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The prospects of developing Biofuels in Mali

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Abstract:
A biofuels race has emerged because of the increasing cost of oil. In parallel, a growing concern for environmental protection has been observed. The expansion of biofuel production has occurs concurrently with raising prices of the foodstuffs. Developing countries like Mali have seen this situation as an opportunity to reduce its dependency on oil imports and generate gains from biofuel production. This development strategy could put pressure on food security in the country. The government of Mali has developed a strategy to promote biofuels production particularly with jatropha. The economic and environmental stakes around this strategy are far from being negligible. In this paper, we provide an analysis of this sector with opportunities and risk of developing this sector.

Keyword: Biofuels, agriculture,
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Introduction

The year 2011 was marked in Mali by a sharp rise in prices of oil; this has forced the Malian authorities to consider liberalizing the energy sector both in terms of imports and for energy production. The strong dependence of the economy on energy imports has recently prompted the Malian authorities to establish a National Security Stock in petroleum products. The stock has a storage capacity equivalent to one month's consumption of major petroleum products (premium gasoline, diesel and butane). Mali is a net importer of energy imports energy amounting to 333 billion CFA francs in 2007 according to national energy authorities of Mali.

The energy consumption of Mali, in 2002, was 3.2 million tons oil equivalent (Mtoe). This consumption was and still is dominated by the biomass to a total value of 81% (mainly wood and charcoal). Also, the country is it strongly dependent on petroleum products imported via the ports of Abidjan (Ivory Coast) and Dakar (Senegal). These petroleum products account for 16% of the energy consumption. The average rates of annual increase in the hydrocarbons imports during the decade 1994-2003 were of approximately +33% for super gasoline, +4% for the regular gas and +13% for diesel fuel. In 2003, the estimates for national demand for hydrocarbons were estimated at one million tons in 2010, nearly 2 million in 2015 and more than 3 million tons in 2020.

As for electricity, its share was 3% in the national energy balance in 2003. In 2004, only 13% of the Malian population had access to electricity with strong disparities between urban area and rural area[5]. Moreover, this weak access is coupled with a weak share of renewable energies. However, Mali has a strong potential in this ambit with solar energy, the wind and bioenergies (pourghere, stems of cotton, etc). Specialized agencies such as NAPO (National Bureau of petroleum products) which is responsible for the creation of the national stock of petroleum products, AMARAP (Malian Agency for Radiation Protection) and AMADER (development agency of domestic energy and the rural energy) are working on development projects focusing on the use of solar energy throughout the country, as well as wind power. AMADER is also considering the production of 1050 MW to reduce the deficit of energy in rural areas through the development of hydropower sites, some of which are already operating (Félou 0.6 MW, 5.2 MW Sotuba; Sélingué 44 MW and 200 MW Manantali). It is only in 2006 that Mali has developed its national strategy for the development and promotion of biofuels over the period 2008 - 2023. The creation of the National Agency for the Development of the Biofuels (ANADEB) in 2009 is an essential element of this strategy.

The growing interest for biofuels in Mali has occurred in a context of constant price growth of various petroleum products. Moreover, concerns over the depletion of fossil fuel stocks and growing interest to increase energy security for the country have been prevalent concerns over the past few years. The world trend to bias policies toward greener energy is also a factor affecting the sector.

In Mali, there are two (2) types of biofuels namely, the oil based biofuel (or biodiesel) or oilseeds primarily produced from pourghere in the region of Koulikoro and alcohol based biofuel primarily produced from sugar cane by the sugar company SUKALA.

[5] See Boccanfuso et al (2009) for a detailed analysis of distribution coverage of the electricity grid in Mali.

Our study describes the main economic and social stakes of the biofuels in Mali. In the first part, we present the situation and describe the development prospects of the biofuels. For this purpose, we examine successively, the level of investment, production and marketing of biofuels and by-products followed by the potential roles of the biofuels. This last point draws mainly from policies and priorities in with respect to food security. We continue with the competitiveness of biofuels in Mali and then present some legislative and regulatory elements of production and consumption of biofuels in the country. Thereafter, we present the prospects for and the research and development ongoing for biofuels in Mali and move on with the prospects for growth of the biofuels in Mali.

In the second part of the paper, we present and superficial economic evaluation of biofuels technologies in Mali. Here, we put emphasis on the costs and benefits, the various varieties of jatropha, the structures of the costs according to the varieties, the competitiveness of the biofuels and then compare their competitiveness.

1. Statement of the situation and prospects

The energy context in Mali is characterized by a prevalence of the biomass energy (charcoal, firewood, vegetation waste, etc) in the energy balance and a strong dependence from the rest of the world for hydrocarbons. Moreover, the conventional electric grig has a very low level of coverage coupled with a marginal use of renewable energies (solar, wind and hydroelectricity) and alternative energies using the biomass (biogas, briquettes, oil of pourghere, ethanol, freezing fuel).

During the 2004-2007 period, petroleum imports grew at an annual rate of 5.7% (see table 1.1). Among these products, fuel-oil that represent a small share of imports, experienced a strong growth of 102.3% over the period. Diesel fuel which accounts for the largest share of imports grew at a rate of 19.2% during the same period. Gas and Jet A1/Argas also grew respectively at rates of 4 and 3%. On the other hand, imports of DDO and lampant oil strongly decreased (-25 and -24%).

Table 1 Imports of oil products (metric tons)

	2004	2005	2006	2007	Accroissement annuel moyen
Gas (regular and super)	103 729	103 472	102 726	117 664	4.29%
Diesel	239 533	354 467	410 356	405 769	19.21%
Lampant Oil	36 166	31 267	31 650	16 129	-23.60%
Jet A1/Argas	19 758	23 875	20 245	21 790	3.32%
DDO	121 094	39 720	34 607	51 223	-24.93%
Fuel-oil	181	659	1 763	1 498	102.28%
Total	**520 461**	**553 460**	**601 347**	**614 073**	**5.67%**

Source : République du Mali (2008)

The total cost of these imports was 260 billion fcfa in 2006 and 242 billion fcfa in 2007.

Since 2006, Mali also implemented an energy sector reform by setting up a national strategy for the development of the biofuels. This reform resulted in the creation of the national agency for the development of the biofuels (ANADEB), the design of the national energy policy and the setting-up of a program for promotion of pourghere plant. In 2007, the

government signed an important agreement (120 million Euros) for an ambitious project on agro-fuels production. According to the Global Exchange for Social Investment (GEXSI 2008): "Initially, very few projects supported by this program up to 2008 exceeded two years in length". But, the situation has evolved since then. The main support for jatropha plantation today is provided to "Foundation Mali Biocarburant", which is well established organization and not a simple project. Many question if this sudden enthusiasm for the development of biofuels will not create a risk for food security that is already fragile in the country. This issue has been a hot issue on policy circles of many developing country since the food crisis of 2007-2008.

According to Diallo et al (2010) in a study on the transmission of food prices in West Africa we learned that most of the price increases recorded have not had the same impact in all countries of the sub-region. Indeed, for Mali, the rising food prices recorded during the period 2007-2008 was tempered by many factors, including the depreciation of the dollar against the CFA (through the fixed parity with the euro). As illustrated in Boccanfuso and Savard (2011), the farmers benefited from the increased food prices and the government implemented measures such as reduction in import duties and taxes to absorb part of the price increase.

