


Mozambique Biofuels Assessment

FINAL REPORT

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EXECUTIVE SUMMARY

The objective of this study is to assess the potential competitiveness of Mozambique's biofuels production in the domestic, regional and international biofuels markets, identifying the most promising feedstocks for development, and recommending a strategy for the promotion of the sector. The study addresses a diverse set of questions raised by the Government of Mozambique (GoM) in the context of increasing investor interest in this sector and rapidly evolving international markets. The study's scope reflects the priorities endorsed by the Ministry of Energy (the need to develop the national energy sector, reduce oil imports and alleviate the economic burden of imports, and enhance energy security), and those advanced by the Ministry of Agriculture (the need to expand the agricultural sector in a socially and environmentally sustainable way, as well as contribute to rural development and employment creation). The study was funded using resources from the World Bank and the Italian Embassy in Mozambique, within the framework of an Italian Cooperation Program with the Ministry of Agriculture of Mozambique.

Mozambique is a largely rural country, and imports the entirety of its fossil fuels. Receipts from income taxes are growing

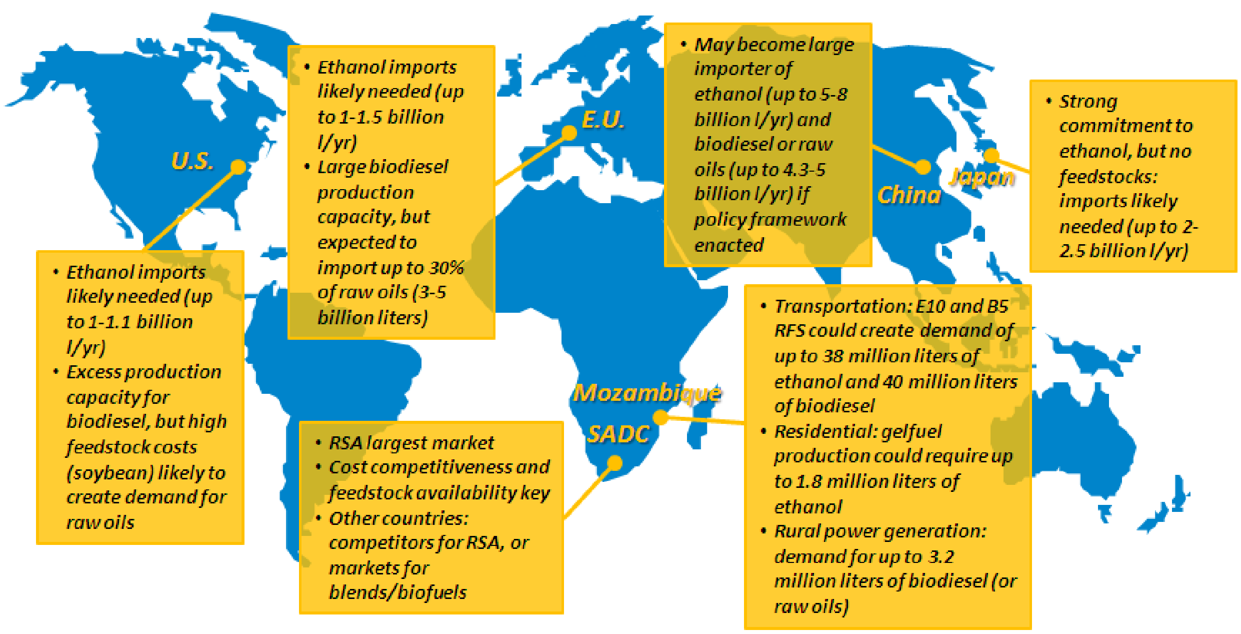
Country background. In spite of the impressive economic turnaround achieved over the past few years, Mozambique remains a largely rural country, suffering from widespread poverty, vulnerability to natural disasters and economic shocks, and major socio-economic imbalances between its rural and urban population. Despite some rapid growth in key sectors such as gas, telecommunications, mining and mineral processing, the country is still heavily dependent on external support to mitigate its structural economic imbalances. The economy continues to rely on imports: the trade deficit in 2006 was approximately 6.5% of GDP, down from 14.5% of GDP in 2000, with fuel imports playing an important role (a recent projection for total imports in 2008 is USD 700 million, compared to exports of about USD 2.4 billion (including large projects) in 2006). Mozambique imports the bulk of its fossil fuels, the bulk of its fossil fuels, which in any case represent a market of very modest size (570 million liters in 2006, of which 66% consisted of diesel), with to date limited use of domestic natural gas, primarily in the industrial sector. As might be expected, the cost of these imports is climbing sharply due to rising petroleum prices. Foreign direct investment has increased substantially, but to date investment has focused on large capital-intensive projects, which require substantial imports of raw materials and make up for the majority of the country's exports, with little value added (tax revenues, employment and demand for inputs) remaining in Mozambique. The large projects illustrate how the country has made considerable steps towards improving its business climate. The metical has enjoyed stable exchange rates, although the cost of borrowing in local currency is still high. At the same time, the GoM has engaged in fiscal reforms that are increasing its revenue collection ability: in particular, the relative importance of receipts from taxes on income, investments and value added as a share of total fiscal revenues is growing, while that of receipts from fuel taxes (less than 10%) is decreasing. Gasoline and diesel are not subsidized (no sales below market price), and they are more heavily taxed than other fuels used by lower-income sectors of the population. *(For a detailed overview of Mozambique's economy and energy/fuels sector, see Chapter 1.)*

Overseas and regional biofuels markets are expanding rapidly

Potential Markets. The current situation of Mozambique's economy and energy/fuels sector can be assessed within the broader context of a rapidly expanding international biofuels market, with governments of an increasing number of countries strongly committed to biofuels policies and programs as part of efforts to reduce emissions of greenhouse gases as well as address energy security concerns. On the ethanol side, distributors and regulators are increasingly interested because of the decrease in ethanol prices that has occurred alongside the steady rise in petroleum and gasoline prices. Opportunities in regional and overseas markets are complemented by an attractive biofuels potential for various uses in the domestic market, as shown in Figure ES 1. However, the rate of growth of biofuels consumption, especially in the major European and U.S. markets, may be affected in the near term as a result of heightened concern over increases in food prices and related political disturbances in 2008, since the price increases are frequently tied to the growth of biofuels consumption. The reality, as briefly described in Chapter 8, is more complex; the implications for biofuels policies of these developments, and the widening food-versus-fuel debate, is unclear at present. *(For a complete analysis of potential domestic, regional and overseas biofuels markets, see Chapter 2.)*

- *Overseas markets*. The global demand for ethanol is expected to grow steadily: imports will likely be necessary in the U.S. and the European Union (E.U.), China is likely to turn into a major ethanol importer if its biofuels policy is implemented, and Japan's commitment to ethanol combined with its lack of feedstocks may also make it a significant importer. The global production of biodiesel is expanding rapidly, led by the E.U. Trade in finished biodiesel is more limited, while that of raw oils is much more noteworthy, and this trend is expected to continue: it is estimated that the E.U. biodiesel industry will import 20-30% of its raw oils (3-5 billion liters) in 2010-2015; that the U.S. will likely display excess production capacity coupled with very high feedstock costs; and that China may also represent a

Figure ES 1: Potential biofuels markets



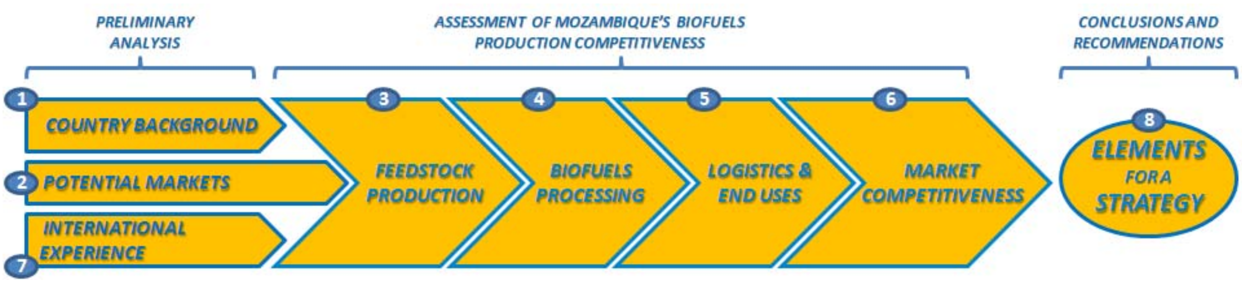
Source: Econergy. Notes: Southern African Development Community (SADC), Republic of South Africa (RSA).

significant market, again provided its policy framework is enacted. At the same time, as Brazil's domestic consumption of ethanol continues to increase (driven by prices as well as increased size in the flex-fuel fleet), ethanol exports to major markets may increase more slowly than has been anticipated.

- *Regional markets*. For Southern African markets, considerable uncertainties surrounding policy frameworks remain, making projections unreliable. The Republic of South Africa emerges as the key potential market due to the size of its transport fuel market. However, its policy framework has been approved at more modest levels than anticipated, which limits its market and may also delay investment by local players, leading to more limited production capacity in the near-term. The extent to which this gives Mozambique (or other regional countries) a comparative advantage in terms of cost competitiveness in production and feedstock availability, however, will depend on the treatment of imports, which is not entirely clear. Depending on the success of their biofuels programs, as well as regional policy coordination, other countries in the Southern African Development Community (SADC) may either compete with Mozambique for the RSA market, or represent markets for Mozambique's finished biofuels, or import fossil fuels through Mozambique.
- *Domestic markets*. Unlike international markets, the domestic market for biofuels can involve not only the transport sector, but also the residential and rural electrification sectors: renewable fuel standards for ethanol and biodiesel use in motor vehicles could be implemented, "gelfuel" (an ethanol-based residential fuel now being sold in the country) could displace some conventional fuels and biomass consumed for residential uses, and new diesel-powered generation to increase the electrification rate in rural areas could also make increasing use of biodiesel blends, or even of raw vegetable oils.

Based on the country's baseline economic situation and on the existence of potentially interesting biofuels market opportunities, and in the light of key lessons learned from international experience (which are reviewed below), the analysis turns towards a specific assessment of what the actual competitiveness of Mozambique's biofuels production would be in different markets.

Figure ES 2. Biofuels value chain and structure of the analysis



Source: Econergy. Numbers indicate the chapters of the study containing more detailed analysis.

The various steps of the analysis move along the biofuels value chain, as depicted in Figure ES 2: the numbers shown in the figure refer to the chapters in the report where an extensive analysis of the various issues may be found. The conclusions and recommendations that close the first phase of the study represent the preliminary elements for the development of a strategy and of a National Biofuels Program for Mozambique, to be outlined in the study's second phase.

Feedstock production. The first element of the biofuels value chain relates to the cultivation of crops that could be used to provide biofuel feedstocks in Mozambique. Several of these crops are already widely cultivated in the country (including cassava, maize and sugarcane for ethanol; and coconut, cotton, groundnut and sesame for biodiesel). Their suitability as biofuel feedstocks, however, requires an assessment of yields, production costs and opportunity costs of each, as well as of general issues affecting the overall agricultural sector, and must also consider potential socio-economic and environmental impacts (both positive, in terms of reduced reduced emissions of greenhouse gases, as well as negative, such as water consumption and associated pollution) if a national biofuels strategy is to contribute to Mozambique's rural development. *(For an extensive assessment of key agricultural sector issues and the various feedstocks' production yields and costs, see Chapter 3. Socio-economic and environmental impacts are introduced in Section 3.5, and discussed more extensively in Section 4.5.)*

- ***Cassava*** *has very low costs and it is widely grown as a staple crop, but it also has low yields, and there are concerns about the logistics of delivering it to processing plants given its tendency towards rapid fermentation.*
- ***Maize*** *is not suitable as an ethanol feedstock because of its implications for food security and its high cost and market price. Similar considerations discount the use of* ***groundnut*** *and* ***sesame****.*
- ***Sweet sorghum*** *and* ***sunflower*** *appear as suitable and low-cost feedstocks respectively for ethanol and biodiesel.*
- *There is extensive experience in* ***coconut*** *cultivation and this crop holds some potential for biodiesel, given that its market price is high, and the spread of lethal yellowing disease makes replanting imperative.*
- *The cost of producing* ***sugarcane*** *is still higher in Mozambique than in the RSA, and established sugar producers have not yet engaged in ethanol production, but yields are very high and sugarcane should be encouraged as a priority crop for ethanol; also, the utilization of sugarcane* ***molasses*** *(which are currently not utilized efficiently) could provide an additional low-cost feedstock, albeit of more limited volume.*
- ***Jatropha*** *seems promising and, although experience with this crop is in its initial phase and data need verification, cultivation of this crop should be encouraged. Similar considerations are valid for* ***African Palm.***
- ***Soy*** *may be attractive, provided there are off-takers for the press-cake resulting from the extraction process, due to its low oil yields.*

- *Mozambican agricultural sector*. Agriculture employs about 80% of Mozambique's population, but productivity is low (agriculture represents only about one-fourth of GDP), and integration in international markets is limited (agriculture provides only 16% of exports): the agribusiness sector is small, with larger-scale plantations accounting for under 1% of total surface area, or 3% of currently cultivated land. The land only belongs to the state, but its use can be the object of long-term renewable concessions to domestic and foreign producers. Rainfall and water resources are abundant in the central and northern parts of the country, where the most fertile land is also located (27 million ha). Five million hectares of land are currently under production, and land available for expansion of production ranges from 10 million to as much as 19 million hectares. Such a wide range in this estimate corresponds to an equally broad spectrum of assumptions to calculate land available for plantations, taking into account social and environmental policy considerations that will affect the issuance of concessions, including decisions regarding allocations of land to agribusiness ventures and areas reserved for small-holders. A recent study conducted by IIAM, which takes into account projections for the expansion of the family farm sector, estimates the potential for expansion between 6.5 million ha and 12.5 million ha.
- *Feedstock yields and costs*. Yields and production costs of the various feedstocks analyzed, as well as opportunity costs (market prices, where available) are summarized in Table ES 1, according to high and low scenarios for both yields and costs, and these data are presented

graphically in Figure ES3 and Figure ES4. The use of modern agricultural technologies instead of those typical of subsistence-type cultivation allows greater scales of production and other efficiencies, and in general, reduces costs. Yields are generally indirectly related to costs: higher yields (tons per hectare cultivated) are associated with lower production costs; where yields are low, preference must be given to lower-cost crops. Some inconsistencies in this pattern – namely for cassava and sunflower – may reflect deficiencies in the data sets as well as large increases in inputs in the higher yield scenarios. Crops may be divided into three main groups according to their agricultural cost of production: low (cassava for ethanol), moderate (maize and sorghum for ethanol; and jatropha and sunflower for biodiesel), and high (sugarcane for ethanol; and coconut, cotton, groundnut, sesame and soy for biodiesel). No data on agricultural production cost are available for African palm as it is not cultivated, while data for castor seed will be available in the near future based on incipient activities at present; however, estimates for these crops based on experience in other countries allowed their inclusion in the later stage of analysis on production competitiveness.

- *Socio-economic and environmental impacts*. The most suitable land for expansion of agricultural production is located in the Center and North of the country, and includes mostly rural and poor areas with high unemployment rates. Suitability reflects both agro-ecological conditions as well as the availability of water resources. The development of biofuels-related activities in these regions could generate income and create opportunities for employment, but could also carry considerable socio-economic risks, mainly concerning food security and land appropriation: large-scale cultivation of feedstock crops may compete with that of crops used for food, inflate the prices of food products and reduce access to land by smaller farmers. New land should be put into production for extensive cultivation for biofuels, but this must be carefully selected and defined so as to ensure that existing cultivation is not displaced, to avoid jeopardizing food security and creating disruptions to Mozambican society. In addition, the employment and income-generation impacts of a program will vary as a function of variables such as the production model employed, such as large-scale plantations or small-scale family farms (*as discussed in Section 6.9*) or the linkages to other agribusiness sectors through the sale of press-cake or meal for animal feed or fertilizer, an effect captured in the economic analysis conducted in Chapter 4. At the same time, however, land-use changes could also reduce the biodiversity or cause loss of habitat in certain regions of a country that remains highly vulnerable to natural disasters. Concerns about the potential social and environmental impacts from biofuels production are the driver for a variety of initiatives by national governments, regional blocs (notably the E.U., which has recently issued a draft directive government biofuels) as well as non-governmental organizations to develop standards and certification schemes for biofuels. *(See Sections 3.5 and 4.5.)*

Biofuels processing. After agricultural production, the subsequent stage in the biofuels value chain relates to the processing of candidate feedstocks for their conversion into ethanol and biodiesel. Based on the costs for feedstock production, production costs of biofuels at the factory gate can be calculated. Energy recovery in production processes and avoided consumption of fossil fuels may also lead to greenhouse gas reductions. *(For a detailed overview of processing technologies and an analysis of associated production costs and GHG reductions, see Chapter 4.)*

Table ES 1. Feedstock yields and costs at farmgate

	Yield (tons/ha)		*Production cost per ton of feedstock (low per-ha yield)*		*Production cost per ton of feedstock (high per-ha yield)*		*Average price per ton of feedstock*		*Biofuel yield (tons/ ha)*
	Low	*High*	*Mt*	*USD*	*Mt*	*USD*	*Mt*	*USD*	*Tons#*
Ethanol									
Cassava*	5.0	10.0	268	10	382	14	1,350	50	0.46-0.9
Maize	1.0	6.0	4,293	159	1,062	39	4,090	151	0.3-1.83
Sugarcane##	60	90	-	20	-	16	-	18	3.7-5.5
Sorghum**	0.7	2.0	3,407	126	2,157	80	3,000	111	*0.21-0.6*
Sorghum cane	20	90							*1.7-7.9*
Biodiesel									
Coconut###	-	-	-	-	-	-	5,000	185	*0.46*
Cotton***	0.8	2.5	4,513	167	2,028	75	5,300	196	0.1-0.33
Groundnut	0.3	2.0	7,367	273	2,668	99	24,060	891	0.12-0.8
Jatropha####	3.0	4.0	3,565	132	3,483	129	7,508	278	0.6-0.8
Sesame	0.4	1.5	6,493	240	3,260	121	11,500	426	
Soy	0.7	3.0	2,550	94	1,338	50	5,500	204	0.1-0.42
Sunflower	0.5	1.5	2,138	79	2,720	101	3,750	139	0.16-0.5

Notes: #Oil yield data are based on Chapter 4: coconut, 62%; cottonseed, 13%; groundnut, 40%; jatropha, 20%; soya, 14%; sunflower, 32%; and assuming a 98% conversion rate to biodiesel from raw oil. *Fresh cassava is sold in markets at higher prices that vary from 3 to 10 Mt/Kg. Data on dried cassava were provided by Sicco Kolijn, International Institute for Tropical Agriculture. ##Based on data from CEPAGRI. Market cost is based on project international market prices for raw sugar in the $130-140/ton range, assuming 13% sucrose for cane in Mozambique, based on LMC (2006). **Price at the Beira market. A representative total yield could be about 3 tons/ha, allowing for increases with productivity improvements. ###Coconut is sold per unit. Price per kg based on purchases in Beira and Inhambane. Yield is based on CEPAGRI (2006), "Futuro do sub-sector de Coco: uma Nota de Reflexao." ***Minimum price to the producer set by the Government for high-quality cotton. ####Price is still theoretical given that there is still no market for jatropha; the value used is twice the production cost. Sources: Costs calculated based on IIAM data, SG 2000 and interview with Julieta Zandamela (2007); prices in general obtained from SIMA and in markets. See Chapter 3.

Table ES 2. Summary of the biofuels feedstock analysis

Feedstock	*Agro-ecologic suitability*	*Socio-economic and environmental impacts*	*Cost of production, opportunity cost and per-hectare output*	*Other factors*	*Conclusion (evaluated in Chapters 4 and 6)*
Ethanol					
Maize	+	-	0	+	Not evaluated
Cassava	+	**0**	+	+	**Evaluated**
Sugarcane and molasses	+	+	+	**0**	**Evaluated**
Sweet sorghum	+	+	+	+	**Evaluated**
Biodiesel					
Sunflower	**NA**	**0**	**0**	+	**Evaluated**
Sesame	NA	0	-	+	Not evaluated
Soy	+	**0**	**0**	+	**Evaluated**
Peanut	+	0	-	+	Not evaluated
Coconut	+	+	**0**	+	**Evaluated**
Cotton	+	0	-	+	Not evaluated
Mafurra	NA	NA	NA	+	Not evaluated
Castor Seed	+	**NA**	**-**	**NA**	**Evaluated**
Jatropha	+	+	**0**	+	**Evaluated**
African Palm	**NA**	**0**	**0**	**NA**	**Evaluated**

Legend: - denotes "low" or "unfavorable;" + denotes "high" or "favorable;" 0 denotes "moderate," and NA denotes "unavailable."

Figure ES 3. Summary of costs and yields – ethanol

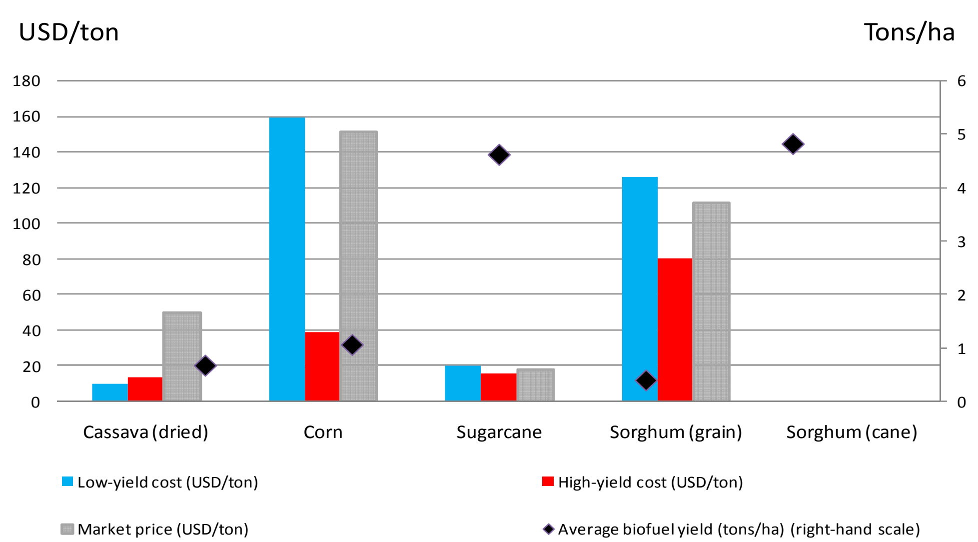
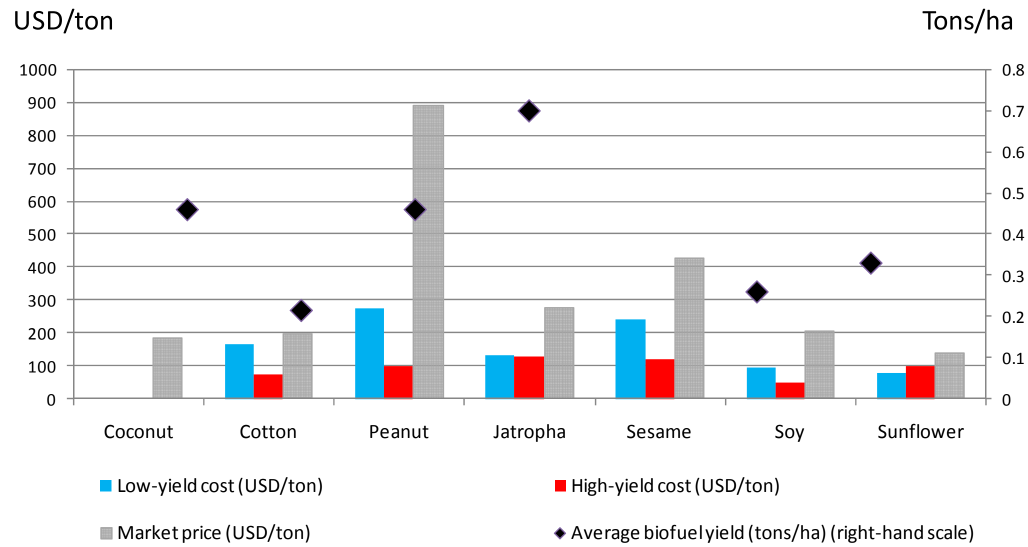


Figure ES 4. Summary of costs and yields – biodiesel



- *Technologies*. Conventional technologies convert a fraction of the feedstocks (sugars or starches for ethanol, oils and fats for biodiesel) into biofuels, while second-generation technologies aim at also converting the remaining ligno-cellulosic biomass.
- *Bioethanol production costs*. Table ES 3 presents an overview of production costs of ethanol (given by the sum of feedstock and refining costs): sweet sorghum is the lowest-cost option for producing ethanol in Mozambique, followed by molasses, sugarcane and cassava. Some margin of error should be allowed for results on sweet sorghum, which are based on assumptions related to grain sorghum that, unlike the sweet variety, is grown in the country: the two crops are similar, although not exactly the same. In addition, it should be noted that these production costs are biased toward a more conservative (that is, high-cost) result because of the assumptions used. Such a bias is desirable when considering the viability of investing in a national biofuels program for Mozambique.

Second-generation technologies aim at also converting ligno-cellulosic biomass into biofuels

- *Biodiesel production costs*. Biodiesel production costs are presented in Table ES 4 according to two scenarios for scale of production (small and large, with the latter using more efficient extraction and refining processes and therefore displaying lower costs), and three scenarios for feedstocks costs (agricultural production costs, domestic market prices, and international market prices, the latter not related the agricultural feedstocks themselves, but to already extracted raw oils). The agricultural production cost scenario subtracts the value of any co-product, yielding negative costs for those crops (soy and cotton) with high-value press-cakes for use as animal feed. Sunflower and soy emerge as the lowest-cost options for producing biodiesel in Mozambique, followed by copra.

Table ES 3. Bioethanol production costs

	Feedstock production cost	*Ethanol refining cost*	*Net production cost*	
	USD/ton ethanol	*USD/ton ethanol*	*USD/ton ethanol*	*USD/liter ethanol*
Cassava	314.9	169.0	483.9	0.38
Sugarcane	309.3	137.8	447.1	0.35
Sorghum	198.2	137.8	336.0	0.27
Molasses	251.9	120.6	372.5	0.30
Maize	492.2	169.0	661.2	0.53

Note: The costs of ethanol production for various feedstocks are USD/metric ton basis. The conversion to USD/liter is based on ethanol density of 0.794 kg/liter or 1,259.45 liters/ton. Actual ratios given may vary due to rounding. These production costs for feedstocks reflect energy and chemicals, maintenance, administration and labor, equipment depreciation, while the ethanol refining costs reflect feedstock costs, energy and chemicals, maintenance, administration and labor, equipment depreciation, and co-products sales where applicable. Source: Econergy. See Chapter 4.

Table ES 4. Biodiesel production costs

	Agricultural production cost (USD/liter)		*Domestic market price (USD/liter)*		*International market price (USD/liter)*	
	Small scale	*Large scale*	*Small scale*	*Large scale*	*Small scale*	*Large scale*
Sunflower	0.11	0.13	0.29	0.25	1.20	1.18
Jatropha	0.63	0.43	1.18	0.80	1.18	0.80
Castor	-	-	0.62	0.42	1.12	1.11
Soybean	(0.58)	(0.32)	0.35	0.31	0.82	0.81
Copra	-	-	0.48	0.36	0.79	0.78
Palm	0.52	0.35	0.77	0.52	0.70	0.69
Cottonseed	(0.10)	(0.00)	0.58	0.45	-	-
Sesame	0.37	0.31	1.31	0.94	-	-

Note: Sales of by-products are credited to the agrigultural production cost, resulting in negative values for crops with high-value press cake. Source: Econergy. See Chapter 4.

- *Production process waste valuation.* Alternative technologies may use the waste biomass deriving from the production process for productive purposes. One of the most important sustainability characteristics of biofuels is that they may also provide energy to be used for processing. Several feedstocks are very conducive for additional energy recovery from the process residues and, while different options exist, the direct combustion of biomass residue represents the most convenient one for thermal energy generation. Biomass can also be used as a fertilizer, and wastewater for ferti-irrigation. Biogas derived from anaerobic treatment of waste may be flared, or fired as fuel in the boilers.

- *GHG reductions and CDM potential.* Beyond their positive economic and social benefits, biofuels can also create significant environmental benefits. Flaring of biogas derived from processed effluents, electricity generation from residual biomass, and avoided consumption of fossil fuels can lead to GHG emissions reductions. According to calculations conducted under two agricultural productivity scenarios, and including a sensitivity analysis for increased consumption of grid-generated electricity and fossil fuels, the only crops with a negative GHG emissions balance (emissions avoided – emissions occurred) would be among those discounted as potential biofuel feedstocks (cotton, peanut and sesame), supporting earlier conclusions on the most suitable feedstocks. Crops with the highest emissions reduction potential are also among the best or most promising ones under an economic standpoint (sugarcane, jatropha, cassava, African palm, and, according to some estimates, sorghum). Emissions reductions could represent opportunities under the Clean Development Mechanism: CDM project types that could be applied to biofuels production in the Mozambican context are power generation based on biomass (including co-generation), and avoidance of methane emissions based on effluent treatment. However, Mozambique's low emission factor, due to the significance of hydro power in the national grid, is likely to reduce the potential volume of Certified Emissions Reductions (CERs) from electric sector projects, since CERs are created as a function of a project's baseline. With respect to use of biofuels to displace fossil fuels for transportation, while this in itself would generate emissions reductions, there is currently no approved methodology applicable, due mainly to difficulties for this type of activity in the monitoring of emissions reductions as well as in the verification process. Finally, the application of CDM instruments to national programs is still in its infancy and, while future developments seem promising, uncertainties are still significant.

One of the most important sustainability characteristics of biofuels is that they may also provide energy to be used for processing

Logistics and end-uses. Once processing technologies and costs at the factory gate are assessed, the following step in the biofuels value chain involves issues associated with their storage, transportation and distribution, and end -uses. Estimated transportation costs were used to assess biofuels costs at major ports in Mozambique, and costs to several overseas destinations, as summarized in Table ES 5. It should be noted that the overseas shipping costs are based on quotes provided by a freight broker familiar with the biofuels trade, and were provided for Maputo, but not Beira and Nacala. While it is unlikely that quotes for the other ports would be more attractive at the present time, in future this situation could change.

Table ES 5. Transportation costs

Overland freight costs			
	Maputo		*Beira*
Road (USD/m^3/km)	0.05-0.24		0.20-0.36
Rail (USD/m^3/km)	0.03		0.17
Barge (USD/m^3/km)	-		0.20
Loading costs (USD/m^3)	*3*		*3-4*
Shipping costs to selected overseas destinations (ex-Maputo)			
	Ethanol	*Biodiesel*	*Vegetable Oil*
Yokohama (USD/ton)	90	88.5	87
Mumbai (USD/ton)	65	63.5	62
New York/Philadelphia (USD/ton)	92	90.5	89
Rotterdam (USD/ton)	85	83.5	82
Cargo size (tons)	*17,000*	*18,000*	*18,500*

Source: Econergy calculations based on interviews and quotes from Pole Shipping (Geneva). See Chapter 5.

The main observations on biofuels logistics and end uses for Mozambique are presented below. *(For a complete analysis of FOB and CIF costs, and a detailed overview of logistics and end-uses, see Chapter 5.)*

Regional coordination of fuel policies (specifications for imported fuels and biofuels standards) will be critical to the success of Mozambique's biofuels program

- Fuel handling and storage capabilities are increasing. PetroMoc has considerable spare fuel storage capacity at the former oil refinery at Matola, near Maputo, it is making investments in storage capacity at several other locations, and has a large (for Mozambique) tanker truck and vessel fleet. PetroMoc is also engaged in projects that will increase its handling volumes for the regional market, such as the expansion of facilities at Maputo and Nacala, and the construction of a pipeline linking Maputo with Witbank in South Africa. Some of the handling and storage infrastructure could be adapted or expanded to accommodate biofuels blending, storage and distribution.
- Overland transportation and distribution still face major issues. The road network is limited and in poor conditions (only 17% of the country's roads are paved), and access to roads is scarce, especially for the rural population. There are also significant inefficiencies in road transportation, including collusive practices between a small number of existing operators that keep freight rates high, and vested interests that make road routes prevail over cheaper rail ones. As a result, overland transportation costs are comparatively high, for example with respect to the RSA.
- There are three major ports on the Mozambican coast, all privately managed: Maputo (South), Beira (Center) and Nacala (North). Activity in Beira has been decreasing, mainly due to reduced traffic from Zimbabwe, and this has made dredging difficult to sustain economically, so that only smaller vessels can be serviced: investments are needed to rehabilitate the port and to protect the town, which is below water level, from flooding. Extensive investments in new infrastructure at Nacala and Maputo are under way or planned, and both ports have good potential for expansion.
- All fossil fuels and petroleum products for Mozambique are imported by IMOPETRO, and sold to distributors; among these, PetroMoc and BP account for over half of the domestic market. The country is a significant node for the regional fossil fuel market, with imports through Beira and Maputo re-exported towards countries in the interior (South Africa, Zimbabwe, Zambia and Malawi). Given current regional fuels logistics, the success of any biofuels program in Mozambique will depend on regional coordination of fuel policies: harmonization in specifications for imported fuels (in particular, reformulated gasoline for ethanol blending) are essential for successful implementation of Mozambique's biofuels policy, and common ethanol and biodiesel standards would be critical for regional biofuels trade.

Fuel handling and storage capabilities are increasing, but overland transportation costs are still high

- Key end-use technologies for biofuels involve automotive, power generation, household and agricultural residential appliances. Ethanol and biodiesel may be blended with fossil fuels (gasoline and conventional diesel) for use in motor vehicles; for blends containing modest amounts of biofuels (up to 20%), required vehicle modifications are limited. Ethanol in Mozambique appears more suitable for direct blending into gasoline rather than in the form of a gasoline additive such as ETBE, which benefits from advanced refining capabilities not found in the country. Biodiesel may be used in thermal power generators, although its energy content is lower; pure vegetable oil may be used in diesel-cycle equipment running at full load, with conventional diesel used for engine start-up and shut-down. Ethanol may be used to produce "gelfuel", with a significant potential for cooking, as well as for other more limited uses in heating and agriculture.

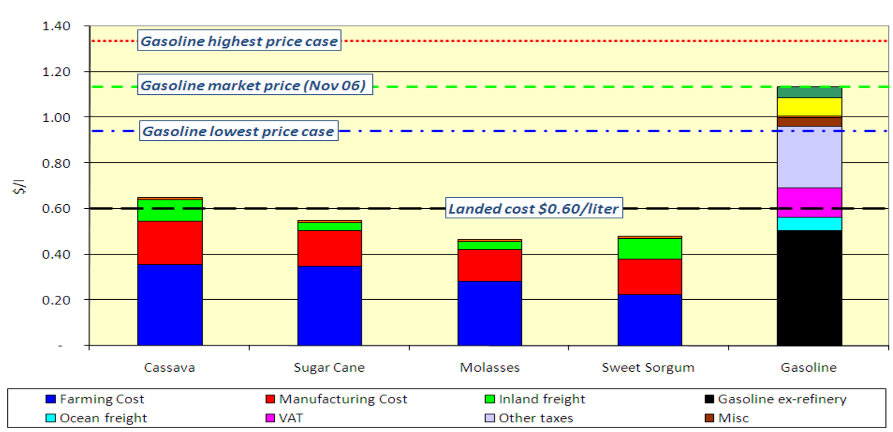
Mozambican ethanol based on sugarcane, molasses and sweet sorghum is likely to be competitive in domestic, regional and overseas markets

Market competitiveness. The final step in evaluating the potential production of biofuels in Mozambique involves an assessment of their specific competitiveness with other liquid fuels on the various markets overviewed above, using information derived along the previous stages of the value chain. This analysis does not consider the allocation of profit at the various stages of the value chain, but rather considers the total margin created along the entire value chain. This margin would be allocated between farmer, producer and distributor in keeping with the commercial arrangements between market participants. The analysis also does not consider regional variations in production costs, as such detailed data are not available. *(For a detailed assessment of biofuels market competitiveness, see Chapter 6.)*

- *Ethanol*. As shown in Figure ES 5, ethanol produced from sweet sorghum and molasses could generate savings relative to the landed cost of gasoline (purchase, storage, transport and distribution) of USD 0.13 and USD 0.12 per liter respectively, while savings from sugarcane-based ethanol would be of about USD 0.05/liter. Cassava, conversely, would be more expensive mainly due to logistics issues in collecting the raw material and transporting it to processing facilities (it should be noted that fossil fuel reference prices refer to November 2006, and do not reflect the surge in the international petroleum prices since then). If the 21% fuel tax on gasoline were waived, prices paid domestically for ethanol would allow building in profits for farmers, producers and distributors involved in ethanol production, and would create a cushion between landed costs for fossil fuel and local costs for biofuel that would allow biofuels costs to put downward pressure on end-user prices for blended fuel, which would be politically desirable.

  With respect to the overseas markets selected for analysis, Figure ES 6 shows how ethanol produced from sugarcane, molasses and sweet sorghum would be competitive, although

Figure ES 5. Ethanol production cost in Mozambique and cost of imported gasoline



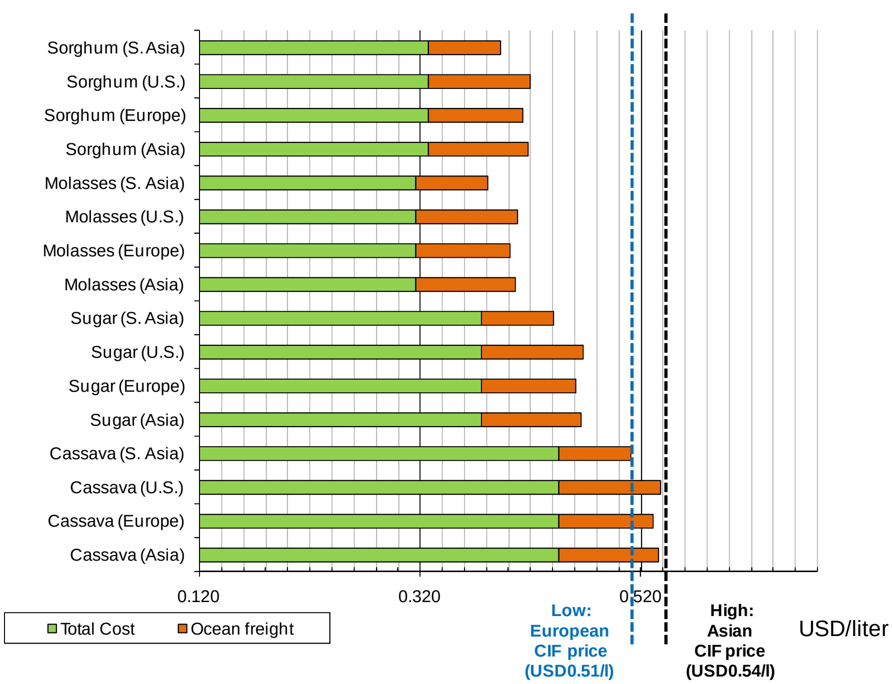
Source: Econergy. Values for ethanol are adjusted to reflect lower energy content of the fuel. See Chapter 6.

volumes of ethanol produced from molasses would be limited. For long-haul exports, sugarcane-based ethanol could be cheaper than Brazil's, which can be taken as an international reference, and the price of which has recently decreased from earlier highs due to rapidly growing output (similarly to that of U.S. ethanol), though Mozambique's potential to secure competitive freight costs would depend on volumes. If ocean freight were to be discounted, however, sugarcane-based ethanol produced in Mozambique could be competitive against Brazil's for regional exports in Southern Africa (a rough estimate for ethanol price in the RSA is USD 0.58/liter).

Mozambican ethanol, therefore, could be competitive in domestic markets (provided the fuel tax is waived, and oil prices remain above USD 60/barrel: prices lower by 20% would lead to parity with imported gasoline), as well as in regional and overseas markets. A national bioethanol program, therefore, should encourage large-scale ethanol production for export, but it should be primarily based on expected volumes for the domestic and regional markets, as the potential for long-term competitiveness will depend on international price trends in ethanol and fossil-based transportation fuels.

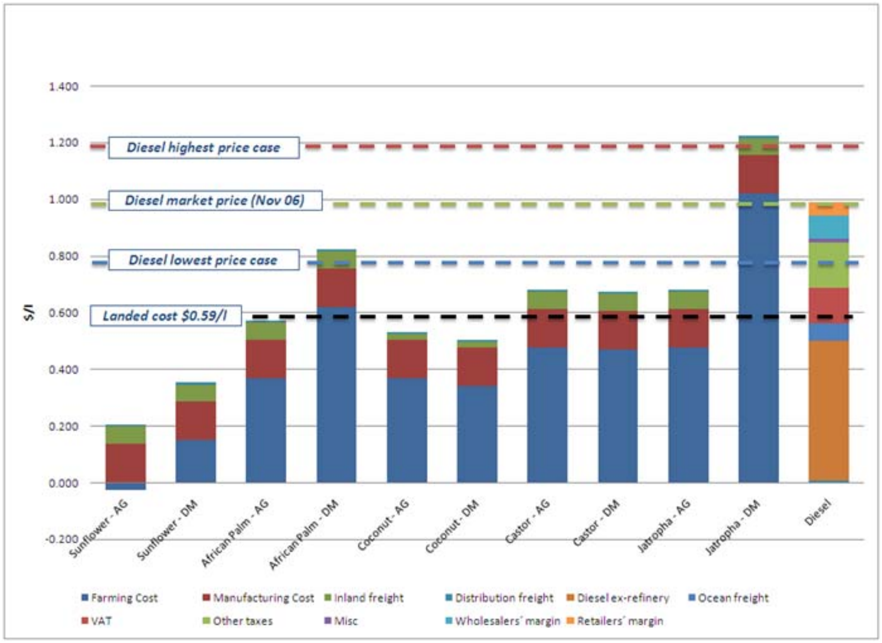
- *Biodiesel*. As shown in Figure ES 7 and Figure ES 8, biodiesel produced from sunflower appears the most competitive against the landed cost of petrodiesel for both small-scale and large-scale production, followed by coconut.

Figure ES 6. Competitiveness of Mozambican ethanol in key export markets



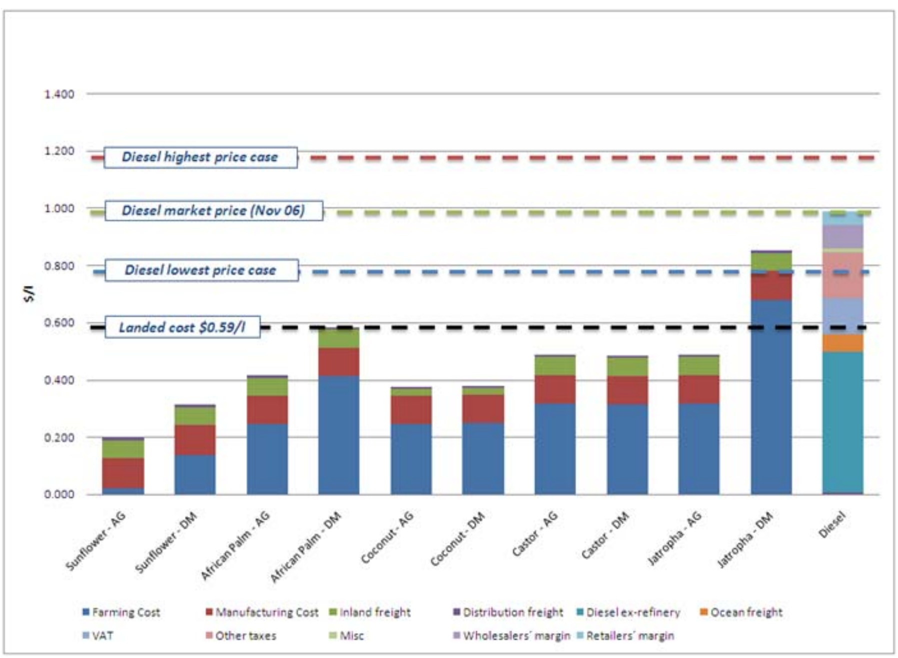
Source: Econergy. Values for ethanol are adjusted to reflect lower energy content of the fuel. See Chapter 6.

Figure ES 7. Biodiesel cost and imported diesel: small-scale production facilities



Source: Econergy. For each crop, the final cost is shown first based on agricultural cost (AG), then on domestic market price/opportunity cost (DM). As noted above, some crops may offer negative agricultural costs when valuable by-products are produced (as in case of sunflower). See Chapter 6.

Figure ES 8. Biodiesel cost and imported diesel: large-scale production facilities

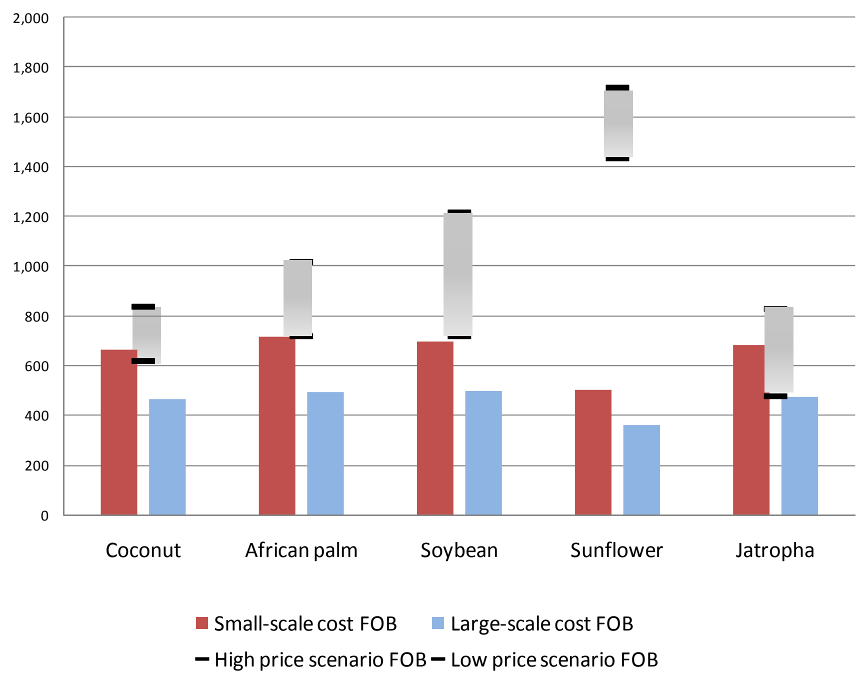


Source: Econergy. For each crop, the final cost is shown first based on agricultural cost (AG), then on domestic market price/opportunity cost (DM). See Chapter 6.

It is expected that castor and jatropha will become more competitive as experience with these emerging feedstocks grows. When agricultural costs of feedstocks are considered, production based on all crops seems viable, while African palm and jatropha become much less competitive when their opportunity cost is factored in. As noted, international trade in finished biodiesel is scarce; the international market for raw vegetable oils, however, is currently very attractive, to a point that biodiesel production may even not be viable for the domestic market in the near term. Also, Mozambique is currently a net importer of raw vegetable oils: increased production of these for export could reverse this trend. (See Figure ES 9 for a comparison of FOB costs and imputed international prices.) With respect to biodiesel, therefore, the scope for promoting large-scale production is much more limited: small-scale production for the domestic market should be encouraged, while an export strategy focusing on raw oils seems more prudent. Raw oils would also represent a significant potential for combustion for power generation in domestic rural communities producing and processing them.

Small-scale production of biodiesel should be encouraged, while exports should focus on raw oils

Figure ES 9. Assessment of international market prices for raw vegetable oil, FOB Mozambique



Note: The prices reflect international market prices with transportation costs Maputo-Europe netted out. The costs are represent Econergy calculations based on feedstock production costs, processing and transportation. Source: Chapter 6.

International experience. Available technologies, agriculture conditions, fuel demand and government incentives vary greatly across different markets, making it challenging to compare and contrast them. The experience in biofuels development of selected emerging markets, however, allows identifying important lessons learned and conclusions that may often serve as guidance to the analysis of Mozambique's biofuels production and to the development of recommendations. *(For case studies on Brazil, India, Colombia, Honduras, Zimbabwe, Tanzania* *and Thailand, and a more detailed discussion of conclusions and key lessons learned, see Chapter 7.)* The most salient lessons include the following:

The launch and expansion of national biofuels programs is possible only with strong government support

- The launch and expansion of national biofuels programs is possible only with government support: various policy tools are applicable to the Mozambican context – such as tax breaks and tariffs protecting domestic production – and are critical in assigning competitive prices to biofuels, making their use attractive, and countering price swings of key commodities associated to biofuels, such as oil and sugar.
- Renewable fuels standards have widely proved a very efficient and cost-effective tool to reach policy objectives, providing strong signals to producers and supporting a more rapid growth in domestic production capacity. Mandates should be tempered by some flexibility in blending percentages required, allowing to adapt to market conditions.
- Ethanol and biodiesel technology-sharing partnerships should be explored, as they are a vehicle for transfer of know-how and investments, and encourage trade opportunities.
- A combination of regulation and economic incentives can mitigate environmental impacts of the biofuels industry while creating an attractive market for producers.
- A diversification in feedstock crop cultivation, with preference given to those with limited potential as staple crops, can effectively help in addressing food security issues.

Financial and macroeconomic impacts. The analysis also encompasses a modeling exercise to estimate the potential impacts of a biofuels program in terms of shifts in fiscal revenues to the state, impact on the balance of trade and job creation. The results (presented in Chapter 6.9) suggest that even a relatively modest expansion of production of biofuels feedstocks (of about 450,000 ha) together with a mandate for use of E10 and B5 in the country, would generate the following:

A relatively modest expansion of feedstock production for a national biofuels program and exports would deliver significant macro-economic benefits

- Decrease in imports of petroleum-based fuels in the range of USD 15 million to USD 20 million annually (based on 2006 petroleum prices, at current price levels this would be higher), representing about a 5% decrease in the total cost of imported fuel as projected for 2008.
- Decrease of tax revenues (import duty, tax on fuel and VAT) in the range of USD 12 million, with the figure likely to be higher at current petroleum price levels.
- Increase of corporate income tax levels of as much as USD 7 million, roughly halving the loss in revenues attributable to decreased fuel imports.
- Creation of some 150,000 jobs, of which two-thirds would be in cultivation of biodiesel feedstocks and the balance in ethanol production.
- Longer-term improvements in the balance of trade resulting from exports of ethanol, vegetable oil and biodiesel, which could amount to as much as USD 450 million based on a conservative expansion of feedstock production, equivalent to as much as 20% of current exports including large projects.
- Increases in traffic at the country's major ports, with associated port revenues, as well as increased business for transportation companies.

Elements for a biofuels strategy in Mozambique. The analysis conducted throughout the various steps of the biofuels value chain leads to a series of key recommendations that represent the preliminary elements for a strategy and a National Biofuels Program in Mozambique. *(For an extensive discussion of conclusions and recommendations and of their underlying justifications, see Chapter 8.)*

- The most effective approach to launch the Mozambican biofuels sector would be to focus on the establishment of a domestic market in the near-term, creating demand for ethanol and biodiesel for transportation and industrial uses currently served by gasoline and diesel. The primary tool to achieve this objective would consist of blending requirements to be phased in over a relatively short period of time to allow production capacity to emerge in response to increasing demand. However, because the domestic market is relatively small and the currently proposed biofuels investments could easily exceed domestic demand, Mozambique's biofuels industry will have to rely on regional and overseas markets.
- With respect to regional market opportunities, Mozambique should begin promoting the inclusion and coordination of biofuels provisions and imported fuel specifications among relevant SADC countries. Regarding overseas markets, Mozambique should explore partnerships with major ethanol and biodiesel international exporters, to expand its own production in the framework of their commercial activities or commitments; and explore ways of linking biofuels production and exports with access to technology and investment in the context of bilateral cooperation agreements with biofuels exporters, as well as with countries that engage in production and that at the same time represent potential export markets (such as China or India).
- Mozambique's biofuels strategy should promote multiple feedstocks: this is likely to ensure more balanced development, limit dramatic price impacts that would mostly affect the poor, ensure that biofuels producers have alternatives to respond to the inevitable price variations in feedstocks (especially those with alternative uses), and extend the creation of potential benefits to several regions of the country. Specific actions that the GoM should consider or support include the rehabilitation of coconut plantations suffering from lethal yellowing disease; the promotion and expansion of soy, sunflower and castor seed cultivation; an active commitment and support to jatropha; further research on African palm; incentives to molasses-to-ethanol projects as well as support for investment in ethanol projects; the promotion of sweet sorghum as a new feedstock crop; and the introduction of small-scale cassava-processing facilities in rural areas, contributing to a gradual improvement in the value and utilization of this crop.
- The key policy incentives to promote biofuels production should be the following:
  - A mandate of biofuel content for gasoline and diesel sold in the country, with a phase-in period to allow production to ramp up. The mandate for biodiesel should be introduced later than the one for ethanol (perhaps 2012 as opposed to 2009-2010), and be subject to a longer phase-in period.
  - Create the potential for a a premium over the CIF cost of imported fuel to be paid by biodiesel blenders to producers, to allow sufficient returns for producers as well as for farmers supplying the producers with feedstock, by introducing a phased-in exemption of the biofuel component of the blended product from the Tax on Fuels over ten years.

- Other than the exemption from the Tax on Fuels for pure biofuels, no other fiscal incentives would be applied: the value-added tax would still be levied on biofuels, and the general method for fuel price setting would remain the same.
- Create a National Biofuels Development Fund (NBDF), supported in part by the charge for the Tax on Fuels that would otherwise be directed to the Ministry of Finance during the ten-year period over which it is phased out, together with donor and other resources as identified.
- Authorization to imports of biofuels and biofuels feedstocks in the country (though not of inputs required for production), with a tariff level consistent with Mozambique's commitments under SADC.
- Establishment of special feed-in tariffs (those paid by utilities to private generators of renewable energy) for electricity produced in cogeneration facilities at biofuels processing plants.

▪ The key measures to ensure economic, social and environmental sustainability to the National Biofuels Program should be the following:
  - Guidelines for the permitting of large-scale monoculture projects that mandate some fraction of the cultivated area be allocated to small-holders.
  - Exemptions from regulatory oversight provisions for biofuels production by small-scale producers (less than 3 million liters per year).
  - Funding and technical support for rural biofuels projects.
  - Eligibility of multiple crops as feedstocks, as noted above, and inclusion of several non-edible crops to address food security.
  - Introduction of feedstock cultivation on land that is put into production for the first time or – for land not cultivated since the pre-Independence period – returned to production, promoting rural development while safeguarding food security.
  - Political, operational and material support to the Ministry for Coordination of Environmental Activity (MICOA) for it to enhance its capability to control and ensure compliance of biofuels projects for all aspects related to environmental impacts.
  - The GoM should monitor efforts to develop standards for biofuels, and maintain a regular dialogue with the appropriate authorities in countries and/or other organizations engaged in the preparation of such standards and certification schemes.

▪ In order to ensure effective implementation of the National Biofuels Program, institutional and technical capacities should be strengthened, and new specific administrative processes and capabilities should be created. This should include reinforcement of the institutional and technical capacity to review project proposals, ensuring the consistency of permitting processes and requirements with the provisions of international standards and certification programs, and adequate laboratory capacities in the country. The support of various donor agencies should be requested for this purpose.

▪ Although the scope of carbon finance is likely to be limited, the Biofuels Working Group established within the GoM should involve MICOA into the process of developing a National Biofuels Program, so that it may begin preparing the relevant documentation to present it as Program of Activities under the Clean development Mechanism (or "programmatic CDM"), and that it may support efforts to prepare individual biomass cogeneration initiatives as CDM projects.

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CHAPTER 6: ANALYSIS OF THE COMPETITIVENESS AND FEASIBILITY OF BIOFUEL PRODUCTION IN MOZAMBIQUE

ACRONYMS AND ABBREVIATIONS

ABI	Agri-Business Incubator
ACP	African, Caribbean and the Pacific
ADB	African Development Bank
AFTEG	African Energy Group
AGOA	African Growth and Opportunity Act
ANP	National Petroleum Agency (Brazil)
BFP	Basic Fuel Price (South Africa)
BTL	Biomass-to-Liquids
CAFE	Corporate Average Fuel Economy
CAFTA	Central American Free Trade Agreement
CAMEC	Central African Mining and Exploration Company (ProCana sponsor)
CBI	Caribbean Basin Initiative
CBO	Community Based Organizations
CDM	Clean Development Mechanism
CEF	Central Energy Fund
CENACARTA	Centro Nacional de Cartografia e Teledetecção
CENAL	National Executive Commission of Alcohol (Brazil)
CEPAGRI	Centro de Pesquisas Meteorológicas e Climáticas Aplicadas à Agricultura
CERs	Certified Emission Reduction Units
CEST	Condensing-Extraction Steam Turbine
CFTD	French Fiber Development Company
CHP	Combined Heat and Power
CIDES	Interministerial Committee for Sustainable Development

CIF	Cost Insurance Freight
CIS	Commonwealth of Independent States
CNG	Compressed Natural Gas
COFINS	Contribution to Social Security Financing (Contribuição Para o Financiamento da Seguridade Social)
CNAL	Brazil's National Alcohol Council
CVRD	Companhia Vale do Rio Doce (Brazilian Mining and Steel Conglomerate)
CTA	Confederation of Business Associations of Mozambique
DDGS	Distiller's Dried Grains and Solubles
DME	South African Department of Minerals and Energy
DNAIA	National Directorate of Environmental Impact Assessment
DNER	Departamento Nacional de Estradas de Rodagem (Brazil)
EAP	Economically Active Persons
EBP	India's Ethanol Blending Program
EdM	Electricidade de Moçambique (Electric utility)
EERE	Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
EPAct	U.S. Energy Policy Act
ETBE	Ethyl Tertiary Butyl Ether
FAME	Fatty Acid Methyl Esters
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization's Database of Info on Production, Consumption, Trade, Prices and Resources
FFV	Flex Fuel Vehicle
FRELIMO	Liberation Front of Mozambique
FUNAE	Fundo Nacional de Energia (Mozambique)

HCB	Cahora Bassa Hydroelectric
IAF	Household Survey (Inquérito Nacional aos Agregados Familiares sobre as Condições de Vida
ICRISAT	International Crops Research Institute of the Semi-Arid Tropics
IIAM	Mozambican Agricultural Research Institute
IIED	International Institute for Environmental Development
IMF	International Monetary Fund
IMOPETRO	Importadora Moçambicana de Petróleos
INE	National Statistics Institute (Instituto Nacional de Estadística
INETI	Ministry of Engineering, Technology and Innovation (Portugal)
INIA	Instituto Nacional de Investigación Agropecuaria
IRCT	French Institute for Research on Cotton and Exotic Fabrics Institut de Recherches de Coton et des Textiles Exotiques
ITDA	Integrated Tribal Development Agency
IRR	Internal Rate of Return
JAMA	Japanese Automobile Manufacturers Association
JBIC	Japanese Bank for International Cooperation
JV	Joint Venture
KLPD	Kiloliter-Per-Day
LDC	Less Developed Country
LMC	Ludin Mining Company
LPG	Liquified Petroleum Gas
MADER	Ministry of Agriculture and Rural Development
MAFF	Japan’s Ministry of Agriculture, Forestry and Fisheries
MCC	U.S. Millennium Challenge Corporation
METI	Japan’s Ministry of Economy, Trade, and Industry

MICOA	Ministry for Co-ordination of Environmental Affairs
MINAG	Ministry of Agriculture
MOTRACO	Mozambique Transmission Company
MTBE	Methyl tertiary-butyl ether
NAFTA	North American Free Trade Agreement
NEB	Net Energy Balance
NEMP	National Energy Management Program
NPK	Nitrogen, Phosphorous and Potash(Potassium)
ONGC	Natural Gas Corporation (India)
OSR	Oil from Rapeseed
PAJ	Petroleum Association of Japan
PARPA	National Poverty Alleviation Strategy (Plano de acção para a redução da pobreza Absoluta)
PEA	Economically Active Population (População Economicmente Activa)
RBD	Refined, Bleached and Deoderized Oils
RBOB	Reformulated Gasoline Blend Stock for Oxygenate Blending
RFA	Renewable Fuels Association
RFG	Reformulated Gasoline
RFS	Renewable Fuel Standards
RPTES	World Bank’s Regional Program for the Traditional Energy Sector
RTFO	Renewable Transport Fuels Obligation
RVP	Reid Vapor Pressure
SADC	Southern African Development Community
SSBET	Sweet Sorghum Based Bioethanol Technology
TANESCO	Tanzanian Electric Supply Company

TIA	Agricultural Survey (Trabalho de Inquérito Agrícola)
TSC	Taxa Sobre Combustíveis (Tax on Fuels)
UEDCL	Uganda Electricity Distribution Company Limited
UEPA	European Union of Ethanol Producers
UNIFEM	United Nations Development Fund for Women
USDOE	U.S. Department of Energy
UTIP	Hydroelectric Project Implementation Unit (Unidade Técnica de Implementação de Projectos Hidroelectricos)
VOCs	Volatile Organic Compounds
VSI	Vasanthadada Sugar Institute (India)
WDG	Wet Distiller’s Grains
WWF	World Wildlife Fund

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INTRODUCTION

This study provides a comprehensive assessment of the potential for biofuels production in Mozambique and assesses the potential competitiveness of biofuels production in comparison to the cost of imported petroleum-based transportation fuels in the domestic market as well as in overseas markets where both conventional and renewable fuels are consumed. The study also estimates the potential macroeconomic benefits from the development of biofuels production in the country, while at the same time identifying the potential risks from this activity. In addition, the study reviews the current market for biofuels in other countries and reports on the experience of several countries with national biofuels programs. Based on this review, the study provides some general recommendations for Mozambican policymakers to enhance the conditions in the country for the development of a biofuels sector in a direction that will maximize the economic, social and environmental benefits for Mozambique and minimize the potentially damaging impacts resulting from development in this sector.

In this way, the assessment and recommendations presented here attempt to address the questions posed by the Ministry of Energy and the Ministry of Agriculture when they commissioned the study with the support for the World Bank and Italian Cooperation. While the concerns of the two Ministries differ, they are complementary. From the agricultural standpoint, the significant questions include: What are the potential feedstocks for biofuels production in Mozambique? What criteria should be used to select one or more from the list of candidate crops? What are the likely costs of production, and do these costs imply that biofuels will be competitive with imported petroleum-based fuels in the domestic market and in overseas markets, relative to fossil fuels as well as biofuels? What are the most promising markets, and for which biofuel? What are the potential environmental and social impacts of biofuels development, and how can these be managed to maximize the positive impacts and minimize the negative outcomes? What types of support and research and development are required to achieve this?

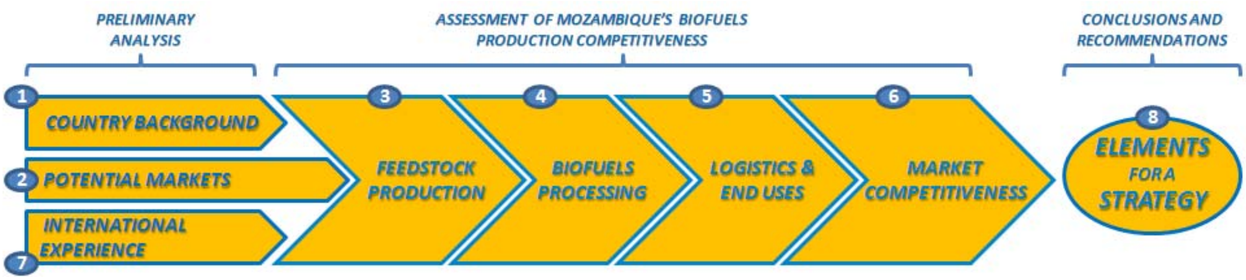
Meanwhile, from the energy standpoint, the key questions are: What is the potential for biofuels development to create a new productive subsector of the energy sector in the country? Can it help improve Mozambique's balance of trade by displacing imports and increasing exports? Can it help address some of Mozambique's pressing needs in the area of expanding access to fuels and electricity, especially in rural areas?

Econergy International Corporation assembled a multinational team to conduct the fieldwork, research and analysis presented in this study. In addition to the core Econergy policy, economic and technical teams based in the United States in Boulder (Colorado) and Washington, DC, and in Econergy's overseas offices in São Paulo and London, the following firms also participated in the work: Alf International, based in São Paulo, and represented by José Zilio; Blueprint Cape, based in Cape Town, and represented by Dave Liddell and Tony Barbour; and in Mozambique, SICS, represented by Dr. Cardoso Muendane, and Efficientia, represented by André Nogueira.

In general terms, the methodological approached employed by the Econergy team has been to complement documentary and periodical resources with interviews and direct observation over the course of two weeks spent in Mozambique. The analytical approach used to estimate production costs for biofuels was to gather production cost data from agricultural agencies in the country, derive estimates of per-unit costs of production, and then apply industry data and empirical observations from biofuels producers to arrive at production costs for ethanol and biodiesel. Transportation and port costs are based on interview data; some direct quotes were used to project CIF costs to major export destinations. Chapters 3, 4, 5 and 6 of the study comprise this segment of the analysis.

At the same time, the Econergy team collected data on the baseline situation in Mozambique (Chapter 1), the status of national and international policies intended to promote biofuels use in major industrial countries, as the basis for potential export markets for Mozambique (Chapter 2), and in Chapter 7, the experience in several emerging market economies with policies to promote production and consumption of biofuels. Following these two major components of the study, Chapter 8 provides some conclusions and preliminary recommendations. Figure 1 provides a conceptual overview of the study, while the following chapter summaries provide more detail about the contents of each chapter.

Figure 1: Overview of the study



Source: Econergy.

Chapter 1 This Chapter provides a general overview of Mozambique from a macroeconomic standpoint and with respect to the energy sector, as well as the details of how fossil fuels are taxed in Mozambique.

Chapter 2 This Chapter reviews the potential domestic and international markets for biofuels, and identifies the potential tariff and non-tariff barriers to entry into the international markets. The international markets reviewed include SADC (principally South Africa), Asia (China, Japan and India), Europe (the U.K., Germany, Portugal, Spain and Italy) and North America (U.S. and Canada).

Chapter 3 This Chapter reviews the state of the agricultural sector in Mozambique, including key issues such as land tenure and land availability, and the characteristics of the rural population of the country. Then it reviews the potential crops that could be used to produce biofuel feedstocks, notably African palm, cassava, castor seed, coconut, cotton, jatropha, maize, peanut, sesame, soy, sugar cane, sunflower and sweet sorghum, and provides the justification for narrowing the list to nine priority crops (African palm, cassava, castor seed, coconut, jatropha, soy, sugar cane, sunflower and sweet sorghum) for analysis in Chapter 4. The crops are evaluated on the basis of their cost of production, and subsequent processing into biofuels (ethanol or biodiesel, depending on the crop). The applicability of different business models employed in Mozambique is also assessed, as are the potential socio-economic and environmental impacts of widespread biofuels production in the country.

Chapter 4 This Chapter reviews the available production technologies for ethanol and biodiesel, as well as technologies that are likely to emerge in the next decade. Based on the cost of feedstock production, the analysis presented in this Chapter develops estimated costs of production of the biofuel at the factory gate, and addresses the issue of opportunity costs for several crops. The analysis also addresses the potential for alternative technologies to transform process waste into readily useful energy. The analysis encompasses the potential emissions reductions associated with biofuels production and use in Mozambique, and the socio-economic and environmental considerations associated with them. Finally, the analysis attempts to quantify the potential macroeconomic benefits of biofuels production.

Chapter 5 This Chapter reviews the relevant issues associated with end uses for biofuels and the infrastructure required for their transportation, storage and utilization. Estimated transportation costs used to develop costs FOB at major ports in Mozambique and costs CIF to major overseas destinations are also presented.

Chapter 6 This Chapter presents an assessment of the competitiveness of each biofuel with other liquid fuels for transportation and residential use in Mozambique as well as for the major export markets. The analysis also encompasses the potential economic returns from producing biofuels in the country.

Chapter 7 This Chapter presents a series of case studies of biofuels development programs in different emerging markets, including Brazil, India, Colombia, Zimbabwe, Tanzania, Thailand and South Africa. The purpose of this review is to identify any common threads and potential lessons for Mozambique.

Chapter 8 This Chapter presents the conclusions of the analysis and offers some recommendations for consideration, in the development of a National Biofuels Strategy for Mozambique.

This report is intended to establish the groundwork for Phase II of the work performed by the Econergy team, which encompasses the preparation of a National Biofuels Strategy for Mozambique. For this reason, the detailed presentation, analysis and recommendations included in this report do not go into more detail regarding the proposed operation of a biofuels program in the country. These issues will be addressed in the forthcoming work of the Econergy team and the relevant agencies of the Government of Mozambique.

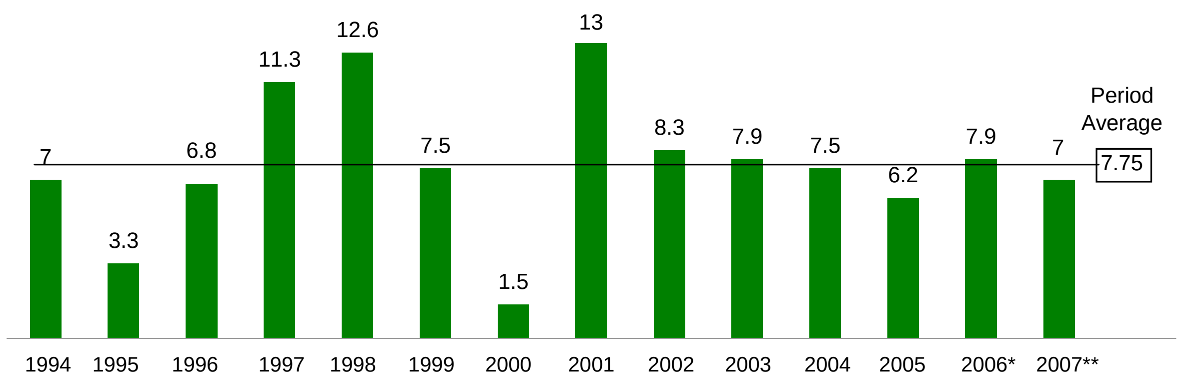
CHAPTER 1: BASELINE CONDITIONS IN MOZAMBIQUE

This Chapter provides a general overview of Mozambique from a macroeconomic standpoint and with respect to the energy sector, as well as the details of how fossil fuels are taxed in Mozambique.

1. Macroeconomic and sectoral review

Macroeconomic context. Since its brutal civil war ended in 1992, Mozambique has achieved a dramatic economic turnaround through the application of conservative fiscal and monetary policies, and the promotion of large investment projects. Between 1994 and 2006, Mozambique achieved an impressive average annual GDP growth of almost 8% in real terms.

Figure 1: Trend in Mozambique's GDP growth, 1994-2006



Source: Instituto Nacional de Estatistica (INE).

These favorable trends flowed from two important political changes: the transition to peace and political stability following the peace settlement; and the implementation, beginning in 1987, of economic reforms to replace the old centrally planned economic system with one that permits private enterprise operating in the context of free markets. With the establishment of democracy and peace, Mozambicans have been able to focus on economic progress in the context of economic and political stabilization. More recently, legislative and presidential elections in December 2005 returned the ruling *Frente de Libertação de Moçambique* (FRELIMO) to power with a renewed majority. Donors appear to be committed to continuing their support; after a slightly cautious period at the outset of the administration of President Armando Guebuza, it appears they are convinced that the President will not make a dramatic break from the economic policies that have prevailed for the last decade.

Major flooding caused by a cyclone in early 2000 affected the center and south of the country, delivering a severe blow to the country's macroeconomic evolution. Accumulated inflation at year-end had reached 56.9% in 1996, decreased for three consecutive years, and reached one-digit levels from 1998 to 2000. The effect of the floods reversed that trend in 2000 and 2001. Post-flood reconstruction in 2001 resulted in a temporary spike in inflation to 22%; that figure fell to 13% in 2003.[1] Over the last five years, the inflation rate has ranged from 7% to 14%.

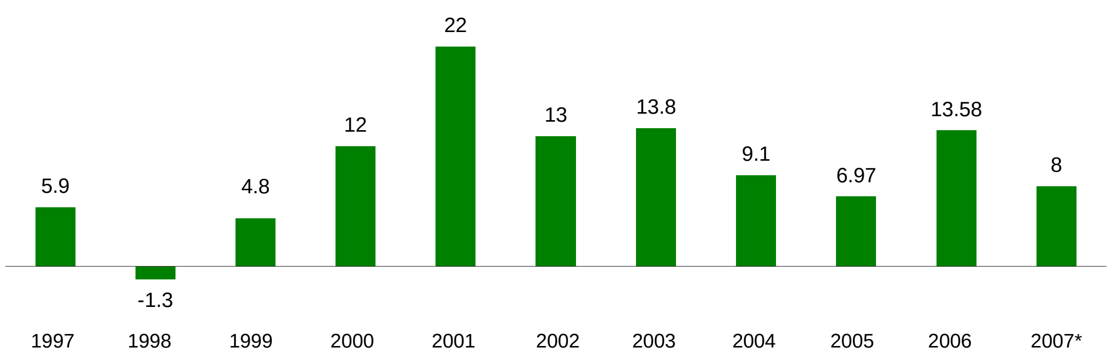
Economic growth is increasingly shifting from large projects to sectors such as construction, mining, transportation and communications, as well as agriculture and cattle ranching. This trend is important for the achievement of balanced development in the country, given the greater potential impact in terms of job creation and poverty mitigation, and the contribution to diversification of the economy. This occurs at a time when oil prices are high, and tight financial targets have been negotiated with the IMF under the "Poverty Reduction and Growth Facility," further reducing fiscal flexibility.

From 2001 onwards, real GDP growth rebounded and settled into a regular pace of around 7%, making Mozambique Africa's fastest-growing economy for several years. The growth rates recorded in Mozambique from 2003 onwards compare favorably to the 4.5% average on the African continent and 4.6% in the Sub-Saharan region in 2003.[2] In addition to more generally widespread economic growth, a number of private sector mega projects, in the area of hydroelectric power and natural resource extraction, are likely to contribute very significantly to medium-term growth.

The strong GDP growth has had a clear impact on the incomes of Mozambicans. Per capita annual expenditures rose to USD 230 in 2000, from an estimated USD 170 in the 1997 census. Lack of data makes it difficult to assess more recent trends, but it is likely that this upward trend has continued through to the present.

The Government of Mozambique has set a target of 8% inflation for 2007, within a broader objective of controlling inflation. This represents a significant challenge since the country is quite exposed to external variables given its large dependency on imports,

Figure 2: Inflation in Mozambique, 1997-2007



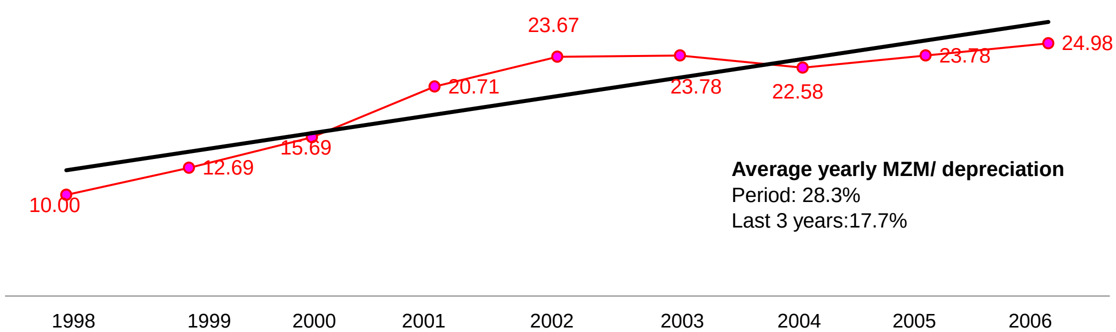
Source: Instituto Nacional de Estatistica (INE), based on World Bank (1994-1997), Banco de Moçambique (1998-2006). *Estimate, annualized from first three quarters of 2006.

[1] "Country Commercial Guide Mozambique Year 2004," (Maputo: United States Embassy, 2005), 1-7.
[2] IMF World Economic Outlook (September 2004).

particularly fuels. Indeed, the higher-than-expected 2006 inflation rate of 14% was mainly caused by fuel and food prices. In the period to September, 2006, total fuel imports reached USD 300 million, compared to USD 218 million for all of 2005. Since most of this variation results from high oil prices rather than increased consumption (consumption decreased), it is clear that the nearly double figure for inflation registered in 2006 is externally induced. The fact that nearly half of the proceeds in external currency from exports – USD 600 million excluding the large projects – were used to pay for the import of fuels underscores the vulnerability of the Mozambican economy to external shocks.

This exposure also influences, and is influenced by, the exchange rate, since it drives government policy in managing the balance of external currency reserves. The relatively high reserve requirement obliges the Central Bank to buy and hold foreign currency to pay for fuel imports, thereby exerting downward pressure on the metical. Even so, to date Mozambique has been able to withstand this impact and actually decelerate the annual depreciation of its currency against the dollar from 27% in 2005 to 10% in 2006. Further, against the South African rand, the metical actually appreciated by 3.3% in 2006, compared to an 11% depreciation in 2005. Figure 3 depicts the variation of the metical/dollar exchange rate over the last nine years. An inflection point in 2002, between the previous period of more rapid depreciation and the subsequent one of more gentle depreciation, is clearly observable. The average yearly depreciation over the 1998-2006 period was 28%, while the rate of depreciation has slowed to 18% over the last three years. Tight monetary policies are successfully and gradually stabilizing the metical, which contributes to the stabilization of the overall economy.

Figure 3: Trend in the Metical/Dollar exchange rate, 1998-2000



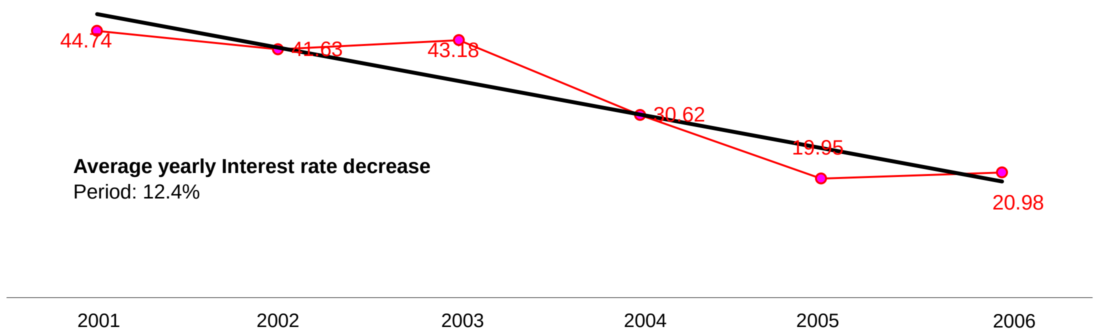
Source: Ministry of Finance

High, albeit decreasing, interest rates reflect the perception that Mozambique is still a risky place to invest. Figure 4 illustrates the evolution of interest rates over the last five-year period.[3] As a result of the high cost of debt in meticais, private sector borrowing is limited, particularly in economically important sectors such as agriculture, where risk is

[3] 7 days active operations interest rate

perceived to be comparatively high, in part because of land tenure issues. Although there are clear signs of improvement, the situation is still far from providing a competitive market where capital may be obtained at a reasonable price. This tends to skew development towards large investment projects implemented by large firms that are able to secure funding outside the local banking system at more attractive rates. Local private entrepreneurs are penalized by the high interest rates, slowing the emergence of a thriving local business community.

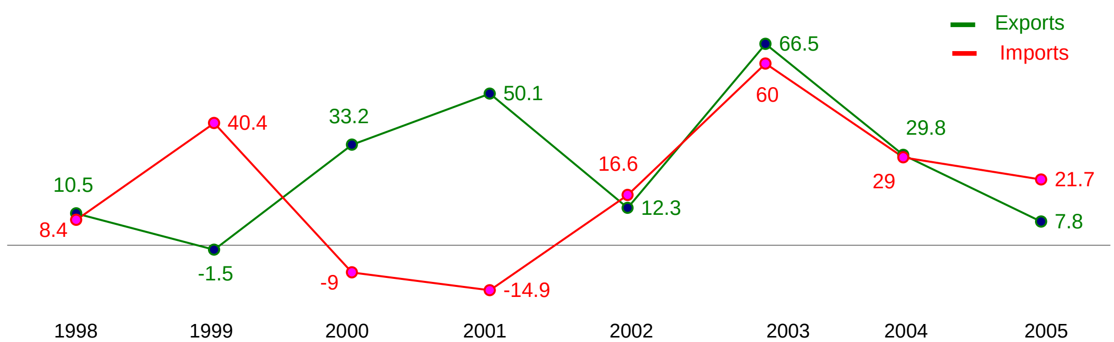
Figure 4: Interest rates



Source: Ministry of Finance

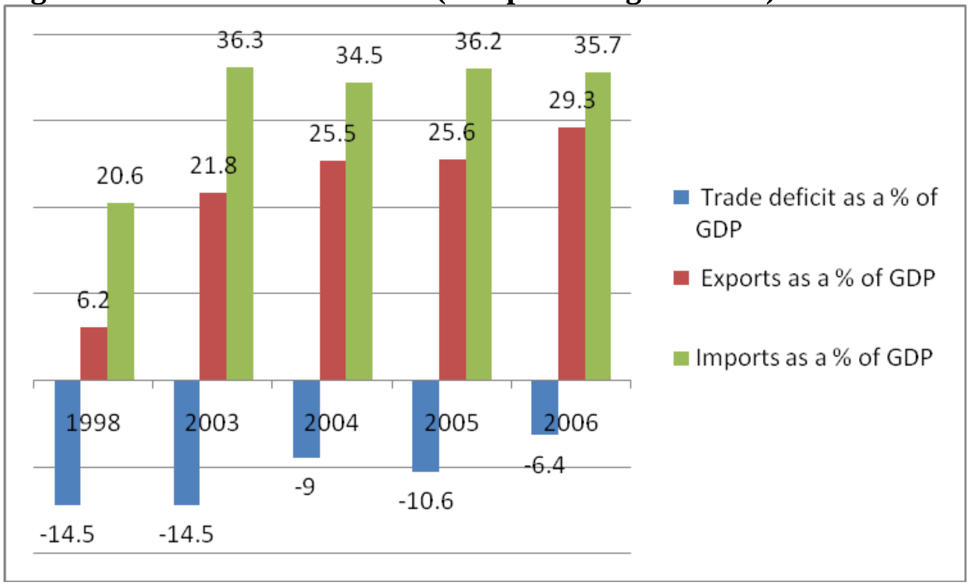
Overall, Mozambique's current account is highly unfavorable, in part because of the implementation of mega-projects, though there has been some improvement. Over the last years exports have grown on average at a faster pace than imports (see Figure 5). As a result we observe a general downwards trend for the trade deficit, shown in Figure 6.

Figure 5: Annual growth rates of exports and imports (percent per year)



Source: Banco de Moçambique

Figure 6: Annual Trade Deficit (as a percentage of GDP)



Source: IMF and Bank of Mozambique

It is important to understand the importance of large investment projects in these general trends. On one hand, a significant proportion of imports correspond to raw materials or capital goods required by investments such as Mozal or mining operations. In 2004 capital goods accounted for around 15% of total imports, although imports related to large projects have decreased, a positive indicator reflecting the end of the construction/ investment phase.[4] On the other hand, projects like Mozal account for a large portion of exports, with little value added remaining in Mozambique. In 2004, Mozal alone accounted for over 60% of total exports, and in 2006 it is estimated that mega-projects accounted for over 70% of total exports, reflecting their disproportionate importance in the economy.[5]

Despite the recent positive evolution shown in Figure 5, imports continue to exceed exports. In 2000, imports stood at USD 1.2 billion, with exports at USD 723 million, yielding an import/export ratio of almost two-to-one. This is an improvement over the four-to-one ratio of the immediate post-war years. In 2006, imports totaled USD 2.6 billion, while exports stood at USD 2.4 billion (including large projects). However, it is expected that in the medium term a number of important investment projects will increase exports and thereby redress Mozambique's trade imbalance. These include the Moatize coal project of Brazil's Companhia Vale do Rio Doce (CVRD), the Moma heavy sands investment, and proposals for new hydroelectric plants on the Zambezi River.

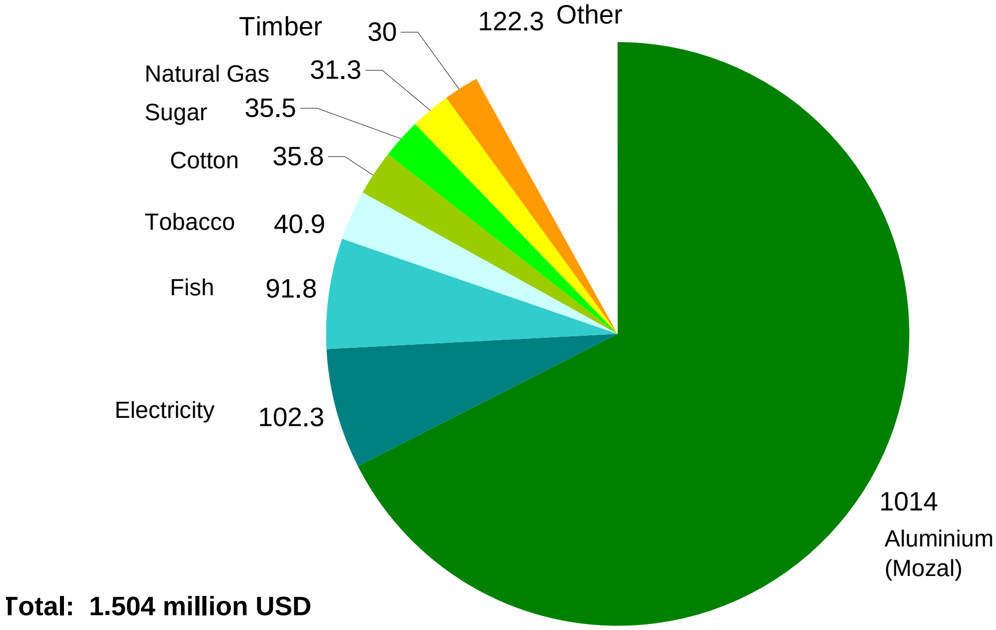
Figure 7 shows the relative importance of the major export products for 2004. The importance of the Mozal aluminum smelter to overall exports is striking. Electricity and

[4] 100 Maiores Empresas, 2004, KPMG
[5] AFDB – OECD 2007 Africa Outlook

natural gas are also important in the overall picture, and both are likely to increase in importance in the medium term, along with new commodities, such as coal.

Traditional Mozambican exports include agricultural and fisheries products with limited processing, such as raw sugar, tobacco, cotton, shrimp and fish. Mozambique is gradually becoming less dependent on imports for basic food and manufactured goods due to steady increases in local production.

Figure 7: Mozambique's leading exports, 2004 (USD millions)

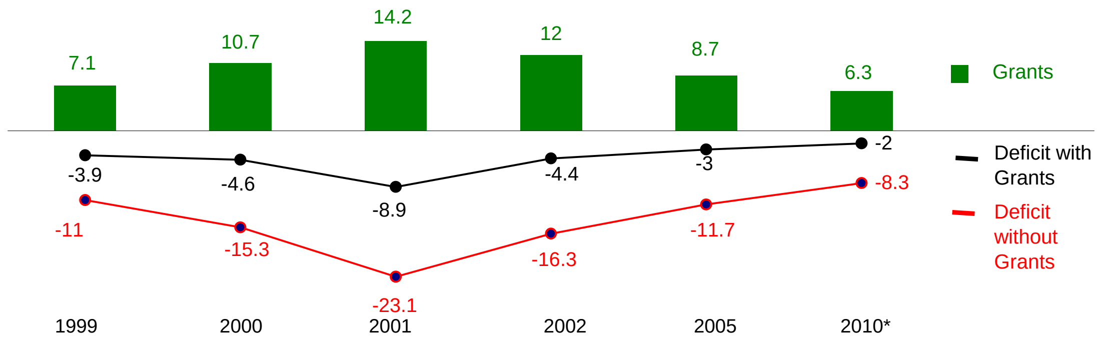


Source: KPMG, "Top 100 Companies of Mozambique," survey, 2004.

Mozambique is highly dependent on external support to mitigate its structural imbalances. Support programs provided by development partners generally compensate for the external trade deficit and improve the external reserves. In 2006, Mozambique was granted a substantial debt relief package of around USD 2 billion from the World Bank, the African Development Bank (ADB), and the IMF. This write-off significantly improved Mozambique's balance sheet and will strengthen the government's accounts.

Figure 8 depicts the state annual deficit and the impact of foreign aid in mitigating it. Foreign aid remains a stabilizing factor, without which the public accounts would be unsustainable. The combination of a high deficit and high donor contributions registered in 2001 reflect the scale of the crisis resulting from the flooding of 2000.

Figure 8: Government budget deficit (as percent of GDP)

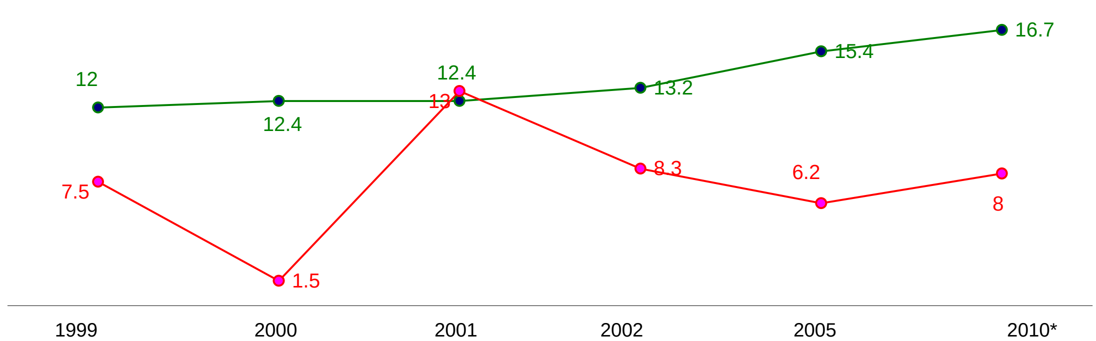


Source: World Bank. *Forecasts.

Still, the Mozambican government is making a significant effort to increase revenues. Fiscal reforms, including the introduction of the value added-tax, and taxes on individual revenues and corporate profits, combined with a reform of the customs service, have improved the government's revenue collection abilities. The role of taxes on fuels is illustrated in greater detail in Section 6 of this Chapter.

Figure 9 depicts the evolution of state revenues compared with GDP growth. Revenues have grown steadily, much more than should be expected from the economic growth alone. The enlargement of the tax base, to balance the public accounts, is a top priority of the government. However, the government's policy of proceeding with Southern African Development Community (SADC) integration, and specifically the elimination of customs duties on trade between SADC countries in 2008, is expected to have a negative impact on state revenues, though it has not yet been estimated. Given the importance of regional trading partners in Mozambique's overall international trade, the government will have to address this revenue shortfall in advance, and determine the best strategy to minimize its effects.

Figure 9: Trends in State tax receipts versus GDP growth (in percent)



Source: World Bank, Banco de Moçambique. *Forecasts.

In the future, efforts to reduce dependence on foreign assistance by increasing internal and foreign direct investment, especially in sectors likely to increase exports and/or reduce imports, will be central to the sustainable development of the Mozambican economy.

Generally, the perception is that Mozambique shows clear improvement in its business climate[6] favoring new investments. Between 1996 and 1999, investment reached an average of around 27% of GDP. This growth was broadly-based, including 9% growth in agriculture and animal husbandry (led by the family sector) and 18% in industry (excluding mega-projects). The annual average growth in private consumption was around 7%.

In 2000, the World Bank defined a number of strategic priorities which serve as the prerequisites for the balanced and sustainable development of the Mozambican economy.

- Substantial productivity gains in agriculture, particularly in the family sector
- Strong improvement in the functioning of market-supporting public institutions, including legal/judicial reform and the reduction of red tape
- Deeper structural reforms in other sectoral programs, removing obstacles to growth
- Continued support from international partners, maintaining high levels of net transfers
- Phased implementation of mega-projects, involving significant new investments
- A rapid growth in exports, particularly agriculture, starting from a low base, rooted in an expansion in the production of cash crops as a means to widespread wealth and the reduction of foreign trade unbalances, a large boost from the mega-projects, and maintenance of a competitive exchange rate
- Continued liberalization of foreign trade, in particular within the SADC region, and expansion of trade flows through the main transport corridors
- Rapid and inclusive growth of trade, transport and non-government services (including construction), boosted by agriculture, foreign trade and public works.

Although major developments have been achieved along these lines, the same macroeconomic objectives still apply today.

Sector analysis. In general, Mozambique has moved toward increased participation of services in the economy. Figure 10 depicts the recent evolution of relative contribution from main sectors to GDP**.** Services account for over 50% of Mozambican GDP, while industry accounts for slightly over one-quarter and agriculture provides the remaining 20%. Over the last decade, agriculture and fishing have lost importance, while industry shows the highest relative growth. This shows progress toward the modernization of the

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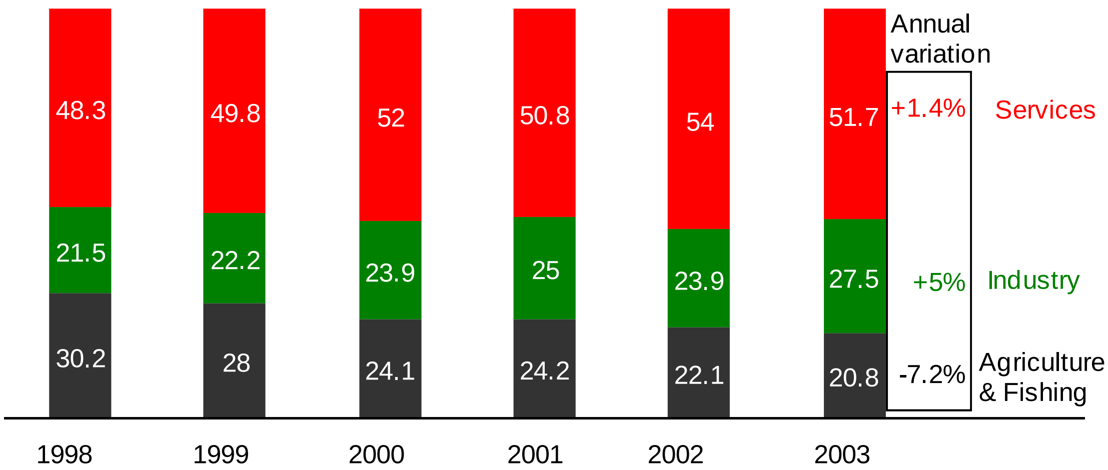
[6] According to the Foreign Investor Survey 2003, UNIDO, p. 74 and 75, only 13% of foreign investors inquired declare that investment and market climate in Mozambique has deteriorated, while a majority declared the investment and market climate (33% and 39% respectively) has been improving. Also according to the survey, a large majority of the inquired declared the investments over the previous 3 years have shown good performance (70%) and seen growing sales (77%).

Figure 10: Structure of production (percent of GDP)



Source: KPMG "Top 100 Companies in Mozambique," survey, 2004.

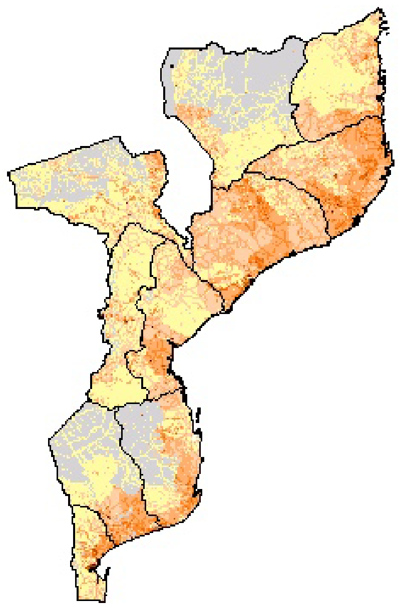
Mozambican economy, although it is still far from achieving a distribution equivalent to developed countries.

Demographics. Mozambique is one of the poorest countries in the world, measured in terms of income per capita. Roughly 95% of the population – over 17 million people – lives on less than USD 2 per day. Nearly 50% of the population is under 14 years of age. Analysis of data from the Inquérito Nacional aos Agregados Familiares sobre as Condições de Vida (Household Survey or IAF) of 1996-1997 has provided a detailed profile of poverty in Mozambique. Nearly 70% of the population lives in absolute poverty, and there are notable urban-rural and regional imbalances. The IAF data also permitted an identification of the main determinants of poverty in Mozambique, which are (i) slow growth of the economy until the beginning of the 1990s; (ii) low education rates among those of working age, particularly women; (iii) high number of dependents supported by the wage earner(s) in each household; (iv) low productivity in the family agriculture sector; (v) lack of employment opportunities; and (vi) poor infrastructure, especially in rural areas.

Besides suffering from acute material poverty, the poor in Mozambique also suffer from a high degree of vulnerability to natural disasters and economic shocks. This was made clear by the 2000-2001 floods, and by the privations caused in recent years by low prices on the international markets for the country's main agricultural products.

In addition, more than 70% of the population lives in rural areas, with an even higher proportion depending on agriculture for survival. Most agricultural production comes from the family sector, which encompasses more than 3 million families. For this reason, agriculture and rural development are a priority of the strategy for poverty reduction and broad-based growth. The principal objective of rural development is to increase income-generating opportunities, especially for the family sector. The largely rural character of the country is illustrated by Figure 11 and Figure 12.

Figure 11: Population density of Mozambique



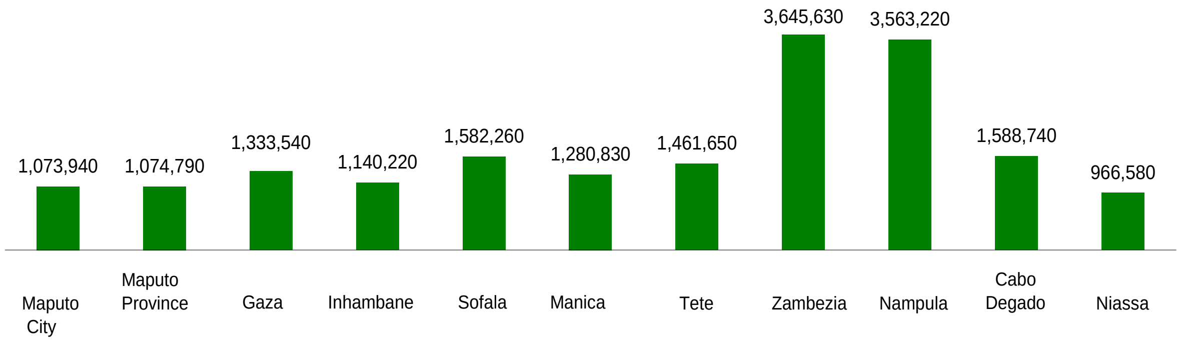
Population (People per Sq Km)
0 - 2
3 - 10
11 - 20
21 - 50
51 - 100
101 - 200
201 - 500
501 - 1000
>1000

Source: FAO Country Profiles and Mapping Information System: http://www.fao.org/countryprofiles.

Almost all rural households have access to at least a plot of land to farm (*machamba*), compared to less than half of urban households. The poor and non-poor have approximately the same amount of land per household, but the non-poor tend to use more equipment (inputs), and to have more irrigated land than the poor. Nevertheless, the use of equipment and inputs is very low and this is reflected in low levels of agricultural productivity in the country. Land is not, therefore, a limiting factor for poor peasants, but rather their capacity (and therefore means of production) to work the land they have, and achieve acceptable levels of productivity. Maize and cassava are the most common crops for both the poor and non-poor, while cash crops are of relatively marginal importance. The non-poor tend to cultivate more cotton and cashews; only low percentages of the poor do so (6.1% of the poor compared to 26% for the non-poor). This is reflected in the low levels of marketed output with, in general, less than 10% of households in each category (poor and non-poor) selling surpluses of maize, cassava, or cotton.

The country is not economically integrated. A summary of the data shows that, as a general trend, socio-economic indicators deteriorate in direct proportion to the distance from Maputo. Economic activity is concentrated in Maputo, which represents 40% of GDP, but only 10% of the population. At the other extreme of the country, in Niassa Province, GDP per capita is one sixth that of Maputo.

Figure 12: Population by province (2004 projection)



Source: INE.

While services and light manufacturing are more important in Maputo (together with raw materials processing at facilities such as the MozAl aluminum smelter), agriculture accounts for more than 50% of economic activity in most provinces. Specific activities are concentrated in certain regions: 50% of agricultural production occurs in Zambézia and Nampula; 40% of livestock production is in Nampula; and 60% of industry is concentrated in and around Maputo. More generally, Mozambique's urban population is only about one-third of the country's total, a comparatively low rate of urbanization but not atypical of the least developed countries.[7]

Poverty Reduction Strategy. The national poverty alleviation strategy developed in cooperation with the World Bank and other donors (*Plano de Acção Para a Redução da Pobreza Absoluta* or PARPA) stresses that economic growth must be both rapid and broad-based to benefit the poor. The strategy is based on an average growth rate of 8% for the period 2001-2010.

The sources of growth include large-scale, capital-intensive projects implemented by foreign investors ("megaprojects"), gains in productivity and value-added in the agricultural and small manufacturing sectors, and a general expansion in internal trade, transport and services. Increases in rural incomes will depend on a rise in agronomic productivity and on access to markets. Food security policy is also fundamental to reducing poverty and risks to the poor. These processes are complemented by public investment directed towards poverty-reduction objectives. In addition, the strategy calls for continued work towards an enabling environment for domestic and foreign businesses.

The priority areas in the strategy are education, health, agriculture and rural development, basic infrastructure, good governance, and sound macroeconomic and financial

[7] United Nations Department of Economic and Social Affairs (Population Division), *World Urbanization Prospects: The 2005 Revision*, pages 36-45. Available at: http://www.un.org/esa/population/publications/WUP2005/2005wup.htm.

management. The complementary areas are: employment and business development, social action, housing, mines, fisheries, tourism, industry, transport and communications, technology, the environment, and protection against natural disasters. In addition, while the likely impact of AIDS in Mozambique has yet to be fully understood and quantified, the high rates of HIV infection (about 16% of the adult population) may also lower the rate of growth.

The PARPA also assigns a central role to the maintenance of macroeconomic stability, including annual inflation of 5-7%, in fostering higher growth. The strategy calls for prudent fiscal policy to limit recourse to domestic financing, and highlights the importance of monetary restraint in maintaining stability. The strategy also is predicated on the assumption that the role of the state in stimulating a market economy and expanding opportunities for the poor lies in the development of basic infrastructure, as opposed to fiscal stimulus. Improvements in the road network will permit better access to markets and lower costs, and will facilitate communication and mobility, especially for those who live in rural areas and depend on agriculture. In parallel, the provision of water and energy is fundamental to the development of human capital and the expansion of national output.

2. Institutional framework

Given the importance of agriculture in the economy of Mozambique and the country's predominantly rural population, as well as the fundamental role of energy in any economy, the issue of biofuels covers the administrative responsibilities of numerous governmental, educational and international agencies. These are reviewed briefly here, with some detail given to the state of regulatory activity on biofuels specifically.

- *Ministry of Agriculture (MINAG)*. The overall mission of MINAG is to contribute to food security and reduction of absolute poverty through the promotion of competitive agricultural production and the development of agro-businesses that add value to production. Its activities encompass the development of policies and instruments conducive to increased per capita income, increased productivity through structural transformation, increased international competitiveness and integration of the sector in the overall economy. Monitoring the evolution of poverty indicators and the economics of the sector is also a responsibility of MINAG.

  Given the role of agriculture in several value chains, MINAG has working relationships with other ministries, including: (i) Industry and Commerce (MIC), particularly in agro-industry where agriculture crops constitute the basic inputs and in the policies regarding the commercialization of agriculture commodities; (ii) Transportation and Communications (MTC), given the critical need to move agricultural production and inputs throughout the country; and (iii) Civil Works, to coordinate the development of basic infrastructure necessary to agricultural expansion and product commercialization. MINAG's relation with Energy (ME) has grown in the context of biofuels, for which agricultural crops provide the raw materials, but is significant in any case because a significant part of the population (estimated in 80%)

relies on vegetable charcoal as a source of energy. Since agriculture plays a central role in Mozambican economy, virtually all areas of government are in some way related to it. The Ministries of Education, Science and Technology, Finance, Health, and Planning all have relevant links to MINAG.

MINAG encompasses several agencies, which may be organized under the following functional categories: (i) research, under the Instituto de Investigação Agrária de Moçambique (IIAM), which aggregates previously separate institutes and research centers (including the Instituto de Investigação Agronómica (INIA), the Instituto de Investigação Veterinária (INIVE), the Instituto de Produção Animal (IPA), and the Centros de Investigação de Sussundenga ou Nampula); (ii) rural extension services, under the Direcções Provinciais de Agricultura (DPAs), which assist over 175,000 small-scale farmers (approximately 15% of total) in nearly 90 districts throughout the country;[8] (iii) specialized sectoral organizations, such as the Cotton Institute, the Sugar Institute, and the Centro de Promoção Agricola (CEPAGRI), which focuses on cash and commercial crops; and (iv) other departments, which include the Direcções Distritais de Agricultura (DDAs), and programs that reflect the geographical scope of agricultural activities and economic relationships such as PROAGRI, as well as programs such as quality assurance, phytosanitary standards and land management (Geografia e Cadastro).

More generally, five critical issues for the biofuel sector are directly related to MINAG: (i) land management, ensuring that land does not pose a constraint, whether in terms of availability or its legal status, as well as concession oversight and water rights; (ii) commercialization of biofuel crops, including regulatory framework (price setting, arbitrage mechanisms, quality assurance); (iii) facilitation of investment projects (CEPAGRI) and articulation with other relevant ministries with respect to issues such as industrial licensing; (iv) extension activities to support small-holders on energy crop production; and (v) research and development activities, specifically for new crops not cultivated in Mozambique (African palm and sweet sorghum).

- *Ministry of Energy (ME)*. ME has authority over the energy sector. This encompasses the oversight of the development of Mozambique's rich energy resources, which include hydroelectric potential, coal and natural gas, the development of appropriate regulatory structures to ensure the availability of energy supplies and investment in energy production to meet future requirements, expand the geographic coverage of the national grid and fuel supply network, and deliver surplus energy resources are exportable commodities to the country's international trading partners. In the case of electricity, trade issues involve Mozambique's membership in the Southern Africa Power Pool (SAPP).

  Relevant entities to the coordination of an effective biofuels strategy with ME are: (i) Direcção Nacional de Energias Renováveis (DNE); (ii) the Direcção Nacional Combustíveis (DNC); (iii) PetroMoc; (iv) the Fundo Nacional de Energia (FUNAE);

[8] Survey data suggest that coverage is much lower than this. See Chapter 3.

and (v) Importadora Moçambicana de Petróleos (IMOPETRO). In addition, the Conselho Nacional de Electricidade (CNELEC), Electricidade de Moçambique (EdM), the Unidade Técnica de Implementação de Projectos Hidroelectricos (UTIP) and the Companhia de Transmissão de Moçambique (MOTRACO) are relevant in that the development of biofuels capacity, which will require power supplies while at the same time being a potential source of generation capacity in instances where the development of biofuels production can also offer biomass-based electricity capacity for sale to EdM with implications for the operation of the national grid. Other entities that may play more limited roles on issues of potential relevance to biofuels policy include the Direcção Nacional de Carvão e Hidrocarbonetos (DNCH) and Hidrocarbonetos de Moçambique (ENH). Some form of coordination and communication with each of these entities on biofuels issues would be desirable, and ME/DNE is the appropriate entity to provide this.

- *Ministry of Industry and Commerce (MIC).* MIC oversees the formulation and implementation of strategies to promote industrial and commercial expansion in Mozambique. While there is potential for some overlap of responsibilities between MIC and ME, given some of the specialized regulatory functions accorded ME for industrial activities specifically related to energy, the main areas where MIC will intervene in issues related to the development of biofuels production capacity will likely include licensing for industrial facilities (Departamento de Licenciamento e Fiscalização), oversight of fuel quality (Instituto Nacional de Normalização e Qualidade), recommendation of tariff and or tax exemptions for specific types of industrial facility, such as biofuels production plants, and interaction with Mozambique's trading partners in the context of the Southern Africa Development Commission (SADC). In addition to the clear requirement that it coordinate with ME on a range of issues, there are several other important areas of inter-agency coordination involving MIC that will be central to the development of the biofuels sector: investment promotion, with the Centro de Promoção de Investimentos (CPI); establishment of any incentives, tax or tariff exemptions or other special arrangements to attract investments, with Ministry of Finance (MF); and coordination with the MTC to ensure the provision of transportation and freight services at rates that do not impede commerce.

- *Ministry of Finance (MF).* MF has overall supervision authority over issues related to taxation and the management of the country's finances. In this capacity, the MF, through the Autoridade Tributaria, oversees the collection of taxes levied on various types of economic activity, including corporate income taxes, the Value-Added Tax (VAT) and the Tax on Fuels (Taxa sobre Combustíveis or TSC). In addition, it has authority over the collection of tariffs on imports. The Banco de Moçambique (BdM) exercises supervisory authority over the financial sector.

- *Ministry for Coordination of Environmental Activities (MICOA).* MICOA has responsibilities in the areas of environmental permitting, oversight and planning of land-use, environmental management, environmental education and information dissemination, enforcement and inter-agency coordination. In the context of

Mozambique's responsibilities under international environmental agreements, MICOA house the Designated National Authority (DNA) for the Clean Development Mechanism (CDM), which must provide host-country approval for projects submitted for registration to the Executive Board (EB) of the Kyoto Protocol. Of particular relevance to the development of biofuels, MICOA's National Directorate for Environmental Impact Assessment (DNAIA) oversees the conduct of the environmental permitting process in coordination with the Direcções Provinciais Ambientais (DPAs) in each province.

- *Ministry of Science and Technology (MCT).* The MST has overall supervisory authority over research and technology development activities in the country. In addition to conducting information gathering and statistical activities, MCT conducts training and supports original research and development activities, supports work at research institutions in the country and establishes links with international research institutions. To date it has conducted some work on potential energy crops, such as jatropha, and it is studying how to create infrastructure to support further development in this area. Specifically, it has been supporting work at Eduardo Mondlane University's Department of Chemistry on biofuels development, there is a proposal to create a biofuels research center at an old military facility in Maputo.

  Ministry of Public Works (MOP). MOP has overall supervision of and regulatory authority over the planning, design and construction of major civil works. This includes the issuance of concessions for major components of public infrastructure. Of particular relevance to the development of the biofuels sector, MOP oversees the National Highways Administration (ANE), which has responsibility of the construction and maintenance of highway infrastructure. Given the sensitivity of biofuels projects to logistics costs, and the difficult condition of the country's roads and related infrastructure, the success of MOP's efforts to improve this critical infrastructure is critical to the emergence of a biofuels market. Among other areas of coordination, MOP must receive timely information of projected transportation needs to take these issues into account as it establishes priorities for construction, maintenance and upgrading of highway and port infrastructure.

- *Ministry of Transportation and Communications (MTC).* MTC has overall supervision of transportation sector issues, as well as matters related to communications, which are not relevant for the purposes of this study. Specifically, MTC has overseen the process of issuing concessions for the ports and matters related to competition policy in the transportation sector, including both highway transportation as well as domestic shipping.

Table 1: National Energy Balance (in kTOE, net calorific value basis), 2004

	Coal	Crude Oil	Products	Gas	Hydro	RE	Biomass	Electricity	Total
Production	**23**	**0**	**0**	**2**	**1,003**	**0**	**7,208**	**0**	**8,236**
Imports	0	0	658	0	0	0	0	527	1,185
Exports	(9)	0	0	0	0	0	0	(818)	(827)
Marine Bunkers	0	0	(43)	0	0	0	0	0	(43)
Stock Changes	0	0	21	0	0	0	0	0	21
TPES*	**14**	**0**	**635**	**2**	**1,003**	**0**	**7,208**	**(291)**	**8,571**
Transfers	0	0	0	0	0	0	0	0	0
Statistical Differences	0	0	(4)	0	0	0	0	0	(4)
Electricity Plants	0	0	(9)	(2)	(1,003)	0	0	1,006	(8)
Other Transformation	0	0	0	0	0	0	(1,211)	0	(1,211)
Own Use	0	0	0	0	0	0	0	(9)	(9)
Line Losses	0	0	0	0	0	0	0	(102)	(102)
TFC**	**14**	**0**	**622**	**0**	**0**	**0**	**5,996**	**604**	**7,236**
Industry sector	0	0	102	0	0	0	527	548	1,176
Transport sector	0	0	443	0	0	0	0	0	443
Other Sectors	14	0	68	0	0	0	5,470	56	5,607
Residential	*0*	*0*	*50*	*0*	*0*	*0*	*5,470*	*39*	*5,558*
Public Services	*0*	*0*	*13*	*0*	*0*	*0*	*0*	*17*	*31*
Agriculture / Forestry	*0*	*0*	*5*	*0*	*0*	*0*	*0*	*0*	*5*
Fishing	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Non-Specified	*14*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*14*
Non-Energy Use	**0**	**0**	**9**	**0**	**0**	**0**	**0**	**0**	**9**
Feedstocks	0	0	0	0	0	0	0	0	0

Source: International Energy Agency

3. Overview of the energy sector and review of fuel sector

National energy balance. Mozambique's energy balance, presented on the previous page, shows the structure of production and consumption, and illustrates the extent to which primary energy supply is dominated by biomass and waste (accounting for some 81% of total energy supply), followed by hydropower (11%), petroleum-based fuels (7%) and coal (less than 1%). The overwhelming importance of biomass and waste fuels reflects the poverty and largely rural character of Mozambique. Charcoal, a basic household supply, is produced in small, family-owned facilities. Only in the major cities, and then for a small segment of the overall population, are petroleum-based fuels and electricity in general use.

It should be interpreted with some caution, as it does not appear to reflect some of the energy trade patterns observed in Mozambique, such as the re-export of petroleum products to countries in the interior of the continent, primarily through Beira.

Energy sector summary. Mozambique boasts substantial energy resources, including hydroelectric potential, significant natural gas deposits offshore in the Inhambane region, and coal deposits in Tete province. The country's hydroelectric potential attracted significant investment beginning in the colonial period, notably the Cahora Bassa hydropower facility; more recently, the country's gas and coal reserves have attracted significant foreign direct investment in the post-war period, at the gas fields in Inhambane Province and the Tete coal reserves at Moatize have likewise provided the basis for a recent USD 123-million investment by Brazil's CVRD.

Electricity. Mozambique has a nominal installed capacity equivalent to 2,390 MW, the vast majority of which is located at the 2,075-MW Cahora Bassa dam on the Zambezi River, in Tete Province in the northwestern part of the country. Of the electricity generated at Cahora Bassa, however, only 300 MW is consumed within Mozambique. The balance is exported, delivering significant export revenues – USD 102 million in 2004. Of the remaining 315 MW, about one-third is provided by smaller hydroelectric projects, and the balance comes from coal-, gas-, and diesel-fired facilities distributed around the country. EDM reports comparatively high technical and non-technical losses of approximately 23%, over twice the figure reported by Eskom and NamPower, but lower than those reported by TANESCO and UEDCL. Still, this loss level poses a challenge to EDM, given that peak demand currently exceeds the 234 MW reported for the 2001-2002 financial year.[9] The following sections address basic issues in the electric sector, including service coverage, tariffs, the major institutions active in the sector, and the regulatory context.

- *Service coverage*. Mozambique's electric system serves less than 5% of the country's population of about 18 million, with coverage in the capital, Maputo, exceeding all other regions of the country by far. In southern Africa, only Malawi exhibits lower

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[9] SADELEC, "Electricity prices in Southern and East Africa," (April 2003).

Table 2: Installed capacity in Mozambique's electric sector

Source	Technology	Nominal capacity (MWe)	Dispatchable capacity (MWe)
Maputo	Coal fired	58	20
Mavuzi	Hydro	52	29
Chicamba	Hydro	38	34
Corumana	Hydro	17	12
Cahora Bassa (HCB)	Hydro	2,075	2,075
Maputo	Gas	79	35
Beira	Turbine	12	12
Nacala	Diesel	21	6
Nampula	Diesel	7	4
Pemba	Diesel	8	6
Quelimane	Diesel	7	6
Various Plants <5MWe	Hydro, Diesel	19	10
Total		2,390	174[1]

Source: EDM, Elgas. [1]All HCB capacity, other than local requirements at the facility, is delivered to South Africa, with 300 MW reimported to Maputo on the MOTRACO line to Maputo. EDM pays HCB directly for this power, and pays a transport charge to Eskom.

electrification rates.[10] For instance, in the northern provinces of Cabo Delgado, Niassa and Nampula, coverage is estimated at about 1.2%, 2.1% and 3.2% respectively. The country's relatively low population density is a significant factor in this situation. Lack of service from the grid does not mean, however, that local populations do not use electricity; rather, their sources of supply are much more costly, generated with batteries or kerosene at costs equivalent to as much as USD 0.40/kWh compared to USD 0.07/kWh charged by EDM. The level of service coverage and the cost disparity between sources of supply provide powerful testimony to the substantial benefits in terms of economic growth and living standards that access to electricity provides.

- *Electric tariffs*. Industrial tariffs range from USD 0.035/kWh to USD 0.045/kWh, depending on maximum demand at a load factor of 80 %; per-kWh rates increase to the USD 0.045/kWh to USD 0.055/kWh range at lower load factors. For residential customers, tariffs range from USD 0.07/kWh to USD 0.08/kWh depending on consumption, with progressive increases allowing lower levels (and hence, socio-economic strata) to pay less, but still close to the average cost of service. Business (commercial) customers pay tariffs in the range from USD 0.105/kWh to USD 0.13/kWh depending on consumption levels. According to EDM officials, the cost of service is in the USD 0.08/kWh to USD 0.09/kWh. The tariffs applied to commercial end-users, in particular, have been a source of complaints on the part of the business community. For example, the Confederation of Business Associations of Mozambique (CTA) commissioned a study of tariffs in 2003 that argued that while electric tariffs are relatively low in Mozambique, the weakened financial condition of

[10] SADELEC.

many Mozambican companies leaves them vulnerable to sharp changes in operating costs. Between 2000 and 2003, the CTA report observed, tariffs increased by about 95% in the course of four tariff adjustments.

- *Electricidade de Moçambique (EDM)*. EDM has a monopoly over distribution, but there has been discussion in the government on plans to restructure the company, splitting into three enterprises covering generation, transmission and distribution, and of injecting private capital, although the assets would remain in state hands. Given the significant costs associated with delivering service throughout the country, EDM applies cross-subsidization on a significant scale, with the wealthier south subsidizing the poorer central and northern regions of the country. EDM has undergone – and continues to undergo – significant restructuring, and is currently operating under a three-year performance contract with the GoM.

- *Cahora Bassa*. In November 2005, Mozambique concluded a formal agreement with Portugal to reclaim the Cahora Bassa Dam and guarantee economic independence as well as control one of the major generation facilities serving the Southern Africa Power Pool (SAPP). The new arrangement gives Mozambique 85% of the Cahora Bassa hydroelectric facility (Hidroeléctrica de Cahora Bassa or HCB), while Portugal will retain 15%. Mozambique paid USD 900 million in the deal, which is less than half of what was being asked. Under an agreement that dates back to the colonial era (pre-1975), HCB sells the bulk of its power to Eskom at favorable rates, although given the tighter supply-demand balance throughout the SAPP, the favorable prices paid by Eskom have been adjusted upwards, increasing revenues for HCB.

- *Proposed hydropower and other megaprojects*. Work on other major hydroelectric projects, including another dam at Mepanda Nkuwa and Cahora Bassa North project, can continue now that the country has reached agreement with Portugal on HCB; Prime Minister Luisa Diogo had noted that these were "in limbo" until negotiations were concluded. Nonetheless, EDM officials indicated that the Technical Unit for Hydroelectric Projects (UTIP) has engaged in discussions with several major mining companies regarding investments in these megaprojects in conjunction with mining and mineral processing projects. In addition, CVRD has been in discussions with Eskom and perhaps other investors regarding the possibility of using low-quality coal from the Moatize mine at a mine-mouth generation facility, with an installed capacity of as much as 1,000 MW.

- *Transmission*. Electric supplies for Maputo and the south are delivered from South Africa via the 850-MW Mozambique Transmission Company (MOTRACO), a joint venture of Eskom, the Swaziland Electricity Board and EDM. The European Investment Bank (EIB) provided financing for the project, which delivers most of the power transported to the aluminum smelter outside Maputo, MOZAL. There are other interconnections between Mozambique and Zimbabwe and a proposed interconnection with Malawi, as well. One proposed project, which is politically significant for the government, is construction of a power line running from HCB south to Maputo and the Tete province. At present, power is routed through South

Africa, using Eskom transmission facilities, and then sent back to the southern province through Motraco's lines, a service for which the state power company Electricidad de Mozambique (EDM) pays Eskom a transit charge. The government has said this line would be one of its priorities, and in 2006 signed a USD 2.3 billion memorandum of understanding with China's Export-Import Bank to complete it together with Mepanda Nkuwa.[11]

- *Regulatory framework for electric sector*. Since 1997, the GoM has taken significant steps to create a favorable climate for private investment in the electric sector. Resolution 5 (1998) establishes the framework energy policy, including promotion of private investment, a competitive private sector more generally, promotion of energy efficiency, exporting power and efforts to strengthen the country's electric sector institutions. Laws 20 and 21 (1997) create the National Directorate of Energy (DNE), which fulfills the need for analytical and planning functions, promotes energy efficiency and diversification of supply, and cooperation between public- and private sector entities. This legislation also created the National Electricity Council (CNELEC), which is intended to become a regulatory body for the electric sector. Also in 1997, the government created the Fundo Nacional de Energia (National Energy Fund, or FUNAE), which has received funding from various donors, including the World Bank, to finance sustainable energy projects, manage on-lending facilities, promote opportunities in the private sector and promote the use of renewable energy resources in the country.

- *Rural electrification*. EDM has plans through 2010 for the extension of the electric grid in several regions of the country that are currently underserved. The plan identifies the order in which districts throughout the country will receive support for electrification efforts. Over the course of 2007, 2008, 2009 and 2010, the program focuses on specific districts in the southern, central, and northern regions in turn; however, large areas in the provinces of Niassa, Cabo Delgado, Manica and Gaza are identified as still awaiting financial support. (See the map for the plan in Annex A.)

  The national energy strategy permits the establishment of private mini-utilities serving mini-grids outside the country's interconnected system. The World Bank's ERAP program has supported the government's effort to promote private investment in such enterprises, in areas where there are promising economic developments that will create the requisite demand for electricity and credit-worthy customers. The purpose of this program is to create a new arrangement that would expand coverage in the region, from the limited level achieved by a privately operated system, under a management contract with EDM. Vilankulos, a private joint venture between a South African and a Namibian company, has a concession to generate and distribute electricity to customers under a 20-year contract, with an incentive to add connections (which are otherwise unaffordable to residential users) provided by a USD 400 subsidy per connection.

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[11] Econergy, "Definitional Mission Report: Energy Projects in Southern Africa", June 2006.

> FUNAE plays an important part in the Government's strategy as well. FUNAE receives part of its financial support from taxes on fossil fuels (discussed below), and uses these resources to provide grants to support rural electrification activities. Projects receiving grants include, installation of mini-grids based on renewable energy resources, solar home systems for residential use, and transmission projections to connect to the national grid where possible. In discussions with FUNAE, it was clear that the Fund views with great interest the possibility of supporting biofuels projects as well.

Natural gas. Mozambique also has significant natural gas reserves that could be used for domestic power generation, as well as industrial development. Gasfields in Inhambane province (with estimated reserves of about 2.75 trillion cubic feet) are currently being developed by South Africa's Sasol, which in 2004 completed a USD 400-million, 536-mile export pipeline to South Africa that could produce USD 148 million in gas exports in 2005, rising to USD 223 million when the facility reaches full production. Sasol has stated that the pipeline will be open to other companies producing natural gas in Mozambique, although it is understood that transmission capacity is subject to certain constraints. Several foreign companies already hold concessions in the country. Malaysia's PETRONAS is one of several other companies currently exploring other blocks in the Zambezi Delta region.

The GoM has joint-venture equity participation in the project, which entitles it to royalty payments in cash or in-kind, if it decides to use some of the gas for its domestic market. The GoM will not tax the project for 10-15 years, when the initial costs have been recouped (Economist Intelligence Unit Country Profile). The GoM, through *Empresa Nacional de Hidrocarburetos* (ENH), could expand its share (held through a subsidiary, CMG) to as much as 25% of the pipeline, by securing USD 85 million in financing to assume guarantees and financing currently held by EIB and Sasol.

According to Elgas, a Mozambique-South Africa joint venture engaged in energy project development in Mozambique, the existing pipeline has compression facilities with the capacity to deliver 120 million gigajoules (GJ) of gas to South Africa. Of this, Sasol has rights to 65%, and Mozambique the remaining 35% (of this, 5% of the total is considered "royalty gas"). At present, gas sales in Mozambique through another ENH subsidiary, Matola Gas Company, which serves the industrial area south of Maputo, amount to no more than about 6 million GJ. Elgas, a joint venture of Eskom, ENH, EDM and private investors (Eskom holds 25%, ENH and EDM together hold 40% and local Mozambican investors hold 25%), examined the possibility of building a gas-fired generation station in Mozambique to provide peaking capacity for EDM as well as the SAPP, which would require at least 15 million GJ of gas annually. Since virtually all the gas delivered by the Sasol line is currently reserved (including part of the Mozambican share, but not the royalty gas), the ability of the project to secure gas supplies will depend on the production of additional gas volumes and high gas compression in the pipeline. There is strong evidence that the gas fields will yield larger volumes of gas, and potentially even additional gas from potential fields in the Buzi area, with an ENH official mentioning figures in the neighborhood of 200 GJ per year. Meanwhile, the line as designed could operate at higher pressures that would double throughput to 240 million GJ, but this would require new compression equipment.

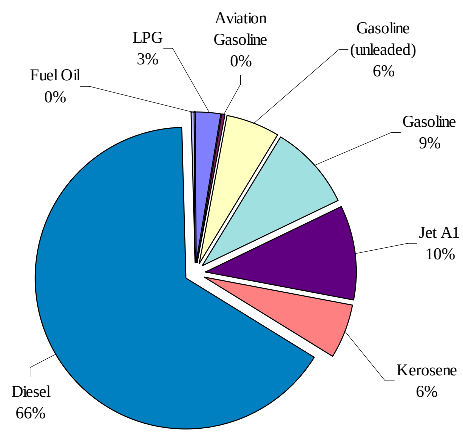
In discussions with ENH, it was apparent that efforts to increase domestic consumption of natural gas are focused on industrial users in the Maputo area, through Matola Gas. Larger volumes could be achieved, perhaps in the range of 9 GJ. Efforts to develop CNG for vehicular use, meanwhile, have not proceeded as quickly as had been anticipated. ENH is awaiting the results of a study of potential markets for natural gas funded by the UK's Department of International Development or DfID (due in August, 2007) to determine where the most attractive opportunities lie and discuss future market development efforts.

Coal. Total reserves are estimated at about 3 billion tons.[12] The concession held by CVRD covers investment in and operation of coal production facilities at Moatize, as well as the rehabilitation of the rail and port facilities at Beira to allow export of coking coal to Brazil. The balance of the production includes steam coal, which could be used for power production.

Petroleum-based transportation fuels and refining. Mozambique's sole refinery, located in Matola, is no longer operational. As a result, the country must import all its liquid fuel requirements. In 2006, Mozambique imported about 570,000 cubic meters (m3) [570 million liters] of petroleum-based fuels; this figure represented a decrease of 0.1% relative to the previous year, following a decline in 2005 relative to 2004. In 2006, as shown in Figure 14 and Figure 15, prices for fuel sold in the country roughly doubled in the period from 2002 to 2006, following a period of general stability from 1997 onwards.

Figure 13: Structure of consumption of liquid fuels, 2006 (by energy value)

Fuel	Energy Content (GJ)
LPG	642
Aviation Gasoline	22
Gasoline (unleaded)	1,354
Gasoline	2,051
Jet A1	2,219
Kerosene	1,312
Diesel	14,723
Fuel Oil	82
Total	22,405



Source: DNC/Ministry of Energy.

[12] ScanTeam, "Alignment, harmonization and coordination in the energy sector, Mozambique," (February, 2005).

As shown in Figure 13, diesel fuel accounted for 66% of consumption in terms of energy content, or 376 million liters, while gasoline accounted for about 15% of energy or 98 million liters (of which unleaded gasoline represented about 39 million liters) in terms of volume.

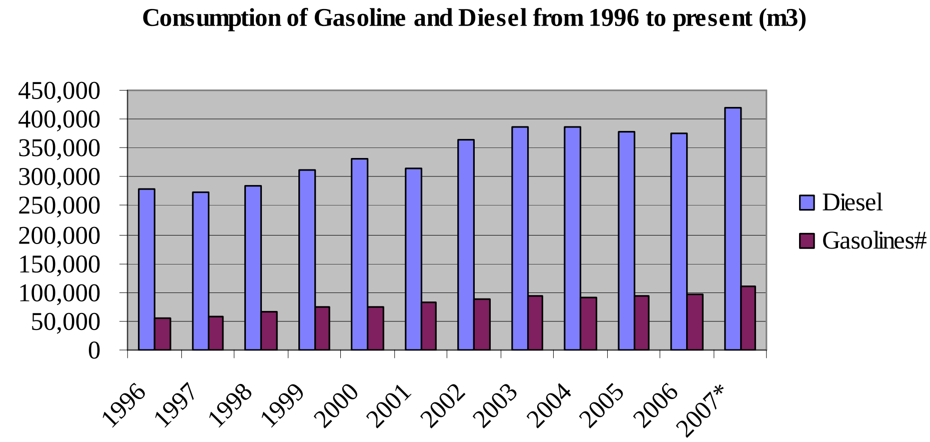
IMOPETRO imports fuel supplies as finished products (with no further blending required) by competitive tenders every six months (annually in the case of LP gas), and sells it to the nine distributors licensed to operate in Mozambique. Fuel is delivered to the three marine terminals in the country to bonded storage facilities, from which fuel is delivered to the distributors after customs formalities are completed. The two major distributors in Mozambique are PetroMoc and BP, which together account for 139 of the roughly 250 retail facilities. PetroMoc accounts for about 258 million liters, or 45% of sales. Fuel is either trucked directly to retail stations or to storage facilities belonging to PetroMoc or BP, from which it is distributed to the retail stations.

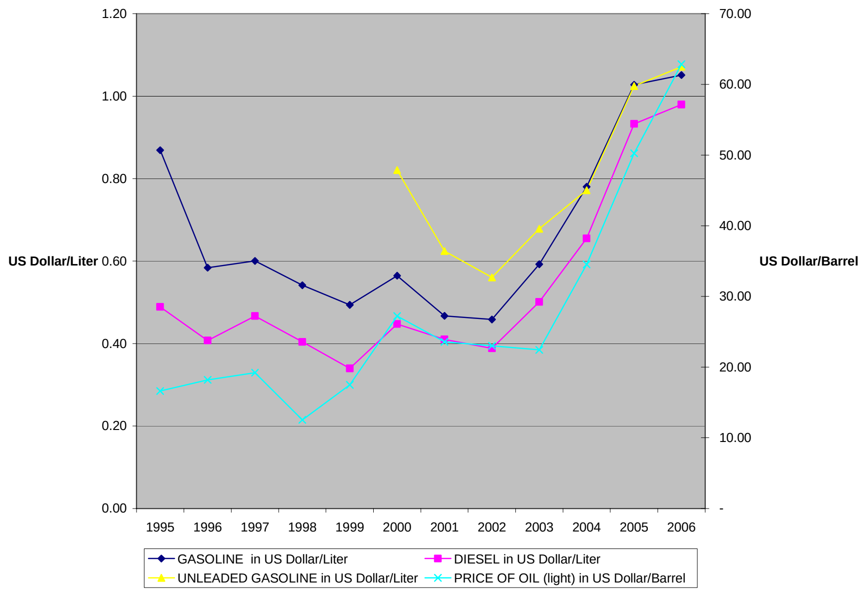
Consumption of gasoline and diesel is concentrated in the southern part of the country, primarily the Province of Maputo. Although the data from the Ministry of Energy showing the regional distribution of sales are inconsistent (because of difficulties in securing reports from the distribution companies), it is apparent that about one third of gasoline sales are concentrated in the city of Maputo, and about 60% in the southern region of the country, comprising the provinces of Maputo, Gaza and Inhambane. The share of the southern region in total sales of diesel is somewhat lower, at about 49%, but still very substantial. It appears also that consumption is concentrated along the coastal areas of the country, with sales in the interior provinces of Niassa, Tete and Manica representing about 7% for diesel and 6% for gasoline.

Fuels for residential use. Residential fuels – primarily kerosene (*petróleo de iluminação*) and LPG – have declined in aggregate terms since 2000, with LPG's share of consumption increasing to about 33% from 13% in 2000 (see Figure 16). The steady upward trend in prices has likely been a determining factor in this decrease in consumption, as households seek to economize on fuel and/or shift to other fuels, most likely charcoal.

Review of price structure for fuels. The prices paid by end users for the main imported fossil-based fuels (leaded and unleaded gasoline, jet fuel, kerosene, diesel, fuel oil and LPG) reflect four general components (i) the underlying prices for the refined products themselves; (ii) port costs; (iii) taxes and tariffs (DA, IVA, TSC), described in greater detail in the following section; and (iv) wholesalers' and retailers' margins and transportation costs. As shown in the graphic in Figure 15, the transportation costs are higher for points in the interior and at locations on the coast that are remote from any of the three ports of entry for fuels.

Figure 14: Trends in Fuel Consumption and Prices

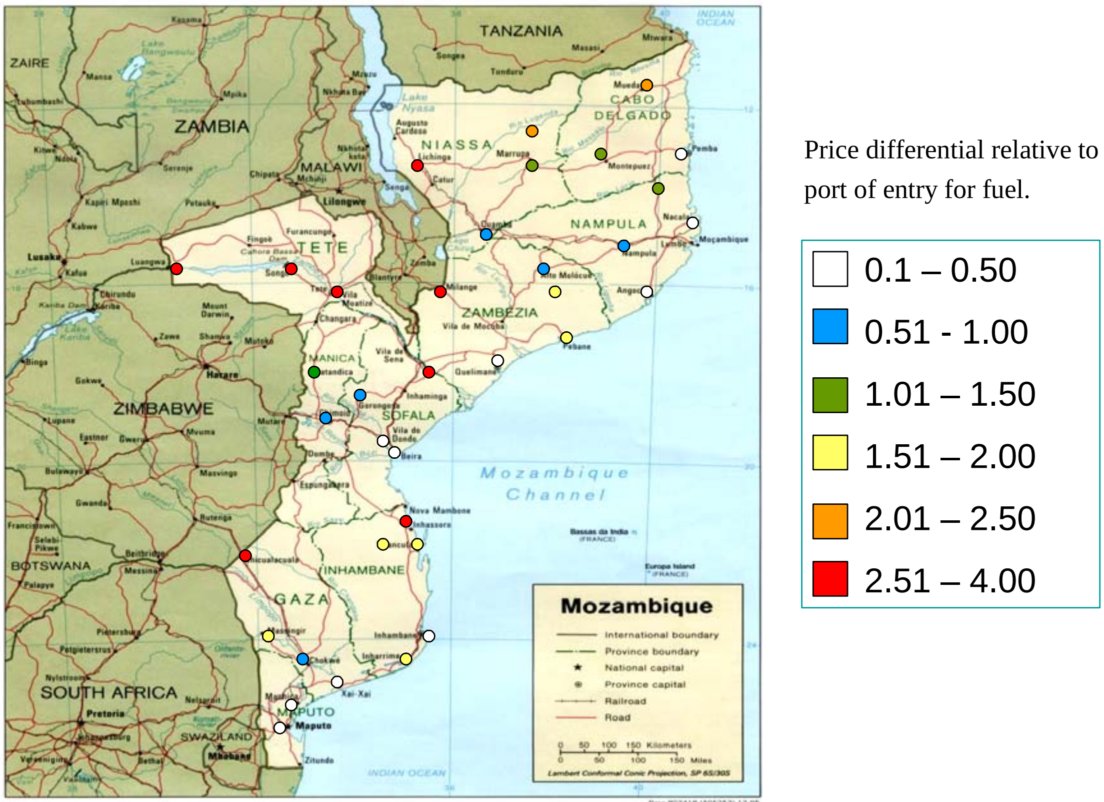




Source: DNC/Ministry of Energy. #Leaded and unleaded. *Projected.

The major price components are determined by various governmental entities, and the overall calculation of the price to end users is conducted every month by the Ministry of Energy in accordance with Decree 1/1997. In Table 3, which is based on information obtained from the National Fuels Directorate (Direcção Nacional de Combustiveis or DNC), the line items include ten components as described below (line numbers in the text refer to those shown at left in the table).

Figure 15: Regional variations in regulated fuel prices

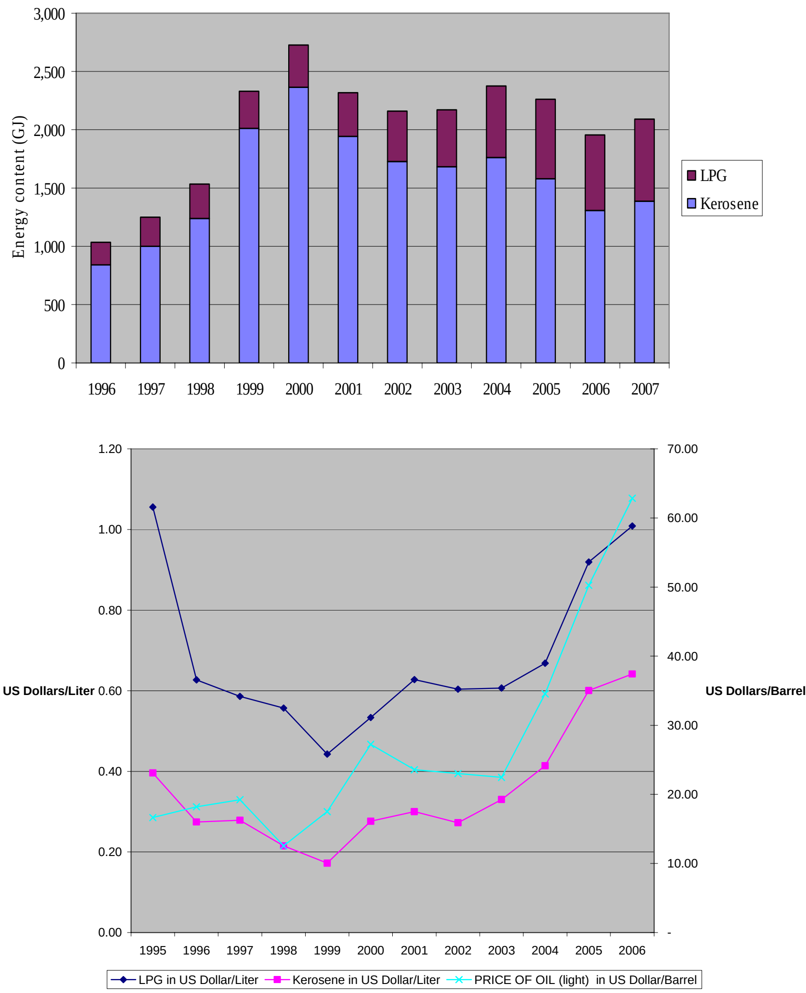


Source: Econergy analysis of transportation cost differentials from PetroMoc price tables.

CIF price (lines 2 and 3). This is the weighted average price CIF at the three main ports where fuels are delivered (Maputo, Beira and Nacala) over the 90 days previous to each review, as reported by IMOPETRO from its competitively bid import contracts for each of the fuels. The dollar-denominated price paid by IMOPETRO is converted to meticais at the established exchange rate, provided by a syndicate of banks under a long-term contract. If the variation from month to month is less than 3%, no adjustment is made to the price.

- *Port fees (custos directos com a importação) (line 5).* These include various costs and fees associated with handling and inspecting the cargos as they are delivered to the three ports, and are reported by IMOPETRO.
- *Import tariff (direitos aduandeiros) (line 7).* Calculated as 5% ad valorem.
- *IVA (on port fees, wholesalers' and retailers' margins and transportation costs) (lines 9, 11, 17 and 20).* The IVA is assessed to reflect valued added at the point of importation into the country, handling by the wholesaler, transportation by the wholesaler, and handling by the retailer. This is included in the retail price.
- *Fuel Tax (Taxa sobre Combustiveis or TSC) (line 12).* This is calculated by the Ministry of Finance and assessed by the wholesaler.

Figure 16: Trend in residential fuel use



Prices for LPG given in USD/MT, and kerosene in USD/M3
Source: DNC/Ministry of Energy.

- *Losses (line 13).* This line item reflects changes of less than 3% in the CIF price, and is intended to protect distributors and retailers from the impact of smaller price shifts. The DNC calculates this value.
- *Adjustments and rounding (line 14).* This was especially necessary in the period before the introduction of the New Metical.
- *Wholesalers' margin (line 10).* This is calculated by the DNC, using a formula that adjusts the established wholesalers' margin to reflect inflation and changes in the exchange rate. The margin is set for each product, from 2.08% for fuel oil to 5.19% for LPG.
- *Retailers' margin (line 19).* This is also calculated by the DNC, employing the same formula as the one applied to the wholesalers' margin to update the fixed margin, which ranges from 1.2% (for kerosene) to 2.62% (LPG).
- *Transportation differential (line 16).* This is also calculated by the DNC, employing the same formula as the one applied to the wholesalers' margin to update the fixed margin, which is 0.31% for LPG and 0.2% for all other products.

Table 3: Structure of fuels prices (ME calculations)

	Preços a vigorar a partir de 17 Novembro 06								
				Gasolinas Auto	**Jet A1**	**Petróleo Iluminacao**	**Gasóleo**	**Fuel Oil 1200**	**GPL**
	COMPONENTES DOS CUSTOS								
	Impostos e Margens		Unidades:	(Lt)	(Lt)	(Lt)	(Lt)	(Lt)	(Kg)
1	**Preço Base- USD/TON**		Custo de Importação	**775.42**	**661.32**	**661.32**	**665.77**	**486.00**	**613.62**
			Factor de conversão para m^3	0.728	0.794	0.794	0.830	0.970	1.000
			Taxa de câmb. à data de Cálc.	26.40	26.40	26.40	26.40	26.40	26.40
			Variação da taxa de câmbio	0.23%	1.38%	1.38%	0.23%	0.23%	0.23%
2	**Preço CIF - USD/m3**			564.5	525.1	525.1	552.6	471.4	613.6
3	**Preço base - Meticais/Unidade**			**14.90**	**13.86**	**13.86**	**14.59**	**12.45**	**16.20**
5	**Custos Directos com a importação**		(em MtN por unidade)	0.72	0.68	0.68	0.71	0.62	1.54
6	**Custo Base**		(3+5)	15.62	14.54	14.54	15.30	13.07	17.74
7	Direitos aduaneiros (DA) @ 5%		(3x5%)	0.75	0.69	0.69	0.73	0.62	0.81
8	**Custo na Importação**		(6+7)	16.37	15.24	15.24	16.03	13.69	18.55
9	**IVA na Importação @**	**17%**	8x17%	2.78	0.00	0.00	2.72	2.33	3.15
10	**Margem do Distribuidor**		Calculado pelo ME	2.15	2.15	2.10	2.14	2.09	5.20
11	**IVA no Distribuidor @**	**17%**	9+10x17%	3.15			3.09	2.68	4.04
12	**Taxa Sobre Combustiveis (TSC)**		Calculada pelo MF	6.36	0.83	0.00	3.52	0.63	0.55
13	Componente re: perdas/ganhos		(3-4)	0.34	(0.45)	0.06	(0.35)	(0.44)	2.76
14	Ajustes/Arredondamentos			(0.06)			(0.03)		
15	**Preço a porta do Distribuidor**		(8+10+11+12+13+14)	**28.31**	**17.77**	**17.40**	**24.39**	**18.64**	**31.10**
16	**Diferencial de transporte**		Calculado pelo ME	0.20	0.20	0.20	0.20	0.20	0.31
17	**IVA no Distribuidor (c/Dif.)@**	**17%**	11+16x17%	3.18			3.12	2.72	4.09
18	**Preço Venda do Distribuidor**		(15+16+17-11)	**28.54**	**17.97**	**17.60**	**24.62**	**18.88**	**31.46**
19	**Margem dos Retalhistas**		Calculado pelo ME	1.25	1.23	1.20	1.26	0.00	2.64
20	**IVA no Retalhista@**	**17%**	17+19x17%	3.39	0.00	0.00	3.34	2.72	4.54
21	**Preço de Venda ao Público (máx.)**		(18+19+20-17)	**30.00**	**19.19**	**18.80**	**26.10**	**18.88**	**34.55**
			Preço de Venda actual	29.60	21.11	18.80	27.22	15.73	28.79

Source: DNC/Ministry of Energy for November, 2006, price adjustment.

Table 4 shows the impact of the different price components on the total price to the end user. Gasoline is taxed the most heavily, with over one-third of the final price to the end user paid in taxes, while at the other extreme jet fuel and kerosene are exempted from IVA and very lightly taxed (indeed, kerosene is exempted from the TSC). This is explained as an effort to reduce the economic burden of purchasing fuel for illumination in poorer households and as an indirect subsidy to air transportation, which is quite important in Mozambique given its large size geographically and the parlous state of much of its highway system. Diesel is taxed substantially, although not as much as gasoline. Figure 17 shows the structure of fuel prices as of November, 2006, in graphic form.

International comparison. It is helpful to situate Mozambique in the international context by comparing the price structure shown above with the breakdown observed in other countries. (See Figure 18 and Figure 19). Two trends are apparent. First, the overall tax burden on fuel in Mozambique is higher than in the United States (and slightly above Japan[13]), but lower than in Europe. Second, in continental Europe, Brazil and Mozambique, gasoline is more expensive than diesel, despite the fact that diesel has a higher energy content per liter (and hence greater distance traveled per liter), in order to subsidize diesel consumers. This policy reflects the perception that gasoline is the fuel of rich automobile owners, while diesel is the fuel of the poor who ride buses as well as the transportation sector that underpins much of the economy. In the case of Brazil, for instance, diesel use by automobiles is prohibited to limit its consumption. Even so,

[13] For a complete review of fuel taxation practices in over 170 countries, see GTZ's survey *International Fuel Prices 2007* (fifth edition), available at http://www.gtz.de/en/themen/umwelt-infrastruktur/transport/10285.htm.

Table 4: Impact of taxes on fuel prices

Figures in MtN/liter except for LPG (MtN/kg)	Gaso-line	Jet A1	Kero-sene	Diesel	Fuel Oil	LPG
1. Base price (CIF)	14.90	13.86	13.86	14.59	12.45	16.20
2. Port fees	0.72	0.68	0.68	0.71	0.62	1.54
3. Import tariff	0.75	0.69	0.69	0.73	0.62	0.81
4. IVA (import, wholesale, retail)	3.39	0.00	0.00	3.34	2.72	4.54
5. Fuel Tax (TSC)	6.36	0.83	0.00	3.52	0.63	0.55
6. Wholesaler's margin	2.15	2.15	2.10	2.14	2.09	5.20
7. Retailers' margin	1.25	1.23	1.20	1.26	0.00	2.64
8. Transportation differential	0.20	0.20	0.20	0.20	0.20	0.31
9. Losses and rounding	0.28	(0.45)	0.06	(0.39)	(0.44)	2.76
10. Price to end user	30.00	19.19	18.80	26.10	18.88	34.55
1. Base price (CIF)	49.7%	72.2%	73.7%	55.9%	65.9%	46.9%
2. Port fees	2.4%	3.5%	3.6%	2.7%	3.3%	4.4%
3. Import tariff	2.5%	3.6%	3.7%	2.8%	3.3%	2.3%
4. IVA (import, wholesale, retail)	11.3%	0.0%	0.0%	12.8%	14.4%	13.1%
5. Fuel Tax (TSC)	21.2%	4.3%	0.0%	13.5%	3.3%	1.6%
6. Wholesaler’s margin	7.2%	11.2%	11.2%	8.2%	11.0%	15.1%
7. Retailer’s margin	4.2%	6.4%	6.4%	4.8%	0.0%	7.6%
8. Transportation differential	0.7%	1.0%	1.1%	0.8%	1.1%	0.9%
9. Adjustments for losses/rounding	0.9%	-2.3%	0.3%	-1.5%	-2.4%	8.0%
10. Price to end user	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Total taxes (lines 3+4+5)	35%	8%	4%	29%	21%	17%
Total margins and transportation (6+7+8)	12%	19%	19%	14%	12%	24%

Source: DNC/Ministry of Energy, with Econergy analysis.

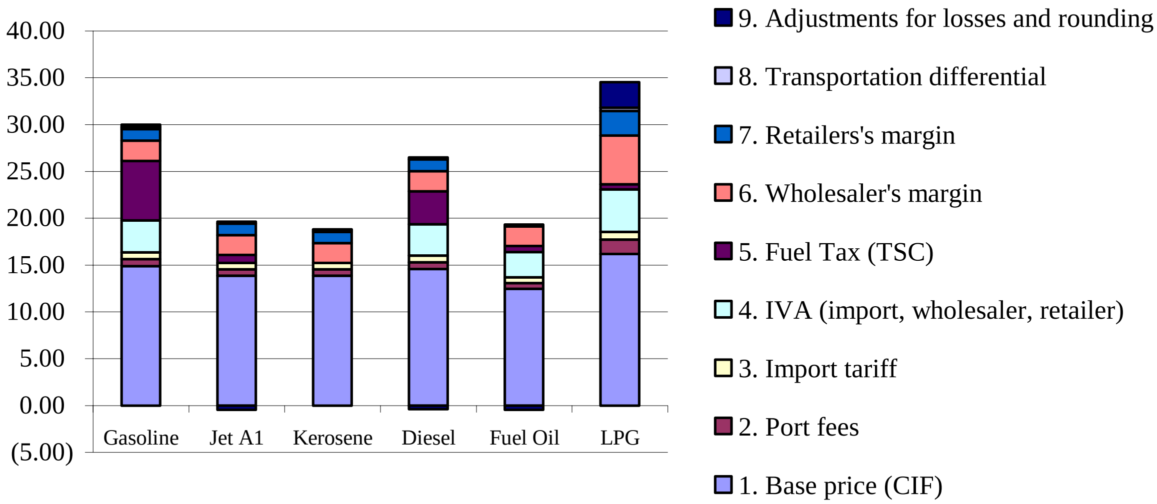
Brazil has a chronic deficit in diesel fuel, a factor that has contributed to the implementation of the biodiesel program there. Whereas Brazil’s diesel prices are typically equivalent to 150% of the gasoline price, the premium for gasoline in Mozambique is a more modest 15%, in line with the policies of continental Europe.

Table 5 illustrates the breakdown of the pricing of the gasoline/ethanol blend in Brazil, showing that roughly half the pump price is comprised of taxes.

4. Primary energy challenges and policy and developer responses

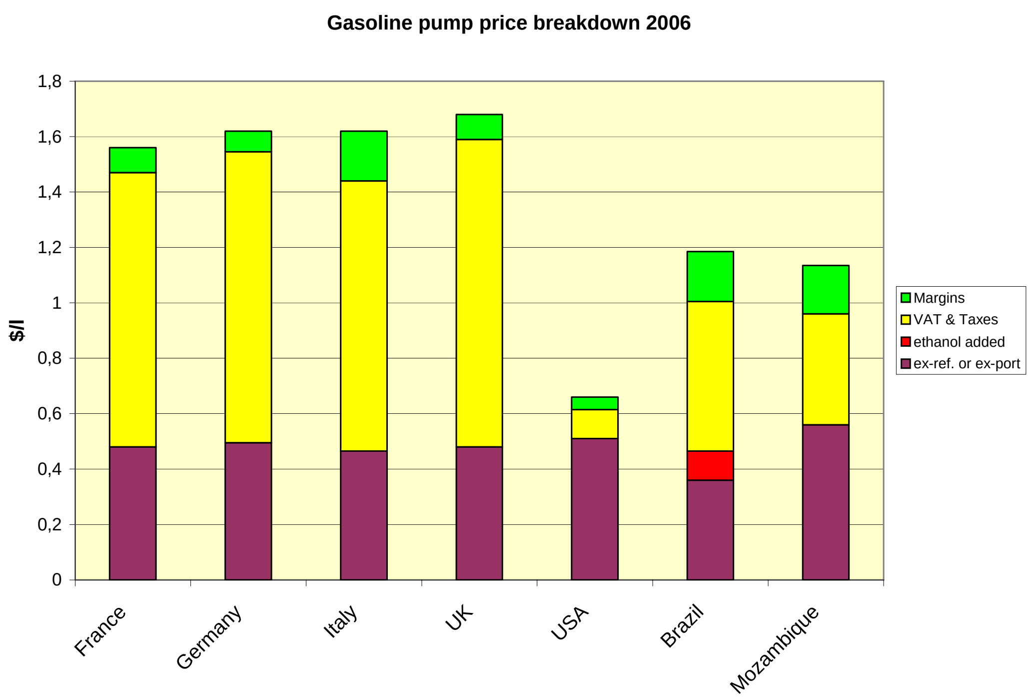
Economic development depends to a significant degree on the availability of economically priced energy in the form of electricity, the highest quality form of energy in terms of its versatility, as well as fuels for the production of thermal energy. Despite Mozambique’s substantial energy resources, including hydropower, coal, natural gas and biomass, there have been constraints on their availability. Fundamentally, the limited size of Mozambique’s economy poses a challenge for energy development in the country, especially in light of the presence of a larger and economically more powerful neighbor

Figure 17: Structure of fuel prices (November, 2006, price update)
MtN/liter except for LPG (MtN/kg)



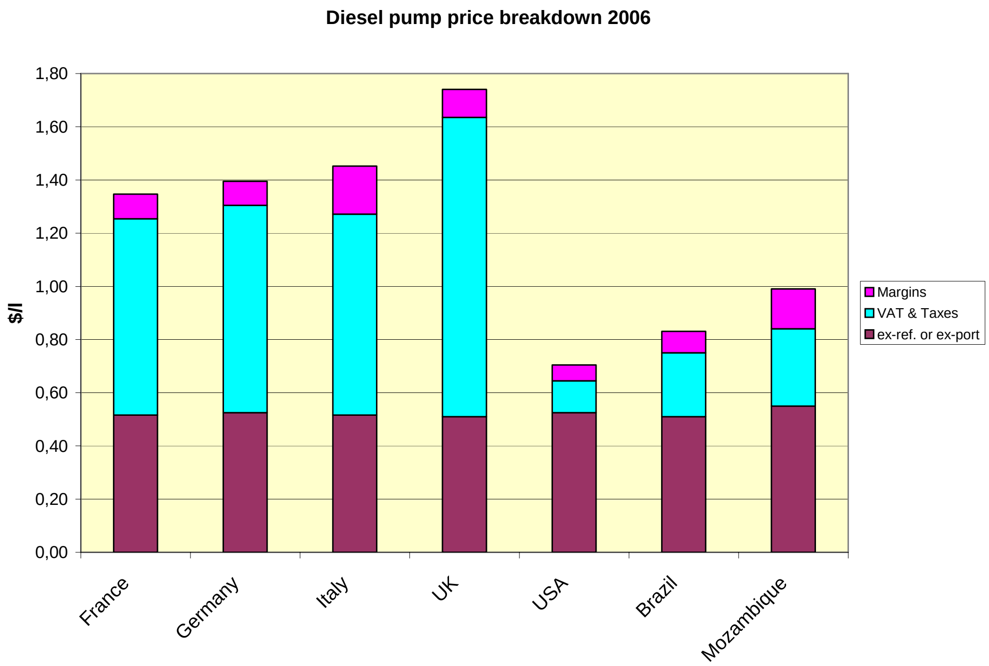
Source: DNC/Ministry of Energy, with Econergy analysis

Figure 18: International comparison of gasoline price structures



Source: Petrobras. See www2.petrobras.com.br/produtos_serviços/port/Composição_Pais.

Figure 19: International comparison of diesel price structures



Source: Petrobras. See www2.petrobras.com.br/produtos_serviços/port/Composição_Pais.

Table 5: Structure of gasohol price in Brazil, May 2007

Price structure at the pump, "C" gasoline, Rio de Janeiro, 77% gasoline/33% ethanol

Description	Amount (per liter)	Share
Product		*37%*
Gasoline (ex-refinery, Duque de Caxias)	R$0.7498	30%
Cost of dehydrated alcohol**	R$0.1828	7%
Transportation and margins		*14%*
Distribution and retail sale*	R$0.3662	14%
Taxes		*49%*
ICMS	R$0.8045	32%
CIDE PIS/COFINS	R$0.4237	17%

Sources: ANP, survey May 20-26, 2007. *Calculated by deduction; includes freight. **Includes purchase from producer and estimate for freight from distillery, based on data from www.cepea.esalq.usp.br.

immediately to the west – South Africa. Demand for electricity and natural gas, and financial constraints, have obliged Mozambique to establish long-term purchase agreements for electricity and natural gas that create the ironic situation that Mozambique cannot fully access its own energy resources.

As it addresses the need to increase the size of its economy and develop its energy resources to support growth, Mozambique faces several important challenges. These are summarized below.

- Expanding coverage of the electric grid and increasing the availability of electricity, especially in rural areas
- Reducing the cost of electricity to end-users
- Reducing the consumption of biomass-based fuels in favor of modern fuels, to reduce pressure on forest resources, improve safety, and improve environmental conditions in residences where biomass is used
- Promoting indigenous energy resources (natural gas, hydropower, biofuels, and coal) as opposed to imported resources, mainly petroleum-based fuels
- Ensuring the lowest possible cost for all energy supplies, in part through the promotion of a competitive market for energy supplies
- Promoting investment in the energy sector, with particular emphasis on securing investment in the timeframes required in mining and industrial projects

The country's energy policy, as originally articulated in the context of Resolution 24/2000, encompassed nine major objectives, which are summarized below. The current strategy of the government continues reflect those objectives, but has incorporated some new elements, which are noted.

- Ensure reliability of energy supplies at the lowest possible cost, to satisfy current demand and the needs of economic development
- Increase the availability of energy to the domestic sector, particularly coal, kerosene, gas and electricity
- Promote reforestation to increase the availability of firewood and charcoal
- Strengthen the institutional capacity of the main agencies that supply energy to improve their performance
- Promote economically viable investment programs to develop indigenous energy resources, (hydropower, forests, coal and natural gas are mentioned in Resolution 24/2000, but clearly this now includes other renewable energy and biofuels resources)
- Increase exports of energy products, including electricity through the Southern Africa Power Pool (SAPP), and, as demonstrated by this study, biofuels
- Increase efficiency in energy consumption
- Promote the development of conversion technologies and environmentally benign energy resources (solar, wind, biomass); presumably, the intent of this is the promotion of development activities, which precede decisions to actually make investments
- Among other development activities that might be considered would be metering campaigns for wind resources, research into new energy resources
- Promote a more efficient, dynamic and competitive business sector

Mozambique has made some progress with the implementation of several aspects of its strategy, but much remains to be done. In recent years there has been significant interest in energy sector investments, with support from numerous donor agencies for feasibility studies (for hydropower and coal-fired thermal generation, in particular), capacity building activities (in the context of the management of EDM as well as Clean Development Mechanism project development), and actual investments (Elgas and

CVRD in the power sector; Anadarko, Artumas and GALP, among others in oil and gas; Principal Energy, D1 Oils and C3 Oils in the biofuels sector).

