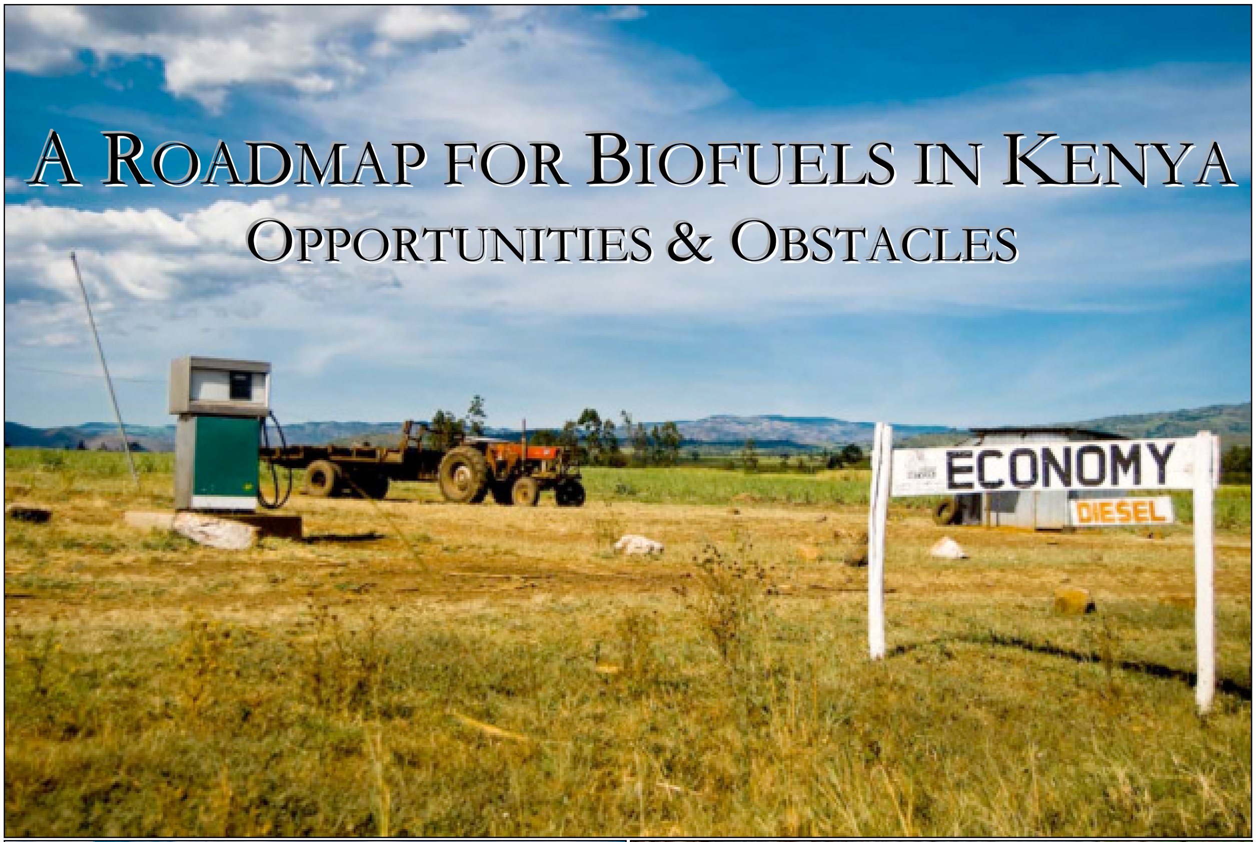
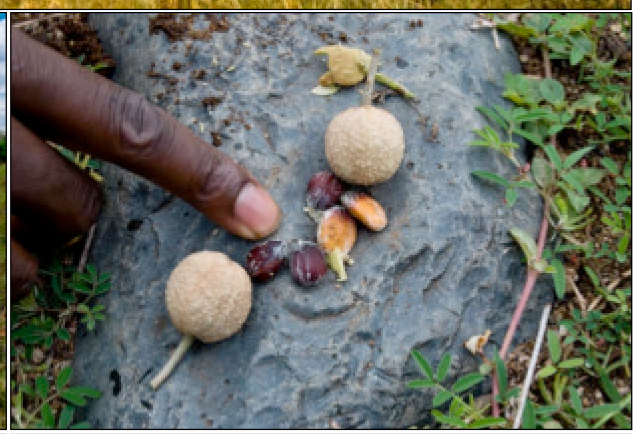
A Roadmap for Biofuels in Kenya

Opportunities & Obstacles





Ministry of Agriculture

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Commisioned by:

Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung

A Roadmap for Biofuels in Kenya
Opportunities & Obstacles

17 May 2008

Commissioned By:

Gesellschaft für Technische Zusammenarbeit (German Technical Cooperation - GTZ) Kenya
&
Ministry of Agriculture, Government of Kenya

Through
Promotion of Private Sector Development in Agriculture Programme (PSDA)
GTZ-Regional Energy Advisory Platform East Africa (REAP EA)
GTZ Sector Project on Bioenergy in Eschborn, Germany

Conducted By:

Endelevu Energy
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Energy for Sustainable Development Africa

PREFACE

The current debate on climate change and rising oil prices has greatly increased interest in renewable energy, such as biofuels. Many industrialized countries and more advanced developing countries are seeking to promote biofuels as a way of reducing fossil fuel consumption and mitigating the adverse effects of climate change.

Despite the myriad benefits of biofuels, it is important to note that they are not a panacea for climate change or the world's addiction to fossil fuels. As recent experience has shown, unsustainably produced biofuels can create more problems than they solve. For example, huge demands for corn-based ethanol in the United States and palm-based biodiesel in Europe have added pressure on already tight world food supplies and contributed to the clearing of virgin rainforests in Southeast Asia.

Policymakers and other stakeholders in Kenya must work to avoid replicating these unsustainable models of biofuels production. We must learn from the mistakes that have occurred elsewhere to ensure the use of environmentally and socially sound practices in domestic biofuels production. Kenya is seeking alternatives to its high dependence on imported fossil fuels and the concomitant outflow of foreign currency. Biofuels could provide many attractive opportunities to reduce this dependence while reinvesting in the country's sustainable development. But, as noted above and discussed in detail throughout this study, many challenges must first be addressed before a thriving industry can be established.

It is on this basis that the German Technical Cooperation (GTZ), on behalf of the German Government, has responded to a request from the Ministry of Agriculture, Government of Kenya, to commission this study, as well as a related study on biogas. In order to imbed the bioenergy study work in Kenya with similar questions regionally and globally, three projects have been cooperating and funding this effort:

- The Kenyan-German Private Sector Development in Agriculture (PSDA) Programme in Nairobi, Kenya
- The GTZ Regional Energy Advisory Platform East Africa (REAP EA) covering Ethiopia, Kenya, Rwanda, Tanzania and Uganda.
- The GTZ Sector Project on Bioenergy in Eschborn, Germany.

The following biofuels study provides a comprehensive overview of the national potential and challenges facing biofuels in Kenya. The goal is to elucidate benefits and analyze viability, while also assessing possible challenges, such as economic feasibility, fiscal and regulatory limitations, and environmental and social impacts, including competition with food. The study highlights the potential of establishing a biofuels industry and analyzes the political and legal environment that will be required to promote the sustainable development of biofuels in Kenya. The study also provides a history and current status of biofuels in Kenya and a critical appraisal of the policy framework within which this sector must develop.

Cover Photos - Top: Abandoned gas pump, Muhoroni; Middle Left: Jatropha plantation, Central Province; Middle Right: Croton seeds; Kerio Valley; Bottom Left: Sugarcane en route to factory, Muhoroni; Bottom Right: Spectre International ethanol plant, Kisumu. Credit: David Newman (2007).

We hope that this biofuels study contributes significantly to a well-informed and well-executed bioenergy strategy in Kenya.

Permanent Secretary Kenya Ministry of Agriculture	Permanent Secretary Kenya Ministry of Energy	Country Director GTZ Kenya

Nairobi, 29 April 2008

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LIST OF ACRONYMNS

B10 – A blend of 10% biodiesel and 90% petrol diesel
CDM – Clean Development Mechanism of the Kyoto Protocol
CIF – Cost, Insurance and Freight
CO_2 – Carbon Dioxide
CRSP – Aga Khan Foundation's Coastal Rural Support Programme
DEG – Deutsche Investitions und Entwicklungsgesellschaft.
E5 – A blend of 5% ethanol and 95% petrol
EIA – Environmental Impact Assessment
EIAL – Environmental Impact Assessment License
EMCA – Environmental Management & Coordination Act
ERC – Energy Regulatory Commission
ESDA – Energy for Sustainable Development Africa
EU – European Union
FAO – United Nations Food & Agriculture Organization
FAOSTAT – United Nations Food & Agriculture Organization's Statistical Database
FFV – Flex Fuel Vehicles
GAF – Green Africa Foundation
GHG – Greenhouse Gases
GIS – Global Information System
GTZ – Gesellschaft für Technische Zusammenarbeit
HA – Hectare, or 2.47 acres
ICRAF – International Centre on Agroforestry (World Agroforestry Centre)
ICRISAT – Institute for Crops Research in the Semi-Arid Tropics
IPA – Investment Promotion Act
KARI – Kenya Agricultural Research Institute
KEBS – Kenya Bureau of Standards
KEFRI – Kenya Forestry Research Institute
KEPHIS - Kenya Plant Health Inspectorate Service
KIA – Kenya Investment Authority
KIRDI – Kenya Industrial Research Development Institute
KRA – Kenya Revenue Authority
MFC – Mali-Folkecentre
MW – Megawatt, equivalent to one million watts
NBC – National Biofuels Committee
NCA – Norwegian Church Aid
NEAP – National Environmental Action Plan Committee
NRDC – Natural Resources Defense Council
NOx – Nitrogen Oxide
PANERECC – Parliamentarian Network on Renewable Energy and Climate Change
RFS – Renewable Fuel Standard
UNDP – United Nations Development Programme
UNEP – United Nations Environment Programme
UNFCCC – United Nations Framework Convention on Climate Change
VCM – Voluntary Carbon Market
VJDF – Vanilla Jatropha Development Foundation

1. INTRODUCTION & EXECUTIVE SUMMARY

Biofuels are liquid, solid or gaseous energy sources derived from renewable biomass.[1] They generally emit fewer toxic air pollutants and greenhouse gasses than petroleum-based fuels and can be produced anywhere sufficient biomass "feedstock" can be grown. At a time of record oil prices and growing concern over global warming, biofuels present a valuable opportunity to reduce dependence on volatile global oil markets, create local economic opportunities in agriculture and industry, and improve the environment.

Global oil consumption is projected to increase by about 36% by 2030.[2] In Africa, oil consumption could nearly double in that time.[3] As more countries scramble for an increasingly limited supply of oil, the price and availability of fuel will become ever more challenging issues. Many countries see biofuels as part of the solution to these problems, which has led to explosive growth in global production. From 2000 to 2006, global fuel ethanol production nearly tripled to 40 billion liters, while biodiesel production grew from one to six billion liters.[4]

As the thirst for biofuels has expanded, so too has the recognition that not all biofuels are created equal in terms of environmental and social sustainability. From the destruction of rainforests for palm oil plantations to the use of staple food crops like maize for ethanol, the impacts on ecosystems and food supplies have grown. This has led some to question the overall value of biofuels as a solution to global warming and tight oil supplies. Unfortunately, the debate over the sustainability of biofuels has evolved in a way that generally has created two rather inflexible and absolute schools of thought: one in favor and the other against. A more nuanced approach, however, shows that biofuels *can* be produced in an environmentally- and socially-beneficial way if the right crops and models of production are prioritized.

Countries like Kenya, with no proven oil reserves but suitable climatic conditions for growing biofuels, could limit the shock of high oil prices by developing its own supply of domestically produced biofuels. Although Kenya has yet to participate in the biofuels boom, it is beginning to lay the groundwork for significant progress in the years to come. The government recently enacted a policy (Sessional Paper, No. 4 of 2004) and legislation (the Energy Act, No. 12 of 2006) that favors the development of ethanol and biodiesel, and the Ministry of Energy has developed a biodiesel strategy through its National Biofuels Committee. In addition, a Kenya Biodiesel Association is being formed with support from all sectors of the biofuels industry. The Ministry intends to turn its attention to ethanol once the biodiesel program is established.

This study is intended to support these efforts with a detailed analysis of the latest information on the agronomy, economics, law and policy, and environmental and social impacts of biofuels in Kenya. The overriding objective is to transcend the standard rhetoric with an informed discussion of the true opportunities and obstacles. The following is a brief summary.

<u>Overview of Ethanol & Biodiesel</u>

Section 2 provides a detailed overview of ethanol and biodiesel, the two main sources of biofuels considered in this study. Ethanol, also known as ethyl alcohol or grain alcohol, is a liquid fuel that can be produced from a variety of sugars and starch containing crops, such as grains. Ethanol was first used as an automotive fuel starting in 1908 with the Model T Ford and has been used as an additive in petrol fuel for over 30 years. Kenya has produced ethanol from sugarcane since the early 1980s and for a time even blended it with petrol as part of its now-defunct gasohol program.

Ethanol can be blended with petrol in any ratio, or used straight, but requires the use of specially designed flex fuel vehicles in blends above 10%, referred to as E10. The energy content of ethanol is about two-thirds that of the equivalent amount of petrol, so an E10 blend will have about 93% of the fuel economy of straight petrol. International and Kenyan fuel quality and blending standards exist to ensure standardized quality and to protect consumers from potentially harmful fuel. The Kenyan standards are a vestige of its earlier gasohol program and need updating.

Ethanol can be produced from sugar crops, such as sugarcane and sweet sorghum; grains, such as corn and wheat; and cellulostic crops, such as switchgrass, although the latter is not yet economically viable for commercial production. The basic production process involves extracting sugars from the biomass, which is much easier and cheaper for sugar crops than grains, and then fermenting the sugar in the presence of yeast. The resulting product is distilled to remove water, leaving alcohol that is concentrated to 200 proof. Methanol, or some other denaturant, is then mixed with the pure ethanol to make it unsuitable for potable consumption.

The following ethanol feedstocks are considered in the study: cassava, sugarcane and sweet sorghum. Other crops, including corn and sugar beet, were discounted from consideration due to potential conflicts with food or incompatible agro-ecological conditions. Detailed information on agronomy, uses, environmental pros and cons, and pests and diseases are included. Working with the World Agroforestry Centre's (ICRAF's) GIS laboratory, we have designed suitability maps for each feedstock that show where they can grow and where they would be competing with existing food and cash crops.

Biodiesel is a liquid substitute for petroleum-based diesel fuel made with vegetable oil derived from a wide variety of oil-bearing plants such as castor, coconut, cottonseed, croton, jatropha, rapeseed (canola) and sunflower. Biodiesel has been around since the beginning of the 20th century, but has only recently been produced in large, commercial quantities. No vehicle modifications are required to use biodiesel blends of up to 20% (B20), although auto manufacturers have varying biodiesel warranty policies on what level of blend is permitted without voiding the warranty. Blends above 20% all the way up to pure biodiesel (B100) can be used in ordinary diesel engines, but may require slight modification of older fuel lines and hoses that are less compatible with pure biodiesel.

International fuel quality and blending standards for biodiesel ensure that the fuel does not harm consumers. Biodiesel contains about 93% of the energy content of petroleum diesel, so B5 will achieve about 0.5% less fuel economy than ordinary diesel. The production of biodiesel involves mixing pure vegetable oil with alcohol and caustic soda, which produces ethyl or methyl esters (biodiesel) and glycerin. This study takes a detailed look at the following biodiesel feedstocks: castor, coconut, cotton, croton, jatropha, rapeseed and sunflower.

History & Current Status of Biofuels in Kenya and Around the World

Section 3 of the study provides a detailed history and current status of ethanol and biodiesel in Kenya, as well as in select countries globally and regionally. Kenya was ahead of its time in producing and using ethanol for fuel, but abandoned its gasohol program over 15 years ago.

Kenya's present-day ethanol industry, which includes Agro-Chemical and newcomer Spectre International, is marked by tremendous opportunities and significant challenges. These two companies have a combined production capacity of 125,000 liters per day, although current supplies of molasses – the only ethanol feedstock being used in Kenya – mean that only about half of capacity is being used, for a total production of about 60,000 liters per day. Fulfilling the full production capacity at the two ethanol plants would require almost the entire supply of molasses from Kenyan sugar companies, which is not feasible given the alternative markets for molasses and the current low productivity of sugarcane in Kenya.

Poor planning and a crumbling infrastructure are also limiting the competitiveness of sugar and ethanol in Kenya. Thriving in an increasingly competitive global commodities market will require the Kenyan sugar and ethanol industries to innovate and diversify, as well as to invest in more efficient methods of production. The integrated production of sugar, ethanol and power that Mumias Sugar Company is planning is a more efficient and sustainable model of production. Undeterred by these developments, Spectre is moving ahead with a major expansion that will increase its production capacity from its current 65,000 liters per day to 230,000 liters per day.

However, limitations on available land and competition with food production is almost certain to preclude all planned ethanol production to be supplied by sugarcane, meaning that alternative feedstocks, such as sweet sorghum, will be required. One of the greatest potential benefits of sweet sorghum is the fact that it can thrive in drier, more marginal agricultural areas than sugarcane, however more practical research needs to be done to maximize its economic potential in Kenya.

At the current rate of growth of petrol consumption of about 2.8% per year, Kenya is projected to consume about 618 million liters of petrol by 2013. A national 10% ethanol blend would require about 93 million liters, up from the 20 million liters Kenya currently produces. Revival of ethanol fuel production in Kenya has widespread support from the stakeholders who were interviewed for this study.

Compared with ethanol, biodiesel production in Kenya is in its nascent stage. However, a flurry of activities among government agencies, NGOs and the private sector indicate great potential. The vast majority of biodiesel projects currently underway or being planned involve jatropha as the main feedstock, although projects involving other feedstocks, including castor, croton and coconut, are also being discussed. The study provides an overview of the activities of various governmental, non-governmental, research and private sector organizations.

Many of these projects and organizations are beginning their own research and development activities to identify superior planting material and best practices for jatropha. Others have expressed interest in doing so. However, these efforts should be better coordinated among participants, donors and investors to avoid overlap and to take advantage of the relative strengths of the various projects.

The role of certain government ministries is key. The Ministry of Agriculture, through the Kenya Agricultural Research Institute (KARI), the Kenya Plant Health Inspectorate Service (KEPHIS) and the Kenya Sugar Board, perhaps has the most critical role in supporting the agricultural development of superior planting materials, silvicultural practices and models for production. The Ministry of Agriculture should also take the lead in promoting particular biofuels crops and growing regions to minimize the conflict with food.

The Ministry of Environment and Natural Resources, through the Kenya Forest Research Institute (KEFRI), the Kenya Forest Service and the National Environmental Management Authority (NEMA) should take the lead in research for tree crops, like jatropha and croton, as well as overall environmental and public health protection along the biofuels value chain. On the policy front, the Ministry of Energy has convened a National Biofuels Committee, which recently released a national strategy on biodiesel, which it is working to implement. The strategy promotes jatropha, with little mention of other potential crops, but demonstrates strong support for biodiesel development, including recommendations for policy and coordination of government and the private sector.

More than 30 countries around the world have launched ethanol fuel programs, with Brazil and the United States leading the way. The European Union is the top producer of biodiesel, with about 4.5 billion liters, or about 72% of global production, in 2006. This section of the study provides an overview of biofuels programs and policies from the following leading biofuels producers from around the world: Brazil, Germany, India, Thailand and the United States. This section also includes descriptions of regional biofuels activities from the following countries: Ethiopia, Malawi, Mali, Nigeria, Senegal, South Africa, Sudan, Tanzania and Uganda.

Economic Analysis of Biofuels in Kenya

Section 4 analyzes the economics of biofuels in Kenya. In general, the economic case for biofuels in Kenya is quite strong. Kenya currently spends about $1 billion per year in foreign currency on imported oil. Since the early 1990s, the Kenyan Government has spent over $169 million exploring for oil and gas, with over 30 wells drilled but no discoveries. To appreciate the potential value of biofuels, one only needs to consider the fact that many African countries currently spend many times more for imported petroleum than they do on health care and poverty alleviation programs. Even if only a portion of this money were redirected towards domestic bioenergy programs, the social and economic benefits would be substantial.

Biofuels feedstock is the primary and most expensive ingredient for biofuels production. Land availability and agricultural practices are the main factors that determine the supply and price of biofuels feedstock. The Study includes three feedstock production scenarios to determine potential availability. The first considered the status quo production of feedstocks and found that enough sugarcane is currently produced for 49 million liters of ethanol if only molasses is used and 345 million liters if all cane went into ethanol instead of sugar. The existing production of castor is enough to produce about 1.3 million liters of biodiesel. Underexploited coconuts and croton seeds, if linked to biofuels processors, likely could produce millions more, although detailed quantities are not available.

The second feedstock production scenario calculates the amount of each crop that could be grown at current yields if half of all suitable areas (according to the suitability maps) were planted. Excluding land that is currently being used to grow other crops, enough new sugarcane could be grown to produce between 30 and 210 million liters (depending on whether molasses or cane juice was used). Alternatively, over 8 billion liters of ethanol could potentially be produced from sweet sorghum and over 3 billion from cassava. Depending on which biodiesel feedstock is used, between 18 million to over 5 billion liters could be produced.

Of course, even 50% of suitable lands would not be possible to plant with a single crop, so these figures would have to be further reduced to come up with a more realistic estimate of what is possible in the real world. The point is that enough suitable land outside of existing agricultural production is available to produce at least tens, if not hundreds of millions of liters of ethanol and biodiesel.

The final scenario calculates production if half of suitable lands were used, but at optimal yields for each crop. Not surprisingly, the numbers are significantly higher than in the second scenario. The lesson is that both available land and increased yield are important factors in producing adequate supplies of biofuels feedstock to support a domestic industry.

The next part of the analysis describes the economic feasibility of producing ethanol and biodiesel in Kenya. Ethanol has been produced in Kenya for many years from the molasses residue of sugar production. Despite Kenya's relatively low molasses prices, the overall cost of ethanol production remains higher than in the other five sugarcane-based ethanol producing countries or regions considered in this study. The current average cost of production at the two ethanol plants in Kenya is approximately Ksh 36.5, or $0.56, per liter. The main reasons for the higher operating costs in Kenya are poor infrastructure and the relative inefficiency of the Kenyan ethanol model.

Another factor to consider is the impact of fuel taxes on economic feasibility. There is a roughly Ksh 30 ($0.46) per liter tax on petrol. For ethanol to be feasible in the market without any help from the government in terms of tax reductions or subsidies, the pre-tax price of each liter of ethanol must be less than roughly Ksh 40 ($0.61) per liter (assuming a retail pump price of ~Ksh 90 per liter and that one liter of ethanol contains about two-thirds of the energy of a liter of petrol). The current average production cost of Ksh 36.5, or $0.56, per liter of sugarcane ethanol is barely economically feasible as a substitute for petrol, assuming the Ksh 3.5 per liter difference between the cost of production and the pump price is sufficient to cover the cost of transport, blending, marketing and profits. Considering that ethanol sold as potable alcohol currently fetches at least Ksh 50 per liter, some sort of incentive will likely be needed to encourage ethanol producers to begin selling their product for gasohol at a cheaper price.

Little information is available on the cost of production for ethanol produced from sweet sorghum and cassava. Using what information is available on current and projected prices, it appears that both cassava and sweet sorghum would be too expensive to be used economically for ethanol absent any support from the government in the form of tax exemptions or subsidies.

We have evaluated three different scales of production for biodiesel: farm scale (~180,000 liters per year), small commercial scale (~2 million liters per year), and large commercial scale (~12 million liters per year, which is not actually large-scale by international standards). The cost of biofuels feedstock is a factor of the price per tonne of the oilseed, the percentage of oil that can be extracted from the seed (known as "oil content"), and the revenue that can be collected from the seedcake that is leftover after the oil has been extracted. Croton and jatropha appear to be the cheapest feedstocks, although farmers have very little, if any, experience growing these two trees as plantation crops and thus the economic assumptions regarding the price of seed and the yield per hectare are much less certain than for the other crops considered. The next two cheapest feedstocks are coconut and castor.

To determine overall feasibility, the cost of production (which includes feedstock, operations and capital costs) plus taxes must be compared to the current pump price for petroleum diesel, which is about Ksh 80 per liter at the time of this publication. However, discounting for the lower energy value in biodiesel, we can reduce the comparative price of petroleum diesel by 7% to Ksh 74.4 per liter. Thus, at current retail prices, biodiesel production is not economically feasible at any scale of production unless the tax burden is reduced or eliminated. At these levels and with the price of diesel likely to fluctuate below its current retail price, investing in a new biodiesel venture in Kenya seems extremely risky without some governmental support.

Markets for ethanol include alcoholic beverages, pharmaceutical and industrial applications, and fuel. Current ethanol production in Kenya amounts to about 20 million liters per year, the vast majority of which is exported to Uganda and the Democratic Republic of Congo for beverage use. A ten percent ethanol blend (E10) in Kenya would require approximately 93 million liters a year by 2013. In 2006, European countries imported 2.36 billion liters of ethanol. Closer to home, African nations imported about 154 million liters of ethanol in 2006, with a demand that is surely to rise in the coming years. Another potential local market is the use of ethanol in cook stoves and lamps.

Biodiesel is used for transport fuel, stationary power, farm equipment use and marine power. A two percent blend of biodiesel (B2) into the local transport market would require about 32 million liters of biodiesel by 2013. Biodiesel could complement, or completely displace, the use of petroleum diesel for many stationary applications. Straight vegetable oil (SVO) that has not been processed into biodiesel could potentially be used in some applications, such as for transport with specially modified vehicles or for farm equipment. SVO and/or biodiesel could potentially be used as a replacement for kerosene as the main source of light and cooking fuel in many parts of Kenya. As indicated above, rapidly expanding markets for export of ethanol and biodiesel provide tremendous growth opportunities for countries like Kenya, although trade restrictions, such as import tariffs, could impede these markets.

The potential employment and income benefits of biofuels in Kenya are enormous. An additional 93 million liters of ethanol (enough for a national E10 blend by 2013) could yield about Ksh 4.65 billion ($72 million) per year to the economy and produce thousands of new farm jobs and between 500 to 1,000 new non-farm jobs. About 229 new non-farm jobs and thousands more farm-related ones would be created if Kenya adopted a B2 policy requiring the production of roughly 32 million liters of biodiesel by 2013.

To be sustainable and to benefit the largest number of Kenyans, any future biofuels industry should maximize smallholder farm income by selecting feedstocks that will yield the highest return on investment. The availability of oilseeds in large enough quantities for commercial biodiesel production will depend on which crops farmers see as the most beneficial. Although revenues can be calculated for each crop, based on yield per hectare and the current market price of each feedstock, net income is more challenging. Information on the cost of production is not readily available for all crops and will require further research. The Kenya Agricultural Research Institute (KARI) has the capacity and the interest in conducting such important work and should be engaged to do so as soon as possible.

Due to the overwhelming focus on jatropha by the Ministry of Energy, private farmers, investors and NGOs, we have analyzed the potential farm income for a theoretical 50-hectare plantation. The plantation is designed to minimize the up-front establishment costs by planting 10 hectares per year over the first five years. This approach would require about 12 years before the entire plantation is fully matured. Based on projected yield and prices, it will take more than five years before the plantation turns an annual operating profit and more than ten years before such an investment produces a cumulative net income. However, over the long-term, such an investment would achieve an internal rate of return of nearly 15%.

Jatropha is similar to other crops like coffee and tea that take years to mature. However, unlike coffee and tea, that are well-understood crops with established yields and production costs, jatropha plantation farming is still in its infancy and many questions remain. Many of the assumptions we have relied upon, such as un-irrigated yield, could vary significantly from the experiences in India we have borrowed from. Nonetheless, it seems nearly certain that farmers will require significant long-term financing to develop commercial jatropha plantations. Smallholders, who do not have such large land areas, and can provide much of the labor themselves, may begin planting on boundaries and unused land, but may also require significant economic support to develop smaller jatropha plantations.

Kenya spent $983 million, or 5.6% of gross domestic product, importing petrol and automotive diesel in 2006. If Kenya offset 10% of petrol imports and 2% of diesel imports with locally produced biofuels by 2013, it would keep a total of $71 million per year from flowing overseas (at current consumption levels, assuming an average price of $90 per barrel of oil).

The potential reduction in greenhouse gas emissions from biofuels could theoretically provide an additional revenue stream for some projects. There are two distinctive markets for carbon credits: the mandatory market created through the Kyoto Protocol of the United Nations Convention on Climate Change (UNFCCC), and market for voluntary credits. The former is more stringent and restrictive, but generally yields a higher price per tonne of carbon. Conversely, the latter is more flexible and easier to gain compliance with, but fetches a lower price, (though the price has increased steadily due to the value placed on the livelihood aspect of voluntary carbon trade). The only type of biofuels project that has been approved for carbon credits within the CDM is for biodiesel made from waste vegetable oil. Thus, income from carbon credits is unlikely to provide much, if any, added incentive for project developers and investors.

Regulatory & Fiscal Analysis

Section 5 includes a comprehensive review of current laws, policies, regulatory requirements and taxes as they apply throughout the biofuels production life cycle. The Energy Act of 2006 mandates that the government pursues and facilitates the production of biofuels, but does not articulate how this shall be accomplished. Under current law, biofuels must comply with local or international fuel quality standards developed or adopted by Kenya Bureau of Standards, although it is unclear whether this would apply to biofuels produced and consumed at the farm level and not for commercial sale. A standard exists for ethanol, but not yet for biodiesel. A petroleum license is required to blend biofuels with petroleum products, but again it is unclear whether this would apply to a farm-based operation that was consuming all of what it produced.

