the most interest in Africa. The technology for producing ethanol has been refined by Brazil and can be readily adapted to Africa. However, the interest in biofuel production is a recent phenomenon in Africa and the basic researches to improve the varieties of feedstock have not been done. That's one of the point that Africa will have to look into.

Another thing is the improvement in the technology of biofuel production. Bridging the gap between the first-generation and the second-generation technology is the key to the future of biofuels in the African region.

We have also seen the economic interest of the biofuel by-products such as bagasse, the sugarcane residue, which can be used to produce surplus electricity that can be sold to the national grid.

Eventually, the carbon credits that could become an important source of revenue in the future since the carbon market has grown rapidly the last few years.

Efforts in these fields and to regulate the biofuel markets will be rentable for the African countries.

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