FEASIBILITY STUDY FOR THE PRODUCTION OF MODERN BIOFUELS AND ELABORATION OF A PROMOTION STRATEGY IN THE DEMOCRATIC REPUBLIC OF BENIN

Maurizio Cocchi[1], Valerie Bennett[1], Giuliano Grassi[2], Aldo Nardi[3], Alain Onibon[3], Sergio Trindade[4], Angela Grassi[1]
[1]Eta-Florence Renewable Energies, Piazza Savonaola 10, Florence, Italy
E-mail: maurizio.cocchi@etaflorence.it
[2]EUBIA, Rue d'Arlon, 63-65, Brussels, Belgium
[3]Private consultant
[4]SE2T International, Ltd., 1A Dickel Road, Scarsdale, NY 10583 USA

ABSTRACT: A technical-economic feasibility study for the production of bioethanol and biodiesel is currently being developed by ETA Renewable Energies on behalf of the Ministry of Mines, Energy and Water of the Democratic Republic of Benin, with the purpose of elaborating a strategy for the production and use of modern biofuels.
The study is divided into two distinct phases: the feasibility study on the production of biofuels, and the subsequent definition of a National Biofuels Strategy. The first phase is a technical, financial, economic, institutional and environmental feasibility study. After an initial overview of worldwide biofuels experience, a more specific look at the possibility of producing biofuels in Benin for internal use and for export is explored; the technical and economic production potential from already available and new possible feedstock will be determined, based on the existing agricultural, environmental and social conditions. Based on the outcome of the first phase, the second phase of the study will be focused on the elaboration of a National Biofuels Strategy, whose purpose will be to develop a supply and production chain for biofuels and an action plan to coordinate public and private activities in this sector. Finally, a consultation process will be implemented, with the purpose of involving all relevant national and international stakeholders in the validation of the proposed strategy.
Keywords: bio-energy complex, bio-energy policy, energy crops, bioethanol, biodiesel

The elaboration of a National Biofuel Program in Benin occurs in a context of heavy energy crisis for the country, characterized by continuous power shortages and constant increases of fossil fuel prices,

In 2007 a feasibility study was co-financed by DGE (Direction Génerale Energie) of the Ministry of Mines, Energy and Water of Bénin and IDA, the International Development Agency of the World Bank, with the aim of assessing the opportunities and constraints and the market potential for the production of bioethanol and biodiesel in the country, and elaborating a promotion strategy and a Biofuel Action Plan for the country.

The project is being carried out by ETA Renewable Energies with the technical support of local and international experts and is divided in two phases.

The first phase was the implementation of a **preliminary feasibility study** which has investigated five main issues:

The ongoing experiences and current biofuel market trends in the world;

The assessment of market potential for biofuel (ethanol and biodiesel) in the two scenarios of national usage and export, as well as the techno-economic analysis of biofuel production from different feedstock the estimation of possible production costs and financial issues;

The identification and evaluation of possible equipments for the use of biofuels in households in order to reduce the use of traditional biomass and fossil fuels;

The analysis of environmental issues related to the production of biofuels;

The assessment of socio-economic issues and the identification of potential financing schemes.

Based on the findings and results of the first phase, the second phase, which is currently being developed, is the elaboration of a proposition for a national promotion strategy and a biofuel action plan.

The Democratic Republic of Benin is a member of UEMOA (the monetary union of West African countries)

which extends over a surface of 114.763 km2 and has a population of 7.833.744 people. As in many other developing countries, agriculture plays a vital role for the national economy, employing nearly 75% of active populations and contributing to 38% of GDP.

In 2005 the total energy consumption of the country was estimated in 2.256 kTOE, almost 50% of which was provided by traditional biomass (mainly for households needs), whereas fossil fuel accounted for 40% of the total energy demand.

Given the growing population and developing economy of the country, all economic sectors show a rising energy demand, transports in particular account for 23% of the total demand with an average growth rate of nearly 11% per year for gasoline and 7% per year for diesel (average 1999-2005).

Even though some recent prospects have shown some potential submarine oil reserves within the national boundaries of Benin in the Guinea Gulf, the demand for fossil fuel is almost completely satisfied by imports from surrounding countries and overseas. In the current scenario of rising oil prices, the country's expenditure for energy provision is a serious concern and poses a strong limit to the economic development of the nation.

In this context the introduction of mandatory biofuel blends in traditional fuels sold at pump stations could help to reduce fossil fuel imports.

Preliminary estimations showed that if the current growth rates for gasoline and diesel consumption remained steady, the introduction of E10 blends would require the production of nearly 90 millions litres of ethanol in 2010 up to more than 400 millions in 2025.