Health, safety and worker protections are also important considerations for any producer or seller of biofuels, and any associated laws or regulations must be complied with. Existing regulations pertaining to these issues under the Energy and Petroleum Acts presumably would govern the distribution and sale of blended biofuels as long as the blended fuels conform to the relevant standards.

Many aspects of biofuels production have direct and indirect environmental implications that would require environmental impact assessments. Laws and regulations governing air and water pollution, hazardous chemicals and waste disposal must also be adhered to. Growing an adequate supply of biofuel feedstock is an essential component of the production process. This may require the purchase and/or importation of seeds, which are activities regulated by the Seeds and Plant Varieties Act and the Plant Protection Act.

Issues of property law and equipment import and purchase are also important components of biofuels production and require attention to the laws and regulations in those areas. Finally, this section describes the current fuel taxes that apply to petrol (about Ksh 30 per liter) and diesel (about Ksh 20 per liter), their implications for biofuels and how they can be reduced or eliminated to promote the industry.

Environmental and Social Impact Assessment

Section 6 reviews the positive and negative environmental and social impacts that biofuels can have. In general, such impacts depend on the type of feedstocks used and the method and scale of production. The air quality and health benefits of biofuels can be quite significant. Air emissions from ethanol are lower than those from petrol in all six types of air pollution listed. For biodiesel, all major air pollutants are also lower than for petroleum diesel, except for nitrogen oxide (NOx) emissions, which are slightly higher. Although biofuels may produce much lower emissions from exhaust, emissions from other sources along the life cycle must also be taken into account.

Biofuels present an opportunity to help mitigate climate change by reducing carbon dioxide (CO_2) emissions from fossil fuels because the carbon that is released into the atmosphere during the combustion of biofuels is equivalent to the amount of carbon that is absorbed during plant growth minus the amount of fossil fuels used for transport and production. These climate benefits can be commoditized and sold as carbon credits through the CDM or the voluntary carbon market. Similar to the discussion above on other air emissions, the climate benefit of a particular biofuel is dependent on the scale and mode of production, as well as the type of feedstock that is used.

These potential GHG benefits may overlook the emissions resulting from land-use change that is caused by the direct growing of biofuels crops, or the indirect conversion of forest and grasslands to agricultural production resulting from the need to increase food production that has been displaced by biofuels crops. The release of GHGs from land-use change that is caused by growing biofuels feedstocks could undermine purported climate benefits and significantly reduce their overall environmental benefits. The use of waste materials, marginal lands and reforestation projects are essential to maximizing overall GHG emission reductions of biofuels compared with fossil fuels.

An issue closely related to GHG emissions is the amount of energy it takes to produce each unit of biofuels, known as net energy balance or energy return on investment. Different studies show a range of net energy balance for biodiesel and ethanol, although most are positive, meaning more energy is produced than used in the manufacturing process.

Biofuels crops may help to prevent soil erosion and reclaim marginal lands for agricultural use. Of course, depending on the crops and the scale of production, many of these potential gains in land use can just as easily be undone by, for example, the deforestation of tropical rainforests to make way for industrial-scale palm oil plantations. Large plantations on new agricultural lands can also push native plant and animal species out of the area, thus reducing biodiversity and overall ecosystem health. Another potential danger is the risk of invasiveness with some crops, such as castor, jatropha and switchgrass.

The conflict between food and biofuels is real. It is beyond dispute that food prices of major staples that are also being used as feedstocks for biofuels production have increased dramatically over the past several years as biofuels production has boomed. What is not entirely clear is the causal link between the two and the best way to minimize the conflict in different parts of the world. On the one hand, the diversion of corn from food in the United States, which is about 40% of global production, and oilseeds in Europe and Southeast Asia *could* be the main driver for the rise in global commodity prices. However, as the U.N. Food and Agriculture Organization reports, most short-term price increases in food is more the result of increased demand for food from many of the world's fastest expanding economies, like China and India, as well as the high price of petroleum, which affects everything from transport to the price of agricultural inputs like fertilizer and pesticides. The success of sugarcane-based ethanol in reducing the price of fuel in Brazil may actually be helping to bring food prices lower.

One very important consideration when selecting potential feedstocks for biofuels production is whether current domestic production levels are sufficient to meet domestic demand for food and animal feed. However, increasing imports of some foods due to increased biofuels production also may not be such a bad thing, especially if the domestically produced crop can fetch more value as a biofuels feedstock than a food crop and the local food market can meet demand at affordable prices.

Another reason for considering using an edible crop for biofuels is if the domestic cost of production for that crop cannot compete in global or regional markets. As long as Kenyan sugar companies enjoy protective tariffs that enable them to charge about twice the price for imported sugar – Ksh 53,540 per tonne compared with Ksh 28,874 per tonne for imported sugar – then it makes more economic sense to continue producing sugar as the primary product, with the molasses by-product used for ethanol. However, if and when protective tariffs disappear, then the ethanol alone would make more economic sense as the amount of income per hectare for the co-production of sugar and ethanol would drop to Ksh 240,505 compared with Ksh 248,500 for ethanol alone.

The environmental sustainability of biofuels is at the center of a global debate over whether they are as green as first advertised. Various sustainability standards have been developed by different organizations with similar features, although no unifying global standard has yet been adopted. Laws promoting biofuels can also help to ensure sustainability. The E.U., which has set an ambitious goal of 5.75% biofuels by the end of 2010, is now considering banning biofuels derived from crops grown on recently cleared forests, wetlands or grasslands.

While most of the efforts towards more sustainable biofuels discussed above are laudable and much needed, many hurdles remain to their successful adoption and implementation. Like other similar standards, the devil is in the details. Verification, compliance and enforcement are also keys to success. Without verifiable assurances that the standards are being adhered with regard to specific batches of biofuels delivered and consumed, then the standard itself is meaningless. Biofuels sustainability standards in Kenya and the rest of the world would do well to copy many of the mechanisms that have been developed for other similar processes, such as the Forest Stewardship Council's system for certifying wood products and the Gold Standard for verified GHG emissions reductions.

HIV/AIDS can have a deleterious affect on biofuels production by depleting the agricultural labor pool due to premature death and re-occurring periods of illness. This can incapacitate agricultural production and rural livelihoods. The impact of high rates of HIV in the community is exacerbated by the fact that those affected are disproportionately between the ages of 15 and 49, the heart of the labor force. Conversely, the introduction of biofuels cash crops to agricultural communities affected by HIV/AIDS could also have many positive impacts. For example, increased income from the sale of cash crops could reduce the need for woman to engage in unprotected sex in exchange for food and money. However, the labor intensity of different potential biofuels feedstocks should be taken into consideration in cases where large portions of the local population may be in a weakened physical state.

Roadmap & Recommendations

With the right combination of governmental support, private sector entrepreneurship and NGO outreach, Kenya could become the biofuels powerhouse of East Africa and beyond. Within five years, Kenya could be blending 10% ethanol (E10) and 2% biodiesel (B2), plus providing surplus production for stationary power and exports. Biofuels could revitalize rural areas, like Nyanza and Western Provinces, and provide an engine of growth throughout the country. Such a program could also provide a model for the sustainable production of biofuels to counter the increasingly unsustainable models being pursued by large industrialized countries. However, achieving these goals will take a concerted and coordinated effort by government, the private sector, research institutions and NGOs.

A combination of feedstocks would be required to achieve these targets. For ethanol, the logical choices based on availability of land, yield and economics are sugarcane and sweet sorghum. Over 58 million liters could be produced if 15,000 hectares of new land were dedicated to sugarcane (16.5% of suitable land that is not currently being used for food or cash crops) and a portion of current sugarcane were diverted to full ethanol production. Another 34.6 million liters could come from sweet sorghum planted on 24,700 hectares (1% of suitable new land). A combination of castor, coconut, croton, jatropha, rapeseed and sunflower would require about 50,000 hectares of land, some of which is already planted, to produce 32 million liters of biodiesel per year.

The Ministry of Energy's recently released biodiesel strategy makes a number of prudent recommendations to promote and develop the biodiesel industry in Kenya. Several key aspects of the following roadmap incorporate these recommendations from the Ministry, including the production of certified seeds, the establishment and upgrading of blending facilities, myriad aspects of research and development, and the creation of pilot biodiesel production plants. The authors of this study appreciate the Ministry's input and support.

- Help develop the value chain for ethanol and biodiesel production by:
  - Providing agricultural assistance to farmers;
  - Supporting programs, such as irrigation, to improve yields;

    - Improving the transport infrastructure;
    - Enabling cogeneration of ethanol at sugar plants and the use of alternative feedstocks at stand-alone ethanol plants;
    - Supporting farm-based biodiesel production;
    - Investing in research to develop optimal seeds and management practices for new crops like croton and jatropha; and
    - Testing different biofuel blends in various potential applications, including vehicles and generators.
- Design and implement an appropriate regulatory and fiscal framework.
    - Establish specific goals for a National Biofuels Program, such as an E10 and B2 by 2013.
    - Select, empower and fund a lead agency to coordinate disparate government agencies and enable the government to speak with a unified voice on biofuels. The Energy Act provides a mandate to the Ministry of Energy to take the lead on defining a national biofuels policy, which it has already begun to do through the formation of the NBC. Because biofuels implicate many sectors that fall outside of the Ministry of Energy's mandate, it makes sense to establish a high-level task force of the various interested ministries, including: Energy, Agriculture, Environment & Natural Resources, Lands, Water and perhaps others. All other potentially affected government agencies, representatives from the business community, NGOs and development partners should also be consulted thoroughly. The most sensible place to locate the National Biofuels Programme is within the Renewable Energy Department at the Ministry of Energy, or with the creation of a new division. Additional personnel and resources will be crucial for this new Programme to flourish.
    - Create a transparent and inclusive process of defining the specific strategy and measures for encouraging the production and use of ethanol and biodiesel.
    - Implement policies that promote biofuels production and protect consumers, workers and the environment. The regulatory and fiscal review contained in this Study can be used as the basis of the reforms.
    - Adopt a blending mandate that specifies the amount of ethanol and biodiesel that should or must be blended by a certain date or dates. As described above, E10 and B2 could serve as reasonable goals.
    - Design fuel quality and blending standards. KEBS must establish or revise fuel quality and blending standards for both ethanol and biodiesel based on the blending mandate and existing standards in Kenya and internationally.
    - Designate priority feedstock crops. Based on economic, agronomic, social and environmental criteria and analysis, optimal crops should be selected for biofuels. For ethanol, sugarcane and sweet sorghum seem to make the most sense; and for biodiesel, castor, coconut, croton and jatropha should be emphasized.
    - Identify and certify optimal seeds for the priority feedstock crops. KEPHIS, KARI and/or KEFRI should be responsible for identifying, testing and certifying high yielding seeds that are adapted to the different agro-ecological zones in which they might be grown.
    - Review and revise all licensing requirements along the entire biofuels value chain where necessary to protect consumers, workers, communities and the environment. If possible, the licensing requirements under the various laws and regulations

discussed above should be integrated, thus eliminating unnecessary and onerous regulation.

- Adopt tax incentives to promote the new biofuels industry. Fuel taxes can make or break the feasibility of biofuels, so some combination of tax exemptions or subsidies will almost certainly be required to promote the industry. Additionally, farm-scale production, where the fuel being produced is not being sold, should also be exempt from fuel taxes, as the cost of production of biodiesel at the farm-scale would be prohibitively expensive if taxed fully.

  Government revenues can be protected even as taxes are reduced or eliminated for biofuels by accounting for the increased revenue from new biofuels businesses and/or marginally increasing the existing fuel tax on petroleum products to make up for exempted biofuels. For example, a Ksh 0.5 per liter increase in the roughly Ksh 20.5 fuel tax on diesel would cover the loss of revenue if biodiesel were completely exempted from fuel taxes up to a national B2 blend. Neither consumers nor the government would be affected by the change, although biodiesel production would become a much more attractive investment for project developers and farmers alike.

- Develop and implement sustainability standards for biofuels that are stringent but achievable.
  - The use of various crops that can grow in semi-arid areas combined with sophisticated mapping to minimize conflicts with existing food production areas, would enable large quantities of biofuels feedstocks to be produced in addition to, rather than at the expense of, existing food production.
  - The reliance on tree crops like croton and jatropha could be combined with reforestation and afforestation projects, as well as efforts to reclaim marginalized lands.
- Support pilot projects and research in the areas of agronomy, fuel and blending standards, production technology and processing, markets and consumer use.
- Inform and create awareness among decision makers and the public.

2. OVERVIEW OF ETHANOL & BIODIESEL

This chapter provides a detailed introduction to the two main types of liquid biofuels: ethanol and biodiesel.[5] Use of straight vegetable oil as a diesel replacement is discussed in the section on biodiesel. We have included information on efficiency, performance and quality; production processes; potentially viable feedstocks for Kenya; and second-generation biofuels. Appendices A and B contain national-scale suitability maps for each feedstock, including conflicts with existing land-uses.

2.1 ETHANOL

Ethanol, also known as ethyl alcohol or grain alcohol, is a liquid fuel that can be produced from a variety of sugars and starch containing crops, such as grains. Examples include: cassava, maize, sugar beet, sugarcane, sweet sorghum and wheat. Cellulose from switch grass, biomass waste and other woody fibers can also be used, although at a premium production cost. Ethanol is produced for fuel, alcoholic beverages, and for various medical, pharmaceutical and industrial uses (see Section 4.3 for more specific information on existing and potential markets for ethanol in Kenya).

Ethanol was first used as an automotive fuel starting in 1908 with the Model T Ford.[7] By 1938, an ethanol plant in Kansas was supplying over 2,000 service stations with about 68 million liters a year.[8] Interest in ethanol as a fuel declined around World War II as concern grew over using food for fuel and as large quantities of cheap petroleum-based fuels became readily available.

Photo 1: Spectre International's ethanol plant in Kisumu.[6]

For the past thirty years, ethanol has been used as an octane-enhancing additive to reduce air pollution. Kenya has been producing ethanol for over twenty years in relatively modest quantities and, for a period in the 1980s, was blending it into the petrol distribution network as "gasohol" (see Section 3.1 for a detailed history and current status of ethanol in Kenya). Over the past decade, ethanol production worldwide has expanded exponentially, rising over 25% in just the past few years alone.[9] The United States and Brazil are by far the two largest producers of ethanol fuel, with over 70% of the world's production.[10]

2.1.1 Performance, Efficiency & Quality

There are two types of ethanol that can be used for transport: hydrous and anhydrous. As the names indicate, the former contains water (about 4% of volume) and the latter has had nearly all of the water removed. Hydrous ethanol can be used for fuel, but only in vehicles that have been specially designed for running on it. Brazil used mainly hydrous ethanol in its transport sector in the early years of its ethanol program (see Section 3.3.1 for more on Brazil's ethanol program). Most ethanol produced today is anhydrous.

Anhydrous ethanol can be blended with petroleum-based gasoline at different levels. Low-level blends of up to 10%, referred to as E10, can be used in automobiles without any engine modification and are approved for use by all major automobile manufacturers.[11] Some vehicle modification is required to operate on ethanol blends above E10 due to the fuel's higher oxygen content.[12] Blends containing between 10% (E10) and 85% (E85) ethanol are in wide use in the United States, Brazil and other parts of the world. Automakers are now mass-producing "Flex-Fuel" vehicles (FFVs) that can run on pure hydrous ethanol or any blend of anhydrous. Even the Indy Racing League, home of the world-famous Indianapolis 500 motor race, recently adopted ethanol as its fuel of choice.[13]

Photo 2: E85 fuel pump.[14]

The energy content of ethanol is about 34% lower than that of petroleum gasoline, although this may vary slightly depending on the feedstock used to produce it.[15] This means that a liter of E10 will have about 93.4% of the energy, and thus fuel economy, as a liter of straight petrol fuel. Thus, it is important to discount the price, and any associated taxes, of ethanol blends in proportion to the percentage of ethanol contained therein to account for the reduction in energy content in the fuel (see Section 4.2.1).

Globally-recognized standards for ethanol fuel quality have been established by the American Society of Testing and Materials (ASTM). The Kenya Bureau of Standards (KEBS) has also adopted both an ethanol fuel standard and a specification for and E10 blend (see Appendix I for the detailed ASTM D-4806 and KEBS standards). The KEBS standard was originally adopted during Kenya's now defunct gasohol program and almost certainly requires updating. These standards help to assure original equipment manufacturers and consumers of the quality of fuel they are using in their vehicles and other equipment. The fuel standards also help to prevent damage to vehicles by ensuring standardized quality. Relying on these standards, many original equipment manufacturers have adopted maximum blends of biofuels they will allow to be used in their vehicles without voiding warranties.

2.1.2 Ethanol Production Process & Technology

The manufacturing process for ethanol from sugar crops and grains is nearly identical to that of producing potable alcohol (see Figure 1). It involves first separating the sugars from the biomass and then fermenting them in the presence of yeast to produce alcohol and carbon dioxide. Producing ethanol from cellulose, a process that is receiving significant attention in research laboratories, but is not yet commercially viable, requires an additional step that first breaks down the fibers to extract the sugar.

There are generally two production methods for converting corn or other starchy grains into ethanol: dry milling and wet milling.[16] Dry milling grinds the entire kernel or grain into flour, or "meal," which is then slurried with water and enzymes to convert the starch to dextrose, a simple sugar. This process is called saccharification. Ammonia is added to control pH and as a nutrient for the yeast and the mixture is heated to reduce bacteria. The mash is then moved into a fermenter, where yeast is added to convert the sugar to ethanol and carbon dioxide. The resulting mixture, called "beer" is then transferred to a distiller, where the ethanol is dehydrated and concentrated to 200 proof. The waste, called "stillage," is then processed to create wet or dried distillers grains, which can be used for animal feed, biogas generation or fertilizer. The carbon dioxide can be captured and used for carbonation in the beverage industry.

Wet milling first soaks the grain in water and sulfurous acid to separate out the corn oil, fiber, gluten and starch. The oil, fiber, and gluten are used for various products including human and animal feed, and other products. The starch is then either fermented into ethanol similarly to the process described above, or converted into corn starch or corn syrup, which are valuable ingredients in many foods.

Producing ethanol from sugarcane, sorghum and other sugar crops is a simpler, cheaper and more efficient process, as the sugars are readily extracted from the crop without the pre-processing described above. The crop is crushed into sugar juice, crop residue (called "bagasse") and, with crops such as sweet sorghum, grain. The sugar juice can be directly fermented into ethanol or first processed into crystallized sugar and molasses. The molasses (which will have differing sugar content levels depending on how much crystallized sugar has been extracted) is then used for ethanol production, as well as other agricultural and industrial uses. The bagasse is burned for energy, which is often sufficient to operate the plant and produce excess to be sold back into the electricity grid. The grains (from sorghum) can be processed into food or converted into ethanol using the pre-processing saccharification step described above. A sugarcane-ethanol plant can increase or decrease the volumes of production of sugar and ethanol depending on the variable market demand of each product.[17]

FIGURE 1: ETHANOL PRODUCTION PROCESS

2.1.3 Ethanol Feedstocks

The following fact sheets provide background information on potentially viable ethanol feedstocks in Kenya. We have chosen to focus on cassava, sugarcane and sweet sorghum due to the history of production in Kenya, climatic suitability and other factors. Many other feedstocks can be used to make ethanol, including maize and potatoes, but we have chosen to avoid crops that would present the greatest threat to food security. Information on uses, diseases and pests, environmental impacts and agronomy are included in the fact sheets.

In conjunction with the International Centre on Agroforestry's (ICRAF's) GIS laboratory, we have developed maps that show where each feedstock is suitable to grow in Kenya and where they would conflict with existing agricultural production (both food and cash crop). As a general note, the maps are comprised of national-scale data layers that are useful for policymakers and the general public, but should not be relied upon by developers of specific projects without more detailed assessments. Some of the land that is considered "suitable" on the maps might conflict with current land uses, like towns and roads, or would be impractical due to transport and/or security restrictions. Significant portions of "suitable" lands also serve other uses, such as wildlife habitat and pastoral grazing, so may be unavailable to grow biofuels crops. We have discounted the acreage for each feedstock by 50% in each category to account for conflicting land uses.

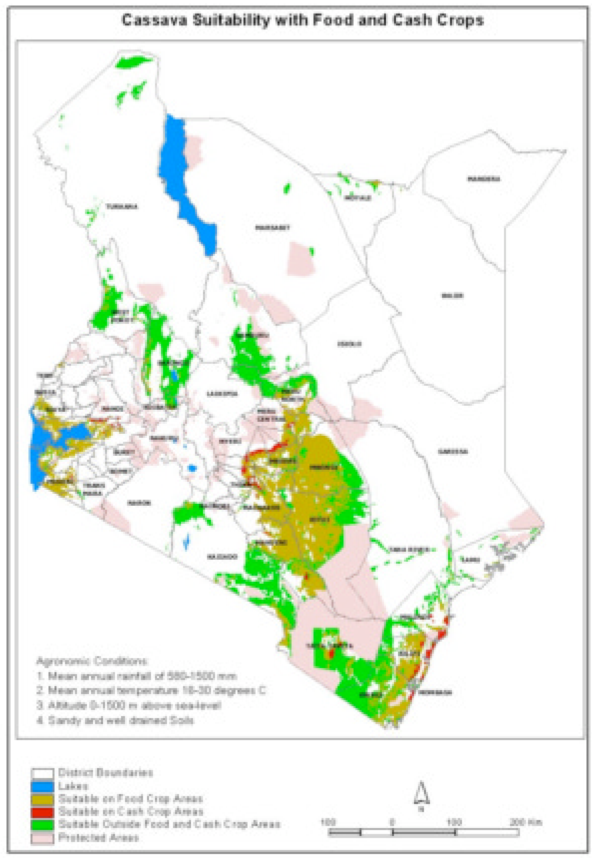
2.1.3.1 Cassava

Scientific Name: *Manihot esculenta.* **Local Names:** *Cassava, manioc, manihot, yucca, muhogo.*

Temp (°C)	Alt. (m)	Rainfall (mm)	Maturity Time (mos.)	Soil Types	Rainfed Yield (T/ha/yr)	Ethanol Yield (L/tonne)
16-30[18]	0-1500[19]	580-1500[20]	6-9	Light sandy loams, medium fertility, well drained.	9.6[21]	160-180[22]

Photo 3: Cassava plantation.[23]

Photo 4: Recently harvested cassava.[24]



Map 1: Cassava Suitability with Food & Cash Crops

Cassava Suitability Areas in Kenya in Hectares[25]			
Overall Suitability	Suitability w/o Protected Areas	Suitable w/o Protected & Food Crop Areas	Suitable w/o Protected, Food, Cash Crop Areas
5,161,025	4,150,316	2,191,765	2,082,978

Uses: The most important use of cassava is as a staple foodstuff, where it is ground into a type of flour and used as a thickener in soups and puddings in the form of tapioca. It is used as a base in canned foods, ice cream, biscuits, confectionary and pharmaceuticals. Starch, a product of cassava, is used in food production, pharmaceuticals, paper manufacturing and textile industries. Other industrial uses of the tuber are in the production of alcohols and manufacture of adhesives.[26]

Agroforestry Potential: Studies have shown that intercropping cassava with tree crops can greatly reduce erosion and increase soil cover, although this could come at the expense of soil fertility. One particular study showed that when intercropped with eucalyptus or leucaena, soil loss was 70%-80%

less than when cassava is grown by itself. Runoff and soil loss were effectively reduced when cassava was grown on staggered soil mounds along with eucalyptus and leucaena, due to better canopy coverage of the soil surface. Canopy coverage by eucalyptus and leucaena was restricted by harvesting, thus reducing their erosion and runoff control potential.[27]

Environmental Pros & Cons: Cassava is non-invasive and highly tolerant to drought but susceptible to water logging and salinity. It is also suitable for mechanization on large scale. Cassava's requirements are few and as a consequence it is frequently cultivated where few other crops could survive. It has no definite maturation point so the roots can be stored in the ground for up to 24 months if the grower wants to use the fresh roots at a later time. Cassava is a staple food crop for many and thus could pose a conflict if diverted for ethanol production. The plant does not produce enough vegetation to cover the soil well. Thus the production of cassava can result in considerable soil erosion during the entire life of the plant. Because little else grows on such soils, the erosion often continues well after the cassava is harvested. Production can also leads to loss of biodiversity. Processing, especially industrial processing, can lead to deposition of cyanide and organic matter on the soil and in water sources, and dust and foul odors in the air.[28]

Pests & Diseases: Major pests include the cassava hornworm (*Erinnyis Ello*), cassava mites (*Mononychellus tanajoa*), thrips (*Frankliniella williamsi*), gall midges (*Jatrophobia brasiliensis*), root knot nematodes, mealy bugs, scale insects, variegated grasshopper, white flies, termites, spider mites, rodents, baboons, monkeys and wild pigs. Major diseases include the African mosaic virus, whose causal agent is as yet unknown, cassava stem rot (various pathogens), leaf spot, bacterial blight, brown spot, brown streak virus disease and cassava anthracnose disease.[29]

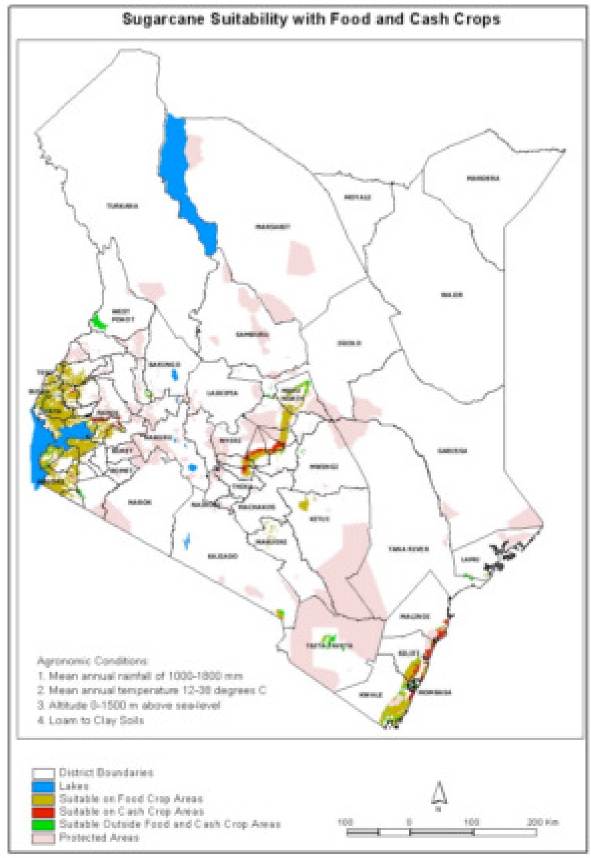
2.1.3.2 Sugarcane

Scientific Name: *Saccharum officinarum.* **Local Names:** *Miwa.*

Temp (ºC)	Alt. (m)	Rainfall (mm)	Maturity Time (mos.)	Soil Types	Rainfed Yield (T/ha/yr)	Ethanol Yield (L/tonne)
12-38[30]	<1500[31]	1000-1800[32]	18-24[33]	Loam to clay.[34]	70-120; '06 Actual: 70.89.[35]	70 (cane juice); 10 (molasses)[36]

Photo 5: Sugarcane plantation.[37]

Photo 6: Cut sugarcane.[38]



Map 2: Sugarcane Suitability with Food & Cash Crops

Sugarcane Suitability Areas in Kenya in Hectares[39]			
Overall Suitability	Suitability w/o Protected Areas	Suitable w/o Protected & Food Crop Areas	Suitable w/o Protected, Food, Cash Crop Areas
866,620	825,922	171,783	93,611

Uses: Sugar manufacture (from cane juice); power and steam generation (from bagasse); potable alcohol, power and industrial/fuel alcohol, methane/biogas (from molasses). Sugarcane is also chewed in its raw state. Ethanol can be produced either from cane-juice or molasses.[40]

Agroforestry Potential: Can be intercropped with suitable multipurpose trees using contour hedgerows to make production and conservation possible in non-mechanized areas.[41]

Environmental Pros & Cons: Can support climate-friendly sustainable development, growing sugarcane can be an important carbon sink; by-products like molasses and bagasse are important energy sources with significant environmental advantages. Loss of biodiversity and conversion of primary forest habitat, soil erosion and degradation, agrochemical use, organic matter from processing effluents can affect aquatic life.[42]

Pests & Diseases: Sugarcane borer (*Diatraea sacchari*), sugarcane smut (*Ustilago scitamine)*, mosaic, ratoon stunting, pineapple diseases.[43] Insect pests of economic importance are sugarcane scales and termites. Sugarcane scales may cause a yield loss of up to 40%. Nematodes also cause significant economic losses. Weeds can cause between 30-100% loss in yield. The major weeds found in sugarcane producing zones include *striga, amaranthus, datura, tagetes* species and the narrowed leaved types such as couch, Johnson, nut sedge and Bermuda grasses.[44]