Mali has great potential in renewable energies. First, solar energy has a potential to produce between 5 and 7 kwh/ m^2/day. Wind power has a potential of 1-3 m/s in the Soudanan zone and 3-6 m/s in the Sahelan and Saharan zones. Mali also has some experiences with biofuels since the first experience dates back to 1942 (Semake 2007). The risks of oil shortages during the war were at the origins of this experience. In 1990, a new experience was undertaken with a biofuel project supported by the German cooperation agency. A major step was then taken in the development of the sector in May 2005 with the inauguration of an electrical power plant powered by biodiesel produced from jatropha in the rural commune of Kéleya.

The issues and concerns raised previously with the development of biofuels are certainly legitimate as a certain number of challenges are related to the development of this type of energy. These challenges are on the one hand economic (reducing the financial burden on the current account balance with high imports of hydrocarbons, poverty reduction by generating wealth and employment, problems of profitability/competitiveness and volatility of the markets. In the last decade, Mali has stabilized its macroeconomic balances and has improved productivity but these positive elements are somewhat offset by the structural weaknesses in World Bank (2005). In addition to the economic issues we can add the environmental ones. In this respect, we can mention the potential of reducing greenhouse gases, reduction in deforestation, fight against erosion and soils enrichment through the sub-products among others.

In addition to these challenges, the development of biofuels, the sector is faced with important obstacles of institutional, technical and social nature. As institutional constraints, one can highlight the large number of actors, the lack of coordination and the low level of organization of the actors active in the sector. On the technical front, the sector is faced with a low productivity of capital, the appropriation of land by foreign investors who have been expropriating traditional family exploitations. The social obstacles consist mainly in the limits of the local knowledge and in the risk of breaking up family units. This last problem is more acute for very small-scaled farming exploitations.

2. Investment, production, consumption and marketing of biofuels and by-products

Mali has a long experience with the production of pourghere. Indeed, this culture was introduced in Mali around 1940 by the Office du Niger. Then, it was popularized by the German cooperation (GTZ) through the *Compagnie malienne pour le développement des textiles* (CMDT) and the *Office de développement rural* (ODR) to fight against soil erosion. It was cultivated in the form of hedges used as enclosure for various crops such as cereals and vegetables. Today, the total perimeter of these hedges of jatropha reaches over 10 000 km with an annual increase rate of 2 000 km (approximately 2 to 15 km per village), which represents a production potential of 1.7 million liters oil per annum.

It is important to highlight that the hedge plantations significantly increased by 76% during the 2000-2007 period going from 17 000 km to 30 000 km. Based on a hypothesis of productivity of 2 kg seeds per linear meter of hedges, the production potential increased by 34000 tons to 60000 tons in the country during this period. In 2007, in addition to the hedges, 2000 ha were planted as part of a biofuel project. The model in Mali (5000 hectares already in place) is 1000 plants per hectare. This surface allows for production of 1 ton of jatropha seeds + 1.5 ton on average per hectare for associated food crop (mostly maize or sorgho). In 2009, the total cultivated surface reached 2643 ha (Table 2), in the four main production zones which are Kayes, Koulikoro and Sikasso (zones of Garalo and Koutiala). The first place is occupied by Kayes which is linked to its history jatropha hedges cultivation. Koulikoro holds the second place with a significant part held by Malibiocarburants company.

Table 2 Surface of cultivated pourghere

Zones	Surface (ha)	%
Kayes	1 013	38
Koulikoro	900	34
Garalo	430	16
Koutiala	300	12
Total	**2 643**	**100**

Source: Pallière and al. (2009)

In these four zones, 3547 producers have been identified and their plants will become ripe in 3 years. A research project in the village of Falan estimated at more than 2000 liters, the oil production in 1994. Whatever the jatropha sub product, the output more than doubled between 1992 and 1994 (Table 3), under the impetus of GTZ which supported the producers of jatropha and more specifically the women producers of the village.

Table 3 Production of oil of pourghere in Falan

	1992	1993	1994	Total	Average annual increase
Crude oil (liters)	235	1 236	1 204	2 675	126%
Pure oil (liters)	199	947	957	2 103	119%
Sediment (kg)	30	260	225	515	174%

Source: Reinhard Henning and al. (1994)

Another research in the village of Keleya in 2002 produced similar encouraging results. The support project had important socio-economic impacts. We can summarize the impact with the following elements: 10000 people having access to electricity with 400 connections to the

local electrical grid. The electric supply had a capacity of 300 kilowatts for 1000 ha of jatropha plantations. The production of 9000 tons per year was sufficient to respond to the energy needs. In addition to the energy production, the plantation offered a good protection of soils against erosion.

In Koulikoro, 1017 producers were identified among which 207 are women. They are orginized in 12 cooperatives within the local union of jatropha producers cooperative (l'Union locale des sociétés coopératives des producteurs de pourghère-ULSPP). These producers have planted 2000 ha and plan to increase the cultivated surface to 5000 ha by 2012. ULSPP also benefits from carbon credits funded by the United Nation Clean Development Mechanism (CDM) fund. The CDM is a fund established as part of the implementation of the Kyoto protocol and it aims to reduce green house gas (GHG) emissions with the use of tradable carbon credit. The program allows countries that cannot achieve their Kyoto objectives, to buy carbon credits or to create new credits by funding projects that will reduce GHG. The carbon credit is seen as a key element that will promote the development of biofuel in Mali. Besides the region of Koulikoro and Kéléya, jatropha is produced in the following regions, Kita, Dioïla, Ouélessébougou, Garalo and Bougouni.

Three methods of jatropha plantation are used namely; direct sowing, the cutting and the out planting (Figure 1). The first method is relatively simple and it is the least expensive. As for the second method, it allows a fast development of the plant, the seedlings being able to give fruits at the end of the first year. Out planting can prove to be expensive with the installation of the seedbeds and the transportation costs of the seedlings to the field. With the availability of quality seeds, the production of seeds will occur only 2 to 3 years after the sowings. However this third method seems to be favored by the biofuel processors since this technique lowers the ratio of waste and offer higher quality control at the processing plant.