Similarly, a B10 blend would require the production of 20 millions litres in 2010 up to 45 million liters in 2025.

The introduction of biofuel blends would not only contribute to reduce fuel imports, but would also bring environmental benefits and provide a potential market for the development of a national agro-industrial sector, thus stimulating rural development and diversification of agricultural activities.

In terms of export potential, Benin could take advantage of the Cotonou Agreements signed in 2000 among USA/EU and ACP countries (Africa, Caribbean, Pacific), that would allow a total exemption of import tariffs for ethanol and biodiesel in U and USA. Moreover, the export of biofuels would help to increase the national reserves of international currencies and Euro in particular; as a general example in the current scenario of foreign currency exchange, (strong Euro and weak Dollar), the export to EU of 1 TOE of bioethanol (exchanged in Euro) could allow to fund the import of 1,5 to 2 TOE of gasoline (exchanged in $).

As several other African countries, Benin has a significant agricultural potential, largely still unexploited: the currently cultivated lands extend on a surface of around 2.500.000 ha but several studies indicated a potential of up to 8.300.000 ha of available arable lands. On the contrary, the development of the agricultural sector is limited by a general lack of infrastructures for logistic and irrigation (only 12.000 ha are currently irrigated despite the large availability of water resources), a low level of organization of farmers and difficulties in accessing fertilizers and improved plant varieties. Despite these limiting factors, the agricultural sector generally covers the country's food demand, the main food crops being cassava, maize, sorghum and groundnuts, whereas the two main cash crops for export are cotton and cashew nuts.

The introduction of E10 blends would demand the cultivation of around 20.000-25.000 ha of energy crops in 2010 up to 80.000-90.000 ha in 2025, whereas a B10 blend program would require 18 to 50.000 ha of land.

Benin's climate conditions vary among different regions, ranging from sub-equatorial climate in the South (1300-1500 mm of annual rainfall with two rainy season) to semi-arid conditions in the North (700 mm and one rainy season).

Based on these climatic conditions and on the current agricultural model, an assessment of the most suitable potential energy crops was performed.

As far as ethanol is concerned three main options were identified: sugarcane (*Saccharum officinarum*), sweet sorghum (*Sorghum bicolor*) and cassava (*Manihot esculenta*), whereas for biodiesel production, Jatropha (*Jatropha curcas*) seems the best option.

Sugarcane is certainly a suitable option for ethanol, well known worldwide, which could yield up to 6.000 litres per hectare if cultivated in the right conditions (preferably in the southern agro ecological zones with sub-equatorial climate and higher annual rainfall); moreover, ethanol from sugarcane has a very positive energy balance as the lignocellulosic biomass derived from the extraction of sugar from canes could be used for heat and power generation instead of fossil fuel. At present at least 4.000 to 5.000 hectares of sugarcane are cultivated in Benin in a single irrigated complex for the production of sugar.

Although sweet sorghum is not yet cultivated in Benin, traditional grain sorghum (which has similar cultivation techniques and requirements) is well introduced in the farming system, being an important food and fodder crop especially in the northern regions with semi-arid conditions. Sweet sorghum could represent a very promising feedstock for ethanol production: compared to sugarcane it has a shorter growth cycle (4-5 months instead of 12-18), it is an annual crop although under proper conditions it could be cultivated in two or even three cycles per year. Moreover it is a multifunctional crop, producing sugar juice in the stalks (around 18° Brix, up to 6-7 tons of sugar per hectare), grains (up to 5-6 t/ha) which could be used for food or ethanol production depending on local needs and lignocellulosic biomass, after juice extraction from the stalks (up to 20-25 tons per hectare d.m.) which could be used for heat and power generation or as fodder for livestock feeding.

As grain sorghum, sweet sorghum is well known for its adaptability to a wide range of soil and climate conditions and particularly tolerant to semi-arid climates: a preliminary comparison of crop's water requirements with rainfall distribution in time and space (performed with the use of CROPWAT, a software developed by FAO) revealed that for sugarcane irrigation would be necessary in most of the agro ecological zones, whereas the water demand of sweet sorghum at different growth stages could be generally met by rainfall, although supplementary irrigation would certainly increase and stabilize productivity. In optimal conditions the potential ethanol yield of sweet sorghum is comparable to that of sugarcane (more than 5.000 litres per hectare).

Cassava is widely cultivated throughout Benin and is an important food crop for the country, especially in rural areas; it is estimated that at least 68% of arable lands are suitable for this crop.