In the fuels sector specifically, there are numerous projects in varying stages of development. On the biofuels side, Table 6 lists the various projects about which information has been transmitted to the Center for Investment Promotion (CPI). As noted in the table, a significant number of the projects are predicated on the possibility of exporting production, due to the absence of a domestic market and uncertainty regarding government policy.

In an effort to create a clearer framework for the biofuels sector, an inter-ministerial working group on biofuels, led by the ME/DNER, has been convened. This study is one of the efforts overseen by this working group. Other activities have included seminars and presentations on specific topics, such jatropha (March, 2007), as well as participation in conferences. At the same time, within the ME, work has commenced on a regulatory framework for biofuels. A draft decree (Decreto 63/2006) that updates previous rulemakings for the fuel sector includes language specific to biofuels. The main points are summarized below.

- Biofuels for blending in hydrocarbon-based fuels may only be sold to licensed fuel distributors, and producers must maintain documentation showing results of laboratory analyses of the biofuel (63/2006, §30).
- The previous provision does not apply to producers who demonstrate output of less than 3,000 m3 (3 million liters), or are otherwise exempted by the Provincial Director of Energy or Finance, but they must report their production levels, and may sell their output under contracts that specify the technical characteristics of their product (63/2006, §31.1 to §31.3).
- Importation of biofuels is prohibited (63/2006, §32.3b).

Clearly, these arrangements do not constitute a comprehensive policy framework for biofuels, but they do indicate that ME has identified blending of biofuels by distributors as the most appropriate method of promoting biofuel development, and that it has identified product quality as a significant concern.

At the same time, there are also plans to develop a new petroleum refinery as part of a comprehensive fuel supply strategy. The Government recently announced approval of the USD 5-billion project led by Ayr Petro Nacala. The announcement indicates that the 300,000 barrel-a-day facility will export two thirds of its production after a six-year production period.[14]

5. Characteristics of current end-use technologies

The World Bank estimates the total road network in Mozambique encompasses 37,500 km of roads, of which only about 17% are paved (5,800 km of national and regional

[14] See news item from Media Fax, October 3, 2007, which cites government sources.

roads, plus 500 km of urban roads).[15] It is estimated that around 41% of Mozambique's rural population has potential access to the road network (a measure of those living within 2 km of any road), but due to poor conditions of the network, the percentage of the rural population having reliable and constant access is much lower (as low as 11%).[16]

The automotive fleet in Mozambique is composed exclusively of imported vehicles, mostly European and Japanese. The gasoline (spark-ignition) fleet includes a small component of relatively new vehicles, and a substantially greater component of much older vehicles (10-15 years or older). The diesel (compression-ignition) fleet is more uniformly aging. According to the World Bank, the total Mozambican fleet adds up to about 57,000 vehicles, almost evenly divided between passenger cars and commercial vehicles.[17] With a population of about 20.2 million,[18] this means there are less than 3 vehicles for 1,000 people,[19] a degree of penetration consistent with other Sub-Saharan Africa countries, but very low when compared to 148 for South Africa and 170 for Brazil, and around 500 for the U.S., Canada and main EU countries.

6. Role of fuel taxes in government revenues

Review of fiscal revenues from taxes and tariffs on fuels. Law 15/1992 establishes the taxation of fuels sold in Mozambique. There are three such levies (i) an ad valorem import tariff, set at 5%; (ii) the Value Added Tax (*Imposto sobre o Valor Acrescentado* or IVA), set at 17%; and (iii) Tax on Fuels (Imposto sobre os Combustiveis), which is adjusted quarterly in accordance with inflation.

The first is fairly straightforward and requires no further explanation. In the case of the IVA as collected on fuels, the tax is collected in a manner consistent with conventional value added tax schemes, at each subsequent stage in the value chain such that the consumer bears the burden of the tax. There was a temporary exemption of 50% given to fuels for agricultural uses, but this has been withdrawn.

Finally, in the case of the Tax on Fuels, which is listed in official reports of the government under the category of "Other Taxes," the quarterly update has been in place since May, 2003, and is based on a formula that uses inflation in the previous trimester as reported by the National Statistics Institute (INE), up to a maximum adjustment of 5%. In the formula, one percentage point of inflation translates into a one-point change in the tax rate. The Correction Factor (Factor de Correcção or FC) is equivalent to the ratio of

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[15] World Bank, *Project Information Document for the Roads and Bridges Management and Maintenance Project*, 22 May 2007
[16] *Ibidem*. Roads are a priority of Mozambique's Action Plan for the Reduction of Absolute Poverty (PARPA II, 2006-2009), as well as of the World Bank's Country Assistance Strategy.
[17] World Bank, *Africa Development Indicators,* 2006 page 68. Available online at http://siteresources.worldbank.org/INTSTATINAFR/Resources/ADI_2006_text.pdf
[18] Economist Intelligence Unit, *Mozambique Country Profile*, May 2007. UN Population Fund estimate for 2006.
[19] World Bank, *World Development Indicators*, 2006

Table 6: Biofuels Projects in Mozambique

Name	Description (development stage)	Feedstock and target market	Location
C3 – Biodiesel	Operational	Jatropha plantation for biofuels production and related activities; exports contemplated	Estrada Nacional 1, Bairro de Rumbana, Maxixe (Inhambane)
DEULCO	In plantation	Jatropha plantation for biofuels production and related activities; exports contemplated	Inhassune, Distrito de Panda, (Inhambane)
ELAION AFRICA	In plantation	Jatropha plantation for biofuels production and related activities; exports contemplated	Localidade de Savane, Dondo, Sofala
ECOMOZ	Under construction	Biofuels production and related activities	Petromoc installations (Maputo, Beira and Nacala)
ADAMA	Not yet presented to CPI		Manica
JATROPHA		Jatropha for biodiesel and related activities	Distrito de Moamba, Maputo
CAMEC (Procana)	Presented to CPI; feasibility study	Sugarcane for production of sugar and refined sugar, electric power and fertilizer; exports contemplated	Massingir (Gaza)
Haha Projects		Biodiesel from jatropha	Provinces of Nampula or Cabo Delgado
Brunellus KFT		Ethanol based on corn and sweet sorghum	
Madal (Technoserve)	Operating in experimental phase	Coconut, jatropha and oilseeds for biofuels (as well as other crops)	Quelimane (Zambézia)
Eng. Petiz	Has 200 ha planted. Will deliver 20,000 tons of sugar cane to Mafambisse	Sugar for export and, from 2009 onward, production of ethanol	Dondo (Sofala)
Girassol Manica	In production	Sugar cane, sunflower, jatropha and soya for ethanol and biodiesel	Sussundega (Manica)
Geralco	Initial testing at existing plantation	Jatropha	Quelimane (Zambézia)
Algas	Research and development of algae-based biofuel production	Biodiesel	Quelimane (Zambézia)
Grupo MOÇFER SA			
Enerterra	Feasibility study	Jatropha; exports contemplated	
Sunbiofuel		Jatropha	Manica
British Petroleum	Feasibility study		
Pete Nel	Feasibility study	Sugar cane for ethanol	Chimoio (Manica)
Somoil	Small-scale demonstration facility		Inhambane
COFAMOSA	Feasibility study to be funded by ADB	Exports contemplated	
Indústria Açucareira		Sugar cane for ethanol	Maputo (Sofala)
Principal Energy	Pre-feasibility studies	Sugar cane and sweet sorghum for ethanol; exports contemplated	Dombe (Manica)

Source: CPI, additional information from Econergy.

the last trimester's Consumer Price Index (Indice de Preços ao Consumidor or IPC) to the previous trimester's IPC. The FC is in turn multiplied by the tax rate in effect to arrive at the revised tax rate. The tax is collected by the distributor from the retailer, who in turn includes the tax in the final price paid by the consumer. According to discussions with the Ministry of Finance, there are no plans under discussion to modify the way the tax is collected, and the Government can modify the tax, where it wishes, to mitigate the impact of increases in fuel prices.

Table 7: Structure of Revenues Received by the Government of Mozambique
(Figures in new Meticais, or MtN)

	Descrição	1998 CGE	1999 CGE	2000 CGE	2001 CGE	2002 CGE	2003 CGE	2004 CGE	2005 CGE	2006 Execução
						VALORES EM MTs				
A	Total Receitas Correntes	5,333.72	6,212.92	7,436.50	9,130.05	11,357.39	14,578.57	15,942.50	22,590.98	26,996.75
B	1. Receitas Fiscais	4,994.06	5,813.64	6,892.80	8,478.22	10,481.71	13,627.22	13,876.46	18,024.17	22,125.37
	Impostos sobre bens e serviços									
Impostos sobre Combustíveis	IVA	1,559.46	2,260.60	2,914.20	3,572.46	4,348.46	5,399.97	5,744.53	6,829.41	9,382.02
C	Operações Internas	0.00	572.22	1,200.62	1,629.14	1,966.80	2,362.73	2,404.87	0.00	3,696.90
D	Importações	0.00	827.57	1,674.90	2,033.62	2,620.69	3,037.24	3,339.66	0.00	5,685.12
	Imposto sobre o Comércio Externo (Das + Taxa de açucar)	937.00	1,012.50	1,279.33	1,476.62	1,851.24	2,228.87	2,222.52	2,816.40	3,284.30
	Outros Impostos + Receitas Consignadas									
E	Combustíveis	751.14	760.90	772.67	824.34	864.80	1,304.66	650.99	569.37	562.80
F	Impostos Sobre Combustíveis	0.00	0.00	0.00	0.00	0.00	0.00	1,007.66	1,228.69	1,267.64
	TOTAL Impostos Sobre Combustíveis	2,310.60	3,021.50	3,648.19	4,487.10	5,452.29	6,704.63	7,403.18	8,627.47	11,212.46
	TOTAL Impostos Sobre Combustíveis (s/ IVA)	751.14	760.90	772.67	824.34	864.80	1,304.66	1,658.65	1,798.06	1,830.44
	Peso das Receitas Fiscais de Combustíveis sobre:									
(C+D+E+F	Receitas Fiscais	46.3%	52.0%	52.9%	52.9%	52.0%	49.2%	53.4%	47.9%	50.7%
(C+D+E+F	Receitas Totais	43.3%	48.6%	49.1%	49.1%	48.0%	46.0%	46.4%	38.2%	41.5%
	Peso das Receitas Fiscais (Excluindo IVA) de Combustíveis sobre:									
(E+F)/ B	Receitas Fiscais	15.0%	13.1%	11.2%	9.7%	8.3%	9.6%	12.0%	10.0%	8.3%
(E+F)/ A	Receitas Totais	14.1%	12.2%	10.4%	9.0%	7.6%	8.9%	10.4%	8.0%	6.8%

Source: Ministry of Finance.

Use of revenues from taxes on transportation fuels. The use of revenues has been earmarked by law as follows: (i) 20% of the tax on diesel and 50% of the tax on gasoline is allocated to general budgetary purposes (Orçamento Geral de Estado); (ii) the Ministry of Transportation receives 5% of the tax on diesel fuel; and (iii) 75% of the tax on diesel and 50% of the tax on gasoline go to the Ministry of Public Works (Ministerio de Obras Públicas or MOP) for the Highway Fund (Fundo de Estradas). This accounts for part of the budget of the National Highways Administration (Administração Nacional de Estradas or ANE). A portion of these receipts may also be allocated to FUNAE.

Analysis of revenues from taxes and tariffs on fuels. The Ministry of Finance provided data on the amounts collected under the three components of the taxes and tariffs on fuels. Analysis of these figures for the last four years shows that while the absolute amounts collected have increased, in keeping with growing consumption of fuels, the overall importance of these receipts as a share of government revenue has declined.

These conclusions seem justifiable despite the fact that there are some discrepancies and evident errors in the collection and maintenance of the data.[20]

Table 7 shows the evolution of receipts from the various taxes and tariffs on fuels in the context of the revenues to the Government of Mozambique (total and fiscal revenues).

The IVA values represent the total amounts collected for this tax, not just fuels. The Ministry of Finance does not disaggregate the various components of the amounts collected under the IVA; once data on imports of fuels are available from IMOPETRO,[21] the separation of the amounts linked solely to fuel imports will be possible. The same applies to the customs duties (Imposto sobre o Comercio Externo or ICE). The rest of the analysis presented here focuses on those taxes applied exclusively to fuels, and excludes IVA and ICE. As a general matter, since these levies are applied on an ad valorem basis, they will track the trend in the taxes applied to fuels only, and hence the general conclusions presented will remain valid, though the exact amounts will not. The two general observations that flow from the review of the Ministry of Finance data from 1998 to 2006 are presented.

First, the nominal as well as absolute values of the tax collections have increased, reaching MtN 1.83 billion in the 2006 budget, up from MtN 751 million in 1998. (When expressed in dollar terms, the trend is similar in the period from 2002 onwards, since the depreciation of the metical from 1998 to 2001 has tended to reduce the absolute amount obtained. See Figure 20.) This trend reflects the increasing consumption of fuel and increasing economic activity in the country. The introduction of the adjustment to the tax based on inflation contributed to a sharper increase in the upward trend, which was quite gentle in the period prior to 2003. The apparent inflexion point in 2005 seems likely to be the result of the sharp increase in fuel prices that occurred that year, driven in part by the increase in international petroleum prices following the damage caused by Hurricane Katrina to oil-production infrastructure in the U.S. Gulf Coast. (See Figure 16, above.)

At the same time, tax receipts have decreased relative to total government receipts, especially in the case of fiscal revenues. This decrease in the relative importance of fuel taxes reflects the expanding tax base in Mozambique, and the introduction in 2004 of two important new taxes on income, the IRPS and the IRPC. As a result of growth in total receipts, the taxes on fuels decreased in importance to 8% of total fiscal revenues from 15% (or to 7% from 14% based on total revenues).

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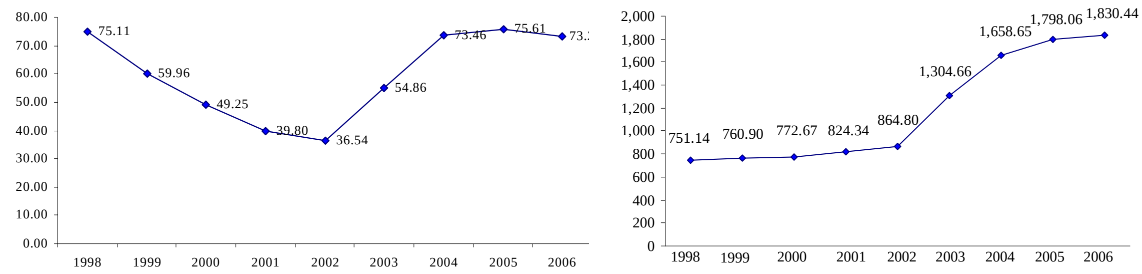
[20] The most important issue detected in the analysis of data from the Ministry of Finance is an apparent double-counting of revenue in 2005, when the amount reported for the Tax on Fuels nearly tripled even as a separate line item referred to as “Consignment of Tax on Fuels,” which was introduced in 2004 and evidently was taken from the total amount collected in the Tax on Fuels, increased just 20%. Other possible factors include: distortions caused by purchases by Zimbabwe directly in the domestic market, for re-export, as opposed to shipments by PetroMoc, which would tend to inflate apparent domestic consumption; alterations in the tax on fuels announced by the government to mitigate the impact of higher prices; errors in the collection or calculation of revenues from the tax (a possibility mentioned by the Ministry of Finance itself).

[21] These data have been requested and once received, will be reflected in the final version of this report.

Figure 20: Trend in fiscal receipts from fuel taxes, 1998-2006

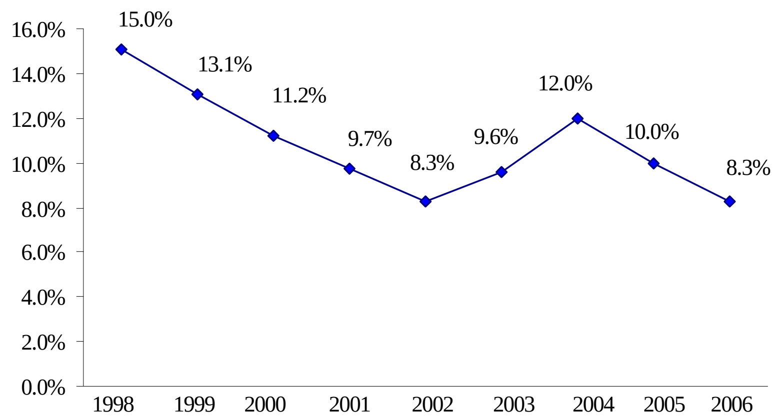
In millions of U.S. dollars

In millions of new Meticais



Source: Ministry of Finance (adjustments by Econergy).

Figure 21: Trend in receipts from fuel taxes as share of total fiscal revenues



Source: Ministry of Finance (analysis by Econergy team).

Figure 13 and Figure 17 illustrate how gasoline and diesel fuel together account for about 80% of total consumption and that these two fuels are among the most heavily taxed. Based on the analysis presented here and in that section, and on the evaluation of fuel pricing and consumption shown in Section 3, it is clear that sales of these fuels must generate the majority of revenues to the government under the rubric of taxes on fuels (including tariffs, the TSC and IVA collected on sales margins and transportation).

7. Trade issues in the context of the Southern Africa Development Commission (SADC)

The SADC Trade Protocol, to which Mozambique is a party, underpins the drive to liberalize trade in the region, providing the framework for an agreement among the Member States to achieve substantial liberalization with (almost) complete elimination of tariffs on intra-SADC trade. The main objectives are to: (i) further liberalize intra-regional trade in goods and services on the basis of fair, mutually equitable and beneficial trade arrangements; (ii) ensure efficient production within SADC, reflecting the current and dynamic comparative advantages of its members; (iii) contribute to the improvement of the climate for domestic, cross-border and foreign investment; (iv) enhance the economic development, diversification and industrialization of the region; and (v) establish a Free Trade Area (FTA) in the SADC Region.

Though signed in August, 1996, the SADC Trade Protocol only came into effect on September 1, 2000, after protracted negotiations. According to the original agreement, the elimination of barriers to trade shall be achieved within a time frame of eight years from entry into force of the Protocol, but this has been extended to 2012. The overall objective was to have 85% of all intra-SADC trade at zero tariff by 2008 and the remaining 15% to be liberalized by 2012, effectively establishing an FTA. However, there are significant weaknesses in the protocol, and the goal of attaining a FTA by 2008 is almost certain to be missed.

The main instrument of trade liberalization is to be the elimination of customs tariffs and non-tariff barriers on the vast majority of intra-SADC trade. In addition, however, the protocol calls for other trade and investment facilitation measures, including harmonization of customs rules and procedures, attainment of internationally acceptable standards, quality, accreditation and metrology (SQAM) and harmonization of sanitary and phyto-sanitary (SPS) measures. Some progress has been made in the areas of customs co-operation, SQAM and related measures. But, so far the focus of the Trade Negotiation Forum (TNF) has been on the reduction of customs duties on intra-SADC trade and the adoption of common rules-of-origin.

The reduction of tariffs is being carried out on the basis of four categories:

- Category A requires immediate reduction of duty to zero at the beginning of the implementation period. These were the commodities that already attracted low or zero tariffs.
- Category B deals with goods that constitute significant sources of customs revenue (including fuel) and whose tariffs are to be removed over eight years, by 2008. Categories A and B should account for 85% of intra-SADC trade so that by 2008 SADC can be regarded as a free trade area in compliance with Article 24 of the General Agreement on Tariffs and Trade (GATT). This required that "substantially all trade" should be duty free.
- Category C deals with sensitive products (imports sensitive to domestic industrial and agricultural activities) whose tariffs are to be eliminated between 2008 and 2012. Category C is limited to a maximum of 15% of each Member's intra-SADC merchandise trade. Category E is goods that can be exempted from preferential treatment under Articles 9 and 10 of the Trade Protocol such as firearms and munitions, comprising of a small fraction of intra-SADC trade.

CHAPTER 2: ANALYSIS OF THE MARKET POTENTIAL FOR BIOFUELS

This Chapter reviews the potential domestic and international markets for biofuels, and identifies the potential tariff and non-tariff barriers to entry into the international markets. The international markets reviewed include SADC (principally South Africa), Asia (China, Japan and India), Europe (the United Kingdom, Germany, Portugal, Spain and Italy) and North America (United States and Canada).

1. Global context

The implementation of a national biofuels program requires an extensive analysis beyond feasibility studies and assessments of competitiveness with respect to fossil fuels. A review of biofuels programs initiated in the past in other countries reveals that these programs were launched in the midst of crisis situations. The Second World War in the 1940s gave rise to the first such program based on maize in the U.S. During that time, more than 100 distilleries were built to compensate for shortages of fuel from domestic and international sources. Europe established its biodiesel program to create demand for surplus canola oil, which was losing market share in the edible oils market to palm oil and soya. Brazil instituted Pro-Alcool in the 1970s to reduce expenditures on imported petroleum (which represented 40% of the import bill at the time).

An initial review of biofuels in Mozambique shows that virtually all fossil fuels in use are imported, but the country does not have agricultural surpluses to transform into biofuels. At the same time, the country has enormous natural resources, to a large extent unexploited, that could significantly expand the production of raw materials based on plant photosynthesis; this is precisely the situation in which Brazil found itself forty years ago.

It is important to adopt a broader perspective than exclusively economic considerations, because liquid fuels based on renewable sources rarely have a lower cost than similar fuels made from fossil sources. Their cost may be lower in the interior of certain countries where there is a surplus of agricultural products together with logistical inefficiencies affecting petroleum products imported into those areas. In 2005, this situation occurred in Brazil when soya oil commanded a market price 50% below that of locally available diesel fuel. This situation led to the consumption of semi-refined vegetable oil in the region, with local farmers mixing 30% into diesel fuel. The savings created in this way were so attractive that the end-users were willing to risk damage to their vehicles. A similar situation occurred in Eastern Europe where refined sunflower seed oil from supermarkets was mixed into diesel; this practice was abandoned with the recent increase in the prices of edible vegetable oils.

Further, it is important to note that the cost of extraction of crude oil ranges from USD 2 per barrel to USD 16/barrel, with the high end reflecting extraction at deep-water wells (see Table 1). The spot price of crude oil (currently about USD 60 to USD 70/barrel) quoted on commodities exchanges is not always considered by vertically integrated petroleum companies in the determination of prices for fuels derived from petroleum. In addition, political considerations (related to inflation control or the generation of tax revenues) significantly distort the calculation of prices for traditional fuels, such as gasoline, diesel, liquid petroleum gas and others.

On the other hand, at the beginning of the last century, agricultural products were used as industrial raw materials (vegetable oils, fibers, pigments, resins, among others), but these were increasingly driven from the market by petroleum derivatives (such as the polymers and lubricants), which were extremely cheap in the period following the Second World War.

Table 1: Costs of raw materials for fuels

	USD/barrel	USD/ton
Petroleum (surface well, Saudi Arabia)*	2	15.5
Petroleum (deep-sea well, offshore Brazil)*	14	124
Petroleum (surface well, Texas)*	16	124
Molasses (ex-mill Brasil)**	36	160
Tallow – FOB Brazil***	56	370
Palm oil (ex-Malasia)#	60	412
Soya oil (ex-Cerrados Brazil)	82	590
Canola oil (ex-Europa)	114	780

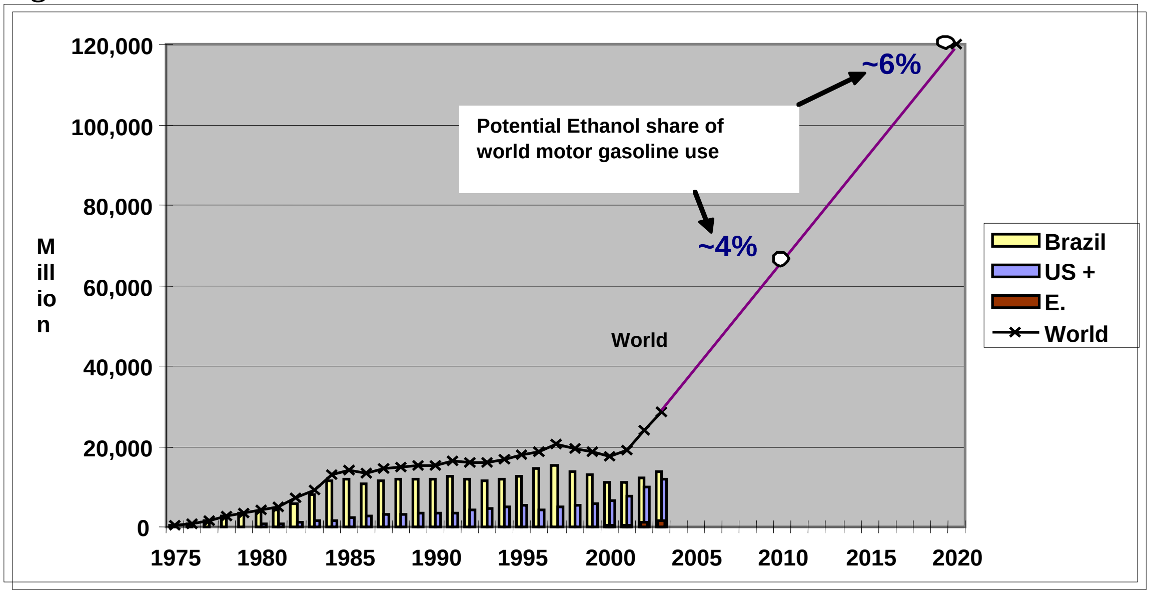
Sources: *Magalhães-REFAP. New Business manager, Petrobras, personal communication. **F.O. Licht, Molasses special report, 2006. ***www.aboissa.com.br. #www.oilworld.com. ##www.abiove.com.br

Recently, however, as a result of developments such as the increased sales price of petroleum on exchanges, or concerns about global climate change, the international community is seeking renewable energy alternatives. Precisely due to their renewable characteristics, these sources of carbon require the commitment of capital and labor for their production. These resources require an economic return, leading to costs that are decidedly in excess of the cost of extraction of petroleum. Table 1 shows this by comparing raw materials costs in common units.

In all the programs to introduce renewable resources (biomass, materials, fuels) in various countries in the last 50 years, direct and indirect supports from governments and the population were necessary. These products do not appear spontaneously based on free-market prices because they are more expensive than fossil fuels.

After 30 years of experience with programs implemented in various countries (Europe and Brazil), there is a clear perception that renewable fuels are not substitutes for fossil fuels; due to their small volume, renewable fuels can only be a complement to traditional products (gasoline and diesel). Indeed, projections by the International Energy Agency (IEA) limit substitution of gasoline by ethanol to 5% globally through large investments, primarily in the U.S. and Brazil. By 2020, the IEA forecasts that ethanol consumption will reach some 120 billion liters [120 million m^3], four times the current amount.

Figure 1: World Ethanol Production - An Ambitious Path



Source: Projections based on IEA review of recent policy initiatives around the world.

In the case of Mozambique, where the consumption is extremely low relative to the available agricultural potential for producing raw materials, this percentage share of biofuels could be much higher, as in the case of Brazil (25% share of anhydrous alcohol). In the long term, this percentage share could be increased to 100% (using hydrous ethanol) with large-scale conversion to flex-fuel vehicles.

For biodiesel, however, some caution is in order. The global consumption of diesel fuel is about 1.3 trillion liters [1.1 billion tons], while production of oils and fats is 15% of this total. Production of this volume of fats and oils has traditionally met demand from the food industry, and has normally been linked to output of other goods. In the case of tallow, the link is with meat; for vegetable oils, the link is with animal feed and thus with meat. To achieve an addition of 5% in global diesel consumption, 50 million tons of any type of fat-bearing raw material of animal or vegetable origin would be needed. Such a volume poses a large challenge to any single country, and opens opportunities for those – like Mozambique – that have unexploited agricultural resources.

Currently, most biofuels are produced and consumed on domestic markets, with only a small amount of trade in biofuels. In the case of ethanol, less than 10% of global production enters the international market. Ethanol is by far the most widely used biofuel for transportation worldwide. Global production reached 33 million liters in 2004, with an average annual growth of 12% over the last five years.[1]

While ten years ago there were only a handful of countries producing biofuels, by 2006 many countries around the world were using them on a large scale. Forecasts for the

[1] Duffy, 2006.

future of this market are very optimistic as all types of countries, industrialized and developing, large and small, are implementing or planning to implement directives to promote greater use of biofuels. Accordingly, production capacity is expected to rise as suggested by the establishment of many new projects around the world. Legitimate concerns have been raised about the socio-economic impacts of expanding biofuels production, most notably in early 2008 after the preparation of much of this report, and these could influence the rapidity with which biofuels development occurs in the major industrial markets. However, it is difficult to predict how the very fluid political situation surrounding international food markets will evolve, and even more so to determine the implications of recent events for biofuels programs. Although the review of the major markets presented in this Chapter does not address recent developments, the discussion in Chapter 8 does incorporate reference to the expanding debate about the trade-off between food and fuels.

While the bulk of biofuel demand is likely to come from the industrialized world, tropical and sub-tropical developing nations may have a comparative advantage in producing biofuels due to their longer or year-round growing seasons, large areas of available arable land, and lower labor costs. This mismatch between consumption and production sets the stage for increased trade in the coming years as developed countries increase their consumption and developing countries scale up production to meet the increased demand.

2. Estimate of potential domestic demand for biofuels over the next decade

Transportation. In the transport sector, the potential demand for fuel ethanol and biodiesel over the next decade in Mozambique will necessarily track projections of demand for gasoline and diesel use and reflect the assumptions of technically realistic blend levels.

- *Ethanol*. As noted in Chapter 5, blend levels in excess of 10% are not recommended as a first step in the introduction of ethanol fuel because of potential damage to vehicles. While it is true that some studies show the possibility of achieving higher blend levels, these were conducted on late-model vehicles with greater receptivity for fuel containing ethanol, and without an accurate analysis of longer-term effects.

  At the same time, however, it is appropriate to anticipate a higher percentage of ethanol than would be provided by limiting ethanol use to the introduction of ETBE (typically around 7.5%), largely because ETBE is not a viable option for use in Mozambique, given the country lacks the advanced refining and petrochemical capacities – indeed any such capacity – that are essential for exploiting the synergies created by ETBE production. While it is true, as discussed in Chapter 5, that ethanol must be blended with a specially formulated gasoline (reformulated gasoline blend stock for oxygenate blending, or RBOB) that would have to be imported for this purpose, this would be possible by adjusting the specifications for gasoline imports set by IMOPETRO (*Importadora Moçambicana de Petroleos)*, although this would entail more significant coordination requirements.

Use of ETBE poses a different, and far less easily surmounted technical and logistical challenge: production and refining capacity for ETBE would have to be built alongside the production capacity required to produce the ethanol itself. While it is possible that reformulated gasoline may be more costly to import than finished gasoline (RBOB currently trades at about a 2% premium to regular gasoline on U.S. futures markets), the capital, time, technical and logistical requirements necessary to establish ETBE production and petroleum refining capacity would be far more significant with respect to the incremental cost of importing reformulated gasoline. Direct blending, as opposed to ETBE, provides for a more immediately viable, cost-effective and simple solution for ethanol use in transportation, as well as one that adequately stimulates domestic ethanol production.

Also, there are strong reasons to suppose that the immediate path forward for Mozambique's ethanol program would be on the basis of a renewable fuels standard, as opposed to a program based on distribution of pure ethanol. As noted in Chapter 5, the primary reasons for this are economic as well as logistical: sales of pure ethanol would require a substantial investment in dedicated pumps and other equipment that would be unnecessary in the case of a blend standard, and such sales would only occur in the presence of automobiles equipped to consume pure ethanol or any mix of ethanol and gasoline (flex-fuel vehicles or FFVs). Once the blend standard has been implemented and ethanol production is well established, however, it would be appropriate for Mozambique to contemplate measures to encourage the importation of flex-fuel vehicles in order to build up a potential market for hydrous alcohol sales, which could be phased in by the fuel distributors beginning in the major market for gasoline in the country, Maputo. Over time, as the vehicle fleet turns over through normal replacement, this measure would contribute to the delinking of ethanol consumption from gasoline use, thereby helping limit further growth in gasoline imports.

Based on the foregoing, the anticipated potential demand for ethanol in Mozambique could reasonably be expected to be as much as 10% of domestic consumption, assuming that there is a renewable fuels standard. Based on projections of gasoline consumption in Mozambique from the Ministry of Energy, this would amount to about 123 million liters of gasoline by 2010. Assuming the 8% per annum growth in consumption used by the Ministry of Energy, this figure would hit 211 million gallons by 2015. Accordingly, the domestic market for ethanol would expand from about 12.5 million liters in 2010 to 21 million liters in 2015.

- *Biodiesel*. As noted in Chapter 5, most engine manufacturers state that use of diesel blends containing more than 5% biodiesel voids the manufacturer's warranty. The World-Wide Fuel Charter, a global association of vehicle manufacturers, also cautions against blends of more than 5%. These indications, which are likely to be conservative given their source, should be balanced by more aggressive positions (as the one of the European Biodiesel Board, that believes that 10% and 15% blend ratios are feasible)[2], and combined with an assessment of a ratio that permits an assured supply of the fuel. The Brazilian biodiesel mandate commenced with a 2% blend ratio, for a market that is far larger than that of Mozambique. In the light of technical and market supply considerations, therefore, a 5% blend ratio appears to be an appropriate reference to assess Mozambique's projected biodiesel's domestic market potential.

Assuming 8% growth in diesel consumption over the next decade, this suggests that the current market of 375 million liters would increase to about 472 million liters in 2010 and some 800 million liters by 2015. Assuming a blend ratio of 5%, this would create a market for biodiesel of about 18.75 million liters in the near term, increasing to 40 million liters at the end of the decade.

Residential uses. In the household sector, conventional fuels (wood and charcoal, kerosene and LPG) may be substituted by bio-fuels for cooking, lighting and space heating. As described in greater detail in Chapter 5, the application likely to offer the greatest potential market is cooking, since the traditional rhythms of activity in rural areas of Mozambique continue to be dominated by natural daylight, and space heating requirements are limited in Mozambique's relatively benign climate.

Manufacturers of a special ethanol-based fuel known as gelfuel are already active in Mozambique, but they have encountered initial difficulties in establishing themselves because of issues in obtaining credit, lack of awareness, an unfavorable fiscal and customs regime hampering the product's cost-effectiveness, as well as the obstacle of the initial cost for the specially equipped stove. More recently, however, sales of gelfuel have been steadily growing, and if this trend continues and expands the potential market for gelfuel is likely to encompass not only a fraction of the market for residential cooking fuel currently served by LPG and kerosene, but also the much larger segment served by firewood, especially in urban areas where the cost of charcoal is likely to be the highest. Further, since the only requirement for switching would involve the purchase of stoves suitable for use of gelfuel, there would be no need to limit the market to some fraction of the total dictated by a blend ratio, as in the transportation sector.

Assuming that the initial market for gelfuel would be in the urban areas of Mozambique, especially Maputo, where incomes will tend to be higher than those observed in the rest of the country, and assuming that the fuel displaced is primarily kerosene or LPG for residential use (not restaurants, institutions and other end-users), the size of the market would represent a portion of the 2,000 GJ of fuel consumed each year. A conservative estimate for the market at the outset would be about 20%, reflecting the fact that a significant portion of LPG demand will come from non-residential users, and the fact that higher-income consumers of LPG and kerosene for residential use may find the much lower energy density of gelfuel (43% and 46% that of LPG and kerosene, respectively, because it is 80% ethanol) to be an impediment. Based on this assessment, the initial market for gelfuel might represent some 400 GJ per year, equivalent to about 23,000 kg

[2] See the EBB website at http://www.ebb-E.U.org/EBBpressreleases

of gelfuel and requiring about 22,000 liters of ethanol. While this initial market is very small and is not likely to justify large-scale investments in ethanol production capacity, it could serve as a secondary market with substantial longer-term growth potential. The growth potential is based on the fact that the consumption of charcoal, especially in Maputo and its surroundings, represents a market (based on data for licensed producers) of about 21,000 GJ of useful energy consumption, which would entail replacement by kg 3.9 million of gelfuel, which would entail some 3.8 million liters of ethanol.

Other uses. In other sectors such as agriculture, off-grid power supply and water pumping, ethanol and biodiesel could also be a useful option. However, based on largely anecdotal evidence from the field visits, it appears that these end uses are largely served by liquid fuels already, and hence are already counted in displacement of total consumption. Except for those limited areas of the country that are served by the national grid (and indeed even some of the major sugar plantations do not have complete access to the grid), the rest of the country relies on diesel fuel. As such, the scale of the market is based on diesel consumption patterns and would fall under the calculation presented above. As in the case of the market for biofuels for residential energy applications, the opportunity for biofuels under the rubric of agricultural and other uses would be in the area of serving the as-yet unserved demand for fuel. This market is potentially large, but also much more difficult to quantify than established energy demand (which, especially in the case of biomass, poses a significant measurement challenge).

The case of off-grid electricity generation may represent a useful example. If EdM achieves its most ambitious rural electrification goals and reaches a coverage ratio of about 25% in 2020 (five times the current coverage ratio), and does so in part through the deployment of new diesel-powered generation in remote areas of the country, this could represent an increase in aggregate diesel-fired capacity of about 50 MW (some of the connections would be served by hydropower facilities, not thermal generators). Assuming a (generous) 90% availability of these units, and a heat rate of about 9.54 MJ/kWh,[3] this implies a minimum of 394,200 MWh of generation annually requiring some 96 million liters of diesel fuel. This volume represents a small but significant portion of current diesel consumption (about 25%), and would create demand for 4.8 million liters of biodiesel by 2020, assuming a blend ratio of 5%.

3. Review of selected potential export markets

This section reviews selected potential import markets in Africa, Europe, Asia and North America. First, general production and consumption trends are reviewed for each region. Then, a summary section for each region presents an overview of the estimated current and projected market size for ethanol and biodiesel, and more importantly, the potential demand for imported ethanol in those markets.

[3] Caterpillar Corporation, personal communication, May 31, 2007. The figure is for small generation sets (under 1.6 MW)

Figures presented to describe these markets' current situation reflect the latest available and reported information (usually for 2006). Figures presented for projected market size, on the other hand, can only represent the best possible estimate on the basis of highly uncertain information. Changes in the biofuels markets are taking place rapidly, to a point that even the collection of previous year data poses significant challenges. Even official sources in an advanced biofuels market such as that of the E.U. (namely, the European Biodiesel Board or the European Union of Ethanol Producers) refrain from making any projection beyond the coming year. Major recent biofuels studies, such as the one conducted by Garten Rothkopf under an Inter-American Development Bank project[4] or the one carried out by the World Watch Institute under a project coordinated by the German Agency for Technical Cooperation (GTZ),[5] only provide general estimates. Projections, particularly on the supply side where producers are responding to evolving policies in a highly dynamic and unpredictable way, are necessarily subject to a strong degree of uncertainty. This situation affects the accuracy of any possible estimate of future market size, limiting the credibility of projections of yearly supply/demand balances. Projections below, therefore, can only represent an estimate of what supply and demand in the markets analyzed may be for a year in the 2010-2015 period, providing general guidance on potential export opportunities.

African markets

South Africa. South Africa's Department of Minerals & Energy (DME) National Biofuels Task Team published its Draft Biofuels Strategy for public comment in November 2006. During the course of 2007, the government staged numerous public hearings throughout the country and collected comments from interested parties. Following the consultations, a long period of uncertainty ensued during which at least two internal deadlines for presenting the plan came and went; finally, in December, 2007, the government announced the final strategy, which had been scaled back considerably and modified in other important ways. Draft legislation to implement the Biofuels Strategy is expected before Parliament during its current session (February-November, 2008).

The final Biofuels Strategy proposes a local production requirement of approximately a billion liters and recommends that this volume be blended into conventional gasoline and diesel. Table 2 shows the sales of petroleum products in 2006.

The mandatory blending ratios proposed are 2% ethanol mix with conventional gasoline (E2) and a 2% biodiesel mix with diesel (B2). The mandatory blending regime would put South Africa in a position to reduce somewhat its dependence on imported crude petroleum, from which about 65% of the country's liquid fuel supplies are produced, and

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[4] *Garten Rothkopf*, "A Blueprint for Green Energy in the Americas: Global Biofuels Outlook 2007", www.iadb.org

[5] *World Watch Institute*, "Biofuels for transport", Earthscan, London/Sterling, VA 2007

Table 2: Fuel consumption in South Africa, 2006 (million liters)

	Q1	Q2	Q3	Q4
Gasoline	2,757	2,779	2,754	2,989
Diesel	2,047	2,121	2,200	2,340
Jet Fuel	588	544	545	592
Kerosene (IP)	179	206	192	161
Fuel Oil	111	130	124	111
Bitumen	68	83	76	86
LPG	133	151	167	154
Total	5,883	6,014	6,058	6,433

Source: DME.

thereby generate annual savings on the balance of payments estimated in the range of R1.6 to 2 billion [USD 205-250 million].[6]

The proposed blending regime would also contribute to achieving South Africa's renewable energy target of 10,000 GWh by 2013, as set out in the 2003 White Paper on Renewable Energy. Liquid fuels for transportation currently make up about 30% of energy consumption by energy content and 70% by value. Given South Africa's current annual consumption of about 20 billion liters of liquid road-transport fuels, this target translates into approximately 400 million liters of biofuels. Originally, in the White Paper, a target of 50% RE energy was proposed, with a biofuels blending ratio of 3.4%. The revised target of 2% average market penetration of biofuels by the 2013 target date for full blending will cover about 44%[7] of the national renewable-energy target.

Government support. The final Strategy provides that licensed biofuels producers will be permitted to sell qualifying biodiesel volumes at 100% of the basic fuel price (BFP) and qualifying ethanol volumes at 70% of the BFP until the biofuels industry achieves an average market penetration of 2%. (The BFP is an import-parity price that includes a refinery margin, which local petroleum producers can charge for refined liquid fuels.)

In addition, the Draft Strategy proposes that the government support the development of the local biofuels industry by exempting bioethanol from the fuel levy completely (currently, the exemption for ethanol is 40%) while limiting the existing fuel-levy exemption on biodiesel production to 50% (currently it is 100% for production of less than 300,000 liters per annum). However, other than these provisions, no other support is contemplated, although the biofuels industry will receive assistance from existing

[6] This figure is a scaled-back estimate based on projections of R3.7 billion based on the initial 4.5% total blend mandate proposed in the draft Biofuels Strategy issued in late 2006.

[7] The Renewable [Energy] White Paper (November, 2003) sets a target of new renewable energy supply of 10,000 GWh per year (equivalent to 0.8 million tons oil equivalent or TOE). Therefore, the projected biofuels component of 2% will account for approximately 175,000 tons of gasoline and a similar quantity of diesel, equivalent to approximately 350,000 TOE.

agricultural support programs.

Initially, the proposed Biofuels Strategy had recommended using the the Central Energy Fund (CEF) Act's Equalization Fund Levy to address fuel-price volatility, by allowing it to act as a hedge to protect the fledgling biofuels industry from low oil prices. If the oil price slips below USD 45/barrel, biofuels producers will be entitled to some form of additional support. On the other hand, at prices above USD 65/barrel, the bio-fuels industry would pay into the fund, slightly reducing pump price increases. It appears that this approach was stripped from the plan before final approval.

Also of note, the final Strategy specifically excludes maize from use as a biofuels feedstock. This step reflected widespread public concern about higher maize prices on global commodities markets in 2007 and their impact on food costs, especially for the poor. However, there has been opposition to this move on the part of grain producers, which suggests that legislators in Parliament may modify the exclusion.

The final Strategy also proposes a petroleum products licensing system that will require existing petroleum wholesalers to buy biofuels according to their respective national market shares.

Anticipated production. Project developers have been actively pursuing ethanol and biodiesel projects in the country. According to F.O. Licht, South Africa produced about 380 million liters of ethanol in 2006, mainly consisting of synthetic industrial ethanol produced by Sasol.[8] The government estimated that, with the introduction of incentives, bioethanol production could soon be in the order of 1.2 billion liters per year, and biodiesel production could reach 450 million liters per year; in light of the scaling back of the program, these figures seem overly optimistic, though some project development is underway. At least four project development activities are currently underway: Sasol and Siyanda are developing a 99 million liter/year [26 million gallon/year] soy biodiesel facility in Newcastle, but final approval is still pending; the CEF and Industrial Development Corporation are planning a similar-sized sugarcane-based ethanol facility in Mpumalanga Province as well as a sugarbeet-based plant in Eastern Cape Province; finally, it is also understood that Principle Energy is also evaluating an investment in sugarcane-based ethanol in Pongola.

Even so, while it remains to be seen the exact extent to which the incentives announced will lead to investment in production capacity, it does appear that low-cost feedstocks are not widely available in South Africa. Perhaps the most widely commented major ethanol project was that of Ethanol Africa, which lost potential investors' backing in 2007 amid uncertainty about the Biofuels Strategy and rising capital costs. The program involved construction and operation of several (at one time eight facilities were considered) corn-based ethanol facilities using a dry-mill configuration. Analyses conducted on the proposed project remain confidential, but the basic premise of the project suggests that costs of production for ethanol would be comparable to those observed in the U.S. – in

[8] http://www.ethanolrfa.org/industry/statistics/

the range of USD 0.41/liter [R 2.95/liter at prevailing exchange rates in 2006] – and higher than ethanol produced by major South Africa mills. With respect to Mozambique's competitiveness vis-à-vis South Africa, there is evidence that Mozambican sugar production is only about 10% more expensive than in South Africa, with potential for downward trends in prices. With respect to biodiesel production, jatropha has been a major focus of development in Southern Africa as a whole, but this particular feedstock faces the significant challenge that cultivation in South Africa has been proscribed. There are differing assessments as to whether this prohibition is likely to be lifted. The fundamental challenge for biofuels production in South Africa is the relative scarcity of arable land and water, which in the long term will contribute to higher costs of production and significant concerns regarding the competition between food and fuel markets for agricultural output.

Anticipated demand. Given South Africa's current consumption of gasoline and diesel, and assuming a modest 5% increase in future demand, E2 and B2 blends could create a demand for respectively 280-330 million liters of ethanol per year, and 200-250 million liters of biodiesel per year in the 2010-2015 period. These figures are likely conservative, because fuel demand growth has exceeded GDP growth recently.

Distribution arrangements. The final Strategy contends that the most efficient approach to distribution is to use the local oil industry's existing infrastructure to blend and distribute biofuels. The document recommends the details and specifics of such a partnership be negotiated with the oil industry to maximize efficiencies and reduce costs. Usually, the lowest cost point of entry for biofuels is blending at the depot.

To limit the cost of transporting biofuels to depots in areas where it is not cost-efficient to produce biofuel crops, the mandatory blending regimes will allow for some flexibility. In reality, the supply of E8 blend will more likely be E10 in 80% of South Africa's petrol with a lower blend ratio in the balance, while the B2 blend would more likely be B5 in certain diesel supply regions. However, flexibility in the actual blend ratio delivered will still be within the overall target of 4.5% of national petrol and diesel volumes by 2013.

Other potential Southern African markets. The interest for biofuels in Africa is growing, and a wide range of initiatives and events are increasingly being organized to explore possibilities in more detail and develop adequate policy frameworks. In July/August 2007, in particular, the African Union (AU), the Government of Brazil and the United Nations Industrial Development Association (UNIDO) organized a seminar in Addis Ababa involving key political and industrial stakeholders on *Sustainable Biofuels Development in Africa: Opportunities and Challenges*. Recommendations from the seminar's sessions were consolidated in a ten-year *Action Plan for Biofuels Development in Africa*, covering the main principles for the promotion of ethanol, biodiesel, biomass gasification and cogeneration. The Action Plan was annexed to the *Declaration on Sustainable Biofuels Development in Africa*, which provided the general guidelines for AU governments to launch a concerted effort for biofuels development.[9]

[9] See http://www.unido.org/doc/70401

Mozambique plays an important role for the import and transit of fossil fuels towards internal regions of Southern Africa, in particular Malawi, Zambia, Zimbabwe and Botswana. The introduction of renewable fuels standards in Mozambique will require action, perhaps including similar policy measures by neighboring countries in the interior. Cooperation will be essential to allow IMOPETRO and PetroMoc to rationalize logistical arrangements for the import of reformulated gasoline and the re-export of blended gasoline into these other countries. In IMOPETRO's view, a double import/re-export track including a traditional line for fossil fuels alongside a new one for reformulated gasoline and blended fuel would simply not be feasible.

While there is considerable interest for biofuels in most Southern African countries, and while several initiatives are being undertaken for their development, information for these markets is scarcely available. A brief overview is presented below.

- *Malawi*. In Malawi, ethanol production started in 1982 at the Dwangwa Sugar Mill, run by the Ethanol Company of Malawi; a second ethanol plant was built in 2004 at the Nchalo Sugar Mill in Chikwawa, and run by Press Cane. Each plant has a production capacity of 15-16 million liters per year. The two plants' combined production levels until 2004 ranged between 9 and 11 million liters, but reached almost 18 million liters in 2006 (7 million from the Dwangwa plant, and 10.8 from the Chickwawa one). In parallel with production, Malawi has been practicing ethanol blending with petrol for a total of over 250 million liters since 1982. The Government of Malawi is funding an experimental project for the use of ethanol in motor vehicles, in collaboration with the Lilongwe Technical College and the Ethanol Company of Malawi: a number of flex-fuel vehicles have been imported from Brazil as part of the project.[10] Malawi has also been exploring biodiesel potential and, under the guidance of its Biodiesel Agricultural Association, the country is reportedly beginning to grow jatropha on plantations previously used for tobacco.[11] Analysts Frost and Sullivan have recently described Malawi's ethanol sector as being in rapid expansion.[12]
- *Zambia*. The Zambian Government is keen to establish a biofuels industry: it recently constituted an inter-ministerial steering committee to lead the development of the sector, helped create the Biofuels Association of Zambia, and allocated USD 150,000 in the 2007 budget to conduct research on various possible feedstocks, including jatropha for biodiesel and sweet sorghum to complement sugarcane for ethanol. Zambia's draft biofuels legislation also considers possible blending targets for 2011,

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[10] Open web sources: "Biofuels in Eastern and Southern Africa", presentation for the AU-UNIDO seminar, available at www.unido.org/doc/70401; www.unep.org/urban_environment/PDFs/DanLiwimbiEthanol.pdf; www.islamonline.net/servlet/Satellite?c=Article_C&cid=1177155906718&pagename=Zone-English-HealthScience%2FHSELayout

[11] Reuters Alert Net, http://www.alertnet.org/thefacts/reliefresources/117224445861.htm

[12] *Frost & Sullivan*, "Sub-Saharan African Biofuels Markets", September 2007, http://www.frost.com/prod/servlet/report-brochure.pag?id=M169-01-00-00-00#Ordering

for both ethanol (5%) and biodiesel (10%).[13] The country's policy framework, however, is still in its nascent stage, and while several private sector actors have been exploring biofuels production, the sector is far from being established. Zambia's ethanol production potential in the near term, based on its sugar industry, has been estimated to stand at 18.5 million liters/year; based on an approximate projection, demand between 2010 and 2015 could range between 17 and 18 million liters/year with a 5% blending ratio, or between 33 and 37 million liters with a 10% one.[14]

- *Zimbabwe*. Due to its lack of oil resources and its dependence on imports, Zimbabwe pioneered the production of fuel ethanol for blending beginning in the 1980s. For a long period, E12-E15 blends were widely available for motor vehicle use. Triangle Limited, a South Africa-owned sugar estate, produced about 40 million liters of ethanol, until operations were suspended after the 1991-1992 drought that severely cut sugarcane production. The plant has more recently been revived, but limits its production at small quantities of industrial ethanol for export:[15] according to F.O. Licht, Zimbabwe produced 26.5 million liters of ethanol in 2006.[16] The Zimbabwean government has also been exploring possibilities for biodiesel: based on encouraging feasibility study results, in 2006 it committed about USD 12 million in funding for a national biodiesel program for the setting up of a production site based on jatropha cultivation. The project has completed several initial tasks including soil tests, site clearing, environmental impact assessment, topographical survey and erection of office infrastructure.[17] In view of the current political and economic conditions in the country, however, it is very difficult to assess the future of ethanol in the country at the present time.
- *Botswana*. The Department of Energy Affairs of Botswana was involved in a study for biofuels potential in the Southern African Development Community (SADC) together with other SADC countries, and began exploring possibilities for biofuels production in the country (assessment of soil conditions, identification of areas suitable for different crops, policies, plant establishment). However, it would seem that – compared with the four countries considered here – Botswana has made more limited progress towards the establishment of a biofuels industry.[18]

Biofuels policy frameworks in other Southern African countries are at an early stage even when compared with that being defined in South Africa, making uncertainties in projections very significant. However, it is possible to envision a scenario where these countries would adopt ethanol and biodiesel blending ratios similar to those that are

[13] Bernadette Lubozhya, "Biofuels Experiences in Zambia", UN Presentation http://www.un.org/esa/sustdev/sdissues/energy/op/biofuels/biofuel_lubozhya_zambia.pdf; and http://biopact.com/2007/07/zambian-scientists-call-for-investments.html

[14] Partners4Africa, cited by IADB Garten Rothkopf, *op.cit.*

[15] Open wources: http://energysavingnow.com/biomass/carsbiofuel.shtml; http://www.grida.no/climate/ipcc/tectran/156.htm;

[16] http://www.ethanolrfa.org/industry/statistics/

[17] http://biopact.com/2007/05/zimbabwes-jatropha-project-receives.html

[18] SADC, *Feasibility Study on the Production and Use of Biofuels in the Southern African Development Community*, August 2005

currently being considered for South Africa and, based on this assumption, to estimate the potential size of this market.

Given current consumption of motor vehicle gasoline and diesel in Malawi, Zambia, Zimbabwe and Botswana,[19] and assuming a 4% growth rate in demand for fossil fuels, blending standards of 8% for ethanol and 2% for biodiesel in these four countries could create a combined market for the 2010-2015 period of 105-120 million liters of ethanol per year, and 30-35 million liters per year of biodiesel. If a wider range of countries in the subcontinent were considered (Angola, Botswana, Democratic Republic of the Congo, Lesotho, Malawi, Mauritius, Namibia, Swaziland, Tanzania, Zambia and Zimbabwe), the same assumptions would lead to an estimated market for 2010-2015 of 250-300 million liters of ethanol, and 100-125 million liters of biodiesel. While these estimates are tentative at best, for purposes of order of magnitude comparison they should be compared with South Africa's projected demand for the same period: as noted, this could be in the range of 280-330 million liters of ethanol and 200-250 million liters of biodiesel.

African markets – Summary

Even based on these rough estimates, in terms of sheer size South Africa emerges as the key potential market for Mozambique, as well as for several other Southern African competitors. Such a potential market does not seem evident from the supply and demand figures shown in Table 3 and Table 4. It remains to be seen how fast production capacity of South Africa builds up to a level sufficient to cover or even surpass demand, the price levels for the market, and the degree to which domestic production can compete on international markets. South Africa's market potential will be determined by factors affecting feedstock availability and cost competitiveness in production, and with respect to which Mozambique (or other countries) may enjoy a comparative advantage.

Table 3. African ethanol markets, 2006 and projected (2010-2015)

Ethanol 2006 (millions of liters)	**Total Consumption**	**Total Production**	**Balance**
Africa	18	18	0
South Africa*	0	0	0
MW-ZM-ZW-BW	18	18	0
Ethanol 2010-2015 (millions of liters)	**Projected Demand**	**Projected Production Capacity**	**Projected Balance**
Africa	385-450	355-420	(30)
South Africa	280-330	250-300	30
MW-ZM-ZW-BW	105-120	105-120	0

Sources: IADB Garten Rothkopf and Econergy estimate, based on open web sources. For Malawi (MW), Zambia (ZM), Zimbabwe (ZW) and Botswana (BW), Econergy estimate based on assumption of 8% fuels standard and adequate response in supply

[19] U.S. Energy Information Administration (EIA) data, available at http://www.eia.doe.gov/emeu/international/oilconsumption.html

It should be expected that production capacity will respond to any blending standard enacted also in other Southern African countries considered. Given various programs that may be set up at the same time in the region, it is not possible to say with certainty what countries may be a potential market for Mozambique, and which are more likely to compete with it for South Africa's or other international markets. Some countries – namely Malawi, Tanzania or, further North, Kenya – are known to be at a more advanced stage in biofuels production. Depending on the timing and results of their biofuels programs, some other countries – such as Zambia, Zimbabwe, or Botswana – may be potential export markets in the shorter term, and become export competitors after a period of consolidation.

Based on objectives set forth in the Southern African Development Community's Trade Protocol (2000) and following a gradual decrease in customs duties since 2001, the SADC Free Trade Area (FTA) took effect as of January 2008. The majority of goods produced in the Community, including biofuels, will enjoy duty-free status among SADC countries: 85% of all goods should be trading at zero tariff by 2008, and the remaining

Table 4. African biodiesel market, 2006 and projected (2010-2015)

Biodiesel 2006 (millions of liters)	**Total Consumption**	**Total Production**	**Balance**
Africa	0	0	0
South Africa	0	0	0
MW-ZM-ZW-BW	0	0	0
Biodiesel 2010-2015 (millions of liters)	**Projected Demand**	**Projected Production Capacity**	**Projected Balance**
Africa	230-285	480-535	250
South Africa	200-250	450-500	250
MW-ZM-ZW-BW	30-35	30-35	0

Sources: IADB Garten Rothkopf and Econergy estimate, based on open web sources. For Malawi (MW), Zambia (ZM), Zimbabwe (ZW) and Botswana (BW), Econergy estimate based on assumption of 2% fuels standard and adequate response in supply

15%, represented by sensitive products (mostly vegetables for food consumption from South Africa), will have tariff barriers removed from 2008 to 2012. Liberalization will only involve customs duties: where applicable, imported goods will still be subject to value added tax. In order to benefit from customs duties exemption, importers will need to produce to customs officials a certificate of origin guaranteeing that products actually originate from within the SADC.[20] The SADC FTA will contribute to the development of a regional biofuels market, stimulating competition for exports to the greatest consumers.

European markets

European Union – Overview. Two key directives adopted by the European Commission in 2003 drive E.U. production of biodiesel and ethanol: E.U. Directive 2003/30/EC

[20] See http://www.sadc.int/fta/index.php (website not yet active as of March 2008), as well as http://thesouthernafrican.com/index.php?option=com_content&task=view&id=1850&Itemid=32

established, as an indicative target, for biofuels to account for 5.75 % (based on energy content) of all transport fuels by 2010; a target of 2% was set for 2005, and not achieved. Directive 2003/96/EC, on the other hand, allowed E.U. member states to exempt from taxation, in full or in part, products containing renewable substances.[21] Member states have consequently adopted legislation and policies with incentives and national targets. However, the target being only indicative, each E.U. member nation has submitted its own individual biofuel goal, and many do not aim to hit the 5.75% target.[22] More recently (March 2007), a summit of E.U. heads of state (European Council) endorsed a proposal for a minimum 10% binding target to be set for biofuels in Europe by 2020: it is expected that this may soon lead to an updated EC directive on biofuels.

Biodiesel is the prevailing biofuel on the E.U. market (81% of biofuels production in 2006), followed by ethanol (19%). The diesel vehicle market in Europe is growing steadily: while in 1999 diesel cars only accounted for 28% of the market, in 2006, for the first time, there were more diesel-powered than gasoline-powered cars sold in Europe (51%). Sales data for the first half of 2007 indicate that the diesel market share is still growing (52.2%).[23] Also, E.U. countries' fuels tax structures generally favor diesel over gasoline.[24] The E.U. biodiesel market can therefore be expected to experience a faster growth than the one for ethanol. The two markets are presented separately below.

- *E.U. Ethanol market*: According to the European Union of Ethanol Producers (UEPA), total production in 2006 stood at over 1.5 billion liters, increasing about 70% from the 895 million liters produced in 2005.[25] Spain and Germany are the largest producers (each produced almost 400 million liters or about 26% in 2006), with France coming in third with 293 million liters produced in 2006. Poland and Italy follow, each with about 130 million liters produced in 2006. Sweden's production dropped from 163 to 72 million liters in 2006, although its imports increased consistently, and the country represents an important market for other countries such as Italy. The emergence of new producer countries like Hungary (35 million liters), Lithuania (18 million liters) and the Czech Republic (16.5 million liters) helps contribute to the overall increase in ethanol production.[26]

  Several E.U. countries were net exporters in 2006: Spain and Italy in first place, with 170 and 130 million liters exported in 2006 respectively, as well as the Poland (20 million liters), Hungary (15.3 million), the Czech Republic (14 million), Latvia (12 million) and Lithuania (5.3 million). The largest importer was by far Germany with 185 million liters in 2006. Total consumption in the E.U. for 2006 amounted to 1.725

[21] E.U. legislation available at http://ec.europa.E.U./energy/res/legislation/biofuels_en.htm
[22] UEPA: European Union of Ethanol Producers. "The Issues of the Agricultural Alcohol Industry."
[23] Automotive Industry Data, August 2007, cited by the U.S. Department of Energy/Energy Efficiency and Renewable Energy http://www1.eere.energy.gov/vehiclesandfuels/facts/2007_fcvt_fotw481.html
[24] GTZ, "International Fuel Prices" 2007
[25] UEPA, "2006 E.U. Fuel Production vs. Consumption", 12 June 2007 at http://www.uepa.be/news.php
[26] European Commission Biofuels website, May 1, 2007.

billion liters, with imports covering the balance of approximately 211 million liters (about 12%).[27]

The dynamics of consumption and production in the E.U. members' domestic markets are likely to change significantly as implementation of the E.U. directive proceeds, and to an even greater extent should binding targets be adopted for 2020. Implementation strategies and policies are still in the process of being defined and, in several countries, production will quickly reach maximum capacity, while domestic consumption can be expected to expand considerably more.

Based on an estimation of the evolution of the domestic market given the current regulatory/policy development and the evolution of petrol prices, total E.U. consumption of ethanol should reach at least 12 billion liters by 2012.[28] Expanded production within the E.U. will cover a substantial part of this increase: production has been increasing at very high rates over the past few years (70% from 2005 to

Table 5: Ethanol production capacity in Europe, 2006 and planned (millions of liters)

Country	In operation	Under construction	Projects in Development	Total (est. 2012-2015)
Austria	--	240	NA	240
Belgium	--	--	600	600
Bulgaria	10	--	12	22
Czech Republic	--	55	388.5	443.5
Denmark	--	--	127	127
Finland	--	--	83.5	83.5
France	668	550	1626	2,844
Germany	676	--	755	1,431
Hungary	100	--	1256	1,356
Italy	270	--	100	370
Latvia	12	--	NA	12
Lithuania	31	--	NA	31
The Netherlands	14	--	342	356
Poland	117	--	140	257
Russia	--	--	380	380
Slovenia	--	--	55	55
Slovakia	--	75	N.A.	75
Spain	521	--	475	996
Sweden	150	--	150	300
Turkey	--	80	N.A.	80
United Kingdom	--	195	745	940
Total	**2,569.0**	**1,195.0**	**7,235.5**	**11,000**

Source: F.O. Licht. For Italy: Assodistil (national ethanol producers association)

[27] UEPA 2007, *cit.*
[28] *Agra CEAS, F.O. Licht*, "Study of the outlook for the E.U./world bioethanol market for Societé Générale", August 2006

2006), new facilities are continuously being constructed, and production capacity is growing at a very high pace. In Germany, for example, three major plants with a combined annual production capacity of more than 600 million liters have recently started operation. Another three large plants are being developed in Italy, and are expected to add 100 million liters capacity by 2010. In addition, Netherlands, Latvia, Lithuania are also now producing smaller volumes of fuel ethanol. Substantial increases in capacity for France, the U.K., and Hungary are also expected. Table 5 provides an overview of existing and planned capacity of ethanol production in Europe, with the main feedstocks used including wheat, rye, and sugar beets. In the future, increasing volumes of maize are likely to be used in countries such as Hungary, Romania, Bulgaria, and the Ukraine. If the entire production capacity shown in the table were operational between 2012 and 2015, it would amount to 11 billion liters.

Despite the growth in capacity within the E.U., however, expanding imports will be required to meet anticipated growth in demand. Assuming a fixed percentage of imports in domestic consumption consistent with that observed over the past few years (about 10%-12%), total E.U. imports would reach 1.0-1.2 billion liters by 2012, the rest being produced domestically. This assumes that the EC will maintain the current import barriers, which will only allow the lowest cost producers (such as Brazil) to sell into the market. There are some important obstacles to ethanol entering the E.U. marketplace, though in some instances these are being eased.

First, there are import tariffs of €0.192/liter for non-denatured bioethanol, and of €0.102/liter for denatured bioethanol.[29] Given an exchange rate of €1=USD 1.5, even the lower of these two tariffs is higher than the USD 0.14/liter U.S. tariff on imported ethanol from countries outside preferential trading agreements such as NAFTA and CAFTA, originally intended to protect E.U. producers of alcohol but now equally applicable to ethanol. E.U. tariffs on ethanol, however, do not apply to imports from countries such as Mozambique, which qualify as least-developed countries (LDCs) granted duty free access to the E.U. market under the Everything But Arms (EBA) Agreement (also see below, preferential trade agreements). Tariffs, conversely, currently apply on imports from Brazil: in order to assess Mozambican ethanol's competitiveness in the E.U. market vis-à-vis Brazil's, the lower €0.102/liter tariff (for a more conservative comparison) should be added to the CIF price of Brazilian ethanol. The advantage of tariff preferences enjoyed by Mozambique, therefore, would partly compensate the disadvantage of production costs higher than Brazil's. Such expected advantage, however, should be considered with caution. As E.U. countries implement their biofuels strategies, it is expected that tariffs may be eliminated.[30] In particular, the E.U. has been negotiating with Mercosur (which includes Brazil) an Association Agreement aiming at establishing a free-trade area.

[29] See http://ec.europa.E.U./energy/res/sectors/doc/bioenergy/legal_issues_biofuels.pdf as well as http://www.fas.usda.gov/gainfiles/200604/146187342.pdf
[30] Credit Suisse, "Renewable/Alternative Energy" equity research report, March, 2007.

Negotiations are currently on hold, but they could resume at any moment. The E.U.'s original offer to Mercosur, based on member countries' needs to comply with the proposed biofuels program, would include a quota of 1 million tons of fuel ethanol per year.[31] On the other hand, Brazil's domestic demand for ethanol has been increasing rapidly, up to 30% in 2007, mostly due to the success of the launching of a flex-fuel vehicle market able to run on hydrous ethanol: [32] this factor may limit Brazil's ability to continue meeting most of the E.U.'s needs, and increase the chances that Europe may have to resort to higher-cost ethanol for at least part of its demand.

Second, the E.U. ethanol standard is more stringent with respect to water content than is the U.S. standard. The E.U. requires no more than 0.3% water in anhydrous alcohol, versus the 0.7% standard applied in the U.S., and, notably, Brazil. According to a Brazilian ethanol project developer, the E.U. standard increases the cost of getting the fuel to Europe, since some accumulation of water in shipments is inevitable due to the hydrophilic properties of pure ethanol; exports to Europe would require construction of special dehydration facilities in the E.U. to treat shipments upon delivery to the continent.[33] At the same time, it will always be more cost-effective to integrate dehydration and production facilities, absent distortions such as tariff requirements.

Finally, although there are concerns that Brazilian ethanol may not qualify under proposed E.U. sustainability criteria, market participants in Brazil do not appear to be overly concerned for reasons related to the nature of production as well as broader market trends. To begin, Brazilian investors dispute assertions that Brazilian ethanol production requires deforestation. One investor notes that Brazil's sugar is primarily produced outside the Amazon region, and there is enough available agricultural land to accommodate the expansion of sugarcane production by some 2 million ha by 2012. Further, this investor argues that the potential for growth in exports to the U.S. makes up for more limited growth in Europe.[34]

- *E.U. Biodiesel market*: In 2006, biodiesel continued to be the leading biofuel in the E.U., representing 81% of biofuel production or about 5.7 billion liters produced (about 4,900 tons), with an increase of over 50% with respect to the previous year's production (3.7 billion liters). Germany alone represented over half (52.4%) of this, with about 3.1 billion liters, followed by France with 870 million liters and Italy with 525 million liters.[35] Figure 2 compares biodiesel production in Europe in 2005 and 2006.

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[31] See the E.U. website at http://ec.europa.E.U./trade/issues/bilateral/countries/brazil/index_en.htm and concerns expressed by UEPA at http://www.uepa.be/issues.php

[32] http://www.ethanolstatistics.com/Ethanol_Reports/The_Brazilian_Ethanol_Market.aspx and conversation with Marcelo Junqueira, March 2008

[33] Marcelo Junqueira, Clean Energy Brazil, personal communication, April 9, 2007.

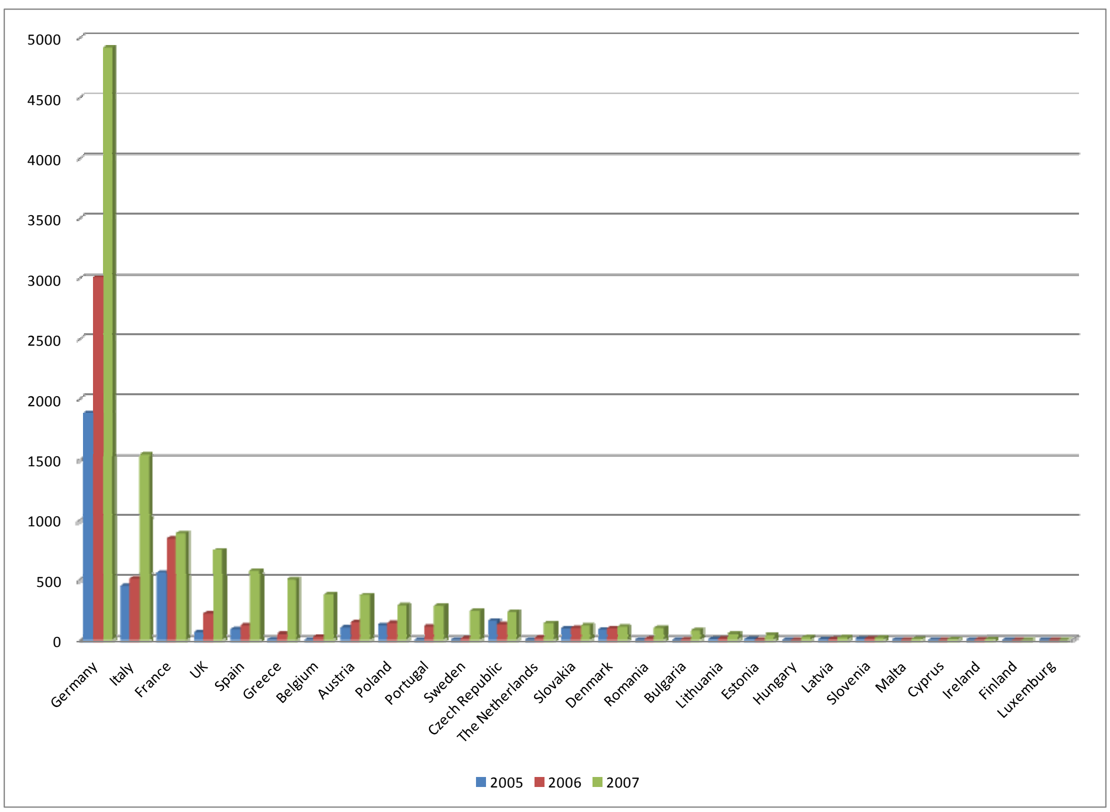
[34] Marcelo Junqueira, Clean Energy Brazil, personal communication, March 12, 2008.

[35] European Biodiesel Board, www.ebb-E.U..org/stats.php

Total biodiesel production capacity in the E.U. is expanding at a pace that official data struggle to keep up with and that prevent any projection beyond the very short term from being accurate. According to an estimate of the European Biodiesel Board (EBB), capacity may reach 12 billion liters by the end of 2007 (over 10 million tons), from 7.1 billion in 2006 (an increase of about 70%). Leading producers are ever increasing their production capacity: German production capacity for 2007 continued to expand, jumping to over 5 billion liters, about 66% from the previous year's actual production; this spectacular growth was the result of favorable legislation granting a total tax exemption for biofuels, in pure or mixed forms. However, this exemption was modified in August 2006, when the German government introduced a €0.10/liter tax for biodiesel used in pure form, and a €0.10/liter tax for biodiesel when mixed at refineries. Many other countries have also entered the market, including the Czech Republic, Poland, Austria, Slovakia, Spain, Denmark, and the UK. According to the EBB, the E.U. produced 77% of the world's biodiesel in 2006.

There are currently 185 fully operational biodiesel plants in Europe, and other 58 are currently under construction. At the end of 2005, biodiesel production represented approximately 1.5% of the European diesel market in terms of energy content, close but not sufficient to reach the 2% target set by the EC Directive 2003/30 for that year.

Figure 2: Biodiesel production capacity in Europe (2005, 2006 and 2007), millions liters



Source: European Biodiesel Board

Thanks to the recent developments and to plants under construction, however, the EBB estimates that Europe's biodiesel production capacity alone (without considering ethanol) could meet the 5.75% target by energy content set for 2010 by the end of 2008: this target corresponds to a 6.5% target by volume for biodiesel, or about 13.5 million tons/16 billion liters of biodiesel. The EBB also estimates that European biodiesel producers could meet the 10% binding target expected to be set for 2020 well in advance.[36] Further policy developments will be critical in ensuring an optimal development of the E.U. biodiesel market and in avoiding idle production: key factors include clearer and more effective binding legislation at the E.U. and member state levels, and an increase in the E.U. diesel fuel standard, currently blocked at 5%.

The general customs duty for biodiesel in the E.U. is 6.5% ad valorem.[37] Given its considerable biodiesel production capacity, however, the E.U. market is very unlikely to need imports of finished biodiesel. This is consistent with the very low levels of international trade in biodiesel, most of the trade in this sector involving raw oils. In addition, E.U. biofuels standards and testing requirements are likely to pose obstacles to finished biodiesel produced from feedstocks other than those commonly used in Europe (mostly rapeseed and sunflower). First, palm oil and coconut oil have much higher melting points (respectively 28°C and 38°C) than common E.U. oils (between -15 and -20°C): this typically makes palm or coconut-derived biodiesel incompatible with E.U. standards. However, there are "winterization" processes that biodiesel producers may use to address the melting point issue: such methods are already patented for palm oil,[38] and indeed E.U. producers have started importing palm oil to produce biodiesel; winterization processes may soon also be developed for coconut oil, although presently no E.U. producer imports or uses coconut oil yet, at least on a large scale. Secondly, current E.U. glycerin testing methods for biodiesel are not applicable to coconut oil, and amount to a non-tariff barrier to coconut oil-produced biodiesel (apart from the high opportunity cost of coconut oil for biodiesel production instead of other more remunerative uses); in the longer term, Mozambique (perhaps through a newly created Mozambique Biofuels Association) could seek to modify or expand glycerin testing methods acceptable in the E.U. In the more immediate term, however, both production capacity and technical considerations make the import of low-cost crude oils in the E.U. represent a much more viable and significant market potential than the import of finished biodiesel. If the oil is to be used to produce biodiesel, it would be up to the producers to find the way to comply with the standards; it should be remembered that E.U. tax incentives apply to biodiesel produced in Europe. According to the EBB, over 90% of the biodiesel produced in

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[36] EBB, 17 July 2007, http://www.ebb-E.U..org/EBBpressreleases. Also see German Renewable Energy Federation (BEE), "Strategy for Biomass and Biofuels", 2006, available at *http*://www.europarl.europa.E.U./hearings/20060601/itre/lackmann_en.pdf

[37] http://ec.europa.E.U./energy/res/sectors/doc/bioenergy/legal_issues_biofuels.pdf

[38] OilTek in Malaysia has a patented process to produce "winter grade" biodiesel from palm oil for the E.U. market: www.oiltek.com.my/palm_biodiesel.html

Europe today is originated from E.U. raw materials: this situation is expected to change over the next five years, E.U. biodiesel raw materials being expected to cover 70-80% of the biodiesel industry demand in the longer term and under the 2002 target.[39] The remaining 20-30% of raw materials would need to be imported. Since there is an almost one-to-one relationship between crude oils and the refined biodiesel product, this suggests that the current market for imports of crude vegetable oils is about 500 million liters (given production levels of 5.75 billion liters), and that it could expand to 3.2-5.4 billion liters between 2010 and 2015 if, as expected, demand reaches 16-18 billion liters per year.

One final issue, however, has recently been affecting the E.U. biodiesel market, and is likely to limit import of raw vegetable oils if unresolved. Since October 2006, U.S.-produced B99 biodiesel (0.1% mineral diesel and 99.9% biodiesel) is being imported in the E.U., enjoying a subsidy granting USD 1 for every gallon of biodiesel blended with mineral diesel.[40] The subsidy gives the U.S. B99 a competitive advantage over E.U.-produced biodiesel in the amount of about Euro 200/m^3: this allows traders to sell it on E.U. markets at the same (or lower) price than the cost of E.U. producers' raw materials. According to the EBB, 100,000 tons (almost 120 million liters) of B99 enter the E.U. each month as of October 2007, and that as a result production may soon start stagnating or even declining if the issue is not properly resolved. After an initial letter to the E.U. Commissioner for Trade, the EBB is preparing a formal countervailing duty complaint with the WTO.[41] The tax incentive at the basis of this issue was originally approved by the U.S. in 2004 as part of the Jobs Creation Act, and due to expire at the end of 2006; in August 2005, however, it was extended as part of the Energy Bill until the end of 2008.

- *E.U. Preferential trade agreements*. The E.U. introduced a Generalized System of Preferences for its trade with developing countries since 1971. Under the current GSP regulation (N.980/2005), provisions include general and specific tariff reductions, as well as a special arrangement known as the "Everything But Arms Regulation" (EBA, Regulation EC 416/2001) for countries officially recognized and classified by the United Nations[42] as Least Developed Countries (LDCs). The EBA grants duty-free access to imports from LDCs of all products, except arms and munitions, without any quantitative restriction.[43] Mozambique, which qualifies as LDC, therefore enjoys duty-free access to the E.U. market: this, as noted, may represent an advantage with

[39] "EBB comments to the European Commission consultation on biofuels issues in the new legislation on the promotion of renewable energy", June 2007, available at the E.U. Commission website at http://ec.europa.E.U./energy/res/consultation/doc/2007_06_04_biofuels/ms_instistution/ebb_en.pdf
[40] The incentive consists of a federal excise tax credit amounting to one penny per percent of biodiesel blended with petroleum diesel. See the EBB letter to the E.U. Trade Commissioner at http://www.ebb-E.U..org/EBBpressreleases/let%20to%20CM%20Mandelson%20unfair%20B99%20and%20DETs.pdf
[41] Conversation with Ms. Stephanie Ho of the EBB, 9.24.2007
[42] http://www.un.org/special-rep/ohrlls/ldc/list.htm
[43] See http://ec.europa.E.U./trade/issues/global/gsp/eba/index_en.htm. Trade in bananas, rice and sugar was not fully liberalized immediately, but duties were gradually reduced. Full liberalization for bananas came in January 2006, sugar will enjoy duty-free status in July 2009 and rice in September 2009.

respect to Brazilian ethanol exports, compensating in part Mozambique's relatively higher production costs. It remains to be seen, however, whether and how long this advantage may last: if the E.U.'s negotiations with Mercosur for a free trade agreement (including a large quota for Brazilian ethanol) resume, as described above, this could bring the tariff preference enjoyed by Mozambican ethanol vis-à-vis Brazil's to an end.

The E.U. has also been negotiating bilateral Economic Partnership Agreements (EPAs) with African, Caribbean and Pacific countries (ACP).[44] The ACP-E.U. Sugar Protocol and the Agreement on Special Preferential Sugar Imports of 2005 provides for imports at favorable prices, and currently amount to approximately 1.3 million tons a year. The main producers in this group include Mauritius (about 490,000 tons), Fiji (204,000 tons), Guyana (195,000 tons), Swaziland (169,000 tons) and Jamaica (150,000 tons). Mozambique is also a beneficiary of these agreements. Under the EBA agreement, however, all LDC sugar exports to Europe will enjoy complete duty-free access from July 2009.

European Union – Case studies. The following sections present more detailed information on a select group of importing countries.

- *United Kingdom*. The U.K. government supports local biofuels through a USD 0.40/liter [£0.20/liter] duty on imports from outside Europe (in effect through 2008). Under the renewable transport fuels obligation (RTFO), which comes into force in April 2008, the government will require 5% of all fuel sold in the U.K. to come from renewable sources by 2010. Oil companies will receive certificates from the government demonstrating how much biofuel they have sold. Companies selling more than the 5% obligation can then sell these certificates to other companies that need additional quantities to meet the obligation. The penalty for non-compliance in the first year is £0.15/liter. The government intends to increase the level of the RTFO above 5% after 2010.

  There are no operating ethanol refineries in the U.K.; fuel ethanol is imported from Brazil. In 2006, total Brazilian ethanol imports in the U.K. were approximately 95 million liters, a decrease from 2005 (120 million liters), but this is expected to grow in the future. Six ethanol plants with total capacity of over 1 billion liters are currently in the construction or planning stage, representing just below 5% of total gasoline demand. Since the U.K. aims to comply with the EC biofuels blending directive of 5.75% by 2010, [45] even with the new domestic capacity, the country will need to import about 200 million liters a year, suggesting that there is potential for small increases in imports in the next several years.

  The Home Grown Cereals Authority expects total demand for biofuels to reach 3 billion liters [2.5 million tons] within the next five years, suggesting total biodiesel

[44] See http://ec.europa.E.U./trade/issues/bilateral/regions/acp/nepa_en.htm
[45] Source: Agra CEAS

demand of about 1.8 billion liters annually (given estimated ethanol demand of 1.2 billion liters a year). The UK produced 225 million liters of biodiesel in 2006, an almost fourfold increase from 2005.

- *Germany*. Germany is the biggest consumer of fuels in Europe as well as the largest producer of biofuels. In 2004, the share of biofuels (both ethanol and biodiesel) in total fuel consumption was 2.2%, the majority of which was biodiesel. The biodiesel industry in Germany is expanding: in 2006 production amounted to 3.1 billion liters, and operational capacity as of July 2007 was estimated at over 5 billion liters.[46]

  Production of ethanol in Germany in 2006 amounted to almost 400 million liters, and ethanol production capacity currently in operation is 676 million liters; given very high growth rates in ethanol as well as in biodiesel production, production data for 2007 are expected to correspond at least to full capacity. In late 2004, the country's first two rye-to-ethanol plants, with a combined annual capacity of 350 million liters, began production. A third 260-million liter/year plant started operation in the third quarter of 2005. In contrast to biodiesel, fuel ethanol is not widely used because of perceived or real technical problems associated with direct blending, so refineries are instead using ETBE for blending purposes.

  Relative to other European countries, Germany provides substantial tax incentives for biofuels producers until 2009. Specifically, German regulations provide that all biofuels are exempt from the tax on mineral oil products (€0.65 per liter), as well as the 1999 ecology tax, which is added to the taxes levied on petroleum products, and there are grants and other types of support available for the construction of biofuel refineries. Pure biofuels have benefited from the mineral oil tax incentive since 1999, while blends, such as ethanol in E10 or ETBE, have been eligible for the tax exemption since January 1, 2004. The result of these provisions plus the increase in petrol price (and thus the competitiveness of biodiesel and ethanol) led to a boom in refinery project development, and the conclusion by the German Ministry of Finance that this industry is overcompensated. As a result, the German government introduced a €0.10/liter tax for biodiesel used in pure form, and a €0.15/liter tax for biodiesel when mixed in refineries.[47]

  The German government plans to require that biofuels represent 5.7% of fuel (by energy content) by 2009 and 6% by 2010. In order to meet this goal with biodiesel alone, Germany would need almost 4 billion liters [3.4 million metric tons] of biodiesel in 2010.[48] As in the U.K., the government will introduce a system of tradable biofuel certificates or credits. Also under consideration is an obligation/penalty system.

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[46] European Biodiesel Board, www.ebb-E.U..org/stats.php, and confirmed by the UFOP (German oil producers association) http://www.ufop.de/english_news.php
[47] Source: USDA, "Germany may reduce the mineral oil tax waiver for biodiesel," 2005, http://www.fas.usda.gov/scriptsw/attacherep/default.asp.
[48] "Germany Oilseeds and Products: Biodiesel in Germany – an overview." USDA Gain Report, 10/24/2002. GAIN Report #GM2021.

- *Portugal*. Portugal does not have any specific mandates requiring biofuels blending, but it has chosen to reduce petroleum taxes on the production of biofuels. First, with the passage of Decree 62/2006, the government formally adopted the 2003 EC biofuels directive. Second, Portugal passed Decree 66/2006, which established tax benefits for the producers of biofuels in the country. This law reduced or exempted petroleum taxes on biofuels producers by €280-300 per thousand liters for fuel destined for the commercial market.

  The European Biodiesel Board cites annual production levels of 107 million liters of biodiesel in 2006 (91,000 tons), whereas 2005 production levels were limited to only about 1.2 million liters (1,000 tons). Portugal's Ministry of Engineering, Technology, and Innovation (INETI) estimates Portuguese biofuels production capacity will approach 600,000 tons by 2010, based on expected tax revenues and project development plans for construction of seven biodiesel plants, two ethanol plants and two refineries in the next three years. As a result of this development, sourcing of feedstock may become an issue for Portugal. Local farmers are unlikely to meet the demand for feedstock, implying that imports of crude oil for processing into biodiesel would be required.

- *Spain*. In Spain, a limited volume (quota) of ethanol is eligible for a full exemption from the mineral oil tax of €0.3956 per liter. This tax incentive is set to expire in 2012. The Spanish government has earmarked €2.85 billion of sales tax breaks for ethanol and biodiesel producers over the 2005-2010 period to meet a total share of 5.83% of biodiesel and ethanol by 2010. As a result, the use of biofuels is expected to more than quadruple by 2010 when it will reach 2.2 million tons of oil equivalent.

  Spain is the largest fuel ethanol producer in the E.U.. Ethanol production in 2006 was 396 million liters, [49] and production capacity (mostly wheat-to-ethanol) is estimated at approximately 521 million liters;[50] it has been expanded this year by a 200 million liter plant in Salamanca built by a Spanish company, Abengoa, which has several more planned. Further Abengoa has plans to develop a commercial scale cellulosic ethanol production facility.[51]

- *Italy*. In recent years, the government's attention to biomass energy has increased substantially. A legislative decree in 2005 was issued to incorporate E.U. Directive 2003/30, establishing targets that were below those set by the European Commission (2.5% of all transportation fuels to be represented by biofuels by 2010, instead of

[49] UEPA 2007
[50] F.O. Licht 2006, *cit.*
[51] Abengoa Bioenergy, which has a pilot plant in Nebraska, is building a plant in Spain to produce 110,000 gallons per month of cellulosic ethanol from agricultural residues.

5.75%), as well as a series of fiscal incentives.[52] The Commission deemed the 2005 policy as not adequately compliant with E.U. directives, as well as in violation of general provisions on state incentives, and issued a notification of violation against Italy. This, in turn, blocked the use of incentives allocated to support a preferential fiscal regime for biofuels in the country.

The 2007 Budget Law, approved by the Parliament in December 2006,[53] was designed to bring Italy into conformity with E.U. Directive 2003/30 on biofuels. The Law modified existing biofuels legislation, and mandated that biofuels represent at least 2.5% of all fuel consumed in Italy (both diesel and gasoline) by the end of 2008, reaching 5.75% by the end of 2010. The Law also obliges companies that sell gasoline and diesel to blend at least 1% of biofuel in 2007, and at least 2% in 2008. Starting in 2008, there will also be penalties for missing these targets. Details for the application of the Law need to be spelled out in forthcoming decrees. As of June 2007, drafts of the three key regulatory decrees had been prepared by the Government, and are being discussed and finalized with the input of specialized industrial associations.[54]

Italy's biofuels sector, therefore, is undergoing a transition towards a regulatory system that combines tax breaks and compulsory blending targets. There are strong expectations in the industry that the new system, once implemented, will provide a substantial boost to production, thanks to a mix of incentives and obligations[55].

- *Biodiesel*. Current total Italian biodiesel production capacity, in spite of a tax relief quota limited to 250,000 tons, has grown to about 1.6 billion liters [1.3 million tons].[56] This represents the second highest biodiesel production capacity in the EU25, after Germany's. Producers have been building capacity on the basis of promising demand forecasts, given that demand from E.U. markets is strong and that the national market holds an increasingly interesting potential. However, production has been limited by modest tax relief quotas, with many plants not operating at full capacity or at times not utilized. Total production for 2005 reached almost 400,000 tons,[57] an increase of more than 20% over 2004. It is expected to grow to 400,000 tons only for the domestic market in 2007, driven in large part by a 1% compulsory blending

[52] Decreto Legislativo 128, 30 May 2005, *Attuazione della direttiva 2003/30/CE relativa alla promozione dell'uso dei biocarburanti o di altri carburanti rinnovabili nei trasporti*, article 3. Available at http://gazzette.comune.jesi.an.it/2005/160/1.htm

[53] Legge 296, 26 December 2006, *Disposizioni per la formazione del bilancio annuale e pluriennale dello stato (Legge Finanziaria 2007)*, commas 367 and following. Available at http://www.governo.it/GovernoInforma/Dossier/finanziaria_2007/doc/legge.pdf

[54] Conversation with Dr. Laura Vecchi of the Italian Ministry for Economic Development, General Directorate for Energy and Mineral Resources. Also see a presentation of the new biofuels policy at http://www.governo.it/GovernoInforma/Dossier/finanziaria_2007/slide/risparmio_energetico_071206.pdf

[55] Conversation with Mr. Luca Amatruda of Novaol, a biodiesel producer member of the European Biodiesel Board (EBB)

[56] E.U. Biodiesel Board, 2006 production capacity levels

[57] *Ibidem*

requirement. For 2008, compulsory 2% blending in diesel may lead to domestic requirements of up to 600,000 tons. Thanks to sustained export opportunities in other E.U. countries such as Germany and France, and increasing domestic demand, the sector is growing considerably and adding production capacity. Production could indeed soon reach full capacity to meet national and international demand for Italian biodiesel; most producers have expansion plans in place.[58] The success of the proposed policy framework, and in particular the possibility that the tax relief quota may increase, will be critical for the sector's development.

- *Ethanol*. Ethanol production is also subject to the new policy established by the 2007 Budget Law, within a framework that combines (a) obligatory blending percentages (1% in 2007, and 2% in 2008) like biodiesel to reach overall E.U. targets for biofuels, and (b) tax breaks (€73 million/year from budget allocation). The dispute with the European Commission has delayed the use of yearly fiscal incentives since 2005, thus limiting the development of major ethanol production. As with biodiesel, the approval and enactment of the new policy is expected to encourage the bioethanol sector, also thanks to the release of previously allocated resources.[59] In 2006, bioethanol production rose to 128 million liters, mostly produced from the distillation of wine surpluses and molasses. Actual domestic consumption, however, has remained virtually non-existent, with most of the production exported to France and Scandinavian countries, particularly Sweden. Three plants with a combined capacity of 100 million liters are being developed and expected to be operational by 2010.

In the near-term, therefore, Italy remains a net exporter of biofuels. When mandatory blending and incentive measures take effect, however, Italian domestic demand should increase considerably, although it seems unlikely that Italy will import biofuels or feedstocks in the near term.

Italy could nonetheless be a source of technology transfer and investments in Mozambique. In late March 2007, Italy's Eni SpA[60] and Brazil's state-run oil and gas company Petrobras signed a memorandum of understanding for joint biofuels development and oil refining. This strategic alliance will allow the two companies to share their technologies and know-how: Petrobras will have access to Eni's slurry technology (EST) for the processing of heavy oils into refined products, which will be useful in Brazil's upstream petroleum production, while Eni will benefit from Petrobras's biofuels experience. In particular, the two companies will combine biodiesel and ethanol technologies to develop joint international projects for biofuels production. The agreement also envisions collaboration in selling those products on

[58] Conversation with Mr. Luca Amatruda of Novaol.
[59] See Assodistil (National Association of alcohol distillers) website at http://www.assodistil.it/cenni_sul_bioetanolo.htm
[60] The Italian government has a 30% stake in Eni

the international market. Eni is considering several projects for biofuels in other countries. The Italian company plans to invest USD480 million in the construction of four biodiesel plants in Brazil, the production from which would be purchased by Eni, Petrobras, Europe Oil and First American Petroleum. Eni and Petrobras also plan to develop joint biofuel production projects in Africa to export biodiesel, and eventually ethanol, to Europe, in particular to Italy. The press mentioned Mozambique and Angola among the possible first options, particularly for biodiesel, given Eni's operations in place in those countries. Eni is currently conducting oil and gas exploration in Mozambique, and the existence of an agreement with the country for such conventional activities could in theory facilitate agreements for biofuels production in the future.[61]

European Union market - Summary

The European biofuels market is growing at very high paces as biodiesel and bioethanol producers build up capacity in response to evolving E.U. policies. A key driver is expected to be a new binding E.U. biofuels target to be adopted for 2020, which will likely set a mandate of 10% of all fuels for transport. It remains to be seen how the industry would respond to the setting of a binding target. Other uncertainties regard Europe's ability to establish effective rules for its biofuels market, implement an efficient system to verify compliance with standards (currently self-regulation by industry associations represents the main tool)[62], set higher renewable fuels standards (especially for biodiesel, currently at 5%), and strike a balance between protection of its biofuels industry and openness to necessary external resources.

Even taking into account all uncertainties, however, the analysis conducted above allows making a rough estimate and an overall assessment of the European ethanol and biodiesel market potential.

- *Ethanol*. Table 6 presents an overview of the E.U. ethanol market in 2006, and an estimated projection for a year in the period between 2010 and 2015. It is likely that the E.U. will need to import ethanol in quantities between 1.0 and 1.5 billion liters each year, and possibly more should a 10% binding target for biofuels in transportation be adopted for 2020. Stringent standards on ethanol's water content, however, are likely to increase the cost of getting ethanol on the European market. Increased domestic demand in Brazil may encourage the E.U. to resort to higher-cost ethanol imports from countries such as Mozambique.

[61] Source: conversation with Mr. Luigi Sampaolo of Eni, 6.15.2007. News of the agreement also available on the Eni Website at http://www.eni.it/eni/internal.do?RID=@2xSLG|0?xoidcmWopk&catId=-1073763205&cntTypeId=1008&portalId=0&lang=it, and in *Italy's Eni and Brazil's Petrobras sign accord on biofuels, refining petroleum*, Associated Press, 3.27.2007

[62] E.U. standards are established, but there is currently no E.U. body dedicated to verify their observance. Producing companies have been conducting tests, and declaring to be compliant. The first real sector-wide initiative with respect to E.U. biodiesel quality, for example, is a "self-regulating" one, undertaken only in December 2006 by the EBB itself by instituting a quality report twice a year 7: see details at http://www.ebb-E.U..org/EBBQR.php

However, as noted, tariff preferences enjoyed by Mozambique as a LDC under the EBA Regulation with respect to Brazil could be limited in their scope should E.U. negotiations with Mercosur for a free-trade area including fuel ethanol quotas succeed.

- *Biodiesel*. The E.U. biodiesel market is largely balanced, with production capacity strongly increasing and European net importers sourcing the fuel from net exporters. This trend will continue, and Europe's overall biodiesel production capacity is expected to cover projected demand well in advance of targets set by E.U. policy. Also, as noted, E.U. standards and testing requirements may limit the import of biodiesel produced from feedstocks other than those commonly used in Europe. There is therefore little potential to export finished biodiesel to Europe. There is, however, an interesting potential for a country like Mozambique to export raw vegetable oils to European biodiesel producers, provided that the issue of subsidized U.S. B99 imports is successfully resolved and the tax incentive is not renewed. According to the EBB, as noted, the market for imported crude vegetable oils could represent 20-30% of the biodiesel industry's demand (3.2-5.4

Table 6. European ethanol markets, 2006 and projected (2010-2015)

Ethanol 2006 (millions of liters)	Total Consumption	Total Production	Balance
Europe	1,725	1,514	(211)
United Kingdom	95	0	(95)
Germany	580	395	(185)
Portugal	0	0	0
Spain	220	396	176
Italy	0	128	128
Ethanol 2010-2015 (millions of liters)	**Projected Demand**	**Projected Production Capacity**	**Projected Balance**
Europe	12,000-13,000	10, 500-12,000	(1,000-1,500)
United Kingdom	1,200-1,700	1,000-1,500	(200)
Germany	1,200-2,000	1,400-2,000	0-200
Portugal	N.A.	18-20	N.A.
Spain	2,500-3,000	1,000-1,500	(1,500)
Italy	N.A.	250-300	N.A.

Sources: European Union of Ethanol Producers (UEPA), F.O. Licht
Note: The countries shown only represent a selection, and not the entirety of the E.U. market

billion liters). Table 7 provides an overview of current and projected E.U. biodiesel markets.

Asian markets

China. Biofuels represent an essential component of the Chinese Government's objective of a more diversified energy policy in support of its growing economy, particularly its booming automotive sector. The Government's desire to increase its consumption of

Table 7. European biodiesel markets, 2006 and projected (2010-2015)

Biodiesel 2006 (millions of liters)	Total Consumption	Total Production	Balance
Europe	5,750	5,750	0
United Kingdom	225	225	0
Germany	3,130	3,130	0
Portugal	107	107	0
Spain	116	116	0
Italy	525	525	0
Biodiesel 2010-2015 (millions of liters)	**Projected Demand**	**Projected Production Capacity**	**Projected Balance**
Europe	16,000-18,000	16,000-18,000	0
United Kingdom	1,100-2,000	800-1,000	(300-1,000)
Germany	4,000-5,000	5,900-6,000	1,000-2,000
Portugal	350-450	700-800	350
Spain	N.A.	400-500	N.A.
Italy	1,000-1,500	2,500-3,000	1,500

Sources: European Biodiesel Board (EBB)
Note: The countries shown only represent a selection, and not the entirety of the E.U. market

biofuels without affecting its food feedstocks is likely to lead to the creation of an attractive export market in China.

- *Ethanol*. China produces the largest volume of ethanol in Asia. In 2005, the country's total fuel ethanol production was 1.2 billion liters,[63]and in 2006 it grew to over 1.5 billion liters: 2007 production capacity is estimated to have surpassed 2 billion liters.[64] Exports in 2005 were approximately 162 million liters, shipped mainly to Japan, Taiwan and South Korea (mostly non-denatured, for alcohol production) , but according to the USDA in 2006 they jumped to over 1 billion liters, mostly due to higher international oil prices. In addition, some Chinese ethanol is shipped to Nigeria, where it is further refined for sale in Europe. Chinese ethanol imports have traditionally been minor, and China has remained a net ethanol exporter: total imports in 2006 amounted to just below 8 million liters only, over half being from China itself (Chinese ethanol production sent to tariff-free zones and re-imported), and the rest from a small group of countries including South Africa (1.2 million liters in 2006) and Japan (1.8 million liters).[65] Most ethanol is produced from grain (corn, cassava, rice), about 10% from sugar cane, 6% from paper pulp waste residue. The remainder is produced synthetically.

  In February 2006, China unveiled the "Law concerning testing for the extensive use of ethanol blended gasoline for automobiles and regulations concerning the conduct of testing for the extensive use of ethanol blended gasoline for automobiles," which instructed five provinces that together account for 16% of the country's vehicles, to

[63] IADB Garten Rothkopf Report on Biofuels, 2005.
[64] USDA Foreign Agricultural Service, China Biofuels 2007 GAIN Report, available online at http://www.fas.usda.gov/gainfiles/200706/146291348.pdf
[65] *Ibid.*

blend 10% ethanol with gasoline (E10). It also provided for the subsequent inclusion of 27 cities in another group of four provinces. In May 2006, the National Development and Reform Commission (NRDC) submitted a report to the government proposing that the E10 blend mandate be extended to three additional cities including Beijing and Shanghai. According to the NRDC, ethanol-blended gasoline now accounts for 20% of the country's total gasoline supply, with a total of almost 12 billion liters [10.2 million tons] of E10 blends produced in the country.

According to a GTZ study cited by the IADB Garten Rothkopf report on biofuels (2005), China has the potential to produce slightly more than 9.4 billion liters [8 million tons] of ethanol annually by 2020. This estimate is consistent with a target established by the NRDC, which calls for the replacement of 15% of fossil-fuel gasoline in the transportation sector, requiring an annual production of 11.8 billion to 14.1 billion liters [10 million to 12 million tons] of biofuels (both ethanol and biodiesel) by 2020. In 2006, the NRDC drafted a five-year plan according to which ethanol production by 2010 should reach about 6.2 billion liters (5.2 million tons) but, following a surge in commodity prices (grain in particular), the State Council did not approve it for food security concerns. No new target has been announced, but the Central Government has emphasized that any biofuels plan shall provide for ethanol feedstocks not to compete with food and to be grown on non-arable land. Industry sources have reported that a more realistic target for ethanol production in 2010 would be between 3.5 and 5 billion liters.[66]

A study conducted by the Tsinghua University also cited by the IADB Report forecasted that there may be 100 million vehicles consuming 228 million tons of gasoline and diesel in 2020; in this event, a nationwide 10% blend would result in a biofuels demand of almost 27 billion liters [22.8 million tons] between ethanol and biodiesel, creating a supply shortfall of approximately 15 billion liters [12.8 million tons] of ethanol in 2020.[67] Therefore, if a nationwide E10 standard were adopted, and given the Government's desire to avoid competition with its own food feedstocks, China could become a net ethanol importer.

- *Biodiesel*. China has adopted no standards for the use of biodiesel as a transportation fuel, and the biodiesel industry in China is consequently far less developed than the national ethanol industry. Production levels stood at 94 million liters [80,000 tons] in 2005 and, thanks to the construction of several new plants, current production is estimated at around 350 million liters (300,000 tons). Exports of biodiesel were estimated at just below 12 million liters (10,000 tons) for 2006, while no imports were reported.[68] Currently, biodiesel produced is of very low quality, making it unsuitable for transport fuel: it is mostly used as a solvent or as an additive to coal in thermal power plants and rural industrial cafeterias where coal is used for cooking. However, diesel is the primary fuel used in China (120 million tons in 2006,

[66] *Ibid*.
[67] IADB G.R., *op.cit.*
[68] IADB G.R., *cit.*

compared to 40 million tons of gasoline) and, according to Garten Rothkopf, the government's strong endorsement of biofuels make it very likely that biodiesel will be soon accepted for blending with fossil diesel and that a standard will soon be adopted: if a nationwide blending ratio of just 5% were adopted (even non-binding), demand for biodiesel could quickly rise at 6-7 billion liters (5-6 million tons) per year. The Chinese biodiesel industry is expected to take off within the next five years and may attain a production total in excess of 1.7 billion liters [1.5 million tons] by 2010. Production capacity could increase further if a nationwide standard were adopted. Given China's current high reliance on imported vegetable oils (in particular soybean), there would be potential to export crude oils to the Chinese market.

India. Biofuels will play an extremely important role in helping India meet its growing energy requirements, which are largely dependent on fossil fuels and involve imports of over 70% of the country's energy resources. In addition, India represents the world's fastest growing motor vehicle market after China. The government's strategy for biofuels aims to promote the use of ethanol for blending with gasoline, and the use of non-edible oils (especially from jatropha) for blending with diesel. The country's biofuels program is recent (and, in the case of biodiesel, still nascent), but it is expected to grow significantly in the coming years.

- *Ethanol*. India's ethanol blended program (EBP) started in 2003, with the mandating of a 5% blend of ethanol in nine states and four union territories. After an interruption in the program's implementation in 2004-2005 due to low sugarcane production, the 5% blending mandate is being gradually expanded to the rest of the country and all oil companies. Starting in October 2008, the Government intends to increase it to 10%.[69] Given projections of India's gasoline consumption, ethanol demand to comply with a 5% mandate is estimated at 650 million liters for 2006-2007 and 800 million liters for 2011-2012; a 10% ratio would require about 1.6 billion liters by 2011-2012.[70] India is the second largest producer of ethanol in Asia, and production is based on molasses rather than on sugar juice, making the country's yields stand at a sixth of Brazil's. In order to address rising fuel demand, however, the Government now intends to lift a ban on direct production of ethanol from sugarcane.[71] Given India's sugar consumption (the largest in the world) and the seasonal variations in sugarcane cultivation, the government is also supporting efforts to produce ethanol from other feedstocks, yet these are still at an experimental stage. Installed ethanol distillation capacity amounts to approximately 2.9 billion liters, although utilization rates are low (at about 1.7 billion liters). Ethanol for blending and potable ethanol (that represents a large amount of total production) share the same regulatory framework, limiting commercial viability of fuel ethanol. In 2006, only about 250

[69] According to Agriculture Minister Sharad Pawar. EP Overviews, 9.24.2007 www.epoverviews.com
[70] Government projections cited by UNCTAD, "An assessment of the biofuels industry in India", 2006, available at http://www.unctad.org/en/docs/ditcted20066_en.pdf
[71] EP Overviews, *cit.*

million liters of ethanol were used for blending with gasoline, compared with the 650 million needed to comply with the 5% target.[72]

Nominal current production capacity is adequate to cover estimated demand to comply with the 5% blending mandate (and even the initial phases of a 10% one), and the policy's objective is indeed that of supporting self-reliance, sourcing all ethanol nationally. The industry's response, however, may be slower than expected, and strong uncertainties are associated to the use of sugarcane and molasses as feedstock: volatility in production has been high, and reliability is consequently low. These considerations have led many analysts to predict that imports of ethanol (as well as of molasses from other Asian agro-industries) will be inevitable, and that actually there is the risk that India's efforts to reduce reliance from oil imports may entail increasing dependence on ethanol imports. Brazil's ethanol exports to India, for example, amounted to 9.5 million liters in 2002, and jumped to 450 million liters in 2004 when India's domestic production dropped.[73]

- *Biodiesel*. India is one of the few countries outside of Europe to have witnessed a significant increase in diesel engine penetration in transport. In 2005, 31% of all new vehicles sold in the country used diesel engine technology, and 80% of India's motor vehicle fuel is diesel: the potential for biodiesel is therefore very significant. The country's biodiesel industry, however, is largely still at an incubation stage. The government launched an ambitious National Biodiesel Mission in 2003, which eventually aims at providing 20% of the country's diesel requirements by 2020. Given India's demand for vegetable oil exceeds supply, it was decided to promote non-edible oil from jatropha as a feedstock. The program includes two phases: (i) a demonstration project (2003-2007), involving the development of high-yielding varieties of jatropha, the cultivation of 400,000 ha of land, tests on motor vehicles, and the construction of a transesterification plant by the government; (ii) a commercialization phase (2007-2012) that will expand cultivation, build additional plants and gradually increase blending requirements from 5% to 20%. A few commercial biodiesel plants are being installed, but the sector still faces a series of difficulties. Infrastructure for seed collection and oil extraction is insufficient; large-scale cultivation of jatropha has not yet begun, as farmers still see it as not rewarding enough and lacking adequate government support (as the establishment of a minimum price); and prices of other vegetable oils is too high to make biodiesel production from them economically feasible. The lack of adequate infrastructure and the unavailability of oilseeds discourage the establishment of further plants, and current production is still negligible (500 tons/year in 2006 at the most, according to the U.S. Department of Agriculture).

  According to India's planning commission estimate, projected biodiesel requirements for 2012 would amount to about 4, 8 or 16 billion liters corresponding to 5%, 10% and 20% blending ratios. The government has identified land for jatropha cultivation

[72] USDA, India Biofuels Annual 2007 GAIN Report, http://www.unctad.org/en/docs/ditcted20066_en.pdf
[73] UNCTAD, *op.cit.*, and IADB Garten Rothkopf,

in amounts that would be able to meet requirements. Unless the industry is set on a fast-growth track by large-scale jatropha cultivation and establishment of adequate infrastructure, however, 5% targets for 2011-2012 are unlikely to be met under current circumstances, let alone 20% targets: projections on possible production capacity are subject to significant uncertainties. Imports of biodiesel, oilseeds and vegetable oils could bridge the gap between demand and domestic supply while the industry consolidates.[74] The nascent biodiesel industry is lobbying the government to allow duty concessions on imports of vegetable oils.[75]

Japan. As the world's third largest oil consumer, Japan has also become one of the fastest growing consumers of biofuels. This is true despite the lack, until recently, of concrete government policies to encourage biofuels consumption. The country produces little ethanol and has consequently become a major importer. In May, 2006, Japan's Ministry of Economy, Trade and Industry (METI), the Ministry of Environment and the Ministry of Agriculture, Forestry and Fisheries (MAFF) introduced a new strategy to decrease fossil fuel dependency by 20% by 2030. The government's plan is to replace 500 million liters (oil equivalent) of fossil fuels with ethanol for the transportation sector by 2010.[76] To meet these goals, this year the government is likely to mandate, or otherwise create, incentives for ethanol blending from 3% to 10% by 2020. This follows a 2003 decision to allow up to 3% blending of ethanol (E3) , and ETBE blending up to 8% ethanol. In support of this, the Japanese Petroleum Association announced it would use 360 million liters of ethanol by 2010 to make an 8% ethanol ETBE blend.

In practice, only a small number of retail stations have offered E3 blended petrol. With respect to biodiesel, there are no standards but the government is considering establishing them, though no time frame has been given. Some observers argue that opposition from the influential oil lobby and other consumer goods manufacturers has slowed movement in the direction of compulsory blending requirements.

The government estimates that inclusive of all taxes, the cost of gasoline is roughly USD 1.02/liter [¥123.7/liter] versus imported ethanol at USD 1.23/liter [¥149.7 per liter]. Thus, imported ethanol costs roughly ¥26 more than petrol and ethanol blends are estimated to cost ¥0.6 more per liter than regular petrol.

There is little production of biofuels in Japan at present, but there are several project development activities under way. Although there is some passing interest in processing domestically used vegetable oil into biodiesel, no concerted effort to produce or import soybeans or other inputs to do this in a substantial way appears to be under consideration. Nippon Oil Corporation and Toyota Motor Corporation announced they have jointly developed a palm oil-based biodiesel product. Nippon Oil aims to develop commercially viable biodiesel by 2010. Annual production of biodiesel from used vegetable oil is

[74] UNCTAD, *op.cit.*
[75] USDA India GAIN Report, *cit.*
[76] Source: USDA, "Japan: Biofuels Production Report," 2006, available at http://www.fas.usda.gov/gainfiles/200605/146197881.pdf

estimated at almost 5.0 million liters,[77] though total potential for domestic production will be limited, due to the size of the agricultural sector in Japan. To adopt biofuels nationwide, Japan would need to import either the raw oils or the actual biofuels. To this end, Japan has begun imports of ethanol from Brazil, and is incorporating them into ETBE production. Total imports were 509 million liters, of which 359 are from Brazil.

- *Ethanol*. Japan produces no fuel ethanol, and the approximately 100 million liters in synthetic and fermentation ethanol it produces annually go largely to its industrial and beverage industries. This amount is supplemented by ethanol imports of 510 million liters [134.7 million gallons]. Japan has no import duty on denatured ethanol.[78] Only six gas stations in the country sell 3% ethanol-blended gasoline.

  According to the Japan Automobile Manufacturers Association (JAMA), there are 70 million automobiles in Japan with a combined annual consumption of 60 billion liters. If the 3% ethanol blend is implemented nationwide, demand for ethanol would reach an estimated 1.8 billion liters. If the blend is later extended to 10%, the annual ethanol requirement would hit 6 billion liters.

  Meanwhile, the Petroleum Association of Japan, which comprises 17 companies in the refining and oil marketing industries, has announced that gasoline blends containing 7% ETBE will be available for public consumption by 2010. This is expected to create domestic ethanol demand of 350 million to 400 million liters. Japan was scheduled to receive its first shipment of ETBE 7.5 million liters [1.9 million gallons] from France in early April 2007. Japanese refiners will look to import ETBE from Europe until they are equipped to produce their own.[79]

  Despite the absence of mandatory measures, Japan does promote a 3% blend of ethanol in gasoline. To encourage private sector involvement in the ethanol industry, the Agriculture Ministry has committed USD 71 million to constructing three ethanol plants with a combined annual capacity of 15 million liters. They are expected to use local crops such as rice, low-quality wheat, sugarbeet and sugarcane as feedstock. A separate proposal by the Hokkaido Prefectural Union of Agricultural Cooperatives calls for the construction of a 15-million liter-a-year ethanol plant in 2007. The Agriculture Ministry estimates that Japan has sufficient feedstock to produce 100 million liters of ethanol annually but has set a more modest target of 10 million liters by 2011. To reach this target, it plans to designate special biofuels districts starting in fiscal year 2007, where drivers will be encouraged to use gasoline with a 3% blend. The Ministry has also set aside USD 91.2 million to build related infrastructure such as biofuels-capable filling stations.

- *Biodiesel*. According to the Japanese Ministry of the Environment, Japan produced 5 million liters of biodiesel in 2005. The biofuel is mainly produced by municipal

[77] IADB R.G. report on biofuels, 2005.
[78] See http://www.fas.usda.gov/gainfiles/200604/146187342.pdf
[79] "Japan's PAJ to get its first 47,000-barrel ETBE cargo April 6," Platts, 4/4/2007.

governments and the feedstock is primarily waste oil. Because Japan is heavily dependent on imported vegetable oil, it has become a national practice to recycle waste oil, an amount equivalent to some 450,000 metric tons annually.

Although there is no legislation regulating biodiesel standards at present, the Agency for Natural Resources and Energy expects that legislation will be passed soon to allow sale of a 5% biodiesel blend. Experts hope this will help create standards and inspire consumer confidence. However, as with the ethanol law, it will not be mandatory and refiners will have a choice as to whether they wish to sell the biofuel. The government is also considering offering financial incentives to biodiesel producers.

Meanwhile, the Japanese Ministry of the Environment has set a target for increasing biodiesel production from the current 5 million liters, to between 10 million to 15 million liters annually by 2010. A substantial amount of waste cooking oil is still being discarded. Therefore, to secure additional waste oil for biodiesel feedstock, government policies are being drafted to encourage more efficient collection of waste cooking oil from households. To prompt grassroots involvement in biodiesel production, the government also has plans to construct five small-scale biodiesel plants.

- *Private investment*. Private sector involvement in the biofuels sector is led by the Petroleum Association of Japan (PAJ), in which oil companies are joined by other Japanese industrial giants like Nippon Steel. PAJ has announced the launch of a pilot plant to process the carbohydrates contained in food waste into sugar, which will then be fermented into ethanol and blended with gasoline to make E3. Studies have projected that 10 tons of such food waste, which will be collected from supermarkets, restaurants, schools and hospitals, can produce 397 liters a day of pure ethanol. Construction on the plant began in September, 2006, and the facility was slated to be operational by April, 2007.

  In addition, the country's largest refiner and auto manufacturer, Nippon Oil and Toyota Motors, announced in October, 2006, that they would commence a development study in 2007 to evaluate the possibility of producing palm oil-based biodiesel by 2009. The study will be undertaken jointly with the Malaysian national oil company Petronas. Under this arrangement, Petronas would provide the palm oil feedstock and Nippon Oil would develop refining technology to convert palm oil into biodiesel fit for transportation. Toyota would run tests to ensure the safety of palm oil-based biodiesel in auto engines.

  Toyota is joined by automaker Honda in developing engines suited to biofuels usage. In 2006, Honda unveiled flex-fuel versions of its Fit and Civic models, which are equipped with exhaust sensors able to detect automatically the fuel mixture in the tank, and capable of running on E20 to E100.

- *Relations with Brazil.* In February, 2005, the Japanese Bank for International Cooperation (JBIC) signed an agreement with Brazil's Ministry of Agriculture, Livestock and [Food] Supply (Ministerio da Agricultura, Pecuária e Abastecimento) stating terms of reference for the future implementation of a bilateral biofuels program to export Brazilian ethanol and biodiesel to Japan. This was followed by the establishment of the Brazil-Japan Working Group on Biomass to share information and explore possible opportunities for bilateral cooperation.

  In May, 2005, following a visit to Brazil by then Japanese Prime Minister Koizumi, Japanese companies committed to invest up to USD 2 billion in the Brazilian ethanol sector. JBIC was the chief Japanese partner in agreements with Petrobras, the National Bank for Economic and Social Development (BNDES), the Ministry of Science and Technology and steel and mining conglomerate CVRD. The deal with BNDES resulted in more than USD 500 million in JBIC loans for CDM projects under the Kyoto Protocol. Japanese investment is expected to finance the installation of new refineries, increase the area under sugarcane cultivation, and modernize infrastructure necessary for transporting ethanol.

  With the passage of legislation in 2003 allowing for the blend of 3% ethanol in transportation gasoline, Brazilian ethanol companies became optimistic that ethanol trade with Japan would increase dramatically, eventually reach 6 billion liters annually. In 2005, Japan imported 510 million liters of ethanol, more than 80% of which came from Brazil; as noted, these imports were intended for the chemicals and beverage industries.

  The expectation of increasing exports to Japan has led to the creation of the Brazil-Japan Ethanol Company, a joint venture between Petrobras and Nippon Alcohol Hanbai, which will operate in Japan and import and market up to 20 million liters of sugarcane-based ethanol from Brazil by 2008. Other Japan-Brazil commercial arrangements include an agreement between Petrobras, CVRD and Mitsui to study ethanol logistics in Brazil.

In conclusion, Japan's limited domestic feedstock availability, combined with an increasing interest in biofuels even in the absence of mandatory blending requirements, are likely to make the country a major importer of fuel ethanol. Amounts that will actually be imported, however, are still uncertain: at the very least, a non-mandatory E3 blend will create a demand of 400-500 million liters, while nationwide mandatory blends of 3% or 10% could increase ethanol requirements to 1.8 billion liters (E3) or 6 billion liters (E10). Still, oil companies' influence in the country may resist the imposition of higher blending requirements. Future policy developments are unclear, given the recent political transition in Japan. Former Prime Minister Abe publicly backed the biofuels initiative and called on the agriculture minister to ensure that 10% of national gasoline demand is substituted with biofuels, but it remains to be seen whether his successor will continue to provide similar support.[80]

[80] IADB G.R. Report, *cit.*

Asian markets - Summary

Asian markets considered in the analysis above include two of the world's fastest-growing economies (China and India, which also happen to have the world's fastest-growing automotive markets), as well as a highly industrialized country like Japan that is proving supportive of biofuels despite its lack of domestic-grown feedstocks. Although some uncertainties remain, the overall potential for export to these markets is therefore high, and can be detailed for ethanol and biodiesel as follows.

- *Ethanol*. As implementation of fuels standards expands, China is likely to turn from a net ethanol exporter to a major importer, particularly given the government's desire to avoid all competition with its own food feedstocks. India's nominal distilling capacity is adequate to cover even an increased E10 standard, but the volatility of its sugar industry may open the way to the need for imports; in addition, it is unclear whether the recent measure allowing production from sugarcane and not just from molasses will have an immediate impact, given India's high consumption of sugar and the changes that producers would need to make in their infrastructure. Japan's lack of feedstocks and commitment to biofuels will certainly make it an interesting ethanol export market, although the actual size of it will depend on whether binding blending requirements are imposed, and to what degree. Table 8 provides an overview of current Asian ethanol markets, and an estimate of their projected size.

Table 8. Asian ethanol markets, 2006 and projected (2010-2015)

Ethanol 2006 (millions of liters)	**Total Consumption**	**Total Production**	**Balance**
Asia	1,180	1,790	610
China	530	1,540	1,010
India	650	250	(400)
Japan	0	0	0
Ethanol 2010-2015 (millions of liters)	**Projected Demand**	**Projected Production Capacity**	**Projected Balance**
Asia	13,600-19,500	8,000-10,000	(5,600-9,500)
China	10,000-15,000	5,000-7,000	(5,000-8,000)
India	1,600-2,000	2,900-3,000	1,000-1,300
Japan	2,000-2,500	13-14	(1,950-2,450)

Sources: For China, IADB/Garten Rothkopf, USDA. For India, UNCTAD, USDA, IADB/Garten Rothkopf. For Japan, IADB/Garten Rothkopf

- *Biodiesel*. In China, no standards for biodiesel have yet been mandated, but given diesel is the country's primary fuel (its consumption is threefold larger than gasoline's), a 5% blend could create a market of about 7 billion liters per year that projected production capacity could cover only in part. India's diesel consumption is equally important, and its biodiesel program has set highly ambitious targets before the conditions to attain them (the viability of large-scale jatropha cultivation, in particular) are established. The potential to export raw material or finished fuel to India also seems interesting. Overall, Asian biodiesel markets' potential seem highly promising, but it is subject to greater policy uncertainties than ethanol's. Table 9 provides an overview of current Asian biodiesel markets, and an estimate of their projected size.

North American markets

United States. The cornerstone U.S. Federal policy document addressing biofuels is the Energy Policy Act (EPAct) of 2005, which includes provisions to promote renewable energy use in electric generation as well as the expansion of production of renewable fuels, in particular – given diesel's secondary importance in the U.S. transport market – ethanol. The comprehensive energy legislation included in the nationwide renewable fuels standard (RFS) is intended to double the use of renewable fuels in the U.S. by 2012. However, the recent combination of high oil prices, blender tax credits, import tariffs, elimination of MTBE as a gasoline additive, and State programs fueled a rapid expansion in biofuel production capacity that has now provoked an oversupply of fuel in producing areas, sparking concerns of a crash. These factors are discussed more in detail below.

Table 9. Asian biodiesel markets, 2005 and projected (2010-2015)

Biodiesel 2006 (millions of liters)	**Total Consumption**	**Total Production**	**Balance**
Asia	339	355	17
China	338	350	12
India	0.58	0.58	0
Japan	0	4.9	4.9
Biodiesel 2010-2015 (millions of liters)	**Projected Demand**	**Projected Production Capacity**	**Projected Balance**
Asia	10,000-15,000	5,700-10,000	(4,300-5,000)
China	6,000-7,000	1,700-2,000	(4,300-5,000)
India	4,000-8,000	4,000-8,000	(0-4,000)
Japan	10-20	10-15	(0-5)

Sources: For China, IADB/Garten Rothkopf, USDA. For India, UNCTAD, USDA, IADB/Garten Rothkopf. For Japan, IADB/Garten Rothkopf

The Federal RFS Program, which went into effect on September 1, 2007, includes the following provisions: (i) establishment of an RFS that starts at 15.1 billion liters [4 billion gallons] of renewable fuels in 2006 and increases to 28.4 billion liters [7.5 billion gallons] by 2012. The RFS also counts each gallon of cellulosic ethanol as 2.5 gallons towards meeting the standards listed above; (ii) provisions for 2.78% by volume renewable fuel use in 2006, if federal regulations have not yet been promulgated by the U.S. Environmental Protection Agency (EPA); (iii) a requirement that a minimum of 946 million liters [250 million gallons] a year of cellulosic derived ethanol be included in the RFS beginning in 2013, at which point the 2.5-to-1 incentive for cellulosic ethanol is eliminated; (iv) compliance flexibility through the creation of a credit trading program allowing refiners to use renewable fuels where and when it is most efficient and cost-effective for them to do so, with a 12-month lifespan for the RFS credits; (v) exemption of small refineries from the RFS program until January 1, 2011, though they may opt into the program and generate credits as do other refineries; (vi) requirement of annual studies on seasonal variations in renewable fuel use and the stipulation that at least 25% of the annual renewable fuel obligation be met in each season, should seasonal variations exist (California is exempted from this rule); (vii) a sunset provision for the reformulated gasoline (RFG) 2.0 wt. % oxygenate standard under the Clean Air Act, 270 days after enactment; and (viii) grant and loan programs for cellulose ethanol, as well as for ethanol production from sugar, including a USD 36-million loan program to convert sugarcane to ethanol in Hawaii, Louisiana, Florida and Texas, a USD 250-million loan guarantee program for sugar-to-ethanol facilities, and a USD 50-million loan guarantee program for sugarcane-to-ethanol facilities.

On June 22, 2007, the U.S. Senate approved legislation proposed by the Energy and Natural Resources Committee calling for 136 billion liters [36 billion gallons] of renewable fuel use by 2022 and authorizing loan guarantees and other incentives for ethanol research and plant construction. If ultimately passed by the U.S. Congress, the

Table 10: Renewable Fuels Standards in Place, by U.S. State

State	Requirement	Date of Compliance
Colorado	All state-owned diesel vehicles and equipment must be fueled with B20. Policy is negated if the blend of 20% biodiesel/80% diesel is USD 0.10 more per gallon than the price of conventional diesel.	2007
Hawaii	At least 85% of gasoline sold must contain 10% ethanol by volume (E10).	2008
Iowa	Equivalent of 25% of gasoline sales must come from renewable sources (either 10% or 85% ethanol blends (E10, E85), or biofuel that is 1% biodiesel by volume (B1) at a minimum.	2020
Louisiana	Total motor gasoline sales must contain 2% ethanol by volume (E2). Total diesel sales must contain 2% biodiesel by volume.	2015 or 6 mos. after in-state production reaches 50 mgy ethanol and 10 mgy biodiesel
Maryland	Half the state fleet normally fueled by diesel must be powered using a blend of at least B5.	2008
Minnesota	Total motor gasoline sales must contain 20% ethanol by volume (E20). Total diesel sales must contain 2% biodiesel by volume (B2).	2013
Missouri	Total non-premium motor gasoline sales must contain 10% ethanol by volume (E10).	2008
Montana	Total non-premium motor gasoline sales must contain 10% ethanol by volume (E10).	3 months after in-state production of ethanol reaches 40 million gallons per year.
Ohio	State owned or leased vehicles shall use at least 60,000 gallons of E85 per year by January 1, 2007, with an increase of 5,000 gallons per year thereafter; and at least 1 million gallons of biodiesel per year by January 1, 2007, with an increase of 100,000 gallons per year thereafter.	2007 and beyond
Washington	Total motor gasoline sales must contain 2% ethanol by volume (E2). Equivalent of 2% of diesel sales must be biodiesel.	2008

Source: Brown, E. K. Cory and D. Arent. "Understanding and Informing the Policy Environment: State-Level Renewable Fuels Standards." National Renewable Energy Laboratory (NREL), January 2007.

measure would essentially establish an overarching goal of reducing future gasoline use by as much as 45% below what it is otherwise expected to be in 2030. This would happen through a combination of more biofuels, such as ethanol, production of more gas-electric hybrid vehicles, and other fuel-saving measures. U.S. production of cellulosic ethanol would receive a dramatic boost under the new bill, which represents a major commitment to the future of the technology. Beginning in 2016, the legislation dictates that a growing percentage of the RFS requirement be met with cellulosic ethanol, resulting in at least 79.5 billion liters [21 billion gallons] of cellulosic ethanol usage by 2022. The bill provides that the maximum amount of corn-based ethanol counted towards the RFS requirement cannot be more than 56.8 billion liters [15 billion gallons per year].[81]

As of late 2007, the U.S. ethanol sector is undergoing a phase of excess production with subsequent drop in ethanol fuel prices in producing areas of the country (Midwest): distribution infrastructure has not kept pace with ever increasing production capacity, with severe bottlenecks in the transport of the fuel from the inland to the coasts where demand is concentrated. There are therefore strong expectations on the part of the industry for continued and increased Federal Government support.[82]

At the state level, there have been a large number of initiatives that have impacted the demand for renewable fuels. Table 10 shows a summary of state-enacted renewable fuel policies as of December 2006. In addition to the ten states cited above that have already implemented RFS, 17 states are examining or are considering implementing their own RFS policies.

- *Fuel Consumption Trends.* In 2005, consumption of fuels in the U.S. reached about 687 billion liters [11.8 million barrels per day (b/d)], broken down into approximately 524 billion liters [9 million b/d] of gasoline, and 163 billion liters [2.8 million b/d] of diesel.[83] The transportation sector was the largest consumer of energy (40%), followed by the residential and commercial sectors (29%) and industry (19%). According to a short-term energy outlook on energy consumption released by the Energy Information Administration (EIA) in June 2007, total petroleum consumption in the U.S. grew 1.9% between the first quarters of 2006 and 2007. By 2008, total petroleum consumption growth is expected to slow to 1.1%. In both years (2007 and 2008), motor gasoline consumption is projected to increase by an average of approximately 1.1% per year.[84]

- *Current and projected ethanol production and consumption.* Consumption of ethanol has increased dramatically, driven in part by the phase-out of MTBE as a fuel

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[81] RFA and Office of Senator Jeff Sessions, Alabama, May 2007.
[82] *New York Times*, "Ethanol's boom stalling as glut depresses prices", September 30, 2007; and *Wall Street Journal*, "Ethanol Boom Runs Out of Gas", October 12, 2007
[83] http://www.eia.doe.gov/emeu/aer/txt/ptb0513c.html
[84] EIA Short Term Energy Outlook, June 12, 2007. (http://www.eia.doe.gov/emeu/steo/pub/contents.html)

oxygenate, and as a result there has been a boom in ethanol production in the country, based almost exclusively on corn as a feedstock. As of April 2007, the U.S. counts a total of 115 ethanol plants in 26 states, with 86 plants being built or expanded. Some 49, or about 43%, of these plants are farmer-owned. Domestic ethanol production had grown to 18.3 billion liters [4.8 billion gallons] per year, as of December 2006, up from 12.9 billion liters [3.4 billion gallons] in 2004. The two-year average growth is 2.4 billion liters [634 million gallons] per year. In January 2007 alone, 1.1 billion liters [488 million gallons] of ethanol were produced. According to the American Council on Renewable Energy, ethanol production capacity could reach over 45.5 billion liters [12 billion gallons] by 2010, but this estimate seems overly optimistic.[85] A more conservative estimate, also taking into account current excess production issues, would assume production to increase at rates observed over the past few years but excluding 2007: in this case, ethanol production capacity could reach 27 billion liters by 2010. In 2005, ethanol made up approximately 3% of the 530 billion liters [140 billion gallons] of gasoline consumed annually, with consumption levels reaching over 20 billion liters [5.3 billion gallons] in 2006. About 30% of all gasoline in the U.S. is blended with ethanol to produce E10.[86]

- As noted, the ban on MTBE use and several provisions under the Clean Air Act are creating new markets for ethanol, and state standards have been largely responsible for driving demand upward. By 2005, 20 states had enacted bans of MTBE, and an additional nine states were proposing such bans. For those states where MTBE has been banned and the use of reformulated gasoline (RFG) is required, ethanol often represents the most cost-efficient alternative to MTBE. In addition, many refiners are expected to use ethanol to replace the lost octane and volume associated with the phase out of MTBE. State bans on MTBE that went into effect in 2004 for California, New York and Connecticut (where approximately one third of all RFG is sold) , increased the sale of ethanol in those states to 3.8 billion liters [1 billion gallons] between 2002 and 2004.[87] The development of regulatory markets throughout the U.S. is expected to create an additional demand in the near term of 5.7 billion liters [1.5 billion gallons] of ethanol, 2.6 billion liters [686.8 million gallons] of which are expected to come from the state of California alone.[88] Based on current demand (over 20 billion liters) and projected additional demand, U.S. ethanol demand may be estimated to reach about 28 billion liters by 2010.

- *Ethanol Tax Treatment.* U.S. gasoline blenders and refiners that incorporate ethanol into automotive fuel receive a USD 0.51 tax credit, equivalent to a 5.1¢ credit on a gallon of E10 blended gasoline. This is referred to as the Blender's Tax Credit, valid until 2010. The tax credit goes to the petroleum industry as an incentive to blend

[85] ACORE, *The Outlook on Renewable Energy in America*, March 2007, www.acore.org
[86] Renewable Fuels Association (RFA), industry statistics, April 2007.
[87] "Regulation of Fuels and Fuel Additives: Renewable Fuels Standard Requirements for 2006." Federal Register: December 30,2005 (Volume 70, Number 250). (Available online at http://www.epa.gov/fedrgstr/EPA-AIR/2005/December/Day-30/a24611.htm)
[88] American Coalition for Ethanol, "The U.S. Ethanol Industry: Exceeding Expectations." Presentation given by Brian Jennings, EVP at South Dakota PUC Energy Conference, April 20,2005.

ethanol into gasoline. In 2004, a total of USD 1.7 billion was passed on to consumers through lower prices for E10 gasoline. Table 11 below provides a summary of the tax provisions applicable to renewable fuels in the U.S.

- *Ethanol Imports and Import Tariffs.* Total U.S. ethanol imports in 2006 reached 2.5 billion liters [653 million gallons]. As of June 2007, the U.S. imported 850 million liters [223.5 million gallons] of ethanol. According to the U.S. International Trade Commission and the Renewable Fuels Association (RFA, the U.S. ethanol industry association), the majority of fuel ethanol imports to the U.S came from Brazil (67%) in 2006. The balance of imports during that year came from the following countries: Costa Rica (5.5%), El Salvador (5.9%), Jamaica (10.2%), and Trinidad & Tobago (3.8%). Imports of ethanol from Brazil grew from 118.1 million liters [31.2 million

Table 11: U.S. Federal Incentives for Biofuel Production

Instrument	Target Industry	Provisions
Volumetric Ethanol Excise Tax Credit (VEETC)	Ethanol	• 51¢ per gallon on production of ethanol.
Volumetric Excise Tax Credit (VEETC)	Agri-Biodiesel, Biodiesel, Renewable Diesel[1]	• Agri-Biodiesel: USD 1.00 per gallon. • Biodiesel from recycled vegetable oil and recycled animal fats: 50¢ per gallon. • Renewable Diesel: USD 1.00 per gallon. • Credit expires December 31,2008.
Tax Credit	Alcohol mixtures not containing ethanol (includes ETBE)	• 60¢ per gallon on production of all alcohol mixtures not containing ethanol, and alcohol-equivalent gallons of ETBE and other ethers produced from qualifying alcohols.
Size Limitation & Small Producer Credit (revised)	Small Ethanol Producers	• Size limitation for ethanol plants eligible for tax credit increased to 60 million gallons. • Production tax credit of 10¢ per gallon on up to 15 million gallons of production annually. • Tax credit capped at USD 1.5 million per year per producer. • Effective through December 31, 2008.
Size Limitation & Small Producer Credit (new)	Small Biodiesel Producers	• Eligible agri-biodiesel plants can have annual capacity of 60 million gallons or less. • Production tax credit of 10¢/gallon on the first 15 million gallons of production annually. • Tax credit capped at USD 1.5 million per year per producer. • Effective through December 31, 2008.
Income Tax Credit	E85 and B20 Infrastructure	• Taxpayers can claim a 30% credit for the cost of installing a clean-fuel vehicle refueling property, on up to USD 30,000. • Credit also applies to the taxpayer who sold the infrastructure property to the tax-exempt entity. • Property must be placed in service before January 1, 2008

[1] Renewable diesel means diesel derived from biomass during thermal depolymerization process.
Source: Renewable Fuels Association (RFA), 2007.

gallons] in 2005, to 1.6 billion liters [433.7 million gallons] in 2006. Total imports during the same year amounted to approximately 12% of total ethanol consumption in the U.S.[89] The U.S. exported a total of 30 million liters [7.9 million gallons] of ethanol in 2005. The RFA reports no exports in previous years or in 2006. Due to the fact that the tax incentive granted to ethanol-blended gasoline does not recognize point of origin, the U.S. applies a USD 0.14/liter [USD 0.54/gallon] tariff on most imported ethanol to offset this exemption and protect local producers. However, a limited amount of ethanol may be imported into the U.S. duty-free under the Caribbean Basin Initiative (CBI), even if most of the steps in the production process were completed in other countries.

As part of the CBI, duty-free status is granted to a large array of products from beneficiary countries, including fuel ethanol under certain conditions. Ethanol may be imported into the U.S. duty-free, provided that fuel ethanol is produced from at least 50% local feedstock (such as ethanol produced from sugarcane grown in CBI beneficiary countries). If the local feedstock content is lower, limitations apply on the quantity of duty-free ethanol. Nevertheless, up to 7% of the U.S. ethanol market may be supplied duty-free by CBI ethanol containing no local feedstock. In this case, hydrous ethanol produced in other countries (historically Brazil or E.U. countries) can be shipped to a dehydration plant in a CBI country for reprocessing. After the fuel is dehydrated, it is imported duty-free into the U.S.[90] The cap for imports of dehydrated ethanol under the CBI is approximately 142.3 million liters [37.6 million gallons], or 7% of total U.S. market demand of 20 billion liters [5.3 billion gallons] in 2006. Given the rate of growth in U.S. ethanol production and consumption, each 40-million-gallon-a-year plant on which construction commences in the U.S. opens the door for an additional 10.6 million liters [2.8 million gallons] of imported ethanol to enter the U.S. through the CBI.[91] Industry experts maintain that the proportionality of CBI imports in comparison to U.S. consumption will stay relatively fixed over time, as long as the 7% clause remains intact. Currently, dehydration plants are operating in Jamaica, Costa Rica and El Salvador. These countries were the largest exporters of fuel ethanol to the U.S. after Brazil, exporting a total of 534.5 million liters [141.2 million gallons] in 2006.[92]

Beyond CBI ethanol imports, additional opportunities exist for tariff-free ethanol imports into the U.S. under NAFTA and the Andean Trade Preferences Pact. Under NAFTA, both Canada and Mexico can avoid U.S. tariffs. Aside from a small number of shipments to the Northwest United States, Canada has sent very limited amounts of ethanol south. Mexican ethanol production has been under evaluation for some time and, after the approval in April 2007 of a biofuels promotion law,[93] several projects are recently being considered or under development there.

[89] RFA Statistics, April 2007.
[90] "Ethanol Imports and the Caribbean Basin Initiative." CRS Report for Congress, January 6, 2005.
[91] Bryan, Tom. "Entering Tariff-Free." *Ethanol Producer Magazine*, January 2004.
[92] RFA, 2007.
[93] http://news.bbc.co.uk/hi/spanish/latin_america/newsid_6598000/6598305.stm

Under the Andean Trade Preferences Pact, Peru, Bolivia, Colombia, Venezuela and Ecuador could also avoid the U.S. ethanol duty; the pact grants preferential status in exchange for efforts to fight narcotics trafficking in those countries.

Other countries that may be eligible for tariff-free importation of ethanol into the U.S. include what are referred to as "Least Developed Countries," a group of 49 African, Asian and South Pacific nations that includes Mozambique[94]. Programs falling under this category include the U.S. GSP Program and the African Growth and Opportunity Act (AGOA), passed in 2000. Ethanol is an AGOA-eligible product.[95]

- *U.S. Biodiesel*. While the U.S. biodiesel industry is not comparable to ethanol's, a small but rapidly growing biodiesel market is under development, supported by the RFS Program (biodiesel is an eligible renewable fuel under the Program; also, several U.S. government fleet vehicles now run on B20), and tax credits. The Volumetric Ethanol Excise Tax Credit (VEETC, or "Blender's Tax Credit") described for ethanol (due to expire in 2010) is accompanied by a similar measure (due to expire in 2008) that grants a USD 1/gallon tax credit of biodiesel blended into mineral diesel, or USD 0.50 for biodiesel made from recycled vegetable oil and animal fats (see Table 11). Production has been growing at a very high pace over the past few years, reaching 946.5 million liters [250 million gallons] in 2006, a tenfold increase from 2004 (94 million liters or 25 million gallons).[96] There is currently excess production capacity of biodiesel in the U.S.: the National Biodiesel Board estimates production capacity as of September 2007 to stand at 7 billion liters [1.85 billion gallons]. Eighty companies have reported that additional plants are under construction and are scheduled to be completed by mid-2009, and four other existing plants are undergoing expansion: these developments will add 5.2 billion liters [1.37 billion gallons] of capacity by 2009, when total production capacity would therefore reach about 12 billion liters.[97] The U.S. Department of Agriculture foresees that production capacity will then grow at a negligible pace, mostly due to increases in soybean prices reducing profitability and to the end of tax credits, and level off after 2011.[98] No data on domestic consumption or exports for 2006 are available at the NBB or the U.S. Energy Information Administration (EIA); one estimate is that biodiesel consumption represents 0.5% (equivalent to about 820 million liters) of the U.S. diesel market.[99] The NBB estimates that biodiesel could displace 5% of the diesel fuel market by 2015

[94] http://www.un.org/special-rep/ohrlls/ldc/list.htm

[95] Mozambique is an AGOA-eligible country. A very large proportion of Mozambique's exports to the US in 2002 consisted of 'agricultural products', most of which were exported under the provisions of AGOA. Mozambique's imports consist predominately of agricultural exports, which increased fourfold in the 2001-2002 period.

[96] National Biodiesel Board, http://www.biodiesel.org/pdf_files/fuelfactsheets/Biodiesel_Sales_Graph.pdf. The NBB confirmed the figure refers to actual production, even if the graph title refers to sales.

[97] NBB estimate, available at http://www.biodiesel.org/pdf_files/fuelfactsheets/Production_Capacity.pdf

[98] USDA biofuels overview, at http://www.ers.usda.gov/Briefing/Baseline/crops.htm

[99] http://www.biofuelreview.com/content/view/465/2/

(corresponding to about 6.5 billion liters, considering EIA projections for U.S. diesel consumption for 2015).[100]

The primary feedstock for U.S. biodiesel is soybean, making it an ideal candidate for the E.U. market: as noted, according to the European Biodiesel Board, the U.S. is exporting as much as 120 million liters [100,000 tons] of B99 each month to Europe , an increase from 35 million liters [30,000 tons] in October 2006 when the phenomenon began, what could bring U.S. exports of B99 to the E.U. to 1 billion liters by the end of 2007 if a linear growth in exports is assumed. The NBB did not confirm this estimate, but deems this phenomenon an abuse of the tax credit and does not support it.[101]

Canada. In December 2006, the Canadian government acted to implement a regulation that will require a 5% renewable content in gasoline by the end of 2010, and a 2% renewable content in diesel and home heating fuel no later than 2012.[102] The political mandate for ethanol will create a demand of about 2.2 billion liters by 2010.[103] These levels could potentially be largely supplied domestically, due to Canada's large wheat surplus. According to the Canadian Renewable Fuels Association, ethanol production capacity as of October 2007 amounts to 715 million liters, with additional 880 million liters currently under construction: about two-thirds of this total 1.6 billion liters capacity will be corn-based, and one third wheat-based. Iogen Corp. also maintains a trial plant for producing ethanol from cellulose in Ottawa with encouraging results, and currently processes wheat straw and corn stalk into approximately 1 million liters [264,000 gallons] of ethanol each year. In addition, C$100 million will be invested to assist in the construction of new ethanol plants under the Climate Change Plan for Canada, in order to meet a target mandating that 35% of Canadian gasoline supply contain 10% ethanol (E10) by 2010.[104] Support is also provided through programs such as the Ethanol Expansion Program and the Future Fuels Initiative, which makes C$118 million available to support the construction of eleven grain based ethanol plants

- *Fuel Consumption Trends.* Consumption of motor fuels – gasoline and diesel – has increased approximately 9% from 2001 to 2005. Net sales of gasoline in Canada rose from 36.3 billion liters [9.6 billion gallons] in 2001 to 38.06 billion liters [10.2 billion gallons] in 2005. For diesel, sales rose from 13.2 billion liters [3.5 billion gallons] to 16.3 billion liters [4.3 billion gallons] over the same period.[105]

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[100] NBB estimate (http://www.icis.com/Articles/2007/02/12/4500682/biodiesel-boom-or-bust.html), also reported by ACORE, "Outlook on Renewable Energy in America", 2007. EIA projections of fuel consumptions available at http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html
[101] Conversation with Andrew Brandt of the NBB, September 28, 2007
[102] Canadian Renewable Fuels Association, 12/20/2006.
[103] Canadian Renewable Fuels Association, www.greenfuels.org/ethfaq.php?id=2. Conversation with Robin Speer of the RFA, 10.1.2007
[104] Okanagan Biofuels Business Plan, October 2006.
[105] Statistics Canada, February 2007.

- *Ethanol production and consumption*. Canada plays a relatively minor role in the international ethanol market, although the sector is growing under the policy framework recently enacted. Production using locally grown cereals grew from 250 million liters in 2004 to about 550 million liters in 2006,[106] and is expected to reach 1 billion liters in 2007 and 2.2 billion liters in 2010.[107] Current consumption levels amount to about 750 million liters, and are expected to grow steadily as the blending mandate is fully implemented.

- *Ethanol Tax Treatment.* The main support instrument for fuel ethanol in Canada is a federal tax exemption for the ethanol portion of blended fuel, amounting to C$ 0.10 per liter.[108] Many provinces also offer exemption on their gasoline excise taxes, and individual policies over fuel ethanol are largely driven by the needs of individual provincial economies. Manitoba provides the greatest such exemption, at C$0.25

Table 12: Tax Exemptions for Fuel Ethanol per Province

Province	Provincial Fuel Tax Exemptions for Ethanol (C¢/liter)	Eligibility for the Subsidy	Duration
Alberta	9	No restriction on ethanol source	5 years after the start-up of an ethanol production plant
British Columbia	14.5	For E85 to E100 and E5 to E25. Ethanol must be produced in BC.	
Ontario	14.7	No restriction on ethanol source.	Until 2010.
Saskatchewan	15	Ethanol must be produced and consumed in SK.	5 years
Quebec (under proposal)	Up to 20 (up to 130% of the 15.2¢/l gasoline tax)	Ethanol must be produced in QC.	1999-2012
Manitoba	C¢20, until August 2007 C¢15, 09/2007-08/2010 C¢10, 09/2010-08/2013 (in addition, C¢1.5/l excise tax reduction for the gasoline blended with 10% Manitoba-made ethanol)	Ethanol must be produced and consumed in MB.	No duration specification.

Source: Université Laval, Faculté des sciences de l'agriculture et de l'alimentation. August 2004.

[106] World Watch Institute, "Biofuels for transport", *cit.*
[107] Canadian RFA
[108] *Study of the Outlook for the E.U./World Bioethanol Market for Société Générale*.

per liter of ethanol produced and consumed in the province. Table 12 shows the provincial fuel tax exemptions for fuel ethanol.

- *Imports and Import Tariffs.* Canada imported 200 million liters of ethanol in 2006, but expects imports to decrease as production capacity expands; the RFA expects the Canadian ethanol market to be largely balanced by the 2010-2015 period. Over 95% of ethanol imports in Canada come from the U.S., while only 30% of Canadian fuel ethanol exports went to the U.S. The Commonwealth of Independent States (CIS) has recently become a major export destination for ethanol from Canada. Exports in that year amounted to approximately 35.6 million liters [9.4 million gallons], with the main destination being the U.S.

  To date no tariffs have been applied to ethanol trade between the U.S. and Canada. It is possible, however, that preferential legislation similar to British Columbia's, as well as that proposed by Sasketchewan and Quebec, could be ruled anti-NAFTA. While Canadian provinces have no recourse to the barriers set by other provinces, restrictive legislation affecting U.S.-Canada ethanol trade could be affected by NAFTA rulings. Canada maintains an import duty on denatured ethanol equivalent to C$0.0554/liter [C$0.21/gallon].[109]

- *Biodiesel*. Canada's small biodiesel industry produced only 9 million liters in 2005, but production in 2006 grew to almost 70 million liters. Although precise data is not available for imports, consumption levels were comparable to actual production. The Canadian Renewable Fuels Association reports a production capacity of 97 million liters for 2007. Unlike the mandate for ethanol, the 2% biodiesel blending requirement for diesel fuels is still only a general target: the RFA reports strong expectations, however, that this will very soon become binding, and that the deadline may even be anticipated from 2012 to 2010. This will create a demand of 500 million liters of biodiesel per year by 2012 at the latest, which the Canadian industry is expected to ultimately cover, although a small component of imports may be needed as the industry completes the build-up of its production capacity.[110]

North American markets – Summary. A summary of the U.S. and Canadian markets is presented below. Table 13 and Table 14 provide an overview of current and projected figures for ethanol and biodiesel.

- *Ethanol*. The U.S. market for ethanol between 2010 and 2015 seems likely to be largely balanced. As of end 2007, as noted above, the U.S. ethanol market is actually experiencing oversupply: production has increased sharply since mid-2006, outstripping demand and leading to a 30% drop in prices over the past five months (from over USD 2.00 a gallon in May to just over USD 1.50 a gallon in September). The price of corn, conversely, is steadily rising again towards USD 4 per bushel after

[109] "Agricultural Situation: Import Duties for Biofuels 2006." U.S. Department of Agriculture Foreign Agricultural Service GAIN Report, 4/6/2006.
[110] Conversation with Robin Speer of the RFA, 10.1.2007

a temporary drop in June 2007. The problematic situation is also linked to logistics difficulties in transporting ethanol from the heartland, where production is mostly based, to the coasts, where the fuel is most needed; distribution infrastructure has not kept pace with the surge in production. Several industry experts deem these issues to be temporary, as government support is revived and increased by new legislation and as infrastructure improves. The sector’s dependence on the U.S. Federal Government’s political support, however, remains critical, and outcomes of legislation being drafted are still uncertain with respect to other factors. While lobbying for protection of U.S. ethanol producers is strong, there are increasing concerns about corn-based ethanol production’s energy balance (fossil-based energy used in the production process is comparable with ethanol output), something that could lead to an increase in imports allowed. Finally, cellulosic-based ethanol, that according to U.S. policy should play an increasingly prominent role, may take more time than expected to become a viable option, what would also favor more imports to meet targets set. With respect to the Canadian market, as noted, imports of ethanol (traditionally coming mostly from the U.S.) are expected to decrease steadily, leading to an overall balance by 2012.

Table 13. North American ethanol markets, 2006 and projected (2010-2015)

Ethanol 2006 (millions of liters)	**Total Consumption**	**Total Production**	**Balance**
North America	21,110	18,934	(2,176)
United States	20,360	18,384	(1,976)
Canada	750	550	(200)
Ethanol 2010-2015 (millions of liters)	**Projected Demand**	**Projected Production Capacity**	**Projected Balance**
North America	30,200-33,500	29,200-32,400	(1,000-1,100)
United States	28,000-31,000	27,000-30,000	(1,000)
Canada	2,200-2,500	2,200-2,400	(0-100)

Sources: U.S. and Canadian Renewable Fuels Association

- *Biodiesel*. The excess production capacity that currently characterizes the U.S. biodiesel market is very likely continue in the near term and beyond 2010, leading to increased pressure for exports. There is therefore no potential for import of finished biodiesel in the U.S. market. Given large production capacity as well as USDA’s projection of increases in soybean prices, however, and assuming a favorable import policy, the U.S. may represent an interesting market for crude vegetable oils. The recent rise in soybean prices (USD 0.27 to 0.40 per pound from 2006 to 2007) is cited by the NBB as the main reason for unutilized capacity. Canada may need small quantities of imports as production capacity is built if it implements a binding standard for biodiesel, although the proximity of the U.S. market with its excess production capacity is likely to be a preferential source. The most relevant market potential therefore remains that of raw material for the U.S. market.

Table 14. North American biodiesel markets, 2006 and projected (2010-2015)

Biodiesel 2006 (millions of liters)	Total Consumption	Total Production	Balance
North America	890	1,017	127
United States	820	947	127
Canada	70	70	0
Biodiesel 2010-2015 (millions of liters)	**Projected Demand**	**Projected Production Capacity**	**Projected Balance**
North America	6,500-7,600	11,400-12,500	4,900-5,000
United States	6,000-7,000	11,000-12,000	5,000
Canada	500-600	400-500	(0-100)

Sources: U.S. National Biodiesel Board, USDA, Canadian Renewable Fuels Association

4. Conclusions and recommendations: Assessment of potential export markets for ethanol and biodiesel

This section presents a summary of the major potential export markets for ethanol and biodiesel produced in Mozambique, based on the various regional markets discussed above. The available data for production, consumption and apparent balances for these markets are presented in Table 15 and Table 17. The considerations made as an overall introduction to the analysis of the different regional markets should be reiterated: there are significant discrepancies between the data available from various sources, about the scale of production and demand in different countries. While this certainly may reflect differences in data collection practices, it also reflects the fact that, as noted above, the sector is growing extremely quickly all over the world, outstripping the capacity of data collection agencies, industry publications and governments to keep abreast of the basic numbers. There is also, as will be noted in the context of international trade agreements, the potential for confusion of ethanol produced for fuel, and production for human consumption. Projections for the 2010-2015 period represent rough estimates based on available information.

Ethanol. Global output of ethanol is currently about 40 billion liters annually, of which just 10% is traded internationally, according to analysts Garten Rothkopf.[111] Of this international market of about 4 billion liters, Brazil's exports (approximately 2.6 billion liters in 2006) account for over 60%. With respect to aggregate production, in 2006 the U.S. overtook Brazil as the largest producer, recording output of about 18.3 billion liters [4.8 billion gallons] in 2006 as opposed to Brazil's 16 billion liters in the 2005/06 season.

As was described in the sections on individual countries above, total demand for ethanol will grow steadily, and imports will likely be necessary in North America and the E.U.. China is likely to turn into a major ethanol importer, and Japan's commitment to ethanol but lack of feedstock will also make it an important market. Any potential for India will depend on the volatility of its sugar production. The competition for the smaller Southern

[111] Garten Rothkopf, "A Blueprint for Green Energy in the Americas: Global Biofuels Outlook 2007," Executive Summary, page 6. Accessed at the website of the Inter-American Development Bank (IDB) at www.iadb.org.

Table 15: Ethanol markets, 2006 (millions of liters)

Ethanol 2006 (millions of liters)	Total Consumption	Total Production	Balance
North America	21,110	18,934	(2,176)
United States	20,360	18,384	(1,976)
Canada	750	550	(200)
Europe	1,725	1,514	(211)
United Kingdom	95	0	(95)
Germany	580	395	(185)
Portugal	0	0	0
Spain	220	396	176
Italy	0	128	128
Asia	1,180	1,790	610
China	530	1,540	1,010
India	650	250	(400)
Japan	0	0	0
Africa	18	18	0
South Africa*	0	0	0
MW-ZM-ZW-BW	18	18	0
Total	24,033	22,256	(1,777)

Sources: See North America, Europe, Asia and Africa regional ethanol tables above

Table 16: Ethanol markets, 2010-2015 (millions of liters)

Ethanol 2010-2015 (millions of liters)	Projected Demand	Projected Production Capacity	Projected Balance
North America	30,200-33,500	29,200-32,400	(1,000-1,100)
United States	28,000-31,000	27,000-30,000	(1,000)
Canada	2,200-2,500	2,200-2,400	(0-100)
Europe	12,000-13,000	10, 500-12,000	(1,000-1,500)
United Kingdom	1,200-1,700	1,000-1,500	(200)
Germany	1,200-2,000	1,400-2,000	0-200
Portugal	N.A.	18-20	N.A.
Spain	2,500-3,000	1,000-1,500	(1,500)
Italy	N.A.	250-300	N.A.
Asia	13,600-19,500	8,000-10,000	(5,600-9,500)
China	10,000-15,000	5,000-7,000	(5,000-8,000)
India	1,600-2,000	2,900-3,000	1,000-1,300
Japan	2,000-2,500	13-14	(1,950-2,450)
Africa	385-450	355-420	(30)
South Africa	280-330	250-300	30
MW-ZM-ZW-BW	105-120	105-120	0
Total	56,185-66,450	48,055-56,000	(8,130-10,450)

Sources: See North America, Europe, Asia and Africa regional ethanol tables above

African market will be played based on cost competitiveness in production and availability of feedstocks. As many countries implement renewable fuels standards in the years ahead, Mozambique will be faced with the opportunity to take advantage of an expanding market of some 8-11 billion liters per year, as illustrated in Table 16.

Biodiesel. Similarly, global production of biodiesel is expanding rapidly, reaching well over 7 billion liters in 2006, a significant increase from 2005, [112] and compared to only around 500 million liters in 1998. Europe represents about 80% of total supply and demand, but rapid growth in Asia and the Americas is likely to reduce the European share to around 50-60% by 2010.[113] In terms of trade, there is far less trade in biodiesel as such, with international movements of raw oil being far more common than shipments of finished biodiesel. See Table 17 for a summary of the 2006 biodiesel markets.

Available data and indications from the European Biodiesel Board suggest that there is a very close balance between domestic production and demand in the E.U., and that this situation is likely to continue in the future, leaving a far smaller international market for biodiesel than is the case for ethanol. Further, trade in biodiesel has been and seems set to continue to be relatively limited compared to trade in biodiesel feedstocks, except in the case of intra-E.U. trade and of the recent disruptive phenomenon of U.S. B99, which is expected to come to an end. E.U. stringent standards and testing requirements also contribute to making the raw oil market a much greater export potential to Europe.

Table 17: Biodiesel markets, 2006 (millions of liters)

Biodiesel 2006 (millions of liters)	Total Consumption	Total Production	Balance
North America	890	1,017	127
United States	820	947	127
Canada	70	70	0
Europe	5,750	5,750	0
United Kingdom	225	225	0
Germany	3,130	3,130	0
Portugal	107	107	0
Spain	116	116	0
Italy	525	525	0
Asia	339	355	17
China	338	350	12
India	0.58	0.58	0
Japan	0	4.9	4.9
Africa	0	0	0
South Africa	0	0	0
MW-ZM-ZW-BW	0	0	0
Total	6,979	7,122	144

Sources: See North America, Europe, Asia and Africa regional biodiesel tables above

[112] The 2006 figure is from the European Biodiesel Board, Ensus and BBI International. A 2005 figure of 2.2 billion liters is reported by Credit Suisse research: the 2005 figure is likely to be low.
[113] Credit Suisse, "Alternative/Renewable Energy," Equity Research note (2007).

Table 18: Biodiesel markets, 2010-2015 (millions of liters)

Biodiesel 2010-2015 (millions of liters)	**Projected Demand**	**Projected Production Capacity**	**Projected Balance**
North America	6,500-7,600	11,400-12,500	4,900-5,000
United States	6,000-7,000	11,000-12,000	5,000
Canada	500-600	400-500	(0-100)
Europe	16,000-18,000	16,000-18,000	0
United Kingdom	1,100-2,000	800-1,000	(300-1,000)
Germany	4,000-5,000	5,900-6,000	1,000-2,000
Portugal	350-450	700-800	350
Spain	N.A.	400-500	N.A.
Italy	1,000-1,500	2,500-3,000	1,500
Asia	10,000-15,000	5,700-10,000	(4,300-5,000)
China	6,000-7,000	1,700-2,000	(4,300-5,000)
India	4,000-8,000	4,000-8,000	(0-4,000)
Japan	10-20	10-15	(0-5)
Africa	230-285	480-535	250
South Africa	200-250	450-500	250
MW-ZM-ZW-BW	30-35	30-35	0
Total	32,730-40,885	33,580-41,035	150-850

Sources: See North America, Europe, Asia and Africa regional biodiesel tables above

According to the EBB, the E.U. market for crude oil imports could range between 20% and 30% of the E.U. biodiesel industry’s demand, corresponding to about 3.2-5.4 billion liters of crude oil. China and India’s diesel markets for transport are very significant, and the setting of biodiesel standards would create two additional major raw oil export markets; uncertainties associated to outcomes of ambitious policies being prepared, however, are greater than for ethanol’s for these two countries. The U.S. projected excess production capacity, coupled with high feedstock prices, may also open possibilities for raw oil imports. See Table 18.