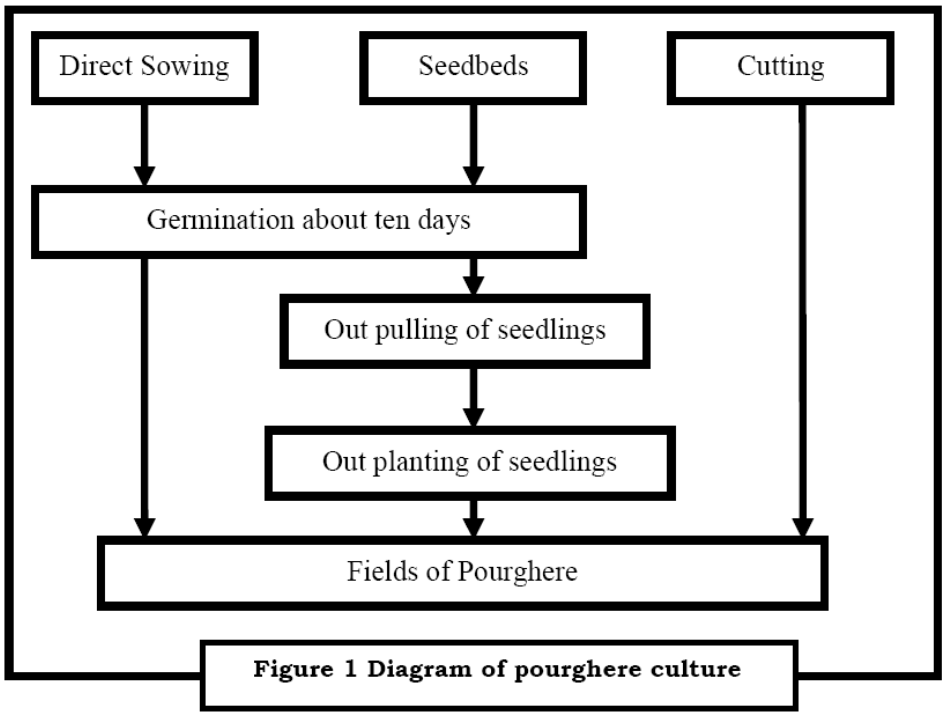

Figure 1 Diagram of pourghere culture

As was mentioned, jatropha can be planted in full field. In other words, it is possible to plant a field of jatropha with spaces of 3 m between the seedlings. This technique makes it possible to insert other crops between the seedlings like groundnut, niebe among others. As we have stated also, the jatropha plant is often planted in form of hedges (for the protection and the delimitation of parcels).

Whatever technique used, jatropha requires one week to germinate. After two to three months, the young plants (30-50 cm in height) are then replanted with spacing of 2*2cm or of 5*2cm for respectively 2500 and 2000 plants per ha. The pruning of branches (removal of small branches) is done 15 to 20 days after replanting. A second pruning is done after 2 years of growth. The plant can survive in a very stern environment albeit; damage by crickets, rates and bats are relatively common.

In Mali, oil is extracted using presses (by a Sundhara press or a Bagani press) and applying cold pressure. This extracted oil is directly filtered. It can be conserved for over a year when it is preserved from the light. The Bagani press is currently manufactured by the central military Workshops of Markala (AMC). Lastly, a new technology of press called “Nieleni press" is an invention of Carl Bienlenberg and has been conceived for the treatment of small quantities of seeds (Henning and al (1994)). It should be noted that these presses are available on national and regional (West Africa) markets.

Today, the density by hectare is established at 2500 seedlings for a production going from 0.5 tons the first year to 10 tons for the fifth year and onwards. The producers receive between 17 and 42 fcfa/kg and the market price for processors between 75 and 90 fcfa. The oil yield of the plant is 37% and oil is sold for 300 fcfa the liter. To respond to the low level of structure and organization for the distribution and marketing of biofuels, the actors plan the creation of new biodiesel sale stations in the medium to long term.

The continuous development of jatropha production and transformation of its seeds into biofuels is done in the context of the following objectives. First, the reduction in the oil import bill to reduce the country’s energy dependence. This objective will help improve the country’s trade balance. Second, the electrification of villages resulting from development of decentralized processing plants. Third, the creation of new agricultural sector with relatively well paid jobs. This could contribute in achieving poverty reduction goals and reducing inequalities.

3. Potential roles of the biofuels according to the policies and priorities on the food availabilities

One of the major challenges of the biofuels race is the risk to compromise food security because the pressure on arable land with intended use for the production of cereal for human consumption. Indeed, the risk is great to see substitution in land use to produce biofuels whcih could have dramatic effects in famine prone country.

As is described in Boccanfuso and Savard (2011), pressures on food prices such as was observed between 2007-2008 could become more frequent in the next decade. The increase in world demand, reduction in investment in agriculture, increasing fuel cost and use of land for the production of biofuels are all factors that have contributed and will continue to contribute

to high food prices. This situation is even more problematic for developing countries vulnerable to drought.

According to Diallo et al (2010), the elimination of subsidies for the production of biofuels from raw material or food staples that compete with land used for the production of food destined to human consumption of for animal feed is seen as an intervention that would reduce the conflict between food production and biofuel production. The fight against soil erosion and the improvement of women's conditions, reduction of poverty and the production of renewable energies are all potential contribution of biofuels produced from jatropha for the development of Mali. In addition to these positive impacts, jatropha can be used to produce electricity and serve as fuel in transports as well as in motorized agriculture. Other projects in the medium and long term are also considered, as increased resources for small farmers in Mali through the cultivation of jatropha curcas associated with drought-resistant corn, 2009-2012

Also, the oil cake which remains after the oil extraction process is used as organic fertilizer. This by-product makes it possible to improve the mineral content of soils which are subjected to an intense exploitation with the corn and cotton culture. These cultures are very demanding in terms of fertilizers. According to Latapie (2007), the expansion of jatropha culture could improve food production through this mechanism. In certain regions of Mali, women use jatropha byproducts as medication. For example, seeds are used as laxative, latex to stop bleedings and infections, and the leaves to treat malaria. Finally, the plant byproduct can be used to produce soap.

4. Analysis of the competitiveness of the biofuels in Mali

The liter of biofuel equivalent to gasoil (diesel) is produced at a cost of 480 fcfa. This price is 30 fcfa less expensive than gasoil in Bamako. Moreover, a kilogram oil cake can sell at 20 fcfa makes it possible to more improve the competitiveness of jatropha based biofuel. The cost of production is estimated that a processor needs 6 kg jatropha seeds to produce one liter biofuel (equivalent to gasoil) and that the price for one Kg of seeds is approximately 80 fcfa. This cost is decomposed into 20 fcfa for pressing and 60 fcfa to purchase the seeds. Staatz et al (2011) also state that jatropha oil cake is composed of 3-5% nitrogen a content similar to poultry manure. It has a value of between 35-85 FCFA / kg on the market as it is an organic fertilizer competitive with inorganic fertilizers (350-400 CFA / kg for 15 - 15-15). This can contribute to decreasing the unit cost drops to 400 to 445 fcfa/kg. At a market price above 500 fcfa/liter of diesel, the profit margin rises from around 55 fcfa to 100 fcfa per liter.

The main equipment used for the extraction process is a Chinese press whose cost is around 2.25 million francs CFA. It has a pressing capacity of 120 tons/year with an output of one ton of seeds per Km of jatropha hedges and a pressing cost of 20 fcfa per kg. Under these conditions, the biofuel is competitive in the country when the price is above 500 fcfa at the petrol station. To improve the competitiveness of jatropha based biofuel, it is important to explore 3 possible avenues. First using presses for multi-purposes and not only for jatropha oil extraction. A second avenue is to reduce the price of seeds and the third option would be to increase the productivity of the jatropha plant.