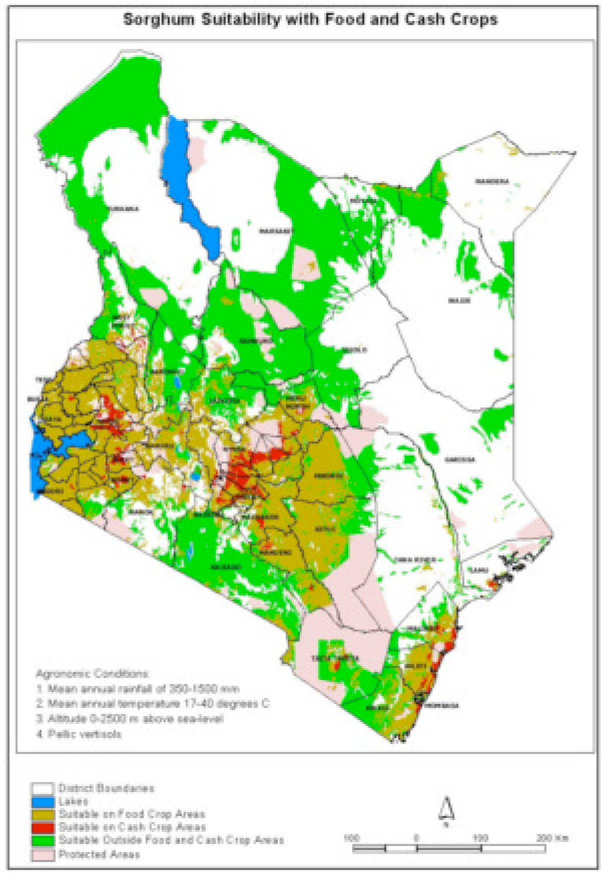
2.1.3.3 Sweet Sorghum

Scientific Name: *Sorghum bicolor.* **Local Names:** *Mtama.*

Temp (ºC)	Alt. (m)	Rainfall (mm)	Maturity Time (mos.)	Soil Types	Rainfed Yield (T/ha/yr)	Ethanol Yield (L/tonne)
17-40[45]	<0-2500[46]	350-1500[47]	3-6[48]	Pellic vertisols.	1.2 (grain); 30-40 (stalk)[49]	40[50]

Photo 7: Sweet sorghum plantation.[51]

Photo 8: Sweet sorghum stalk.[52]



Map 3: Sweet Sorghum Suitability with Food & Cash Crops

Sweet Sorghum Suitability Areas in Kenya in Hectares[53]			
Overall Suitability	Suitability w/o Protected Areas	Suitable w/o Protected & Food Crop Areas	Suitable w/o Protected, Food, Cash Crop Areas
13,198,257	11,063,652	6,305,979	5,897,124

Uses: Sweet sorghum can be used for human food (cereal, snack food, baking and brewing), ethanol production, animal fodder and the manufacture of wallboard and biodegradable packaging material. Sweet sorghum produces edible grains and a sweet stalk that is suitable for ethanol production, which can help mitigate the potential conflict with food that occurs with other feedstocks.[54]

Environmental Pros & Cons: Shorter growth period of 3-5 months compared to about 12-18 months for sugar cane. While it is sensitive to low temperatures, it can withstand temperature fluctuations better than sugar cane. Two crops can therefore be produced per year. Sugarcane is propagated from cuttings, requiring 4,500-6,000 kg/ha of cane. Sweet sorghum, on the other hand, is propagated from seed, requiring a minimum of 4-7.5 kg/ha of seed. The quantity of water needed by sweet sorghum is only one third that needed by sugarcane. It has high water use efficiency and is drought tolerant. It also tolerates some degree of salinity, alkalinity and poor drainage and therefore can be grown on a wide range of soils. Certain difficulties and limitations make sugar produced from sweet sorghum more expensive than that from sugarcane or sugar beet.[55]

Pests & Diseases: Leaf diseases, including northern corn leaf blight, maize dwarf mosaic and anthracnose, which can be problems in areas with high rainfall and humidity. Charcoal rot, which develops under hot, dry conditions after the plants have bloomed, can cause serious lodging problems. Major insect pests include wireworms, seed beetles, cutworms, aphids (especially greenbugs), sorghum midge, chinch bugs, spider mites, armyworms and earworms. Greenbugs are probably the most damaging sorghum insect pest. Aphids feed on the underside of leaves and inject toxins that destroy leaf tissue. Bird damage may also cause serious losses.[56]

2.1.4 Second-Generation Ethanol Production


Photo 9: Switchgrass plantation.[57]

Sometimes referred to as second-generation biofuels, ethanol made from cellulose such as switchgrass has heretofore been limited to the research laboratory.[58] The process involves using chemicals to extract sugars from the woody fibers contained in waste biomass. The currently uncompetitive cost of production for cellulostic ethanol is likely to change thanks to large government subsidies, especially in the United States where the Department of Energy is providing $385 million to six biorefineries.[59] The plan envisions the production of nearly 500 million liters of cellulostic ethanol over the next several years and the development of the technology to become self-sustaining without subsidies thereafter. Such technologies could one day in the future become a key part of ethanol production in Kenya that does not depend on food crops for feedstock. However, that day is unlikely to come anytime in the next five to ten years, at the earliest.

2.2 BIODIESEL

Biodiesel is a liquid substitute for petroleum-based diesel fuel made using vegetable oil derived from a wide variety of oil-bearing plants such as castor, coconut, croton, jatropha, rapeseed (canola), and sunflower. Waste vegetable oil can also be used for biodiesel. Unlike ethanol, which has several markets aside from energy, biodiesel's only use is as an alternative source of fuel for transport and stationary power.

The use of vegetable oil derived fuels has been around for over a century. Rudolph Diesel, the inventor of the compression diesel engine, routinely tested vegetable oils as fuel.[60] At the 1900 World Exhibition in Paris, the French Otto Company unveiled a diesel engine using 100% peanut oil.[61] The use of straight vegetable oil in diesel engines has been promoted as a cheaper alternative to processing the vegetable oil into biodiesel, but it is generally not considered a viable alternative for large-scale or long-term use.[62] It is possible to use straight vegetable oil, although vehicle alterations such as a pre-heater are necessary, and performance and wear on the engine and fuel lines is also a question. Given these limitations, we have chosen to focus on transesterified biodiesel instead of the use of straight vegetable oil.

2.2.1 Performance, Efficiency & Quality

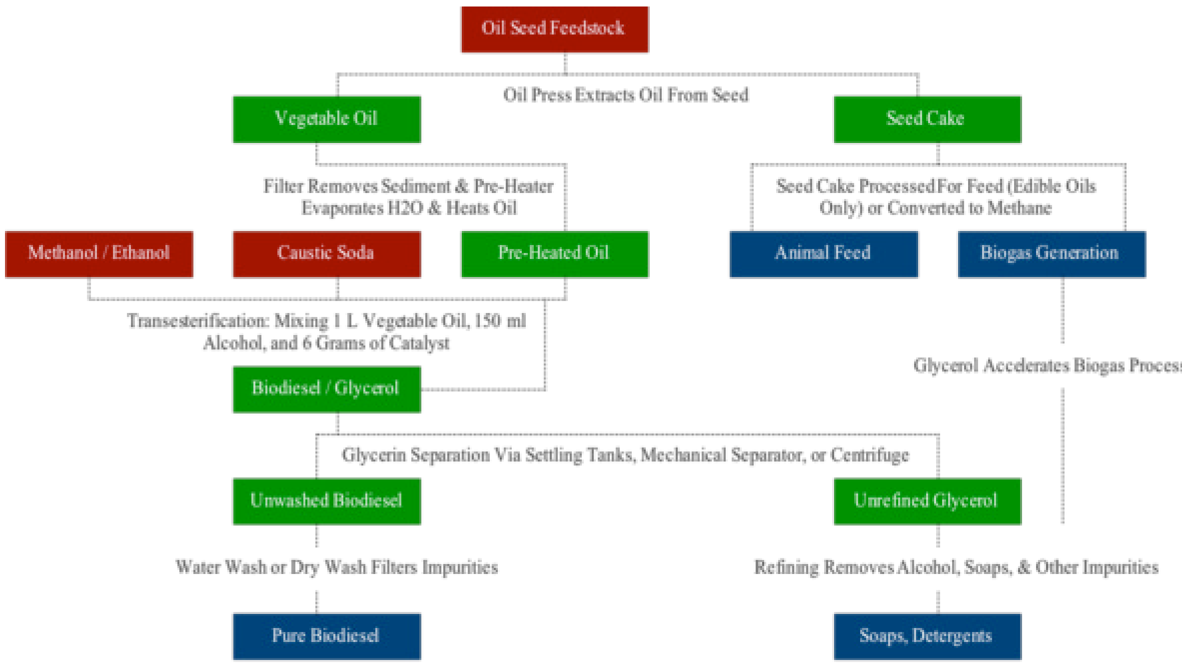
Biodiesel can be blended with petrol diesel in any proportion, with B5 (5% biodiesel) and B20 (20% biodiesel) being the most common. No vehicle alternations are necessary if blended at levels of B20 or lower, although original equipment manufacturers have varying policies approving different blends for use in their vehicles (see Appendix E for a listing of auto manufacturers' biodiesel policies). Blends up to B20 have not shown significant adverse effects on engine performance or wear.[63] However, blends higher than B20, and in particular pure biodiesel, can soften and degrade certain types of elastomers and natural rubber components such as fuel hoses and seals.[64] The use of low sulfur diesel blends in recent years has caused manufacturers to switch to components that are also more suitable for use with biodiesel.[65] Incompatible components in older vehicles can also be replaced.[66]

Biodiesel performs similarly to petrol diesel in terms of fuel consumption, horsepower, torque, and haulage capacity.[67] According to the United States Department of Energy, biodiesel is "safe," "biodegradable," and "by several important measures…performs better than petroleum diesel."[68] One study tested the use of 50% biodiesel blends over a 12 year period in a variety of vehicles without any appreciable adverse impact on the vehicles' performance or wear.[69] In particular, the lubricity of biodiesel is higher than that of petroleum diesel, which helps reduce engine wear.[70] In climates colder than nearly all of Kenya, biodiesel can gel faster than petroleum diesel, which can be prevented with the use of fuel additives.[71] Biodiesel has 93% of the energy of petroleum diesel.[72] This means that B5 will reduce fuel economy by about one half of one percent, and B20 by about two percent.

Photo 10: Eurofueltech CR2400 biodiesel reactor.[73]

Globally recognized standards for biodiesel fuel quality have been established by the ASTM and the European Union (see Appendix II for the detailed ASTM and EN biodiesel fuel standards). These standards help to assure consumers of the quality of fuel they are using in their vehicles and other equipment. The fuel standards also help to prevent damage to vehicles by ensuring standardized quality. Relying on these standards, many original equipment manufacturers have adopted maximum blends of biofuels they will allow to be used in their vehicles without voiding warranties. For example, Chrysler recently announced that it intends to endorse the use of B20 in its diesel vehicles once ASTM finalizes its proposed standard for B20 in early 2008.[74]

FIGURE 2: BIODIESEL PRODUCTION PROCESS



2.2.2 Biodiesel Production Process & Technology

Through a chemical reaction called transesterification, vegetable oil is combined with alcohol (methanol or ethanol) and a catalyst, such as caustic soda (sodium hydroxide), to produce biodiesel (methyl or ethyl esters) and glycerol. Approximately one liter of biodiesel is produced for every liter of vegetable oil fed into the process. There are two types of biodiesel production processes: batch and continuous. Both processes rely on the basic chemical reaction described above, although batch reactors are generally used for smaller levels of production, while continuous reactors are employed for larger commercial plants.[75]

The two main byproducts of biodiesel manufacturing – glycerol and seedcake – have value that help to reduce the overall cost of production. Glycerol can be processed into soap, burned for energy or composted. However, before glycerol can be used for soap or other industrial processes, the impurities introduced during the biodiesel manufacturing process must be separated from the glycerin through a refinement process. Burning glycerol for energy also poses environmental risks if not done at high enough temperatures due to the release of a toxic air pollutant called acrolein.[76] If the feedstock is an edible crop, like rapeseed, the seedcake can be used for animal feed. If the feedstock is inedible, like jatropha, the seedcake can be used for fertilizer or biogas generation.

2.2.3 Biodiesel Feedstocks

The following fact sheets provide background information on potentially viable biodiesel feedstocks in Kenya. Various factors, such as the history of production in Kenya and climatic suitability have led us to focus on the following biodiesel feedstock crops: castor, coconut, cotton, croton, jatropha, rapeseed and sunflower. Many other biodiesel feedstocks can be used, including palm and soya, but we have chosen to avoid crops that would present the greatest threats to competing land-uses and food security. Information on uses, diseases and pests, environmental impacts and agronomy are included in the fact sheets.

In conjunction with ICRAF's GIS laboratory, we have developed maps that show where each feedstock is suitable to grow in Kenya and where they would conflict with existing agricultural production (both food and cash crop) (see Appendices A and B). As a general note, the maps are comprised of national-scale data layers that are useful for policymakers and the general public, but should not be relied upon by developers of specific projects without more detailed assessments. Some of the land that is considered "suitable" on the maps might conflict with current land uses, like towns and roads, or would be impractical due to transport and/or security restrictions. Significant portions of "suitable" lands also serve other uses, such as wildlife habitat and pastoral grazing, so may be unavailable to grow biofuels crops. We have discounted the acreage for each feedstock by 50% in each category to account for conflicting land uses.

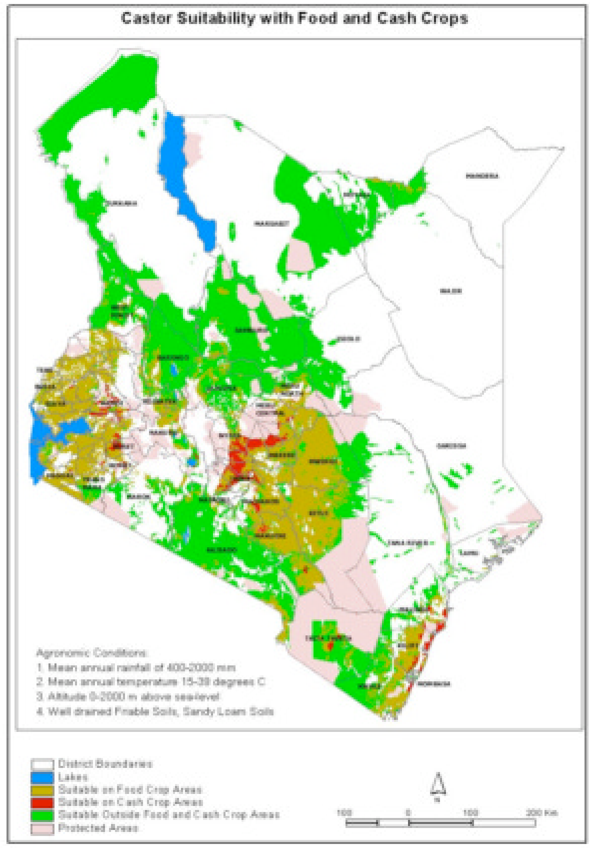
2.2.3.1 Castor

Scientific Name: *Ricinus communis.* **Local Names:** *Castor oil plant, castor bean.*

Temp (°C)	Alt. (m)	Rainfall (mm)	Maturity Time (mos.)	Soil Types	Yield (T/ha/yr)	Biodiesel Yield (L/tonne)
15-39[77]	0-2,000[78]	400-2,000[79]	5-10[80]	Well drained friable, sandy loam.	0.23 (rainfed)[81] 1.2 (irrigated)[82]	448[83]

Photo 11: Castor plants fruiting.[84]

Photo 12: Castor beans.[85]



Map 4: Castor Suitability with Food & Cash Crops

Castor Suitability Areas in Kenya in Hectares[86]

Overall Suitability	Suitability w/o Protected Areas	Suitable w/o Protected & Food Crop Areas	Suitable w/o Protected, Food, Cash Crop Areas
12,057,692	10,424,004	7,092,892	6,818,810

Uses: Castor has many industrial, medicinal and automotive uses, including: aircraft lubricants, hydraulic fluids, explosives, dyes, nylon, sebacic acid, placticizers, heavy duty automotive greases, coatings and inks, surfactants, polyurethanes, soaps, polishes, flypapers, paints, varnishes, fibre, insecticide, repellent and purgatives. Castor is also increasingly being promoted for biodiesel due to its high oil yield and relatively low water requirements. Cellulose from the stems is used for making cardboard and paper products.[87]

Agroforestry Potential: Castor is very suitable for agroforestry. It is one of the short-to-medium term species recommended for growing in agroforestry systems involving food crops, trees and nitrogen species.[88]

Environmental Pros & Cons: Castor is an invasive plant that has medium tolerance to drought, and suitable for mechanization on a large scale. It is also easy to cultivate and needs little attention. It has a high oil content and relatively low cost of production. Castor does best on fertile, well-drained soils, therefore it may conflict with food uses on arable lands. However, as the suitability maps below indicate, castor's ability to grow on semi-arid lands enable land-use planners to select lands for plantation that are not in direct competition with food. Castor is known to exhaust the soil very quickly, requiring the addition of fertilizers. Intercropping with crops that help to replenish soil nutrients also helps to maintain soil nutrients.[89]

Pests & Diseases: Many pests are reported to affect castor in Africa, including up to 50 species of insect: grasshoppers, various larvae, capsid bugs, green stink bugs, lygus bugs, helopeltis, semi-looper (said to be the most devastating in India), capsule borer, tobacco caterpillar, jassids, white flies, and thrips while other diseases include seedling blight, wilt and root rot. Diseases are reported to seldom do much damage, with leaf spot (*Cercospora reicinella*), rust (*Melampsora oricini*) and *Alternaria* leaf spot being the most common.[90]

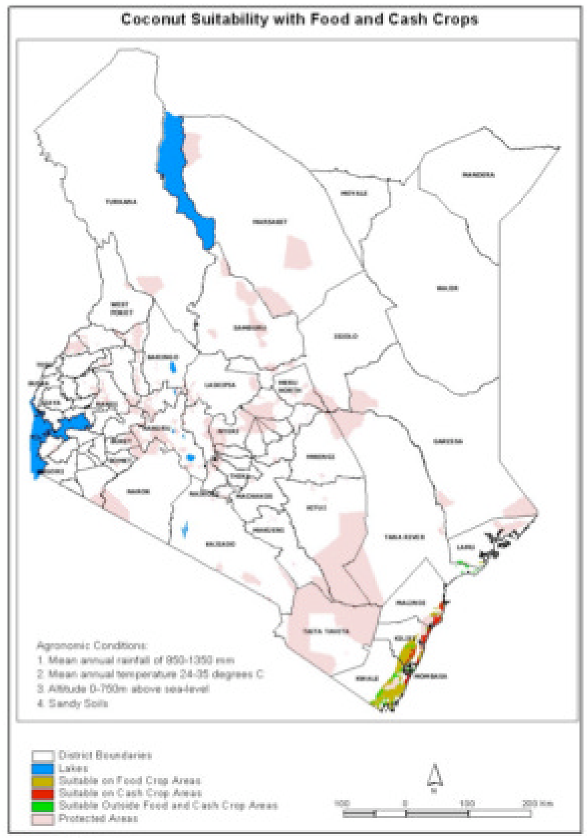
2.2.3.2 Coconut

Scientific Name: *Cocos nucifera.* **Local Name:** *Mnazi.*

Temp (ºC)	Alt. (m)	Rainfall (mm)	Maturity Time (mos.)	Soil Types	Yield (T/ha/yr)	Biodiesel Yield (L/tonne)
20-35[91]	0-750[92]	950-1,350[93]	48 – 60 to mature; 11 – 12 for fruiting	Sandy[94]	1.64 (Kenya)[95] 3.33 (Optimal)[96]	364[97]

Photo 13: Coconut trees growing near the beach.[98]

Photo 14: Recently harvested mature nut.[99]



Map 5: Coconut Suitability with Food & Cash Crops

Coconut Suitability Areas in Kenya in Hectares[100]			
Overall Suitability	Suitability w/o Protected Areas	Suitable w/o Protected & Food Crop Areas	Suitable w/o Protected, Food, Cash Crop Areas
224,428	183,746	68,821	33,201

Uses: From the leaves to the fruit to the trunk, coconuts are trees of many uses. The nut is used for food and beverages, like palm wine. The coconut oil that is extracted from the copra is used in the manufacture of soaps, cosmetics and pharmaceutical products. The husk and shells can be used for fuel that can also be processed into 'activated' charcoal for use in gas masks and other filtration devices. Coconut is a carbon source for the manufacture of various chemicals such as carbon disulphide, calcium carbide, silicon carbide, carbon monoxide, paint pigments, pharmaceuticals, molding resins, black powder, electrodes, catalyst reactor, brake linings and gas cylinder absorbent. The oil from the copra is not only edible but can also be used to manufacture paints and varnishes.

The leaves and trunk are used for: building materials and timber for furniture; fiber for ropes, mats, brushes, and brooms; and shells for the manufacture of utensils and ornaments. The trees themselves give shade and are planted as boundary markers. Coconut also has religious uses in India and other Asian countries. The trunk and roots also produce exudates with several applications in folk and modern medicine. Another interesting application is in plant tissue culture, on account of the fact that the liquid endosperm contains a plant hormone, cytokinin. This cytokinin is the crucial ingredient to get single cells to develop into embryos.[101]

Agroforestry Potential: Agroforestry systems involving coconut are extremely common throughout the world, including in Kenya. These systems enable farmers to increase their incomes while diversifying products from the farms.[102]

Environmental Pros & Cons: Coconut is non-invasive, has medium tolerance to drought, but is susceptible to water logging.

Pests & Diseases: The American Phytopathological Society lists dozens of bacterial, fungal, viral, and phytoplasmal diseases that afflict coconut trees. Major Pests include termites, coconut bug, rhinoceros beetle, coconut mite, coconut scale, and palm weevil. Diseases include lethal bole rot, lethal necrosis disease, and bud rot. The Kenyan Ministry of Agriculture reports that the rhinoceros beetle and the coreid bug could threaten future production.[103]

2.2.3.3 Cotton

Scientific Names: *Gossypium hirsutum, G. barbadense* and *G. harbeceum.* **Local Name:** *Pamba.*

Temp (ºC)	Alt. (m)	Rainfall (mm)	Maturity Time (mos.)	Soil Types	Yield (T/ha/yr)	Biodiesel Yield (L/tonne)
20-30[104]	0-1,400[105]	600-1,100[106]	5[107]	Black cotton, sandy loams, well drained.	0.34 (rainfed)[108] ≤3 (irrigated)[109]	146[110]

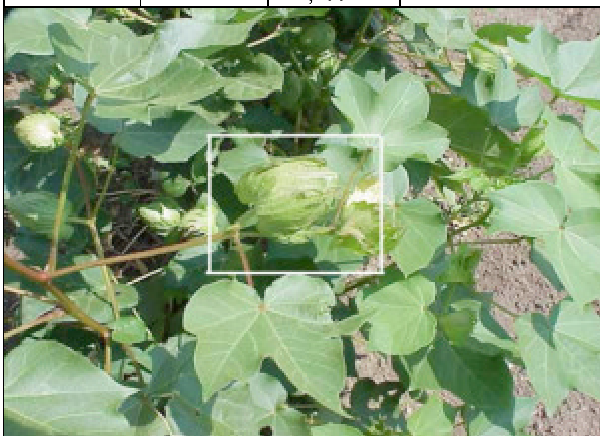
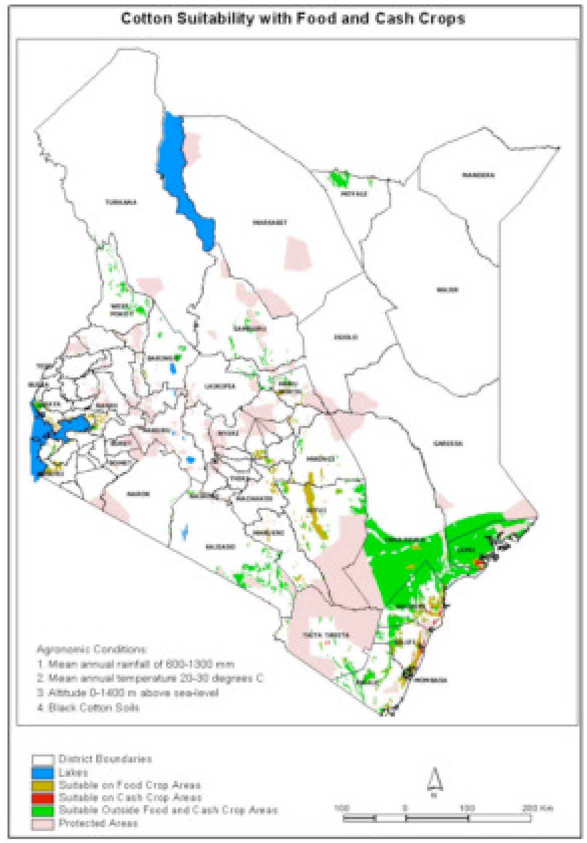


Photo 15: Cotton beginning to flower.[111]

Photo 16: Cotton flowering.[112]



Map 6: Cotton Suitability with Food & Cash Crops

Cotton Suitability Areas in Kenya in Hectares[113]			
Overall Suitability	Suitability w/o Protected Areas	Suitable w/o Protected & Food Crop Areas	Suitable w/o Protected, Food, Cash Crop Areas
2,069,515	1,755,169	1,442,397	1,417,398

Uses: Cotton is best known for its use in the manufacture of textile products. It is also used to make fishnets, coffee filters, tents, gunpowder (nitrocellulose), cotton paper and in bookbinding. The residual cottonseed after the cotton is ginned is used to produce cottonseed oil and animal feed. Cotton fiber is used to manufacture cotton wool, compress, gauze bandages, sanitary towels and cotton swabs. Cottonseed oil not only has several food applications but can be further refined for use in soaps and cosmetics. Additional uses include the application of seedcakes as fertilizer, manufacture of oilcloth and putty.[114]

Agroforestry Potential: Multiple advantages could be gained by intercropping cash crops, such as cotton, and trees. The recommended system for such intercropping is alley cropping, which consists of planting herbaceous or other crops between widely spaced rows of trees or shrubs. Apart from the multiple products obtained, the system is beneficial by reducing erosion and increasing carbon sequestration potential.[115]

Environmental Pros & Cons: Cotton is non-invasive, has medium tolerance to drought, is non-susceptible to water logging and is suitable for large-scale mechanized farming. Cotton can require large quantities of fertilizers and pesticides, which affect human health, biological diversity, and surface and groundwater quality. On the processing and manufacturing side, the use of industrial chemicals is of concern, especially those associated with dyeing textiles and finishing clothes. These chemicals affect not only the environment but also workers in the processing and apparel industries.[116]

Pests & Diseases: Insect pests comprise one of the most potentially damaging threats to cotton production. Nematodes (microscopic worm-like organisms) cause the cotton plant to exhibit disease-like symptoms. They attack the roots causing the plant to stop growing, reducing the yield. Crop rotation is the primary method of managing nematodes. Other major pests include: boll weevil (*Anthonomus grandis*), cotton aphid (*Aphis gossypii*), cotton bollworm (*Helicoverpa armigera*), and native budworm (*Helicoverpa punctigera*), brown-tail garden dart (*Hypercompe campinasa* – which feeds exclusively on *G. herbaceum*), the nutmeg and turnip moths, green mirid (*Creontiades dilutus*), spider mites (*Tetranychus urticae*, *T. ludeni* and *T. lambi*), and thrips (*Thrips tabaci* and *Frankliniella schultzei*). Major Diseases include: alternaria leaf spot (caused by *Alternaria macrospora* and *Alternaria alternata*), anthracnose boll rot (caused by *Colletotrichum gossypii*), black root rot (caused by the fungus *Thielaviopsis basicola*), blight (caused by *Xanthomonas campestris pv. Malvacearum*), fusarium boll rot (caused by *Fusarium* spp.), phytophthora boll rot (caused by *Phytophthora nicotianae* var *parasitica*), and sclerotinia boll rot (caused by fungus *Sclerotinia sclerotiorum*).[117]

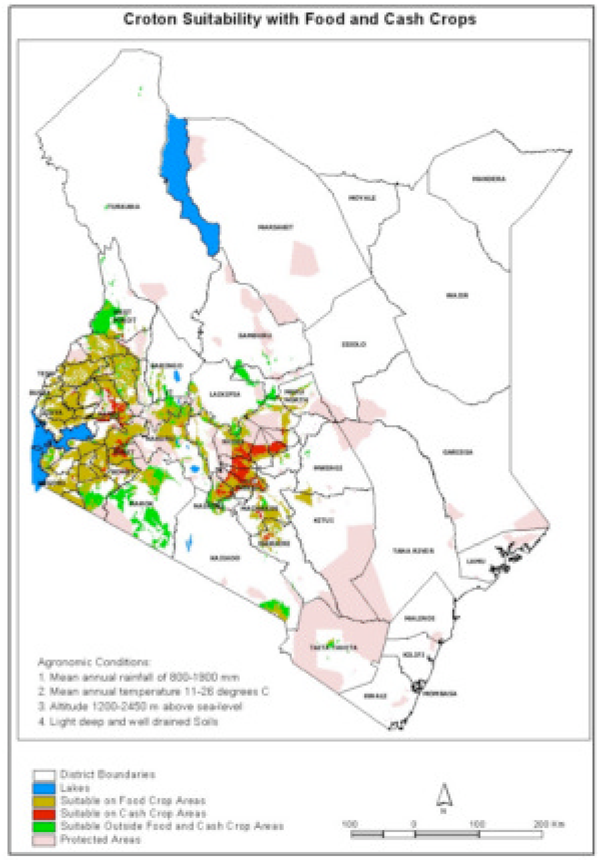
2.2.3.4 Croton

Scientific Name: *Croton megalocarpus.* **Local Names:** *Mlalai, muhande and musine.*

Temp (ºC)	Alt. (m)	Rainfall (mm)	Maturity Time (mos.)	Soil Types	Yield (T/ha/yr)	Biodiesel Yield (L/tonne)
11-26[118]	1,200-2,450[119]	800-1,900[120]	48[121]	Light deep and well drained.	2.5[122]	336[123]

Photo 17: Croton tree in the Kerio Valley.[124]

Photo 18: Croton fruit and seeds.[125]



Map 7: Croton Suitability with Food & Cash Crops

Croton Suitability Areas in Kenya in Hectares[126]			
Overall Suitability	Suitability w/o Protected Areas	Suitable w/o Protected & Food Crop Areas	Suitable w/o Protected, Food, Cash Crop Areas
3,138,651	2,560,358	880,943	652,866

Uses: Croton has several important uses: medicines, land improvement, animal feed and fuel (firewood and biodiesel). Medicinal extracts from the leaves, roots and bark are used to treat stomach problems and pneumonia. The seed has a high oil content (~30%) and high protein content (~50%), and is reported to be a forceful purgative. The bark is used to treat stomach worms and whooping cough. The tree makes a good live fence and/or as a source of shade. The leaves, which have high levels of nitrogen and phosphorous, are used for mulch and green manure. The wood is used as firewood but generally not for charcoal as the smoke stings the eyes. The wood is termite-resistant and quite strong and therefore used in general construction and heavy-duty flooring. The seeds are incorporated into poultry feed in many parts of Kenya and beyond.[127]

Agroforestry Potential: Croton is a hardy and fast-growing tree that can survive in harsh climatic conditions and is generally not browsed by animals. The tree plays many beneficial roles around the farm: demarcating boundaries, breaking the wind and reducing soil erosion. One report showed that in the Kenyan coffee-based land-use system of Embu District, more than 10% of the farms have croton hedges, with an average length of 70 metres, although it adds that when managed as a hedge the species is unlikely to produce as many fruits. It is also reported that older trees are competitive with crops. For this reason, the species is often confined to certain niches on the farm such as roadside boundaries, woodlots and paddocks. However, because of its multiple uses as a source of poultry feed and biodiesel, it is recommended that research into more suitable germplasm for on-farm use be conducted.[128]

Environmental Pros & Cons: Croton's deep tap root can withstand drought. The tree produces well for many years once established, has many other uses and benefits on the farm, as noted above.