Prices. Table 20 presents an overview of available current prices for fossil fuels and biofuels (E.U. average prices in USD are affected by the Euro/USD exchange rate).

Major fuel price monitoring institutions, such as Platts or ICIS Pricing, have only recently begun following biofuels, mainly focusing on North American and Europe, where market information is more readily available. Regular monitoring of Asian markets is at an initial stage (ICIS Pricing provides one biodiesel assessment for South East Asia and, as of August 2007, Platts is also considering starting doing so[114]). Monitoring of African markets is still not readily available. The price monitoring situation in the various markets reflects the development stage they have reached as well as expectations of their growth. As of mid-March 2008, futures prices of ethanol in Brazil and in the U.S., following sharp decreases in both markets in 2007 that left them more or less aligned at USD 0.406 and USD 0.408 /liter, respectively, are diverging, with U.S. prices exceeding

[114] www.platts.com, *Proposed biodiesel assessment in Asia*, 20 August 2007

Brazilian quotes, USD 0.65/liter versus USD 0.52/liter; however, on spot markets Brazilian ethanol remains slightly more competitive.[115]

Price projections for the months and years ahead are inevitably fraught with uncertainty. Even so, it is possible to identify several trends that are likely to support prices for ethanol and biodiesel feedstocks at levels higher than observed in the period before 2005.

- After declining sharply in 2007 in the U.S. and Brazil, which together account for most of global output, ethanol prices have stabilized and, at least in the U.S., appear to be edging higher, spurred by increasing demand associated with the steady increase in petroleum prices from mid-2007 through to early 2008.[116] Values appear to be moving in the range of USD 0.53/liter or USD 2/gallon (see Figure 3). In Brazil, market observers report that rapid domestic demand (30% in 2007) associated with economic growth and proliferation of flex-fuel vehicles has helped stabilize prices in the face of market fundamentals (large sugar harvests in India and existing stockpiles) that would tend to push prices lower.[117] Values in USD doubled in the period from 2004 to 2007; while part of the increase attributable to the steady slide of the dollar against the real since 2004, ethanol prices in reais have also increased by a factor of about 30% during the same period (see Figure 4). Given that these two markets represent the bulk of global ethanol production, and are generally lower than ethanol prices reported for a large number of other countries (see Table 20), and in view of Brazil's use of sugarcane as a feedstock, it is appropriate to adopt the Brazilian price (plus relevant transportation costs) as the global reference price for ethanol.
- Prices for various biodiesel feedstocks and major agricultural commodities such as maize, wheat and soybeans have increased dramatically in recent years, driven by increased consumer demand worldwide, new industrial demand for ethanol production (in the case of maize), localized weather conditions (drought conditions that affected crops in parts of the U.S., Canada, France, Germany and Australia), as well as increased energy prices.[118] This has created a situation where biodiesel is more expensive than fossil diesel in Europe (by as much as USD 0.35/liter in late 2007[119]), although prolonged high petroleum prices will eventually erode this price premium. See Figure 5 and Figure 6.
- International petroleum markets have experienced a dramatic increase in recent years, because of rapidly increasing consumption in emerging markets such as China and India together with supply-side constraints related to weather (such as Hurricane Katrina in 2005), geopolitical instability (Nigeria, Venezuela and the Persian Gulf), and a decreasing pace of major new discoveries. These conditions suggest continued support for petroleum prices in the near term, though they may weaken somewhat as

[115] http://www.ethanolstatistics.com/commodity_prices/brazilian_ethanol_and_commodity_prices.aspx
[116] Ibid.
[117] Interview with Marcelo Junqueira, Clean Energy Brasil, March 14, 2008.
[118] Interview with Bruce Babcock, Center for Agricultural and Rural Development (CARD), Iowa State University, "To the Point," National Public Radio, December 20, 2007. See also Babcock, Bruce, "Do biofuels mean that inexpensive food is a thing of the past?," *Iowa Ag Review*, 13:3 (Summer, 2007), at http://www.card.iastate.edu/iowa_ag_review/.
[119] Reported by the Kingsman Biodiesel Report (February 13, 2008). See www.kingsman.com.

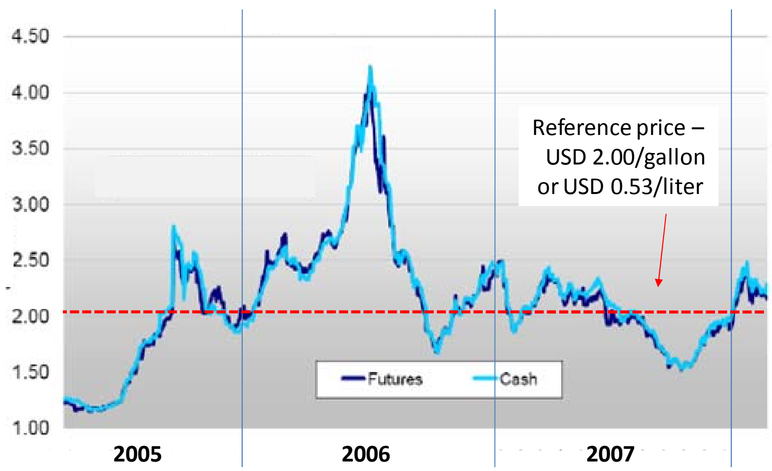
investor interest shifts to other markets in the aftermath of the current increase. Although short-term factors, such as the role of speculative investors, as well as the weakness of the dollar in the medium turn, are cited by some analysts and especially the producing countries as a reason for higher prices, the extent to which prices might weaken in the months ahead is open to question. Recent developments on futures markets suggest that investor sentiment has shifted towards factoring in higher prices for contracts for as far in the future as 2016, reflecting supply-side fundamentals as well as expectations of higher inflation in the future, increased taxes in producing countries and lack of access to reserves controlled by national oil companies in major producing countries.[120] Furthermore, petroleum price projections based on a fundamental shift in the supply-demand balance also appear to be emerging as U.S. policy: recent statements by senior U.S. officials including President George Bush clearly indicate this, and they note that while global demand has increased by 15% since 2000 to 87 million barrels a day (b/d), estimates for spare production capacity (most of which is resident in Saudi Arabia) indicate a roughly 50% decrease, to about 2.1 million b/d, with the specter of decreasing output in major non-OPEC producers such as Mexico, Russia, Norway and the U.K.[121] Based on this, the U.S. Department of Energy's Energy Information Administration projects an average price for petroleum (the U.S. benchmark WTI) at USD 101/barrel for the balance of 2008, and USD 92.50 in 2009.[122] See Figure 6 and Figure 7 for historical data.

- Even so, because of the broader implications of the weak dollar and a global credit squeeze for the world's major economies and consumers of energy, it is important to underscore the basic uncertainty about longer-term price movements for petroleum as well as biofuels. In March, 2008, the dollar plumbed record lows against the euro and yen, and reached dramatically lower levels versus the Brazilian real, among other emerging market currencies. Demand in the U.S. has been a significant driver for growth in major emerging markets such as China; should the U.S. trade deficit reverse direction dramatically and for a sustained period of time due to the weak dollar, U.S. economic downturn and broader international credit contraction in the wake of the sub-prime mortgage crisis in the U.S., this may well lead to slower growth in rapidly developing markets. The extent to which this manifests itself depends on the degree to which economic growth in emerging markets mitigates the impact of the U.S. downturn on those economies. In the past, the U.S. represented a much greater part of the global economy; now that the share of the U.S. in global output is diminishing, the dynamics of the global economy are more difficult to predict. Even so, recent data suggest that growth in global trade is slowing, providing evidence that overall economic growth is likewise decelerating.[123]

[120] Blas, Javier, "Investors bet on high oil prices as long-dated futures pass $100," *Financial Times* (March 17, 2008): page 1.
[121] King, Neil, "White House sets long view on oil," *The Wall Street Journal* (March 20, 2008): page A7.
[122] King, Neil, "Energy agency sees oil averaging $101 this year," *The Wall Street Journal* (April 9, 2008): page A6.
[123] "Beattie, Alan, "World trade decelerates almost to a standstill," *Financial Times* (March 20, 2008): page 8.

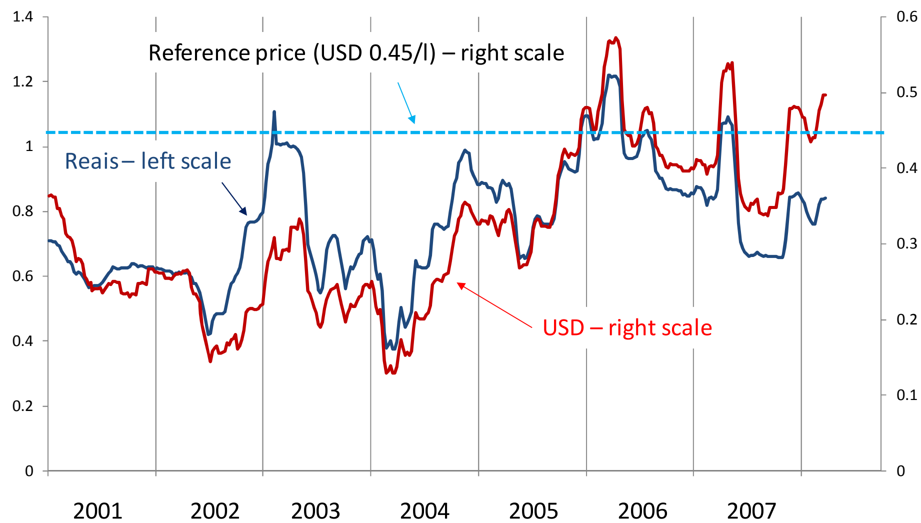
For the purposes of evaluating the competitiveness of Mozambican biofuels production, there are fundamentally three reference prices to consider: the price of petroleum, specifically a 'light' crude from the Middle East such as Arab Light, to serve as a representative benchmark feedstock for gasoline and diesel production; ethanol prices, the most representative of which would be anhydrous ethanol traded in Brazil; and biodiesel feedstocks, the most representative market quotations for which are recorded in Europe, typically FOB or CIF at Antwerp/Rotterdam/Amsterdam, depending on whether it is an imported feedstock (RBD palm oil) or produced/processed in Europe (rapeseed, soybean or sunflower).

Figure 3: Ethanol price trends, U.S. (USD/gallon), March 2005-January 2008



Sources: CBOT (2008), www.cbot.com.

Figure 4: Ethanol price trends, Brazil (anhydrous alcohol), USD/liter



Brazil: Centro de Estudos Avançados em Economía Aplicada (Universidade de São Paulo), www.cepea.esalq.usp.br/cepea/. Reference price is USD0.45/liter.

As discussed in greater detail in Chapter 6 and Chapter 7, the price of ethanol in Brazil is the most logical reference when assessing most overseas markets for ethanol (CIF prices), because of Brazil's importance as an exporter. With the exception of the U.S., which has its own domestic market, the Brazilian price plus shipping is used to arrive at the reference price for ethanol landed in Europe, South Asia and Asia. The reference values for the U.S. and Brazilian ethanol markets are indicated in Figure 3 and Figure 4.

For export markets for biodiesel, meanwhile, for reasons described in greater detail in Chapter 6, reference prices for vegetable oil are used, but these vary depending on the feedstock, as shown in Chapter 3 and Chapter 4. These values, when adjusted to provide a reference FOB Mozambique, represent the opportunity cost of producing biodiesel from vegetable oil that would otherwise be exported to Europe.

Figure 5: Maize and soybean oil futures prices (USD cents/bushel)

Maize (CBOT May, 2008 contract) Soybean oil (CBOT May, 2008 contract)

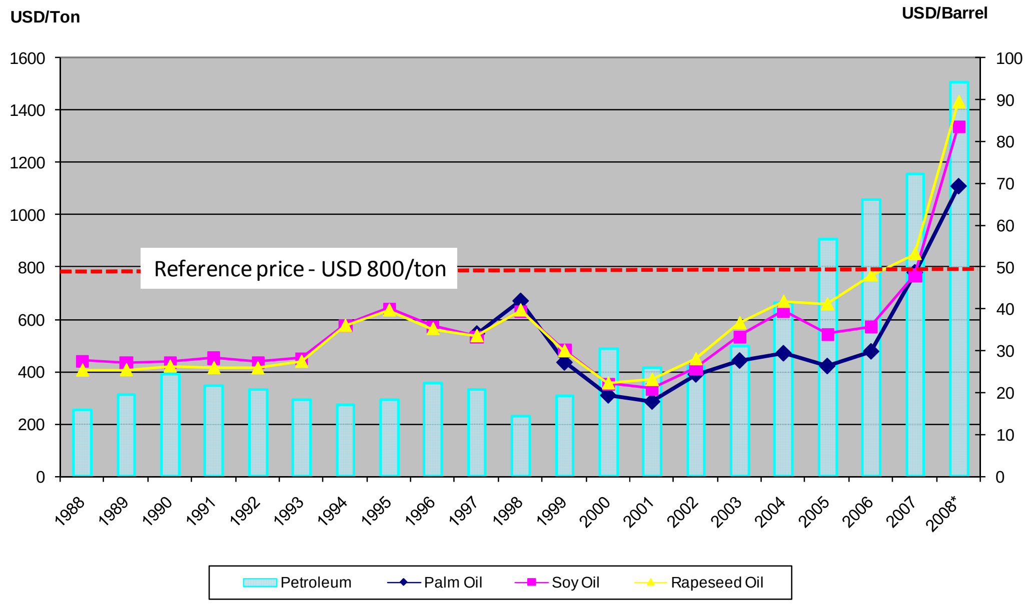
Sources: Wall Street Journal/CBOT.

As for the domestic market for ethanol and diesel, the analysis is based on the reference CIF prices of fossil fuels in Mozambique (presented in Chapter 1.3), which were recorded in late 2006 when the reference grade of crude petroleum, Saudi Light, traded around USD 54/barrel, or some 40% lower than current levels, as shown in Figure 7.

It is important to stress that in all cases, the values used in the analysis presented in Chapter 6 are below those currently observed in the market, thereby increasing the robustness of the results of the analysis. The values used as reference prices for the competitiveness analysis presented in Chapter 6 are summarized in Table 19; Table 20 shows some representative values for end-user prices of fossil-based fuels as well as biofuels.

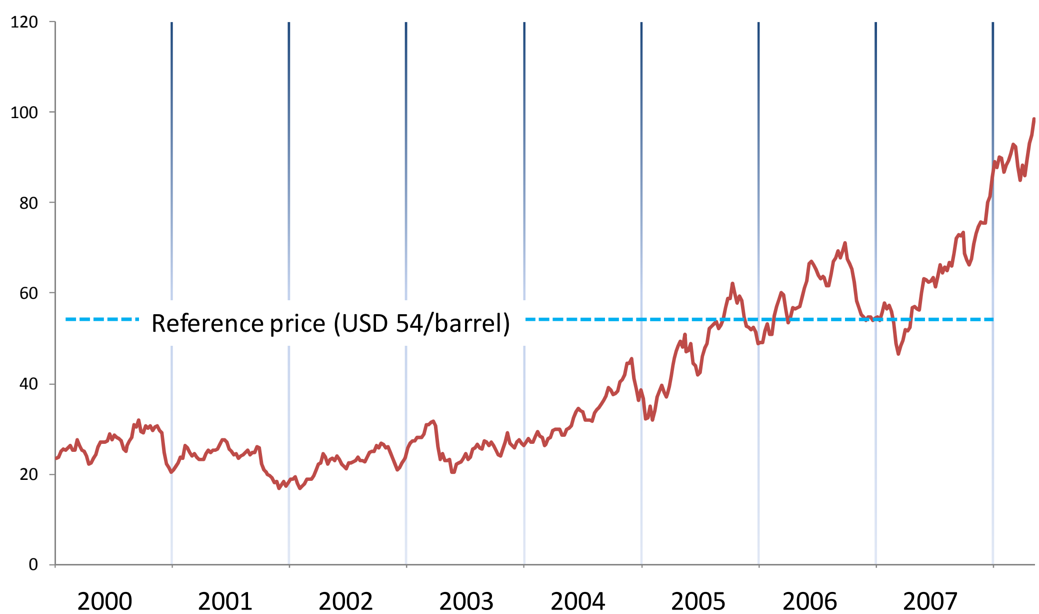
Market size. Based on the discussion of theoretical market potential both within Mozambique as well as outside the country, a preliminary estimate of the overall market potential for biofuels produced in Mozambique is presented in Table 21. The estimates reflect the following assumptions:

Figure 6: Vegetable oil prices, CIF Europe, versus petroleum, 1988-2008



Source: BBI International. Note: 2008 figures are for January-February only. Petroleum grade is WTI, FOB Cushing, Texas.

Figure 7: Weekly petroleum prices, 2000-2008 (Arab Light, 34° API), USD/barrel



Source: Energy Information Administration, DOE. Reference prices for refined products in Mozambique used in the analysis in Chapter 6 are for November, 2006, when Saudi Light was quoted at around USD 54/barrel.

Table 19: Reference values used

Market	Reference	Source/Method	Current
Ethanol – Brazil	USD 0.45/liter	Figure 4	USD 0.50/liter
Ethanol – United States	USD 0.53/liter	Figure 3	USD 0.59/liter
Ethanol – Europe	USD 0.51/liter	Brazil+USD 0.06/liter	
Ethanol – South Asia	USD 0.52/liter	Brazil+USD 0.07/liter	
Ethanol – Asia	USD 0.54/liter	Brazil+USD 0.09/liter	
Vegetable Oil – Europe	~USD 800/ton	CIF Rotterdam	USD 800-1,400
Gasoline – CIF Mozambique	USD 0.61/liter	Chapter 1.3	
Diesel – CIF Mozambique	USD 0.59/liter	Chapter 1.3	
Petroleum –Gulf (Saudi Light)	USD 54/barrel	USDOE	USD 98/barrel

Table 20: End-user price data for petroleum-based fuels and biofuels, 2006/2007

	Fossil Fuels (US$/liter)		**Biofuels (US$/liter)**	
	Gasoline	*Diesel*	*Ethanol*	*Biodiesel*
North America				
United States	0.57	0.61	0.41	0.86-0.87
Canada	0.76	0.82	0.42	0.86-0.90
EU average			0.76-0.79	0.99-1.01
United Kingdom	1.93	1.66		
Germany	1.82	1.31		
Portugal	1.75	1.40		
Spain	1.43	1.13		
Italy	1.79	1.32		
Asia			0.40-0.46	0.69-0.72
China	0.61	0.69	0.56	N.A.
India	0.56	0.51	0.47-0.53	0.67-1.26
Japan	1.251	1.063	1.10-1.28	N.A.
Africa				
South Africa	1.03	0.98	0.58	0.67

Sources: U.S. : EIA October 2007 (fossil fuels), Wall Street Journal October 2007 (ethanol), ICIS Pricing U.S. Biodiesel Report, 4 October 2007 (biodiesel). Canada: EIA 2007 (fossil fuels), Chicago Board of Trade October 2007 (key reference for ethanol, according to Canadian RFA), Agriculture and Agri-food Canada 2007(AAFC indicates biodiesel sells at 5-10% premium on diesel). E.U.: IEA August 2007 (fossil fuels), ICIS Pricing Fuel Ethanol Report/Europe 3 October 2007 (ethanol), ICIS Pricing Biodiesel Report/Europe 3 October 2007 (biodiesel). E.U. prices originally reported in Euros, standing at high values due to the exchange rate with the USD. Asia: ICIS Pricing Ethanol Report/Asia 3 October 2007 (ethanol), ICIS Pricing Biodiesel Report/Asia 3 October 2007 (biodiesel). China: GTZ International Fuel Prices 2007 (fossil fuels), USDA 2007 (ethanol, price set at 91.1% of gasoline). India: EIA May 2007 (fossil fuels), USDA India Biofuels Annual 2007 (ethanol and biodiesel). Japan: Presumably includes taxes. IEA August 2007 (fossil fuels), USDA Japan Biofuels Annual 2006 (ethanol) Note: E3 blends and ETBE-blended gasoline are to be sold at same price of ordinary fuel). South Africa: Department of Minerals and Energy October 2007 (fossil fuels, ethanol and biodiesel. Biofuels assumed to be sold at Basic Fuel Price in accordance with draft strategy: BFP published by DME October 2007).

- Implementation of a blend mandate (renewable fuel standard) of E10 and B5, reaching these levels by 2010, followed by phase-in of hydrous alcohol sales in Maputo and then other urban areas beginning in 2010.
- Sales of a small volume of ethanol for gelfuel production to displace 20% of cooking fuels and biomass (charcoal) in 2010, and 30% by 2015 (5% annual demand growth rate assumed for both cooking fuels and biomass).
- Linear build-up towards a 25% coverage rate in rural electrification by 2020 with new diesel-powered generation in remote areas of the country, and a blend ratio of 5%.
- Entry into the U.S. market under AGOA provisions by 2010, with 19 million liters (equivalent to one cargo), but no exports to the E.U., China or Japan until 2011 or 2012.

  By 2015, export of one 19 million liter cargo each month from Mozambique, for a total of twelve cargos per year, distributed between the U.S. and E.U. (two cargoes/year each), and Japan and China (four cargoes/year each) markets: this would achieve import market shares of 3-4% for the U.S. and the E.U., 3% in Japan, and 1-2% in China.
- No exports of biodiesel, with all international trade taking the form of exports of raw vegetable oil.

Table 21: Preliminary overall market assessment

Summary of potential markets	**Near-term (2010)**		**Longer-term (2015)**	
(million liters)	Ethanol	Biodiesel	Ethanol	Biodiesel
Domestic market segments	***13.42***	***19.95***	***39.76***	***43.20***
Transportation*	12.5	18.75	38	40
Residential**	0.9		1.8	
Other***		1.2		3.2
Regional market segments	***20***	***0***	***30***	***0***
South Africa	20	0	30	0
Other SADC				
International market segments	***19***	***0***	***228***	***0***
U.S. #	19		38	
European Union #			38	
Japan #			76	
China #			76	
Total domestic and international	***52.42***	***19.95***	***297.76***	***43.20***

Source: Econergy estimates. *Assumes E10 and B5 standard in place by 2010, and phase-in of hydrous alcohol sales beginning in 2010. **Assumes that gelfuel displaces 20% of the kerosene/LPG and of the biomass market by 2010, and 30% by 2015, with demand in both markets growing by 5% per year. ***Assumes a linear progression towards the 2020 rural electrification goal (25% coverage rate) with new diesel-powered generation units running at a 5% blend ratio. #Assumes one 19-million liter cargo/year just to the U.S. in 2010, and twelve cargoes/year by 2012, distributed between U.S., E.U., Japan and China.

CHAPTER 3: ECONOMIC, ENVIRONMENTAL AND SOCIAL ASSESSMENT OF DIFFERENT FEEDSTOCKS FOR BIOFUELS PRODUCTION

This Chapter provides a general overview of the agricultural sector in Mozambique in terms of its economic importance, productivity and relevance to understanding patterns of employment and poverty in the country, together with an overview of the vegetable oil sector in the country. There is also a presentation of land-use patterns, agro-ecological characteristics of the country's major regions, existing irrigation infrastructure and relevance of rainfall patterns as well as plans for hydraulic infrastructure improvements in the future. The bulk of the Chapter is dedicated to a review of 14 crops (corn, cassava, sugarcane, sweet sorghum, sunflower, sesame, soya, peanut, coconut, cotton, mafurra, castor seed, jatropha and African palm) that identifies current cultivation patterns, where relevant, agro-ecological suitability, environmental and social impacts of cultivation, together with a comparative assessment of these crops that provides the basis for identifying the most promising ones for development. The Chapter concludes with some general recommendations regarding specific crops considered most suitable for further development.

1. Overview of the Agricultural Sector

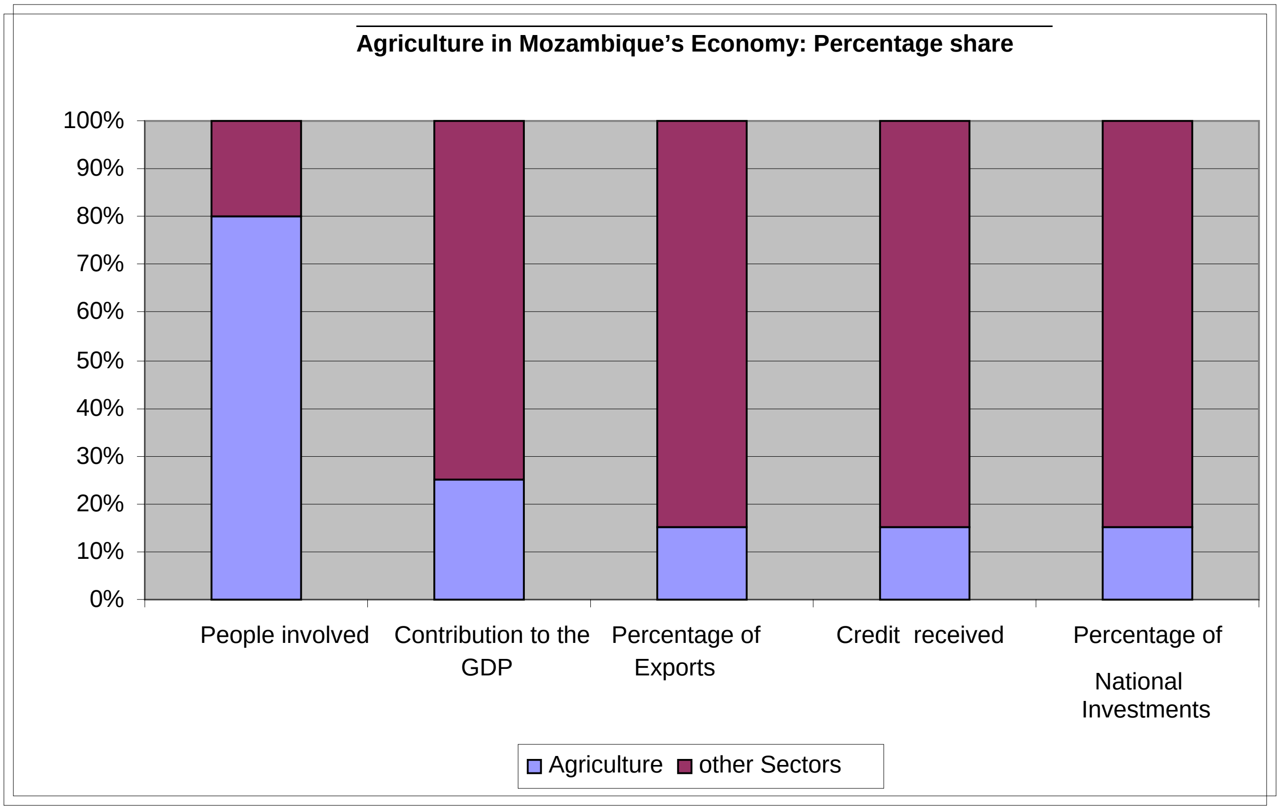
Mozambique is largely an agricultural country. About 80% of its population lives off of agriculture, but the sector only accounts for 25-26% of the Gross Domestic Product (GDP), and 20% of the volume of exports.[1] In recent years, with the privatization of domestic banks, lending to agricultural companies has been reduced drastically, from 50% of credit to the economy in 1987 to around 10-20% more recently. Private investment projects in the agriculture and agribusiness sectors authorized by the Centro de Promoção de Investimentos (Investment Promotion Center or CPI) have altogether averaged about 15-20% of total investments in the country in the last decade.

Hence, despite the fact that 80% of the population works in agriculture, agriculture's contribution to the country's economy is disproportionately small.[2] This situation reflects low agricultural productivity and the limited international trade in Mozambican agricultural products. Because of its importance, this Section will examine the evolution of agriculture's role within GDP and exports in greater detail.

Contribution of Agriculture to GDP. The contribution of agriculture[3] to GDP (Gross Domestic Product) has been declining steadily over the last fifteen years, from a peak of

[1] This refers to products derived from plants, which, according to the INE classification, include: fruits, cereals, vegetables, products from industrial mills, oilseeds and others, excluding woods.
[2] With few exceptions, including South Africa, Seychelles, and other countries of SADC, this situation is common in poor countries, generally in African countries, and particularly in Southern African countries.
[3] The organization of national accounts does not allow for the isolation of the contribution of agriculture itself to GDP. The agricultural sector includes livestock production, hunting and forestry. For the purpose of this report, fishing, aquaculture, and other activities of related sectors are included. Within industries, extractive industries and manufacturing are included. Within services, all other sectors are included, among them: electricity and water; construction, commerce and repair services; hotels, restaurants and the like; transportation, storage and communications; financial activities, real estate; rentals and business-to-

Figure 1: Share of agriculture in Mozambique's economy



Source: INE (2007)

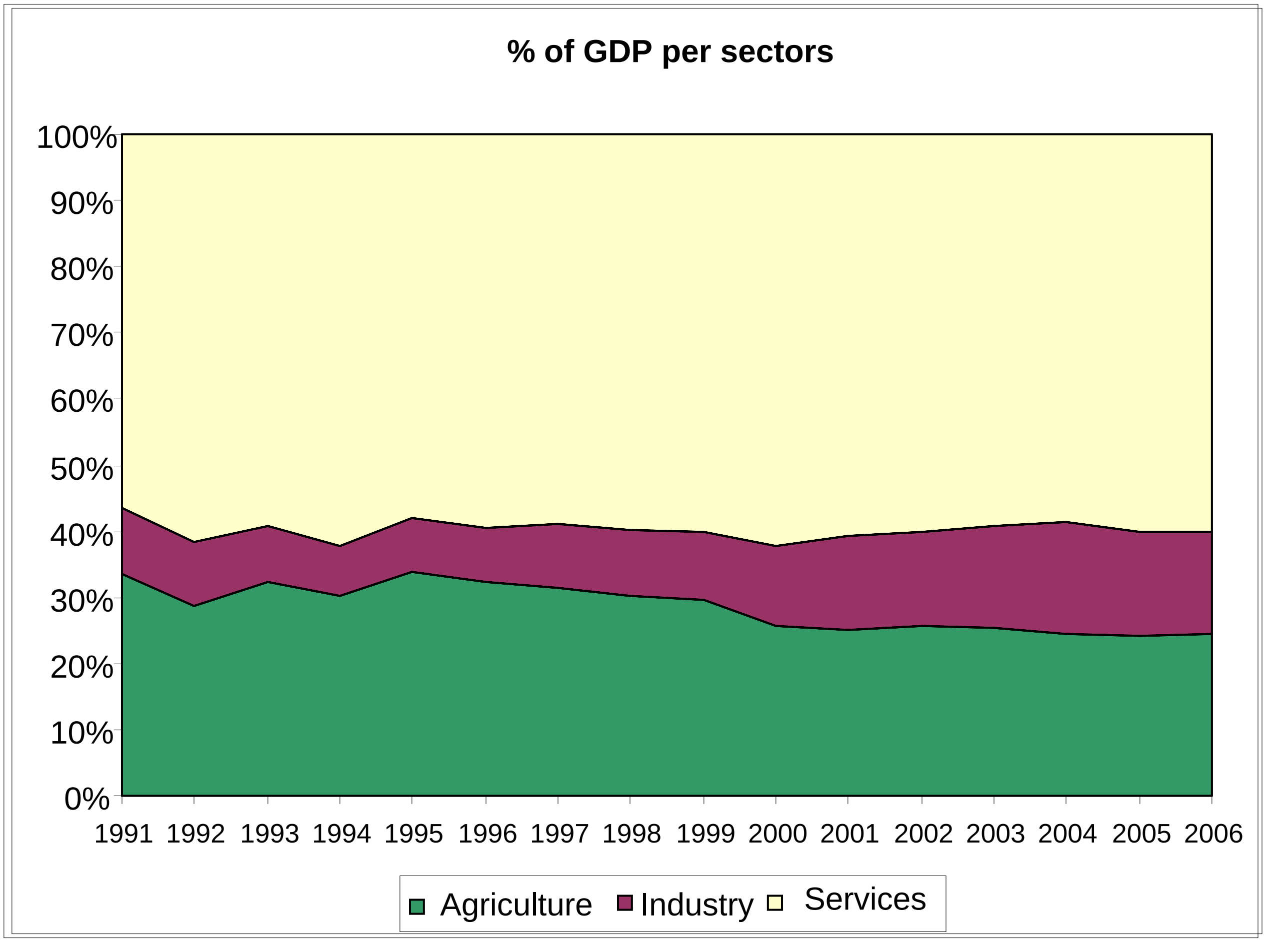
38% in 1991 to approximately 25-26% in 2005 and 2006. The lowest level observed during that period was 20% in 2000, as a result of the floods that devastated much of the Southern region of the country.

From 1996 to 2006, agricultural production in Mozambique increased an average of 6% per year, slower than the overall average of the economy (9.1%) as well as services (9.4%) and significantly below industrial growth, which rose 16.1% during that same period. The growth of agriculture up to that point was due to the expansion of cultivated areas, or recovery of areas that had been abandoned because of the war. In the future, however, growth should have an impact on the yield per unit of cultivated area.

The implementation of megaprojects in the industrial field had a significant influence in the growth of this sector, which has been characterized by large variations from gear to gear. In general, the growth rate of industry over the last decade always exceeded the average growth of the economy and of other sectors. During the last five years, however,

business services; public adminsitration; defense, obligatory social security; education, health and social services; and other activities of community, social and personal services.

Figure 2: GDP of Mozambique per sectors



Source: INE (2007)

the three main sectors of the economy have tended to converge towards the national average rate of growth.

Share of Agricultural Production in Exports: The participation of agricultural production in national exports[4] has fallen from 18% in 2004 to 15% and 16% in 2005 and 2006 respectively. The other most important exports are aluminum from Mozal (60%), electric power from Cahora Bassa (7%), and natural gas from Sasol (4%). Agricultural exports increased significantly in that period (7% in 2005 and 47% in 2006), but total exports rose more rapidly, 25% in 2005 and 36% in 2006.

Major Agricultural Products. The main agricultural staples in the country during the 2005-2006 harvest included cassava, corn, sorghum, rice, peanuts, beans and *mexoeira* (a native cereal). Among cash crops, sugar cane, cashew, and cotton have been the

4 The agricultural exports include wood and shrimp.

Figure 3: GDP Growth by sector

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Agriculture	9%	9%	8%	6%	-12%	10%	11%	5%	5%	6%	9%
Industry	17%	31%	15%	14%	16%	34%	9%	17%	15%	2%	6%
Services	18%	10%	14%	9%	6%	9%	8%	4%	7%	11%	8%
Total	15%	11%	12%	8%	2%	12%	9%	6%	8%	8%	8%

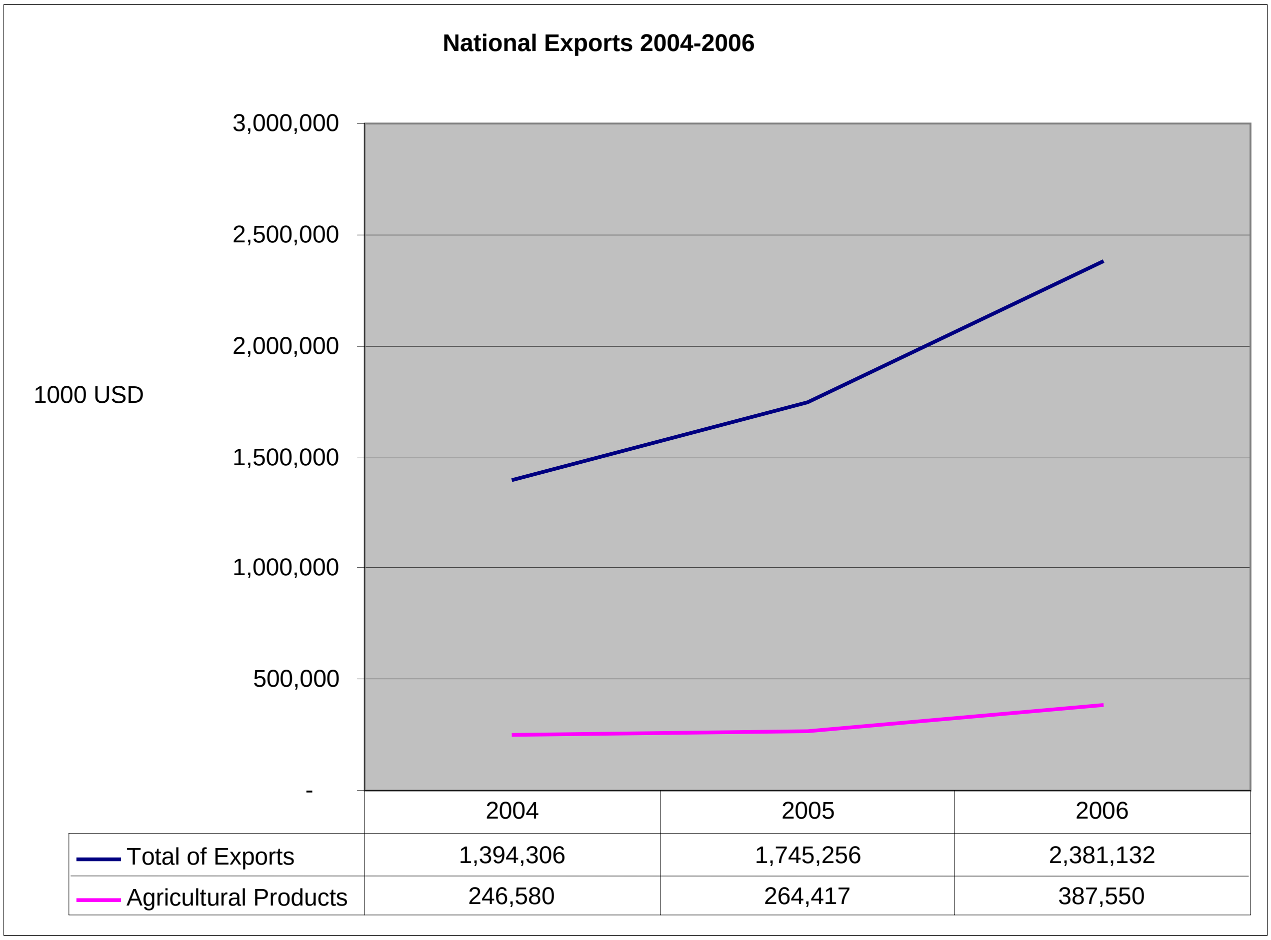
Source: INE (2007)

traditional source of income.

In total, cash crops have shown steady, albeit slow, growth over the last 30 years (Figure 5 shows the trend for cassava and corn), notwithstanding some fluctuations due to political circumstances and natural disasters. Corn production, for example, shows significant variation during the last years of the Colonial War (1973-1975). The growth in production observed after independence was again undermined by 16 years of civil war, especially in the late 1980s and early 1990s. The period of peace and stability that followed the 1992 Peace Treaty led to a regular increase of production at the national level, hampered only by the floods of 2000 and 2001. Annex E shows comprehensive data, showing the levels of regional production for three products: sorghum, cassava, and groundnut.

As illustrated in Figure 5, cassava production shows regular growth from 1960 to 1995, with the exception of a positive peak recorded in 1990 followed by a decline until 1994;

Figure 4: National Exports



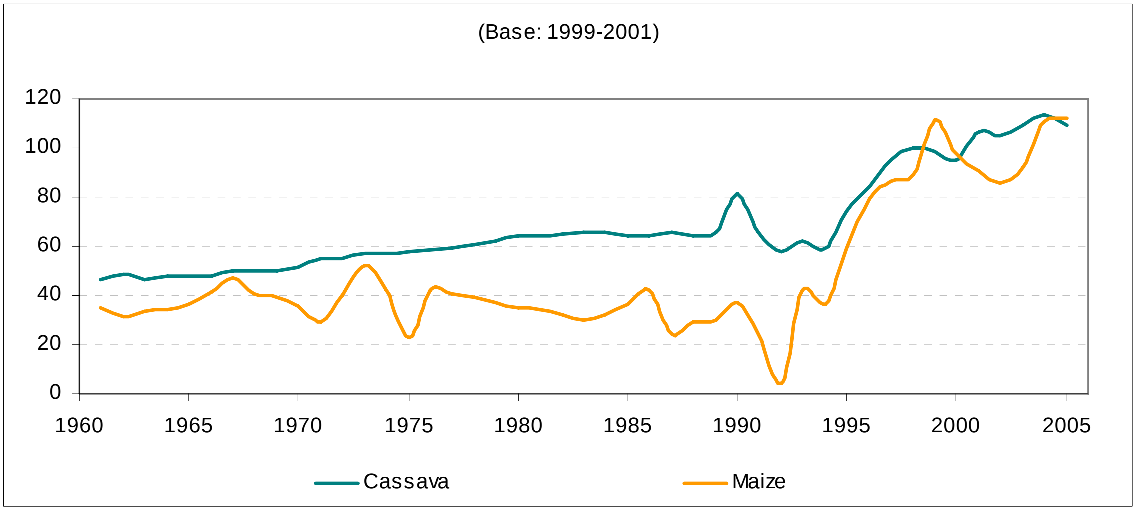
Source: INE (2007)

Table 1: Main food and commercial crops produced in Mozambique, 2005-2006
(Figures in metric tons)

Products	Production	Commercial Crop	Production
Cassava	7,551,727	Sugarcane	2,060,317
Corn	1,533,520	Chestnut	62,821
Sorghum	338,693	Coconut	17,000
Rice	182,573	Tea (leaf)	16,000
Beans	219,096	Cotton	114,829
Groundnut	145,584	Citrus	32,000
Mexoeira (cereals)	42,856	Tobacco	65,000

Source: MINAG (2007)

Figure 5: Index of net production of cassava and corn, 1960-2005



Source: FAOSTAT 2006.

starting in 1995, a significant increase may be observed. The regularity in the growth of cassava is most likely due to a combination of factors, including: (i) that it is a semi-perennial crop, whose cycle is longer than one year, supported by the fact that there have been cases reported where crop life is extended for several years[5]; (ii) that cassava in Mozambique is usually grown in poor, sandy areas that are not affected by floods; (iii) that cassava is harvested on an "as needed" basis, and is not normally targeted for the market but for self-consumption; (iv) that production estimates are made based on the area planted considering the intensity and yields per unit area, and not in direct relation with harvest or consumption.

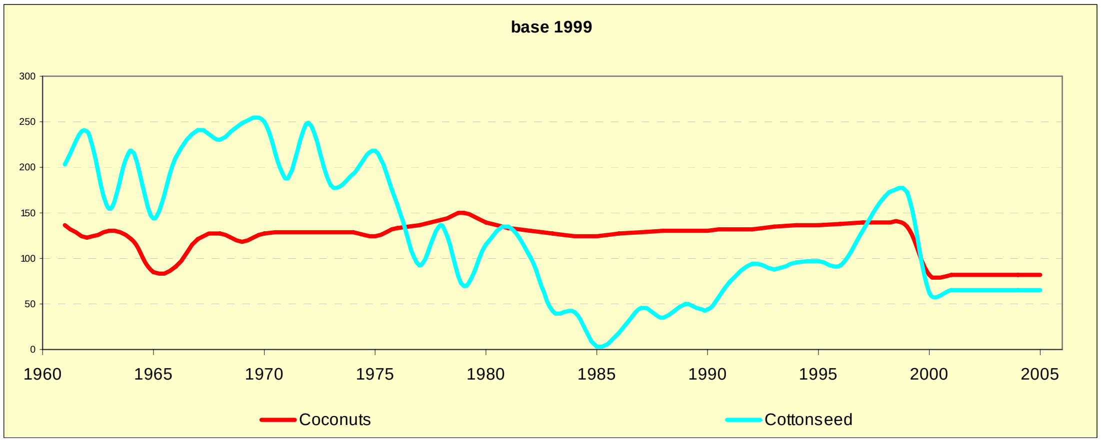
Cashew nuts and cotton seed were the main products in Mozambique during the colonial period, and they reached their highest levels of production in the 1960s and early 1970s. Production has since declined significantly, most notably between 1984 and 1986.

Since 1986, growth in production of cotton improved steadily until a rapid decline began in 1999. Nevertheless, cotton still represents a large part of commercial agricultural production, as shown in Figure 6. Cotton production depends considerably on international prices, and therefore undergoes significant variations, including a large decrease since 1975, the year of independence. In 1985, the cotton industry almost entirely collapsed, but subsequently enjoyed a slight recovery during the time of peace and national reconciliation.

Just like cassava, the coconut production, which is also a perennial crop, shows regular production over the last 45 years. There was a significant fall since 2000, mainly due to

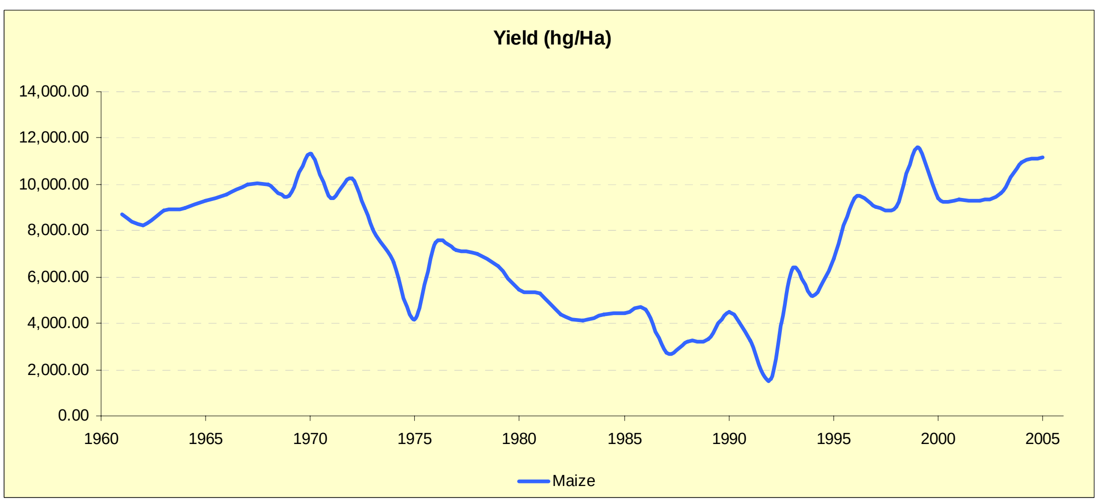
[5] In general, when the farmers remove a cassava plant, they replace it with another.

Figure 6: Index of net production of coconuts and cotton, 1960-2005



Source: FAOSTAT (2006).

Figure 7: Corn yield, 1969-2005



Source: FAOSTAT (2006).

"lethal yellowing" disease that affected the palm groves in Zambézia, the largest in the country.

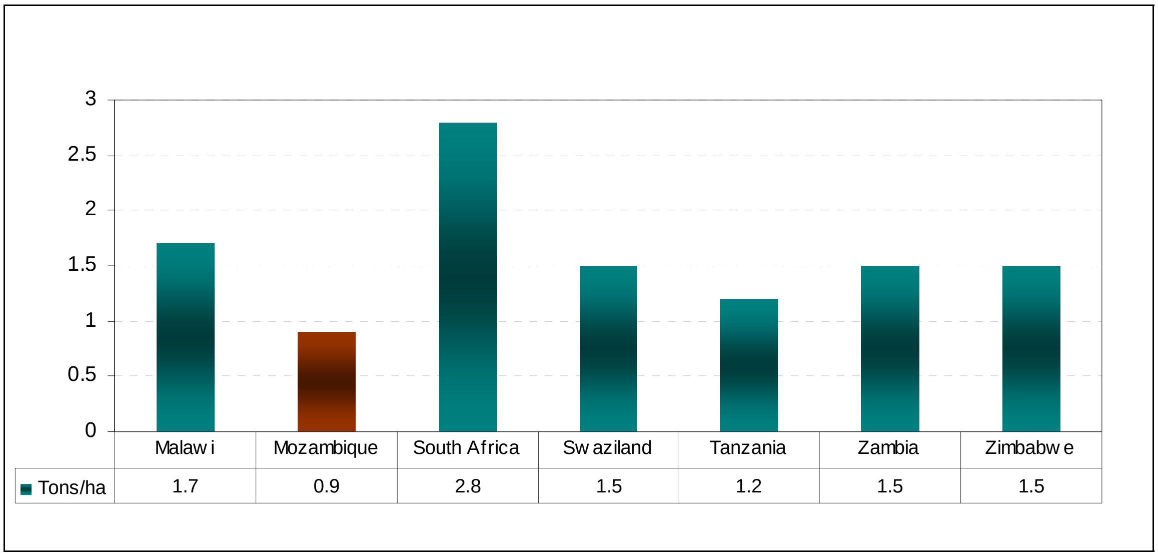
Per-hectare yields are low, both in production for commercial and food markets, and efforts for improvements have been severely affected by two decades of war because of the lack of replanting as well as disease (in the case of coconuts), both of which have limited production. Production is slowly rising to pre-independence levels.

The average per-hectare yield in Mozambique for corn, one of the main cereals produced in the country and in the region, is approximately 0.9 tons/ha, which is significantly below regional averages (see Figure 9). Average global production of corn is close to

4.5 t/ha, and the average in European countries is in the range of 8 to 9 tons/ha, although some countries have recorded yields of more than 15 tons per ha.

One of the factors contributing to low agricultural production in Mozambique is the limited attention given to agricultural inputs.[6] According to an agricultural survey done in 2005, the Trabalho de Inquérito Agrícola (Agricultural Survey Study or TIA), only 4% of small- and medium-size farms use fertilizers.[7] Another critical factor for improvements in agricultural productivity is limited access to technology and extension services. In 2005, and for a period of 12 months, only 15% of small- and medium-size enterprises had access to them, and only 6% used irrigation technology systems. A recent study carried out by the World Bank emphasizes the limited and uneven coverage of these services, which reach a small fraction of the population: there are an average of 1.3 workers for every 10,000 inhabitants.[8] The study also shows that the coverage of these services is even lower in the poorest areas.

Figure 8: Corn yields in SADC countries



Source: Calculated based on data from FAOSTAT (2005).

Mozambique's agricultural sector is mostly comprised of small landowners. The so-called family sector (approximately 99.6% of owners of farms), has small plots of land, which together represent 95% of the country's total cultivated area. These farmers practice subsistence agriculture primarily based on production of corn and cassava. Their productivity is very low, largely due to limited capital and poor access to financial supports (such services either do not exist, or cannot be accessed by small landowners who lack the required guarantees), making it very difficult, if not impossible, to secure access to improved seed, fertilizers and technology. Moreover, beyond the limited

[6] The so-called family sector, in fact, hardly uses agrucultural inputs and commercial sectors use them irregularly and in quantities below those recommended by the Institute of Agrarian Research of Mozambique (IIAM).
[7] MINAG, 2006a.
[8] World Bank 2005a

coverage of the extension services, the distribution network for inputs is poorly developed in Mozambique. Most of it is concentrated in urban areas, or those with large-scale production, targeting the agribusiness sector, which represents only 1% of the country's total cultivated area.

Population trends in the agricultural sector. Mozambique's estimated population counts approximately 20 million people in 2007, of which 52% are women and 48% men. Fifty percent of the total population is 15 years old or older, with 92% making up the economically active population (EAP).[9] Some 79% of the workforce is engaged in agriculture, animal husbandry, hunting, fishing and forestry. In rural areas, almost the entire working force (93%) is engaged in these sectors (INE 2006).

The agricultural sector covers 3.3 million agricultural production units (referred to as *explorações* or farms[10]) of which 98% are considered small-scale, and 2% are medium-to-large scale farms.[11] About 87% of the rural population is engaged in agriculture and livestock production. For 60% of that population, these activities represent the main source of income, while 27% of that total is supplementing other sources of income with farming, animal breeding or other activities. Only a few (4%) of the farmers have access to credit, and only 6% of them belong to some association. Women participate more actively in associations in the Southern region (66%), while men participate more in the Central and Northern regions (58%).[12]

Small farms, in general, belong to families, a quarter of which are headed by women, although these constitute 52% of the total of the agricultural population. Half of this population is illiterate, and 97% have no more than a seventh-grade education. The vast majority of people involved in agricultural work in the so-called family or subsistence sector, with no pay (88%), while 12% are being paid but they have no basic training in agriculture.[13]

Families produce a variety of crops at the same time, occasionally practicing intercropping, but sometimes not. Almost 80% of families produce corn, 73% cassava, 20% rice, 29% sorghum, 13% large peanuts and 29% small peanuts. Most production is for consumption: only 22% of corn is sold, 11% for rice, 5% for sorghum, 25% for large peanuts and 23% for small peanuts. Families practicing crop cultivation for profit are relatively few: 7% for cotton, 3% for tobacco and 8% for sugar cane. Generally, families also grow various types of fruit trees.

Unemployment. Unemployment rates are higher in urban areas (31%) than in rural areas (13%), and are higher among women than among men, 36% and 26%, respectively, in urban areas, and 16% and 9% respectively, in rural areas (see Table 3). Most people in

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[9] Economically active population (EAP), is the entire working population that is 15 years old or older, working in the period of reference. (INE 2006).
[10] Of these farms, only a quarter are exploited by women.
[11] A small-scale farm is defined as one of less than 10 ha, among other criteria. Average-scale farms are between 10 and 50 ha and large scale farms have more than 50 ha.
[12] TIA 2005.
[13] MINAG 2006.

rural areas are engaged in agricultural activities, being either self-employed (66%) or family workers with no pay (30%) (INE 2006). However, revenues for people working in the fields (99% have small farms with less than 10 hectares)[14] are so low, that for the most part they would prefer to be employed if there were a possibility; in other words, they are among the disguised unemployed.[15]

Table 2: Unemployment Rates by General and National Definition, 2004/5

Unemployment Categories	Rural	Urban	Total
A: Actively looked for work	0.3	8.4	2.9
B: Did not actively look for work	1.0	12.6	4.7
A+B: International definition (ILO)	1.3	21.0	7.6
C: Employed in unsustainable situations	11.7	10.0	11.1
A+B+C: National definition	13.0	31.0	18.7

Source: INE (2006).

Overall, employment and underemployment are higher in the Northern region, followed by the Central region, and are lowest in the Southern region. Naturally, unemployment shows the reverse order. There is greater unemployment in the provinces with more developed urban centers, such as Nampula (population 39,171) Sofala (24,466) and Maputo (18,087).

Based on data from the Provincial Labor Departments (Direcções Provincias de Trabalho or DPTs), unemployment affects men to a greater degree than women, 83% and 17%, respectively. Moreover, these numbers conceal another issue: in general, women are less educated and usually carry out domestic work and, for this reason, are not reflected in data on workers. Furthermore, women are largely present in the informal sector, both when working on farms and in commercial activities, especially agricultural ones.

Given these conditions, the analysis presented in Chapter 6 illustrates how the development of a national biofuels program could contribute substantially to resolving the problem of rural unemployment. If implemented, it will increase agricultural production of some traditional crops and allow the introduction of new crops.

Poverty and distribution of income. Poverty in Mozambique is still mainly a rural problem. While the incidence of poverty is greater in rural areas (55%) than in urban areas (51%), the rate of poverty has declined more rapidly in rural areas than in the urban centers between 1996/1997 and 2002/2003.[16]

Inequality in income distribution is lower in rural areas, but the Gini coefficient remained stable between 1996/1997 and 2002/2003, while in urban areas it has increased. Overall,

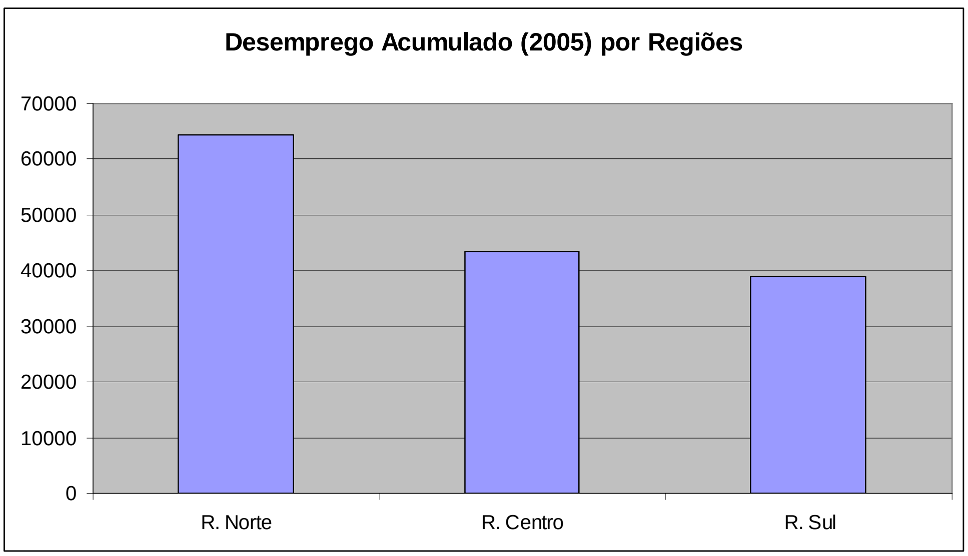
[14] Although the TIA defines a "small farm" as a farm of 10 hectares, the family farms in the area average less than one hectare, according to the PROAGRI data.
[15] Interviews conducted by the authors with several farmers, in almost all provinces of the country (excluding Niassa that was not visited for the present study)
[16] PARPA II

Table 3: Employment, Underemployment, and Unemployment by type and by region, in %

Category	Employment	Under-employment	Unemployment	
			A+B ILO Definition	A+B+C National Definition
North	78.0	14.2	4.4	16.6
Urban	60.4	14.2	16.5	29.4
Rural	84.1	14.2	0.6	12.7
Center	77.6	13.0	3.3	16.2
Urban	63.5	10.1	10.8	24.2
Rural	82.9	13.8	0.7	13.7
South	66.3	11.4	18.3	25.0
Urban	53.2	8.1	30.6	36.7
Rural	83.1	14.0	4.0	11.5

Legend: A: Actively looked for work; B: Did not actively look for work; C: Works but unsustainable.
Source: INE 2005.

Figure 9: Unemployment by Region



Source: INE (2006)

inequality is greater in the Southern region compared to the Central and Northern regions (See Table 4).

Conditions for the use of land and types of deals for production. The Constitution of the Republic of Mozambique stipulates that “the land is owned by the State and cannot be sold or by any other manner alienated, mortgaged or pledged” (Article 46). However, Law 19/97 provides that rights of use are granted to Mozambicans or foreigners “for purposes of economic activities for a maximum period of 50 years, renewable for an equal period of time.”

Table 4: Inequality of the Distribution by Geographic Area, 1996/97-2000/03

Area	Gini coefficient *	
	1996-97	2002-03
National	0.40	0.42
Rural	0.37	0.37
Urban	0.47	0.48
North	0.38	0.39
Center	0.37	0.39
South	0.43	0.47

* The Gini coefficient indicates the distribution of population in relation to income. A coefficient equal to zero represents a situation without inequality. Source: PARPA II.

For some crops, like cotton and tobacco, there is a system of concessions that mainly assigns a particular concessionaire the exclusive right to develop a particular crop in a given area. The development consists in providing farmers with agricultural inputs such as seeds, fertilizers, pesticides and, in some cases, tools. In exchange, the concessionaire purchases the products at a fixed, pre- determined price. The award of the concession is made with contracts signed between the Government and the concessionaire (dealer), and between the concessionaire (dealer) and the farmers.

This system has been the object of continued criticism since the colonial period. These critiques have focused in particular on farmers' weak bargaining power and on the use of fixed prices, which lead to a situation where farmers take all production risks, while concessionaires benefit from the possible rise in prices on the international markets. When market conditions are unfavorable, concessionaires renegotiate the purchase price with farmers. Moreover, the definition of product quality is often subjective, and farmers feel ill-treated when, during the sale process, traders claim that the product does not conform to standards of quality and, as a consequence, lower the selling price. The criticism reflects the discontent of the farmers, who often abandon the cultivation of the crop. In other cases, such as coconut, where producers do not abandon production because it is perennial, the question of product quality still represents an obstacle for the development and maintenance of production. As noted in detail below, some copra producers observe that family-scale farmers tend to ignore price signals for better-quality copra, and prefer to sell to another producer, or at a lower price.

At the same time, this system can also prove problematic for large-scale producers and investors. Traders are sometimes subject to dishonest practices on the part of some farmers who during the harvest sell to other traders who did not participate in the promotion scheme and, therefore, will pay more. These kinds of events have caused significant damage that ultimately leads to the abandonment of concessions.

In order for a scheme to achieve a greater growth to be viable, and for the initial investments of sponsors to be secure, a few pre-conditions must be ensured. The sponsorship for an agricultural product creates a local or regional market for certain agricultural goods. When this happens, a sponsor risks that the production in which he invested may be acquired by a competitor or intermediary, who will in turn resell it. In such case, a sponsor will not be able to recover inputs provided in advance to farmers, given that he loses the chance to deduct them from the price at the time of purchase. Furthermore, farmers have no incentive to sell to the investing company, given that they can obtain a better price from a third party that did not invest in the production stage, and therefore does not need to discount the price at the time of purchase. Without a mechanism to correct this, investment companies will continue to suffer financial losses.

This type of situation has occurred in Mozambique as well as in other countries. In Tanzania, in the early years after 2000, tobacco companies faced situations where sponsored farmers sold their production to competitors. When a company is caught in this process, it is very difficult for it to extricate itself, while other companies will try to limit their losses. The final result is a widespread loss as a result of companies buying from rival farmers and recovering very little from them. In the end, the three largest tobacco companies in Tanzania suffered significant financial losses, and one also had to leave the market. While farmers profited from this conflict, their profits were actually not very large, and they risked losing an important source of income because of the withdrawal of tobacco companies due to the lack of a fair solution.

The solution generally adopted in such situations is the creation of areas of influence, where private firms have exclusive rights to sponsor the cultivation of a specific area – that is, a system of concessions. Such system of concessions exists in Mozambique for tobacco and cotton. These cultivation concessions are defined at the district level, and are considered sufficient to create isolated markets strong enough to prevent external interference. Concessions are granted following an application filed with the DPA, and they are for specific crops. This means that different sponsors can work in overlapping areas as long as they work with different products.

It is important to note that investment companies are necessary because they are the only organizations willing to assume the risk of financing an agricultural enterprise. Without their resources, production cannot develop. If there were financial institutions willing to advance resources for production, or if farmers had the required resources, companies should not need to provide resources in advance, and could simply act as buyers of production. The separation of financing and market (purchases), if feasible, would reduce or even eliminate the need of a system of concessions.

It is possible that some farmers may be financially self-sufficient, or have the capacity to secure funding without the help of investors. In that case, they should have the right to decide to sell their production wherever they consider the best terms are offered. Since they are not sponsored by any particular company, there is no reason for them to use the concession system. The tobacco law makes such distinction between farmers, and protects independent producers who are not connected to any sponsor. In theory, all farmers should reach this stage. If they did not need sponsors, sale prices would be more competitive and would favor producers.

Concessions create local or regional monopolies that can be harmful to farmers, since they are forced to sell to a single buyer who may pay below-market prices. To mitigate investment companies' monopolistic power and reach a balanced solution acceptable to all parties, the concession system could be coupled with a price-setting mechanism.

Necessary Enforcements for Agriculture: To ensure a viable pattern growth and guarantee the safety of investors, some issues must be resolved. The following paragraphs discuss these issues.

- *Breach and enforcement of contracts.* There is a widespread belief in Mozambique that the judicial system is highly inefficient. Enforcement of contracts is difficult, especially in remote areas and specifically in situations where a company is dealing with literally thousands of contracts. In case of breach of contract by a farmer, it is unlikely that a company may have effective tools to secure compensation, which increases risk for companies. In the tobacco sector, a 10% rate of unrecovered credits is considered a reasonable parameter, but it is not uncommon for rates to reach 20% or more. When compared to equivalent indicators in the microfinance sector, however these values are extremely high (in microfinance, unrecovered credits generally range between 1% and 2%). This damage to investors could be offset by higher margins.

  The arbitrary revocation of concessions is another important risk for investors. Recently, a tobacco company operating in Mozambique lost an important concession, jeopardizing the viability of its entire operation. As a result, the company suspended all operations in the region, highlighting the risk of investing in countries where administrative decisions may jeopardize large investments, and illustrating the risk for the country of losing investors.

  Law enforcement and protection of investments are critical factors for investors. Despite the existence of a legal framework, however, there is a general perception that a concession title is of little value in terms of investment protection. The fact that concessions are awarded on a yearly basis increases the real weakness of the current system of concessions. These factors impede long-term investment and result in a clear barrier for further investments.

- *Price-setting system.* Because a concession system creates artificial markets to control competition, and introduces distortions in the free market, it is important to have an agreement on prices. For internationally traded goods such as tobacco or cotton, international prices will determine profit margins for all actors along the value chain from producer to processor, including intermediates. However small producers, however, find it difficult to understand that prices may change due to external factors with which they are not familiar. A farmer sees the local price as the factor that defines his profit. For a sponsor company, on the other hand, foreign markets determine profits. While international prices are volatile, the prices for producers tend to be rigid and increase continuously. In addition, prices for producers are generally expressed in the local currency, while international prices are expressed in foreign currency, for example U.S. dollars. The divergence of these variables, affecting both internal and international prices, creates serious disputes and leaves all players in a difficult position. Negotiations on the price are key to balance the distribution of wealth generated by a particular merchandise. Because local monopolies are created through the concession system, these negotiations are crucial for producers to ensure their profits.

- *Arbitrary acts and dispute resolution*. Legal mechanisms can be created to prevent and resolve disputes such as violations of concessions. Instead of relying completely on the legal system, which is considered to be too slow and ineffective, a committee could be formed to settle disputes between parties. For example, an association could be created to serve as a kind of discussion forum, and it could also include an arbitration mechanism. Another alternative could be the creation of a quota system by which sponsor companies could reach an agreement on the distribution of the final harvest. In Tanzania, tobacco companies established a board that is in charge of administering excess harvest. This joint venture distributes inputs, provides assistance to producers and delivers the output to its shareholders on a quota basis, according to their needs and to total production. This eliminates the incentive for generalized competition for production, and establishes a common basis for price margins and legal settlements.

- *Adequate size of concession.* There is debate on whether the District [as an administrative] division is the appropriate level for concessions. In the biofuel industry, the minimum scale for industrial processing may require large amounts of agricultural output that, in turn, require thousands of hectares of land. Since in a concession area different products must coexist, major concessions may be necessary for industrial investments to be viable.

- *Concession system for a single product versus multiple products.* Competition for farmers and the production could result from the promotion of different products, not just a single one. Sponsors for cotton, tobacco and paprika compete among themselves for the increase in their own concessions, possibly in overlapping areas. On the one hand, this will mitigate the monopoly power of the sponsors, since farmers can choose to grow alternative products, but, on the other hand, it will prevent the sponsors from investing in the area where they see their agricultural bases reduced due to changes in other crops. Because inputs are to some extent similar, there is also the risk that farmers may use fertilizers (or other inputs) purchased from a competitor, which frequently increases the risk of diversion.

  The multi-crop system may alternate this problem, but it is not easily implemented. Investors generally focus on single crops and have no interest in investing in different businesses (technology, markets, crops).

- *Commercial agriculture versus a system of surpluses*. Commercial farming in Mozambique is rare, and accounts for a small part of agricultural production. With the exception of a limited number of products, such as sugar, tea and bananas, most of the production is done in small scale or based on the system of promotions. Despite this, a commercial agricultural system would adjust better to the products for biofuels, providing greater efficiency and lower costs. At the same time, there should be room for a concession system to create opportunities for the surplus.

2. Land-use patterns and agro-ecological regions of Mozambique

Patterns of land use

Mozambique’s territory covers a total surface of 79 million hectares (ha), of which one million are inland waters and 78 million ha are land (INE 2000). Of this area, 36 million ha are considered cultivable, while the remaining 42 million ha are covered with forests (20.3%), or are not appropriate for agriculture (19.5%), or are national parks or conservation areas (12.6%), or urban areas (0.9%). Of the 36 million ha of arable land, only 5 million ha are effectively used for production, corresponding to 13.8% of the cultivatable land and 6.3% of the total area of the country.

The use of land for agriculture by province is presented in Table 5. A complete presentation of land use in Mozambique appears in Table 6. The CENACARTA maps included in Annex B show the type and quality of the soil (Annex B.1), current coverage of the land (Annex B.2), agricultural patterns (Annex B.3) and areas designated as reserves and national parks (Annex B.4).

Analyzing such data, the importance and substantial potential of the northern part of the country, specifically the provinces of Zambézia, Nampula, Cabo Delgado and Niassa, is evident. Moreover, the presence of substantial areas in the provinces of Maputo, Gaza and Cabo Delgado that were cultivated in the past and now are considered as “previously cultivated” (see Annex B.3) suggests that these areas could potentially return to cultivation without major changes in the land use, and presumably without significant environmental impacts such as those that occur when preparing more natural land cultivation.

There is no official estimate of the availability of land for increased production or for the introduction of new crops. Difficulties facing these calculations mainly relate to problems of information. First, official estimates of land use do not include the use of land without title (*titulo de terra*), as may happen based on standards and customary practices provided by law (Article 12 of the Land Law), such as illegal occupation or displacement due to

Table 5: Distribution of arable land by province

Province	% Arable	Province	% Arable
Maputo	16.7%	Tete	8.9%
Gaza	7.4%	Nampula	23.4%
Inhambane	14.2%	Cabo Delgado	8.8%
Manica	8.3%	Niassa	6.0%
Sofala	9.6%		
Zambézia	26.2%	**Country Total**	**12.8%**

Source: JVA Cenacarta-IGN France International (1999).

the war. Fully 94% of the farmers interviewed by TIA (2005) did not have a title to their farms, 4% did not know if they had it, and only 2% did have it. Of those who had no title, 7% received the land from traditional authorities, 39% simply occupied the land, 23% inherited it, 18% were given it by relatives, 5% bought the land without a title and the rest leased it.

Furthermore, the agro-ecological map of Mozambique shows the potential suitability of the various areas in accordance with soil and climate characteristics but does not identify the potential in terms of crops.[17] Different crops may be suitable in each agro-ecological area, and they either can compete with one another or be grown concurrently.

Finally, there is no estimate of areas that are actually used – nor a forecast of how these will evolve – at the family or community level, for various activities such as agriculture, and some of which may be itinerant, and livestock breeding.

For the purpose of making a preliminary estimate of the area where new crops could be developed, the following reasoning may be considered. Of the 36 million ha of arable land, 9 million are considered of no use due to conditions of topography, climate, hydrology and soil structure conditions, such as steep slopes of mountains, areas with high levels of erosion, or soil with high salt content. Therefore, land that is actually cultivable and viable amounts to 27 million hectares[18] (MADER 1997). Out of this area, 5 million ha are currently cultivated, from a total of 8 million that were once used for

Table 6: Patterns of land use in Mozambique

Description	Area (ha)	%	Description	Area (ha)	%
Non-irrigated cultivated land	4,956,275	6.35	Degraded grasslands subject to flooding	99,792	0.13
Irrigated cultivated land	100,617	0.13	Grasslands	4,061,679	5.21
Plantations	45,311	0.06	Shrubs (low bushes)	2,965,473	3.80
Areas of maintained vegetation	80	0.00	Medium forest	3,753,818	4.81
Urbanized residential areas	6,726	0.01	Dense forest	608,139	0.78
Semi-urbanized residential areas	21,067	0.03	Open jungle (mixed forest)	17,169,388	22.01
Non-urbanized residential areas	34,820	0.04	Grassland with trees	18,962,644	24.31
Production and transport areas	7,485	0.01	Grassland with emerging trees	143,930	0.18
Salt Flats	1,709	0.00	Low altitude open forest	19,979,262	25.61
Soil without vegetation	949,492	1.22	Low altitude closed forest	842,191	1.08
Grasslands subject to flooding	1,887,074	2.42	Evergreen forest	31,936	0.04
Flooded grasslands	523,631	0.67	Continental waters	456,723	0.59
Mangroves (locally degraded)	397,854	0.51	**Total**	**78,007,116**	**100.0**

Source: JVA Cenacarta-IGN France International (1999).

[17] http://www.minag.gov.mz/ (visited on May 24, 2007). There is also a document by Kassam et al (1982) that describes potential areas for some products like cassava and peanuts, but it does not address the issue of overlapping nor does it cover all feedstocks considered in this study.
[18] From the climatic point of view, about 2.6 million ha are high risk, that means that there is a 40% to 70% chance to lose the harvest; 4.5 million ha are at moderate risk, there is a 20-40% chance to lose the harvest; and 20.3 million ha are at low risk, which corresponds to less than a 20% chance to lose the harvest. The various levels of climatic risk in different regions of the country determine the need to research about adequate crops for the production of bio-fuels. (MADER 1997, 2000).

agriculture[19] (CENACARTA 1999). So, it may be estimated that 19 million ha would be available for the expansion of existing crops or the introduction of new crops.

However, the consultant team believes that a more detailed study must be carried out for a better estimate of area available. The study should consider, for example, the possibility of pasture activities, small-scale forestry (cashew nut and fruit trees, among others), and the need for area reserve for population growth. Assuming, for example, an area of 4–5 ha for each family, 3.3 million families would require between 13.2 and 16.5 million ha that should be subtracted from the total of 27 million ha. In this case, the available area would be between 13.2 and 10.5 million ha. This estimate, however, would not include plantations, agriculture and its expansion. The use of this land for the introduction of biofuels would require a significant political commitment on the part of the State.

A more recent study undertaken by the IIAM, which addresses the suitability of land and their current use, arrives at similar conclusions regarding the availability of land for new crops. It presents two scenarios, which are presented in Table 7.

Table 7: Senarios for future land-use patterns, all uses

Land-use category	**Scenario 1 (ha)**	**Scenario 2 (ha)**
Agriculture	2,347,600	1,343,200
Agriculture/Forest plantations	2,442,400	729,200
Agriculture/Forest plantations/Pasture	3,052,400	985,200
Agriculture/Pasture	4,644,000	3,424,000
Forest plantations	1,001,200	228,800
Pasture	2,695,200	2,519,200
Limited use (maginal areas)	2,803,600	2,787,200
Total	**18,986,400**	**12,016,800**

Source: Calisto Bias, IIAM (2008).

The IIAM supports the second scenario more than the first because it forecasts an expansion in the lands currently occupied by farmers, particularly the family sector. Irrespective of which scenario applies, if the areas unsuitable specifically for agriculture are excluded, that is, those areas more suited to plantations, grazing and marginal lands, the available surface area would be approximately 12.5 million hectares in Scenario 1 and 6.5 million hectares in Scenario 2 (see Table 8).

It is important to note that, excluding the first line, the rest of the lines indicate a combination of types of suitability, including agriculture, forest plantations and pastures. This means that the uses to which these lands are put depend a great deal on government policy. This could also be true for the land identified as being dedicated to forest plantations, which again would depend on the commitment of the government to implement a biofuels program.

[19]These areas can be used again. See Annex B.3.

Table 8: Estimate of lands available for expansion of productions

Land use categories	*Scenario 1 (ha)*	*Scenario 2 (ha)*
Agriculture	2,347,600	1,343,200
Agriculture/Forest plantations	2,442,400	729,200
Agriculture/ Forest plantations	3,052,400	985,200
Agriculture/Pasture	4,644,000	3,424,000
Total	12,486,400	6,481,600

Source: Fonte: Calisto Bias, IIAM (2008).

In its presentation of the study, the IIAM put aside the principle of using only marginal lands for the production of biofuels.

Agro-ecological areas of Mozambique

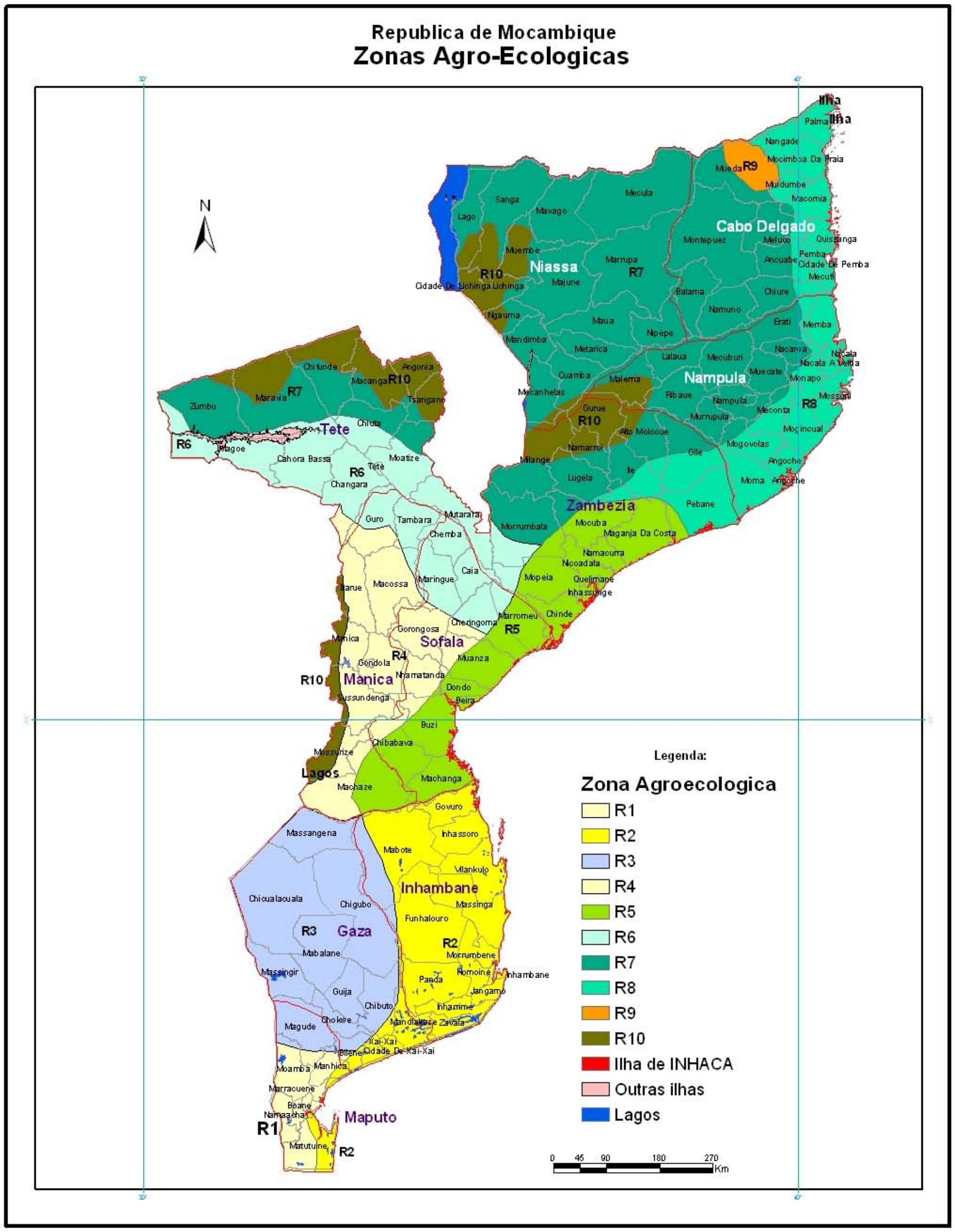
Mozambique is usually divided into ten agro-ecological areas, according to Table 9 and the map in Figure 10.

Table 9: Description of Agro-Ecological Areas

Agro-Ecological area		**Rainfall mm/year**	**Type of Soil**	**% of rural house-holds**	**% of cultivated area**
Area	**Name**				
R1	Semi-arid Inland South	570	Sandy	2%	2%
R2	Semi-arid Coastal South	500-600	Deep Sands	12%	11%
R3	Arid Inland South	400-600	Mud-clay	3%	4%
R4	Mid-elevation Central	1000-1200	Argillaceous	6%	8%
R5	Coastal Central	1000-1400	Vertisols and fluvisols	14%	13%
R6	Semi-arid dry: Zambézia and Tete	500-800	Sandy- Argillaceous	8%	11%
R7	Inland Central and North	1000-1400	Sandy-Argillaceous	23%	21%
R8	Coastal North	800-1200	Mainly sandy, small-scale argillaceous	21%	18%
R9	Inland North of Cabo Delgado	1000-1200	Limes and sands	1%	1%
R10	High altitude	>1200	Hard ferrasols	10%	11%
				100%	100%

Source: IIAM (2006)

Figure 10: Agro-ecological areas of Mozambique



Source: Kassam at al. (1982)

Region 1, designated as *Maputo Inland and Southern Gaza*, is characterized by soils of alluvial and basaltic origins, usually flat, of medium texture, with average to good fertility. Fertile soils are suitable for cultivation of crops such as corn, cassava and peanuts, among others. Among the perennial crops, cashew, mafurra and citrus stand out. The annual rainfall reaches 570 mm, irregular, with a rainy season from November to March. The type of soil is generally sandy, not suitable for cultivation without irrigation, with the exception of the valleys of the Incomati and Sabie rivers and their tributaries. Close to 2% of family households are located in this area, with an equal share of total cultivated area.

Region 2, *Southern Coast of Rio Save,* is an extensive area that goes from the south of the Maputo province to the north of Inhambane. It has one of the highest population densities in the country. Most of this region is characterized by a hot and rainy season from November to March. With the exception of alluvial lands and certain small areas, the soils have a sandy texture. The most important annual crops, among others, are corn, cassava and peanuts. Because land in the region is scarce there is a tendency to grow different crops concurrently. The region contains about 12% of family households, and covers nearly 11% of the cultivated area in the country.

Region 3, *Center and North of Gaza and West Inhambane*, is a vast area with a relatively small population. It is one of the many areas in the country with an annual rainfall of 400-600 mm, concentrated in the months of November and February. Because of the lack of moisture, its population typically cultivates sorghum and mexoeira. This region is the country's largest irrigated area: the irrigation of Chokwe has 20,000 ha of irrigated land, half of which is occupied by small farms of less than 4 ha each. 3% of the existing households in this area cultivate about 4% of the total area.

Region 4, *Medium Altitude in Center Mozambique,* includes areas between 200 m and 1000 m above sea level, located in the provinces of Sofala and Manica. It has an annual rainfall of 1,000-1,200 mm, concentrated in the months from November to March. Most soils are light, although there are some heavy soils. Predominant crops are corn, sorghum and cassava. The land has great potential for cotton production. The population density is medium to high. Some 6% of the population living in this area accounts for 8% of the total cultivated area.

Region 5, *Low Altitude Sofala and Zambézia*, has sandy soils in general, alternating with areas with heavy texture (fluviosoils and vertisoils). Annual rainfall is between 1,000 and 1,400 mm. The rainy season starts in November and continues until March-May, depending on the location. Inhabitants of this region cultivate different products, among them corn, sorghum, mexoeira cereal, cassava and cotton. The region includes 14% of family households who cultivate 13% of the total of the national cultivated area.

Region 6, *Semi-Arid Zambeze Valley and Southern Tete Province*, consists of a large area extending from the dry areas of Zambeze (district of Mopeia) to the limit with Zambia. Altitude in most areas does not exceed 200m and rainfall ranges from of 500-800 mm between the months of November and March. The predominant crops are sorghum and mexoeira cereal. Cassava is not grown because of the complete lack of rain during the cold season, and the high rate of evapo-transpiration. This region also includes areas with considerable potential for cotton production. Some 8% of the households of the area cover 11% of the total national cultivated area.

Region 7, *Medium-Altitude Zambézia, Nampula, Tete, Niassa and Cabo-Delgado*, is a vast area that includes high altitude lands between 200 and 1,000 m (low and medium altiplano). Annual rainfall amounts to 1,000-1,400 mm and the texture of the soils varies from sandy to largely composed of clay. Inhabitants of the region mostly grow corn and sorghum, and cassava and peanuts are also produced. The region has a great potential for the production of cotton. It is the area with the greatest concentration of households (23%), contributing with the greatest part to total national cultivated land (21%).

Region 8, *Coastal Zambezia, Nampula and Cabo-Delgado*, include areas from Zambézia to Cabo Delgado, with mostly sandy and clay-like soils, and a predominant production of cassava and mexoeira cereal. It has a yearly rainfall of 1,000-1,200 mm and includes 21% of the country's households and covers 18% of the national cultivated area.

Region 9, *Mueda Plateau and Inland Area of Cabo-Delgado*, include the plateau of Mueda and Macomia, and areas at more than 200 m. Annual rainfall is 1,000-1,200 mm, with rains concentrated between December and March. Rains are usually regular. Soils have a muddy sandy texture, and some of them are heavy. The predominant crop is corn. Sorghum, cassava and sunflower are also extensively cultivated. This region only contains 1% of households and covers 1% of the cultivated area.

Region 10, *High Altitude Zambézia, Niassa, Angónia and Manica*, includes land above 1,000 meters, particularly in the plateaus of Lichinga, Angónia, Maravia, high Zambézia, Serra Choa, Manica and Espungabera. The annual rainfall amounts to more than 1,200 mm. The types of soils are predominantly ferrasoils of heavy texture. Corn is the predominant crop, while mexoeira is also important. The region covers a cultivated area of 11% of the national total, and represents 10% of the country's households.

Irrigation Systems

The risk of losing the harvest in dry areas with no irrigation exceeds 50% in the region south of the River Save, and reaches over 75% in the Gaza province. The central and northern regions are, in general, more favorable for agriculture with no irrigation, given that the risk of losing harvest in such regions decreases to levels between 5% and 30%. Farmers, in general, do not use any type of irrigation (96.4%). Those who do, make use of the following irrigation systems: gravity (12.8%), manual irrigation (81.1%), mechanical pumps (5.6%) and foot pumps (0.5%).[20]

The most important infrastructure for agriculture is therefore related to water management, such as irrigation systems. It is estimated that 120,000 ha of land (3.3% of the potential area) are equipped for irrigation, but only 35,000 ha (about 0.1% of the

[20] MINAG 2006.

potential area) of it are in production. Irrigation systems are classified, according to their size in three categories (A, B and C) as shown in Table 10.

Irrigated lands are concentrated: 75% are found in the Maputo and Gaza provinces, 22% in Sofala and Zambézia, and just 3% are located in other provinces. About half of the questioned irrigated areas are used for sugar plantations. Table 10 shows the percentage of distribution of the irrigation by class.

Table 10: Irrigation in Mozambique per class and operation

Class	Equipped (ha)	Working (ha)	Used (%)
A (<50 ha)	6,490	2,862	44.1%
B (50-500 ha)	19,960	4,089	20.5%
C (>500 ha)	93,550	28,049	30.0%
Total	120,000	35,000	29.2%

Legend: (A) Equipped: total area with infrastructures, includes working and non-working area; (B) Working: area in working condition but in need of small repairs for its recovery; (C) Used: area fully used at the time of survey. Source: Direcção Nacional de Hidráulica Agrícola/ Fundo Nacional de Hidráulica Agrícola, "Levantamento Nacional dos sistemas de Irrigação" (2002)

The vast majority of the irrigation systems were constructed during the colonial era, although significant efforts have been made after independence. The combination of low rains, existence of commercial agriculture –including the production of sugarcane – existence of rivers, existence of agro-industry and existence of a market explain a greater concentration of irrigation systems in the South.

- Class C irrigation systems basically include the sugar cane plantations in Sofala and irrigation in Chokwe and Xai-Xai in Gaza. In Maputo, in addition to the sugarcane plantation in Xinavane and Maragra, there are irrigation systems in Sabie, Magude and Moamba and other large isolated blocks in different districts, such as Matutuine. These irrigation systems were areas occupied by large state companies after independence.
- Class B irrigation systems are concentrated in the South (more than half) and cover profitable crops such as the production of rice, fruits and vegetables.
- Class A irrigation systems are concentrated in the province of Maputo (three quarters), and consist of small systems along the Limpopo, Incomati and Umbeluzi rivers beyond the green areas surrounding the city of Maputo.

Given limitations in water management infrastructure, agricultural production depends on rainfall, in a situation where cycles of periodic droughts and floods are typical for the country's major rivers. The lack of infrastructure is worsened by the fact that around 60% of the water surface (the main source for irrigated agriculture) comes from international rivers.

Precipitation patterns. The climate of Mozambique is predominantly semi-arid, with 80% of the land area classified as tropical semi-arid, and 15% as sub-humid. The extreme zones –both arid and humid –represent 2% and 3% respectively of the country's total area. The average annual rainfall ranges from 800 mm to 1,400 mm in the northern region, and from 600 mm to 800 mm in the southern region. The average annual amount of potential evapo-transpiration is 1,280 mm. The regions with the greatest deficit of water are in the South of the River Save, in the northern part of the Manica province, and in the South of the province of Tete. Monthly rainfall in the provincial capitals is shown in Table 12.

Table 11: Irrigation in Mozambique per class and province

Class/Province	A (<50 ha)	B (50-500 ha)	C (>500 ha)
Cabo Delgado	1%	0%	0%
Niassa	0%	0%	0%
Nampula	5%	10%	0%
Zambézia	2%	14%	1%
Sofala	2%	0%	43%
Manica	8%	16%	0%
Tete	8%	4%	0%
Inhambane	1%	3%	0%
Gaza	1%	13%	25%
Maputo	74%	39%	31%
Country	**100%**	**100%**	**100%**

Source: DNHA/FNHA, 2002

Table 12: Monthly average rainfall measured at provincial capitals (in mm)

City	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*
Maputo	40.0	51.6	76.3	80.7	82.5	92.9	133.5	72.9	30.9	71.7	37.9
Xai-Xai	77.1	63.5	83.9	78.8	73.0	101.3	163.6	102.5	63.9	74.8	76.6
Inhambane	84.9	63.2	67.3	74.6	88.6	102.8	131.9	113.4	41.8	70.4	40.3
Beira	84.8	169.4	129.3	131.5	148.2	141.2	109.6	159.5	97.0	125.1	139.1
Chimoio	69.5	65.4	95.4	144.4	91.8	95.9	105.5	128.2	55.3	66.5	45.7
Tete	48.5	45.8	90.0	53.7	52.7	62.0	110.1	24.8	92.3	71.9	45.4
Quelimane	123.5	151.8	124.6	117.6	122.3	149.0	142.1	78.0	154.5	98.9	93.5
Nampula	87.6	98.7	96.9	88.2	104.2	105.6	86.7	117.7	150.0	107.1	72.1
Pemba	63.2	77.6	61.2	64.3	72.4	85.9	104.3	64.1	74.7	57.9	44.9
Lichinga	57.9	70.7	81.3	106.1	70.0	131.0	109.5	90.2	119.8	94.7	90.5

Source: INE (2006)

As shown in Table 12, rainfall in central and northern areas is above the national average during the rainy season, although the northern area enjoys a lower level of rainfall than the national average during the dry season. The southern region scores the lowest level of rainfall compared to the national average in the rainy season and the highest in the dry season, displaying lower variation over the year. Average monthly rainfall per province is shown in Annex C together with a map of the country's river system, which illustrates the relative lack of water resources in the South of the country, particularly in the province of Inhambane.

Implications of future water infrastructure development. In a recent assessment of the World Bank's assistance strategy for Mozambique's water resource sector,[21] it is evident that the country's economic growth and poverty alleviation objectives are closely tied to the reliability of water supplies for agriculture as well as industrial and residential requirements. Although Mozambique is not classified as a water-scarce country, it does face significant vulnerabilities with respect to water resources because of the following factors: (i) over 50% of the estimated 216 km3/year in total runoff is generated outside the country in the upper riparian nations of South Africa, Swaziland, Zimbabwe and Malawi, or shared, as with the Rovuma River, which marks the border with Tanzania; (ii) significant hydrological and climatic variability, which manifests itself in dramatic swings intra-annually, as noted previously, as well as year to year; (iii) particular vulnerability to "water shocks," especially drought, in the Southern region, which is much drier than the Central and Northern regions; (iv) limited water diversion and storage infrastructure to manage available resources adequately. The Bank's analysis suggests that GDP growth decreases an average of 5.6% during a water shock, and these occur once every five years, on average.

As noted in this Section, the vast majority of agricultural production involves subsistence farming on rain-fed lands, a major factor in the persistence of rural poverty in the country. The report notes that investments in irrigation to convert existing rain-fed areas to irrigated production would yield increases in agricultural productivity of two to four times, while increases in overall productivity would be somewhat less in the creation of new irrigated areas. Overall, conversion of 5% of suitable agricultural land to irrigation would generate a 15% increase in economic activity in those areas.[22] The report recommends a two-pronged strategy of supporting small-scale hydraulic structures to benefit small-holders, who among the most vulnerable to existing resource variability, while at the same time supporting commercial farming, with particular focus on the Maputo, Beira-Chimoio and Zambezi corridors.

Of particular importance for the development of biofuels in Mozambique, however, is the report's assessment that planned hydraulic infrastructure improvements in the Southern region should not be used to support significant expansion of irrigated agriculture in that region because of anticipated demand for water by residential and industrial users. A report addressing the water resource situation in the South,[23] completed in conjunction with the assessment of the assistance strategy, stresses the need for two projects, in particular: (i) completion of the Corumana Dam (costing about USD 81 million), which is currently operating at below full potential, in time to meet projected shortages in Maputo in 2011-12; and (ii) construction of the USD-300 million Moamba Major Dam, which could be implemented with or without a small hydropower facility, depending on budget conditions. Already, approval has been given to expansion of sugarcane planting at the

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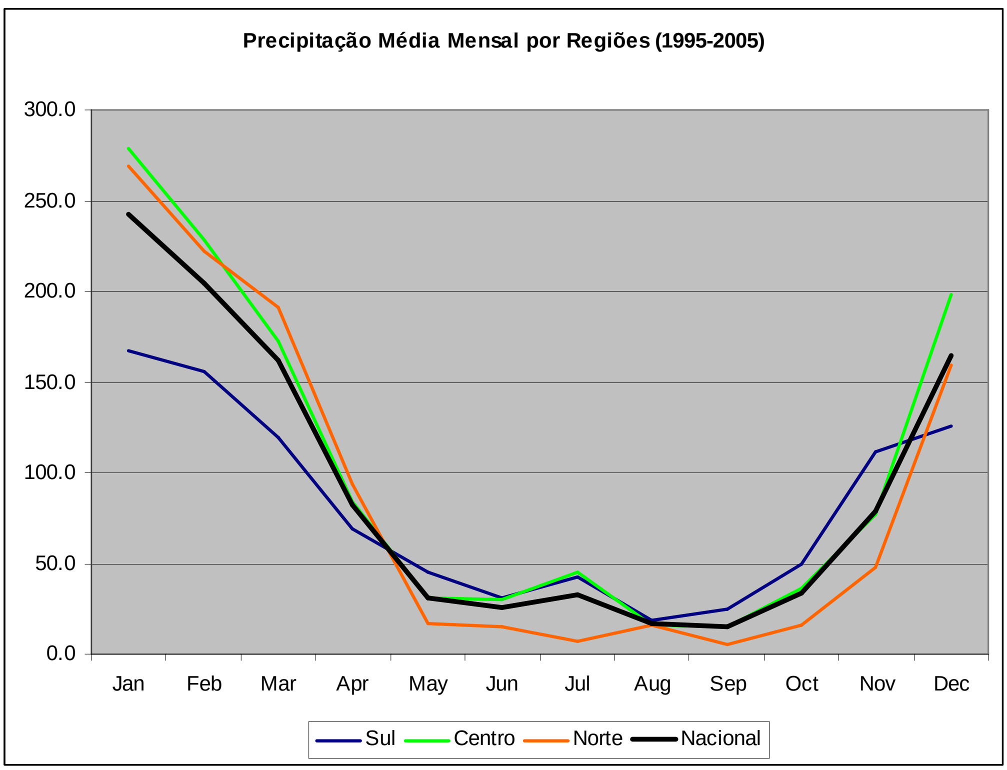
[21] World Bank, AFTWR (Africa Region), "Mozambique country water resources assistance strategy: making water work for sustainable growth and poverty reduction," August, 2007.
[22] Ibid., page 15.
[23] Annex II to the World Bank AFTWR document, entitled "Preliminary economic analysis of Maputo bulk water source development," July, 2007.

Xinavane mill, and other projects under development include sugarcane expansion by COFAMOSA and Maragra, which could add twice the surface area planned by Xinavane, for a total addition of about 20,000 ha. At this time, however, the withdrawals for existing use are not metered, creating uncertainty about the ability of the existing and proposed water storage facilities to support the agricultural requirements. Accordingly, the report recommends that no further authorizations be given until withdrawals are adequately metered. Moreover, because the Corumana and Moamba Major projects would generate surpluses in excess of Maputo's requirements for a relatively limited time, the study also recommends that "any permanent allocation for irrigation of the additional water made upgrading the Corumana should not be permitted."[24]

The implication of these findings for a national biofuels program is that it is desirable to foster growth in production of biofuels feedstocks in the comparatively wetter Central and Northern regions of the country, as opposed to the South. While some development in the South is already inevitable, and could provide the basis for initial deliveries of ethanol for blending into gasoline for use in the Maputo market, which accounts for the bulk of consumption in the country, it is advisable that the government avoid any further expansion of sugarcane cultivation in the South.

Figure 11: Average monthly precipitation per region (1995-2005)



Source: Designed based on INE (2006)

[24] Ibid., page 25.

Implications of estimated impacts of climate change induced by global warming. The scientific evidence that climate change is occurring due to the build-up of greenhouse gases in the atmosphere has become clearer in the last decade, documented in particular by the work of the Intergovernmental Panel on Climate Change (IPCC). Of particular importance to developing countries such as Mozambique are the projections that climate change will have an impact not only on surface temperatures but also rainfall patterns and frequency of extreme events. While the research summarized in the IPCC's Fourth Assessment Report (2007)[25] suggests a mixed forecast for Mozambique: increased rainfall in the Northern part of the country combined with drier conditions in the Central and Southern regions. Specifically, the average results of global climate models reviewed in the Fourth Assessment point to increased temperatures in the central areas of Southern Africa, with lesser increases along the southeastern coast of the continent. At the same time, however, Equatorial Africa is expected to record increased rainfall patterns, some of which would be anticipated to have an impact on the northeastern regions of Mozambique, specifically Nampula and Cabo Delgado provinces. The models predict drier conditions in the Central and Southern regions of the country.[26]

The implications of these projected trends for Mozambique must be gleaned from more generalized assessments for the Southern Africa region or the continent as a whole. Among the more relevant impacts noted in the second part of the Fourth Assessment, the authors of the chapter on Africa[27] include:

- Africa is among the most vulnerable regions to the effects of climate change because of 'multiple stresses' and generally low adaptive capacity;
- Yields and net crop revenues from agricultural activities could drop significantly in semi-arid areas of the continent;
- Water stresses will worsen in areas that already suffer from water scarcity, and areas that do not currently suffer from water scarcity may experience water stresses;
- Ecosystem impacts are already noticeable and are likely to accelerate;
- Flooding is likely in low-lying areas;
- Ecological change will lead to shifts in disease vectors, resulting in more widespread exposure to infectious diseases.

These results broadly support the rationale behind a recommendation to promote biofuels feedstock production in the Central and Northern regions as opposed to the South, since any negative impact on rainfall patterns would tend to have a greater impact in the already semi-arid South, and any positive impact on rainfall is more likely to occur in the Northern region.

[25] IPCC, UNEP and WMO, *Climate Change 2007: the physical science basis* (Working Group I contribution to the Fourth Assessment Report (New York: Cambridge University Press, 2007).
[26] Ibid., particularly Figures 11.2 and 11.3, pages 869-870.
[27] IPCC, UNEP and WMO, *Climate Change 2007: impacts, adaptation and vulnerability* (Working Group II contribution to the Fourth Assessment Report (New York: Cambridge University Press, 2007): page 435.

3. Edible oil industry in Mozambique

The domestic oilseeds industry is composed of small- and medium-sized companies whose production is monitored by the government through the Ministry of Industry and Commerce (MIC), and micro-enterprises that use manual presses, outside of the oversight by MIC. The micro-enterprises are generally promoted by NGOs and the greatest number are located in the Northern region.[28]

The refined oil production facilities registered with MIC appear in Table 13. Total capacity for processing oilseeds is about 985 tons/day. The average extraction efficiency is about 41%. Half of this capacity is located in the Northern region, 42% in the Southern region and 8% in the Central region.

Domestic production of oils reached a volume of 22,500 tons in 2006 and has posted rapid growth in the last three years: 6% in 2004, 31% in 2005 and 26% in 2006 relative to the moving average.

Costs of oilseed processing

Production of raw oil. In Mozambique, raw oil is produced from several different oilseeds, using two processing technologies: (i) using manual presses for human consumption with a production cost estimated at about 2 Mt/kg, using primarily sunflower (Sofala, Nampula, Niassa, Cabo Delgado, Tete and Manica) with high loss rates (extraction from 10% to 20% or 30%), leaving about 20% of the oil in the presscake; (ii) through the medium-sized companies, in which case several raw materials are used, including copra and cotton (G.S. Holding [Nacala] of Grupo Samaria, C.I. Monapo, and Sanoil).

In general, refined oil is processed from the raw cottonseed oil. Raw coconut oil has two markets in Mozambique: the domestic soap industry (Ginwala) or export (Geralco and Somoil), primarily to South Africa for the cosmetics industry. A sample of the production costs for raw oil appears in Table 14.

In the calculation of the costs, a 10% loss ratio was adopted for the seed, that is 90% of the seed purchased is actually processed. From the seed, an oil extraction rate of 52% was used, corresponding to 46.8 tons (out of 100 tons of seed purchased) and 28% presscake, corresponding to 25.2 tons. The price of the raw oil in the market is USD 750/ton and USD 90/ton for the presscake.

The direct variable costs are based on the raw material, which in the case of copra has an estimated price of about 5,500 Mt/kg.

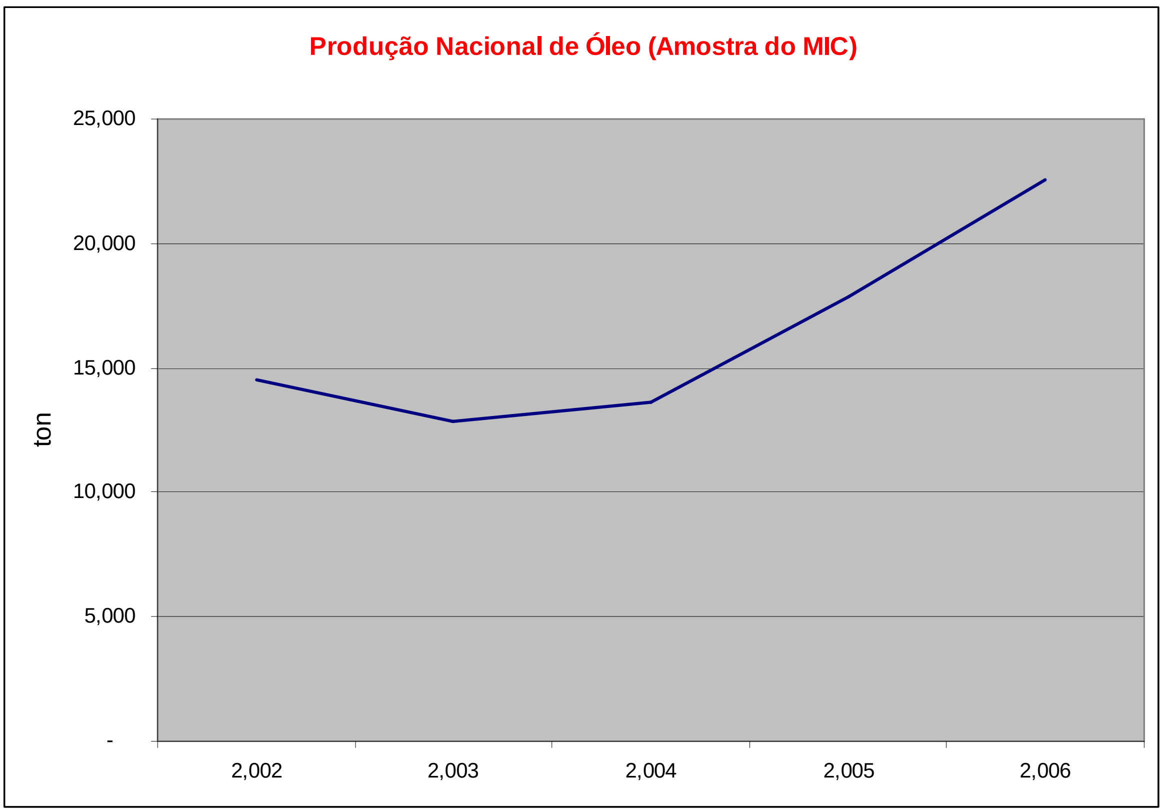
[28] There are no statistics on manual press oil extraction businesses in the country. However, the NGOs that support agricultural markets are primarily active in the Northern region (45%), Central region (36%) and the South (19%). Source: Cardoso Muendane, "Options for the New Market Linkage Program," PAMA, 2007.

Table 13: Existing oil production facilities

Company	Location	Region	Capacity (t/day)	Utilization
Fasol	Matola	Sul	150	30%
Ginwala	Maputo	Sul	25	90%
G.S. Holding	Nacala/Nampula	Norte	300	55%
Southern Refineries	Matola	Sul	200	30%
Sanoil	Namialo/Nampula	Norte	150	30%
C.I. Monapo	Monapo/Nampula	Norte	40	30%
Somoil	Inhambane	Sul	40	20%
Alif. Química	Quelimane	Centro	80	60%
Total			985	41%

Fonte: Interview with Dr. Muchine, Associação Moçambicana de Produtos Oleaginosos e Afins.

Figure 12: Oil production in Mozambique, 2002-2005 (tons/year)



Source: MIC.

Table 14: Extraction costs for coconut oil

Description	Value (Mt/t)	%
Sales	**990,252**	**100%**
Raw copra oil	930,150	**94%**
Copra bagasse	60,102	**6%**
Direct variable costs	**550,000**	**56%**
Gross margin	**440,252**	**44%**
Other costs	**311,929**	**32%**
Net margin	**128,323**	**13%**

Source: Ginwala (2007).

The other costs include maintenance and repairs (about 5.5% of sales), salaries for labor and rent (both about 5%), fuel and lubricants (3%), water and energy, communications and transportation (2% each) and other inputs. Table 14 shows a detailed cost structures.

Production of refined oil. Refined edible oil is obtained from raw oil produced from oilseeds such as sunflower and cotton (partly of domestic production) and palm oil (all of which is imported. The coconut oil is not used in foodstuffs because it has a very high melting point and it solidifies in cookware, which gives it a disagreeable appearance. People also say that it has a strange taste. Imports of raw material (raw oil) are observed due to the lack of domestic supplies. The imports of raw oil come primarily from Malaysia, Singapore, the U.S., Argentina and South Africa. A sample structure of prices for imported oil is shown in Table 15.

Domestic demand for edible oils is about 30,000 to 45,000 tons/year, but it is difficult to estimate with greater precision because of contraband. Therefore, given domestic production of about 22,500 tons, there is a deficit of about 10,000 to 25,000 tons, which is covered by donations, irregular imports (including contraband, dumping and other activities that affect the regular functioning of the market) and legal imports.

The oil industry is showing rapid growth, based in part on investments of more than USD 20 million in the last five years by the following companies: Fasorel, Sadan Refiners, GS Holding and Sanoil.

Imports and exports of oilseeds. Both imports as well as exports have shown substantial growth in the last three years, which shows the rapid change in the sector.

About 60% of oilseed imports are provided by palm oil and 13% by soy oil. Exports include primarily peanut, coconut oil and other oilseeds (a graphic of import and export trends appears in Figure 13).

Biodiesel industry in Mozambique. There is already an embryonic biodiesel sector in Mozambique, in the provinces of Zambêzia and Inhambane, all using coconut oil as a feedstock. The plants in Mozambique cannot sell the product yet, and are limited to

Table 15: Structure of sales price for imported vegetable oil

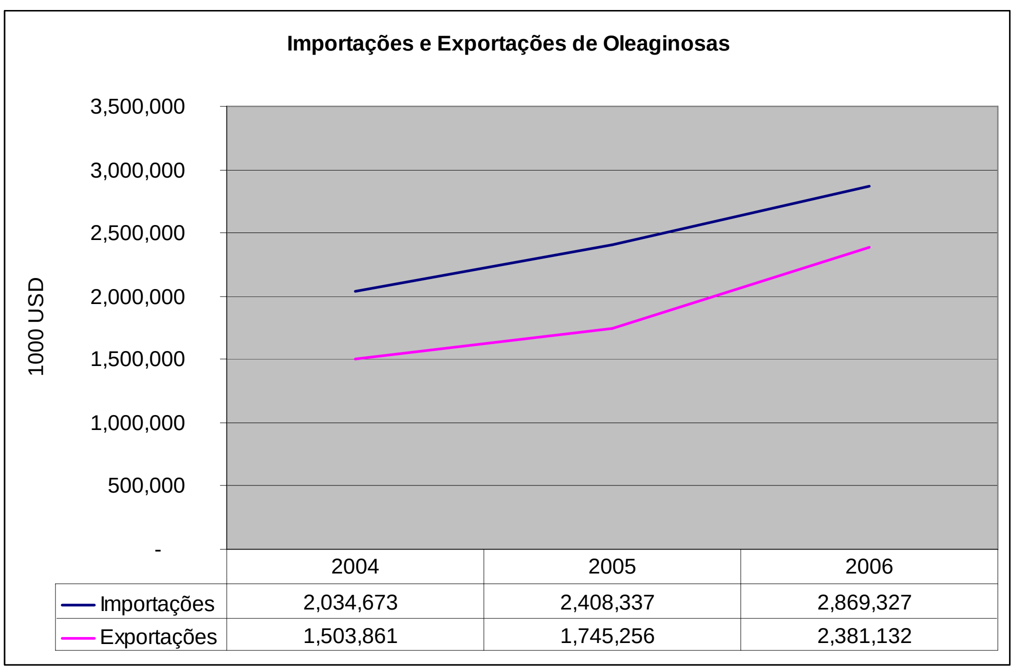
Sales	100%
Direct Variable Costs	72%
Cost of merchandise/Consumable materials	65%
Commercial packaging	7%
Gross margin	28%
Costs with personnel	10%
Salaries	5%
Other charges	4%
Charges with personnel	1%
Suppliers and third-party services	14%
Operating margin	4%

Source: Ginwala (2007).

using the fuel in their own vehicles. The facilities are very much small-scale production facilities.

The traditional industry, shown on the left in the Figure above, uses equipment that is largely made locally without any quality control. The owner, when interviewed by the consultant team, commented that "when the tank runs dry I don't go to the filling station, but rather to the kitchen." The modern industry, shown at right, was introduced in Mozambique with the support of Technoserve and therefore it has some quality control even though it is of small scale.

Figure 13: Imports and exports of oilseeds, 2004-2006 (USD thousands)



Source: MIC.

The efforts of Technoserve to promote the use of biodiesel at the small scale for self-supply have yielded several examples of biodiesel production (Somoil, Madal). There are others that began producing biodiesel on a small scale using home-made equipment (Isol). Finally, there are other projects planned that involve industrial production of biodiesel (C3), although these also must limit themselves to self-supply in the absence of an established government policy on this question. Companies such as C3 are also trying to export coconut oil for biodiesel production, but they have encountered problems such as high transportation costs, insufficient port storage space and competition with other uses of oil, which now imposes a high price on international markets. Beyond this, the volumes of coconut oil available on international markets represent a small but growing segment of traded oil (now about 5%).

Figure 14: Existing small-scale biodiesel production facilities in Mozambique

Source: Cardoso Muendane

4. Evaluation of the main feedstocks for biofuels

The purpose of this section is to assess the suitability of a selection of possible feedstocks for biofuels production in Mozambique. Crops selected for initial consideration are: corn, cassava and sugarcane for the production of ethanol, and sweet sorghum, sunflower, sesame, soybeans, peanuts, coconut, cotton, mafurra, castor oil plant, jatropha and African palm for the production of biodiesel.

The objective of this feedstock pre-selection is to conduct an initial screening of products to be analyzed in greater detail, and it is based on the apparent viability measured, among others, by the following elements:

- *Soil and climate suitability*: the presence in the country of soil and climate conditions that satisfy requirements for the production of a specific cultivation.
- *Socio-economic and environmental impact*: both positive and negative, and mainly the local impact, because virtually all crops generate global environmental benefits.
- *Cost of production and opportunity cost*: the cost of production is estimated based on crop tables (*cartas tecnológicas*); opportunity cost is defined as the price that could be attained in the domestic or international markets if the product were not sold to

biodiesel producers.

- *Other factors*: factors not previously listed that may affect, positively or negatively, the viability of a given crop, such as culture and tradition.

As a conclusion of this section, a selection of nine priority crops is presented (sugar cane, sweet sorghum, and cassava for the production of ethanol; and coconut, sunflower, cassava, and castor oil for biodiesel).

Some of these factors are inter-related, and the final feasibility will be analyzed in the next chapters.

Corn

Soil and climate suitability: Corn is produced almost everywhere throughout the country, although most of production is concentrated in a few areas, namely 3, 4, 5, 6, 7 and 10, where 70% of the total national output is produced.

Although production tends to be concentrated in areas of greatest suitability, there are some exceptions related to issues such as infrastructure for water management, as in the case of Region 3, and favorable or non-favorable dietary habits.

Cost of production. Production of corn, as with other products, can be carried out following different models that vary according to agro-climatic conditions, and the availability of resources, and traditions in each location. Two basic models are presented, which broadly reflect two technologies differing as to the use or non-use of tractors for soil preparation.

In the case of corn, the use of more modern and capital-intensive technologies is justified because it lowers the price per ton about four times, although the price per hectare is 50% more expensive.

Table 16: Suitability for corn by agro-ecological area

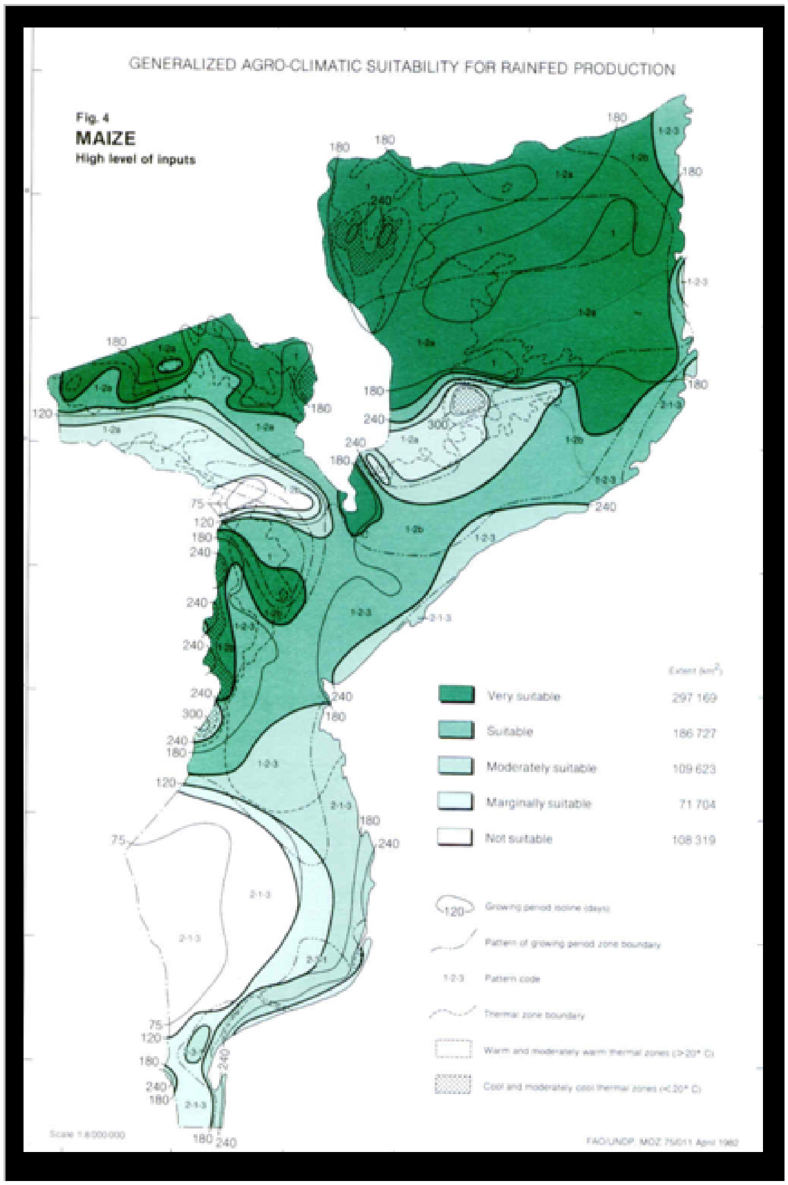
Area		% Production	% Cumulative Production
R4	Mid-elevation Central	17%	17%
R10	High altitude	16%	33%
R6	Semi-arid dry: Zambézia and Tete	14%	47%
R7	Inland Central and North	11%	58%
R3	Arid Inland South	11%	69%
R9	Inland North of Cabo Delgado	9%	78%
R5	Coastal Central	8%	86%
R1	Semi-arid Inland South	5%	91%
R8	Coastal North	5%	96%
R2	Semi-arid Coastal South	4%	100%

Source: IIAM

Socio-economic and environmental impact. Corn is considered a basic food crop in almost all the country, as is the case in almost all SADC countries. The use of corn for ethanol production may jeopardize food and nutritional security, both from the point of view of the crop's availability and of its price. No negative impact is expected from environmental point of view.

Moreover, Mozambique is home to an agro-industrial sector composed of small-, medium- and large-scale mills that transform corn into meals using domestic raw materials. Such plants could also be harmed by the use of corn for ethanol.

Figure 15: Suitability for corn



Source: Kassam at al. (1982)

However, if there were ways to expand areas [for cultivation] and, especially, to increase yield per hectare, corn could be considered for the production of ethanol. The northern and southern areas of the country (the largest producers of corn) consume more sorghum than corn in their diet. In many areas, corn is considered a corn crop for profit, while sorghum is mostly a staple crop for consumption.

Table 17: Cost of production of corn

Model		*Manual*				*With Tractor*		
Conditions of Cultivation		Cultivation of corn with the use of traditional technologies (without improved inputs)				Preparation of soil with tractors, manual harvest and threshing: use of improved seeds.		
Item	Indicators	Unit	Cost/Ha (Mt)	Cost/Unit (Mt)	Cost/Ha (Mt)	Norm	Cost/Unit (Mt)	Cost/Ha (Mt)
1	Cultivation Operations				**3,900**			**3,223**
	Work	c)	90	20.00	1,800	1	1,500.00	1,500
	Harrowing 1	MT/ha				2	200.00	400
	Harrowing 2	MT/ha				2	200.00	400
	Soil Preparation	MT/ha				2	200.00	400
	Soil Ploughing	Man/Days				2	10.00	20
	Sowing	Man/Days	15	20.00	300	10	10.00	100
	Application of herbicides	Man/Days				2	10.00	20
	Application of insecticide	Man/Days				1	10.00	10
	Weeding b)	Man/Days	80	20.00	1,600	2	10.00	20
	Ploughing of surface	Man/Days				0.25	10.00	3
	Harvest	Man/Days	10	20.00	200	25	10.00	250
	Threshing	Man/Days				10	10.00	100
2	Production Factors				**393**			**3,150**
	Seeds a)	Kg	25	12.50	313	25	14.00	350
	Herbicides							-
	Bullet	liters				3	320.00	960
	Insecticides							-
	Cypermethrine	liters				1	160.00	160
	Fertilizers							-
	Urea (46%)	kg				100	9.00	900
	NPK (12:24:12)	kg				100	7.00	700
	Sacs	Unit	20	4.00	80	20	4.00	80
3	**Total**				**4,293**			**6,373**
4	**Yield per hectare (t/ha)**				**1**			**6**
5	**Cost per ton (Mt/t)**				**4,293**			**1,062**

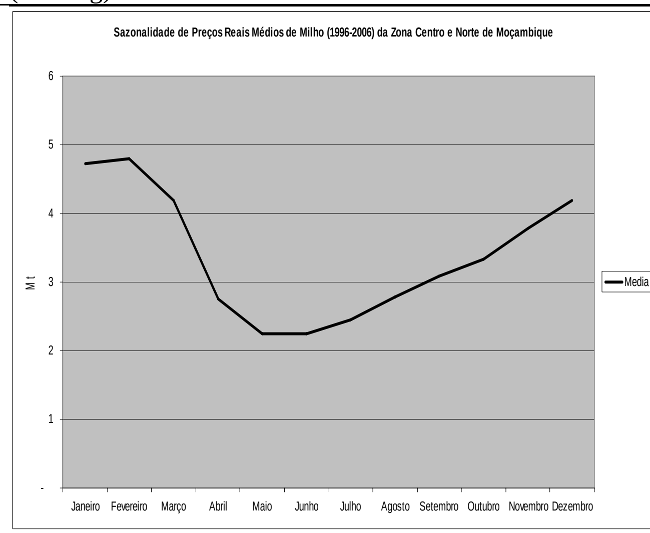
Source: Cartas tecnològicas, IIAM (updated by Carlos Zandamela, 2007). Notes: a) Manual (Matuba) and Tractor (Sussuma)

b) Manual (2 weedings)

c) Manual (Man/Day) Tractor (Mt/ha)

Opportunity cost: Considering the socio-economic issues presented above, the consulting team believes that the opportunity cost using corn for bio-fuels would be relatively high. In general, the prices of corn raised in Mozambique increase every year, just like those of any other agricultural products (Chart A in Figure 16), and they vary by season (Chart B in Figure 16).

Figure 16: Annual and Multi-year Price Trends for Corn

A. Average Price, 1996-2006 (MtN/kg)	B. Seasonal Trend of Prices, North Area , 1996-2006 (MtN/kg)
	

Source: A. MINAG (2007). B. Calculated based on data from MINAG (2007).

The average price of corn in 2006/7 in Maputo's main markets is 4,090 Mt per ton.

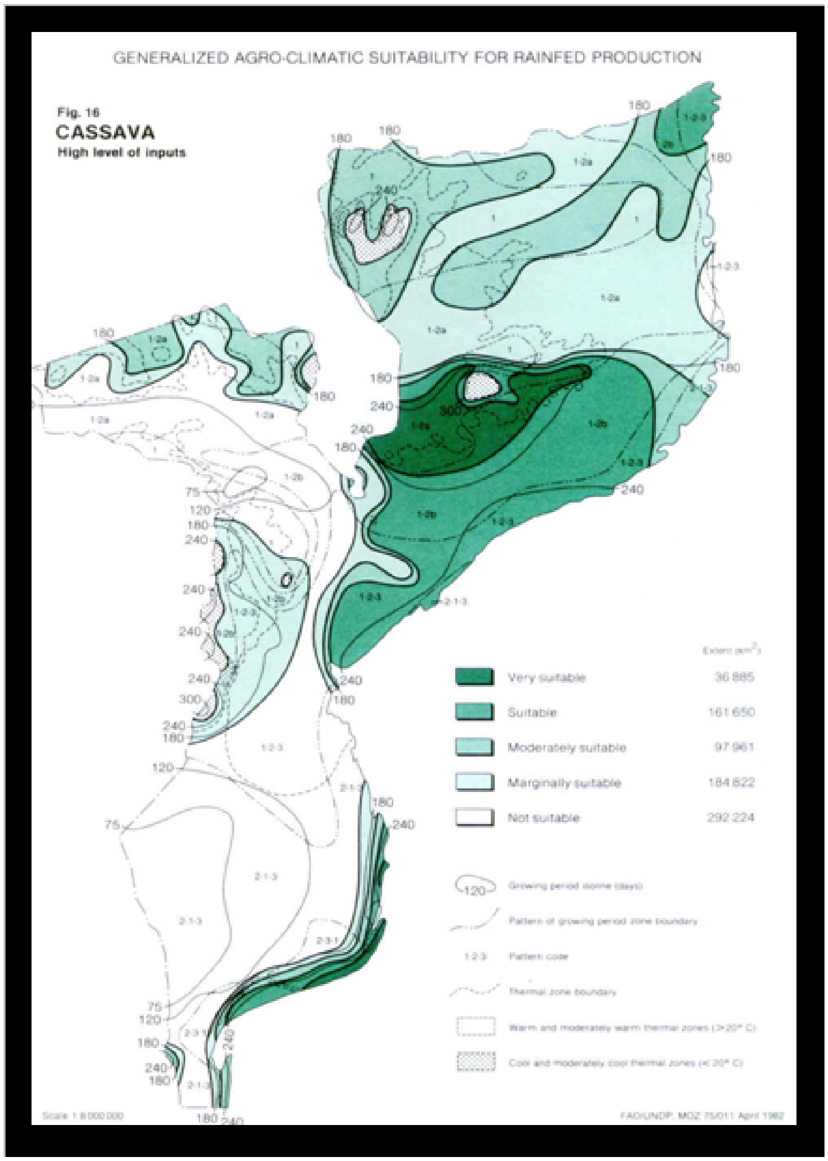
The use of corn for the production of ethanol in the U.S. will boost international demand for this product, increasing its price. In a higher price environment, Mozambique could become a supplier.

Other Factors. Cultural aspects appear favorable to an increase in production of corn, both in the traditional way and with more capital-intensive methods.

Cassava

Soil and climate suitability: Cassava is one of the major food crops produced in Mozambique, reflecting the suitability of a large part of the country to grow this crop, as illustrated in Figure 17. It is produced mainly on the coast of the provinces of Zambézia,

Figure 17: Agro-climatic suitability for Cassava



Source: Kassam at al. (1982)

Nampula, Cabo Delgado, Sofala and Inhambane. It is estimated that cassava occupies about 50% of total cultivated area (Zacarias et al. 1994; Andrade et al. 1998). As in the case of corn, production does not match the geographic distribution of agro-ecological potential. Close to half of cassava output occurs in regions 5, 8 and 9, as showed in the following chart.

The cultivation of cassava is relatively advantageous because of its tolerance of low fertility soils and its resistance to drought. However, its most important limitation is the ease with which fresh roots deteriorate because of toxic compound. Given its limited

Table 18: Suitability of cassava by agro-ecological region

Region		% Production	% Cumulative Production
R9	Inland North of Cabo Delgado	19%	19%
R5	Coastal Central	15%	34%
R8	Coastal North	14%	48%
R6	Semi-arid dry: Zambézia and Tete	13%	61%
R10	High altitude	11%	72%
R7	Inland Central and North	11%	83%
R2	Semi-arid Coastal South	7%	90%
R1	Semi-arid Inland South	5%	95%
R4	Mid-elevation Central	3%	98%
R3	Arid Inland South	2%	100%

Source: IIAM

capacity for conservation and fresh storage, the cassava processing is essential for better use and exploitation of this crop.

According to UNIFEM (1993) there is a wide range of methods for processing cassava. This large variety of methods corresponds to requirements of specific treatments to render cassava fit for optimal human consumption. The variety of methods for processing cassava leads to a variety of processed products with different flavor, texture, color and conservation qualities. Sour varieties are especially delicate since they require careful processing, while sweet varieties may be eaten fresh.

Kassam et al. (1982) estimated a large increase in levels of production for the country, between 2.9 million tons and 12.8 million. More recent studies show that it is possible to obtain greater yields than those estimated by Kassam. For example, considering a yield of 10 tons/ha (still low by international standards, but higher than the Kassam study), production could increase to 20 million tons, three times current production.

Traditional cassava processing. To date, the processing of cassava is limited to the use of traditional rudimentary techniques, which are considered unproductive and labor-intensive. The sweet varieties of cassava are essentially eaten fresh or sold in markets close to production areas. They are harvested in small amounts, which are then sold and consumed in the next 72 hours. Alternatively, cassava is processed into toasted flour (known as ralí) or fermented.

Small machines, promoted by various NGOs, are used to mill cassava, and mainly involve an improvement in process quality through a reduction of time of drying and detoxification, as well as a substantial increase in productivity and in the commercial value of products processed. The various machines are for *chipping* – or the cutting of cassava into small pieces – mechanical shredding, and mechanical pressing. Experience in cassava processing in the country encountered, among various difficulties, that of the quality of national cassava, especially the fact that the plant contains fiber.

International References. The apparent difficulty of exploring increased and profitable cultivation of this crop derives from the non-existence of external demand for it or of a new market segment in the country. Other countries have faced similar situations. Brazil tried to expand this traditional crop that, in the pre-Colombian era, could sustain three million native Indians. When competing with corn among the products of higher value added (starches, glucose, flours), cassava has evolved little as a commercial crop that generates value.

At the beginning of the Brazilian Ethanol Program (ProAlcool), this crop was selected to test its use as a source of carbon for ethanol, with a European technology based on the sugar beet industry. Eventually, sugarcane prevailed because it does not require fragmented logistics for collection from small family properties, whereas cassava is cultivated as a staple crop. Large farms always preferred to bet on crop with greater liquidity (cane, citrus, soybean) than to compete with small producers whose costs are unknown or understated. The Pro-Alcohol Program concentrated on sugarcane, and the six industrial units that existed then to ferment cassava were lost.[29]

At that same time (in the 1980s decade), Thailand chose to export dehydrated cassava (*chips*) as an energy source for animal feed creating significant dynamism in local production. Currently, exports to other countries tend to decrease because Thailand, which produces a yearly average of 20 million tons of cassava, also seeks alternatives to produce ethanol.

This creates the opportunity for Mozambique to export, in a first stage, dehydrated cassava in bulk, occupying the place left by Thailand mainly in Europe. It should be noted that Europe is also investing in fermentation plants for second-quality cereals (mainly wheat). This will create shortage of cheap carbohydrates in the European continent. As the United States is also expected to use 20% of corn for ethanol, there is a larger opportunity for other countries to provide non-traditional carbohydrates. Mozambique may soon be a new source for these products if there were a positive evolution in logistics for solid granaries at the main ports (Maputo and Beira).

Cost of Production. The cost of production shown in the table below reflects two models of production (manual and mechanized). However, the use of tractors is almost non-existent in Mozambique. The use of capital-intensive technologies within the current conditions in Mozambique is not a compensating factor, since the yield per ha is relatively low. This situation is made worse by low wages for work in the fields. This may be one of the reasons for which this crop is not grown at an industrial scale in Mozambique.

[29] Veja www.canis.rpc.com.br, People's Gazzette 10-112006.

The commercial use of cassava implies the need for higher yields to make the process possible viable, which in turn will imply the use of more fertile soils and the supply of fertilizers, organic as well as inorganic.

Although varieties with a greater genetic potential exist in Mozambique, unfortunately there is no technological information on levels of fertilization and water management adequate to turn cassava into an attractive industrial crop. Based on studies for improvement already carried out by IIAM, however, it could be possible to compile the data required to obtain more acceptable and higher yields per unit area, in the range of 40 tons per ha or more.

Table 19: Costs of production of cassava

Production model		Manual				With tractor		
Production conditions		Manual preparation, tillage, planting and harvest				Soil preparation with tractor; manual harvest and threshing		
Activities		Unit	Standard/ ha	Cost/unit	Cost/ha	Standard/ ha	Cost/unit	Cost/ha
1	Culture operations				**1,320**			**2,970**
	Tillage	Day	30	20	600	1	1,500	1,500
	Grading					1	750	750
	Planting	Day	2	20	40	2	20	40
	Weeding	Day	4	20	80	4	20	80
	Harvest	Day	30	20	600	30	20	600
2	Inputs				20			100
	Stakes/Location	kg	10	2	20	20	5	100
3	Total cost/ha				1,340			3,070
4	Yield per hectare (t/ha)				5			10
5	Total Cost per ton				268			307

Source: Cartas tecnolôgicas, IIAM (updated by Carlos Zandamela, 2007).

Processing with small-scale improved techniques. The mechanical processing of cassava in the country has already been tested, and the technical efficiency has been proved. The SARRNET, the National Program of Roots and Tubers of IIAM and the DNEA at the MINAG, are some of the institutions directly involved in the promotion of the use of machinery. The main areas covered were the two provinces with the largest production in the country: Inhambane (Inharrime and Morrumbene) and Nampula (Erati and Nacarroa) (Monjane, et at., 2000 and Monjane and Mabota, 2000). Also according to these authors the introduction of manual machinery can contribute to the increase in labor productivity, quality of products resulting from the processing, and reduction of cyanide levels and drying time.

Socio-Economic and Environmental Impact. Just like corn, cassava is produced in almost all of the country. In many areas, it is considered a staple or subsistence crop. Its use for biofuels may affect food and nutritional security in terms of availability as well as of access to it (increase in prices because of the increase in demand) if it is not done in parallel to a substantial increase in land production and productivity. No negative impact is expected from an environmental point of view.

Opportunity cost. The eventual use of cassava as a feedstock for biofuels could have a high opportunity cost because of its importance to food and nutritional security, but the current characteristics of production reduce such effect. The cost of production of cassava is relatively low due to the production system used, but low prices are hardly an incentive for higher production.

Production of cassava in Mozambique, as most of the country's agricultural production, is carried out in the traditional sector, and profits are relatively low. A study done by Agroges/Austral concludes that the best estimate of cassava yields in Mozambique is on average 11 tons/ha, which is close to the average yield reported by many agencies: from a minimum of 6 tons/ha to a maximum of 80 tons/ha in irrigated areas of production.[30]

The production of cassava has been relatively stable in recent years, reflecting the fact that it serves as a kind of guarantee for the livelihood of farmers who also produce corn and/or other agricultural products, also reflecting the lack of a well-organized market. The study carried out by Agroges and Austral states that:

> " ....unless major production programs – that will seek more uses of cassava for direct consumption and also for the food industry – are launched, the domestic market will remain very small...[31]."

Therefore, the opportunity of considering cassava as a potential feedstock for the production of ethanol depends on the real costs of production, and on the feasibility of creating a non-food market for one of the key food crop for rural communities.

Furthermore, cassava offers advantageous conditions for the production of starch, glucose and flours, in competition with corn. Cassava also can be used for the production of *chips* as a source of energy for animal feed. As a shortage of corn is expected in the market because of its use for the production of alcohol in the U.S., cassava could be considered as a substitute product not only in Mozambique but in the region.

Other factors. Cultural aspects are favorable to an increase in the production of cassava, both in the traditional way and according to capital-intensive methods. A particularly important aspect concerns the development of research on this tuber in Mozambique.

Sugarcane

Soil and climate suitability: In Mozambique, sugarcane is grown in irrigated fields, so its production is not directly related with agro-ecological suitability.

The average yield is 65-75 ton/ha[32] compared to 105-115 ton/ha in the region (Malawi, Zimbabwe, Swaziland). Sugar is produced in the provinces of Maputo (Maragra, Xinavane) and Sofala (Mafambisse, Marromeu). There are several reasons for the low yields. Environmental factors, especially the types of soils and the topography, are often

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[30] Agroges and Austral, *Subsector strategic study on cassava: inception report*, February, 2006: page 9.
[31] Agroges and Austral, page 20.
[32] Some fields already have a yield of over 90-100 ton/ha.

less than optimal. Often, soils are heavy, easily fractures black soils "that crack", with high levels of clay, and poor drainings, that are prone to the accumulation of water, leading to problems with salinization in some areas. Many varieties of sugarcane used in Mozambique are suitable for dryer areas in South Africa and Swaziland, in contrast with the more humid conditions of certain parts of the central region of Mozambique. Agronomists agree that there is a potential for excellent sugarcane yields, provided that the rehabilitation of the sugar sector of Mozambique continue, land previously cultivated with sugar is replanted, and is new land is used for production, the cycle of sugar cane can be restored.

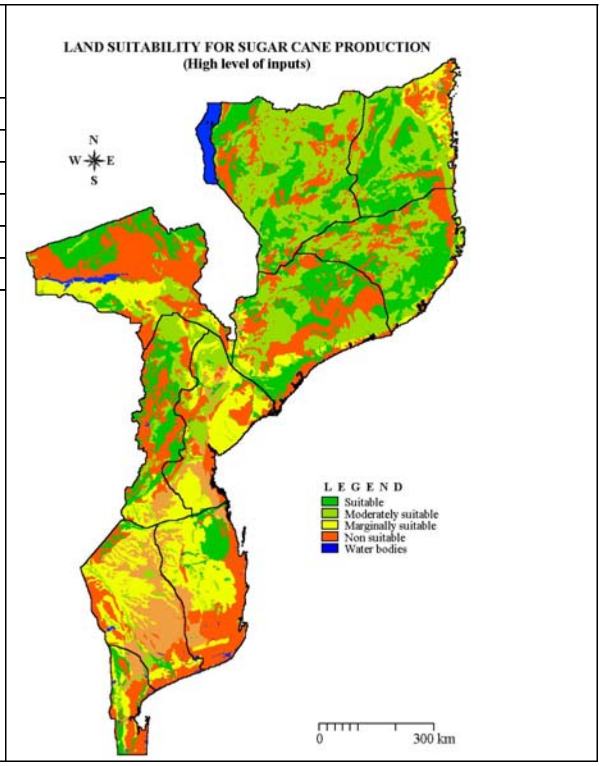
Table 20: Land suitability for sugarcane cultivation and projected yields

Sugar cane crop (ton/ha) – High level of production factor inputs

Level of suitability	Yield
Highly suitable	> 95
Suitable	72-95
Moderately suitable	44-72
Marginally suitable	30-44
Not suitable	< 30

Conversion factors for cultivation practices:

Medium entry level of inputs: 0.55
Low entry level of inputs: 0.30



Source: IIAM (2007).

These projections should also be considered in context of yields obtained in other areas of the region with similar irrigation conditions. Zimbabwe, Swaziland, and Malawi consistently reach yields in the range of 105 to 115 tons/ha/year. It would be difficult to obtain such yields for any other sugar industry in the world. Even with conservative estimates of 80 to 90 tons/ha/year, the yield for sugar projected in Mozambique would be exceeded only by Colombia and the irrigated sugarcane fields of Northern Queensland, Australia.

Cost of production. Production of sugar cane is primarily carried out by the sugar industry.[33] In general, production methods of the four existing plants are similar, although

[33] The small sugarcane producers receive support from the sugar industry to establish sugar cane plantations (preparation of soil, sugarcane seed, sowing, harvesting and transportation of canes to factories)

yields per hectare vary depending on agro-ecological conditions. For instance, Xinavane presents an average yield of 90 ton/ha, while Mafambisse produces less that 60 ton/ha. The major constrain in yields increases and include irrigation systems efficiency, drainage, land salinity, and operational issues such as the purchase of agro-chemicals and spare parts in the domestic market, power failures and availability of labor.[34]

Table 21: Examples of the cost of production of sugarcane in Mozambique

Description	Mt/Ha	USD/Ha
Planting	4,584	170
Labor	7,640	83
Herbicide	5,730	12
Fertilizers	7,640	83
Water and water pumping	6,112	226
Equipment (operation post harvest)	3,629	34
Harvesting and transportation (filed/plant)	4,278	58
Overheads	4,966	84
Streets and maintenance	1,337	50
Total	45,916	1,701
Yield per ha	90	3
Cost per ton	510	9

Notes: (a) Plantation costs approximately ZAR12,000/ha and has a duration of ten years. Exchange rates used are: ZAR 1=3.82 Mt and USD 1=27 Mt. Source: Xinavane sugarmill (2007)

Sugarcane is a perennial plant that takes 14 months to grow, after which it is cut and sent to the mill. After the first harvest, the following ones are done on an annual basis. The cut cane is fertilized so it can grow again. The same plant can be used again for an average of 5 to 7 years, and still offer a good yields.

Cane Harvesting/Loading and Hauling. Most of the sugarcane in Mozambique will continue to be cut and loaded manually in the near future.[35] Labor productivity during harvests is low by international standards (one to two tons of burnt cane per day), and it is lower than that achieved by some other countries that enjoy even less favorable conditions to harvest green cane. One of the goals of the domestic sugar companies is to improve the productivity of the cane cutting process.

Productivity of the cutters depends on several factors, such as motivation of workers: in Swaziland (where most of the cutters come from Mozambique), workers reach a yield of 7 tons/day. In South Africa the yield is lower, 4 to 5 tons/a day. The re-establishment of cutting skills among the rural workforce and improvements in standards of the cane should also boost cutters' productivity.

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and, in some cases, to install irrigation systems (as the associations of Maguiguane and Macuvulane do, both in Xinavane). The farmers' work is centered on cultivation (fertilizing, weeding, watering and managing plants as they grow).

[34] It is difficult to find workers during the peak of agricultural operations, because there is a overlap with the work at individual farms for food production.

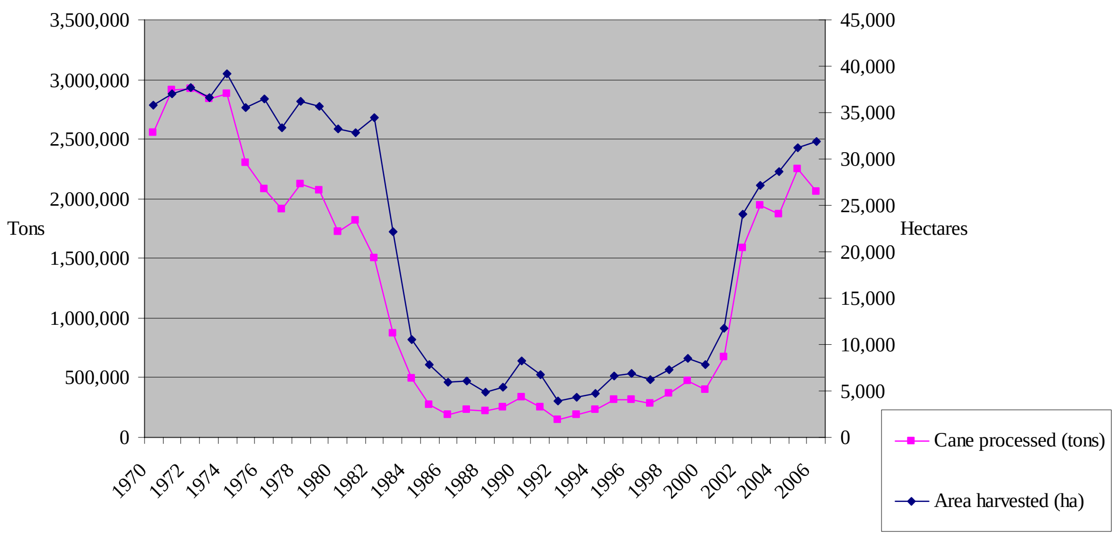
[35] Approximately 10% of the cane is cut mechanically at the Marromeu plantation, with a machine for cutting and harvesting. The cane is cut manually in other plantations.

Typically, Mozambique's cane estates are planted in large blocks close to sugar cane factories and accessible through a network of internal roads. The continuity and expansion of this practice should have positive benefits, considering the average size of cane loads, levels of cane losses, the use of equipment, such as tractor/trailer units, and the quality of distributed cane. With a relatively high percentage of cane under the mills' own control, there will be benefits also for harvest programming[36].

Sugar is a traditional industry in Mozambique, and it was destroyed during the war. Since 1992, when the war ended, it has grown back significantly, starting with a production of 13,000 tons and reaching 242,000 tons in the 2006/7 campaign. The increase in production was mainly due to two factors: low cost of production and the domestic market. Starting in 2001, the European market opportunity emerged, through the EBA initiative.

Buzi is the only manufacturer that produces ethanol. Current production stands at 1,500 ton/year, half of potential capacity, and is sold to hospitals and for the beverage market.

Figure 18: Area harvested and sugarcane processed, 1970-2006



Source: Based on data from CEPAGRI.

The use of molasses varies significantly from factory to factory. The total production of molasses ranged between 66,000 tons to 81,000 tons per year during the 2003-2006 period. During the pre-independence era, production reached roughly 100,000 tons.

[36] Even if these benefits are observed in other countries such as Swaziland, Zimbabwe, Malawi, Colombia as well as Central and South Brazil, and by private factories in other countries, like USA and Argentina, they are not universal.

Today, only part of production actually makes it to the market. In the case of Sena sugar, molasses is dumped in the river because they lack a viable market, while factories located in the province of Maputo, with better access to the transport infrastructure, send the molasses by train to be sold on international markets. The port of Maputo has a storage capacity of 3,000 tons in two relatively old tanks.

Socio-Economic and Environmental Impact. The sugar industry's most significant impacts are labor (currently it supports about 20,000 jobs, directly affecting about100,000 people), the reduction of imports and the increase of exports.

The domestic price of sugar is based on the international price, and it is almost unaffected by domestic demand. No negative environmental impact is expected.

Opportunity cost. In the case of production expansion, production of ethanol does not directly compete with that of sugar, making opportunity cost issues irrelevant. Other than that, the lack of markets for the molasses produced in the country shows that their opportunity cost is not significant.

Other factors. Competition for ethanol production in Mozambique's sugar sector is relatively low compared to that of several international competitors, especially Brazil. This is due to the following: (i) sugarcane in Mozambique requires irrigation, whereas production in Brazil is rain fed; (ii) inadequate infrastructure, including limited access to electricity for the operation of water pumps, and expensive logistics due to inadequate river and maritime transportation; (iii) inefficiency of operations due to vandalism and theft; and (iv) low labor productivity levels during the harvest.

Despite drawbacks mentioned above, Mozambique also enjoys a few major advantages for large-scale sugarcane ventures. Advantages include: millions of hectares of plains located in proximity to the Indian Ocean and access to international markets, available labor and a network of rivers, and hydro-electric potential that could be used for water pumping. This said, there are molasses available from existing sugar cane factories that could be used in the short-term to launch ethanol production for the domestic market. Molasses are currently not used consistently: part are sold locally, part are exported to Europe, but otherwise there is a lack of markets. A strategy to consider could be that of concentrating all molasses in one location (perhaps Beira) to quickly start an ethanol program for the local fuel market. Although small, this initiative would be politically important to encourage production of ethanol in the country.

Sweet Sorghum

Capability soil-climate: Sorghum grain, in general, is cultivated in all agro-climatic regions of Mozambique. Over the past five years, an average of 419,000 ha of the country yielded 0.65 tons of grain per hectare. About 50% of sorghum production is cultivated in regions 4, 5 and 9, as shown in the chart below.

Table 22: Suitability for sorghum per agro-ecological region

Region		% Production	Cumulative % of Prod.
R4	Mid-elevation Central	17%	17%
R6	Semi-arid dry: Zambézia and Tete	16%	33%
R9	Inland North of Cabo Delgado	15%	48%
R7	Inland Central and North	14%	62%
R3	Arid Inland South	11%	73%
R5	Coastal Central	10%	83%
R8	Coastal North	9%	92%
R10	High altitude	7%	99%
R2	Semi-arid Coastal South	1%	100%

Source: IIAM

Given Mozambique's favorable climate for production, its experience with grain sorghum, and the higher yields by farmers growing sweet sorghum, this crop should be seriously studied within a strategy for biofuels feedstock production.

Sweet sorghum is superior to grain sorghum as a biofuel feedstock, and it can yield 40 tons of fermentable sugar stems per hectare and two tons of grain per hectare. The grain is rich in starch and similar to corn, allowing production of ethanol as well as that of animal feed. In contrast, stems of grain sorghum are composed of ligno-cellulosic material.

ICRISAT states that sweet sorghum would be a better feedstock from the point of view of resource use, as well as of promoting rural development and increasing profits for small-holders. Although yields of sweet sorghum are similar to those of sugarcane, sorghum requires much less water (about 22% of the volume, or 8,000 m3/ha/year, as opposed to 36,000 m3/ha/year for sugarcane). Besides requiring less than a quarter of water than the sugar cane, sweet sorghum may be planted from seed, and is therefore easier and less time-consuming to grow than from the stem cuttings used to plant sugar cane. Water savings, combined with small requirements of fertilizer and intensive labor, suggest that the cost of one hectare of sweet sorghum (main and ratoon harvest in nine months) is approximately 60% lower than for sugarcane (one harvest in nine months to a year; in some areas, there can be more than one harvest per year, depending on the region[37]). Although the yield of ethanol from sweet sorghum per unit of weight of feedstock is lower than that of sugarcane, it is offset by the lower cost of production. In terms of total costs, it takes USD 0.29 to produce one liter of ethanol from sweet sorghum compared to USD 0.33 for ethanol from sugar cane, although these costs will of course vary depending on a range of local production factors.[38] Finally, after extraction of the juice,

[37] In Peru, three and even four harvests are possible. The 90-day rotation is possible if the top of the stem is pruned at around 60 days, therefore preventing the formation of the grain and leaving more recoverable sugar in the stem. Jaime Gianella, Monder SAC, personal communication, April 24, 2007.
[38] Rao et al. (2004).

the bagasse is an excellent fuel for boilers. Given its low water requirements and properties similar to sugarcane's, sweet sorghum is well suited to semi-arid tropical regions lacking the infrastructure and water required for irrigation, and it is valuable both as a food and as a biofuels crop.

A survey by ICRISAT also indicates that gross returns from sweet sorghum are approximately 8% higher than those from grain sorghum in India. The potential ethanol feedstock market also seems to be much larger than the one for grain sorghum, due to a reduction in human consumption of sorghum, while rice and wheat are becoming more popular. This has important implications with respect to food and nutritional security.

Concerns about the viability of cultivating sorghum are closely tied to crop yields. The sorghum stem stores large amounts of water (over 70% by mass), which complicates the crop's removal and transportation. Furthermore, sugars begin to ferment or decay soon after harvest, decreasing profits and making it harder to store the harvest. In cases where there are three or four harvests, efficient logistics are essential. FAO research indicates that regions suitable for grain sorghum are also suitable for sweet sorghum; therefore, production of grain sorghum, which is already proven in Mozambique, should represent a useful reference. Apparently, sugar mills in Zimbabwe obtained positive results using sweet sorghum as a secondary crop to extend their crushing season and increase cane availability.[39]

Cost of Production of Sorghum. Production models considered here demonstrate that the introduction of improved technology can significantly increase yields per unit area. Investments required could apparently be compensated considering increased profits.

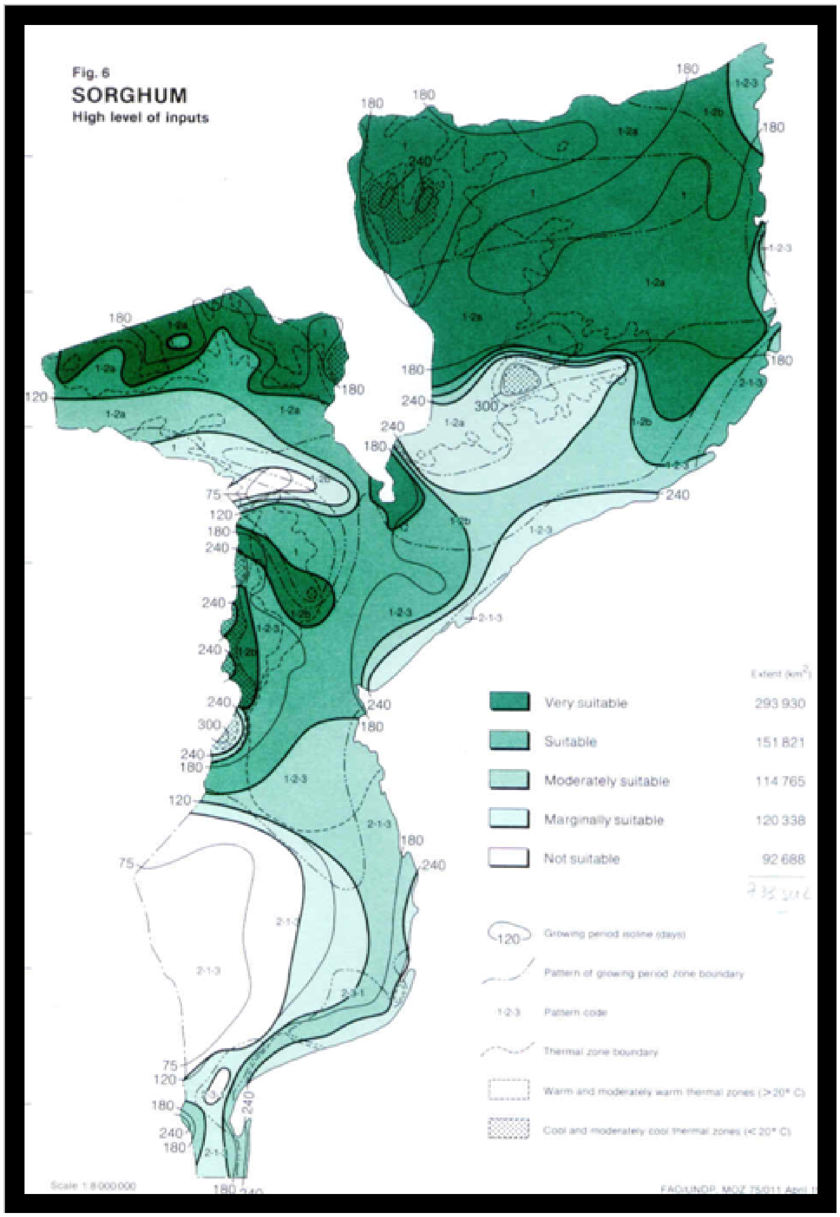
Socio-economic and environmental impact: Like corn, sorghum is considered a staple crop, especially in the Central and Northern regions, where its cultivation is more attractive. It is considered a subsistence crop and, in this function, it sometimes substitutes corn, when corn is sold as a corn crop. Its use as a feedstock for ethanol production may jeopardize food and nutritional security, unless production and productivity are considerably enhanced by substituting grain sorghum and corn. No negative impact is expected from the environmental point of view.

Opportunity cost: Alternatively, sorghum can be used for production of starch other than for animal feed. Its price behaves in a way similar to that of corn, and stands at 3.000 Mt/ton on average.

Other factors. Cultural aspects are favorable to an increase in production of sorghum, both according to traditional and to capital-intensive processes. Further research on this crop in Mozambique is also a very important.

[39]Gianella reports that Dr. Jeremy Woods (King's College, London) completed a dissertation on Zimbabwe's experience in 2001. The Econergy team has requested a copy.

Figure 19: Suitability for sorghum



Source: Kassam at al. (1982)

Table 23: Costs of production of sorghum

Production model		Manual				With tractor		
Production conditions		Manual preparation, tillage, planting and harvest				Soil preparation with tractor; manual harvest and threshing		
Activities		Unit	Standard/ ha	Cost/unit	Cost/ha	Standard/ ha	Cost/ unit	Cost/ ha
1	Culture operations				**2,310**			**2,504**
	Tillage	Day	90	15	1,350	1	1,500	1,500
	Planting	Day	2	15	30	2	15	30
	Application of Insecticide					1	10	10
	Fertilization					2	15	34
	Weeding 1	Day	2	15	30	2	15	30
	Harvest	Day	30	15	450	30	15	450
	Threshing	Day	30	15	450	30	15	450
2	Inputs				75			1,810
	seeds/area	kg	5	15	75	10	15	150
	Fertilizer					100	7	700
	Insecticide					3	320	960
3	Total				**2,385**			**4,314**
4	Yield per hectare (t/ha)				**0.7**			**2**
5	Cost per ton				**3,407**			**2,157**

Source: Cartas tecnològicas, IIAM (updated by Carlos Zandamela, 2007).

Furthermore, the southern regions of the country (which is relatively rain poor) may provide suitable areas for sorghum production for bio-fuels, considering that there is no strong tradition involving its consumption as a food crop, freeing up this crop for the ethanol industry.

Sunflower

Soil and climate suitability. No map was available for the assessment of sunflower's agro-climatic suitability. However, sunflower is an oleaginous crop, best suited for the agro-ecological conditions found in the provinces of the country's central areas, Manica and Sofala. Currently, districts in Ribawe, Malema and Gurue stand out as the areas offering the largest production volumes.

Sunflower was reintroduced in Mozambique a relatively short time ago. The greatest production volume was recorded in 2001, with close to 7,000 tons, of which 45% came from Manica, followed by 37% from Nampula, 10% from Sofala and 8% from Zambézia (MINAG/DE).

Unlike countries with larger production volumes, where cultivation of sunflower is mechanized, local farmers harvest the crop manually and sun-dry the crop. Small plots of land cultivated by families can be competitive because of the high oil content of the plant and the use of the sunflower bagasse for animal feed. In some areas, sunflower may represent a second-stage crop after the harvest of corn, soybeans and other commercial crops, as in Brazil.

Table 24: Production costs for sunflower

Production model		Manual				With tractor		
Production conditions		Manual preparation, tillage, planting and harvest				Soil preparation with tractor; manual harvest and threshing		
Indicators		Unit	Standard/ ha	Cost/unit	Cost/ha	Standard/ ha	Cost/ unit	Cost/ha
1	Activities	Days			**740**			**1,335**
	Subsurface fertilization					2	15	30
	Planting		2	20	40	15	15	225
	Surface fertilization					2	15	30
	Thinning out+first weeding		10	20	200			
	Second weeding		5	20	100			
	Third weeding		5	20	100			
	Harvest		4	20	80	70	15	1,050
	Threshing		4	20	80			
	Selection		4	20	80			
	Drying		2	20	40			
	Packing/transport		1	20	20			
2	Inputs				**57**			**2,055**
	Seed		3	15	45	1	15	15
	Herbicide							
	Round-up					4	70	280
	Insecticide							
	Cipermethine					1	160	160
	Fertilizer							
	Urea					100	9	900
	NPK					100	7	700
	Sacks		4	3	12			
3	Total				**797**			**3,390**
4	Yield per hectare (t/ha)				0.4			1.5
5	Cost per ton				1,993			2,260

Source: Cartas tecnolôgicas, IIAM (updated by Carlos Zandamela, 2007).

Sunflower producers can be classified as follows: (i) farmers that own processing units (ii) and family farmers that grow sunflower as a corn crop to sell to traders who will re-sell to processing factories, or to owners of manual presses. Sometimes, these farmers press their seeds locally paying for the processing with a fraction of the oil obtained. In areas of middle-sized processors, such as Manica, some farmers produce sunflower under a contract with crop processors.

Cost of production. Two sets of production model are presented, each with two models: the first is for manual cultivation and the second using a tractor for soil preparation. (See Table 24 and Table 25.)

Sunflower, like cassava, is not suited to intensive cultivation given the current production conditions in Mozambique. Improvements in the viability of sunflower production would require significant increases in per-hectare yields which may be achieved through improved technologies combined with use of agro-chemicals in sufficient quantities.

Socio-economic and environmental impact. Sunflower is currently used for production of edible oil by small and large-scale industrial firms. There is strong demand for the oil for human consumption [in Mozambique], but it is also exported. There are some NGOs in the country that are creating incentives for its production for this purpose, benefiting low-income family farmers in the Central and Northern regions. Even so, the quantities produced to date are not substantial.

Table 25: Production costs for sunflower

Production model		Manual				With tractor		
Production conditions		Manual preparation, tillage, planting and harvest				Soil preparation with tractor; manual harvest and threshing		
Indicators		Unit	Standard/ ha	Cost/unit	Cost/ha	Standard/ ha	Cost/unit	Cost/ha
1	Activities				**740**			**1,335**
	Subsurface fertilization	Days				2	15	30
	Planting	Days	2	20	40	15	15	225
	Surface fertilization	Days				2	15	30
	Thinning out+first weeding	Days	10	20	200			
	Second weeding	Days	5	20	100			
	Third weeding	Days	5	20	100			
	Harvest	Days	4	20	80	70	15	1,050
	Threshing	Days	4	20	80			
	Selection	Days	4	20	80			
	Drying	Days	2	20	40			
	Packing/transport	Days	1	20	20			
2	Inputs				**57**			**2,055**
	Seed		3	15	45	1	15	15
	Herbicide							
	Round-up					4	70	280
	Insecticide							
	Cipermethine					1	160	160
	Fertilizer							
	Urea					100	9	900
	NPK					100	7	700
	Sacks		4	3	12			
3	Total				**797**			**3,390**
	Yield per hectare (t/ha)				0.4			1.5
	Cost per ton				1,993			2,260

Source: Cartas tecnolôgicas, IIAM (updated by Carlos Zandamela, 2007).