The other inputs and equipment for production include, oil for industrial production unit for 72 millions fcfa, storage tanks for raw oil, biodiesel (mixture of oil and ethanol) and glycerin (derivative obtained from the raw oil) at around 15 millions fcfa per unit, seed shucking

machine at 65'000 fcfa per unit, oil press at prices ranging from 2.25 to 10 millions fcfa per unit, sieving machines, and lab equipment.

A few projects in Mali have organized their biofuel production nearby their jatropha production. They also implemented a supply chain with producers from which they buy their jatropha seeds for example by paying 50 fcfa/kg for seeds. In 2011, the price per Kg for jatropha seeds increased slightly with a range between 50 and 70 fcfa/Kg. According to Staatz et al (2011), 5000 ha are exploited for the sole production of biofuels and they argue that land used for food crops will not be converted for the production of biofuels alone in the future.

4. Legislative and regulatory measurements on the production and the consumption of the biofuels

Mali is still at the stage of setting up the entire legal arsenal when it comes to the framework for the development of biofuels. This began with the development of a national energy policy which aims “the development of the energy sectors through the promotion of renewable energies and the biofuels, in particular the oil from jatropha and ethanol from sugar cane" (Republic of Mali [2006]).

Four specific objectives were retained for this national energy policy, namely: i) the satisfaction of the energy needs in quality, quantity and at lower cost, ii) the protection of the people, the goods and the environment against the risks inherent in the energy production, iii) the reinforcement of the capacities of orientation, management, control and strategic piloting of the energy sector and iv) the reinforcement of taking advantage of international cooperation for the energy sector.

The national strategy for the development of biofuels is thus an essential element of this program which extends over the period 2008 - 2023. It aims in the long term, to the increase in local energy production by the development of the biofuels in a decentralized nature to provide lower energy cost to satisfy the socio-economic needs. It also aims for the replacement of 20% of the gasoil (diesel) and distillate diesel oil (DDO) by the jatropha based biodiesel.

This strategy was born from the observation that the access to energy still remains very weak in the country with a rate of connection to the electric grid of 16% at the national level and only 7% in rural area. Moreover, the strong reliance on wood as an energy source accelerates deforestation/desertification and environmental damage in the country.

The implementation of any project, program and action within the framework of the national energy policy is based on 7 principles, namely the decentralization, the liberalization, the program approach, the participative approach, the competitiveness, the transverse coherence and private public partnerships.

The policy does not mention biofuels specifically at least not in the electric sector. Nevertheless, one can attach the sector of the biofuels to various objectives of the sub-sectors of electricity and renewable energies, *inter alia*: (sub-sector of electricity) to increase the rate of rural electrification from 1% in 2005 to 12% in 2010 and 55% in 2015 and (sub-sector of renewable energies) to promote a broad use of technologies and equipment of renewable energy to increase their share in the national production of electricity from less than 1% in

2004 to 6% in 2010 and 10% in 2015, then to develop a true structured sector for biofuels and more specifically for jatropha for various types of uses (production of electricity, transport, farm motorization, etc).

This strategy also aims to increase the proportion of vegetable based oil in the total biofuel production, to support the development of industrial infrastructures and small scale production and distribution of biofuels. Lastly, this strategy targets a reduction of 10% of the volume of fossil fuel (diesel and other types of oils) imports for 2012, 15% in 2017 and 20% in 2022. These targets would result in an estimated annual production of jatropha based biofuels of 39 million liters in 2012, 56 million in 2017 and 84 million in 2022.

The second article of the Ordonnance n° 09-006/P-RM adopted on March 4th 2009 lead to the creation of the national Agency for the development of the biofuels. This structure has the role of promoting the biofuels in the country. It has the mendate to i) taking part in the definition of the standards with regards to the biofuels, the monitoring of these standards as well as their implementation ii) insure of availability of the biofuels on the market at all times, iii) establish the tariff scheme and take part in the design of the price structure of the biofuels, iv) support research and development of biofuels, v) train, structure and support biofuel producers, vi) monitor and evaluate the activities of the operators intervening in the sector, and finally, vii) ensure the dialogue between national and international partners interested in the development of biofuels to favor technological transfers and develop partnerships.

The framework of the national energy policy and more specifically the national Program of energy dissemination of jatropha (PNVEP) intervenes in the regions of Kayes, Koulikoro, Sikasso and Segou with the following objectives. The program supports the design and implementation of jatropha based energy development program, it provides capacity building and evaluation of potential for jatropha future expansion, and well as training and dissemination of plantation techniques, harvesting, and environmental protection within rural populations. Moreover, it promotes the energy consumption from jatropha through various activities, as well as promoting the use of by-products of jatropha in the soap production, the cosmetics, the soil fertilization and the treatment of cultures. Finally, it encourages the promotion of rural development and women in particular as part of a sustainable development for the country.

In addition to the PNVEP, the "*Cadre Strétégique pour la Croissance et la Lutte contre la Pauvreté*" (CSCRP 2007-11) states that for the uses of energy, the objectives are namely to improve access to all form of energy for the population with emphasis on modern renewable energies and to insure efficient use of existing sources of energies.

Furthermore, to encourage the development of biofuels, the government of Mali adopted a decree that suspends VAT collection and other taxes on imported equipment to produce renewable energies for a period of 5 years starting in 2009 (***Decree*** n° 503/P-RM 23 September 23rd 2009). It concerns cast iron, iron and steel equipment, engines and mechanical appareals, electrical material and appareals, medical instruments and appareals, and lighting material.

In addition to these programs and measures, the law for agricultural development (LOA) sees jatropha culture as an alternate source of income for rural farm households. Studies are underway to prepare legislation for the development of the sector and on certification issues necessary to establish a norm of (5% biofuel + 95% diesel). It is quit evident that the biofuel

sector needs important adjustments to reach its full growth potential. Among some adjustments needed are: the capacity building of the various local governments, improvements of the financial institutions to provide more loans to small farmers and also a better definition of property rights for land and water.

5. Research and development of the biofuels in Mali

In Mali, the research agenda on jatropha based biofuel began in 1986 with the support of the German cooperation (GTZ). A power generating unit functioning with jatropha based oil was installed in Keleya. This unit functioned during more than a year with biodiesel. Today, it is fed by standard gasoil. In Garalo, a pilot experiment was conducted by MaliFolkCenter (a Malian NGO). A power generating unit and two vehicles of this organization were powered by biodiesel.

These various experiments were stopped because of insufficient supply of biodiesel and given the recurrence of breakdowns of vehicles. In Koulikoro, the company, Malibiocarburants installed a production unit for jatropha based biodiesel in the industrial park. This unit started in 2007 and has a production capacity of 2 000 liters per day.

MaliFolkeCenter located in the Sikasso region initiated that plantation of 530 hectares of jatropha which are primarily destined to rural electrification. Another project in Koulikoro lead by Mali SA biofuel aims to supply the local market for biofuels. In 2008, the project included over 900 ha of plantation and the project plans to expand the plantation to 3000 ha in the near future. In addition to these two projects a jartropha Mali initiative aimed primarily promoting the local market and the domestic market for jatropha biofuel is being drafted. Finally, a project managed the "*Association Malienne d'Eveil au Developpement Durable*" (AMEDD) based in four commues (Koury, Yorosso, Ourikel and Kimparana) aims to produce oil from jartropha for rural electrification. The goal is to produce 400 000 litres of biofuel from a 800ha plantation by 2012 (Pallière and Fauveaud (2008).