Pests & Diseases: There is generally a lack of information of pests and diseases affecting Croton, but ambroia beetles have been reported to damage the tree in areas between 1,300 and 2,100 meters in Kenya. The insect scolytidae may also prey on croton.[129]

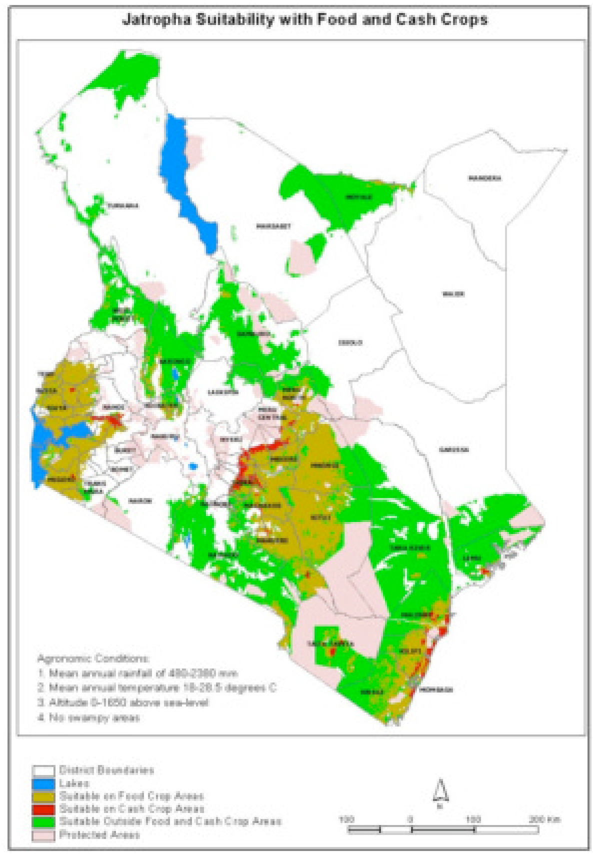
2.2.3.5 Jatropha

Scientific Name: *Jatropha curcas.* **Local Names:** *Barbados nut, fig nut, physic nut, mbono or mfinya.*

Temp (°C)	Alt. (m)	Rainfall (mm)	Maturity Time (mos.)	Soil Types	Yield (T/ha/yr)	Biodiesel Yield (L/tonne)
18-28.5[130]	0-1,650[131]	480-2,380[132]	60-84[133]	Well drained sandy or gravelly soils.[134]	2.5 (rainfed)[135] 4.2 (irrigated)[136]	336[137]

Photo 19: Jatropha plantation in Shimba Hills.[138]

Photo 20: Jatropha fruit and seed.[139]



Map 8: Jatropha Suitability with Food & Cash Crops

Jatropha Suitability Areas in Kenya in Hectares[140]			
Overall Suitability	Suitability w/o Protected Areas	Suitable w/o Protected & Food Crop Areas	Suitable w/o Protected, Food, Cash Crop Areas
11,096,859	9,414,526	6,459,783	6,264,433

Uses: Originally from Latin America, jatropha has been used in Kenya and many other parts of the world for years for a variety of uses. Of course, the one use that has provided jatropha so much publicity of late is as a source of oil for biodiesel. ICRAF reports the following uses from around the world: ashes from the roots and branches are used as cooking salt; young leaves are eaten when steamed or stewed; fruit hulls and shells can be used as fuel; leaf juice and ashes are used in dyeing and tanning; the oil is used in wool spinning and textile manufacture; the bark contains a wax composed of a mixture of melissyl alcohol and its melissimic acid ester; the oil is used fish poison and pesticide; leaf extracts have been effective in controlling *Sclerotium spp.*, an *Azolla* fungal pathogen; the nuts have been used as a purgative; the latex has antibiotic properties against *Candida albicans*, *Escherichia coli*, *Klebsiella pneumoniae*, *Staphylococcus aureus* and *Streptococcus pyogens*.[141]

Agroforestry Potential: Under suitable management regimes and spacing, jatropha can be intercropped, although there is some disagreement over this. In Kenya, this is already happening where the shrub is used as a support for vanilla plants. Jatropha is widely used in agroforestry systems throughout India, and trials are underway in Zimbabwe, Egypt and other countries.[142]

Environmental Pros & Cons: Jatropha is used to control soil erosion, especially in semi arid areas, and its seedcake, which is high in nitrogen, can be used to improve soils. Fencing can help keep animals out of croplands. On the downside, the tree takes five to seven years to reach maturity and full production, seeds contain a highly toxic substance called curcasin, and plantations cannot easily be mechanized. Jatropha is also considered invasive in many parts of the world. One of jatropha's most attractive characteristics is its ability to withstand drought and to grow in semi-arid areas with poor soil fertility. However, a survey of jatropha farmers in Kenya indicates that these purported strengths may have been exaggerated. It seems that jatropha is very sensitive to fertilizer and water, so that yields may be significantly reduced if grown on marginal, arid lands without significant additional inputs.[143]

Pests & Diseases: Despite claims to the contrary, jatropha is susceptible to many pests and diseases. Common pests include: scutellarid bug (*Scutellera nobilis*), inflorescence and capsule-borer (*Pempelia morosalis*), blister miner (*Stomphastis* (*Acrocercops*) *thraustica*), semi looper (*Achaea janata*), flower beetle (*Oxycetonia versicolor*), and golden flea beetle (*Podagrica* spp.). Jatropha is also host to the fungus "frogeye" (*Cercospera* spp.) common in tobacco. Termite infestation has also been reported in overage trees. Some diseases reported for Jatropha include: root rot (*Clitocybe tabescens*), leaf spot (*Colletotrichum gloeosporioides*), rust (*Phakopsora jatrophicola*), cassava superlongation disease (*Sphaceloma manihoticola/Elsinoe Brasilinesis*). In Zimbabwe and Kenya, powdery mildew damages leaves and flowers, *Alternaria* causes premature leaf fall, and golden flea beetles eat young leaves and shoots. Red spider mite has also been reported in Kenya. KEFRI is currently conducting a study of pests and diseases affecting jatropha in Kenya, due out sometime in 2008.[144]

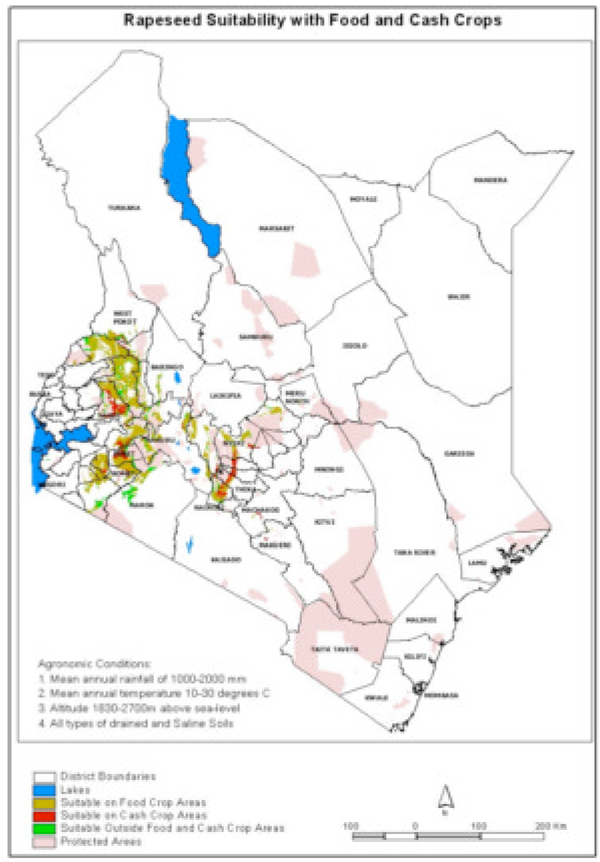
2.2.3.6 Rapeseed (Canola)

Scientific Name: *Brassica napus* **Local Names:** *Rapa, rape, oilseed rape and canola.*

Temp (ºC)	Alt. (m)	Rainfall (mm)	Maturity Time (mos.)	Soil Types	Yield (T/ha/yr)	Biodiesel Yield (L/tonne)
10-30ºC [145]	1,830-2,700[146]	1,000-2,000[147]	3-4	All types, drained, saline soils.	2.0 (Rainfed)[148] 3.5 (Irrigated)[149]	392[150]

Photo 21: Rapeseed plantation in full bloom.[151]

Photo 22: Rapeseed.[152]



Map 9: Rapeseed Suitability with Food & Cash Crops

Rapeseed Suitability Areas in Kenya in Hectares[153]			
Overall Suitability	Suitability w/o Protected Areas	Suitable w/o Protected & Food Crop Areas	Suitable w/o Protected, Food, Cash Crop Areas
1,188,160	815,755	248,924	156,367

Uses: Rapeseed, which is related to mustard, broccoli and turnip, is mainly grown for oil and animal feed. Rapeseed oil has many valuable industrial uses, including: as lubricating oil, polymer in paints and varnishes, and in the manufacture of emulsions to coat photographic paper and film. Its high erucic acid content also makes it valuable for biodiesel due to its high calorific value, low flash point and high cetane levels. Most of the biodiesel produced in Europe is derived from rapeseed. Canola is a particular cultivar of rapeseed that has been bred to have a lower erucic acid level because tests have shown that infants may not have the appropriate enzymes to properly break it down. Rapeseed is also beneficial as a cover crop that protects soils, suppresses weeds and can break up the soil with its extensive root system. Wheat farmers in Laikipia and Timau grow rape for these purposes.[154]

Agroforestry Potential: Although trials have shown that rapeseed can be intercropped with trees, the most economical production is in mechanized plantations.[155]

Environmental Pros & Cons: Rapeseed is a good cover crop and a good source of oil, which can be used for human and animal consumption, as well as in biodiesel production. Rapeseed is generally grown on a mechanized scale, which often relies on energy-intensive and chemical-intensive methods of farming, which can lead to various detrimental environmental impacts.

Pests & Diseases: Major pests include: flea beetle, diamondback moth, bertha armyworm, root maggot, cabbage seedpod weevil, aphid, and harlequin bug. Major diseases include beet western yellows virus, blackleg, clubroot, *Sclerotinia* stem blight, *Pythium* (damping off) and white rust disease.[156]

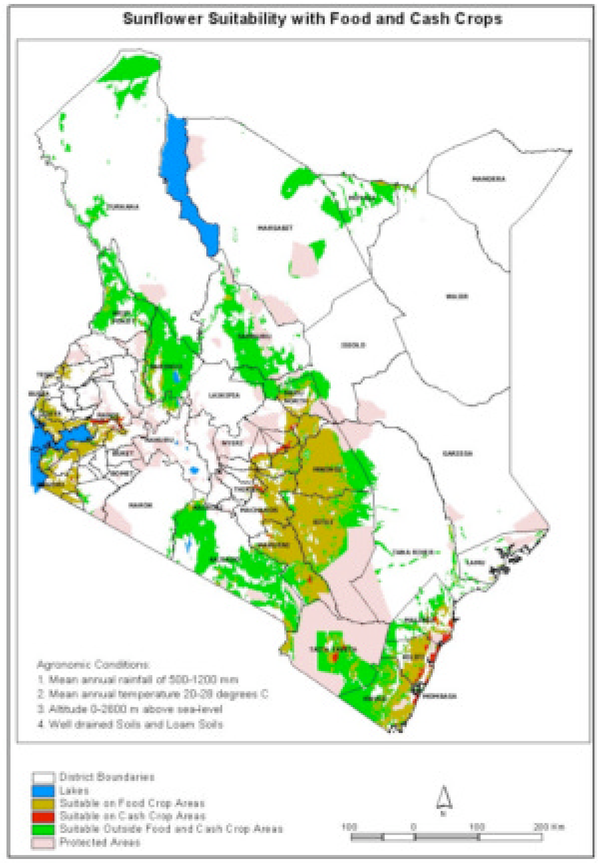
2.2.3.7 Sunflower

Scientific Name: *Helianthus annuus.* **Local Names:** *Sunflower, marigold of Peru, Sola indianus.*

Temp (ºC)	Alt. (m)	Rainfall (mm)	Maturity Time (mos.)	Soil Types	Yield (T/ha/yr)	Biodiesel Yield (L/tonne)
20-28ºC[157]	0-2,600[158]	500-1,200[159]	4-6[160]	Well drained soils, loam soils[161]	0.92 (current)[162] 3.0 (irrigated)[163]	414[164]

Photo 23: Sunflower plantation.[165]

Photo 24: Sunflower seeds.[166]



Map 10: Sunflower Suitability with Cash & Food Crops

Sunflower Suitability Areas in Kenya in Hectares[167]			
Overall Suitability	Suitability w/o Protected Areas	Suitable w/o Protected & Food Crop Areas	Suitable w/o Protected, Food, Cash Crop Areas
7,000,169	5,777,377	3,576,861	3,477,635

Uses: Sunflower is used mainly for edible oil and animal feed formulations. Sunflower oil is also used in certain paints, varnishes and plastics because of good drying properties that do not affect color. Sunflower can also be used as a silage crop. It can be used as a double crop after early harvested small grains or vegetables, an emergency crop, or in areas with a season too short to produce mature corn for silage. Besides producing edible oil, the seeds themselves can be eaten as snacks, whereas the leaves and other parts are reported to have various medicinal uses.[168]

Agroforestry Potential: Sunflower can be intercropped with trees because of its ability to restore nitrogen used up by other crops. A recent study showed that when trees are intercropped with sunflower and other crops, soil erosion and nitrogen leaching were significantly reduced, while landscape biodiversity and carbon sequestration increased.[169]

Environmental Pros & Cons: A joint document by North Dakota State University and the United States Department of Agriculture describes sunflower as high-risk crop, under threat from four main agents, namely: insect pests, disease, birds and weeds.[170]

Pests & Diseases: The major insect pests of sunflower include the jassids and white fly which are sucking pests, tobacco caterpillar, Bihar hairy caterpillar and semi loopers which are foliage pests, and the gram pool borer, a cepitulum borer. Major diseases include: Alternaria, leaf spot, rust, powdery mildew and sunflower necrosis disease (a viral disease).[171]

2.2.4 Second-Generation Biodiesel

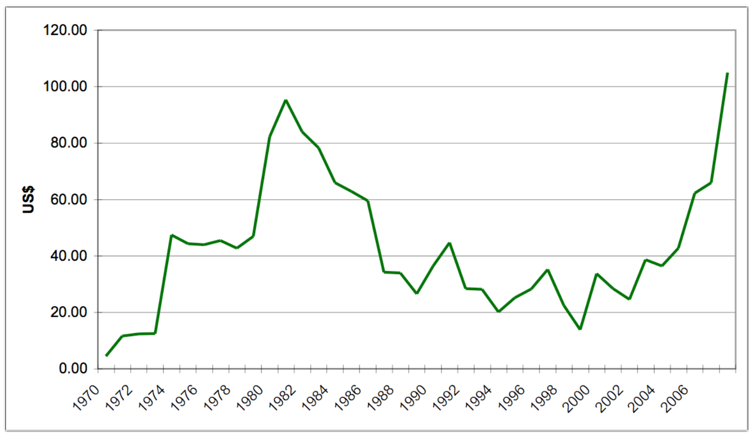
Similar to ethanol, second generation of biodiesel production is being explored in research laboratories throughout the world. Oil production from algae has been under development for at least three decades, but has yet to become commercially viable.[172] Some companies are beginning to market and sell off-the-shelf algae bio-reactors, but they are not yet commercially proven or economically competitive with existing oil crops.[173]

3. HISTORY & CURRENT STATUS OF BIOFUELS

This section provides the history and current status of ethanol and biodiesel in Kenya, as well as a brief review of various biofuels programs globally and regionally. The aim is to inform the reader of the status of Kenya's biofuels industry in comparison to her neighbors and the world's leading producers. The section is also meant to guide policy makers, potential industry players and other stakeholders so that they can learn from experiences in other parts of the world.

3.1 ETHANOL IN KENYA

FIGURE 3: INFLATION ADJUSTED OIL PRICES 1970-2007[174]



Kenya was ahead of its time in producing and using ethanol for fuel, but abandoned its gasohol program over 15 years ago. Starting in the early 1980's, Kenya produced and blended ethanol into the national petrol distribution network. The Government of Kenya initiated its gasohol policy in response to the record oil prices of the late 1970s and early 1980s (see Figure 3), and the impact this price spike was having on the nation's foreign currency reserves.[176] The policy mandated a 10% ethanol blend, but due to production limitations, only achieved that level in the Nairobi market. One company, Agro-Chemical, produced all of the ethanol used in the program, which was transported to the Nairobi fuel depot and blended by the petroleum retailers. A number of factors made gasohol uneconomical by the late 1980s, including: a drop in global oil prices, a surge in the price of ethanol for alcoholic consumption in export markets, and a deterioration of the ethanol production and transport infrastructure in Kenya. The blending program ceased, although ethanol continues to be produced to this day for the alcohol beverage market in Kenya and throughout East Africa.

Photo 25: Water treatment at Spectre International's ethanol plant.[175]

The Kenyan ethanol industry, which now includes Agro-Chemical and newcomer Spectre International, is marked by tremendous opportunities and significant challenges. Despite more than two decades of experience in the industry and a recent increase in production from about 11 million liters in 2004 to nearly 19 million in 2006, serious limits on growth remain.[177] Nonetheless, expansion of current ethanol production capacity is beginning. In order to succeed, a coordinated effort will be required to dramatically expand current feedstock production and to ensure a rational policy framework is adopted. If these efforts are successful, it seems entirely possible that at least 10% of Kenya's petrol consumption could be offset by ethanol within the next five to ten years. Along the way, thousands of farmers and workers, as well as Kenya's struggling sugar industry, stand to benefit from a long-awaited economic boom. Many of the key suggestions for realizing this vision are contained in latter parts of this study.

Photo 26: Sugarcane backlog outside of the Muhoroni Sugar Co. and the adjacent, idled Agro-Chemical ethanol plant.[178]

Agro-Chemical and Spectre International have current production capacities of 60,000 and 65,000 liters per day, respectively, although current supplies of molasses – the only ethanol feedstock being used in Kenya – mean that only about half of capacity is currently being used, for a total average daily production of about 60,000 liters per day.[179] Most of the ethanol produced is being sold to the beverage markets in Uganda and the Democratic Republic of Congo, with some also being sold for various industrial purposes as methylated spirit.

Fulfilling the full production capacity at the two ethanol plants would require almost the entire supply of molasses from Kenyan sugar companies, which is not feasible given the alternative markets for molasses and the current productivity of sugarcane in Kenya.[180] About half of the molasses currently produced in Kenya is being sold off to farmers and small-scale brewers in Uganda, who are typically willing to pay a higher price than the ethanol plants can afford. If Kenyan sugarcane growers were able to irrigate their crops and grow faster maturing types of cane, as many of their competitors in Egypt, India and Mauritius do, then they could increase yields by up to 100%. This would enable greater overall competitiveness of the Kenyan sugar industry, as well as provide larger quantities of available molasses for ethanol.[181] However, irrigation is a very costly input, so the returns must be high enough to justify the additional costs.

Poor planning and a crumbling infrastructure are also limiting the competitiveness of sugar and ethanol in Kenya. This point was well demonstrated by a recent scene outside of the Muhoroni Sugar Factory and the adjacent Agro-Chemical ethanol plant where over 200 tractor-loads of sugarcane sat idly waiting to be unloaded into the crushers at Muhoroni. Although the precise reason for the delay was not clear, the effect was that Agro-Chemical had to cease ethanol production due to the lack of molasses. Another unfortunate effect was that farmers were forced to sit helplessly watching their two-year-old crops lose sugar content, and thus value, by the hour (sugarcane starts losing sugar content within two days of harvesting).

Thriving in an increasingly competitive global commodities market will require the Kenyan sugar and ethanol industry to innovate and diversify, as well as to invest in more efficient methods of production. As the Plant Manager at Mumias explained, "the unit cost of production of sugar in Kenya is one of the highest in the world. If we don't diversify, then we'll shut down."[182] Ethanol production and other products like power generation from bagasse could provide the lifeline that the sugar industry desperately needs to survive. Privately owned Mumias and Spectre International seem to have embraced this vision of the future, while some of their government-run competitors appear stuck in a past of guaranteed markets and a general lack of accountability. Mumias, which produced 226,666 tonnes of sugar in 2006, or 48% of total production in Kenya,[183] is planning to begin producing ethanol from its steady supply of molasses rather than continue selling it off to Agro-Chemical and Spectre International.[184]

The integrated production of sugar, ethanol and power that Mumias is planning is a more efficient and sustainable model of production. Rather than hauling tonnes of molasses via crumbling roads from the sugar factory to a distant ethanol distillery, the integrated approach is environmentally and economically superior. Indeed, Mumias predicts that it will be able to produce ethanol for significantly less than the current cost of production at Agro-Chemical and Spectre.[185] Mumias' plans will mean less molasses available to Spectre and Agro-Chemical, which will force them to develop alternative ethanol feedstocks if they plan to continue operating.

Undeterred by these developments, Spectre is moving ahead with a major expansion that will increase its production capacity from its current 65,000 liters per day to 230,000 liters per day.[187] Plans by Spectre and Mumias, if realized, will expand Kenya's ethanol production capacity to over 340,000 liters per day from its current 125,000 liters per day (see Table 1).[188] This expansion represents a major opportunity for rural economic development in Western Kenya and perhaps other regions as well. Increasing sugarcane yields on existing lands with irrigation and improved varieties, as well as expanded production into suitable areas (see Sugarcane Suitability Maps in Appendix A) that are not currently growing sugar, can meet some of this demand. For example, investing in irrigation on some lands currently used to grow cane could enable farmers to grow cane varieties that could mature in about half the time, which would not only nearly double production per hectare, but also help the sugar companies compete with the price of imported sugar. Mumias is also planning a large sugar and ethanol factory near the Tana River that will use irrigation to increase yields. According to Mumias, the goal is to produce a globally competitive sugar product while also producing large quantities of ethanol for domestic and export markets.[189]

TABLE 1: CURRENT & PLANNED ETHANOL PRODUCTION CAPACITY [186]

Ethanol Production (L/day)	Agro-Chem	Spectre	Mumias	Totals
Current Capacity	60,000	65,000	0	125,000
Current Production	27,400	30,000	0	57,400
Current & Planned Capacity	60,000	230,000	~50,000	340,000

However, limitations on available land and competition with food production are almost certain to preclude all planned ethanol production to be supplied by sugarcane. Without a substantial increase in sugarcane productivity, or a wholesale shift from sugar to ethanol production (which could produce over 900,000 liters per day of ethanol),[190] about 80% of the planned and current capacity will have to be met with new feedstocks. Spectre is planning to meet this increased capacity with sweet sorghum and perhaps other crops.[191] Spectre already has a test plantation in the ground and plans to begin recruiting outgrowers by mid-2008. Agro-Chemical is also talking about sweet sorghum as an alternative to molasses, but is further behind than Spectre in developing an outgrower program. One potentially innovative proposal from Spectre is to pay outgrowers based on the sugar content of the sorghum as opposed to the weight of the raw feedstock delivered. This should provide an incentive to farmers to increase their effort to produce optimal, high-yielding crops.

One of the greatest potential benefits of sweet sorghum is the fact that it can thrive in drier, more marginal agricultural areas than sugarcane (see Sections 2.1.3.2 & 2.1.3.3, and suitability maps in Appendix A, for a comparison of sorghum and sugarcane), however more practical research needs to be done to maximize its economic potential in Kenya. Both companies mentioned that the ethanol industry would benefit greatly from agronomy research and development assistance. The International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), which has a sweet sorghum program and offices in Nairobi, has met with both ethanol companies about providing such assistance, but little on-the-ground support has yet materialized from these meetings. This is one area where research assistance can and should be provided.

At the current rate of growth of petrol consumption of about 2.8% per year, Kenya is projected to consume about 618 million liters of petrol by 2013.[192] Full capacity of current and planned ethanol production could provide about 13% of domestic demand.[193] This could enable a nationwide blend of 10%, which would be consistent with current blends in many other parts of the world, leaving about 30 million liters for export or other non-fuel markets. Of course, it is unrealistic to assume production at full capacity, so additional ethanol plants would be necessary to reach this level of production. The economic analysis contained in Section 4 provides detailed information on ways of realizing such levels of production, as well as the potential income, employment and foreign currency exchange benefits. Section 5 on fiscal and regulatory policy and Section 7 on recommendations describe the regulatory framework that would be required.

Revival of ethanol fuel production in Kenya has widespread support from the public. In a countrywide survey (conducted as part of this study) involving interviews with over 80 potential stakeholders and interested parties in seven provinces, almost all respondents expressed support for the revitalization of the gasohol program. Reasons for their support included: rising petroleum prices, past success and the availability of existing infrastructure, and better use of waste from sugar factories. Respondents urged the government to put policy guidelines in place and sensitize people on the importance of ethanol as a substitute for petroleum.

3.2 BIODIESEL IN KENYA

Compared with ethanol, biodiesel in Kenya is in its nascent stage. However, a flurry of activities among government agencies, NGOs and the private sector indicate great potential. The vast majority of biodiesel projects currently underway or being planned involve jatropha as the main feedstock, although projects involving other feedstocks, including castor, coconut and croton, are also being discussed.

Many of the jatropha projects that are being run by NGOs and development organizations seem primarily focused on selling seeds and getting jatropha trees planted as quickly as possible. In the rush to move forward, too little attention seems to have been paid to coordinated research and development of high yielding seed provenances and general agronomic advancements of growing jatropha, although research is starting in this area. In some cases, unsuspecting farmers have been sold seeds at prices in excess of Ksh 2,000 per kilogram, with unfulfilled promises of agronomic extension services and agreements to buy back seeds produced. This has begun to fuel cynicism among some farmers about the crop's potential, as well as to distort the market for jatropha seeds, thus undermining its potential as a viable biodiesel feedstock.[194] Here is a brief description of some of the jatropha activities currently underway throughout the country:

The Green Africa Foundation (GAF) works in partnership with the private sector, individuals, self-help groups and the government.[196] GAF is working with investors from Japan who are seeking to set up plantations and processing industries from Taita Taveta all the way to Lamu. GAF claims to be working with thousands of farmers in Kajiado, Namanga, Kitui, Machakos, Nakuru, Naivasha, Coast Region and Marakwet. In addition, there are demonstration plots in Kitui, Shanzu, Marakwet, and Rarieda where farmers are not only taught how to plant jatropha, but provenance and management trials are also conducted. GAF's role is mainly in training farmers on proper planting procedures and supplying seeds and seedlings.

Photo 27: Agri-Business Group's plantation near Nakuru; Green Fuels (K)'s plantation near Thika; Energy Africa extension services with participating smallholder.[195]

The Mpeketoni (Lamu) Jatropha Project is a partnership of three main groups: Norwegian Church Aid (NCA), the Lamu Cotton Growers Association and ESDA.[197] The project aims to develop a Jatropha Energy System through an integrated approach of cultivation of jatropha for use either as a biodiesel blend or as straight jatropha oil, which will be used to run small power generation units with capacity totaling over 3MW. The project will commence in 2009 and benefit up to 10,000 farmers. The first harvest is expected after two years and estimated to yield 60 tonnes of oil. Initial land area to be cultivated is 400 hectares, which will be scaled up to 1,000 hectares after seven years.