Opportunity cost. Although sunflower is not considered a staple food, its economic importance in the Central and Northern regions, especially to low-income peasant communities, discourages its use in the near-term for biofuels. Its use as a feedstock for biofuels might affect food and nutritional security in the absence of a significant increase in production and productivity. Average prices for sunflower are around 3,750 Mt/ton. No environmental impacts are anticipated.

Other factors. No cultural factors were identified that might be unfavorable to the increase in production of sunflower, either in the traditional methods or more capital-intensive methods. One aspect that is particularly important is the development of research on this crop in Mozambique and for export markets, for the production of oil and for export.

Sesame

Soil and climate suitability. No map for the suitability of sesame was found for Mozambique. However, sesame is currently planted in the Center and North of the country. It was initially promoted in the Nampula province to use the seed as a rich source of oil and protein. However, due to its great success, its cultivation has immediately spread to the Zambézia, Sofala and Manica provinces. The percentage of oil in the seed varies between 43% and 57%, with an average of 50%. The litter is valuable both for domestic animal and human consumption.

The white seed varieties have a high export value. According to the study by Tickner et al (2001), sesame producers have responded positively to high prices on the international market, where there has been an increased demand. Initially, it was cultivated for the local extraction of oil, but now it is, in large part, produced for export. In the Nampula province, the largest zone of production, there are several purchasers and exporters of sesame.

Cost of production. Two production models are presented: the first is for manual cultivation and the second using a tractor for soil preparation.

Sesame, like sunflower, is not suited to capital-intensive cultivation given current production conditions in Mozambique. Improvements in the viability of sesame production would require significant increases in per-hectare yields which may be achieved through improved technologies combined with use of agro-chemicals in sufficient quantities.

Socio-economic and environmental impact. Sesame, like sunflower, is used for the production of edible oil in small-scale industries. Its oil enjoys strong demand for human consumption, and there is an export market. There are some NGOs in the country that have fostered its production for these markets, generating income for low-income family farmers in the Central and Northern regions. Even so, the quantities produced to date are not substantial.

Opportunity cost. Although it is not considered a stable foodstuff, its economic importance in the Central and Northern regions, especially for low-income peasant communities, discourages its use for biofuel production. Its use as a biofuels feedstock could have an impact on food and nutritional security. On the other hand, prices for this product, influenced by the export market are relatively high, reaching levels around 11,500 Mt/ton. No negative environmental impacts are foreseen from sesame production.

Other factors. The production of sesame has come to replace that of sunflower because of favorable international market prices. No cultural factors were identified that would limit the attractiveness of increases in sesame production, whether using traditional or more capital-intensive methods. One aspect that is particularly important is the development of research on this crop in Mozambique and for the export market, for oil production as well as export.

Soy

Soil and climate suitability. Soy is a crop from the legume family, like beans, but often it is classified as an oilseed due to its high oil content, which varies from 13% to 20%. However, for an oil seed, this percentage is low (FAO, 1989). It is essentially a sub-tropical crop grown in tropical Africa and Asia. Currently, it is considered the most important legume in the world and the largest source of edible oils and vegetable proteins (FAO, 1989).

In Mozambique, there are numerous areas identified as suitable for soy bean cultivation, including large areas of Niassa, Cabo Delgado, Zambezia and Inhambane provinces (see Figure 20).

Soy is potentially a cash crop in many tropical regions where it is cultivated for the extraction of oil, animal feed or for commercialization to industrialized countries with advanced technology for processing.

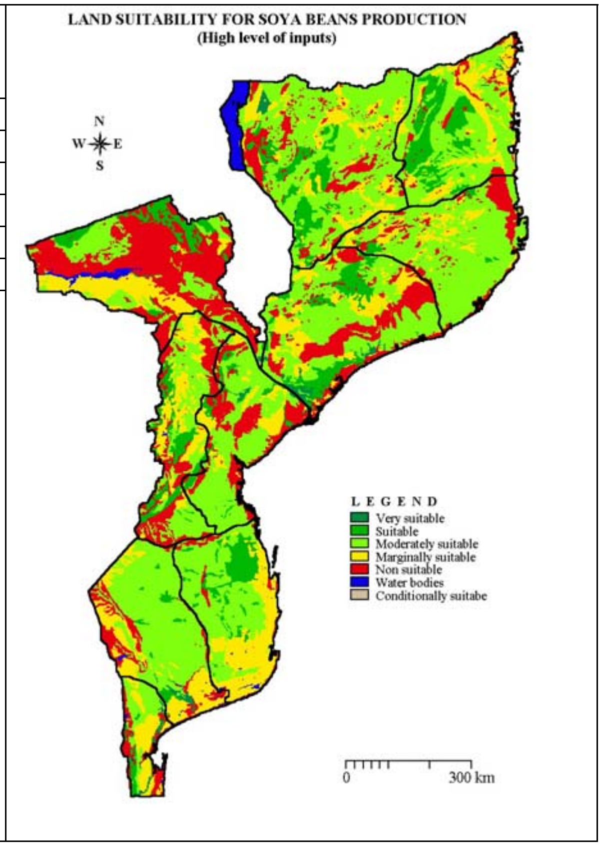
Figure 20: Agro-climatic suitability of soy and yields

Soy crops (ton/ha) – High level of production factors inputs

Level of suitability	Yield
Highly suitable	> 1,70
Suitable	1,40-1,70
Moderately suitable	0,80-1,40
Marginally suitable	0,60-0,80
Non suitable	> 0,60

Conversion factor for cultivation practices:

Medium level of input: 0.85
Low level of input use: 0.75



Source: IIAM (2007).

Cost of production. As in previous cases, two production models are presented, the first traditional and the second mechanized.

As in the case of corn, the use of capital-intensive production techniques generates economies of scale and reduces the cost per ton.

Socio-economic and environmental impact. There is no commercial-scale production of soybeans in Mozambique, although some initiatives have been undertaken. At the moment, Norway is supporting the development of soy cultivation in some regions of the country. Apparently, there are no difficulties from the social and environmental perspective with soy's use as a biofuels feedstock.

Opportunity cost. Soy is not the most suitable feedstock for biofuels production, precisely because it is a legume rich in protein with a relatively low oil yield on a per-hectare basis (500 kg/ha). It is more appropriate for local production of vegetable protein dedicated to poultry production. For this purpose, Mozambique definitely should consider this crop, but without necessarily expanding production to have an excess supply for biofuel production. Its price is around 5,500 Mt/ton.

Other factors. With respect to international markets, the strong competition between the three big producers of this legume (USA, Brazil and Argentina) does not leave room for African producers in the export market. In the Americas, prices are based on the operation of large farms, which are well structured with the latest mechanical equipment, large areas (5,000 to 10,000 ha) and advanced agricultural technology.

Table 26: Production costs for soya

Production model		Manual				With tractor		
Production conditions		Manual preparation, tillage, planting and harvest				Soil preparation with tractor; manual harvest and threshing		
Activities		Unit	Standard/ ha	Cost/unit	Cost/ha	Standard/ ha	Cost/unit	Cost/ha
1	Culture operations				**1,710**			**2,204**
	Tillage	Day	90	15	1,350	1	1,500	1,500
	Planting	Day	2	15	30	2	15	30
	Application of Insecticide					1	10	10
	Fertilization					2	15	34
	Weeding 1	Day	2	15	30	2	15	30
	Harvest	Day	20	15	300	20	15	300
	Threshing	Day			300	20	15	300
2	Inputs				**75**			**1,810**
	seeds/area	kg	5	15	75	10	15	150
	Fertilizer					100	7	700
	Insecticide					3	320	960
3	Total				**1,785**			**4,014**
4	Yield per hectare (t/ha)				**.7**			**3**
5	Cost per ton				**2,550**			**1,338**

Source: Cartas tecnolôgicas, IIAM (updated by Carlos Zandamela, 2007).

There are technical challenges related to oil extraction, and market considerations that have also limited interest in soy in Mozambique. According to FAO (1989) the extraction of soy oil on a small-scale lacks simple and efficient technology that allows separation of the oil from the seed. This source argues that the techniques traditionally applied for palm oil or coconut oil extraction, (which involve grinding, extracting the water and boiling), when applied to soy, result in the production of soy milk. As of the publication of the FAO paper, no viable lower-cost technology had been developed for separating the oil from the protein through the emulsion that is produced.

Even the extraction methods for medium scale production, such as hydraulic presses or screw presses, were not widely used in the commercial production of soy oil because the extraction rate (18% to 20%) is below the economically optimum level, when compared with other commercially available oil seeds.

Given the low oil content in the seed (<20%) and the toughness of the bean, mechanical pressing only removes 10-13% of the oil, leaving a residue of 10% to 7% in the presscake. This operation does not generate sufficient value for the following reasons:

- *Oil*. The 10% yield from the bean does not permit soy to compete with other oils from softer oilseeds that usually generate 20% to 50% of the raw material, consuming less energy per unit processed.
- *Presscake*. The global quality standard for soy meal is 1% residual oil and 48% protein. This is the meal resulting from resulting from hexane solvent extraction. Soy presscake from crushing typically has 7% to 10% residual oil and 40% protein. The market normally does not assign value to the meal according to oil content because the meal is used for poultry feed, for which protein content is the priority. The alternative of installing a hexane oil extraction facility could be considered, but when the primary objective of the project is the production of animal protein in the form of poultry.

In this case, the basis for conducting the economic calculation are based on parameters that are different from those of biodiesel:

- *Oil*. This is sent to the existing market for edible oils, normally with higher margins.
- *Meal*. Animal feed for production of protein for human consumption, in regions where there are no more economic sources of inputs (shortage of grain).

The commercialization of these two by-products in traditional markets with established demand and volumes on the order of 1,000 ton/day makes the installation of solvent-based facilities viable. Besides the investment in the industrial facility, the soy-based undertaking should originate raw material at international costs, to avoid the risk that the local agricultural activity cannot compete with soy that would inevitably be imported from Argentina or Brazil.

The possible exports could be offered for animal protein (for frozen poultry production) in the event that there is surplus of maize, a component of the principal feed. The export of soy meal by Mozambique to overseas markets, however, would find it hard to compete with meal from the Americas. There is fierce competition between the U.S., Brazil and Argentina, which dominate the principal markets with logistical infrastructure that would neutralize potential competitors. The market in South Africa and bordering countries would be an alternative for meal produced in Mozambique, given the limited scope of soy production in those countries.

No cultural issues were identified that would be unfavorable to the increase in soy production, whether based on traditional or capital-intensive production methods. To date, the lack of habit, different taste preferences and excessive cooking time are some of the factors (related to suitability as a crop for human consumption) that discourage the extensive cultivation of soy, although some zones of the country show a high level of agro-ecological adequacy. One aspect that is especially important is the development of research and development on this crop in Mozambique.

Peanuts

Soil and climate suitability. Peanuts represent an source of oil that is indispensable to human dietary needs, especially in developing countries where oil is one of the food products that is not accessible because of cost. Domestic production is led by Nampula province, followed by Zambézia and Cabo Delgado. Neverthless, the greatest consumption levels are recorded in the South. Nearly 70% of peanut production is observed in regions 6, 7, 8, 9 and 10, as shown in Table 28.

Table 27: Yields and potential for peanut

Province	Potential Area (ha)	Potential yield with inputs (t/ha)	Potential yield with-out inputs (t/ha)	Potential yield with inputs (t)	Potential yield with-out inputs (t)
Total	**542,166**	**1.9**	**0.5**	**1,026,562**	**246,688**
Cabo Delgado	78,963	3.0	0.7	236,888	55,274
Niassa	7,019	2.6	0.6	18,586	4,362
Nampula	125,585	2.3	0.5	290,683	66,817
Zambézia	60,889	1.7	0.4	101,598	26,489
Tete	31,461	2.2	0.5	69,793	16,811
Manica	8,641	2.0	0.5	16,953	4,357
Sofala	15,007	2.2	0.6	33,055	8,532
Inhambane	142,759	1.3	0.3	184,680	45,009
Gaza	49,872	0.9	0.2	47,366	12,116
Maputo	21,970	1.2	0.3	26,960	6,921

Source: Kassam et al. (1982).

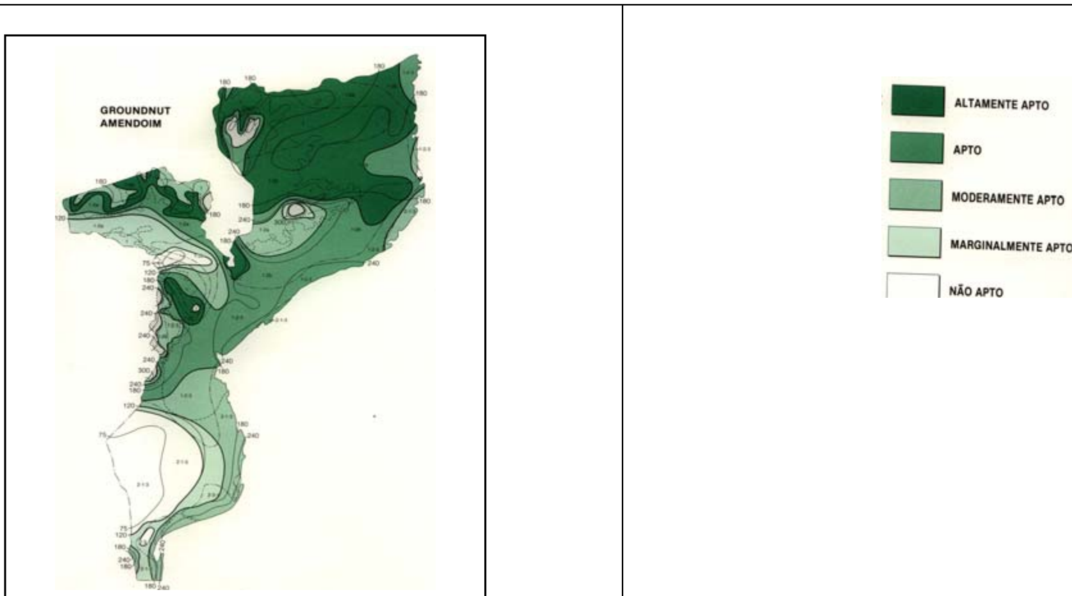
Table 28: Suitability of peanut by agro-ecological region

Region		% Production	% Cumulative Production
R7	Inland Central and North	20%	20%
R8	Coastal North	18%	38%
R9	Inland North of Cabo Delgado	12%	50%
R6	Semi-arid: Zambézia and Tete	9%	60%
R10	High altitude	9%	69%
R4	Mid-elevation Central	7%	76%
R2	Semi-arid Coastal South	7%	83%
R5	Coastal Central	6%	89%
R3	Arid Inland South	6%	95%
R1	Semi-arid Inland South	5%	100%

Source: IIAM

A potential area for peanut cultivation is approximately 542,000 ha, with a possible average yield (with a high level of inputs) is 1.9 tons/ha. With a low level of inputs, the possible average yield is 0.5 tons/ha. The provinces that present the best possible yield are Cabo Delgado, Niassa and Nampula with, respectively, 3 tons/ha, 2.6 tons/ha and 2.3 tons/ha. Tete and Sofala show 2.2 tons/ha and Manica 2 tons/ha. The lowest regional

Figure 21: Agro-climatic suitability of peanut



Source: Kassam at al. (1982)

yield, with a high use of inputs, is Gaza, with 0.9 tons/ha. The average national yield for peanuts is 0.5 tons/ha, reflecting the limited use of inputs and the rudimentary techniques of cultivation employed. The provinces that show the greatest productivity are Nampula, Manica and Zambézia with 0.6 tons/ha, followed by Tete with 0.5 ton/ha. The minimum productivity level recorded for a province is 0.3 tons/ha, recorded for Maputo and Gaza (Kassam et al, 1982).

In Mozambique, peanuts are not used for oil production, and hence are not subjected to any other type of processing. They are used in direct consumption by the population and efforts to export have been blocked n have been blocked by quality problems: the high content of aflatoxins. Although not in practice today, peanuts could be used as rotation crops for sugar cane, serving as a source of nitrogen. Following Brazil's example, peanuts planted for the renewal of sugar cane fields could generate oil for biodiesel in the sugar mill and feed for local animal nutrition, avoiding exportation.

Based on the analysis conducted by Kassam, it appears that the area currently under peanut cultivation could be doubled and, with the application of suitable inputs, yields could be quadrupled, thereby generating yields of eight times or more the current production levels.

Cost of production. Although there is practically no verified mechanized peanut production in Mozambique, the two productions models are presented for comparative purposes.

The use of technology does generate higher returns, hence its use is recommended. Nevertheless, the contamination of peanut crops with the fungus that produces aflatoxins poses a significant barrier to accessing international markets.

Socio-economic and environmental impacts. Peanuts are considered a basic food in the Southern region and in the Central and Northern regions, it is a cash crop. Given the highly visible place accorded peanuts in food sales and the demand in urban areas, it is a crop that contributes significantly to the incomes of farming families.

The possible use of peanuts as a feedstock for biofuels could affect food and nutritional security without significant increases in production and productivity.

Opportunity cost. For the time being, the guaranteed market for a large part of peanut production in Mozambique is domestic consumption. There are low levels of export of smaller varieties of peanut, from the Northern region. Price behavior for peanuts is similar to that of maize. Prices range around 24,060 Mt/ton, which is too high for the use of the crop for biofuels.

In spite of the issues noted above, with careful adoption of measures to promote expanded production areas and, above all the increase of per-hectare yields, peanuts could be a crop for selection as a biodiesel feedstock. Indeed, using more appropriate technologies it would be possible to achieve higher per-hectare yields, as indicated in the production model for mechanized production.

Other factors. No cultural issues were identified that would be unfavorable to the increase of peanut production, whether using traditional or capital-intensive techniques. One aspect that is particularly important is the development of research on this crop in Mozambique.

The contamination of the peanut with a fungus that creates aflatoxin, is one of the major obstacles to accessing the international market. Given the special position the peanut occupies in sales, and its demand in urban centers, it makes a substantial contribution to the incomes of farm families. So far, the Mozambican peanut has not been used to extract cooking oil. According to Tickner et al (2001) the varieties currently produced are not competitive for the local extraction of oil.

Table 29: Production costs for peanut

Production model		Manual				With tractor		
Production conditions		Manual preparation, tillage, planting and harvest				Soil preparation with tractor; manual harvest and threshing		
Activities		Unit	Standard/ ha	Cost/ unit	Cost/ha	Standard/ ha	Cost/unit	Cost/ha
1	Culture operations				**1,010**			**3,210**
	Tillage	Day	1	500	500	9	200	1,800
	Grading					1	750	750
	Planting	Day	2	15	30	2	15	30
	Fertilization					4	15	60
	Application of Insecticide					6	15	90
	Weeding	Day	2	15	30	2	15	30
	Harvest	Day	30	15	450	30	15	450
2	Inputs				**750**			**1,675**
	seeds/area		50	15	750	50	15	750
	Fertilizer (triple superphosphate)					100	7	700
	Insecticide	kg				1	250	225
3	Total cost/ha				**1,760**			**4,885**
4	Yield per hectare (t/ha)				**0.3**			**2**
5	Total Cost per ton				**5,867**			**2,443**

Source: Cartas tecnolôgicas, IIAM (updated by Carlos Zandamela, 2007).

Coconut

Soil and climate suitability. Coconuts are produced mainly in the provinces of Zambézia, Inhambane, Nampula and Cabo-Delgado. Zambézia produces the most coconut, with 69% of the national production, followed by Inhambane with 19%, Nampula with 8% and Cabo-Delgado with 5%. National production is estimated at 60,000 tons, of which 41,250 tons come from Zambézia, 11,250 tons from Inhambane, 4,500 tons from Nampula and 3,000 tons from Cabo-Delgado. The cultivated area is at least 110,000 ha, as described in Table 30 and illustrated in the map contained in Annex D.4.

The production arrangements differ in each area. A large part of Zambezia's output is based on plantations, but harvesting in Inhambane is done by smallholders who deliver copra to oil producers through a system of intermediaries. The family sector accounts for over half of total area under coconut, as shown in Table 30.

Table 30: Area of Coconut trees per sector

Sector	Area (ha)	
Family		63,000
Business		47,000
Madal Group	23,200	
Zambézia Company	8,000	
Murroa Company	3,000	
Boror	4,000	
Geralco	3,000	
Sena Sugar State	1,500	
Entreposto Comercial	1,500	
Small Businesses	2,800	
Total		110,000

Source: Interview Eng. Danilo C. Abdula (SIMA), cited in CEPAGRI (2006).

Mozambican coconut production in general is threatened by the "lethal yellowing" disease (to date, actual damage has occurred only in Zambézia and further North). This disease was identified in the country in 1992, in Cabo Delgado, in Palma District and confirmed in 1996. That year, the die-off of coconut palms observed in some groves in Mocimboa da Praia was 80%. In 1999, the die-off of palms in some groves in districts of Inhassunge (in Gonhane area) and Chinda (Micaune) was 100%. In Nampula also, there have been reports of outbreaks of the disease in the areas of Angoche and Moma.[40] The photograph in Figure 22 shows the condition of coconut palms in Zambêzia in two different phases of the lethal yellowing disease.

Measures to contain the disease are going to be implemented, but there is an urgent need to replant. Apart from the disease described above, the advanced age of the palm trees (in many areas, in excess of 50 years), as well as theft and poor maintenance of the plantations, especially in the family sector are factors that contribute to the reduction in the profitability of the plantations. Interviews with producers suggest that theft is a significant problem: Madal reported that 40% of coconut production is stolen and then sold back to the company by the inhabitants of neighboring regions. The potential for theft is viewed as an obstacle to investment in new plantations.

Cost of production. Credible data on production costs for coconut were not available. Production arrangements differ in each region. While production in Zambêzia takes place on the basis of large plantations, harvesting in Inhambane is done by small

[40] Some apparently suitable steps are already being taken to result in a definitive solution ot the problem through an intervention by the U.S. Millennium Challenge Corporation (MCC). The MCC is a program for the promotion of businesses, investment and employment in Mozambique. There are two objectives: (i) promote businesses and generate employment; and (ii) increase the welfare of the population in the Northern region of the country (Cabe Delgado, Niassa, Nampula and Zambêzia). The program has a duration of five years.

Figure 22: Situation of coconut palms in two phases of lethal yellowing disease

Source: Cardoso Muendane

producers who distribute copra to oil producers through a system of intermediaries. The area cultivated by the family sector corresponds to more than half of coconut, as shown in Table 30.

The consultant team's interviews with coconut oil producers in both Inhambane and Zambezia indicated that supplies of copra for oil processing seem inadequate to keep their current processing capacity in operation full time. Further, processors reported significant problems related to copra quality. Beyond the issue of slipping production due to disease and the diminishing productivity of existing trees, it appears there are other factors that also contribute to the problems reported. These include theft (in Zambezia), logistical challenges regarding shipments of raw oil for processors (in Inhambane), and the mechanism by which intermediaries deliver copra to the oil processing facilities (in Inhambane). On this last issue, the presence of a large number of intermediaries appears to have introduced a significant degree of competition, which has made it difficult for oil processors to introduce a price signal for higher quality copra. The processors report that, in effect, they are obliged to "take what they can get."

Technoserve's efforts to promote small-scale biodiesel production for self-supply have resulted in several examples of biodiesel production (Somoil, Madal). There are others who have begun producing biodiesel on a small scale, using home-made equipment (ISOL). Finally, there are more industrial biodiesel production projects planned (such as C3), though these will also have to be limited to self-supply in the absence of a clear government policy on the issue. Companies such as C3 are looking to export coconut oil for biodiesel production, but they face obstacles such as high transportation costs and competition from other uses for the oil, which now commands a high price on international markets. Further, the volumes of copra oil available in international markets represent an increasingly small segment of the oil market (now about 5%). Palm oil, the dominant product, costs much less to produce and may replace copra oil in many uses.

Socio-economic and environmental impacts. Half of the coconut produced in Mozambique is consumed domestically, amounting to some 30,000 tons. The other half is sold as fresh coconut or as copra for export and for soap production. In Mozambique, copra oil is not in much demand for human consumption. Industrial use of coconut reached a peak in 1998 at around 7,000 tons.

In Zambêzia and in Inhambane, the economic and social importance of coconut is significant. The population depends on many parts of the coconut palm, for direct consumption of the coconut as well as other uses of the plan, as timber and for palm fronds for use in roof thatching for their homes.

Opportunity costs. In Europe, there is a market for coconut oil in the agro-industrial market sector as a substitute for cocoa butter. This sector demands special oils with good stability and performance similar to that of cocoa butter. Until recently, cheap vegetable oils were hydrogenised to attempt to imitate cocoa, but due to concerns about *trans-fatty acids* that alternative is losing appeal, fostering demand for coconut oil. Madal exports oil at prices ranging from USD 600/ton to USD 800/ton to Switzerland. Producers such as C3 are trying to export coconut oil for biodiesel production, but they encounter obstacles such as the high cost of transportation and competition from other uses of the oil, which now drive higher prices for the oil on international markets. Therefore, given domestic consumption and the international market, it may be concluded that the opportunity cost of using coconut for biodiesel is too high.

Other factors. Neverthless, there is a fact about which there cannot be any controversy: all the experience with biodiesel in Mozambique were conducted with coconut oil. In addition, coconut production in Mozambique is highly localized.

No cultural factors were identified that would be prejudicial to an increase in coconut production, either in the traditional context or in more capital-intensive setting. Again, an important consideration is the development research and development for coconut in Mozambique.

Cotton

Soil and climate suitability. The agro-ecologic suitability of cotton is presented in the following graphic. Neverthless, the majority of cotton production in Mozambique is in Nampula (58% of output in 2001) then Cabo Delgado (22%) and Sofala (10%); Zambézia (5%) and Niassa (3%) (MINAG, 2002).

Fiber obtained from cotton is exported, and the seed is used to extract edible oil. Cotton bolls are cleaned, and cotton seeds are obtained from this process, containing 16% to 19% oil. From this, factories can extract 11% to 13%, with the rest of the oil in the presscake. The highest production of oil from cotton occurred about 15 years ago, when domestic industry processed around 23,000 tons of cotton seed. Since then, production has decreased until the complete collapse consumption of this oil by domestic industry and its substitution with imported oil. In the past, there was a strong demand for cottonseed oil, because it was more stable than soy oil. Currently, palm oil has reduced this market, except in countries with less efficient cultivation.

Costs of production. As in the previous cases, two production models are presented, one for manual production and the other for mechanized cultivation. The two models presented here suggest that the use of a tractor together with fertilization is more attractive based on the increases in yields per unit area. This has justified the agro-industrial development of cotton since the Colonial period.

Socio-economic and environmental impact. Cotton production was introduced in Mozambique in the Colonial period and constitutes the source of economic livelihood for thousands of peasants and a source of income for the country. Cotton oil is sought after for human consumption. Its use as a raw material for biodiesel could affect food and nutritional security, unless a large increase in production and productivity is achieved.

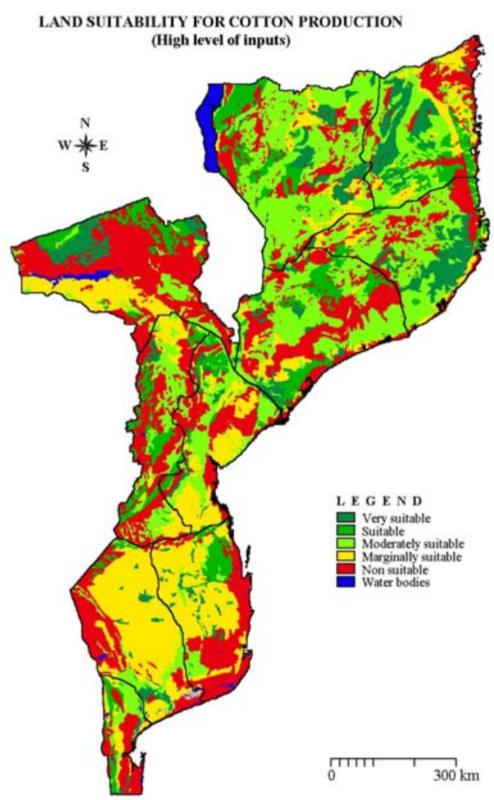
Figure 23: Suitability of land for cotton production and estimated yields

Cotton Crop (ton/ha) – High level of production factor inputs

Class of suitability	Yield
Highly suitable	> 1,5
Suitable	1,2-1,5
Moderately suitable	0,7-1,2
Marginally suitable	0,5-0,7
Non suitable	< 0,5

Conversion factor for cultivation practices:

Medium level of inputs: 0.55
Low level of input:30



Source: IIAM (2007).

Cotton is being increased in other countries such as Brazil as an alternative to soy, whose profitability has leveled off. The profitability of cotton comes from the fiber and the lint. The cotton boll is a sub-product that can be turned into oil and chaff or used directly for animal feed. In some micro-regions, especially those far from refineries, there is excess supply of bolls, freeing up this feedstock for oil extraction and biodiesel production. The presscake is an excellent source of energy and protein for dairy cattle. This suggests that cotton, like soy, could be used to achieve two objectives in the context of a biodiesel program – increasing production of oil for biodiesel production and valuable presscake for use in meat and dairy production.

Opportunity cost. The price of cotton seed is established on the basis of international prices. The average price is about 5,300 Mt/ton. Given its use in food production, the opportunity cost of using it for biodiesel production would appear to be too high.

Other factors. No cultural factors were identified that would appear to be unfavorable to an increase in cotton production, whether using traditional methods or capital-intensive ones.

Table 31: Production costs for cotton

Production model		Manual				With tractor		
Production conditions		Manual preparation, tillage, planting and harvest				Soil preparation with tractor; manual harvest and threshing		
Activities		Unit	Standard/ ha	Cost/unit	Cost/ha	Standard/ ha	Cost/unit	Cost/ha
1	Culture operations				**3,160**			**3,030**
	Tillage	Day	90	15	1,350	1	1,500	1,500
	Subsurface fertilization	Day				2	15	30
	Planting		18	15	270	15	15	225
	Thinning out	Day	5	15	75	5	15	75
	Application of Insecticide (X3)	Day				6	15	90
	First weeding	Day	15	15	225	2	15	30
	Thinning out+first weeding					2	15	30
	Application of Insecticide 1	Day	2	15	30			
	Second weeding	Day	15	15	225			
	Application of Insecticide 2	Day	2	15	30			
	Third weeding	Day	15	15	225			
	Application of Insecticide 3	Day	2	15	30			
	Harvest	Day	70	10	700	70	15	1,050
2	Inputs				**0**			**1,760**
	Cipermethine	Liter				1	160	160
	Urea	kg				100	9	900
	NPK	kg				100	7	700
3	Total				**3,160**			**4,790**
4	Yield per hectare (t/ha)				**0.75**			**2.5**
5	Cost per ton				**4,213**			**1,916**

Source: Cartas tecnolôgicas, IIAM (updated by Carlos Zandamela, 2007).

Mafurra

Soil and climate suitability. Mafurra is an oil seed crop used for extracting oil and producing soap, mainly in Inhambane province. Besides its industrial use, it is also used to manufacture home-made oils that are very popular in Inhambane. No agro-climate map

Table 32: Production of mafurra

Province	Plantings	Trees	% of Trees
Maputo	38,251	175,630	10
Inhambane	129,509	1,123,689	62
Sofala	420	980	0
Outras	111,646	512,368	28
Nacional	279,826	1,812,667	100

Source: INE. NB: Zambézia, Nampula, Niassa and Cabo Delgado did not report production of mafurra

of mafurra's suitability was found. Nevertheless, the production of mafurra by province is shown in Table 32.

In Mozambique, only two factories use mafurra to make soap: Ginwala and Saboeira in Inhambane. The highest quantity processed was close to 300 tons in 1998. From there, the industrial consumption of mafurra has declined.

Cost of production. For the cultivation of mafurra, no agro-economic research data were found that could provide any recommendations regarding the production models. The same was true in the case of the traditional system – no data consistent with the cultivation practices were available.

Socio-economic impact. Mafurra is produced and used almost exclusively in the Southern region of the country. It is consumed immediately or in the form of oil. It is also utilized for soap production. However, the low levels of consumption and limited industrialization suggest that its possible use as a biodiesel feedstock would not affect food security. On the other hand, nothing indicates that it could have environmental impacts, either.

Opportunity cost. There is no price for mafurra that is monitored by the MINAG, nor is there any indicator tracked by any other system. For this reason, no systematic source of price information was found. Still, given the low consumption, the consultant team believes that the opportunity cost should be low.

Castor seed

Soil and climate suitability. Like jatropha, castor seed is a wild plant originally from North Africa that is now found virtually everywhere. It is the best option for areas that are dry (less than 600 mm rain/year), rocky or hilly.

At present, there appears to be only incipient production of castor seed in Mozambique. According to a report apparently prepared in early 2006, an investor is developing a castor seed plantation in Nampula province, with some 100 ha under cultivation as of late 2005. The report estimates the total area under cultivation in the country is about 1,000 ha, putting Mozambique well behind several other African countries in terms of output, not to mention leading producers such as India, which has some 650,000 ha.[41]

Cost of production. No data on production costs for castor seed in Moazmbique were found. Traditionally, castor seed is a ‘wild’ plant in Mozambique that is used to produce medicinal products. Therefore, there are no systematic cost data available for this crop, nor price series. The only prices that exist are those for the medicinal products derived from castor seed, and hence not related to the cost of price for the seed. In addition, these prices have not been systematized.

Average yields in Mozambique are well below those reported elsewhere: yields in Mozambique have averaged about 0.3 tons/ha, compared to 0.9 kg/ha in China and 1.2 tons/ha in Paraguay. This reflects the impact of factors such as the quality of the varieties used as well as whether cultivation takes place in irrigated areas. Given the estimates of the suitability of land for castor seed shown in Figure 24, it also suggests that improvements in land selection should be assessed.

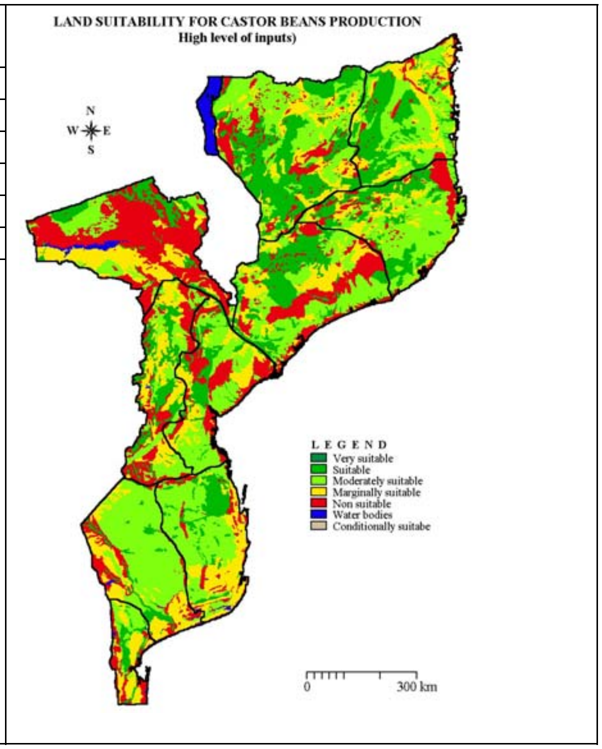
As with other crops, the suitability of castor seed as a biodiesel feedstock will depend in part on the profitability of competing uses for castor seed oil. The oil commands very high prices on the international market because of its suitability for specific industrial

Figure 24: Suitability for castor seed production and projected yields

Castor seed crop (ton/ha) – High level of production factor inputs	
Class of suitability	Yield
Highly suitable	> 1,70
Suitable	1.25-1,70
Moderately suitable	0,75-1,25
Marginally suitable	0,50-0,75
Non suitable	< 0,50

Conversion factors for cultivation practices:

Medium level of inputs: 0.80
Low level of inputs: 0.70



Source: Kassam at al. (1982)

[41] CEPAGRI, “Anexo I-Informação sobre of sub-sector de rícino em Moçambique,” undated document.

applications. In spite of this, the investor involved in castor seed production in Nampula reports his production is intended for a biodiesel producer in South Africa.

Socio-economic and environmental impact. Although castor seed oil commands a high price in Europe, its present market (industrial use for high-performance oils and polymers) is very limited to absorb additional volumes. India and Brazil have a well established industry serving the traditional market. Mozambique may wish to consider this crop, given its African origins, since castor seed will not compete with food crops. In this way, it would emulate Brazil in its biodiesel program, where castor seed has an important role in semi-arid regions.

Figure 25: Experimental castor seed plantation in Nampula

Source: Cardoso Muendane

Opportunity cost. As in the case of mafurra, the consultant team did not find agronomic research data that could suggest any recommendations for the production models for castor seed production. Similarly, it was not possible to find consistent data for the practices and techniques used in the traditional sector. Still, given the low consumption volumes, it is likely that the opportunity cost will be similarly low, even though castor oil reaches high price levels (up to USD 1,000/ton), because the market is limited. India supplies the international market that was originally led by Brazil, and it would be difficult to establish a presence in the international market without triggering a sharp drop in prices. Even so, Technoserve contends that in the near term, the opportunity cost could be moderate or even quite high.

Other factors. No cultural factors were identified that would be contrary to the expansion of castor seed, whether in the traditional context or in the capital-intensive sector. One factor that is particularly important is the development of research on this plant in Mozambique.

Jatropha

Soil and climate suitability. There are no data on the agro-ecological suitability of jatropha in Mozambique, nor a register of its production and commercialization. Even so, has engaged in a veritable national campaign to plant and cultivate jatropha, heeding President Guebuza's call to propagate the plant as a source of fuel.

Traditionally, jatropha grows wild in Mozambique and has been used as a medicinal plant, for decorative purposes or to establish boundaries between small-holder plots. There are also numerous plantation-scale projects in place in various parts of the country, including Zambézia and Inhambane provinces. This suggests that there are perhaps 1,000 ha in the country now planted with jatropha, and plans for up to 20,000 ha more in the next few years. Other than the plantations, every district has planted about 8 – 15 hectares of jatropha, based on government instructions.

Most international investment in biodiesel involves the development of jatropha plantations. The consultant team has observed that a large number of farmers who previously grew tobacco are now switching to jatropha because they anticipate higher and more reliable prices. Investment in jatropha is apparent throughout the region: 200,000 ha have been planted in Malawi, another 15,000 ha in Zambia, 3,000 ha in Tanzania, and a significant area in Swaziland.

There is some controversy about jatropha, however. To date the government of South Africa has refused to authorize planting in that country on the grounds that it is an alien species whose broader environmental impacts are not well understood (although some companies, such as D1 Oils (Africa) plan to process jatropha oil into biodiesel in the country). There is concern, too, that jatropha plantations will encroach on the land suitable for food production. While this concern does not appear to be as salient in Mozambique, where a substantial amount of land is available, it does illustrate the weakness of arguments that jatropha will not compete with food production: in order to secure commercially viable volumes and yields of oil, plantation owners will want to use good land for jatropha cultivation.[42] Only in the family sector will cultivation of jatropha on marginal land, with correspondingly low yields and volumes of production, appear to be likely.

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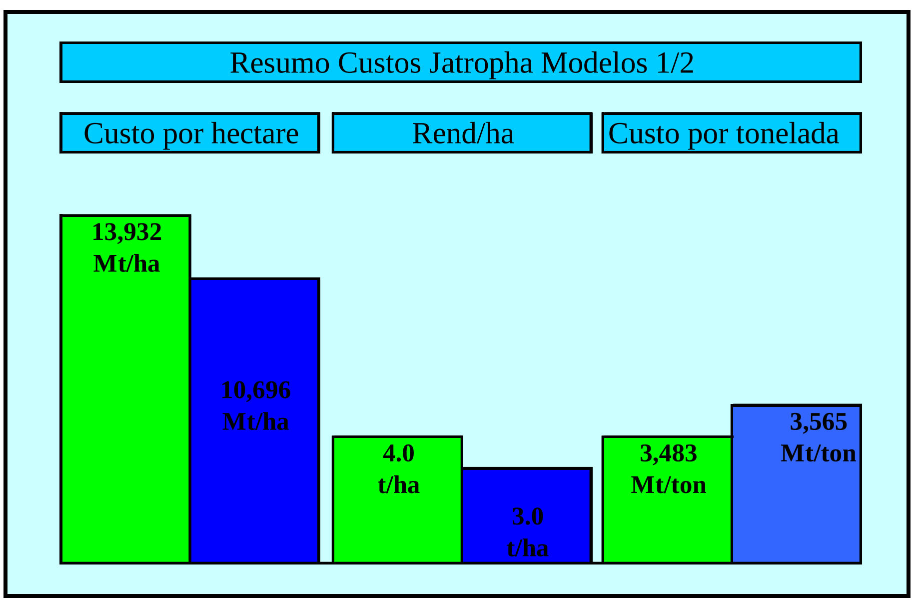
[42]At the seminar on jatropha hosted by CEPAGRI in Maputo on March 9, 2007, Reinhard Henning argued that jatropha is not as hardy or trouble-free a crop as initially believed. Its water requirements appear to be on the order of at least 600 mm/year.

Figure 26: Jatropha plantation near Nampula

Source: Cardoso Muendane

Figure 27: Production costs for jatropha in Mozambique



Source: Interviews by Econergy.

Cost of production. Very little reliable information is available about jatropha yields and oil production, though some initial, demonstration-scale projects (including one in Mali) and various laboratory studies indicate that it is an excellent source of vegetable oil suitable for biodiesel production. At present, however, it appears that good quality jatropha seed is worth more to farmers engaged in the establishment of plantations (prices of USD 600/ton have been reported) than it is to oil producers, since at current prices, the resulting oil would not be competitive with fossil diesel. The following table summarizes the cost and yield data that were collected on jatropha production.

The situation with jatropha in Mozambique is similar to that reported in previous sections on mafurra and castor seed with respect to the availability of technical information. Although the IIAM has already initiated some work to prepare agronomic studies on this crop, consistent results are not yet available to provide the basis for recommendations on production models for the crop. Similarly, it was not possible to find consistent data for the traditional sector on practices that could lead to reliable studies on its economic viability.

Socio-economic and environmental impact. Organized production of jatropha in Mozambique is new. Nevertheless, taking into consideration its tolerance for dry conditions and the possibility of cultivation in marginal areas, its oil yields , the consultant team believes that the crop could have a favorable impact.

Opportunity cost. Taking into consideration the information presented above, the consultant team believes that the opportunity cost is low compared with other oils, and are based on the alternative use of the land and the labor required to cultivate the crop. Some traders in the European market predict higher values in that market, based on a 30% discount to the price of soy oil, although they admit that these values are still theoretical at present.[43] The value proposed in this analysis is approximately twice the cost of production.

Other factors. No cultural factors were identified that would militate against increasing jatropha production, whether in the traditional context or in the capital-intensive sector, other than the fact that some varieties of the plant are toxic. One aspect that is particularly important is the development of research on this plant in Mozambique.

African Palm

There are no data on African palm in Mozambique, nor history of its production. Technoserve reports that it has not considered African palm for further assessment as a potential vegetable oil crop in Nampula because the plan requires a more humid climate than that province can provide. However, irrigated land could be available for palm

[43] One value for the feedstock, expressed as a price FOB Maputo, based on a discount of 30% to the value of soy oil (Rotterdam) less freight Maputo-Rotterdam of USD 82/ton, would be USD 855. With extraction rates between 24% and 36%, this would yield a price for the raw material of between USD 200/ton and USD 300/ton. Interview with Christine Ake, EDF Man, 14 February, 2008.

cultivation, creating an opportunity to produce African palm, which is a widely used feedstock for biodiesel and potentially a lucrative one, given the plant's yield and low cost of production relative to international prices. It seems that Benin is going in that direction. It is important to note, however, that development of palm oil production would take a significant amount of time – Malaysia began its program in the 1970s.

The primary question regarding the suitability of African palm as a biofuel crop, however, is the fact that international prices are now higher than the price of fossil diesel (excluding taxes), limiting its attractiveness to those markets where biodiesel is accorded favorable tax treatment and the taxes on fossil diesel are sufficiently high that biodiesel remains economically attractive (this is the case in Europe, which is importing large volumes of palm oil for biodiesel production). At the same time, African exporters would enjoy a logistical advantage relative to the major exporters, Malaysia and Indonesia. In addition, if a plantation program in Mozambique were implemented with appropriate care for land-use conversion, it is possible that the country could gain market share with importers concerned with the environmental impacts associated with palm oil production.

5. Summary of analysis of biofuel feedstocks

Production costs vary as a function of the technology used. In this way, a schedule of costs would exist for the family sector as well as the agro-industrial sector. Or course, in reality between the two extremes there are an infinite number of actual models that vary almost from one farmer to the next.

In Mozambique, almost all of the agriculture is in the family sector and hence there is practically no monetary outlay involved, there are no expenditures although there are costs. Many of the cultivated plants naturally reproduce and man intervenes solely for small acts of maintenance.

In general, costs increase significantly with the use of more modern technologies, such as machinery (tractors) and inputs such as fertilizers, quite the opposite of the traditional subsistence practices in which intensive labor is used with practically no inputs to improve yields. In the first case, the cost per hectare is higher but the higher yield per hectare justifies this. The traditional system survives only because in the majority of cases, labor is not paid and its opportunity cost is almost zero.[44] In this way, the traditional system perpetuates poverty.

The assessment of the costs of production for the different crops reviewed in this Chapter is based on estimates of costs of production from MINAG, based on the models of production. In the case of the crops not widely cultivated in Mozambique, such as African palm and castor seed, no production cost is shown. In the case of soy, which is not extensively cultivated in Mozambique, the IIAM developed some data and these are the basis for the estimates. The data from the so-called "technological datasheets"

[44] The labor factor of production is family based and does not have alternative employment, hence its application in the agricultural context is always better than nothing, which is the alternative.

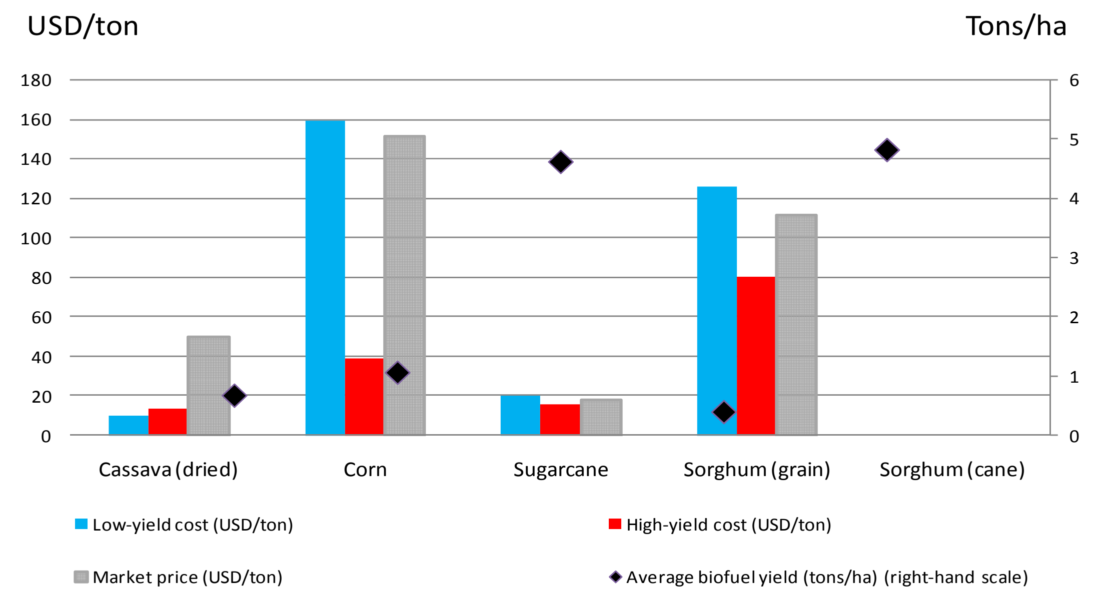
[*cartas tecnolôgicas*] and the average annual and monthly prices have been presented in Section 4. Table 33 shows the prices and average costs for some products, showing the yields by hectare, followed by per-hectare costs derived from the production costs estimated in the technological datasheets. For the low-yield cases, the costs in per-hectare terms are higher, with the exception of cassava and sunflower. For the high-yield case, the per-hectare costs are relatively less. The same data are shown graphically in Figure 28 and Figure 29. Then Table 34 shows a summary of the analysis of the remaining evaluation criteria other than costs and prices, and Table 35 presents a matrix with more details regarding the analysis of the biofuels feedstocks developed in Chapter 4.

Table 33: Summary of representative feedstock costs

	Yield (ton/ha)		**Cost/ton (Low per-ha yield case)**		**Cost/ton (High per-ha yield case)**		**Average price/ton (Feedstock)**		**Biofuel yield (ton/ha)**
	Low	High	Mt	USD	Mt	USD	Mt	USD	Tons#
Ethanol									
Cassava (dried)*	5.0	10.0	268	10	382	14	1,350	50	0.46-0.9
Corn	1.0	6.0	4,293	159	1,062	39	4,090	151	0.3-1.83
Sugarcane##	60	90	-	20	-	16	-	18	3.7-5.5
Sorghum**	0.7	2.0	3,407	126	2,157	80	3,000	111	*0.21-0.6*
Sorghum (cane)	20	90							*1.7-7.9*
Biodiesel									
Coconut ###	-	-	-	-	-	-	5,000	185	*0.46*
Cotton***	0.8	2.5	4,513	167	2,028	75	5,300	196	0.1-0.33
Peanuts	0.3	2.0	7,367	273	2,668	99	24,060	891	0.12-0.8
Jatropha####	3.0	4.0	3,565	132	3,483	129	7,508	278	0.6-0.8
Sesame	0.4	1.5	6,493	240	3,260	121	11,500	426	-
Soy	0.7	3.0	2,550	94	1,338	50	5,500	204	0.1-0.42
Sunflower	0.5	1.5	2,138	79	2,720	101	3,750	139	0.16-0.5

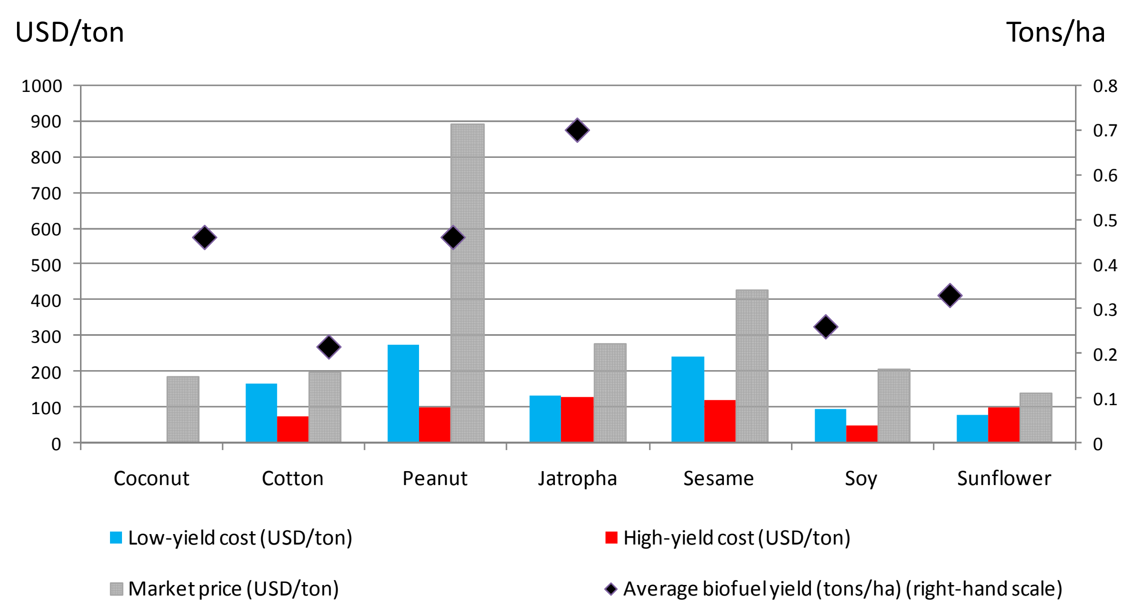
Notes: #Oil yields are based in Chapter 4: coconut, 62%; cotton, 13%; peanut, 40%; jatropha, 20%; soy, 14%; sunflower, 32%; and assuming a conversion rate from oil to biodiesel of 98%. *Fresh cassava is sold in markets at higher prices that vary from 3 to 10 Mt/Kg. Cassava data provided by Dr. Sicco Kolijn, International Institute of Tropical Agriculture. ##Based on CEPAGRI data. Cost in the market is derived from projected prices in the international sugar market in the range of USD 130-140, assuming 13% sucrose in cane in Moçambique, derived from LMC (2006). ** Price at the Beira market. A representative yield could be at 3 toneladas/ha, assuming that it will increase in keeping with productivity improvements. ###Coconut is sold by the piece. Price per kilo is based on purchases made in the markets of Beira and Inhambane. Yield is based on (2006), "Futuro do sub-sector de Coco: uma Nota de Reflexão." ***Minimum price to the producer as set by the Government for first-grade cotton. ####Price is still theoretical given that there is still no market for jatropha; the value used is twice the production cost. Sources: Costs are calculated based on IIAM data (SG 2000) and an interview with Julieta Zandamela (2007); prices in general are obtained on the SIMA and on the markets.

Figure 28: Summary of costs and yields – ethanol



Source: Table 33.

Figure 29: Summary of costs and yields - biodiesel



Source: Table 33.

Table 34: Summary of the biofuels feedstock analysis

Feedstock	*Agro-ecologic suitability*	*Socio-economic and environmental impacts*	*Cost of production, opportunity cost and per-hectare output*	*Other factors*	*Conclusion(evaluated in Chapters 4 and 6)*
Ethanol					
Maize	+	-	0	+	Not evaluated
Cassava	**+**	**0**	**+**	**+**	**Evaluated**
Sugarcane and molasses	**+**	**+**	**+**	**0**	**Evaluated**
Sweet sorghum	**+**	**+**	**+**	**+**	**Evaluated**
Biodiesel					
Sunflower	**NA**	**0**	**0**	**+**	**Evaluated**
Sesame	NA	0	-	+	Not evaluated
Soy	**+**	**0**	**0**	**+**	**Evaluated**
Peanut	+	0	-	+	Not evaluated
Coconut	**+**	**+**	**0**	**+**	**Evaluated**
Cotton	+	0	-	+	Not evaluated
Mafurra	NA	NA	NA	+	Not evaluated
Castor Seed	**+**	**NA**	**-**	**NA**	**Evaluated**
Jatropha	**+**	**+**	**0**	**+**	**Evaluated**
African Palm	**NA**	**0**	**0**	**NA**	**Evaluated**

Legend: - denotes “low” or “unfavorable;” + denotes “high” or “favorable;” 0 denotes “moderate,” and NA denotes “unavailable.”

6. Business models observed in the bio-fuels sector

The Econergy team met with several project sponsors, including ethanol projects involving CAMEC (ProCana), EcoEnergía (BAFF/SEKAB), NetFinance (COFAMOSA), and Principle Energy (which is now commencing planting). On the biodiesel side, the team met with Elaion, JFS, ESV Bio Africa and Geralco.

From the discussions with these developers of new bio-fuels production capacity, as opposed to the existing producers such as C3 and Somoil, it is clear that investors are examining bio-fuels production possibilities in Mozambique with the explicit objective of exporting ethanol or raw oil for further processing in the destination country, to benefit from fiscal and other incentives to process biodiesel in the market where it is consumed. While this clearly, and predictably, reflects the desire of European-based investors to increase profitability, it also reflects the fact that there is no specific regulatory and fiscal framework in Mozambique to promote biofuel use. In any case the domestic market for ethanol is too small to support a facility large enough to exploit economies of scale. The feedstocks contemplated in the case of the ethanol and biodiesel projects under

Table 35: Summary of analysis of crops by evaluation criteria

Feedstock	*Agro-ecologic suitability*	*Socio-economic and environmental impact*	*Cost of production and opportunity cost*	*Other factors*	*Conclusion*
Ethanol					
Maize	Concentrated in the Northern region and certain areas of the Central region, but produced throughout the country.	Staple food in almost the entire country; agribusiness companies exist that use domestic maize as input for producing flour. Does not deliver as significant GHG reduction as other feed-stocks. (See Chapter 4.)	Moderate. Production costs are among the lowest of the crops analyzed and the domestic market price is not high. Moderate per-ha biofuel output.	Cultural aspects that are favorable to its production.	Its use as a feedstock for biofuels could affect food and nutritional security unless producting and producivity increase significantly. **Will not be analyzed in Chapter 4 or Chapter 6.**
Cassava	Concentrated in the Central region and some areas of the Northern region. Produced throughout the country.	Staple food in almost the entire country; only small machines exist for processing cassava. Can deliver a significant GHG reduction, especially with higher productivity. (See Chapter 4.)	Low production cost and sale in the domestic market. Does not have strong demand, crop used as a food reserve. Low per-ha biofuel output at current productivity levels.	Cultural aspects that are favorable to increase in production.	Use as a biofuel feestock could affect food and nutritional security, unless production and productivity. However, its status as a reserve crop justifies consideration. **Is analyzed in Chapter 4 and Chapter 6.**
Sugarcane and sugarcane molasses	Although there are various zones that there is production of sugarcane, in Mozambique it is produced industrially only in the irrigated areas developed by industry.	Employs 20,000 people directly and 100,000 indirectly. Is a source of hard currency and import substitution. Can deliver significant GHG reductions. (See Chapter 4.)	Low to moderate. Underutilized molasses is available. Production of ethanol might not compete directly with production of sugar if produced in new indus-trial facilities. The opportunity cost in-volves resource use, among them, water. High per-ha biofuel output.	National yield is relatively low. Domestic consumption of gasoline is low, and international markets may be more competitive due to the number of new producers.	The decision requires further consideration, taking into account the international market and limited consumption of gasoline. Water efficiency should be considered. **Will be analyzed in Chapter 4 and Chapter 6.**

Feedstock	*Agro-ecologic suitability*	*Socio-economic and environmental impact*	*Cost of production and opportunity cost*	*Other factors*	*Conclusion*
Sweet Sorghum	Concentrated in the Northern region and some zones of the Central region. Grain sorghum is produced is produced throughout the country. Areas of suitability are similar to those for maize.	Staple crop in the Central and Northern regions; no industrial processing facilities that use this cereal as a feedstock. Can deliver GHG reductions, though analysis presented in Chapter 4 shows somewhat lower GHG benefits than other sources. Lower water requirements are important feature.	Moderate. Low to moderate costs, with moderate prices in market – taking into consideration the fact that the sorghum market does not exist yet. Moderate to high per-ha biofuel output.	Cultural factors favor increases in its production.	Use as a biofuel feedstock could affect food and nutritional security due to displacement of maize, unless there is a significant increase in output and productivity. Further research by IIAM is required on cultivation on industrial scale. **Will be analyzed in Chapter 4 and Chapter 6.**
Biodiesel					
Sunflower	No agro-ecologic suitability map is available. Produced in the Central and Northern regions.	Oil extracted primarily from small presses is used for human consumption. Is a cash crop in the Central and Northern regions. Can deliver GHG reductions, though analysis presented in Chapter 4 shows relatively small savings.	Moderate. Costs of production are low, while the price in the market is moderate. Low per-ha biofuel output.	Cultural aspects favor increase in production.	Its use as a biofuels feedstock should not affect food and nutritional security, in part due to use of presscaske as animal feed. **Will be analyzed in Chapter 4 and Chapter 6.**
Sesame	No agro-ecologic suitability map is available. Produced in the Central and Northern regions.	Oil extracted primarily with small presses and is used for human consumption. Is a cash crop in the Central and Northern regions. Analysis suggests GHG emissions reductions may be limited.	High opportunity cost. Low per-ha biofuel output.	Cultural factors favor increase in production.	Its use as a raw material for biofuels could affect food and nutritional security, unless there is a significant increase in production and productivity. **Will not be analyzed in Chapter 4 or Chapter 6.**

Feedstock	*Agro-ecologic suitability*	*Socio-economic and environmental impact*	*Cost of production and opportunity cost*	*Other factors*	*Conclusion*
Soy	Suitable areas exist in all three regions of the country. Produced in the Central and Northern regions.	Regular production is not recorded currently. Will receive support from some NGOs in the Central and Northern regions. Analysis suggests GHG emissions reductions may be limited.	High opportunity cost. Is only a suitable feedstock for oil production with demand for animal feed using meal. Production cost may be low, but international price is high. Low per-ha biofuel output.	Cultural factors favor increase in its production.	Its use as a biofuel feedstock could affect food and nutritional security, unless there is a significant increase in production and productivity. **Will be analyzed in Chapter 4 and Chapter 6.**
Peanut	Concentrated in the Northern region and some areas of the Central region. Produced throughout the country.	Is a cash crop in the Central and Northern region, and a subsistence crop in the South. Analysis suggests GHG emissions reductions may be limited.	High opportunity cost. Moderate per-ha biofuel output (for biodiesel feedstocks).	Cultural factors favor increase in its production. There is a limitation due to toxicity of peanut fungus.	Its use as a biofuels feedstock could affect food and nutritional security, unless there is a significant increase in production and productivity. **Will not be analyzed in Chapter 4 or Chapter 6.**
Coconut	Produced in coastal areas: Zambézia, Inhambane, Nampula and Cabo delgado.	Is important for human consumption and as a feedstock for the soap industry and for export of raw oil. Production characteristics make it likely to deliver a significant GHG reduction, especially with higher productivity. (Not analyzed in Chapter 4.)	High opportunity cost. Costs of production are not well identified, but prices on the international market are high. Low per-ha biofuel output.	Cultural factors favor increase in its production.	Its use as a biofuel feedstock could affect food and nutritional security, unless there is a significant increase in production and productivity. Rehabilitation of existing trees is needed. **Will be analyzed in Chapter 4 and Chapter 6.**

Feedstock	*Agro-ecologic suitability*	*Socio-economic and environmental impact*	*Cost of production and opportunity cost*	*Other factors*	*Conclusion*
Cotton	Concentrated in the Northern region and some areas of the Central region.	Is a subsistence crop in the Central and Northern region and is an export product. The seed is utilized for production of edible oil. Analysis suggests GHG emissions reductions may be limited. (See Chapter 4.)	Elevated opportunity cost. High costs of production and high prices in the market. Low per-ha biofuel output.	Cultural factors favor increase in its production.	Its use as a biofuels feedstock could affect food and nutritional security unless there is a significant increase in production and productivity or that production is additional and permits the use of presscake for dairy production. **Will not be analyzed in Chapter 4 or Chapter 6.**
Mafurra	Agro-ecological suitability map is not available. Produced in the Southern region.	Oil is produced for consumer use, primarily by SMEs. It is a cash crop in the Southern region. (Not analyzed in Chapter 4.)	Production costs are not well understood, nor are market prices reasily available, but these seem likely to be low. Per-ha productivity not well understood either.	Cultural factors favor increase in production.	Use should not affect food security. **Will not be analyzed in Chapter 4.**
Castor Seed	Areas with good suitability for the crop are located in the three regions of the country. Produced in the Central and Northern regions.	Production is not regular or widespread. Is about to be produced in an experimental setting by a company in Nampula. (Not analyzed in Chapter 4.)	High opportunity cost. Prices on international market are extremely high. Low per-ha biofuel output.	Cultural factors favor increase in production.	There is a possibility of competing with other crops. Further study is required at IIAM. **Will be analyzed in Chapter 4 and Chapter 6.**

Feedstock	*Agro-ecologic suitability*	*Socio-economic and environmental impact*	*Cost of production and opportunity cost*	*Other factors*	*Conclusion*
Jatropha	Agro-ecological suitability map not available, but evidence points at good distribution. Produced in the entire country as a "wild plant."	Production is not regular. Currently being cultivated on an experimental basis by various companies in the country and as a result of government promotion. Can deliver significant GHG reductions. (See Chapter 4.)	High opportunity costs, but likely to decrease. Moderate per-ha biofuel output (for biodiesel feedstocks). Low per-ha biofuel output.	Cultural factors favor increase in production. Is toxic.	There is a possibility of competition with other crops if jatropha cultivation becomes widespread. Studies by IIAM are needed. **Will be analyzed in Chapter 4 and Chapter 6.**
African Palm	No information. Appears that the Central region would be suitable for cultivation. Would require irrigation and several years of development.	Production not recorded in Mozambique. GHG reductions can be significant, especially if it occurs on land already cleared. GHG reductions not analyzed in Chapter 4.	Moderate to high. The international market offers high prices. Experience of other producers is that opportunity costs have rendered domestic projects non-viable. Moderate per-ha biofuel output (for biodiesel feedstocks).	No tradition of production.	Requires studies by IIAM. **Will be analyzed in Chapter 4 and Chapter 6.**

development are sugar cane and jatropha; existing producers of biodiesel, on the other hand, use coconut oil.

7. Relevant technical, social and environmental issues associated with crop choice

A comprehensive review of the social and environmental issues associated with bio-fuels production is presented in Chapter 4. However, it is appropriate to address a key issue associated with the presentation of the demographic aspects of the agricultural sector in Mozambique: the extent to which selection of specific crops may have a positive or negative impact on rural incomes and employment.

The reduction in poverty incidence in the country, between 1997 and 2003, from 69.1% to 54.1% was not accompanied by a reduction in hunger. On the contrary, the prevalence rate for chronic malnutrition (low height by age) worsened, moving from 36% to 41%. Malnutrition is responsible for about half of the deaths registered among children less than five years old. The situation is even more serious in rural environments (46%) than in urban (29%), and is more pronounced in Northern provinces where it can reach 56% (Cabo-Delgado). This makes clear it that is not enough to have economic growth to reduce hunger; it is necessary to guarantee the availability and access to food for all social strata.

On the other hand, the population does not feed itself only on the formal production carried out in agricultural production units, but also on various “wild” products and from game. A national program that fundamentally alters forest cover, such as a national program to promote bio-fuels feedstocks, would need to be accompanied by a program to increase food production, to guarantee food security in the country.

By and large, the most favorable areas of the country for expansion of agricultural production are located in the Center and North of the country, which tend to be poorer, more rural and to have higher indices of unemployment. To the extent that bio-fuels production is concentrated in these regions, the potential benefit in terms of income generation and employment is significant, but the potential risks cannot be overlooked.

The major risks include rapid price inflation for basic foodstuffs, including staple crops and meat produced using feed from staple and cash crops, reduced access to land for small-holders, and the environmental impacts of land-use conversion. Each of these is discussed in turn.

- *Price inflation*. This will tend to affect urban populations not associated with agriculture more than rural populations. Since there are some major population centers in the Center and North regions of the country, such as Beira, Nacala, Nampula and Quelimane, the potentially affected population is important. The potential for inflation will be greatest to the extent that farmers who are currently producing a crop decide to switch to a biofuel feedstock, whether or not it is edible (cassava) or non-edible (jatropha). If new areas are opened for production, and draw underemployed labor from subsistence and cash-crop farming on small farms, the impact may be diminished somewhat, but it seems likely to still be a concern.

The potential for price inflation underscores the need for efforts to ensure that urban incomes increase at the same time that rural incomes do as a result of expanded cultivation. One strategy for achieving this would be to ensure that smaller-scale bio-fuels production facilities be sited near urban areas in the regions where expanded cultivation will take place, as opposed to relying on large movements of feedstocks to small numbers of large-scale processing facilities.

- *Competition for land*. This is a significant concern based on the Brazilian experience, noted in Chapter 7, but the particular characteristics of Mozambique suggest that the potential for competition to adversely affect small-holders might be mitigated. Large-scale producers, unlike small-holders, will have to secure concessions, giving some measure of protection to farmers resident on the land, provided their situation is taken into consideration by the authorities. This underscores the immediate need for the vast majority of small-holders, who do not have title to the land they work, to secure this documentation, and to ensure that concessions are issued to commercial farmers in accordance with established regulations.
- *Environmental impacts.* The provinces of Sofala, Manica, Zambezia and Nampula, given the extent of existing agricultural activities and the significant production potential identified there, may well be the focus of a rush to secure land to produce bio-fuels. As noted in Chapter 4, there are also notable natural areas in these provinces that have been targeted for protection, or for which greater protections are deemed desirable from a biodiversity standpoint. This underscores the need for effective enforcement of existing environmental laws and procedures, as well as their possible reinforcement.

8. Conclusions and recommendations

Biodiesel production will require an increase in oilseed production. This process could also contribute indirectly to greater availability of oil for edible uses.

Conclusions. Of the “suitable” products for biofuel production in Mozambique, some are basic for food crops and their production in the harvest season of 2005-2006 were: cassava (7.55 million tons), corn (1.53 million tons), sorghum (some 339,000 tons), peanuts (almost 146,000 tons); others are cash crops like cotton (63.4 million tons) and sugar cane (5.69 million tons).

In the long term, the behavior of agricultural products in Mozambique can be divided into two large groups: “permanent” plants (that last more than one year and whose harvest is mainly done in accordance with the needs of the consumer) and “non-permanent” plants that last less than one year and are planted and harvested yearly. The production of the former tends to be more regular over time, varying only with major [economic] changes, whereas the production of “non-permanent” plants is more irregular and more dependent on various seasonal and political factors.

It is common to divide agricultural products into "cash crops" and subsistence crops, depending on the degree of "commercialization" that each product has. Therefore there are the products mainly meant for the market, like cotton, sesame and sunflower among other cash crops and the crops mainly meant for self-consumption like cassava, corn and beans as subsistence crops. These classifications are not rigorous and vary according to space (from place to place) and according to farmers' incomes.

The average yield per hectare, in general, is low in Mozambique, due to the technological systems used, in particular the lack of irrigation for appropriate water management to the low use of agricultural inputs such as fertilizer and pesticide. On the other hand, almost all the agricultural production is done on a subsistence basis, in small plots of one hectare or less. This situation increases the unit costs of production so agricultural production survives only because of the low opportunity cost of labor in rural areas. However, prices of national products show large seasonal variation, due to the lack of adequate storage facilities.

The land belongs to the State and for its use, the Government concedes on the basis of the "right of use and utilization" for renewable periods of 50 years. However, almost none of the population has a title, using the land based on traditional rights or by inheritance from ancestors. At the same time, there are large plots of land granted to some people who are not using them.

Mozambique has an arable land area of 36 million hectares, of which 5 million are cultivated out of a total of 8 million that were once used. There is no official estimate of the land available for future cultivations or for the extension of the existing ones. In a rough estimate, it is possible to say that at least 10 million hectares are available for the introduction of bio-fuels, if there were a strong political commitment from the government. The most fertile lands are found in the Central and Northern regions, where there is also greater rainfall.

Despite this potential, there are significant bottlenecks for agricultural development in Mozambique, which will hamper the development of a bio-fuels sector. These include: (i) poor development of rural infrastructure, including storage, irrigation and transportation systems; (ii) limited access to information, and imperfect distribution across the value chain; (iii) weak and limited support by extension services and appropriate technology; (iv) underdeveloped domestic and export markets; (v) absence of formal financial services (credit and insurance schemes); (vi) vulnerability to disease and natural disasters; and (vii), a weak regulatory framework.

The combination of these bottlenecks results in high transaction costs and uncertainty and, consequently, a significant level of risk associated with agricultural production all across the value chain. These harsh conditions make it difficult for smallholders to step up out of the subsistence mode and for the commercial sector to emerge and develop in a sustainable manner.[45]

[45]MINAG 2006b.

Recommendations. The most attractive crops for production of bio-fuels feedstocks are those available at the lowest costs with the fewest potential implications in terms of effects on prices that will limit availability to the poorest strata of the population. Based on the review presented here, it would appear that the best-suited crops for biodiesel that are currently cultivated include coconut and sunflower, along with African palm, castor seed and jatropha, which are either unknown or only emerging in Mozambique. For ethanol, sorghum and sugar cane are clear priorities, but cassava should also be included given its very low production cost. It seems appropriate to identify multiple feedstocks for promotion, to ensure balanced development, avoid to the greatest extent possible dramatic price impacts, and create alternatives for biofuel producers. Each crop is discussed in turn, below.

- *Coconut*. There is no question that the coconut sector is vital to Mozambique and must be rehabilitated given its current situation. Since it forms the basis for economic activity in Zambêzia and Inhambane, and is currently used as a feedstock, it does not make sense to discourage its use by any other means than price. In time, the attractiveness of other feedstocks, such as jatropha, is likely to become clearer to producers. The competing uses of coconut oil are, however, well developed and will continue to provide a market for output in Mozambique.
- *Sunflower*. The steady increase in vegetable oil prices on international markets will continue to make sunflower cultivation attractive, as well as other crops. Given the existing trends in cultivation of sunflower, it seems appropriate to identify sunflower as a candidate for use in biodiesel, especially in remote areas, for self-supply applications, and in the future for larger-scale production.
- *Castor seed*. The incipient production of castor seed in Mozambique should be encouraged, because the potential market for the oil is attractive, irrespective of the possibility of using it for biodiesel production. At this stage, it is too soon to determine whether improvements in yields might be achievable.
- *Jatropha.* Mozambique is already committed to cultivation of jatropha, and the available information about the oil suggests it could be an excellent feedstock for biodiesel. Further, available information on experience in other countries suggests that jatropha can be successfully cultivated. What is less clear at this stage, however, is whether the cost of production is as low as some promoters have suggested, and whether the yields achieved in marginal lands are substantial enough to generate significant volumes.
- *African palm.* This is the only crop for which a new research and development program may be appropriate (research and developing being necessary on all the existing crops, as well), given the lack of production in Mozambique at present. While the humidity requirements of African palm could complicate its cultivation in the country, and accordingly the cost of production, the low-cost production achieved elsewhere suggests that it could still be attractive to produce in Mozambique.
- *Sweet sorghum.* The presence of grain sorghum in Mozambique, with reasonably attractive yields, makes this crop a natural for consideration as a secondary feedstock for ethanol production, alongside sugar cane. Given its lower water requirements, it

may be most appropriate to promote its cultivation in the southern parts of the country, but its apparent suitability for other areas may justify broader promotion.

- *Sugar cane.* The presence of major sugar producers in Mozambique makes it a foregone conclusion that investment in ethanol production will take place if a local market is created. Given water requirements, it seems most likely that new sugar cane cultivation should occur in the Center and North of the country, with an emphasis on siting new plantations and ethanol distilleries near major port facilities to facilitate logistics, both for receipt of molasses from other producers as well as for exporting ethanol.
- *Cassava*. This crop is perhaps the most sensitive as a feedstock for ethanol production given its status as a staple in Mozambique. However, the relative underdevelopment of cassava production in the country – low yields and very low prices – suggests a strategy of promoting the use of cassava as a secondary feedstock (alongside molasses, sugar cane and sweet sorghum) could increase incomes for small-holder growers and stimulate increased domestic distribution of cassava, especially in the form of dried roots and chips.

With respect to the other crops considered, these do not seem to be well suited for promotion, either due to their high price (groundnut/peanut, sesame) or their significance as a staple crop (corn). With regard to soya and cotton, while it is true that both could be suitable feedstocks, their suitability is diminished by the potential for more attractive prices in competing uses (cottonseed, given its advantages as a cooking oil) or because of technical limitations (soya has lower oil content, with higher protein values, making it better suited as a source of animal protein). Even so, projects involving the utilization of either of these feedstocks (cottonseed and soya) should not be discouraged in the event that investors wish to develop them, since there are important synergies between both crops and other agricultural production that would help expand and improve food supplies in the country, especially meat production.

Exhaustive research on the available land in Mozambique. To define a more rigorous biofuel strategy, it would be convenient to clearly define the available space, to avoid compromising food security and the harmonious development of Mozambican society.

CHAPTER 4: BIO-FUELS PROCESSING: ECONOMIC, ENVIRONMENTAL AND SOCIAL ASSESSMENT OF PROCESSING OF DIFFERENT RAW MATERIALS FOR BIO-FUEL PRODUCTION IN MOZAMBIQUE

This chapter outlines the different processes that are used to convert various candidate agricultural feedstocks into ethanol and biodiesel. Both processes to convert sugar-based and starch-based feedstocks into ethanol are discussed, since these feedstocks and the respective processes are fundamentally quite different. This chapter also outlines the various processes that are employed to extract oil from the biodiesel feedstocks under consideration. Since the process of refining vegetable oils and conversion into biodiesel are essentially the same independent of the source feedstock this is discussed separately. Also, a short discussion of the relevant second generation biofuels production technologies has been presented as a general overview. Unlike first generation technologies which convert only a fraction of the feedstock (oils, sugars and starches) to fuel, second generation technologies represent an incremental improvement in feedstock utilization efficiency by attempting to convert the remaining ligno-cellulosic matter into fuel as well. These technologies are still in the very early stages of commercialization in Europe and the U.S. and therefore are not considered in the analysis of industrial biofuels production costs pertaining to the Mozambican case.

Finally, the major focus of this chapter quantifies the industrial cost of producing biofuels in Mozambique considering the agricultural cost of feedstock production as identified in Chapter 3, as well as the domestic and international market values used as the opportunity costs in manufacturing biofuels.

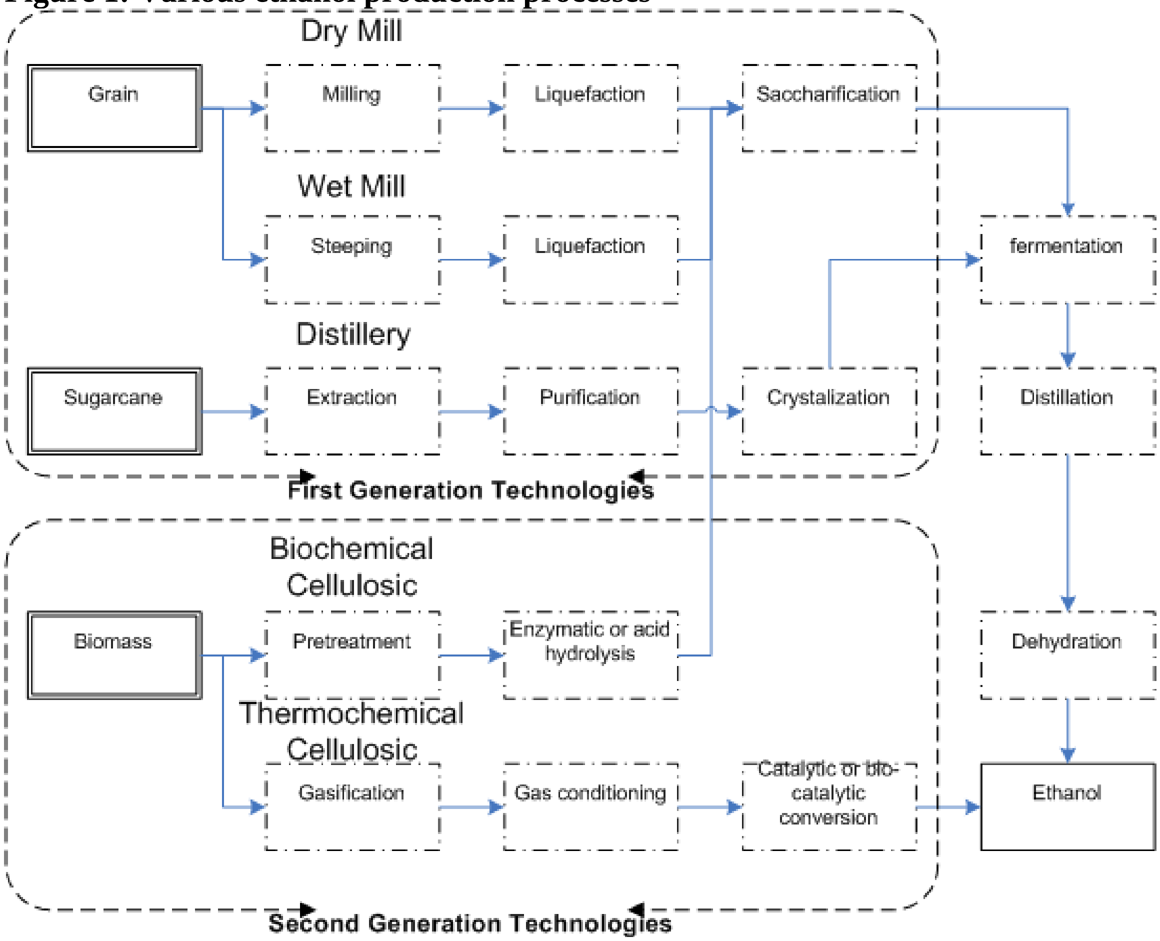
1. Global biofuels production trends and technologies

Ethanol

A number of options exist for the production of fuel ethanol from biomass feedstocks. Conventional technologies are only capable of fermenting sugars found in sugar cane or those converted from simple starches. First generation ethanol plants using conventional technologies receive grain or sugarcane as feedstock, and produce fuel ethanol as a final product. Second-generation ethanol production processes have the ability to convert cellulosic biomass into fermentable sugars. Several commercial demonstration plants are under construction at in The United States and Europe at the time of writing. Intensive research and development currently underway is creating an opportunity for emerging producers such as Mozambique to adopt them, as major growth in biofuels occurs in Africa. Figure 1 provides a general overview of the steps involved in the various ethanol production processes. The dry mill process, utilizing grains, and the sugarcane ethanol distillery are particularly relevant for Mozambique's case.

This section provides some technical considerations for the processing of the following feedstocks into ethanol: sugarcane and molasses, sweet sorghum, grain sorghum and cassava.

Figure 1: Various ethanol production processes



Source: Econergy

Sugarcane ethanol production process. The sugarcane ethanol production process is the simplest, most cost-effective and energy-efficient process for producing biofuel. Brazil has been the world leader in this area, based on its comparative advantage in sugarcane production. In the Brazilian setting, harvested sugarcane is transported to distilleries in large, specially-built trucks. At the mill, the sugarcane is roller-pressed to extract the juice, leaving behind a fibrous residue called bagasse. This juice is subsequently fermented by yeast, which breaks down the sucrose into ethanol and CO_2. The resulting "wine" is distilled, yielding hydrated ethanol (5% water by volume) and "fusel oil." The hydrated ethanol may be sold as such and directly used as a fuel in specially designed ethanol automobiles. Distillation produces alcohol that is at least 90% pure by volume, suitable for vehicles using 100% ethanol. Alternatively, ethanol can be dehydrated and used as a gasoline additive for gasohol cars, that is, cars that can run on a gasoline/ethanol blend. For blending with gasoline, purities of at least 99.5% are required, to avoid the separation of the alcohol from the gasoline. Ethanol in water cannot be purified beyond 96% by distillation. Presently, the most widely used purification methods are cyclohexane azeotropic distillation and physical absorption processes using molecular sieves such as zeolites.[1]

Many sugar mills in Brazil process sugarcane into both ethanol and sugar.[2] Data for a typical Brazilian sugar mill producing sugar, hydrous and anhydrous ethanol are shown in Table 1, and the process is illustrated in Figure 2. In this example, the facility processes 7,000 tons of cane per day, and operates for a six month crushing season. One metric ton of harvested sugarcane contains approximately 280 kg of bagasse and 138 kg of sucrose. Of the latter, 112 kg can be extracted as sugar, leaving 23 kg in low-value molasses. If the cane is instead processed for alcohol, all of the sucrose is used, yielding 80 liters of ethanol. In addition, mills in Brazil burn the bagasse to produce heat for distillation and drying, and generate electricity using high-pressure boilers and steam turbines. Back pressure steam from turbines is used to heat the distillery. In this example, 10.65 kWh of electricity is required per tonne of cane processed, and 1.13 kWh can be exported to the grid. The available bagasse is more than enough to supply the plant's total energy requirements. The combined heat and power plant (CHP) consumes 68 tonnes per hour of bagasse, converting it into steam at 75% efficiency. In the mill, 530 kg of steam at 20 bar per tonne of cane are used to power mechanical drive turbines, and the extracted steam at 1.5 bar is delivered to the distillery. This process produces excess electricity and excess biomass energy, in the form of bagasse.

Table 1: Production and energy consumption in a typical Brazilian sugar mill

Plant Capacity	Quantity	Unit
Harvested cane	1,300,000	ton/yr
Crushing rate	292	ton/hr
Operating hours	4,457	hr/yr
Production		
Sugar produced	400	t/day
Bagasse produced	82	ton/hr
Anhydrous ethanol	177,000	l/day
Hydrous ethanol	177,000	l/day
Total ethanol (anhydrous)	64,097,231	l/yr
Process energy required		
Bagasse consumed	68	ton/hr
Excess bagasse	14	ton/hr
Steam	530	kg/ton
Electricity consumed	10.65	kWh/ton
Electricity exported	**1.13**	kWh/ton

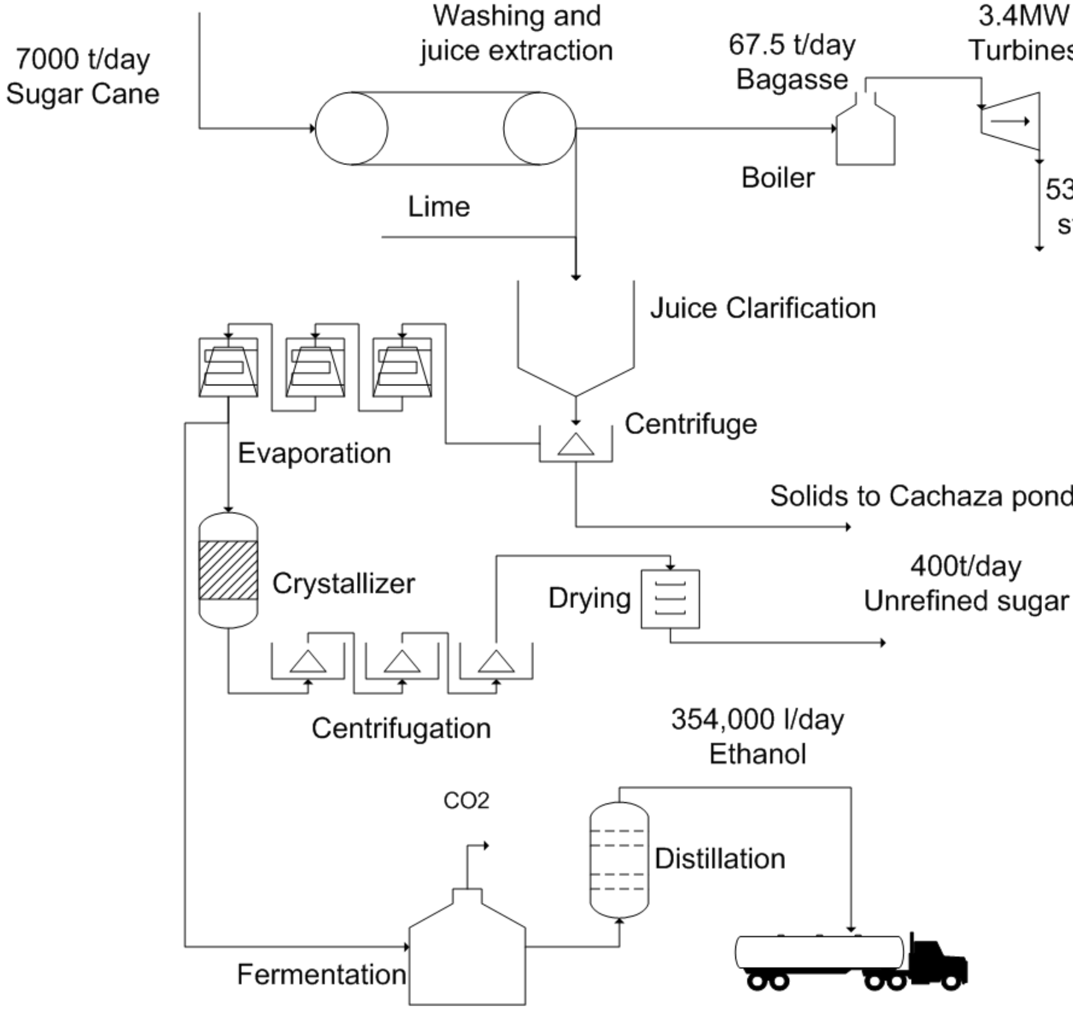
Source: Econergy

Figure 2 illustrates the typical process used by sugar mills in Brazil to date. More recent efficiency improvements to these mills, however, have allowed for decreased steam consumption, for process energy, and increases in electricity exports for the generation of carbon credits. The next generation of these improvements will likely integrate

[1] "Biofuelling Brazil." www.re-focus.net, May/June 2006: pp. 57-59.
[2] See section on Brazil in Chapter 7 for more background on biofuels development in that country.

gasification combined cycles for the production of process thermal and electrical energy. With aggressive efficiency improvements to pumps, heat exchangers and other equipment, steam consumption can be reduced to as little at 280-340 kg per ton of cane, reserving more bagasse for off-season electricity generation.

Figure 2: Sugarcane sugar and ethanol production process illustrating typical mill

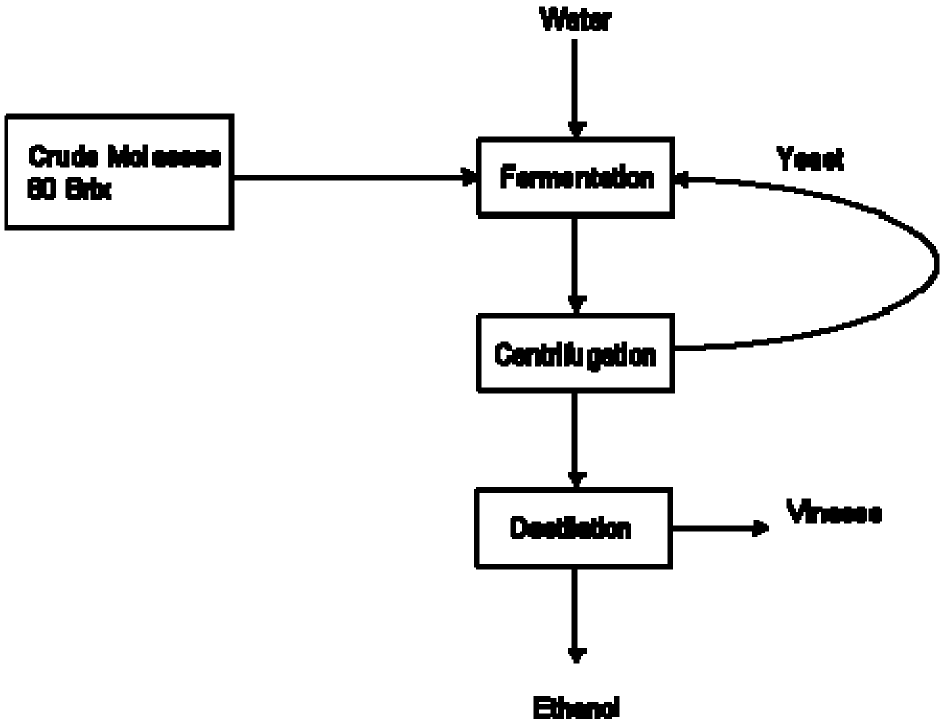


Source: Econergy

Molasses-to-ethanol production process. Molasses is a co-product derived from crystal sugar production. Molasses is sold in viscous liquid state, as a raw material for other processes, as a source of energy for animal nutrition, fermentation media (aminoacids and antibiotics, among others) and ethanol. Molasses is a competitive feedstock for ethanol production because it has a high concentration of sugar (around 50%) and can be pumped as liquid. In the global trading market, molasses competes with corn, DDGS, cassava chips, citrus, and beet pulp, all of which are sources of energy in feed compounds.

Europe has been a net importer of molasses from several sugar producing countries, but global trade is decreasing, in keeping with the increases in ethanol production in sugar producing countries. The production process is simple, as illustrated in Figure 3.

Figure 3: Ethanol production process based on molasses



Source:

Sugarcane molasses is composed of approximately 49% sucrose, which yields about 290 liters of ethanol per metric tonne.[3] However, one tonne in Mozambique is believed to yield roughly 250 liters of hydrous ethanol.

Plants producing ethanol from molasses are the same used to ferment sugarcane juice to make ethanol. This simple process requires the addition of water to dilute the molasses to 10-15% sugar content. The main technical issue that discourages sugar producers from installing ethanol distilleries is plant size. As molasses represents just 12-15% of total sugar extracted from feedstocks (either beet or sugarcane). Therefore, it is difficult for small scale sugar producers to obtain the economies of scale needed to include ethanol production at the plant.

Brazil was long an exporter of molasses. From 1 million tons exported in 1980, the country then drastically reduced shipments, and currently uses molasses as feedstock for fuel ethanol. Hundreds of distilleries were built to ferment molasses and sugar juice. This practice brought another interesting benefit to sugar mills: improved sugar quality. As the crystallization step was no longer critical, because molasses could carry some sucrose, final sugar quality improved (the sugar is dryer and whiter) when compared to the production of other countries.

[3] USDA – The economic feasibility of ethanol production from sugar in the US 7/2006

Mozambique could follow the Brazilian path; the country has five sugar mills and none of them is currently recovering molasses in an ethanol distillery. To reach profitability, a joint-venture company should be considered, to process all the molasses in one large facility. Such a plant could be located in the harbor, or in one of the existing sugar mills, to ensure access to additional feedstock (sugarcane juice), energy from bagasse, and utilization of vinasse.

There is currently one operating ethanol distillery in Mozambique in the Buzi Region about 50 km from the Beira Port. The distillery produces roughly 10,000 liters per day of ethanol for beverages and pharmaceutical applications using molasses as a feedstock. The facility has access to the Zambeze River and is able to transport the final product to the port of Beira by truck and 50-ton barges.

Figure 4: Fermenters at molasses distillery (Buzi)

Source: José Zilio

Sweet sorghum ethanol production process. Sweet sorghum is also a potential feedstock for ethanol production. Sweet sorghum stalks harvested for biofuels production are brought to a central processing facility where juice can be extracted. The first step involves rolling the stalks and squeezing out the juice, a mixture of water and sugars. Solids are screened out of the juice in several steps, and the juice can be fermented immediately after extraction. The bagasse residue of the stalks makes an excellent boiler fuel to supply process energy to the plant. Considerable experience with sweet sorghum cultivation has been accrued, notably in India, over the past twenty-five years. A summary of India's sweet sorghum production data is shown in Table 2. The juice extracted from this feedstock can then be processed in conventional fermentation and distillation equipment. The average ethanol yield is approximately 3,500 liters per ha of cultivated land.

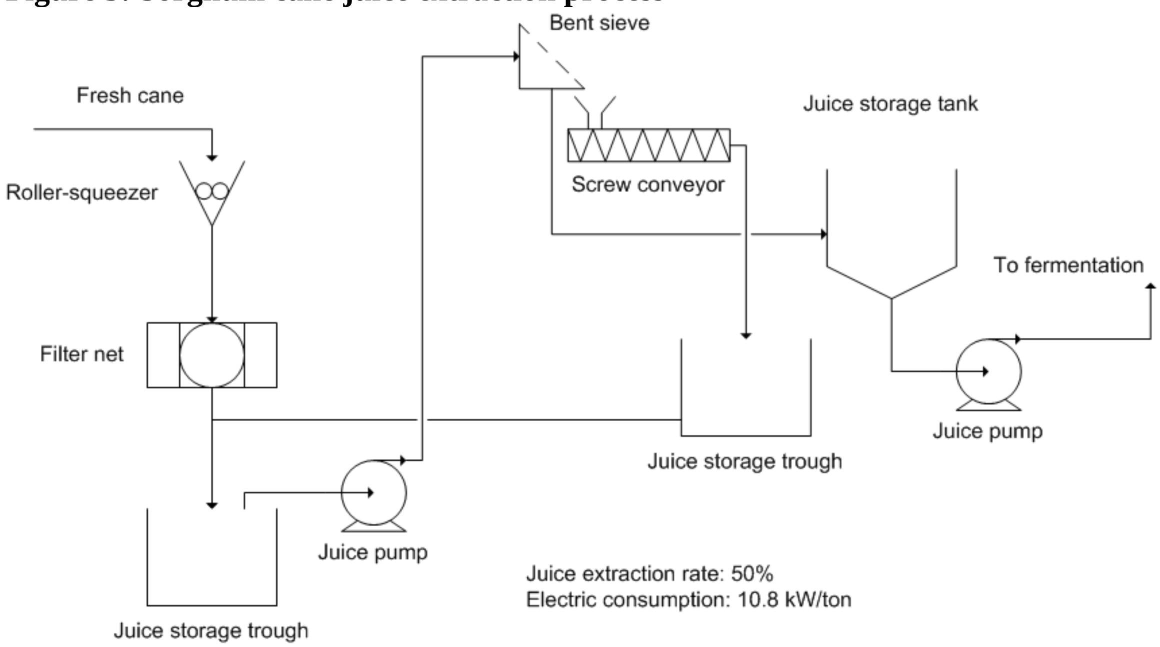
Table 2: Production of Sweet Sorghum in India

Yearly production from 1 ha of Sweet Sorghum (tonnes)	
Sweet Sorghum	75-100
Stripped stalks	60-80
Grain	2-4
Leaves (dry)	5-7
Bagasse (dry)	15-20
Juice	30-40
Ethanol	2.4-3.1
Effluent	33-37

Source: Nimbkar Agricultural Research Institute (NARI)

Potential yields and production data for sweet sorghum in Sub-Saharan Africa have been estimated by the International Crops Research Institute of the Semi-Arid Tropics (ICRISAT) and are shown in Table 3.

Figure 5: Sorghum cane juice extraction process



Source: Econergy

Table 3: Sweet Sorghum potential in Sub-Saharan Africa[4]

Cane yield (t/ha/yr)	92 t/ha/yr
Sugar content	14%
Ethanol yield (l/t)	108 l/t *
Production cost (USD/ha)	439 USD/ha
Crop Duration	4.5 months
Water use	8000 m^3/ha for 2 crops

***** Assumes two crops per year which is possible in many parts of Africa
Source: ICRISAT

Grain ethanol production processes. The process for producing ethanol from grains such as maize, wheat, and grain sorghum is very similar to the ones described above. While the corn ethanol production process is used as an example, it is actually relevant for all grain ethanol production processes. In the U.S., two methods have dominated in fuel ethanol production from corn: the dry grind process and the wet milling processes. The primary difference between these processes is that a wet mill is considerably more versatile in its product output capabilities.

A wet mill has the ability to separate starch and gluten from the corn grain prior to further processing, using advanced front-end fractionation technologies. A wet mill will generally produce both ethanol and high fructose corn syrup, in varying ratios depending on seasonal demand. Corn oil and two animal feeds are also produced at a wet mill. Corn gluten meal is a high-protein animal feed, and corn gluten feed is sold primarily to be mixed with other feeds to alter their composition. The production process along with the product outputs are shown in Figure 6.

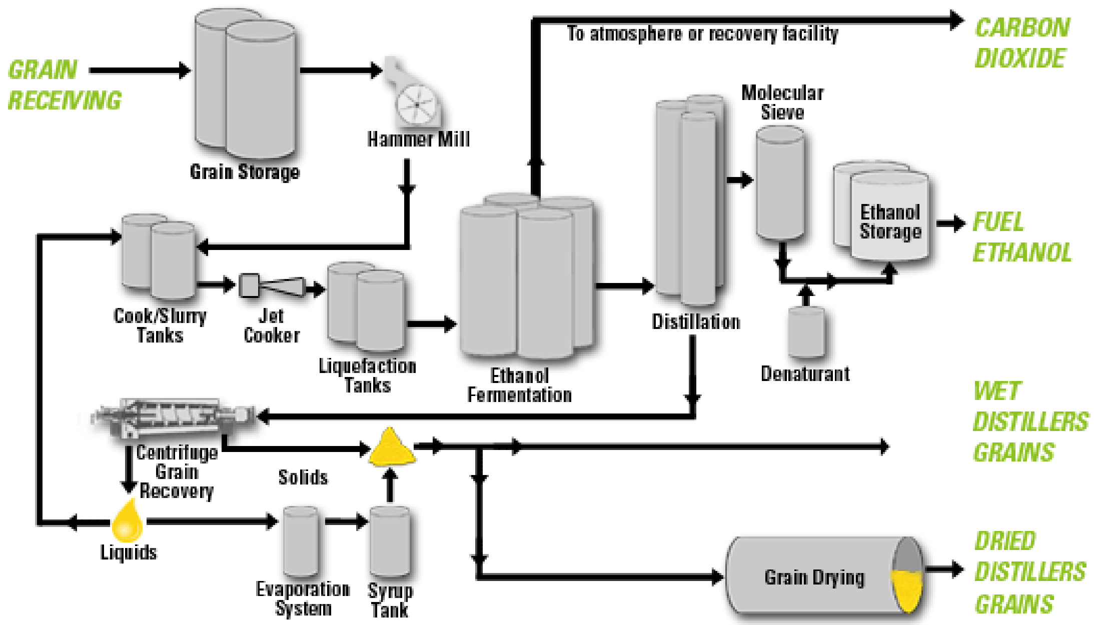
A dry grind plant operates for the sole purpose of producing fuel ethanol from corn. This process does not separate gluten and starch; instead the starch is liberated from the kernel and the entire mash is delivered to the fermenter. First, the grains are steeped at high temperatures in water and amylase enzymes. Next, the starches are converted into sugars in the saccharification process, using an enzyme called gluco-amylase. This stream is then delivered to a fermenter, where active yeast converts the fermentable sugars into ethanol. The beer formed in the process typically has an ethanol content of 15%, and it is increased to 97% in distillation columns. Removal of the remaining water is accomplished through molecular sieves. Net water consumption for a plant of this type is four to five liters of water per liter of ethanol produced. However, there is a wide variation in the industry, depending on the amount of water recycled and the treatment employed.

Vinasse from the fermentation process is first mechanically dried to a solids content of about 37% in a centrifuge. The liquids can be recovered and used again for grain soaking. The centrifuged vinasse is then delivered to a gas-fired rotary drum dryer, and dried to a solids content of 90% before it can be sold as distillers dried grains and

[4] Belum V S Reddy, A Ashok Kumar and S Ramesh, Sweet sorghum: A Water Saving Bio-Energy Crop, ICRISAT. Andra Pradesh, India.

solubles (DDGS). DDGS from corn ethanol is produced at a rate of 2.98 kg per gallon of ethanol produced. Drying the product uses significant energy; about 10.5 MJ of fuel are required per gallon of ethanol produced. Typical capacities in the U.S. for dry grind facilities have ranged from 113 to 227 million liters [30 and 60 million gallons] per year in the past, but new, much larger plants are being built: 378 million liter capacities are now almost standard.[5] This is consistent with the initial proposals for dry grind plants developed by Ethanol Africa for the South African market.

Figure 6: Dry Grind Ethanol Production Process



Source: ICM Inc.

There are several grain byproducts that can be produced in the dry grind process: wet and dried distiller's grains, wet and dried distiller's grains with solubles, a mixture of wet and dried distiller's grains called wet cake and condensed distiller's solubles. Of the distiller's grains with solubles produced in the U.S., approximately 60% are sold dried, while the balance is sold as wet product.[6]

DDGS is dried from a moisture content of 63.7% down to about 10% by weight.[7] Roughly 0.78 kg of DDGS per liter of ethanol is produced.[8] The value of this product is typically assessed as a function of the protein content. A significant amount of thermal

[5] Jessen, H. (2006) Feedstock Flashback. In *Biodiesel Magazine*.
[6] Shurson, G.C. Issues and Opportunities Related to the Production and Marketing of Ethanol By-Products. in *Agricultural Outlook Forum* 2005.
[7] Jason R. Kwiatkowski, A.J.M., Frank Taylor, David B. Johnston, Modeling the process and costs of fuel ethanol production by the maize dry-grind process. *Industrial Crops and Products*, 2006(23): p. 288-296.
[8] McAloon, A., Shelled Maize-to-ethanol Process Analysis, M. Huisenga, Editor. 2006. Personal communication.

energy can be saved by producing wet distiller's grains (WDG) instead. However, while WDG may provide savings in energy costs, it may offer lower financial returns.

Carbon dioxide produced in the fermentation step is also produced at roughly the same rate as DDGS, that is, 0.72 kg of CO2 per liter of ethanol produced[8]. Generally the CO2 produced during fermentation is not captured, but in some instances, where local markets exist, this can be done. It is typically scrubbed and dispersed into the atmosphere, but the CO2 stream may also be ideal for co-locating an algae biodiesel processing unit next to the ethanol plant.

Table 4: Typical grain dry mill ethanol plant

	Value	Units
Production capacity	378,000,000	l ethanol/yr
Operating hours	7920	hr/yr
Ethanol yield	417	l ethanol/ton
DDGS production	0.78	kg/l ethanol
CO2	0.72	kg/l ethanol
Consumables		
Water consumption	4.7	l water/l ethanol
Electricity	0.24	kWh/l ethanol
Process thermal energy	8.4	MJ/l ethanol
Costs		
Capital	0.4	USD/annual l
Variable	0.5	USD/l

Source: USDA

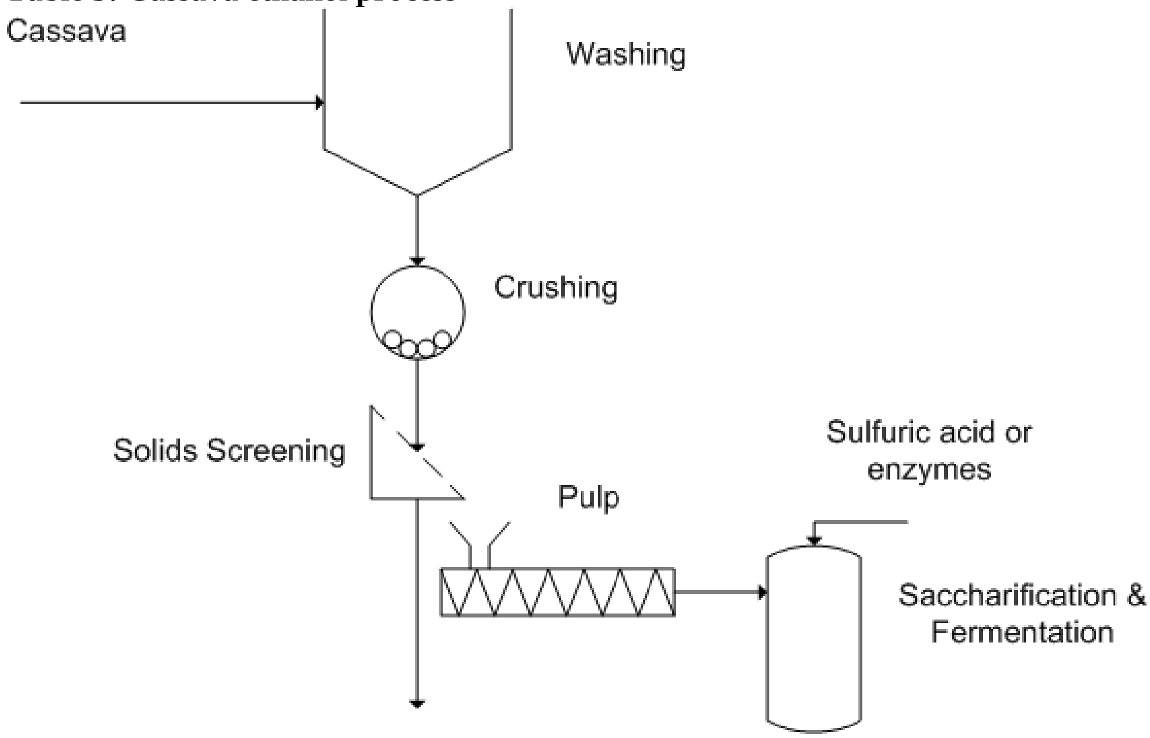
Although corn oil recovery is not a standard practice in a dry grind facility, several companies, such as GS CleanTech and others, have recognized the added value in extracting corn oil from the wet distiller's grains. Corn oil sells on the edible oils market, but can also be used as a biodiesel feedstock, which would enhance the fuel output per ton of feedstock for a given plant. The technology can extract 2 kg of corn oil for every 18 kg of distiller's grains produced. If the ethanol yield is 2.8 gallons per bushel, with corn oil extraction for biodiesel production, this can be raised to 3.0 gallons for fuel per bushel, a modest but cost-effective enhancement.[9] The units are also cost-effective, meaning this process may soon become standard practice. The alternative to centrifugation is front-end fractionation, which could cost ten times as much.[10] Furthermore, DDGS may be an attractive gasification or boiler feedstock, allowing plants to produce thermal energy in-house, thereby displacing natural gas purchases. Corn oil extraction prior to gasification of DDGS is therefore necessary to remove the remaining high-value components.

Cassava ethanol production process. The production of biofuels from cassava requires a relatively simple process. Fresh cassava is delivered to a central processing facility and washed. Next, the cassava is ground in a mill, and the pulp or solids are separated from

[9] CleanTech, G. DDGS Gasification Technology Data Sheet.
[10] BBI International (2007) Corn oil extraction opens new markets. In *Distillers Grains Quarterly*

the water. The pulp contains starches that can then be processed in a simultaneous saccharification and fermentation process, just as starches from grains are processed. The stillage (*vinasse* or *vinaza*) contains mainly fiber and protein.

Table 5: Cassava ethanol process



Source: Econergy

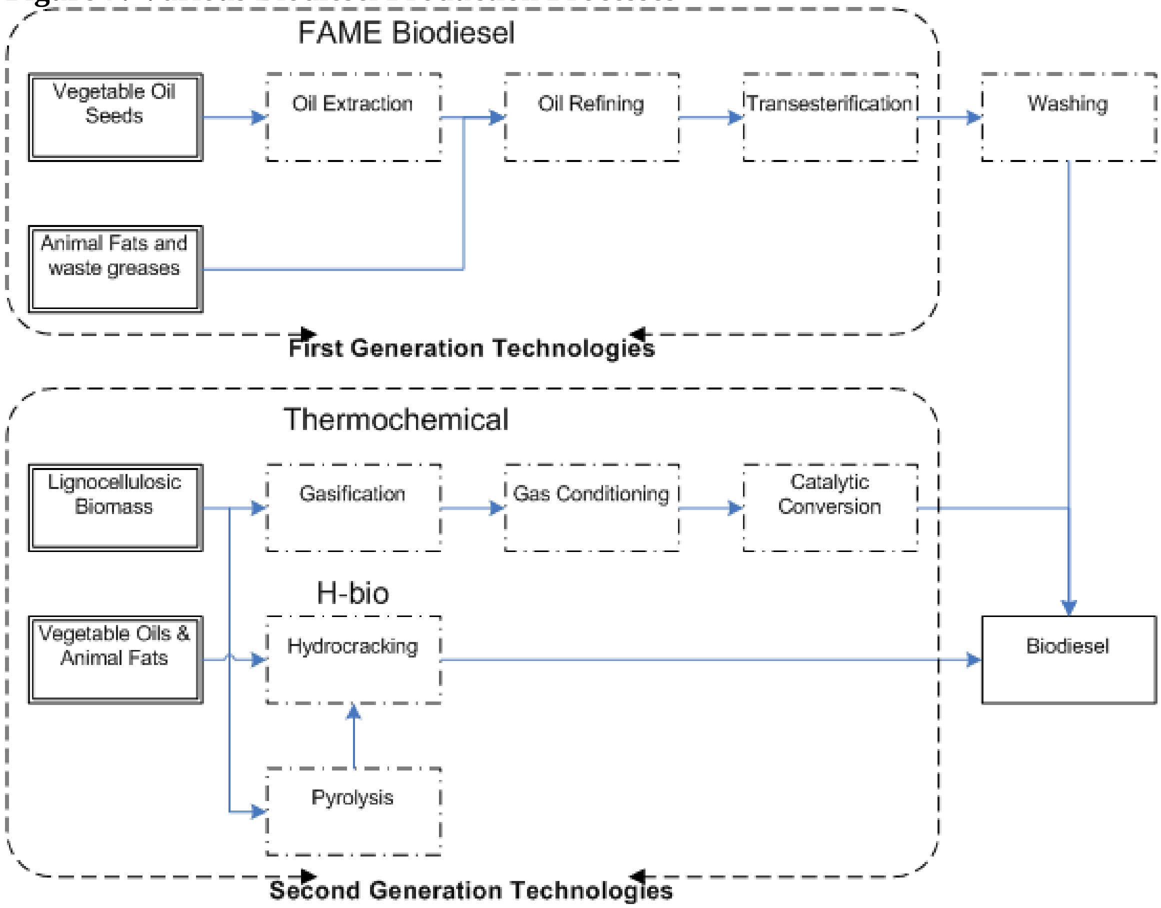
Biodiesel

As in ethanol production, a number of technically viable biodiesel feedstock options exist for Mozambique. Conventional batch reaction and continuous flow systems can use a wide range of refined vegetable oils and animal fats to produce biodiesel. This section presents the technologies currently available for extracting vegetable oil, refining crude oils and producing biodiesel from these oils.

Feedstocks considered in this section include: coconut, African palm, castor seed, cottonseed, jatropha, soybean, and sunflower.

Oil extraction and refining. Vertical integration of biofuels production processes involves securing feedstocks and fuel purchase arrangements. In the production of biodiesel, oil extraction and refining are also very important considerations, since refined oils on the market are increasing in cost. Additionally, refining some oils, such as palm oil for the edible markets, requires processing steps, such as deodorization and bleaching, that are unnecessary when the oil is used for biodiesel production. It is therefore ideal for a biodiesel production facility to also have the capability to extract and refine oils in-house, or at the least to purchase crude oil from an extraction facility and refine it in-house.

Figure 7: Various Biodiesel Production Processes



Source: Econergy

Depending on the type of oil, different steps are needed to prepare the oils for trans-esterification into biodiesel. Preparation and extraction of oil is the first step, and begins with heating, crushing and de-hulling the seed or fruit. Heat is generally applied to deactivate enzymes that are naturally present in the seed, and to convert the oil into other compounds that decrease oil yields. Mechanical pressing is then used to extract the oil from the pretreated seeds and, for large scale production; solvents such as hexane are used to encourage extraction. Finally, the solvents are evaporated; the oil produced at this stage is known as "crude oil." If the extraction is done on a small scale using manual labor, hexane extraction is not included, and some of the oil will remain in the filter cake.

The simplest method for extracting oil from oil seeds involves a screw press. Screw presses can handle a wide range of oil seed types and can be purchased in a range of sizes, but are primarily intended for small-scale, on-the-farm production. The Täby oil press can process all small oil seeds such as cotton and castor, but can also be used to process ground nuts like peanuts. Prices for various units are shown in Table 6. The cost in terms of USD/ton-year assumes an average production rate for each unit operated of 7,000 hours per year. Also shown is the electricity consumption per ton of seed processed, with an electric price of USD8/MWh; the cost of electricity ranges from USD3.4 to USD7.3 per ton to operate these units.

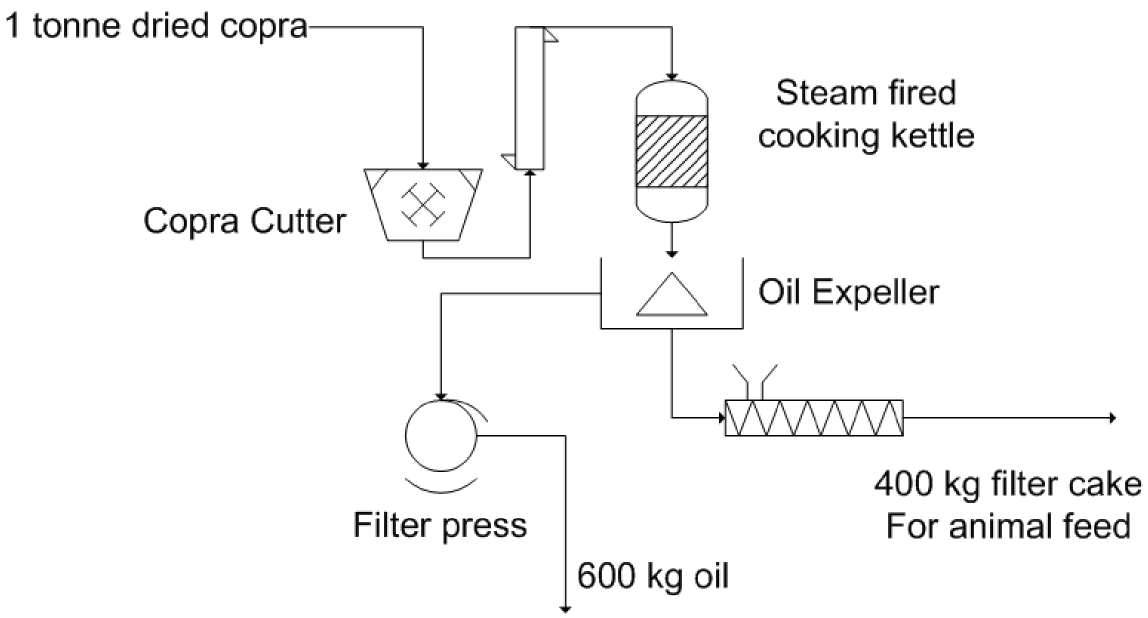
Table 6: Täby oil press types and costs

Model	kg/hr	Power (kW)	Cost (USD/unit)	Cost (USD/ton-yr)	electricity consumption (kWh/ton)
Type 20	4 to 8	0.55	1,238	29	91.7
Type 40	8 to 16	1.1	3,638	43	91.7
Type 55	20 to 36	1.5	6,867	35	53.6
Type 70	40 to 60	2.2	10,081	29	44.0
Type 90	80 to 108	4.0	14,318	22	42.6

Source: Täby http://www.oilpress.com/middel.htm

Coconut oil extraction process. Extraction of coconut oil must be performed using dried copra which has a moisture content of 3-4.5%. Fresh coconuts, with a moisture content of 40-50%, are dried in the fields. Figure 8 shows a small-scale manually operated oil pressing operation based on 100 tons of dried copra. The process yielded 60 tons of raw oil, which can then be turned into biodiesel. Forty tons of filter cake are produced and can be used as animal feed.

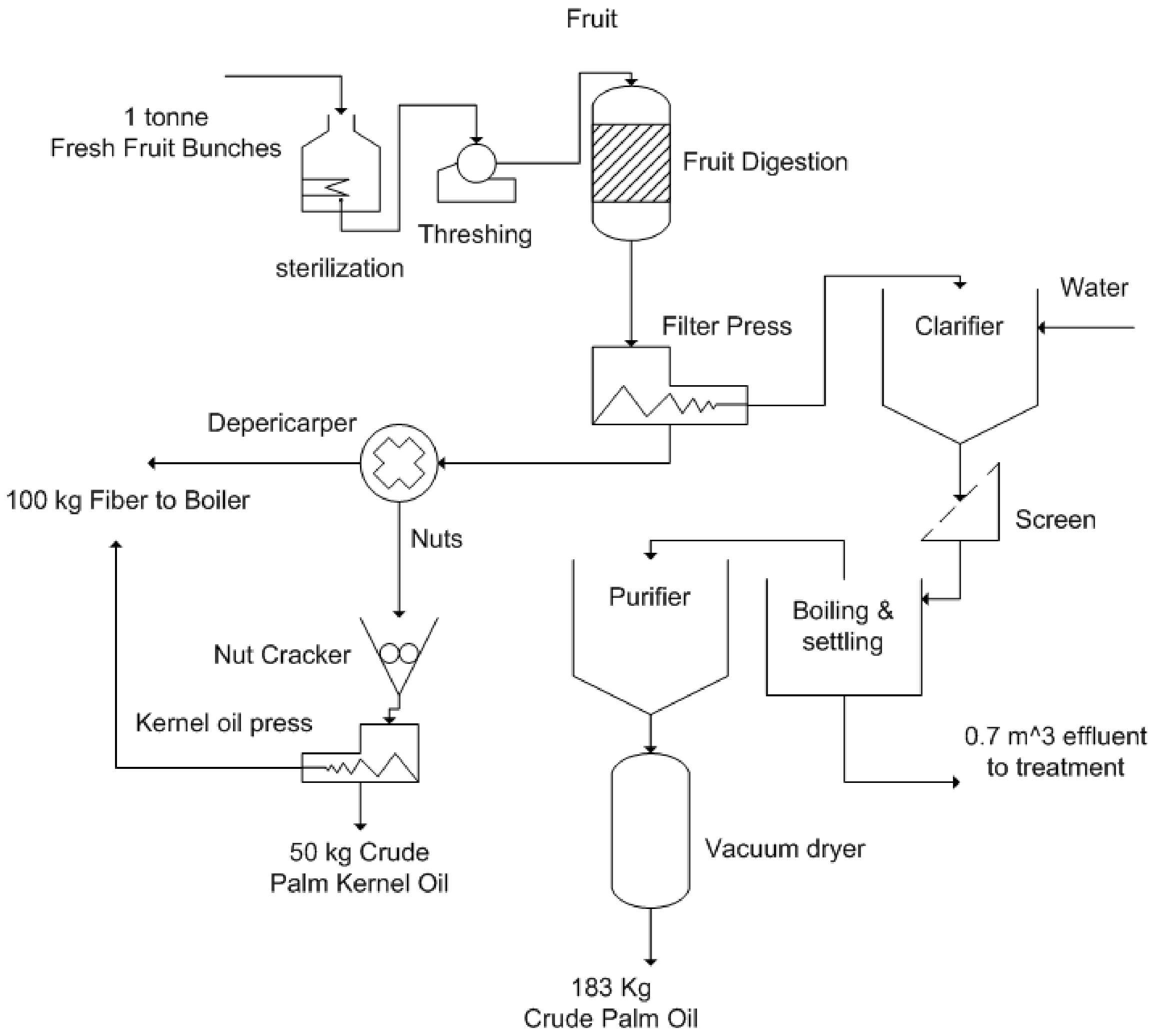
Figure 8: Small-scale extraction of coconut oil



Source: Econergy

African Palm oil extraction process. In Africa, extracting palm oil from the fruit is primarily done in villages on a small-scale manual basis, particularly if the production is for local consumption. Areas with high levels of production may have larger semi-continuous facilities, with much higher throughputs. Regardless of the scale of the processing facility, the same basic steps are employed, however. Fresh fruit bunches arrive at the facility and the fruit is threshed off of the bunch. The bunch is usually combusted as boiler fuel, and the ash is delivered back to the plantation and spread around the base of the trees. The fruit is sterilized in a cooker that may be either steam-fired or simply a hot water tank. This step is needed to de-activate enzymes present in the fruit, which could degrade the oil quality; it also weakens the pulp structure and helps release the kernel from the shell walls. It is important that this step be carried out without the presence of air to avoid oxidation when temperatures rise. The fruit is then delivered to a digester where it is again heated and mashed by rotating paddles, to disrupt the cell walls holding the oils. The mashed fruit is pressed to extract oil either manually in a hydraulic press, or in rotating filter presses. Palm kernel nuts are removed and must be processed separately. They are chopped and delivered to the digester for extraction of the palm kernel oil in a process similar to that of the copra process.

Table 7: Palm oil extraction process



Source: Econergy

The extracted oil is mixed with water and run through a screen to remove fibers. The emulsion is heated and settled; oil is skimmed from the top. This process produces crude palm oil that must be further processed, using more advanced processing equipment, into refined oil (see Figure 10), and finally biodiesel (see Figure 11).

Table 8: Typical African Palm production values

Product	Quantity	Unit
Fresh Fruit Bunches (FFB)	18	Tons FFB/ha
Crude Palm Oil (CPO)	183	kg CPO/Ton FFB
Crude Palm Kernel Oil (PKO)	50	kg PKO/Ton FFB
Palm Oil Mill Effluent (POME)	0.7	M3/Ton FFB

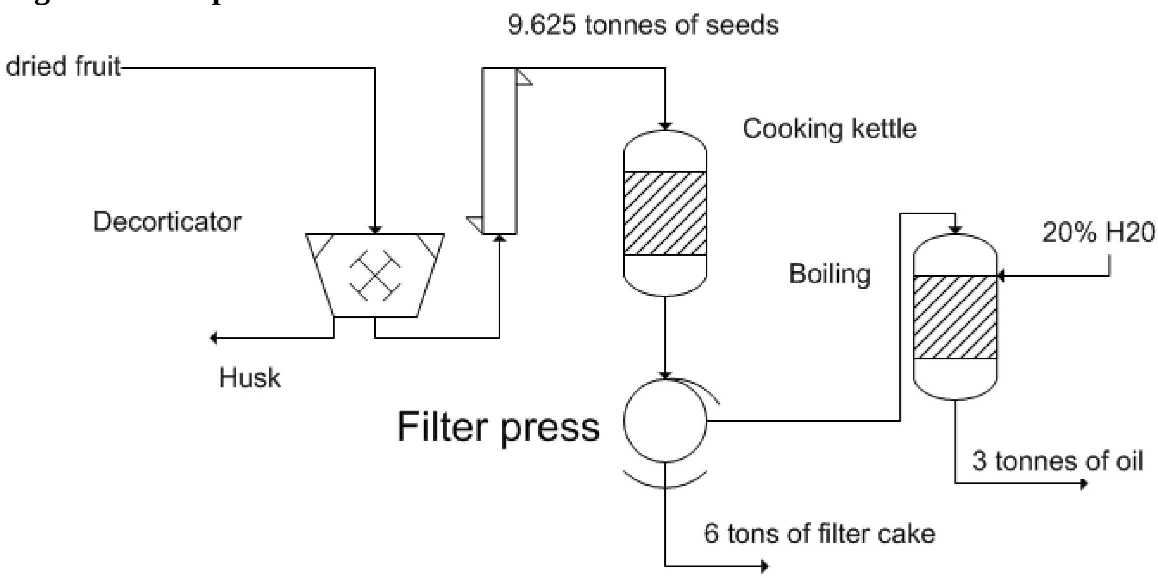
Source: MPOB and Kyushu Institute of Technology, "Sustainable biomass industry in palm oil mills in Malaysia" accessed June 6th, 2007 at http://unit.aist.go.jp/internat/biomassws/01workshop/material/Yoshihito%20SHIRAI.pdf

Table 9: Costs of industrial scale palm oil extraction and refining equipment

Company	Type	Cost	Capacity	USD/ton-year
GA Expertise Inc.	Palm Oil Mill (equipment only)	USDMM 3-4	4.4 mt CPO/hr	97 to 130
GA Expertise Inc.	Crude Oil Refinery (equipment only)	USDMM 2.5	4.4 mt CPO/hr	81
TechnoChem	Crude Oil Refinery (turnkey plant)	USDMM 3.5	2.75 mt CPO/hr	181

Sources: GA Expertise Inc.; TechnoChem

Figure 9: Jatropha oil extraction from one hectare



Source: Centre for Jatropha Promotion

Jatropha oil extraction. Oil extracted from jatropha nuts is roughly 31% by weight for a manual mechanical extraction unit and 36% if a solvent extraction system is used.

The fruit is picked and dried in the sun. Prior to extraction, the fruit is either warmed by sunlight or roasted for ten minutes. The shell is removed by a decorticator and the seeds are cooked in a kettle to liberate oil from the cells. Next, the seeds are mechanically pressed by hand or with electrically driven motors. 20% water is then added to the stream and boiled off, purifying the oil. Generally, plantations will use mechanical extraction methods on a small scale, but solvent extraction is more appropriate at plantations larger than 5,000 to 7,000 hectares. The by-product – filter press cake – can be used as an organic fertilizer, returning nutrients to the fields. Typical nutrient contents are 6% nitrogen, 2.75% potassium, and 0.9% phosphorous, one ton of which is equivalent to 200kg of NPK 12:24:12 synthetic fertilizer.[11]

Soy oil extraction. Costs for extracting oil from soybeans in the United States are summarized in Table 10. The cost of soy beans is not included, because the total only reflects the additional costs to process the beans into oil. The extraction facility can process soybeans into oil and soybean meal for a cost of USD11.65 per ton of oil.

Table 10: Soy oil crushing costs USA

Cost item (USD/t)	Unit	USA (USD/ton)
Soybeans	16 ton/ton oil	
Steam	213 Mcal/t	1.98
Power	38 kWh/t	1.99
Solvent	0.94 l/t	0.22
Chemicals		
Labor		3.24
Maintenance & Other (2)		4.21
Total Costs		11.65

Source: Alf International

Crushing Margin. The crushing margin has been assessed for several of the oil crops considered and is shown in Table 11. These values have been taken from large established markets; values for soy, peanut, cottonseed and sunflower have been obtained from the USDA oil crops outlook monthly report. Statistical data available on the Malaysian palm oil industry have been used for palm, and the World Bank provides information on copra prices and coconut oil. This analysis calculates the difference between the cost of the raw unprocessed feedstock and the sum of the market value of oil and meal generated at the extraction facility. Thus the difference is the value added to a feedstock by processing it and is referred to as the crushing margin. For a profitable business the crushing margin must be positive, as the equation below summarizes.

Crushing margin = Sale of oil and co-products – cost of seed

The crushing margin essentially captures the industrial material and energy costs required for processing, overhead, depreciation and profit gained by the processing company. Data from U.S. soy bean crushers indicate that the material and energy costs represent roughly a third of the crushing margin or about USD12 per ton of feedstock processed. Experience also shows that processing costs in the palm oil industry in Central America are about a fifth of the crushing margin or USD4 per ton of fresh fruit processed. These business models are very different because U.S. crushers generally purchase soybeans at market prices or operate as a cooperative of farmers. Conversely, the Central American palm industry is more vertically integrated with one company generally owning a mill

[11] Centre for Jatropha Promtoion. www.jatrophaworld.org

and a palm plantation. Likewise, in the U.S. soy oil is typically sold to biodiesel producers as feedstock where in Central America, the palm oil mills have been the first to install production capacity. The difference here is that the biofuels industry is that soy in the U.S. sees essentially three profit centers while only one exits in the Central American palm industry.

The crush margin is used later to infer the cost of oil extraction, where these costs are unknown, along with known costs for feedstocks. This calculation is useful because it illustrates the where monetary value is added in the processing chain for various feedstocks.

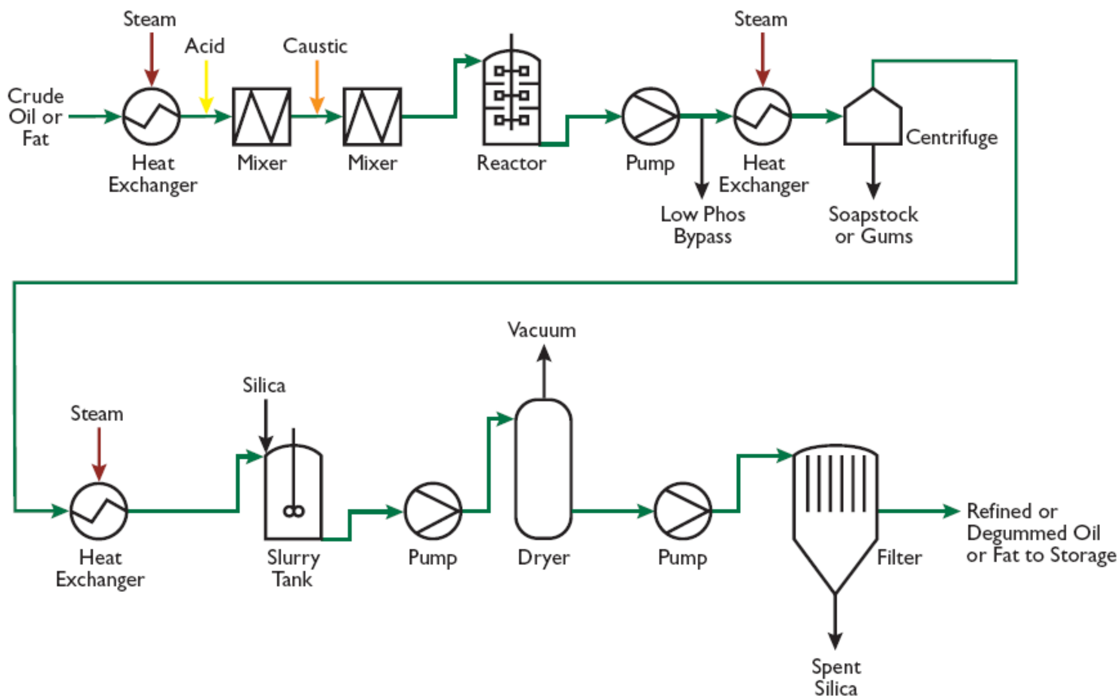
Table 11: Crushing costs and analysis of various oil seeds

	Cottonseed	Sunflower	Peanut	Soybeans	Copra	Palm
	2007-2008	2007-2008	2007-2008	2007-2008	2007 ave	2007 ave
Feedstock Value (USD/t)	148.8	305.2	443.2	257.4	521.5	130.1
Market Price of Oil (USD/t)	716.6	882.0	1,179.7	694.6	786.5	712.0
Oil Yield (%)	15%	37%	48%	19%	72%	18%
Value of Oil in Feedstock (USD/t)	107.5	326.3	566.2	131.0	566.3	129.3
Market Value of Meal (USD/t)	181.9	143.3	165.4	220.5	88.0	383.4
Meal Yield (%)	77%	57%	47%	73%	25%	5%
Meal value (USD/t oil)	139.2	81.3	77.4	162.1	22.2	18.6
Percent protein in Meal	41%	28%	48%	48%	20%	NA
Value of protein in meal (USD/t)	443.7	511.9	344.5	459.4	440	NA
Meal Value in Feedstock (USD/t)	139.2	81.3	77.4	162.1	22.2	18.6
Meal + Oil Value in Feedstock (USD/t)	246.7	407.6	643.6	293.0	588.4	148.0
Crush Margin (USD/t)	97.8	102.4	200.4	35.7	66.9	17.9

Sources: Malaysian Palm Oil Board, World Bank pink sheets May 2007; USDA Oil Crops Outlook, May 2007

Crude vegetable oil refining. Crude oils are sold on some markets, but most often the oil is processed at the extraction facility into refined and bleached (RB) oils, or into refined, bleached and deodorized (RBD) oils. Vegetable oils require some refining prior to biodiesel production. Degumming is a process that removes phosphates, waxes and other impurities by converting them to hydrated gums, which are oil-insoluble and can be skimmed from the stream. Figure 10 shows the process of producing refined oil from crude oil. Vegetable oils with particularly high free fatty acid contents require additional steps to reduce this level prior to trans-esterification. This process is most likely to be used for the processing of palm oil.

Figure 10: Vegetable Oil and fat Refining (Pre-treatment)

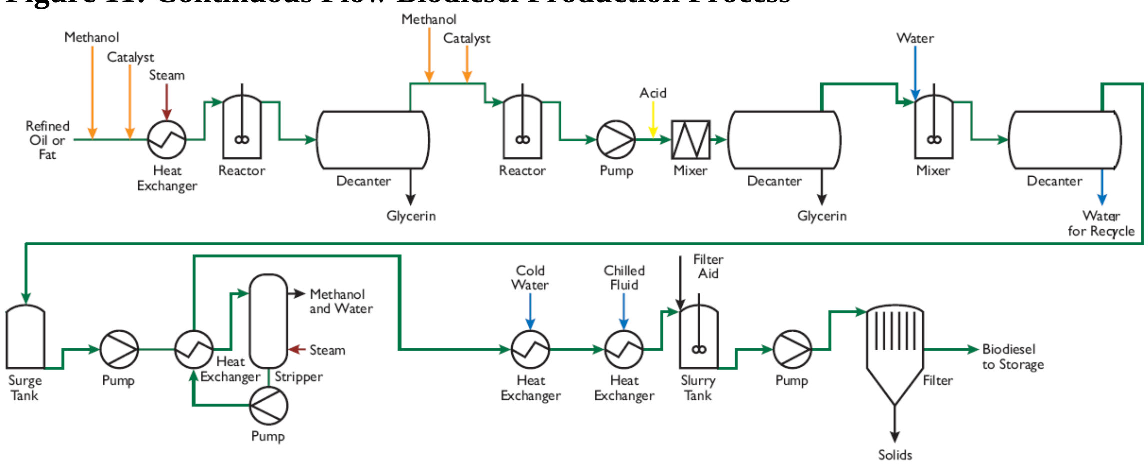


Source: Crown Iron Works Company

Conventional biodiesel processing technologies. Batch production and continuous processing have traditionally been used to convert refined vegetable oils or fats into methyl or ethyl esters (biodiesel). The batch production technique can be used with many different feedstocks to produce low-cost fuel. Batch production equipment is used for small-scale operation; in general, facilities using this technology produce less than 5 million gallons of fuel per year. Batch processing is relatively simple. Oil, methanol, and a catalyst such as potassium or sodium hydroxide are placed in a reactor, which is then sealed. The reaction producing biodiesel is called trans-esterification of the triglyceride molecule. Methyl or ethyl esters present in the vegetable or animal oil are cleaved off of the triglyceride molecule, producing biodiesel and glycerol. The biodiesel is washed to remove catalyst, glycerol and methanol, and is removed from the process. Typically, methanol is recycled back into the process, although some older facilities do not have this capability. Even if methanol recovery is used, additional amounts must be supplied as some methanol is consumed in the reaction. Often this reaction is performed in several steps, requiring multiple reactors. Reaction times for batch processors can vary, but usually require about ten hours to complete a single batch. The advantages of this process are that one batch reaction is sufficient for the complete conversion of biodiesel, the cost of the necessary equipment is low, and limited space is required. Further, the limited equipment requirements mean that fewer pumps and motors are required, thereby reducing electrical power consumption.

In contrast, continuous flow processes use multiple reactors to accomplish the reaction step-by-step. These processes use the same reactions and inputs as the batch process, but may, for example, include two steps for adding methanol and catalyst, and two steps for washing. These processes can produce fuel much more quickly than a batch facility. Residence times are in minutes rather than hours, and therefore produce more fuel per unit volume of facility. However, this system is more sophisticated and integrated, making engineering design a more crucial consideration in the construction of a profitable facility. Continuous flow facilities typically require about five times more electricity to run the additional equipment. Generally this does not significantly affect product cost. To make up for their higher capital costs, these facilities are also larger in size; the average size of a continuous flow system built in the U.S. two years ago was on the order of 76-113 million liters [20-30 million gallons] per year, this has increased tremendously since then. Now, facilities producing 113-227 million liters [30-60 million gallons] annually are much more common, with 378 million liters [100 million gallons] as the upper limit. These facilities operate 24 hours a day, whereas many small batch processing facilities can produce a batch during work hours and may be left idle overnight. Labor requirements for operating a continuous process facility are therefore higher. A schematic design for a continuous flow facility is shown in Figure 11.

Figure 11: Continuous Flow Biodiesel Production Process

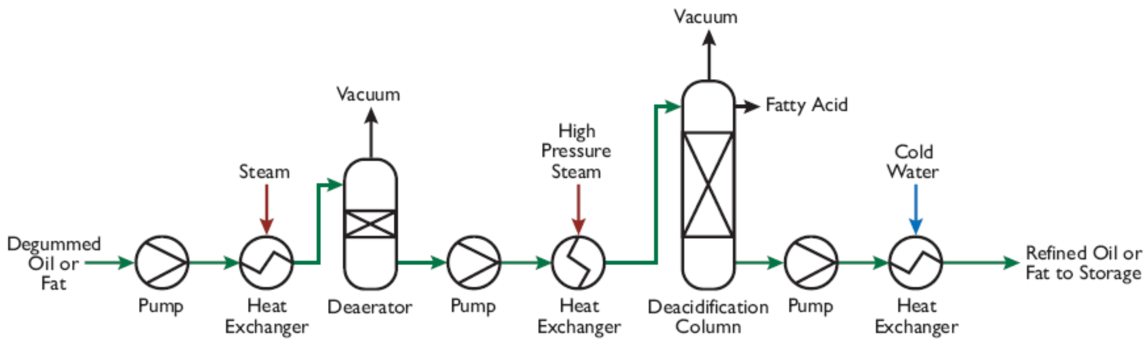


Source: Crown Iron Works Company

The schematic shows that methanol, catalyst, steam, water and acid are all required for the production of biodiesel from refined oils and fats. Additional processing must be used for certain oils that are high in free fatty acids (FFA) such as palm oil; this process is shown in Figure 12.

Biodiesel production technology uses conventional equipment such as stainless steel reaction vessels, pumps, boilers and centrifuges. This equipment has been commercially available for years, and costs relatively little. Furthermore, processing facilities have modest demands for electricity and steam when compared, for example, with an ethanol production facility. The vegetable oil feedstock is the largest operating expense, accounting for 70-80% of final product price. Although the prices of biodiesel feedstocks on the world market are not likely to decrease in the near term, other strides are being made in efficiency that should yield lower operating costs.

Figure 12: High FFA oil pre-processing



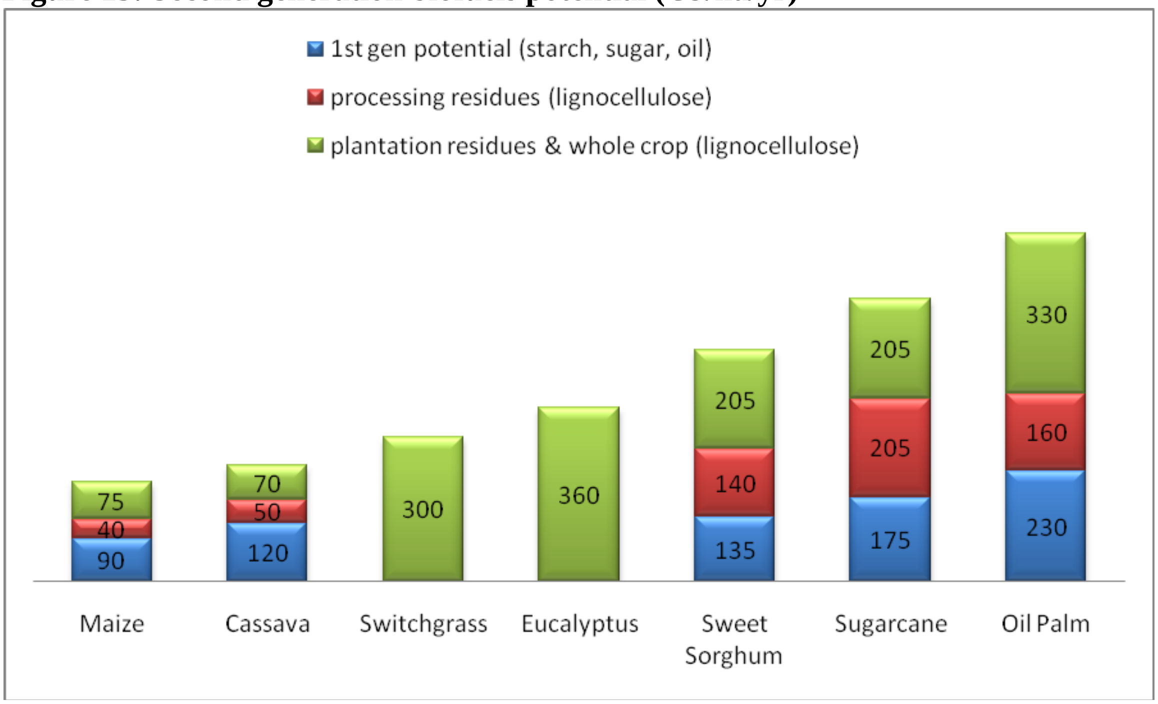
Source: Crown Iron Works Company

Second-generation biofuels technologies

First-generation biofuel technologies convert sugars and starches into ethanol and vegetable oils into biodiesel. Ethanol production feedstocks are considered suitable, if they contain high concentrations of starch or sugar and produce high mass yields per hectare. Likewise, biodiesel feedstocks should exhibit high oil content, and should include high value by-products like feed or fuel. Feedstocks which satisfy these criteria are often not located near the demand for consumption. The vast majority of high-yielding biofuel feedstocks are located in the tropics where rainfall is high and year-round growing is possible. For Europe and Japan particularly, this means importing biofuels from overseas where labor ethics and crop sustainability may be questionable. Use of lignocellulosic crops, which are native to Europe, the U.S., and China, will be critical to the expansion of biofuels production to the level where it can substantially offset oil imports. This is because most of the high-yield dedicated energy crops do not contain oils or sugars, but are rather comprised mostly of lignocellulosic material, a structural polysaccharide made up of cellulose, hemi-cellulose and lignin. Just like conventional biofuels crops, these can also be converted into renewable fuels using more advanced second generation technologies. Conventional biofuels crops also contain lignocellulosic materials and will continue to be important as biomass feedstocks, even after the technology is perfected.

Figure 13 shows the energy potential for several common biofuels crops based on the potential to use the starch, sugar and oil content for first generation biofuels technologies shown in the blue. The potential use of the lignocellulosic residues generated during oil, starch or sugar industrial processing as a second generation process feedstock is shown red. The potential to use the agricultural lingo-cellulosic material, which are usually left in the field as a second generation process feedstock is shown in blue. Two of the feedstocks shown, switchgrass and eucalyptus, are only composed of lignocellulosic material and therefore offer no benefit for first generation fuel production. Sweet sorghum, sugarcane, and African palm all offer high first generation biofuels yields, coupled with the availability of processing residues at the plant suitable for boiler fuel. Additionally, in the future field residues will be valued and can be converted into biofuels via new technology pathways. It will be important to consider the advantages of each biofuels feedstock as a future energy provider, and not just its first generation biofuels potential. The chart only shows one conventional biodiesel feedstock, oil palm, with the remainder being ethanol feedstocks. Additionally, the residues from all of these feedstocks will likely be converted into ethanol, not biodiesel, in second generation processes, a reflection of the massive push for the development of the bio-chemical fractionation conversion pathway.

Figure 13: Second generation biofuels potential (GJ/ha/yr)



Source: Adapted from Biopact, 2007

Ethanol. Several technology pathways for producing ethanol from lignocellulosic materials are nearing commercialization and are being used in several commercial demonstration facilities. The two pathways are often termed “cellulosic ethanol” because, unlike conventional ethanol production processes, no starches or sugars are required for feedstocks. The technology can process other fractions of biomass instead, namely lignocellulose (which consists of lignin), cellulose and hemi-cellulose, into alcohols. The two technologies addressed in this section are biomass fractionation of “BF ethanol” and biomass to liquids or “BTL ethanol.”

- *BF ethanol.*The first technology pathway, called biomass fractionation ethanol or “BF ethanol”, utilizes a series of chemical and biochemical conversion steps. The first step focuses on pre-treating the biomass, and generally involves separation of one or more of these three cellulocic components. Pre-treatment methods include steam explosion and various chemical treatments such as dilute acid pre-hydrolysis. Biomass pretreatment is in many respects still in its developmental stage. The processes are energy intensive, often require significant quantities of water and/or steam, and do not yet allow energy self-sufficiency. Table 12 shows various pre-treatment options, companies marketing them, and a brief process description.

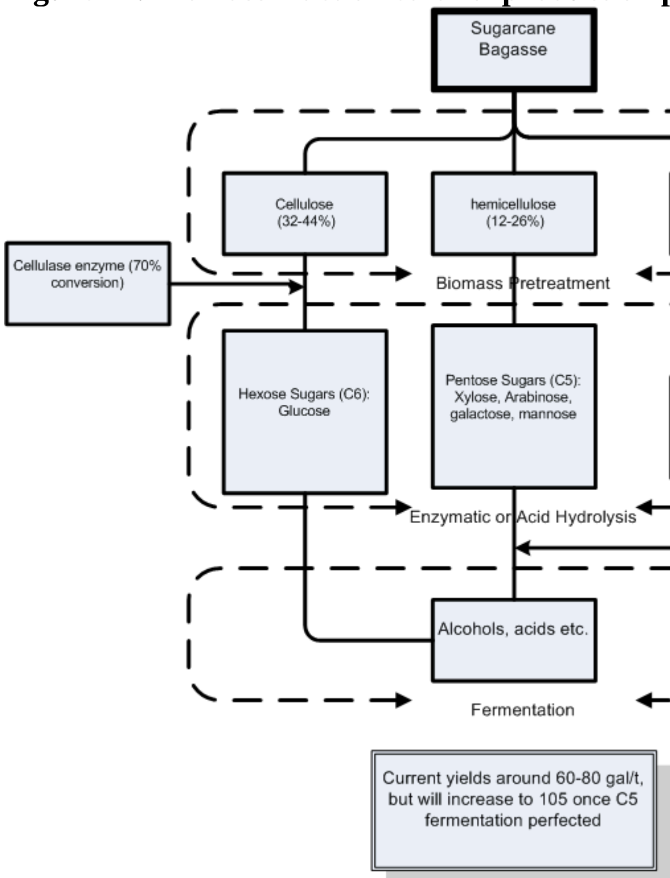
Table 12: Biomass pre-treatment process characteristics

Technology	Company	Description
Steam Explosion	Iogen; SunOpta	Biomass is fed to a reactor and steam (200-450 psig) is allowed to saturate for 0.5-8 minutes (autohydrolysis). Explosive decompression, and acids are used to catalyze the reaction (1 t steam/t biomass). Biomass and steam are released.
Reactive fractionation	PureVision Technology	Liquid hot water is coupled with mechanical grinding of raw biomass. Counter-flow of biomass and hot water
Dilute acid pre-hydrolysis	NREL; PureEnergy	Biomass is pre-steamed at 100 C, then H_2SO_4 diluted with condensate added (1%). After extraction steam, (191 psi) pressurizes for several minutes and the vessel is flash cooled.
Two Stage concentrated acid hydrolysis	Arkenol	Concentrated H_2SO_4 and steam perform the first stage hydrolysis. Solids are delivered to second stage hydrolysis (steam, acid), where the sugars are purified and fermented.
Supercritical fluid extraction (CO_2)	Globex	CO_2 is pressurized to the supercritical phase. This treats the biomass and acts as a solvent similar to hexane. This process has been used for oil extraction from coffee and for decaffeination.
Organosolv pulping	Lignol	Biomass treated with 50/50% ethanol and H_2SO_4 as a catalyst, at 190° C for 30 minutes. "Black liquor" containing lignin is removed.
Ammonia fiber explosion	None	Similar to a steam explosion, using ambient temperatures,of 190 psig, and 1-60 minutes residence time (1-2.5 t NH_3/t biomass)
Acid Hydrolisis	DHR Brazil	Bagasse is injected into a continuous reactor (extruder feeding system) to react with H_2SO_4 diluted in ethanol. The resulting sucrose is separated from lignin and further fermented to produce ethanol.

Source: Econergy

During pre-treatment, hemi-cellulose and cellulose are generally separated from the lignin component. Concurrently, the hemi-cellulose is hydrolyzed into five carbon sugars, such as xylose, aribinose, mannose, and galactose. The industry has not yet perfected the efficient and cost-effective fermentation of these five-carbon sugars coming from hemi-cellulose. The next step is known as hydrolysis. Through the action of acids or enzymes, the cellulose portion of the biomass is hydrolysed into six-carbon sugars, such as glucose, which can readily be fermented into ethanol. Following hydrolysis, the aqueous solution of dissolved sugars can be fermented, and the ethanol distilled using conventional process technology. A scheme describing these steps is shown in Figure 14 for sugarcane bagasse as a sample biomass feedstock. Because the five carbon sugars cannot be fermented, ethanol yields from this process are still poor (in the range of 60-80 gallons per metric ton). Once C5 fermentation is perfected, however, yields should easily increase to over 100 gallons per metric ton.

Figure 14: Biomass fraction ethanol production process



Source: Econergy

Some of the inefficiency of this production process stems from the biomass pre-treatment process. This process leaves a residue of high moisture lignin from which energy recovery is difficult. Recovering the energy or value from lignin is one of several crucial steps required to allow more profitable commercialization of this process.

- *BTL Ethanol.* The second technology pathway for producing ethanol from biomass is called biomass-to-liquids (BTL) and is a thermochemical approach to converting biomass into alcohols. The first of the two steps in the process is gasification. During gasification, biomass is partially oxidized to release heat, which is in turn used to drive the endothermic reactions required by the gasification process. These reactions transform raw biomass into a flammable mixture of hydrogen, carbon monoxide, methane and other gases. Gasification will make use of all of the organic matter in biomass, converting it into what is commonly known as "synthesis gas." Many high-value products, such as liquid fuels, can be derived from synthesis gas. Fuel synthesis technology can produce higher alcohols such as methanol, ethanol and propanol, using higher alcohol synthesis catalysts and gasoline and diesel using Fischer-Tropsch catalysts. In additional to solid inorganic catalysts, micro-bacteria can be used to ferment synthesis gas into ethanol and organic acids using bio-reactors.

Typical yields for this thermochemical approach are roughly 378 to 435 liters per ton of dry biomass. Additionally, this process is energy self-sufficient in that the entire process can be sustained by the energy present in the biomass that is converted. This can be done by recovering heat from gas cleaning equipment and catalytic reactors, and by using portions of the syngas for energy. Since syngas is composed of combustible gases, it can be converted in conventional prime moves as boilers, engines and turbines to generate electricity. Thus, BTL offers the dual advantage of high yields within an energy self-sustaining process.

Biodiesel. In addition to conventional transesterification of biogenic triglycerides, other options exist for producing diesel fuel from renewable sources. The first of these processes, called H-bio, can be used to convert vegetable oils or animal fats into diesel fuel at a conventional petroleum refinery, producing a blend of conventional diesel and renewable diesel. These processes require very significant capital, an oil refinery and technical expertise unavailable in Mozambique for the time being.

- *The H-bio production process.* This process has been adapted from conventional processing of petroleum in reactors known as hydrocrackers. A hydrocracker processes petroleum at elevated temperatures and often in the presence of a catalyst. The cracking process breaks carbon-carbon bonds found in the high molecular weight compounds. These reactors also introduce hydrogen at high partial pressures, which encourages the reformation of lower molecular weight compounds such as diesel, jet fuel, gasoline and kerosene. This process also acts to remove sulfur, creating final products with lower sulfur contents. Vegetable oils and animal fats are processed in these hydrocrackers and mixed with petroleum refining by products such as hydrogen and butane. The solid catalyst recombines the mixture of fossil and renewable hydrocarbon molecules into diesel.

- *NExBTL*. Neste Oil Company of Finland is perhaps one of the first companies to experiment with introducing vegetable oils into the reaction with a process called NExBTL. The cloud point can be adjusted to suit different regional needs, and the fuel can be used in conventional diesel vehicles without modifications. Petrobras, the Brazilian oil company, is also investing in three h-bioplants. There are strong doubts about whether this process makes sense for vertically integrated oil companies, given that oil costs much less than vegetable oil.

- *Pyrolisis*. In addition to using vegetable oils in hydrocrackers, the possibility exists to introduce other liquid feedstocks. Of particular interest for this process would be using pyrolysis oils generated from biomass, and crude oils formed during the thermal depolymerization process. Pyrolysis is very similar to hydrocracking, but is used to process solid biomass feedstocks into a liquid product called bio-oil. Bio-oils, which have high moisture, oxygen and nitrogen contents, could be co-fed and it is thought that they can be co-fed with petroleum in small fractions into hydrocrackers. Thermal depolymerization is another similar process which treats solid feedstock at high pressures (600 psi) and moderate temperatures (250 °C) with steam, forming a crude oil. This process is being considered to make use of waste from slaughterhouses. Once again, the moisture content of the final oil is high, and the feedstock will likely need to be mixed with petroleum prior to the cracking process.

- *Biomass-to-liquids.* Another attractive option for producing diesel from biomass uses gasification and the Fischer-Tropsch process. This process was pioneered in Germany and is still used today to convert coal into liquid fuels in South Africa. As a first step, the solid biomass feedstock is gasified forming synthesis gas, a mixture of hydrogen and carbon monoxide. This synthesis gas is then cleaned, and often upgraded and processed into liquid products such as diesel using catalytic reactors. Diesel fuel produced in this process is also extremely low in sulfur and has very good performance characteristics. CHOREN Industries, a German company, is marketing this process for diesel fuel production in the EU, and is building a commercial demonstration facility. The capital cost for these plants is quite high, and they are only economically feasible at large-scale production capacities.

2. Production costs

Ethanol from cassava, sugarcane, sweet sorghum and maize

Maize. A production cost model was generated to identify production costs associated with energy, materials, labor and capital depreciation. Data related to these costs are generally available for sugarcane and maize ethanol production, but not for sorghum and cassava. It was therefore assumed that costs for processing sugarcane and sorghum into ethanol will be identical, since the processes are very similar. The production costs to turn maize into ethanol have been estimated using a production cost model generated by the USDA Agricultural Research Service and modified by Econergy to reflect current equipment prices, as well as the specific energy, materials and labor costs known for Mozambique. The known inputs have been used in the model for a 25-million-gallon (119,175 t/year) per-year plant. At this size, production costs excluding the cost of corn are estimated at USD169 per ton of ethanol[8] in Mozambique. The relative cost of production in USD/ton of ethanol will decrease with an increase in production capacity thanks to economies of scale. However, a larger facility is unlikely to be built, initially, in Mozambique. Table 13 presents the total production cost for maize in this mid-sized facility.

Table 13: Maize ethanol production cost summary (119,175 t/yr)

Unit	Cost (USD/t ethanol)
Grain	558.0
Gasoline	58.6
Other Materials	27.2
Gas & Electric	64.6
Labor, Supplies and Overheads	18.5
Depreciation	31.5
Co-Product Credit	-97.0
Total Production	661.3
Total Product excluding feedstock	169.0

Source: Adapted from USDA production cost model

Sugarcane. The expected agricultural production costs for sugarcane in Mozambique have been obtained from an LMC study prepared for the National Sugar Institute in Mozambique. The expected feedstock production cost is equal to USD11.48 per metric tonne of cane based on current prices and trends.[12] Assuming a yield of 76.92 liters per metric tonne, based on the expected sucrose content of Mozambican sugarcane, the estimated feedstock cost per tonne of ethanol is USD188. This value is about 14% higher than the production cost in Brazil.

Table 14: Sugarcane ethanol production costs

	Brazilian cost (USD/t ethanol)	Correction factor (Alf)	Mozambique cost (USD/t ethanol)
Feedstock Production Costs	164.85		309.28
Cash flow expenses			
Operational costs	27.64	1.10	30.37
Administration	16.01	2.95	47.18
Maintenance	15.60	1.10	17.14
Others	7.68	2.95	22.64
Fixed costs			
Depreciation	12.47	1.10	13.70
Working capital	6.17	1.10	6.78
Opportunity cost of agricultural land	17.51	0.00	0.00
Total Refining costs	103.09		137.81
Ethanol From Sugar Cane Production Cost	267.93		447.09

Sources: LMC International Ltd.; Alf International

Production costs in the refinery for a sugarcane-to-ethanol production process have been estimated and adapted from costs known from the Brazilian process. Alf International has estimated factors for scaling up the various costs associated with ethanol production from the Brazilian case to the reality in Mozambique. It is especially important to note that the fact that land is free in Mozambique (other than the cost of securing a concession) helps offset some of the higher operating and fixed costs in the country. These costs along with the total are shown in Table 14.