The jatropha based oil is also used in the production of the soap. Some research on this by product made it possible to use the nitrogen rich jatropha based oil cake as fertilizer. Lastly, research results have shown that jatropha almond powder can be used as insecticide. This research output was one of the main issues discussed during the national forum on the biofuels held in Bamako in September 2007 (Samaké 2007)

There is also some ongoing research on variaties of jatropha, the sources, the conditioning, the certification of seeds and also on farming methods (monoculture or associated cultures). Some of this research if performed by researcher at the IER (Institute of rural economy) of Bamako (Sangaré and Riedacker 2002).

6. Prospects and growth of the biofuels in Mali

The development of a national strategy for the biofuels, the existence of a national energy policy, the creation of the ANADEB and the high interest of the technical and financial partners illustrate the great prospects for the development of the biofuel sector in Mali. On their part, FAO estimates that in 20 years, 25% of the energy consumption will originate from biofuels and this figure may be revised upwards if Mali and other large markets like the

United States, European Union implement their biofuel development strategies (M. Banse 2008). The requirements for Mali would be around 60 million liters of diesel per month. With the possibility of large oil companies like Shell to include 20% of biodiesel in the diesel, Mali could have an outlet for its biofuel of 12 million liters. For the time being, jatropha based biofuel is used to replace the gasoil (diesel) mixture used in the diesel engines of multifunctional platforms which powers grain mills and the water pumps in the rural areas of Mali.

The national strategy for the development of biofuels (June 2008) states that potential for development of the jatropha sector is large since large surfaces of land are idle and some of these offer low productivity for other types of cultures. These surfaces could easily be converted from idle land to productive jatropha parcels. *Inter alia*, the strategy aims to have energy sources available to the population at a low cost in order to promote socioeconomic activity while promoting national energies. Moreover, finding sustainable energy solutions at a low cost, systematically consider environmental impact, establish an institutional framework with a legal and regulatory setting favorable for the development of the sector are all key elements of the strategy. Finally, linking to and supporting sub-regional, regional and international energy programs are an integral part of the strategy.

The prospects of biofuel development in Mali are a great source of hope and optimism in light of vast potential of the country (land availability, water and abundant human resources) that can be used in project of intensive labor (Haute Intensité de Main-d'Oeuvre-HIMO) including a vast network of actors. Table 4 presents jatropha oil production objectives for the 2008-2023 place in relation to oil imports. With an annual average growth rate of 7.2 % of its relative share, jatropha oil would reach 20% of total fuels consumed by 2023 for a volume of 84 millions de liters. This forecast should be accompanied by an increase in productivity of the plant as a result of ongoing research and development as well as a reduction in surfaces exploited after 2013.

Tableau 4. Jatropha based biofuel production objectives

	2008 – 13	2014 – 18	2019 – 23	Accroissement annuel moyen à partir de 2013
%Volume imported hydrocarbon	10	15	20	7.18%
Quantities produced (millions litres)	39.2	56	84	7.92%
Requirements of seed production (mille tonnes)	224	336	448	7.18%
Estimation in seeds (kg/arbre)	5	10	15	11.61%
Production of seeds per ha (t/ha)	3	4	6	7.18%
Superfice to cultivate (thousand ha)	72	54	48	- 3.97%

Source : Republique of Mali (2008)

This objective of cultivating 72000 hectares of land (720 km²) represents 0.6% of the country total surface. When excluding the deserts, this represent 1.5% of the land. If this culture is done in the sahalean and soudanean zones, it would take up 2.5% of that land and 1% of the soudano-guienan zone. Hence, we can see that land availability is not an obstacle to the development of this production. Moreover, jatropha can be cultivated along with other cultures such as cereals, oleaginous and tubers. This land can also be used by other plants from which ethanol (sugar cane, cassava and sunflower) can be produced. It is important to highlight that jatrophe can grow on land unsuitable for most other cultures which can reduce the risk of conflict in land use with other farmers.

It is for these reasons that Mali has chosen to include ethanol in its energy strategy for which the production objectives are outlines in table 5. From 2013, 25000 ha are planned to be exploited to produce 25 million liters of alcohol at 95° and 25 000 tons of ethanol per year for both outputs.

Table 5. Ethanol production objectives

	2013	2018	2023
Cultivated surfaces (thousand ha per year)	25	25	25
Quantity of alcohol 95° (millions liters/year)	25	25	25
Quantity of ethanol (thousand tones/year)	25	25	25

Source : République du Mali (2008)

According to the governments' plan, this strategy should contribute to achieving the following multipronged objectives. These include the Millennium development goals (MDG), The National Energy Policy (PEN), The national poverty reduction framework strategy (CSCRP), The rural development plan (SDDR), The national policy in environmental protection (PNPE), The decentralization policy, The law for agricultural development (LOA).

To date, about twenty actors are playing a role in the biofuel sector in Mali. Some of the listed companies such as MaliBiocarburants initially existed as development projects working along with the Investment promotion Agency (API). For this reason, production data is publicly available and allows analyst to forecast positive prospects for the future development of the sector. We exploit some of these figures in the following sections of this paper.

7. Economic evaluation of technologies of the biofuels in Mali

We have identified three means to increase consumption of biofuels in the various strategies of the government. First, operators can adapt the engines to allow for intake of pure vegetable oil. This can be done by installing a pre-heating kit on the engines. Second, the pure vegetable oil can also be modified by transesterification. This is a chemical process consisting in transforming pure vegetable oil into biodiesel and third, the vegetable oil can be mixed with regular fossil fuels.

In Mali, the first two techniques have been tested; the first by the NGO Malifolkcenter jointly with other institutions such as the national Center of solar energy (CNESOLER), and the second technique was tested by Malibiocarburants in its Koulikoro factory. In addition, to obtain jatropha oil, two technics are used. First, by manual or electric presses (Malifolkcenter, CNESOLER). The second method is with a power station for the biodiesel production (Malibiocarburants).

According to the seed pressing process, to obtain 1 liter of jatropha oil (HVP), 3 to 4kg of seeds are required. This crude oil is then processed by sedimentation to produce oil usable as fuel in the engines (Figure 2). In same time, the HVP makes it possible to directly obtain soap or after sedimentation. The residues are rich in organic matter and can be used as fertilizer for soil as was mentioned earlier.