Nyumbani Eco-Village in Kitui, which is home to many AIDS orphans, is being developed into a model of sustainability. The project is working to house about 1,000 orphans and 250 elders, with a goal of becoming self-reliant in terms of food production, energy and use of local resources. It is currently planting jatropha trees in and around the village.

Vanilla Jatropha Development Foundation (VJDF) is another NGO that works with farmers, government and the private sector to increase the production of jatropha throughout the country.[198] The biggest projects are located in Kibwezi, Koibatek and Kisumu. Its main role is in training extension workers for partner organizations, which then incorporate jatropha planting as part of their activities in the regions where they operate. However, some of these organizations have stated that they have yet to receive much, if any, of the promised training and support once the seeds or seedlings were sold to them.

VJDF also claims to be involved in testing various properties of jatropha in cooperation with the Kenya Industrial Research Development Institute (KIRDI), the Kenya Forestry Research Institute (KEFRI), Kenyatta University and the Kenya Bureau of Standards (KEBS). VJDF's Kambu project in Kibwezi is a unique concept whereby VJDF will supply seedlings to Safaricom at Ksh 10 per seedling, which Safaricom in turn will sell to farmers at a subsidized price of Ksh 5 per seedling and guarantees the market for the seeds after harvest. Safaricom is interested in using biofuels to power its remote relay towers, which are now powered by diesel generators.

The United Nations Development Programme's Small Grants Programme has been working with community based organizations in Kwale and Malindi districts to assist over 1,500 farmers plant over 200,000 jatropha trees on and around their farms.[199] The project's goals are to conserve biodiversity by reducing pressure on natural forests, decreasing land degradation and soil erosion, promote a clean, affordable, and locally-produced alternative fuel, and to enhance gender equity by empowering women. The first oil is expected to be pressed after the long rains of 2008.

Several private companies have begun developing jatropha plantations and are striving to expand production to a commercial scale.

Better Globe Forestry Limited has planted 48 hectares field trial of jatropha in Kiambere.[200] They are dealing with many of the same problems as other jatropha pioneers in Kenya: diseases and pests, and poor initial growth. It is not clear whether this is the result of poor seed germplasm or the result of particularly harsh environmental conditions. What is clear is the need for coordinated agronomy research into jatropha throughout Kenya. Private entrepreneurs like Better Globe Forestry and the many smallholders who have bought expensive seeds and seedlings from NGOs have put their own resources on the line and need support in terms of improved planting material and plant husbandry to realize the potential of their investments, and of jatropha in general as a viable feedstock for biodiesel in Kenya.

Green Fuels (K) Limited has a jatropha nursery and two-acre test plantation north of Thika near the Tana River.[201] The seeds produced by the plantation are being used to grow seedlings for sale to other farmers who are beginning to plant. Green Fuels is also providing seedlings free of charge to nearby smallholders.

Energy Africa Limited has been working since 2006 with over 200 smallholders in Shimba Hills near Kwale to begin planting jatropha.[202] Over 200,000 trees have been planted, with plans for many more. The project has encountered similar challenges to other jatropha projects in Kenya including poor establishment and pest and disease problems, but is beginning to correct some of these issues. The company has also established a sister company in Uganda, with ongoing jatropha test production in Mukono and Moyo Districts.

Agri-Business Group is an agricultural consulting business based in Nakuru, but working with farmers throughout Kenya.[203] They have planted a five-acre test plantation with an eye towards much larger plantations in the area. To date, the performance of the jatropha trees has been highly dependent on the quality of inputs. For example, trees that were not treated for pests have suffered tremendously, especially from an infestation of red spider mite.

Due mainly to the lack of available biodiesel feedstock, very little biodiesel is actually being produced. One company, Green Power East Africa Limited, is currently producing biodiesel on a small scale using a single BioKing reactor unit with an approximate capacity of 1,000 liters per day.[204] They use whatever oil feedstock is available on the local market, including cottonseed, and sell the produced biodiesel to local customers in the Enterprise Road area of Nairobi's Industrial area. The Kenya Industrial Research Development Institute (KIRDI) is also experimenting with crude homemade reactors using a variety of feedstocks. Such a program is ripe for increased research and development funding.

Several of the projects or organizations listed above are beginning their own research and development activities to identify superior planting material and best practices. Others have expressed interest in doing so. Two new projects are currently being planned to test best silvicultural practices and high yielding seed provenances. One project, which is being funded partly by the German private investment agency DEG, involves various farmers throughout East Africa who are bearing some of the costs of the trials, along with land and labor.

The other research project involves a number of Kenyan farmers, Endelevu Energy, KEFRI, ICRAF, and the Aga Khan Foundation's Coastal Rural Support Project (CRSP) in Kilifi and Malindi. The farmers will commit land and labor, KEFRI and ICRAF will design the trials and analyze the results, and CRSP will be working with smallholders who are eager to introduce a cash crop to their existing agricultural regime. Both projects expect to get underway in 2008. Some individual farmers are also beginning to plant trials of castor for biodiesel.

KEFRI has been conducting research on various tree and shrub species to ascertain their potential for biodiesel production.[205] The priority species are jatropha, croton, yellow oleander *(Thevetia peruviana)* and pongamia *(Milletia pinnata)*. Most of the research to date has focused on jatropha and includes the following:

- Jatropha Provenance Trial: Seeds will be collected from various areas and planted in potential sites and their performance monitored.
- Yield Determination: Focusing on quantity and quality from selected individual trees from different sites.
- Genetic Improvement and Fingerprinting: Selected provenances will be selected and the genotypes fingerprinted and monitored for consistency and further breeding.
- Genetic Diversity Studies: KEFRI intends to establish the genetic diversity of jatropha to be able to address future problems associated with genetic origin, such as inbreeding.
- Silvicultural Practices: This is intended to optimize quality and quantity based on the best silvicultural practices like spacing and intercropping.

The various research projects described above are encouraging, but should be better coordinated among both participants and donors to avoid overlap and to take advantage of the relative strengths of the various projects.

On the policy front, the Ministry of Energy has convened a National Biofuels Committee (NBC) comprised of representatives from the petroleum industry, government ministries, agricultural producers and NGOs. The Committee has drafted a biodiesel policy strategy with nearly exclusive focus on jatropha.[206] Other crops, like castor and croton are given passing mention in the document, but jatropha is the only crop that receives any serious attention. In some respects, these other crops may present a better opportunity for large-scale production in the short- to medium-term, as they are proven crops and can produce large quantities of feedstock within a season rather than in several seasons, as would be the case for jatropha.

While it is understandable to favor inedible oil crops that are less likely to compete for land with food crops, not considering the potential for other crops to serve as potential feedstocks just because they may be edible is overly simplistic and possibly counter productive. For example, the use of inedible crops can still have an adverse affect on food production by competing with food crops for land and labor. As explained below, the impact of biofuels crops on rural economic development, whether edible or inedible, is much more complex and requires a more nuanced approach. For one thing, detailed mapping and planning can enable certain areas to begin growing biofuel cash crops in lieu of food crops as long as the income generated from such cash crops and the local market can provide at least as much food as current practices do.

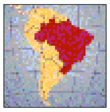
Regarding taxes and incentives, the Strategy proposes to undertake an economic analysis to "reveal details of taxation incentives that should be offered to stakeholders to encourage growth of the industry."[207] Two criteria are listed for whether tax incentives should be provided for biofuels: that the country does not lose revenue previously accruing from taxation of mineral diesel; and that incentives only apply to biodiesel for local consumption.[208] The Ministry of Energy also supports local ownership of investments and incentives such as tax waivers on imported equipment for use in the biodiesel industry.[209]

The economic analysis contained in Section 4 is intended to facilitate the research and decisionmaking process regarding appropriate biofuels tax policy. The analysis shows that most, if not all, biofuels will not be cost-competitive with petroleum-based fuels at current prices if faced with the same tax burden. Moreover, carbon credits are unlikely to provide much, if any, additional income for biofuels producers, as is also discussed in Section 4. We recommend ways of easing the tax burden on biofuels that maintain existing revenues for the government (see Section 7).

3.3 GLOBAL BIOFUELS PROGRAMS

More than 30 countries around the world have launched ethanol fuel programs, with Brazil and the United States leading the way. Meanwhile, the European Union is the top producer of biodiesel, with about 4.5 billion liters, or about 72% of global production, in 2006.[210] As discussed in more detail below, the growth in biofuels throughout the world has been the result of favorable fiscal and regulatory policies. For example, in 2003, the EU implemented a policy allowing member states to exempt biofuels from taxes, while also setting a target of achieving 5.75% biofuels throughout the E.U. by the end of 2010.[211] China, India and other countries are also launching large biofuels programs.

3.3.1 Brazil



Brazil is the second largest producer of ethanol in the world behind the United States and was the first country to launch a comprehensive bioethanol program in 1975, called Proalcool. The program had the following major elements:

- A fixed quota on blending with petrol;
- Incentives for the production of engines that could run on straight ethanol;
- Special credit lines for agriculture & industry;
- A fixed price for ethanol below that of petrol; and
- Tax exemptions for car owners purchasing cars that could run on straight ethanol.[212]

The program was so successful that by the mid-1980's four out of every five new cars sold were ethanol only and by 1988 ethanol had overtaken petrol as the main source of transport fuel.[213] The drop in global petroleum prices in the early 1990's, combined with a rise in global sugar prices, led to a shortage of hydrous ethanol. The government responded by passing a law requiring a 18-26% blend of anhydrous ethanol. By the late 1990's the government liberalized the ethanol industry by deregulating pricing. Flex-fuel vehicles (FFVs), which can run on pure ethanol or any blend of ethanol and petrol, now account for about 80% of all new cars sold in Brazil.[214]

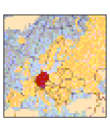
In 2006, Brazil produced nearly 49 million liters of ethanol per day, several times Kenya's total daily petroleum consumption.[215] The current policies supporting ethanol include the following:

- 20-25% blending mandate;
- Total value-added tax, excise and other duties are about half what they are for petrol;
- Tax breaks for flex-fuel vehicles.

Brazil has also launched a biodiesel program that includes a B2 mandate by 2008 and a B5 by 2010.[216] Biodiesel producers must be licensed by the government, which helps to ensure quality standards are met, and all diesel distributors are required by law to purchase all licensed quantities of biodiesel produced.[217] Low-interest government loans and reduced tax burdens along the entire production value chain also play a crucial role in promoting the industry.

By the end of 2007, Brazil was expected to have 24 large biodiesel plants with a total production capacity of 1.14 million tonnes per year.[218] Actual production has surged from 650 tonnes in 2005 to 60,000 in 2006 and an estimated 300,000 tonnes in 2007.[219] Brazil expects an exportable surplus of 2 million tonnes of soyabean oil in 2007-2008, much of which could be used for biodiesel production.[220] Other feedstocks for biodiesel include palm oil, castor and possibly jatropha.[221]

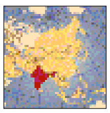
3.3.2 Germany



Germany is the world's leading producer of biodiesel with nearly 3 billion liters in 2006.[222] Biodiesel represents about 7% of all diesel consumption nationwide.[223] One of the key drivers for Germany's growth in biodiesel production has been an exemption on excise tax for biodiesel. However, that is changing. In 2006, the German Government implemented a Euro 0.09 per liter tax on biodiesel, which is still below that of petroleum diesel. The plan is to completely eliminate the tax treatment disparity between biodiesel and petroleum diesel by 2012.[224]

On the ethanol front, Germany has launched a 1.2% blending mandate (E1.2), which will grow to 3.6% by 2010. Suppliers will be penalized for failing to meet the mandated levels, but the share of ethanol in each liter of fuel will be fully taxed.[225] In 2006, Germany produced 765 million liters of ethanol, about 75% of which came from grains, about 22% from non-agricultural resources like ethylene, and the remainder from potatoes, sugar beets and other feedstocks.[226] Planned ethanol plants are expected to utilize sugar beet as the main feedstock in the future.

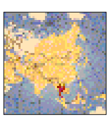
3.3.3 India



India produced 1.65 billion liters of ethanol in 2006, of which 200 million were used for fuel.[227] Molasses and cane juice are the primary feedstocks used for ethanol production. After a number of fits and starts, India adopted an E5 blending policy for part of the country in 2006. The policy was expanded nationwide in 2007, and increased to E10 by October 2008 due to expected sugarcane surpluses. Fixed prices for ethanol and mandatory blending requirements are the main regulatory tools employed for achieving the targets.

India has ambitious biodiesel plans, but an uncertain strategy for achieving them. As a net importer of vegetable oil, the country is betting its biodiesel future on relatively untested feedstocks of jatropha and pongamia. The government is planning to finalize its biofuels strategy in early 2008, and is expected to endorse a B20 policy by 2012, which would require 13.4 million tonnes per year. Actual biodiesel production in 2007 was about 100,000 tonnes, and is predicted to increase to a mere 200,000 tonnes by 2010.[228] Economics and untested agronomy for jatropha are the biggest hurdles to biodiesel in India. Current production costs for jatropha biodiesel is about \$1.10 per liter compared with about \$0.92 per liter of petroleum diesel.[229] To produce sufficient quantities of biodiesel from jatropha to meet the country's B5 mandate will require a \$7 billion investment and 11 million hectares of land.[230] To date, only about \$500 million has been invested on 0.4 million hectares.[231]

3.3.4 Thailand

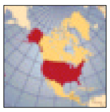


Thailand produced about 150 million liters of ethanol in 2006, mainly from sugarcane and cassava. The sugar industry, which is one of the world's largest has suffered under drought in recent years, as well as low yields in terms of production and sugar content of the cane.[232] In some ways, the Thai and Kenyan sugar industries face similar problems. Low productivity and a relatively high cost of production is in part the result of protective regulations that maintain artificially high domestic prices and provide few incentives to increase efficiency. Efforts are underway to reform the system in Thailand, although little progress can be reported to date.

The government has implemented a national ethanol policy, which oversees the approval of new projects and grants fiscal incentives to increase production, especially from domestically produced feedstocks. The use of 10% ethanol in all government vehicles has been planned, and all producers of E10 are exempt from certain fuel and excise taxes. The national goal is to increase gasohol consumption to 20 million liters per day by 2011.[233]

The Thai government also plans to introduce a B2 biodiesel mandate beginning in 2008, which would amount to about 345 million liters per year.[234] Feedstock limitations will make this target difficult to reach, although the government has launched a 1 million hectare palm plantation initiative with the support of about US$34 million.[235] It is also encouraging new palm plantations in Laos, Cambodia, and Burma.

3.3.5 United States



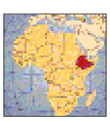
The United States has overtaken Brazil as the world's leading producer of ethanol, with over 18 billion liters in 2006 and more than 23 billion liters projected in 2007.[236] The explosive growth in ethanol production in the U.S. is due in large part to a bevy of subsidies and incentives. These include a production tax credit of $0.51 per gallon ($0.135 per liter) for ethanol and $1.00 per gallon ($0.264 per liter) for biodiesel.[237] Total subsidies and incentives from all levels of government are estimated at between $1.42-$1.87 per gallon ($0.375-$0.494 per liter) of ethanol and between $1.69-$2.15 ($0.446-$0.568 per liter) for biodiesel.[238]

Various other factors have also spurred the ethanol boom in the United States. First, the Clean Air Act set requirements for oxygenated fuel as a way of combating air pollution. Until recently, MTBE was the fuel additive of choice, but has been phased out due to its impact on water pollution. Ethanol has replaced MTBE as the main oxygenator of petrol in the U.S. Second, in 2003, the Bush Administration launched a major initiative to support corn-based ethanol. The program sets a renewable fuel standard of 28.4 billion liters by 2012, which represents a 58% increase in production from 2006.[239] As mentioned above, the U.S. Department of Energy has launched a major initiative to develop a commercially viable cellulostic ethanol industry within the next several years.

The biodiesel industry in the U.S., while significant in absolute terms, is only a small fraction of the size of the ethanol industry. About one billion liters was produced in 2006, which is expected to double over the next few years. Many of the same incentives mentioned above, including tax credits and the renewable fuels standard, are responsible for the growth in biodiesel.[240]

3.4 REGIONAL BIOFUELS PROGRAMS

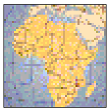
3.4.1 Ethiopia



Ethiopia currently produces about eight million liters per year of ethanol from molasses, with enough molasses available from its sugar industry to increase that output by as much as 300%, according to one report.[241] The Minister of Mines and Energy has announced a policy to begin blending 5% ethanol into the country's transport petrol pipeline, starting in late 2007 or early 2008.[242] A UNDP sponsored program is also looking into using ethanol as a fuel for home cooking.[243]

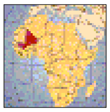
The Ethiopian Government recently announced that the government is committing 24 million hectares of land to growing jatropha.[244] Of course, it is extremely hard to fathom how the government intends to dedicate this huge amount of land – more than 20% of the entire country – to growing a single, generally untested, and inedible crop.[245] Less than 1,700 hectares have so far been committed by plantation developers.[246]

3.4.2 Malawi



Malawi has two ethanol plants, one that was opened in 1982 on the shores of Lake Malawi in Dwangwa and the other in 2004 in Chikwawa.[247] The ethanol is made from sugarcane molasses. In 2006, Malawi produced 18.6 million liters of ethanol[248] and since the early 1980's over 224 million liters have been blended with petrol in Malawi.[249]

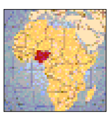
3.4.3 Mali



The Mali-Folkecentre (MFC) has been developing "energy service centres" involving 20-hectare jatropha plantations that provide energy to local communities for activities such as millet grinding and battery charging.[250] In partnership with UNEP, UNDP, and the Global Village Energy Partnership, MFC has launched a 15 year, 1,000 hectare jatropha project that will provide power to more than 10,000 local residents.

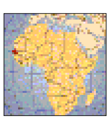
Mali Biocarburant, a Dutch-backed start-up is betting that it can create an economically-viable biodiesel company based on collections of jatropha seeds from thousands of smallholder farmers.[251] The difference with other similar projects is the lack of any central plantation. Instead, they will rely entirely upon existing jatropha trees, mainly planted as fencing to begin production in the first half of 2008. The goal is to produce five million liters per year within five years, which will require the annual collection and processing of approximately 20 billion jatropha seeds.

3.4.4 Nigeria



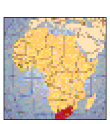
Nigeria has been producing ethanol since 1973, and is in the process of adopting a 10% blending policy, which would require an estimated one billion liters of fuel alcohol per year.[252] Nigeria Yeast & Alcohol Manufacturing PLC, the country's sole ethanol plant, produced 30 million liters of in 2006.[253] The Nigeria National Petroleum Company recently signed an agreement with Brazil's Petrobras to construct a $200 million ethanol plant.[254] Nigeria is Africa's largest cassava producer, with an annual production of over 30 million tonnes per year, which could supply the country with hundreds of millions of liters of ethanol.[255]

3.4.5 Senegal



Compagnie Sucriere du Senegal announced in 2006 that it was planning to start producing ethanol from molasses within 12 months.[256] It is unclear whether production has commenced. Senegal recently formed Pays Africains Non-Producteurs de Petrole, the Pan African Non-Petroleum Producers Association, which is currently comprised of 15 countries. Little official documentation is currently available on the overall purpose and proposed programs of the organization, but it appears that a major focus will be joint creation of institutional, organizational, and financial mechanisms for expanded biofuels production. The 15 countries that have signed on have an arable land base of 378.8 million hectares, of which about 11% is currently being used for agricultural production.[257]

3.4.6 South Africa

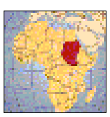


South Africa accounts for about 70% of total ethanol production in Africa, although most of that has been of the synthetic kind derived from coal and gas.[258] The country is now increasing its bioethanol and biodiesel production levels and the government has recently adopted a national biofuels strategy. Two large ethanol plants have a current production capacity of 97 million liters per year. Three large biodiesel plants are now being planned, with a total production capacity of more than 300 million liters per year.[259]

In December 2007, the South African Department of Minerals and Energy released its "Biofuels Industrial Strategy." The strategy sets a biofuels target of 2% of petroleum consumption within the next five years, with a proposed blending ratio of 2% for biodiesel (B2) and 8% for ethanol (E8).[260] The government is encouraging the program with a 50% fuel levy exemption for biodiesel and a 100% exemption for ethanol.[261] Small biodiesel producers (less than 300,000 liters per year) are completely exempt from the fuel levy.[262] Biofuels prices will be fixed at the equivalent of $65 per barrel of petroleum oil, which will provide consumers with a discount as long as oil prices remain above that point.[263] Producers will be protected by pegging the sales price above the cost of production that allows for a return on the capital investment commensurate with the risk.[264]

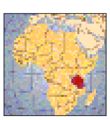
The South African government expects that the biofuels program will create 25,000 jobs, achieve a balance of payments savings of R 1.7 billion (approximately Ksh 15.7 billion).[265] To ensure quality and to protect consumers, the South African Bureau of Standards has developed the required analytical and technical capacity to perform biofuels analysis, as well as fuel quality standards, based on accepted standards in the United States, Europe, and Japan.[266] Interestingly, the crops being proposed include: sugarcane and sugar beet for ethanol, and sunflower, rapeseed, and soya for biodiesel.[267] The policy explicitly excludes the use of maize and jatropha due to "food security concerns," the need "to test usability of these [crops]," and concerns over jatropha's potential invasiveness.[268]

3.4.7 Sudan



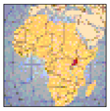
The Kenana Sugar Company, which is the largest in Sudan, has a ten-year expansion plan to produce 200,000 liters of ethanol per day from molasses.[269] Sixty percent of the feedstock will be produced by the parent sugar factory and the remaining 40% by other sugar mills throughout the country.[270] The company also has an additional 45,000 hectares of land suitable for sugar cane.[271]

3.4.8 Tanzania



Tanzania may be very well situated for large biofuels production. It's climate and soils are suitable to grow a range of biofuels feedstocks and, by one estimate, has over 40 million hectares of agricultural land that is not being fully utilized and could be used for biofuels.[272] The government has created a National Biofuels Task Force, but does not appear to have yet formulated a developed strategy. Nonetheless, several projects are beginning to develop. Kakute Ltd. buys and sells jatropha seeds and seedlings throughout East Africa. They have a small test plantation and provide consulting services to aspiring jatropha farmers.[273] However, according to anecdotal reports and a review of a proposal they put forth for a project in Kenya, they do not seem to have collected much scientifically rigorous information on the agronomy or economics of jatropha farming. D1 Oils, a publicly-owned British company, had announced plans for developing tens of thousands of acres of jatropha, but according to their website their activities in Tanzania are now "dormant."[274]

3.4.9 Uganda



Uganda produces large quantities of sugar, grain, and oil crops that can be used for ethanol and biodiesel production, but has yet to develop a comprehensive program for harnessing this potential. Large quantities of crude ethanol are already being produced from molasses, cassava, sorghum, and millet, but it is being consumed as beverage alcohol rather than fuel. According to the World Health Organization, Uganda is one of the highest per capita consumers of beverage alcohol in the world at about 19.4 liters of pure ethyl alcohol per year.[275] Uganda also produces about 400,000 tonnes of vegetable oil per year, of which 146,000 is exported.[276] About 25% of Uganda's petroleum imports could be offset if the country converted its surplus vegetable oil to biodiesel.

Despite this potential, development of a biofuels industry in Uganda has been slow, although the country is discussing introducing an E20 mandate. The lack of a comprehensive government policy and poorly considered projects are both part of the problem. In early 2007, President Yoweri Museveni outraged many Ugandans by proposing to hand over a large swath of the previously protected Mabira Forest to a company planning to plant sugarcane for ethanol.[277] The government eventually withdrew the proposal after public protests led to the looting and the death of at least one person.[278]

Smaller biofuels projects are beginning to develop in Uganda, particularly biodiesel from jatropha ad other crops. BIDCO Oil Company, a Thika-based vegetable oils company, is planning some sort of biodiesel project, although very little information is currently available. Given the sheer volumes of oils being processed by BIDCO – over 120 tonnes per day in Kenya alone[279] – they may be very well positioned to move forward rather quickly.

4. ECONOMIC ANALYSIS

The economic case for biofuels in Kenya is quite strong. Kenya currently spends about $1 billion per year in foreign currency on imported oil.[280] Since the early 1990s, the Kenyan Government has spent over $169 million exploring for oil and gas, with over 30 wells drilled but no discoveries.[281] To appreciate the potential value of biofuels, one only needs to consider the fact that many African countries currently spend many times more for imported petroleum than they do on health care and poverty alleviation programs.[282] Even if only a portion of this money were redirected towards domestic bioenergy programs, the social and economic benefits would be substantial.

The economic analysis in this section contains the availability of biofuels feedstocks and other inputs, the economic feasibility for each feedstock, an overview of regional and national markets, the potential income and employment benefits, current and projected consumption of petroleum, land requirements for blending targets, potential foreign currency savings, and opportunities for carbon financing. It is important to note that the analysis is based on the best available data. We indicate where there are gaps in the analysis due to the lack of credible data and suggest areas for further research. The most significant gaps are contained within the income and employment section. A detailed survey of the cost of production, including labor, should be conducted for each feedstock in order to assess which crops would provide the greatest benefits, and thus incentives, to farmers.

4.1 THE AVAILABILITY OF FEEDSTOCK, INPUTS & TECHNOLOGY

Biofuels feedstock is the primary and most expensive ingredient for biofuels production. Other inputs, such as brewer's yeast for ethanol fermentation and methanol and caustic soda for biodiesel transesterification comprise a relatively small portion of each unit of biofuel produced and are generally available in the local market. Thus, the supply and price of the feedstock is generally what limits the quantity of biofuels that can be produced economically.

Land availability, agricultural practices and demand from competing uses are the main factors that determine the supply and price of biofuels feedstock. Various scenarios for biofuels production in Kenya can be envisioned. All of these are potentially feasible, but may not be practical due to competing priorities such as food production (see Section 6.5 for an in-depth discussion of the conflict between food and fuel). The analysis that follows lays out the most realistic potential biofuels production scenarios (i.e., how much could be produced under different investment and policy regimes), but leaves to latter sections of the study the discussion of what scenario may be most appropriate for Kenya and what policies are most likely to achieve different levels of production.

4.1.1 The Availability of Biofuels Feedstocks in Kenya

This Study analyzes three potential ethanol feedstock crops (cassava, sugarcane and sweet sorghum) and seven biodiesel crops (castor, coconut, cottonseed, croton, jatropha, rapeseed and sunflower). Three scenarios are discussed for each feedstock: status quo, potential production and optimized potential production. The status quo scenario further distinguishes between "non-food competing" and "food competing." The "non-food competing" scenarios exclude feedstock currently being used for food and animal feed. The "food competing" scenarios include all feedstock that is currently being produced regardless of whether any of it would otherwise be used for food and feed consumption. The two "potential" scenarios distinguish between "new farm land" and "existing farm land." The former includes lands that are suitable for those crops but are not currently being used for any agricultural production; the latter includes all suitable lands outside of protected areas like National Parks.

The "status quo" scenario is based on actual production and consumption data from 2005 and 2006 from the United Nation's Food & Agriculture Organization's statistical database, which contains the latest information provided by the Kenyan Ministry of Agriculture, as well as from industry data supplied by the Kenya Sugar Board. The two other scenarios consider the potential production of each feedstock based on suitability mapping conducted by GIS experts at ICRAF (see Appendices A and B for feedstock suitability maps). The amount of acreage that is potentially suitable has been discounted for each crop by 50% due to security, logistical or infrastructure limitations in certain parts of Kenya. Additional reductions may be necessary to account for other conflicting land-uses in certain areas.

The "optimized potential production" scenario considers the potential production capacity using state-of-the-art agricultural inputs methods, such as high-yielding varieties under irrigation. Projected yields for each crop under the "optimized potential production" scenario is based on experiences from different parts of the world.

For sugarcane under the "status quo," the "non-food competing" scenario utilizes the molasses byproduct of sugar production, whereas the "food competing" scenario foregoes sugar production in favor of using all of the cane juice for ethanol. Under the "potential" scenarios, only molasses is considered for both "new" and "existing farm lands."

Sorghum is also a peculiar case that warrants a special note. The type of sorghum currently grown in Kenya does not contain a sweet stalk, as it is primarily grown for food. The sweet sorghum varieties that can be used for ethanol can produce much higher yields, according to studies conducted by ICRISAT in India and Thailand, and can also produce grain for food and sugar for ethanol simultaneously. Thus, the "status quo" scenario does not include current production data for sorghum, as it is unrealistic to assume that the grain currently being harvested from sorghum in Kenya would ever be used for ethanol production. However, it is useful to note that over 163,000 hectares of land were used to grow sorghum in 2006, which could be replaced with sweet sorghum varieties that would yield at least as much edible grain per hectare, as well as a significant cash crop of sweet stalks for ethanol production.[283]

For castor, there is no difference between the "non-food" and "food competing" scenarios because it is an inedible crop. Regarding croton and jatropha, very little reliable information exists on current production in Kenya, although quite a number of croton and jatropha trees are already growing wild or as natural fencing throughout the country. Jatropha is also being grown in plantations of various sizes in increasing quantities. Finally, a note about rapeseed, the primary feedstock for biodiesel in Europe. Rapeseed is being grown in Kenya in small quantities, mainly as a rotational crop, but little hard information exists in exact production numbers, so we have left it blank under the "status quo" scenarios.