Sweet sorghum. Several studies have been conducted on the production costs for sweet sorghum ethanol. One study conducted by ICRISAT has particular relevance for India, but also quantifies production costs for Sub-Saharan Africa.[4] Other studies have quantified production costs for growing sweet sorghum in the U.S. and compared them with Brazilian ethanol production costs.[13] This study, conducted for the Iowa Energy Center, estimates production costs for ethanol from sorghum including agricultural production of feedstock at USD302 – USD365 per ton of ethanol, assuming yields of 4,000 liters of ethanol per hectare. ICRISAT provides a production cost of USD408.2 per ton of ethanol based on a yield of 2,800 liters of ethanol per hectare in India.

[12] LMC International Ltd. Appraisal of the Impact of Sugar Pricing Policy and Investment in the Sugar Industry of Mozambique. Prepared for National Sugar Institute Mozambique, October 2004.
[13] Robert P. Anex, Evaluation of Scenarios for the Industrial Use of Sorghum. Final Technical Report to The Iowa Energy Center.

Mozambique ethanol yields are likely to be closer to those predicted in India where fertilizer use is minimal and manual labor is used for cultivation and harvesting. The cost for producing sorghum in Mozambique has therefore been estimated, based on the Indian case, at USD440 per ha of cultivated land, which translates to USD198 per ton of ethanol when a yield of 2,800 liters per hectare is assumed. The same cost for refining the sorghum cane into ethanol has been used for the sugarcane ethanol production, namely USD137.81 per ton of ethanol. Thus, the total production cost, excluding transportation, is equal to USD336 per ton of ethanol, as shown in Table 17.

Cassava. The cultivation of cassava is likely to offer Mozambique a cost-effective route for producing biofuels. Because the agricultural production cost is estimated at only USD50 per ton and the ethanol yields are so high (200 liters per ton of feedstock[14]) the feedstock cost is USD315 per ton of ethanol produced. On the ethanol production side, little is known about production costs, because cassava is an alternative ethanol feedstock that has not yet been used for industrial purposes. A conservative estimate assumes that production costs for cassava are similar to those of maize. Similarities between the two include the entire processing train, from converting starches enzymatically into sugars, to ethanol, and then to distillation. The primary difference between the two is the pre-processing step, in which the starch is liberated from the feedstock. Grupo Petrotesting Colombia predicts that production costs of USD204 to USD237 per ton of ethanol, including the agricultural feedstock production cost, are possible for an annual production capacity of roughly 270 million liters based in Colombia.[14] Expected yields in Colombia are between 30 and 40 tons of cassava per ha, while for Mozambique observed yields are only 5 to 10 tons per hectare. With proper management of a plantation aimed at biofuels feedstock production, it would not be difficult to realize at least a 20 ton per hectare yield. Using the current agricultural cost of production and the ethanol refining cost used for maize ethanol, the estimated total ethanol production cost is USD236 per ton of ethanol. This is consistent with what is predicted in Colombia.

A pilot plant started in Colombia by Grupo Petrotesting Colombia indicates that production costs for ethanol from cassava at a pilot scale facility could be in the range of USD0.22-0.23/liter [USD0.84-0.89/gallon], depending on the agricultural yield of the cassava.

Table 15: Ethanol Production from cassava in Colombia

Yield (T/ha)	**30**		**35**		**40**	
(Year 1)	USDMM	USD/l	USDMM	USD/l	USDMM	USD/l
Gross earnings	72	0.24	72	0.24	72	0.24
Production costs	51	0.19	46	0.17	43	0.16
Production (MMl/yr)	271		268		265	
Capital investment	65	0.238	65	0.240	65	0.243
Ethanol yield (l/t)	200		200		200	
Cassava consumed (t)	1,353,723		1,341,040		1,327,160	
IRR	40%		43%		45%	

Source: Grupo Petrotesting Colombia

[14] Frank Kanayet and Jaime Jaramillo, Grupo Petrotesting Colombia, Ethanol by Cassava Presentation

The company is planning to scale up production by constructing a facility with the capacity to produce 1,050,000 liters per day at a more reasonable production cost of USD0.04-USD0.05/liter [USD0.16-0.19/gallon]. This could provide investors an IRR in the low 40% range. The planned expanded facility will produce about 270 million liters per year. Capital investment required is roughly USD0.24 per annual liter of production capacity for such a facility, including the cost of the agricultural land. Table 15 summarizes the financial and technical performance of this project for several cassava yield scenarios.

Molasses. It is estimated that each ton of molasses in Mozambique can be refined into 250 liters of ethanol. Because the infrastructure required to move molasses great distances is often not in place, the value of molasses can vary greatly. In some instances the commodity is actually dumped in nearby rivers or spread on roads, rather than processed and therefore is has no market value. There is at least one plant presently converting molasses to ethanol in Mozambique in the Buzi region as mentioned previously.

Production cost summary

Net production costs for biofuels can be estimated by adding the feedstock cost and the cost of refining the feedstocks into ethanol. Several price scenarios are considered for the cost of feedstock converted, these are shown in Table 16. Net costs do not include profit margins for producers and refiners, and are intended to represent only consumables and

Table 16: Bioethanol feedstock price scenarios from Chapter 3

Feedstock	Agricultural cost of production (USD/ton)	Domestic market price (USD/ton)
Cassava	12	50
Sugarcane	19	-
Sorghum	91	111
Molasses	-	-
Maize	99	151

Source: Econergy

depreciation. Table 17 shows the summary and net production cost both in US dollars per ton and per liter for ethanol from the different feedstocks considered. Sweet sorghum, sugarcane and cassava are the lowest cost options for producing ethanol in Mozambique. Production based on molasses would entail very low costs due to these coming from existing sugar production, where currently they often represent waste. Scope of production based on molasses, however, would be more limited.

Table 17: Bioethanol production cost summary

	Feedstock cost	Ethanol refining	Net production	Net production
	USD/t of ethanol	USD/t ethanol	USD/t ethanol	USD/l ethanol
Cassava	314.9	169.0	483.9	0.38
Sugarcane	309.3	137.8	447.1	0.35
Sorghum	198.2	137.8	336.0	0.27
Molasses	251.9	120.6	372.5	0.30
Maize	492.2	169.0	661.2	0.53

Source: Econergy

Biodiesel production cost presentation

Two models were constructed to estimate costs of various feedstocks associated with both small scale and large scale operations. In the small scale production scenario, it is assumed that small plantations provide feedstock to local, village-based, mechanically operated, extraction facilities. For the oil seed crops, it is assumed that screw presses are used to separate oil from the seeds. For copra and palm fruit, small scale mechanical presses are used, as described in the previous section. At the small scale level it is assumed that biodiesel production would be accomplished in batch process facilities in the size range of 1 to 20 million liters annually. At the large scale, larger plantations will be used in conjunction with centrally located and automated industrial scale extraction facilities. Biodiesel refining likewise would be accomplished with continuous flow process technology in the size range of 40 to 200 million liters annually. This represents a more distant future scenario in which both export and local markets have been established for fuel byproducts, and where access to water, electricity and other infrastructure requirements is available.

To estimate the potential costs for biodiesel production, necessary elements are agricultural production cost of feedstock, operational costs for oil extraction, operational costs for oil refining, and operational costs for transesterification of oil into biodiesel. The agricultural cost for oil is simply calculated as the agricultural production cost of the feedstock (presented in Chapter 3) divided by its extractable oil content, minus the value of any co-products. The oil extraction cost captures labor costs along with energy and materials costs for removing oil from the feedstocks. Neutralization of crude oil has been considered a constant cost per ton for all oils, USD45 per ton for small scale operations and USD30 per ton for large operations.

Oil extraction yields. The technical feasibility of oil extraction from the fresh fruits, nuts and seeds has a fairly large impact on the production cost of vegetable oils. This is especially true for feedstocks having high production costs and therefore care must be taken to achieve efficient extraction. The extractable oil, expressed as a percent of the total mass of the feedstock, encompasses two factors. The first factor is simply the oil content of the feedstock and the second factor is technology specific and refers to the effectiveness of the extraction equipment to release the oils. The product of these two factors dictates the mass percent of oil which can be extracted from each ton of feedstock. These values are shown in Table 18 for both solvent based systems, which enjoys extraction efficiencies on the order of just under 100%, as well as for mechanical techniques which are less efficient. These numbers are representative of the feedstocks but are not specific to Mozambique. The oil content of each feedstock is a function of rainfall and sunlight in addition to other factors. Some of these data were available for Mozambican crops while others were assumed. Therefore, average values from experience worldwide have been used as placeholders where the feedstock's oil content in unknown. For the cases where values are not available for both mechanical extraction and solvent extraction, a simple relationship was used to estimate these values, specifically that mechanical extraction results in one-third of the original oil content remaining in the meal.

Table 18: Oil extraction assumptions

Feedstock	Extractable oil using Solvent extraction (%)	Extractable oil using mechanical extraction (%)
African palm	18%	12%
sesame	35%	23%
Castor	52%	35%
Copra	52%	35%
Cottonseed	15%	10%
Jatropha	36%	24%
Peanut	48%	32%
Soybean	19%	13%
Sunflower	37%	25%

Source: Econergy

Table 19: International refined oil price index

	Market price reference	Price (USD/ton)	Freight and Insurance cost (USD/ton)	Equivalent Mozambican ex-factory cost (USD/ton)
Coconut Oil	c.i.f. Rotterdam	922	105	817
Groundnut Oil	c.i.f. Rotterdam	1345	105	1240
Palm Oil	c.i.f. N.W. Europe	820	105	715
Soybean Oil	Dutch f.o.b. ex-mill	959	105	854
Sunflower	c.i.f. Rotterdam	1380	105	1275
Castor	ex-tank Rotterdam	1295	105	1190

Sources: Oil prices for coconut, groundnut, and palm oil obtained from World Bank commodity price data July, August and September average values. Oil prices for soybean, sunflower and castor oil in Rotterdam obtained 10/04/2007 from:
http://www.brecorder.com/index.php?id=633283&currPageNo=1&query=&search=&term=&supDate

Oil extraction leaves a meal cake as residue which is sold as an animal feed. Since solvent extraction is more efficient at removing oil from the feedstock, the volume of meal generated is lower than with mechanical extraction. The meal from a mechanical press has a lower concentration of protein, but on a net basis it has the same mass of protein as meal generated by a solvent extraction process and therefore the two meal cakes are assumed to have the same revenue generating potential. A material loss of 10% of the entering feedstock is assumed for both processes. The international market prices representing the opportunity cost of vegetable oils used for biodiesel production in

Mozambique have been generated in Table 19. The cost of inland and ocean freight have been subtracted, as presented in Chapter 5, to determine the relevant ex-factory equivalent price relevant in Mozambique.

The relevant cost scenarios are presented in Table 20 and Table 19. The price scenarios considered as inputs feedstock costs are the agricultural cost of production at the field, the opportunity cost at the domestic market price and the opportunity cost at the international market price. The agricultural cost of production is taken as the median value of the high and low prices reported in Chapter 3. Also presented in Chapter 3 were the domestic market feedstock prices. The international market prices of oil are not shown in Table 20 because these refer not to the feedstocks, but to raw oils, and are therefore hardly comparable. The international market price of oil was evaluated separately to determine its equivalent biodiesel production cost.

Table 20: Biodiesel feedstock price scenarios

Feedstock	Agricultural Cost of Production (USD/ton)	Domestic Market Price (USD/ton)
Cottonseed	121	196
Sunflower	90	139
Castor	NA	185
Peanut	171	891
Soybean	72	204
Copra	NA	185
African Palm	69	103
Sesame	181	426
Jatropha	130	278

Sources: Agricultural cost of copra and palm unavailable for Mozambique so it has been estimated from Brazil, Agrianual 2006 and FAO Stat. Domestic market for Jatropha doesn't exist and the feedstock has been assumed to have a value 50% higher than its production cost. Agricultural cost of palm fruit production estimated at twice the price in the Malaysian Industry[15], its market price has been estimated at 150% of this cost.

Small-scale Biodiesel Production Costs

Small-scale production costs of biodiesel from the candidate feedstocks are presented in Table 21 and Table 22, where the first shows the production cost calculation using the agricultural cost of feedstock production as the input price and the second using the feedstock's domestic market price. In this calculation the assumed price of feedstock is used to compute the net biodiesel production cost. In the top section of the tables the unit cost of oil is computed by taking the feedstock cost and dividing it by the expected oil yield, from Table 18, obtainable by means of mechanical extraction equipment.

[15] Azman Ismail, Mohamed Arif Simeh and M Mohamed Noor. "The production cost of oil palm fresh fruit bunches: the case of independent smallholders in Johor, *Oil Palm Industry Economic Journal* Vol. 3 (1) 2003.

Table 21: Small-scale biodiesel production cost calculation using agricultural feedstock production cost

		Sunflower	Jatropha	Soybean	Palm	Cottonseed	Sesame
Production cost of oil							
Feedstock prod. cost	USD/t	90	130	72	69	121	181
Mechanical oil yield	%	25%	24%	13%	12%	10%	23%
Cost of Oil	USD/t oil	365	542	568	573	1,210	774
Meal and Co-product							
Meal/co-product value	USD/t meal	143	0	221	383	182	176
Meal/co-product yield	%	68%	68%	79%	5%	81%	69%
Meal/co-product credit	USD/t oil	394	0	1,368	155	1,473	520
Cost of oil less co-products	USD/t oil	-29	542	-800	418	-263	253
Industrial Process. costs							
Crude oil extraction	USD/t oil	35	35	35	35	35	35
Crude oil refining	USD/t oil	45	45	45	45	45	45
Oil trans-esterification	USD/t BD	75	75	75	75	75	75
Net biodiesel prod. cost	**USD/t BD**	**127**	**709**	**-660**	**583**	**-112**	**415**
Net biodiesel prod. cost	**USD/l**	**0.11**	**0.63**	**-0.58**	**0.52**	**-0.10**	**0.37**

Source: Econergy

Next, the value of the feedstocks co-product is computed. In most cases this is the market value of the meal based on world meal prices and is computed based on the expected protein content. Palm has the highest co-product value because in this case the co-product is the palm kernel whose oil has a higher market value on a per ton basis. The co-product yield is then multiplied by a product loss factor of 10% to account for miscellaneous feedstock product losses. The meal and co-product credit is computed as its value on a per ton of oil basis. This co-product value is shown in the table and is deducted from the cost of the oil. The cost of oil then reflects the value of the oil as a biofuels feedstock assuming that its co-products are sold accordingly.

The lower section of the tables computes the industrial costs of converting the resulting oil feedstock into biodiesel. First the cost of oil extraction is shown at USD30 per ton, the cost of neutralizing the oil is shown at USD 45 per ton, and the cost of trans-esterification of oil into biodiesel is shown at USD75 per ton including a conversion efficiency of 98%. The net biodiesel production cost shown accounts for the feedstock cost and the industrial cost of refining and is shown both on a per ton and a per liter basis. It is worth noting that no value is given to the meal of castor and jatropha since these feedstocks are poisonous and therefore have no value as an animal feed. Their value as a fertilizer has been set at zero since it has been assumed that fertilizer would not otherwise be purchased.

Table 22: Small-scale biodiesel production cost calculation using feedstock domestic market price

		Sunflower	Jatropha	Castor	Soybean	Copra	Palm	Cottonseed	Sesame
Market value of Oil									
Feedstock Value	USD/t	139	278	185	204	185	103	196	426
Oil yield	%	25%	24%	35%	13%	35%	12%	10%	23%
Cost of raw Oil	USD/t oil	563	1,157	534	1,608	534	860	1,963	1,825
Meal and Co-product									
meal /co-product value	USD/t meal	143	0	0	221	88	383	182	176
Meal/co-product yield	%	68%	68%	59%	79%	59%	5%	81%	69%
Meal/co-product credit	USD/t oil	394	0	0	1,368	149	155	1,473	520
Cost of oil less co-products	USD/t oil	169	1,157	534	240	385	704	489	1,305
Industrial Processing Costs									
Crude oil extraction	USD/t oil	30	30	30	30	30	30	30	30
Crude oil refining	USD/t oil	45	45	45	45	45	45	45	45
Oil trans-esterification	USD/t BD	75	75	75	75	75	75	75	75
Net biodiesel prod. cost	**USD/t BD**	**324**	**1,333**	**697**	**396**	**544**	**870**	**651**	**1,483**
Net biodiesel prod. cost	**USD/l**	**0.29**	**1.18**	**0.62**	**0.35**	**0.48**	**0.77**	**0.58**	**1.31**

Source: Econergy

Large-scale Biodiesel Production Costs

The same analysis has been performed for large scale operations and is shown in the previous tables. Since the processes used in large scale oil extraction and refining are more efficient, the production costs are accordingly lower than for small scale processes. Again the calculation is shown for both the agricultural cost of production and the domestic market price of feedstock as input scenarios in Table 23 and Table 24 respectively.

Table 23: Large-scale biodiesel production cost calculation using agricultural feedstock production cost

		Sunflower	Jatropha	Soybean	Palm	Cottonseed	Sesame
Agricultural Production cost							
Feedstock Production cost	USD/t	90	130	72	69	121	181
Hexane extraction oil yield	%	37%	36%	19%	18%	15%	35%
Cost of Oil	USD/t oil	243	361	379	382	807	516
Meal and Co-product							
Meal/co-product market value	USD/t meal	143	0	221	383	182	176
Meal/ co-product yield	%	57%	58%	73%	5%	77%	59%
Meal/co-product credit	USD/t oil	220	0	854	103	928	294
Cost of oil less co-products	USD/t oil	24	361	-475	280	-121	222
Industrial Processing Costs							
Crude oil extraction	USD/t oil	30	25	32	22	30	30
Crude oil refining	USD/t oil	30	30	30	30	30	30
Oil trans-esterification	USD/t BD	59	59	59	59	59	59
Biodiesel production cost	**USD/t BD**	**144**	**484**	**-362**	**397**	**-3**	**347**
Biodiesel production cost	**USD/l**	**0.13**	**0.43**	**-0.32**	**0.35**	**0.00**	**0.31**

Source: Econergy

Production cost summary

To summarize the production costs, Table 25 shows the small- and large-scale production costs for manufacturing biodiesel from each feedstock for the three feedstock price scenarios considered. When the agricultural production cost of feedstock is considered, the resulting biodiesel production cost is artificially low because it assumes no profit for the farmers. This is shown only as an illustration but is useful because an integrated agricultural and industrial operation would be able to obtain feedstock at lower prices than the domestic and international market prices.

It is important to make two observations regarding Table 25. The first is that the negative values for biodiesel production cost for cotton and soy reflect the fact that the value of the resulting meal is actually higher than the agricultural cost of the feedstock plus the processing costs. Because these two feedstocks have particularly low oil yields (and thus high meal yields), the meal sales at market values drive the results of the cost calculation. This provides support for the argument that it really does not make sense to use the agricultural cost of producing feedstocks as an input assumption for biodiesel production. Instead, it makes more sense to use the domestic market price as the input, for which the costs are shown in Table 22, Table 24 and Table 25.

Table 24: Large-scale biodiesel production cost calculation using domestic market feedstock price

		Sunflower	Jatropha	Castor	Soybean	Copra	Palm	Cottonseed	Sesame
Market value of oil									
Feedstock Value	USD/t	139	278	185	204	185	103	196	426
Oil yield	%	37%	36%	52%	19%	52%	18%	15%	35%
Cost of raw Oil	USD/t oil	375	772	356	1,072	356	573	1,309	1,217
Meal and co-product									
Meal/co-product value	USD/t meal	143	0	0	221	88	383	182	176
Meal/co-product yield	%	57%	58%	43%	73%	43%	5%	77%	59%
Meal/co-product credit	USD/t oil	220	0	0	854	73	103	928	294
Cost of oil less co-products	USD/t oil	156	772	356	218	283	471	381	923
Industrial Processing costs									
Crude oil extraction	USD/t oil	30	25	25	32	25	22	30	30
Crude oil refining	USD/t oil	30	30	30	30	30	30	30	30
Oil trans-esterification	USD/t BD	59	59	59	59	59	59	59	59
Net biodiesel prod. cost	**USD/t BD**	**279**	**902**	**479**	**345**	**404**	**592**	**509**	**1,062**
Net biodiesel prod. cost	**USD/l**	**0.25**	**0.80**	**0.42**	**0.31**	**0.36**	**0.52**	**0.45**	**0.94**

Source: Econergy

Table 25: Biodiesel production costs for various price scenarios

	Agricultural production cost (USD/liter)		**Domestic market price (USD/liter)**		**International market price (USD/liter)**	
	Small scale	Large scale	Small scale	Large scale	Small scale	Large scale
Sunflower	0.11	0.13	0.29	0.25	1.20	1.18
Jatropha	0.63	0.43	1.18	0.80	1.18	0.80
Castor	-	-	0.62	0.42	1.12	1.11
Soybean	(0.58)	(0.32)	0.35	0.31	0.82	0.81
Copra	-	-	0.48	0.36	0.79	0.78
Palm	0.52	0.35	0.77	0.52	0.70	0.69
Cottonseed	(0.10)	(0.00)	0.58	0.45	-	-
Sesame	0.37	0.31	1.31	0.94	-	-

Source: Econergy.

The second observation is that processing the feedstock into biofuel will yield a marketable animal feed cake for all feedstocks except for castor and jatropha. The biodiesel production cost models presented in Table 22 and Table 24, therefore, do not credit jatropha and castor with being able to produce a marketable co-product. This may unfairly penalize those two crops as candidate biofuel feedstocks, however, because their meal will likely have some value as a boiler fuel or a fertilizer for continued cultivation of those crops. If a credit were awarded for the use of meal as a boiler fuel to supply thermal energy requirements, for instance, it would displace natural gas, diesel or fuel oil purchases. Based on a credit equal to the average cost of steam when diesel and natural gas are used, a value of approximately USD82 per ton of meal would be realized. By applying this credit in the same manner that animal feed cake credits are applied to the other feedstocks, adjusted production costs for jatropha and castor may be determined. These are shown in below along with the previous costs, again when the domestic market price is used as the feedstock price assumption. This reduces the production cost for Jatropha biodiesel an average of 22%, while it reduces the production cost for castor biodiesel by 17%.

Table 26: Adjusted production cost with energy credit

Feedstock	Jatropha		Castor	
	Small scale (USD/liter)	Large scale (USD/liter)	Small scale (USD/liter)	Large scale (USD/liter)
As-is production cost (domestic market)	1.18	0.80	0.62	0.42
Production cost with energy credit	0.97	0.68	0.49	0.36

Source: Econergy.

3. Production process waste valuation

Electric and Thermal Energy in the Sugar Industry in Brazil

Sugar mills always used sugar cane bagasse as fuel in their boilers but, because bagasse was considered a waste product that had to be eliminated, the boilers used were characterized by low levels of pressure and temperature and, consequently, by low efficiency. A surplus of electricity can be obtained by the replacement or retrofit of boilers and/or steam turbo generators, and by more efficient equipment, able to operate under higher conditions of pressure and temperature.

The amount of electric energy generated depends on four things: (i) the quantity of existing biomass; (ii) the amount of steam generated and consumed by the industrial process; (iii) the electricity demanded by the process; (iv) the required investment.

Table 27: Operational parameters of boilers

Pressure (kgf/cm2)	Temperature (oC)	Kg steam/kg bagasse	Efficiency to LHV(%)	Average Consumption on Turbo generators (kg steam/kW)
21	300	2,47	87	12
42	420	2,28	87	8
65	480	2,19	87	6

Source: Dedini S/A Indústria de Base, 2007

The pressure and temperature of a boiler are the most important technical specifications, with economic implications, for consideration in equipment selection. In Brazil, according to an important boiler manufacturer, the operational parameters of the most common types of boilers used in the sugar and alcohol industry are described in Table 27.

An important operational parameter to consider in turbo generators is the difference between inlet and outlet pressure. The higher this difference is the more power will be generated. There are many models of steam turbine on the market. Specifications for the three types are shown in Table 28.

Table 28: Types of Steam Turbines available in Brazilian Market

Type of Steam Turbine	Pressure (bar)	Temperature (^oC)
High Pressure and High Temperature	120	530
	85	520
Mean Pressure and Mean Temperature	45	450
Low Temperature and Low Pressure	22	320

Source: TGMTurbinas, 2007

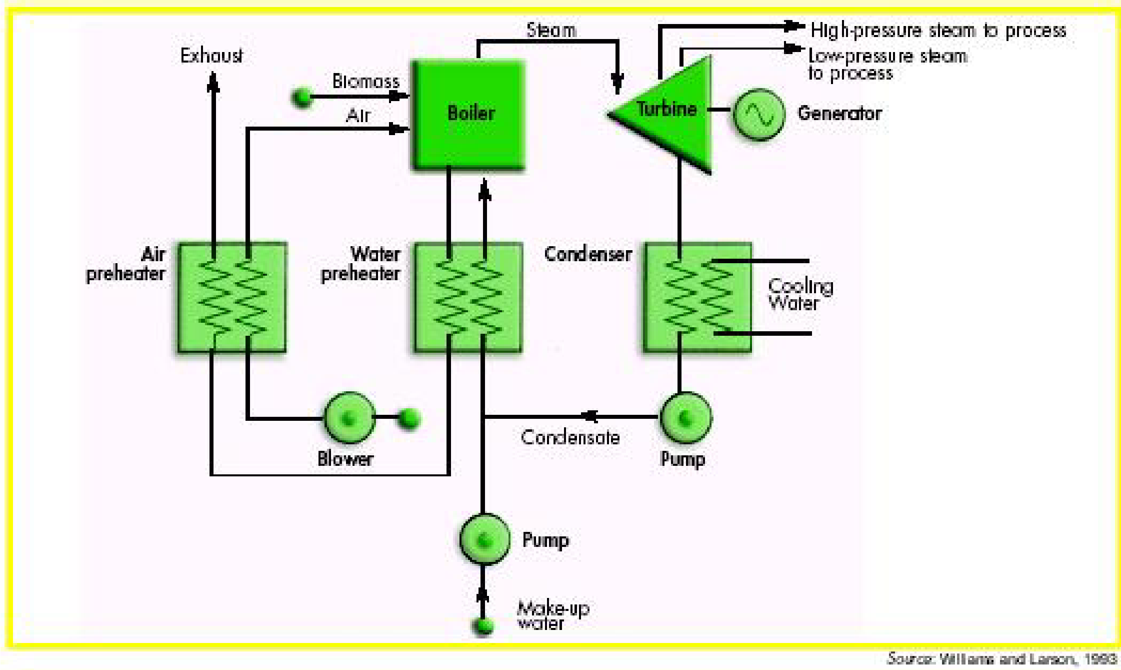
The most established technology to generate electricity from biomass on a megawatt scale is the steam-Rankine cycle. The cycle consists of direct combustion of biomass in a boiler to generate steam, which is then expanded through a turbine. Most steam cycle plants are located at industrial sites, where the waste heat from the steam turbine is recovered and used for industrial process heating. Such combined heat and power (CHP), or cogeneration, systems provide greater levels of energy services per unit of biomass consumed than systems that generate electric power only.

The steam-Rankine cycle involves heating pressurized water. The resulting steam expands to drive a turbine-generator, and then condenses back to water for partial or full recycling to the boiler. In some cases, a heat exchanger is used to recover heat from flue gases to preheat combustion air; a de-aerator must be used to remove dissolved oxygen from the water before it enters the boiler.

Steam turbines are designed as either "backpressure" or "condensing" turbines. CHP applications typically employ backpressure turbines, wherein steam expands to a pressure that is substantially above ambient pressure. It leaves the turbine as steam and is sent to satisfy industrial heating needs, where it condenses back to water. It is then partially or fully returned to the boiler. Alternatively, if process steam demands can be met using only a portion of the available steam, a condensing-extraction steam turbine (CEST) might be used. This design includes the capability for some steam to be extracted at one or more points along the expansion path for process needs, as illustrated in Figure 15. Steam that is not extracted continues to expand to sub-atmospheric pressures, thereby increasing the amount of electricity generated per unit of steam compared to the backpressure turbine. The non-extracted steam is converted back to liquid water in a condenser that utilizes ambient air and/or a cold water source as the coolant.[16]
The steam-Rankine cycle uses different boiler designs, depending on the scale of the facility and on the characteristics of the fuel being used. The initial pressure and temperature of the steam, together with the pressure to which it is expanded, determines the amount of electricity that can be generated per kilogram of steam. In general, for

[16] Williams & Larson, 1993 and Kartha & Larson, 2000, p.101

Figure 15: Schematic diagram of a biomass-fired steam-Rankine cycle for cogeneration using a condensing-extraction steam turbine



Source: William and Larson, 1993

higher peak steam pressures and temperatures, the cycle is more efficient, sophisticated, and costly.

Moreover, the technology for expanding electricity availability from biomass in the sugar industry is an advantage for the local utility companies, as the base loads for utilities in Brazil are supported mainly with hydro-generation. The sugar mill, coincidentally, supplies electricity during the dry season, when hydro power is less available. In Mozambique these facilities could be engineered to export electricity to the grid as well, or configured inefficiently to consume all of the bagasse at the plant if grid export is not an option.

Process residue valuation

Biomass for boiler fuel. One of the most important sustainability characteristics of biofuels is the energy used during processing. Several feedstocks are very conducive for additional energy recovery from the process residues. There are additional options for energy recovery, such as anaerobic digestion of the process wastewater, but the direct combustion of biomass residue represents the most convenient option for free thermal energy generation. The nut and fiber meal from copra is sometimes used for animal feed, if a market exists, but should also be considered as boiler fuel because of its high energy content and low moisture resulting from the required drying before processing. Sunflower seed hulls may be removed in some operations, especially where solvent extraction is used. In these processes the seeds are de-hulled, then processed with a screw press to extract the majority of the oil.

A second pass through a solvent extraction process extracts the remaining oil in the seed. When this is done, the high-protein meal can be sold. Small-scale oil extraction operations are not likely to involve seed de-hulling; the hulls would be sold along with the meal in a lower protein content meal. Manual harvesting of sunflower seeds in Africa would typically also deliver the head of the flower to the extraction plant, representing an additional biomass resource.

Figure 16: Potential energy recovery from residues

Feedstock	Process Residue	Quantity (kg/t feedstock)	Energy Potential (GJ/t feedstock)
African Palm FFB	Press cake	100	1.129
Sugarcane	Bagasse	280	2.128
Sweet Sorghum stems[17]	Bagasse	250	2.263
Coconut (copra)	Press cake	400	7.234
Sunflower seeds	Seed hulls	147	2.723

Assumptions: African palm press cake moisture content: 40%; bagasse moisture content for sorghum and sugarcane: 50%; coconut moisture content: 6%; sunflower moisture content: 5%,

Biomass for fertilizer. Often the process residues are used to fertilize the next growing season's crop. This is done most typically with residues that are not brought out of the field, but may include residues from the extraction facility, brought back to the fields. Empty fruit bunches from African palm trees are often carbonized and left at the base of the tree for carbon uptake. Likewise fiber from coconut is often buried around the base of a tree to return nutrients and carbon to the tree. Thus, competing uses for residues exist, and the benefits must be weighed against one another. Filter press cake from the processing of jatropha and castor bean is used as fertilizer because the meal is toxic and not suitable for animal consumption. Press cake or meal from sunflower, cottonseed, sesame and peanut essentially have no energy recovery except, as animal feed, because of its high market value.

Wastewater and effluent output

Sugarcane. Vinasse is the name given in Brazil to the wastewater stream from an ethanol distillery. It may contain filter cake, boiler ash, bagasse and even trash from sugarcane and water. In Brazil, vinasse is commonly used as fertilizer in the sugarcane field. In other countries, further treatment is required to reduce the organic pollutant concentration, and generally anaerobic methods are preferred.

The water required to wash the cane, ferment the sugar and evaporate is quite significant: around 21 m^3/t of cane. Most of this can be recycled, and the process consumes a net quantity of roughly 1 m^3/t of cane processed. Further process refinements can reduce this

[17] Jeremy Woods, King's College London, Sorghum, Chapter IV.

substantially. At a production yield of 80 l/t of cane, this amounts to 12.5 liters of vinasse per liter of ethanol produced. Characteristics of vinasse generally include a BOD_5 of 175 g/l, a pH of 4-5 and temperature of 90°C.

Table 29: Brazilian vinasse characteristics, 1995

Category	Units	min	average	max	standard dev.
pH		3.50	**4.15**	4.90	**0.32**
Temperature	°C	65	**89**	111	**9.78**
BOD5	mg/l	6,680	**16,950**	75,330	**9,953**
COD	mg/l	9,200	**28,450**	97,400	**13,943**
Total Solids	mg/l	10,780	**25,155**	3,868	**6,792**
Total Suspended Solids	mg/l	260	**3,967**	9,500	**1,940**
Total Dissolved Solids	mg/l	1,509	**18,420**	33,680	**6,488**
Nitrogen	mg/l	90	**357**	885	**177**
Total Phosphorous	mg/l	18	**60**	188	**36**
Total Potassium	mg/l	814	**2,035**	3,852	**804**
Calcium	mg/l	71	**515**	1,096	**213**
Magnesium	mg/l	97	**226**	456	**71**
Chlorine	mg/l	80	**1,219**	2,300	**417**
Sulfate	mg/l	790	**1,538**	2,800	**514**
Sulfite	**mg/l**	**5**	36	**153**	**32**

Source: Alf International

Table 30: Characteristics of Malaysian POME[18]

Parameter	Raw POME	Units
BOD5	22,700	mg/l
COD	44,300	mg/l
Soluble COD	17,140	mg/l
Total volatile fatty acid	2,510	mg acetic acid/l
Suspended solids	19,780	mg/l
Oil and grease	4850	mg/l
TKN	780	mg/l
pH	4.05	
Temperature	80-90	°C

Source: Zinatizadeh et al.

African palm. Characteristics for a palm oil mill in Malaysia, which can be taken as typical for Malaysian mills, are presented in Table 30.

Ferti-irrigation of wastewater

Agricultural production of sugarcane requires between 1,500 and 2,500 mm of rainfall per year.[20] Areas with the highest rainfall in Mozambique receive more than 1,200 mm of

[18] A.A.L. Zinatizadeh et al. *Process modeling and analysis of palm oil mill effluent treatment in an up-flow anaerobic sludge fixed film bioreactor using response surface methodology (RSM)*, Elsevier, September 2006.

rain annually, which is less than the minimum required for sugarcane cultivation.[19] Inclusion of the vinasse produced during the process only adds a small portion of additional water, possibly 10 mm/yr.

Ferti-irrigation has been the Brazilian ethanol industry's exclusive choice since the late 1970s. Twenty of twenty-one cubic meters of water per ton of cane are recycled back into the processes at the plant, including the wastewater streams from cane washing, cooling water, condensed water, among other steps. The remaining 1 m^3/t of cane is either trucked to the fields or delivered via channel and pumped pipe networks. Application via tankers is less expensive, but results in soil compaction and increased fuel consumption. If sprinklers are used, solids must be removed from the vinasse prior to application to avoid clogging. Standards developed in Germany recommend that individual vinasse doses not exceed 80 mm, while the yearly total should not exceed 500 mm.[20] In Brazil various methods are used for distributing vinasse on the fields, and the average application rate is 131.5 l/ha (13.5 mm).[21] The value in using this technique is to fertilize the soil with the wastewater by returning nutrients present in the dissolved solids of the wastewater. Table 31 shows the recommended rate of application for NPK fertilizers in São Paulo.

Table 31: Recommended rate of fertilizer application in São Paulo

	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
Plant	50	120	120
Ratoon	100	30	130

Source: Alf International

Anaerobic treatment of wastewater

Anaerobic treatment is a biological process in which different types of anaerobic bacteria digest complex organic compounds, converting them into less complex products, such as methane and carbon dioxide. Generally, the wastewater is delivered to lagoons where the digestion occurs below the surface. Enclosing the lagoons with tarps allows the biogas to be collected and piped away. A second option involves the installation of anaerobic digestion reactors, which accomplish the same objectives as enclosed lagoons with more precisely-controlled process conditions and a smaller footprint. The biogas formed during these processes will have a methane content of 55-60%. This method is preferred because it may yield reduced methane emissions, which can earn Certified Emission Reduction credits under the Kyoto Protocol. The recovered biogas can also be returned to the processing facilities and fired in the boilers. The latter option is not common in sugar mills, because the energy contained in the bagasse is more than enough to sustain

[19] Land Suitability Maps for Rainfed Cropping, http://www.fao.org/ag/agl/agll/cropsuit.asp?crop=soyb&inputlevel=h&search=Display+map+%21

[20] Edward Smeets, Martin Junginger André Faaij, Arnaldo Walter, Paulo Dolzan, *Sustainability of Brazilian bio-ethanol*, UNICAMP, Report NWS-E-2006-110, August 2006.

[21] Isaias de Carvalho Macedo, Manoel Regis Lima Verde Leal, Joao Eduardo Azevedo Ramos da Silva, *Greenhouse Gas (GHG) Emissions in the Production and Use of Ethanol in Brazil: Present Situation (2002),* December 2003.

plant operation. Finally, sludge formed during the process is used as a fertilizer, after being returned to the cane fields. The sludge effectively concentrates the nutrients found in the vinasse thereby reducing the cost of transporting fertilizer to the field.

One of the most common anaerobic treatments that releases methane into the atmosphere is open lagoons. Ideally, these lagoons should have: (i) at least 1 meter of depth, (ii) organic matter residence time of at least 30 days, (iii) temperature higher than 10ºC.

The value of choosing this method is in reduced methane emissions in the carbon markets, as well as offset fertilizer purchases. Using IPCC default values for methane, emissions from the anaerobic treatment of sugarcane vinasse would result in roughly 2.8 MJ of methane per liter of ethanol produced. This would result in a fuel savings of roughly USD20 per thousand liters based on a natural gas price of USD7.5/MMBtu.

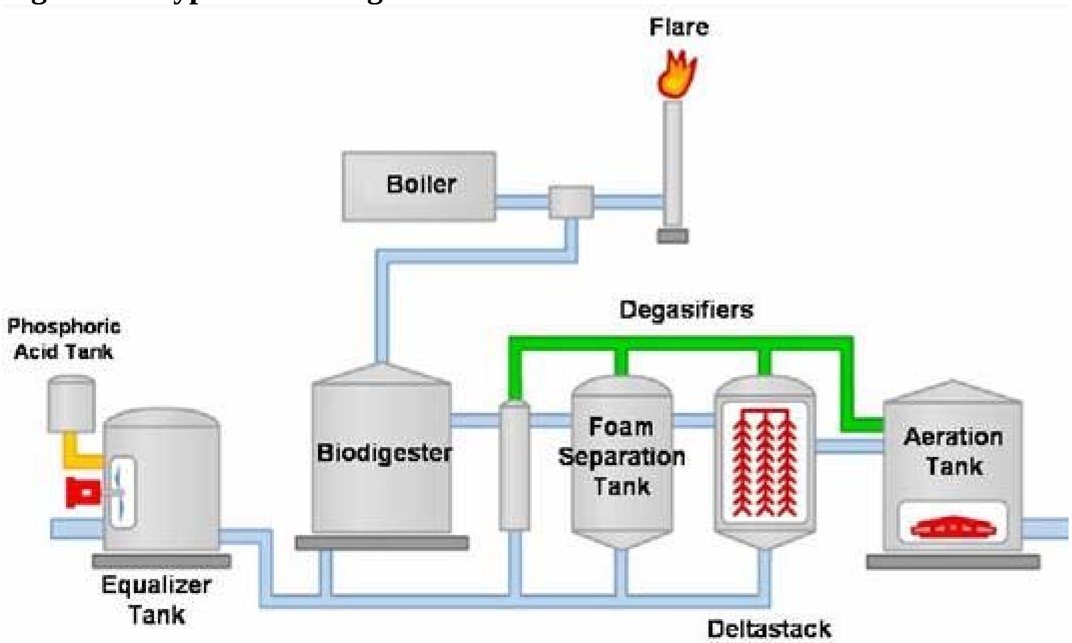
Similar value could be realized in capturing methane and flaring it to generate CERs. With an assumed value of €7/tCO2, which falls at the low end of current CER contract prices, revenues of roughly USD9.7 per thousand liters of ethanol are possible. If methane is used as a boiler supplement, and CERs are also obtained, the total added value would be nearly USD30 per thousand liters produced.

Sugarcane vinasse. A typical up-flow anaerobic contact biodigestion system is shown in Figure 17. The vinasse comes from the distillery and, depending on its organic load, it may be used directly or it may need dilution. A heat exchanger is required to reduce the temperature of the vinasse from 90°C to 38°C. The water is then cooled for recycling. The vinasse is transported to an equalization tank, where sodium hydroxide is added, to increase its alkalinity (an increase from pH 5 to 6.8-7.5). Phosphorous is also added, to increase the efficiency of decomposition in the biodigesters. The effluent flows to the biodigesters, where it is retained for 14 days, and then it passes to the degasifiers, to separate the last of the gas from the effluent. The effluent from each biodigester flows to a foam separation tank, where the foam-containing sludge is separated from the effluent.

The flow then continues to a sludge separator tank, where the remaining sludge is separated from the effluent; both the foam and the sludge are re-injected into the biodigester to maintain the required level of anaerobes. The excess sludge flows to a storage tank for mixing with the aerobically-treated effluent, and this stream is then sent to the lagoon, where it is later used for irrigation. The biogas generated goes to the boilers, where the methane is converted to energy. If the boilers go offline, an atmospheric flare burns the methane. No methane is released into the atmosphere, except normal system leakage, which is monitored *in situ* and reaches a maximum of only about 5% of total biogas production.

African palm oil mill effluent (POME). Anaerobic treatment of palm oil mill effluent is not always common practice, but has gained popularity through the Clean Development Mechanism (CDM). Effluent generated by palm oil extraction, like sugarcane vinasse, contains large amounts of organic materials and must be treated appropriately before the water can be discharged.

Figure 17: Typical UAC digester for vinasse



Source: Compañía Licorera de Nicaragua, S. A. (CLNSA)

Often the biogas generated through this process is flared to destroy the methane, resulting in an emissions reduction of about 12.35 kg of CO2e per cubic meter of methane. However, often the collected gas is scrubbed of acidic gases and used as a supplementary boiler fuel to produce electricity for the grid. This results in additional emissions reduction benefits, but also in a reduction in operating costs. A case study of a palm oil mill in Honduras processing about 100,000 tons of fresh fruit per year is presented in Table 32. In this project, open lagoons at the site were covered to capture biogas which was then cleaned and fired in reciprocating gas engines, which export power to the grid. The project earns two sources of revenue from the project, including sales of electricity at USD6/MWh and carbon sales at USD13.5/t CO2e.

Table 32: PALCASA palm oil biogas project

Details	Quantity	Units
Production capacity	100,000	t FFB/yr
POME production	68,000	m^3/yr
Biogas production	3,000,000	m^3/yr
Emissions reductions	27,000	tCO2e/yr
Electricity generation	5500	MWh/yr
Investment Cost	17,000,000	USD
O&M cost	150,000	USD/yr
CDM project verification cost	10,000	USD
Electricity revenue	330,000	USD/yr
CER sales revenue	430,000	USD/yr
Payback period	2.8	yr

Source: Ecofys

Aerobic treatment of wastewater

Aerobic treatment is the simplest method for reducing the organic content of vinasse. Unlike anaerobic methods, aerobic treatment lagoons should be shallow and well mixed or aerated, to ensure oxidization of the organic content. This system, however, yields little in financial returns and most industries are moving away from aerobic treatment methods.

Factors for successful aerobic treatment of wastewater include: (i) a depth of less than one meter, (ii) the surface area of the lagoon, (iii) the condition of the soil in contact with the water, and (iv) local weather conditions.

Glycerol recovery from biodiesel production

Glycerol is a by-product of biodiesel production that can be purified and sold. However, because of surplus volumes on the world market for glycerol due to increasing biodiesel production (every 4.5 gallons of biodiesel produced generates 1 gallon of crude glycerol), the available volumes of glycerol simply cannot be absorbed by conventional markets. It is estimated that, from 2003 to 2005, some 181 to 204 million kg of glycerol were consumed in the U.S. Expected glycerol production in the U.S. biodiesel industry for 2007 alone is expected to reach 91 million kg.[22] Other countries building biodiesel industries also have to consider the implications of increasing volumes of glycerol, as this represents a waste stream if not properly handled. The decrease in price for glycerol is not only putting pressure on synthetic producers of glycerol, but it is also forcing biodiesel producers to find alternative uses for the product. It is estimated that the local market in Brazil amounts to roughly 40,000 metric tons per year, and it is expected that, with increasing biodiesel production, glycerol production will reach 100,000 metric tons within two years. Clearly the traditional markets will not absorb this excess production, and it is expected that glycerol will mainly be utilized as a boiler fuel.

Energy recovery is perhaps the most appealing option at the moment, and it can be accomplished through anaerobic digestion, direct combustion or gasification. Anaerobic digestion may represent an efficient option if there are already lagoons or bioreactors on site, which could accept glycerol as a secondary feed. The Lurgi Group is reported to be developing a glycerol gasification process that would allow the resource to be processed into other valuable chemicals and fuels, of which methanol is one possibility. This process, however, is not commercially used or available. This works to Lurgi's advantage, given that they are already one of the world's largest suppliers of biodiesel processing technology. Refining glycerol into other chemicals such as propylene glycol also seems promising. Integrating these processes into production facilities would require greater economies of scale, which are not likely to be realized early in the Mozambican context or any context in the near future. Although higher value uses for glycerol exist, the most attractive option for Mozambique in the near term may be combustion for process energy production, due to a lack of refining capacity and transportation infrastructure. The higher heating value of glycerol is 18.5 MJ/l which is

[22] *Biodiesel Magazine*, "December 2006 Biodiesel Industry Year in Review," BBI International.

just less than half of fuel oil; if utilized in a boiler and steam turbine scheme, it would offset much of the process thermal energy and half of the electricity required to run the plant.

Options for processing glycerol into value added products. Reactive distillation could be used to create propylene glycol, acetol or hydroxyacetone. Propylene glycol – as an antifreeze substitute for ethylene glycol – could reduce biodiesel production cost by USD0.1 per liter.[23] Gasification to syngas, followed by catalytic synthesis to methanol, which could be returned to the biodiesel production process, would eliminate the cost of methanol.

Biodiesel production facilities also produce waste streams of impurities washed out of the final product, which consist of unused sodium hydroxide, methanol and other minor constituents. New developments in solid heterogeneous catalysis will soon allow plants to run without consuming other chemical catalysts, such as sodium hydroxide, potassium hydroxide. One company producing such a catalyst is Axens, which is already testing the technology called Esterfip-H in a biodiesel refinery in Siete, France. Use of these catalysts will cut operation and maintenance costs by reducing consumables purchased and transported. Despite the new technologies described above, new biodiesel plants are using the traditional transesterification process. Mozambique projects should do the same, to avoid the costs of the learning curve for a new process.

4. Clean Development Mechanism Opportunities

Greenhouse gases and global warming

The rapid global development of biofuels has largely been driven by the promise of reduced emissions of greenhouse gases (GHGs), especially CO2 from combustion of fossil-based transportation fuels. However, in order to reduce carbon emissions into the atmosphere, biofuel crops must yield more energy than is consumed in growing and processing them, thereby producing a positive Net Energy Balance (NEB). Different crops and farming systems require and yield different amounts of energy, with the inputs taking the form of actual energy consumption (such as diesel for farm machinery) as well as intrinsic and fossil-based energy inputs (as in fertilizers), and the outputs in the form of biofuels. While NEB calculations are complex, and are dependent on assumptions about the borders of the system under analysis, differences do appear to be large for different crops (ICRISAT, 2007).

Biodiesel yields greater reductions in air pollution than ethanol, because fossil-fuel diesel is extremely polluting, especially when used in the diesel-engine technologies commonly used in developing countries, and it has a larger carbon fraction than gasoline. Compared to fossil fuel-derived diesel, biodiesel reduces non-burnt hydrocarbons by 30%, carbon monoxide by 20% and particulate matter by 25% (ICRISAT, 2007). The EU is the world's largest producer of biodiesel, which is derived from rapeseed, while in the U.S. soybeans are the main biodiesel source. In the developing world the production of

[23] http://www.chemicalprocessing.com/articles/2007/003.html

biodiesel is still in the developmental stages; there is, however, growing interest in feedstocks such as jatropha and pongamia. The environmental benefits could nonetheless be lost if the expansion of energy crops leads to further deforestation and input-intensive cultivation (IIED, 2007). The available evidence shows considerable variation in greenhouse gas savings from biofuel use, depending on the type of feedstock, cultivation methods, conversion technologies, and energy efficiency assumptions. In some cases, notably where fossil fuels are used in the production process, biofuels may not fare better than conventional fuels.

Table 33: Energy balance of gasoline and ethanol by feedstock

Feedstock	Energy output/fossil energy input
Sugarcane	8.3
Sugar Beet (European Union)	1.9
Maize (United States)	1.3-1.8
Wheat (Canada)	1.20
Switch grass	4.4
Fossil fuel (Gasoline)	0.8
Sweet sorghum (Hosein Shapouri, USDA)	8.0 (12-16 in temperate areas)

Source: ICRISAT, 2007.

Biofuels have also been promoted and, in some instances, have been mistakenly perceived to be ‘carbon neutral,’ in that they do not add any GHGs to the atmosphere. Burning them simply returns to the atmosphere the carbon dioxide that the plants remove while growing in the field. This approach in some instances ignores the carbon emissions costs associated with the extraction, production and transportation of the fertilizer and pesticides used for growing the crops, of the farming implements, processing and refining, refinery plants, transport, and infrastructure for transport and distribution. Table 34 provides a summary of the energy balance and carbon savings for biodiesel and bioethanol. In the table, oilseed rape (OSR) (EU) represents oil from rapeseed.

The extra costs associated with energy and carbon emissions can be quite substantial, particularly if the biofuels are made in one country and exported to another; or worse, if the raw materials, such as seed oils, are produced in one country to be refined for use in another. Both are very likely, if current trends continue. The issue of global sustainability, therefore, needs to be looked at more carefully.

The potential loss of tropical forests due to the expansion of the biofuel industry (see below) also has potential implications for global warming. Tropical forests represent the richest carbon stocks and the most effective carbon sinks in the world. Estimates run as high as 418 t C/ha in carbon stock, and 5 to 10 t C/ha a year sequestered, 40% of which is in soil organic carbon (ISS, 2006). The carbon stock in old growth forests is even higher. In many developing countries, the additional pressure on land from biofuel crops will result in more deforestation accompanied by an increase in the rate of global warming. The practice of burning sugarcane fields prior to harvest has also been linked to air pollution, GHG emissions and health risks.

Table 34: Energy Balance and Carbon Saving of Biodiesel and Bioethanol

Biodiesel	Energy Balance	C Saving
Rapeseed (OSR) (EU) [7]	1.59	52%
Rapeseed (OSR) (UK) [26]	1.78	
Rapeseed (OSR) (EU) [5]	1.90	
Rapeseed (OSR) (Australia) [27]		50%
Soya (USDoE) [28]	2.22	40%
Soya (US) [29]	0.53*	
Bioethanol		
Wheat & sugarbeet (EU) [7]	1.08	27%
Corn (US) [7]	1.13-1.34	13%
Corn (US) [29]	0.78*	
Corn (US) [30]	1.14	11%
Corn (US) [7]	0.61	-30%
Corn (US) [7]	1.65	
Maize (N France) [7]	1.03	24%
Maize (N. France) [7]	0.94	17%
Sugarbeet (EU) [5]	1.18	
Wood (US) [7]	0.64	
Wood (Scandinavia) [7]	0.80	
Sugarcane (Brazil) [31]	8.30– 10.20	85 – 90%

Source: ISIS Press Release 11/12/06

Analysis of carbon emissions reductions from a national biofuels program

This section presents a more detailed review of the potential emissions reductions from large-scale biofuels production in Mozambique based on several assumptions regarding agricultural productivity. The section includes methodological sections on the energy balance and emissions balance calculations employed, reviews the results of calculations prepared based on preliminary assumptions for Mozambique, and then reviews the outlook for CDM project development opportunities in the country.

In the case of biomass derived from agricultural products, the energy balance provides an appropriate tool for quantifying its environmental benefits. This is done by comparing the total quantity of energy consumed during its production, including agricultural content and industrial processing, with the energy produced from the biomass residue, all the while taking into account its end use.

The energy balance can also provide an analysis of green house gas emissions. The balance compares emissions generated by biomass production, including agriculture and industry, with emissions avoided due to biomass use as an energy input.

In order to complete the energy balance and green house gas emissions balance for Mozambique, this analysis begins with certain assumptions to permit comparison of the ten agricultural products, which are sugar cane, cotton, peanuts, cassava, sweet sorghum, corn, seaseme, sunflower, soybean and jatropha.

As described in this section, the methodology used to calculate the energy and green house gas emissions balances for Mozambique, took into account the use of waste biomass for electric power generation, as well as biofuel use. This approach enabled evaluation of environmental benefits generated from biofuel use and energy generated from biomass.

Energy Balance Framework and Greenhouse Gas Emissions

The emissions and energy balance can be achieved on different levels, in agreement with the specific objectives of the study and available data. According to the publication from the Secretary of Environment of the State of São Paulo,[24] the energy balance consists of three different levels:

- Level 1 – Consumption of fossel fuels or electrical energy from the industrial facilities engaged in processing biomass;
- Level 2 – Consumption of energy from inputs used in biomass processing (such as fertilizer, lime, and others), in addition to the parameters in Level 1;
- Level 3 – Energy consumption due to production of equipment and installation maintenance used in biomass production, such as production of steel for boilers and construction of industrial infrastructure, in addition to parameters described in Level 2.

After definining the appropriate level to determine the energy balance and greenhouse gas emissions, this analysis outlines the source and types of gases emitted and/or avoided by biomass, which involves five different groups:

- Group 1 – The removal of atmospheric carbon by photosynthesis and discharge of carbon due to the oxidation processes. This group includes: (i) photosynthesis; (ii) carbon dioxide emitted when burning biomass (when applicable); (iii) oxidation of unburned biomass; (iv) carbon dioxide emitted during the process of biomass fermentation (when applicable); (v) carbon dioxide emitted from combustion of residual biomass for energy production (if applicable); (vi) carbon dioxide emitted into the atmosphere from combustion of biofuels. The carbon flow referred to in this group is considered negligible (equal to zero), once it is accepted that all carbon emitted into the atmosphere is removed again due to the biomass production cycle.
- Group 2 – Fossil fuel use in different chain segments of biomass production. This group includes the following sources of green house gas emissions: (i) agricultural operations, such as harvesting, irrigation and transport of biomass; (ii) production of agricultural inputs, such as fertilizers, seeds and pesticides; (iii) production and maintence of agricultural equipment; (iv) production of industrial inputs; (v) industrial installations.
- Group 3 – Emissions of greenhouse gases, coming from activities besides burning of fossil fuels, especially nitrous oxide (N_2O) and methane (CH_4). The following are included in this group as emission sources: (i) methane Methane derived from

[24] Methodology applied by the Secretary of Environment of the state of São Paulo in the study referred to the energy balance and green house gases from ethanol production in 2004.

burning of biomass (if applicable); (ii) N_2O incurred from the use of nitrogen fertilizers; (iii) emissions of other gases, apart from CO_2 generated through combustion of biofuels (if applicable).

- Group 4 – Greenhouse gases emissions that would otherwise occur if biomass is not produced or used. This group refers to emissions avoided, incurred from: (i) consumption of fossil fuels that reoccur due to not using biomass, such as mobile sources as well as stationary sources (if applicable); (ii) consumption of electricity from the local network in the event that residual biomass is not used for the electricity production.

Based on the aforementioned framework, it is clear that the preparation of detailed mass and energy balances must take into account the whole biomass production cycle, which implies a quantity of data that encompasses diverse economic sectors.

The analysis, which is presented in detail as Annex F and summarized in the section that follows, takes into account two scenarios of agricultural productivity, shown in the data of Table 35. The table illustrates an expected increase of 31% productivity for sugar cane, which corresponds to the data obtained on site. This is the given value for the remaining products as there are no other specific criteria.

Table 35: Values of Agricultural Productivity

Feedstock	Scenario 1	Scenario 2	Productivity Increase (%)
	Productivity (t/ha)	Productivity (t/ha)	
Sugar Cane	78	102	31%
Cotton	0.75	0.98	31%
Peanut	0.3	0.39	31%
Cassava	5	6.54	31%
Sorghum	0.7	0.92	31%
Corn	1	1.31	31%
Sesame	0.4	0.52	31%
Sunflower	0.45	0.59	31%
Soybean	0.7	0.92	31%
Jatropha	3	3.92	31%

Source: Econergy

Results of Greenhouse Gas Emissions Balance

To best display the data behind the greenhouse gas emissions balance, Table 36 and Table 37 show the two different scenarios of agricultural productivity.

An analysis of Table 36 leads to the conclusion that the products with a negative emissions balance – cotton, peanut and sesame – are not considered recognized as biofuel feedstocks.

Accordingly, beyond the positive economic and social benefits of biofuels, their environmental benefits also are an important consideration. The same conclusion follows from the results presented in Table 37, given that the balances remain negative for the same feedstocks.

Similarly, a sensitivity analysis was also conducted for the emissions balance, applying the same hypotheses as in the energy balance and using the same reference values shown in Table 37.

Table 38 presents various occurances of simultaneous increases in electrical energy and diesel consumption. In this case, data show that no product results in a emissions balance deficit, besides the products that already had a negative balance in the initial calculation. These data support the earlier conclusion that these products are not particularly viable for biofuel production.

The same pattern occurs in Table 39 and Table 40, where the results obtained, considered separately, show increases in electrical energy from the grid and fossil fuel consumption.

In the baseline sensitivity analysis derived from the green house gas emissions balance, only the products that were not used for biofuel production show a negative emissions balance. This further supports the positive environmental benefit that results from biofuel production.

5. Prospects for the implementation of Clean Development Mechanism (CDM) projects in the biofuels sector in Mozambique

Before proceeding with the evaluation of potential CDM projects, this section will briefly review the steps involved in securing carbon credits, beginning with project conception.

Procedures and risks for CDM project approval

The development of carbon projects require the application of methodologies that have previously been approved by the UNFCCC[25] for various project types. Basically, these methodologies consider three distinct aspects:

- Determination of the baseline – this is the parameter against which the GHG emissions for each project type are calculated. Accordingly, this analysis takes into account the situation before and after the implementation of the carbon emissions reduction project.

[25] The approved methodologies are available online at: http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html?searchmode=advanced&searchon=1&fulltext=&scales=1&scales=2&scales=3&number=&title=&scopeoperation=or&scopes%3Alist=1&button=Search

Table 36: Results of emissions balance using Scenario 1

Agricultural Product	**Emissions Occurred**						**Emissions Avoided**				**Results from Scenario 1**
	Fossil Fuel Consumption in Agricultural Sector (l/yr - assumed)	Fossil Fuel Consumption in Industrial Sector (l/yr - assumed)	Consumption of Electrical Energy from Grid (MWh/yr)	Consumption of Electrical Energy for Fertilizer Production (MWh/yr)	N2O Emissions from fertilizer use only	**Total Emissions (tCO2 eq/yr)**	Energy Potential Generation from Residual Biomass (MWh/yr)	Emissions reduction from avoided consumption of diesel (tCO2 eq/yr)	Emissions reduction from avoided consumption of oil (tCO2 eq/yr)	Emissions reduction from avoided due to electrical energy generation (tCO2 eq/yr)	**Emissions balance w/ substifution of diesel and electrical energy generation (tCO2 eq/yr)**
Sugar cane	5,000.00	10,000.00	35,325.33	1,953.56	178.73	**322.01**	4,626,414	0.00	2,891.41	12,762.54	**15,331.94**
Cotton	5,000.00	10,000.00	35,325.33	1,953.56	178.73	**322.01**	104,670	0.00	0.00	288.75	**(33.26)**
Peanut	5,000.00	10,000.00	35,325.33	1,953.56	178.73	**322.01**	41,868	0.00	0.00	115.50	**(206.51)**
Cassava	5,000.00	10,000.00	35,325.33	1,953.56	178.73	**322.01**	348,900	0.00	9,934.57	962.48	**10,575.05**
Sorghum	5,000.00	10,000.00	35,325.33	1,953.56	178.73	**322.01**	48,846	0.00	1,390.84	134.75	**1,203.58**
Corn	5,000.00	10,000.00	35,325.33	1,953.56	178.73	**322.01**	139,560	0.00	1,986.91	384.99	**2,049.90**
Sesame	5,000.00	10,000.00	35,325.33	1,953.56	178.73	**322.01**	27,912	0.00	0.00	77.00	**(245.01)**
Sunflower	5,000.00	10,000.00	35,325.33	1,953.56	178.73	**322.01**	31,401	1,016.34	0.00	86.62	**780.96**
Soybean	5,000.00	10,000.00	35,325.33	1,953.56	178.73	**322.01**	97,692	1,580.98	0.00	269.50	**1,528.46**
Jotropha	5,000.00	10,000.00	35,325.33	1,953.56	178.73	**322.01**	209,340	6,775.61	0.00	577.49	**7,031.09**

Source: Econergy.

Table 37: Results of emissions balance for Scenario 2

Agricultural Product	Emissions Occurred						Emissions Avoided				Results from Scenario 2
	Fossil Fuel Consump-tion in Agricul-tural Sector (l/yr - assumed)	Fossil Fuel Consump-tion in Industrial Sector (l/yr - assumed)	Consump-tion of Electrical Energy from Grid (MWh/yr)	Consump-tion of Electrical Energy for Fertilizer Production (MWh/yr)	N2O Emissions from fertilizer use only	**Total Emissions (tCO2 eq/yr)**	Energy Potential Generation from Residual Biomass (MWh/yr)	Emissions reduction from avoided consumption of diesel (tCO2 eq/yr)	Emissions reduction from avoided consumption of oil (tCO2 eq/yr)	Emissions reduction from avoided due to electrical energy generation (tCO2 eq/yr)	**Emissions balance w/ substifution of diesel and electrical energy generation (tCO2 eq/yr)**
Sugar cane	6,538.46	13,076.92	70,650.66	2,554.66	224.19	**479.01**	6,054,967.61	0.00	3,784.22	16,703.38	**20,008.59**
Cotton	6,538.46	13,076.92	70,650.66	2,554.66	224.19	**479.01**	136,876.15	0.00	0.00	377.59	**(101.42)**
Peanut	6,538.46	13,076.92	70,650.66	2,554.66	224.19	**479.01**	54,750.46	0.00	0.00	151.04	**(327.98)**
Cassava	6,538.46	13,076.92	70,650.66	2,554.66	224.19	**479.01**	456,253.85	0.00	12,991.36	1,258.63	**13,770.98**
Sorghum	6,538.46	13,076.92	70,650.66	2,554.66	224.19	**479.01**	63,875.54	0.00	1,818.79	176.21	**1,515.99**
Corn	6,538.46	13,076.92	70,650.66	2,554.66	224.19	**479.01**	182,501.54	0.00	2,598.27	503.45	**2,622.71**
Sesame	6,538.46	13,076.92	70,650.66	2,554.66	224.19	**479.01**	36,500.31	0.00	0.00	100.69	**(378.32)**
Sunflower	6,538.46	13,076.92	70,650.66	2,554.66	224.19	**479.01**	41,062.85	1,249.65	0.00	113.28	**883.91**
Soybean	6,538.46	13,076.92	70,650.66	2,554.66	224.19	**479.01**	127,751.08	1,943.89	0.00	352.42	**1,817.30**
Jotropha	6,538.46	13,076.92	70,650.66	2,554.66	224.19	**479.01**	273,752.31	8,330.97	0.00	755.18	**8,607.14**

Source: Econergy.

Table 38: Sensitivity analysis – increase in consumption of electricity from the grid and fossil fuels

Increase in Consumption of Grid Electrical Energy and Fossil Fuels (%)	Sugar Cane	Cotton	Peanut	Cassava	Sorghum	Corn	Sesame	Sunflower	Soybean	Jatropha
	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)
Situation from Table 37	20,008.59	(101.42)	(327.98)	13,770.98	1,515.99	2,622.71	(378.32)	883.91	1,817.30	8,607.14
20%	19,959.03	(150.98)	(377.53)	13,721.43	1,466.43	2,573.16	(427.88)	834.35	1,767.74	8,557.58
40%	19,909.48	(200.54)	(427.09)	13,671.87	1,416.87	2,523.60	(477.43)	784.80	1,718.19	8,508.03
60%	19,859.92	(250.09)	(476.64)	13,622.32	1,367.32	2,474.05	(526.99)	735.24	1,668.63	8,458.47
80%	19,810.37	(299.65)	(526.20)	13,572.76	1,317.76	2,424.49	(576.55)	685.69	1,619.07	8,408.91
100%	19,760.81	(349.20)	(575.76)	13,523.21	1,268.21	2,374.93	(626.10)	636.13	1,569.52	8,359.36

Source: Econergy.

Table 39: Sensitivity analysis – increase in consumption of electrical energy from the grid

Variation (%)	Increase in Consumption of Electrical Energy (MWh/yr)	Sugar Cane	Cotton	Peanut	Cassava	Sorghum	Corn	Sesame	Sunflower	Soybean	Jatropha
		Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)
Situation from Table 37	70,651	20,008.59	(101.42)	(327.98)	13770.98	1515.99	2,622.71	(378.32)	883.91	1,817.30	8,607.14
20%	84,781	19,969.61	(140.40)	(366.96)	13732.00	1477.01	2,583.73	(417.30)	844.93	1,778.32	8,568.16
40%	98,911	19,930.63	(179.38)	(405.94)	13693.02	1438.03	2,544.75	(456.28)	805.95	1,739.34	8,529.18
60%	113,041	19,891.65	(218.36)	(444.92)	13654.04	1399.05	2,505.77	(495.26)	766.97	1,700.36	8,490.20
80%	127,171	19,852.67	(257.34)	(483.90)	13615.06	1360.07	2,466.79	(534.24)	727.99	1,661.38	8,451.22
100%	141,301	19,813.69	(296.32)	(522.88)	13576.08	1321.09	2,427.81	(573.22)	689.01	1,622.40	8,412.24

Source: Econergy.

Table 40: Sensitivity analysis – increase in consumption of diesel

Variation (%)	Sugar Cane	Cotton	Peanut	Cassava	Sorghum	Corn	Sesame	Sunflower	Soybean	Jatropha
	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)	Emissions Balance (tCO2 eq/yr)
Situation from Table 37	20,008.59	(101.42)	(327.98)	13,770.98	1,515.99	2,622.71	(378.32)	883.91	1,817.30	8,607.14
20%	19,998.01	(112.00)	(338.55)	13,760.41	1,505.41	2,612.14	(388.90)	873.33	1,806.72	8,596.56
40%	19,987.44	(122.58)	(349.13)	13,749.83	1,494.83	2,601.56	(399.48)	862.76	1,796.14	8,585.98
60%	19,976.86	(133.15)	(359.71)	13,739.26	1,484.26	2,590.98	(410.05)	852.18	1,785.57	8,575.41
80%	19,966.28	(143.73)	(370.28)	13,728.68	1,473.68	2,580.41	(420.63)	841.61	1,774.99	8,564.83
100%	19,955.71	(154.30)	(380.86)	13,718.10	1,463.11	2,569.83	(431.20)	831.03	1,764.42	8,554.26

Source: Econergy.

- Additionality – this parameter, which may be analyzed through financial calculations or through the evaluation of investment, policy or technology barriers to project implementation, must result in a conclusion that the CDM project in question will only be implemented with the participation of carbon finance. Accordingly, in order for a project to be considered additional it is essential that it employ a technology not common in the region where the project is proposed and also that the project be voluntary, meaning that it is implemented in order to comply with the law. The tools for assessing additionality are included with the approved methodologies.
- Monitoring – this parameter, also included in the methodologies, describes the procedure used so that the required carbon credits may be verified, that is, for each project modality, the parameters that must be managed for all equipment linked to the carbon project will be identified.

A CDM project must go through the following steps until the carbon credits may be issued and traded.

1. Preparation of the Project Concept Document (PCD) – this document must be prepared in accordance with the format established by the UNFCCC and must contain the following, among other topics:
    - Presentation of the company or sector in which the CDM project will be implemented;
    - Detailed explanation of the choice of methodology for calculating the baseline;
    - Confirmation that the CDM project to be carried out will contribute to sustainable development;
    - Estimation of carbon credits to be generated;
    - Period for generation of carbon credits;
    - Additionality analysis;
    - Monitoring plan.

2. When elaborated, PCD is submitted for the process of a Global Public Consultation by a Designated Operational Entity (DOE). The DOE is typically an auditing company accredited by the UNFCCC and able to work on CDM projects for the disclosure of the PCD via the Internet, opening it up for comments.
3. The validation process may commence once the project is presented for the Global Public Consultation. The validation process consists of an onsite audit carried out by the DOE, based on the PCD baseline that has already been prepared. During this audit, the following, among other aspects, will be checked:

    - All environmental licenses required by local legislation;
    - Information regarding new and old equipment linked to the CDM project, such as: useful life, capacity, operation time, installation date;
    - Legal documentation (articles of incorporation) of the company where the project will be implemented, indicating the name of the person on site responsible for the CDM project;
    - Frequency of maintenance of equipment;

- Documentation on company ownership;
- Documentation on training for project operation.

After the audit validation, the DOE must issue a validation report.

4. In the case of projects in Brazil, other documents must be incorporated along with the validation report, for transmission to the Designated National Authority (DNA), which represents the government for issues related to the CDM. The DNA must provide Letter of Approval for the project in order to initiate the process of project registration with the UNFCCC. In some countries, the Letter of Approval may be secured before obtaining the validation report.

5. After registration, it generally takes one year for credits to be produced. After this period, it is necessary to carry out a second field audit – in the case of large-scale projects – called a verification audit, by a DOE different from the one that executed the validation report. In preparation for this, a monitoring report must be produced.

6. The objective of the validation audit is to verify, independently of the environmental licenses, whether the monitoring proceedures were fulfilled according to the criteria established in the applied methodology, and, in this way, verify whether the amount of carbon emissions reductions described in the monitoring report, which is prepared by the CDM project developer, actually occurred.

7. After approval of the monitoring report, the DOE must issue a verification report. During this step, the DOE may contact the project manager in an effort to resolve any inconsistencies or disagreements made during the audit. Only after this step can the carbon credits be issued.

   In the context of Kyoto, carbon is traded under the designation of Certified Emissions Reductions (CERs), the price of which can reach a value equal to €15/tCO_2 for projects that deliver CERs through the end of 2007.

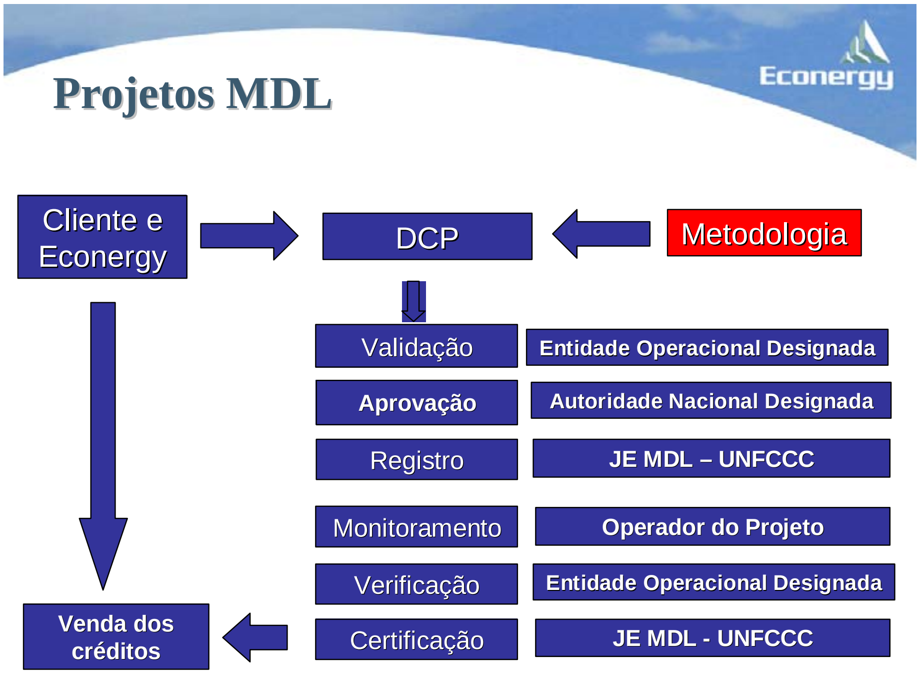
Figure 18 presents a schematic diagram of the steps involved in the development of a CDM project in Brazil. It is important to emphasize that, in the case of Brazil, it can take up to two years for the total cycle of a project.

From the conceptualization of a CDM project, Figure 19 shows the estimated time to develop a methodology and the steps completed from the time the project is registered.

CDM Projects in Mozambique

In accordance with the existing methodologies and data presented in this study, in Mozambique the applicable project modalities include power generation based on

Figure 18: Development cycle of CDM projects in Brazil



Source: Econergy, 2007

biomass, possibly including implementation of a cogeneration cycle in the facilities for processing the agricultural products presented Chapter 3, and/or based on effluent treatment in order to avoid methane emissions.

Another possibility for Mozambique is the use of biofuels. Even though it is possible, based on the assumptions used in this study, to measure the volume of carbon that could be generated through use of biofuels, currently there is only one approved methodology for this project type, and it does not fit in the conditions verified in Mozambique.

CDM projects addressing power generation. The project modalities dealing with production of electrical energy, in accord with methodologies already approved, have three possibilities:

- New cogeneration or electricity generation units that use renewable resources;
- Already existing generation units that, due to an increase in agricultural productivity or efficiency, are able to produce excess electricity for sale to the grid;
- Substitution of energy generation units located in the industrial facility, that use fossil fuels and are converted to using a source of renewable energy.

In the framework of this project type, large- and small-scale project methodologies may be used. The small-scale methodologies are restricted to installed capacity (not effective capacity) of up to 15 MW, and in the case of cogeneration plants, the restriction is for the

Figure 19: Steps and chronology for registering a CDM project including development of new methodology

Task/Event	Month																	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Additionality analysis																		
Baseline methodology development																		
Monitoring plan development																		
Completion of necessary forms																		
Preliminary PCD development related to new methodology																		
CDM project submission to UNFCCC																		
New methodology disclosure at UNFCCC site with 15 working days to receive comments																		
New methodology appraisal by the UNFCCC Methodology Panel																		
Preliminary recommendations by the UNFCCC Methodology Panel																		
Response to the recommedations by the UNFCCC Methodology Panel																		
Methodology Panel recommendation by the UNFCCC Executive Committee (check Portuguese)																		
Final recommendation of UNFCCC Executive Committee																		
Development of final PCD																		
Global public consultation																		
PCD validation																		
Project registration process																		

Source: Econergy, 2007

Table 41: Carbon credits potential for agricultural productivity Scenario 1

Agricultural Production	Scenario 1					
	Productivity (t/ha)	Agricultural Production (ton/yr)	Generation of Residual Biomass (ton/yr)	Minimum Calorific Value (kcal/kg)	Energy Generation Potential from Residual Biomass (MWh/yr)	Emissions Reduction Due to Generation of Electrical Energy (tCO2 eq/yr)
Sugar cane	78	78000	11700	1700	4,626,414.00	**12,763**
Cotton	0.75	750	150	3000	104,670.00	**289**
Peanut	0.3	300	60	3000	41,868.00	**115**
Cassava	5	5000	1000	1500	348,900.00	**962**
Sorghum	0.7	700	140	1500	48,846.00	**135**
Corn	1	1000	200	3000	139,560.00	**385**
Sesame	0.4	400	80	1500	27,912.00	**77**
Sunflower	0.45	450	90	1500	31,401.00	**87**
Soybean	0.7	700	140	3000	97,692.00	**269**
Jotropha	3	3000	600	1500	209,340.00	**577**

Source: Econergy, 2007

project to have thermal capacity of no more than 45 MW_t in addition to 15 MW already cited.

For Mozambique, according to the assumptions adopted here and the calculation of avoided emissions through energy generated from biomass, the generation potential of

Table 42: Carbon credits potential for agricultural productivity Scenario 2

Agricultural Production	Scenario 2					
	Productivity (t/ha)	Agricultural Production (ton/yr)	Generation of Residual Biomass (ton/yr)	Lower Calorific Value (kcal/kg)	Energy Generation Potential from Residual Biomass (MWh/yr)	Emissions Reduction Due to Generation of Electrical Energy (tCO2 eq/yr)
Sugar cane	102.00	102,085.00	15,312.75	1700	6,054,967.61	**16,703**
Cotton	0.98	980.77	196.15	3000	136,876.15	**378**
Peanut	0.39	392.31	78.46	3000	54,750.46	**151**
Cassava	6.54	6,538.46	1307.69	1500	456,253.85	**1,259**
Sorghum	0.92	915.38	183.07	1500	63,875.54	**176**
Corn	1.31	1,307.69	261.53	3000	182,501.54	**503**
Sesame	0.52	523.08	104.61	1500	36,500.31	**101**
Sunflower	0.59	588.46	117.69	1500	41,062.85	**113**
Soybean	0.92	915.38	183.07	3000	127,751.08	**352**
Jatropha	3.92	3,923.08	784.61	1500	273,752.31	**755**

Source: Econergy, 2007

carbon credits for each agricultural product is presented in Table 41 and Table 42, for each of Scenarios 1 and 2 of agricultural productivity.

CDM projects involving biofuels use. As noted, for a given biofuel project to be carried out in Mozambique, a new methodology must be proposed. The time periods of such a methodology, through registration of the project with the UNFCCC, are described in Figure 19. The total time period for these steps, leading to the issue of carbon credits, can take up to three years.

The major difficulty regarding approval of methodologies for biofuel use is monitoring, or the manner in which verification of the CDM project can be executed. For this reason, methodologies developed for captive vehicle fleets, where property of the company developing the project is involved in the project, are the most likely to succeed.

Furthermore, a life-cycle analysis of biofuel production is necessary to determine the energy inputs used in producing ethanol or biodiesel. If not derived from biomass, the emissions factor of biofuel could be equal to or exceed the emissions factor of the fossil-based alternative.

Table 43 and Table 44, below, present an estimate of the volume of carbon credits that could be obtained in Mozambique from biofuels use, based on the two scenarios developed above.

Beyond the production of biofuels and electricity, other possibilities could be explored, but more detailed survey data on the processing of each agricultural activity would be required.

CDM projects for methane emissions avoided. This activity principally involves methane capture through operation of an effluent treatment system or by treatment of solid waste, for example at landfills installed at industrial plants. This type of activity involves capture of the methane emitted and burning, or 'flaring,' it.

In particular, for sugar producing plants (and/or alcohol), this project type includes the treatment of liquid effluent, or vinasse, which, because of its elevated organic content, is commonly processed using anaerobic treatment systems.

Anaerobic treatment systems consist of a biological process, using various types of microorganisms which, in the absence of oxygen digest organic material, emitting methane and carbon dioxide as a result of this biological process. Since this project type focuses on capturing methane, industrial plants should have an anaerobic treatment system for their effluents.

The most common system for anaerobic treatment of effluents is the use of open lagoons that must contain the following characteristics in order to be eligible for UNFCCC approval:

- Have a depth of at least one meter;

Table 43: Estimated carbon from biofuel use in Mozambique for agricultural productivity Scenario 1

Agricultural Product	Scenario 1							
	Productivity (t/ha)	Agricultural Production (ton/yr)	Biofuel Production (ton/yr)	Lower Calorific Value of Biofuel (kcal/kg)	Diesel Substitution Potential for Biofuel (ton/yr)	**Emissions Reduced from Avoided Diesel Consumption (tCO2 eq/yr)**	Gasoline Substitution Potential for Biofuel (ton/yr)	**Emissions Reduced from Avoided Gasoline Consumption (tCO2 eq/yr)**
Sugar cane	78	78,000	1,164	8,560	0.00	**0.00**	931.34	**2,891.41**
Cotton	0.75	750	0	9,104	0.00	**0.00**	0.00	**0.00**
Peanut	0.3	300	0	9,104	0.00	**0.00**	0.00	**0.00**
Cassava	5	5,000	4,000	8,560	330.85	**0.00**	3,200.00	**9,934.57**
Sorghum	0.7	700	560	8,560	0.00	**0.00**	448.00	**1,390.84**
Corn	1	1,000	800	8,560	0.00	**0.00**	640.00	**1,986.91**
Sesame	0.4	400	0	9,104	0.00	**0.00**	0.00	**0.00**
Sunflower	0.45	450	360	9,104	316.69	**1,016.34**	0.00	**0.00**
Soybean	0.7	700	560	9,104	492.63	**1,580.98**	0.00	**0.00**
Jotropha	3	3,000	2,400	9,104	2,111.28	**6,775.61**	0.00	**0.00**

Source: Econergy, 2007

Table 44: Estimated carbon from biofuel use in Mozambique for agricultural productivity Scenario 2

Agricultural Product	Scenario 2							
	Productivity (t/ha)	Agricultural Production (ton/yr)	Biofuel Production (ton/yr)	Lower Calorific Value of Biofuel (kcal/kg)	Diesel Substitution Potential for Biofuel (ton/yr)	**Emissions Reduced from Avoided Diesel Consumption (tCO2 eq/yr)**	Gasoline Substitution Potential for Biofuel (ton/yr)	**Emissions Reduced from Avoided Gasoline Consumption (tCO2 eq/yr)**
Sugar cane	102	102,085	1,524	8560	0.00	**0.00**	1,218.93	**3,784.22**
Cotton	2.5	2,500	0	9,104	0.00	**0.00**	0.00	**0.00**
Peanut	2	2,000	0	9,104	0.00	**0.00**	0.00	**0.00**
Cassava	10	10,000	8000	8,560	661.71	**0.00**	6,400.00	**19,869.15**
Sorghum	2	2,000	1600	8,560	0.00	**0.00**	1,280.00	**3,973.83**
Corn	6	6,000	4800	8,560	0.00	**0.00**	3,840.00	**11,921.49**
Sesame	1.5	1,500	0	9,104	0.00	**0.00**	0.00	**0.00**
Sunflower	1.5	1,500	1200	8,560	992.56	**3,185.37**	0.00	**0.00**
Soybean	3	3,000	2400	8,560	1,985.12	**6,370.74**	0.00	**0.00**
Jotropha	3	3,000	3200	8,560	2,646.83	**8,494.32**	2,560.00	**7,947.66**

Source: Econergy.

- The effluent must have a residence time in the system of at least 30 days;
- The operational temperature of the anaerobic ponds must be greater than 10º C.

For the development of the CDM project, this treatment system, which would correspond to the baseline, must be replaced by another system capable of capturing and burning methane by flare, whether or not it generates electrical energy.

It is important to note that this type of project is only viable in large-scale configurations with credit volumes greater than 60,000 tCO_2 eq/year. In this case, emissions reductions are calculated by subtracting GHG emissions before and after implementation of the CDM project.

Other project modalities for avoiding methane emissions involve the disposal of solid waste. In this case, it is necessary to demonstrate that these solids would have been disposed of in such a way that their decomposition would have emitted methane into the atmosphere before the CDM project, and that these emissions no longer occur as a result of the project.

Other Options for Carbon Project Development

Beyond the projects involved in the context of the Clean Development Mechanism, another option for consideration is the Chicago Climate Exchange (CCX). This North American entity is the first in the world to create a voluntary system for registering, commercializing and reducing emissions, taking into account all GHGs. The CCX is a self-regulated market whose commercialization rules are conceived and administered by its own members.

In its first period of operation, from 2003 to 2006, each of its full members[26] assumed a voluntary, legally binding compromise to reduce its GHG emissions. Alongside this condition of full membership, the CCX also permits the commercialization of emissions reductions coming from projects outside the CCX.

In this case, it is necessary that the project be presented through an "offset provider," which is a provision of Econergy International's agreement with CCX. The types of projects accepted by the CCX are: (i) gas transport; (ii) landfill methane; (iii) carbon sequestration from reforestation; (iv) *offsets* including renewable energy and fuel switching.

Figure 20 illustrates the steps and timetable for registration of a CCX project. It is important to highlight that it is not necessary for the projects to demonstrate additionality, hence the sales price of the offsets, equivalent to about USD3.00/tCO_2 is substantially lower than the price for CERs.

[26] Participants of CCX, their conditions as full members—that can be companies, municipalities and other entities that emit green house gases with a reduction objective—is available online at: http://www.chicagoclimatex.com/

Figure 20: General Timetable for the Commercialization Offsets joint with the CCX

Step	Month								
	1	2	3	4	5	6	7	8	9
Development of project and approval by CCX									
Generation of 2007 offsets									
Verification of retroactive offsets (2003-2007)									
Verification report 2003-2007									
Audit of verification report									
Registration									
Offset emissions 2003-2007									
Commercialization of offsets 2003-2007									

Source: Econergy, 2007

Conclusion

This section presents results of energy and GHG emissions balance for ten different types of agricultural products that might be used as biofuel feedstocks in Mozambique. For the energy balance as well as emissions, it is possible to conclude that biofuel production could be a significant factor in making it possible for agricultural activities to deliver real environmental benefits.

The scenarios for agricultural productivity applied show that greater agricultural output, measured in tons per hectare, have a considerable influence in the balance results. The same can be said about the use of residual biomass to produce electricity.

With respect to the production of carbon credits, it is possible to develop CDM projects through the use of two modalities: generation of electricity and reduction of methane emissions. With reference to the first, one needs to take into account the low emissions factor from the grid. This could impede the economic viability of the project, given that it would be necessary to generate a very large quantity of energy, implying a substantial investment in generation equipment, and hence, a limited incremental financial benefit from the sale of the emissions reductions.

The second project type requires a field survey that focuses on an effluent treatment system in the agro-industrial sector linked to the agricultural products evaluated in this work.

As for the development of CDM projects based on biofuel use, it is necessary to precisely define the end use and quantity of biofuel produced.

6. Socio-economic and environmental issues

Introduction. The supply of biofuels required to meet the growing demand in the developed world will, to a large extent, be met by the developing world, where the land available for growing biofuel crops is more plentiful, climatic conditions are more favorable and labor is cheaper. Biofuels, therefore, have the potential to create significant and unique opportunities for investment in rural growth in the developing world that, if managed and implemented properly, could play a major role in alleviating poverty and hunger. Potential benefits occur at both the national and local level. At the national level, potential benefits are linked to the generation of foreign exchange through the sale of processed biofuels to the developed world, and a reduction in the reliance on imported oil products. The net effect of this is an improvement in the balance of payments position of developing countries. If the foreign exchange savings are used to address rural poverty without damage to food and land security, then the biofuel industry can make a significant contribution to equitable economic development and energy self-reliance, while reducing carbon emissions into the atmosphere.

Some of the main benefits from biofuel production at the local level are rural employment and generation of additional income. Other local benefits from biofuels usage are improved indoor air quality, increased access to energy/electricity and less destructive use of traditional biomass.

There are, however, a number of potential risks associated with the biofuels industry, critics argue. This viewpoint cites the experience in Southeast Asia, for instance, and argues that to be competitive with traditional fossil fuels, the biofuels industry requires a large, constant, reliable flow of feedstock. This will keep the unit costs of production per liter of biofuels as low as possible. These large-scale requirements could result in a move toward large-scale commercial farming, which in turn could push small-scale rural farmers off the land and exclude them from the potential opportunities and benefits associated with biofuels. Large-scale production of biofuels could also result in the replacement of food crop cultivation with biofuel crops. This would, in turn, trigger an increase in food prices, increasing poverty and hunger.

The cultivation of energy crops for the production of biofuels may also trigger – or exacerbate – several of the environmental problems typically associated with large scale, agricultural commodity production such as deforestation, monocropping, water usage, land degradation and water pollution (IIED, 2007). Of these, the increased land take associated with biofuels production is a key concern, especially the impacts this may have on tropical forests, savannahs and biodiversity. It is not only the growing of biofuel crops that creates potential impacts. Processes put in place to produce biofuels also generate waste products that can affect the environment.

The key socio-economic considerations are linked to land take and food security, job creation, CDM opportunities, beneficiation, international trade agreements and legislative as well as policy setting. Health improvements and traditional biomass conservation are also believed to have a considerate positive impact.

Various organizations and scholars have created different potential scenarios in order to predict the development of the biofuel industry. According to Mark Rosegrant of the International Food Policy Research Institute (IFPRI), the most likely international scenario is that of aggressive biofuel growth with productivity change and cellulosic conversion. Rosegrant outlines this scenario[27] and concludes that, with good governance, productivity improvements and technology changes, some of the voiced concerns on land conversion, food competition and biodiversity loss can be avoided.

The international community is however aware of the potential problem with unsustainable biofuels development. Various actors have called for the establishment and implementation of biofuels standards to ensure a socially and environmentally sustainable production. Green organizations like the WWF, international bodies like the FAO, regional actors like the E.U. and independent private round table initiatives like the Forest Stewardship Council as well as the Roundtable for sustainable Palm Oil are all developing proposals for a sustainable standards. The various proposals will be discussed later in this section.

Land take and food security. Poorly conceived and implemented large-scale biofuel programs can lead to displacement and marginalization of vulnerable rural communities that depend on agriculture for their livelihoods. Appropriately designed and carefully implemented programs, however, do create potential opportunities for rural communities to supplement their incomes and improve their livelihoods.

The potential threat to food security on a local and global scale is linked to the fact that many of the crop options for biofuels are also major food crops: palm oil, maize, sugarcane and grain sorghum. The exceptions are sweet sorghum and jatropha. The growing demand for biofuels has turned traditional food crops into bioenergy crops. Food and energy now compete for the same feedstock, with the result that food prices have risen substantially in recent years, over and above the production cost increases associated with energy increases.

Many critics of the biofuel industry therefore argue that the conversion of resources from food crops to biofuels inputs poses a serious risk to food security in the developing world. It is true that, in rural economies, the production and trade of subsistence food crops plays a critical role in livelihood strategies of the people. Critics of biofuels insist any disruption to the supply and availability of subsistence crops would be detrimental to the well-being of rural communities. The biofuels industry does have the potential to disrupt the supply of and demand for cash crops, which, together with subsistence crops, form the cornerstone of the livelihood strategies for rural communities. The increased demand on commodity markets for biofuels could lead to land being drawn away from other uses including food production, and to potential changes in food prices and availability for the poor.

Along these lines, a statement released by the Global Forest Coalition (GFC) on October 31, 2006 lists a number of concerns relating to the biofuel industry, specifically with respect to the potential impact on rural communities. The statement was supported by a

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[27] See Mark Rosegrant, Siwa Msangi, Timothy Sulzer and Rowena Valmonte-Santos, "Biofuels and the global food balance," in Hazell, Peter and Pachauri, R.K. , eds. *Bioenergy and Agriculture: Promises and Challenges, IFPR Focus Report 14* (International Food Policy Research Institute: Washington, DC, 2006).

wide range of NGOs and CBOs, but does reflect an extreme assessment of the potential impacts of biofuels. The concerns included those listed here.

- Increased land competition in rural areas, leading to further land concentration and the marginalization of small-scale commercial and subsistence agriculture;
- The widespread conversion of indigenous forests and other natural ecosystems into agricultural land;
- The conversion of arable land now used to grow staple food crops, into land for biofuel crops, which has the potential to drive up prices for staple foods, followed by hunger, malnutrition and impoverishment amongst the poorest and most vulnerable members of the community;
- Rural unemployment and depopulation;
- The destruction of the traditions, cultures, languages and spiritual values of indigenous peoples and rural communities;
- The use of agro-chemicals and the potential impacts on human health and ecosystems;
- Destruction of watersheds and the pollution of rivers, lakes and streams;
- Droughts and other local and regional climatic extremes;
- The potential risks associated with the extensive use of genetically modified organisms.

The GFC also raised concerns that the existing legislation, standards, regulations and enforcement mechanisms, in developing countries that have been identified as potential producers of biofuels, are not adequate and do not address many of the potential impacts associated with biofuel projects. As a result, the potential negative social and environmental impacts of the large-scale production of monocultures have been largely ignored in the drive to expand the biofuel industry. In addition, the existing international trade laws and treaties do not address the potential social and environmental issues and tend to favor developed nations.

To address these problems, the Global Forest Coalition calls for all governments to develop, and effectively enforce, environmental and social standards and regulations, ensuring that national biofuel production industries do not destroy the livelihoods and ecosystems of indigenous peoples and local communities. Corporations should be held strictly liable for any social or environmental damage that has occurred, and they should be effectively prosecuted if they do not uphold environmental and labor laws.

The move to a single cash crop, in the form of biofuel stock, also increases the vulnerability of rural communities to a range of risks, such as climate change and fluctuations in global commodity markets. Assessing the potential impacts and identifying appropriate mitigation measures require a good understanding of local community operations and livelihood strategies.

Closely linked to the issue of food security is the potential impact the biofuel industry could have on land rights and conflicts over land use. Competition for land is an issue for many people in developing countries. This has resulted in rural dwellers losing access to the land, key natural resources and environmental services. Large-scale plantations of palm oil in Indonesia, for instance, have been linked to the violation of traditional land rights of local communities (IIED, 2006). The result is that many rural dwellers are forced to migrate to urban areas where they place additional pressure on the already strained local services.

On the other hand, there are those who argue that large-scale production of biofuels does not imply food security trade-offs, and that most of the concerns presented above will be monitored by international certification programs. These are some of the main arguments supporting this position:

- There is enough land available to accommodate bioenergy production without endangering the future supply of food or further deforestation (Sachs, 2005).
- Land competition will not be a problem considering the technology improvement and the research and development currently undertaken to increase productivity and efficiency in the biofuels production.
- Biofuels will not totally displace oil-based fuel. Rather, they will be an alternative or a complement, within a wide range of alternative renewable sources of energy. In this regard it is estimated that biofuels could supply between 20 and 30% of global demand in an environmentally responsible manner without affecting food production (Koonin, 2006).
- There are possible synergies between fuel and food production, given that certain perennial energy crops, like trees and grasses, require fewer inputs; they can be grown on much degraded land too marginal for food crops and can even promote land restoration before food production is able to take place.
- Food shortages and famine are more a function of poor distribution and a shortage of jobs and disposable income to buy food, than to agricultural production (Trindade, 2005). In this regard the livelihoods created by biofuel revenues could increase food affordability for rural communities in producing areas.

Research and development is at the same time being carried out in the fields of yield productivity and efficiency improvements for harvesting. Whether these improvements will take out the increased land competition is difficult to say but it is important to notice that technology development is undertaken.

It is clear the impact of the biofuels industry on rural economies and livelihood strategies therefore needs to be carefully assessed, including an examination of how to achieve the right balance between food and fuel co-production in different regions (IIED, 2006). Potential strategies for addressing the needs of small scale rural farmers are discussed below, in the section of this chapter labeled *Maximizing opportunities for small-scale farmers.*

Job creation. In addition to the environmental benefits of biofuels, a primary motivation for the promotion of biofuels in the EU is rural economic development. The production of biofuels can also have a positive impact on agricultural employment and livelihoods, especially when the cultivation involves small-scale farmers and the conversion facilities are located near the crop sources (IEA, 2004).

There are various international examples of biofuel industries creating employment both in rural and urban areas. In Brazil, the sugarcane-based ethanol fuel industry is credited with creating 1 million direct jobs and between 1.5 and 3 million indirect jobs (Moreira, 2005). This number is expected to grow by 20% over the next five years. Estimates of the relative performance of the sector in terms of job creation suggest that the biofuels sector outperforms other subsectors in the energy industry; one analysis shows the ratio of jobs created by the biofuel industry compared to those created by the fossil fuel industry is 22:1 at 100% ethanol use and 6:1 at 25% ethanol use in transport vehicles.[28]

Meanwhile, the Colombian government anticipates that every farming family engaged in bioethanol production will earn two to three times the minimum salary (USD4,000/year), once the national Bioethanol Program is implemented (Etcheverria-Campuzano, 2002). Further, job creation ranges from 0.2 to as much as 1.0 jobs per hectare per year, depending on the feedstock cultivated, as reported by the Ministry of Agriculture and Rural Development and shown in Table 45.

In India, of the 1.7 million jobs in 2004 related to the renewable energy industry, almost 1 million were associated with biofuels. India's national commitment to the development of jatropha as a biodiesel crop is expected to generate 16 million person days/year of employment, while improving degraded land resources. Based on experience with current

Table 45: Estimated job creation potential, by biofuel feedstock

Ethanol		**Biodiesel**	
Crop	Jobs (industrial and agricultural) (per ha per year)	Crop	Jobs (industrial and agricultural) (per ha per year)
Sugarcane	1.00	African palm	0.27
Yuca (cassava)	0.60	Castor seed	0.64
Sugarbeet	0.65	Jatropha	0.30
Sweet sorghum	0.20		
Maize	0.41		

Source: Secretariat of Agriculture, Livestock, Rural Development Fisheries and Food (SAGARPA), Mexico, "Proposal for a national bioenergy strategy," (August, 2007), citing data from the Colombian Ministry of Agricultureand Rural Development.

plantations in India, biodiesel plantations and the associated processing activities are estimated to generate 370 person-days of employment per hectare.[29] According to the government of India's Department of Land Resources, the country has 63.9 million ha of wastelands that are potentially available for biodiesel crops (ICRISAT, 2007).

Information from operations undertaken by Rusni Distilleries (Pty) Ltd., which operates a 40 kiloliter-per-day (KLPD) sweet sorghum-based ethanol distillery in Andhra Pradesh,

[28] See http://www.americanprogress.org/.
[29] See http://www.jatrophabiodiesel.org/indianPrograms.php?_divid=menu5.

India, indicates that the biofuel industry can be relatively labor intensive and create significant stream employment opportunities downstream and upstream (ICRISAT, 2007).

Table 46: Generation of employment by 40 KLPD unit

Country	Beneficiary farmers	Labor (man days)	Direct staff (man days)
India	5,000	40,000	100,000
Philippines	2,500	20,000	50,000
Uganda	2,500	20,000	50,000

Source: Rusni Distilleries (P) Ltd.

In the U.S., bioethanol production is now responsible for creating more employment in rural areas than any other activity (IIED, 2006). Biofuel production in other parts of the world does, therefore, create additional opportunities for family farmers and rural workers. In China, the liquid biofuel program is expected to create up to 9.26 million jobs, and contribute to significant increases in income generation and rural development (Bhojvaid, 2006).

In terms of job opportunities, most bioethanol-related jobs require little skill and are therefore accessible to the workers in poor and rural areas. In many cases the quality of the jobs is better than other low-skilled jobs, because they are not seasonal and potential for increasing wages over time (Macedo, 1995). In Sao Paulo, 23% of cane cutters, who comprise the largest category of unskilled workers, are women (IIED, 2006).

The potential socio-economic benefits associated with biofuels are linked to the positive impact on agricultural employment and livelihoods. However, the cultivation of some energy crops tends to be associated with large-scale, commercial production methods that often have a limited positive impact on rural labor. Soya is an example. While there are some cooperatives of small-scale soya producers, a key factor in their long-term viability is whether they can organize themselves in a way that will enable them to achieve economies of scale. The need to lower production costs of biofuels offers considerable incentives for the wide-scale adoption of new and less labor-intensive technologies. Achieving a balance between mechanization and the number and quality of new jobs created by the industry is therefore crucial. At the same time, the Rusni Distilleries case, as well as the Brazilian experience, suggest that biofuels sector production may be less capital intensive, and comparatively more labor intensive, than other areas of development.

A separate potential negative feature of biofuels production is that widespread biofuel production may result in, or enhance, poor labor practices. In many developing countries, certain types of feedstock (notably sugarcane and palm oil) have been produced under poor working conditions, which expose workers to health and safety risks. The production of biofuels has also been linked to child labor and/or forced labor. However, job quality and worker welfare are also important developmental issues in assessing potential benefits associated with biofuel programs. Social criteria required to evaluate social sustainability have been derived through the Social Accountability Standards (as defined by SAI 8000:2001).

The biofuel program in Mozambique has the potential to create significant job opportunities at all stages in the process: preparation of land, planting, maintenance, harvesting, transporting raw material and final product and processing. However, the trend towards increased mechanization, both in agriculture and processing, has resulted in substantial decreases in labor requirements. Increased mechanization in agriculture is particularly prevalent in large-scale monoculture farming activities. In addition, the necessary skills may not be available in developing countries. In countries like Mozambique, HIV/AIDS, malaria and other diseases have also affected the productivity of the labor force. This has further served to increase the level of mechanization. Effects of issues such as mechanization and poor labor conditions will need to be assessed, most likely on a case-by-case basis for new investments and through enforcement of labor codes, to maximize the potential employment opportunities associated with the biofuel program in the country. The assessment should also consider how best to include local communities in program design, implementation and management.

There have been initiatives in South Africa and India to support and increase the involvement of small-holder production in the multinational agro-industries, particularly in the sugar and forestry industry. Their experience shows that large-scale, foreign-owned, highly mechanized agro-industries bring limited micro or macro-economic benefits to the local communities they are associated with. Examples of small-holder production initiatives in India are provided in the section entitled *Maximizing opportunities for small-scale farmers*.

Clean Development Mechanism opportunities. As noted previously, the development of biofuels creates the potential for CDM opportunities that may be exploited in the context of small projects for rural communities, and potentially, larger-scale projects. More investigation of these opportunities is required, especially to overcome methodological obstacles to biofuels projects based on displacement of fossil transportation fuels. There are some precedents for such initiatives, such as a partnership between Brazil and the German Government (predating the entry into force of the Kyoto Protocol), which allowed for the purchase of emissions reductions derived from utilization of ethanol fuel by taxi drivers, and the initiative undertaken by the village of Powerguda in Adilabad to plant pongamia (See Box 1) illustrate the significant opportunities for securing support for biofuels initiatives. In addition to climate change mitigation, biofuels use may also serve as a way to meet the Millennium Development Goals for poverty reduction and rural development (IIED, 2006).

Beneficiation. Research carried out on several agricultural commodity markets indicates that the benefits from export production in the developing world have largely accrued to the owners/operators of production and refining facilities, while the benefits to the rural farmers have been limited. Many biofuels supply chains will target export markets with (as noted above) the risk that the value added process takes place in the importing countries. This, coupled with concentrated international market power structures (currently two companies, Cargill and Archer Daniels Midland/ADM, control about 65% of the global grain trade: Vorley (2003) raises concerns about how the costs and benefits associated with biofuel programs in the developing world will be distributed along the value chain.

Many of the social benefits of biofuels – particularly those related to poverty reduction – accrue from the pro-poor/small farmer nature of the production system. However, if producers are dependent on a limited number of international traders bringing their products into the international market, there is a risk that the primary producers will receive very few benefits. The section below *Maximizing opportunities for small-scale farmers* discusses ways in which poor, small scale rural farmers can benefit from the biofuel industry.

The development of a strategy for the Mozambique biofuels program should therefore seek to maximize the benefits associated with local beneficiation. In this regard, Mozambique should develop its capacity to carry out the processing and conversion internally, as opposed to selling its primary biomass on the international market.

International trade agreements. The potential developmental and economic benefits of the biofuels industry for countries such as Mozambique are contingent upon international trading. In terms of comparative advantage, the most efficient producing countries will be developing countries, while the main consumers are, and will continue to be, industrialized countries. In terms of the current international trade agreements, however, there are a number of trade-related policies and agreements that prevent developing countries from reaping the benefits of the biofuels trade. These barriers may well compromise the profitability of Mozambican biofuels, creating a challenge for the country. The Government of Mozambique could pursue changes in these policies together with cooperative development of social and environmental criteria with developed countries so as to avoid being marginalized by rigid standards with which exporting countries such as Mozambique will not be able to comply.

Several trade barriers distort the biofuel trade and jeopardize the potential benefits for developing countries (IIED, 2007). Tariff barriers commonly insulate domestic producers from external competition. The United States, for example, applies an extra USD0.54 to each gallon of imported bioethanol on top of the 2.5 percent tariff, bringing the cost of Brazilian bioethanol in line with that produced domestically (Severinghaus, 2005). In addition, the tariff escalation systems that prevail in many industrialized countries encourage developing countries to export feedstock, such as unprocessed molasses and crude oils, while the final biofuel conversion – and associated value addition – takes place in the importing country.

The European Union currently applies trade protectionist measures through its tariff barrier on Brazilian bioethanol. Several Member States have however recently called for the abandoning of the disadvantageous tariff, some of the strongest proponents being Finland and Sweden. Another international agreement with impact on the biofuels market is the E.U. 1998 Fuels Quality Directive. This specifies regulations for petrol, diesel and gas-oil used in cars and other vehicles, in order to protect human health and the environment. In January 2007, the Commission proposed amendments to the Directive with aim to permit higher volumes of biofuels to be used in petrol. From 2009, the Commission is further proposing a mandatory monitoring and reporting of lifecycle GHG emissions from fuels. The amendment of the directive strives to combat climate change by reducing emissions through an increased use of biofuels. (ENDS, 2007)

Subsidies are another key concern. In the majority of industrialized countries, the domestic production of energy crops and the processing of biofuels are subsidized. The impacts of these policies on developing countries' efforts for sustainable development need to be understood and assessed. Not only do these subsidies undermine the competitiveness of developing countries, they also affect the potential of the biofuel industry to reduce poverty and promote sustainable development in the developing world.

The lack of a clear classification of biofuels within the multilateral trading system constrains effective trade. At present there is no agreement on whether biofuels are industrial or agricultural goods. On the one hand, biofuels are traded as "other fuels," or as alcohol (in the case of ethanol) and are subject to general international trade rules under the World Trade Organization (WTO) (IIED, 2007). The WTO Agriculture Agreement, on the other hand, addresses energy crops, and categorizes domestic support into three 'boxes': an 'Amber Box' containing actionable or trade-distorting subsidies; a 'Blue Box' containing Amber Box subsidies that satisfy certain conditions designed to reduce the trade distortion; and a 'Green Box' containing non-actionable subsidies, or subsidies not linked to production subsidies, which would permit certain subsidies aimed at environmental objectives (IIED, 2007).

Biofuels may also be included in a list of environmental goods slated for accelerated trade liberalization under the Doha Round. All of this means that at the multilateral level there is no specific forum for discussions on how to deal with the trade in biofuels. The proliferation of different technical, environmental and social standards and regulations for biofuels – without a system for mutual recognition – is also likely to cause additional difficulties (IIED, 2007). Although some form of environmental and social assurance is needed, there are some concerns that, if these schemes are developed by industrialized nations with little participation by producer country stakeholders, there will be no reflection of these countries' environmental and social priorities. An additional problem will arise if the costs of implementing these standards are to be borne by small producers in developing countries. To avoid some of these problems, and to initiate discussion towards mutual recognition or more unified schemes, existing standard schemes need to be mapped out against sustainable development criteria (IIED, 2007).

International sustainability initiatives. Some governments, research organizations and NGOs that have cited potential negative environmental and social impacts from biofuels production (land competition, food security, exclusion of small scale farmers and loss of biodiversity are the most notable) have also voiced concerns about weak institutional arrangements in producing countries for managing these risks. There is an emerging political consensus, especially in the E.U. and the U.S. on the importance of these issues, as evidenced by the proposed biofuels certification schemes to enhance the global environmental benefits of biofuels, preserve biodiversity and protect vulnerable labor.

However, the definition and implementation of standards face some serious challenges. Further, compliance with WTO rules and international treaties for the proposed certification schemes is being questioned while various sustainability initiatives overlap others due to insufficient international coordination. Additional costs of meeting the sustainability criteria as well as lack of capacity to comply with implementation, monitoring and reporting of the standards further present a huge challenge for developing countries.

A common criticism from both proponents and critics of the development of biofuels is the lack of a multidisciplinary and global approach. On the international level, the FAO initiative, "International Bioenergy Platform" (IBEP), strives to fill that gap and is expected to provide analysis and information for policy support; to build and strengthen institutional capacity at all levels and to facilitate opportunities for effective international collaboration. The IBEP has various objective areas with one activity directly related to biofuels. The IBEP is aimed to assist the development of an international scheme to develop workable assurances and certification based on verifiable indicators, to ensure that bioenergy systems be demonstrably sustainable and last, to significantly contribute to sustainable development. While the IBEP so far has focused more on knowledge management, the FAO Forestry Department is more concretely working on biomass certification by evaluating principles, criteria and indicators for both biomass from forest used for energy as well as for food fuel and charcoal production systems. As a compliment to the environmental focus of the Forestry Department, the FAO has recently launched a food security initiative called, Bioenergy and Food Security (BEFS). The BEFS project is designed to mainstream food security concerns into national and sub-national assessments of bioenergy potential. The initiative's key objective is to develop methodological guidance and strengthen capacity-building for policymakers when analyzing food security impacts.

On regional level the European Union is pro-actively developing standards and criteria applicable to all biofuels used in the Union, regardless of geographical source. The E.U. policy for biofuels is part of a larger E.U. initiative to increase energy efficiency, halt climate change and encourage the use of renewable energy sources. In March 2007, the Council of Ministers approved a renewed biofuels strategy COM/2006/34 – "A EU strategy for Biofuels" containing a 10% binding target for the share of biofuels in petrol and diesel in each Member State in 2020, to be accompanied by the introduction of a sustainability scheme for biofuels.

The E.C. proposes that legislation listing the "sustainability criteria" should define biofuels used to fulfill the national biofuels target. Biofuels failing to meet the criteria will thus not be eligible for tax reductions and be countable toward the national biofuels obligations. International voluntary schemes governing standards of agricultural and forest products are recognized as complements to the E.U. biofuels standard. In order to protect and follow up land use change and biodiversity loss a proposed solution is to sign multilateral agreements with third countries in order to support the controlling capacity in the countries of origin. (EC, 2007) The proposed criteria are:

- *Achieve a minimum level of GHG savings*. Biofuels should not emit more GHGs in production than they save by avoiding the use of petrol or diesel. The directive would define 'default values' for net greenhouse gas savings.
- *Avoid major reduction in carbon stocks through land use change*. Biofuels should not use raw material from land associated with high carbon stocks that previously was used otherwise.
- *Avoid major biodiversity loss from land use change*. Biofuels should not use raw material from land associated with exceptional biodiversity that previously was used otherwise.

From an international perspective, the E.C. discourages any discrimination between domestic production and imports. Furthermore, the proposed standard should not act as a barrier to trade. The E.U. development policy aims to help suitable developing countries capture the benefits offered by biofuels. (EC 2006). The proposed criteria are to be debated in December 2007. However, both the U.K. and the Netherlands have meanwhile developed and implemented their respective sustainability schemes.

In November, 2005, the U.K. announced the introduction of a new policy to ensure the inclusion of biofuels in UK transport fuels. The 'Renewable Transport Fuel Obligation' (RTFO) is described in more detail in Chapter 2 in this report. Parallel to the RTFO, the U.K. is developing an assurance scheme to ensure, as far as possible, that biofuels are produced from a sustainable source (Department for Transport 2006).

Table 47: Summary of U.K. biofuels sustainability criteria

Environmental principles

1. Biomass production will not destroy or damage large above or below ground carbon stocks
2. Biomass production will not lead to the destruction or damage to high biodiversity areas
3. Biomass production does not lead to soil degradation
4. Biomass production does not lead to the contamination or depletion of water sources
5. Biomass production does not lead to air pollution

Social principles

6. Biomass production does not adversely affect workers rights and working relationships
7. Biomass production does not adversely affect existing land rights and community relations

Source: Ecofys (2007).

The biofuel criteria model is a risk-based approach, focused on the most pressing sustainability issues, in the form of a Meta-Standard, aiming to maximize use of existing standards. Both E.U. and non-E.U.-produced biofuels are targets for the U.K. sustainability scheme. (Ecofys, 2007) Biofuel producing companies have a substantial responsibility within the model and are proposed to report on the overall sustainability of their feedstock producers, and thus hopefully give preference to sustainable feedstock producers. The U.K. proposal also addresses social standards, such as workers' right to contracts, restrictions on child labor and work place safety regulations. (Ecofys, 2007) The proposed criteria are summarized in Table 47.

The Netherlands have also been proactive in developing standards for biofuels. A set of generic sustainability criteria and corresponding sustainability indicators have been formulated in the *Testing Framework for Sustainable Biomass* prepared on behalf of the Dutch government. The proposed criteria are applicable to all biomass regardless of origin, and follow the 'people, planet, and profit' approach, aiming to keep in line with existing conventions and certification systems. (Cramer et al., 2007) Six areas of standardization are proposed.

1. *Greenhouse gas emissions*. Calculated over the whole production chain, the use of biomass must produce fewer emissions of greenhouse gases net than on average with fossil fuel. The emission reduction must amount to at least 30% in transportation fuels.
2. *Competition with food or other local applications*. The production of biomass for energy must not endanger the food supply and other local applications
3. *Biodiversity*. Biomass production must not affect protected or vulnerable biodiversity and will, where possible, have to strengthen biodiversity.
4. *Environment*. In the production and processing of biomass, the quality of soil, surface and ground water and air must be retained or even increased.
5. *Prosperity*. The production of biomass must contribute towards local prosperity. Criteria for this have not yet been developed.
6. *Social well-being*. The production of biomass must contribute towards the social well-being of the employees and the local population.

The focal areas are further sorted in nine principles with respective indicators and reporting instructions (Cramer et al., 2007).

- Principle 1: The greenhouse gas balance of the production chain and application of the biomass must be positive.
- Principle 2: Biomass production must not be at the expense of important carbon sinks in the vegetation and in the soil.
- Principle 3: The production of biomass for energy must not endanger the food supply and local biomass applications (energy supply, medicines, building materials).
- Principle 4: Biomass production must not affect protected or vulnerable biodiversity and will, where possible, have to strengthen biodiversity.
- Principle 5: In the production and processing of biomass the soil and the soil quality are retained or improved.
- Principle 6: In the production and processing of biomass ground and surface water must not be depleted and the water quality must be maintained or improved.
- Principle 7: In the production and processing of biomass the air quality must be maintained or improved.

- Principle 8: The production of biomass must contribute towards local prosperity.
- Principle 9: The production of biomass must contribute towards the social well-being of the employees and the local population.

In contrast to the E.U. proposal, the Netherlands and the U.K. criteria consist of both environmental and social standards. In order to analyze compliance with local conditions and traditions Mozambique would benefit from a study of national compatibility with European and international proposals. If international sustainability standards are developed without input from developing countries they risk to act excluding and prevent developing countries for participating on the international biofuels market. (Lerner, 2007)

Legislative and policy setting. The key elements of the environmental framework in Mozambique are the National Environment Management Program, Environmental Law, EIA Regulations and EIA Guidelines. The Environmental Impact Assessment of the Next Road Sector Program in Mozambique (February 2001), undertaken for the Mozambique Road Agency by SMEC and Impacto, provides a detailed summary of the legislative environment.

The National Environmental Management Program (NEMP), approved by the Council of Ministers in 1995, seeks to promote and implement sound environmental policy. The program was formulated by the Ministry for Co-ordination of Environmental Affairs (MICOA) and contains a National Environment Policy, a proposal for Framework Environmental Legislation and an Environmental Strategy. MICOA is vested with the authority to oversee the implementation of the NEMP.

The NEMP consists of Sectoral Plans for the medium- and long-terms that are intended to guide sustainable development in Mozambique. Three key policy areas are defined in terms of the program: rural, coastal and urban policy areas. The rural policy area is the most relevant for the biofuels industry, particularly with respect to agriculture and forestry issues.

In accordance with the NEMP, MICOA, in close co-ordination with other ministries, private and civil groups, is required to work towards the following objectives described below.

- Development of inter-sectoral policies for sustainable development (including roads);
- Development and promotion of integrated resource-use planning;
- Promotion of sector legislation, establishment of norms and criteria for environmental protection and sustainable use of the country's natural resources;
- Creation of conditions for law enforcement and environmental monitoring

The Mozambican Parliament passed the Framework Environmental Law in July, 1997. This law acknowledges the responsibility of the Government of Mozambique in the promotion and implementation of the National Environmental Management Program. The law is intended to provide a legal framework for the use and correct management of the environment and its components, and to ensure the sustainable development of Mozambique. Key provisions of the law include are listed here.

- Those who pollute, or in any way degrade the environment, are liable and under obligation to rehabilitate the environment or to compensate for the resulting damage
- Pollution of the soil, subsoil, water or atmosphere by any polluting substances, is forbidden, as is any other form of degradation of the environment that fall outside the limits stipulated by the Law itself
- Projects and operations that are likely to have a negative impact on the environment are subject to an environmental impact assessment by independent assessors. The Law also forbids all activities that may threaten the conservation, reproduction, quality and quantity of biological resources, especially those in danger of extinction
- Protections of environmental components that have a recognized ecological and socio-economic value. Environmental protection zones can be created. These protected zones may be national, regional or local, and may cover land areas, lakes, rivers, marine waters and other distinctive natural zones
- Activities that are liable to cause significant environmental impacts must be licensed
- Issuance of an environmental license is dependent on the completion and acceptance of an appropriate level of environmental impact assessment

The Framework Environmental Law also establishes a regime of environmental licensing based on an environmental impact assessment. Decree 76/98 of 29 December 1998 defines EIA Regulations for Mozambique. The Regulations are contained in 19 articles.

Article 2 specifies the scope of application. The provisions contained in the Decree are applicable to all public or private activities that may have a direct or indirect impact on the environment. All activities not covered in the appendix of the EIA Regulations (discussed below), but capable of causing significant environmental impact, are subject to a pre-assessment undertaken by the MICOA (Article 5). The pre-assessment will determine whether or not an environmental impact study is necessary.

Article 6 refers to the contents of an environmental impact study. The preparation of an environmental impact study and monitoring program is entirely the responsibility of the proponent of the activity. An environmental impact study must include the elements listed below.

- The geographical location of the area of influence of the activity, and a description of the baseline environmental situation
- A description of the activity and its alternatives in the planning, construction, operation and (in the case of a temporary activity) de-commissioning phases
- A comparison of the alternatives and a prediction of the environmental impacts of each
- The identification and assessment of mitigation measures
- An environmental management program, including the monitoring of impacts, accident prevention and contingency plans
- The identification of the team that carried out the study

The environmental impact study must also contain a non-technical summary covering the main issues and conclusions for purposes of public consultation.

Article 7 refers to public consultation. The public consultation process, including mechanisms for receiving petitions, must be publicized by a proponent so it reaches all affected stakeholders. MICOA must also call for public hearings whenever the scale or likely effects of the project justify, or when this is requested by affected parties, public or private.

Article 8 establishes these criteria for assessing a proposed activity.

- The number of persons and communities affected
- The ecosystems, plants and animals affected
- The location and size of the area affected
- The duration and intensity of the impact
- The direct, indirect, potential, overall and cumulative effects of the impact
- The possibility of reversing or mitigating the impact

Article 9 deals with the review procedures of the environmental impact study. On receipt of an environmental impact study, MICOA undertakes a technical review, provided the EIA process is in compliance with the norms established in the EIA regulations. The review is undertaken on the basis of the Terms of Reference approved during the pre-assessment period. Based on the review, the MICOA makes a decision on the environmental viability of the proposed activity.

An Appendix in the EIA Regulations lists activities which may have significant impact on the environment and which require environmental impact studies. Activities relevant to the biofuel industry include:

- ❑ Clearing, dividing and exploiting the natural vegetation cover of individual or cumulative areas greater than 100 hectares;
- ❑ Programs and projects that imply the permanent or temporary displacement of populations and communities;
- ❑ Plans, programs and projects that may affect, directly or indirectly, sensitive areas such as: coral reefs, mangroves, natural forests, small islands, zones of potential erosion, including dunes along the coastline, areas exposed to desertification, conservation or protected zones or areas, wetlands, zones where the habitats and ecosystems are in danger of extinction, zones of outstanding landscape beauty, zones of archaeological, historical and cultural value that should be preserved, zones where plant or animal species threatened with extinction are located, ground waters used for public consumption, areas for the protection of spring and water sources.

The EIA Regulations (Decree 76/98) were replaced by Decree 45/2004 published on September 29, 2004. MICOA, through the National Directorate of Environmental Impact Assessment (DNAIA) is the authority responsible for Environmental Assessments.

MICOA uses three categories to screen projects and identify the appropriate level of environmental assessment required.

- *Category A:* These are projects that could have significant impacts due to the proposed activities or the sensitivity of the area and, as such, require a full EIA (including EMP). Category A projects are listed in an annex of the Regulations for Environmental Impact Assessment
- *Category B:* These projects have negative impacts of lower duration, intensity, extension, magnitude and/or significance, and, as such, require a simplified EA. Category B projects are listed in an annex of the Regulations for Environmental Impact Assessment
- *Category C:* These projects do not require an EA

For Category A projects, a scoping and environmental feasibility study must precede the EIA. The EIA's Terms of Reference must also be submitted to MICOA for approval. Category B projects do not require a scoping and environmental feasibility study, although they need prior approval of the EIA's TOR.

According to the EIA regulations, public participation is compulsory for Category A projects. Ministry Diploma 130/2006 defines the public participation process as the communication link between the government and the different sectors of civil society, local communities and environmental groups as per Article 1 of the Decree 45/2004. This Diploma further indicates that the public participation process should be initiated during the project conception phase and continued throughout all phases of the EIA process.

The General Guidelines for Elaboration of the EIA were approved by MICOA (Ministry Diploma 129/2006) on 19 July 2006. The Guidelines for Public Participation Process were also approved on 19 July 2006 (Ministry Diploma 130/2006).

Land acquisition and resettlement. Earlier land legislation in Mozambique, as set out in the 1979 Land Law *(Lei de Terras)* and the 1987 Regulation *(*Regulamento 16/87), have been superseded by the Land Law of 1997 (Law 19/97). Article 3 of the Land Law stipulates that in the Republic of Mozambique all land is the property of the State. This is also reflected in Article 98 of the Constitution of the Republic. Consequently, land may not be sold, alienated, mortgaged or encumbered.

The Land Law (1997) states, however, that although land is owned by the State, all Mozambicans have the right to use and enjoy the land or the right to land use and benefits thereto. Specifically, Article 10 provides for the right of land use and benefit by occupancy in good faith by national individuals. The new land law legislation also covers various situations of land acquisition by the people of Mozambique, including, among others: (i) the acquisition of the right of land use and benefit by customary occupancy in good faith, (ii) the acquisition of the right of land use and benefit through official channels, (iii) the rules governing protection zones, (iv) the relationship between the public and the Cadastre Services, and (v) the rights and duties of the titleholders.

Private persons get access to land through a licensing system. Two systems exist.

- One can acquire the right by mere occupation "in good faith." This system is only valid for small-scale family farms. A central feature of this system is that one does not have to register one's title, although this can be done without any payment (the *Certificado de Occupação Familiar).* The use of the land is free; the farmer does not have to pay rent to the state.
- The second type of land title entails a fifty-year concession that is automatically renewed unless one of the parties decides to dissolve the agreement. This title (the *Titulo de Utilização e Exploração)* is attributed to the so-called "private sector," or commercial farmers. (Pereira and Alves 1994; Myers, Eliseu and Nhachungue 1993). (Note: §22 of *Regulamento* 16/87 of 15 July 1987 uses the term *Uso e Aproveitamento).* For this title, a tax has to be paid to the State (§41 of Regulamento 66/98). This is more likely to apply to the development of biofuel plantations.

The new Land Law has several articles that pertain to land administration in Mozambique. These include the Land Policy, the Land and Water Law, the Framework Environmental Law, and the National Heritage Protection Law. However, the provisions in this legislation are not adequate to accord fair compensation and resettlement arrangements, as per the international best practices for involuntary resettlement.

In terms of loss of land, the Right of Eminent Domain (Article 98 of the new Constitution of Mozambique) says that individuals and entities have the right to equitable compensation for expropriated assets and the right to a new and equal plot of land. According to earlier legislation, the State is by law obliged to compensate for land (and construction on the land) if it is claimed for public use, such as road works, but only if the land is held under a title and/or the construction on it is duly licensed (Land Law 6/79, §23). This may also apply to the development of biofuel plantations as part of the national strategy.

- *Traditional land tenure.* The Land Law recognizes the rights acquired through systems of customary occupancy, the role of communities in the management of land and natural resources, and conflict resolution. This is spelled out in §24 of the Land Law (1997).
- *Traditional land tenure systems*. These vary among different groups in Mozambique. They are generally based on the principle that land rights are multi-layered. Chiefs, clan-elders, family-elders, heads of household, all have certain rights. For example, the decision of a man to grant a part of his land to his wife entails the tacit or explicit approval of his clan-elders and the village chief, as these are considered the "original owners." In practice, the ownership rights appear quite individualized. This means that in practice chiefs have little or no control over land held by individual families, and that these families will settle land allocation among themselves. Because of the variation in traditional land tenure systems, individual road rehabilitation or maintenance projects have to be accompanied by inquiries into the specific local tenure arrangements. These land tenure issues will need to be taken into account when potential sites for biofuel plantations are being considered.

- *Resettlement.* The establishment of new plantations may result in the displacement of people and the disruption of livelihoods, and may require involuntary resettlement. The regulations governing resettlement are contained in the Land Law and its Regulations (§50 ff of Decree 16/18 of 15 July). However, the provisions in the existing land legislation are not adequate to accord fair compensation and resettlement arrangements according to international best practices for involuntary resettlement. In this context, the Mozambique Roads Authority has recommended the following procedures (ANE, Environmental Guidelines For Road Works in Mozambique, December 2006):

    - Any transfer of land should be preceded by an inventory of all families and family members on the land
    - The inventory should include the size of all occupied lands, and whether each is cleared
    - This inventory must be certified and confirmed by the local administration
    - The size of the compensation to be awarded will be set by a Governmental Commission especially created for that purpose, or will follow the recommendations of a resettlement policy framework /resettlement plan. (§50 and 53)
    - Transfer shall start only after the payment of the compensation, and when it has been guaranteed that the family/ies will maintain the same living standard as before the removal, and that the new land is of the same quality and value (§52.1)
    - All expenses related to the transfer are to be paid by the interested party: this means these expenses should be included in the budgets of road construction and rehabilitation projects (§52.2)

Environmental issues. The key environmental issues are linked to: greenhouse gases and global warming, air quality, biodiversity and habitat loss, water supply and quality, soil loss and genetically modified products. The potential impacts in terms of greenhouse gas emissions have been discussed previously. The other issues are reviewed in turn, below.

- *Air quality.* In addition to assisting in the reduction of GHG emissions, biofuels also have the potential to reduce emissions of key toxic substances usually associated with standard fuels. Table 48 summarizes emissions associated with bioethanol, biodiesel and Fisher-Tropsch for transport use, based on data from the U.S. Environment Protection Agency (EPA) (IIED, 2006). The findings suggest that engines running on these types of biofuels, or on a blend of standard fuels and biofuels, tend to have lower particulate and CO emissions and lower sulphate emissions (IIED, 2006). However, while ethanol also shows reductions in ozone-forming volatile organic compounds, it has higher rates of ethanol and acetaldehyde volatilization. Biodiesel shows higher emissions of nitrogen oxide, though the differences are not substantial.

Table 48: Emissions associated with bioethanol, biodiesel and FT for transport use

BIOETHANOL (E85)	BIODIESEL (B20 & B100)	FISCHER-TROPSCH
• 15% reductions in ozone-forming volatile organic compounds. • 40% reductions in carbon monoxide. • 20% reductions in particulate emissions. • 10% reductions in nitrogen oxide emissions. • 80% reductions in sulphate emissions. • Lower reactivity of hydrocarbon emissions. • Higher ethanol and acetaldehyde emissions.	• 10% (B20) and 50% (B100) reductions in carbon monoxide emissions. • 15% (B20) and 70% (B100) reductions in particulate emissions. • 10% (B20) and 40% (B100) reductions in total hydrocarbon emissions. • 20% (B20) and 100% (B100) reductions in sulphate emissions. • 2% (B20) and 9% (B100) increases in nitrogen oxide emissions. • No change in methane emissions (either B20 or B100).	• Nitrogen oxide reductions due to the higher cetane number and even further reductions with the addition of catalysts. • Little or no particulate emissions due to low sulphur and aromatic content. • Expected reductions in hydrocarbon and carbon monoxide emissions.

Source: EPA

There are also reductions in household air pollution when crop-based biofuels substitute other traditional forms of fuels typically used in the poorest countries, such as charcoal, fuel wood and paraffin. This has important health implications as these forms of fuel have been identified as major causes of death of women and children in developing countries (Woods, 2005). However, as indicated above, the burning of sugarcane fields just prior harvest, which is a common practice in developing countries, has been linked to air pollution, GHG emissions and health risks in cities such as São Paulo in Brazil. Likewise, the use of fires to clear fields for the cultivation of large-scale palm oil plantations in Indonesia, for instance, has resulted in considerable increases in air pollution (IIED, 2006).

- *Biodiversity and habitat loss.* The cultivation of energy crops for the production of biofuels may also trigger or exacerbate several of the environmental problems typically associated with large-scale agricultural commodity production, such as deforestation, monocropping, water usage, land degradation and water pollution. Of these, the increased land take is a key concern, especially the impact this may have on tropical forests, savannahs and biodiversity. For example, in Indonesia and Malaysia, indigenous forests have been cleared for palm oil production. In Brazil, an increase in soy production would affect the sensitive drier savannah areas of north-central Brazil (the *cerrado*) and the Amazon forests (IIED, 2007). Brazil's sugarcane plantations that feed the country's bioethanol industry also encroach on the Amazon, but far more so on the Atlantic forest and the Cerrado, a bio-diverse grassland ecosystem, two-thirds of which is already destroyed or degraded (ISS, 2006).

For example, in Indonesia and Malaysia, indigenous forests have been cleared for palm oil production. In Brazil large areas of the Amazon forest have been cleared for soybean cultivation to support the world's meat industry.

The production of biofuels in Mozambique has the potential to impact on the country's biodiversity in two ways:

- Biofuel plantations are established in ecologically sensitive areas (biodiversity hotspots)
- Biofuel plantations are established in areas that are not ecologically sensitive but still result in the loss of natural ecosystems (conversion of natural areas for the establishment of new biofuel plantations)

Unless the program is carefully managed, these threats could, in turn, pose a threat to rural communities that rely on natural resources for their livelihoods and to Mozambique's tourism potential. The impacts associated with the development of biofuel plantations are the same as those posed by all agricultural and forestry activities. However, the additional demand for land created by biofuels will place increased pressure on the biodiversity and natural habitats.

The potential environmental impacts should be accounted for as part of an Environmental Impact Assessment process, when identifying areas that are potentially suitable or unsuitable for the establishment of biofuel plantations. As in other emerging economies, there are concerns that the in Mozambique, the legislative and regulatory framework is not developed enough to assess and monitor the establishment of new areas for growing feedstock and the operation of biofuel plants. The development of a biofuel industry in Mozambique will therefore need to receive external support to ensure that adequate care goes into planning, implementing and managing biofuels development to minimize the ecological and social impacts while maximizing the potential socio-economic benefits.

- *Sensitive areas in Mozambique*. A detailed assessment undertaken for the Mozambique Roads Agency (ANE) in 2001, the Environmental Impact Assessment of the Next Road Sector Program in Mozambique, February 2001, provides detailed information on the environmental conditions in the country. The information presented below is drawn from this report.

  In terms of vegetation types, 22 broad vegetation/habitat types can be distinguished in Mozambique. The main vegetation type, in terms of structure, is savanna woodland. The most common woodland type (based on species composition) is *miombo* woodland. Miombo is the term used to describe woodland types dominated by members of the genus *Brachystegia* and/or closely related genera such as *Julbernardia*. In Mozambique miombo covers much of Niassa, Cabo Delgado, Nampula, Zambezia, Sofala, Manica and Inhambane Provinces.

The second most extensive woodland type is *mopane* woodland present in the Limpopo-Save area and in the mid-Zambezi Valley. Mopane woodland is dominated by the tree species *Colophospermum mopane.* Other woodland types include *Acacia* woodland (in drier southern and central areas) and sub-littoral coastal woodland in southern coastal Mozambique. Non-woodland vegetation types include:

- Small islands of African mountainous habitats (forests and heaths) along the eastern border with Zimbabwe and Malawi where the Mozambican plains rise up sharply to the western rim of the great southern African plateau and other isolated mountainous areas
- Inland halophytic communities in the valley of the Changane River, a tributary of the Limpopo River
- Freshwater swamps/sudd occur on the Mozambique-Malawi border, the largest being associated with Lake Chilwa
- Vegetation formations on alluvial plains are predominant in the Zambezi, Limpopo and Nkomati valleys
- Parabolic dune forests along the southern sector of the Mozambican coast
- Mangroves in sheltered bays, estuaries and deltas

The report also identifies eight areas of outstanding ecosystem, biological and/or scenic value which warrant special attention in Mozambique:

- *Gorongosa Mountain-Rift Valley Complex*. This area encompasses the isolated massif of Gorongosa Mountain which rises to 1,863m and the southern-most, Mozambican sector, of the African Rift Valley (known as the Urema Trough). Gorongosa Mountain is an isolated montane block 160km inland from the sea. The Complex is diverse in terms of ecosystems, plant formations, habitat types, unique assemblages of big game population and rare or confined (endemic) plants and animals. The outstanding value of this area thus encompasses high scenic values, broad geological diversity, endemic plants and animals, high ecosystem and biological value, and potential big game spectacle.
- *Cheringoma Plateau.* The Cheringoma Plateau, rising 300 m above sea level on Cretaceous sediments, comprises tropical forests containing a mixture of local endemics with equatorial, north-east coast and southern African flora. The forests on the Plateau contain several commercially important hardwood species, such as *Milletia stuhlmani* (panga-panga), *Afzelia quanzensis* (chanfuta) and *Pterocarpus angolensis* (umbila). Current access to these forests is via the Dondo-Caia road, which is in poor condition. Access to these forests will be increased when the Gorongosa-Caia road is completed.
- *Zambezi Delta and grasslands.* The Zambezi Delta covers an area of about 18,000 km2, from its apex at Chupanga, to its 120 km front with the Indian Ocean coast, extending from Quelimane south-west to Machesse. Wetland scientists believe the Zambezi Delta qualifies as a Wetland of International Importance under the Ramsar Convention, and is of great socio-economic and cultural value to Mozambique.

- *The Great lnselberg Archipelago.* The lnselberg archipelago presents a truly remarkable landscape of tall granite core remnants in a savanna plain. This series of habitats occurs south of the Lurio River occupying a rectangular area of approximately 500km by 160km, lying in a south-west to north-east direction (approximately between 140 to 17°S; 35°40'E to 380 E thence NE-wards to 39°40'E). The Inselberg Region has high scenic and biological value. The latter is characterized by unique flora and fauna (endemics and biogeographical outliers) contained in the isolated rainforest, patches of which form aprons around the flanks and base of the inselbergs. Many of the areas are unknown biologically and it is highly likely non-described species remain to be discovered. The forests are characterized by high levels of endemism. The Namuli apalis *(Apalis lynesi)* is one of the world's most restricted bird species and is known to occur only in the woodlands and forests of Mount Namuli. The Namuli forests are also home to a further five globally threatened bird species and 14 biome restricted species. The outstanding global value of the Great Inselberg Archipelago encompasses spectacular and unique inselberg scenery and high biological diversity and endemicity.
- *Chimanimani Massif.* The Chimanimani Massif forms part of the great eastern escarpment of the Interior Continental Plateau of South Central Africa, along the Mozambique-Zimbabwe frontier. Although relatively small in area, the massif is characterized by an exceptionally high diversity of habitats and species. The scenery is stepped with a series of spectacular steep rocky scarps and ravines separated by flattened undulating terrain, with high waterfalls plunging off each step. The outstanding universal values of the Chimanimani Massif are: the spectacular mountain and waterfall wilderness scenery, with big game; high plant endemism; high plant community diversity, from montane heaths and grasslands down to lowland; tropical rainforest in the gorges and valley bottoms; and well preserved San Rock Art.
- *Maputaland Center of Endimism (MC).* The MC (26 734 krn2) is defined as that part of southern Mozambique and north-eastern Kwazulu-Natal bounded in the north by the Inkomati-Limpopo River, in the west by the western foothills of the Libombos, in the south by the St. Lucia estuary and in the east by the Indian Ocean. The area is characterized by a flat low-level coastal plain, with a maximum elevation of 150 m. The eastern shoreline is characterized by a parabolic dune system, rising to almost 200 meters above sea level in certain places, considered to be the tallest vegetated dunes in the world. The MC contains extensive wetland, notably Lake St. Lucia (about 350 km2), Lake Sibaya (65 km2) and the Kosi Lake System in South Africa, and Lakes Piti, Xingute and Satine in Southern Mozambique. Several of the endemics are rare and known only from a few collections. The associated fauna of the MC is interesting and rich. Of the more than 472 species of birds in the MC (57% of South Africa's total), 47 subspecies are endemic/near-endemic to the center. The MC is of exceptional biogeographical interest because of the sharp biogeographic transformation in the region.
- *Coastal Barrier Lakes* The extensive coastal lakes, swamps and temporary rain-filled pans, which occur behind the parabolic dune systems, are characteristic

features of the Ponta do Ouro-Bazaruto stretch of coast. The most important coastal lakes from north to south are: Lagos Dongane, Poelela (9,250 ha), Maiene, Quissico (3,250 ha), Nhamabvale, Nhamzume, Uembje (Bilene) (3,200 ha), Muandje (2,250 ha), Pati (1,850 ha), Piti (2,700 ha), Xingute (1,150 ha) and Satine (500 ha). These lakes are located on a plain of low elevation and most are separated from the sea by a well developed longshore dune system. Besides their biological importance, these coastal systems also have high scenic value. A proposal has been developed to declare the Maputaland wetlands (between Ponta do Ouro and Inhaca island) a Natural World Heritage Site. This proposal will be submitted to the Mozambican Government for consideration. The South African component (St. Lucia Estuary/Kosi Bay) of this unique wetland system has been declared a RAMSAR Wetland.

- *Pebane Evergreen Coastal Forests.* Evergreen Coastal Forests in northern coastal Zambezia Province have been encroached upon by slash and burn agriculture. Recent surveys have highlighted the biological importance of these forests.

- *Water supply and quality.* Mozambique does, on the whole, have large untapped supplies of water. However, water consumption and contamination as a result of biomass production and conversion for biofuels production do need to be assessed and managed. For example, during peak growing periods, sugarcane can require up to 10mm of rain equivalent water per day to meet the crop's evapo-transpiration requirements. Likewise, sugar mills and ethanol plants require substantial amounts of water and can emit significant amounts of liquid pollutants with high biological and chemical oxygen demands (COD and BOD). After the fermentation process that produces ethanol, the wastewater must be treated, used as fertilizer in or processed to generate biogas. The wastewater effluent from sweet sorghum-based ethanol production is less polluting than that from sugarcane molasses, having one-fourth of biological oxygen demand (BOD; 19,500 mg/liter) and lower chemical oxygen demand (COD; 38,640 mg/liter), according to the results of a pilot study conducted by the Vasanthadada Sugar Institute (VSI), Pune, India (ICRISAT, 2007). Development of appropriate water quality guidelines and licensing requirements for biofuel production, therefore, needs to be considered as necessary pre-requisites for biofuels production.

  The impact of biofuel plantations and processing plants on existing water supplies and water quality needs to be assessed and monitored. The impact of new water supply schemes, such as dams, also needs to be assessed to meet the needs of the biofuel program.

- *Soil losses.* Monocultures, such as biofuel crops, deplete soil nutrients and reduce soil fertility, especially in the long term. This, in turn, affects the future suitability of the soil for food crops. The wastes generated from the production of biofuels also damage the environment. These effects have been assessed in a preliminary way based on research in some countries, but could benefit from further review.[30] In less

[30] See, for example, Sara Scherr, "Soil degradation: a threat to developing-country food security by 2020" Food, Agriculture and the Environment Discussion Paper 27, IFPRI, 1999.

developed countries that lack the necessary regulatory framework and resources to monitor environmental pollution, these impacts can pose a significant threat to the natural environment and human health.

The potential impact on soils will depend on a number of factors, including the soil type, farming techniques, annual rainfall, fertilizer requirements and biofuel crops, that are considered. On the other hand, because certain energy crops such as trees and grasses require fewer inputs, they can sometimes be grown on degraded land, promoting land restoration. Crops such as jatropha, due to their fast growth, drought-resistant nature and soil-improving properties, have the potential to extend the land base available for agricultural activities and to create new markets for farmers in marginal areas – and provide local biofuels through simple processing plants. The use of perennial crops, where they replace annual crops, can also assist in reducing soil disturbance and lowering erosion rates.

In India, biofuel plantations have been linked to community forest management initiatives that aim at improving the care of neglected and deteriorating forest and public common-access areas by involving local communities in their management ((ICRISAT, 2007). The projects in India involve providing landless peoples' self-help groups with assistance to develop biofuel operations in non-forest, low-quality private and common property lands near their villages. The Indian Ministry of Rural Development, Ministry of Agriculture, and Ministry of Environment and Forests are pursuing these programs on a large scale in poor villages.

In addition to direct benefits for local communities associated with sale of high-oil seeds for the biofuel industry, these initiatives can also assist in the rehabilitation of degraded lands and soils. The crop/tree roots of biofuel plants break up hardened soils, fix nitrogen and add organic matter to them. They also reduce wind erosion and capture wind-blown soil for local deposition. Soil fertility-boosting amendments, added by farmers to improve shrub/tree growth, simultaneously stimulate the growth of soil flora and fauna (microbes, worms, insects) that rejuvenate these poor soils (ICRISAT, 2007).

These programs, however, have also created land tenure problems. As long as the areas are abandoned and unproductive, few care about them. However, as soon as they become productive, land claims quickly arise. In partnership with the Government of Andhra Pradesh State, and through a Government of India-supported project, ICRISAT has developed a model to rehabilitate degraded lands (300 ha common property resources) in Ranga Reddy District by helping landless residents form self-help groups. In an attempt to overcome the land tenure issues the State Government, through the District Collector, has awarded farmers usufruct rights for harvesting the tree produce, without transferring the land rights. The ownership of the common lands falls under the jurisdiction of the village Panchayat, or local council (ICRISAT, 2007).

This compromise approach may provide a useful model for tree-based biofuels development in many other developing countries, such as Mozambique, where issues associated with communal land ownership are unclear. By allowing use by the poor, but not ownership, the state achieves a compromise among parties that allows the poor to profit from these lands. This model is also being studied by the Hyderabad Mega-City Project, for linking bio-diesel plantations with livelihood enhancement and environment protection objectives for the urban poor, in degraded peri-urban areas (ICRISAT, 2007). This may have implications for looking at ways in which the biofuel industry in Mozambique can help to address poverty and unemployment in larger towns such as Maputo.

- *Genetically modified products.* While there is opposition to genetically modified food crops in many of the world's developing countries, the advantages of strains with special genetic modifications (drought-resistant or, conversely, flood-resistant genes, for instance) are also of interest. To overcome opposition to GM crops, some biotech companies have started to promote GM crops as bioenergy crops in the hope of attracting less regulation and more public acceptance. However, the threat of contamination by GM crops, whether they be food or biofuel crops, to natural ecosystems and food crops remains a concern for many developing countries and NGOs. The U.K. Energy Research Centre, which consists of members from all the government research councils, has already included "public perception and use of GM technologies for bioenergy" in its "Short term Research Challenge" (ISS, 2006).

  Indeed, biotechnologies are expected to play a key role in the development of the biofuel industry because of the need to improve both the economic efficiency and the energy efficiency of biofuels, (IIED, 2006). In this regard, genetic improvements have been highlighted as one of the keys to the increased yields and environmental benefits of energy crops, while reducing agricultural inputs. While genetic improvement for some feedstocks such as soya and corn are more advanced, genetic research for other energy crops such as switchgrass, poplar, and jatropha is in its infancy. The combination of modern breeding and transgenic techniques are expected to achieve greater results for food crops than the Green Revolution achieved, and in far less time (Koonin, 2006). However, the use of genetically modified organisms (GMOs) is a very sensitive issue. The main arguments against GM technologies relate to food safety concerns, and their impact on biodiversity and farmers' livelihoods. There is considerable concern that biofuel development will lead to a wider spread use of GMOs, the pros and cons of which require further investigation (IIED, 2006).

Maximizing opportunities for small-scale farmers

As indicated above, there are a number of potential economic, social and environmental opportunities and threats associated with the biofuel industry. The key challenge facing governments in the developing world will be to implement strategies and programs that maximize the potential opportunities associated with biofuels, specifically for rural, small scale farmers. At the same time they will need to ensure that potential threats posed by biofuels to biodiversity and food security are minimized. Maximizing the potential socio-economic opportunities requires an understanding of the local needs and conditions. The lessons learned from other countries are useful. Some of these lessons, including the importance of crop selection, are summarized below.

- *Ethanol crops.* The selection of feedstocks can have important implications for the success of the biofuel strategy. For example, the molasses from sugar production is widely used to produce ethanol. However, sugarcane plantations require access to reliable supplies of water and, as such, lend themselves to larger scale commercial farming. The majority of poor farmers are unlikely to have access to irrigation water and the capital needed to bear the cultivation costs of sugarcane. Sugarcane is therefore not necessarily an ideal biofuel feedstock when it comes to maximizing the potential benefits for rural, small-scale farmers.

  Research undertaken by ICRISAT (ICRISAT, 2007) indicates that sweet sorghum is a more appropriate biofuel crop for rural farmers in areas where access to water is an issue. The findings of research undertaken by Rajvanshi (2003) and Reddy and others (2005), indicate that the juice from sweet sorghum (*Sorghum bicolor* L. Moench) stalks is a viable source for bioethanol production. Sweet sorghum is similar in appearance and agronomic performance to grain sorghum. It grows rapidly, is photosynthetically efficient due to its C4 metabolism, and is widely adaptable. The difference is that sweet sorghum stores much of its photosynthate as sugar in the stalks, although it also gives reasonable grain yields (ICRISAT, 2007). Sweet sorghum as a biofuel crop therefore appears to have a number of potential benefits for small-scale rural farmers:

  - Lower cost of production than sugarcane, making sweet sorghum more appropriate for poor, rural farmers;
  - Lower water requirements than sugarcane, allowing , sweet sorghum to be grown in drier environments and by rural, small scale farmers who tend to have less access to water for irrigation;
  - Sweet sorghum, while offering lower yields, can be grown in drier regions with less reliable rainfall or irrigation, and as a feedstock it can therefore enable large dry regions, where poverty is deepest, to benefit from the potential opportunities associated with the biofuels industry;
  - The demand for grain sorghum crop is decreasing, due to government subsidies for rice, corn and wheat, for human consumption. Sweet sorghum, which is not edible, offers rural farmers an alternative crop;
  - Sweet sorghum can create opportunities for small scale rural farmers to earn income, enabling them to purchase rice and wheat to eat. Sweet sorghum can therefore help address potential threats to food security;
  - For Africa, the additional benefit is that normal grain sorghum is already grown on 23.4 million hectares (55% of global sorghum area); these areas are also suitable for sweet sorghum (ICRISAT, 2007)

- *Biodiesel crops.* As indicated above, biodiesel yields even greater reductions in air pollution than ethanol and, therefore, has significant implications for global warming and climate change. Biodiesel can be produced from a number of edible oilseed crops such as soybean, rapeseed, sunflower, as well as non-edible oilseeds such as jatropha (*Jatropha curcas),* pongamia *(Pongamia pinnata)* and neem (*Azadirachta indica).* Jatropha and pongamia have attracted the most interest in recent years. Both species can be grown in areas that are generally unsuitable for food crops, such as wastelands and village or field border areas, minimizing competition for valuable land.

Pongamia also has a number of additional attributes that make it an attractive option for rural, small scale initiatives. The seeds contain 30-40% oil and are inedible by animals, therefore reducing the losses to animals and costs associated with managing the plants. It is also one of few nitrogen-fixing trees that produce high oil-content seeds. The plant is tolerant to waterlogging, saline and alkaline soils, and it can withstand harsh climates (medium to high rainfall). It is widely used in India and the Asian subcontinent to control soil erosion and stabilize sand dunes. Its roots, bark, leaves, sap, and flowers are also used for medicinal purposes. Pongamia oil can also be used for cooking fuel and lighting lamps. The oil is also used as a lubricant, water-paint binder, pesticide, and in soap-making and tanning. Dried leaves are used as an insect repellent in stored grains (ICRISAT, 2007). The plant therefore provides number of by products and services, other than feedstock for biofuels, that make it an attractive option for rural, small scale farmers.

Linking small-scale farmers to the market

Large-scale production of feedstocks has the potential to crowd out small-scale farmers. This poses a number of challenges for the biofuel industry in the developing world. These challenges include: (a) finding ways for small scale farmers and rural communities that can access markets to benefit from a large-scale, industrial biofuels program; and (b) finding ways for more isolated, self-sufficient villages and communities to benefit from biofuel crops. This would include growing and using biofuel crops to generate additional cash income and improving their energy self-sufficiency. In most developing countries, small-scale farmers have limited direct access to consumers and are therefore forced to sell their farm output to village brokers or commission agents at low prices. Price vulnerability is therefore an issue that needs to be addressed when developing strategies aimed at maximizing the benefits of the biofuel industry for small-scale farmers.

In addition to the limited access to markets issue, locally owned farms in the majority of developing countries are becoming smaller in size as they are handed down from one generation to the next and land is lost to urban development, roads and industry. At the same time the demand for energy in increasing. This is likely to create potential problems and challenges for the biofuels industry in the developing world and expose small-scale farmers to exploitation by the processing arm of the industry. If the demand for feedstocks is controlled by a few large producers, in competition with the farmers for profits, the farmers are likely to lose out over time (ICRISAT, 2007).

To keep small-scale farmers from losing out to middlemen or large-scale processors, farmers may need to form commodity associations and cooperatives with the assistance of the government. These structures can enable them to coordinate production and consolidate output. Small scale farmers may also look at ways of getting involved in processing and marketing. The formation of farmers associations raises the political profile of small scale farmers and improves their access to power and resources, such as national research and development institutes. Unlike small farmers, farming associations and cooperatives are also more likely to be able to access credit at competitive rates. The inability of small scale farmers to access credit at market rates is regarded as a major stumbling block to rural development in most developing countries.

If such associations are well managed, they also facilitate the flow of information, expertise and services between different farming groups, government, research institutions and the private sector, which ultimately can lead to an increase in skills and expertise, improved farming techniques and a reduction in production costs. However, experience has also shown that farming associations often have a tendency to become bureaucratic and inefficient if they are poorly managed. They are also subject to political interference. The collapse of state marketing boards in many African countries is evidence of this risk (ICRISAT, 2007).

The challenge facing developing countries who want to benefit from the biofuel industry is to look for ways of balancing the demands and needs of small scale farmers and the processing sector. In this regard, biofuel industry needs are linked to a reliable stream of quality feedstock at a predictable price and in high volumes. Small scale farmers, on the other hand, need to have a fair share of the benefits, a predictable price and market, and technical and credit assistance (ICRISAT, 2007). To address these needs in an equitable and efficient way requires careful planning and the involvement of all of the affected parties, namely farmers, government, and the private sector.

ICRISAT has reviewed a number of agricultural projects and initiatives in the developing worked that provide useful lessons for the biofuel industry. Three cases are highlighted in Boxes 1, 2 and 3.

Lessons learned. The lessons learned from the White Revolution in India, CMDT cotton in Africa, and soybeans in India, provide insight into the factors that need to be addressed when assessing the potential for the biofuel industry to create benefits for poor small-scale rural farmers. One lesson is that it is possible to integrate large numbers of small-scale farmers into large-scale commodity production, processing and marketing chains, but this requires dedicated, skilled management. The other is that public-private partnerships are needed to integrate essential policy, entrepreneurial, investment and research elements. Some current biofuel initiatives with small scale farmers are discussed here.

Box 1: White Revolution in India

The biggest cooperative success story in contemporary Indian agriculture is the 'White Revolution' for dairy products. In the early 1950s farmers in the Keira District of Gujarat State formed the Kaira District Co-operative Milk Producers' Union. This was in response to dissatisfaction of the role played by middlemen. The cooperative was expanded to become the Gujarat Cooperative Milk Marketing Federation (GCMMF). Approximately 2.5 million farmers now participate in GCCMF, producing 6.3 million liters of milk per day that are collected, processed and marketed cooperatively. Benefits associated with the collective resources have enabled the Federation to invest in technology, quality control and marketing, and to diversify its product line. The 'Amul' brand is now recognized throughout India and is also exported (see: http://www.amul.com/organisation.html). While the initiative was a great success, it required large government and donor support. In the meantime, India has embraced the free market approach, which could have a bearing on adopting the approach for the biofuels industry.

Source: (ICRISAT, 2007).

Box 2: Soybean in India

Production and demand for soybean, an oil and feed crop, have grown rapidly since the 1980s in Madhya Pradesh, India, at a yearly rate of approximately 15%. The crop is now grown on more than 3 million hectares there. The growth was largely driven by the processing industry, which provided price and purchase security through contract arrangements, and the introduction of modern production technologies. In addition, the growth was supported by improved access to capital, research, technology, transport and storage infrastructure, the implementation of quality standards, capital investment in the processing industry, government deregulation and supportive policies.

Source: (ICRISAT, 2007)

Ethanol initiatives. ICRISAT is involved in a number of biofuel-related initiatives involving small scale farmers in the developing world. The basic approach adopted by the ICRISAT is to develop an Agri-Business Incubator (ABI) entity to promote the implementation of its research findings by the private sector. The approach has been used to consider how the benefits of the biofuel industry can be maximized for small scale farmers and rural communities. Many of the initiatives have focused on the potential of sweet sorghum as a biofuel feedstock, referred to as *Sweet-sorghum based bioethanol technology (SSBET).* Examples of some of the initiatives involving production of ethanol are summarized below.

Box 3: Cotton in Burkina Faso

In 1952 a French cotton company, *Compagnie Française pour le Developpement des Fibres Textiles* (CFDT), became involved in cotton production in southwestern Burkina Faso. The company supplied inputs, provided technical recommendations, and purchased the cotton. The approach adopted by CFDT resulted in a 740% growth in cotton production in the former French Colonies between 1960 and 1985. In contrast, cotton production in neighboring Anglophone countries increased by only 60 % over the same period. This support based approach to cotton production, often with governmental support, is now found all over the former French colonies of Sub-Saharan Africa.

The essential components of the CFDT approach are linked to providing farmers with support in the form of fertilizer on credit, timely payment for cotton at a price determined before planting, and technical support backed up by research. The French research agency *Institut de Recherches du Coton et des Textiles Exotiques* (IRCT), established in 1946 to coordinate French colonial research, worked closely with CFDT to provide the research needed to steadily increase the productivity of the cotton enterprise. With independence, national research agencies and cotton parastatals took over, but both the IRCT and the CFDT maintained technical contacts with cotton operations in the former French colonies by sending short-term and long-term consultants. CFDT also is an investor in these national cotton parastatals.

The success of the CFDT model is based on a combination of institutional, financial, research, technological and business management expertise, and demonstrates that well-organized, market-driven, parastatal cooperative arrangements can succeed on a large scale in Africa. The CFDT model also provides valuable lessons for the biofuel industry in Africa and in other developing countries.

Source: (ICRISAT, 2007)

Based on its ABI approach, ICRISAT has established partnership with Rusni Distilleries (Pty) Limited which has played a critical role in promoting the development of the sweet sorghum based bioethanol technology (SSBET) industry in India. Rusni is located near Sangareddy, Medak district, Andhra Pradesh, India, and aims to produce 35−40 kiloliters of ethanol per day (KLPD), for at least 105 days during each of two seasons per year. To reach this target, it requires 800 to 875 tons of sweet sorghum stalks per day. This will require entering into agreement with around 3,200 small-scale farmers (approximately 2 ha holding size) to enable sweet sorghum to be grown on approximately 6,400 ha per year (ICRISAT, 2007).

The business model for the project involves the appointment of agricultural experts by Rusni, to train the local farmers and provide them with the expertise to grow sweet sorghum. High quality seed for the farmers is provided by a seed company. ICRISAT provides technical advice on crop management, identification of agro-ecological areas for sweet sorghum cultivation, seed production, partnership-building and capacity-building. This input is based on its expertise and research on sweet sorghum. A percentage of the profits from the operation are reinvested to support further research and development as well as marketing, farmer education and services. Based on current information, the production costs for ethanol production are in the region of 39 U.S. cents per liter versus an expected sale price of 51 to 60 US cents per liter. This is competitive with fossil fuel petrol prices (ICRISAT, 2007).

Similar initiatives have been launched in the Philippines. Five private enterprises have signed memoranda of understanding (MOUs) with ICRISAT to form a Sweet Sorghum for Ethanol Consortium: Guidance Management Corporation (200 KLPD), International Resource Management (40 KLPD), SEAOIL (40 KLPD), Americana Orient Capital Partners (Philippines) Inc. (50 KLPD) and Farmers Federation of the Philippines (40 KLPD. Rusni Distilleries will guide the construction and commissioning of SSBET units in the Philippines.

ICRISAT and Rusni are assessing potential SSBET opportunities in Africa. Discussions have been initiated with J. N. Agritech International Ltd. in Uganda, and NeGSt in Nigeria. There is also strong interest in southern African countries such as Mozambique and South Africa. ICRISAT believes Africa holds enormous potential for pro-poor SSBET, which could provide a huge stimulus to agriculture, through hybrid sorghum and the greater use of productivity-enhancing inputs, increasing sorghum food grain and livestock fodder and bioethanol feedstock.

Biodiesel initiatives. In the village of Powerguda in Adilabad district of Andhra Pradesh State, the Integrated Tribal Development Agency (ITDA) donated an oil extracting machine (worth about USD8,000) to the village. Powerguda is inhabited by tribal people living in extreme poverty. The machine is used to crush and extract biodiesel oil from the seeds of pongamia, neem and other plants. The oil is either used locally or sold on the market. The establishment of the oil mill has provided the village with an important source of income. Women earn approximately four US cents per kilogram from pongamia seeds. The machine crushes about 50 kg of seed per hour and runs on the biodiesel it produces. Women also sell the press cake (residue remaining after oil is squeezed out) to farmers for about 10 US cents per kg as a soil enhancer (ICRISAT, 2007).

The planting of pongamia also qualifies for carbon credits offsetting global warming. In this regard the World Bank purchased 147 ton of carbon offsets for USD645 from the Powerguda Village to neutralize the emissions from air travel and local transport by the participants of an international conference held in Washington on 19-21 October 2003 (ICRISAT, 2007). The money from the sale of carbon credits was used by the village to establish a nursery for pongamia trees. To date 20,000 saplings have been grown; approximately 50 % have been planted on land belonging to the village and the remaining 50% have been sold to nearby villages and the local Department of Forestry. The income generated from the sale of saplings has been used to expand the existing nursery.

The biofuel industry has, therefore, provided the village of Powerguda with a unique opportunity to generate income through the sale of biodiesel oil and generation of carbon credits. The program has also created a mechanism for increasing the production of biodiesel through the establishment of a nursery for Pongamia trees. The majority of workers employed at the nursery are also women. The biodiesel produced by the oil mill is also used to meet local energy needs.

Similar initiatives have been implemented in the tribal village of Chalpadi. In this case straight pongamia oil is used to run a 7.5 KVA generator, which uses 5 to 6 liters to produce 10 to 12 kwh of electricity. The electricity is used to light tribal homes. The power system is being run by the village women. The state government has now replicated this experiment successfully in another 100 villages (ICRISAT, 2007).

ICRISAT has also used the ABI model for the biodiesel market by linking up with the Indian company Nandan BioMatrix Limited. The aim of the partnership is to look at how the jatropha biodiesel industry in India can be developed for the benefit of the rural poor. Nandan has entered into an agreement with the State Government of Andhra Pradesh to develop 200,000 ha of pro-poor biodiesel plantation. Two other projects have been identified, in two other Indian states, that will increase the total to 1 million ha by 2010. Nandan has established forward sales agreements with a number of companies to purchase the biodiesel. Nandan's role is summarized below.