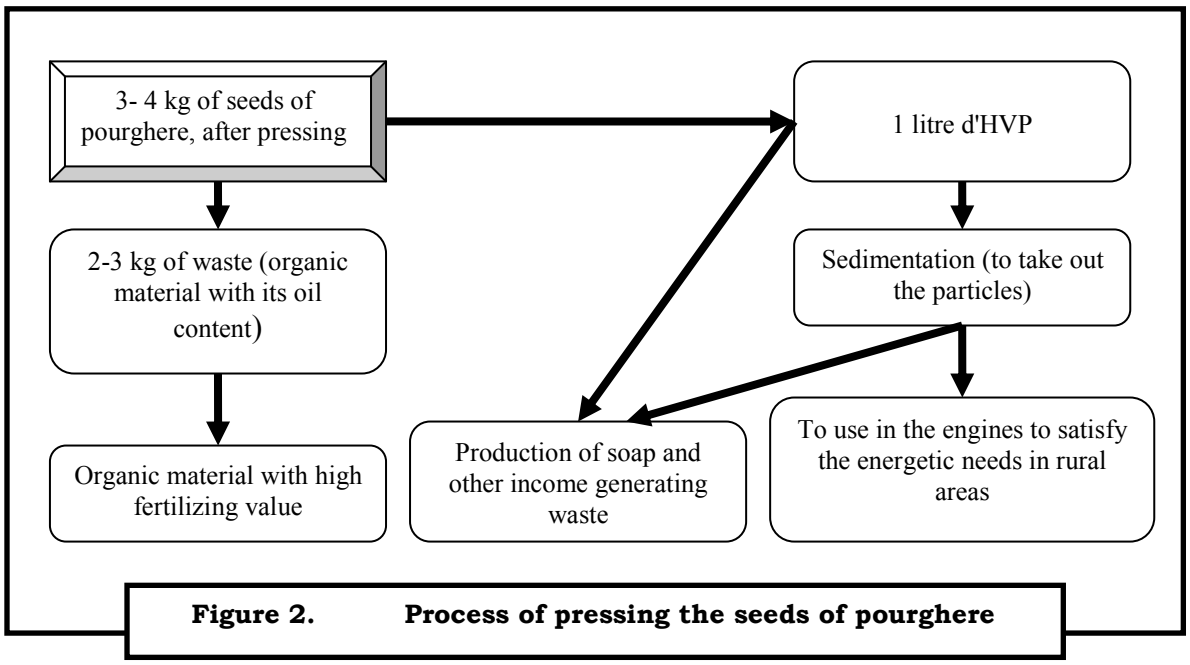

Figure 2. Process of pressing the seeds of pourghere

Source: UEMOA (2006)

Presses for the triturating jatropha seeds that are sold in Mali at the average price of 1.5 fcfa million, the equivalent cost of a mill used to grind millet/sorghum seeds. They are generally from India or local NGO manufacturer. These presses make it possible to obtain 3700 liters of biofuel from 10 tons of seeds. This corresponds to the yield of one ha of jatropha plantation. The cost of exploiting this press to produce this biofuel is estimated at 78000 fcfa.

Some biofuel producers have installed power stations for production of biodiesel. In these units, unrefined vegetable oil undergoes a chemical transformation called "transesterification" which consists in adding methanol or ethanol in order to separate by catalysis, the glycerin from alcoholic esters. Such units are supplied with jatropha seeds by networks of producers to produce large quantities of oil.

8. Costs-benefits analysis

Poverty reduction is one of the important objectives of the development strategy for the jatropha sector. This could take place by diversifying the producers' incomes. Indeed, cultivating jatropha on parcels jointly with other type of cultures can generate additional income for the producers. This option can provide as much as 100000 fcfa in additional income per ha. Moreover, processing plants (manual or electric) can generate between 10 to 115 million fcfa depending on the technology used.

Downstream, in the processing stages, the installation of large manufacturing units requires relatively large investments of approximately 500 million francs CFA on average. The construction and engineering cost represent more than have of the investment. The machinery and various equipments take up around 40% of the total cost and 10% of the capital is required to pay for other operating costs (Table 6).

Table 6. Structure of the investment in the production of biofuel

	In %
Construction and engineering fees	50
Equipment	35
Various materials	9
Variable operating costs	6
Total	100

Source: The authors computations for from API project cards in Mali

The various taxes and fees to which to producers are faced with include, licenses fees, tax on wages (ITS), permits fees, a land tax (IRF) and profit tax (IBIC). By far, the licensing fees represent the largest share taxation at nearly 35%, followed by lump sum fees and tax on wages at 28%, the remainder of the taxes are composed of license fees and IRF.

The investment projects in the sector have a perspective of 80% returns on gross income. This value added will be use for amortization, to pay wages and towards profits. The share of the first component will decrease over time and the third will grow. As for intermediate input, it will be dominated by construction, various equipment and consultancies (CVEC) and this share will also decrease in time as seen in table 7.

Table 7. Forecasted operating account (%)

	2012	2013	2014	2015
Turnover	100%	100%	100%	100%
Intermediate inputs among which	18%	18%	18%	18%
CVEC	12%	7%	6%	5%
Transport	1%	1%	1%	1%
others	5%	10%	12%	13%
Value added among which	82%	82%	82%	82%
Wages	16%	17%	17%	16%
Banking/financial	0%	0%	0%	0%
Amotization	35%	24%	20%	18%
Operting surpluses	18%	33%	39%	43%
Others	13%	8%	6%	6%

Source: Computed by authors from Malibiocarburant project reports

9. The varieties of Jatropha

Jatropha is known to exist in approximately 160 throughout the world. The six most common species are: jatropha curcas whose seed can provide oil of industrial use which can be used as biofuel, jatropha, jatropha gossypifolia produces a purgative oil and its root can be used as a treatment for leprosy, jatropha integerrima grows with a decorative red flowering, jatropha multifida (tree coral) whose leaves can be consumed (i.e. in Mexico), jatropha podagrica, is a decorative plant and jatropha phyllacantha or favela of Brazil.

In Mali, the curcas variety is almost the only one cultivated. Nevertheless, the "*Institut d'Economie Rurale*" (IER) undertakes research on other types of jatropha to evaluate their adaptability to the Sudanese or Sahelien or Saharan climates. Commonly called "*pourghere"* in Mali, jatropha curcas is used to produces many products as we have described previously.

10. Structure of the costs according to the varieties

The cost of cultivating of one hectare of jatropha is estimated at 78000 fcfa. The expenditure is primarily composed of the purchase the plants' cuttings, labor (mostly unskilled) and of various maintenance fees of the seedlings until maturation. The sales of the seeds generate revenues of 300000 fcfa on average per hectare at a rate. This figure is obtained with a productivity of 5 tons/ha sold at a price of 60 fcfa/kg. The transformation process yield a high value added at a rate upward to 92% of the total revenues. Approximately, two-thirds of this value added value represents the gross benefit of operations. The wage bill represents on average 8% and financial fees reach 5% of the value added.

The same data from the projects allowed us to compute the average annual increase in the value added of almost 20% with gross income that grew at a rate of 45% per annum over the first 5 years after installing the processing plant. The growth rate of gross income was estimated 11% over a longer period (10 years). These estimates are made with the assumption of an increase in of price of 3% per annum over the whole period.

11. Competitiveness of the biofuels

By comparing the gross income generated with the cultivation of jatropha with those of other cereals or cash crops, it appears that jatropha is more profitable than sorghum and corn, whatever the assumption of productivity retained. Even if it is less profitable than groundnut under certain conditions, it is by far more profitable than the cotton whatever the aforementioned conditions (Table 8) are.