4.1.1.1 *Status Quo Feedstock Production Scenario*

The numbers for acreage, production and biofuels produced are presented in thousands of hectares, tonnes or liters. The yields are the average real-world production per hectare in Kenya, which notably are lower than in many other parts of the world.

TABLE 2: STATUS QUO FEEDSTOCK PRODUCTION SCENARIO[284]

			Non-Food Competing		Food Competing	
	Hectares ('000)	Yield (T/Ha)	Production ('000 tonnes)	Biofuel ('000 liters)	Production ('000 tonnes)	Biofuel ('000 liters)
Ethanol						
Cassava	68.5[a]	9.6[a]	n/a[a]	n/a[a]	657[a]	111,690[e]
Sorghum+						
Sugarcane	147.7[b]	33.4[b]	4,933[b]	49,330[d]	4,933[b]	345,310[d]
Biodiesel						
Castor	13.0[a]	0.23[a]	3[a]	1,344[f]	3[a]	1,344[f]
Coconut	37.1[c]	1.64[c]	n/a[c]	n/a[c]	61[c]	22,204[g]
Cottonseed	36.3[c]	0.62[c]	n/a[c]	n/a[c]	22.5[c]	3,285[h]
Croton++						
Jatropha++						
Rapeseed+++						
Sunflower	13.0[c]	0.92[c]	1.31[c]	542[i]	12[c]	4,968[i]

Under the non-food competing scenarios, only sugarcane is currently available in sufficient quantities to offset a significant amount of petroleum consumption, especially if competition from imported sugar makes it more economically viable to produce ethanol from cane juice than from molasses (see Section 6.5). Existing production of biodiesel feedstocks are not sufficient to offset much current diesel consumption, although could be used for small-scale farm and community-based projects.

4.1.1.2 *Potential Feedstock Production Scenario*

The numbers for acreage, production and biofuels are presented in millions of hectares, tons or liters. The yields are the average real-world production per hectare in Kenya, which notably are lower than in many other parts of the world.

TABLE 3: POTENTIAL FEEDSTOCK PRODUCTION SCENARIO[285]

		New Farm Lands			Existing Farm Lands		
	Yield (T/Ha)	Land (m. Ha)[u]	Production (m. tonnes)	Biofuel (m. liters)	Land (m. Ha)[u]	Production (m. tonnes)	Biofuel (m. liters)
Ethanol							
Cassava	9.6[a]	2.08	19.97	3,395[i]	4.15	39.84	6,773[i]
Sorghum+	35.0[c]	5.90	206.50	8,260[k]	11.06	387.10	15,484[k]
Sugarcane	33.4[b]	0.09	3.01	30[j]	0.83	27.72	277[j]
Biodiesel							
Castor	0.23[a]	6.82	1.57	703[l]	10.42	2.40	1,075[l]
Coconut	1.64[d]	0.03	0.05	18[m]	0.18	0.29	105[m]
Cottonseed	0.6[d]	1.42	0.85	124[n]	1.76	1.06	154[n]

Croton	2.50[e]	0.65	1.63	548[p]	2.56	6.40	2,150[p]
Jatropha	2.50[f]	6.26	15.65	5,258[q]	9.41	23.53	8,578[q]
Rapeseed	2.00[g]	0.16	0.32	125[r]	0.82	1.64	643[r]
Sunflower	0.92[d]	3.48	3.20	1,325[o]	5.78	5.32	2,202[o]

Sorghum would provide the greatest opportunity to increase ethanol feedstock production without competing with existing agricultural production. If just over 57,000 of the 5.9 million hectares that are potentially suitable (but outside of existing agricultural production areas) were planted with sweet sorghum, Kenya could produce enough ethanol to offset about 10% of current petrol consumption. Jatropha and sunflower seem to provide the greatest amount of biodiesel feedstock, based on available and suitable lands. However, the untested nature and long maturation period for jatropha, and the difficulty of growing sunflower due to pests, as well as its competing food uses, make these feedstocks somewhat less attractive (at least in the short run). Croton, although it has a long maturation period similar to jatropha, is not only suitable in large areas, but it is also already being grown in many areas, so could begin providing an immediate source of biodiesel feedstock, which could grow over time. Castor and rapeseed could provide large quantities of feedstock in the near term, with castor maximizing more semi-arid areas and rapeseed being grown in conjunction (as a rotational crop) with wheat, barley and other staples.

4.1.1.3 Optimized Potential Feedstock Production Scenario

The numbers for acreage, production and biofuels are presented in millions of hectares, tonnes or liters. The yields are optimized based on performance from other parts of the world and from scientific literature. The "optimized" scenario is intended to show what a difference higher yields would make in terms of the availability of biofuels feedstocks, rather than to demonstrate an easily attainable amount of production.

TABLE 4: OPTIMIZED POTENTIAL FEEDSTOCK PRODUCTION SCENARIO[286]

		New Farm Lands			Existing Farm Lands		
	Yield (T/Ha)	Land (m. Ha)[u]	Production (m. tonnes)	Biofuel (m. liters)	Land (m. Ha)[u]	Production (m. tonnes)	Biofuel (m. liters)
Ethanol							
Cassava	20.00[a]	2.08	41.6	7,072[k]	4.15	83	14,110[k]
Sorghum+	70.00[c]	5.90	413	16,520[m]	11.06	774	30,968[m]
Sugarcane	68.34[b]	0.09	6.15	61.5[l]	0.83	56.72	567[l]
Biodiesel							
Castor	1.2[d]	6.82	8.18	3,666[n]	10.42	12.05	5,602[n]
Coconut	3.33[e]	0.03	0.1	36.4[o]	0.18	0.6	218[o]
Cottonseed	3.00[f]	1.42	4.26	622[p]	1.76	5.28	771[p]
Croton	2.50[h]	0.65	1.63	546[r]	2.56	6.4	2,150[r]
Jatropha	4.20[i]	6.26	26.29	8,834[s]	9.41	39.52	13,279[s]
Rapeseed	3.50[j]	0.16	0.56	220[t]	0.82	2.87	1,125[t]
Sunflower	3.00[g]	3.48	10.44	4,322[q]	5.78	17.34	7,179[q]

4.1.2 The Availability of Non-Feedstock Inputs

Other inputs, such as electricity, labor, transport and processing chemicals used to convert the feedstock into either ethanol or biodiesel must also be factored in. Electricity prices in Kenya average about Ksh 6.7 per kilowatt-hour for small to medium sized industrial customers, and slightly less for larger commercial customers.[287] The cost of manual labor, for agricultural production and processing, is relatively low compared with much of the rest of the world. Experienced engineers and managers are also available in the local employment pool. Skilled workers for ethanol production exist in Western Kenya, although many more skilled workers will be needed to meet anticipated increases in ethanol production.

Transport in Kenya is a logistical hurdle that can also drive up the cost of production. Poorly maintained roads and lorries, and the lack of any viable rail alternatives, means that biofuels production should be centered as close to where the feedstock is produced as possible. The scale of production also should be based in part on how much feedstock can be sourced locally. Security is another concern that may require extra costs to protect equipment and supply routes, especially considering the instability that has followed the disputed 2007 national elections. While these factors increase the overall cost of production to a degree, relatively cheaper labor costs combined with the potential to cogenerate electricity from the byproducts of feedstock processing (bagasse for sugar and sorghum, and biogas from oil seed cake) can help to offset these added costs of production.

Certain chemicals are essential to biofuels production. These include yeast and enzymes for ethanol, and methanol, caustic soda, and magnesium silicate for biodiesel production. Some of these chemicals are readily available in the larger urban markets, while others would have to be imported.

4.1.3 The Availability of Biofuels Processing Technology

Technology for biofuels production either already exists in Kenya, as is the case for ethanol, or can be imported rather easily, as is the case for biodiesel. Virtually no practical experience exists in Kenya regarding biodiesel manufacture, although KIRDI has begun to experiment with biodiesel production technology on a very small scale. Expertise in biofuels production can be transferred along with the technology needed for manufacture. The production processes and the technology required are well understood and not particularly difficult to emulate. Machinery and equipment can be fabricated locally once the scale of biofuels production justifies the capital cost of manufacturing plants.

4.2 ECONOMIC FEASIBILITY ANALYSIS

This section analyzes the economic feasibility of producing ethanol and biodiesel in Kenya. There are three main components to the cost of production: feedstock costs, capital investment and operating expenses. Fuel taxes, which can account for one-third of the retail price in Kenya, are also a key part of the equation. The cost of feedstock comprises a majority of the overall costs for both ethanol and biodiesel. Feedstock costs can also fluctuate widely based on the elastic demand for competing uses. For example, the cost of sugarcane-based ethanol is highly influenced by the competing price of sugar. We distinguish between the current cost of production for each feedstock, which is estimated from various sources including: ethanol production companies, the

Ministry of Agriculture, the Kenya Sugar Board, the United Nation's Food and Agriculture Organization's statistical database (FAOSTAT), ICRISAT, and a survey of farmers and agricultural officials throughout Kenya conducted in November and December of 2007. Citations to the specific sources of information for each feedstock are included.

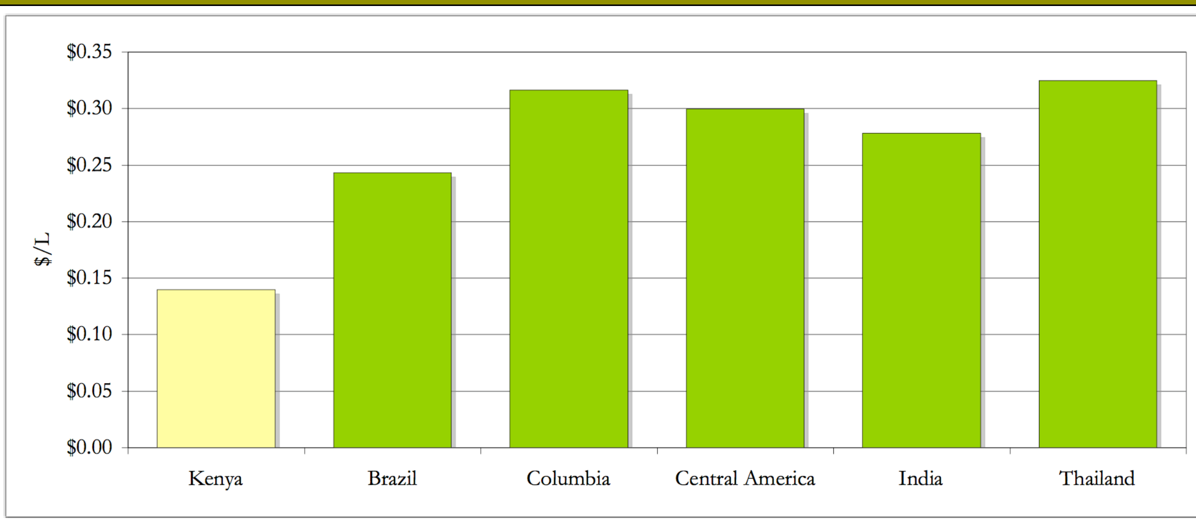
We chose to conduct the economic feasibility analyses for ethanol and biodiesel differently due to the fact that ethanol is already being produced on a commercial scale and biodiesel is not. For ethanol we analyze the current cost of production of sugarcane-based ethanol compared with production costs from other parts of the world. The cost of production for ethanol produced from sweet sorghum and cassava in other countries is then compared with projected costs from those feedstocks in Kenya. For biodiesel, we compare the projected costs of production for seven different feedstocks at three different scales of production.

4.2.1 Economic Feasibility of Ethanol

Ethanol has been produced in Kenya for many years from the molasses residue of sugar production. The cost of molasses as of the date of this publication ranged between about Ksh 2,000-2,500, or $31-38, per tonne.[288] At an average of about 4 tonnes of molasses per cubic meter (1,000 liters) of ethanol, the cost of the feedstock portion of ethanol production is on average about Ksh 9, or $0.14, per liter, which is extremely cheap by global standards (see Figure 4).

Despite Kenya's relatively low molasses prices, the overall cost of ethanol production remains higher than in the other five sugarcane ethanol producing countries or regions considered in this study. The current cost of production at the two ethanol plants in Kenya is approximately Ksh 33-40, or $0.51-$0.61, per liter.[289] The next most expensive production costs, from highest to lowest, are: Thailand ($0.44); Central America ($0.43); India ($0.42); Colombia ($0.39); and Brazil ($0.32) (see Figure 5).[290] Thus, even though feedstock costs in Kenya are less than 60% of those in Brazil (the next cheapest), the overall cost of ethanol production is 75% more in Kenya.

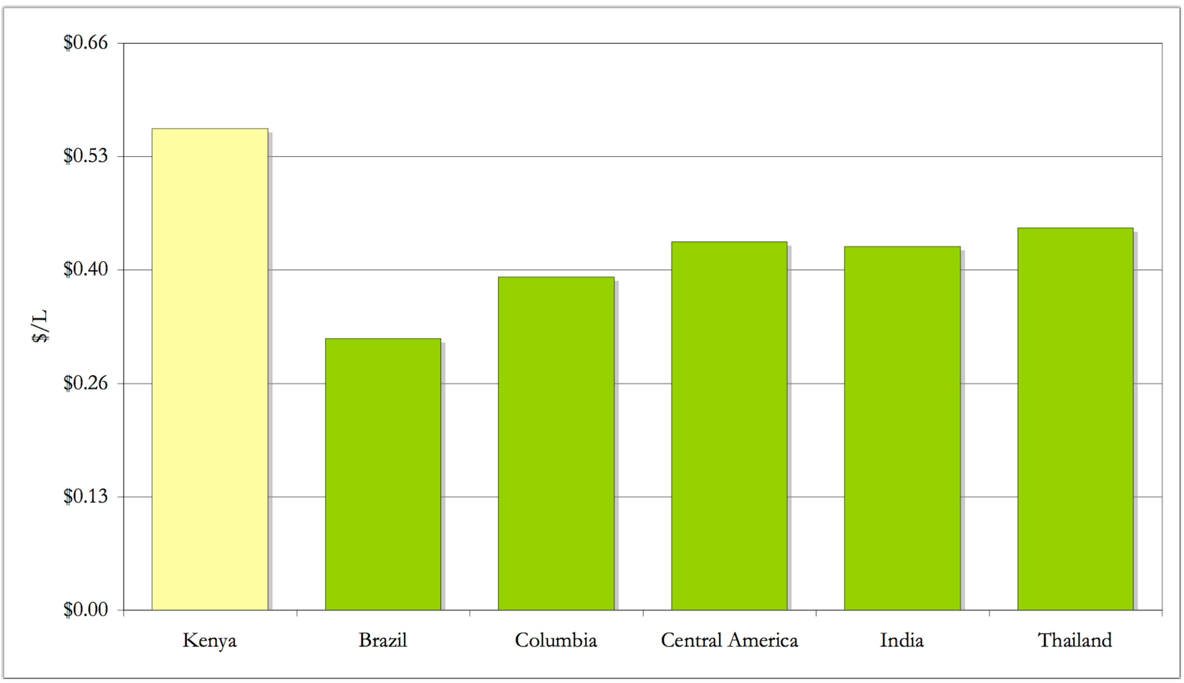
FIGURE 4: COST OF MOLASSES FEEDSTOCK IN KENYA & THE WORLD[291]



Country	Kenya	Brazil	Colombia	Central America	India	Thailand
$ per liter	$0.14	$0.24	$0.32	$0.30	$0.28	$0.32

The main reasons for the higher operating costs in Kenya are poor infrastructure and the relative inefficiency of the Kenyan ethanol model. All of the other countries analyzed produce sugarcane ethanol as part of the sugar production process, whereas ethanol production in Kenya is a stand-alone industry. The integrated approach harnesses the heat and electricity from the cane bagasse to power the plant, significantly reducing power costs. In Kenya, heavy fuel oil is the main source of power for ethanol production, although biogas produced from ethanol wastes does offset some of these costs.[292] Other benefits of the integrated approach are lower capital and employment costs due to the lack of duplication in running two separate enterprises. Not surprisingly, Mumias Sugar, which is planning to integrate ethanol production into its sugar factory in Western Kenya, expects to cut the cost of ethanol production to about Ksh 25, or $0.38 per liter.[293]

FIGURE 5: COST OF SUGARCANE ETHANOL IN KENYA & THE WORLD[294]



Country	Kenya	Brazil	Colombia	Central America	India	Thailand
$ per liter	$0.56	$0.32	$0.39	$0.43	$0.42	$0.44

Little information is available on the cost of production for ethanol produced from sweet sorghum and cassava. However, relying on preliminary assumptions from research conducted by ICRISAT in India and Thailand, sweet sorghum appears to have potential to augment the supply of sugarcane feedstock in Kenya. Similar to sugarcane, sweet sorghum can produce two products simultaneously, a sweet stalk for ethanol and grain for food. The potential yields are similar to sugarcane, although sweet sorghum has the potential to grow in somewhat drier climates and can produce at least one crop per year (as opposed to the 18-24 months required by sugarcane). Because very little sweet sorghum has been grown in Kenya, it is difficult to predict its economic feasibility.

High yielding varieties of sweet sorghum that have been developed by ICRISAT reportedly can produce between 30-40 tonnes of sweet stalk per year un-irrigated over two crops, in addition to about 1.2 tonnes of grain. Yields could reach twice that much under irrigation. The estimated cost of production from India is about Ksh 55,800 per hectare. Subtracting Ksh 14,400 from income received from grain leaves Ksh 41,400 per 35 tonnes of sweet stalk, or Ksh 1,183 per tonne. At Ksh 1,200 per tonne, which is enough to produce about 40 liters of ethanol, the per liter cost of production for sweet sorghum would be about $0.46, which is $0.32 more than the current cost of molasses. Even if we incorporate energy savings in the production process through the use of bagasse, the cost of feedstock must be reduced significantly to make sweet sorghum an economically attractive alternative to sugarcane. Planting trials, which are currently being conducted by both Agro-Chemical and Spectre, will help to verify some of these assumptions and determine the precise viability of sweet sorghum as an ethanol crop in Kenya.

Ethanol from cassava in Thailand costs about $0.37 per liter at an 18 million liter per year plant.[295] Operations costs are higher than for molasses ethanol production in Thailand, but feedstock costs are about 34% lower for cassava.[296] In Kenya, it is difficult to ascertain a price for cassava that would be used as a feedstock for ethanol, although the Ministry of Agriculture Guidelines put the price of cassava at Ksh 6,500 per tonne, which is equivalent to about $0.59 per liter.[297] However, the estimated cost of production is only about Ksh 3,300 per tonne, so the price as an ethanol feedstock could potentially be lower than the current market price.[298] This is more than 1.6 times the cost of cassava feedstock in Thailand. Thus, for cassava to become a feasible ethanol feedstock in Kenya, prices must come down substantially.

Another factor to consider is the impact of fuel taxes on economic feasibility. As is described in Section 5.9, there is a Ksh 30 ($0.46) per liter tax on petrol. Considering that ethanol has about two-thirds the energy content as petrol, it would take about three liters of ethanol to replace two liters of petrol. Thus, applying the equivalent tax per unit of energy would amount to about Ksh 20 ($0.31) per liter of ethanol. Applying the same 3:2 ratio to the retail price, would competitively price ethanol at about Ksh 60 ($0.92) per liter with petrol at the current price of about Ksh 90 ($1.38) per liter. Thus, for ethanol to be feasible in the market without any help from the government in terms of tax reductions or subsidies, the pre-tax price of each liter of ethanol must be less than roughly Ksh 40 ($0.62) per liter. Of course, this will fluctuate with the price of petrol.

The current average production cost of Ksh 36.5, or $0.56, per liter of sugarcane ethanol is barely economically feasible as a substitute for petrol, assuming the Ksh 3.5 per liter difference between the cost of production and the pump price is sufficient to cover the cost of transport, blending, marketing and profits. However, competitive markets for ethanol, as discussed more in Section 4.3.1, provide ethanol producers with more lucrative alternatives, such as potable alcohol and methylated spirit, to ethanol fuel. Both Agro-Chemical and Spectre are currently selling ethanol for drinking alcohol and industrial uses at a pre-tax average price of about Ksh 50, or $0.77, per liter.[299] Thus, absent some incentive in the form of a tax reduction or subsidy, ethanol producers would have to discount their product by about 24% for it to be economically feasible as an alternative to petrol. Alternative sources of ethanol, such as sweet sorghum and cassava, that could be even more expensive to produce, would require even more support to become viable petrol replacements. Section 7 discusses how tax policy could be used to make ethanol fuel competitive.

4.2.2 Economic Feasibility of Biodiesel

We have evaluated three different scales of production for biodiesel: farm scale (~180,000 liters per year), small commercial scale (~2 million liters per year), and large commercial scale (~12 million liters per year). By international standards, a 12 million liter per year plant is actually quite small.

However, we have purposely limited the large commercial plant size evaluated in this study considering the very nascent stage of the biodiesel industry in Kenya and the fact that very large, centralized production plants for biodiesel are not likely to prove practical in the near-term given limitations on land availability for growing oil crops for biodiesel and the country's poor transport infrastructure. We also feel that it is much more sustainable to scale production to the amount of feedstock that can be grown within a particular location and to have many smaller plants near to where the feedstock is produced and the fuel will ultimately be consumed.

The cost of biofuels feedstock is a factor of the price per tonne of the oilseed, the percentage of oil that can be extracted from the seed (known as "oil content"), and the revenue that can be collected from the seedcake that is leftover after the oil has been extracted. For edible crops, such as coconut, cottonseed, rapeseed and sunflower, the seedcake can be sold as animal feed. For inedible crops, such as castor, croton[300] and jatropha, the seedcake can be converted into bioenergy, either in the form of biogas or electricity, which can be sold or used to power the biofuel plant. The estimated price of seed is based on discussions with farmers, data from the Ministry of Agriculture, KARI and FAOSTAT. The revenue from the seedcake is estimated from the market price of animal feed and a discounted value of the biogas that could be produced. The added capital cost of a biogas digester is included for the three feedstocks for which biogas revenue is projected.

TABLE 5: BIODIESEL FEEDSTOCK COSTS[301]

FEEDSTOCK COSTS	Castor[a]	Coconut[b]	Cotton[c]	Croton[d]	Jatropha[e]	Rapeseed[f]	Sunflower[g]
Cost of Seed (Ksh/tonne)	20,000	29,327	20,000	15,000	15,000	26,000	31,984
Oil Content (%)	40%	65%	13%	30%	30%	35%	37%
Unrefined Oil (Ksh/L)	44.64	40.28	137.36	44.64	44.64	66.33	78.24
Seedcake Revenue							
Animal Feed (Ksh/L)		2.33	89.63			19.90	24.85
Biogas (Ksh/L)	6.04			9.40	9.40		
TOTAL (Ksh/L)	38.60	37.95	47.73	35.24	35.24	46.43	53.39

Croton and jatropha are the cheapest feedstocks, although they take the longest to mature and thus are potentially less attractive for farmers, especially if they cannot readily obtain financing for a long-term investment. As demonstrated in Section 4.4.2, a jatropha plantation could take more than 10 years to pay back the initial investment. Another caveat is that jatropha is among the least understood oil crops in Kenya, with very little practical experience in growing and no source of certified seeds yet identified. Thus, jatropha's overall potential is much less certain than the other oil crops considered in this study, despite its attractive qualities.

At current prices, coconut is the third cheapest feedstock. The coconut sub-sector is also quite underutilized, despite a broad potential market for many valuable products. One recent survey estimated that only 25% of the coconut economy is currently being exploited.[302] Income from biofuels could provide farmers with an incentive to increase production by planting higher yielding varieties and taking better care of the trees they grow. Castor oil is the fourth cheapest feedstock and has great potential to be grown in large quantities in marginal areas that do not compete with food. Another advantage of castor is that it can be harvested within nine months of planting and then does not require replanting for another four years. Kenyans have a history of growing castor, and so are familiar with the crop, although the local market has caused many farmers to lose interest. Biofuels could reignite enthusiasm for this potentially important crop.

The three most expensive crops – cottonseed, rapeseed and sunflower – have competing uses for human and animal consumption. The global price for these commodities has skyrocketed in the past two years to such a degree, that they have become prohibitively expensive in most parts of the world for use in biofuels without large subsidies. To the degree that these crops are promoted by government and the private sector, the priority market should be for edible oils, first at the local level and then for export as production permits. If significant surpluses can be produced, which is doubtful considering the amount of edible oils Kenya imports, then these crops could be considered for biofuels.

In addition to feedstock, the other three components of cost are capital investments, operations and taxes. Table 6 provides a per liter breakdown of these costs (the specific breakdown of capital and operations costs are included In Appendix F). We assume financing with 50% debt and 50% equity. Capital costs plus six months of operations costs are included. The debt is based on a 10-year loan with an annual interest rate of 10%. The equity investment assumes a 15% annual return. These costs are summarized on a per liter basis in the first line of Table 6.

The sale of glycerol, which is a byproduct of biodiesel production, is an added source of revenue. However, global prices for raw, unrefined glycerol have plummeted due to the oversupply that has been created by the biodiesel industry. As of May 2007, the sale of unrefined glycerol was worth about EUR 10 per tonne of biodiesel produced, which is the equivalent of about EUR 0.009, or Ksh 0.89, per liter of biodiesel.[303] The local price of unrefined glycerol in Kenya may be at least a bit higher, but we have chosen not to include it within the economic analysis due to the uncertainty of the local market and the extremely low and falling prices worldwide. Adding glycerine processing to the production process is another option for increasing the value of the byproduct, as refined glycerine will fetch a higher price, although this will also add substantial costs to the capital investment.

TABLE 6: BIODIESEL NON-FEEDSTOCK COSTS

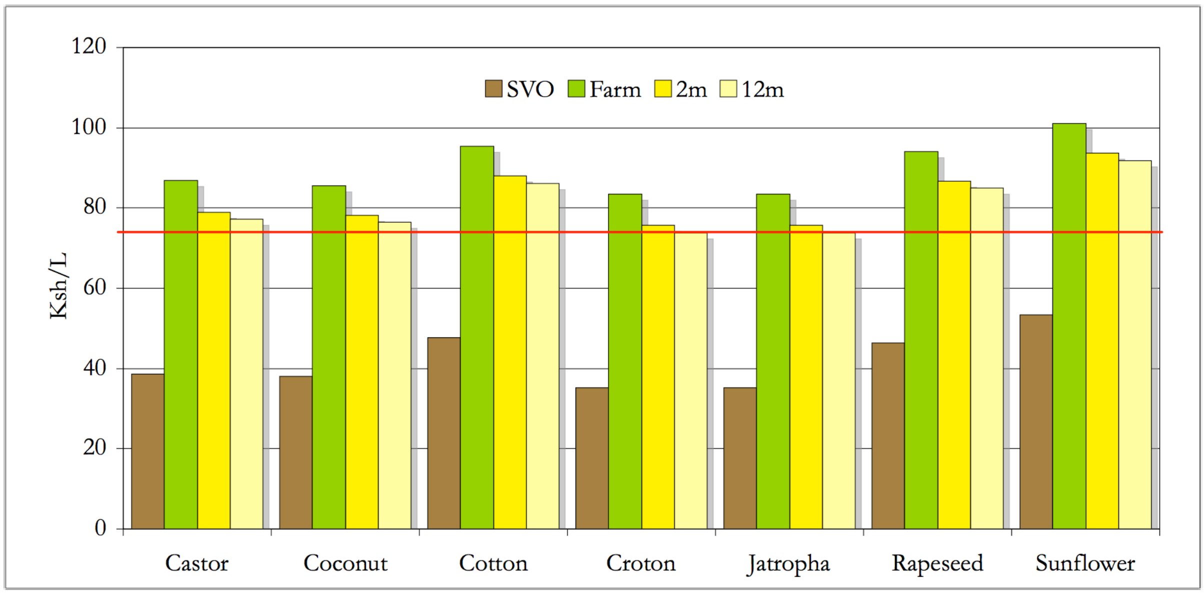
NON-FEEDSTOCK COSTS	Farm	2m	12m
Capital & Start-Up Financing	5.61	2.90	3.15
Operations	22.94	13.24	11.23
Taxes	19.10	19.10	19.10
Transport, Blending & Profit		5.00	5.00
TOTAL NON-FEEDSTOCK	47.64	40.23	38.47

Not surprisingly, the scale of production is inversely proportionate to the cost of production per liter, with the exception of the capital and start-up financing being slightly cheaper for the small commercial than the larger commercial. The cost of methanol, sodium hydroxide, and magnesium silicate is based on market prices in Nairobi as of December 2007. All chemicals are readily available in the local or regional market. Taxes are calculated based on the current combined tax burden per liter of petroleum diesel, discounted by 7% to account for the reduced energy content of biodiesel (it will take 7% more biodiesel to replace each unit of petroleum diesel, so the overall revenues to the government would be the same). The cost of transport, blending and wholesale profit must also be accounted for, although only for the two commercial scales of production.

The overall cost of production presented in Figure 6 includes all feedstock and non-feedstock costs for each feedstock at the three different scales of production. To determine overall feasibility, the cost of production plus taxes must be compared to the current pump price for petroleum diesel, which is about Ksh 80 per liter at the time of this publication. However, discounting for the lower energy value in biodiesel, we can reduce the comparative price of petroleum diesel by 7% to Ksh 74.4 per liter, which is represented by the red horizontal line in Figure 6.