- Linking farmers to the local state administration
- Facilitating financial assistance through banks for eligible farmers
- Providing technical support to farmers, especially for the production and distribution of good quality seedlings
- Providing technical guidance to biodiesel farmers for the establishment of business enterprises
- Providing buy-back guarantees for the harvested seeds
- Making crop insurance available to farmers
- Establishing biodiesel processing units in the area

To prevent arable land that is suitable for cultivating food crops from being lost to biodiesel crops, the focus of the scheme is on cultivation of unutilized wastelands. It is estimated that 165,000 small-scale farmers in the region will benefit from the project.

In terms of state involvement, the Government of Andhra Pradesh is providing a 100% subsidy (Rs. 24,200/ha) to support the establishment of smallholder biodiesel plantations. The funds for these subsidies are from the National Rural Employment Guarantee Scheme (NREGS), facilitated through the Ministry of Rural Development, Ministry of New & Renewable Energy, Ministry of Agriculture and other agencies (ICRISAT, 2007). ICRISAT provides research and technical advice.

A similar initiative is in place in the Nalgonda District of Andhra Pradesh. In this project, Southern Online Biotechnologies (SBT), with support from the German funding agency, GTZ, is providing technical support to farmers. This support permits farmers to establish biodiesel plantations, and collect biodiesel seeds from existing plantations, for feedstock for processing by SBT (40 KLD capacity). SBT assures the price for the seeds and the seed cake from the processing is returned to the farmers and used to improve their soils. SBT also provides assistance to local farmers to establish their own oil extraction units (ICRISAT, 2007).

Concluding Comments

The key socio-economic and environmental issues and challenges facing the biofuel industry in the developing world are linked to land appropriation and impact on biodiversity, habitat loss and food security. Concerns about the verifiability of reductions in greenhouse gases, as a result of biofuels projects have been raised on a global level .

An internal position document on biofuels prepared by the WWF in September, 2006, highlights a number of the key issues associated with biofuels. This document states that it will only support biofuels that are environmentally and socially sustainable, the definition of which appears to encompass the following basic parameters.

Biofuels must deliver greenhouse gas (GHG) and carbon life-cycle benefits over conventional fuels. Energy crops to be used as biofuels must be selected on the basis of the most efficient carbon (soil and air) and energy balance, from production through to processing and use. Energy-intensive fertilizer input increases nitrous oxide (N2O) emissions, a highly potent GHG, and intensive cropping may release soil-bound CO2. Some conventional crops can provide these benefits if produced and processed in a sustainable way, and they are already available for use as biofuels. However, future investments and research should be oriented towards crops offering better options to reduce CO2 emissions, as well as a reduced impact on the environment.

Biofuels must ensure positive natural resource use and careful land-use planning. Permanent grasslands, natural forests, natural floodplains, wet and peat lands, important habitats for threatened species and other high conservation value areas (HCVA) must not be converted into intensive forest or farmland, even when the objective is to produce a potential environmental good, such as a biofuel crop.

Environmental and social assurance. From an environmental perspective, there is no justification for biofuels that do not provide positive gains in GHG and carbon life-cycle emissions over conventional fuels, and are not produced in a sustainable way. WWF promotes the adoption of a mandatory GHG certification scheme for all biofuels, produced in the EU or imported. Biofuels should not be counted as 100% carbon-free in national GHG inventories. Carbon life cycle and GHG emissions should be accounted for through a mandatory accounting system. Such a scheme would help identify, document and eventually reduce GHG leakage in biofuel-related processes. This includes such processes as fertilizing or converting carbon-rich lands, especially from importing countries. Over time, such a scheme may help direct governments to only account for the real carbon benefit of biofuels and thus decrease their incentives for GHG-intensive biofuels.

The sustainability of the following issues should be addressed in the development and use of biofuels:

- *Where biofuel feedstocks are produced*. It is necessary to ensure the integrity of high conservation value forests, floodplains, natural and semi-natural grasslands as habitats, and the needs of the biodiversity they harbor, with particular emphasis on threatened species, including corridors and effective management of buffer zones.
- *How biofuel feedstocks are produced.* It is necessary to use agricultural and forestry management techniques that can guarantee the integrity and/or an improvement of soil and water resources.
- *Food, land and water displacements*. It is necessary to address price increases for many of these commodities, which can challenge the capacity of poor farming communities to continue buying them for their own needs. This is an issue of particular concern in the third countries with which the EU will trade in biofuels .

The findings of the WWF study also indicate the biofuel industry can create significant benefits for small scale rural farmers. It is possible to integrate large numbers of small-scale farmers into large-scale commodity production, processing and marketing chains, but this requires dedicated, skilled management. Also public-private partnerships are needed to integrate essential policy, entrepreneurial, investment and research elements.

CHAPTER 5: TRANSPORTATION, END USE, STORAGE AND DISTRIBUTION ISSUES

This Chapter reviews the relevant issues associated with end uses for biofuels and the infrastructure required for their transportation, storage and utilization. Estimated transportation costs used to develop costs FOB at major ports in Mozambique and costs CIF to major overseas destinations are also presented.

1. Transportation infrastructure

The World Bank estimates that the total road network in Mozambique comprises about 37,500 km of roads, of which only about 17% are paved (5,800 km of national and regional roads, plus 500 km of urban roads).[1] It is estimated that around 41% of Mozambique's rural population has potential access to the road network (defined as being located within 2 km of any road), but due to the poor conditions of the network, the percentage of the rural population having reliable and constant access is much lower (as low as 11%).[2]

It appears that road transport is controlled by a small number of operators. According to industry sources, routes are often established in a collusive manner, and freight rates are kept high. In Nacala, for instance, BP stopped import operations nine months ago, and all fuel is now trucked from Beira.[3] PetroMoc has formed an alliance with transport companies to move fuel, and this is reported to be highly profitable. Indeed, some preliminary assessments of highway shipping costs (which must be verified with independent price quotes) suggest that PetroMoc's transportation costs are higher on a per-unit basis than other shippers. For instance, the per-liter price differential reported by PetroMoc for fuel delivered to Inhambane from Maputo is approximately USD 0.08/liter (MtN 2.12/liter) for fuel, whereas a coconut oil producer in Inhambane reports a cost of USD 50/ton or USD 0.05/kg, equivalent to USD 0.054/liter, for the same run.[4] By comparison, highway shipping costs in South Africa are lower.

It is likely that these conditions are typical of other routes, as well. From Beira, for instance, approximately 80 trucks per day move fuel to Malawi. It would be much more cost effective to ship by rail, but vested interests prevent this. On the other hand, the previous monopoly on transport to the Port of Maputo is no longer in place. All transporters are privately managed and compete. However, transport costs are still high due to inefficiency.

Mozambique's three primary marine terminals are Maputo, Beira and Nacala. The secondary ports include Inhamabane, Quelimane and Pemba. Due in part to natural

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[1] World Bank, *Project Information Document for the Roads and Bridges Management and Maintenance Project*, 22 May 2007

[2] *Ibidem*. Roads are a priority of Mozambique's Action Plan for the Reduction of Absolute Poverty (PARPA II, 2006-2009), as well as of the World Bank's Country Assistance Strategy

[3] Officials at BP/London, personal communication with David Liddell, June, 2007.

[4] Assuming a density of 0.925 kg/liter. See http://hypertextbook.com/facts/2000/IngaDorfman.shtml.

conditions prevailing at the major ports, but also because of management issues, the utility and efficiency of the three primary ports varies significantly. Maputo and Nacala constitute far better options than Beira, the utility of which is rapidly declining.

- *Beira*. Given its central location, with access to Tete Province, Zimbabwe and Malawi, Beira could be a strategic port for Mozambique. However, due mainly to the decrease in traffic from Zimbabwe, activity at the port has decreased, making dredging increasingly difficult to support economically. There have been delays in the dredging program at the port. As a result, the port has silted up and only smaller vessels can be serviced. In the dry season, vessels of up to 14,000 tons can berth, increasing to 20,000 tons in the rainy season. Some sources reported that cabotage (inter-port transfers by sea) rates are very expensive, to the extent that it is usually cheaper to move goods by road between ports than by barge or lighter. The reasons for these high costs should be determined. The viability of Beira as a port and entrepôt is complicated by the fact that the town is below water level, leading to frequent flooding and cutting off access to the port. Soil conditions are poor, making foundations expensive. Clearly, efforts to rehabilitate the port must be accompanied by investment in complementary infrastructure to protect the city from flooding from the Pungoe River, and from storm surges coming from the Indian Ocean.
- *Nacala*. There has been substantial investment in recent years in Nacala, the deepest port in Mozambique (36 meters). The Port of Nacala reports efforts to increase efficiency and add to the port's infrastructure. The port has a number of available bays and ample space for expansion. There are plans to install a new tanker terminal to facilitate handling fuels, which are stored at a tank farm owned by BP, located about 2 km from the port.
- *Maputo*. As in Nacala, there has been substantial investment in new infrastructure at the Port of Maputo. Maputo is installing a new tank farm, but this is designed for imports of various liquid products. The current 5,000-ton vegetable oil tanks (owned and managed by Manica) are utilized by oil processors that use the tank as bonded storage, and only draw down stocks as required. One oil processor in Inhambane noted that this storage facility is not available to his company, obliging him to find alternative means of shipping his output.

Available spare capacity for oil and fuel storage. PetroMoc reports that it is making investments in storage capacity at several locations around the country to enhance its position as the premier transporter of fuels in Mozambique. Among other resources, PetroMoc has some 140,000 m3 of currently unused crude oil storage capacity at the former oil refinery at Matola, located across the Maputo River from the Port of Maputo, which could be adapted to storage of other fuels. PetroMoc reports that it has another 135,000 m3 in capacity at Matola for all types of products in operational condition, including 30,000 m3 for diesel and 25,000 m3 for gasoline. Another 130,000 m3 of storage capacity is listed as installed but not operational, including about 40,000 m3 for gasoline and 22,000 m3 for diesel. At Beira, some 24,000 m3 are operational, including 14,000 m3 for diesel and almost 2,000 m3 for gasoline; another 20,000 m3 is installed, including an additional 10,000 m3 for diesel and an additional 1,000 m3 for gasoline. Finally, at Nacala, there is 22,000 m3 in operational storage, primarily for diesel (15,000 m3) and gasoline, 2,500 m3; an additional 2,500 in installed capacity is available, primarily for gasoline.[5] Overall, this suggests that PetroMoc could rapidly increase its fuel handling and storage capacity (including some 30,000 m3 for diesel and about 43,000 m3 for gasoline) with comparatively small incremental investments in tank farms, pipelines and handling equipment. These expansions are underway already, through joint ventures between PetroMoc with Kuwait's Independent Petroleum Group (Inpetro) and Trafigura (PetroBeira).

PetroMoc also has a fleet of 45 tanker trucks of different sizes, with a total capacity of 709,000 liters, in addition to one tanker vessel for transportation between the three major ports. To complement its ability to move product domestically, PetroMoc is also engaged in two port terminal upgrades and pipeline construction programs. Mozambique currently has pipelines suitable for transporting fuel from Beira to Zimbabwe as well as other pipelines serving South Africa. However, the Zimbabwe pipeline is not being used because politically connected transportation companies from Zimbabwe are moving fuel to that country by highway. The 450-km Petroline project will link Matola and Witbank in South Africa, providing transportation capacity for up to 5 million m3 a year of refined products; it is expected to be completed in 2009. A second project with Glencore involves rehabilitation, expansion and modernization of facilities at Maputo and Nacala, including installation of buoys for off-loading refined product from deep-water moorings to enable deliveries by larger vessels than those currently calling on Mozambican ports.[6] Once completed, these facilities will enable PetroMoc to expand the volumes it handles for the regional market, and increase the availability of storage capacity that might be converted for storage of pure biodiesel and ethanol and to establish blending capacity at locations close to the marine terminals where refined products are delivered.

2. Estimates of transportation costs for biofuels

In interviews with representatives of sugar mills, oil processors, fuel distribution companies and port authorities, the Econergy team gathered data on domestic transportation costs by road, railway and barge, as well as port costs. In addition, Econergy requested quotes for long-haul freight costs from Maputo to selected overseas ports (Rotterdam for Europe, New York/Philadelphia for North America, Mumbai for India and Yokohama for Japan). These data are presented in Table 1 through Table 4.

The quoted freight rates are notional at best, as there appears to be a great deal of volatility in the marketplace, according to Pole Shipping. Further, two important trends are emerging regarding shipping of ethanol, biodiesel and feedstocks.

Regulations in place since January, 2007, include several changes governing the transport of vegetable oils, especially with regard to the type of vessels. It is now compulsory to carry oils in ships built with a double hull, meaning the tanks' bulkheads must have an open space between them and an outer layer of steel (as categorized in IMO type II regulations) both on the side of the ship as well the bottom.

[5] Presentation by Eugenio Silva, PetroMoc, National Biofuels Seminar, July 12, 2007.
[6] Presentation by Eugenio Silva, PetroMoc, July 12, 2007.

Table 1: Representative overland freight costs

Project	Origin	Mode	Port	Distance	Route Cost	Unit Cost	Comments
				(km)	USD/m3	USD/m3/km	
Xinavane	Xinavane	Road	Maputo	117	6.40	0.05	60% more than rail
		Rail	Maputo	125	4.00	0.03	Interview
Maragra	Macia	Road	Maputo	141	28.50	0.20**	Based on Buzi figures
Procana	Massingir	Road	Maputo	324	63.95	0.20	Petromoc data
		Rail*	Maputo	250	8.00	0.03	Under construction; not linked to Massingir
Marromeu	Marromeu	Road	Beira	315	113.57	0.36	Beira too shallow; needs dredging
		Rail	Beira	300	9.60	0.03	Rail line under construction (Inconsistent with Sena figures)
Buzi	Buzi	Road	Beira	136	27.52	0.20	Petromoc data
		Barge	Beira	25	5.00	0.20**	Estimate
Cofamosa	Sabie	Road	Maputo	100	20.00	0.20**	Estimate
Sena Sugar	Marromeu	Road	Beira	120	40.00	0.33	Interview
		Rail	Beira	120	20.00	0.17	Now dumping molasses
		Barge	Quelimane	30	43.00	1.43	Barges old and inefficient. Volumes below break-even. Quelimane is closer, but Beira infra-structure is better
Mafambise	Mafambise	Road	Beira	--	--		
		Rail	Beira	--	--		

Sources: Interviews. *Assumed. **Estimated.

Table 2: PetroMoc transportation costs

Origin	Destination					
Maputo	Manhica	Ressano G.	Massingir	Inhambane	Maxixe	Morrumbene
Distance (km)	80	86	324	467	455	477
Differential	0.49	0.49	1.65	2.12	2.35	2.57
Cost (MtN/l/km)	0.00613	0.00570	0.00509	0.00454	0.00516	0.00539
Cost (USD/m3)	18.99	18.99	63.95	82.17	91.09	99.61
Beira	Buzi	Marromeu	Manica	Moatize		
Distance (km)	136	315	251	550		
Differential	0.71	2.93	1.46	3.36		
Cost (MtN/l/km)	0.00522	0.00930	0.00582	0.00611		
Cost (USD/m3)	27.52	113.57	56.59	130.23		
Exchange rate	25.8	MtN/USD				

Source: PetroMoc data.

Table 3: Estimated costs FOB Beira/Maputo

Source	Place	Cost (USD/m3)	Port	Loading (USD/m3)	FOB Cost (USD/m3)
Xinavane	Xinavane	6.40	Maputo	3.00	9.40
Maragra	Macia	28.50	Maputo	3.00	31.50
Massingir	Massingir	63.95	Maputo	3.00	66.95
Marromeu	Marromeu	113.57	Beira	4.00	117.57
Buzi	Buzi	27.52	Beira	4.00	31.52
Cofamosa	Sabie	20.00	Maputo	3.00	23.00
Sena Sugar	Marromeu	40.00	Beira	3.00	43.00
Morrumbene	Morrumbene	99.61	Maputo	3.00	102.61
Manica		56.59	Beira	4.00	60.59
Madal				3.00	

Source: Interviews and data from Table 1 and Table 2.

Table 4: Shipping costs

Ethanol		Biodiesel		Vegetable oil	
Destination	Shipping (USD/ton)	Destination	Shipping (USD/ton)	Destination	Shipping (USD/ton)
Yokohama	90.00	Yokohama	88.50	Yokohama	87.00
Mumbai	65.00	Mumbai	63.50	Mumbai	62.00
NY/Philadelphia	92.00	NY/Philadelphia	90.50	NY/Philadelphia	89.00
Rotterdam	85.00	Rotterdam	83.50	Rotterdam	82.00
Cargo size (tons)	17,000	Cargo size (tons)	18,000	Cargo size (tons)	18,500

Source: Quote provided by Pole Shipping, Geneva (www.poleshipping.ch), for monthly cargos. Greater frequency of service and/or volume increases would likely lead to changes in offered rates.

As a result, a substantial amount of older tonnage (IMO III type), which traditionally carried raw oils, can no longer do so, leading to increased demand for the younger and more sophisticated chemical carriers that comply with these rules, and consequently, higher freight rates. There are some routes where the rates have increased over 50%; one example is that of the Argentina/Mediterranean route. Ethanol, however, remains as category IMO III type cargo, meaning it can be carried in tanks with a single hull, that is, the tanks' bulkheads are at same time the ships' external side or bottom. This allows greater flexibility in the available tonnage, although to deliver cargos in the U.S., vessels must be no more than 15 to 20 years old, approval of the vessel by a major oil company is generally required.

An alternative scenario being used by owners of IMO II/III type ships, which have center tanks flanked by wing tanks that are then considered the second hull, is to combine raw oils in center tanks and IMO III cargoes such as ethanol in the wing tanks, and thereby comply (provided low-flash cargoes are allowed in transit for raw oil discharge). With respect to rates, this increase in demand for space has led to firmer prices in the market; however, the market is expected to balance out again during 2008-2009 with the delivery of a significant number of new vessels from shipbuilders. Therefore, the freight rates for ethanol will be sensitive to shipment sizes and destinations as shippers optimize their services in the shifting competitive environment.[7]

3. End-use technologies

Automotive sector. While the automotive sector is not the only one involved in biofuels development, it is often the key one. The fleet's size and characteristics are key factors for consideration in the context of decisions to introduce biofuels into the transportation fuels market, and this affects not only the share of biofuels that are likely to be consumed domestically, but also the costs of modifications in transportation vehicles as well as fuel storage and distribution facilities. The modifications needed for a vehicle to run on biofuels are relatively smaller compared to those required by other alternative fuels such as compressed natural gas (CNG), liquefied petroleum gas (LPG) or hydrogen, which typically require completely different devices rather than simple modifications. Unlike other alternative fuels, ethanol and biodiesel can also be blended with fossil fuels, gasoline and conventional diesel, respectively. For blends containing modest amounts of biofuels (up to 20%), the requisite vehicle modifications are limited. Each biofuel has its own set of concerns.

- *Ethanol*. The use of ethanol as a vehicle fuel presents several concerns. Ethanol can corrode a motor vehicle's metallic parts, and degrade rubber or plastic materials. Ethanol also has lower energy content than gasoline (about one-third less), resulting in lower fuel economy (distance traveled per unit of fuel used), though this is partly compensated for by its higher octane values and oxygen content. This increases engine efficiency, and makes fuel burn more completely, resulting in reduced emission of pollutants.

  Results of different studies vary according to different blends and vehicles used for tests, but fuel economy reductions reported range from 15% to 26% for E10, and up to 30% for E85.[8] Concerns of inferior performance, such as hesitation or loss of power, have also been associated with ethanol, due to its different air/fuel ratio for combustion. Pure ethanol has a lower Reid Vapor Pressure (RVP), resulting in problems with starting at low temperatures and poor warm-up performance. However, ethanol has a very high blending RVP, which means that it increases the vapor pressure of gasoline when blended into it. This can increase the finished fuel's volatility and emissions, worsen drivability, and decrease fuel economy. Refiners usually prepare special gasoline blendstocks with lower vapor pressure before blending by extracting a few of its light components.[9]

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[7] Daniel Buckley, Pole Shipping Geneva, personal communications, May-June, 2007.
[8] World Bank, ESMAP, *Potential for Biofuels for Transport in Developing Countries*, October 2005, page 82. Also available online at http://wbln0018.worldbank.org/esmap/site.nsf/files/312-05+Biofuels+for_Web.pdf/$FILE/312-05+Biofuels+for_Web.pdf
[9] *Ibid*, page 83. Also see Chapter 1 discussions on ETBE and on reformulated gasoline blendstock for oxygenate blending (RBOB).

Concerns associated with ethanol used as a fuel for vehicles depend on various factors, and in particular (i) the amount of ethanol blended with gasoline; (ii) vehicle age, closely related to its technological level and ability to operate on higher ethanol blends; and also (iii) climate and altitude. Low-percentage ethanol blends such as E5 or E10 are distributed in many fueling stations worldwide, with almost no incompatibility problems and no vehicle modifications required. It is generally recognized in the specialized literature, as well as by major international vehicle manufacturing associations and communities, that virtually all recent conventional gasoline (spark-ignition) vehicles are fully compatible with blends containing up to 10% ethanol, without any major technical intervention or modification required.[10]

One U.S. study, conducted in 1999 on a sample of 15 vehicles aged 1-15 years, showed that unmodified gasoline vehicles could operate on ethanol blends up to 30% by volume with no drivability or compatibility issues.[11] However, this study did not test for effects due to longer term use or warm climate, both of which are important considerations when evaluating applicability in Mozambique. For blends containing more than 10% ethanol, a majority of sources agree that some modifications are required, and recommend that fuel ethanol programs should involve maximum blends of E10 at least during the launching or initial phases.[12] Figure 1 provides a description of conventional vehicle modifications required according to the Brazilian Automotive Industry Association (Associação Nacional dos Fabricantes de Veículos Automotores or ANFAVEA). A small modification to the carburetor is described as the only "probably necessary" intervention for operation with E10, while more modifications are necessary for higher blend ratios.[13]

In warmer climates or at higher elevations (generally, above 1,500 meters), greater care is required to control fuel vapor pressure; while of Mozambique's territory lies below 1,000 m in elevation, the country's warm climate would necessitate special consideration of vapor pressure in the blended fuel. For vehicles older than 15 years, concerns for the use of even limited ethanol blends are legitimate, given that since 1990 most manufacturers have increased their vehicles' ethanol compatibility. There are several countries, including Mozambique, where the share of older vehicles circulating is still rather high, and it is possible that the most obsolete may not be fully compatible even with E10. The characteristics of a country's car fleet are thus critically interrelated to the success of any biofuels program. Brazil has mandated ethanol blending in all gasoline at levels ranging from 20% to 26%, and electronic injection cars sold there include minor special features – such as tuning of engine timing and increased compression ratio – and have operated with such blends since the mid-1990s with almost no reported problems. Ethanol currently accounts for 20-25% of all Brazil's vehicular fuel, compared with 3.5% in the U.S.

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[10] See for example Organization of Economic Cooperation and Development (OECD), International Energy Agency (IEA), *Biofuels for Transport*, 2004, page 102, also available online at www.iea.org.textbase/nppdf/free/2004/biofuels2004.pdf

[11] Minnesota State University, Center for Automotive Research (MNCAR), *Use of mid-range ethanol/gasoline blends in unmodified passenger cars and light duty trucks*, July 1999.

[12] IEA, *op. cit.*, pages 103-104

[13] ESMAP, *op. cit.*, page 29

Figure 1: Modifications required in existing fleets for gasoline-ethanol blends

	Ethanol content in fuel				
	<5%	5%-10%	10%-25%	25%-85%	>85%
Carburetor	N	Y	Y	Y	Y
Fuel injection	N	N	Y	Y	Y
Fuel pump	N	N	Y	Y	Y
Fuel pressure device	N	N	Y	Y	Y
Fuel filter	N	N	Y	Y	Y
Ignition system	N	N	Y	Y	Y
Evaporative system	N	N	Y	Y	Y
Fuel tank	N	N	Y	Y	Y
Catalytic converter	N	N	Y	Y	Y
Basic engine	N	N	N	Y	Y
Motor oil	N	N	N	Y	Y
Intake manifold	N	N	N	Y	Y
Exhaust system	N	N	N	Y	Y
Cold start system	N	N	N	N	Y

Legend: Y: Modifications are probably necessary; N: Modifications are not necessary
Source: ANFAVEA, 2005[14]

For fuel blends with more than 10% ethanol, the needed modifications become so substantial that it is not practical to intervene on existing conventional vehicles, and specially made vehicles are required instead. Specifically designed vehicles are necessary to run on pure hydrous ethanol (95-96% ethanol and 4-5% water), which is cheaper than the anhydrous ethanol used for blending, since it does not involve the additional dehydration process; over four million cars run on pure hydrous ethanol in Brazil.[15] The flex-fuel vehicles (FFVs) introduced in Brazil in 2003 can run on hydrous ethanol or any gasoline-ethanol blend, and represent about 80% of all cars currently sold in the country.[16] E85 FFVs in the U.S. can run on either gasoline or blends up to E85, and currently number over two million.[17] FFVs incorporate special mechanisms that detect the type of blend being used and automatically adjust engine combustion parameters for optimal performance.

Even though ethanol is mostly blended into gasoline for spark-ignition vehicles, it is also possible to blend it into conventional diesel fuel. However, this so-called “E-diesel” is not a blend but rather an emulsion (a suspension between two liquids that does not involve mixing of their respective molecules).[18] This fuel is still very limited due to performance and safety issues. Ethanol has a high octane value (resistance to auto-ignition), which is beneficial in spark-ignition engines where a

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[14] ANFAVEA, *Alcohol Fuel Vehicles and Flex Fuel Vehicles*, Presentation by Henry Joseph Jr. of Volkswagen Brazil, available online at http://www.unfoundation.org/files/misc/biofuels_presentations/Joseph%20Session%205%20FINAL.pps#256,1,Alcohol Fueled Vehicles & Flex Fuel Vehicles
[15] *Ibidem*
[16] Credit Suisse, *Alternative/Renewable Energy*, March 2007, page 108
[17] IEA, *op. cit.*, page 104
[18] IEA, *op. cit.*, page 106

spark begins the combustion. Accordingly, ethanol has a low cetane value (tendency to auto-ignite), which is an unfavorable characteristic in compression-ignition or diesel engines where fuel is injected into heated compressed air to induce auto-ignition. According to several sources, ethanol-diesel blends also represent potential fire or even explosion hazards.[19] For these reasons, E-diesel is still an experimental fuel; tests and demonstrations are being conducted on its use in heavy-duty trucks, buses, and farm machinery.[20] The World-Wide Fuel Charter, a joint initiative of U.S., European and Japanese automobile and engine manufacturers' associations, argues that until these issues are resolved, no ethanol should be blended with diesel due to significant safety concerns.[21]

- *Ethanol in ETBE.* Apart from being used as a fuel either neat or blended, ethanol can also be used as an ingredient to produce ETBE, a gasoline oxygenate. Oxygenates (hydrocarbons containing oxygen) are added to gasoline to increase the share of oxygen, making the fuel burn more cleanly (reducing formation of carbon monoxide) and enhancing its octane rating (a measure of gasoline's resistance to auto-ignite: a high octane rating is desirable in spark-ignition engines). Lead was traditionally used as an octane enhancer, until the 1980s and 1990s, when most governments phased it out for health reasons. Methyl tertiary butyl ether (MTBE), another oxygenate, was increasingly used as a gasoline additive. However, due to tank spills and leakages, and its high solubility in water, MTBE often leached into reservoirs and ground water supplies, creating health and environmental impact concerns. Ethanol offered a solution to such issues.[22]

  Ethanol can be a feedstock in the production of ethers used as gasoline additives, the most common of which is ethyl tertiary butyl ether (ETBE). ETBE is produced by combining ethanol and isobutylene, and contains 47% ethanol.[23] While both ETBE and MTBE are oxygenates, ETBE contains less oxygen. Since the blending of oxygenates and gasoline usually targets a certain weight percentage of oxygen in the finished fuel, more ETBE than MTBE is blended in gasoline to obtain the same oxygen share. In the U.S., the mandated weight percentage of oxygen was 2%, but today no single value is mandated. Under the State Winter Oxygenated Fuel Program, selected areas in the country are required to comply with oxygen percentages during winter months. Requirements vary across the country, with 2.7% as the average and most common value.[24] Similarly, in Europe the maximum oxygen

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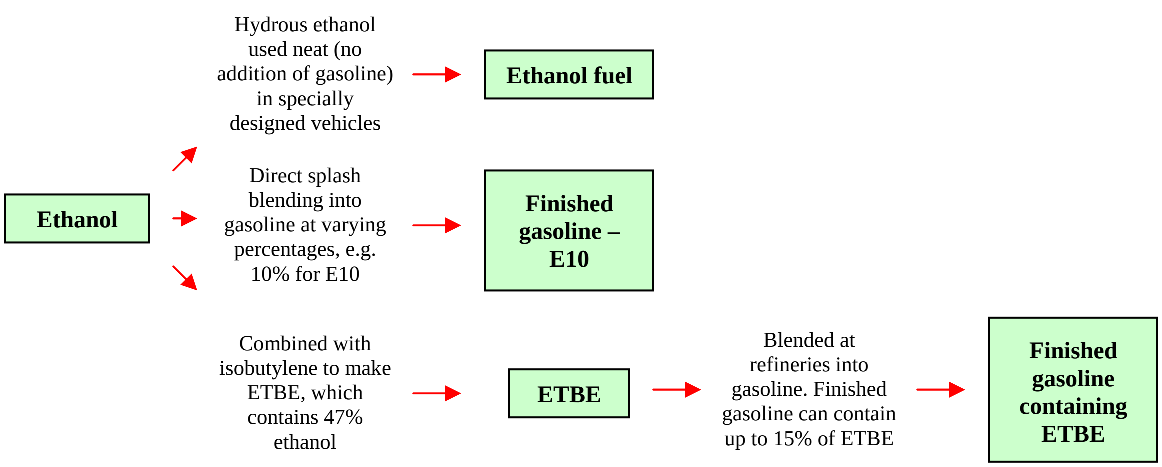
[19] As quoted in ESMAP, *op. cit.*, page 87
[20] See Department of Energy – Energy Efficiency and Renewable Energy Office (DOE-EERE) at http://www1.eere.energy.gov/biomass/renewable_diesel.html
[21] World-wide Fuel Charter, available at http://www.autoalliance.org/archives/wwfcbrochure.pdf
[22] U.S. Department of Energy, Energy Information Administration (EIA), *MTBE, Oxygenates, and Motor Gasoline*, available online at http://www.eia.doe.gov/emeu/steo/pub/special/mtbe.html
[23] The E.U. considers 47% of ETBE as biofuel: see the E.U. Directive 2003/30/EC at http://eur-lex.europa.E.U./LexUriServ/site/en/oj/2003/l_123/l_12320030517en00420046.pdf, as well as the page http://ec.europa.E.U./research/energy/nn/nn_pu/renews/003/article_2273_en.htm. According to ESMAP, ETBE contains 44% of ethanol: see *Potential for Biofuels for Transport in Developing Countries*, October 2005, page 17, available online at http://wbln0018.worldbank.org/esmap/site.nsf/files/312-05+Biofuels+for_Web.pdf/$FILE/312-05+Biofuels+for_Web.pdf.
[24] U.S. Environmental Protection Agency (EPA), see http://epa.gov/otaq/oxygenate.htm

weight content in gasoline is 2.7%, but the E.U. recently issued a proposal to increase this to 3.7%.[25] For an average 2.7% weight percentage of oxygen, finished gasoline can contain up 15% of ETBE which, in turn contains less than 50% ethanol.[26]

Economic and industrial actors undertake different strategies to reach established targets. For ethanol, this is accomplished through the widespread production and use of ETBE (illustrated by the E.U. example below), or by directly blending ethanol into gasoline (illustrated by the U.S. example).

Figure 2: Different uses of ethanol as a fuel and as an additive



Source: Econergy

- *European Union*. The E.U. Directive on the promotion of biofuels establishes that by 2010 a minimum 5.75% of energy content of all transportation fuels will need to be provided by biofuels, leaving member states to decide the best strategies and fuel mixes to reach the objective.[27] Ethanol accounts for most of the remaining 20%, mostly as ETBE. About 77% of all ethanol used in gasoline in the E.U. is in the form of ETBE, and 23% is in the form of directly blended ethanol.[28] In countries such as France, ethanol from sugar beets is primarily used in the form of ETBE added into gasoline.[29] It is expected that ETBE will continue to be a key tool to introduce and increase ethanol use in Europe.
- *United States*. Under the Renewable Fuel Standard Program, the U.S. mandated 7.5 billion gallons per year of renewable fuels to be used by 2012.[30] Ethanol is by

[25] See the E.U. page at http://europa.E.U./rapid/pressReleasesAction.do?reference=IP/07/120
[26] Total corporation biofuels information at http://www.total.com/en/corporate-social-responsibility/special-reports/biofuels/biofuels-focus/biofuels_first_generation_11305.htm. Also based on a conversation with Mr. Bob Reynolds of Downstream Alternatives, May 2007
[27] E.U. Directive 2003/30/EC, *cit.*, article 3.1.b.ii
[28] Lyondell, *Bio-ETBE: Easy-To-Blend Ethanol, A Major Contributor to European Expansion*, Hart World Refining Fuels Conference, Washington, DC 2006
[29] ESMAP, 2005 (*op. cit.*), page 17
[30] 2005 Energy Policy Act. See the Renewable Fuel Standard Program, U.S. Environmental Protection Agency, at http://epa.gov/otaq/renewablefuels/index.htm

far the most important player in this sector. In the U.S., however, ETBE is currently not used; 100% of all ethanol in gasoline is directly blended. The phase-out of MTBE did not lead to use of ETBE; rather, an increasing number of states, lead by California and New York, banned MTBE for its contamination drawbacks. However, concerned that ETBE may create similar issues, distributors simply resorted to increased blending of pure ethanol and gasoline without using ETBE.[31] In other words, they substituted MTBE with outright ethanol, which by itself is a satisfactory means for achieving cleaner-burning gasoline and octane enhancement, and has a positive impact on gasoline costs as well as spurring in-country ethanol production.[32]

While the production of ETBE is a relatively simple process, involving the combination of isobutylene and ethanol, it benefits from the presence of an established petroleum refining or petrochemical complex nearby. Typically, the isobutylene needed in the process of manufacturing ETBE is distilled from a C4 hydrocarbon mix at refineries or petrochemical plants with steam cracking capacity. Steam cracking involves the breakdown of complex, heavy hydrocarbon molecules of into simpler, lighter ones such as isobutylene, by cracking the carbon-carbon bonds. Isobutylene can be bought ready-made, but it costs almost twice as much as a C4 mix (USD 900 to USD1,000 per ton as opposed to USD 400 to 500 per ton), which is also more easily available on the market. Also, by-products other than isobutylene from C4 cracking can be re-utilized at the refinery. Hence, ETBE production and petrochemical/refining activities typically enjoy a symbiotic relationship. In the U.S., a relatively small ETBE producing unit with a capacity of 2,000 b/d involves a capital cost of about USD 15 million, assuming no additional costs are needed to provide dehydrated ethanol and isobutylene for the process.[33]

- *Biodiesel*. Biodiesel is suitable for use in conventional compression-ignition engines designed to run on fossil-fuel based diesel fuel. Unlike ethanol, existing engines require few or no technical modifications to operate on pure biodiesel or any blend level.[34] However, minor modifications (seals, piping) are required for use at higher percentage blends or 100% pure biodiesel, unless the initial equipment is specifically guaranteed by car manufacturers for use with biodiesel; this partly explains why biodiesel is most often used as a blend with petro-diesel.

  Vehicle manufacturer warranties for biodiesel blends are an additional issue that should be considered separately to assess the technical feasibility of using biodiesel. For light vehicles, most engine manufacturers currently do not provide warranties for blends above ratios of 5%. Problems reported when using high percentage blends include degradation of certain synthetic and natural rubber compounds in vehicles

[31] There is no federal ban on MTBE in the U.S., but 25 state legislations currently ban it. An EPA Blue Ribbon Panel only recommended substantially reducing the use of MTBE nationwide and accelerating research on its substitutes: see http://www.epa.gov/mtbe/action.htm
[32] Report for California State by Downstream Alternatives. See http://www.ethanol-gec.org/summer2000/sum0027.htm
[33] Source: ETBE production industry representatives (confidential), June 2007.
[34] IEA, *op. cit.*, pages 108-109 and Credit Suisse, *op. cit.*, page 113

(especially vehicles more than 15 years old) due to biodiesel's solvent action. Other problems stem from the cleansing action of biodiesel that releases carbon and other deposits of conventional diesel that accumulate on tank walls or in piping, leading to clogs in injection systems or filters or actual damage. Also, deposits may form if biodiesel is left sitting in tanks for several weeks. This may require substituting certain rubber components with more resistant materials or more often, and more frequent or thorough maintenance of engine parts.

Biodiesel also entails a decrease in fuel economy given its lower energy density (expressed in MJ or BTU per liter or kg) with respect to conventional diesel, ranging between 0.9-2.1% for B20 and 4.6-10.6% for B100[35] (these reductions are more moderate than those observed with ethanol). On the other hand, biodiesel has higher viscosity than conventional diesel, thereby reducing the potential for leaks and increasing engine efficiency, and biodiesel blends also improve overall engine lubrication. Officials involved in a pilot project to use biodiesel in the municipal bus fleet in Tegucigalpa, Honduras, cited this as a benefit and reported slightly lower operation and maintenance costs in addition to the cost savings that applied in 2006. However, other cases suggest there may be other sources of increased operation and maintenance costs.

Biodiesel may require special handling, depending on the local climate where it is used. Pure biodiesel freezes or gels at higher temperatures than conventional diesel, making heated fuel lines and tanks necessary, even in moderate climates. Also, biodiesel's lower cetane values, compared to conventional diesel, can create minor issues with cold starting and ignition performance, especially in cooler climates. Additives are available to address such concerns.

Overall, modifications are required only for higher blends, and they are very modest, so that biodiesel may be considered the "car-ready alternative diesel fuel" as its proponents assert. [36] In spite of many comments arguing for greater biodiesel blends, however, the World-Wide Fuel Charter still advises that a maximum 5% biodiesel should be blended in country categories 1, 2 and 3, and that no biodiesel at all should be included in the environmentally most stringent diesel category 4 markets (those with the most advanced emission control requirements).[37]

Biodiesel is commonly used as B5 in Europe, which accounts for about 80% of global biodiesel supply and demand. The European Biodiesel Board has stated that the fact that use of biodiesel blends above 5% voids most vehicle engine manufacturers' warranties is a major constraint to reaching the 5.75% target set by the E.U. for all fuels by 2010, [38,39] and it has been promoting the case for more consistent biodiesel

[35] ESMAP, *op. cit.*, pages 83-85
[36] Credit Suisse, *op. cit.*, page 112
[37] World-wide Fuel Charter, 4th Edition, September 2006, available online at http://www.autoalliance.org/archives/wwfcbrochure.pdf
[38] *Ibid*, page 114
[39] E.U. Directive 2003/30 available online at http://europa.E.U./scadplus/leg/en/lvb/l21061.htm

policies and vehicle warranties across the E.U. The EBB argues that tests by motor vehicle manufacturers in the E.U. on the use of blends of 5-10%, 25-30% and 100% suggest that the technical difficulties are not so significant, and they suggest the development of guarantees for each type of use, with only minor modifications for the higher blends.[40] Countries like Germany, Austria and Sweden have promoted the use of pure biodiesel for truck fleets; France has tested B30 for some fleet applications.[41]

The U.S. market for biodiesel is much more modest than the ethanol market. The most common blend used is B20, particularly in federal, state and alternative fuel provider truck fleets,[42] and 1-2% blends are also used as lubricant additives for ultra-low sulfur diesel fuels which have limited lubricating properties. The Energy Efficiency and Renewable Energy (EERE) office of the U.S. Department of Energy (USDOE) states that B20 can be used in vehicles with no modifications, as well as in fuel oil and heating oil boilers and turbines, while higher blend levels (B50 to B100) may require modifications such as changing seals and gaskets with biodiesel-compatible models, or the use of tank or fuel line heaters. Most engine manufacturers' warranties acknowledge that biodiesel blends up to 5% do not cause any problems, provided the biodiesel used meets U.S. or E.U. specifications, and some manufacturers recognize even higher blend levels. However, the U.S. diesel engine sector is conducting more evaluations before endorsing warranties for use of higher blends. Damage directly attributable to biodiesel is not covered by most engine manufacturer warranties, but is often covered by fuel suppliers' general liability insurance.[43]

Vehicle modification costs. Costs to make vehicles biofuel-compatible are particularly difficult to quantify in general terms, because the modifications required vary depending on the blend level and the status and age of the specific vehicles involved. The difficulties in quantifying costs also reflect the fact that some interventions required for biofuel use can take the form of slightly more frequent or additional maintenance and replacements.

- For ethanol blends up to 10% requiring only very minor modifications, the cost may be on the order of only a few U.S. dollars per vehicle; most manufacturers have already made such modifications standard in most recent models. For blends in the range used in Brazil (E20-E26), costs can be higher, but these are usually factored into the price of new vehicles sold in such markets. For even higher blends, the U.S.

[40] European Biodiesel Board (EBB), http://www.ebb-E.U..org/biodiesel.php
[41] IEA, *op. cit.*, pages 108-109
[42] The 1992 Energy Policy Act requires that new purchases of certain federal, state and alternative fuel provider fleets be alternative fueled vehicles; the EPAct was amended in 1998 by the Energy Conservation and Reauthorization Act (ECRA), which recognized B20 or higher biodiesel blends as complying with EPAct's requirement, thus increasing use of B20. The greatest user is today the Department of Defense. See http://www1.eere.energy.gov/biomass/renewable_diesel.html
[43] Department of Energy (DOE), Energy Efficiency and Renewable Energy (EERE), *Biodiesel handling and use guidelines*, September 2006, http://www1.eere.energy.gov/biomass/renewable_diesel.html

experience with flex-fuel vehicles suggests that a few hundred dollars may be enough to make a vehicle compatible with up to 85% ethanol.[44]

- For biodiesel, limited-percentage blends require virtually no modifications, so that costs are almost negligible and could be considered as ordinary maintenance. For higher percentage blends, few modifications are needed and, similarly to conversions for higher ethanol blends, their cost is limited to a few hundred dollars. Experience in a pilot project introducing biodiesel for public buses in Tegucigalpa, Honduras, suggests that the actual cost of converting a bus to pure biodiesel can be as low as USD 500, and mostly in the range of USD 500 to USD 1,000;[45] all interventions passenger cars typically involve lower costs than large ones used for public transportation.

Power generation. Biodiesel may be used not only in compression-ignition engines, but also in other equipment designed for diesel fuel, particularly fuel oil or heating oil boilers used for space or water heating, and turbines for power generation. The same observations made regarding use in vehicles apply for these applications. The USDOE observes that B20 has been tested and can be used with no modification in all equipment designed to run on diesel fuel, and with limited modifications to ensure compatibility of some materials for higher percentage blends.[46] However, while the use of biodiesel in power generation may be beneficial from the standpoint of reducing emissions, their lower energy content does result in lower thermal efficiency and erodes the economic performance of projects.[47] For instance, an analysis conducted by Econergy for use of ethanol in gas turbines in the Caribbean concluded that the profitability of implementing this type of project was insufficient to attract investor interest.

In addition, and perhaps of greatest interest for Mozambique, is the possibility of using pure vegetable oil in diesel cycle equipment. Several countries report experience with power generation in remote areas using crude vegetable oil as opposed to biodiesel; two are presented in Box 4 and Box 5.

Household and agricultural appliances. With a national electrification rate of 8%, households in Mozambique have limited access to power for such basic needs such as lighting and cooking, particularly in rural areas where about 63% of the population resides.[48] Small-scale agriculture is still predominant in Mozambique, with larger-scale plantations developing more recently in selected areas of the country.

Fuels used for the main household functions are firewood, paraffin and charcoal for cooking and, to a very limited extent, for heating. Paraffin, especially, is used for lighting. As in many other regions in Africa, the pattern of rural fuel use in Mozambique is not sustainable due to environmental issues associated with deforestation and emissions, as well as health and safety concerns about burning traditional fuels in poorly

[44] IEA, *op. cit.*, pages 178-179
[45] USTDA – Econergy, Clean Air Program for Tegucigalpa Definitional Mission, May 2007
[46] DOE/EERE, *op. cit.*, pages 13-14
[47] Thermal efficiency is a measure of the efficiency of converting a fuel to energy and useful work
[48] World Bank, *World Development Indicators 2006*, data for 2004: http://devdata.worldbank.org/wdi2006

ventilated spaces. There are significant environmental and public health benefits associated with the development of alternative and more sustainable fuels for rural use, namely renewable biofuels like ethanol, biodiesel and vegetable oil. Ethanol-based gelfuel, in particular, could play a key role for cooking activities.

The current situation for the main fuels used in rural areas of Mozambique is briefly described below.

- *Lighting*. Current lighting in rural areas of Mozambique is extremely limited; the majority of economic and social activities following the cycle of sunrise and sunset.[49] Household lighting needs are mostly met with a widespread use of paraffin, which is subsidized and costs much less (up to 50%-60%) than alternative lighting fuels such as kerosene or LP gas. The rural population would certainly welcome the development of renewable lighting fuels, and the benefits could be considerable. The immediate scale of displacing lighting fuels with biofuels, however, would be limited when compared to opportunities for cooking fuels.
- *Heating*. Mozambique's tropical and subtropical climate does not give rise to systematic space heating needs, but fuel wood and charcoal are used for very limited or occasional heating in households during the winter months (June – August). The coldest month in Mozambique is July, with average temperatures in Maputo ranging from 13° to 24° C. The western inland and mountainous regions are slightly cooler (5° less) and more humid in the rainy season (October to March).[50] As with lighting uses, resorting to biofuels for heating would certainly be beneficial, although with a much more limited scope with respect to the traditional fuel displacement associated to cooking.
- *Cooking*. Among basic household functions, potential biofuel opportunities are the most interesting. Rural and suburban households primarily rely on firewood, paraffin or charcoal for cooking purposes. Environmental concerns associated to widespread deforestation are serious in Mozambique, as well as grave safety and health hazards that families are exposed to when cooking with traditional fuels. In South Africa, as in several other countries on the Continent, most runaway shack fires in informal settlements or suburban areas are caused by knocking over candles or paraffin stoves thereby starting fires that spread rapidly because houses are made of highly inflammable material and closely packed another. For example, Johannesburg's suburbs alone record about 600 shack fire incidents each year, leaving almost 3,000 people homeless.[51]
- *Agricultural uses*. Gas and paraffin have a wide variety of agricultural uses, including water pumping, water heating, refrigeration and heating for breeding.

On the basis of current trends in rural fuel use, the following sections provide an overview and recommendations for the most promising opportunities for biofuels in Mozambique.

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[49] Conversation with Simon McPartland, Maputo, May 2007
[50] Economist Intelligence Unit, *Mozambique Country Profile 2007*
[51] See for example the City of Johannesburg website at http://www.joburg.org.za/2005/feb/feb25_fire.stm, or for Cape Town http://www.capegateway.gov.za/eng/pubs/news/2006/jan/123057

Gelfuel. Gelfuel is produced from ethanol, and primarily used for cooking, although it may also be used for limited heating purposes such as those practiced in Mozambique, and potentially for other alternative uses, displacing gas or paraffin, as described in more detail below. While patents cover gelfuel's key components (in particular, the imported thickening agent and specially designed stoves), the product itself is manufactured by a simple process, and is not patent-protected.

Box 4: Rural electricity production using raw jatropha oil in Mali

Straight vegetable oil has been used in place of conventional diesel fuel for power generation in Mali. A jatropha plantation for biodiesel production in the Garalo region extracts vegetable oil for use directly in diesel generators providing electricity to surrounding villages.* This project, implemented by the Bamako-based Mali Folkecenter, aims to use locally produced jatropha oil to operate small-scale diesel generators for power and productive applications. The project will eventually result in a planting of 1,000 ha of jatropha, 115 of which have already been planted. It is expected that approximately 900 remaining ha will be planted over the next three years. Key project parameters are described below.

Yields. Jatropha fruit yields depend heavily on soil quality and rainfall. Under normal circumstances, relatively good soil quality and rainfall levels exceeding 700 mm/year will result in jatropha fruit yields of approximately 4 tons/ha. Enhanced soil quality and above average rainfall will result in even higher yields. With respect to oil yields, 4 kg of jatropha fruit will produce approximately 1 liter of oil; the Mali project has reported oil yields of 1 liter from 3.5-4.5 kg of harvested seed. A typical plant takes an average of two years to produce harvestable fruit. In the Garalo region in Mali, rainfall levels have reached 1,400 mm/year, which has resulted in a yield of 5-6 tons of jatropha fruit per hectare.

Processing. The project in Mali uses a mechanical screw press to extract the oil from the harvested jatropha seed. The press is locally manufactured and can process up to 100 kg of seed in one hour. For larger amounts of seed, imported presses are used. The project underway in the Garalo region is seeking a press with the capacity to extract oil from 24 tons of seed per day.

Oil quality. The extracted oil is of high enough quality to be used in the diesel engines already in place at the plantations. To run on 100% vegetable oil, the engine's injection tubes required modification. The Mali Folkecenter is also testing a two-tank configuration for operating the engines on a diesel/vegetable oil combination. In this case, the engines are started up using regular diesel fuel, then run on pure vegetable oil while at full load, and are again shut down using conventional diesel fuel for engine cleaning. This second scenario does not require any modifications to the diesel engine.

Pricing. The current price of diesel in Mali is approximately FCFA 525/liter (USD 1.08/L). Cotton seed oil is priced at FCFA 400/L (USD 0.82/L), and it is expected that jatropha oil would be even cheaper.

* Information on the project was provided by Ibrahim Togola of the Mali Folkecenter (MFC) in May, 2007. The project was in its testing phase based on limited biodiesel production. Power generation from pure vegetable oil is an established practice already in Mali. See also, Lydia Polgreen, "Mali's farmers discover a weed's potential power," *New York Times*, September 9, 2007, for a description of another jatropha project in Mali.

Box 5: Rural electric generation based on vegetable oil in the Brazilian Amazon

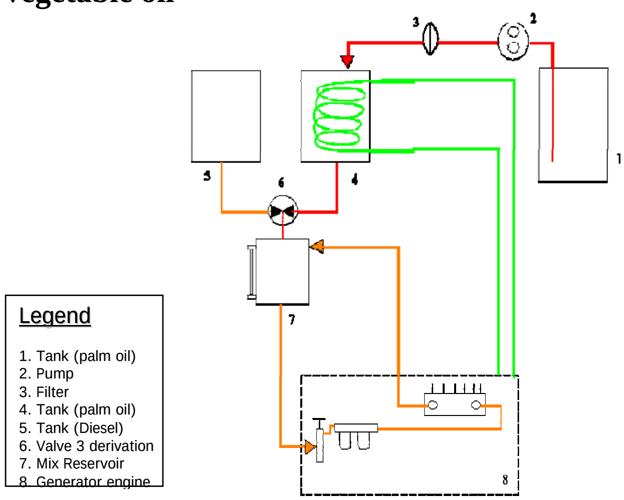
Straight vegetable oil is being used for power generation in the Amazon Basin, where conventional electric distribution for isolated communities is economically and technically impracticable.* In the Vila Soledade community, Moju, in Pará State (700 inhabitants, 120 households), electricity was previously provided by a conventional diesel engine, which involved technical inefficiencies and imperfections in supply, as well as economic inefficiencies given that the fuel used was all delivered from long distance. To promote more sustainable community development, the Brazilian Biomass Reference Center/Energy and the Electrotechnical Institute of São Paulo University (CENBIO IEE/USP) developed a pilot project for the implantation and testing of a vegetable oil-compatible power generation unit (PROVEGAM). The PROVEGAM project installed a diesel generator adapted with a conversion kit to operate with crude palm oil to test a vegetable oil-fueled engine in real operational conditions. Key project features are:

- The engine used has an installed capacity of 115kVA, with a feeding system that, thanks to a conversion kit, allows its operation with diesel oil in the beginning and at the end of its cycle. The system also reduces the palm oil's viscosity through heat, using the outlet cooling water from the engine as the heat source. The system is presented in Box 6.
- The engine starts its operation using diesel oil and, after 15-20 minutes (during which the palm oil is heated), the valve is manually switched to the palm oil tank, which starts feeding the engine. A few moments before the end of engine operation, the valve is switched again to diesel, in order to clean any palm oil residues inside the engine.
- The engine operates six hours per day (17:00-23:00) and has been generating about 72,500KWh/year, with a cost of 0.382 R$/kWh (0.19 USD/kWh).
- After approximately 4,500 hours of operation, project monitoring found fuel consumption with palm oil to be around 10% higher than diesel oil because of its lower calorific value (diesel's energy density is 10,150 kcal/kg while palm oil's is about 9,104 kcal/kg). Diesel oil consumption is about 10 liters/hour, while palm oil consumption is about 11 liters/hour.
- Palm oil use put the engine under greater strain particularly with respect to the injection system, fuel filters and the combustion system. A preventive maintenance program was designed to address such issues, although it entails increases in maintenance costs between 20% and 25%.

* CENBIO-Centro Nacional de Referência em Biomassa, *The Use of raw palm oil as fuel to electric generation in isolated communities in Amazon*, by Suani Teixeira Coelho; Orlando Cristiano Da Silva; Sílvia Maria S. G. Velázquez; Ana Flávia De Andrade Rebello Lisboa; Fabio De Godoy. Available online at www.cori.rei.unicamp.br/BrasilJapao3/resul_trbs.php?cod=294.

A pioneer project for the development of gelfuel in Southern Africa was launched in late 2000 in Zimbabwe. The Millennium Gelfuel Initiative[52] was carried out with support from the World Bank's Regional Program for the Traditional Energy Sector (RPTES) of the Africa Energy Group (AFTEG) and the Development Marketplace 2000 competitive grant program, in association with a Zimbabwean company (MGC, now Greenheat). The initiative included the technical optimization of MGC's "Greenheat Gelfuel", the design and adaptation of stoves, and the reduction of products' production, packaging and marketing costs. One year into the program, overall costs to consumers of gelfuel were reduced by 50%. The program has established the key parameters for economic and commercial viability of this system for cooking applications in Africa, on the basis of successful consumer tests and marketing assessments conducted in countries including Mozambique, Ethiopia, Malawi, Mali, Senegal and Zimbabwe, and it has identified potential follow-up projects and investment opportunities for the scaling-up of production according to market needs.

Box 6: Diesel engine adaptation for firing crude vegetable oil



Source: CENBIO, IEE/USP

In Malawi, experience with gelfuel provides an example of how policy can be critical to this fuel's success. The company D&S Gelfuel Ltd., in cooperation with Greenheat, began production and marketing of gelfuel in 2002. The product was sold in supermarkets for about USD 0.65/liter. A GEF/World Bank program was due to begin between 2002 and 2003, following specific studies carried out also on the basis of the government's intention to support gelfuel. However, due to various issues and concerns, the Malawi government did not conclude the agreement. Between 2005 and 2006, the government then imposed a 17.5% value added tax on gelfuel sales in spite of having committed to providing incentives for the product. As a result, gelfuel cannot compete with charcoal or paraffin in rural areas of Malawi, and D&S has interrupted its sale on the national market, concentrating activities on export to other countries such as Zambia. The company has been exploring options to develop a community-based ethanol plant based on the cultivation of cassava, which could considerably reduce the price of ethanol used to produce gelfuel.[53]

[52] Information on the Millennium Gelfuel Initiative available online on the World Bank website at the page http://web.worldbank.org/WBSITE/EXTERNAL/OPPORTUNITIES/GRANTS/DEVMARKETPLACE/0,,contentMDK:20208149~menuPK:867620~pagePK:180686~piPK:180184~theSitePK:205098,00.html

[53] Conversation with Sandy Wynne-Jones of D&S. Also see http://www.bioenergy-lamnet.org/publications/source/LamnetPublications/5-Wynne-Jones.pdf

Zoe Enterprise, based in Matola, is importing gelfuel from the South African company Greenheat (previously MGC), and selling it in the Maputo suburbs, in a pilot project to market gelfuel that commenced in February 2007. The product is marketed in Mozambique under the name of *Chama Azul* ("blue flame," from the ethanol-based fuel's color when burning) and comes in 350-ml bottles at a cost of 25 Mt (USD 1), 1-liter for 65 Mt (USD 2.5) and 5 liters for 290 meticals (USD 11). The project's plan for the longer term is to set up gelfuel production plants directly in Mozambique, using locally grown feedstock. According to Thelma Venichand of Zoe Enterprise, availability of local feedstock would enable Zoe Enterprise to reduce the cost per liter to around 40 Mt.[54]

The marketing of imported finished merchandise, however, is a necessary step in introducing the product to local customers still largely unfamiliar with it. This also helps prove the product's commercial viability to financial institutions such as the Fundo Nacional de Energia (FUNAE), increasing their awareness of gelfuel's many benefits and thus their willingness to provide the resources needed to develop an in-country production.[55] This introductory phase, however, is proving particularly challenging since, unlike in most other countries in Southern Africa (Malawi, Botswana, Zimbabwe, Swaziland, and South Africa), gelfuel is not duty-free in Mozambique, nor are any incentives provided. In Mozambique, a 20% customs tax adds to 17% VAT and 17% sales taxes, worsening gelfuel's already unfavorable price competitiveness with respect to traditional household fuels. This situation risks creating a vicious circle by which, due to a disadvantageous policy framework, gelfuel may never prove that commercial viability it needs in order for its in-country production to be supported by local financial institutions. There is a critical scope for policy to eliminate duties and enact effective incentives for a fuel with a key potential for daily use of the poorest sectors of Mozambique's population.

Key characteristics for gelfuel are the following.[56]

- *Product features*. The product consists of a thick green jelly with a consistency similar to hair gel, stored in plastic bottles, which is used by being poured into special burners and lit. A key advantage of gelfuel with respect to traditional fuels is that it is very safe and spill-proof, thanks to its consistency and stable form. If spilt, it does not burn as paraffin easily does, avoiding accidental fires. Also, gelfuel is non-toxic, has no smell and does not contaminate food like charcoal, fuel wood or paraffin. It is

[54] Thelma Venichand, interview, July 16, 2007.
[55] The Zoe Enterprise representative indicated a rough estimate of USD 500,000 for resources needed to start up in-country production of gelfuel. Before production is considered, however, the project's introductory phase would greatly benefit from financial support for marketing activities, with needs estimated to range between USD 20,000 and USD 30,000.
[56] Most of the information and description of gelfuel is based on information obtained from the following companies involved in the production and/or marketing of the product: Greenheat (South Africa), Mr. Eric Barrett; D&S (Malawi), Mr. Sandy Wynn-Jones; and Zoe Enterprises (Mozambique), Ms. Thelma Venichand.

clean and virtually smoke-free when burning, leaving practically no residue.[57] Gelfuel reduces a family's safety risks from fires or respiratory problems, decreases workload and cleaning associated to cooking activities, and makes storage safer, easier and not vulnerable to water. The benefits of developing this product locally also include economic growth and increased employment in rural areas.

- *Product manufacturing*. Gelfuel does not require an expensive or technologically advanced manufacturing process. The product contains about 80% ethanol, about 1.6-2.5% of a chemical thickening agent, and the rest is water. The thickening agent is imported from various European providers, and the quantity blended varies depending on quality of ethanol used and viscosity desired. The manufacturing process requires storage and blending tanks, and filling stations with pneumatic fillers similar to large medical syringes. No heat is required in the process. Ethanol, being an alcohol, tends to corrode metals with which it is in contact. Most material involved in the preparation of gelfuel must be rust-resistant or treated against corrosion.
- *Manufacturing costs*. Costs can vary considerably according to price of ethanol, the main ingredient for gelfuel. In South Africa, for example, the price of ethanol can range between 2 and 5 ZAR/liter (28-70 U.S. cents/liter) depending on quality. In Malawi, over a few years the price of ethanol has risen considerably, from USD 0.10 to USD 0.80/liter. While ethanol prices might be expected to rise as the fuel is used for motor vehicles, expanded production in Mozambique would allow for lower-cost supplies and no import duties. The thickening agent can be bought at prices ranging from 48 to 78 ZAR/kg (USD 6.8-11), depending on negotiations with different suppliers. On average, 17 to 20 kilograms of thickening agent are used for 1,000 liters. Packaging also affects final prices; the cost for bottles in South Africa is about ZAR 2.35/USD 0.33 (5 liters), or ZAR 0.95/USD 0.13 (1 liter). Given varying ingredient prices, different manufacturing locations and different tax regimes, it is impossible to state one figure for gelfuel production costs. An estimated maximum of USD 0.7/liter may provide a very rough indication. The cost of ethanol remains the key variable. Community-based production of ethanol may significantly reduce costs. A project for a village cassava-based ethanol plant in Malawi is expected to produce finished gelfuel for as low as USD 0.25/liter.[58]
- *Retail price*. In South Africa, a five-liter bottle (the most cost-effective size) is sold for ZAR 28 (USD 3.90). In Malawi, gelfuel used to be marketed at USD 0.65/liter a few years ago, but the value added tax recently introduced would have raised the price to USD 0.8/liter. This would not be competitive with charcoal in rural areas, and the product is therefore currently not being marketed. It is estimated that community-produced gelfuel in Malawi could be sold for as low as USD 0.45. In Mozambique, a 5-liter bottle is sold for USD 11, and a 1-liter bottle for USD 2.5,

[57] Some analyses have challenged this claim. Philip Lloyd and Eugene Visagie of the Energy Research Centre, University of Cape Town, note that CO emissions "did not meet an emissions standard of a CO:CO2 ratio of <0.02, … gave off excessive unburned hydrocarbons … [and] some gelfuels had excessive water …" See "The testing of gelfuels and their comparison to alternative cooking fuels," available at http://www.erc.uct.ac.za/publications/Lloyd%20Visagie%20DUE%20PAPER%202007.pdf.
[58] Conversation with Mr. Sandy Wynn-Jones, D&S, Malawi, May 2007

reflecting the very unfavorable situation for the launch of this product in the country and the need for a more supportive policy framework.

- *Burners*. Gelfuel stoves or burners are similar to fondue stoves, and gelfuel has actually been also developed in small volumes for up-scale recreational or catering applications in industrialized countries such as Sweden. Since the year 2000, the Millennium Gelfuel Initiative developed and optimized several types of gelfuel-dedicated stoves, including a burner designed to allow retrofitting into more than 15 traditional African stoves. Original gelfuel stoves were also modified starting in 2003 to enable the safe use of straight ethanol, which costs less than gelfuel manufactured from it (roughly two thirds, depending on the country).[59] Stoves sold in South Africa today cost about ZAR 75-80 (USD 10-11) for stainless steel models (also manufactured in India) and ZAR 60-65 (USD 8.5-9.2) for coated steel models (mostly locally produced). These materials have been introduced to avoid degradation and rusting of the metal. Municipalities have also tried distributing gelfuel stoves at no cost, in suburban areas, to encourage the diffusion of the fuel. Stoves distributed for free have typically been of low-quality and rust easily. Stoves designed by Greenheat are covered by a design copyright.
- *Quantities involved*. In a typical stove, gelfuel consumes at about 3 grams/minute. For an average family of six, it is estimated that about 2 liters of gelfuel for cooking purposes are needed every week.
- *Uses*. Cooking is the main use for gelfuel. However, other uses have been tried. For limited heating purposes, gelfuel can also be burned in the cooking stoves. In some regions of South Africa, gelfuel has been used for frost prevention, burning it in tank drums beneath trees with new buds to dissipate frost, displacing the burning of truck tires. Several other applications for gelfuel have been reported, all displacing the burning of paraffin or gas, including water heating (also for fish farms), refrigeration, heating for baking, and heating for chicken breeding.

While the most immediate market for Chama Azul is the population that currently uses kerosene or LPG, Venichand says that the population using charcoal is the more attractive market, given size of the population that still relies on it for its cooking needs. A preliminary analysis of the competitiveness of the fuel, however, suggests that gelfuel in Mozambique, if based on domestic feedstock is not competitive without tax incentives and other support from the government. Table 5 presents the results of analysis based on fuel costs plus the annualized, undiscounted cost of the end-use device over a period of five years, which shows that gelfuel is approximately two to three times more costly than kerosene and gel fuel and about seven times more costly than charcoal (the end-use device has been assumed to be the most efficient, but the cost data have not been validated for Mozambique). This analysis is partly consistent with the results of the Ethiopian study, which argued that gelfuel would be more about twice as expensive as kerosene and 50% more than charcoal; only LPG proved considerably more expensive than gelfuel in Ethiopia. The results for Mozambique suggest that the favorable taxation regime for kerosene and LPG, together with the very low cost of charcoal, would pose a

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[59] World Bank, *Renewable Energy for Development*, 2004, page 19, available online at http://siteresources.worldbank.org/INTENERGY/Resources/Renewable_Energy_Brochure.pdf

major obstacle to widespread use of gel fuel without government intervention to reduce its relative cost.

Table 5: Comparative analysis of gelfuel and other household energy sources

Fuel	Unit	HV (MJ/unit)	Useful energy	Cost	Cost	Stove Cost	Stove Life
		(MJ/unit)	(MJ/unit)	(Mt/unit)	(Mt/MJ UE)	(USD)	(Years)
		[1]	[2]	[3]			
Gelfuel	liter	22.3	10.7	40.00	3.74	7.00	5
Kerosene	liter	35.3	17.7	18.80	1.06	20.00	5
LPG	kg	45.2	24.9	34.55	1.39	18.00	5
Charcoal	kg	29.0	12.2	7.00	0.57	1.25	4

Fuel	Annual Use*	Annual Cost	Monthly	Ranking
	MJ	(USD)	Expenditure	(% of lowest)
Gelfuel	17,400	1,200	100.15	742%
Kerosene	17,400	356	30.03	222%
LPG	17,400	512	42.93	318%
Charcoal	17,400	162	13.50	100%

Source: Heating and useful energy values, stove costs and characteristics, are taken from "Ethiopia: assessment of the potential to produce and market milennium gelfuel and straight ethanol as renewable household cooking fuels," undated (about 2001), provided by Boris Utria, World Bank/Maputo; Thelma Venichand, Zoe Enterprise. *Energy equivalent of one 50-kg sack of charcoal per month; monthly expenditure assumes five-year period.

Even so, the development of gelfuel could lead to the emergence of a domestic industry tied to consumption of domestically produced ethanol, while at the same time displacing imported fuels as well as domestic charcoal, which is likely to be associated with unsustainable harvesting of firewood. However, the product is not as competitive in Mozambique as it is in other countries because of the current tax regime for fuels as well as tariffs on gelfuel feedstocks; in the event that domestic supplies of ethanol could be used in gelfuel production, the cost to the consumer of the fuel would come down, but it would likely still exceed the alternatives. Considering the benefits it could create, it is recommended that gelfuel be exempt from excessively onerous fiscal regimes, and granted greater support by public policymakers.

4. Storage and distribution practices

Biofuels' liquid forms make them relatively easy to handle compared to gaseous fuels like compressed natural gas (CNG), which generally require pressurization, greater infrastructure changes and more expensive and complex interventions as part of their adaption. However, the handling of biofuels and their blending into gasoline do involve a few specific precautions and practices, particularly for ethanol.

Ethanol storage and distribution practices. Hydrous ethanol, obtained from the fuel's first distillation, contains about 95% pure ethanol and 5% water, and can only be used neat – it cannot be blended into gasoline. Ethanol must be dehydrated, producing anhydrous ethanol, for blending with gasoline. Ethanol is highly soluble in water, and any arrangement for its storage or distribution must avoid contact between the two. While the least expensive method for shipping ethanol over a long distance would be to use pipelines, it is very easy for ethanol to be contaminated by water normally found in petroleum pipelines and tanks, and the fuel would arrive at its destination “off specification” an unsuitable for blending into gasoline. Ethanol shipping through existing pipelines is almost never practiced due to water contamination concerns and other issues. For example, ethanol blends tend to degrade the anticorrosion coating inside the pipes, requiring more extensive use of corrosion inhibitors or pipe treatment with special coatings. Ethanol’s solvent action, which releases rust or gum deposits previously accumulated in pipes, necessitates extensive cleaning to avoid product contamination.

In Brazil, Petrobras has been transporting ethanol through three main multi-use pipelines for several years, but quality issues have not been completely resolved; there are a limited number of dedicated ethanol pipelines in the country, and Petrobras plans to expand and upgrade them.[60] The construction of dedicated pipelines is also being considered in the U.S., but great volumes of fuel are required to justify the investments needed, and there are still major concerns about the inevitable absorption of condensation water into ethanol. It is always possible to separate ethanol and water, but the cost of this process is such that the most widespread practice is to blend ethanol directly into gasoline just before its final distribution, to retail points by “splash blending” (loading two fuels into a vessel and driving the vehicle for some distance is often considered a sufficient means to blend the two fuels together).

These are the steps involved in the storage and final distribution of ethanol: (i) distillation of anhydrous ethanol at the ethanol production facilities, followed by denaturing it to make it unfit for human consumption, typically by adding a small quantity of a poisonous substance such as methanol or benzene; (ii) shipment from the production plants to a common bulk storage terminal; (iii) storage at the terminal, maintaining sufficient volumes are reached for distribution to fuelling stations; (iii) blending into gasoline immediately before loading trucks directed to filling stations (“splash blending”); and delivery of the blend (such as E10) to filling stations. Technically, splash blending is a relatively simple process requiring neither refining capabilities nor particularly sophisticated equipment or temperature or pressure controls. Its implications from a logistical standpoint, however, are rather cumbersome and involve an extensive use of trucks; this can prove difficult depending on the condition of the road network, and entail considerable costs, if long distances between the various points are to be covered. Also, direct blending of ethanol into gasoline can cause volatility problems, discussed in the next section.

Gasoline blendstock preparation for ethanol. Blending ethanol into gasoline has positive effects on the finished fuel’s octane rating, thanks to ethanol’s high blending octane rating. Markets with advanced refining and petrochemical industries enjoy an advantage in manufacturing ETBE from isobutylene and ethanol, and typically use this oxygenate as an octane enhancer instead of MTBE (which causes water contamination) or lead, the

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[60] Garten Rothkopf, *A Blueprint for Green Energy in the Americas, Pillar III: Infrastructure*, page 560, available online at http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=945774

traditional octane enhancer until the 1990s, when it was phased out due to its health risks. For countries such as the U.S. that have chosen not to use any ethers, or for others such as Mozambique with limited or no refining and petrochemical capabilities, ethanol can be directly used instead of ETBE to enhance gasoline's octane rating, oxygen content and clean burning properties, avoiding additional expenses for ETBE production.[61]

Splash blending of ethanol into gasoline, however, increases the finished fuel's RVP and thus its volatility, resulting in greater emissions of volatile organic compounds (VOCs). This is a concern particularly in warmer climates; regulated RVP ceilings for fuels marketed in temperate climates also vary according to the season.

For a country like Mozambique, which has been importing finished petroleum products and that is expected to start blending ethanol into gasoline, the composition of gasoline traditionally imported may prove inadequate for blending, because it would entail unacceptably high RVP values, which would be of particular concern in Mozambique's hot climate. Changes in the composition of gasoline imported by IMOPETRO to be blended with ethanol would be recommended. Refiners can prepare special low-RVP gasoline grades for ethanol blending (also known, particularly in the U.S., as "reformulated gasoline blendstock for oxygenate blending" or RBOB) by extracting a few of gasoline's light components. These changes also affect the costs for the refining of gasoline blendstock. Ethanol has high blending RVP and high blending octane values; lowering a gasoline blendstock's RVP by extracting some of its lighter components (such as butane) to make it suitable for blending with ethanol carries an additional cost for refiners, even though the components extracted can be used for other purposes. Butane may be used, for example, to produce isobutylene, which in turn is used to produce ETBE. On the other hand, manufacturing gasoline with lower octane value can be cheaper for many refiners, and ethanol blends can be seen as an effective alternative to boosting octane ratings.[62]

Biodiesel storage and distribution practices. Biodiesel is much easier to handle than ethanol. Thanks to its physical and chemical properties, which are similar to petroleum-based diesel, the same storage and distribution facilities and equipment as conventional diesel can be used with no major problem. Biodiesel made from fatty acid methyl esters (FAME) is not toxic, so there are no special safety measures required for its handling. The handling of pure biodiesel (B100) may involve a series of minor issues, which are significantly reduced or completely eliminated when handling lower percentage blends up to B20. Key considerations for biodiesel storage and distribution practices are described below.[63]

- Many procedures that are recommended for storage, transport and distribution of petroleum-derived diesel also apply to biodiesel. Inspections of loads, facilities and the resulting residue should be carried out. Gasoline, lubricants, water and raw vegetable oils are not acceptable residues and must be washed out. Only petroleum-

[61] See the previous discussion on ETBE, above.
[62] ESMAP, *op. cit.*, page 108
[63] For a more extensive description of practices suggested, see DOE-EERE, *op. cit.*

derived diesel leaves an acceptable residue. Additionally, because of the solvent action of B100, it may cause the release of sediments created over time by conventional diesel in tanks and pipes. These should be cleaned before using them with biodiesel.

- The main concern in storage and distribution is low temperatures. B100 starts to gel and freeze at higher temperatures than conventional diesel. Pure biodiesel's cloud point (the temperature at which small solid crystals are first visually observed as the fuel is cooled, usually taken as the safest and most conservative measurement of cold flow properties) ranges between -3° and 12° C, while petro-diesel's ranges between -15° and 5° C. B100 should be stored at about 10-15° C higher than cloud point. Storage at a minimum of 7°C is good for most biodiesel, but certain types may require higher temperatures. Use of insulated heated tanks, pipes and pumping equipment may be necessary, even in moderate climates. Temperatures in Maputo in July, the coldest month, can drop to 13° C.[64] These issues are likely to be very minor in Mozambique, but they must be taken into account.

Overall, however, the use of biodiesel as a transport fuel does not require any special practices for storage or distribution.[65] Moderate biodiesel blends present few issues (especially in warm climates) and significantly reduce or eliminate materials compatibility issues.

Biodiesel blending preparation. Unlike ethanol into gasoline, biodiesel can be blended into conventional diesel without any fuel standard modification or particular blendstock preparation. Biodiesel's physical and chemical properties allow it to be blended easily and completely with any distillate or diesel fuel. These include jet fuel, kerosene, commonly used military fuels, heating oils for boilers or home heating and normal diesel fuels. Gasoline, on the other hand, must never be blended with biodiesel. Blending can be carried out by splash blending just before final distribution, by in-tank blending, by storing the final blend for longer periods, or even by in-line blending, as many additives are blended into diesel at terminals, by continuously adding biodiesel into a stream of flowing petrodiesel. One factor to consider is that biodiesel is slightly heavier than conventional diesel, so blending should ensure that biodiesel does not form a deposit at the bottom of a tank (as could occur if it is poured separately prior to very slow pouring of petrodiesel). Provided they are not exposed to temperatures close to cloud point, biodiesel blends stay together as one fuel, do not separate over time, and should be handled in the same way as any petroleum-based diesel.[66]

5. Storage and distribution infrastructure

Similar to what occurs for their handling, biofuels' liquid characteristics are also convenient with respect to the facilities and equipment required for their storage and distribution. Unlike other alternative fuels, such as compressed natural gas (CNG), liquefied petroleum gas (LPG), hydrogen or electricity, modifications to biofuel storage,

[64] Economist Intelligence Unit, *Mozambique Country Profile 2007*
[65] European Biodiesel Board, http://www.ebb-E.U..org/biodiesel.php
[66] DOE-EERE, *op. cit.*, pages 39 and following

distribution and refueling facilities are relatively smaller and less expensive. This compensates in part for the very considerable production costs for biofuels, which represent the greatest component of their retail price.

Biofuels storage and distribution infrastructure, however, does require considerable investment for the sector to be competitive. Inadequacies and high costs associated with the logistics systems (transport, storage and distribution) create the most significant bottleneck, curbing an optimal development even of advanced biofuels industries such as Brazil's.[67] Mozambique would be no exception to this rule. Moreover, given that its domestic market is likely to be of a relatively small size in the medium-term, a successful biofuels policy for Mozambique must contemplate export activities happening at an early stage, to take advantage of economies of scale in all the phases of the supply chain. As for transport infrastructure, investments for storage and distribution infrastructure need to be made in a way that avoids constraining the development of the biofuels industry, but supports effective business operations as the sector expands.

There are nine distributors licensed to operate in Mozambique, the two major ones being PetroMoc and BP. Together they account for 139 of the roughly 250 retail stations; PetroMoc alone accounts for about 258 million liters per year, or 45% of sales. IMOPETRO imports finished petroleum products by competitive tenders every six months (or annually for imports of LPG). It then sells supplies to licensed distributors that truck fuels either directly to filling stations, or to storage terminals owned by PetroMoc or BP, for later distribution to retail points. The southern region of Mozambique, and in particular the Province of Maputo, accounts for about 60% of the country's gasoline consumption (one third in the city of Maputo alone), and almost 50% of diesel sales.[68]

Ethanol storage and distribution infrastructure. The solubility of ethanol and ethanol-gasoline blends into water creates an infrastructure barrier to more widespread use of this fuel. The difficulty associated with transporting ethanol through the normal petroleum pipeline distribution network makes it necessary to blend at final storage terminals just before retail distribution. This in turn creates additional requirements for storage capacity, blending equipment and modifications in retail points receiving the finished products.[69]

Ethanol can be shipped from production facilities to bulk storage terminals that accommodate output from several ethanol plants, to create increased volumes. Ethanol needs to be shipped by truck, rail or river, while the gasoline for the blending can also be shipped to the terminal by pipeline. The terminal must include separate tanks for gasoline and ethanol, as well as blending units at the transport loading rack for splash blending. Tank capacity at terminals must be large enough to provide for both ethanol

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[67] Garten Rothkopf, *op. cit.*, pages 545 and following,
[68] Data provided by the Mozambique Ministry of Energy
[69] Downstream Alternatives Inc. (DAI), *The Current Fuel Ethanol Industry: Transportation, Marketing, Distribution, and Technical Considerations*, 2000, page xvi, available online at http://www.ethanolrfa.org/objects/documents/111/4788.pdf

blending operations and storage of incoming shipments from ethanol plants and a gasoline distribution network.[70] If special blendstocks of gasoline are prepared for ethanol blending (with lower RVP or octane values), it should be noted that these grades are not fungible with normal gasoline grades because, if commingled, they lose their specifications. If a terminal is to handle both traditional fossil fuel and ethanol operations, additional storage capacity will be needed; if special blendstocks replace conventional finished gasoline, only additional facilities to handle the ethanol will be required.[71]

Tanks previously used for other purposes can be adapted for use with ethanol or gasoline-ethanol blends, provided they include mechanisms preventing vapor loss and minimizing moisture absorption. For instance, a storage tank with a fixed roof should have an internal floating roof covering the fuel and adapting to the volume contained. As an alternative, it could be provided with a pressure/vacuum valve equalizing tank pressure, staying closed under certain pressure values preventing vapor loss, and reducing the intake of ambient moisture when fuel is removed from the tank.[72] Storage facilities should be cleaned and prepared prior to storage, following standard procedures for any tank.

For a terminal's blending system, various options are possible. The simplest one, used for splash blending, may only require installing piping from the blending unit to the meter and loading rack, and a dedicated meter and loading arm to pump the blend. More sophisticated systems include computerized control of proportioned amounts of the two fuels to produce the blend level targeted, and at the same time provide for other measuring, accounting and inventory operations that make specific compliance with fuel regulations easier to manage.[73] Pipelines at the terminals must be designed so that tanks allow for both receipt of incoming product, and delivery of fuel to blending units or truck loading racks, depending on each terminal's configuration.

The cost to install a new 25,000-barrel tank [3.975 million liters] (a common capacity in most ethanol terminals) is estimated to be around USD 500,000. Costs for larger tanks can be calculated using a scale-up factor of 0.7 (USD 850,000 for a 50,000-barrel tank). Tanks with a capacity of more than 100,000 barrels are uncommon even in the U.S.

Blending system costs for a tank vary greatly depending on the degree of sophistication, and can range from USD 150,000 to USD 500,000. If only truck transport is required, costs to provide for fuel receipt in the terminals is on the order of a few thousands of U.S. dollars only, whereas if rail or river transport is used, modifications are more complex and expensive.[74]

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[70] IEA, *op. cit.*, pages 88-89
[71] DAI, *op. cit.*, page 5.6
[72] *Ibid*, page 5.3
[73] *Ibid*, page 5.4
[74] *Ibid*, page 5.5, and IEA, *op. cit.*, page 89

The finished product is trucked to retail points for distribution like all other fuels. Filling stations can be adapted to dispense blends up to E10 at relatively little or no cost, whereas blends with higher concentrations may require certain upgrades in station equipment. The three key steps to carry out a conversion of a filling station are: (i) ensuring that all equipment is ethanol-compatible, replacing or modifying material that could be degraded; (ii) cleaning all equipment; and (iii) eliminating all water and moisture contamination issues.[75] The cost of converting a retail unit to E10 is estimated to be around USD 0.002 per liter of fuel, while for E85 the cost can be more than ten times as much, exceeding USD 0.02 cents per liter.[76] In the U.S., the average cost of converting a typical retail unit with three underground storage tanks, excluding major equipment upgrades, is estimated be several hundred up to one thousand dollars.[77]

Biodiesel storage and distribution infrastructure. As noted, biodiesel's physical and chemical properties make it suitable for use with the same storage and distribution infrastructure and equipment as conventional diesel. Most tanks designed to store or to transport petrodiesel can be used for pure biodiesel (B100). For both petrodiesel and biodiesel, acceptable materials for trucks, railcars, and storage tanks include aluminum, stainless steel, carbon steel, and fiberglass, and materials such as fluorinated polyethylene, fluorinated polypropylene, and Teflon. On the other hand, materials such as copper, lead, brass, bronze, tin and zinc are likely to accelerate the process of oxidation of both petrodiesel and biodiesel, potentially creating sediments, and should be avoided or replaced.[78] As noted for vehicle technologies, certain rubber, plastic or metal components may be incompatible with pure biodiesel. In particular, non-compatible rubber components may be degraded over time, and contact with metals such as copper can create deposits that may cause filter clogging. All equipment devoted to B100 should be checked for compatibility with biodiesel, and substituted if necessary.

Regional coordination on biofuels policy. IMOPETRO has observed that any change in the specifications of imported fuel to accommodate blending of ethanol (biodiesel does not require changes in blendstock specifications) for domestic consumption would have to be done in coordination with the countries that receive gasoline shipments via Mozambique. Given the small size of the Mozambican market, it would be logistically difficult for Mozambique to begin receiving RBOB for blending into E10 while at the same time receiving finished gasoline for transit to the interior countries that rely on the ports of Beira and Maputo for transshipment of cargoes. Not only would this entail different cargoes of smaller sizes, but it would also pose new challenges with respect to storage and handling in the ports. Mozambique faced a similar issue when it decided to phase out leaded gasoline; according to IMOPETRO, the negotiations by the Ministry of Energy and its counterparts took five years. Accordingly, IMOPETRO recommends that Mozambique's neighbors be engaged in an effort to assess the potential for coordination

[75] See DAI, *op. cit.*, pages 6.8 and following
[76] IEA, *op. cit.*, page 90
[77] *Ibidem*
[78] DOE-EERE, *op. cit.*, page 27

of biofuels policy and establishing agreements on fuel import practices, fuel specifications and logistical issues.[79]

Quality Assurance and product testing. Internationally, there are existing specifications for ethanol and bio-diesel for use in blending. South Africa is using SANS 465:2005 and SANS 1598:2004 for bio-ethanol and SANS 1935 (adapted from EN 14214) for biodiesel. As South Africa is potentially a large export market, consideration should be given to adopting the same standards. An advantage of this option is that the SABS will be available to test products.

Testing of product can be very onerous and is potentially a major expense, especially for small, remote producers. However, in reality any producer will have to establish testing procedures for production control, and these facilities should be suitable for ongoing quality control. It is probably most practical to select the most suitable standards for both domestic and export products, and to then install facilities according to the testing regimes required.

The Brazilian experience is also useful, where product quality is tested on delivery to the distribution depot – off-specification product is either rejected or is stored separately for later blending into other ethanol. The advantage here is that the fuel distributor has more sophisticated laboratories and can perform a larger range of tests. For export, product testing can be performed at the export terminal prior to loading. It is recommended that testing and quality control practices in Brazil, especially those applied to smaller producers, be investigated and implemented.

Unfortunately, the Mozambique National Institute of Standardisation and Quality (INNOQ), is still in its infancy, and does not have capacity to develop new standards and carry out the required tests. Therefore, the biofuels industry, in conjunction with the Fuels companies, will have to assist INNOQ in adopting standards and ongoing testing.

Mozambique does not have an accreditation laboratories, so an independent laboratory will have to be appointed.

6. Conclusions and recommendations

Logistics. Inadequacies and high costs associated with biofuels logistics (transportation, storage and distribution) represent a key bottleneck even in advanced biofuels markets; the characteristics of ethanol pose more significant problems than those of biodiesel.

Several efforts are under way in Mozambique to increase fuel storage and handling capabilities, but transportation and distribution still face major issues of high costs, limited infrastructure and various inefficiencies due to vested interests or collusive practices. Continued and additional investments in logistics infrastructure, as well as the ability to establish more efficient practices and strategies, will be critical to Mozambique’s biofuels sector competitiveness.

[79] Interview with Manuel Braga, director general, and Helena Lohing, IMOPETRO, July 17, 2007.

As transport is critical for competitiveness, it is recommended that the National Roads Agency (ANE) be involved at an early stage of projects to provide for planning of efficient roads for transport of ethanol or biodiesel to the market or distribution points. Transport routes for input materials (sugar cane, molasses, oil seeds) to production plants may also need to be upgraded.

ANE has already established plans and budgets for development of the national road network, and it is difficult to build new roads on an ad-hoc basis. As all projects must be submitted to and approved by CPI, a mechanism to communicate details of biofuel projects to ANE is recommended. At this stage, the available road network serving the plant can be assessed, and the feasibility of upgrading can be determined, in conjunction with the project proposer. It is recommended that CPI and ANE formalize a process to gather the required data, conduct the analysis and feed back results. ANE also requires a biofuels-focused planning process to allow new roads or upgrades to be executed in a timely way. As budget constraints exist, it is recommended that a dedicated budget line for targeted industries (including biofuels) be considered.

As rail infrastructure requires higher investment and follows a macro-level industry development policy, it is unlikely that biofuels production will, in itself, justify building of new rail lines. However, biofuels will form part of larger regional development plans, and new rail capacity that can serve the biofuels industry may be feasible.

Blending for vehicle uses. Even though higher percentage blends are technically feasible, key economic and logistical considerations on vehicle compatibility and fuel handling suggest that a renewable fuels standard involving 10% blends for ethanol and 5% blends for biodiesel represents a safe and effective first step in the introduction of renewable fuels in Mozambique.

For ethanol, in spite of issues associated with vapor pressure increase and sensitivity to moisture, direct blending into gasoline currently represents the simpler, more cost-effective and more immediate solution than ETBE, which strongly benefits from the presence of advanced refining or petrochemical industries, and which would require the establishment of dedicated production capacity in addition to that required for ethanol. Changes in the composition of imported gasoline to be blended with ethanol are recommended, and will likely involve inferior costs and logistical complications than the establishment of ETBE production. International experience from the U.S. and Brazil shows that direct blending on the basis of a fuel standard is a feasible and effective solution for ethanol use in transportation, and one that more than adequately stimulates the domestic ethanol industry. In the longer term and depending on various market and technological dynamics in the country, fuel standards could be scaled up, and ETBE could also become a more viable and interesting solution, following the experience developed in Europe.

Residential and other rural uses. There is potential for biofuels to offer a much more sustainable fuel use pattern in Mozambique’s residential sector, especially in rural areas.

In particular, gelfuel could offer a promising solution for the poorest sectors of Mozambique's population, especially for cooking activities but also for a wider range of other daily applications. The small gelfuel initiative currently taking place in Mozambique, however, is encountering major difficulties associated with an unfavorable fiscal and customs treatment harming its competitiveness, an inability to obtain credit from financial institutions, and a persistent lack of awareness. Targeted policies, including incentives for the purchase of stoves and preferential customs and tax treatment, are strongly needed to allow this product's market to expand, involving a broader spectrum of stakeholders and delivering benefits to the population.

Other biofuels applications to be considered include water pumping, water heating and off-grid power generation, all of which are currently served by diesel fuel in the vast areas of the country not covered by the electricity grid. Biodiesel and ethanol could play a role in meeting as yet unserved demand for liquid fuels. Biodiesel, in particular, can be used in most diesel-cycle equipment with no major modification, although its lower energy content and the lower thermal efficiency this involves may prevent it from being an economically viable solution. The possibility to use crude vegetable oil for power generation in diesel-cycle engines in remote areas should also be considered.

Regional coordination. It will be essential for Mozambique to coordinate the implementation of its biofuels policy with its trading partners in the region on two overarching points: fuel specifications, particularly for gasoline, and standards for both gasoline and biodiesel. In the absence of the first, there may be significant obstacles to implementation of the national policy; in the absence of the second, the regional commercial opportunities may be much diminished.

CHAPTER 6: ANALYSIS OF THE COMPETITIVENESS AND FEASIBILITY OF BIOFUEL PRODUCTION IN MOZAMBIQUE

Based on the analysis presented in the previous chapters, this chapter compares the competitiveness of biofuels production in Mozambique relative to fossil fuels, and assesses the feasibility of investing in production of biofuels, summarizing the analysis. It also assesses the microeconomic impact of implementing a national biofuels program. Notwithstanding the observation that raw materials for biofuels production are normally more expensive than petroleum, in this Chapter we examine the situation in Mozambique based on the raw materials pre-selected in Chapter 3 and analyzed in Chapter 4 relative to imported fossil fuels. Ethanol produced from cellulose (biomass waste) will not be analyzed, because the technology is not commercially available within the timeframe covered by this study, and also given that its implementation would involve a long learning curve.

1. Options for agricultural raw materials

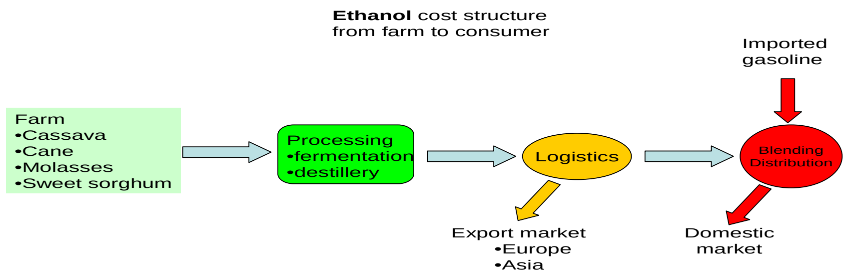
The options for increasing the production of agricultural raw materials in Mozambique for use in biofuels were described in Chapter 3. Two groups of crops were selected to produce carbohydrates for ethanol and oils and fats for biodiesel. The pre-selection in Chapter 3 is based on existing natural resources: (i) tens of millions of hectares of flat land, (ii) high levels of solar radiation, at latitudes from 11°S to 26°S, and (iii) water resources and infrastructure that compensate for the variability in rainfall. A rise in future agricultural production becomes even more feasible because most of the population (70%) lives in rural areas, as is shown in detail in Chapter 3. Although migration to the cities is inevitable, a rise in rural income would slow such population movement, providing time for the secondary and tertiary sectors (industry and services) to create more jobs.

This chapter analyzes the chains of production for producing biofuels - ethanol and biodiesel - from the different agricultural raw materials, comparing them with their fossil equivalents (gasoline and diesel). The analysis is done by quantifying all costs, from agricultural origin to processing, logistics of transfer to the blending centers and distribution. The comparison allows for the identification of the main economic factors governing selection of raw materials for biofuels for local use then export in a first phase, to support the viability of investments that require economies of scale or greater liquidity for their commercialization.

2. Costs of ethanol for use in gasoline in Mozambique

Table 1 below shows that there is no significant difference in the final cost of ethanol produced from three different raw materials – sugarcane, molasses and sweet sorghum. Cassava has a higher cost, due to the complexity of the process that transforms it into ethanol. The cost of producing ethanol from molasses is low in the short-term, due to the lack of transport infrastructure in some regions that could open up new markets for alternative uses.

Figure 1: Structure of the ethanol value chain



Source: Alf International

Table 1: Costs of producing ethanol from several crops, compared with the price of gasoline in Mozambique

Raw Material	**Cassava**	**Sugarcane**	**Molasses**	**Sorghum**	**Gasoline** (1)	**% Total**
Farming Cost (USD/l) (2)	0.25	0.25	0.20	0.16		
Processing Cost	0.13	0.11	0.10	0.11		
Cost Ex-Plant (USD/l) (2)	0.38	0.35	0.30	0.27		
Domestic Transport (3)	0.06	0.02	0.02	0.06		
Distribution Freight (4)	0.01	0.01	0.01	0.01	0.01	1%
Gasoline Ex-Refinery					0.50	44%
Ocean Freight					0.06	5%
VAT					0.13	11%
ISC and Other Taxes					0.27	24%
Miscellaneous					0.04	3%
Wholesalers' Margin					0.08	7%
Retailers' Margin					0.05	4%
Cost of Ethanol	0.46	0.39	0.33	0.34		
Cost of Ethanol / 0.7 (5)	0.65	0.55	0.47	0.48		

Source: Table 17, Ch.4
(1) The gasoline price structure is from Table 4 (Chapter 1), converted into Mt$ at a rate of USD 1.00=Mt$26.00. (2) Cost shown/demonstrated in Table 17 of Chapter 4, with conversion to USD/liter from USD/ton for the agricultural cost. (3) Freight between distillery and the primary facilities of the gasoline distributors (ports). (4) Distribution freight from the primary facilities to the gasoline pumps. (5) Ethanol costs were increased by 30% to compensate for the difference in energy content between dehydrated ethanol and gasoline.

The structure of the ethanol value chain is presented in Figure 1.

In addition to technical considerations, the higher domestic transport costs associated with cassava and sweet sorghum are based on the premise that these crops will be produced in those regions of the interior more distant from the Indian Ocean coast. In this regard, the Brazilian experience is relevant: production of ethanol from cassava was attempted at the beginning of the *Pro-Alcool* program. However, the six planned distillery projects were not successfully completed because of the great difficulty in collecting perishable raw material from thousands of family farms that normally produce this as a subsistence crop. The large landowners chose to switch to crops with greater market liquidity and potential for mechanization (sugarcane, oranges, soy, and corn). Sugarcane cultivation developed rapidly because of its use to produce sugar, ethanol and energy. Currently, there is a controversy over the real productivity of cassava, precisely because of the lack of efficient large-scale operations in Mozambique. The various ongoing projects in South Africa and Colombia may confirm whether this crop is competitive for ethanol production.

Sugarcane is already traditionally cultivated in Mozambican coastal regions, which leads to lower logistical costs for ethanol that is produced from molasses or from sugarcane juice itself.

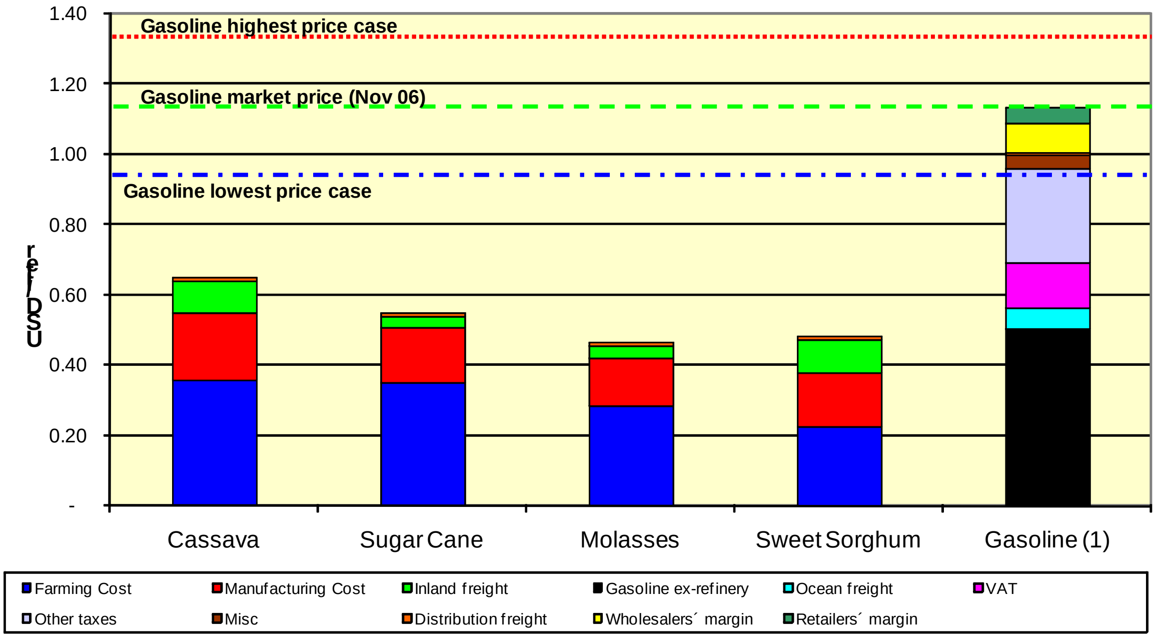
For the purposes of assessing the competitiveness of ethanol fuel in Mozambique, production costs were presented beside the reference price for gasoline taken from Table 4 of Chapter 1. The costs are those estimated in Chapter 4 (Table 17) without the inclusion of profit in any step of the chain. The reason for excluding profit at this stage of the analysis is to avoid any implicit decisions regarding the allocation of profit to the different participants in the value chain shown in Figure 1. Clearly, however, the decision on how to allocate profits among the participants will have to be made in due course. Based on the gasoline market price presented in Chapter 1, two scenarios were created: a "low petroleum price" scenario with a 20% drop in the price of gasoline and a "high petroleum price" scenario with a 20% rise in future prices in the domestic market. The reference price for gasoline was published by the Ministry of Energy in November 2006.

As may be observed in the graph shown in Figure 2, there is no major cost difference between the various options for producing ethanol. On the other hand, there is a rather significant difference between the cost of ethanol and the price of gasoline. This justifies the projection of a price margin sufficient to pay for investments in agriculture, processing, blending and distribution, in addition to taxes and other fees. The participants in the value chain are presented in Figure 1. Note that the price difference is significant even in the "low petroleum price" scenario.

A comparison between these costs and international market prices can be seen in Figure 3. The international prices on the graph were calculated based on FOB prices at Brazilian ports (2006 average) plus the ocean freight from that country to Rotterdam (Europe) and Yokohama (Asia), given that the world market is based on the price of the largest exporter (Brazil). In 2007, ethanol export prices were lower due to the strong surplus supply, both in Brazil and from U.S. producers. The international demand is expected to adjust to the extent that ethanol fuel becomes established as a commodity.

Based on data from Chapter 5, the estimated ocean freight cost to Rotterdam was USD 60/ton, this being a large shipment on a direct route. For the Brazil-Asia route, the estimated cost was USD 90/ton, a figure that was also used for the Mozambique-Asia route because the longer distance to Brazil is compensated by a larger flow of shipments and vessel capacity, compared with those serving Mozambique. Similarly, freight to the U.S. is estimated at USD 92/ton, and to South Asia (Mumbai), at USD 65/ton. These data are shown in Table 2. Clearly, some variation in international freight costs is expected in the

Figure 2: Comparison of production costs and price structure of imported gasoline



Notes: (1) ethanol costs are adjusted to reflect the difference in energy content. Source: Econergy

Table 2: Ethanol derived from several raw materials for export from Mozambique to Asia and Europe (values not adjusted to gasoline equivalent, USD/liter)

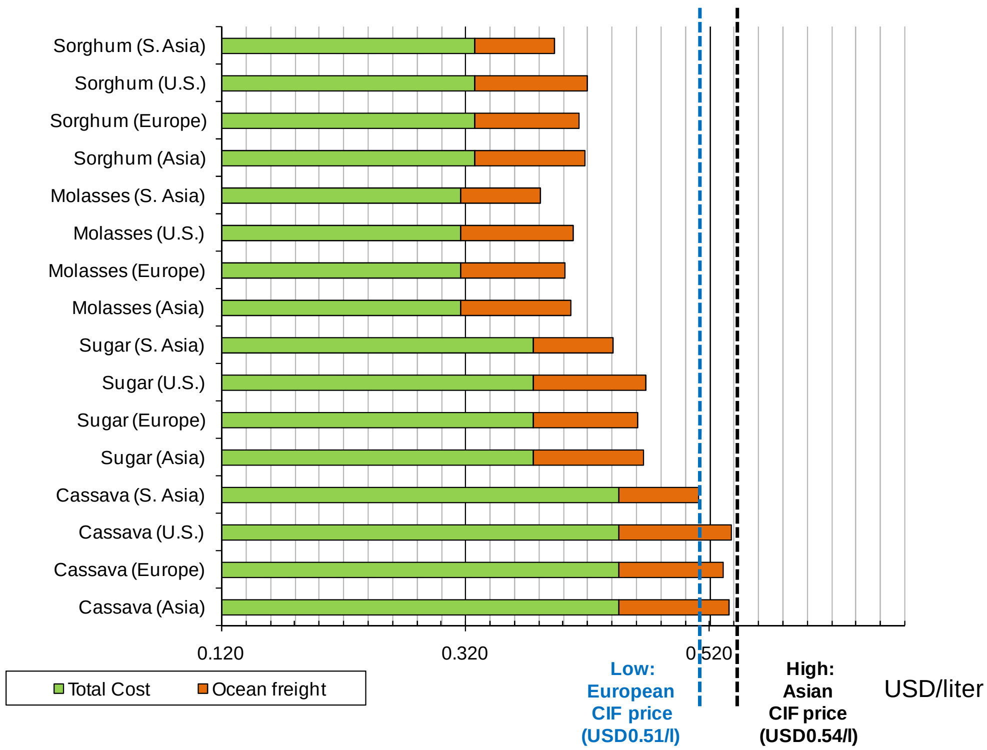
	Total Cost	Ocean Freight	Total CIF
Cassava (Asia)	0.45	0.090	0.540
Cassava (Europe)	0.45	0.085	0.535
Cassava (U.S.)	0.45	0.092	0.542
Cassava (S. Asia)	0.45	0.065	0.515
Sugar Cane (Asia)	0.38	0.090	0.470
Sugar Cane (Europe)	0.38	0.085	0.465
Sugar Cane (U.S.)	0.38	0.092	0.472
Sugar Cane (S. Asia)	0.38	0.065	0.445
Molasses (Asia)	0.32	0.090	0.410
Molasses (Europe)	0.32	0.085	0.405
Molasses (U.S.)	0.32	0.092	0.412
Molasses (S. Asia)	0.32	0.065	0.385
Sweet Sorgum (Asia)	0.33	0.090	0.420
Sweet Sorgum (Europe)	0.33	0.085	0.415
Sweet Sorghum (U.S.)	0.33	0.092	0.422
Sweet Sorghum (S. Asia)	0.33	0.065	0.395

Source: Derived from the quote presented in Table 4, Chapter 5.

future; ocean freight costs are globalized and vary mainly with the price of petroleum (for bunker fuel). Inversely, Mozambique could also achieve a relative lowering of freight rates after port improvements (including dredging) as well as by achieving substantial export volumes to increase demand for cargos.

When compared with reference prices in the different export markets, which were introduced in Chapter 2.4 (Table 19), these CIF export costs suggest that margins on sale of Mozambican ethanol in overseas markets will be somewhat lower, reflecting the strong competitiveness of Brazil on world markets, but still potentially attractive. Only cassava is not a competitive feedstock for ethanol production for export. As mentioned above,

Figure 3: Comparison of CIF values of Mozambican ethanol in the major international markets



Source: Econergy

molasses may be the most attractive raw material, but one that is limited as a function of the sugar business, as it is a byproduct of that economic activity.

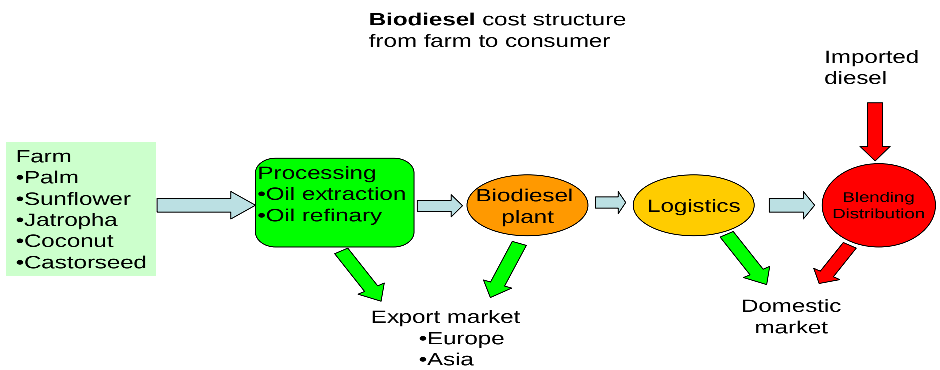
3. Analysis of the cost of biodiesel compared with the price of imported diesel

The cost structure of the biodiesel production chain is represented in Figure 4 below.

Table 3 and Figure 5, below, show there is a significant difference between the cost of biodiesel, put into the fuel blending tank, and the final sale price of diesel at the pump. The figures also show that biodiesel costs vary in accordance with the raw material used and/or the cost model. Despite such variations, it is possible to project the existence of a margin to provide a return on investments in agriculture, production and blending, beyond the taxes and fees that may be applicable. Finally, it may be observed that even under the low petroleum cost scenario there is still a significant cost differential.

The reference price for diesel is that shown in Table 4 of Chapter 1. Based on this reference price, two scenarios were created, a “low petroleum price” scenario, with a 20% drop in the price of diesel and a “high petroleum price” scenario, with a 20% rise in the future domestic market prices. The biodiesel costs are those estimated in Chapter 4, without including profit in any step of the chain for the same reason explained for ethanol.

Figure 4: The steps for the production of biodiesel



Source: Alf International

4. Raw materials at market cost (opportunity cost)

Table 3 and Table 4 compare the cost of biodiesel produced from raw material (oils) at agricultural cost with diesel at the sale price on the local market, the details of which are described in Chapter 4. However, market prices (opportunity costs) should be viewed with considerable caution, given their volatility as well as the lack of a significant flow of business transactions to ensure the liquidity typical of more mature markets characterized by a large number of actors (producers/buyers/speculators). The agricultural derivatives sector in Mozambique is not yet at that stage. The price volatility is a result of fluctuations in worldwide demand and supply, as well as of intercontinental logistics. Future caution is even more justified when the domestic logistic infrastructure is limited. Prices at the ports may increase considerably when the transport charges to markets in the interior of the country are added. Domestic price levels drop in those places where there is no infrastructure to transport agricultural commodities to other markets where high prices can be obtained.

Table 3: Biodiesel production costs of various crops compared with the price of diesel in Mozambique – Large-scale production: raw material at "agricultural cost" and "opportunity cost"

Costs (USD/liter)	Sunflower		African Palm		Coconut		Castor		Jatropha		Diesel (1) USD/liter	%
Cost of oil (less co-products) (2)	0.021	-	0.246	-	0.246	-	0.318	-	0.318	-		
Opportunity Cost (domestic) (2)	-	0.137	-	0.414	-	0.249	-	0.313	-	0.679		
Processing Cost	0.105	0.105	0.098	0.098	0.100	0.100	0.100	0.100	0.100	0.100		
Cost Ex-Plant USD/liter (3)	**0.126**	**0.242**	**0.344**	**0.512**	**0.346**	**0.349**	**0.418**	**0.413**	**0.418**	**0.780**		
Domestic Transport (4)	0.064	0.064	0.064	0.064	0.023	0.023	0.064	0.064	0.064	0.064		
Distribution Transport (5)	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.01	1%
Diesel Ex-Refinery											0.49	50%
Ocean Transport											0.06	6%
VAT											0.13	13%
ISC and Other Taxes											0.16	16%
Miscellaneous											0.01	15%
Wholesalers' Margin											0.08	8%
Retailers' Margin											0.05	5%
Cost of Biodiesel	0.20	0.31	0.42	0.58	0.38	0.38	0.49	0.49	0.49	0.85		
Price at the Pump											0.99	100%

(1) The price structure of diesel is that of Table 4 of Chapter 1 converted into Mt$ at a rate of USD 1.00 = Mt$ 26.00.
(2) The estimates of the cost of the oil from the feedstocks are presented in Chapter 4. Figures for the cost of oil based on the agricultural cost are from Table 23, "cost of oil less co-products;" figures for the cost of oil at opportunity cost are from "cost of oil less co-products," Table 24. Values in USD/ton are adjusted by the density of raw oil (0.886 kg/liter) to arrive at USD/liter.
(3) Cost presented in Tables 23 and 24 of Chapter 4, "net biodiesel production cost."
(4) Transport between the biodiesel plant and the diesel distributors' primary facilities (ports).
(5) Distribution transport from the primary facilities to the diesel pumps.

Source: Econergy

Table 4: Biodiesel production costs of various crops compared with the price of diesel in Mozambique – Small-scale production: raw material at "agricultural cost" and "opportunity cost"

Costs (USD/liter)	Sunflower		African Palm		Coconut		Castor		Jatropha		Diesel (1) USD/liter	%
Cost of oil (less co-products) (2)	(0.03)	-	0.37	-	0.37	-	0.48	-	0.48	-		
Opportunity Cost (domestic) (2)	-	0.15	-	0.62	-	0.34	-	0.47	-	1.02		
Processing Cost	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14		
Cost Ex-Plant USD/liter (3)	**0.11**	**0.29**	**0.51**	**0.76**	**0.51**	**0.48**	**0.62**	**0.61**	**0.62**	**1.14**		
Domestic Transport (4)	0.06	0.06	0.06	0.06	0.02	0.02	0.06	0.06	0.06	0.06		
Distribution Transport (5)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1%
Diesel Ex-Refinery											0.49	50%
Ocean Transport											0.06	6%
VAT											0.13	13%
ISC and Other Taxes											0.16	16%
Miscellaneous											0.01	15%
Wholesalers' Margin											0.08	8%
Retailers' Margin											0.05	5%
Cost of Biodiesel	0.18	0.35	0.57	0.82	0.53	0.50	0.68	0.67	0.68	1.22		
Price at the Pump											0.99	100%

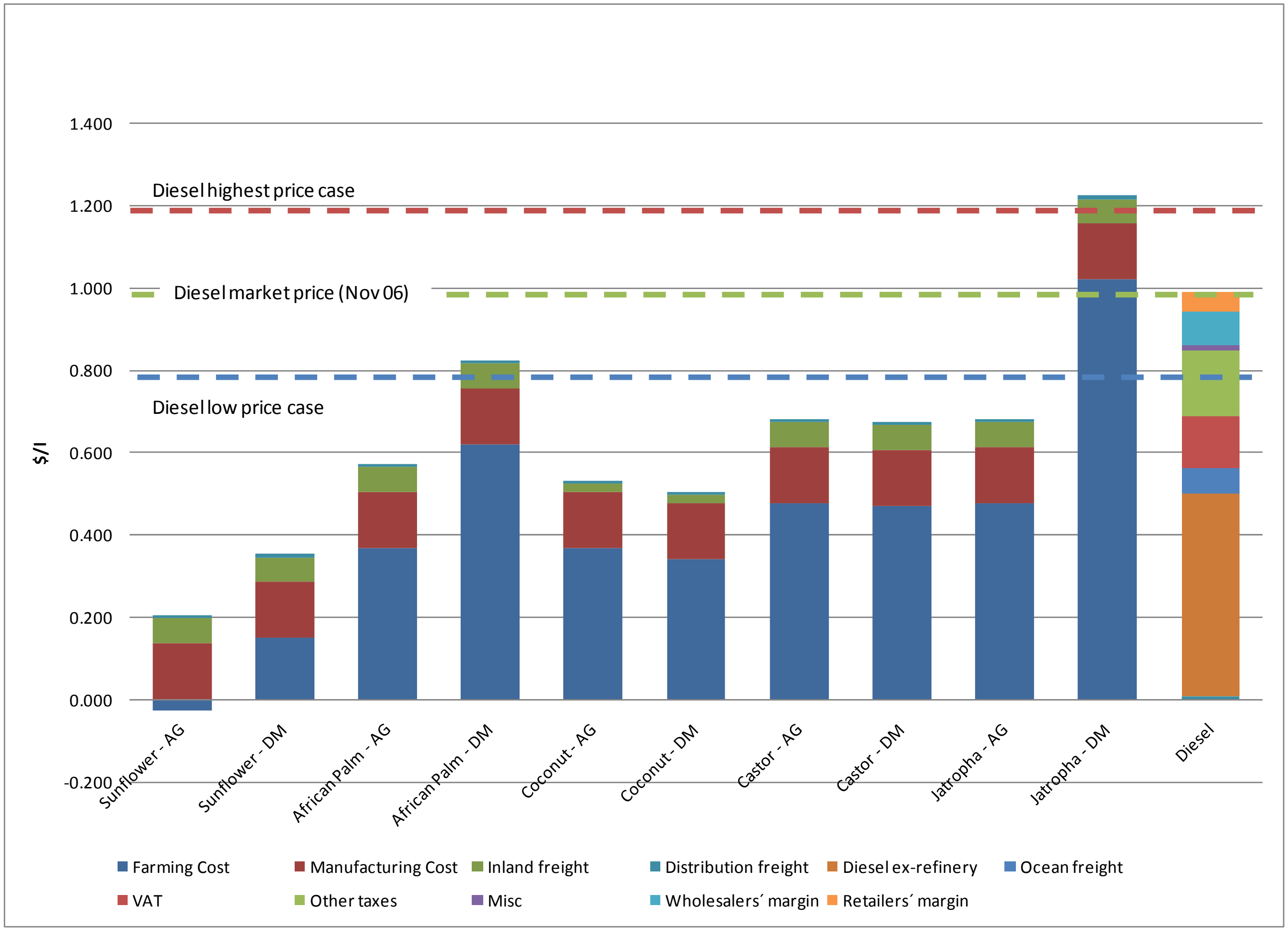
(1) The price structure of diesel is that of Table 4 of Chapter 1 converted into Mt$ at a rate of USD 1.00 = Mt$ 26.00.
(2) The estimate of the cost of the oil from these feedstocks is presented in Chapter 4. Figures for the cost of oil based on the agricultural cost are from Table 21, "cost of oil less co-products;" figures for the cost of oil at opportunity cost are from "cost of oil less co-products," Table 22. Values in USD/ton are adjusted by the density of raw oil (0.886 kg/liter) to arrive at USD/liter.
(3) Cost presented in Tables 21 and 22 of Chapter 4, "net biodiesel production cost."
(4) Transport between biodiesel plant and the diesel distributors' primary facilities (ports)
(5) Distribution transport from the primary facilities to the diesel pump

Source: Econergy

Figure 5: Comparison of biodiesel based on different raw materials and costs with the sale price of diesel at the pump, with large-scale production units

Source: Econergy

Figure 6: Comparison of biodiesel based on different raw materials and costs with the sale price of diesel at the pump, with small-scale production units



Source: Econergy.

- *Ethanol*. For ethanol production, the four raw materials selected in Chapter 3 have little or no liquidity other than for the distillery that promoted the planting of those crops. The market price of cassava itself can be affected quite negatively if the supply resulting from expanded production leads to an increased risk of exposure to risk of losses due to weak demand in that region itself. For this biofuel, no comparison was made between agricultural cost and opportunity cost.
- *Biodiesel*. The relatively narrow margins on Table 3 and Table 4 above suggest that it may be more profitable to sell some oilseeds or their respective raw oils to third parties than to produce biodiesel. Since the "domestic price" used as a reference for the opportunity cost of producing biodiesel in Mozambique is not the same as the prevailing international prices for crude vegetable oil delivered to Europe, which is the emerging as the largest market for crude vegetable oil for biodiesel, an analysis of the benefits of exporting vegetable oil instead of biodiesel must compare the agricultural production costs to the international prices after subtracting transportation costs. This is shown in Table 5. This conclusion is the opposite of the conclusion from the analysis conducted in 2001, considering that in that year the prices for vegetable oils were very low as a result of the excess supply of oil from soy and African palm on the world market.

Analysis of exports of vegetable oil

The strong prices for various types of vegetable oil on international markets noted in Chapter 2, together with the incentives in major importers in the E.U. to import raw oil for processing in Europe, provide a strong incentive for Mozambican producers to consider exports of crude vegetable oil as opposed to biodiesel. Table 5 shows the estimated cost FOB at Mozambican ports for five vegetable oil feedstocks based on the same agricultural costs used in Chapter 4, together with the same assumed extraction rates, as well as extraction and refining costs, presented there. Transportation costs from production areas to one of the three main ports in Mozambique are the same as those assumed in Table 1 in the case of the large-scale operation case, and they are 10% higher in the case of the small-scale facilities, to reflect the higher rates that truckers will require to handle smaller cargos as well as more frequent pick-ups. Figure 7 shows the resulting costs, FOB Mozambican ports, alongside the purchase prices for the oil, also expressed as FOB values based on observed prices in Europe less transportation to Europe from Mozambique (based on the Maputo-Rotterdam quote for vegetable oil presented in Chapter 5, Table 3).

The results suggest that the five feedstocks analyzed would command prices that would deliver margins of up to 71% for small-scale production of certain feedstocks (in a low price scenario, jatropha and coconut show negative margins), and as high as 79% for large-scale production. The negative margins shown for jatropha and coconut are comparatively unlikely outcomes because both crops are likely to have lower production costs over time; in the case of coconut, the cost used is a market cost, which is necessarily higher than its agricultural cost, while the cost of jatropha is expected to decrease as producers move up the learning curve with this new crop. The results shown for sunflower underscore the potential profitability of this crop for producers in Mozambique even in the event that there is a retreat in prices to levels observed last year from current values.

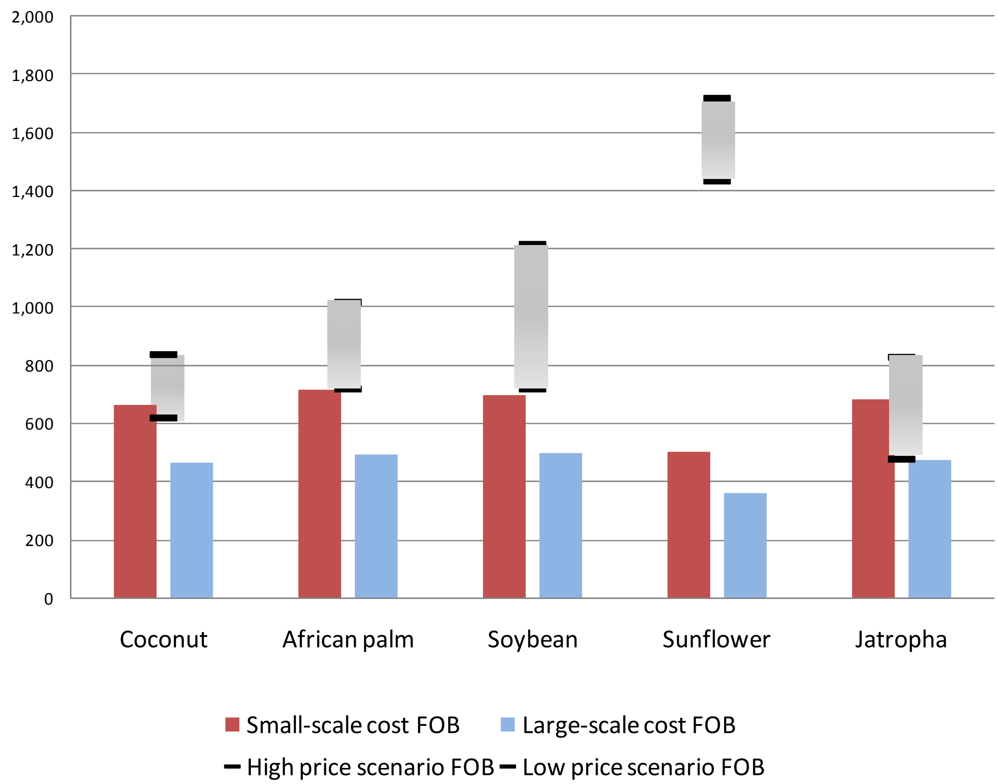
Table 5: Export costs for vegetable oil, FOB Mozambique

	Coconut*	African palm#	Soybean	Sunflower	Jatropha**
Feedstock (USD/ton)	185	69	72	90	130
Extraction rates					
Mechanical	35%	12%	13%	25%	24%
Solvent	52%	18%	19%	37%	36%
Cost of oil (USD/ton)					
Small-scale	529	575	567	364	542
Large-scale	356	383	379	243	361
Extraction costs (USD/ton)					
Small-scale	35	35	35	35	35
Large-scale	25	22	32	30	25
Oil refining costs (USD/ton)					
Small-scale	45	45	45	45	45
Large-scale	30	30	30	30	30
Domestic freight (USD/ton)					
Small-scale##	63	63	63	63	63
Large-scale##	57	57	57	57	57
Net Cost (FOB Mozambique ports)					
Small-scale	671	718	710	507	684
Large-scale	468	492	498	360	473

Source: Econergy calculations, based on data presented in Chapter 3 and Chapter 4. Notes: *No agricultural cost for coconut is available; this figure is based on market prices in Mozambique (Table 33, Chapter 3). #As noted in Chapter 4, cost is estimated based on data from other countries. **Jatropha costs are estimates and are likely to decrease over time. ##Internal freight costs are same as those assumed in Table 1, adjusted to per-ton basis.

While there is a potentially lucrative vegetable oil export trade for producers in Mozambique, the fact that the country is a net importer of vegetable oils creates an opportunity for producers to serve the domestic market as well. However, the relatively small size of the domestic market for vegetable oil (approximately 30,000 to 45,000 tons or between 33 million and 50 million liters, based on the discussion in Chapter 3.3) would limit the potential for growth in the sector, and investor interest, in the absence of other developments or a strategy based on exporting some part of production. As described in Section 8, below, the potential output of biofuels in Mozambique is ten times larger in the least optimistic scenario. This increases the importance to domestic producers of supplying an additional increment in domestic demand that would result from a biodiesel program, alongside the potential export opportunities. In view of the potential for volatility in international prices of vegetable oils in the future, a domestic biodiesel program would play an important role in expanding domestic demand for vegetable oils, thereby driving the expansion of vegetable oil production in Mozambique.

Figure 7: Comparison of FOB costs for vegetable oil and sales price scenarios



Source: Table 5.

Policy implications

The description of the various biofuels programs already implemented in other countries, described in Chapter 2 and Chapter 7 of this report, demonstrate that programs are typically created to consume their own agricultural surpluses or to generate revenues for the local agricultural sector. Although secondary demand does exist for imported products (biofuels or their raw materials), it can be eliminated by a policy adapted by the consumer country. Accordingly the consultants maintain the recommendation of beginning the biofuels program in Mozambique based on variables that are controlled by the country itself. Those variables are:

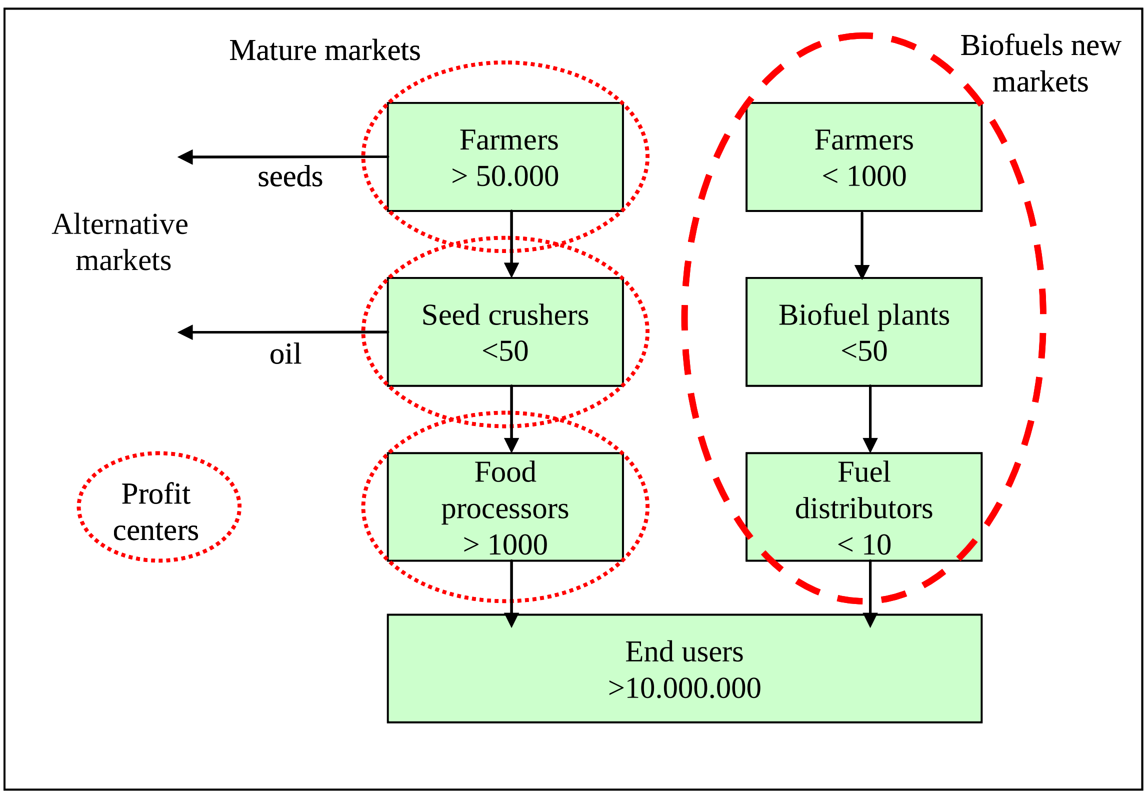
- Legislation for the compulsory creation of domestic demand for ethanol and biodiesel;
- Gradual phase-in of blending requirements in accordance with the installed production potential, both for ethanol and for biodiesel;
- Support for the primary sector (agricultural production) through the provision of sufficient operating margins;
- Diversification of sources of raw materials and regions for developing them;
- Freedom for private groups to invest with the dual objective of meeting the needs of the national program and of exploiting opportunities in export markets, with the inherent risks falling upon investors themselves.

This recommendation seems prudent as it aims at avoiding the risks inherent in having thousands of family farmers involved in programs to plant perennial or semi-perennial crops such as jatropha, castor, African palm and sugarcane to supply the potential future demand in developed countries, and particularly the very negative consequences that can result from the volatility of such demand. Industrial assets can be redirected or adapted for other purposes, but planting the crops mentioned above should always be based on a stable and irreversible demand guaranteed by the local market. The farmers in Mozambique are an integral part of that market and the risk, if shared, should be much less than if it were to depend on exogenous variables such as possible consumption overseas. Such external demand can and should contribute to accelerating the program, but it most definitely should not be overestimated, nor should it replace the local demand.

5. Calculation of the IRR based on various raw materials

In order to calculate the internal rate of return (IRR) on investment for an agro-industrial biofuels project, it is important to define the economic actors involved. For this study, we have taken into consideration the following: (i) the agricultural producers of raw materials, (ii) the industrial processor, (iii) the petroleum company that blends the biofuel into the fossil fuel, and (iv) the government, which regulates and inspects the production chain.

Figure 8: Structure of the biodiesel value chain



Source: Alf International.

The existence of the various economic actors mentioned above complicates an *a priori* allocation of economic margins among them. For this study, it is more important to quantify the existence of the margin for the whole operation by adopting a vertical model from agricultural production to the sale of the blended fuel at the service station pump. The quantification of this total margin makes it possible to select the raw materials that accumulate more value in the production cycle. The allocation of the margin among the economic actors identified above is dealt with in a second step, after the pre-selection of projects for more detailed study. This vertical model facilitates the grouping of all economic actors around one goal, which is that of implementing renewable fuels projects in Mozambique. The diagram in Figure 8 below compares the model for value creation in mature markets, where there are structured business transactions at each stage (agricultural, industrial, logistical and governmental), with the single profit center model.

Simplification of the model, which in our opinion is more appropriate for this study, makes it possible to envisage the total margin created in the production chain, thus avoiding discussions over how to allocate the returns among the economic actors mentioned above.

In addition to the consolidation into a single profit center, the model adopted focuses on biofuels as the core business. All the revenues generated from the sale of co-products, waste and excess energy are taken into consideration to reduce the cost of raw material (vegetable oil, sucrose). This model is based on a single objective, which is to produce a biofuel, either ethanol or biodiesel.

An oilseed processing company operates with this formula:

[crushing margin = sale of oil and co-products – cost of the seeds]

A sugarcane processing plant adopts a similar model:

[crushing margin = sale of sugar + ethanol + energy – cost/price of the sugarcane]

For an integrated biofuel business, the basic management formula is:

[margin = sale of biofuel – (cost of oil or sucrose)]

This is true where the cost of the oil/sucrose is equal to the cost of the agricultural raw material minus the sale of waste/energy and co-products (animal feed, glycerine, etc.). Under this approach, biofuels are the core business, while the co-products serve to reduce the cost of the raw material that is an input for the fermentation or trans-esterification unit.

This system is accepted in regions or countries that do not have the volume to manage each stage of the business through a partial profit center. Mozambique is one such country, as it lacks the infrastructure to compete with oilseed producers such as Brazil, Argentina and the United States, and to compete for the traditional vegetable oil export market or the food or animal feed markets, through the alternative manufacture of products such as margarines, refined oils and mayonnaise.

For ethanol, the same concept of an autonomous distillery was applied, but the alternative or parallel production of sugar is not contemplated. The surplus energy generated has the effect of reducing the cost of the sucrose to be fermented.

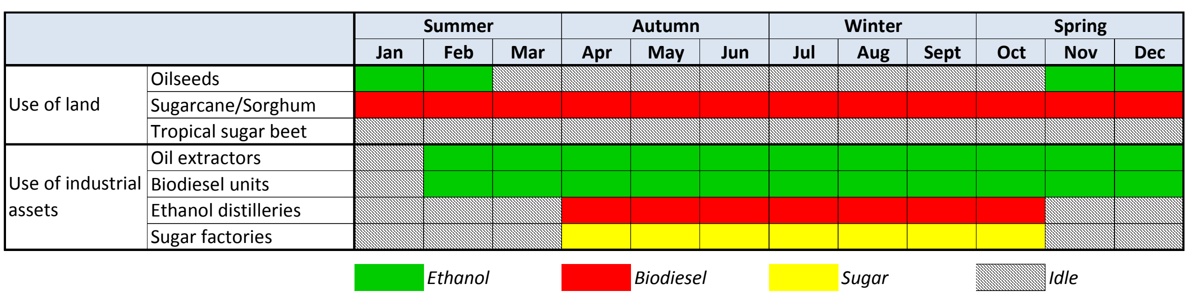
6. Capacity of the production units

Ethanol distilleries. For the production of ethanol fuel, it is important for the fermentation/distillation unit to have a minimum capacity that covers the fixed expenses and provides a return on capital. That capacity, based on the Brazilian experience, is at least 80 metric tons/day of ethanol (one distillation column).

Currently, there is only one distillery in Mozambique (in Búzi), with a nominal capacity of 10 metric tons/day, but it is equipped for the manufacture of potable ethanol for use in drinks and in hospital facilities. The prices of these products are totally unrelated to the energy matrix, which is characterized by competitive pressures, and should not be used as a parameter.

The fundamental question is how to supply raw material to meet the needs of a unit with a capacity of 80 tons/day. Mozambique's own experience over time in the five sugar distilleries suggests that the cultivation of sugarcane, sorghum, and molasses should be on commercial plantations. In order to maintain cost competitiveness, the independent farmers should be a minority. In Brazil, the plantations controlled by a distillery vary between 50% and 75% of the overall total.

Figure 9: Scheme for the operation of an industrial plant with multiple inputs



Source: Alf International

In the case of the cultivation of cassava, this question remains open, because there has not been enough experience to recommend creation of associations that supply a distillation unit. One hypothesis to consider is a combined operation to supply cassava to the same distillery during periods between the sugarcane seasons.

This seemingly bold hypothesis should be pursued in the country to optimize the industrial assets of the future distilleries that operate only 160 days per year for sugarcane. Australia is already seeking an alternative, using the tropical sugar beet to use the assets that are idle (six months per year) in the sugarcane distilleries. Brazil already uses land in the fall for a second crop of oilseeds (sunflower and corn) after the soybean harvest.

The Value Chain Return (VCR) is calculated like the IRR, but with the following caveats: (i) income tax is 0%; (ii) profit is not included in any of the steps of the production chain, the assumption being an operation that is 100% vertical from agricultural production to delivery of the product at the pump; (iii) there is no investment in land, given that land in Mozambique is owned by the State and the cost of a land concession is negligible.

Table 6: Economic returns from ethanol production

	Raw Material			
P&L for Ethanol production	Cassava	Sugarcane	Molasses	Sweet Sorghum
Volumes (m^3)				
Domestic (80%)	10,400	10,400	10,400	10,400
Export (20%)	2,600	2,600	2,600	2,600
Total	13,000	13,000	13,000	13,000
Price (USD/liter)				
Domestic (1)	0.71	0.71	0.71	0.71
Export	0.52	0.52	0.52	0.52
Total	0.67	0.67	0.67	0.67
Net Sales (USD million)				
Domestic	7.34	7.34	7.34	7.34
Export	1.34	1.34	1.34	1.34
Total	8.68	8.68	8.68	8.68
Unit Cost (USD/liter)	0.46	0.39	0.33	0.34
Total Cost (USD million)	5.92	5.02	4.27	4.40
Economic profit (USD million)	2.75	3.66	4.41	4.28
Capex (USD million) (2)	10.00	10.00	10.00	10.00
Working Capital (USD m)	1.00	1.00	1.00	1.00
Total (USD million)	11.00	11.00	11.00	11.00
Value Chain Return (IRR) (3)	21%	31%	39%	37%

(1) Prices do not take into account VAT or other taxes
(2) Farming capex is not included (land, machinery, irrigation and so forth). Investment is based on an equivalent distillery in Brazil—Table 6 project B.C.
(3) See explanatory note
Source: Alf International

These assumptions generate high VCR (IRR) values when compared with other countries where the capital for acquiring land is a predominant factor. This indicator makes it possible to evaluate the investment as a national project, which could be called the National Return on Biofuels Investments. The economic actors involved unite with the State to replace a portion of the imported fuels. The great challenge of the project is that the allocation of the VCR be fair, thus maintaining those economic agents united around the shared objective of import substitution.

The chart shown in Table 6 above compares the rates of return (VCR) of the entire chain for each of the four crops, operating in a distillery producing 80 tons/day of ethanol. A sales mix of 80% domestic and 20% exports is used, based on the precept that a biofuels program should prioritize the producing country. Allocating a portion (20%) to foreign countries makes it possible to establish trade channels for the future and monitor the domestic costs compared with other foreign producers. The sale price in the domestic ethanol market was calculated based on the price of gasoline, subtracting the margins and import expenses as well as domestic transport costs to distant places, and deducting 30% from the net value to compensate for ethanol's lower energy content, relative to gasoline. For the export price of ethanol, the 2006 FOB price in Brazil was used, plus the cost of ocean transport to Europe and Asia. The market prices in the U.S. and Europe were not taken into account, given that those prices include high import tariffs to protect domestic production derived from raw materials (corn, wheat, wine, beet, etc.) that are local, but which are not sustainable over the long term in a competitive market environment. As previously noted above, operational profit was not provided for in any of the stages of the production chain.

As a reference, Table 7 provides data on the existing or proposed ethanol plants in Brazil. The usual metric to quantify the value of an industrial facility is USD per ton of sugarcane processed annually. The B.C. Brazilian project was used to calculate the VCR. Its capacity is sufficient to produce enough ethanol to add 10% to the gasoline in Mozambique, and is also consistent with the industrial distillation models that exist in the market for a distillation column.

Table 7: Investments in distilleries with different capacities in Brazil

	Capacity		Investments in Industrial Assets	
Plant	Cane Crushing (kt/year)	Ethanol Production (1000 m^3/year)	USD million	USD/ton Cane
B.M.	2,000	180	85	43
N.E.	600	50	30	50
B.C.	150	13	10	67

Source: ALF International

The ethanol plant derived from molasses currently allows for processing the annual molasses production of the sugar plants in Mozambique. As each liter of ethanol consumes approximately 4 kg of molasses, the above model will require 52,000 metric tons of molasses, or 75% of the 2006 production, as is shown in detail in Figure 11 of Chapter 3, which shows the trends of molasses production in Mozambique.

Plants for oil and biodiesel. The production of vegetable oils derived from some crops is vertically integrated. In the case of African palm and coconut, such integration is technically important and the industrial plant exercises majority control of the crop, in much the same manner as is done in the sugarcane industry. In those countries that have traditionally produced African palm there is also a minority of independent suppliers with long-term contract agreements with the oil extraction facilities.

For oilseed crops like sunflower, castor and jatropha, independent operations are possible, but quite unlikely in Mozambique in the next few years. To guarantee supply, a strong operational link must exist between farmers and processors. The size of the crushing unit will determine the structure. It is easier for independent agricultural production of exportable grains (soybeans, corn, etc.) to develop when the logistics favor export of the raw material. In the cases of jatropha and castor, they have limited liquidity abroad, given that the meal made from them (used as fertilizers) is worth too little to justify transporting the seed over long distances. The total dependence on imported diesel and the low levels of related exports of vegetable oils (as described in Section 3 of Chapter 3) favors biodiesel projects in Mozambique integrated by means of associations or capital investment, due to the possibility that the company will supply sunflower oil for the domestic market and for biofuel production. Such integration with oilseeds will ensure the liquidity of the planted crop, in view of the uncertainty of the demand from abroad.

Capacity of the production facilities. An industrial analysis would not recommend small oilseed crushing facilities (presses), as they lose efficiency because of the comparatively high loss of oil in the meal and other residues. In the specific case of Mozambique, however, where there are no clusters of small producers to produce millions of tons/year of oilseeds, small-scale facilities should also be considered during the first ten years to meet the needs of a biodiesel program derived from sunflower and other oilseeds with a high fat content.

This recommendation is based on the analysis of the trends of the crushing activities in other countries, where oilseed crushing activities typically began with small pressing facilities distributed throughout agricultural regions. Only in the second half of the twentieth century did large solvent extraction plants appear, installed in agricultural clusters in the Americas and in European ports (Rotterdam and Hamburg), which processed imported raw materials.

This model of large processors cannot be easily adapted to Mozambique, due to the fragmentation of the cultivation of agricultural raw materials and to an insufficient logistical infrastructure.

It is possible to install such industrial plants (over 1,000 tons/day of oilseeds) if agro-industrial projects (300,000 hectares) are made feasible through local associations or business groups. The implementation of such plants is made difficult by the lack of alternative markets and also by the fact their sustainability is based on a single domestic biodiesel market. The lack of experience and data for this new product adds to the uncertainty and inhibits the implementation of large-scale projects in which the raw material will be used exclusively for the manufacture of biodiesel (jatropha and castor, for example). When the raw materials have traditional uses in other market segments, such as human food or animal feed (e.g. oil and meal), the major projects are more easily justified because the risk diminishes drastically. Biodiesel production can ensure the supplementary demand for oil. The edible protein-rich portion (meal) will depend, for example, on a structure for the production of animal protein with parallel cultivation of corn. The complexity of the operation demands substantial investments that should be justified by the food market, which has a well-known track record. The existence of options in other countries with more significant agricultural traditions reduces the opportunities for such mega-projects in Mozambique, particularly if they depend on strategic foreign investors who will have other more attractive alternatives for their investments.

It would be prudent to learn the results from growing different oilseed crops in the various regions of the country before allocating significant resources in a sub-region (*mesoregião*). The climatic variations and lack of proven technologies for growing certain crops (jatropha, castor and African palm, among others) also recommend prudence, and explain why major projects for these crops have not yet been implemented, despite land being available. The most likely alternative is the installation of dozens of mini-plants in agricultural regions to produce vegetable oil and co-products for animal feed or fertilizers, which are always needed in those regions. As for the industrial plants for biodiesel production, Table 8 shows two selected alternatives, which can be installed alongside storage locations for diesel and methanol.

Table 8: General parameters for small- and large-scale biodiesel facilities

	Investment (USD million)	Biodiesel m^3/year	Pressing	Solvent Extraction	Location
Small scale	1.76	2,640	Yes	No	Countryside/Port
Large scale	44.0	100,000	Yes	Yes	Port

Source: Alf International

The tables below show the VCR of the two selected hypotheses. As noted previously in the comments regarding ethanol, the sale price of biodiesel was calculated based on the sale price of diesel to the consumer, without including taxes and fees. Similarly, in the cost of biodiesel, no allowance was made for operational profit at any of the intermediate stages of the production chain.

Results of the analysis of total economic returns from biofuels production suggest that there is a substantial opportunity for Mozambique to develop the sector, creating the potential for profit at each stage of the value chain. The degree to which each farmer, fuel producer, distributor and the State will benefit will depend on the arrangements proposed under the National Biofuels Strategy.

The VCR is calculated, as in the case of ethanol, with the following caveats: (i) the income tax is 0%; (ii) profit is not included in any of the stages of the production chain based on the premise is that of an operation that is 100% vertically integrated from agricultural production to delivery of the product at the pump; and (iii) there is no investment in land, given that the land in Mozambique is State-owned and the cost of the land concession is negligible. That assumption generates high VCR (IRR) values when compared with other countries where the capital for land acquisition is a significant factor.

This indicator makes it possible to assess the investment as a national project of Mozambique, which could be called a National Return on Biofuels Investments. The economic actors involved work in collaboration with the State to replace a portion of the imported fuels. The major challenge of the project is to see that the allocation of the VCR is fair, thus maintaining the economic actors united around a shared goal, which is to replace imports.

The VCR (IRR) rates in Table 9 and Table 10 are high for both large and small plants when the cost of the raw material is calculated based on agricultural costs, and to a lesser degree when the baseline cost is the opportunity cost. The figures collected in the agricultural area and in the end-use market indicate that the prudent strategy is the diversification of crops in specific regions and small-scale industrial facilities. The existence of distant regions with

Table 9: Economic returns from biodiesel production – small-scale facilities

	Raw Material - Small Capacity Plants (metric tons/year of biodiesel)				
P&L for biodiesel production	Sunflower	African Palm	Coconut	Castor	Jatropha
Volumes (m^3)					
Domestic (80%)	2,640	2,640	2,640	2,640	2,640
Export (20%)	-	-	-	-	-
Total	2,640	2,640	2,640	2,640	2,640
Price (USD/liter)					
Domestic (1)	0.86	0.86	0.86	0.86	0.86
Export					
Total	0.86	0.86	0.86	0.86	0.86
Net Sales (USD million)					
Domestic	2.27	2.27	2.27	2.27	2.27
Export	-	-	-	-	-
Total	2.27	2.27	2.27	2.27	2.27
Agricultural Cost					
Unit Cost (USD/liter)	0.18	0.58	0.54	0.68	0.68
Total Cost (USD million)	0.48	1.52	1.41	1.81	1.81
EBIT (USD million)	1.79	0.75	0.860	0.46	0.46
Capex (USD million) (2)	1.76	1.76	1.76	1.76	1.76
Working Capital (USD m)	0.20	0.20	0.20	0.20	0.20
Total (USD million)	1.96	1.96	1.96	1.96	1.96
Value Chain Return (VCR) (3)	91%	37%	42%	20%	20%
Opportunity Cost					
Unit Cost (USD/liter)	0.35	0.82	0.50	0.67	1.22
Total Cost (USD million)	0.93	2.17	1.33	1.78	3.23
EBIT (USD million)	1.34	0.10	0.94	0.49	(0.96)
Capex (USD million) (2)	1.76	1.76	1.76	1.76	1.76
Working Capital (USD m)	0.20	0.20	0.20	0.20	0.20
Total (USD million)	1.96	1.96	1.96	1.96	1.96
Value Chain Return –VCR (3)	68%	(11%)	47%	21%	--

(1) Prices do not consider VAT or other taxes
(2) Farming capex not included (machinery, irrigation etc)
(3) Income tax = 0
Source: Alf International.

agricultural potential and distribution hubs for imported hydrocarbons creates the right conditions to distribute the biofuels projects geographically. Installing a large plant for ethanol or biodiesel will not be justified in the next few years. Such large plants are viable in Europe for biodiesel and in Brazil for ethanol, but not in Mozambique.

Table 10: Economic returns from biodiesel production – large-scale facilities (100,000 metric tons/year)

	Raw Material – Large Capacity Plants (metric tons/year of biodiesel)				
P&L for biodiesel production	Sunflower	African Palm	Coconut	Castor	Jatropha
Volumes (m^3)					
Domestic (80%)	100,000	100,000	100,000	100,000	100,000
Export (20%)	-	-	-	-	-
Total	100,000	100,000	100,000	100,000	100,000
Price (USD/liter)					
Domestic (1)	0.86	0.86	0.86	0.86	0.86
Export					
Total	0.86	0.86	0.86	0.86	0.86
Net Sales (USD million)					
Domestic	86.02	86.02	86.02	86.02	86.02
Export	-	-	-	-	-
Total	86.02	86.02	86.02	86.02	86.02
Agricultural Cost					
Unit Cost (USD/liter)	0.20	0.42	0.38	0.49	0.49
Total Cost (USD million)	19.74	41.56	37.76	48.95	48.95
EBIT (USD million)	66.28	44.46	48.26	37.06	37.06
Capex (USD million) (2)	44.00	44.00	44.00	44.00	44.00
Working Capital (USD m)	8.00	8.00	8.00	8.00	8.00
Total (USD million)	52.00	52.00	52.00	52.00	52.00
Value Chain Return (VCR) (3)	127%	85%	93%	71%	71%
Opportunity Cost					
Unit Cost (USD/liter)	**0.31**	**0.58**	**0.38**	**0.49**	**0.85**
Total Cost (USD million)	31.35	58.37	38.02	48.51	85.12
EBIT (USD million)	54.66	27.65	48.00	37.50	0.90
Capex (USD m) (2)	44.00	44.00	44.00	44.00	44.00
Working Capital (USD m)	8.00	8.00	8.00	8.00	8.00
Total (USD million)	52.00	52.00	52.00	52.00	52.00
Value Chain Return –VCR (3)	105%	52%	92%	72%	--

(1) Prices do not consider VAT or other taxes
(2) Farming capex not included (machinery, irrigation etc)
(3) Income tax = 0
Source: Alf International.

7. Conclusions of the discussion of competitiveness

Fossil fuels in Mozambique are not subsidized. Fees, taxes and margins of the various economic actors involved in the import and distribution chain are added to the CIF price. The price components added to the CIF price at the local port are similar to those in Europe and Brazil, with variations in the rates, which is normal. There are nine distributors that create competition, thereby maintaining business margins at normal levels. The cost calculations for ethanol and biodiesel in Mozambique were done based on local estimates and comparisons with other countries, because there is no production of these products on a commercial scale for the transport sector.

Ethanol. The cost comparison for ethanol made from the four pre-selected crops shows a slight variation when derived from sucrose (sugarcane, molasses, sorghum). The cost when derived from cassava (starch) appears to be higher.

This slight variation among the different sources could arise from the lack of market components, given that all the values were calculated from cost estimates. Such a convergence of costs is to be expected, because all four crops have little or no alternative liquidity (i.e. usage). Except for molasses, the others cannot be transferred to other regions or uses due to their limited shelf life.

The characteristics of these four alternatives suggest that there should be a strong association between the agricultural and industrial activities. Vertical integration appears to be the option that would make the potential business ventures viable. Cassava is an exception, but previous experience in other countries suggests caution in establishing logistical arrangements, given the location of origin of feedstocks to supply an ethanol distillery.

Biodiesel. The cost comparison of biodiesel derived from the five pre-selected crops shows a balance among the more traditional feedstocks (sunflower, palm and coconut). The two unusual crops (castor and jatropha) have a higher cost due to the absence of high value co-products. As they are not edible, these oilseeds produce waste byproducts, such as fertilizer with little market value. Some crops (palm and coconut) have the advantage of producing heat from the biomass wastes, an important factor in Mozambique.

The production cost of sunflower oil makes this seed worthy of special attention, primarily because it is annual and is already adapted to the country. African palm also appears to be a good choice to produce large volumes (4 metric tons/hectare) of oil. Since the country's climate is insufficiently humid throughout the year, irrigation should be considered as an alternative. The calculated margin between the sale price of fossil diesel fuel and the cost of biodiesel from African palm is sufficient to absorb the irrigation costs.

Except for sunflower and coconut, the other three oilseed crops should not interfere with the country's food supply if they are implemented in new areas, without encroaching on traditional subsistence crops.

Biofuels to replace the various fossil fuels. The use of liquid biofuels to replace complementary fuels, such as jet fuel, kerosene, fuel oil and liquefied petroleum gas (LPG), was not numerically analyzed. Following the example of other countries, the priority for replacement should be given to those with large volumes and those for which setting the final price is least affected by government protectionism. In addition, it is appropriate to exclude those that are technically incompatible with biofuels.

- *Jet Fuel*. Similar to diesel, this fuel should be removed from the list for possible blending with biodiesel. The presence of residual methanol in biodiesel reduces the flash point in a blend with aviation fuel. This blend is prohibited internationally.

- *Fuel oil and kerosene*. These have historically been used for lighting in homes and industrial generation of steam and/or heat. Their prices are lower because fuel oil is a refinery waste byproduct and kerosene is taxed at lower rates. These lower prices reduce the possible margin when compared with biodiesel. Therefore, it is not prudent, during the initial stage of the program, to conduct studies comparing these fuels with biodiesel.

- *LPG*. Liquefied petroleum gas uses its own specific equipment for industrial and home heating. There is a marginal opportunity to use gelfuel for the same purpose. The consumption of ethanol as gelfuel is still marginal and does not represent enough volume to justify national distribution beyond the normal distribution of the ethanol-gasoline mix. The low energy content per kilo of gelfuel also adds questions regarding the cost of its distribution in rural areas.

In due course, private sector initiatives will arise to buy hydrated ethanol to manufacture gelfuel, which could replace the use of firewood or charcoal in poor homes. It is not prudent to stimulate the sale of liquid ethanol fuel for use in homes. The social costs are high due to the accidents that occur, mainly with children. As a reference, Brazilian laws currently prohibit the sale of inflammable alcohol products in retail packaging for home use.

Scale of production and industrial assets. The current volume of fossil fuels consumed in Mozambique is not sufficient to justify a petroleum refinery. The volume of hydrocarbons imported by Mozambique stands at approximately 570,000 m^3/year (Figure 13 of Chapter

Table 11: Recently constructed ethanol and biodiesel production facilities

	Output – m^3/year	
Place – country	Ethanol	Biodiesel
Teeside – UK Marl – GE Livorno – IT		250,000 200,000 60,000
San Martinho – BR Vale do Rosário – BR Santa Elisa – BR	250,000 250,000 150,000	

Source: Alf International.

1). This volume is equivalent to a refinery of 12,000 b/d, a capacity insufficient to cover the fixed costs in any country. A petroleum refinery could be justified if a substantial portion of the derivatives were destined for export to the interior of the continent (to the west) and to small markets in the Indian Ocean.

Because of the lack of a refinery in Mozambique, the country does not produce hexane (a solvent used in extracting vegetable oils), methyl tertiary butyl ether (MTBE), ethyl tertiary butyl ether (ETBE), methanol and other petrochemical derivatives. This observation suggests caution in the sizing of ethanol distilleries and facilities for vegetable oil extraction and trans-esterification of such oils if the objective is to export. The logistical costs of importing these inputs would undermine competitiveness. Large plants are feasible in Europe for biodiesel and in Brazil for ethanol. Table 11 provides information about the capacities of large plants in some countries that have already been in the biofuels market for more than ten years.

For Mozambique, the biofuels program does not require large volumes. Based on the antecedents researched so far, both in the field and in the final market, the prudent strategy is to diversify crops and process them in several small-scale facilities in different regions. Economies of scale should be sought in the next decade when crops have reached significant volumes.

8. Macroeconomic impact of a biofuels program

This section analyzes the macroeconomic impact of a biofuels program, beginning with estimating its potential output and then expanding the analysis to the potential demand for this output. Building on this supply-demand relationship, we broaden the scope of the analysis to include the relevant macroeconomic variables and, based on what are believed to be reasonable assumptions, we develop estimates of the sector's direct impact on the economy of Mozambique.

As a note of caution, it is important to understand the limits inherent in extrapolating projections based on the scarce information that exists on an emerging sector and, in particular, for some of the new feedstock crops for biofuels. In this model, we are more interested in highlighting the main trends and trade-offs associated with the sector than in determining the precise values of the relevant variables. In the final analysis, the actual amounts will depend on several factors, the trajectories of which are difficult to determine in advance. Through this exercise we intend to identify the policies that will best contribute to the balanced and sustainable development of the biofuels sector – those that could have a positive impact on the main trends – while identifying the key variables that should be monitored in order to fine-tune such policies while the sector develops.

The sector itself will require different policies, depending on its stage of development and the several underlying strategic options and goals set by the Government of Mozambique (GOM). In general terms, the initial stages should be accompanied by policies that favor growth to the detriment of revenues, particularly government revenues, in the form of taxes and fees. During this period, creating the conditions to attract investment is most important. To the extent that such investment is made and reaches an economically stable scale and a competitive industry takes shape, the priority will shift to distributing the wealth that is generated. The scope and depth of the policies – whether they involve taxes and fiscal policies, management of land concessions, exports or legal requirements regarding use of biofuels – must be sufficiently flexible and established in a manner that allows for evolution to accommodate and provide for incentives in accordance with the goals of the GOM and the development stage of the biofuels sector.

Supply. Supply refers to the production in terms of biofuels – or intermediate products such as vegetable oils – that Mozambique will be able to provide, given its natural conditions.

In estimating the production output, a number of factors should be considered: (i) land area currently cultivated, assessed based on the best data estimates currently available, and the area available for each crop, that is, the potential incremental land area for the biofuel crops; (ii) current productivity estimates (for the relevant crops); and (iii) the potential crops for production of biofuels.

Given the current state of the use of the land, our initial cautious estimates point to a low-end figure of 10.5 million hectares available for crops to be used for production of biofuels (Chapter 3). Under this scenario, there is no pressing need to select the most appropriate crops, based on the limited availability of land. It would seem reasonable to agree that, by the time production of biofuel feedstock reaches the stage at which land becomes a scarce commodity, a natural competitive selection of the most viable crops will have already been made. This means that, at this time, it is premature to assess scenarios involving trade-offs between different alternative crops. Indeed, the existing data point to a total of about five million hectares of land currently in use. The estimated potential additional land that could be allocated for production of biofuel feedstocks (incremental area) is roughly double the area of all the land currently in use. This situation reinforces the idea that there is plenty of space for developing multiple crops without the need for unnecessary considerations regarding the reliable availability of existing land in the near and medium-term. The selection of crops and of the surface area to allocate to each should therefore be determined by other factors, such as their productivity in terms of generating biofuels, the quality of the final product, the existence of demand for byproducts or the potential impact on food security and limits in the availability of water for irrigation and, ultimately, by its sustainability and economic viability.

In our model, we assess different scenarios of incremental land, within the limits of the estimated potential, taking into account a few assumptions.

With respect to biodiesel:

- In order to create a baseline scenario from which we can estimate the future growth of the various crops, based on their estimated potential, we take as a starting point the following initial marginal areas: (i) for African palm, castor, jatropha and sunflower, an initial area of 50,000 hectares each; (ii) for coconut, cottonseed and soybeans, a marginal increase of 5% above the estimated current land area used for the production of vegetable oil for biodiesel; (iii) no area is considered for peanut as it is now a crop of interest for biodiesel.

- We take into consideration the crops identified as having the highest potential (per our recommendations presented in Chapter 8) – jatropha, sunflower, castor, coconut (copra) and African palm – by assigning these feedstocks a higher rate of expansion in the land area cultivated. The formula used to simulate the growth in the land area used for each crop is given as: "Base area" * (1+0.25 * "Period #" * 2) for those crops deemed to have higher potential.
- Given the limits on expanding the more perennial crops (African palm and copra), we assigned a lower rate of expansion to these crops, adjusting the formula to: "Base Area" * (1+0.25 * "Period #" * 2/2).
- We also take into consideration the fact that the crops identified as having lower potential (soybeans, cotton) will contribute only marginally to the production of biofuels. In this case, we assumed an expansion of 5% of the cultivated area per period.
- For the sake of simplicity, we aggregate the various crops into a single "average crop" in terms of productivity per hectare of vegetable oil (and also for ethanol). In this way, we consider the average potential output for the cultivated area for biofuels. Given that we do not know which choice will finally determine the areas assigned to each crop, this indicator will give us a generic perception of potential overall production without the need to speculate about details or trend lines for each crop. This potential will serve as a baseline for analyzing the macroeconomic impacts of the sector.

With respect to ethanol:

- Sugarcane and sweet sorghum, the crops indicated as having the greatest potential, similar to the biodiesel feedstocks, follow a trajectory of expansion, according to the formula "Base Area" * (1+0.25 * "Period #" * 2)
- For cassava and maize, to be used marginally in the production of ethanol, the simulation of their expansion follows a similar logic to that defined for the biodiesel feedstocks, i.e. 5% growth in land area per period.

These assumptions, though perhaps somewhat arbitrary (although simulating reality), should illustrate trends that may reasonably be expected. As noted above, the interest lies more in understanding the overall trends than in speculating about absolute final values.

Based on assumptions outlined above, three alternative scenarios with different land areas dedicated to the production of biofuels were considered. These different scenarios serve as indicators of the magnitude of the impact that the sector will have on the relevant macroeconomic variables, especially the total volume of business transactions, tax revenues, job creation and impact on the balance of payments abroad.

- The **Less Optimistic Scenario** assumes that only a limited portion of land, relative to the identified potential, will be used for production of biofuels. This scenario reflects low international feedstock and biofuels prices and the lack of clear policies in importing countries, as well as depressed oil prices. It can be viewed as a scenario with slow growth of the sector, due to the variety of difficulties investors face in obtaining land and getting their projects to materialize.
- The **Intermediate Scenario** assumes more extensive additional land use and greater production volumes. The underlying determinants in this scenario are a more favorable

trend in prices for biofuels or feedstocks, a confirmation of international commitments in deciding on policies for the sector, and sustained high petroleum prices.

- The **Optimistic Scenario** is characterized by an even more favorable trend for the sector, whether due to an international rise in biofuel prices or to strong renewable fuel standards (RFSs) requiring the use of biofuels in major importing countries, especially Japan, along with high petroleum prices.

Under all the above scenarios, production remains significantly below the potential supply represented by the 10 million hectares of land estimated to be available for the production of biofuels feedstocks. This means that a reasonably conservative expectation for the biofuels sector was adopted in the analysis, taking into consideration the countless limitations this sector is likely to face (such as the lack of infrastructure to collect water for large-scale irrigation projects, a variety of other infrastructure deficiencies, or the possibility that the land allocation processes may take a long time), as well as a variety of identified uncertainties, such as future trends in overall demand and the competitiveness of the Mozambican biofuels sector in international markets. Table 12 illustrates the various scenarios outlined.