Table 8. Profitability and comparative competitiveness of jatropha with other cultures (fcfa/ha and %)

	Food crops		**Commercial Cultures**		**Pourghere**	
	Sorghum	Corn	Cotton	Groundnut	Shea tree assumption	Kolondieba assumption
Charges	45 457	98 494	135 747	63 273	76 000	35 250
Products	75 000	138 500	179 300	150 000	150 000	150 000
Results	29 453	38 006	43 553	88 727	74 000	114 750
Profitability	65%	39%	32%	140%	97%	326%
Competitiveness	61%	71%	76%	42%	51%	24%

Source: Latapie (2007)

Taking into consideration the competitiveness rate, jatropha remains more competitive under the Kolondieba assumption compared to all other cultures. The groundnut under the Shea tree assumption is the only case of higher competitiveness for other cultures. These assumptions refer only to the harvesting method of the jatropha seeds.

For the shea tree assumption, the harvesting is done in a similar fashion as for harvesting shea nuts and for the Kolondiéba assumption, the harvesting is done according the method described by Latapie (2007) in the region of Sikasso. Under the shea assumption, the

harvesting of one hectare is done at a pace of two hours per day over a period of two months while for the Kolondiéba, the assumption is that one worker will harvest 162.5kg/day. Each assumption has a specific cost for the same volume of output.

Considering the investment data of projects, the competitiveness of biofuel is estimated at 85% in term of ratio total cost over gross revenues (turnover). The expenditures can be broken down into raw materials purchase, wage costs, amortization, financial fees and other operational costs (water, electricity, transport, etc). The cost structure is as follow 44% for raw materials, 8% for the wage bill, 21% for amortization, 5% for financial fees and 22% for other intermediate inputs. The gross margin is estimated, at more than 60% of the total revenues. And so, the gross net income before income tax can reach up to 30%.

12. Compared competitiveness of the biofuels

According to Aidenvironment (2008), "The African biofuels are generally not yet competitive on the world market. The production costs are between 0.25 US$ and 0.60 US$ per liter for ethanol". By comparing the competitiveness of the various types of biofuels, ethanol outperforms biodiesel by far. In the sub-group of the biodiesel, jatropha has a stronger potential for the small farmers than palm oil, both having a low mechanization requirements (Table 9). In term of ethanol, Mali strong prospects of expansion for sugar cane production which could be used for sugar production or biofuels. To date, only small quantities of ethanol are sold on the European market by African countries, namely Congo, Swaziland and Zimbabwe taking advantage of exemption and facilities programs offered to African products.

Table 9. Yields and contributions in manure of the biofuels

	Ethanol				Biodiesel	
	Sugar cane	Corn	Sweet sorghum	Manioc	Palm oil	Jatropha
Maximum time between harvesting and transformation	2 days	1 year	1 - 2 days	2 - 3 days	2 days	Several months
Economic scale of competitive production (ha)	17 500	n.a.	15 000	15 000	400–4 000	400–1 000
Potential of mechanization	Middle	strong	strong	Weak	Weak	Weak
Potential of the small farmers/growers	Weak	strong	Middle	Middle	Weak	strong

Source: AIDEnvironment (2008)

AIDEnvironment (2009) also conclude that 3 major conditions need to be met to make African biofuels competitive on world markets. First, by increasing the scale of production, since the factories are currently too small to produce at competitive cost, second, by improving and extending the infrastructure of distribution and transport and third by creating a reasonably insured (secured) market, i.e. by long term contracts, in order to attract larger investments.

AIDEnvironment (2009), propose various building-blocks for a sustainable strategy for biofuel operations that could be interesting to integrate in national development strategies for the sector. Their building blocks can be summarized in the following figure:

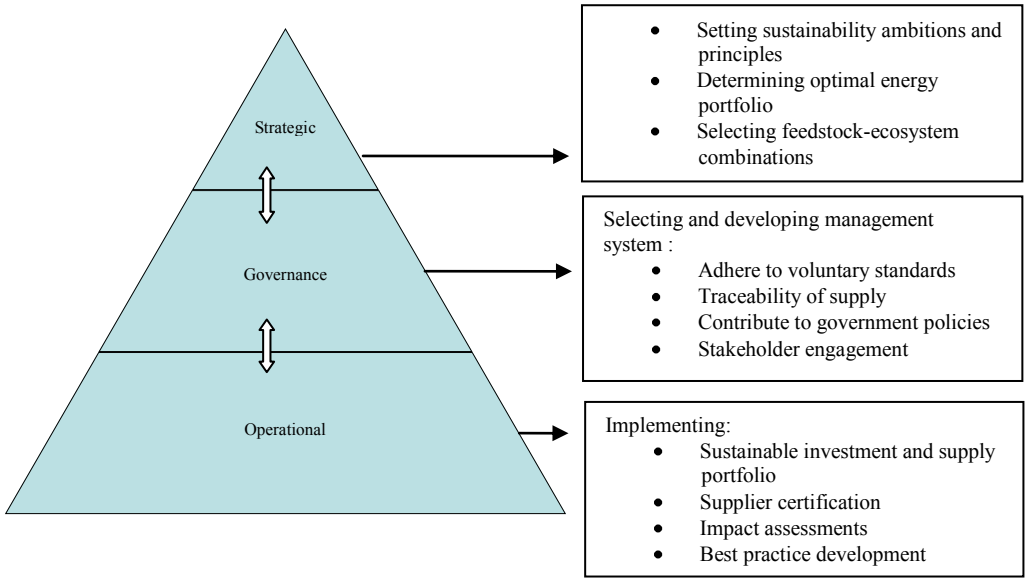

Figure 3: Building blocks for biofuel development strategies

Source : AIDEnvironment (2009)

Conclusions

The pourghere was introduced in Mali to set up the jatropha system with the objectives to fight soil erosion and the soil improvement. It was used thereafter by the rural women as medication. The seeds were used as laxative, the latex used to stop bleeding and counter infection and leaves to treat malaria. The seeds were also used to produce soap. Today, its its development is seen as an opportunity to contribute to poverty reduction and the development of renewable energies. The jatropha based biofuel can become an important input to run grains mills, water pumps and other engines such as the power generating units (multifunctional platforms present throughout the country).

In spite of its strong potential (economic, social and environmental), the production of biofuels is faced with a number of constraints, *inter alia*, the competition for use of land with food crops when the country is consistently facing food insecurity, the dependence of the foreign investments to develop the sector, the persistent doubt with regard to long term commitment by small scale farmers and biofuel producers, the lack of control of local authorities over key parameters such as land use legislation and property rights but also lack of control of the central government over local development strategies in the context of decentralization and finally, the insufficient incentive policies to promote investments in the sector.

Moreover, on world markets, the trade networks for biofuels remains relatively weak given the low level of investment for production and transformation. However, there are significant

positive prospects for substitution of biofuels with fossil fuels given the prospects of rising prices of fossil fuels in the future. As we have shown in the paper, Mali has ambitions to increase the market share of jatropha based oil in the next 10 to 20 years. The rural mechanization strategy should contribute to achieving this goal by freeing to labor for jatropha production.