Thus, at current retail prices, biodiesel production is not economically feasible unless the tax burden is reduced or eliminated. However, fuel taxes that ordinarily attach at the point of sale may be inappropriate for an on farm venture where no commercial sale is taking place (more on tax policies in Section 5.9 and Section 7). Nor would it be feasible to produce biodiesel at the commercial scale at current prices with a full fuel tax burden. At these levels and with the price of diesel likely to fluctuate below its current retail price, investing in a new biodiesel venture in Kenya seems risky without some governmental support.

FIGURE 6: BIODIESEL COST OF PRODUCTION BY FEEDSTOCK & SCALE OF PRODUCTION



B100 COST (Ksh/L)	Castor	Coconut	Cotton	Croton	Jatropha	Rapeseed	Sunflower
Farm	86.84	85.59	95.38	83.49	83.49	94.07	101.03
2m	79.01	78.18	87.97	75.66	75.66	86.66	93.62
12m	77.14	76.42	86.20	73.78	73.78	84.90	91.86

4.3 KENYAN AND GLOBAL BIOFUELS MARKETS

4.3.1 Ethanol Markets

Ethanol is used for alcoholic beverages, pharmaceutical and industrial applications, and for fuel. Seventy-seven percent of global ethanol production was used for fuel in 2006, with fourteen and nine percent for beverages and industrial use, respectively.[304]

Current ethanol production in Kenya amounts to about 20 million liters per year, the vast majority of which is exported to Uganda and the Democratic Republic of Congo for beverage use.[305] A small share is also denatured with methanol and sold as methylated spirit for industrial uses in Kenya. The current expansion in ethanol production that is being planned by Spectre International and Mumias Sugar would add over 100 million liters of production at full capacity.

A ten percent ethanol blend (E10) in Kenya would require approximately 93 million liters a year by 2013. At full production capacity, the two current ethanol plants in Kenya could produce about half the required amount, or 45 million liters per year. However, current expansion plans at Spectre and Mumias would add nearly 80 million liters additional capacity. In 2006, European countries imported 2.36 billion liters of ethanol.[306] With average production costs, excluding capital costs, of about Ksh 38 per liter for grain-based ethanol produced in Europe, such a market could be attractive for any surplus ethanol produced in Kenya.[307]

Closer to home, African nations imported about 154 million liters of ethanol in 2006, with a demand that is surely to rise in the coming years.[308] Uganda would need about 10.6 million liters a month to comply with its proposed E20 mandate, much of which would have to be imported. In 2006, Uganda produced enough molasses for about 20 million liters of ethanol.[309] If all cane produced in Uganda went directly into ethanol, Uganda could produce roughly 11.37 million liters per month.

Another potential local market is the use of ethanol in cook stoves and lamps. If affordable, this domestic market could reduce the use of unsustainable charcoal and fuel wood. However, studies using ethanol for domestic fuel purposes have not yet demonstrated economic feasibility.[310]

4.3.2 Biodiesel Markets

Biodiesel is used for transport fuel, stationary power, farm equipment use and marine power. A two percent blend of biodiesel (B2) into the local transport market would require about 32 million liters of biodiesel by 2013. Many communities throughout Kenya currently derive electricity from diesel generators. Biodiesel could complement, or completely displace, the use of petroleum diesel for many stationary applications. Safaricom and Celltel alone use millions of liters of diesel to power remote cell phone towers throughout the country and have expressed interest in using biodiesel in lieu of petroleum diesel.

Straight vegetable oil that has not been processed into biodiesel could potentially be used in a wide variety of industrial applications, such as for transport with specially modified vehicles and farm equipment. This could reduce the costs of production and provide significant savings as a replacement for petroleum diesel. Based on the feedstock costs listed above, a customer might save as much as Ksh 30 per liter. However, it must be stressed that most vehicle manufacturers will not extend their warranties to customers using straight vegetable oil (see Appendix E for manufacturers' policies on biodiesel). Plus, the cost and logistics of modifying the engine with a pre-heating system would make such use prohibitive in many situations. Nonetheless, research should be undertaken to test the use of SVO in various transport markets.

Another possibility is the use of straight vegetable oil as a fuel replacement for stationary power. Safari camps and other off-the-grid users could benefit from the simplicity and cost of using locally supplied vegetable oil, and avoid the need for long transport of fuel and processing costs for turning the SVO into biodiesel. However, before people start experimenting on their own equipment, studies should be undertaken for performance and engine modifications necessary for using SVO in generators. This type of project could be undertaken by KIRDI in conjunction with interested private parties.

A third avenue for SVO is for use as a substitute for kerosene, firewood and charcoal. Domestic lighting and cooking needs are often met with environmentally damaging and unhealthy fuels. The use of SVO can provide an economical alternative. However, more research needs to be done to identify and develop affordable and practical lamps and stoves that can burn SVO.

As indicated above, rapidly expanding markets for export of ethanol and biodiesel provide tremendous growth opportunities for countries like Kenya, although trade restrictions, such as import tariffs, could impede these markets. The Harmonized Commodity Description and Coding System of the World Customs Organization does not yet have a clearly defined code for biofuels under which ethanol and biodiesel could be classified.[311]

4.4 EMPLOYMENT & INCOME BENEFITS

The potential employment and income benefits of biofuels in Kenya are enormous. It is estimated that the jobs-to-investment ratio for biofuels is about 100 times higher than for crude oil refineries.[312] Expanded agricultural production of biofuels feedstocks would provide farm jobs, as well as opportunities for smallholders to expand production into new cash crops. By focusing on crops that can grow in semi-arid agro-ecological zones, economic activity could revive poor rural economies that currently have few other options.

4.4.1 Ethanol Employment & Income

An additional 93 million liters of ethanol (enough for a national E10 blend by 2013) could yield about Ksh 4.65 billion ($72 million) per year to the economy.[313] Approximately 500 to 1,000 new jobs could be created in the manufacturing and transport sectors by the planned ethanol production expansion, according to estimates based on current and planned employment at ethanol plants in Western Kenya and job creation projections for ethanol plants in the developed world.[314] Mumias planned ethanol plant is expected to employ up to 100 new people, including at least 20 professional staff, who will earn an average of Ksh 100,000 per month.[315] The workers at the Mumias ethanol plant will earn between Ksh 15,000 and 35,000 per month.[316]

Tens of thousands of hectares of new feedstock production would be necessary to produce an additional 93 million liters in Western Kenya (see Table 9). This would require thousands of farm workers and managers, although more research is required to calculate the specific number of workers that would be required for cassava and sweet sorghum. Based on the current number of farm workers in the sugar industry, one wage farm job is created for every 54.9 hectares planted and one casual farm job for every 30.4 hectares.[317] Thus, growing enough sugarcane for an additional 93 million liters of ethanol would create 341 new wage farm jobs and 617 new casual farm jobs if the sugarcane is turned directly into ethanol without first producing any sugar. If sugar is produced and the ethanol is made from molasses, than approximately seven times as many farm jobs would be created. Of course, this is all dependent on land availability for this scale of production.

Another way of considering the benefits is to compare the potential net income from each feedstock. Reliable data on cost of production, yields and market prices are only available for cassava and sugarcane. As sweet sorghum is not yet established in Kenya, we can estimate costs based on the projected cost of production by ICRISAT in India. As Table 7 indicates, farmers stand to make about three times from cassava over sugarcane. However, ethanol from cassava would be prohibitively expensive at Ksh 6,500 per tonne (see Section 4.2.1), so prices would have to come down to become a viable ethanol feedstock.

TABLE 7: FARM INCOME FROM DIFFERENT ETHANOL FEEDSTOCKS[318]

Feedstock Costs	Cassava[a]	Sugarcane[b]	Sweet Sorghum[c]	
			Stalk	Grain
Cost of Production (Ksh/Ha)	31,700	57,000	57,200	
Sale Price (Ksh/tonne)	6,500	2,027	n/a	n/a
Current Yield per Hectare	9.6	33.4	35	1.2
			n/a	n/a
Current/Projected Income (Ksh/Ha)	30,700	10,702	n/a	

4.4.2 Biodiesel Employment & Income

Approximately one non-farm job could be created for every 100,000 to 180,000 liters of biodiesel production capacity.[319] Thus, about 229 new non-farm jobs would be created if Kenya adopted a B2 policy requiring the production of roughly 32 million liters of biodiesel by 2013. Thousands of farm jobs would also be created, although the precise number will depend on the efficiency of production in terms of yield per hectare, which is currently quite low for many of the feedstock crops. Further research must be conducted to ascertain the specific number of farm jobs that would be created for each different biodiesel feedstock.

To be sustainable and to benefit the largest number of Kenyans, any future biodiesel industry should maximize smallholder farm income by selecting feedstocks that will yield the highest return on investment. The availability of oilseeds in large enough quantities for commercial biodiesel production will depend on which crops farmers see as the most beneficial. Although revenues can be calculated for each crop, based on yield per hectare and the current market price of each feedstock, net income is more challenging. Information on the cost of production is not readily available and will require further research. KARI has the capacity and the interest in conducting such important work and should be engaged to do so as soon as possible.

Due to the overwhelming focus on jatropha by the Ministry of Energy, private farmers, investors and NGOs, we have analyzed the potential farm income for a theoretical 50-hectare plantation. The calculation assumes a yield of 2.5 tonnes per hectare (1.5 kilograms per tree) after seven years with a 3 by 2 meter spacing (1,666 trees per hectare).[320] The price per tonne of seeds is Ksh 15,000, which is the price used in the feasibility analysis contained in Section 4.2.1 above. Importantly, the cost of land is not included. These numbers are mere estimates and should not be relied upon for planning specific projects.

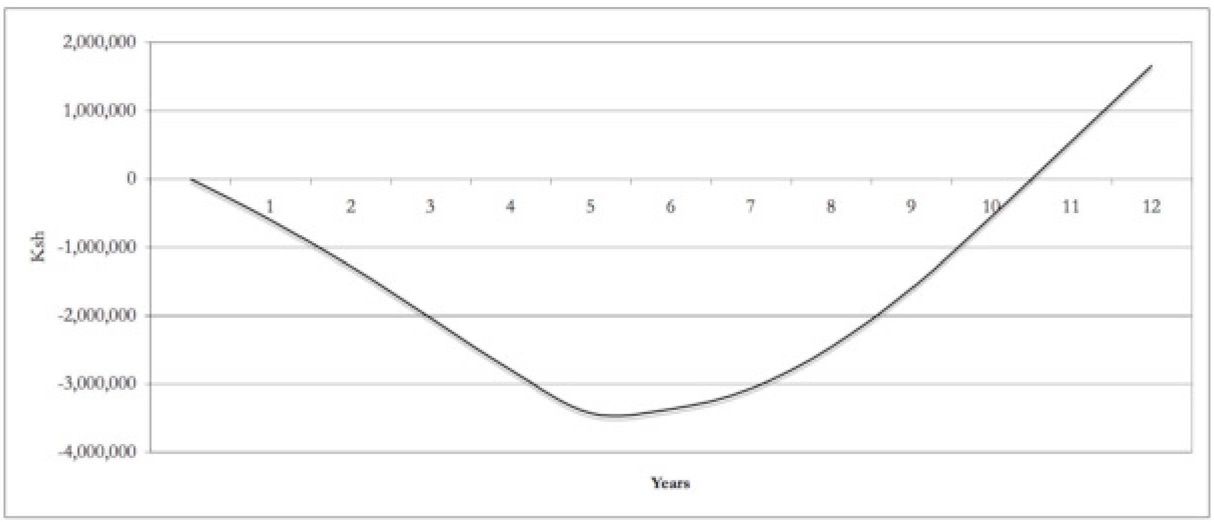
The plantation is designed to minimize the up-front establishment costs by planting 10 hectares per year over the first five years. This approach would require about 12 years before the entire plantation is fully matured. It will take more than five years before the plantation turns an annual operating profit and ten years before such an investment produces a cumulative net income (see

Figure 7 with accompanying table). The investment is projected to have a 16.19% internal rate of return over 30 years.

TABLE 8: 50 HECTARE JATROPHA PLANTATION COSTS & REVENUE

Costs							Revenue			
Yr	Ha	Est.	Filling In	Maint.	Harvest	Total Cost	Seed (T)	Oil (L)	Ksh/T	Total Revenue
1	10	320,073	32,950	249,000	0	602,023	0.0	0	15,000	0
2	20	320,073	32,950	279,000	62,400	694,423	0.8	280	15,000	12,495
3	30	320,073	32,950	309,000	124,800	786,823	2.5	840	15,000	37,485
4	40	320,073	32,950	324,000	187,200	864,223	6.7	2,239	15,000	99,960
5	50	320,073	32,950	339,000	249,600	941,623	15.0	5,038	15,000	224,910
6	50			105,000	312,000	417,000	31.7	10,636	15,000	474,810
7	50			90,000	374,400	464,400	51.6	17,353	15,000	774,690
8	50			75,000	436,800	511,800	75.0	25,190	15,000	1,124,550
9	50			75,000	499,200	574,200	95.8	32,187	15,000	1,436,925
10	50			75,000	561,600	636,600	112.5	37,785	15,000	1,686,825
11	50			75,000	624,000	699,000	120.8	40,584	15,000	1,811,775
12	50			75,000	686,400	761,400	125.0	41,983	15,000	1,874,250
						7,864,899				9,558,675

FIGURE 7: CUMULATIVE NET INCOME 50 HECTARE JATROPHA PLANTATION OVER 12 YEARS



Yr	Costs	Revenue	Net Income	Cumulative Income
1	602,023	0	-602,023	-602,023
2	694,423	12,495	-681,928	-1,283,951
3	786,823	37,485	-749,338	-2,033,288
4	864,223	99,960	-764,263	-2,797,551
5	941,623	224,910	-716,713	-3,514,264
6	417,000	474,810	57,810	-3,456,454
7	464,400	774,690	307,708	-3,062,963
8	511,800	1,124,550	609,002	-2,453,962

9	574,200	1,436,925	857,935	-1,596,026
10	636,600	1,686,825	1,044,602	-551,424
11	699,000	1,811,775	1,106,736	555,312
12	761,400	1,874,250	1,106,603	1,661,914

Jatropha is similar to other crops like coffee and tea that take years to mature. However, unlike coffee and tea, that are well-understood crops with established yields and production costs, jatropha plantation farming is still in its infancy and many questions remain. Many of the assumptions we have relied upon, such as un-irrigated yield, could vary significantly from the experience in India we have borrowed from. Nonetheless, it seems nearly certain that farmers will require significant long-term financing to develop commercial jatropha plantations. Smallholders, who do not have such large land areas, and can provide much of the labor themselves, may begin planting on boundaries and unused land, but may also require significant economic support to develop smaller jatropha plantations.

4.5 CURRENT & PROJECTED PETROL & DIESEL CONSUMPTION

Kenya consumed a total of 509 million liters of petrol and 1.22 billion liters of automotive diesel in 2006, or about 1.4 and 3.3 million liters per day, respectively.[321] Consumption of petroleum products overall has risen by an average of 1.6% over the past 25 years and 3.7% since 2003.[322] Assuming an average growth of 2.8% per year, Kenya will require 2.7 and 6.5 million liters per day of petrol and diesel, respectively, by 2030.

An additional 77 million liters of ethanol would be needed to supply sufficient quantities for a national 10% (E10) blend at current consumption levels, but would have to grow to 93 million liters by 2013 and to 148 million liters by 2030. A national B2 would require about 26 million liters of biodiesel at current consumption levels, which would have to grow to 32 million liters by 2013 and to 50 million liters to meet projected demand by 2030.

4.6 LAND AVAILABILITY FOR PRODUCING E10 & B2

Another significant factor in choosing which crops should be emphasized for biofuels is to consider the amount of land that would be required to meet certain ethanol and biodiesel production levels. For purposes of this study, we have chosen to analyze the land that would be required to produce 93 million liters of ethanol and 32 million liters of biodiesel, enough for E10 and B2 blends by 2013. Suitability mapping is also very helpful in determining where different crops can grow without competing with existing agricultural production.

Tables 9 and 10 list the number of hectares that would be required for each feedstock to produce E10 and B2 blending levels by 2013 and, based on calculations derived from the suitability maps, what percentage of suitable lands outside of existing food and cash crop areas would be required. Ample non-competitive, but suitable, land is available for cassava and sweet sorghum. If sugarcane was used, about one-fifth of potentially suitable land that is not currently being used for food or cash crops would be required. Not enough suitable land exists to produce an additional 93 million liters from molasses.

TABLE 9: LAND REQUIRED FOR 10% (E10) ETHANOL PRODUCTION BY 2013[323]				
	Ethanol Yield (liters per hectare)	Hectares (needed for E10 blend)[d]	Existing Hectares Planted	Percentage of Non-Food & Cash Crop Land
Cassava	1,632[a]	56,985	68,500[e]	2.7%
Sugarcane	4,962[b]	18,742	149,700[f]	20%
Molasses	709[b]	131,171	149,700[f]	141%
Sorghum*	1,400[c]	66,429	n/a	1.1%

The feedstock crops with the most land available for biodiesel are jatropha, castor, sunflower and croton. Both cottonseed and rapeseed is more limited, although could contribute a share of the feedstock required. Coconut is even more limited, but again could provide a portion of production, especially on a local level.

TABLE 10: LAND REQUIRED FOR 2% BIODIESEL (B2) PRODUCTION BY 2013[324]				
	Biodiesel Yield (liters per hectare)	Hectares (needed for B2 blend)	Existing Hectares Planted	Percentage of Non-Food & Cash Crop Land
Castor	448[a]	71,429	13,000[h]	1.0%
Coconut	597[b]	53,601	37,100[h]	161%
Cottonseed	87[c]	367,816	36,300[h]	26%
Croton*	840[d]	38,095	n/a	5.8%
Jatropha*	840[e]	38,095	n/a	0.6%
Rapeseed**	784[f]	40,816	n/a	26%
Sunflower	381[g]	83,990	13,000[h]	2.4%

4.7 FOREIGN CURRENCY SAVINGS & DOMESTIC REINVESTMENT

Kenya spent $983 million, or 5.6% of gross domestic product, importing petrol and automotive diesel in 2006.[325] The country also ran a current account deficit of $874 million in 2006.[326] With domestic consumption and the price of oil both continuing to rise, the amount spent on imported oil is nearly certain to increase in the years to come. Domestically produced biofuels could reduce the need for a portion of petroleum imports, thus leading to significant foreign currency savings. Hard currency that is currently enriching international trading partners could instead be reinvested in the Kenyan economy, creating jobs and new opportunities, especially for poor rural areas. If Kenya offset 10% of petrol imports and 2% of diesel imports with locally produced biofuels by 2013, it would keep a total of $71 million per year from flowing overseas (at current consumption levels, assuming an average price of $90 per barrel of oil).

4.8 CARBON FINANCE POTENTIAL

The potential reduction in greenhouse gas emissions from biofuels may provide an additional revenue stream for some projects (see Section 6.2 below on biofuels and greenhouse gasses). There are two distinctive markets for carbon credits: the mandatory market created through the Kyoto Protocol of the United Nations Convention on Climate Change (UNFCCC), and market for voluntary credits. The former is more stringent and restrictive, but generally yields a higher price per tonne of carbon. Conversely, the latter is more flexible and easier to gain compliance with, but fetches a lower price, (though the price has increased steadily due to the value placed on the livelihood and sustainability aspects of specific projects within the voluntary carbon markets).

4.8.1 Clean Development Mechanism (CDM) Market

With the exception of one project, biofuels have yet to benefit from the existing carbon funding mechanisms through the Clean Development Mechanism (CDM) of the Kyoto Protocol. The CDM enables countries to meet their emissions reduction obligations in part by funding projects that reduce emissions in other parts of the world, particularly developing countries that are not themselves bound to reduce emissions under the Climate Convention. In order for a project to qualify for emission reduction credits under the CDM, several requirements must be met.

First, the methods for counting the precise amount of emissions that have been reduced, as well as verification for what is claimed, must meet the very strict guidelines of an approved methodology. Six methodologies have been proposed to date, but only one – which applies to projects that produce biodiesel from waste vegetable oil – has been approved.[327] The remaining five methodologies either have been rejected or are in the process of being resubmitted to the CDM Executive Board.

A second requirement is the need to demonstrate that the project will result in emissions reductions that would not have occurred in the absence of CDM carbon financing. This is called additionality. The project must also meet the requirements of the host country for sustainable development. Participating governments are required to build up human and institutional capacities in order to implement CDM projects. This can be a significant barrier in Africa and other parts of the developing world. Not surprisingly, as of this publication, only 2.8% of all current CDM projects were registered in Africa.[328]

Another limitation on the viability of biofuels carbon projects, and part of the reason for so few approved methodologies, is the challenge involved in accounting for GHG reductions, especially regarding those that come from land-use change. As discussed in Section 6.2 below, certain biofuels produced today may actually be net GHG emitters if all direct and indirect land-use changes are accounted for. This is because of GHG emissions that are released when forests and grasslands are cleared for biofuels crops or for other agricultural crops that are displaced by biofuels production. Emissions that occur as a result of the project outside of the project baseline are referred to as leakage.

Despite all of these obstacles, it may be possible to obtain certification for a CDM biofuels project. Several initiatives that have been launched to promote the CDM in Africa may provide support to biofuels carbon financing. These include:

- The Nairobi Framework – Initiated by the United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP), World Bank Group, African Development Bank, and the Secretariat of the UNFCCC with the goal of helping developing countries, especially those in sub-Sahara Africa, to improve their level of participation in the CDM.
- Capacity Development for the CDM (CD4CDM) Activities – A multi-year program with local partners, mostly undertaken in Cote d'Ivoire, Mozambique, Uganda, Ghana, Egypt, Morocco, Tanzania, Mauritius and Algeria. The donor is the Netherlands Ministry of Foreign Affairs, which has provided $15 million for the project.

- Carbon Finance for Sustainable Energy in Africa – This is a program mostly implemented in Mali, Cameroon, Ghana, Mozambique and Zambia. Accomplishments will include the set-up of national institutions for regulation and promotion of CDM projects and the development of national action plans. The main donor is the UN Foundation and the World Bank, which has given $1 million.
- UNEP Project: Forestry/Bioenergy CDM in Africa – A three-year program mostly undertaken in French speaking Africa (Benin, Cameroon, Democratic Republic of Congo, Gabon, Madagascar, Mali and Senegal). The main objectives are to meet short and long-term capacity needs and to pilot existing and future CDM projects in the forestry/bioenergy sectors.

4.8.2 Voluntary Carbon Market

As mentioned above, the voluntary carbon market (VCM) offers a potentially less rigorous alternative for carbon financing than the CDM market. Generally speaking, the methodologies used in the VCM are very similar to those used for compliance with the CDM. However, the transaction costs for obtaining credit are usually lower in the VCM due to a shorter certification process. Also, the additionality requirements are generally more lenient in the VCM, since buyers are more interested in the sustainable development aspects of the project more than whether the project would have occurred in the absence of the carbon financing (the basic test for additionality).

5. REGULATORY & FISCAL ANALYSIS

Before you begin building a house, it is wise to survey the landscape. Similarly, before we create an appropriate biofuels policy framework in Kenya, we must assess the existing fiscal and regulatory regime. The survey contained in the following section includes a comprehensive review of current laws, policies, regulatory requirements and taxes as they apply throughout the biofuels production life cycle. The scope of the research includes relevant laws and regulations under the authority of the Ministries of Agriculture, Energy (specifically the Renewable Energy Department), Environment and Natural Resources, and Finance and Revenue, among others.[329]

As a preliminary matter, it is important to distinguish between law and policy. Generally speaking, the former is mandatory while the latter is merely advisory. Both can change over time, but laws tend to be more permanent as they are harder to modify or amend than policy. Another distinction is that laws usually bind both the government and the public at large, whereas policies usually only apply to governmental agencies or institutions.

The information gained from this research should act as a *guide* to project developers, investors, and government officials as to what regulatory requirements, obstacles or benefits currently exist for biofuels in Kenya. Section 7 provides a detailed list of recommended regulatory and fiscal reforms that would promote biofuels while protecting consumers, workers, communities and the environment. Investors and project developers should not rely on the information contained herein without an independent assessment by a qualified expert assessing the legal and regulatory implications of their specific projects.

5.1 ENERGY REGULATION

The Energy Act of 2006 mandates that the government pursues and facilitates the production of biofuels, but does not articulate how this shall be accomplished.[330] Liquid biofuels are only accorded a passing mention in the Act, although it does at least distinguish between bioethanol and biodiesel.[331] The Ministry of Energy drafted a policy paper on biofuels in 2004 and, through its National Biofuels Committee recently produced a biodiesel strategy (see Section 3.2 for more information on the Committee). The policy and strategy together provide an important starting point for the construction of a comprehensive regulatory framework. As the strategy acknowledges, more analysis is required to determine a precise policy on blending targets, tax incentives, overall economics, production capacities, and the use of multiple feedstocks in addition to jatropha. No similar efforts have begun regarding the ethanol industry, although the Ministry of Energy intends to do so upon completion of the biodiesel framework.

Biofuels activities clearly fall under the provisions of the Energy Act and may be regulated accordingly.[332] The newly formed Energy Regulatory Commission (ERC) has been given the explicit authority to regulate biofuels production and distribution, in addition to more traditional forms of energy such as electricity and petroleum products.[333] The NBC has called for the adoption of new regulations and, where appropriate, the application of existing regulations regarding: environmental impact assessments, child labor, penalties for non-compliance within the Energy Act, handling and safety standards, and the creation of material safety data sheets.[334]

For electricity and petroleum, the Energy Act explicitly requires a license for the generation, importation, exportation, refining, transmission, distribution, sale, storage or transportation.[335] Significantly, no such requirement for a license or permit is included in the section governing biofuels.[336] This omission seems prudent given the nascent stage of the biofuels industry in Kenya and the need to adopt rules that support, rather than suppress, the development of the new industry. However, a licensing requirement is probably wise once commercial production and sales begin. A license was required for the *possession* of power alcohol (ethanol) under the recently repealed Industrial Alcohol (Possession) Act.[337] The authority to introduce licensing requirements now rests in the hands of the ERC if and when it deems the need to do so.

5.2 CONSUMER PROTECTION

The underlying purpose of fuel quality and blending standards is to protect consumers from harmful products. The Energy Act generally supports the production, sale and use of biofuels.[338] However, current gaps and vagaries in the law make it unclear whether it is permissible to produce, sell or use biofuels in the absence of clear standards from the Kenya Bureau of Standards (KEBS). Section 115 of the Act states that:

> No person shall use or employ for or in connection with any of the purposes of producing, generating, transforming, transmitting, distributing, supplying, or importing, exporting, transporting, refining, storing, selling or using, *any form of energy*, any mode, material or apparatus other than that which complies with the specification or standard of the Kenya Bureau of Standards or where no such standard exists, any international standard approved by the Kenya Bureau of Standards.[339]

What seems clear is that none of the above-listed activities are permitted with regard to biofuels if they are conducted in a way that contravenes any specification or standard adopted by KEBS. What is less clear is whether such activities can occur legally if no such specification or standard has been established. It is arguable that in the absence of an established standard, the activities may continue. However, a plain reading of the law, as well as a consideration of the very purpose of a government agency like KEBS, seems to indicate that KEBS should adopt relevant standards before commercial biofuels activities begin on a large scale, and certainly before they are sold for use by the general public.

KEBS has already adopted standards for a 10% ethanol blend with petrol, which means that commercial fuel ethanol production is lawful as long as the fuel meets the standard, regardless of how Section 115 is interpreted (see Appendix C for Kenya and international ethanol fuel quality and blending standards).[340] No similar standard exists for biodiesel in Kenya, although KEBS claims to be developing one and several international standards could rather easily be approved.

Once biofuels are lawfully produced, a petroleum license is required for blending them with petroleum products, and such blending is also subject to approved KEBS standards.[341] The ethanol blending standard cited above would permit the blending of 10% ethanol with 90% petrol, however, a similar blending standard would be required before biodiesel could lawfully be mixed with petrol diesel. It would be wise to review all existing Kenyan and international biofuel quality and blending standards and adopt appropriate ones for each category of fuel before large-scale production occurs.

Fortunately, the Energy Act creates the framework for doing so without needing to enact new legislation.

As noted above, the Energy Act delegates broad authority to KEBS to determine fuel quality and blending standards for biofuels. According to the Environmental Management Coordination Act (EMCA), which is discussed more fully below, KEBS is required to conduct an environmental impact assessment (EIA) analyzing the environmental impact of any biofuels standards it proposes.[342] The EMCA also requires that KEBS provide public notice and opportunities for public comment before it finalizes its decisions.[343]

5.3 HEALTH, OCCUPATIONAL SAFETY & WORKER PROTECTION

Health, safety and worker protections are also important considerations for any producer or seller of biofuels, and any associated laws or regulations must be complied with. Existing regulations under the Energy and Petroleum Acts presumably would govern the distribution and sale of blended biofuels. Health and safety regulations exist for vehicles and drivers used to transport petroleum products as well as facilities and equipment used to manufacture and process petroleum products.[344] Licenses and certificates are required for drivers, vehicles and facilities that verify the standards are being adhered to.

A manufacturer's license is also required by the Factories Act, which is intended to provide a protective layer for workers and surrounding communities.[345] Perhaps more importantly from the perspective of occupational safety, rules setting specific exposure thresholds for a variety of chemicals, including some that are used throughout biofuels production processes, have been adopted.[346] The Factories Act should be consulted prior to commencement of production activities to ensure all other requirements, such as health and safety regulations are met.