In the optimistic scenario, with a total incremental land area on the order of 3.379 million hectares, the production of biofuels would amount to about 5 billion liters (including both bioethanol and vegetable oils/biodiesel) and would generate around USD 3.5 billion at current market prices. This scenario is well below the estimated potential land available for the expansion of biofuel crops. Given that the combination of production assumptions (i.e. of land allocation and feedstock crops) is arbitrary, this scenario is sub-optimal even for the land area that is used, so it is reasonable to assume that both the volume of output and the potential dollar value (at current prices) may actually be higher. As noted above, the future allocation of land to each feedstock crop will go through a “natural selection” process: as more projects are implemented and become operational, more data will become available. The less competitive crops and production methods will gradually be abandoned (as they prove impracticable), which will make it possible to achieve full potential over the long-run.

Under this perhaps optimistic but also realistic scenario, volumes and sales generated are quite significant in the context of the Mozambican economy. Even under the more conservative assumptions of the other two scenarios, volumes and sales to be generated by the sector are of great significance to the country’s economy and cannot be disregarded. These scenarios can also be seen as an evolutionary path to be followed by the sector, beginning with its inception and growing until it achieves a significant scale; furthermore, they illustrate how the scale of the biofuels sector affects the overall economy.

Demand. This section analyzes demand in both the domestic and international markets. The primary question addressed is how Mozambique’s potential supply compares with the size of the market, i.e. both the domestic demand (in Mozambique) and the most important overseas markets, such as Europe, the United States and Japan.

- *Ethanol*. Given the amounts cited above, which were also mentioned in Chapter 1, the global market for ethanol is expected to reach 120 billion liters by 2020 (at a 6%

blending ratio). In the scenario presented for Mozambique, vest in which it produces 2.7 billion liters, the country's market share would be about 2.25%. At that level of production and market share, ethanol in Mozambique would generate US D1.5 billion in sales, primarily destined to meet the demand for ethanol abroad.

A critical underlying assumption for this is that Mozambique's biofuels industry be able to compete within the context of a global competitive market. The bioethanol market is highly competitive, with Brazil as the leading force that drives market prices.

It is also a highly protected market in most end-user countries, which complicates the efforts of many emerging market countries, such as Mozambique, to become competitive in the near future. Despite such difficulties, given that Mozambique would account for a small market share (2.25% in 2020, for example), it is reasonable to assume that the export market presents a good opportunity for Mozambique in the long run. The fact that there is already an emerging sugar industry in Mozambique, where important global companies already operate, further supports this possibility.

- *Biodiesel (and vegetable oils).* Based on the market projections for biodiesel (see Table 20 in Chapter 2) the total estimated volume of the major potential markets for Mozambique in 2010 will be in the range of 10.2 to 14 billion liters (assuming a blend ratio of 5% to 6%). Mozambique has the potential to produce large quantities of vegetable oil. With an incremental land area of just 200,000 hectares dedicated to the production of biodiesel feedstocks (under the less optimistic scenario), Mozambique could produce roughly 365 million liters per year, equivalent to between 2.6% and 3.5% of the market.

  In the long run, Mozambique offers the potential to increase its production several times from the volume indicated in this baseline scenario. As more land is used for growing biodiesel feedstocks and production increases in scale, Mozambique could produce several billion liters annually. In a scenario in which land usage reaches 2 million hectares (roughly ten times the baseline scenario), Mozambique's total output of vegetable oils could reach as much as 2.7 billion liters per year, or between 20% and 25% of the estimated market size in 2010 in the same key countries. It is unlikely that Mozambique will supply this much of the major markets. Other economies, some already proven to be far more competitive in a global context, such as Brazil, are increasing their output, which will limit the market share of the emerging suppliers.

  It is also foreseeable that the markets will increase substantially in scale. Combined with the increase in fuel demand, various countries are likely to raise their blending rates in the years to come, which will have a direct impact on the overall market size. Countries such as Portugal are already establishing 10% blending rates, well above the 5% to 6% rate that was used to estimate the 2010 market. With a further widespread increase to 15%, the global market (represented by the selected key markets) could reach 30 to 42 billion liters, substantially increasing its capacity to absorb production from countries such as Mozambique.

  There are two fundamental factors that will contribute to a relatively gradual market

Table 12: Estimates of production levels and land requirements for the biofuels sector

Biodiesel feedstocks	CURRENT		Low Scenario				Medium Scenario				High Scenario			
	Production (tons)	Area in Production (ha)	Incremental Area (ha)	Composition Incremental Area	Potential Biodiesel Output (kl)	Value (USD)	Incremental Area	Composition Incremental Area	Potential Biodiesel Output (kl)	Value (USD)	Incremental Area	Composition Incremental Area	Potential Biodiesel Output (kl)	Value (USD)
			32%				138%				298%			
African palm	--	--	**50,000**	**23%**	253,950	171,975,399	**150,000**	**16%**	**761,851**	515,926,196	**300,000**	**15%**	**1,523,702**	1,031,852,392
Castorseed	--	--	**50,000**	**23%**	56,433	63,694,592	**250,000**	**27%**	**282,167**	318,472,960	**550,000**	**27%**	**620,767**	700,640,513
Copra (1)	103,500	140,000	**7,000**	**3%**	3,621	3,065,461	**21,000**	**2%**	**10,864**	9,196,384	**42,000**	**2%**	**21,728**	18,392,769
Cottonseed	44,400	137,888	6,894	**3%**	326	279,410	8,380	**1%**	**396**	339,625	9,701	**0%**	**458**	393,158
Jatropha	--	1,000	**50,000**	**23%**	42,325	36,305,917	**250,000**	**27%**	**211,625**	181,529,587	**550,000**	**27%**	**465,576**	399,365,092
Peanut	145,584	363,960	0	0%	0	0	0	0%	0	0	0	0%	0	0
Soybean (3)	3,221	6,726	336	**0%**	25	20,106	409	**0%**	**31**	24,439	473	**0%**	**36**	28,291
Sunflower (4)	11,000	22,000	**50,000**	**23%**	9,029	7,643,351	**250,000**	**27%**	**45,147**	38,216,755	**550,000**	**27%**	**99,323**	84,076,862
Total (or average)	**307,705**	**671,574**	**214,231**	**100%**	**365,711**	**282,984,237**	**929,789**	**100%**	**1,312,081**	**1,063,705,947**	**2,002,174**	**100%**	**2,731,590**	**2,234,749,076**

Ethanol feedstocks	CURRENT		Low Scenario				Medium Scenario				High Scenario			
	Production (tons)	Area in Production (ha)	Incremental Area (ha)		Potential Ethanol Output (kl)	Value (USD)	Incremental Area (ha)	Composition Incremental Area	Potential Ethanol Output (kl)	Value (USD)	Incremental Area (ha)	Composition Incremental Area	Potential Ethanol Output (kl)	Value (USD)
			9%				27%				52%			
Cassava	7,551,727	1,258,621	62,931	**26%**	44,422	24,782,757	76,493	**11%**	53,995	30,123,596	88,550	**6%**	62,506	34,871,828
Molasses (tons)	60,000	--			15,000	8,368,421			33,750	18,828,947			56,250	31,381,579
Maize	1,533,520	1,333,496	66,675	**28%**	29,719	16,580,286	81,044	**12%**	36,124	20,153,441	93,818	**7%**	41,818	23,330,127
Sugarcane (2)	2,060,317	34,693	8,673	**4%**	44,117	24,612,908	43,366	**6%**	220,587	123,064,539	95,406	**7%**	485,292	270,741,987
Sweet sorghum grain (5)	--	--	**50,000**	**21%**	56,250	31,381,579	**250,000**	**36%**	281,250	156,907,895	**550,000**	**40%**	618,750	345,197,368
Sweet sorghum cane (5)	--	--	**50,000**	**21%**	130,000	72,526,316	**250,000**	**36%**	650,000	362,631,579	**550,000**	**40%**	1,430,000	797,789,474
Total (or average)		**2,626,810**	**238,279**	**100%**	**319,509**	**178,252,267**	**700,903**	**100%**	**1,275,707**	**711,709,998**	**1,377,774**	**100%**	**2,694,616**	**1,503,312,363**
Total (or average)		**3,298,384**	**452,510**		**685,219**	**461,236,503**	**1,630,692**		**2,587,788**	**1,775,415,945**	**3,379,949**		**5,426,207**	**3,738,061,439**

Source: Econergy.

Table 13: Analysis of market share – ethanol

Analysis of Mozambique share of the International key markets under different putput scenarios

BIOETHANOL

Assumptions	Low Scenario	Medium Scenario	High Scenario
Land Usage (ha)	238,279	700,903	1,377,774
Output (Kl)	444,025	1,275,707	2,694,616
Revenues (USD)	178,252,267	711,709,998	1,503,312,363

Share as a % of total market size

1) Ethanol for 2020 demand (average 6% blending)

Ethanol	Low Scenario	Medium Scenario	High Scenario
2020 Estimate	0.3%	1.1%	2.2%

1) Ethanol for 2006 demand

Ethanol	Low Scenario	Medium Scenario	High Scenario
2006 Total	1.3%	5.3%	11.1%

Table 14: Analysis of market share - biodiesel

Analysis of Mozambique share of the International key markets under different putput scenarios

BIODIESEL (Vegetable Oils)

Assumptions	Low Scenario	Medium Scenario	High Scenario
Land Usage (ha)	214,231	929,789	2,002,174
Output (Kl)	365,711	1,312,081	2,731,590
Revenues (USD)	282,984,237	1,063,705,947	2,234,749,076

Share as a % of total market size

1) Biodiesel for 2010/2015 demand (average 5-6% blending)

Biodiesel	Low Scenario	Medium Scenario	High Scenario
High	3.6%	12.9%	26.8%
Low	2.6%	9.4%	19.5%

growth. There is the need to guarantee a stable equilibrium between supply and demand (which, to a certain extent, requires establishing relatively low blending ratios); and to allow for the necessary investments to occur in terms of capacities in logistics, refining, adapting consumer product technologies such as flex-fuel vehicles, increasing the agricultural output of feedstock, etc., so that blending ratios become truly feasible

Over the long term, it is theoretically possible that blending ratios be increased (at the limit of 100%, completely replacing diesel fossil fuel). Such a scenario would render current projections much more limited by comparison, in terms of how much further the market could be taken.

> As demand will grow in stages, in accordance with future blending ratio trends, the increase in the amount of land required to satisfy that demand will also tend to be gradual and is not likely to occur within a short period. This should be viewed from a long-term perspective, due to the various constraints that such a transition will face from the launching of investment projects up to the phase where industrial facilities become operational, with deployment of logistical capacity and infrastructure adequate to accommodate the volume of output involved. This gradual evolution of the biofuels sector suggests an incremental relationship between the land area growing feedstock, the amount of production and the amount of money involved. The scenarios presented can be seen as an incremental path (in stages) towards creating the biofuels industry, but most of all they are designed to allow for a "what if" analysis of what may happen if the industry reaches a certain scale. Therefore, these scenarios do not necessarily represent the trends that are expected to occur in the industry.

Domestic Market. Up to this point, the analysis has focused on the international market for bioethanol and diesel, but it is also important to take into consideration the potential domestic demand. Although the domestic market is much smaller in size than regional or international markets, the transition from fossil fuels to biofuels in Mozambique presents two noteworthy additional factors: (1) it has a direct impact on economic structural variables (such as the trade deficit and government budget deficit, through tax revenues), and (2) it involves an important role for the Government of Mozambique (GOM) in the biofuel industry, in that its policies will outline and establish the shape the industry itself, especially regarding the domestic market. Given that decisions to be made by the GOM will determine the size of the market, it will be easier to prepare more precise market scenarios and estimates based on policy options adopted. Such factors will determine the relevance of the domestic market analysis, despite its relatively small size.

Establishing mandatory blending rates can create an incentive to quickly launch the domestic market. Despite being small compared with the country's production potential, the simple act of creating a domestic market will stimulate increased local production. To supply the necessary output of biodiesel (estimated at 20 million liters in 2010 or twice that volume in 2017, per estimates in Chapter 2, Section 1), an estimated 12,000 to 24,000 additional hectares will be needed to ensure the necessary supply of the feedstock. In the case of bioethanol, the introduction of a mandatory blending rate for gasoline could, for example, create conditions for the use of the molasses currently produced by the sugar mills.

Nevertheless, the domestic market is not large enough to provide the basis for a large-scale industry. The most significant consequence of this fact is that, unlike other countries, particularly Brazil, the domestic market is not large enough to allow for mechanisms that create the necessary incentives for the development and functioning of a national biofuels industry. In other words, the Mozambican biofuels industry will always depend on the dynamics of international supply and demand. This also means that the Brazilian model is not really applicable in Mozambique insofar as internal demand will not be sufficient to guarantee the market for output, even at relatively modest levels of production. Thus, mechanisms such as setting minimum prices or protecting against imports will have only a marginal effect on the industry, after its initial stage. Therefore, Mozambique will be a "price taker" and its ability to retain the small volumes of production needed to satisfy domestic demand will depend on its ability to pay the international price for its domestic production. In short, Mozambique will be completely exposed to the fluctuations in world biofuels prices.

The preceding discussion provides some perspective by comparing the current level of land use in Mozambique as a baseline for estimating its potential output. It also describes the capacity of foreign and domestic markets to absorb the potential output. This discussion points to a need to analyze the biofuels sector in the context of the global industry, and also to consider the capacity to compete, in this context, as a factor that will be critical to the success of the biofuels industry in Mozambique. The experience of Thailand, described in Chapter 7, demonstrates the harmful consequences of failing to be competitive in international markets. In that case, the government was first to feel the impact of not being able to compete internationally, given that it had pledged to purchase all of the country's unsold production. On the other hand, the Brazilian experience demonstrates how market competitiveness proved to be highly profitable.

9. Macroeconomic Analysis

Taking as our point of reference the scenarios presented in Section 1 of this Chapter, it is possible to estimate the magnitude of the impact of the biofuels sector on several key macroeconomic variables. Specifically, this analysis covers tax revenues, job creation, the foreign trade balance and the impact on the economy as a whole.

Tax revenues. Basically, the logic underlying the first part of the effect on tax revenues is the choice or trade-off between two alternatives: the revenues the government collects from taxes on fossil fuels, and those the government will collect from taxes on biofuels, to the extent that the latter will replace the former. Given that biofuels replace fossil fuels, the taxes on biofuels should also replace taxes on fossil fuels. Thus, deciding on the tax structure to be applied to biofuels will ultimately determine the government's tax revenue balance.

Given the current composition of fuel tax revenues in three parcels (import duties, VAT and a tax on fuels), it is important to understand how new tax policies would compare to this structure in terms of potential tax revenues and the underlying dynamics. For instance, given that some imports will in principle be replaced by domestic production, it is clear that some import duties will be lost, and may need to be compensated by adopting a different tax structure, perhaps through direct taxation of producers' profits (if any compensation should be made).

It is important to note that, while on the one hand the tax revenues on fossil fuels pertain only to consumption in the domestic market (the country imports almost 100% of its needs, when analyzing the fiscal impact of biofuels, on the other hand, we should consider the fact that Mozambique will, in all likelihood and to a great extent, become a net exporter of biofuels (or their intermediate products). Thus, the taxes and fees on biofuels consumed locally will likely constitute a small portion of the total taxes applicable to biofuels (understood here as both direct and indirect taxes, including, for example, taxes on producers' profits, income taxes on the earnings of employees in jobs created in the industry, export taxes, etc.). Thus, the tax substitution effect should be understood in a broader perspective.

There is also another important trade-off to consider, which is the different taxation timeframe, particularly the short-term loss of tax revenues and a corresponding increase in revenues in the medium and long-term. The general idea is that potential tax revenue losses resulting from tax incentives created to promote development of the biofuels sector in its early stages can be recovered once the sector matures, either through taxation of profits (direct taxes) or through direct taxation of biofuels (for example, in a manner similar to taxes on fossil fuels, or fees on exports of unprocessed intermediate products, or in another manner). Once again, the example of loss of customs duties to be compensated for in the future by taxes on producers' profits illustrates a trade-off of tax revenues over time.

Achieving a balanced government budget presents a critical structural challenge for the Mozambican economy. Although the deficit figures have clearly improved in recent years, the budget deficit still constitutes an important economic weakness. For this reason, fiscal policies conducive to a concerted effort to increase tax collections are essential for the Mozambican Government. The government's efforts to reverse the structural deficit are reflected in the fact that tax revenues have been growing slowly but steadily, at a pace much faster than that of economic growth (as noted in Chapter 1). Even so, it is important to recognize that the Government of Mozambique is under strong pressure to balance its budget, a fact that has been accentuated by the country's planned integration in 2008 into a Southern Africa Development Community (SADC) free trade area, which is expected to reduce custom revenues, aggravating the budget deficit and leaving little room to maneuver in terms of providing tax reductions or incentives.

The crucial point on this issue is to estimate the impact of tax policies for the biofuels sector and the impact such policies have, in terms of contributing to balancing the government budget. In most countries, biofuels have benefited from favorable tax incentives, and the dilemma for a country with quite limited financial resources, such as Mozambique, is (1) how far it can go in offering tax incentives without further aggravating the fiscal imbalance, while simultaneously (2) creating the necessary incentives for the industry to prosper.

An important factor to consider is the gradual decline in the relative weight of taxes on fossil fuels as a share of the government's total revenues, combined with the stagnation, in absolute dollar terms, of revenue from such taxes (as noted in Chapter 1), primarily as a result of introduction of VAT (indirect tax) and the IRPC/S (direct taxes). The gradual expansion of the tax base and the introduction and expansion of the new taxes (VAT and IRPC/S) has not only substantially increased government tax revenues, but has also reduced the relevance of traditionally important revenue, particularly customs duties and fuel taxes, the latter being more important in the context of biofuels. The smaller relative contribution of taxes on fuels to the government budget allows for more flexibility in deciding on such taxes.

As described in Chapter 1, gasoline and diesel are moderately taxed in Mozambique, at about 41% of the final price to the consumer for gasoline and 30% of the equivalent price for diesel. The fuel tax (ISC) is the largest component of the total tax burden, accounting for 26% of the consumer price for gasoline and 14% for diesel, with the VAT accounting for 12% for gasoline and 13% for diesel. (See Table 4, Chapter 1).

According to estimates for replacement of fossil fuels by biofuels, and assuming E10 and B5 blending standards in force by 2010, the impact in terms of imports displaced and lost tax revenues (in volumes and values, respectively) is shown in Table 15.

The loss in tax revenue on all fossil fuels due to such displacement, based on the current size of the domestic market, would amount to about USD 12 million, reaching an expected USD 31.4 million by 2015 (long term). With E10 and B5 blending ratios, the inherent substitution of volumes will account for roughly 7% of overall revenues from taxes on fuels.

It is important to note that of the three tax components, the import fees would disappear by virtue of displacing imported fuel; the other two would remain in place or not, depending on the government's policy on biofuels.

Different scenarios can be developed to achieve the best balance of tax incentives (such as eliminating the ISC but maintaining the VAT, or waiving both), but it is clear that the overall amounts involved are relatively insignificant in the context of total government revenues.

The other side of the equation in analyzing the fiscal impact is to include taxes on earnings in projected government revenues.

Given that at this time there are no tax revenues on profits, any taxation, however small, can only have a positive impact on revenues. There are therefore sound reasons to consider tax incentives in these direct taxes from the very beginning: such incentives could go as far as tax a tax exemption. In order to estimate the potential revenues from a tax on earnings (a direct tax on company profits) that the biofuels sector may generate, we can assume a profit, or net margin, as a percentage of the total volume of business transactions. Assuming this profit margin to be 5% of that total revenue, and taking as a baseline the different scenarios, Table 16 describes this relationship and estimates the potential tax revenues that the sector would generate for the government, based on an effective tax rate of 20%.

Of course, it is quite difficult to estimate the revenue from taxes on earnings, given that this will depend on the profitability of the various individual projects, which certainly is likely to vary both from one project to another and over time. It is to be expected that most companies would generate losses during the first few years due to amortization of their investments and all the additional start-up costs associated with new projects.

Table 15: Estimate on the impact on tax revenues of displacement of fossil fuels by biofuels

IMPACT ON FISCAL REVENUES - Substitution Effect (Trade-off)				
		Reference Value	Short Term	Long Term
1. Substitution of fuel imports			**$17,851,140**	**$44,311,000**
Gasoline consumption	US$		$7,010,640	$21,280,000
Volume	Litros		12,519,000	38,000,000
Price (CIF)	US$/l	**$0.56**		
Diesel consumption	US$		$10,840,500	$23,031,000
Volume	Litros		20,075,000	42,650,000
Price (CIF)	US$/l	**$0.54**		
1.1 Fiscal revenue fuel replacements			**$12,222,869**	**$31,431,038**
Fiscal revenues on gasoline		Import Duty	350,532	1,064,000
		Fuel Tax	3,864,907	11,731,487
		VAT	1,782,399	5,410,268
		Total	**5,997,838**	**18,205,755**
Fiscal revenues onDiesel		Import Duty	544,265	1,156,309
		Fuel Tax	$2,993,457.42	$6,359,699.08
		VAT	2,687,308	5,709,275
		Total	**6,225,031**	**13,225,283**
1.2 Fiscal Revenues on replaced fuel as a % of total tax revenues from fuels				**7.02%**

Source: Econergy.

As production efficiency is gradually optimized and reaches economically profitable volumes, it is likely that profits would become more significant, as would receipts from taxes on such profits.

The key factor in determining the actual amount of revenue from a tax on earnings will be the profitability of the biofuel projects. Tax revenues are a direct and proportional function of the profit margin achieved by private investors. In order to fine-tune tax policies to be more effective, the Tax Authority should assess trends in the companies' profitability in order to (1) ensure the viability of the investments and (2) maximize government revenue.

However, building on the analysis presented above, which shows substantial VCRs for specific feedstock crops, the likelihood of profitability appears strong: it therefore seems reasonable to recommend that tax policy for such businesses not include any special exemption. Indeed, the strongest argument for not giving biofuels ventures any special tax exemption is the fact that several investors are already proceeding with large-scale biofuels ventures in the country.

It is expected that the sector will grow significantly over the next decade, based on both domestic demand and exports, sustaining several profitable ventures. If one assumes incentives based on exemptions from the ISC, or even the VAT, for the biofuel component of the mandated blends, it is likely that increased revenues from taxes on earnings will

Table 16: Estimate of revenue from a Tax on Corporate Earnings (IRPC) on biofuels

	Low Scenario			Medium Scenario			High Scenario		
Biodiesel feedstocks	Value (USD)	Profit Margin (USD)	Income Tax (20% effective)	Value (USD)	Profit Margin (USD)	Income Tax (20% effective)	Value (USD)	Profit Margin (USD)	Income Tax (20% effective)
African palm	171,975,399	8,598,770	1,719,754	515,926,196	25,796,310	5,159,262	1,031,852,392	51,592,620	10,318,524
Castorseed	63,694,592	3,184,730	636,946	318,472,960	15,923,648	3,184,730	700,640,513	35,032,026	7,006,405
Copra (1)	3,065,461	153,273	30,655	9,196,384	459,819	91,964	18,392,769	919,638	183,928
Cottonseed	279,410	13,971	2,794	339,625	16,981	3,396	393,158	19,658	3,932
Jatropha	36,305,917	1,815,296	363,059	181,529,587	9,076,479	1,815,296	399,365,092	19,968,255	3,993,651
Peanut	0	0	0	0	0	0	0	0	0
Soybean (3)	20,106	1,005	201	24,439	1,222	244	28,291	1,415	283
Sunflower (4)	7,643,351	382,168	76,434	38,216,755	1,910,838	382,168	84,076,862	4,203,843	840,769
Total	**282,984,237**	**14,149,212**	**2,829,842**	**1,063,705,947**	**53,185,297**	**10,637,059**	**2,234,749,076**	**111,737,454**	**22,347,491**
	Low Scenario			Medium Scenario			High Scenario		
Ethanol feedstocks	Value (USD)	Profit Margin (USD)	Income Tax (20% effective)	Value (USD)	Profit Margin (USD)	Income Tax (20% effective)	Value (USD)	Profit Margin (USD)	Income Tax (20% effective)
Cassava	24,782,757	1,239,138	247,828	30,123,596	1,506,180	301,236	34,871,828	1,743,591	348,718
Molasses (tons)	8,368,421	418,421	83,684	18,828,947	941,447	188,289	31,381,579	1,569,079	313,816
Maize	16,580,286	829,014	165,803	20,153,441	1,007,672	201,534	23,330,127	1,166,506	233,301
Sugarcane (2)	24,612,908	1,230,645	246,129	123,064,539	6,153,227	1,230,645	270,741,987	13,537,099	2,707,420
Sweet sorghum grain (5)	31,381,579	1,569,079	313,816	156,907,895	7,845,395	1,569,079	345,197,368	17,259,868	3,451,974
Sweet sorghum cane (5)	72,526,316	3,626,316	725,263	362,631,579	18,131,579	3,626,316	797,789,474	39,889,474	7,977,895
Total	**178,252,267**	**8,912,613**	**1,782,523**	**711,709,998**	**35,585,500**	**7,117,100**	**1,503,312,363**	**75,165,618**	**15,033,124**
Total	**461,236,503**	**23,061,825**	**4,612,365**	**1,775,415,945**	**88,770,797**	**17,754,159**	**3,738,061,439**	**186,903,072**	**37,380,614**

Source: Econergy.

more than compensate forgone receipts from indirect taxes due to the possible incentives. In the scenarios presented, even assuming moderate projections (Intermediate scenario), the tax on earnings will exceed any revenue loss due to exemptions from indirect taxes (even in the case of a 100% exemption from indirect taxes). Over the long run, the tax on earnings should be a stable additional source of revenue with a broadly positive impact. Moreover, the initial tax exemptions could be gradually phased out, adding to the overall positive result from the set of taxes and fees applicable to the sector. Given that revenues from taxes on profits in this sector do not exist at the present time, any direct taxation of profits, however small, can only have a positive impact on revenues.

Job creation. The emergence of the biofuels industry is expected to have a rather significant impact on job creation. The industry is based on agricultural production, which is generally labor-intensive, particularly in a country such as Mozambique where most agricultural output is generated by small-scale and family farms. It is estimated that about 70% of the population lives in rural areas where the feedstock crops for biofuels will be grown. In absolute terms, this translates into roughly 14 million people. In these rural areas, poverty is more pronounced and per capita income is lower than in urban areas.

The potential for job creation can be estimated as a function of incremental land areas that will be allocated to production of biofuel feedstocks. The production of such crops requires a specific labor force that can be quantified based on the number of hectares used.

The previous analysis introduced three scenarios regarding the incremental land areas that will be allocated for specific crops. Incremental land usage under the three scenarios will respectively amount to about 452,000 hectares (less optimistic), 1.63 million hectares (intermediate), or 3.38 million hectares (optimistic). Land area per family farmer (which can be considered a full-time job) or farm worker (in this context, considered to be a full-time employee) for various similar crops we have examined would be up to 2.5 hectares per person, a figure that is based on observations made in India.[1] Assuming an average area of 2.0 hectares per farmer, Table 17 projects job creation estimates under each of the scenarios for expansion of cultivated land. Given that the primary biodiesel feedstocks are ones that most likely would include production mainly by small family farms, it is reasonable to view the estimates presented in Table 17 as an upper limit for job creation in the biodiesel segment of the biofuels industry as a whole.

The numbers are quite significant, even in the less optimistic scenario, which assumes that only a relatively small portion of the estimated available land is in fact brought into production (some 210,000 hectares out of the 10 million hectares estimated as land potentially available for production of biofuel feedstocks). Under the more optimistic scenario, the equivalent job creation would reach about 1 million new jobs generated directly in agriculture – a truly impressive number. To the extent that large areas of land are brought into cultivation, this would probably involve large-scale commercial farms, so the number of jobs created would be less than the estimate given.

Table 17: Estimate of job creation based on the ratio of land area (ha) per family farmer - biodiesel

Job creation	Low Scenario average holder surface (ha)			Medium Scenario average holder surface (ha)			High Scenario average holder surface (ha)		
	Low	High	average	Low	High	average	Low	High	average
Area per farmer (ha)	1.5	2.5	**2.0**	1.5	2.5	**2.0**	1.5	2.5	**2.0**
Incremental area Biodiesel (ha)		214,231			929,789			2,002,174	
Total New Jobs Biodiesel	142,820	85,692	**107,115**	619,859	371,916	**464,894**	1,334,783	800,870	**1,001,087**

Source: Econergy.

Table 18 presents an equivalent estimate for the expansion of production based on large commercial-scale farms, which is likely to predominate in the bioethanol segment of the biofuels sector. As may be expected, the number of workers per unit of land area (hectare) is considerably lower, about ten percent of the corresponding figures used in the case of small family farms. These figures are in the range of various estimates for the sector in Colombia, Mexico and India, as well as information from the ProCana project in Mozambique. In this case, the job creation figures can be viewed as a lower limit for the number of jobs estimated to be created in the ethanol segment of the biofuels sector, given that even the commercial farming projects will involve some cultivation by family farmers, or rural laborers, working on small plots. Under the less optimistic scenario, 47,000 new jobs would be created, while under the more optimistic scenario the number of jobs created could reach 275,000.

[1] Agicultural Census Division, India.

Taken together, the total number of jobs created in these two segments of the biofuels sector could range from 150,000, under the less optimistic scenario, to 1.25 million under the more optimistic scenario.

Table 18: Estimate of job creation based on plantation development - ethanol

Job creation	Low Scenario average holder surface (ha)			Medium Scenario average holder surface (ha)			High Scenario average holder surface (ha)		
	Low	High	average	Low	High	average	Low	High	average
Ethanol: Workers per area (ha)	0.15	0.25	0.20	0.15	0.25	0.20	0.15	0.25	0.20
Incremental area Ethanol	238,279			700,903			1,377,774		
Total New Jobs Ethanol	35,742	59,570	**47,656**	105,135	175,226	**140,181**	206,666	344,444	**275,555**

Source: Econergy.

The potential significance of such job creation in the biofuels sector underscores its potential impact on the economy of Mozambique. It is important to understand that this would also correspond to an extremely wide distribution of earnings generated by the sector among a large portion of the population. Consequently, development of the biofuels industry presents a good opportunity to significantly reduce the endemic poverty the country faces, especially in those regions where it is felt most intensely. Unlike the other economic sectors in which Mozambique offers a high potential, such as mineral extraction or hydroelectric power generation, which are typically capital intensive, the biofuels sector offers a disproportionate potential to create jobs, distribute wealth and reduce poverty.

The biofuels sector integrates large-scale projects with the capacity to generate significant revenues – along the lines of some clear examples of such large projects in Mozambique, such as Mozal or Cahora Bassa – but with the additional advantage of fostering balanced and sustainable economic and social development in the country. In contrast, mega-projects have frequently been criticized for the relatively modest benefits they bring to Mozambique. In addition to their limited capacity to generate employment, these projects have normally been predicated on generous tax benefits, extensive use of imported inputs, negative environmental impacts and/or export of unprocessed raw materials, which tends to leave most of the value to be added through processing outside of Mozambique. The biofuels sector could constitute a break from this trend, making a sustainable and decisive contribution to the development of the Mozambican economy as a whole.

Foreign trade balance and impact on the overall economy. Mozambique has traditionally posted a large international trade deficit. In 2004, total exports were USD 1.5 billion. During the same period, imports were USD 10.8 billion, which translates into a massive trade deficit weakening the economy. This is a strongly negative situation, even more so because a large portion of the exports (nearly 66%) are generated by Mozal, which imports a significant portion of its consumable inputs, leaving little value within the country and generating rather limited tax revenues.

The trade deficit harms the economy by contributing to a net loss of exported resources that cannot be reinvested domestically to generate more wealth. It also contributes to increasing the demand for hard currency needed to pay for imports, with a direct impact on the stability and value of the national currency, the Metical. The trade deficit also has a negative impact on interest rates, hindering the ability of investors to finance investments within Mozambique and increasing the country's consequent reliance on international donors and additional debt. This structural imbalance can only be mitigated with the shift to export-oriented projects and/or domestic production of the goods and services that are needed within the country. Fuel certainly fits these criteria.

The first direct impact of the production of biofuels in Mozambique and their domestic consumption would be the displacement of fossil fuel imports by locally produced fuel. This substitution effect returns the funds that otherwise would be spent on such imports directly into the domestic economy, in the form of salaries, taxes and increased economic activity, in general (such as domestic transportation). Table 19 below estimates the potential savings obtained in this manner for the quantities to be displaced in 2010, assuming that E10 and B5 blend standards are in place. Although positive, the resulting impact is rather small relative to overall foreign trade volumes, due to the limited size of the domestic market for fuels.

Table 19: Estimated impact on the trade balance of displacement of fossil fuels

Imports substituted by internal production (diesel and Gasoline) 2010			
	Diesel (Liters)	Import Price (USD)	Total Value Yearly Savings (USD)
Bio Diesel	20,075,000	0.48	9,645,777
	Gasoline (Liters)	Import Price (USD)	Total Value Yearly Savings (USD)
Ethanol	12,519,000	0.43	5,443,874
Total			15,089,651

Source: Econergy.

More important in the context of the foreign trade deficit is the potential for Mozambique to become an important producer and net exporter of biofuels (or intermediate products). The estimated quantities projected for production in Mozambique in the scenarios presented will for the most part be directed to the international markets (minus the volumes mentioned in the preceding paragraph about the domestic market).

The value-added from biofuels exports that is retained in Mozambique includes the following: (i) government revenues via taxes (discussed previously), (ii) the direct earnings of farmers and other workers (analyzed above), (iii) the portion of the producers' margin that is spent or reinvested in Mozambique, and (iv) the revenues generated by various domestic suppliers of products and services. The logistical chain of production processes and distribution will capture an important part of this value.

A number of local businesses, such as those in transportation and port operations, will consequently benefit considerably from the increase in activity that the biofuels sector will bring. If, for example, we assume that biofuels will be transported on average over a distance of about 100 km from the agricultural areas to the ports in 20,000 liter tanks, we can estimate the additional annual revenues for the transport sector. Table 20 below describes the different scenarios in terms of the dollar value of the total estimated production.

Given that most of the output will be exported, these figures correspond to the additional revenues resulting from biofuels exports that the sector will generate for Mozambique. Aside from that portion of profits that the foreign investors will probably repatriate at some point in time, and the cost of the imports necessary for operations (e.g. agricultural inputs, such as fertilizers or machinery, industrial equipment for processing biofuels and vegetable oils, etc.), the remainder will remain in Mozambique and will be directly reflected in the growth of the domestic economy. It is reasonable to expect that a significant portion of this production value will remain in Mozambique. Considering the current import/export ratio of large industrial or mining projects in Mozambique, which is about 17%,[2] and adapting this ratio as a reference of calculating the net effect the biofuels sector will have on the trade balance (that is, the average net revenue retained in the Mozambican economy), it is possible to calculate the scale of the impact that the biofuels sector will have on the economy and, most important, its contribution to reducing the country's balance of trade deficit.

It can be roughly estimated that about 80% of the value generated by the sector will have a direct impact on the trade balance, whether through the displacement of fuel imports (to the extent to which the domestic output is consumed locally), or through the increase in exports (to the extent to which local output is exported). In fact, under the optimistic scenario presented, the biofuels sector alone would more than double total Mozambican exports relative to their 2004 levels (USD 1.5 billion). Since these exports will be denominated, bought and sold in hard currency, the biofuels industry will also contribute to balancing the national hard currency reserves, allowing for natural "hedging" of the economy and strengthening of the national currency, while diminishing the country's dependence on donors and foreign debt.

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A number of local businesses, such as those in transportation and port operations, will consequently benefit considerably from the increase in activity that the biofuels sector will bring. If, for example, we assume that biofuels will be transported on average over a distance of about 100 km from the agricultural areas to the ports in 20,000 liter tanks, we can estimate the additional annual revenues for the transport sector generated by biofuels to

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[2] The mega-projects account for 17% of total imports and 72% of total exports, or 17% of USD 1.75 billion and 72% of USD 2.47 billion (2005 estimates), which yields a 16% ratio of imports over exports generated by these mega-projects. These calculations are based on data from AFDB-OECD 2007 *African Economic Outlook.*

Table 20: Impact of biofuels exports on the trade balance

Biodiesel feedstocks	Low Scenario		Medium Scenario		High Scenario	
	Potential Biodiesel Output (kl)	Value (USD)	Potential Biodiesel Output (kl)	Value (USD)	Potential Biodiesel Output (kl)	Value (USD)
African palm	253,950	171,975,399	**761,851**	515,926,196	**1,523,702**	1,031,852,392
Castorseed	56,433	63,694,592	**282,167**	318,472,960	**620,767**	700,640,513
Copra (1)	3,621	3,065,461	**10,864**	9,196,384	**21,728**	18,392,769
Cottonseed	326	279,410	**396**	339,625	**458**	393,158
Jatropha	42,325	36,305,917	**211,625**	181,529,587	**465,576**	399,365,092
Peanut	0	0	**0**	0	**0**	0
Soybean (3)	25	20,106	**31**	24,439	**36**	28,291
Sunflower (4)	9,029	7,643,351	**45,147**	38,216,755	**99,323**	84,076,862
Total (or average)	**365,711**	**282,984,237**	**1,312,081**	**1,063,705,947**	**2,731,590**	**2,234,749,076**

Ethanol feedstocks	Low Scenario		Medium Scenario		High Scenario	
	Potential Ethanol Output (kl)	Value (USD)	Potential Ethanol Output (kl)	Value (USD)	Potential Ethanol Output (kl)	Value (USD)
Cassava	44,422	24,782,757	53,995	30,123,596	62,506	34,871,828
Molasses (tons)	15,000	8,368,421	33,750	18,828,947	56,250	31,381,579
Maize	29,719	16,580,286	36,124	20,153,441	41,818	23,330,127
Sugarcane (2)	44,117	24,612,908	220,587	123,064,539	485,292	270,741,987
Sweet sorghum grain (5)	56,250	31,381,579	281,250	156,907,895	618,750	345,197,368
Sweet sorghum cane (5)	130,000	72,526,316	650,000	362,631,579	1,430,000	797,789,474
Total (or average)	**319,509**	**178,252,267**	**1,275,707**	**711,709,998**	**2,694,616**	**1,503,312,363**
Total (or average)	**685,219**	**461,236,503**	**2,587,788**	**1,775,415,945**	**5,426,207**	**3,738,061,439**

Source: Econergy.

Table 21: Revenues for transportation sector

Transporters Estimated Revenues	Low Scenario	Medium Scenario	High Scenario
Number of truck loads	23,062	88,771	186,903
Average Price (USD per Km)	1.25	1.25	1.25
Average distance per load (Km)	100	100	100
Total transporters Revenue (USD)	2,882,728	11,096,350	23,362,884

Source: Econergy

be between USD 2.8 and USD 23.3 million, depending on the scenario, as shown in Table 21.

Countless indirect jobs, tax revenues and other spillover effects will also flow from this increased activity. Port operations and cabotage shipping along the Mozambican coast, storage facilities and services, maintenance services and suppliers of agricultural inputs are other important examples of economic segments that will benefit directly from the development of the biofuels sector.

CHAPTER 7: SELECTED INTERNATIONAL EXPERIENCE WITH BIOFUELS POLICIES

The purpose of this Chapter is to review the experience with policies to promote the use of biofuels in several representative emerging markets. The presentation on Brazil is the most detailed, given the long experience of that country with ethanol and more recently, with biodiesel. A summary of the material presented in the country sections is presented at the end of the chapter.

1. Brazil

Introduction. Through the active involvement of both the government and the private sector, Brazil has become the lowest-cost sugar and ethanol producer in the world; until recently, it was the largest producer and consumer of ethanol. Though the U.S. has surpassed it in terms of production and consumption, largely thanks to U.S. emphasis on corn-based ethanol, Brazil remains a leader in terms of technological development in the area of sugarcane-based fuel ethanol.

Between 1975 and 2004, the Brazilian ethanol program succeeded in substituting approximately 230 billion liters of gasoline; ethanol currently accounts for more than 40% of the local fuel market. The country has shown that integrated production of ethanol from sugarcane has lowered its dependence on fossil fuels, reduced GHG emissions, and significantly benefited the rural economy.

As a modern and efficient agricultural producer, Brazil has the potential to play a major role as an exporter of renewable technologies (namely bagasse cogeneration and ethanol production) to other countries. Today, observers increasing look to Brazil as they explore methods to reduce their countries' dependence on expensive imported oil. The successful practices of the Brazilian ethanol program can be applied to other countries as they seek to replicate Brazil's experience.

Production statistics for Brazil. In the Brazilian setting, one metric ton of harvested sugarcane contains approximately 145 kg of bagasse and 138 kg of sucrose. Of the latter, 112 kg can be extracted as sugar, leaving 23 kg in low-value molasses. If the cane is instead processed into alcohol, all of the sucrose is used, yielding 72 liters of ethanol. In addition, mills in Brazil burn the bagasse to produce heat for distillation and drying, and generate approximately 288 MJ of electricity (per ton of harvested sugarcane) through steam boilers and turbines. 180 MJ of electricity is used by the plant itself, while the excess is sold into the national grid. Table 2 summarizes several key statistics of the Brazilian ethanol production process.

Brazil Ethanol Transport Logistics and Tax Regulations. With respect to the commercialization and transport of ethanol, all mills must be registered with the National Petroleum Agency of Brazil (ANP) before selling the ethanol on the market.[1] A template of the form used by mills to register with the ANP is provided in Annex (a) at the end of

[1] The mills registered in the ANP are available on www.anp.gov.br/doc/alcool/Lista_de_usinas.pdf

this chapter. It is important to highlight that, according to ANP legislation, only alcohol producers already registered with the Brazilian Agricultural Ministry will be able to be registered as suppliers.

Table 1: Ethanol Program Statistics

Brazil Ethanol Program Production Statistics (2003/2004 season)	
Land Use	45,000 km^2 in 2000
Labor	1 million jobs (50% farming; 50% processing)
Sugarcane	344 million metric tons (50% sugar, 50% alcohol)
Ethanol	14 million m^3 (7.5 anhydrous, 6.5 hydrated, 2.4% is exported)
Dry Bagasse	50 million tons
Electricity	1350 MW (1200 for processing, 150 sold to utilities) in 2001

Source: Econergy

The commercialization of ethanol in Brazil is regulated by an ANP Ministerial Directive (passed on February 13, 2006 and published on February 14, 2006)[2]. In addition to regulating the commercialization of ethanol produced in Brazil, the Directive sets forth the procedures necessary to register a mill as an ethanol supplier for automotive use, and the obligations of the supplier.

According to Brazilian law, a registered ethanol producer may sell only to an ANP-registered distributor, who is then responsible for transporting the ethanol from that specific mill. The distributor subsequently sells the ethanol to a gas station that offers the automotive ethanol to the consumer.

The taxes in Brazil's ethanol distribution structure have two parts.

- From the ethanol producers (calculated on the price paid to the distributor – R$1.07/ liter – USD 0.52/liter): COFINS (Contribution to Social Security Financing), equal to 3 %; ICMS (Tax on Goods and Services), equal to 12% (in São Paulo State); PIS (Social Integration Program) 0.65 %; and agro-industry Contribution, equal to 2.85% calculated on the mills revenue (this tax is applicable only to mills owning agricultural land. If the mill is involved only in the industrial ethanol production process, this tax is excluded).
- From the distributor to the retail gas station: PIS of 0. 65 % and COFINS of 3%.

Based on the information presented above, the table below allows for a comparison of ethanol tax regimes in Brazil and the U.S., the two most important ethanol producers in the world.

Brazil Ethanol Pricing Dynamics. Brazil is by far the cheapest ethanol producer in the world, in production and at the pump. According to the U.S. Congressional Research Service, "Brazilian production costs are 40% to 50% lower than in the United States." Production costs dropped by over 70% between 1980 and 2002, which has enabled the

[2] Available on www.anp.gov.br/petro/legis_abastecimento.asp

government to eliminate command and control tactics in the industry in the way of production quotas, price controls and production subsidies. The result of these production advantages is that, as of October, 2006, Brazilian ethanol sells at around 90 U.S. cents per gallon, whereas U.S. corn-based ethanol costs between USD 1.70 and USD 2.00 per gallon.

Figure 1: Comparison of Brazil and U.S. tax regimes for ethanol

Brazil	**U.S. (Federal Incentives)**
COFINS (Contribution to Social Security): 3 %	VEETC (Volumetric Ethanol Excise Tax Credit): 51¢/gallon produced
ICMS (Tax on Goods and Services): equal to 12% (in São Paulo State)	Tax Credit, Small Ethanol Producers: production tax credit of 10¢/gallon
PIS (Social Integration Program): 0.65 %	Income Tax Credit, E85 Infrastructure: 30% credit for cost of installing refueling property
Agro-industry Contribution: 2.85%	

Source: Econergy.

According to World Bank estimates, the financial cost of ethanol production in Brazil is in the range of USD 0.23-0.29 per liter. The reasons for this are mainly agricultural advances in yield, advanced techniques in agricultural management and increasingly significant demand. Beyond this, the comparative advantage is due to the fact that Brazil's feedstock costs – which account for about 60% of production costs – are significantly cheaper than other producing countries. This is even true when compared to other tropical countries.

Regarding prices at the pump, the story is a bit more nuanced. Because gasoline yields superior gas mileage, it is generally accepted that ethanol is a better buy if priced at 70% or less of the price of gasoline. By this measure, ethanol is very price competitive, as ethanol sells for roughly one-half the cost of gasoline at the pump. However, this trend is not without exception. For example, the first quarter of 2006 saw increases in ethanol prices above the 70 % level and a significant decline in ethanol consumption. Due to this sensitivity of demand, the government of Brazil provides consumption incentives and tax breaks. According to the U.S. Department of Commerce, the government provides preferential treatment for ethanol consumption under both its CIDES and PIS/COFINS federal tax programs. The differential in these assessments was estimated by industry contacts at approximately R$ 0.30/liter (USD 0.51/gallon) in October 2005. Ethanol was free from CIDE assessments while gasoline sales included R$ 0.28/liter in CIDE payments. Ethanol was also charged a lower assessment on PIS/COFINS. Differential treatment under state tax regimes may be even greater. In October of 2005, it was estimated that ethanol enjoyed an advantage of approximately R$ 0.50/liter on state assessments in São Paulo. As a result, while São Paulo pump prices in late 2005 were R$1.14/liter for ethanol and R$ 2.22/liter for gasoline, these prices included a differential of R$ 0.80/liter in taxation rates.

Current Ethanol Pricing Context. In May 2007, Brazilian ethanol prices fell roughly 30% for both hydrous and anhydrous ethanol, with the onset of Brazil's enormous 2007-2008 sugarcane harvest (May-April) and increased ethanol output. Hydrous ethanol prices at the São Paulo mill gate in late May 2007 averaged just under R$0.61/liter

(USD0.31) without taxes. Anhydrous ethanol prices also dropped to R$0.76/liter (USD0.39) without taxes. In gasoline equivalent terms, a liter of hydrous ethanol without taxes costs USD1.52/gallon (USD0.40/liter), anhydrous ethanol USD1.92/gallon (USD0.51/liter).

Local traders and analysts in Brazil have generally noted that there is a bright side to falling local ethanol prices, namely that the export market has become more robust, with buyers from the U.S., Europe and Asia once again looking for deals. On the local ethanol market, meanwhile, slipping São Paulo ethanol prices at the mill gate have not yet reached the consmer at the gas station, which has kept demand stable for the moment.

The Brazilian government is also contemplating increasing the mandated ethanol mix in gasoline to absorb more of the excess supply in the face of the rapid decline in local prices. It is not clear when or if this hike in the ethanol blending ratio would actually be implemented. Additionally, the fall in ethanol prices has led to growing interest in using ethanol as an alternative fuel for energy generation and process heat in the industrial sector.

Historical Background – Proálcool

Background. Brazil is a leading producer in several major agricultural and agro-industrial sectors; it is the world's leading sugar and ethanol producer and exporter, with the Center-South region (including São Paulo State), accounting for 85% of sugarcane and ethanol production. Of the 320 sugarcane processing units in operation during the 2003/2004 sugar season, 226 are based in this region and have been divided into mills, mills with distillery plants, and independent distilleries. The first mills only produce sugar, while those with distillery plants produce both sugar and ethanol. The independent distilleries only produce ethanol. In addition, the country's North-East region also accounts for a large portion of sugarcane cultivated in Brazil.

In the 2004-2005 crop season, Brazil produced one-quarter of the world's total sugarcane output, harvesting 5.4 million ha and producing close to 12.5 billion liters of anhydrous alcohol.[3] As of December 2004, 303 plants were producing ethanol, and 82 of these were autonomous distilleries producing only ethanol. 221 plants were combined sugar mill/distillery facilities, capable of shifting the production mix from 60/40 to 40/60 sugar/ethanol depending on the variability of the sugar and oil markets.

Development of the Ethanol Industry: Proálcool. Brazil's experience with fuel-grade ethanol can be traced back to the 1930s, when a 5% anhydrous ethanol blend in gasoline was initially authorized and made into law. The national ethanol program as it is recognized today, however, did not take flight until several decades later.

Faced with the twin problems of rising oil prices and falling sugar prices, the Brazilian government established the Brazilian National Alcohol Program (Proálcool) by decree

[3] Kojima, Masami and Todd Johnson. *Potential for Biofuels for Transport in Developing Countries.* World Bank ESMAP report, October 2005.

76,593 in November 1975. The objective of Proálcool was to reduce the need for oil imports and provide an additional and diversified market for Brazilian sugar. The guidelines for the program were defined by a number of instruments enacted by the Instituto do Acúcar e do Álcool (IAA, Institute of Sugar and Alcohol), a government agency that was part of the Ministry of Industrial Development and Commerce. As a first step, the federal government began promoting the production of ethanol for blending into gasoline, to the maximum extent feasible in existing vehicles – approximately 20% by volume (see Box 1).

In promoting ethanol as a transportation fuel, the Brazilian government had many tools at its disposal. Five principal factors helped advance the ethanol industry: (i) the government offered credit guarantees and low-interest loans to sugar companies for construction of new ethanol refineries; (ii) a state trading enterprise began purchasing ethanol at favorable prices; (iii) gasoline prices were set to give ethanol a competitive advantage; (iv) a marketing program was launched; and (v) the state-owned oil company, Petrobras, began making investments for distribution of ethanol throughout the country. Though not an actual producer of ethanol, Petrobras immediately became a key player in Brazil's ethanol industry, establishing itself as the largest purchaser and marketer of ethanol in the country. The oil company was able to take advantage of its extensive network of tank farms and pipelines to aid in the promotion of the Proálcool program. The GoB participated in a range of activities that included: guaranteeing ethanol purchases; implementing technical studies and research and development initiatives for the ethanol industry; and transporting and blending ethanol.[4] The results of the government-sponsored program were dramatic, with ethanol production increasing more than 500% between 1975 and 1979 going from 600 million liters per year (1975/76) to 3.4 billion liters per year (1979/80).

In the 1970s, an estimated 200 and 250 plantation families controlled two-thirds of cane production in Brazil, as well as all of the processing. By 1979, 104 ethanol distilleries were in operation, as a direct result of extremely attractive incentives in the form of credits provided for distillery construction. The incentives offered a government subsidy of as much as 75% for these projects, to the point where overcapacity became a concern. The principal beneficiaries of credit programs were large producers, who were also able to take advantage of the rapid expansion of cane cultivation areas. As an example, total areas under cane cultivation in São Paulo increased by 31% between 1978 and 1979, much of the increase occurring as a result of larger plantations buying up surrounding land belonging to small farmers who at the time were primarily food producers. Existing incentives for food production were not competitive with those of Proálcool, and many chose to sell out and move. According to reports, some farmers were forced off their land by economic pressure, or by direct physical intimidation.[5]

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[4] Petrobras presentation at World Bank seminar on "Brazil's Ethanol Experience and its Transferability;" April 25, 2006.
[5] World Bank, 2005.

Table 2: Milestones in Brazil's Ethanol Industry

Year	Milestone	Production Level (million tons)
1975	Proalcool: success of alcohol-fueled vehicle	91
1980	-	149
1990	Beginning of sugar exports by private sector	263
1995		303
2003	Development of flex fuel vehicle	350

Source: UNICA, 2004.

During the 1980s, the ethanol program continued to grow and produce positive results for the Brazilian economy. With the help of Brazilian government pricing policies that kept the cost of ethanol significantly lower than the cost of gasoline, as well as support from the World Bank in the form of a loan to help cover the costs of the program, ethanol production more than tripled between 1979 and 1985. In response to a second oil shock in 1979/80, the Brazilian government committed to full-scale implementation of Proálcool, and created two national committees, the National Alcohol Council (CNAL) and the National Executive Commission of Alcohol (CENAL), to help facilitate the program. Proálcool was expanded to promote the use of hydrous ethanol as an automotive fuel, giving tax incentives for the purchase of cars fueled by hydrous ethanol and subsidizing ethanol prices. A fiscal goal was set to ensure that the retail price of hydrous ethanol was, at most, 65% of the retail price of gasoline. This made ethanol cheaper than gasoline, even after accounting for hydrous ethanol's lower fuel economy. By the mid-1980s, ethanol made up roughly half of Brazil's liquid fuel supply, reaching peak production levels of 12.3 billion liters in 1986/87.[6] At that point, the majority of new cars sold in Brazil ran on ethanol alone.

In 1985, however, Brazil's ethanol program started to experience problems attributed to the rapid decrease in world oil prices in 1985/86, from between USD 30-40 a barrel to USD 12-20. Ultimately, the immediate benefits of replacing oil imports with ethanol were nullified. At the same time, Brazil faced serious inflation problems and began a series of trying economic reforms, which included a broader cut back on subsidies that eliminated the price differential between ethanol and gasoline. Soft loans for the construction of new refineries were cut, and transport for the ethanol program from state trading companies was slowed and then entirely stopped. The changes had a significant impact on ethanol production, which stagnated. By the late 1980s, ethanol production even began to decline slightly, as world sugar prices rose and export markets for refined sugar became more profitable. In 1988, the government opened? the sugar export market, and sugarcane growers diverted crops to the export market, creating a shortage of ethanol in the second quarter of 1989. Low oil prices and the government's policy of maintaining a strong Real made ethanol uncompetitive with gasoline. The shortage resulted in a loss of consumer confidence in the security of the ethanol supply and

[6] Biodiesel Brasil: www.biodieselbr.com, 2006.

ultimately discredited Proálcool. In response, the Brazilian government authorized ethanol imports, and Brazil became the world's largest importer of the biofuel. Between 1989 and 1996, the country was forced to import an average of 0.6 billion liters of ethanol annually.[7] The IAA was officially abolished in 1990, and anhydrous ethanol was deregulated in May 1997.

Despite the elimination of many incentives under the Proálcool program, the downward trend in ethanol production had little impact on Brazilian automakers, which continued to manufacture ethanol-only cars in increasing quantities. By the late 1980s, almost all new cars in Brazil were made to run solely on ethanol, which contributed to the serious shortage described above. In addition to importing ethanol, Brazil was also forced to turn to methanol, or ethyl alcohol, to keep cars on the road. Due to the erosion of political support for the Proálcool program, Brazilian auto manufacturers eventually retooled to build gasoline cars, and by the mid-1990s, the sales of ethanol-fueled cars amounted to less than 1% of total annual auto sales – only fleet vehicles such as taxis and rental cars were being produced to run on ethanol.

Box 1: Private Sector Involvement in Brazil's Ethanol Industry

The Brazilian ethanol industry survived in the 1990s largely due to the fact that the government maintained the incentives for the private sector to stay engaged in some capacity – be it through the automobile sector or sugar production. The continued involvement of the private sector also precipitated the gradual improvement of ethanol technology, making the industry more cost-efficient. More recently, much of the financing for the ethanol industry has gradually moved to the private sector, despite the continued involvement of the Brazilian government. Along these lines, Cosan, a leader in the Brazilian sugar and ethanol sector, recently went to the capital markets for funding by raising money via an equity Initial Public Offering (IPO), and then turning to the U.S. corporate bond market. The company accounts for 8.2% of Brazil's total crushing capacity, 9% of the country's sugar industry, and 7% of its ethanol industry.

While the Brazilian model of state-private sector development is not perfect, Latin America's largest economy has made considerable progress in buffering its economy from oil price volatility in international markets. This progress is possible because of the government's sustained and active engagement in the development of the ethanol business, making use of a combination of subsidies, grants and other policy measures. It also sought private sector involvement, sometimes forcing participation through policy changes.

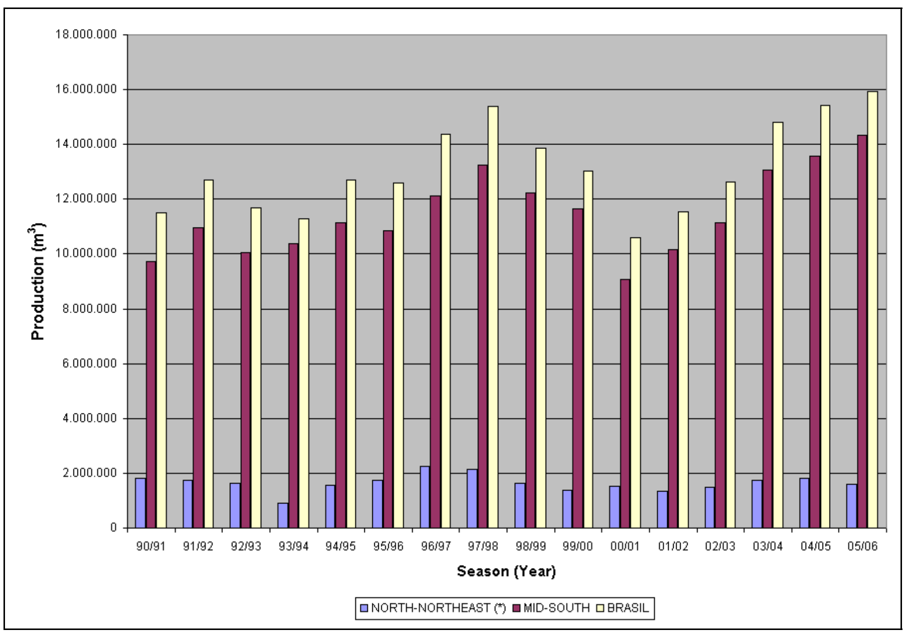
With deregulation and privatization underway throughout the Brazilian economy, and world oil prices remaining low, the 1990s were a quiet decade for Brazil's ethanol program, and there was little political support for returning to programs of the kind that helped build Brazil's ethanol infrastructure during the 1970s and 1980s. The government had become plagued with loan repayment problems for public loans and state-guaranteed private bank loans that had been provided to sugarcane processors and growers over the course of Proálcool. An interdepartmental commission to investigate the status of repayment and to promote refinancing measures was established, and agreements on debt rescheduling were eventually reached in 1989 and again in 1991. Debt reached USD 2.8

[7] World Bank, 2005.

billion by 1991, and the total debt to Banco do Brasil alone in 1997 amounted to USD 2.5 billion.[8]

Nevertheless, the national government continued to require that all gasoline sold in Brazil contain roughly 20% ethanol by volume throughout the 1990s. As the decade progressed, some Brazilian engineers and policymakers showed increasing interest in flex-fuel vehicles (FFVs), i.e. vehicles that can run on any mixture of anhydrous ethanol/gasoline, as well as on 100% ethanol (hydrous ethanol), of the kind being built by U.S. manufacturers seeking credits under the CAFE law.[9] Toward the end of the decade, several manufacturers began talking with Brazilian government officials about manufacturing FFVs for the Brazilian market. This ultimately led the Brazilian government to agree to treat FFVs as ethanol-fueled cars in 2001, thus rendering them eligible for preferential tax treatment (a 14% sales tax, as compared to a 16% sales tax on non-ethanol cars). Ford Motor Company launched the first flex fuel prototype in 2002, and Volkswagen followed suit in 2003.

Figure 2: Production of Ethanol in Brazil, 1990-2006



Source: UNICA (União da Indústria de Cana de Açúcar), 2007.

At the heart of Brazil's fuel ethanol program is mandatory blending of ethanol with gasoline. The actual blending ratio is determined by an inter-ministerial committee made

[8] World Bank, 2005.

[9] Corporate Average Fuel Economy (CAFE) is the sales weighted average fuel economy, expressed in miles per gallon, of a manufacturer's fleet of passenger cars or light trucks with a gross vehicle weight rating of 8,500 pounds or less, manufactured for sale in the U.S. The "Energy Policy Conservation Act," enacted into law by Congress in 1975, added Title V, "Improving Automotive Efficiency," to the Motor Vehicle Information and Cost Savings Act and established CAFE standards for passenger cars and light trucks. The Act was passed in response to the 1973-74 Arab oil embargo. The near-term goal was to double new car fuel economy by model year 1985.

up of representatives of the Ministry of Agriculture, Ministry of Finance, Ministry of Mines and Energy, and Ministry of Industrial Development and Commerce. The blending rate has varied between 20% and 26% in recent years, and tends to be increased when ethanol prices are low and decreased when ethanol prices are high. Ethanol is given a further boost in the Brazilian market through a ban on diesel-powered cars, an Alcohol Storage Program to support producers holding alcohol stocks, and an import duty on ethanol to protect domestic producers (21.5% as of late 2003).

Brazil now mandates a fuel blend of E25 nationally, and ethanol provides approximately 40% of transportation fuels in Brazil, a higher percentage by far than in any other nation and a trend that has largely been attributed to the explosive growth of FFVs in recent years. In 2005, Brazil produced just over 16 billion liters of ethanol, and FFVs vehicles represented 35% of new car sales in the country. By February 2006, more than 70% of new cars sold in Brazil were flex-fuel, and all new light vehicles are expected to be flex-fuel capable by 2010.

As shown in Figure 1, ethanol production has been steadily increasing since its low point during the 2000/2001 crop season. Today, Brazilian companies are investing USD 9 billion in dozens of new sugar mills to boost ethanol production, while aiming to double exports by 2010, the eventual goal being to spread new ethanol industries to countries in Asia and Africa. Petrobras representatives, who oversee the Brazilian ethanol exports, maintain that the industry is moving at a rapid pace toward the wholesale export of ethanol. In 2005, Brazilian ethanol exports of 2.5 billion liters were more than 10 times the 2000 figure. Domestic demand continues to soar in 2006, and has recently put a strain on supply causing an increase in prices, which are expected to keep foreign shipments relatively flat. Brazil currently accounts for 53% of the embryonic global ethanol trade; Europe is a distant second with a market share of 12%.[10] Table 3 below shows Brazil ethanol exports from 1998 to 2003.

Determinants of the Success of Brazil's Ethanol Industry. Brazilian analysts have concluded that the world oil price needs to remain above USD 30 per barrel for Brazil's ethanol program to be commercially viable; it is more competitive than gasoline at or above USD 35 per barrel. A study undertaken for the Brazilian government in 2005 also concluded that West Texas Intermediate crude needs to be above USD 42-47 per barrel for new ethanol producers to be viable beyond 2015 without government assistance. The importance of this is made evident in Brazil's experience, when periods of high crude oil prompting the launch and expansion of the Proálcool program were followed by the sharp decline in the price of oil in the mid-1980s that undermined the viability of the Brazilian ethanol program. Though the Brazilian government had originally intended subsidies provided under the program to be temporary, it was politically difficult to reverse the process of biofuel production in a time of collapsing world oil prices. The government ended up adopting job and industry protection measures with implicit and explicit subsidies in the latter half of the 1980s.

[10] Lynch, David J. "Brazil hopes to build on its Ethanol Success." *USA Today*, March 29, 2006.

Table 3: Brazil Ethanol Exports and Imports, 2001-2006

Brazilian Ethanol Exports (000 liters)	2001	2002	2003	2004	2005	2006 1/
Hydrous	340,929	737,107	690,466	2,210,970	2,484,672	597,598
Anydrous	1,196	14,116	59,132	172,593	89,241	33,713
Total	342,125	751,223	749,598	2,383,563	2,573,913	631,311

Source: ATO/Sao Paulo based on SECEX figures. 1/ Jan-April.
Note: Hydrous refers to NCM 2207.10.00 and Anhydrous refers to NCM 2207.20.10

Brazilian Ethanol Imports (000 liters)	2001	2002	2003	2004	2005	2006 1/
Hydrous	108,471	1,687	6,111	374	222	50
Anydrous	8,179	25	30	1	5	0
Total	116,650	1,711	6,141	375	227	50

Source: ATO/Sao Paulo based on SECEX figures. 1/ Jan-April.
Note: Hydrous refers to NCM 2207.10.00 and Anhydrous refers to NCM 2207.20.10

Given that the cheapest path to biofuel production today is ethanol from sugarcane, it is worth exploring the factors that have contributed to the low cost of ethanol production in the Center-South region of Brazil. A surrogate for the cost of production is the price paid to ethanol producers in Brazil: in 2001 U.S. dollars, it was more than USD 0.60 per liter in 1980. The price fell to USD 0.50 by 1983, and after remaining unchanged for two years, it more than halved between 1985 and 1999. The price per liter reached an all-time low of less than USD 0.20 in 1999, before rising again to USD 0.30 in 2001. The price paid to producers of hydrous ethanol in June 2005 was USD 0.24 per liter.

To date, none of the countries that account for 78% of global sugarcane production and 80% of the world's harvested areas[11] have been able to achieve the same low cost of production as the Center-South region of Brazil. It is a region endowed with plentiful land, rainfall, and other favorable climatic and soil conditions. The region also has solid infrastructure, a functioning capital market, and a sugar industry structure that enables cooperation among various players along the supply chain. This leads to high efficiency matching different microclimates and conditions; the average mill/distillery deals with approximately 15 varieties. Computer programs are routinely used to optimize agricultural and plant operation, as well as to determine when to harvest so as to maximize the sucrose content and optimize the distribution of cane varieties on the basis of available soil types, distance to the cane processing plant, and other considerations. In cane processing, automation is aimed at increasing extraction, fermentation, and distillation efficiency, and each process uses computer-aided operational controls. These optimization methods are in large part facilitated by a high level of managerial skills, research and development technical capability, and the existence of economies of scale for sugarcane and ethanol production in Brazil. Because most plants are hybrid mill/distillery complexes, there is no opposition to ethanol production from sugar

[11] These countries include: Brazil, India, China, Thailand, Pakistan, Mexico, Australia, Colombia, Cuba, Philippines, U.S., Indonesia, and South Africa.

producers, and vice versa. Similarly, the significant scope of expanding cane production eliminates the potential for sugar and ethanol having to compete for land.[12]

Impacts of Ethanol Production in Brazil

Socioeconomic Implications. Brazil's three decade-long alternative energy campaign will have helped the country achieve energy independence by 2006. By diversifying its sugar industry to include the production of ethanol, Brazil saves approximately USD 4.2 billion per year, USD 2.2 billion of which is generated by the displacement of fossil fuel use. The use of fuel alcohol in the country has provided foreign currency savings of almost USD 55 billion from 1975 to 2003 – if interest on foreign debt is accounted for, the savings rise to USD 118 billion. Furthermore, the ethanol industry's permanent potential for creating, maintaining and improving job quality from the farm to fuel production levels, as well as the fact that it serves as a viable alternative to hydropower generation during periods of drought, make it a stable activity that has succeeded in distributing income throughout the country. Although there were questions regarding the quality of new jobs created in the ethanol industry during the first 10 years of Proálcool, sugarcane workers in São Paulo in the late 1990s were receiving wages that were on average 80% higher than those of workers holding other agricultural jobs. Their incomes were also higher than 50% of those in the service center, and 40% higher than those in industry.

Environmental Implications. In addition to its positive social implications, the ethanol industry has played a decisive role in reducing carbon dioxide (CO2) emissions in Brazil,

Box 2: Present Day Petrobras Activities in the Ethanol Market

The Brazilian state oil company Petrobras is emerging as an important player in the export of ethanol, having sent its first shipment of anhydrous ethanol to Venezuela in July 2005, and taking an active role in negotiations over ethanol purchase and technology-sharing deals with other countries. Also in 2005, Petrobras and Nippon Alcohol Hanbai, a Japanese company, signed a contract creating the Brazil-Japan Ethanol company, which will operate in Japan with the objective of importing and commercializing some 20 million liters of sugarcane-based ethanol made in Brazil by the year 2008. The association will be used to seek solutions to technical problems in introducing ethanol in Japan.

Brazil's Petrobras also plans to build a US$ 500 million network of sugarcane ethanol pipelines by 2008, a move that could help the oil company become one of the world's largest distributors of the fuel additive. The main pipeline, which will travel 950 km, is key to allowing Petrobras to cheaply transport ethanol to export-oriented Atlantic port terminals in São Paulo State. A second ethanol export route that Petrobras plans to use would involve transporting ethanol by river barge from Mato Grosso do Sul State through the western part of Sao Paulo state and down to the southern Brazilian state of Parana. This plan would involve a second, 90-km pipeline linking Replan to the route.

Petrobras has committed to allocating 0.5% of its annual investments to renewable energies, and has listed wind power generation, biomass energy (including ethanol production), photovoltaics, and biodiesel as top priority projects.

Source: Petrobras, 2006.

[12] World Bank, 2005.

as FFVs can be potentially 20% less polluting than vehicles powered by regular gasoline. Experts have determined that the substitution of ethanol for gasoline avoids the emission of 2.6 tons of CO2-equivalent per cubic meter of anhydrous ethanol, and 1.7 tons of CO2-equivalent per cubic meter of hydrous ethanol. In addition, each ton of sugarcane used to produce fuel ethanol absorbs 0.18 tons of CO2. The production of 14 billion liters of ethanol per year in Brazil mitigates more than 40% of the total emissions from the use of fossil fuels in the country's transportation system. By 2010, Brazil is expected to have an additional consumption of 7 billion liters of ethanol, which will reduce CO2 emissions by approximately 49 million tons per year.[13]

Despite its considerable success, the ethanol industry in Brazil is not without its problems. The large number of ethanol distributors in comparison to the handful of refineries has created enforcement problems for the government in terms of tax collection, black market sales of ethanol, and fuel adulteration. Concern over tax evasion led the state of São Paulo in 2004 to halve its value-added tax for ethanol, and the National Petroleum Agency (ANP) reported that some distributors were also adulterating ethanol with chlorinated tap water to take advantage of the lower tax rate on ethanol. Not only has this contributed to tax evasion problems, but it has also raised levels of chlorine contamination and environmental issues.

Historically, the choice of biofuel crops has often been restricted to intensively cultivated crops, as is the case in Brazil. The economics of biofuel production improve with decreasing cost per unit yield, and intensified use of genetically engineered crops, irrigation and fertilizer, pesticide and herbicide application is intended to increase yields and lower costs. In the worst case, lands are cleared to make way for sugar cultivation. In countries other than Brazil, maize has been planted in regions that require considerable irrigation, resulting in nutrient losses, contamination of ground and surface waters, eutrophication, and a drop in biodiversity (as pesticides and other toxins kill invertebrates in the soil, interrupting the food chain for birds and animals). Fertilizer and herbicide run-off into streams and waste water from the production process constitutes another category of environmental concerns, thus underscoring the notion that the production of renewable energy can in fact give rise to serious environmental damage. Ideally, these externalities should be compared to those resulting from the production and combustion of petroleum gasoline and diesel to assess the relative damages of biofuels.

In Brazil, two major environmental problems encountered in the past were the improper disposal of untreated vinasse and field burning prior to the harvesting of sugarcane. One liter of ethanol produces approximately 10 to 15 liters of vinasse, a hot corrosive pollutant with a very low pH and an extremely high mineral content. In the mountainous areas of northeastern Brazil, the pumping cost and the cost of land to store vinasse proved prohibitive in the past, prompting their release into rivers and resulting in a significant fish kill at every harvest. Today, vinasse and wastewater are recycled and used for ferti-irrigation.

[13] UNICA, 2005.

The second major environmental problem associated with ethanol production in Brazil has been the procedure of setting sugarcane fields on fire to eliminate the voluminous amount of biomass and pests found in the areas to be harvested. When this is done, huge clouds of black smoke blanket the area. To address this issue, the state of São Paulo and the federal government have passed legislation to ban the burning of fields and move to more mechanized sugarcane harvesting practices. At present, only São Paulo is enforcing the time table set for gradually phasing out the burning of sugarcane fields – 20% of fields no longer burn the cane trash before harvesting (see Table 4 below).[14]

Main Lessons Drawn from the Brazilian Ethanol Experience. Brazil's fuel ethanol industry is mature, low-cost, well established, and has the capacity to expand significantly in response to rising demand. In light of potential oil shortages and rising fuel prices, many countries today are looking to Brazil in hopes of replicating the Brazilian ethanol industry success story, both in terms of sugarcane production costs and in terms of other attributes that make Brazil an efficient producer of both sugar and ethanol. Naturally, certain aspects of Brazil's ethanol industry are more easily transferable than others. Engineering design and plant construction can be imported, although many developing countries will not be able to take advantage of domestic ethanol plant equipment manufacturers as in Brazil, and will consequently have to pay more for plant construction, at least initially. Entrepreneurial and managerial skills, as well as a cadre of technical people capable of developing new commercial cane varieties, will take more time to develop.

Several countries in Africa share key attributes with the South American country, especially with regard to warm climates, low wage rates, and more intricate characteristics, such as low cultural attachments to automobiles. All of these similarities

Table 4: Legislation Requiring Phase-out of Sugarcane Field Burning in Brazil: Percentage of Land where Burning is Phased Out

	São Paulo State Decree 2002[1]			**Federal Law 1998**[2]	
Year	*Mechanical harvesting*[3]	*No mechanical harvesting*[4]	*Year*	*Mechanical harvesting*[3]	*No mechanical harvesting*[4]
2002	20%		1998	-	-
2006	30%		2003	25%	-
2011	50%	10%	2008	50%	-
2016	80%	20%	2013	75%	-
2021	100%	30%	2018	100%	
2026		50%			
2031		100%			

- Not applicable
[1]Law number 11,241 of September 19, 2002
[2]Decree number 2,661 passed by the federal government on July 8, 1998
[3]Areas where mechanical harvesting is possible; an incline of less than 12 %
[4]Areas where mechanical harvesting is possible; an incline of more than 12 %
Source: World Bank, 2005.

[14] World Bank, 2005.

speak to the potential of basing African ethanol industries on the Brazilian model. The differences between many potential ethanol-producing African countries and Brazil, however, are stark. Brazil is a continent-sized country and has long been considered an agricultural powerhouse. In addition, Brazil's domestic automobile industry is relatively mature, which has allowed for the ethanol industry to grow to the extent that it has. With these comparisons in mind, there are several valuable lessons that can be drawn from the Brazilian experience:

- Rapid expansion of ethanol production is possible with government support. Matching the growth rates in the Brazilian industry during the 1970s – when ethanol production grew 500% from a small base in just a few years – is not and should not be considered a realistic objective. The Brazilian experience does, however, suggest several policy tools that could be used in other countries as they strive to expand their ethanol industries. Credit guarantees and low-interest loans such as those used in Brazil could help speed construction of the first generation of ethanol facilities. Given that the financial sector in most African countries is not mature enough to issue such types of financial products, the involvement of international financial institutions such as the World Bank and other regional development banks will be critical in the development of the industry.
- Perhaps one of the most important component of the Brazilian ethanol program over the past three decades has been the requirement that ethanol make up a certain percentage of the national fuel supply. These types of mandates provide powerful signals to producers and help promote rapid growth in capacity. The Brazilian experience has used the fuel standard angle to help control the ethanol market, varying the percentage somewhat based on market conditions. Even during periods of relatively modest political support for the ethanol program, the requirement did not disappear, thus helping to sustain the industry through hard times.
- The history of Brazil's ethanol industry suggests that any ethanol program must anticipate commodity price swings: enthusiasm for ethanol is always highest when oil prices are high and sugar prices are low. One vital way of dealing with price swings has been with flex-fuel vehicles. The explosive growth of FFVs in Brazil during the past few years is a positive sign of the ability of auto companies to quickly scale up production and the instant acceptance of such cars by consumers. Precisely because commodity prices will vary, as Brazil witnessed in the 1980s and 1990s, a vehicle fleet in which FFVs predominate is essential to a successful long term ethanol program.
- Finally, it is important to consider that, as with many technologies, ethanol technologies improve steadily with time. The Brazilian experience provides compelling data when it comes to ethanol: between 1975 and 2000, production of ethanol per hectare in Brazil more than doubled. During the same period, harvesting costs fell by half. Similar improvements can be expected in other agricultural sectors, especially as the global market for ethanol remains dynamic.

A crucial issue in the development of a national ethanol industry is that, to be viable, an alcohol-based economy should have a positive net fuel energy balance, i.e. the total fuel energy expended in producing the alcohol should not exceed the energy content of the product. Unfortunately, this energy balance is very difficult to establish. Many processes are involved in the ethanol production process, including fertilizing, farming, harvesting, transport, fermentation, distillation, and distribution. In addition, the amount of fuel used to build farms and distilleries, as well as the cost of fuel plant equipment, has to be taken into account. In the end, the calculations depend on what is included or excluded, and on the methods employed in accounting for the energy value of byproducts, and consideration of alternate uses of feedstock.

In the long run, production of biofuels from more widely available and cheaper biomass is likely to become commercially viable, enormously increasing the scope for economic production of biofuels both in terms of the total volume manufactured and the number of countries where manufacturing takes place. Agricultural residues, woody biomass, dedicated energy crops (such as switchgrass), and municipal solid waste are some of the potential feedstocks for ethanol production. While numerous technical issues remain to be addressed, visible progress is being made.

Brazil's Biodiesel Program[15]

The first attempts to create a biodiesel program in Brazil occurred in the 1980s. These efforts originated more in the scientific community than in the industrial sector. Despite the strong demand for diesel, prices were too low to justify the use of vegetable oils for producing biodiesel. Interest in biodiesel required the creation of demand of native vegetable oils that did not have a traditional market.

In 1981, a patent was awarded for a process developed at the University of Ceará (Professor E. Parente) that visualized the use of microwaves to accelerate the trans-esterification process. Only in the 1990s was the program reactivated, at that time because of the excess supply of soy oil in the market. Through a grant from ASA, a successful trial involving use of soy biodiesel was conducted in Curitiba in the city's public bus fleet.

After 2001, when soy oil reached a very low value (USD 270/ton in the producing regions), the Brazilian Association of the Vegetable Oil Industry (Associação Brasileira da Indústria de Óleos Vegetais, or ABIOVE) firmly embraced the idea of a biodiesel program for Brazil. Other similar organizations as well as government agencies organized to neutralize the passivity of the automobile industry and some sectors involved in distribution of fossil-based fuels. Some state governments, interested in the reactivation of agribusinesses that were in decline and had prioritized raw materials exports to China, also supported the idea.

[15] For more information, see MDA (http://www.mda.gov.br/), ANP (http://www.anp.gov.br/) and the Ministerior de Minas e Energia (http://www.mme.gov.br/).

At the prompting of the President, the national legislature opened the public debate with a well-structured program of hearings to gather the views of all segments of society. This program allowed for the grouping of the interests of the primary sector (agricultural producers), the secondary sector (processing industry) and the tertiary sector (fuel distributors and vehicle users). The Government of Brazil, through the National Petroleum Agency (Agência Nacional de Petróleo, or ANP) and other ministries, coordinated the various areas to achieve the common objective of a national biodiesel policy.

The basic components of the program are:

- Obligatory use of biodiesel from 2008 through a blend mandate (2% by 2008, 5% by 2012);
- National quality standards enforced by the ANP;
- All feedstocks, with preference for castor and Africa palm;
- Tax policy favors non-traditional crops (African palm and castor seed) produced in the family sector in poorer regions of the country (North and Northeast);
- No technology restrictions
- Producers must be licensed by the ANP;
- Blending and marketing is via refineries and distribution companies;
- Limited direct sales under contract between companies with risk shared by the parties;
- Lending at subsidized interest rates for investments

From the time of the pasage of the law in 2005 and the entry into force of the blending mandate in 2008, the government instructed Petrobrás to purchase 1 million tons through public auctions in order to support investments during the early-stage development of the program. The auction system adopted during the period prior to the program becoming mandatory on January 1, 2008, served as the starting point of the program. The volumes slated for purchase by Petrobrás during the two years from 2006 to 2007 in accordance with the Govnerment's instructions are presented in Table 5. These purchases enabled industrial projects to begin making sales and helped all participants in the sector to learn the business. The auction rules (which were conducted via Internet) are described in the a document reproduced in Annex G.

The auction rules may be summarized as follows:

- Petrobrás notified participants of the maximum price and volume for each auction, with the establishment of the maximum price intended to be enough to guarantee a return on investment for investors;
- The registered participants offer volumes and prices equal to or less than the maximum price;
- The manager of the auction (Banco do Brasil) selects the bids in order of price, and disseminates the winners;
- The system is public and may be followed by any person registered with the system manager, the Banco do Brasil;

- The auctions will no longer be used in 2008, since all the diesel distributors will be obliged to purchase 2% biodiesel for mixing at the distribution center, leaving the negotiation to the processor and the distributor in conformity with the quality standard established by the ANP.

Table 5: Results of the Biodiesel Program auctions

Empresas / Municícios	Volume Arrematado 1° leilão (m³)	Volume Arrematado 2° leilão	Volueme Arrematado 3° leilão	Volume Arrematado 4° leilão (m³)	Volume Arrematado 5° leilão	Volume Arrematado Total (m³)
Região Norte	**5.000**	**0**	**2.200**	**90.000**	**0**	**97.200**
Agropalma	5.000		2.200			7.200
Brasil Biodiesel / Porta Nacional-TO				90.000		90.000
Região Nordeste	**38.000**	**21.780**	**40.000**	**218.220**	**17.000**	**335.000**
Brasil Biodiesel / Floriano-PI	38.000		40.000			78.000
Brasil Biodiesel / Crateús-CE		1.780		88.220	2.000	92.000
Brasil Biodiesel / Iraquara-BA		20.000		80.000	6.000	106.000
Brasil Biodiesel / São Luis-MA				50.000		50.000
IBR / Simões Filho-BA					9.000	9.000
Região Centro-Oeste	**0**	**38.220**	**0**	**79.129**	**28.000**	**145.349**
Binatural / Formosa-GO		1.320				1.320
Granol / Anápolis-GO		36.000			28.000	64.000
Renobrás / Dom Aquino-MT		900				900
Agrosoja / Sorriso-MT				5.000		5.000
Fiagril / Lucas do Rio Verde-MT				27.500		27.500
Barrálcool / Barra do Borges-MT				16.629		16.629
Caramuru / São Simão-GO				30.000		30.000
Região Sudeste	**27.000**	**110.000**	**7.800**	**2.651**	**0**	**147.451**
Soyminas / Cássia-MG	8.700					8.700
Granol / Campinas-SP	18.300		1.800			20.100
Ponte Di Ferro / Rio de Janeiro-RJ		31.000				31.000
Ponte Di Ferro / Taubaté-SP		19.000				19.000
Charqueada / Charqueada-SP		60.000				60.000
Fertibom / Cantanduva-SP			6.000			6.000
Biominas / Itatiaiuçu-MG				2.651		2.651
Região Sul	**0**	**0**	**0**	**160.000**	**0**	**160.000**
Brasil Biodiesel / Rosário do Sul-RS				80.000		80.000
Bsbios / Passo Fundo-RS				70.000		70.000
Oleoplan / Veranópolis-RS				10.000		10.000
Total	**70.000**	**170.000**	**50.000**	**550.000**	**45.000**	**885.000**

Fonte: ANP

Fonte: ANP.

Certification. Recently, Brazil began receiving questions from European entities and governments regarding the use of lands in the Amazon Basin for the production of oil seeds. The Government of Brazil and the private sector committed to create certification mechanisms that would document the origin of the feedstocks used. Documents available from ABIOVE prepared by the sector agencies describe the results of the moratorium on new cultivation and provide details on the standards and certification arrangements.[16] The Government of Brazil, beginning with statements made by the President in Europe, also guaranteed that a formal certification system would be launched by the end of 2007. These mechanisms will be applied to oil seeds in view of the fact that sugarcane is not cultivated in the humid tropical areas such as the Amazon Basin. It should be noted that cane is a member of the *gramineae* family that requires stress,

[16] See http://www.abiove.com.br/ss_moratoria_br.html.

whether thermal (cold) or in terms of moisture (dry conditions) to generate sucrose in the stem immediately prior to harvesting. Tropical forests do not generate the necessary stress, thereby limiting the suitability of cane crops and contributing only to the development of foliage without increasing the sucrose content in the juice once extracted.

2. Zimbabwe

National Biofuels Industry: Ethanol. In 2004, Zimbabwe produced a total of 6 million gallons of ethanol, and slightly less, 5 million gallons, in 2005. Although potable alcohol is produced, no biofuels are being produced commercially.

Malawi and Zimbabwe began looking at ethanol in the 1970's for the same reasons as Brazil, namely to address rising oil prices, save foreign exchange and develop a domestic resource. In both cases, public-private partnerships and market coordination (for blending, distribution and transportation) were critical to establishing the programs. Ethanol distilleries were built adjacent to existing sugar factories, where the availability of molasses as feedstock could be assured and the price of ethanol was linked to that of gasoline, plus an incentive of about 5%.

Triangle Ltd. (Zimbabwe) began ethanol production in 1980, and was the only fuel ethanol plant in the country before it shut down production a decade ago. Domestic labor and local construction reduced construction cost by 60 % compared with a turnkey plant. All key aspects of prices, distribution, marketing, and related infrastructure had been finalized before the plant was built. The targeted blending ratios established through the national oil company were 8-13%.

Annual production during the 1980s ranged from 30 to 40 million liters. A drought in 1991-93 resulted in almost no sugarcane production and thus practically no ethanol production due to unavailability of molasses. After the drought, attempts to settle the arrangements to begin blending again were unsuccessful. Triangle needed to optimize sugar production for financial reasons, resulting in less molasses and less ethanol, and the national oil company was reluctant to blend at a lower scale. At the same time, structural adjustment programs and tax incentives in Zimbabwe were encouraging exports, and Triangle found exports to international buyers of potable alcohol, which generally commands a price premium, a more attractive option than the production of fuel ethanol. Consequently, even though Triangle is again producing 30 million liters of ethanol per year, it is mainly sold on the potable market and is no longer blended with gasoline.

South Africa's Tongaat-Hulett Group is planning to revitalize the Triangle Ethanol Plant in Zimbabwe in 2007. The group, which last year paid USD 36 million to acquire Hippo Valley Limited, intends to begin blending fuel grade ethanol with petrol. The company has also announced a relatively low-cost expansion to one of its sugar mills to the tune of approximately R2-billion, which could raise sugar production capacity to one million tons per year. This would boost sugar production from Zimbabwe by some 400 000 tons per year. Tongaat-Hulett is actively involved in exploring the viability of bioethanol, and is assessing the possibility of establishing a cogeneration plant.

History of Biofuels Policy: Ethanol and Biodiesel. Zimbabwe has no policy for biofuels, and has not implemented any fiscal subsidies or preferential tax treatment programs at this stage. However, as part of a drive to promote the use of renewable sources of energy and reduce consumption of imported fuels, Zimbabwe's Ministry of Energy and Power Development is spearheading the production of biodiesel. The main aim is to substitute at least 10% of the daily consumption of imported fuel with biofuels within the next five years.

The Ministry of Science and Technology has embarked on projects to complement the Ministry of Energy's efforts. According to the Minister, plans were at an advanced stage to construct the first national pilot plant for the production of biodiesel. Given the almost total lack of foreign exchange, and the skills required, it is difficult to see how this plant can be built.

In 2005 the University of Zimbabwe produced a feasibility study which showed that locally produced biodiesel and ethanol offer a sustainable solution to the country's energy crisis. Immediately afterwards, Harare Polytechnic launched the first biodiesel project, using jatropha and involving poor farmers. The buying price of jatropha seeds was benchmarked against international diesel prices to promote farmers to grow the crop.

The initiative caused a lot of excitement in the country, but almost a year after the launch, progress towards the commercial production of the actual fuel has been checked by operational challenges.

Conclusions and Results. With no biofuels production at this stage, it is impossible to draw conclusions with respect to relevant lessons in terms of competition for land, deforestation, impacts on food prices, among other issues. However, it can be said that since Zimbabwe imports large quantities of maize, it is unlikely that any land would be dedicated to the production of biofuels until food sufficiency is reached. Land is in fact available for sugar growing, and some of this will certainly be used to grow sugar for bio-ethanol. In addition, most commercial farms are currently lying fallow, and some of these may well be converted to jatropha, sunflower or other oil crops in the future.

3. India

Summary. To help reduce its reliance on oil imports, the Indian government is increasingly looking to develop a home-grown biodiesel (and to a lesser extent ethanol) industry, which in part will be based on domestically sourced jatropha and sugarcane. In 2003, India made the use of 'gasohol' - petrol mixed with five per cent ethanol derived mainly from sugarcane - compulsory in nine of its states. The mandate was subsequently withdrawn by the Indian government, however, due to the rising cost of ethanol.

The government is now developing a program to promote fuel blending in a select number of States, which could result in a total demand for fuel ethanol of 1.5 billion liters in 2010. The suggested targets were a 5 % mix in 2012, a 10 % blend by 2017 and 20%

beyond that. Current production capacity is likely to be adequate for the first phases of this program.

Today, the Indian government has set up a planning commission committee to study biofuels, which has recommended a target of selling 20 % blended bio-diesel by 2011/12 and that jatropha be planted widely. To meet this target India would need to plant 11 million ha with jatropha to produce 13 million tons of biodiesel a year. India has an estimated 40 million ha of "wasteland" on which the trees could be grown.

Introduction. India imports more than 70% of its energy needs and is home to the fastest growing motor vehicle industry in the world, after China. These factors have accelerated the government-backed development of a biofuels industry to diversify that national energy mix. India's huge land mass and long agricultural tradition give it the potential to become a world leader in both ethanol and biodiesel. However, India is just beginning its biofuels program, and because it has chosen to produce ethanol from lower-yield sugarcane molasses and promote jatropha-based biodiesel, which has not been commercially proven, the viability of its program remains uncertain.

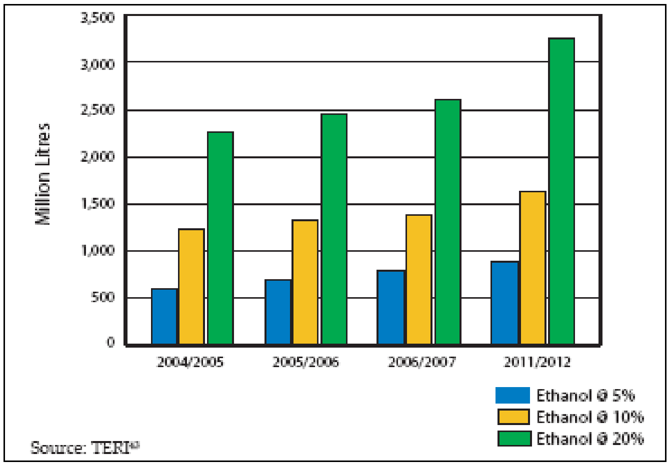
Summary of Biofuel Production and Industry: Ethanol. India is the second largest producer of ethanol in Asia after China. In 2005, India produced 1.7 billion liters of ethanol, of which 200 million liters were fuel ethanol. The ethanol industry is fragmented, with 120 separate producers. Most producers however, are concentrated in the sugarcane growing states of Maharashtra and Uttar Pradesh.

In keeping with its policy of not using food crops as energy sources, India produces ethanol from sugarcane molasses rather than from sugar directly. The lower sucrose content in molasses as compared to sugarcane juice means that the country's ethanol yield is only a sixth of Brazil's even though the countries are almost even in terms of sugarcane production. It seems unlikely that the area under cultivation will grow significantly, and the government projects an increase of only 0.6 million liters hectares in the country's 10th Five Year Plan (2002-2007). This assessment is back up by industry experts, who project that the total area under sugarcane cultivation is unlikely to exceed 5 million ha.

The sugar industry has said that output will be sufficient to meet demand for the nationwide 5% ethanol blend and even for the proposed hike to 10% in 2006, though some industry stakeholders disagree. Private sector oil refiner Reliance Industries has said that it is opposed to the 5% ethanol blending policy because Indian ethanol capacity is insufficient to meet such a goal. It has estimated that the policy would require that its refineries secure an additional 150 million liters of ethanol, which even its new Maharashtra sugar plants will be unable to sustain. Figure 2 shows the varying levels of ethanol demand based on various blending schemes.

History of Biofuel Policy: Ethanol. Under the Ethanol Blending Program (EBP), the blending of 5% ethanol in gasoline was made mandatory in nine states and four union territories in January 2003. Oil companies were offered incentives such as an exemption

Figure 3: Ethanol Requirements in India in Transportation Sector



Source: Garten Rothkopf, 2007.

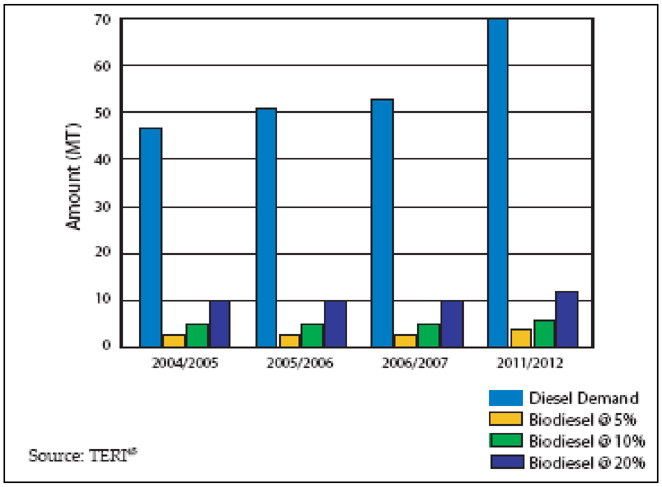
in the excise tax duty. However, difficulties in obtaining sufficient ethanol were reported in four states, and oil companies were only able to purchase 196 of the 363 million liters needed in early 2004 as a result of lower sugar production due to drought. In 2004, the policy was amended to oblige oil companies to adhere to the EBP under the following conditions: (i) the price of ethanol for supply of ethanol-blended petrol is comparable to the price of ethanol for alternative use; (ii) the delivery price of ethanol offered for the EBP in a particular state is comparable to the import parity price of petrol in that state; and (iii) the ethanol industry of that state is able to maintain the availability of ethanol for the EBP at such prices

As a result, ethanol blending was halted until late 2005, when a stronger sugar crop raised the availability of sugarcane molasses for ethanol production. In October 2006, the blending of 5% ethanol with gasoline was made mandatory for all private and public sector oil companies. It was also announced that, pending the availability of sufficient ethanol, 10% ethanol-blended gasoline would be introduced in June 2007.

Summary of Biofuel Production and Industry: Biodiesel. There is a huge market for biodiesel in India, where 80% of auto fuel is diesel. India's young biodiesel industry, however, is still largely operating on an experimental scale. In 2005, two small biodiesel plants went on-line. Achieving the National Mission on Biodiesel's goal of a 20% biodiesel blend by 2013 depends first and foremost on the expansion of jatropha cultivation to produce sufficient biodiesel feedstock. Figure 3 below shows the varying levels of biodiesel demand based on various blending schemes.

Given that the Indian government has already identified 39 million ha of land suitable for growing jatropha, meeting the target of roughly 11 million ha appears realistic. Table 6 shows the hectare requirements under various blend scenarios.

Figure 4: Biodiesel Demand in India in Transportation Sector



Source: Garten Rothkopf, 2007.

Table 6: Diesel and Biodiesel Demand and Area Required under Jatropha for Different Blending Rates

Year	**Diesel Demand** *(MMT)*	**Biodiesel @ 5%** *(MMT)*	**Area for 5%** *(Mha)*	**Biodiesel @ 10%** *(MMT)*	**Area for 20%** *(Mha)*
2001-02	39.81	1.99	n/a	3.98	n/a
2006-07	52.33	2.62	2.19	5.23	8.76
2011-12	66.90	3.35	2.79	6.69	11.19

Source: *A Blueprint for Green Energy in the Americas*, report prepared for the Inter-American Development Bank, 2007.

History of Biofuel Policy: Biodiesel. In 2002, rising oil import bills prompted the Planning Commission of the Indian government to establish the Committee on Development of Biofuel in a bid to diversify the national energy mix. In April 2003, it submitted a report, which surveyed the country's potential in biofuels and recommended establishing a National Mission on Biodiesel. Because India is facing a shortage of both edible and non-edible oils and does not use food crops as fuel feedstock, jatropha, which is inedible and thrives even in marginal lands, is a logical choice for biodiesel production.

To boost biodiesel consumption, the Ministry of Petroleum and Natural Gas implemented a biodiesel purchase policy that came into effect in January 2006. The policy requires public sector oil marketing companies to purchase biodiesel at Rs 0.25 per liter for blending with diesel from 20 purchase centers. An initial blend of 5% biodiesel was stipulated, with the option of increasing the blend to 20% in phases.

Other Government Initiatives on Biofuels. To better coordinate the biodiesel and ethanol policies cited above, India's Ministry of New and Renewable Energy is in the process of drawing up a draft National Policy on Biofuels. One of its recommendations is the creation of a National Biofuel Development Board, which will be headed by the prime minister.

With respect to financial incentives, it has been reported that the Ministry of Finance opposes granting biofuels an excise tax duty exemption because biodiesel-blended diesel and ethanol-blended gasoline are being sold at the same price as fossil diesel and gasoline, even though a lower duty is already imposed on biofuels. However, the Ministry of Finance has acquiesced in lowering the customs duty rate on non-indigenous manufacturing equipment for processing oil seeds if used in industrial projects with less than USD 1.1 million in plants and machinery. Industrial projects with plants and machinery exceeding USD 1.1 million are already eligible for 10% import tariffs under a separate arrangement for project financing.

In 2002, India and Brazil signed an MOU to promote technological research cooperation on the use of ethanol as a transportation fuel. The main goal of the MOU was to provide a diplomatic framework that would allow Brazil to share its advanced technological expertise on ethanol for transportation with India.

The existence of this official framework as well as growing trade between the two countries has led to a flurry of ethanol-related deals. In April 2006, the state-owned Oil and Natural Gas Corporation (ONGC) offered Brazil's Petrobras an equity and technology stake in a venture to set up a greenfield ethanol refinery to produce ethanol-blended oil products. In May 2006, Bajaj Hindusthan, India's largest sugar and ethanol manufacturing company, which has a sugarcane crushing capacity of more than 61,600 tons per day, announced plans to set aside USD 500 million to acquire mills in Brazil. A major factor in the decision was the significantly lower cost of Brazil's ethanol production. These acquisitions are projected to increase the company's total cane crushing capacity to 110,000 tons by the end of 2006. Because of the difficulty of increasing India's sugarcane area due to the lack of available land and competition with food sources, Bajaj Hindusthan hopes to establish plants in countries with large sugarcane outputs, to increase its ethanol production capacity from 320,000 to 800,000 liters per day. Brazil, with its huge land availability, is a key country under consideration.

India was the largest importer of Brazilian ethanol in 2005 (410 million liters) due to a poor sugarcane harvest. Its imports from Brazil are projected to rise further following the implementation of the mandatory blend.

Results and Conclusions. Although it is the second-largest producer of sugar in the world, India is unlikely to become an ethanol exporter. Food security concerns in the country mean that sugarcane will remain primarily destined for sugar production, thus restricting ethanol feedstock to molasses, which results in lower output. Although sugarcane production may grow marginally, India lacks the available land necessary for significant increase. The country is exploring other means of producing ethanol, such as through cellulosic materials, but this technology will not be commercially viable in the medium term. It is likely, therefore, that India will have to import ethanol to meet the demand generated by mandatory blends, especially as the country's growing industrial sector consumes ethanol for the manufacturing of products such as petrochemicals and pharmaceuticals. The biodiesel industry is also in an uncertain position because jatropha-based biodiesel is still commercially untested. However, firm government support behind the National Mission for Biodiesel as well as the potential price competitiveness of the fuel blend may make the country's biodiesel effort a qualified success.

4. Colombia

National Biofuels Industry: Ethanol. Colombia has long been regarded as a country with especially high potential for the efficient production of ethanol, yielding more sugar per hectare than Brazil. Colombia's sugar-cane growing Valle de Cauca region currently houses five mills that produce a total of 360 million liters (95.1 million gallons) of ethanol per year. Two additional facilities are under construction. The current production capacity supplies only Bogota and the southern and western regions of the country, although output should increase by half a million liters to cover other important regions to the north and east. Some 200,000 ha of sugar cane plantations exist in the country, and approximately 50,000 ha are dedicated to the production of ethanol. Between 15 and 20% of surplus sugar, which was formerly sold on the market at a low price, is now used for biofuel production.

Cassava has become the second largest source of ethanol production in Colombia, and the first cassava-based plant currently produces 20,000 liters (5,283 gallons) of ethanol per day. The plant is expected to increase its output to 1 million liters/day in the medium term. Two other cassava-based ethanol plants, in the northern regions of Sucre and Cordoba) produce a total of 75,000 liters (19,800 gallons) of ethanol. Some 128,000 ha of cassava are currently planted in Colombia, mainly for human consumption.[17]

Despite Colombia's relatively high levels of ethanol production, existing production satisfies only 57% of national demand, due largely to a policy requiring that motor gasoline be blended with biofuel in Bogota, Valle del Cauca and Eje Cafetero (see below). In order to satisfy demand from the remaining regions, an additional 600,000 liters (158,500 gallons) per day of capacity are needed.

Ethanol production costs in Colombia have been estimated to range between USD 0.90 and USD 1.15 per gallon.[18] Ethanol prices in Colombia are low in comparison to the U.S. (USD 1.74/gallon), making export to North American markets attractive. Colombia also benefits from free trade agreements with the U.S.

There are various ethanol consortia in Colombia, including Ethanol Consortium Board S.A., Alcol S.A., Maquiltec, and Petrotesting, among others. These groups have been promoting the construction of eleven additional ethanol facilities. Three of these facilities will be built in Bolivar, Sucre and Cordoba by Juan Manuel Hernandez, an

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[17] "Harvesting Sunshine for Biofuels." *Inter Press Service News Agency*, October 12, 2006. (http://ipsnews.net/news.asp?idnews=35088)
[18] Corpobid, 2006. (http://www.iea.org/Textbase/work/2002/ccv/ccv1%20echeverri.pdf)

entrepreneur previously employed by Ecopetrol, Oxy, BP and Schlumberger. The facilities will have a daily production capacity of 300,000 liters of ethanol (approximately 79,000 gallons), 750,000 liters of which have already been sold to Svenck Ethanol Kemi AB, Sekab, one of the largest ethanol distributors in Europe. Funding for the facilities will come from Swedish, Brazilian, Spanish, Philippine and Scottish sources, as well as from the Grupo de Inversionistas de Colombia, led by Juan Manuel Giraldo.

In addition, the Grupo Petrotesting de Colombia (GPC) is completing a study on the production of ethanol from yucca. The objective is to develop a facility with a daily capacity of 200,000 liters.

National Biofuels Industry: Biodiesel. There is no local biodiesel production in Colombia, although Colombia is the world's fifth largest producer of palm oil. The country's production capacity is 640,000 tons per year (in 2004), and approximately 250,000 tons are exported annually. Colombia has approximately 152,000 ha of palm oil plantations and one of the highest oil production yields at 4.5 tons per ha. The palm oil industry is generally well organized and is represented by Fedepelma, the palm oil producers association. Production costs for palm oil are estimated to range from USD 300/MT to USD 350/MT. The purchasing price for palm oil is approximately USD 419/ton, and operating and maintenance costs for biodiesel production facilities are expected to cost approximately USD 120/ton.

According to studies undertaken by Asilea Resources, LLC, biodiesel production from palm oil in Colombia is competitive with diesel when oil prices remain around USD 45/barrel, and when the tax burden on diesel is heavier than on biodiesel (as is presently the case in Colombia; see below).

There are several Colombian palm grower groups interested in moving forward with biodiesel production for domestic consumption to enhance the value of their palm oil, which is for the most part exported. According to Asilea, interested groups include Propalma S.A., Fedepalma. Government promotion agencies (Coinvertir and Proexport) have identified at least two groups located in the northern and central Colombian palm growing regions that have also expressed interest in biodiesel production.

National Biofuels Policy: Ethanol. Colombia's ethanol industry has grown considerably, thanks especially to a series of legal incentives that have encouraged and mandated and the use of the biofuel in the transportation sector. The *Law 693 of 2001* calls for a transition in the composition of motor gasoline, which is now required to be blended with ethanol. In January 2005, Colombia began to mix gasoline with 10% ethanol produced from sugar cane, with the objective of increasing this proportion to 25% in 20 years.[19] The blending mandate has been implemented only in Bogota and the Valle del Cauca and Eje Cafetero regions.

To satisfy growing local demand, the national government has proposed the creation of a USD 30 million venture capital fund to promote the construction of additional ethanol

[19] http://cecodes.org.co/boletin/50/archivo/Etanol.doc (March 2007)

plants in regions that would otherwise be unattractive to potential private sector investors. Other measures to support the growth of a national biofuels industry include tax reductions, broadening eligibility criteria for VAT exemptions, and the removal of consignment taxes and other barriers to foreign investment.[20]

National Biofuels Policy: Biodiesel. Colombia became a net importer of diesel fuel in 2004, when demand for the fuel surpassed local refining capacity. In response to increasing demand for high-priced imported fuels and a drop in Colombia's oil reserves, President Alvaro Uribe announced in August 2006 that the production of biofuels would become a national priority. Recent policy related to biofuel production and use in Colombia established a compulsory B5 fuel blending (5% biodiesel/95% diesel) requirement for vehicles, which is set to be implemented in January 2008. Demand in the local market is expected to rise to 200,000 tons of biodiesel per year, based on current consumption levels of diesel (for 2005) equal to 4 million tons per year.

Through *Law 939 of 2004* (see Article 7), the Colombian government established that diesel fuel could be blended with biodiesel for use in vehicles with diesel engines in quantities to be set by the Ministry of Mines and Energy and the Ministry of Environment. The ministries subsequently issued *Resolution 1289 of 2005* through which a 5±0.5% blending requirement for biodiesel was set, as well as a requirement addressing the quality of the biodiesel and the overall blend (Fluid point 3ºC).

A further resolution *(Resolution 18 1780 of 2005)* established a methodology to set the price for the biodiesel fuel blend, which is based on a 5% biodiesel/95% diesel ration, and must remain between set floor and ceiling prices.

National Incentives for Biofuel Production and Use. Colombia is in the process of implementing fiscal incentive packages for the production and use of biodiesel and ethanol. Law 939 of 2004 provides a sales tax exemption on biodiesel that is blended with diesel fuel for use in vehicles. The exemptions are applied to the VAT (16%), as well as on the Global Tax (23.26%). In addition, Law 260 of May 2004 states that biodiesel production facilities are entitled to fiscal exemptions for a period of 10 years followed commercial operation of the plant.

For ethanol, a law passed in 2002 renders any fuel alcohol destined for blending with motor gasoline exempt from VAT and Global Tax.

5. Honduras

National Biofuels Industry: Biodiesel. Biofuels represent a very small portion of today's overall fuel mix in Honduras: the government has not considered it economically attractive to produce bioethanol from sugar cane, and has only recently considered promoting biodiesel from palm oil on a scale large enough to optimize a national fuel production, transportation and distribution system.

[20] *Ibid.*

Honduras currently has 83,000 ha of African palm under cultivation, and produces about 240,000 metric tons of palm oil each year. This industry plays a significant role in the country's economy and is a major source of export revenues, with roughly 115,000 metric tons of palm oil exported yearly. The only biodiesel manufacturers in Honduras today are palm oil producing companies. Several of these companies, such as Dinant and Hondupalma, have found that they can conveniently manufacture biodiesel and use it as a fuel for their generators. Fish oil and beef tallow have also recently been introduced as biodiesel feedstock by companies such as Biocombustibles, and government officials believe jatropha is for Honduras's future biodiesel industry. A trial cultivation of jatropha is under way, and results are soon expected to provide a more sound assessment of this feedstock's potential in terms of yield and biodiesel production costs in the country.[21]

Honduras biodiesel production currently amounts to 3.96 million gallons per year (14.9 million liters), with production costs for palm oil biodiesel ranging from 42 to 48 Lempiras per gallon (USD 2.2-2.5/gallon). Animal oil-based biofuels, on a much smaller scale, enjoy a slightly lower production cost of 37 Lempiras (USD 1.9) per gallon.[22] After being competitive with petro-diesel in 2005 and the first half of 2006, thanks to relatively high petroleum prices, since mid-2006 biodiesel has suffered a disadvantage due to a simultaneous decrease in international oil prices and a rise in international palm oil prices. This represents the opportunity cost of not selling palm oil on the world market and using it for biofuel production instead. In the longer term, improvements in biodiesel production economics and government support will be critical to the strengthening and development of this sector in Honduras.

National Biofuels Policy: Biodiesel. Biodiesel development has been an item on Honduras's recent policy agenda. At a national level, in February 2006 the Honduras hgovernment decided to promote the cultivation of African palm, with the objective of boosting job creation, developing additional feedstock for biodiesel, reducing the country's dependency from imported fuels and improving air quality. The government aims at eventually having a total of 200,000 hectares growing African palm, producing up to 200 million gallons (757 million liters) of biodiesel per year.[23]

On the basis of growing political will and emerging favorable market condition in early 2006, a draft Law (*Anteproyecto de Ley*) for the production and consumption of biofuels was submitted to the National Congress and incorporated in its agenda in September of the same year.[24] Incentives proposed include a 15-year exemption from all state and municipal taxes on all equipment for the construction, installation, maintenance and operations of biofuels production plants; a 10-year exemption from taxes on revenues starting from commercial operations activities; a 15-year exemption on fuel production

[21] Jatropha trial cultivation is being conducted by the Fundación Hondureña de Investigación Agricola (FHIA), a privately funded agricultural research organization. See www.fhia.org.hn
[22] Source: information obtained from the companies Dinant, Hondupalma, San Alejo and Biocombustibles
[23] http://www.biocombustibles.gob.hn/index.htm
[24] The Anteproyecto de Ley para la Producción y el Consumo de Biocombustibles can be found online at http://www.biocombustibles.gob.hn/marco%20juridico.htm

taxes for the biofuels component of gasoline, after which the tax is to correspond to 25% of that for fossil fuels; and import duty incentives for biofuels production equipment. In addition to obtaining an official license and respecting technical, safety and fuel quality standards, eligibility requirements for these incentives also include national clauses: biofuels production plants must be located on national territory, and at least 51% of inputs must be of national origin. The draft law also provides for sanctions. Biofuels production without a license and alteration of fuel quality or blend constitute violations of the law and give rise to civil, administrative and criminal penalties. Detailed technical regulation will be enacted following the law's approval and entry into force, and discussions for technical specifications of B100 biodiesel have already begun in the context of the Central American Customs Union. As of May 2007, however, the approval and ratification process for the *Anteproyecto de Ley* is still pending.

Biofuels development is also being promoted in Honduras at the municipal level. The Mayor of Tegucigalpa is engaged in an effort to promote the use of clean transportation fuels in the Honduran capital, including biodiesel derived from domestically produced vegetable oil, fish and animal fats, as well as LP gas in place of gasoline. The Tegucigalpa program is supported by the Honduras government, and complements the national biodiesel program. These two initiatives emphasize different objectives – job creation for the national program, and cleaner air in the capital for the municipal one – but they share the same ultimate objective of displacing consumption of imported fossil-based transportation fuels. Together, the two programs support both sides of the country's supply-demand equation for biodiesel. The President's program emphasizes expanded cultivation of biodiesel feedstocks, while the Mayor's program focuses on creating demand for biodiesel and LP gas by Tegucigalpa public transportation system operators.

In August 2006, the Honduras Presidency and the Tegucigalpa Municipality facilitated the signing of a multi-sectoral agreement[25] that created a pilot program promoting biodiesel use in the capital. The agreement covers a period from September 2006 until the end of 2007, and involves several participants. Palm oil and biodiesel producers commit to provide pure biodiesel (B100) to fuel retailers, who commit to make biodiesel available to bus owners at locations specifically equipped for the sole use of buses serving selected routes in Tegucigalpa. This would provide blends containing fractions of biodiesel increasing over time, reaching a 20% blend (B20) for year 2007. Bus owners are involved as "voluntary participants," meaning they have the opportunity, but not the obligation, to purchase biodiesel at selected facilities. Various government agencies commit to monitor and enforce provisions agreed for blend percentages, fuel quality and palm oil production environmental impacts.

Other Government Initiatives and Next Steps. Several obstacles prevent biodiesel from becoming a sustainable energy option in Honduras, mainly related to relatively high production costs and lack of adequate policy tools. The success of government and municipal initiatives will therefore depend on improvements in biodiesel production economics as well as on the effectiveness of policies enacted.

[25] Convenio de implementación: proyecto piloto de introducción del biodiesel en el mercado nacional, septiembre 2006 a diciembre 2007

With respect to the economics, the international price of palm oil, seen as an opportunity cost, will affect biodiesel competitiveness in Honduras, as well as international petroleum prices. Production costs are expected to decrease with larger volumes, attracting actors other than current palm oil producers and increasing the production of the latter. These factors are critical in the longer term development of this sector, but also affect current initiatives. In the Tegucigalpa pilot program, bus owners have no obligation to purchase the biodiesel, and their willingness to do so depends on the distributors' ability to offer the fuel at a discount compared to straight petro-diesel, which mainly depends on economics given that no discount is specified in the agreement.

The main item on the policy agenda is finalizing and ratifying the *Anteproyecto de Ley* on biofuels. The ratification process may also have been delayed by ongoing unresolved issues in the country's new international bidding process for fossil fuel procurement, under which annual oil import licenses are to be awarded to the international supplier submitting the most competitive bid. A swift approval of the biofuels draft law would be beneficial to the establishment of a coherent legal framework for the sector, including a specialized governmental technical unit in charge of biofuels promotion, and the provision of a series of effective incentives for biofuels production.

The experience developed in the Tegucigalpa pilot project provides precious insight on a series of obstacles and issues to be addressed, with useful lessons learned for the design of effective policy measures. Key concerns involve the challenge for individual end-users to overcome the initial cost of vehicle conversion, conversion safety, fuel quality and reliability, and the continued availability of fuel at competitive prices with respect to fossil-based alternatives. To address these concerns and achieve broader clean air targets, the Tegucigalpa municipality is seeking to expand its program, involving additional bus routes and vehicle types (including LPG for taxis), and extending environmental and economic benefits of alternative fuel use.

6. Tanzania

Tanzania has potable ethanol capacity that could be upgraded or converted to produce fuel quality ethanol. The main potential feedstock for ethanol available in Tanzania is sugarcane, while a variety of potential feedstocks exist for the production of biodiesel, including: oil palm, coconut, cashew nut, sunflower, sesame, soy beans, cottonseed, peanut, castor, and jatropha. There is no commercial production of biofuels or regulatory instruments in place to support biofuels production in Tanzania.

Biofuels have demonstrated good potential as transport fuels in Tanzania largely because they can be produced from locally grown oil and sugar/starch plants. Alternative fuels for transport have only recently entered the debate in the country, and the potential for local biofuel production has to date remained for the most part untapped. This is mostly due to lack of technical know-how and inadequate policy support for biofuels development.

In the field of biodiesel, research and development efforts are spearheaded by groups such as Kakute Ltd., FELISA, D1 Oils, the University of Dar es Salaam, TaTEDO and other stakeholders. Some of the objectives of these groups include disseminating knowledge about producing and processing the jatropha plant into biodiesel, assisting small farmers in this process, and ensuring that oil from palm trees produced in large quantities will be used as a source for alternative fuels in Tanzania. The production of jatropha oil is relatively small scale at this point, and is traded for USD 2/liter in northern regions such as Arusha, Engaruka, and Mto wa Mbu. It is, therefore, not yet deemed a financially attractive substitute for diesel oil.

Tanzania also has a large potential for the production of ethanol. A research project conducted by the Applied Microbiology Unit at the University of Dar es Salaam in 2003 identified the possibility of producing ethanol from lignocellulosic waste materials, primarily from the national sugarcane industry. In addition to sugarcane waste, the project sought to identify other types of biomass waste that could be used for the production of ethanol. Sugarcane yields are approximately 1,446 metric tons of cane per ha, which could in turn yield a potential 70 liters of ethanol (from one ton of harvested cane).

Production of ethanol from primary agricultural products in Tanzania has not been deemed cost-effective, largely because the value of the crops often exceeds the value of the ethanol produced. Several studies have been carried out to evaluate the viability of producing ethanol for use as vehicle fuel and in the chemical industry. In 1979, the National Chemical Industries (NCI) commissioned a detailed power alcohol feasibility study, determining that the country has substantial potential for producing ethanol from a variety of agricultural crops and waste. Potential agricultural wastes for ethanol production include sugarcane molasses, which is for the most part considered waste in the sugar production chain. Only about 30% of molasses generated in Tanzanian sugar factories is exported or used as animal feed. In addition, the conversion of lignocellulosic agricultural waste into bio-ethanol also may be an effective way for producing ethanol and effectively reducing regional pollution caused by the on-field burning of sugarcane tops and leaves just prior to the harvest. Overall, the current market in Tanzania for residues of agricultural production is still low and not well documented. Further studies to identify the actual uses of agricultural residues in the different regions of the country are required.

The promotion of ethanol production at the national level in Tanzania will require several changes in the country’s transportation system, and strong policy support would be critical to encourage the blending of ethanol with gasoline. Enacting a supportive policy framework has been estimated to take several years, although it is possible that several policies and regulations will be implemented in the nearer term.

Policy on biofuels. Current activities to promote biofuels in Tanzania include these.

- Under the guidance of the Tanzanian Ministry of Energy, a Biofuels Task Force has been established in April 2006. The Task Force provides guidance and recommendations for the elaboration of biofuel policies and regulations suitable for Tanzania. Among its objectives is to ensure close cooperation between the various government ministries involved in the development of such policy, and to channel information between the government and stakeholders in the biofuel market, ranging from industry groups, farmers associations, NGOs, and members of civil society

- Development of Biofuels Guidelines and a national Biofuels Strategy, Legislation and Regulations (under preparation)
- Support for the Tanzanian Biofuels Task Force through the Partnership Dialogue Facility (PDF) of the EU Energy Initiative (EUEI)

Representatives from three of the four large sugar factories in Tanzania (Kilombero Sugar Company, Mtibwa Sugar Estates, and Kagera Sugar Ltd.) have already confirmed strong interest in large scale production of ethanol as a transport fuel on behalf of the sugar sector. Sugar producers in the country have already conducted internal feasibility studies for installing and operating ethanol production technology, forming a base from which to rapidly implement a national program.

Nevertheless, it has been clearly stated by national stakeholders that the development of clear, stable and supportive policies and regulations will be an essential prerequisite for the sugar sector's engagement and eventual investment in the technology. Among the policies that have been proposed is a mandatory blending of gasoline with ethanol (the equivalent of E10), initial price guarantees for ethanol and protection of local producers against cheaper imports of the biofuel. According to studies undertaken by GTZ, a nationwide program requiring the blending of ethanol with gasoline (to produce an E10 blend) is feasible by 2010. If Tanzania were to implement an E-10 standard, it is expected they would need about 27 million liters.

7. Thailand

Thailand's Energy Market. Due to rising gasoline prices and an energy saving campaign launched by the national government, many Thai consumers have started to turn towards alternative fuels such as gasohol (ethanol-gasoline blend, see below), liquefied petroleum gas (LPG) and natural gas for vehicles. Accordingly, the use of premium gasoline dropped 34%, and regular gasoline sales showed a 5% decline, with total gasoline consumption in 2006 declining slightly, from 7,248 million liters in 2005 to 7,215 million liters.

Gasohol in Thailand is a mixture made up of 10% ethanol and 90% gasoline; ethanol is largely used to replace imported MTBE. Gasohol consumption has increased by 83.5% (from 646 million liters in 2005 to 1,185 million liters in 2006), thanks in part to ethanol's ability to compete with the price of gasoline and a variety of public relations campaigns implemented by both the government and the private sector to increase public awareness of and promote the production and consumption of biofuels. Consumption of gasohol is expected to increase further in 2007; current consumption levels (as of June 2007) have reached 3.95 million liters/day, an increase of almost 13% over 2006 levels (approximately 3.5 million liters/day).

Total consumption of B5 biodiesel remains small in comparison to figures for diesel consumption. In 2006, 21,149 million liters of diesel were consumed, up 1.6% from 2005 levels. According to Thailand's Department of Energy Business, biodiesel demand is expected to further increase to 1.1 million liters/day in the first quarter of 2007.

Summary of Ethanol Production and Industry. The Government of Thailand has thus far approved 45 new ethanol plants, which represent a total production capacity of 10.9 million liters/day; over half of these facilities are cassava-based ethanol plants and account for 70-80% of total ethanol production. The rest of the facilities are sugar/ molasses-to-ethanol plants.

There are currently seven operational ethanol plants in the country (with total production capacity of 955,000 liters/day), six of which are producing molasses-based ethanol, accounting for 86% of total ethanol production. These six ethanol plants, however, supply only approximately 545,000 liters/day to domestic oil refineries for the production of ethanol-blended gasoline (gasohol), thusleaving the country with a surplus of approximately 400,000 liters/day. As a result, the government has temporarily allowed exports of the surplus in order to retain enough storage capacity for continued domestic ethanol production. However, exporters have found it hard to find markets for this ethanol because of poorly developed policy frameworks for ethanol in other East Asian countries – notably Japan – and stiff competition from Brazil.[26]

By the end of 2007, the total number of operating ethanol plants in the country is expected to increase to 9, increasing total production to approximately 1.2 million liters/day. Most of these plants will be molasses-based ethanol facilities, in addition to two cassava-based ethanol plants that are expected to supply 200,000 liters/day for gasohol production. Two pilot sugarcane/molasses-to-ethanol plants are also expected to come online by the end of 2007, in order to test the sugarcane-to-ethanol production process in Thailand. Meanwhile, an additional 10 ethanol plants are under construction and expect to be operational in 2008, increasing production capacity by 1.7 million liters/day, of which 1.1 million liters/day will be from cassava-based ethanol plants.

The government has also recently revised its plan to promote gasohol consumption through price incentives, as opposed to implementing a strategy mandating the compulsory phasing out of premium gasoline sales. The Ministry of Energy has set a target for gasohol sales to reach 8 million liters/day by the of 2007, and 20 million liters/day by the end of 2011, largely by increasing the number of gasohol pumps at gas stations throughout the country, particularly small-scale facilities that normally have limited access to gasohol supplies. The government has set gasohol prices to be approximately 2.8-3.30 baht/liter (USD 0.09-0.11/liter) cheaper than regular and premium gasoline. Table 7 and Figure 5, below, illustrate the current biofuels market in Thailand, as well as projections until 2011, which depict a strong increase in domestic gasohol production capacity and a resulting rise in the level of exports.

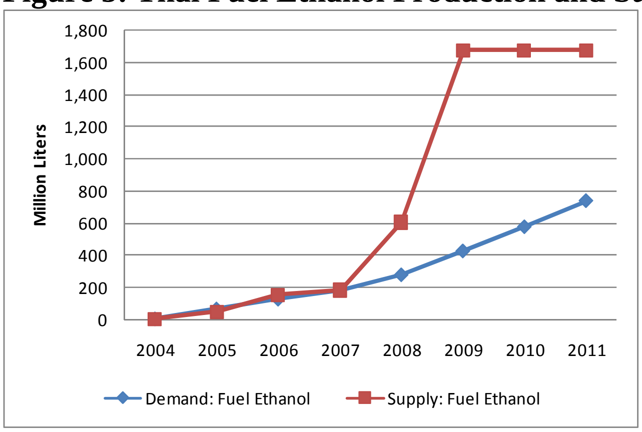
[26] Dr. Nattapon Nattasomboon, Office of Industrial Economics at the Ministry of Energy, Ministry of Industry of Thailand, presentation at National Biofuels Seminar, Maputo, July 12, 2007.

Table 7: Ethanol Demand, Supply, Imports and Exports (million L), 2004-2011

Year	Demand: Fuel Ethanol	Supply: Fuel Ethanol	Imports	Exports
	Total (million L)	*Total (million L)*	*Total (million L)*	
2004	6.0	6.0	0	0
2005	67.5	46.7	20.8	0
2006	127.9	152.0	0	24.1
2007	183.6	184.0	0	0.4
2008	279.2	606.0	0	326.8
2009	427.0	1,674.0	0	1247
2010	577.4	1,674.0	0	1096.6
2011	739.2	1,674.0	0	934.8

Source: Dr. Nattapon Nattasomboon, Office of Industrial Economics, Ministry of Industry, Thailand.

Figure 5: Thai Fuel Ethanol Production and Supply Trends, 2004-2011.



Source: Dr. Nattapon Nattasomboon, Office of Industrial Economics, Ministry of Industry, Thailand.

The data included in the table above and the figure below represent total production and supply of gasohol 95 and gasohol 91.

History of Ethanol Policy. The Government of Thailand established its National Ethanol Program and Gasohol Strategic Plan on December 6, 2003, with an ethanol production target of 1.0 million liters/day by the end of 2006, increasing to 3.0 million liters/day by the end of 2011. Since government approval in December 2006 of a plan to liberalize the domestic ethanol sector, fuel ethanol production and distribution have been separated from the beverage ethanol industry. The total number of registered ethanol plants recently increased from 27 plants to 45, with anticipated production capacity of 10.9 million liters/day once they are all operational.

Despite the current operation of 7 ethanol plants with a total production capacity of almost 1 million liters/day, actual ethanol production in Thailand is well below full capacity. Current capacity utilization has been estimated to lie around 50-60%, reflecting the domestic ethanol surplus situation cited above. The government's plan to replace premium gasoline with gasohol at the beginning of 2007 has been delayed over concerns of a domestic ethanol shortage. The situation is further complicated by the fact that approximately half a million older vehicles are not ethanol compatible.

As cited above, the export of the ethanol surplus is only temporary, and export approval is considered on a case-by-case basis, as all seven ethanol producers are registered without export licenses. Only three approved ethanol plants currently have valid export licenses; one of these facilities is expected to start molasses-based production in the second half of 2007, with a production capacity of 200,000 liters/day, half of which will be destined for export.

The following measures are currently in place to promote gasohol in Thailand:

- 0% excise tax for fuel ethanol
- 0% Conservation Fund tax for fuel ethanol
- Lower Oil Fund tax applied to gasohol
- Higher marketing margin for oil companies
- Higher ex-refinery price to benefit refineries
- All government vehicles must be run on gasohol
- Standards specifications for gasohol, ethanol and base oil
- Issuance of vehicle performance guarantee from auto manufacturers and oil companies
- Program for the expansion of gasohol-dispensing fuel stations
- Gasohol 95 3.30 baht/liter (USD0.11/liter) cheaper than unleaded 95 gasoline
- Gasohol 91 2.80 baht/liter (USD0.09/liter) cheaper than unleaded 91 gasoline

History of Biofuel Production and Industry: Biodiesel. In early 2007, total biodiesel production capacity for B5 blended biodiesel (5% biodiesel, 95% diesel) in Thailand was recorded at approximately 33 million liters/month (approximately 1.1 million liters/day). The biodiesel is largely derived from used vegetable cooking oil, stearin and crude palm oil.

PTT Public Company Limited (PTT) and Bangchak Petroleum Public Company Limited (BCP) currently own 511 fueling stations which supply biodiesel to consumers. According to the Thai Department of Energy Business, sales of biodiesel during the month of April 2007 reached 32.2 million liters, which is equivalent to approximately 1.07 million liters/day.

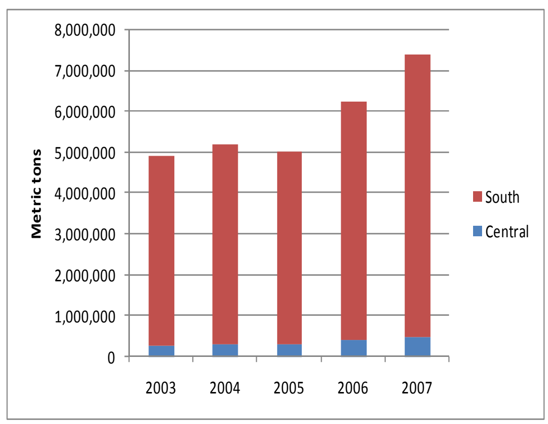
The PTT group plans to produce 1-1.5 million liters of biodiesel per day once biodiesel use becomes mandatory in Thailand. The company has already started building one plant, Thai Oleo Chemica Co., Ltd., which is scheduled to become operational by the end of 2007, with a production capacity of 600,000 liters/day. A 1,000 liters/day biodiesel plant developed as a joint venture between PTT and Bio Energy Plus Company has been completed, and may be expanded to 200,000 liters/day in the near future. PTT also has plans with Southern Palm Company to build a biodiesel plant in Surat Thani Province in 2008, with a production capacity of 300,000 liters/day.

Figure 6 below shows Thailand's palm oil production capacity in the south and central regions of the country.

History of Biodiesel Policy. On April 2, 2007, the Energy Policy Management Committee of Thailand agreed that all high-speed diesel production must contain biodiesel B100, two percent by weight (equivalent of B2 biodiesel-diesel blend), as of April 2008. It is estimated that, once this mandate has been implemented, demand for biodiesel could reach 1 million liters/day. The Committee will provide a refund, at a rate set by the Committee, to diesel manufacturers producing B2 blends. In addition, the government will lower the amount of the fee paid by biodiesel B5 manufacturers to the Conservation Fund, which will effectively lower the cost of biodiesel-diesel B5 blends by 0.70 Baht/liter (USD0.02/liter).

Figure 6: Thailand Palm Oil Production Capacity (million tons), 2003-2007

Year	Palm Oil Production (metric tons)		
	Central	South	Total
2003	293,392	4,609,183	4,902,575
2004	310,358	4,871,439	5,181,797
2005	311,647	4,691,023	5,002,670
2006	428,707	5,812,046	6,240,753
2007	497,508	6,880,722	7,378,230



Source: Dr. Nattapon Nattasomboon, Office of Industrial Economics, Ministry of Industry, Thailand.

In order to increase the production of raw materials destined for biodiesel production, the government of Thailand plans to expand palm plantations by approximately .96 million hectares by 2012. Furthermore, the government plans to encourage palm plantations in Laos, Cambodia and Burma on a contract farming basis. To this end, the government has approved a budget allocation of 1,300 million baht (USD 43.5 million) to promote palm production. It has been estimated that, if the palm oil expansion succeeds, biodiesel production levels could reach 8.5. million liters/day by 2012, which is equivalent to 10% of total diesel demand nationally. Thus far, however, high prices for rubber have discouraged the replacement of rubber trees with new palm trees.

The following measures are currently in place to promote biodiesel in Thailand:

- 0% excise tax on biodiesel

- Lowered Oil Fund tax
- B5 is 0.70 baht/liter (USD 0.02/liter) cheaper than regular diesel fuel
- Higher marketing margin for oil companies
- Higher ex-refinery price for refineries
- Standards specifications for B5
- Program to expand biodiesel-dispensing fuel stations
- Support to palm oil plantations of 0.8 M hectares (working capital of 800 million baht (USD 26.7 million) + 500 million baht (USD 16.7 million) for R&D)
- Program for promoting community-based biodiesel production (100 liters/day)

Thai Biofuels Import and Export Regimes. Thailand does not apply a quota system or any other types of trade barriers to gasohol and biodiesel imports. While the government has in the past applied a tariff rate of 2.5 baht/liter (USD 0.08/liter) on imported ethanol (largely because imported ethanol is used in alcohol production), insufficient domestic ethanol supplies in 2005 led the government to repeal the tariff and allow for the import of 24 million liters of ethanol into the country duty-free.

In 2007, Thailand is expected to export approximately 1-2 million liters of ethanol due to an excess in the domestic ethanol supply. For the moment, about 350,000 liters have been approved for export to the Philippines.

8. Summary and Conclusions

While Table 8 provides a side by side comparison of the biofuels markets in the countries analyzed in this chapter, it should be noted that it is difficult to compare and contrast different markets given that the technologies, fuel demands, and government incentives in each country vary significantly. Nonetheless, the following set of conclusions and lessons learned listed below have been extracted from the country experiences highlighted in this Chapter.

Government Support/Policy Tools. The expansion of national biofuels programs is possibly only with government support. Several policy tools employed in the countries analyzed above can be used in Mozambique. Credit guarantees and low-interest loans such as those implemented in Brazil could help spur the construction of first generation ethanol and biodiesel facilities. The involvement of international financial institutions such as the World Bank or the African Development Bank will be crucial in the implementation of such financial tools and ultimately in the development of the industry in Mozambique.

The policy approaches reviewed in this chapter have also been critical in assigning competitive prices to biofuels. Tax breaks and tariff protections have made the use of biofuels attractive and affordable to end users, and serve to protect the integrity of the domestic economy. Included in this category is the notion that any ethanol program must anticipate commodity price swings; enthusiasm for biofuels is always highest when oil prices are high and sugar prices low. In order to counter these price swings, Brazil's program relied on the use of flex fuel vehicles, which quickly became essential to its successful long term ethanol program. Other means of countering commodity price swings to protect a national biofuels industry can be demonstrated through Colombia's ethanol price setting mechanism, which is directly related to the international price of white sugar.

That said, it is also important that a national biofuel policy not create a net cost to the economy in terms of impact on tax revenues from fuel sales, taxes on income, and imports.

Renewable Fuel Standards. The international experiences highlighted in this chapter have demonstrated that policy objectives can be achieved by establishing a standard, provided that local supply is secure. The standard-based approach seems especially attractive in the Mozambican context in that it limits the necessity of regulatory changes required to put a policy in place, and avoids the perhaps unnecessarily high cost of implementing a policy grounded on government subsidies and tax incentives.

The Brazilian experience underscores the fact that one of the most important components of its national ethanol program has been the requirement that ethanol make upa certain percentage of the national fuel supply. These types of mandates have ultimately provided strong signals to producers and help to promote more rapid growth in domestic production capacity. It is important to maintain a certain level of flexibility in the fuel standard approach by varying the percentage according to market conditions.

Technology Improvements. As with many technologies, ethanol and biodiesel production methods will improve over time, as more national industries develop, and increasing amounts of funds are dedicated to research and development in the sector. In this sense, the development of technology sharing partnerships between countries will grow in importance. India's partnership with Brazil's Petrobras to promote technological research cooperation for use of ethanol as a transportation fuel has led to growing trade between the two countries the development of several ethanol-related deals. Mozambique should build on this example by exploring partnerships with major biofuel countries, as well as explore how biofuels production and exports might be a vehicle for increasing investment and improving technological know-how.

Environmental Issues & Food Security. As can be concluded from the presentation of the various national biofuels programs cited above, the development of such industries is not without its problems. In Brazil, the growing number of ethanol production facilities has raised concerns over a number of environmental issues, including those related to land clearing, field burning, fertilizer and herbicide contamination, waste disposal, etc. In order to mitigate environmental impacts of ethanol production, national policy has included legislation to ban the burning of fields, and to encourage a move towards more mechanized sugarcane harvesting practices.

Table 8: Biofuels Production Summary Table: Relevant International Experience with Biofuels Policies

Country	Total Production Capacity (year)	Feedstocks	Exports (year)	Imports (year)	National Biofuel Policy; description
Brazil	Ethanol: 16 billion L (2007) Biodiesel:	Ethanol: Sugarcane Biodiesel:	2.5 billion L (2005) of ethanol	227,000 L (2005) of ethanol	• Ban on diesel-powered cars • Alcohol Storage Program (supports producers holding alcohol stocks) • Import duty on ethanol to protect domestic producers (~20%). • Preferential tax treatment for ethanol consumption under CIDES and PIS/COFINS federal tax programs • Differential tax treatment under state tax laws varies
Zimbabwe	18.9 million L (2005) – potable alcohol only; no biofuels	Sugarcane	N/A	N/A	None: Ministry of Energy and Power Development spearheading the production of biodiesel with the aim of substituting 10% of imported fuels with biofuels within 5 years.
India	**Ethanol**: 200 million L fuel ethanol (2005) (1.7 billion L total) **Biodiesel**: Experimental scale	**Ethanol**: Sugarcane molasses **Biodiesel**: Jatropha	N/A	**410** million L (2005) from Brazil **Wants** plants in countries w/large sugarcane outputs to increase ethanol production capacity	• Ethanol Blending Program (EBP) requiring 5% blend reinstated 10/2006. • Possibility of 10% blend introduced in 2007. • No financial incentives.
Colombia	**Ethanol: 360.1** million L (2005) **No** commercial biodiesel production	**Ethanol**: Sugarcane (99%), cassava (1%) **Biodiesel**: World's 5th largest producer of palm oil.	**N/A**; low domestic ethanol prices ($1.74/gal) make export to U.S. attractive	N/A	• Law 693 (2001): requires gasoline be blended w/ethanol (implemented in Bogotá Valle del Cauca). • 10% blend since 2005 increasing to 25% by 2020. • Compulsory B5 blending to be implemented in 2008. • Laws 939 (2004) and 260 (2004) provide tax exemptions for biodiesel blends • Law passed in 2002 provides tax exemption on fuel alcohol destined for blending
Honduras	**Ethanol**: None **Biodiesel**: 14.9 million liters (biodiesel only)	**Biodiesel**: African palm oil for biodiesel **Limited** use of fish oil, beef tallow recently introduced for biodiesel production	N/A	N/A	Biofuels policy in its infancy stage: • Government program (2006) aimed at increasing African palm cultivation to 200,000 ha (current area is 83,000 ha) to) and eventually producing 200 million gallons (757 million liters) of biodiesel annually • Draft biofuels law submitted to Congress in (2006;): approval is pending • Pilot program for the promotion of alternative fuels promotion (including biodiesel) in the capital Tegucigalpa (2006-2007).
Tanzania	**Potable** alcohol capacity only; no commercial biofuel production	**Ethanol**: Sugarcane **Biodiesel**: Oil palm, coconut, cashew nut, sunflower, soy beans, cottonseed, jatropha	N/A	N/A	None: Proposed mandates include: • Establishment of Biofuels Task Force (04/2006). • Proposed mandatory blending of gasoline w/ethanol (E10 equivalent). • Proposed price guarantees for ethanol and protection of local producers against cheap imports. • National-scale program will be feasible by 2010, including a demand of 27 million L of fuel ethanol.
South Africa	**Potable** alcohol capacity only; no commercial biofuel production **Local** (farmer) production of biodiesel	**Ethanol**: Maize **Biodiesel**: Sunflower, soy	N/A	N/A	South African Biofuels Strategy (final version submitted 05/2007): • Local production requirement of 1 billion liters of biofuel to be blended w/fuels • Proposed mandatory blends: E8 and B2. • Flexibility in blending targets will be within overall target of 4.5% of national petrol and diesel volumes by 2013 (translates into ~ 1 billion L)
Thailand	Ethanol: 348 million L (current) Biodiesel: 396 million L (current)	Ethanol: Cassava (~70% total production) and sugarcane/molasses (remainder) Biodiesel: Palm oil, veg. cooking oil, stearin	Ethanol: 400,000 L (2007) Biodiesel: N/A	Ethanol: 0 Biodiesel: N/A	Nat'l Ethanol Program & Gasohol Strategic Plan (2003) • Production target 1 mm L/day (2006) increasing to 3 mm L/day by 2011 • Tax exemptions on fuel ethanol • Export of ethanol surplus is temporary Nat'l Biodiesel Policy • All diesel production must contain 2% biodiesel by weight (B2) by April 2008 • Refund to B2 manufacturers & tax incentives = lower biodiesel price at pump • Measures to increase palm plantations – contract farming in neighboring countries

Source: Econergy

A biofuels program in Mozambique will need to ensure that adequate control is exercised over the implementation of new projects and once they are operational. Brazil's experience suggests that a combination of regulation and economic incentives can have the effect of adequately mitigating the adverse environmental impacts of a biofuels industry, all the while creating an economically attractive market for producers.

In India, a different category of negative impact relates to the diversion of traditional food crops (in this case sugar) to the production of biofuels. In keeping with its policy of not using food crops as energy sources, India produces ethanol from sugarcane molasses, and has set limits on the amount of land that is to be dedicated to energy crops. As a result, India must look to importing the balance of ethanol it will need to meet its mandatory fuel blend.

India's situation highlights the importance for Mozambique to ensure that multiple energy crops are involved in the biofuels program, so as not to severely encroach on the supply of staple crops such as sugar. Ideally, the crops selected for biofuels production will be those with limited potential for negative impacts on food availability and hence prices.

CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS

This chapter reviews the key conclusions of the previous chapters, and includes some more general observations on the overall economic, social and environmental sustainability of biofuel production in Mozambique. A series of nine recommendations are included in the context of the following Sections. These recommendations are presented as ways to address the concerns described here (and presented in previous Chapters in more detail) or as strategies for exploiting the opportunities that have been identified. In Section 6, the final part of this Chapter, the Econergy team offers some general principles for the formulation of a National Biofuels Program. These provided the basis for discussions conducted in the context of the National Biofuels Seminar, which was held in Maputo on July 11-12, 2007.

1. Target markets for biofuels produced in Mozambique

The presentation included in Chapter 2 illustrates the potential scope of the domestic and international markets for biofuels, while the analysis in Chapter 6 demonstrates that the estimated costs of production, plus logistics and overseas shipping costs, would make Mozambican production broadly competitive in the major Asian, European and North American biofuels markets when using sugarcane as well as sorghum as feedstocks, as well as for consumption in the domestic and regional market.

Domestic markets. With respect to the domestic market, the largest segment in the market is diesel (66% by energy content), followed by gasoline (15%) and jet fuel (10%). Accordingly, transportation is responsible for the largest segment of fuels consumption, and offers the most significant potential market in the near term for domestically produced fuels based on carbohydrate and oil crops. Some diesel consumption comes from electricity generation and industrial uses, but this is comparatively small.

The existing infrastructure for importing, storing, distributing and selling liquid fuels could be adapted, at relatively limited expense, to the use of fuels containing small percentages of ethanol and biodiesel. Through the establishment of a blending requirement for gasoline (10%) and diesel (5%), the biofuels industry would have an established market in Mozambique for volumes of about 12 million liters of ethanol in 2010 and 21 million liters in 2015, and 19 million liters of biodiesel in 2010 to about 40 million liters in 2015.

There are other potential markets for biofuels in the country, most notably in the residential sector, through the commercialization of a special form of ethanol, gelfuel, which is already available in Mozambique, based on imported ethanol. However, gelfuel distributors are struggling to establish themselves due to low consumer awareness, difficulties in obtaining credit and an unfavorable tax and customs regime, on top of the fact that the fuel’s cost is still higher than the available alternatives, principally kerosene. In the near term, the potential market could be based on the existing levels of consumption of liquid fuels, particularly kerosene and LP gas, provided that it receives a more favorable tax and customs regime; even so, gelfuel will likely remain a niche player in the residential market. However, in the longer term, given the steady rise in charcoal prices, gelfuel could displace larger volumes of charcoal and create demand for larger volumes of ethanol, though it could never rival the market for ethanol as a transportation fuel. The extent to which this market develops would depend on the establishment of programs to promote conversion from charcoal to ethanol-derived products such as gelfuel, but it is not clear that the current market environment and ability to pay in rural areas are conducive to this.

Finally, the third potential market area involves the creation of demand for fuel through the expansion of the national grid. This amounts to establishing a market where there are currently unserved energy needs. This market could add a considerable amount of new demand for biodiesel or, potentially, raw vegetable oil in isolated regions of the country, but it is unlikely that it would be larger than the market for biodiesel as a transportation fuel.

International experience with biofuels suggests that most efforts to develop a robust biofuels sector have involved a mandate for domestic consumption of biofuels. Mozambique's case poses the special challenges (similar to those experienced in Honduras) of a small market that is absolutely dependent on imported fossil fuels. However, unlike Honduras, which has a large export sector based on African palm and incipient production of ethanol, also for export, Mozambique is a net importer of vegetable oil and has virtually no fuel ethanol production, although there are several export ventures in development. The most readily available ethanol feedstock in Mozambique is molasses from existing sugar production. This material is either being dumped or, where infrastructure allows, exported for use in animal feed production; it is understood that domestic sugar producers would consider investment in ethanol production if given a clear signal by the government of a market for their output. In the near term, the molasses supply could be used to produce sufficient ethanol to cover a domestic 10% blend standard.

Recommendation 1 Based on the foregoing, the most logical approach for development of the biofuels sector involves a near-term focus on creating demand for ethanol and biodiesel for transportation and industrial uses currently served through the distribution of gasoline and diesel. Residential fuel use and new demand for fuel could be served as relatively small subsectors of the biofuels market, and supported by complementary policies and incentives specific to those subsectors. The primary mechanism for creating domestic demand would be to mandate a blend requirement for ethanol, phased in over a period of three to five years. Biodiesel, however, poses a greater challenge because of the alternative markets for vegetable oil. While a biodiesel blend standard is desirable, it should be phased in over a longer period, preceded by intensive development of local production for domestic and international markets.

International markets. Producers of ethanol and biodiesel (or biodiesel feedstocks) in Mozambique could conceivably export far larger volumes to several international markets than would be sold domestically. The implementation of programs to displace increasing amounts of petroleum-based fuels in all the major industrial countries is creating rapidly expanding markets for ethanol, and to a lesser extent, biodiesel, which Mozambican producers should target, though recent calls for changes to biofuels policy in the midst of rapid increases in food prices may moderate this process to some extent.

The most interesting of these overseas markets is Japan, primarily because that country does not have significant indigenous production of ethanol, nor will it be able to develop much in the future, due to its geographic and climatic circumstances. In addition, Mozambican output could be competitive in Japan, as opposed to the U.S. and European markets. There are other factors that may make Japan an especially attractive market, as well. Brazil and Japan have engaged in extensive discussions regarding agreements for delivery of ethanol to Japan. Mozambique could exploit its geographic position, together with its growing commercial and existing cultural ties with Brazil, to support the efforts of Petrobras to meet Japanese demand. Elsewhere in Asia, India could also be a promising market for Mozambican production, and China could also become a large importer if its biofuels policy framework is enacted.

There is little doubt that there will also be demand for imports of ethanol, biodiesel or crude vegetable oil in Europe and North America, but there are some potential challenges, not least the strong competition of other countries that as well established in these markets, such as Brazil in ethanol and vegetable oil, as well as Argentina, Indonesia and Malaysia in vegetable oil. In light of increasing concerns about the impact of biofuels production on food production and prices, as well as the environmental impacts, greater scrutiny of production practices is a certainty, leading to a significant additional challenge during the industry’s start-up phase in Mozambique. In addition, in the case of Europe, existing technical and tariff barriers pose a challenge, though not an insurmountable one. In the longer term, E.U. countries will increase ethanol imports, and some countries are looking abroad to find new resources to meet their increasing demand. Italy’s Eni, for example, has concluded a technological exchange agreement with Brazil’s Petrobras involving joint development of biofuels projects in third countries, particularly in Africa (Mozambique has been mentioned among other possible locations, especially for biodiesel). The existence of an agreement between Eni and Mozambique for traditional oil and gas exploration activities provides a framework for expanding cooperation to biofuels. In the case of North America, Mozambique would enjoy preferential access to the U.S. market under existing programs, though competition from producers in the Caribbean region, as well as Brazil, will be significant.

Closer to home, the South African market is also potentially attractive for Mozambique, given its proximity and the established economic and commercial ties between the two countries. The potential competitiveness of Mozambican biofuels production is strong, for two reasons. First, gasoline prices in the two countries are generally aligned because of their reliance on imported fuels (South Africa’s consumption of domestically produced diesel, based on coal-to-liquids technology and local oil production, is limited). Second, Mozambique's agricultural potential is greater than that of South Africa; water and land constraints will limit South Africa's ability to meet its anticipated target of about 500 million liters of biofuels consumption through indigenous resources. While it is true that South African sugar production is now more competitive than Mozambique's, this situation will likely shift to the benefit of Mozambican producers as they improve efficiency, while South Africa's ability to allocate new land to sugar is constrained by the relative scarcity of productive land there.

However, the big caveat regarding South Africa is that the policymaking process remains incomplete – though action is anticipated during 2008. Further, access to the South African biofuels market is not yet clearly delineated, pending definition of tariff treatment of biofuels imports under the biofuels program. In the longer term, SADC provisions would play a role, but again, it is unclear how biofuels can be addressed in this context. It should be noted, however, that market access provisions that create opportunities for Mozambique will also require that Mozambique relax limitations on imports of biofuels.

Other countries in the Southern Africa region may offers a potential market in the context of the existing trade in fuels that are trans-shipped through Mozambican ports to markets in the interior, including Zambia, Malawi, Zimbabwe and parts of South Africa. However, there is also a challenge in this context, because IMOPETRO imports fuels according to specifications that were previously approved by Mozambique and its regional trade partners. Since any given shipment of gasoline may cover domestic needs as well as the re-export market, any change in the specifications for gasoline to accommodate blending with ethanol for use in the domestic market would require a change in specifications for gasoline re-exported to the interior; the unblended gasoline would not be suitable for use without adding ethanol. According to IMOPETRO, therefore, it will be necessary for Mozambique to reach agreement with its partners to change the gasoline specifications, either to RBOB for blending with ethanol in the destination countries (all three have sugarcane sectors) or E10.

Finally, there is evidence of potentially relevant developments at major international petroleum companies in their thinking on biofuels. Discussions with BP's Global headquarters in London revealed that they have very aggressive targets for biofuels (especially butanol). Among other approaches to simplify logistics, major petroleum companies may negotiate exchange deals to swap gasoline for ethanol/butanol in order to minimize transportation costs across their global markets, integrating large-scale biofuel projects in their supply chains. This suggests that Mozambique could engage with petroleum companies – possibly within the context of plans for a new refinery at Nacala – to develop the framework for such a swap agreement.

Recommendation 2 Based on the foregoing, Mozambique should begin promoting the inclusion of biofuels provisions in the relevant SADC chapters, as well as begin working with South Africa on the development of markets for regional biofuels producers. This activity should also cover the relevant specifications for gasoline traded between

Mozambique and countries in the interior. Second, Mozambique should explore partnerships with major biofuels exporters, such as Petrobras for ethanol (for the purpose of expanding production as a supplier for Petrobras to meet its commercial commitments in Japan) and Italy's Eni for biodiesel; in addition to commercial opportunities, these partnerships should aim at enhancing access to investments and technology transfers. Third, Mozambique should explore how biofuels production and exports might be linked to access to investment and technologies also in the context of bilateral cooperation with major Asian export markets, notably China and India.

2. Relative suitability of feedstock crops and competitiveness of production

The analysis presented in Chapter 3 outlines the potential for production of various carbohydrate and oilseed crops, while Chapter 4 assesses the potential cost of processing and production of ethanol and biodiesel.

The most attractive crops for production of biofuels feedstocks are those available at the lowest costs, with the least potential effects on prices that will limit availability to the poorest strata of the population, with the most easily managed environmental impacts in terms of land take, soil nutrient loss, water requirements and biodiversity impacts. The analysis in Chapter 3 suggests that current vegetable oil crops, such as coconut and sunflower, along with emerging crops such castor seed, jatropha and soy, would be the most promising in the near term; in the longer term, the crops commonly used as feedstock may expand to include African palm as well.

- *Coconut*. The coconut sector is vital and must be rehabilitated given its current decline and the threat of lethal yellowing disease. As a biodiesel feedstock, however, its use may become less attractive because of the opportunity cost of foregone sales on international markets. Coconut also generates by-products of potential commercial value, as well as biomass for thermal energy production. Rehabilitation and expansion of production would occur primarily in Inhambane and Zambézia provinces, as well as Nampula and Cabo Delgado.
- *Sunflower*. The steady increase in vegetable oil prices on international markets will continue to make cultivation of sunflower, as well as other crops, attractive. Given the existing trends in cultivation of sunflower, it seems appropriate to identify sunflower as a candidate for use in biodiesel, especially in remote areas for self-supply applications as well as for larger-scale production, with linkages to poultry production. Manica and Sofala provinces appear to offer the best conditions for this crop. Sunflower is especially attractive given its relatively high yield and low production cost, and the high prices it commands on international markets.
- *Castor seed*. The incipient production of castor seed in Mozambique should be encouraged, because the potential market for the oil is attractive, irrespective of the possibility of using it for biodiesel production. Press cake from castor seed may also

be used as a fertilizer on castor plantations. The most attractive areas are understood to be the interior regions of Nampula, Cabo Delgado, Niassa and Zambezia.

- *Jatropha*. Mozambique is already committed to jatropha cultivation, and the available information about the oil suggests that it could be an excellent feedstock for biodiesel, with the press cake suitable as fertilizer for jatropha plantations. Available information on the experience in other countries suggests that jatropha can be successfully cultivated and its oil used in unprocessed form, or for biodiesel. Available data are limited, and suggest that jatropha cultivation costs may be relatively high, though poised to decrease with more experience and offset by similarly high per-ha yields of biofuel; data on the market for jatropha oil are largely speculative, given that there are no very active markets for the feedstock or the oil. As new data become available regarding costs of production it will be possible to determine whether the yields achieved in marginal lands are substantial enough to generate feedstock at attractive costs. Commercial investors are already developing large-scale plantations on more fertile land, and there will continue to be interest in cultivation in more productive areas, as long as there is demand for jatropha as a feedstock. There is no agro-climatic suitability map for jatropha in Mozambique available at this time, but recently established jatropha plantations in Inhambane, Manica, Zambézia and Nampula provinces provide evidence of suitability, and available data from northeastern South Africa suggest that jatropha would be very well suited for cultivation in contiguous regions of Mozambique.[1]
- *Soy*. There is increasing interest in soy as a cash crop as a feedstock for animal feed as well as oil production. Indeed, the production cost of biodiesel using soy is rendered highly attractive because of the market value of the press-cake. Available data on agro-climatic suitability indicate that soy is likely to do well in areas of Manica, Sofala, Zambézia, Nampula, Cabo Delgado as well as in Inhambane and Gaza in the south.
- *African palm*. This is the only crop for which a significant research and development program may be appropriate, given the lack of production in Mozambique at present. While the humidity requirements of African palm could complicate its cultivation in the country, and accordingly the cost of production, the low-cost production achieved elsewhere suggests that it could still be attractive to produce in Mozambique. The most suitable areas for African palm are likely to be coastal regions in the central part of the country. The projected margins generated by sales of biodiesel based on African palm suggest that they could support the cost of developing the irrigation infrastructure necessary to cultivate it.

For ethanol, sweet sorghum and sugar cane are clear priorities, but cassava should also be included given its relatively low production cost and the fact that small-holders frequently report that they cannot find a market for their output.

- *Sugarcane*. The presence of major sugar producers in Mozambique makes it a foregone conclusion that investment in ethanol production will take place if a local market is created – indeed several projects already have targeted sugarcane. Given

[1] See presentation by Fred Kruger from the National Seminar on Biofuels, July 11-12, “The potential and limitations of jatropha as a biodiesel feedstock.”

water requirements, it seems most likely that new sugarcane cultivation should occur in the Center and North of the country, with an emphasis on locating new plantations and ethanol distilleries near major port facilities to facilitate logistics, both for receipt of molasses from other producers and for exporting ethanol. Suitable land for sugarcane has been identified throughout the country, but the defining constraint is typically the presence of irrigation systems, which are limited in Mozambique, as well as availability of water, which is greater in the Center and North of the country than in the South.

- *Sweet sorghum*. The presence of grain sorghum in Mozambique, with reasonably attractive yields, makes its cousin, sweet sorghum, a natural candidate for consideration as a secondary feedstock for ethanol production, alongside sugarcane. Given its lower water requirements, it may be most appropriate to promote its cultivation in the southern parts of the country, but its apparent suitability for other areas may justify broader promotion. While biofuel yields from sorghum are somewhat below those of sugarcane, these are offset by lower production costs. Given sorghum's lower input and labor requirements, the crop is also more suitable for small producers in outgrower schemes.
- *Cassava*. This crop is perhaps the most sensitive as a feedstock for ethanol production given its status as a staple in Mozambique. However, the relative underdevelopment of cassava production in the country – low yields and depressed prices – suggests that a strategy of promoting the use of cassava as a secondary feedstock (alongside molasses, sugarcane and sweet sorghum) could create a new market for the crop, thereby increasing incomes for small-holder growers and stimulating increased domestic distribution of cassava, especially for processing in the form of dried roots and chips. Cassava could emerge as a feedstock for ethanol in the future, but it does not seem appropriate to stress its development in the early stage of any biofuels initiative.

With respect to the other crops considered, these are not suited for promotion either due to their high price (groundnut/peanut, sesame) or their significance as staples (maize) or combination of the two. With regard to cotton, while it is true that it could be a suitable feedstock, its attractiveness is diminished by the potential for more favorable prices in competing uses (cottonseed, given its advantages for use in cooking).

Recommendation 3 The Mozambique Biofuels Strategy should promote multiple feedstocks to ensure balanced development; avoid, to the greatest extent possible, dramatic price impacts that would negatively affect the poor; and ensure alternatives for biofuel producers given the inevitable price variations of some feedstocks, especially those for which there is strong demand for other uses. Development of multiple feedstocks also broadens the scope of potential benefits in different regions of the country. Permitting procedures for cultivation of biofuels feedstocks should establish the eligibility of multiple feedstocks by recognizing several as potential energy crops.

Crop-specific recommendations for biodiesel feedstocks are noted below.

i. *Coconut*. It is imperative that the GoM engage in a comprehensive rehabilitation program for existing coconut plantations, including the development of varieties resistant to lethal yellowing disease. Coconut oil may be supplanted by cheaper feedstocks if international prices remain high.
ii. *Soy, sunflower and castor seed*. Existing cultivation should be expanded and oil from these crops may be used for biodiesel production, although castor seed oil, in particular, may have opportunity costs that are too high for it to be used as biodiesel feedstock in the long-term. Soy should be encouraged because of its dual markets.
iii. *Jatropha*. It is imperative that the existing cultivation of jatropha, which is extensive in terms of geographic coverage (if not hectares), find a market in the near term. If not, the large investment of time and resources that has already been made will be wasted, and many smaller farmers will be reluctant to enter the sector again. It is important for Mozambique to participate actively in international exchanges on jatropha. Given the importance of jatropha plantations in regional biodiesel developments, Mozambique should host more frequent international meetings, such as the one staged in Maputo on March 9, 2007, with participation by jatropha specialists from India, Brazil and elsewhere in Africa.
iv. *African palm*. Not enough research has been conducted on the feasibility of cultivating African palm in Mozambique. The Centro de Promoção Agricola (CEPAGRI) could conduct a detailed feasibility study, together with the Instituto de Investigação Agrária de Moçambique (IIAM), to assess the feasibility of developing African palm plantations in coastal areas of Mozambique.