The recent implementation of a program for the development of roots and tubers (PDRT) aimed at introducing improved varieties and promoting more efficient cultivation techniques has led to a significant increase of cassava production and unitary yields in the last 6 years, which are now close to 20 t/ha of fresh roots. Cassava is adaptable to a wide variety of soils, has low water requirements and is quite tolerant to pests and diseases. A major advantage of cassava is the possibility of storing dried roots for several months before processing. Average ethanol yields could vary between 2.500 and 3.500 litres per hectare, and recent researches indicated a positive energy balance, around 3,5 units of bioenergy for each unit of fossil energy spent.

Despite these important advantages the study indicated that being a major food resource for the country, the use of cassava as feedstock for biofuel production should be carefully managed and planned, to avoid possible negative interactions with food price trends;

As far as oil crops for biodiesel are concerned, the study analyzed the availability of potential resources among the crops already widely cultivated in Benin, especially cotton oil (cotton is the country's main cash crop) and palm oil; the results of several interviews with local companies involved in the food oil industry revealed that the current production of edible oils in Benin is significantly lower than the demand for the food

market and a large part of the production is exported to other African countries (Nigeria in particular) at prices that are not competitive for the production of biodiesel; therefore a possible augmentation of palm oil or cotton oil production should be primarily addressed to cover the demand for the food market.

Jatropha is already cultivated in several rural areas of Benin, even though not at commercial scale; during the last year a local NGO (Geres) has started a project for the cultivation of local genotypes at village scale in the central regions. Well known for its adaptability to different soils and for its low water requirements, Jatropha could be successfully cultivated at commercial scale in most of the agro-ecological zones of Benin; nevertheless, a preliminary effort of research and development is needed before the implementation of large scale projects, with the purpose of identifying the best genotypes and cultivation techniques. In the immediate future, jatropha could represent an important resource for the implementation of several rural electrification projects through the establishment of village scale plantations.

As seen before the implementation of a program for the development and production of biofuels in Benin will require the cultivation of thousands of hectares of energy crops; for this reason the identification of an optimal agricultural development model will be necessary, in order to ensure a reliable and sustainable production of feedstock.

With regard to this issue several options could be adopted, each one having its advantages and disadvantages, from contract farming (already widely used for cotton cultivation), where the production of feedstock is managed by single or associate farmers through the negotiation of agreements with industrial counterparts, to the establishment of private complexes where the lands for the cultivation of the energy crops are privately owned and managed by large agro-industrial companies themselves.

A possible option for bioethanol production proposed in the study was the implementation of **integrated agro-industrial complexes** based on annual energy crops in rotation with food crops. An example of that would be a complex based on the cultivation of **sweet sorghum** and **cassava** in rotation with **soybean or groundnut**. The adoption of this model would have several advantages, such as:

- The minimization of the risk of food Vs fuel competition, since the feedstock for ethanol would be produced only inside the complex, whereas the current production of food commodities would not be diverted to energy use;
- The combined use of starch based and sugar based feedstock would allow to extend the period of operation of processing plants, thus allowing to reduce investment costs and unitary production costs;
- The possibility to build infrastructures for irrigation and logistics and to introduce mechanization;
- Food crops in rotation with energy crops would take advantage of the resources provided to the latter ones (irrigation, mechanization, residual fertility of soils etc.) thus increasing potential yields.

The integrated agro-industrial complex could represent a basis for the implementation of a modern biorefinery based on sweet sorghum, that could serve as an important driver for rural development and provide the following products to the rural populations:

- Green power;
- Heat for EtOH distillation and other uses (freezing/cooling);
- Bioethanol (for domestic uses and transport);
- Distillers's Dried Grains (DDGs) for animal feed;
- Agropellets (for sale or green power production);
- Liquid CO_2 (or solid ice);

And if needed also food:

- Grains;
- Liquid sugar (at very low cost).

An integrated approach to these three models (contract farming, agro-industrial complexes and village scale community managed plantations) would help to establish a balance between the need to achieve a high production capacity of cost competitive, high quality standardized biofuels (mainly through the adoption of the complex model at least at the beginning), and the need to promote rural development, farmer's entrepreneurship and organizational and productive capacity (mainly through contract farming and village scale plantations).

The results and findings of the feasibility study have provided a base for the formulation of a strategy document, which is currently under development and which will be address to policy makers, possible investors and all relevant stakeholders. The document will define the priorities and set a road map for the development of biofuel projects in Benin and will offer detailed principles for the set up of a national policy as well as an institutional and regulatory framework for the promotion and development of biofuel production and use.