Beyond the requirements of rural development, the promotion of the biofuels can contribute to the reduction of the CO2 emissions and thus taking part of the safeguarding of the layer of ozone and the fight against the climatic reheating. Also, Mali and some of its partners including GTZ, UNDP, NGO Malifolkecenter and ICRISAT currently finance research and popularization programs of the pourghere growing. These programs understand the PNVEP, Garalo, Bagani and the power station of Keleyal, the project Yelen Kura in the south west of Mali, the company Bagani S.A and Malibiocarburant as well as the Mali biofuel development and production project. The future of biofuel production in Mali is very promising with the presence of potential outlets such as a large basin of consumers and large number tractors, multifunctional platforms, diesel cars and mini electricity power plants (EDM) and diesel powered generators.

However, the country must learn from past negative experiences in promoting cash crops among which groundnut (that face many problems on world markets). This crop has been outpaced by soya and cotton over the last few years. It is also important to consider the hurdles facing authorities to modify the culture of farmers to changes farming practices to adopt new technologies in the context of low human capital in rural Mali. Moreover, the liberalization of world agriculture makes it even more challenging for the government to achieve the objectives of a joint energy and agricultural strategy. Besides the choice of agriculture techniques, the development of biofuels requires selection of best variety, selecting the best production processes, conditioning and marketing systems for seeds and biofuel. Furthermore, it is important to improve varieties and conduct research and development on this front.

On the other hand, the development of biofuel is coherent with the global agenda for climate change and its potential to contribute to the reduction of green house gases (GHS) should be supported in the future. The potential for poverty reduction is also a key element to take into account while keeping in mind that the level of competition for land with food crops is likely to be a key factor in generating strong positive impacts for the country (either on the economic or social front).

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Appendices

Mali _ Inventory of the actors in biofuels

Company	Contact	Telephone	Email
Tissina sarl	Moussa Yattara	20 24 97 46 /66 75 34 18	tissinasarl@yahoo.fr
Bio Diesel Mali S.A	Ousmane Daou	20 22 36 30 /76 40 55 32	ocsmali@hotmail.com
Sud Agro-Industrie	Mohamed Diarra	66 75 18 26 /76 36 85 23	sudexel@afribone.net.ml
CGGE (Crest Global Green Energy)	Youssouf Sy	76 36 56 95	
Mali Bioénergie	Philippe Poitevin	66 55 32 17 /78 86 00 88	ppoitevin@noos.fr
Mali Biocarburants	Hugo Verkuul	44 38 10 73 /76 12 99 73	dg@malibiofuel.com
Groupe Tomota	Cheick Hamallah Simpara /Charles Ndoye /Abdoulaye Diallo		dpcg@huicoma.net
Association Mali Aqua Viva (Teriya Bugu)	Jean Christophe	21 33 10 00/01 /75 74 74 77	info@tb-mali.com
FKN & Fils	Cheick Amadou Niono	20 20 78 35 /66 75 06 56	ncasarl@yahoo.fr
Petrotech-ffn Agro Mali Biofuel	Amadou Sanoussy Daffé	79 24 62 72	daffepetrotechmali@yahoo.fr
Deguessi Vert	Baba Siby	20 21 52 50 /76 49 28 14	sibirake@yahoo.fr
ADECK (Association pour le développement de la commune de Kendié)	Amadou B. Karambé	76 23 84 14	abdramseyba@yahoo.fr
Association des ressortissants des villages de Ségouna et de Kamita	Bakary Sidibé	76 45 86 88	segounois@yahoo.fr
Société coopérative de Markala et banlieue		76 51 72 21	
Bagani	Madani Diallo	66 74 00 50	mdiallo@teliman.net
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Association des jeunes pour l'appui au développement de Banamba	Mohamed Simpara	20 24 80 61 /66 75 44 17	simpara.mohamed@voila.fr
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Gaoussou Fofana	Gaoussou Fofana	66 90 28 80	
SUKALA	Madame Lu	21 34 20 23	
N-SUKALA	Feng Sheyong	20 21 30 84	fsy@cletc.com

Mali _ Zoning of the companies of biofuels

Company	Zones of intervention
Tissina sarl	Circles of Kita /Kati /Bougouni /Baraouéli
Bio Diesel Mali S.A	Zone Office du Niger
Sud Agro-Industrie	Circles of Sikasso and Kadiolo
CGGE (Crest Global Green Energy)	Circle of San
Mali Bioénergie	Markala
Mali Biocarburants	Circles of Koulikoro /Kati (commune of Ouéléssébougou) /Banamba /Kita (commune of Kokofata)
Groupe Tomota	Zone Office du Niger
Association Mali Aqua Viva (Teriya Bugu)	Circles of San and Bla (10 communes)
FKN & Fils	Zone Office du Niger
Petrotech-ffn Agro Mali Biofuel	Circles of Macina /Kita(communes of Djidian and Namala) /Téninkoun (communes of Dioura and Togéri Coubé)
Deguessi Vert	Circle of Kita
ADECK (Association pour le développement de la commune de Kendié)	Circle of Bandiagara (commune of Kendié)
Association des ressortissants des villages de Ségouna et de Kamita	Circles of Kita(commune of Gadagou /arrondissements of Sagabaré (Ségouna) and Kamita
Société coopérative de Markala et banlieue	
Bagani	Sikasso, Bougouni, Sansanding,
Eco-carbone	Circles of Kita /Kati /Bougouni /Baraouéli
Association des jeunes pour l'appui au développement de Banamba	Circles of Koulikoro /Kati (commune of Ouélésséboug ou) /Banamba /Kita (commune of Kokofata)
APFEF	The 8 regions of Mali
Gaoussou Fofana	Circles of Koulikoro /Kati (commune of Ouélésséboug ou) /Banamba /Kita (commune of Kokofata)
SUKALA	Zone Office du Niger
N-SUKALA	Zone Office du Niger

Mali _ planned Surfaces of pourghere growing

Company	Surface (ha)					
	2007	2008	2009	2010	2012	Planned
Tissina sarl	0	0	0	400	4 000	4 000
Bio Diesel Mali S.A	0	0	0	0	0	10
Sud Agro-Industrie	0	0	2000 - 2500	0	0	50 000
CGGE (Crest Global Green Energy)	0	0	0	0	0	351 000
Mali Bioénergie	0	0	50	0		100
Mali Biocarburants	500	500	3 000	0	0	30 000
Groupe Tomota						100 000
Association Mali Aqua Viva (Teriya Bugu)	0	80	150	230	0	230
FKN & Fils	0	0	0	0	0	300 000
Petrotech-ffn Agro Mali Biocarburant	0	100	0	200	0	30 000
Deguessi Vert						12 000
ADECK (Association pour le développement de la commune de Kendié)	0	0	0	0	0	0
Association des ressortissants des villages de Ségouna et de Kamita	60 in hedges	60	60			12 500
Société coopérative de Markala et banlieue Bagani			255			20 000
Eco-carbone	0	0	1 000			3 000
Association des jeunes pour l'appui au développement de Banamba	0	0	12.5 & 2 200 in hedges	5	21	40
APFEF	0	0	60	1 905		
Gaoussou Fofana	6	6	6			107
SUKALA						20 000
N-SUKALA						