Similarly, recommendations for ethanol feedstocks are noted below.

v. *Sugarcane*. The proposed projects involving production of sugarcane exclusively for ethanol production should receive the GoM's support. Immediate support should also be given to a joint-venture or other project to utilize existing molasses output from the mills for ethanol production. The facility, with a capacity of about 15 million liters/year, could be sited at one of the major ports (Beira might be suitable given its proximity to mills facing the greatest logistical challenges, but the Port of Maputo or Matola may be a better choice given proximity to the main domestic market and availability of storage capacity). The GoM should encourage the existing sugar mills to consider this option, possibly by assisting with access to funding for a feasibility study.

vi. *Sweet sorghum*. The GoM should promote the introduction of sweet sorghum as a feedstock crop, in conjunction with new sugarcane development, but also independently. In the near term, CEPAGRI and IIAM should develop technical materials for the introduction of this crop into agricultural extension system.

vii. *Cassava*. The GoM should promote the introduction of small-scale drying and chipping facilities in rural areas of Mozambique to generate a supply of cassava chips for sale as animal feed, first in the domestic market and then, as volumes increase, for export. Gradual growth in this market should lead to a gentle improvement in cassava prices, triggering increased production. Once volumes reach a scale suitable for an ethanol facility to be built, this could be sited close to the largest concentration of cassava production in Nampula and Zambezia provinces, possibly in Beira or Nacala. Alternatively, chips could be transported to Beira or Maputo for processing into ethanol.

3. Incentives for promoting the production of bio-fuels

Given the estimated costs of production presented in Chapter 4, Mozambican production of biofuels is cost-competitive with imported petroleum-based fuels, when CIF costs for gasoline and diesel are in the range of USD 0.60/liter and USD 0.55/liter, respectively. These price ranges may be expected when petroleum prices are in the range of USD 54 to USD 56 per barrel (for Arab light, FOB Saudi Arabia). Prices for this grade of crude petroleum are now in the range of USD 85 to USD 90 per barrel, and have been above the November, 2006, levels continuously since March, 2007.[2]

Further, the analysis presented in Chapter 6 demonstrates that production of biofuels could yield a significant overall economic return to the participants in the biofuels value chain in Mozambique (including farmers, biofuel producers [distillers and biodiesel producers], blenders [distributors] and the government, given its current role as collector of tax revenue on the sale of fuels and market regulator. While the returns are most attractive when agricultural production costs are used, the leading crops remain attractive even when domestic market prices (the opportunity cost) for the feedstock are considered but less so when international prices are considered (making exports of raw vegetable oil more attractive). The fact that jatropha's relatively high opportunity cost undermines its attractiveness must be weighed against the likelihood that production costs for this crop will recede in the months and years ahead as producers gain experience with the crop and select for higher-yielding varieties. The emergence of a sustainable biofuels sector will

[2] See the EIA website at http://tonto.eia.doe.gov/dnav/pet/hist/wepcsaltw.htm.

occur if the relevant actors can secure a portion of this overall economic to justify the investments required. The decision to support the creation of the market will determine the scope of these benefits, and may also influence how they are allocated.

Based on the foregoing, the Econergy team has concluded that if biofuels are sold at the same end-user price as petroleum-based fuels, there would be a substantial margin between the retail price and the landed (CIF) cost of the imported fuel. It would be desirable to allocate this differential (which, for imported fuel is composed of taxes, logistics and sales margins) differently, through market-driven as well as governmental action. The rationale for doing this is three-fold: (i) the possibility that the farmer and the fuel producer could receive a share of this margin, possibly through prices paid to them for domestically produced biofuels in excess of the CIF cost of imported fuel, would create the economic incentive necessary to drive investment in the sector; (ii) funds that would otherwise go to the Ministry of Finance could be allocated to programs and institutional development directly related to the needs and necessary oversight of the emerging biofuels sector in Mozambique; and (iii) the differential will to some extent protect producers from downward pressure on the prices paid to them for biofuels in the event of a decrease in petroleum prices to levels observed in 2006, though not necessarily to lower price levels.

The Econergy team has contemplated two potential approaches to creating a market for biofuels: (i) establishing a mandate for blending ethanol and biodiesel into gasoline and petroleum-based diesel, respectively and (ii) inducing consumption through the establishment of a more attractive price, supported by tax breaks and tariff protection, to achieve cost competitiveness, and allow distributors to mix up to specified amounts in the fuel they sell. The former is the renewable fuels standard approach, while the latter might be termed the market subsidy approach. Virtually all the policy approaches reviewed in Chapter 2 and Chapter 7 encompass variations on the renewable fuels standard approach; most of them include fiscal and trade measures of the sort contemplated in the market subsidy approach as well. Table 1 summarizes the advantages and disadvantages of each with respect to the following parameters: (i) effectiveness, defined as the certainty of achieving specified goals, (ii) pricing, referring to how price is determined, (iii) administrative simplicity, (iv) fiscal impact, (v) allocation of risk from fuel price volatility, and (vi) allocation of commercial risk from change in the relative pricing of biofuels and petroleum-based fuels. The issues of socio-economic and environmental impacts are addressed in Section 8.4, below.

For Mozambique, the objectives behind the assessment of a possible biofuels strategy are: spurring rural and agricultural development and reducing the economic burden of fuel imports and vulnerability to price volatility. Equally important to the GoM, it is desirable that the strategy avoid creating a burden to the state in terms of the impact on tax revenues from fuel sales, taxes on corporate income, and imports, or if it is likely to have an impact, that it be minimized. Lastly, it is desirable that the strategy contribute to an improvement in the country’s balance of trade.

The renewable fuel standard approach is demonstrably superior to a policy predicated on inducing the consumption of biofuels through protection and subsidization. First, international experience shows that policy objectives can be achieved by establishing a standard, provided there is a basis for securing local supply. While it is true that policy objectives of diversification can be achieved through inducement, this must be especially attractive, and the attendant subsidies more difficult to remove in the longer term, in order to achieve the same result as the standard.

Second, in the case of Mozambique, the administrative simplicity of the program is an especially important criterion, given the limits in the capabilities of public administration and in the existing mechanism for overseeing the importation of fuels. The standard-based approach seems especially attractive in that it limits the scope of regulatory

Table 1: Comparison of policy approaches

	Renewable fuels standard	Market subsidy approach
Effectiveness	More likely to achieve target, with failure to do so linked to lack of supply due to inadequate local production and/or inadequate pricing.	May fall short or exceed target, depending on degree to which consumption is induced by pricing.
Pricing	Set by market or may be regulated.	Depends on pricing of petroleum-based fuels.
Administrative simplicity and cost of imple-mentation	Allows for application through oversight of fuel distributors. Cost of implementation is limited to modifications required by blend.	Oversight of fuel distributors required to ensure quality compliance, but requires changes in tax and trade policies as well. May involve additional infrastructure.
Fiscal impact	May be applied without any fiscal impact at all.	Will have a fiscal impact.
Allocation of fuel price risk	Consumer bears fuel price risk.	State bears fuel price risk.
Allocation of commercial risk	Biofuel producer is guaranteed a market.	Biofuel producer is guaranteed a market so long as subsidies remain in place.

Source: Econergy

changes required to put the policy in place. Further, a market subsidy approach raises the possibility of the need for infrastructure investment over and above what is absolutely necessary to handle blending the fuel, perhaps even for arrangements for retailers to offer a biofuel blend alongside a pure petroleum product. In the Mozambican context, this seems like an unnecessary expense in the near term.

Third, the fiscal impact of the program will be an important consideration in securing its approval. It is possible that a standard-based approach could be implemented without any fiscal impact at all, though it must be recognized that this could lead to increases in costs to end-users in direct proportion to the blend that is mandated. On the other hand, the market subsidy approach would shift the burden to the state, with significant considerations about overall sustainability of the approach. Further, the impact of commercial risk is potentially greater in the market subsidy approach given that the impact of large-scale shifts in the relative prices of biofuels and petroleum fuels falls on the state, insofar as it deems it necessary to continue supporting biofuels production in the event of a collapse in petroleum prices.

Finally, in Mozambique, where economic development and income generation for the poor, especially in rural areas, is a paramount objective, the opportunity to create more rural employment makes the promotion of biofuels very attractive. While the state could support biofuels extensively by applying the market subsidy approach, the renewable fuel standard approach makes the achievement of this objective more an issue of income redistribution, since gasoline consumption, in particular, is confined to the wealthier segments of society.

Recommendation 4 The primary recommendation from this study is that Mozambique should mandate a biofuel content for gasoline and diesel sold in the country, with a phase-in period to allow production to ramp up over a reasonable period of time, beginning in 2009 or 2010. Biodiesel should be phased in over a longer timeframe than ethanol, perhaps beginning in 2012 through 2015. The program should stipulate that blending should take place at the point of introduction of the fuel into the country (ex-customs) at the three major ports through which fuel enters the country, and should be handled by the licensed fuel distributors already operating in the country. Further, it should mandate that the fuel price paid to the producer by the blender should include a premium over the CIF cost of the imported fuel, sufficient to allow a suitable return on capital for the producer as well as the farmer supplying the producer with feedstock; because a tax break would be accorded to the biofuel, however, the price to the end-user would not increase as a result of including the biofuels blend component.

From a fiscal standpoint, the Tax on Fuels (*Taxa sobre Combustíveis* or TSC) would not be levied on the pure biofuel provided to the blender, although Value-Added Tax (VAT) would apply. The fuel price to the end-user would be calculated as it is currently, by the Direcção Nacional Combustíveis (DNC), with the exception that a renewable fuel cost would be incorporated into the calculation. The details of how this price should be computed need to be defined in Phase II of this study, but some basic principles for implementation are noted below, in Section 6.

In general, the objective of this approach is to ensure consistency with the existing method for setting prices and to allow for oversight of how biofuels producers are to be compensated for their product. In addition, a national fund would be established to support project development, research and development, institutional strengthening to provide regulatory oversight and communications with the public about biofuels. Financial sources for this fund would include: the TSC that would be applied on the biofuels component; revenues from actors in the sector; and exogenous sources such as sales of Certified Emissions Reductions (CERs). Finally, importation of biofuels or biofuels feedstocks (though not inputs required for production) would be permitted, contrary to what is proposed in the biofuels language in the rulemaking on fuels (§32.3 of 62/2006), with tariff levels consistent with Mozambique's commitments under SADC.

An important complement to the provisions related to the production of the liquid biofuel is that special feed-in tariffs be established for electricity produced in cogeneration facilities at distilleries based on the biomass residues from biofuel production, as well as biogas capture facilities that process liquids with high biochemical oxygen demand (BOD) levels. Electricity sales can be an important additional source of revenue for integrated projects, which, if given this incentive, will help add new capacity to the Mozambican grid in relatively small packets in areas where new generation assets could provide valuable system balancing and load management services.

4. Economic, social and environmental sustainability issues and opportunities

Socio-economic impact. The socio-economic impacts of biofuels production encompass a range of likely outcomes that vary in terms of difficulty of measurement from the relatively straightforward (impact on foreign exchange and fiscal/non-fiscal revenues) to the less easily quantified or projected outcomes such as the impact on regional development or job creation. Several likely outcomes are discussed below.

- *Net impact on fiscal and customs revenues*. Before assessing this important consideration for policymakers, it is necessary to stipulate that the operating premise for this assessment is that the TSC will not be applied to biofuels, but the VAT will be levied. Further, it must be assumed that the end-user purchase price of biofuels will be the same as the petroleum-based fuel. Finally, it is also assumed that no customs fees or VAT will be charged on imported equipment or inputs for the production of biofuels.

  Based on these assumptions, the net impact is estimated on the basis of the <u>lost revenues</u> (comprised of (i) Import Tariff [*Direitos Aduaneiros*], together with (ii) VAT on the import cost of the fuels [which includes the base (CIF) price, port handling charges and the Import Tariff], and (iii) the TSC), after deducting revenues generated by the VAT on biofuels. In the near term, the revenue decrease from lost taxes, VAT and tariffs on gasoline and diesel is estimated to be about USD 12 million, based on a decrease of about USD 18 million in fuel imports. However, the net impact on Mozambique's trade balance would be greater, since a large part of biofuel production would be exported.

Since no TSC will be charged on the biofuel component in the context of the biofuels program envisaged here, the total value of the prices paid to the farmer, fuel manufacturer, transporter, distributor and retailer could be greater than the import cost of the petroleum-based alternative. As a result, the VAT calculated on these prices would be greater than VAT component for unblended fuels, thus partially offsetting the lost tax on the imported fuel. While the model of estimated production and consumption presented in Section 6.9 suggests that under these circumstances there will be a net loss of fiscal and customs revenues, this is before considering the potential revenue from income taxes on the companies producing biofuels in Mozambique.

Clearly, income tax receipts are more difficult to predict, as they depend on more than consumption forecasts. However, assuming a relatively modest level of profitability (5%) and an average tax rate of 20%, income tax receipts could compensate for lost revenues if the net increase in area dedicated to feedstock crops reaches about 1.6 million, a figure equivalent to between 10% and 15% of the surface area available for cultivation. This suggests that even a marginally ambitious biofuels program could pay for itself in fiscal terms.

- *Net impact on foreign currency flows.* The impact of biofuels production on foreign currency flows is based on the CIF cost of the imported petroleum fuel that is displaced. Clearly, imports of inputs would generate some need for foreign currency, but these are expected to be far lower than the requirements for imported fuel, and would be more than offset by the increased revenue from biofuels exports.

- *Port revenues*. The major ports serving Mozambique are the points of entry for all of the country's imports of liquid fuels. To the extent that imports of liquid fuels will decrease as a result of their displacement by biofuels, the revenues received by the ports from fuel imports for port services and handling, which are assessed on an *ad valorem* basis, would be expected to decrease.

  At the same time, however, port activity might be expected to increase in the near term during the construction of biofuels production facilities, and over the long term there would also be additional revenues associated with port services and handling for exports of biofuels feedstocks (in the case of vegetable oil), as well as the ethanol and biodiesel themselves. To the extent that these latter are assessed on a volume basis, these will generate some revenue for the ports, although given the rates typically applied this is unlikely to fully compensate for lost revenues on the fuel-import side.

- *Job creation.* Given the level of disguised unemployment in rural areas, it is difficult to assess the real employment benefit associated with the production of agricultural feedstocks, except in the case of large-scale plantations for feedstock production. At the production stage, it is easier to assess the potential impact, given the more direct relationships between the size and throughput of production facilities and the number of jobs required. For the assessment of job impacts, two methods have been applied.

For the sugar sector, data on total employment and area under cultivation have been used to calculate a ratio of jobs per hectare of sugar cultivated, including both agricultural as well as industrial jobs. Given the anticipated importance of expansion in the sugar sector in the development of the biofuels industry in Mozambique, it is likely that the jobs created in this sector will play an important part of the overall employment impact. Since molasses is already being produced by the existing sugarmills, the only job impact associated with conversion of molasses to ethanol involves the jobs associated with the actual ethanol production. The estimates based on sugar cultivation data suggest that some 50,000 jobs might be created in a relatively modest net increment in the cultivated area dedicated to sugar (240,000 ha), while in the most ambitious case (increment of 1.3 million ha), some 275,000 jobs might result.

For the rural family agricultural sector, which is most likely to engage in cultivation of oilseed crops, a similar approach is based on data for agricultural and industrial jobs allowing for an estimate of the agricultural workforce based on net hectares brought into cultivation results in somewhat larger job creation figures. Assuming an increase of roughly 215,000 ha, about 100,000 jobs would result; assuming the high-end increase in land brought into production (2 million ha), about 1 million jobs could result.

- *Regional development*. The selection of crops for biofuels production will have a substantial impact in terms of regional development opportunities, as will the selection of sites for biofuels production facilities. It is generally understood that the development impacts are desirable, in that these will involve job creation and stimulation of the development of other businesses through the forward linkage to other sectors, especially agribusinesses such as poultry and meat production, transportation and energy production. The main consideration in assessing the impact is whether other investment and development activities should be undertaken in coordination with the development of biofuels, and how to ensure that the benefits are distributed as widely as possible in geographic terms. In addition, the construction of small oil extraction facilities in rural areas, as well as biodiesel production facilities, would foster economic development in more remote regions. To achieve this, some cautious initial steps are recommended: first, the production of distinct oilseed crops in different regions with specific suitability; second, the extraction of crude oil in mini-plants (presses) in those same regions; third, the use of the co-products locally and transfer of the crude oil to the port, whether for export or for production of biodiesel in a trans-esterification facility located near the port or diesel tank.

Recommendation 5 The appropriate recommendations here have to do with mechanisms for promoting regional development and job creation in rural areas. Three mechanisms are appropriate: (i) guidelines for permitting of large-scale monoculture projects that mandate some fraction of the cultivated area be allocated to small-holders; (ii) exemptions from regulatory oversight provisions for biofuels production by small-scale producers (less than 3 million liters per year); and (iii) funding and technical support for rural biofuels projects.

i. *Permitting*. The permitting process for investments in large-scale biofuels production should include a review of the mechanisms for sourcing feedstock such that projects that contemplate outgrowing arrangements under the concession system will be given more favorable treatment than those that do not. This review could be contemplated in the context of the environmental permitting process, as an aspect of the socio-economic impact of the project, or it could be added as a follow-on review requirement associated with concessions issued for biofuels production.
ii. *Small-scale production*. The proposed rulemaking for biofuels (62/2006) exempts small producers (defined as producing up to 3 million liters/ year) from the requirement of delivering their biofuel production to licensed fuel distributors. As noted, this poses the risk of allowing low-quality biodiesel to enter the marketplace, with potentially negative consequences for vehicles and the overall biofuels program. It seems unlikely that the requirement to maintain documentation of laboratory fuel quality tests will be feasible, given the limited laboratory facilities available in the country, and further, the substantial potential for variations in product quality, complicating the effectiveness of this requirement in any case. The threshold should remain at 3 million liters, and producers would be required to inform purchasers that their product has not been tested and that any risks inherent in its use are borne by the purchaser.
iii. *Funding for TA*. Small-scale production of biodiesel as well as raw oil for consumption without transesterification could be supported by government agencies such as FUNAE and other sources of agricultural financing, such as GAPI.

Food security. The potential impact of biofuels production on food security and the poor (especially the urban poor who do not have the opportunity to engage in cultivation of feedstock crops) is a significant concern for policymakers. Beginning in early 2007 with Mexico, and continuing through into 2008 with the recent experience of many countries including Haiti, the Philippines, Egypt, Indonesia, Senegal and Mozambique itself with the socio-economic fall-out from price increases in staple foods, which are attributable in part to new demand for grain from biofuels producers, it is likely that demand for biofuels feedstocks created by a domestic biofuels program in Mozambique could contribute to price increases for staple foods.[3] At the same time, however, it must be recognized that even if Mozambique does not implement a biofuels program, global food prices will likely remain higher than in the past, based on increases in the last two years, broad changes in global demand for staples as well as meat, and partly as a result of the implementation of biofuels programs.[4]

It is also the case that Mozambique is likely to see positive impacts associated with increased agricultural production supported by a biofuels program that could enhance food security in the country. Increased production of edible oilseeds could help narrow the trade deficit in vegetable oil as well as contribute to an expanding export business.Price increases have already been observed to a limited degree in the case of copra, where rising international prices for coconut oil are enough to make the opportunity cost of diverting that feedstock to biofuels production too high. However, a broadly based biofuels program could stimulate production of a variety of feedstocks, thereby supporting increased production and productivity in the agricultural sector. This increase would lead in turn to job formation, especially in rural areas where the majority of the country's population still resides, and would likely drive increases in productivity among the more traditional family producers. The cassava sector offers an example of a segment of agricultural producers who see increased incomes and an incentive to become more productive if local prices for cassava were to increase.

Aside of the implications of biofuels programs on demand for feedstocks and their prices, it is important to identify the numerous other factors that have contributed to the recent increase in world prices for grains and oilseeds. These include: (i) increased demand driven by economic growth and increasing affluence in major emerging markets, notably India and China; (ii) concurrent shifts in food consumption patterns, in particular, increased demand for meat; (iii) higher petroleum prices lead to increases in prices of various agricultural inputs as well as transportation; (iv) the short- and medium-term impact of droughts, such as those affecting agriculture in Australia; and lastly, (v) the perverse impact of other economic policies, such as export curbs, implemented by major agricultural producers, as well as long-standing distortions of market signals caused by price controls and subsidies.[5] The challenge for policymakers in Mozambique, therefore, is to design a biofuels program that will mitigate the potential negative impacts in the area of food prices for the urban poor, while contributing to rural job formation and income generation, and foster improvements in key macroeconomic indicators,

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[3] An as-yet unpublished paper, by Arndt, Channing, Benfica, Rui, Tarp, Finn, Thurlow, James and Uaiene, Rafael, "Biofuels, poverty and growth: A computable general equilibrium analysis of Mozambique," addresses the impact on food prices as well as rural incomes.

[4] See Runge, C. Ford and Senauer, Benjamin, "How biofuels could starve the poor," *Foreign Affairs* (May/June 2007): 41 ff. Also, Barta, Patrick, "Crop prices soar, pushing up cost of food globally," *The Wall Street Journal* (April 9, 2007): A1.

[5] See "The new face of hunger," *Economist* (April 19, 2008): page 32, citing a World Bank study that identified price controls, export restrictions, consumer subsidies or lower tariffs in 48 of 58 countries where developments have been tracked; the result is that agricultural production has not increase because demand and price signals have been muffled. See also Beattie, Alan and Blas, Javier, "Precious grains: how export curbs are exacerbating the food crisis," *Financial Times* (April 14, 2008): page 9, and Krugman, Paul, "Grains gone wild," *New York Times* (April 7, 2008): page A27.

particularly the balance of trade, generation of hard currency receipts and inward investment, all of which will help offset the impact of higher prices.

The extent to which the implementation of a biofuels program in Mozambique will trigger inflationary increases in staples will depend on the potential for competition between the primary feedstocks for biofuels and staple crops, such as maize, cassava, grain sorghum, millet, beans and peanuts, other foods such as coconut, and the links to production of meat, poultry, eggs and other goods. The potential for competition does exist, given the presence of coconut, cassava and a close relative of grain sorghum on the list of promising energy crops for Mozambique. However, competition may be mitigated by ensuring a balance between annual and perennial feedstock crops. For perennial crops harvested in the so-called family sector, notably coconut, there is evidence that higher prices have only a limited impact on producer behavior. For instance, coconut oil producers in Inhambane report that they have had limited success in securing higher-quality copra from producers by offering a premium. This suggests that higher prices will not necessarily lead to increased output of coconut (and corresponding decreases in output of other crops) in the near term, a conclusion that is supported by the communities' limited capacity to embark on even small-scale planting or replanting of coconut trees. At the same time, it is also true that in the face of lower prices communities would be unlikely to reduce area dedicated to coconut. Another approach to limit competition would be to restrict permits for large-scale production projects to cases where new land is being brought into production. Indeed, the list of proposed crops also includes some not yet widely cultivated in Mozambique, which are therefore less likely to have strong linkages to local food production, and to the extent that they expand, would likely be tied to other agribusiness activities, as in the case of poultry farming and sunflower cultivation. Several of the promising energy feedstocks are perennial crops requiring substantial up-front investment (such as sugarcane and African palm); this will complicate short-term efforts to expand the area dedicated to their production, thereby diminishing potential competition, and it will depend on larger investments whose land use may be controlled more effectively.

The impact of forward linkages between energy crops and other agribusiness sectors is also cited as a potential concern in the global debate about the food-versus-fuel trade-off. In Mozambique, however, the links between these crops and meat and poultry production does not appear to be as powerful as the link between maize and various agribusiness sectors in the U.S., because meat production in Mozambique is limited in scope and relies far less on cassava or grain sorghum than on other inputs. Indeed, the forward linkages may actually foster additional growth elsewhere; Technoserve is currently involved in promoting poultry production in one of its programs. In addition, in many rural areas, many inhabitants continue to rely on wild game. Finally, in the case of cassava, the crop for which serious concerns could be identified, there is strong evidence that the low levels of productivity in Mozambique are partly tied to the lack of strong demand for the crop, which in turn explains the low prices for cassava that are frequently cited as justification for letting the crop stay in the ground to serve as a backup staple.

Contrary to expectations of negative impacts on other sectors, the expansion of cultivation of certain energy crops may well have beneficial impacts for other agribusiness sectors. In the case of sunflower seed and coconut, the presscake is valuable as a source of protein for animal feed. In the case of jatropha and castor seed, their utility is more likely to be as sources of soil nutrients,[6] most likely in replenishing soils on the plantations where they are cultivated, or as a source of fuel for thermal energy production or electric power generation. The economic impacts of these co-products have been factored into the economic analysis presented in Chapter 4.

In general, the critics of biofuels production as a strategy for achieving diversification of fuel supplies do not recognize that for countries such as Mozambique, where a substantial segment of the population does rely on agricultural activities for its livelihood, large- or small-scale production of biofuels is likely to redress the balance in terms of trade between rural and urban populations, attracting more income for agricultural products than has been the case in the past. Further, the critics tend to overlook the fact that low productivity in many areas is very likely to persist unless crop prices increase, thereby generating extra income that can lead to a cycle of productivity enhancements over time.[7] While it is true that landless rural populations, as well as the urban poor, could be affected by higher prices, these appear to represent a small, though politically visible,segment of the population in Mozambique relative to the overall rural population of the country, and, given their concentration in the urban areas, these people might be more easily reached by compensatory government programs.

Recommendation 6 To address concerns related to food security, the National Biofuels Program should ensure that: (i) demand for fuels is phased in gradually, but with a solid government commitment to create incentives for investment; (ii) multiple energy crops (though not corn/maize) are involved to diversify feedstocks for the program; (iii) agricultural production of the feedstocks be secured from land put into production for the first time, or returned to production, in the case of lands that have laid fallow since the pre-Independence period; (iv) new enterprises include arrangements for outgrower schemes and commitment of a portion of land to food production to maximize rural job formation and increase food output; and (v), crops selected for the program include several that are not edible. The specifics of each recommendation are reviewed below.

i. Eligibility of multiple crops will be established in the context of permitting for biofuels production projects, as noted in Recommendation 3. The addition of new crops should be permitted, subject to review by the appropriate agency.
ii. Restrictions on the dedication of land to the production of energy crops would form part of the process for issuing

[6] Fred Kruger, in his presentation at the National Biofuels Seminar, noted that concerns about toxins in jatropha are overblown and can be mitigated, as they are in the case of cassava.
[7] See, for example, Runge and Senauer, op. cit.

concessions for land, with exemptions accorded to projects that specifically propose to export all production from Mozambique, as well as those related to biofuels production of any scale that commenced before the relevant decree and/or legislation creating the National Biofuels Program.

iii. As in the establishment of eligibility, the crops selected for biofuels production will be limited to those with marginal potential for negative impacts on food prices, whether because of weak linkages to other agribusiness sectors or because of other considerations, as in the case of cassava.

Environmental impacts. The potential environmental impacts associated with biofuels production were outlined in Chapter 4. There are significant concerns, notably the potential for habitat and ecosystem destruction as the result of conversion to large-scale monoculture production of energy crops, as well as the impacts in terms of water pollution, pollution from increased movement of heavy trucks transporting unprocessed feedstocks and raw vegetable oil or finished biofuels. At the same time, there are advantages, specifically the reduction in greenhouse gas emissions that result from the use of the biofuels themselves to displace conventional ones and the use of the by-products as fuel for power generation or methane gas production.

Chapter 4 presented a detailed review of the environmental impact review process in Mozambique, which clearly would require presentation of environmental impact studies for larger-scale facilities and plantations. The primary concern that arises in the Mozambican context is whether the national authorities responsible for the application of the existing environmental legislation have the manpower and institutional capacity to do so, especially in the event that the pace of development is extremely rapid at present. Given the number of projects under development, it is likely that the authorities will see an increasingly large number of submissions.

Among the other important of the potential environmental impacts identified is the potential for effluents from biofuel production, including generation of vinasse and palm oil mill effluent. As noted in Chapter 4, these materials have value in the production of energy and as fertilizer. The experience of Brazil’s sugar industry suggests that with a combination of regulation and economic incentives, a large part of the potential environmental impact may be avoided by creating an economically attractive market for energy produced in the context of biofuels production.

Other critical considerations include loss of habitat and biodiversity through conversion of sensitive areas to biofuels production, and pressure on water supplies. These are important considerations, especially in the context of large-scale production. At the same time, the application of appropriate controls for permitting of new projects can be instrumental in ensuring that the negative impacts from projects that do proceed are limited.

Concerns about the potential social and environmental impacts from biofuels production are the driver for a variety of initiatives by national governments, regional blocs (notably the E.U.) and non-governmental organizations to develop standards and certification schemes for biofuels. The approaches differ in terms of stringency and comprehensiveness, and the details of how they will be applied are still being worked out. Given this, it is incumbent upon the GoM to monitor these developments and to plan on ensuring consistency between its national environmental controls for permitting biofuels projects and the requirements of the proposed standards.

Recommendation 7 It is important that the area responsible for environmental impacts at the Ministry for Coordination of Environmental Activities (MICOA) receive the political and material support necessary to ensure that it can exercise adequate control over the implementation of biofuels projects, and ensure compliance once they are operational. A complementary measure that would create a greater incentive for the execution of projects using the full scope of energy-recovery technologies (bagasse-fired cogeneration, biogas production from biodigestion, and glycerin use as fuel) would involve setting special feed-in tariffs for the purchase of electricity generated using these resources. Finally, the GoM should monitor efforts to develop standards for biofuels, and maintain a regular dialogue with the appropriate authorities in countries and/or other organizations engaged in the preparation of such standards and certification schemes. The biofuels program should include appropriate incentives to ensure adherence by biofuels producers in the country.

Institutional capacity. The recommendations presented above will imply some administrative burden on the GoM and various specialized agencies for the implementation and management of the proposed National Biofuels Program. Specifically, the mechanism for regulating prices paid for biofuels in the context of the proposed market structure will require an analytical process similar in terms of methodology, but perhaps more extensive from the data collection standpoint, as the process for establishing fuel prices. In addition, the environmental permitting process will certainly require the capacity to review a large number of applications for approval of biofuels production facilities, most of which will include proposals for cultivating energy crops. Further, the process of issuing concessions for land will also have to be revised to reflect the recommendations made regarding crop selection, avoidance of conversion of existing cultivation to energy crops. In the future, biofuels exports to Europe (and possibly Japan and the U.S.) will be required to present certification of the source and production process used for biofuels. As part of the process of promoting several crops that are not currently produced in Mozambique, the agricultural agencies responsible for research and development activities, as well as the extension services, will need to develop knowledge of these new crops.

With respect to quality assurance for biofuels, the existing availability of laboratory facilities for testing fuel quality are limited to the BP installations at the Port of Maputo; new capacity is required, and should be operated by a third party, not a participant in the marketplace. The national standards agency, INNOQ, will require support and technical cooperation to establish national standards for biofuels, reflecting the priorities and characteristics of the national program while at the same time taking into consideration the needs of neighboring countries through the regional coordination process. IMOPETRO will need to alter its product specifications to accommodate the process of blending in Mozambique to suit the target blend ratio, which will shift during the phase-in process. Finally, regulations governing the importation of vehicles should communicate that gasoline and diesel available in the country from the time the phase-in period begins will contain a small amount of ethanol or biodiesel, respectively. The GoM will consider the most appropriate way to communicate to the public the introduction of biofuels on the market.

Recommendation 8 The GoM should arrange for some fiscal resources to be allocated to to establish the administrative processes and capacity necessary for the implementation of the National Biofuels Program, including reinforcement of the institutional and technical capacity to review project proposals, ensuring the consistency of permitting processes and requirements with the provisions of international standards and certification programs, and adequate laboratory capacity in the country to monitor fuel quality. The GoM should also request that various donors provide support for these activities. Various aspects of the operation could be supported individually by different donor agencies working in coordination with one another, as part of a Donor Biofuels Working Group, the nucleus of which has already been established.

5. Potential for carbon finance to support investments in bio-fuels production

As described in Chapter 4, the use of carbon finance mechanisms to support the implementation of the biofuels investments faces significant challenges, despite the fact that the use of biofuels in Mozambique would generate significant emissions reductions. The level of emissions reductions varies depending on the feedstock used, with several of the crops that are among the economically most interesting also offering the greatest emissions reduction potential. However, for these reductions to be monetized, there are additional considerations. At present there is only one approved methodology involving biofuel production and distribution, but the methodology applies to biodiesel from waste cooking oil, not biodiesel prepared from raw vegetable oils. Other, more relevant methodologies for the Mozambican context have been proposed, in particular for biodiesel based on African palm and sunflower seeds, but have faced significant scrutiny on grounds related to the potential for deforestation induced by the establishment of palm plantations, as well as the potential for double-counting. In general, the CDM Executive

Board has criticized several projects for not adopting calculations that are sufficiently conservative.[8]

The application of CDM instruments to national programs is still in its infancy. There have been some so-called Programs of Activities (or "programmatic" CDM projects) implemented and registered in the context of the CDM to date, but these have faced significant methodological scrutiny. In the future, on the basis of the agreements made on the subject of programmatic CDM projects in Montreal in 2005, it is hoped that this will change. However, the process is likely to be slow, and will certainly be influenced by efforts to establish the basis for international negotiations on the national commitments after 2012, and by the market mechanisms in operation at the time. While the system in effect after 2012 could in theory be a continuation of the CDM, an expansion of it or a departure from its structure and operating principles, it seems likely that the institutional and economic interests in the current mechanism will create strong pressures for continuity rather than a sharp break with the CDM as it stands now.

With respect to projects in the electric sector, carbon finance may be more accessible given the long experience in many countries with biomass-to-power generation projects in the sugar sector and in other agribusiness sub-sectors. However, it must be noted that the particular circumstances of Mozambique's power sector mean that baseline calculations performed in accordance with existing methodologies may result in relatively low emissions factors because of the significance of hydropower in the national grid. Mozambique could request approval for modifications to some of these methodologies, but this is a time-consuming process.

Given this, agencies supporting development of the biofuels program in Mozambique should consider the potential for carbon finance, but they should not assume that carbon finance will generate significant sales that would be decisive in facilitating the financial close of individual projects: in general, CER sales tend to add a few percentage points to the project returns even in the best of circumstances (when favorable baseline conditions apply, which is not the case in Mozambique). In light of this, the Government could consider presenting the National Biofuels Program as a "programmatic CDM" project with the objective of allocating proceeds from CER sales to the creation of the financial mechanisms to support the National Biofuels Program, such as through a fund to support the development of the sector infrastructure, as noted above. The government project presentation could focus on the fuel switching pathway for generating emissions reductions (for which no approved methodology yet exists), leaving aside the emissions reductions delivered by the individual projects from grid-connected biomass-to-electricity production (for which methodologies do exist) so that individual projects can determine if they wish to present that particular aspect of the project in a separate submission to the CDM's Executive Board. The individual projects (some of which are already beginning construction) are likely to be significantly advanced by the time a methodology for transportation fuel switching with biofuels is finally approved by the CDM Executive Board.

[8] "Bioenergy projects ignore fuel users and miss out on credits," *Bioenergy Business*, April 2007: page 7.

Recommendation 9 The GoM's Biofuels Working Group should bring MICOA into the process of developing a National Biofuels Program and request that it begin the process of developing the relevant documentation for the presentation of the National Biofuels Program as a programmatic CDM project. MICOA should also be charged with supporting efforts to prepare biomass cogeneration projects as CDM projects.

6. General principles for implementation of a Biofuels Program in Mozambique

To guide further discussion regarding the proposed National Biofuels Program in Mozambique, this section offers a set of general principles for the establishment of the policies and structures required.

Mandate biofuels content in gasoline and diesel. The biofuels program must be implemented to benefit the country as a whole, and requires strong leadership at the very highest levels. However, breaking the paradigm of reliance on hydrocarbons for motor vehicles is not easy; history shows that this substitution is not a spontaneous act. Typically, people support this type of program in periods of fossil fuel shortage, but then withdraw it quickly when the situation normalizes. In the periods of scarcity, the price of hydrocarbons does not oscillate wildly, because there are accounting tricks that lessen the effects on the final price. These are more frequent in more centralized economies where the government acts directly in economic activity – indeed the GoM has used this approach to soften the impact of high petroleum prices on consumers, by temporarily reducing the TSC. The oil industry and the distributors often adopt a neutral or even opposite position; they rarely engage actively in long-term actions to substitute hydrocarbons. The automobile industry also joins in, but only when pressured to do so. The GoM has already begun to create the political space for launching a coherent biofuels strategy, and the public has responded positively; the popular response to President Guebuza's advocacy of jatropha cultivation demonstrates this. What is needed now is decisive action to set the policy in motion.

Plan for the biofuels sector to develop in multiple stages over time. As in Brazil and other countries more recently, the development of the biofuels sector has involved several stages of development. The first stage involves the creation of the market through the mandate for blending of ethanol and biodiesel into the petroleum-based fuels in use. These mandates will need to be phased in over a relatively short period of time to allow production capacity to emerge. Once production is in place, it would be desirable for Mozambique to begin contemplating further steps to expand the domestic market for biofuels, in large part because the existing transportation fuels market is very small by global standards. The larger market would allow for greater economies of scale in ethanol and the consolidation of biodiesel production. One important strategy for creating a larger domestic market will be the encouragement of imports of flex-fuel vehicles, which will be available in increasing numbers from the major manufacturers that export to Mozambique. Another would be support for more wide-spread use of ethanol-based gel fuel for low-income households.

Give priority to benefiting the agricultural producer for value creation. A fundamental objective of a National Biofuel Program is to generate a surplus of agricultural raw materials so that feedstock production does not interfere with the ability to meet basic nutritional needs. To create a significant increase in the supply of sucrose, starch and vegetable oil, it is absolutely necessary to guarantee the agricultural producers healthy margins for their products and to guarantee absolute liquidity for the products harvested on a long term basis. For these two things to occur, the public and the government need to endorse a basic rule for the program: the economic return of the farmer should be assured, and assured over time. The implementation of a National Biofuels Program will require breaking paradigms. One is the necessity to generate a significant part of the GDP in the primary sector and to give back a larger percentage of the additional income. Chapter 6 shows that apparently there is a margin to pay the farmer more than traditional returns. The system should guarantee positive margins to the farmers, even in tough times. Part of the value of the sector should be given back to the farms; higher income levels for these jobs would reduce the exodus to the cities. This change will only happen if a biofuel program is implemented. The demand for food is not creating enough value, in many countries, to reverse migration to the cities.

Develop new crops. The earlier chapters showed that Mozambique has abundant natural resources to diversify and develop agricultural crops. Chapter 3 showed a greater dedication to subsistence crops (corn and cassava) and two crops for industrialization (sugarcane and coconut) whose derivative products are allotted for export. Chapter 4 lists a wider series of agricultural alternatives for the production of ethanol and biodiesel. Precisely because there is no prior experience with some alternative crops, the risk involved in their introduction is higher, and these risks should be shared by society as a whole. Every learning curve has its cost. This learning process must be supported by the GoM, and should receive donor support to set it in motion.

Exchanges between nations and organizations are prevalent in the sectors that produce raw materials for biofuels. Therefore, it is recommended that the public-private programs designed to promote new crops use the knowledge of others that have experience. India is an example: it has the most similar agrarian structure to that of Mozambique (small family-owned farms) and has had great success with sugarcane and jatropha. Brazil has the technology to reduce the costs of ethanol and recently started programs for planting oil seed crops in dry, rural areas, where the population lacks technological experience, making it difficult to for families to share in the economic progress.

The diversification of crops and the expansion into new areas, even in family units, demands prior investment in economic resources (fertilizers, seeds, equipment, irrigation, among others) and technological resources (information, knowledge, motivation). Such resources should come from objective programs and focus on each crop and its region. The implementation strategy will depend on each crop and region. Large-scale 'mega-projects' are welcome, as they bring cost-reducing technologies from other countries, but should remain under the aegis of private investors.

Governmental organizations are responsible for structuring projects that develop small farms and associations so they can interact with the mega-projects in the region. Sugarcane and sweet sorghum are different from the rest because they are crops grown for mega-projects, especially if the ethanol produced is intended for export. Cassava is a suitable satellite crop to complement the sugarcane. It can be processed in the same distillery, during the sugarcane processing off-season, thereby increasing the productive use of the distillery.

The oil seed crops are more flexible in agricultural cells, and are feasible in the family agricultural model, as long as the cells are consolidated in micro-regions, with a stable sales strategy and guaranteed demand. The limited experience with new crops in the country will demand long-term planning, with clear rules, to guarantee sustained healthy returns. The planning for agricultural expansion should be linked to industrial projects for vegetable oil extraction in parallel, or in cooperation with, a biodiesel production unit. The projects currently being implemented should incorporated in this national plan, for their success will stimulate similar actions by potential associations or nuclei, but these do not have the profile to assume the business risk of the free market.

Link other energy policy mandates to those governing biofuels. To ensure the environmental integrity of the biofuels projects implemented in Mozambique, it is important that the energy value of by-products generated in the process of producing biofuels be given its appropriate value. EdM has resisted the idea of a special feed-in tariff for electricity produced from bagasse or other sources. However, it must be noted that this type of mechanism has been important to the development of Brazil’s ethanol program and would be a useful strategy for supporting increased domestic generation in relatively small packages of additional capacity. Mandated purchases of electricity from sugar mills would provide a mechanism for diversifying generation resources and providing additional support to ethanol businesses, resulting in additional capacity more quickly than large-scale hydropower projects. The latter require large amounts of external financing and long timetables for implementation. Even South Africa’s ESKOM and provincial authorities in South Africa are now putting feed-in policies in place after years of resistance.

Manage environmental impacts from biofuels production. The reduction of the potential environmental impact of large-scale biofuels production will be a requirement in the context of any donor financing for the National Biofuels Program, and will be essential to securing carbon financing for the Program. This can be achieved through attention to the administrative requirements of the relevant agency, and the requirements of the agency that issues concessions for the production of energy crops. At the same time, the requirements must ensure that the co-products of biofuels production are valued appropriately.

Support industrial investment. Investment in industrial assets has agronomic risks, since they are specific to certain types of agricultural production. While the land can be used for new crops, the industrial plants have high costs in the case of eventual change in feedstock. To reduce these risks, it is necessary to locate distilleries close to sugar refineries. Typically, autonomous distilleries are viable five or more years after the consolidation of the ethanol market, but only if associated with plantations in large productive areas of sugarcane/sorghum or perhaps cassava. It does not seem feasible that such investments could be provided independently by the mills, since they have postponed such projects until now.

Similar to the agricultural investment, the program should promote the consolidation of a distillery between current molasses manufacturers. This distillery should be built in a zone more suited for mixing and/or exporting anhydrous ethanol, and securely within a sugar-alcohol complex, to benefit from the steam, energy and complimentary sugarcane juice. Such an initial unit would guarantee ethanol at a low cost and serve as a technological center to train a technical cadre, which could then train other specialists for work at the additional ethanol units.

PetroMoc and IMOPETRO are natural candidates to take over the management of blending and responsibility for the industrial investment in the trans-esterification plant. This will avoid the risk of spreading dozens of chemical plants (trans-esterification) in the interior of the country, which would compromise the quality of biodiesel and the national program.

The installation of the vertically integrated mini-plants with agricultural nuclei should not be stopped, however, unless there is no possibility of financing with government resources. The management risk and responsibility are assigned to one economic agent, which will classify those that have technological competence and are self-financing.

Implement standards for biofuels quality. Vehicles are valuable goods to their owners, especially in developing countries. While proper maintenance of a vehicle is essential, it should not be compromised by failures in fuel standards. Accordingly, national biofuels standards and adequate enforcement provisions are essential to avoid damaging motors and consequently destroying trust in the program, for ethanol and biodiesel. While the recommendation to mix small percentages in traditional fuels will minimize quality problems, the enforcement of standards should nonetheless be strict to avoid problems. At the same time, however, it is inevitable, in a large country with many remote areas, such as Mozambique, that there will be small-scale producers that do not operate according to national standards. Such producers may be exempted, but local representatives of national agencies must communicate the risks inherent in using locally produced biofuels to the greatest extent possible.

The establishment of a standard should balance the technical needs of the motors in use with the raw material and technological competency of the country. It is not convenient to import standards from other continents; this risks making the two biofuels unfeasible or making them absurdly expensive.

As noted in other chapters, the specifications established on other continents serve regional interests in those areas more than technical justifications. It is evident that for eventual export, the consuming country will determine the contractual specifications. In the case of ethanol, there is a tendency to perform dehydration in the destination country, to avoid high importation taxes or to guarantee that the fuel meets the relevant standard.

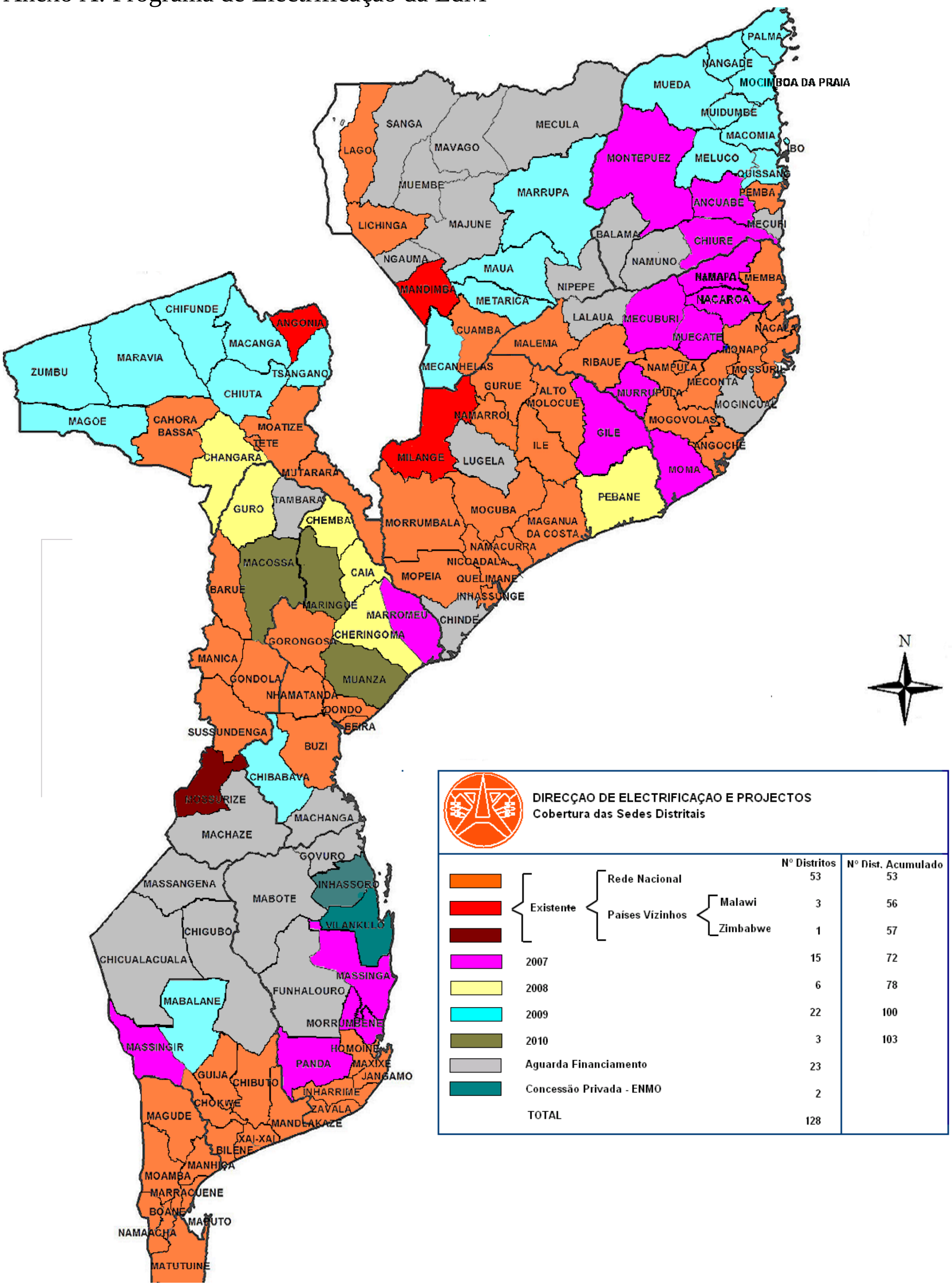
In Mozambique's situation, the dehydration stage will be a mandatory part of the distilleries, since there are no automobiles that use hydrous ethanol in the country (this category has disappeared with the advent of the *flexfuel* motor). Even with the arrival of these new motors in the future, the current fleet will be in use for 15 or more years and will require pure gasoline or gasoline mixed with anhydrous ethanol. The distillery will have the flexibility to serve both the domestic and foreign markets. For export, they could offer hydrous or anhydrous ethanol; the former is 12% cheaper.

The biodiesel standard needs to be sufficiently flexible to accommodate the use of ethanol or methanol in the industrial process. Tropical countries where ethanol is or will be used in the medium term, as an alternative to fossil-based methanol, could differentiate themselves in the international market; the concept of a 100% "green" biofuel, produced from vegetable oil and bioethanol, could command a premium from consumers who are concerned about the danger of global warming. This technological evolution seeks to eliminate the current inconvenience of lost industrial capability when methanol is substituted for ethanol in transesterification. It is important to remember that the risks (fires and illness) are higher when methanol is used in chemical operations in developing countries.

Inspection for the standards of pure biofuels and of the final mixtures with gasoline and diesel should be established from the very first day. This responsibility should maintain the same structure used today for inspection of fossil fuels.

ANNEXES

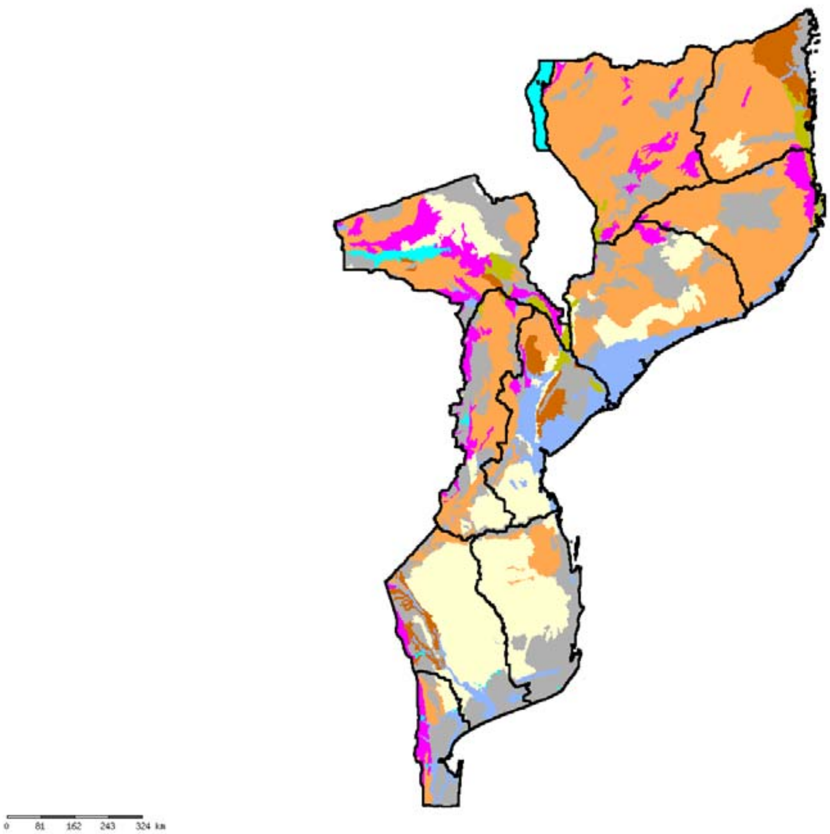
Annex A: EdM Electrification Program
Anexo A: Programa de Electrificação da EdM



Source: EdM

Annex B: Land-use and Agriculture
Anexo B: Uso da Terra e Agricultura

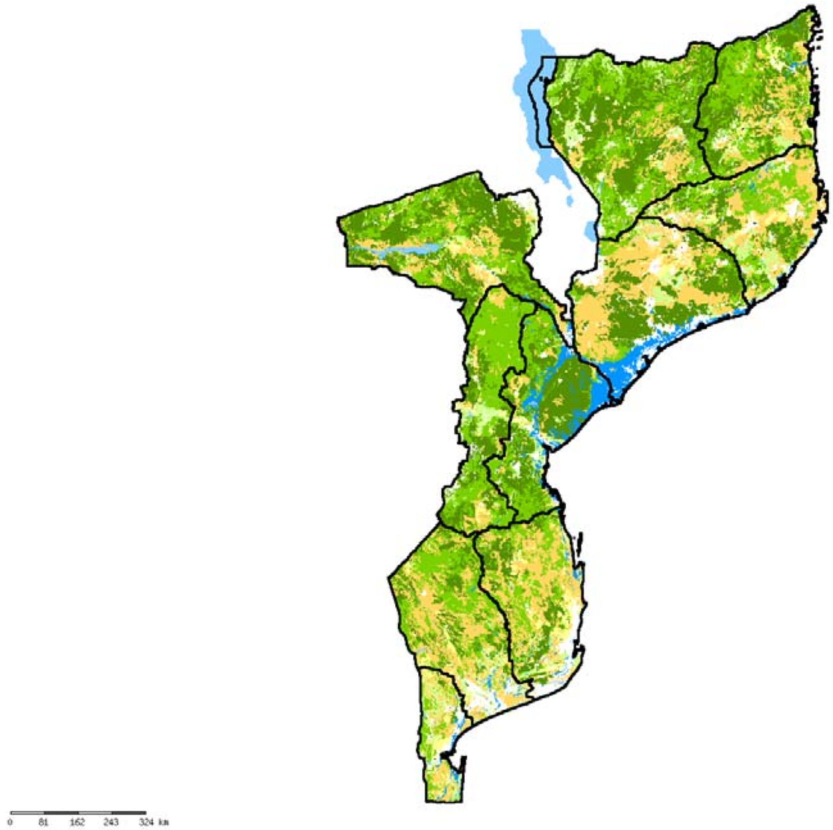
Annex B.1: Soil Characteristics
Anexo B.1: Caracteristicas do Solo



Soil Type

- Muito aptos / Highly suitable
- Drenagem pobre / Poor drainage
- Muito difícil desenvolver agricultura / Difficult to develop agriculture
- Agricultura não recomendada / Agriculture not recommended
- Sem grandes limitações / No limitations
- Gestão agrícola difícil / Agricultural management difficult
- Baixa fertilidade / Low fertility
- Corpos de água / Bodies of water

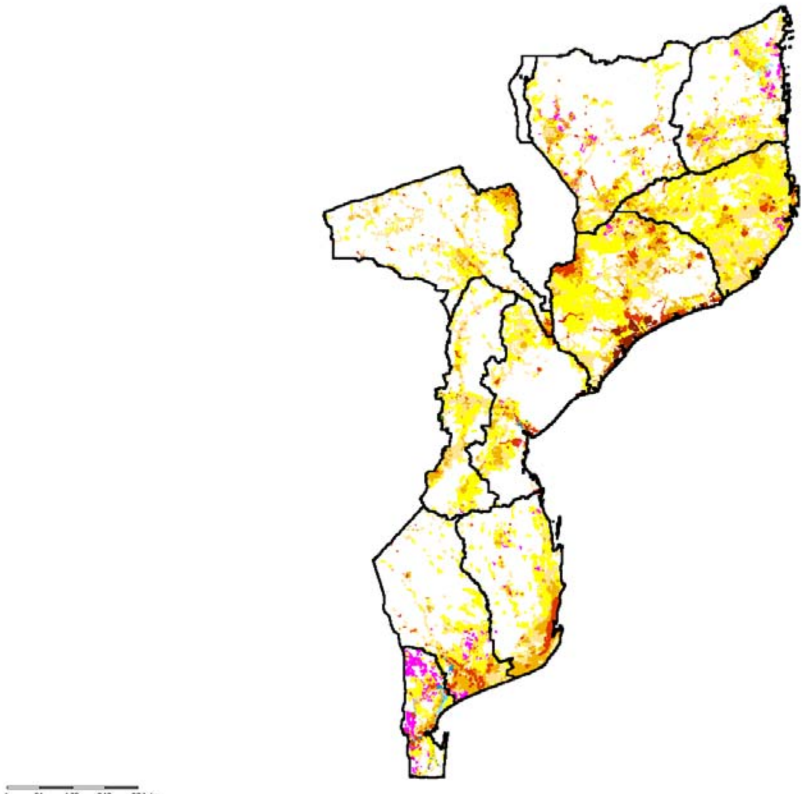
Annex B.2: Vegetation
Anexo B.2: Vegetação



Land Coverage

- Zona habitada / Inhabited areas
- Zona inundada o inundável / Flood zones
- País fronteiriço / Frontier area
- Arbustos / Bush
- Zona herbácea arborizada / Wooded grassland
- Corpos de água / Bodies of water
- Sem vegetação / No vegetation
- Arbustos baixos / Low bush
- Zona herbácea / Wooded areas
- Floresta / Forest

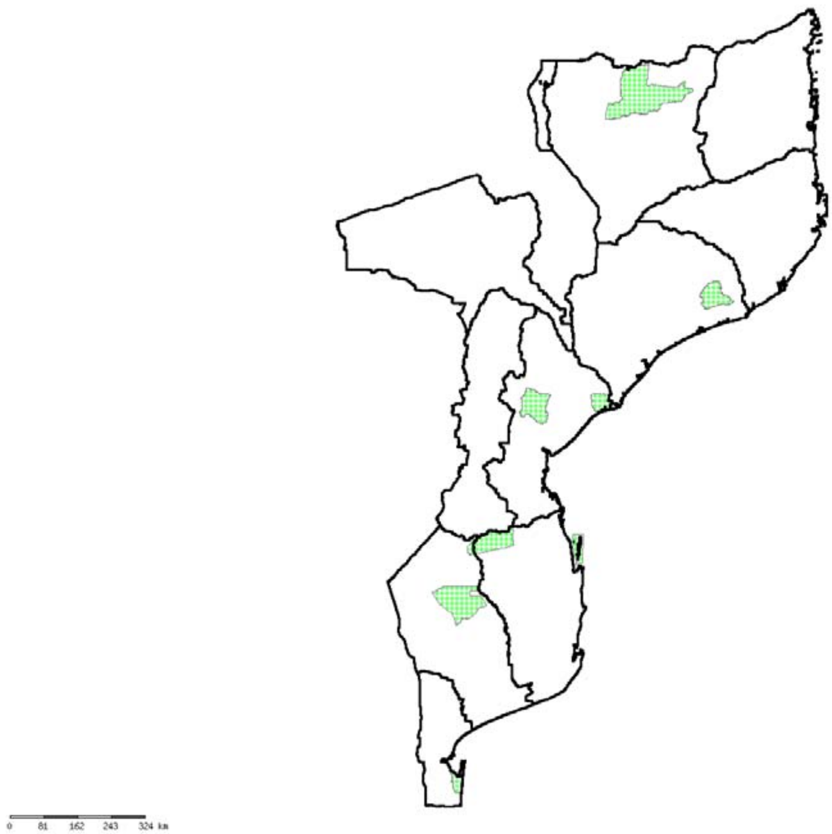
Annex B.3: Agricultural areas
Anexo B.3: Areas cultivadas



Agricultural Use

- Sequeiro 5% / Dry land farming
- 30%
- 70%
- Antigo cultivo / Previously cultivated areas
- 20%
- 70%
- 100%
- Plantações 30% / Plantations
- 60%
- 100%
- 20%
- 50%
- 90%
- Regadio 5% / Irrigated areas
- 50%
- 90%
- Antigo regadio / Previously irrigated areas
- 40%
- 70%

Annex B.4: Parks and reserves
Anexo B.4: Parques e reservas



Reserves and National Parks / Reservas e Parques Nacionais

Annex C: Precipitation and Hydrography
Anexo C: Precipitação e Hidrografía

Annex C.1: Precipitation
Anexo C.1: Precipitação

Precipitação Média Anual* por Estação em mm, 1995-2005
Average annual precipitation by station in mm, 1995-2005

Descrição	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Maputo	40.0	51.6	76.3	80.7	82.5	92.9	133.5	72.9	30.9	71.7	37.9
Xai-Xai	77.1	63.5	83.9	78.8	73.0	101.3	163.6	102.5	63.9	74.8	76.6
inhambane	84.9	63.2	67.3	74.6	88.6	102.8	131.9	113.4	41.8	70.4	40.3
Beira	84.8	169.4	129.3	131.5	148.2	141.2	109.6	159.5	97.0	125.1	139.1
Chimoio	69.5	65.4	95.4	144.4	91.8	95.9	105.5	128.2	55.3	66.5	45.7
Tete	48.5	45.8	90.0	53.7	52.7	62.0	110.1	24.8	92.3	71.9	45.4
Quelimane	123.5	151.8	124.6	117.6	122.3	149.0	142.1	78.0	154.5	98.9	93.5
Nampula	87.6	98.7	96.9	88.2	104.2	105.6	86.7	117.7	150.0	107.1	72.1
Pemba	63.2	77.6	61.2	64.3	72.4	85.9	104.3	64.1	74.7	57.9	44.9
Lichinga	57.9	70.7	81.3	106.1	70.0	131.0	109.5	90.2	119.8	94.7	90.5

Source/Fonte: INAM
*Based on monthly averages / Com base nas médias mensais

Precipitação Média Mensal por Estação em MM, 1995-2005

Average annual precipitation by station in mm, 1995-2005

Estacao: MAPUTO

Descrição	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Jan.	112.2	109.7	308.4	129.5	365.5	100.4	234.8	76.9	184.8	171.6	155.3
Fev.	31.1	47.6	189.2	88.2	52.1	263.8	502.1	148.6	33.9	160.0	75.5
Mar.	47.0	66.9	36.4	84.6	96.9	97.8	364.8	33.6	12.0	112.2	73.7
Abr.	52.3	22.6	53.2	27.7	37.6	65.8	59.8	32.2	7.4	42.0	32.1
Mai.	11.2	73.8	84.3	69.0	3.0	44.3	30.7	40.5	0.0	18.5	22.2
Jun.	7.0	13.3	5.3	19.8	0.0	14.6	4.5	4.8	5.3	24.6	
Jul.	0.1	1.3	11.5	71.6	4.9	0.0	13.8	10.4	4.8	69.9	29.1
Ago.	33.1	11.9	33.0	1.7	27.4	2.4	3.5	15.1	0.0	7.0	0.6
Set.	14.4	1.7	0.8	63.0	28.5	77.9	65.1	1.3	9.3	17.0	5.9
Out.	76.8	108.0	3.2	79.3	73.0	161.5	60.4	69.3	44.1	37.2	11.5
Nov.	48.5	53.7	44.0	273.0	164.6	162.6	150.6	290.9	21.9	155.7	6.6
Dez.	46.7	109.2	146.1	61.0	136.7	124.2	111.6	150.7	46.9	44.8	42.8
	40.0	51.6	76.3	80.7	82.5	92.9	133.5	72.9	30.9	71.7	37.9

Estacao: XAI-XAI

Descrição	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Jan.	253.4	5.5	147.0	139.2	232.9	234.6	417.5	118.7	26.5	175.3	76.1
Fev.	48.7	65.6	123.1	70.4	58.8	401.1	343.1	329.7	59.0	70.9	84.3
Mar.	41.6	70.9	181.0	163.8	46.8	81.9	198.1	223.7	54.3	136.0	136.6
Abr.	61.0	149.6	221.3	19.3	16.2	63.8	69.0	77.6	131.3	111.3	87.6
Mai.	46.2	104.5	131.8	123.0	20.7	12.0	67.3	17.2	25.1	34.2	16.6
Jun.	45.2	32.6	68.7	9.3	3.8	21.1	53.1	0.0	143.7	89.8	16.8
Jul.	167.5	12.0	66.0	56.1	16.9	10.6	52.1	74.0	33.5	98.6	60.8
Ago.	22.3	65.6	5.0	109.9	26.1	18.1	2.9	5.4		1.2	
Set.	32.8	7.5	1.9	26.9	54.1	14.5	106.0	25.0	40.9	58.0	15.3
Out.	68.9	82.4	6.5	55.2	85.3	56.2	24.7	28.9	79.6	0.0	28.1
Nov.	18.2	52.2	5.3	89.7	103.0	218.1	567.8	106.3	85.2	37.5	98.2
Dez.	119.0	113.0	48.7	82.2	211.4	83.0	61.9	224.0	87.8	85.2	298.5
	77.1	63.5	83.9	78.8	73.0	101.3	163.6	102.5	63.9	74.8	76.6

Estacao: INHAMBANE

Descrição	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Jan.	240.1	74.6	233.2	290.1	263.2	216	153.7	40.2	78.5	90.4	61.4
Fev.	74.9	71.8	142.8	72.0	54.7	562.2	451.9	275.4	57	107.7	17.9
Mar.	164.0	47.6	132.1	87.5	158.2	109.3	295.9	336.4	16.1		87
Abr.	15.8	123.8	61.8	43.2	24.6	99.9	195.2	105.7	13.5	115.5	37.3
Mai.	2.0	152.2	69.0	16.0	57.3	24.2	84.1	9	10	16.6	65.8
Jun.	19.3	49.3	54.5	12.1	0.9	11.3	87.2	31.8	26.5	72.7	51.5
Jul.	60.8	26.5	32.5	63.9	10.3	48.2	35.4	46.4	68	107.9	44
Ago.	36.7	16.9	1.6	32.6	14.6	19.7	10.9	11.7		0.1	
Set.	22.2	15.8	2.9	24.8	7.3	3.7	5	3.9	28.2	25.4	2.9
Out.	41.5	20.5	2.2	113.2	51.1	19.3	7	16.7	80.6	26.7	16
Nov.	15.6	69.9	37.7	127.9	94.0	52	155.9	115.6	112.1	58	100
Dez.	325.4	89.5	37.8	12.4	327.2	68	100.2	367.6	10.6	224.1	
	84.9	63.2	67.3	74.6	88.6	102.8	131.9	113.4	41.8	70.4	40.3

Estacao: BEIRA

Descrição	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Jan.	318.8	118.2	468.0	208.5	480.7	532.5	118.8	389.8	83.6	319.5	392.6
Fev.	199.5	127.5	448.0	292.0	153.3	502.5	406.7	342.9	229.8	227.0	274.6
Mar.	150.9	179.4	207.6	302.5	242.4	99.5	213.4	395.8	145.4	414.9	229.5
Abr.	67.2	85.0	126.1	202.5	121.0	141.0	99.5	170.3	145.8	123.6	133.0
Mai.	41.3	17.0	28.9	7.6	9.5	35.4	74.8	55.6	26.6	28.3	49.6
Jun.	22.4	47.4	81.3	6.8	45.7	36.3	80.9	35.6	63.2	38.8	61.5
Jul.	21.8	59.1	87.8	39.9	47.7	49.1	66.6	25.8	112.6	35.7	52.5
Ago.	1.5	72.8	2.1	14.8	34.9	51.3	4.9	42.0		6.0	3.6
Set.	32.5	27.0	2.5	46.2	15.1	13.6	4.8	33.6	33.0	8.8	12.5
Out.	18.3	58.1	28.0	77.5	52.6	24.1	157.8	4.8	213.6	28.5	0.8
Nov.	4.5	260.3	23.5	127.6	433.6	48.9	86.4	65.0	61.9	8.1	14.2
Dez.	138.8	980.5	47.2	252.2	186.1	160.5	288.6	352.2	48.4	261.9	444.8
	84.8	169.4	129.3	131.5	151.9	141.2	133.6	159.5	97.0	125.1	139.1

Estacao: CHIMOIO

Descrição	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Jan.	201.7	195.2	437.9	547.4	261.1	331.0	276.6	185.9	160.1	347.9	218.5
Fev.	77.8	55.6	214.8	388.6	115.1	346.1	247.4	380.5	66.9	0	85.1
Mar.	74.9	75.5	53.6	161.3	127.4	174.1	193.8	379.3	61.2	173.6	35.5
Abr.	31.5	31.3	83.2	120.9	18.8	74.2	63.4	58.6	81.3	63.2	
Mai.	16.9	33.7	70.1	0.5	0.3	12.1	16.1	16.0	9.1	4	32.4
Jun.	4.1	2.2	24.3	0.1	12.5	4.4	47.5	21.5	21.9	12.5	13.1
Jul.	0.1	28.6	22.0	25.1	27.4	25.3	22.8	33.4	4.9	4	61.1
Ago.	23.5	13.0	0.1	9.3	48.9	9.8	5.2	25.0		7.5	3.5
Set.	31.3	10.3	4.7	114.2	24.0	7.1	10.4	3.1	24.4	1.5	0.2
Out.	118.0	26.0	6.5	93.4	120.5	14.0	50.0	47.8	81.9	67.2	19
Nov.	8.0	31.9	134.8	106.4	108.2	113.4	112.0	117.6	97.8	23.8	80.5
Dez.	246.1	280.9	92.4	165.4	237.1	39.3	221.3	270.1	53.5	93.2	
	69.5	65.4	95.4	144.4	91.8	95.9	105.5	128.2	55.3	66.5	45.7

Estacao: TETE

Descrição	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Jan.	181.2	85.8	236.0	166.7	292.1	181.8	158.5	80.2	199.9	191	272.3
Fev.	8.6	199.1	418.5	58.4	138.9	202.9	521.4	42.9	130.1	210.4	7.3
Mar.	17.9	47.5	105.7	24.5	62.8	143.9	330.9	63.1	127.5	81.6	3.8
Abr.	0.6	4.8	174.6	1.6	6.1	8.2	1.0	10.5	2.6	7	3
Mai.	0.3	25.7	0.0	0.0	0.5	5.1	8.6	1.1	1.4	5.4	
Jun.	1.6	7.0	0.2	1.1	4.2	2.9	0.9	0.1		5.6	10.8
Jul.	0.0	9.1	5.6	0.6	6.0	9.3	11.7	0.0		0.3	3.9
Ago.	0.4	0.0	0.2	2.1	0.2	0.8	14.5	4.5		0	
Set.	0.0	0.0	5.6	0.0	0.0	0.0	0.3	2.1		0.3	17.8
Out.	15.6	12.0	8.7	0.1	0.0	4.1	0.0	7.7		0.3	0.3
Nov.	1.8	10.5	36.0	116.9	71.4	115.0	85.5	51.8		103.6	41
Dez.	354.3	147.8	89.1	272.5	50.4	70.0	187.7	33.6		257.4	184.2
	48.5	45.8	90.0	53.7	52.7	62.0	110.1	24.8	92.3	71.9	45.4

Estacao: QUELIMANE

Descrição	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Jan.	303.0	465.3	156.5	463.8	294.4	436.6	600.8	220.1	387.3	166.6	145.3
Fev.	238.8	221.9	576.0	267.6	212.0	170.7	316.8	253.1	256.0	189.9	205.1
Mar.	237.5	308.6	117.9	155.3	185.1	197.0	395.2	172.4	326.7	101.7	300.7
Abr.	153.3	81.7	94.6	53.2	365.6	261.5	54.0	16.3	67.3	156.1	53.6
Mai.	82.3	30.7	34.8	26.4	43.0	126.9	118.5	18.6	38.8	155.2	62.9
Jun.	54.6	76.7	2.4	20.6	37.5	63.2	1.7	78.7	94.2	137.9	34
Jul.	63.8	408.1	91.7	54.0	112.3	169.1	55.7	6.0	50.9	34.3	29.3
Ago.	7.7	3.8	17.5	106.5	8.3	25.7	18.4	36.4	14.6	9.5	2.3
Set.	0.2	0.1	40.7	11.4	5.1	13.9	5.1	18.5		42.1	20.4
Out.	0.3	9.2	32.3	67.0	21.4	18.0	1.0	41.2		4.7	2.9
Nov.	88.8	7.8	116.9	71.0	59.7	96.0		10.7		59.5	1.6
Dez.	251.5	207.1	213.7	114.8	122.8	209.3	138.4	63.4		129.1	264
	123.5	151.8	124.6	117.6	122.3	149.0	142.1	78.0	154.5	98.9	93.5

Estacao: NAMPULA

Descrição	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Jan.	439.5	169.7	164.8	230.1	191.2	371.4	300.2	180.6	835.6	269.9	414.4
Fev.	327.6	269.9	452.7	351.0	215.4	201.7	175.3	429.2	183.9	124.8	224.2
Mar.	85.3	274.7	173.0	79.5	282.5	105.8	299.4	233.1	106.3	184.8	81.8
Abr.	32.3	115.4	57.7	131.0	152.3	162.4	77.2	170.6	53.5	187.4	9.4
Mai.	20.2	15.3	11.5	0.0	6.5	9.0	23.3	20.2	2.9	11.5	15.4
Jun.	10.4	34.1	0.7	12.0	30.8	30.1	4.2	33.1	4.7	13.5	18.3
Jul.	6.5	20.0	34.6	0.1	5.9	7.3	20.8	0.0	10.0	8.9	7
Ago.	1.6	22.1	0.3	36.2	143.2	10.7	22.0	38.3	3.2	1.7	6.6
Set.	1.6	4.3	1.2	8.5	4.8	0.0	0.2	20.9		9.1	2.3
Out.	0.9	7.6	17.7	70.8	2.4	4.9	17.0	4.6		0	19.1
Nov.	7.0	1.7	20.6	0.6	62.5	213.7	4.0	25.4		87	8.7
Dez.	118.8	253.1	227.7	138.1	152.6	149.9	96.8	256.7		386.1	58.1
	87.6	99.0	96.9	88.2	104.2	105.6	86.7	117.7	150.0	107.1	72.1

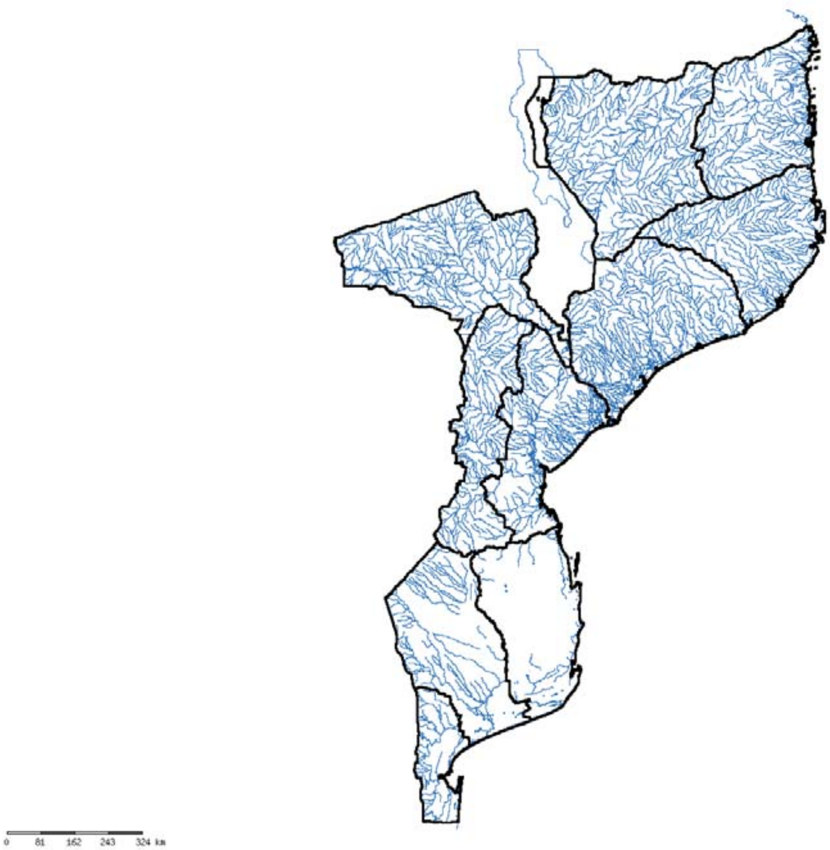
Estacao: PEMBA

Descrição	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Jan.	204.9	234.5	211.7	101.6	321.7	139.7	182.4	95.1	261.0	121.4	170.7
Fev.	304.5	247.0	258.1	301.8	260.4	95.8	151.5	125.3	204.0	119.9	115.5
Mar.	114.5	256.5	104.5	143.5	112.0	312.5	481.3	272.8	143.3	6.4	131.5
Abr.	47.4	41.9	26.1	36.1	75.2	232.1	13.3	147.1	52.6	369.2	25.2
Mai.	1.2	29.9	32.4	1.0	8.2	7.9	51.2	3.0	1.4	11	13.1
Jun.	2.2	0.3	15.0	31.7	22.0	7.1	72.5	11.3	30.7	59.6	5.9
Jul.	1.0	0.0	11.5	13.9	3.1	23.5	17.1	5.8	0.1	0	4.9
Ago.	25.2	7.9	0.0	4.2	4.7	27.1	20.1	9.6		1.5	25.4
Set.	0.0	0.7	2.2	0.2	2.1	2.5	0.0	0.0	69.6	0	1.4
Out.	1.9	0.9	11.3	0.0	4.0	0.2	26.5	13.4	0.0	5.3	36.6
Nov.	19.7	41.6	0.0	13.9	28.6	42.4	45.1	0.7	35.6		
Dez.	35.7	70.4	61.1	123.8	26.5	139.5	190.2	85.1	97.6		
	63.2	77.6	61.2	64.3	72.4	85.9	104.3	64.1	74.7	57.9	44.2

Estacao: LICHINGA

Descrição	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Jan.	271.8	246.4	221.8	224.2	286.5	370.6	375.2	180.3	550.1	254.6	269.9
Fev.	153.5	223.9	220.0	129.3	61.5	291.4	201.3	247.2	371.2	175.8	123.6
Mar.	85.9	147.7	257.6	65.1	156.5	558.0	245.7	359.8	153.3	124.2	160.5
Abr.	56.7	28.9	86.6	166.2	71.9	94.5	32.8	39.9	73.4	126.1	93.4
Mai.	0.0	23.0	16.4	106.2	4.8	30.9	0.0	12.5	2.0	7.0	70.1
Jun.	1.2	0.0	1.1	0.0	0.0	15.3	1.7	0.0	3.8	3.8	11.7
Jul.	0.5	0.7	0.2	1.9	0.0	0.5	3.7	0.0	0.0	2.1	7.9
Ago.	0.0	0.0	0.0	0.0	97.8	0.0	1.4	0.5		1.9	1.5
Set.	0.0	0.0	18.8	0.0	0.0	0.2	0.0	0.0	2.8	1.4	11.9
Out.	13.3	0.0	5.2	67.8	81.4	6.2	13.0	24.7	1.4	36.1	7.6
Nov.	64.8	12.4	0.7	112.4	9.5	110.1	219.7		64.4	74.8	
Dez.	47.3	165.1	146.6	399.8	70.1	94.4	219.6	217.5	215.3	328.6	327.7
	57.9	70.7	81.3	106.1	70.0	131.0	109.5	90.2	119.8	94.7	90.5

Annex C.2: Hydrography
Anexo C.2: Hidrografía



Rios / Rivers

Annex D: Sugar Industry and Coconut Sector
Anexo D: Industria Açucareira e Setor de Côco

Anexo D.1: National Sugar Production, 1970-2006
Anexo D.1: Produção Nacional de Açúcar, 1970-2006

Ano	Área Plantada (has)	Area Cortada (has)	Cana Moida (tons)	Rendimento Agricola (tons/há)	Produção Açúcar (tons)	Produção Melaço (tons)	Rendimento Industrial (%)	TC:TA
1970	6,021	35,811	2,554,683	71.3	287,614	75,413	11.3	8.88
1971	5,966	37,016	2,914,011	78.7	324,271	93,334	11.1	8.99
1972	6,965	37,682	2,923,213	77.6	325,051	102,348	11.1	8.99
1973	9,667	36,564	2,839,190	77.7	298,501	86,485	10.5	9.51
1974	10,870	39,199	2,884,721	73.6	285,563	104,067	9.9	10.10
1975	10,395	35,529	2,297,829	64.7	231,736	79,271	10.1	9.92
1976	10,248	36,525	2,079,556	56.9	216,065	69,427	10.4	9.62
1977	10,453	33,383	1,917,894	57.5	182,941	62,221	9.5	10.48
1978	9,981	36,274	2,125,062	58.6	215,907	66,637	10.2	9.84
1979	10,173	35,627	2,074,677	58.2	203,782	62,214	9.8	10.18
1980	10,473	33,287	1,719,340	51.7	170,366	45,635	9.9	10.09
1981	7,042	32,828	1,822,855	55.5	169,711	54,133	9.3	10.74
1982	8,745	34,509	1,505,806	43.6	125,731	44,369	8.3	11.98
1983	4,527	22,128	875,868	39.6	73,706	26,907	8.4	11.88
1984	3,812	10,531	490,703	46.6	39,256	15,538	8.0	12.50
1985	1,686	7,801	277,791	35.6	23,643	9,171	8.5	11.75
1986	-	5,922	194,320	32.8	16,289	6,858	8.4	11.93
1987	-	6,028	227,777	37.8	19,429	7,231	8.5	11.72
1988	1,809	4,931	220,631	44.7	19,227	7,792	8.7	11.48
1989	-	5,356	255,415	47.7	24,864	8,649	9.7	10.27
1990	-	8,196	331,569	40.5	31,699	10,640	9.6	10.46
1991	3,265	6,764	252,769	37.4	24,603	8,776	9.7	10.27

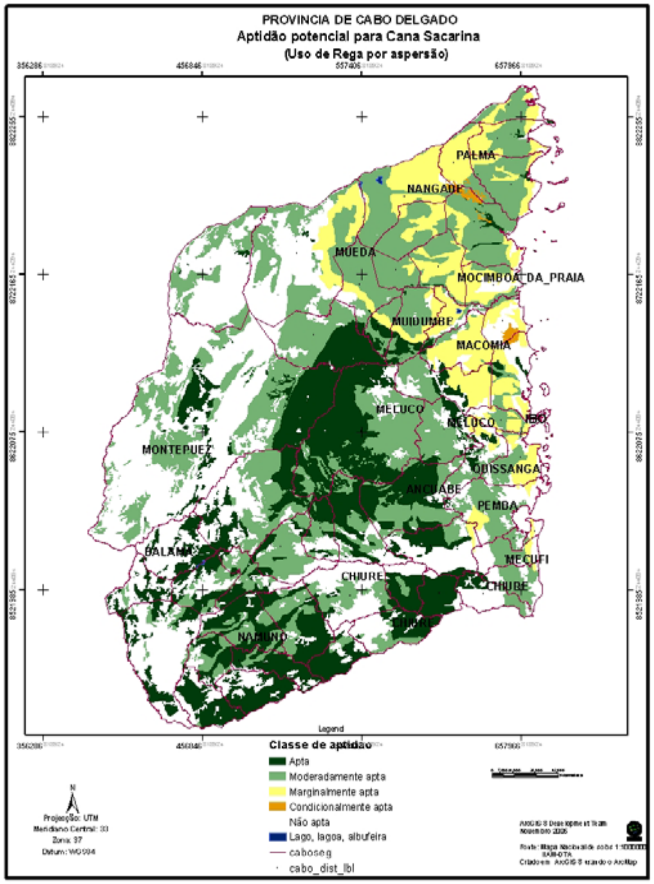
Continued next page / Continuação na siguiente página

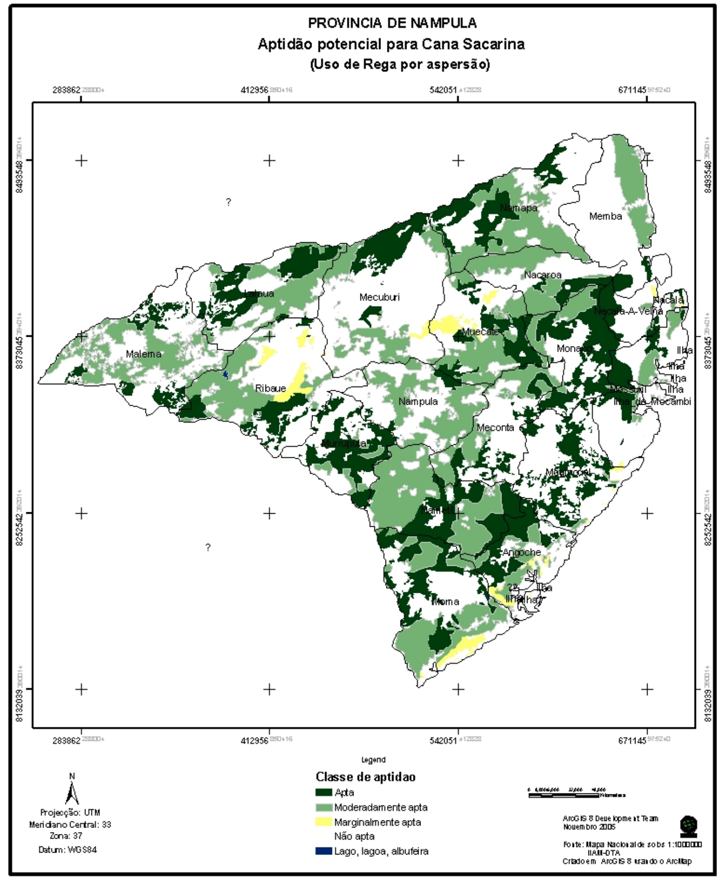
Anexo D.1: National Sugar Production, 1970-2006, continued
Anexo D.1: Produção Nacional de Açúcar, 1970-2006, continuação

Ano	Área Plantada (has)	Area Cortada (has)	Cana Moida (tons)	Rendimento Agricola (tons/há)	Produção Açúcar (tons)	Produção Melaço (tons)	Rendimento Industrial (%)	TC:TA
1992	2,248	3,941	151,070	38.3	13,224	6,060	8.8	11.42
1993	2,930	4,363	184,502	42.3	15,554	5,250	8.4	11.86
1994	-	4,761	233,950	49.1	19,214	5,764	8.2	12.18
1995	4,590	6,620	313,239	47.3	28,351	14,646	9.1	11.05
1996	5,331	6,861	315,850	46.0	29,288	11,175	9.3	10.78
1997	7,442	6,240	278,939	44.7	25,229	11,237	9.0	11.06
1998	10,674	7,266	368,675	50.7	38,555	14,167	10.5	9.56
1999	11,896	8,462	469,456	55.5	50,745	19,587	10.8	9.25
2000	14,540	7,900	397,276	50.3	39,035	15,844	9.8	10.18
2001	22,426	11,772	675,623	57.4	67,269	28,749	10.0	10.04
2002	27,806	24,006	1,586,262	66.1	171,108	55,378	10.8	9.27
2003	30,245	27,227	1,940,799	71.3	212,194	69,507	10.9	9.15
2004	32,635	*28,696*	*1,873,262*	*65.3*	*205,114*	*66,079*	*11%*	*9.13*
2005	32,858	31,199	2,246,985	*72.0*	265,478	81,452	*12%*	*8.46*
2006	34,693	31,874	2,060,317	*64.6*	242,525	69,128	*12%*	*8.50*

Source: CEPAGRI. Based on survey data reported by the sugarmills. Not all mills responded with data, hence these data are incomplete.
Fonte: CEPAGRI. Basados nos dados do inquérito feito ás usinas. Não responderam tudas as usinas, assim os dados não estão completos.

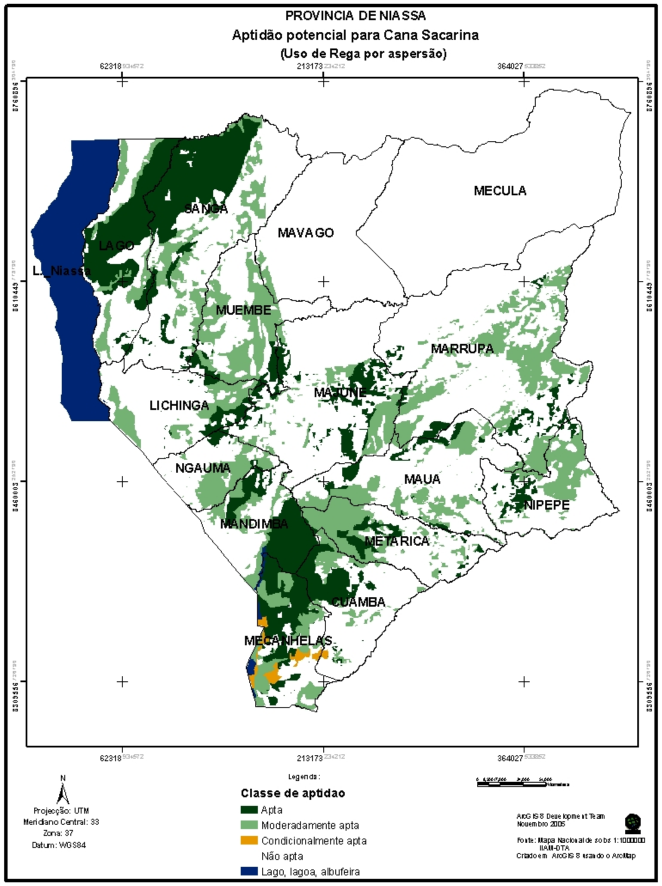
Annex D.2: Aptitude for sugarcane cultivation
Anexo D.2: Aptidão para cultivo de cana-de-açucar

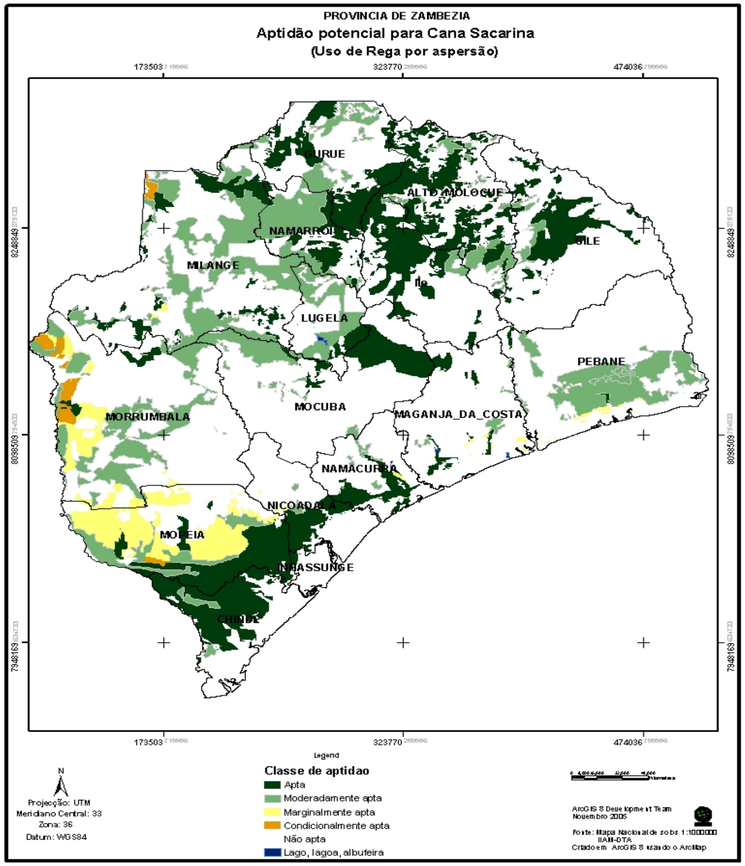




Source/Fonte: CEPAGRI

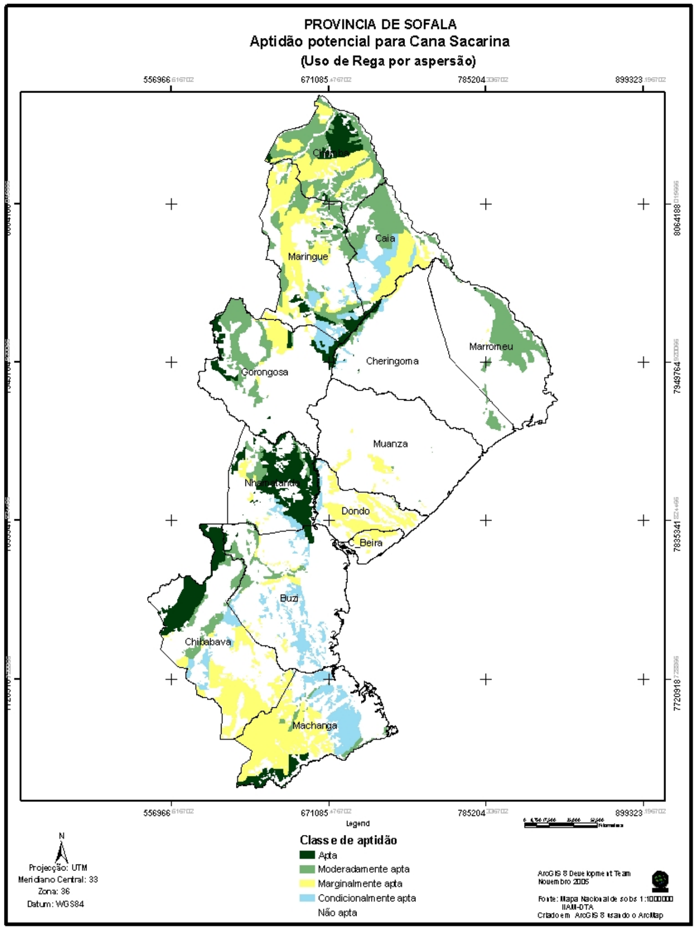
Annex D.2: Aptitude for sugarcane cultivation, continued
Anexo D.2: Aptidão para cultivo de cana-de-açucar, continuação

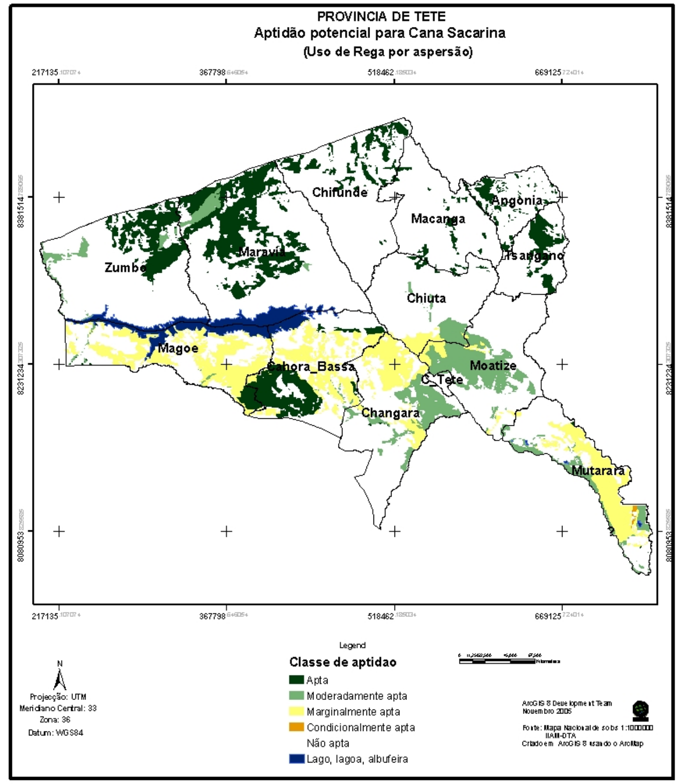




Source/Fonte: CEPAGRI

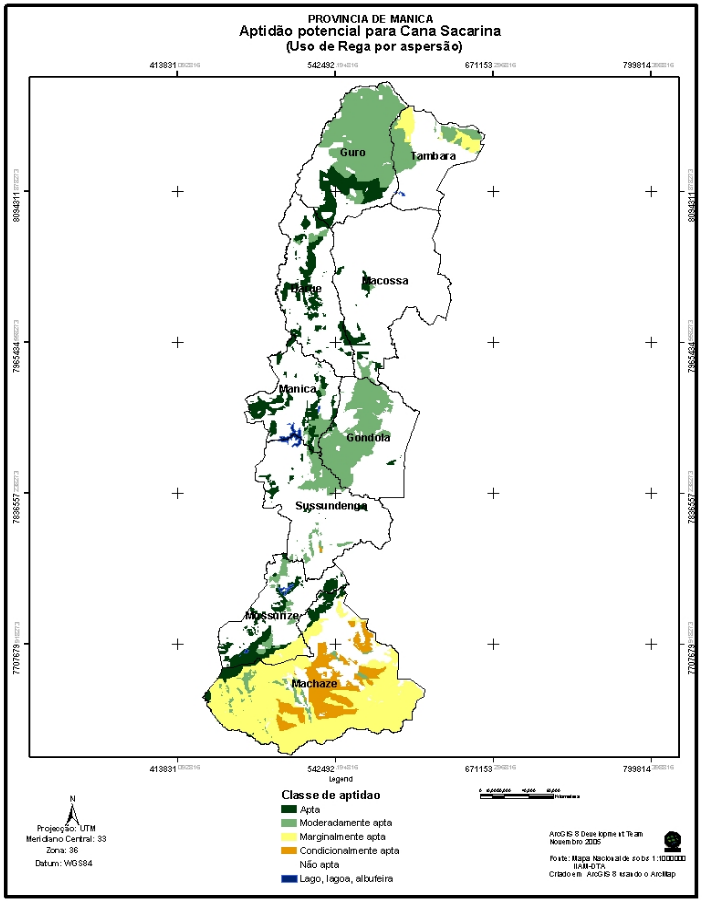
Annex D.2: Aptitude for sugarcane cultivation, continued
Anexo D.2: Aptidão para cultivo de cana-de-açucar, continuação

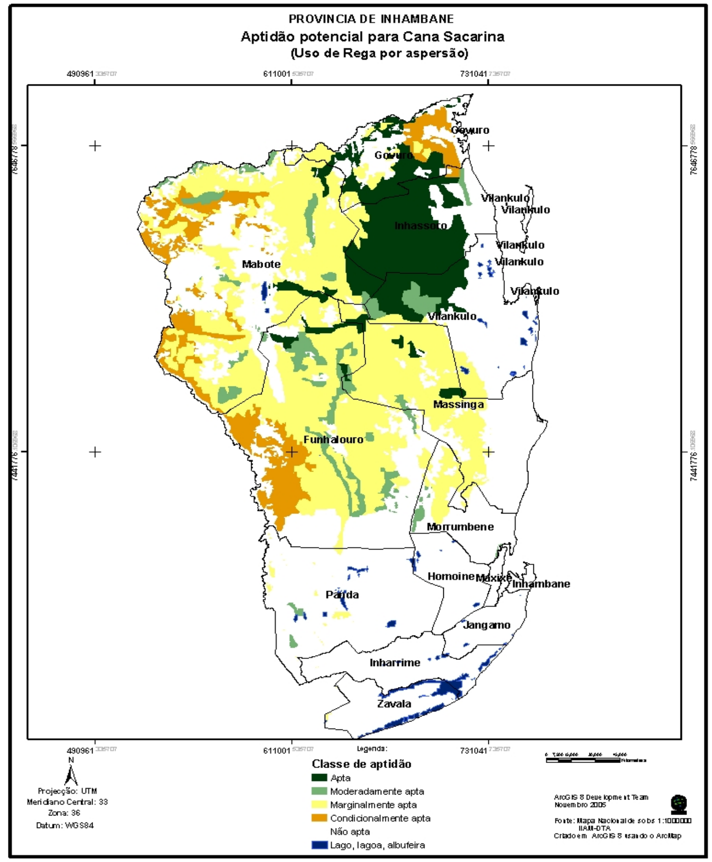




Source/Fonte: CEPAGRI

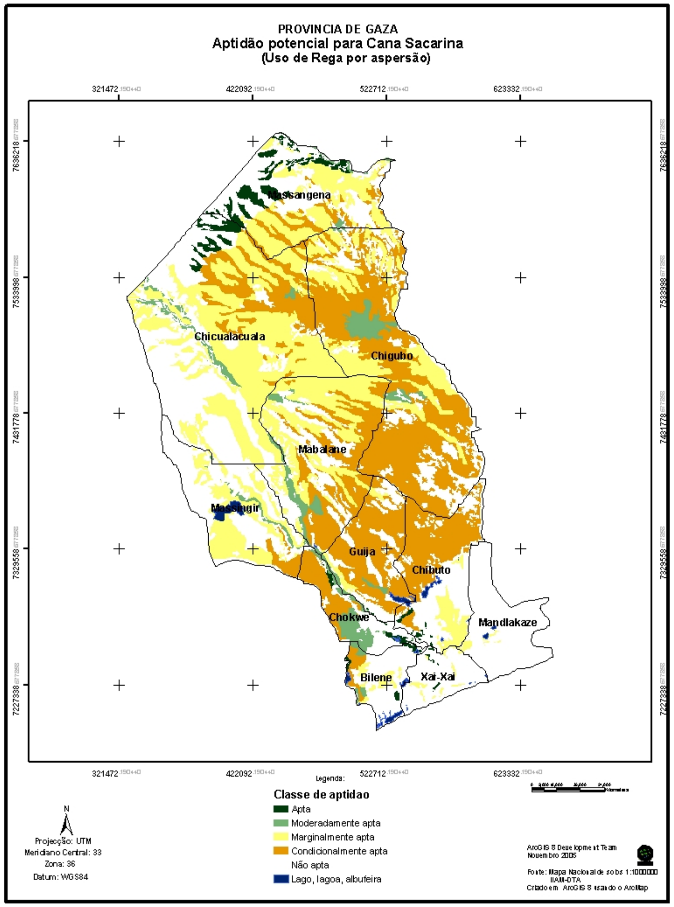
Annex D.2: Aptitude for sugarcane cultivation, continued
Anexo D.2: Aptidão para cultivo de cana-de-açucar, continuação

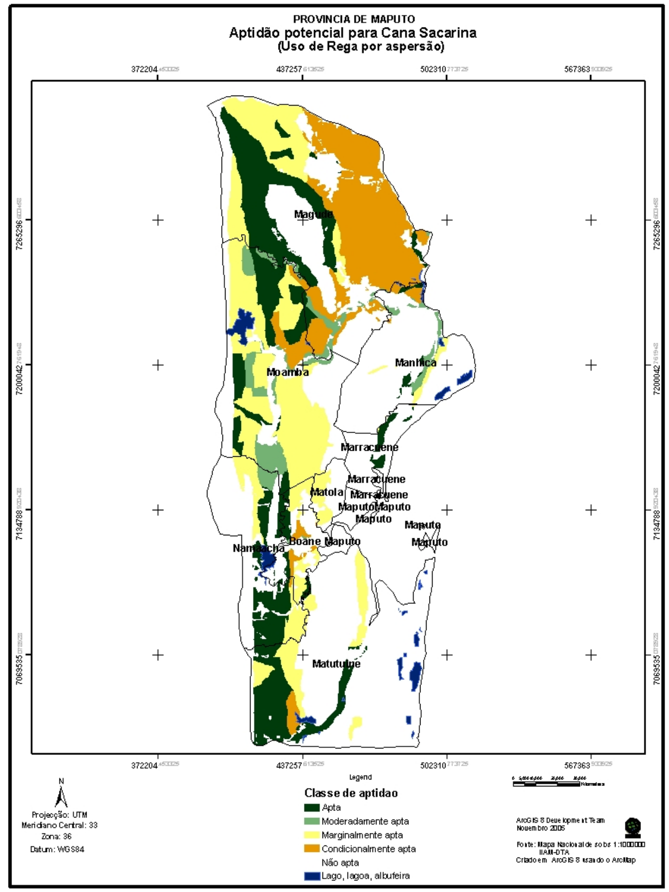




Source/Fonte: CEPAGRI

Annex D.2: Aptitude for sugarcane cultivation, continued
Anexo D.2: Aptidão para cultivo de cana-de-açucar, continuação





Source/Fonte: CEPAGRI

Annex D.3: Areas of Coconut Cultivation
Anexo D.3: Areas de Cultivo de Côco

Presence of Coconut / Presença de Côco

Annex D.4: Areas of Coconut Cultivation
Anexo D.4: Areas de Cultivo de Cana-de-Açúcar

Presence of Sugar Cane / Presença de cana-de-açúcar

Annex E: Agricultural production data for some crops
Anexo E: Dados de produção de alguns produtos agrícolas

SORGHUM / MAPIRA

Províncias	Produção (Ton)													
	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	001/002	002/003	003/004	004/005	005/006
Total	142,787	163,710	243,000	249,000	262,491	317,145	326,350	252,460	313,792	313,643	314,589	331,035	307,543	338,693
Cabo Delgado	20,226	22,514	37,000	24,000	27,164	34,245	34,708	28,606	36,931	49,805	48,165	49,305	56,126	57,547
Niassa	13,957	13,298	24,000	21,000	23,028	24,816	23,363	25,335	29,146	28,203	26,907	27,584	31,992	34,002
Nampula	42,498	43,628	73,000	78,000	85,827	90,122	89,064	63,162	79,058	83,828	83,828	84,809	91,903	97,205
Zambezia	16,219	22,096	33,000	35,000	33,410	44,512	44,948	41,647	45,888	48,409	49,160	49,651	46,624	48,066
Tete	18,610	13,660	10,000	17,000	20,463	31,618	42,297	24,232	31,115	29,119	26,882	30,077	18,743	27,589
Manica	10,373	14,057	14,000	19,000	19,761	28,132	28,566	23,279	30,708	23,087	25,741	29,298	27,380	34,097
Sofala	13,906	23,452	34,000	35,000	32,165	39,781	40,146	29,549	41,004	33,562	40,841	43,052	23,373	24,146
Inhambane	6,045	9,157	14,000	17,000	14,818	15,042	15,695	12,327	13,172	11,259	8,580	12,453	10,176	14,498
Gaza	639	1,674	3,000	2,000	4,994	7,985	6,728	4,056	6,290	5,744	4,047	4,355	1,228	1,542
Maputo	314	174	1,000	1,000	861	892	835	267	480	627	438	451	0	0

Source:/Fonte: Food Security Early-warning Department /Depto de Aviso Prévio para a Segurança Alimentar

Annex E: Agricultural production data for some crops
Anexo E: Dados de produção de alguns produtos agrícolas

CASSAVA / MANDIOCA

Províncias	Produção (Ton)													
	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06
Total	3,511	3,294	4,178	4,733	5,336	5,638	5,552	5,361	6,292	6,244	6,149	6,412	6,634	7,551
Cabo Delgado	498	525	592	665	736	760	784	811	1,011	1,094	1,203	1,236	1,261	1,468
Niassa	98	83	108	120	140	138	122	127	150	162	179	183	211	220
Nampula	1,878	1,555	1,984	2,317	2,555	2,654	2,689	2,451	2,605	2,593	2,221	2,248	2,216	2,849
Zambezia	679	829	1,066	1,146	1,351	1,490	1,461	1,460	1,593	1,776	1,965	2,009	2,080	2,147
Tete	6	4	3	3	6	6	7	6	7	7	7	8	9	9
Manica	2	1	3	3	3	5	5	4	7	7	7	8	11	12
Sofala	35	41	57	63	65	60	59	44	66	78	81	91	96	98
Inhambane	212,	199	255	293	331	341	295	295	635	315	347	403	419	483
Gaza	88	46	92	101	123	157	106	143	187	179	123	195	200	230
Maputo	12	6	18	18	22	23	18	17	33	29	12	25	28	30

Source:/Fonte: Food Security Early-warning Department /Depto de Aviso Prévio para a Segurança Alimentar

Annex E: Agricultural production data for some crops
Anexo E: Dados de produção de alguns produtos agrícolas

PEANUT/ AMENDOIM

Províncias	Produção (Ton)													
	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	001/002	002/003	003/004	004/005	005/006
Total	49,526	73,654	102,000	117,000	126,214	142,836	147,001	114,517	110,621	111,175	109,915	132,068	131,886	145,584
Cabo Delgado	7,503	11,011	17,000	11,000	10,829	15,551	15,718	12,849	14.774	17,693	18,050	23,856	24,402	25,185
Niassa	1,153	1,015	2,000	2,000	2,081	1,688	1,559	1,512	1.535	1,757	1,792	1,856	2,168	2,192
Nampula	16,099	23,713	32,000	37,000	45,478	45,200	41,291	37,819	33.353	33,318	34,027	36,892	40,586	45,265
Zambezia	5,927	8,655	14,000	16,000	16,992	21,054	20,722	18,400	19.089	18,895	19,373	20,893	21,095	22,541
Tete	2,224	1,482	2,000	3,000	4,478	5,279	16,466	3,613	5.183	5,158	4,817	6,724	6,952	7,160
Manica	825	997	1,000	2,000	2,114	2,174	2,647	2,265	2.761	1,788	1,210	1,680	1,785	2,011
Sofala	979	1,901	3,000	4,000	3,519	3,729	3,651	2,416	3.438	3,631	3,411	3,820	3,979	4,075
Inhambane	9,672	18,857	24,000	33,000	28,166	33,010	31,596	26,413	19.65	18,880	19,654	19,908	18,337	21,012
Gaza	2,880	4,150	4,000	5,000	7,574	10,247	8,445	6,840	7.504	6,375	4,259	13,022	9,521	11,896
Maputo	2,264	1,873	3,000	4,000	4,983	4,904	4,906	2,390	3.334	3,680	3,322	3,417	3,061	4,246

Source:/Fonte: Food Security Early-warning Department /Depto de Aviso Prévio para a Segurança Alimentar

Annex F: Description of methodology used to prepare energy balance

This methodological note provides more detail on the approach employed in Chapter 4 to arrive at estimates of the potential emissions reductions from cultivation and utilization of different biofuels feedstocks.

To prepare the energy balance, values for the following parameters for each agricultural product listed above were converted to Terajoules (TJ):

- *Energy consumption*: (i) energy consumption due to fossil fuel use, including agricultural and industrial operations; (ii) electrical energy consumption from the grid; and (iii) electrical energy consumption due to the production of fertilizers;

- *Energy production*: (i) potential of electrical energy production coming from residual biomass; (ii) biofuel production use coming from biomass.

In order to calculate the energy balance, initially all values within consumption and production are added, then the total value of energy consumed is subtracted from the total value of energy produced. The result is positive when energy generation exceeds energy consumed and negative when energy consumed exceeds energy generated. The purpose of this section is to present how the values in the energy balance calculation were obtained, how much energy is produced and how much energy is consumed for each item considered.

Energy consumed. The first item presented in this topic refers to the consumption of fossil fuels, in particular diesel used in agricultural and industrial operations for the products presented. Even though it was not possible to quantify these values during the field survey carried out in Mozambique, it is important to recognize two important aspects of the energy balance calculation: (i) despite the low diesel consumption due to a small degree of agricultural mechanization, emissions still occur; (ii) diesel may be considered as a fuel option for industrial use to generate heat as well as a source of electrical power.

Aside from the reasons presented, the calculation of diesel consumption also allows for the preparation of a sensitivity analysis, which is relevant in the final result of energy balance.

Based on the foregoing for Scenario 1 of agricultural productivity, consumption values of 5,000 liters/year and 10,000 liters/year for agricultural and industrial operations respectively were adopted for all products. For Scenario 2, the values were multiplied by the percentage increase in agricultural productivity of each product. (Note: Graph 1 was deleted in AV’s corrections, therefore I removed this last phrase)

After establishing the volume of diesel consumed, the next step is to quantify the energy content. To do this, incorporate the density of diesel and its calorific value, as done in Equation 1:

$$E_{do} = V_{do} * D_{do} * PCI_{do}, \text{ where:} \qquad \text{Equation 1}$$

- E_{do} – Energy content in the volume of diesel (TJ);
- V_{do} – Volume of diesel (liters/year);
- D_{do} – Density of diesel (tons/liter);
- PCI_{do} – Lower calorific value for diesel (TJ/ton).

Electrical energy consumed from the grid needs to be accounted for in the energy emissions balance. In Scenario 1, the value of 35,325.33 MWh/year for all products is equivalent to the average of the three years of total consumption of electrical energy for a sugar producer in Mozambique.

The second scenario results in a value that is twice the electrical energy consumption of Scenario 1. The assumption is that this value corresponds to double the capacity for the crop period. To convert the electrical energy measure to TJ, use the following formula:

1TJ = 280 MWh

For the next step, it is necessary to calculate electrical energy consumption from fertilizer production for each agricultural product. For this calculation, the relevant values are shown in Table 1 for the NPK-type fertilizers.

Table 1: Energy Consumption of NPK-Type Fertilizer

Nitrogen	58.14	MJ/kg
Phosphorus	6.98	MJ/kg
Potassium	4.65	MJ/kg

Source: Brazilian Magazine of Energy, Agriculture and Environment, 2005

Since the values in the table are expressed in units of energy/kg, it is necessary to determine the quantity of fertilizer consumed in kg for each agricultural product. Data obtained in Mozambique indicate that the application of NPK-type fertilizer is 100 kg/ha for all products.

For Scenario 2 of agricultural productivity, the value of 100/kg/ha is multiplied by the percent increase in agricultural production. Therefore, starting from a baseline of 1,000 ha, the energy calculation is carried out in Equation 2:

$$E_{NPK} = V_{apl} * B_C * 58.14/10^6, \text{ where:} \qquad \text{Equation 2}$$

- E_{NPK} – energy consumed (TJ);
- B_C – calculation base (1,000 ha)
- V_{apl} – volume of fertilizer applied (kg/ha);
- 58.14 – consumption equivalent of nitrogen (MJ/kg –Table 1);
- 10^6 – conversion of MJ into TJ.

In order to calculate energy consumption for phosphorus (P) and potassium (K), Equation 2 is used while integrating its respective consumption values shown in Table 1.

Energy produced. To calculate the potential generation of electrical energy, initially assigned an efficiency of industrial processing as 80%. That is to say, for each ton processed, 800 kg will be converted in products and 200 kg will be discarded as residuals, generating a biomass used for the electrical energy production for industry.

The adoption of 80% as an assumption provides for a conservative scenario. Since the higher levels of production efficiency result in lower volumes of waste generated, and consequently, less biomass quantity available for electrical energy generation.

Another important parameter considered in the calculation for the potential of energy generation is the conversion efficiency. Assuming that a Rankine cycle will be the technology used, a conversion factor of 20% is incorporated due to this technology's wide availability in the market and flexibility in terms of its operational parameters.[1]

Using the above specifications, an electrical energy generation potential is calculated in Equation 3:

η = W/(mb*PCI), where: Equation 3

- η – Conversion efficiency, expressed in % (value used - 20%);
- mb – Biomass consumption (t/year – converted to kg/s)[2];
- PCI – Minimum calorific value of biomass waste, expressed in kcal/kg (converted to kJ/kg);
- W – Installed capacity, expressed in kW (parameter to be calculated).

The quantity of electrical power generated was calculated by multiplying the annual operation time of the industry by the potential already calculated in Equation 3. The results referring to generation potential of electrical energy for each type of agricultural product are shown in Table 2 and Table 3, for productivity Scenarios 1 and 2.

In addition to electrical energy generation, biofuel use will also be accounted for in energy production. The assumption is that 80% of annual agricultural production will be converted into biofuel. The sum of the energy production quantity of biofuel is calculated in Equation 4:

Ebio = Vbio*PCI bio, where: Equation 4

- Ebio – Energy contained in biofuel;

[1] The average efficiency of a Rankine cycle is approximately 30% according to parameters provided by the Brazilian government. This value implies use of large-scale boilers that require high investment. For this reason, the adopted efficiency level corresponds to a cycle with higher commercial availability.
[2] The conversion of biomass consumption into kg/s is due to the fact that the unit W is obtained from the quotient J/s.

- PCIbio – Lower calorific value of biofuel (TJ/ton);
- Vbio- Volume of biofuel produced (ton/year).

The volume of biofuel produced is displayed in Table 4 and Table 5.

Table 2: Electrical energy generation potential from biomass waste

Agricultural product	Scenario 1				
	Productivity (t/ha)	Agricultural Production (ton/year)[3]	Generation of Residual Biomass (ton/year)	Lower Calorific Value (kcal/kg)	Energy Generation Potential from Residual Biomass (MWh/year)
Sugar Cane	78	78,000	11,700	1,700	4,626,414.00
Cotton	0.75	750	150	3,000	104,670.00
Peanut	0.3	300	60	3,000	41,868.00
Cassava	5	5,000	1,000	1,500	348,900.00
Sorghum	0.7	700	140	1,500	48,846.00
Corn	1	1,000	200	3,000	139,560.00
Sesame	0.4	400	80	1,500	27,912.00
Sunflower	0.45	450	90	1,500	31,401.00
Soybean	0.7	700	140	3,000	97,692.00
Jatropha	3	3,000	600	1,500	209,340.00

Source: Econergy, 2007

Table 3: Electrical Energy Generation Potential from Residual Biomass

Agricultural Product	Scenario 2				
	Productivity (t/ha)	Agricultural Production (ton/year)	Generation of Residual Biomass (ton/year)	Lower Calorific Value (kcal/kg)	Energy Generation Potential from Residual Biomass (MWh/year)
Sugar Cane	102	102,085	15,312.75	1,700	6,054,967.61
Cotton	2.5	2,500	500	3,000	348,900.00
Peanut	2	2,000	400	3,000	279,120.00
Cassava	10	10,000	2,000	1,500	697,800.00
Sorghum	2	2,000	400	1,500	139,560.00
Corn	6	6,000	1,200	3,000	837,360.00
Sesame	1.5	1,500	300	1,500	104,670.00
Sunflower	1.5	1,500	300	1,500	104,670.00
Soybean	3	3,000	600	3,000	418,680.00
Jatropha	4	4,000	800	1,500	279,120.00

Source: Econergy, 2007

[3] The value is calculated by multiplying agricultural productivity by the area given in this study, which corresponds to 1,000 ha.

Table 4: Volume of biofuel production

Agricultural Product	Scenario 1			
	Productivity (t/ha)	Agricultural Production (ton/year)	Biofuel Production (ton/year)	Lower Calorific Value of Biofuel (kcal/kg)
Sugar Cane	78	78,000	1,164	8,560
Cotton	0.75	7,50	0	9,104
Peanut	0.3	300	0	9,104
Cassava	5	5,000	4,000	8,560
Sorghum	0.7	700	560	8,560
Corn	1	1,000	800	8,560
Sesame	0.4	400	0	9,104
Sunflower	0.45	450	360	9,104
Soybean	0.7	700	560	9,104
Jatropha	3	3,000	2,400	9,104

Source: Econergy, 2007

Table 5: Volume of biofuel production

Agricultural Product	**Scenario 2**			
	Productivity (t/ha)	**Agricultural Production (ton/year)**	**Biofuel Production (ton/year)**	**Lower Calorific Value of Biofuel (kcal/kg)**
Sugar Cane	102.00	102,085.00	1,523.66	8,560
Cotton	0.98	980.77	0.00	9,104
Peanut	0.39	392.31	0.00	9,104
Cassava	6.54	6,538.46	5,230.77	8,560
Sorghum	0.92	915.38	732.31	8,560
Corn	1.31	1,307.69	1,046.15	8,560
Sesame	0.52	523.08	0.00	9,104
Sunflower	0.59	588.46	470.77	8,560
Soybean	0.92	915.38	732.31	8,560
Jatropha	3.92	3,923.08	3,138.46	8,560

Source: Econergy, 2007

Results obtained from energy balance

The results obtained indicate that agricultural productivity is an essential factor in yielding a positive energy balance for all products. This is indicated in Table 6 and Table 7, which takes into account the increase of electrical energy from the grid and the increase in consumption of fossil fuels.

As shown in Table 6, it is apparent that in Scenario 1 the sesame and sunflower agricultural products result in a negative balance. Sesame shows a deficit of 34TJ while sunflower has a deficit of 7.82 TJ. These results can be directly attributed to low agricultural productivity, since in the case of sesame, it is important to note that its use does not include the possibility of electric generation using biomass waste.

Table 6: Results of energy balance for Scenario 1 of agricultural productivity

Agricultural Product	**Energy Consumed**				**Energy Produced**			**Energy Balance (TJ)**
	Energy Consumed from Diesel Use (TJ)	Energy Consumed from Electrical Grid (TJ)	Energy Consumed from Fertilizer Production (TJ)	Total Energy Consumed (MJ)	Energy Generation Potential due to Residual Biomass (TJ)	Energy Produced from Biofuel Use (TJ)	Total Energy Produced (TJ)	
Sugar cane	0.55	126.16	6.98	133.68	16,522.91	41.72	16,564.63	16,430.95
Cotton	0.55	126.16	6.98	133.68	373.82	0.00	373.82	240.14
Peanut	0.55	126.16	6.98	133.68	149.53	0.00	149.53	15.84
Cassava	0.55	126.16	6.98	133.68	1,246.07	143.36	1,389.43	1,255.74
Sorghum	0.55	126.16	6.98	133.68	174.45	20.07	194.52	60.84
Corn	0.55	126.16	6.98	133.68	498.43	28.67	527.10	393.41
Sesame	0.55	126.16	6.98	133.68	99.69	0.00	99.69	(34.00)
Sunflower	0.55	126.16	6.98	133.68	112.15	13.72	125.87	(7.82)
Soybean	0.55	126.16	6.98	133.68	348.90	21.35	370.25	236.56
Jatropha	0.55	126.16	6.98	133.68	747.64	91.48	839.12	705.44

Source: Econergy, 2007

Table 7: Results of energy balance for Scenario 2 on agricultural productivity

Agricultural Product	Energy Consumed				Energy Produced			**Energy Balance (TJ)**
	Energy Consumed from Diesel Use (TJ)	Energy Consumed from Electrical Grid (TJ)	Energy Consumed from Fertilizer Production (TJ)	**Total Energy Consumed (MJ)**	Energy Generation Potential due to Residual Biomass (TJ)	Energy Produced from Biofuel Use (TJ)	**Total Energy Produced (TJ)**	
Sugar cane	0.71	252.32	9.12	**262.16**	21,624.88	54.61	**21,679.49**	**21,417.33**
Cotton	1.82	252.32	23.26	**277.40**	1,246.07	0.00	**1,246.07**	**968.67**
Peanut	3.64	252.32	46.51	**302.48**	996.86	0.00	**996.86**	**694.38**
Cassava	1.09	252.32	13.95	**267.37**	2,492.14	286.71	**2,778.85**	**2,511.49**
Sorghum	1.56	252.32	19.93	**273.82**	498.43	57.34	**555.77**	**281.95**
Corn	3.28	252.32	41.86	**297.46**	2,990.57	172.03	**3,162.60**	**2,865.14**
Sesame	2.05	252.32	26.16	**280.53**	373.82	0.00	**373.82**	**93.29**
Sunflower	1.82	252.32	23.26	**277.40**	373.82	45.74	**419.56**	**142.16**
Soybean	2.34	252.32	29.90	**284.56**	1,495.29	91.48	**1,586.77**	**1,302.20**
Jatropha	0.73	252.32	9.30	**262.35**	996.86	121.97	**1,118.83**	**856.48**

Source: Econergy, 2007

Regarding Scenario 2, a 31% increase in the consumption of diesel for the industrial process was assumed. In addition, other than sesame and sunflower, in the cases of peanut and sorghum, both resulted in an energy deficit equal to 66.62 and 7.79 TJ respectively.

In the case of peanuts, other than low productivity, this result may be attributed to the fact that the product is not used in the production of biofuels. For the case of sorghum, meanwhile, the energy deficit can be directly linked to its low productivity.

A sensitivity analysis was carried out in Scenario 2 of agricultural productivity, which helps to assess the action of each agricultural activity by taking into account three different hypotheses:

- Hypothesis 1 – Simultaneous increase in consumption of electrical energy from the grid and consumption of fossil fuels;
- Hypothesis 2 – Increase in the consumption of electrical energy from the grid;
- Hypothesis 3 – Increase in the consumption of fossil fuel.

For each of the hypotheses, increases of 20%, 40%, 60%, 80% and 100% for every agricultural product were added to the results of the energy balance and displayed in Table 7.

For Hypothesis 1, apart from the products that already show an energy deficit, this analysis demonstrates that soybean and cotton generate energy deficits when consumption of electricity and diesel increase by 100%.

When considering Hypothesis 2, only taking into account energy consumption from the electrical grid, the sensitivity analysis demonstrates the same conclusion, which is shown in Table 9.

Illustrated in Table 10, an increase in consumption of electrical energy from the grid appears as a larger part of the energy balance, while at the same time the consumption of fossil fuels results in a small reduction in the final energy balance though not enough to cause an energy deficit, as shown with cotton and soybean for example .

Description of Methodology to Obtain Emissions Balance in Mozambique

The methodology for calculating the GHG emissions balance is similar to the energy balance. First, all emission sources are identified and totaled. Then, all avoided emissions are totaled and subtracted from the total emissions source. The evaluation of this result, whether positive or negative, is similar to what is described in the energy balance.

For agricultural activities in Mozambique, the following categories of emission sources and avoided emissions apply:

- Emissions occurred: (i) fossil fuel consumption of agricultural activities; (ii) fossil fuel consumption due to production of each type of biomass; (iii) electrical energy consumption for industrial processing of each type of biomass; and (iv) carbon dioxide emissions coming from nitrogenous fertilizers (NPK and urea).

Table 8: Sensitivity analysis – increase in consumption of electricity and fossil fuels

Simultaneous Increase in Electrical Energy Consumption from the Grid and Fossil Fuel Consumption (%)	Sugar Cane	Cotton	Peanut	Cassava	Sorghum	Corn	Sesame	Sunflower	Soybean	Jatropha
	Energy Balance (TJ)									
Situation from Table 42	21,417.3	968.67	694.38	2,511.49	281.95	2,865.14	93.29	142.16	1,302.20	856.48
20%	21,366.7	917.84	689.70	2,460.80	231.18	2,814.02	42.41	91.33	1,251.27	805.87
40%	21,316.1	867.01	638.51	2,410.12	180.40	2,762.90	(8.46)	40.50	1,200.34	755.26
60%	21,265.5	816.18	587.32	2,359.44	129.62	2,711.78	(59.34)	(10.33)	1,149.40	704.64
80%	21,214.9	765.36	536.12	2,308.75	78.85	2,660.66	(110.21)	(61.15)	1,098.47	654.03
100%	21,164.3	714.53	484.93	2,258.07	28.07	2,609.54	(161.08)	(111.98)	1,047.54	603.42

Source: Econergy, 2007

Table 9: Sensitivity analysis – increase in consumption of electricity from the grid

Simultaneous Increase in Electrical Energy Consumption from the Grid and Fossil Fuel Consumption (%)	Sugar Cane	Cotton	Peanut	Cassava	Sorghum	Corn	Sesame	Sunflower	Soybean	Jatropha
	Energy Balance (TJ)									
Situation from Table 42	21,417.33	968.67	694.38	2,511.49	281.95	2,865.14	93.29	142.16	1,302.20	856.48
20%	21,366.86	918.21	667.17	2,461.02	231.49	2,814.67	42.82	91.70	1,251.74	806.01
40%	21,316.40	867.74	639.96	2,410.56	181.02	2,764.21	(7.64)	41.23	1,201.27	755.55
60%	21,265.93	817.28	589.50	2,360.09	130.56	2,713.74	(58.11)	(9.23)	1,150.81	705.08
80%	21,215.47	766.81	539.03	2,309.63	80.09	2,663.28	(108.57)	(59.70)	1,100.34	654.62
100%	21,165.01	716.35	488.57	2,259.16	29.63	2,612.81	(159.04)	(110.16)	1,049.88	604.15

Source: Econergy, 2007

Table 10: Sensitivity analysis – increase in fossil fuel consumption

Increase in Consumption of Fossil Fuel (%)	Sugar Cane	Cotton	Peanut	Cassava	Sorghum	Corn	Sesame	Sunflower	Soybean	Jatropha
	Energy Balance (TJ)									
Situation from Table 42	21,417.33	968.67	694.38	2,511.49	281.95	2,865.14	93.29	142.16	1,302.20	856.48
20%	21,417.19	968.31	716.91	2,511.27	281.64	2,864.48	92.88	141.80	1,301.73	856.33
40%	21,417.04	967.94	716.18	2,511.05	281.33	2,863.83	92.47	141.43	1,301.26	856.18
60%	21,416.90	967.58	738.71	2,510.83	281.02	2,863.17	92.06	141.07	1,300.80	856.04
80%	21,416.76	967.22	737.98	2,510.61	280.71	2,862.52	91.65	140.71	1,300.33	855.89
100%	21,416.62	966.85	737.25	2,510.39	280.39	2,861.86	91.24	140.34	1,299.86	855.75

Source: Econergy, 2007

- Emissions avoided: (i) potential of electrical energy generation for each type of residual biomass; (ii) emissions avoided due to use of biofuels as a substitute of diesel and gasoline.

Calculation of GHG emissions balance

For the calculation of GHG emissions balance, energy quantities must be associated with their respective emission factors, which are provided by the IPCC.[4] These factors refer to different types of fossil fuel use.

For comparison, the calculation of emissions balance used the same values assigned for diesel consumption that were applied to energy balance, retaining the same proportions as fuel consumption in Scenarious 1 and 2 for agricultural productivity.

Calculation of GHG emissions occurred. In the case of electrical energy, the associated emissions factor, expressed in tCO_2 eq/MWh, must be calculated for each country according the breakdown of its subsystems. In calculating this figure, the methodology "ACM 0002 Consolidated methodology for grid-connected electricity generation from renewable sources - Version 6" is used, as approved by the UNFCCC[5] and applied in projects for the Clean Development Mechanism.

This calculation takes into account all existing energy sources in Mozambique by adding the amount of energy produced per generated source. Next, it is necessary to calculate the consumption of fossil fuels used for the generation of electrical energy and calculate its respective emissions. Then, figure out the quotient of total energy generated in the country and the volume of carbon dioxide emissions equivalent.

Table 11: Data required for the calculation of grid emissions factor

Conversion efficiency	20%	(assumed)
Operation time	8760	hours/year
Capacity factor	80%	(assumed)
Natural Gas Calorific Value	0.04333	TJ/ton
Natural Gas Emissions Factor	15.3	tC/TJ
Specific Consumption of Diesel	0.3000	liters/kWh (ANEEL)
Specific Mass of Diesel	0.00084	ton/l

Source: ANEEL, IPCC e BEN[6]

[4] IPCC – Intergovernmental Panel on Climate Change – emissions factors are available online at http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1wb1.pdf

[5] UNFCCC – United Nations Framework Convention on Climate Change methodology ACM 0002 available online at: http://cdm.unfccc.int/UserManagement/FileStorage/CDMWF_AM_BW759ID58ST5YEEV6WUCN5744MN763

[6] ANEEL – Agência Nacional de Energia Elétrica do Brasil, organization responsable for the regulation of the Brazilian electrical sector indicates a specific consumption of diesel for energy generation at 0.3 liters/kWh. BEN – Balanço Energático Nacional (National Energy Balance) – Document published by the Ministry of Energy and Mines of Brazil

In the case of Mozambique, the data of electrical energy generated for this calculation come from a statistical energy study, elaborated by the Ministry of Energy in collaboration with the Ministry of Planning and Development of Mozambique. The adopted premisses for this calculation of the emissions factor are displayed in Table 11, whereas the values of energy generated in the country are shown in Table 12.

Table 12: Production of electrical energy in Mozambique

Source	Plant	2000	2001	2002	2003	2004	2005
Hydro	HCB	9,397,700	11,583,500	12,411,400	10,626,600	11,559,400	13,105,022
	EdM	254,567	257,788	262,576	243,100	108,824	158,670
Thermal	Diesel	41,599	42,210	33,854	33,500	38,594	14,000
	Natural Gas	1,500	2,000	3,686	3,328	6,752	7,218
Total Energy Produced (MWh/yr)		9,697,366	11,887,499	12,713,518	10,908,531	11,715,574	13,286,915
Share of hydropower (%)		99.53%	99.61%	99.69%	99.64%	99.60%	99.83%

Source: Energy Statistics, 2007

In the analysis of Table 12, it is important to note the significance of hydro resources in Mozambique, which correspond to almost 100% of generation in the whole country. While it is true that not all of the hydropower produced in the country is actually consumed in Mozambique, given the significant exports of power from HCB to the SAPP, the requirements of the CDM methodology are such that this generation much be counted. This leads to a low emissions factor for Mozambique, equal to 0.0028 tCO_2 eq/MWh and creates a low fossil fuel consumption for the generation of electrical energy.

For diesel, the consumption values of electrical energy calculated in the emissions balance are the same values assigned in the calculation of the energy balance.

The calculation of emissions coming from fertilizer use is based on the procedures described by the IPCC[7] regarding emissions from nitrous oxide (N_2O), soil handled and later converted to CO_2 equivalent, and emissions from CO_2 coming from the use of urea.

This calculation considered two types of fertilizers used for agricultural activities in Mozambique, NPK and urea. In the case of NPK, CO_2 emissions are calculated as shown in Equation 5:

$$CO_{2NPK} = [(Q_{NPK} + Norg)*FE_N] * 310, \text{ where:} \qquad \text{Equation 5}$$

- CO_{2NPK} – Emissions coming from NPK use (tCO2 eq/year);
- Q_{NPK} – Total quantity of NPK applied (Kg/year);
- Norg – Quantity of organic nitrogen contained in soil (kN/year – a value of 10,000 was assumed in this case);
- FEN – Nitrogen emissions factor (value corresponds to 0.01 kg N2O/kg of N – IPCC);

[7] Disponível em http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf

- 310 – Global warming potential of N_2O (convert N_2O emissions to its CO_2 equivalent, IPCC).

Calculation of GHG emissions avoided. The analysis considered avoided emissions through use of biomass for generation of electricity and its use in the production of biofuels, as done in the energy balance.

To calculate avoided emissions from electricity generation using biomass, take the product of energy generated (as calculated in Equation 3 above) with the emissions factor from the grid, which equals 0.0028 tCO2 eq/MWh.

Emissions avoided through to biofuel use represents the quantity of fuel not consumed as a result of the provision of biofuels on the market. Therefore, it is necessary to calculate the volume of fossil fuels displaced, as shown in Equation 6:

$$Qcf = mbio*PCIbio/PCIcf, \text{ where:} \qquad \text{Equation 6}$$

- Qcf – Quantity of fossil fuel displaced;
- mbio – Volume of biofuel produced;
- PCIbio –Minimum calorific value of the biofuel;
- PCIcf – Minimum calorific value of fossil fuel.

Once the volume of fossil fuel substituted is quantified, the calculation of avoided emissions is shown in Equation 7:

$$tCO2\ eq/year = ccf*\rho*PCIcf*FEcf*(44/12), \text{ where:} \qquad \text{Equation 7}$$

- tCO2 eq/year – Tons per year of carbon dioxide emitted;
- ccf – Comsumption of fossil fuel (litros/ano)
- ρ – Specific gravity (tons/liter – to be used when fossil fuel consumed is expressed in liters/year);
- PCIcf – Minimum calorific value of fossil fuel (TJ/ton);
- FEcf – Fossil fuel emissions factor (TC/TJ);
- (44/12) – Ratio of the atomic masses of carbon dioxide and carbon, respectively.

AGÊNCIA NACIONAL DO PETRÓLEO, GÁS NATURAL E BIOCOMBUSTÍVEIS

EDITAL DE LEILÃO N.º 007/06 - ANP

A Agência Nacional do Petróleo, Gás Natural e Biocombustíveis – ANP, considerando a Resolução n.º 03, de 23 de setembro de 2005, do Conselho Nacional de Política Energética – CNPE, a Portaria n.º 483, de 03 de outubro de 2005, do Ministério de Minas e Energia, e a Resolução ANP nº 31, de 4 de novembro de 2005, divulga as regras e condições relativas a leilão de compra de biodiesel.

1. DO OBJETO DA COMPRA

1.1. cento e setenta mil metros cúbicos de biodiesel a serem entregues pelos fornecedores de biodiesel em tancagem própria ou de terceiros, observadas as especificações de qualidade constantes da Resolução ANP n.º 42, de 24 de novembro de 2004, publicada no Diário Oficial da União de 9 de dezembro de 2004, com retificação publicada em 19 de abril de 2005.

2. DAS DEFINIÇÕES

2.1. Produtor de biodiesel: agente autorizado pela ANP a exercer a atividade de produção de biodiesel em conformidade com a Resolução ANP n° 41, de 24 de novembro de 2004, detentor de Registro Especial da Secretaria da Receita Federal, nos termos da Instrução Normativa n.º 516, de 22 de fevereiro de 2005, e do selo "Combustível Social" instituído pelo Decreto n.º 5.297, de 6 de dezembro de 2004, na forma da Instrução Normativa n.º 01, de 5 de julho de 2005, do Ministério do Desenvolvimento Agrário - MDA.

2.2. Fornecedor de Biodiesel: produtor de biodiesel, conforme item 2.1, e sociedade detentora de projeto de produção de biodiesel, ambos reconhecidos pelo MDA, até o dia 24 de março de 2006, como detentor do selo "Combustível Social" ou possuidor dos requisitos necessários à obtenção do selo "Combustível Social", sendo neste último caso em conformidade com a Instrução Normativa n.º 2, de 28 de setembro de 2005, do referido Ministério.

2.3. Produtor de óleo diesel: agente autorizado pela ANP a exercer a atividade de refino e produção de óleo diesel, de que tratam as Portarias ANP n° 28, de 5 de fevereiro de 1999, e n ° 84, de 24 de maio de 2005.

2.4. Importador de óleo diesel: agente autorizado pela ANP a exercer a atividade de importação de óleo diesel.

2.5. Sistema "Licitações-e": serviço de comércio eletrônico que o Banco do Brasil S.A. disponibiliza na Internet, no endereço eletrônico www.licitacoes-e.com.br, para a realização de compras e contratações de serviços.

3. DOS ADQUIRENTES DO BIODIESEL A SER OFERTADO

3.1. A ANP indicará, no Anexo I deste Edital, o percentual de participação dos produtores e importadores de óleo diesel na aquisição do biodiesel ofertado, conforme previsto no art. 4º da Resolução ANP nº 31, de 4 de novembro de 2005.

3.2. Os produtores e importadores de óleo diesel com participação no mercado inferior a 1% (um por cento) poderão ser adquirentes por opção própria, respeitados os seus respectivos percentuais de compra, devendo comunicar à ANP o interesse em participar do certame até o dia 24 de março de 2006, pelo endereço eletrônico leilaobiodiesel@anp.gov.br

4. DA FINALIDADE DA COMPRA

4.1. O biodiesel arrematado destina-se à mistura com o óleo diesel de petróleo nas condições previstas na legislação vigente.

5. DO SISTEMA E DA MODALIDADE DE COMPRA

5.1. As aquisições de biodiesel tratadas neste Edital serão negociadas por intermédio do sistema “Licitações-e” do Banco do Brasil, cujas informações e instruções a respeito da sua utilização podem ser obtidas pelo endereço www.licitacoes-e.com.br ou por intermédio do portal www.bb.com.br.

5.2. O leilão será realizado por intermédio do sistema “Licitações-e” e conduzido por leiloeiro, indicado pela ANP, a quem caberá coordenar, decidir e ordenar o cumprimento das regras e medidas necessárias à sua realização.

5.3. O leiloeiro informará o preço máximo de referência do biodiesel, na posição FOB, com incidência, na forma da Lei nº 11.116, de 18 de maio de 2005, das contribuições PIS/PASEP e COFINS, sem ICMS, em reais por metro cúbico, na data e horário previstos no Anexo I do presente Edital, mediante a edição de mensagem eletrônica no sistema “Licitações-e”.

5.4. A partir do horário de início da fase de acolhimento de proposta, previsto no Anexo I do presente Edital, o fornecedor terá o prazo de até 2:00h (duas horas) ininterruptas para a apresentação de sua proposta no sistema “Licitações-e”.

5.5. Cada fornecedor de biodiesel participante do leilão deverá submeter uma única proposta fechada, composta por até 03 (três) ofertas individuais de preço, em conformidade com o item 5.5.5, e de quantidade para venda de biodiesel, com indicação do local de entrega do produto.

5.5.1. Para que seja iniciado o processamento das propostas no sistema “Licitações-e”, deverá, obrigatoriamente, ser preenchido o campo “Preço Unitário Proposto” com o valor correspondente ao preço máximo de referência indicado no item 5.3, em reais por metro cúbico de biodiesel, com duas casas decimais. Este valor não comporá as ofertas individuais de preço, prevalecendo, para todos os efeitos, as que constarem da proposta de que trata o item anterior.

5.5.2. A proposta contendo todas as ofertas, até o limite de 3 (três), deverá ser encaminhada em arquivo no formato *Zip*, conforme modelo do Anexo II do presente Edital.

5.5.3. O arquivo de que trata o item 5.5.2 deverá ser enviado eletronicamente mediante sua inclusão no sistema "Licitações-e", conforme procedimento operacional de encaminhamento das propostas. Não serão acatadas propostas encaminhadas por outro meio, eletrônico ou documental.

5.5.4. A quantidade total da proposta, resultante do somatório das quantidades das ofertas individuais que a compõem, não poderá ser superior à capacidade instalada anual de produção de biodiesel do proponente, computada, se for o caso, a sua expansão, ou, quando couber, à informada pelo MDA.

5.5.4.1. Para efeito de conversão da capacidade instalada de produção de biodiesel, de diária para anual, serão considerados 300 (trezentos) dias de operação por ano.

5.5.4.2. Caso o somatório das quantidades das ofertas individuais seja superior à capacidade instalada anual de produção, computada, se for o caso, a sua expansão, conforme disposto no item 5.5.4 do Edital, a quantidade excedente será desconsiderada da última oferta, permanecendo, entretanto, o preço indicado.

5.5.5. O preço de cada oferta individual, na posição FOB, incluindo PIS/PASEP e COFINS, sem ICMS, informado em reais por metro cúbico de biodiesel, com duas casas decimais, será fixo e irreajustável e não poderá ser superior ao preço máximo de referência de que trata o item 5.3, observado o disposto no Capítulo 8 deste Edital, sob pena de desclassificação da oferta.

5.5.6. Toda oferta individual é considerada divisível. Assim, uma oferta vencedora cuja quantidade não é totalmente necessária para o atendimento da quantidade total de 170 (cento e setenta) mil metros cúbicos será parcialmente atendida, isto é, a quantidade efetivamente arrematada será inferior à quantidade indicada na oferta quando esta corresponder à última oferta necessária para completar a referida quantidade total.

5.6. O envio de proposta pelo fornecedor de biodiesel participante do leilão implica a sua manifestação de pleno conhecimento e aceitação das regras e condições propostas pelo leilão

5.7. Encerrado o prazo para acolhimento das propostas, o leiloeiro procederá à sua abertura.

5.8. O leiloeiro agrupará as ofertas de todos os fornecedores participantes do leilão e as ordenará por ordem crescente de preço.

5.8.1. Em havendo ofertas de preços iguais, o critério para desempate será o da ordem cronológica de apresentação das propostas, registrada no sistema eletrônico.

5.8.2. O leiloeiro calculará a quantidade acumulada das ofertas ordenadas.

5.9. Finalizado o ordenamento das propostas de que trata o item anterior, o leiloeiro abrirá imediatamente a "Sala de Disputa" do sistema "Licitações-e", no horário previsto no Anexo I.

5.9.1. A "Sala de Disputa" tem por finalidade assegurar transparência e publicidade da negociação eletrônica, bem como possibilitar canal de comunicação entre o leiloeiro e os participantes. Nessa fase, apenas o leiloeiro irá incluir mensagens eletrônicas no sistema "Licitações-e" para conhecimento imediato dos fornecedores de biodiesel e do público em geral.

5.9.2. Antes da abertura da "Sala de Disputa", o sistema "Licitações-e" informará o preço de referência, nos termos do item 5.5.1. Entretanto, para todos os fins, serão consideradas arrematadas todas aquelas ofertas divulgadas pelo leiloeiro na referida "Sala".

5.9.3. Os fornecedores de biodiesel participantes do leilão não poderão, em qualquer hipótese, submeter proposta, oferta ou lance na "Sala de Disputa".

5.10. O leiloeiro divulgará por meio de mensagens na "Sala de Disputa" todas as ofertas individuais participantes do leilão, ordenadas na forma do item 5.8, com indicação dos respectivos preços e quantidades ofertadas, 170 (cento e setenta) mil metros cúbicos, observado, quando couber, o que dispõe o item 5.5.6 deste Edital.

5.11. Para proceder à declaração pública das ofertas arrematadas na "Sala de Disputa", o leiloeiro inicialmente conferirá o atendimento aos requisitos previstos no Capítulo 7 deste Edital para participação no leilão.

5.12. O leiloeiro procederá às verificações necessárias e informará por meio de mensagens na "Sala de Disputa" se todas as ofertas arrematadas atendem aos requisitos estabelecidos neste Edital e na Resolução ANP n° 31, de 4 de novembro de 2005, bem como, em havendo a desclassificação de um participante ou de uma ou mais de suas ofertas, a(s) razão(ões) para tanto.

5.12.1. Ocorrendo a desclassificação posterior de alguma oferta já declarada arrematada ainda que no prazo final para análise do recurso de que trata o item 5.13, ela será desconsiderada e será(ão) declarada(s) arrematadas(s) a(s) oferta(s) subseqüente(s) pela ordem crescente de preços, observados o disposto no item 5.8 e a quantidade total leiloada.

5.13. Imediatamente após a declaração das ofertas arrematadas na "Sala de Disputa", e após o término do tempo randômico, inicia-se a contagem de tempo do período de 30 (trinta) minutos para que os participantes manifestem sua intenção de interpor recurso contra o resultado do processo.

5.13.1. A manifestação de interesse em interpor recurso, bem como eventuais questionamentos do fornecedor participante do leilão, deverão ser formalizados através do sistema "Licitações-e", no *chat* de mensagens, acessado por meio do "Relatório de Disputa".

5.13.2. Depois de manifestado o interesse em interpor recurso, o fornecedor participante do leilão terá 3 (três) dias úteis para informar, por meio eletrônico leilaobiodiesel@anp.gov.br, os motivos e, quando couber, por outro meio, a documentação que os consubstanciam.

5.13.3. O resultado do julgamento do recurso será disponibilizado no endereço eletrônico da ANP (www.anp.gov.br) e o resultado final do Leilão publicado no Diário Oficial da União, na data prevista no Anexo I.

5.13.4. Concluso o prazo para interposição de recurso ou o seu julgamento, se houver, o leiloeiro procederá à finalização do certame.

6. DA DATA E DO HORÁRIO DO LEILÃO

6.1. Fixados no Anexo I deste Edital.

7. DOS PARTICIPANTES

7.1. Poderão participar do leilão:

7.1.1. produtor de biodiesel que atenda, cumulativamente, aos seguintes requisitos:

7.1.1.1. esteja autorizado para o exercício da atividade de produtor de biodiesel, nos termos da Resolução ANP n.° 41, de , de 24 de novembro de 2004;

7.1.1.2. seja detentor do Registro Especial da Secretaria da Receita Federal, nos termos da Instrução Normativa SRF n.º 516, de 22 de fevereiro de 2005;

7.1.1.3. seja detentor do selo "Combustível Social" concedido pelo Ministério do Desenvolvimento Agrário, nos termos da Instrução Normativa MDA n.º 01, de 5 de julho de 2005, observada a data disposta no item 2.2;

7.1.1.4. esteja cadastrado no sistema "Licitações-e" do Banco do Brasil;

7.1.1.5. que comprove o cadastramento obrigatório perante o Sistema de Cadastramento Unificado de Fornecedores – SICAF, constando todas as certidões no prazo de validade ou protocole, aos cuidados da Superintendência de Abastecimento, localizada na Avenida Rio Branco 65, 16º andar, Centro, Rio de Janeiro, RJ, CEP 20.090-004, identificando no envelope "Leilão Biodiesel", as seguintes certidões que o compõem:

- quitação de tributos e contribuição federal (SRF);
- quitação da dívida ativa da União (PGFN);
- negativa do FGTS; e
- negativa do INSS.

7.1.1.6. no caso de expansão da capacidade de produção de biodiesel comprovada pela ANP, o produtor deverá protocolar na ANP, aos cuidados da Superintendência de Abastecimento, localizada na Avenida Rio Branco 65, 16º andar, Centro, Rio de Janeiro, RJ, CEP 20.090-004, identificando no envelope "Leilão Biodiesel", declaração do MDA reconhecendo que a empresa mantém, computada a ampliação, os requisitos necessários para obtenção do selo "Combustível Social".

7.1.1.7. Para participar do leilão, o produtor de que trata o item 7.1.1 deverá atender aos subitens 7.1.1.1 a 7.1.1.5 e, adicionalmente, no caso de expansão da capacidade ao item 7.1.1.6, até 24 de março de 2006.

7.1.2. sociedade que atenda, cumulativamente, aos seguintes requisitos:

7.1.2.1. que tenha protocolado na ANP o requerimento para o exercício da atividade de produtor de biodiesel e o relatório técnico, contendo informações sobre o processo e a capacidade instalada de produção da planta produtora de biodiesel.

7.1.2.2. que detenha projeto reconhecido pelo MDA como possuidor dos requisitos necessários à obtenção do selo "Combustível Social", em conformidade com a Instrução Normativa nº 2, de 28 de setembro de 2005, do referido Ministério

7.1.2.3. para participar do leilão, a sociedade de que trata o item 7.1.2 deverá atender aos subitens 7.1.1.4, 7.1.1.5, 7.1.2.1, assim como protocolar na ANP, aos cuidados da Superintendência de Abastecimento, localizada na Avenida Rio Branco 65, 16º andar, Centro, Rio de Janeiro, RJ, CEP 20.090-004, identificando no envelope "Leilão Biodiesel", declaração do MDA reconhecendo que a sociedade possui os requisitos necessários para obtenção do selo "Combustível Social", até 24 de março de 2006.

7.2. Os fornecedores que não cumpriram suas obrigações em outros leilões públicos anteriores, quando for o caso, estarão impedidos de participar do presente certame.

8. DA COTAÇÃO DE PREÇO NO LEILÃO

8.1 O preço a ser cotado no leilão corresponderá ao valor do biodiesel, na posição FOB, colocado pelo fornecedor de biodiesel na tancagem para entrega do produto ao adquirente, conforme o item 10.1 deste Edital, com incidência, na forma da Lei nº 11.116, de 18 de maio de 2005, das contribuições PIS/PASEP e da COFINS, sem ICMS.

8.2 O preço máximo de referência será comunicado pelo leiloeiro aos participantes pelo sistema "Licitações-e", na forma do item 5.3.

9. DA CONFIRMAÇÃO DA AQUISIÇÃO

9.1. Concluído o leilão, o leiloeiro disponibilizará a ata e os relatórios do procedimento de aquisição pelo sistema "Licitações-e".

9.2. O resultado final das ofertas vencedoras será publicado no Diário Oficial da União e no endereço da ANP na internet (www.anp.gov.br), na data prevista no Anexo I.

9.3. A ANP informará as quantidades que cada produtor e, se couber, que cada importador de óleo diesel deverá adquirir de cada fornecedor de biodiesel vencedor do leilão, e publicará o resultado no Diário Oficial da União.

10. DAS CONDIÇÕES DE ENTREGA

10.1. O biodiesel leiloado deverá ser entregue pelo fornecedor em tancagem própria ou de terceiros, na quantidade negociada no leilão, no prazo compreendido entre 01 de julho de 2006 e 30 de junho de 2007, observadas as disposições pertinentes contidas na Resolução ANP nº 31, de 4 de novembro de 2005.

10.2. Volumes de entrega inferiores a 15 (quinze) metros cúbicos, por fornecedor, poderão deixar de ser retirados pelos adquirentes de biodiesel, em função da capacidade dos caminhões-tanque utilizados para retirada do produto.

10.3. Até 30 (trinta) dias após a publicação, no Diário Oficial da União, do Aviso de Adjudicação e Homologação do resultado do certame, os fornecedores e os adquirentes deverão celebrar contrato de compra e venda, contendo cláusulas relativas: i) às quantidades de biodiesel negociadas e respectivos locais de entrega; ii) ao cronograma de entrega e retirada; e iii) as penalidades para os casos de inadimplementos de quaisquer das partes, inclusive relacionados com o referido cronograma.

10.3.1. O cronograma de entrega e retirada do produto deverá ser pactuado entre as partes no referido instrumento contratual, observado o Capítulo 9 deste Edital, e, conforme o §4º do art. 3º da Resolução ANP nº 31, de 4 de novembro de 2005, deverá atender à condição do percentual mínimo de 20% (vinte por cento) do volume total negociado ser entregue até 30 de novembro de 2006, sob pena do cancelamento da quantidade arrematada do fornecedor.

10.4. O extrato do contrato referido no item 10.3, acompanhado do cronograma de que trata o item 10.3.1, deverá ser encaminhado à ANP pelo fornecedor, até 10 (dez) dias após sua celebração.

10.5. O cronograma de entrega e retirada pode ser ajustado de comum acordo entre as partes no decorrer do prazo estipulado no item 10.1, respeitado o percentual de que trata o item 10.3.1.1, devendo o fornecedor encaminhar à ANP o novo cronograma em até 10 (dez) dias da repactuação.

10.6. Até 10 (dez) dias úteis antes do início do prazo de entrega do biodiesel, o fornecedor que participou do leilão na forma de sociedade detentora de projeto de produção de biodiesel, nos termos do disposto no item 2.2, deverá encaminhar à ANP, aos cuidados da Superintendência de Abastecimento, localizada na Avenida Rio Branco 65, 16º andar, Centro, Rio de Janeiro, RJ, CEP 20.090-004, identificando no envelope "Leilão Biodiesel", cópia da seguinte documentação:

10.6.1 selo "Combustível Social" instituído pelo Decreto n.º 5.297, de 6 de dezembro de 2004, na forma da Instrução Normativa n.º 01, de 5 de julho de 2005, do Ministério do Desenvolvimento Agrário – MDA.

10.6.2 protocolo do pedido do Registro Especial da Secretaria da Receita Federal, nos termos da Instrução Normativa SRF n.º 516, de 22 de fevereiro de 2005.

10.7. Até 10 (dez) dias úteis antes do início do prazo de entrega do biodiesel, o fornecedor deverá ratificar o local onde está depositado o biodiesel, com vistas à realização de vistoria prévia pelo adquirente quanto às condições operacionais das instalações de carregamento do produto, e encaminhar aos adquirentes a seguinte documentação:

10.7.1. certidões negativas de débito perante o INSS e o FGTS;

10.7.2. as certidões de que trata o item anterior, acompanhadas dos documentos relacionados nos itens 7.1.1.1, 7.1.1.2 e 7.1.1.3 deste Edital, no caso de sociedade detentora de projeto de produção de biodiesel;

10.7.3. as certidões de que trata o item 10.7.1, acompanhadas do documento a que se refere o item 7.1.1.3, no caso de expansão da capacidade de produção de biodiesel.

10.8. Quando da entrega do produto, o fornecedor de biodiesel deverá apresentar ao adquirente o certificado de qualidade, de acordo com a Resolução ANP nº 42, de 24 de novembro de 2004.

10.9. Atendidos os requisitos de que trata o item 10.7 o fornecedor de biodiesel, em situação regular perante o INSS e FGTS, estará apto a emitir nota fiscal de venda em favor do(s) adquirente(s).

10.10. Caso, durante o prazo de entrega, o fornecedor apresente novo local de entrega para o biodiesel, será necessária a prévia concordância do(s) adquirente(s), sendo admissível, nesse caso, a cobrança do frete envolvido na alteração em valor acordado entre as partes.

10.11. A entrega do produto arrematado no leilão poderá ser cancelada total ou parcialmente, nos casos em que:

10.11.1. o fornecedor de biodiesel não atender aos itens 10.6 e 10.7 deste edital;

10.11.2. o biodiesel não atender às especificações constantes da Resolução ANP nº 42, de 24 de novembro de 2004;

10.11.3. as instalações para carregamento do biodiesel não forem aprovadas na vistoria prévia do adquirente, caso que demandará, necessariamente, confirmação da ANP;

10.11.4. a entrega do produto não tiver ocorrido de acordo com o cronograma de retirada e entrega, consoante o item 10.3 deste Edital, por responsabilidade do fornecedor;

10.11.5. o fornecedor não tiver comprovado sua regularidade perante o INSS e o FGTS.

10.12. O cancelamento da entrega do produto arrematado no leilão poderá imputar ao fornecedor a condição de impedido para participar de leilões subseqüentes.

11 DO PAGAMENTO

11.1 pagamento das quantidades de biodiesel negociadas será efetuado nos prazos acordados em contrato

12 DAS DISPOSIÇÕES FINAIS

12.1 Todas as referências de tempo citadas no Edital, nos Avisos e durante a sessão pública observarão o horário oficial de Brasília – DF.

12.2 A ANP poderá, a seu critério, emitir Avisos de alterações do presente Edital, fazendo-os publicar no Diário Oficial da União e no site www.anp.gov.br .

12.3 A ANP exercerá, direta ou indiretamente, a fiscalização do cumprimento das disposições deste Edital.

12.4 Os casos omissos e divergências entre as partes serão dirimidos pela ANP.

12.5 O Banco do Brasil S.A. disponibiliza a sua central de atendimento através do telefone 0800 729 0500, para esclarecer eventuais dúvidas de cadastramento e uso do sistema "Licitações-e", bem como sobre o procedimento de configuração do computador a ser utilizado.

12.6 Qualquer pedido de esclarecimento de eventuais dúvidas na interpretação do presente Edital e Anexos deverá ser encaminhado, por escrito, ao leiloeiro, pelo fac-símile (21) 2112-7719, até três dias úteis antes da data marcada para o recebimento das propostas.

12.7 O foro competente para dirimir quaisquer questões oriundas do presente Edital é o da Justiça Federal, Seção Judiciária do Rio de Janeiro, com exclusão de qualquer outro, por mais privilegiado que seja.

12.8 Para efeito do disposto no item 2.2, o MDA informará à ANP a capacidade nominal do fornecedor de biodiesel, em metros cúbicos por dia.

AGÊNCIA NACIONAL DO PETRÓLEO, GÁS NATURAL E BIOCOMBUSTÍVEIS

EDITAL DE LEILÃO N.º 007/06 - ANP

ANEXO I

1. DA REALIZAÇÃO DO LEILÃO

1.1. Data de realização do leilão: 30 de março de 2006.

Horários:

Abertura da sessão: 08:30 horas;

Divulgação do preço máximo de referência: 08:40 horas;

Início da fase de acolhimento de propostas: 09:00 horas;

Término da fase de acolhimento de propostas: 11:00 horas;

Abertura da "Sala de Disputa": 14:00 horas;

Divulgação das ofertas classificadas e das desclassificadas: 14:20 horas;

Declaração das ofertas arrematadas: 14:30 horas;

Início de prazo para manifestação de interesse em interpor recurso: 14:40 horas;

Fim de prazo para manifestação de interesse em interpor recurso: 15:10 horas;

Encerramento da "Sala de Disputa": 15:20 horas.

1.2. Prazo para envio do(s) motivo(s) e documentação do recurso: até 04 de abril de 2006 .

1.3. Publicação do julgamento do recurso e do resultado final: 25 de abril de 2006

2. DOS ADQUIRENTES

Percentual de participação dos produtores e importadores de óleo diesel, excluídos os agentes com participação inferior a 1% (um por cento), correspondente ao período de janeiro de 2005 a dezembro de 2005 :

Petróleo Brasileiro S.A.	93 %
Alberto Pasqualini - REFAP S/A	7 %

OBSERVAÇÃO: conforme disposto no item 3.1 deste Edital, os percentuais dos adquirentes poderão ser ajustados até a abertura do leilão.

AGÊNCIA NACIONAL DO PETRÓLEO, GÁS NATURAL E BIOCOMBUSTÍVEIS

EDITAL DE LEILÃO N.º 007/06 - ANP

ANEXO II

<u>Identificação do Fornecedor</u>

1. **Produtor de biodiesel:**

Razão Social:

CNPJ:

Autorização ANP n.º: ___, de __ de __________ de _____

Registro Especial na Secretaria de Receita Federal n.º: ________/____

2. Sociedade Detentora de Projeto de Produção de Biodiesel:

Razão Social:

CNPJ:

<u>Proposta</u>

Oferta	**Volume (m^3)**	**Preço Unitário (R$ / m^3)**	**Local de Entrega (Município – UF)**
01			
02			
03			
Total		--------	--------------------------

Annex H: References
Anexo H: Referenças

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