The Employment Act stipulates that an employer must inform his/her employees of their rights by conspicuously displaying a statement in the prescribed form of the employee's rights under the law, which is accessible to all the employees.[347] Every employee in Kenya has the right to participate in forming a trade union and no employer has any lawful right to discriminate against an employee or potential employee for doing so.[348] Employers are required by law to submit trade union dues (membership subscriptions) to the respective trade unions that their employees subscribe to within a prescribed time period and with notice. These dues are to be deducted from the respective employee's salary.[349]

Employers must maintain an insurance policy or surety covering any liability the employer may incur regarding his employees.[350] Employers must also register with the Director of Occupational Safety and Health Services and provide details of their business activities.[351] An employee who is involved in an accident while at work that is not caused by the employee's willful or deliberate conduct that results in a permanent disability must be compensated by the employer.[352]

5.4 ENVIRONMENTAL PROTECTIONS

Many aspects of biofuels production have direct and indirect environmental implications (see Section 6 for a complete discussion of the environmental impacts of biofuels). As a result, various regulations are in place to protect land, water, air, genetic biodiversity and other resources. In terms of setting new policy, the National Environmental Management Authority (NEMA) is mandated to create incentives for the promotion of renewable sources of energy.[353] This is to be effected through a Committee of NEMA known as the National Environmental Action Plan Committee (NEAP),[354] which has been empowered under the EMCA to *recommend* appropriate *legal and fiscal incentives* that may be used to encourage the business community to incorporate environmental requirements into their planning and operational process.[355] This section analyzes environmental laws and regulations that are germane to biofuels production.

5.4.1 Environmental Impact Assessments

While the small-scale planting of biofuels crops may not require any environmental permits, large-scale biofuels plantations will require environmental impact assessments (EIAs) and licenses (EIALs). Risk assessments and performance trials may also be required for new crops under the Seeds and Plant Varieties Act.[356] The following activities along the biofuels value chain would require consideration in an EIA:[357]

- any activity or structure out of character with its surrounding;
- major changes in land use;
- all roads in scenic, wooded or mountainous areas and wetlands;
- railway lines;
- oil and gas pipelines;
- water transport;
- river diversions and water transfer between catchments;
- drilling for the purpose of utilizing ground water resources;
- timber harvesting;
- clearance of forest areas;
- reforestation and afforestation;
- large-scale agriculture;
- use of pesticides, including aerial spraying;
- introduction of new crops;
- use of fertilizers;
- irrigation;
- fertilizer manufacture or processing;
- oil refineries and petro-chemical works;
- chemical works and process plants;
- bulk grain processing plants;
- management of hydrocarbons including the storage of natural gas and combustible or explosive fuels;
- waste disposal, including: sites for solid waste disposal; sites for hazardous waste disposal; sewage disposal works; works involving major atmospheric emissions; works emitting offensive odors.

EIAs must be performed by a NEMA-approved expert for any biofuels project, program or policy that *may* have an impact on the environment.[358] An environmental impact assessment license (EIAL) from NEMA must be obtained before the project can be started.[359] A fee of 0.1% of the total project cost is required to obtain an EIAL.[360] NEMA must respond within three months and if no response is given, then the project is tacitly approved.[361] Before a project is considered, NEMA must provide public notice and an opportunity for comments on the project.[362] EIAs must conform to the EIA Regulations,[363] as well as the provisions of the EMCA itself.[364] NEMA has broad discretion as to whether to approve a project and, once approved, may reconsider or revoke approval at any time thereafter.[365] An updated EIA may be required under some specifically defined circumstances.[366] EIA licenses, which are issued upon approval of an EIA by NEMA, can be transferred along with the transfer of a business; however, both the transferor and transferee must jointly notify NEMA in writing within 30 days of the transfer.[367]

5.4.2 Water Pollution

Written approval from the Director General, Ministry of the Environment is required before erecting or constructing any structure in a waterbed or beside it for purposes of irrigation.[368] Approval is also required before introducing or planting a substance, biological or human made, in any natural water body that would or is likely to have adverse environmental effects, or before changing or blocking a river's natural course.[369] Cultivation or any agrarian activity is prohibited six meters from any riverbed.[370]

As authorized by the EMCA, the Ministry of Environment and Natural Resources has established water quality standards for myriad chemicals.[371] The Regulations require that all sources of water comply with the scheduled standards.[372] Effluent Discharge Licenses are required of all point sources.[373] Licensees are required to carry out regular effluent discharge quality and quantity monitoring and submit quarterly reports to NEMA.[374] NEMA in consultation with the relevant lead agencies monitors compliance with the relevant standards.[375]

5.4.3 Hazardous Chemicals

Importing or purchasing inputs such as fertilizers, pesticides and herbicides may require special licenses under either the Pharmacy and Poisons Act or the Use of Poisonous Substances Act.[376] Farmers and other agricultural experts should have experience with these regulatory requirements. Other chemicals necessary for the production of biofuels, such as methanol, sodium hydroxide and magnesium silicate, may also fall under these regulations.

NEMA prescribes standards to regulate the importation, exportation, manufacture, storage, distribution, sale, use, packaging, transportation disposal and advertisement of toxic substances.[377] NEMA is also mandated to provide procedures for the registration of toxic substances[378] and to prescribe measures for the establishment of enforcement procedures and regulations for the storage, packaging and transportation of toxic substances.[379]

5.4.4 Waste & Byproduct Disposal

Biofuels production creates certain waste streams that must be dealt with before they are put back into the environment. Some, such as seedcake, are extremely valuable byproducts that can readily be sold as fertilizer, animal feed, or biomass for biogas generation. Others, like glycerol, must be treated before they are reused or disposed of in the environment.

The EMCA provides that every person whose activities generate wastes must employ measures essential to minimize wastes through treatment, reclamation and recycling.[380] Selling the waste seedcake produced after biofuels production and the agricultural residue produced after harvesting crops can be viewed as reclamation of wastes. If the seedcake that is leftover after oil extraction is to be used as a fertilizer or animal feed, then such seedcake would fall under the provisions of the Fertilizers and Animal Foodstuffs Act, and must conform to the relevant standards for such products.[381] A license is required to distribute or manufacture animal feed or fertilizer.[382] NEMA has enacted regulations prescribing standards for waste handling, storage, transportation, segregation and disposal.[383] A valid license from NEMA is required to transport certain wastes.[384]

5.5 PURCHASE, DOMESTIC MOVEMENT & IMPORTATION OF SEEDS & OTHER GENETIC MATERIAL

Growing an adequate supply of biofuel feedstock is an essential component of the production process. This may require the purchase, domestic movement and/or importation of seeds, which are activities regulated by the Seeds and Plant Varieties Act[385] and the Plant Protection Act.[386] Their overriding purposes are the protection of the domestic seed market in Kenya and the limitation on the introduction of potentially dangerous organisms. The statutes apply stringent plant and seed introduction and certification procedures which are intended to prevent the importation and domestic transfer of diseased seeds, noxious weeds and injurious pests. All phytosanitary measures are based on or have equivalent international standards.[387] The Kenya Plant Health Inspectorate Service (KEPHIS)[388] is charged with testing, certification, quarantine, and grading, as well as the implementation of the national policy on the introduction and use of genetically modified seeds and plants.[389]

Any commercial seed dealer or merchant must be licensed under the Trade Licensing Act.[390] This License is issued by the respective District Trade Development Officers under the Ministry of Trade and Industry, who are located in most, if not every, district in Kenya.[391] Prior to importation of any type of seed, the seed merchant must also be registered with KEPHIS and given an Importation Certificate.[392] The following documents are required for the import of most types of seed into Kenya:[393]

- Suppliers Invoice - describing the seed as well as their quantity.
- Packing List - detailing the contents of the consignment containing the seed.
- A Bill of Lading/Airway Bill - a contract of carriage of goods between a shipper and a carrier of goods.
- Import Declaration Form (IDF Form C-61) - this form is issued by the Kenya Revenue Authority's (KRA's) Customs Services Offices and is required for all imports. One needs to pay a processing fee of Ksh 5,000 minimum or 2.75 percent of the Cost Insurance and Freight (CIF) value, whichever is greater.
- Declaration of Customs Value (Form C-52) - This form is used to declare the true and accurate value of the seeds being imported.
- Phytosanitary Certificate - These are obtained from the applicable agency in the exporting country and processed by KEPHIS. Where the import is categorized as a Schedule I (one) seed then it must be up to standards of the Organization for Economic Cooperation and Development (OECD) system, which ensure compliance with phytosanitary standards such

as, treatment of seed by any specified means for the control of plant disease and regulating the importation, quality, testing and sale of any material used in such treatment.[394]

- International Orange Certificate - All imported seed shall be accompanied by an International Orange Certificate of the International Seed Testing Association (ISTA), and shall meet Kenyan quarantine standards requirements as set out in the Plant Protection Act, Chapter 324 of the Laws of Kenya.[395]
- Plant Import Permit - This is obtained prior to its shipment from the importing country and it specifies the requirements of plant health, indicating prohibitions, restricted quarantine importations and additional declarations with regard to pre-shipment treatments. This permit must be sent to the plant health authorities in the country of origin for adherence with Kenya's import permit requirements.

All potential biofuels feedstocks considered in this Study are subject to a 2.75% CIF tax and an excise duty of between 10-35%.[396] The excise on castor and sunflower seeds is 10%; for cotton, coconut, rapeseed, sorghum and sugarcane it is 15%; for cassava it is 35%; and the excise on croton and jatropha has yet to be set by the Ministry of Finance.[397] A 16% VAT applies to the sale of all seeds except croton and jatropha.[398]

5.6 ACQUIRING & USING LAND

Land is a form of property.[399] The most crucial issues to consider when dealing with land are the questions of ownership, control and rights of access and use. Land in Kenya is regulated by several Acts of Parliament[400] and most of these Acts define land in their own way.[401] These definitions are extremely crucial in transactions involving land and will be applicable to any category of land to which the parent Act refers.

A biofuels producer can obtain the necessary ethanol or biodiesel feedstock in any of the following four ways:

- Freehold ownership whereby they manage a plantation on land that they or their company owns outright.[402]
- Leasehold ownership whereby they manage a plantation on land that they or their company leases.[403]
- A contract with a landowner or lessee that creates an ownership right to the crop or portion of the crop, called a servitude.[404]
- Purchasing crops from a farmer or on the open market.

The requirements of a particular project's business model will determine what level of control over the land is needed. Generally speaking, the size of the initial investment in the land is proportional to the level of control the investor will receive. There are various categories of property rights or estates that are capable of ownership or control.

A prospective biofuels investor should be aware that Kenya has two distinctive and not always consistent land title registration systems, each of which have particular procedural and substantive requirements that their property lawyer must be fully conversant with. Here are the main components of a land transaction in Kenya:

- Due Diligence Search – A title search checking that the land is free from any encumbrances or fetters such as a charge for a mortgage. This can be carried out by a title insurance agency.
- Purchase Documentation – A sale agreement prepared by a duly registered Advocate of the High Court of Kenya, which stipulates all the requirements of the purchase transaction such as payment schedule and completion time for a conveyance transaction.
- Lease/Transfer Documentation – A transfer of title or possession and control of property from the owner to the purchaser or lessor for the stated duration of time.
- Acquisition of Title Documents – Documents that prove ownership of the land and are issued to the new owner once a lease/transfer of property has been registered in the lands office and payment is complete.
- Land Rent Certificate – Since all land is actually owned by the state, then the "purchase" of land from the state is on leasehold and an annual rent is payable to the state. A land rent certificate is issued before land is transferred to a new owner, indicating no rent is pending.
- Land Rate Certificate – A valuation indicating the amount owed to the city council/municipal council for the "maintenance" of the land.
- Stamp Duty – A tax amounting to four percent of the value of the property being leased or sold.
- Commissioner of Lands' Consent – Required because the land is technically owned by the State.
- Land Controls Board's Consent – Required where use of land is changing from residential to agricultural use.

5.7 EQUIPMENT PURCHASE & IMPORTATION

This section analyzes issues related to the purchase and importation of agricultural and biofuels processing equipment. Under Kenyan law, the purpose for which machinery will be used may affect how it is taxed or otherwise regulated. For instance, agricultural machinery and certain processing or production equipment may, in certain cases, be subject to tax exemptions. See Table 11 for examples on regulatory and tax treatment for importing and/or purchasing certain pieces of equipment.

TABLE 11: TAXES & REGULATIONS ON IMPORTING MACHINERY

	Hydrams	Plows	Harvesters	Liquid Pumps	Root Harvesters	Generators
Taxes	2.75% CIF 10% Excise	2.75% CIF Excise - Manual 25% Other 0%	2.75% CIF 0% Excise	2.75% CIF Excise - Non-Fuel 10%	2.75% CIF 0% Excise	2.75% CIF 10% Excise
Licenses	. Trade License . Import License					
Import	. Suppliers Invoice . Packing list . Bill of lading . Import Declaration Form . Declaration of customs value (Form C-52)					
Certificates	. Certificate of Conformity . Meet KEBS standard specification					

Any equipment or goods must meet Kenyan standards before they are shipped. The Standards Act prescribes that the supplier or exporter obtains a Certificate of Conformity issued by a Pre Export Verification of Conformity (PVoC) office before shipment. There are three possible routes for obtaining a Certificate of Conformity: product licensing, product registration, or consignment inspection and testing for unlicensed/unregistered products. The method used is dependant on the exporters' shipments' frequency to Kenya and level of compliance they are able to demonstrate when applying for certification.

5.8 TRADE & INVESTMENT

The Trade Licensing Act prohibits anyone from conducting any business[405] except under and in accordance with the terms of a current license.[406] Non-citizens of Kenya are prohibited from conducting business in any place that is not a designated general business area;[407] or in any specified goods, unless their license specifically authorizes them to do so.[408] Persons are also prohibited from entering any business transaction unless the business with which the transaction is entered into is carried on under a license.[409]

The Investment Promotion Act (IPA) promotes and facilitates investment by assisting investors in obtaining the licenses necessary to invest and by providing other assistance.[410] The IPA makes provision for applications for investment certificates[411] to the Kenya Investment Authority[412] (KIA), by any potential investors in Kenya. Investment certificates entitle investors to 71 different types of licenses that are required under different Kenyan laws, as well as entry and employment permits under the Immigration Act.[413] Ultimately, the purpose of the IPA is threefold: to aid investors in complying with bureaucratic requirements of establishing a business, to keep track of investments, and to protect Kenya and the local investor market from potentially detrimental investments.

5.9 TAXES & FISCAL POLICY

As discussed in Section 4.2 above, biofuels may not always be economically competitive with petroleum fuels, especially as the industry is first getting established. The cost of production and the cost of petroleum will dictate the competitiveness of biofuels at any given time. Tax policy can play a key role in either supporting or obstructing the development of a new biofuels industry. Of particular importance is the issue of how fuel taxes will be imposed on biofuels. The following table lists the current fuel taxes in Kenya for petrol (premium and regular) and automotive diesel (gas oil):

TABLE 12: FUEL TAXES ON PETROL & DIESEL IN KENYA (KSH/L)[414]

Type of Fuel	E.D.	V.A.T.	R.M.L.	P.D.L.	I.D.F.	Remission	Totals
Regular Petrol	19.505	n/a	9.00	0.40	1.33	-0.45	29.785
Premium Petrol	19.895	n/a	9.00	0.40	1.23	-0.45	30.075
Automotive Diesel	10.305	n/a	9.00	0.40	1.13	-0.30	20.535

Key: E.D. – Excise Duty; **V.A.T.** – Value Added Tax; **R.M.L.** – Road Maintenance Levy; **P.D.L.** – Petroleum Development Levy; **I.D.F.** - Import Declaration Fee (2.25% of cost, insurance and freight (CIF), assumed to be Ksh 59 for premium petrol, Ksh 55 for regular, and Ksh 50 for diesel); **Remission** – This is an amount of money that is remitted to the client by the K.R.A., for refining petroleum in the government refineries, for every liter of petroleum that is refined. This amount is deducted from the Excise duty payable to the government.

Tax holidays that reduce or eliminate the fuel tax on biofuels have been used very effectively to spur the growth in the industry in Europe and other parts of the world. Production tax credits – essentially the inverse of a tax holiday – have been the tool of choice in the United States to counter the stifling effect that fuel taxes can have on biofuels. These devices are often implemented for a set period of time – usually about 3-5 years – to enable the scale of biofuels production to rise to the point where it can compete with petroleum products on an even footing. Although this approach may forego some short-term revenues for the government, the domestic investment and job creation that such measures will spur should more than make up for the lost revenue in terms of overall economic benefit to the country (see Section 4.4 for more on income and job creation benefits of biofuels). Whereas there is no guarantee that revenues raised from fuel taxes will flow back into the country in a way that produces permanent employment and raises incomes, spurring industrial biofuels development with tax incentives will absolutely have that effect. Another factor to consider is the fact that the corporate and personal tax revenue from those involved in the new biofuels industry will offset at least a portion of the lost revenue from fuel taxes. A more in-depth analysis of tax trade-offs should be conducted to assess quantitatively the actual trade-offs.

The EMCA provides that the Finance Minister *may* propose to the government to put in place tax or fiscal incentives to induce or promote proper environmental management.[415] These incentives may include: a customs and excise waiver in respect of imported capital goods which prevent or substantially reduce environmental degradation caused by an undertaking, tax rebates to industries or other establishments that invest in plants, equipment and machinery for pollution control, recycling of wastes, water harvesting and conservation, prevention of floods and *for using other energy resources as substitutes for hydrocarbons*.[416]

Section 7 provides a detailed list of recommended regulatory and fiscal reforms to promote biofuels, including which government agency should take the lead.

6. ENVIRONMENTAL & SOCIAL IMPACTS

Biofuels can have both positive and negative environmental and social impacts depending on the type of feedstocks used, the methods and scale of production, and other factors. According to the assistant production manager at Mumias, "dealing with the environmental impacts of ethanol production can be difficult and tedious, and the initial investment costs high."[417] Many unanticipated and overlooked consequences of the recent global biofuels boom, such as higher food prices and high greenhouse gas emissions, are increasingly changing the debate amongst policymakers and the general public. Many of the existing models of biofuels production are proving to be quite unsustainable for many of the reasons discussed below. The following section describes some of these impacts from a life cycle perspective. The section concludes with a discussion of sustainability standards, or criteria, for the production of environmentally benign biofuels.

6.1 AIR & WATER POLLUTION

The environmental and health benefits of biofuels can be quite significant, depending on the type of feedstock and the mode of production. As anyone who has walked along the streets of Nairobi and many other large cities can attest, air pollution from automotive exhaust is noxious and ubiquitous. Fossil fuel emissions are not only a nuisance, but are downright dangerous. Studies have shown that diesel pollution contributes to premature death, lung cancer, decreased lung function, chronic bronchitis, increased respiratory and cardiovascular hospitalizations, and aggravated asthma.[418]

Air emissions from ethanol are lower than those from petrol in all six types of air pollution listed (see Figure 8). For biodiesel, all major air pollutants are also lower than for petroleum diesel, except for nitrogen oxide (NOx) emissions, which are slightly higher (see Figure 9).[419] Reductions in polycyclic aromatic hydrocarbons, which are probable human carcinogens, and particulate matter, which triggers respiratory illness such as asthma, could yield large public health benefits. The potential increase in NOx emissions, which contribute to the formation of ground-level ozone (smog), is small relative to the greater reductions in all other significant air pollutants. The use of fuel additives may also neutralize increased NOx emissions.[420]

Another benefit is the reduction in air pollution that comes from the co-generation of power and steam at biofuels plants. Ethanol plants running on sugarcane and sweet sorghum can use the bagasse waste from the sugar extraction to generate enough electricity to power their operations, plus a surplus to sell back into the electrical grid. For example, Mumias is investing in a cogeneration plant that is expected to generate 35MW of electricity into the Kenyan power grid, in addition to the 11-14MW that it currently produces to offset all of its electricity use at the sugar plant.[421] Spectre International's ethanol plant in Kisumu also generates biogas from the biomass residues of its operations, which it uses to offset part of its use of heavy fuel oil.[422]

Biodiesel is biodegradable and considered nontoxic by the United States Environmental Protection Agency. Pure biodiesel (B100) degrades 85% to 88% in water within 28 days.[423] Biodiesel's biodegradability also makes it much more benign on marine environments such as wetlands, marshes, rivers and oceans.[424]

Although biofuels may produce much lower emissions from exhaust, emissions from other sources along the life cycle must also be taken into account. Vehicles used for transport and agricultural production, as well as the pollution generated from the manufacture of pesticides and fertilizers, can outweigh some of the gains from reduced exhaust emissions. According to one study, biodiesel has the potential to produce more particulates throughout the entire life cycle of production than petroleum diesel, although the type of particulates may be less carcinogenic from biodiesel.[425]

FIGURE 8: 85% (E85) & 10% (E10) ETHANOL VS. PETROL[426]

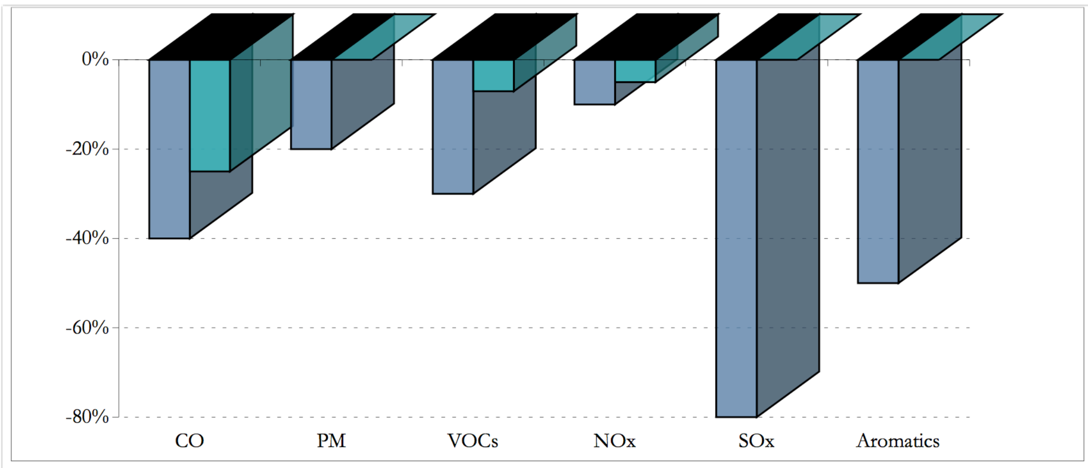
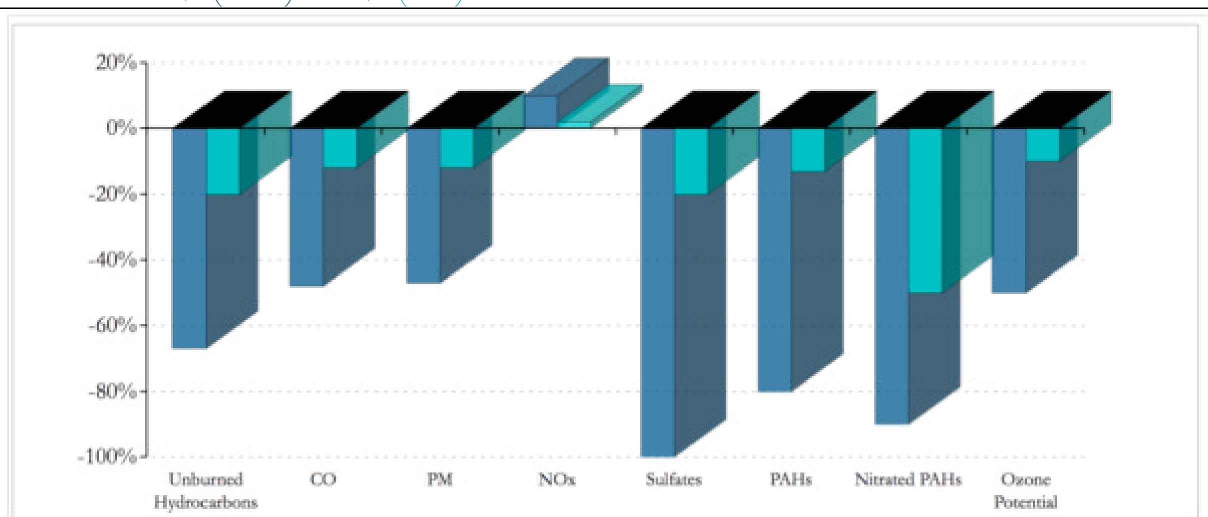


FIGURE 9: 100% (B100) & 20% (B20) BIODIESEL COMPARED VS. PETRODIESEL[427]



Ethanol production utilizes large quantities of water and produces significant wastewater effluents. In Brazil, between 1,000-2,000 liters of water are used to process a tonne of sugarcane into sugar and ethanol.[428] According to Agro-Chemical, the spent wash from ethanol production has a malodorous smell and dark brown color that regularly attracts complaints from the local community when it is discharged into the nearby river. It is unclear what type of wastewater treatment they are doing. Spectre International has invested in a state-of-the-art wastewater treatment facility that first treats incoming water from Lake Victoria and then processes wastewater before it is released back into the environment.[429] The water treatment facility also provides free potable water to the surrounding community.

6.2 GREENHOUSE GAS (GHG) EMISSIONS

Greenhouse gasses (GHGs) are natural and human-made atmospheric chemicals that contribute to global warming. One of the most common GHG's, carbon dioxide (CO_2), is largely caused by the combustion of fossil fuels in power plants, automobiles and industrial facilities. Biofuels present an opportunity to help mitigate climate change by reducing CO_2 emissions from fossil fuels because the carbon that is released into the atmosphere during the combustion of biofuels is equivalent to the amount of carbon that is absorbed during plant growth minus the amount of fossil fuels used for transport and production. These climate benefits can be commoditized and sold as carbon credits through the CDM or the voluntary carbon market. The sale of carbon credits could increase the viability of biodiesel projects that may not otherwise be economical and help to expand biodiesel development into other African countries (see Section 4.7 on Carbon Finance).

Similar to the discussion above on other air emissions, the climate benefit of a particular biofuel is dependent on the scale and mode of production, as well as the type of feedstock that is used. Machines and vehicles burning fossil fuels that are used to grow and process biofuels, as well as petrochemical-based fertilizers and pesticides, will increase the GHG footprint of the biofuel being produced. Some feedstocks, such as maize and soya, are generally more energy intensive than others, such as sugarcane and rapeseed, meaning that their GHG footprints are larger.[430] Several studies have shown GHG emission savings from biodiesel of up to 61% compared with conventional diesel emissions.[431] One study by the United States National Renewable Energy Laboratory found soy based biodiesel reduced GHG emissions by 78.4% over its entire production life cycle.[432] Another study found that corn-based ethanol reduced GHGs by only 12-13% compared with petrol.[433]

These potential GHG benefits may overlook the emissions resulting from land-use change that is caused by the direct growing of biofuels crops, or the indirect conversion of forest and grasslands to agricultural production resulting from the need to increase food production that has been displaced by biofuels crops. A recent study calculating the impact of land-use change on the overall GHG emissions footprint of some biofuels found that corn-based ethanol actually produces 93% more GHGs than petrol.[434] The study found that even switchgrass, an ethanol feedstock that has been hailed for its potential GHG benefits, when grown on land that would otherwise would have grown corn, would produce about 50% more GHGs than petrol.[435] Because the GHG emissions that are caused by converting forests or grasslands to agricultural production cause a one-time release of carbon from the soil and the plant matter that is removed, the GHG's that are reduced from the annual growing of biofuels feedstocks will "pay back" the initial release over time. For corn, the pay back period is calculated at 167 years; switchgrass grown on land previously used to grow corn would take 53 years.[436] Ethanol produced from Brazilian sugarcane is said to take 4 years to pay back the initial emissions caused by land-use change if grown on tropical grazing land, but even this relatively efficient source of ethanol would take over 50 years to pay back the initial GHG emissions if grown on land converted from tropical rainforest.[437]

In Kenya, the few remaining rainforests are protected and off limits to development. Given the limitations on arable land, the most logical strategy for biofuels would be to exploit semi-arid areas as much as possible, as well as parts of the sugarcane belt that are suitable for expanded cane and sweet sorghum plantations. For biodiesel, the optimal balance would be to use feedstocks that can either grow in semi-arid areas, such as castor and jatropha, or trees that can be part of a larger agroforestry or reforestation program, such as croton. Edible oil crops, like rapeseed and sunflower, could be used for biodiesel in cases where they are grown as a rotation with wheat and other food staples. Such a combined strategy would significantly reduce GHG emissions from land use change and make biofuels produced in Kenya extremely carbon friendly.

The release of GHGs from land-use change that is caused by growing biofuels feedstocks could undermine purported climate benefits and significantly reduce their overall environmental benefits. The use of waste materials, such as agricultural residues and used vegetable oil, thus are much more attractive feedstocks than crops that are grown primarily for biofuels. The use of marginal lands that would not otherwise be used for agricultural production to grow biofuels feedstocks is another key to reducing GHG emissions from land use change. Afforestation and reforestation projects involving tree species like croton and jatropha could also enable the biofuels produced to provide an overall GHG emission reduction compared with the fossil fuels it replaces. As discussed in more detail below, sustainability standards and legal restrictions should be adopted to promote the least GHG intensive biofuels (see Section 6.6).

6.3 NET ENERGY BALANCE & ENERGY RETURN ON INVESTMENT

An issue closely related to GHG emissions is the amount of energy it takes to produce each unit of biofuels, known as net energy balance or energy return on investment. A positive net energy balance means that more energy is produced than consumed in the production process. If the energy contained in a unit of biofuel is equal to the nonrenewable energy input required for production, the fuel is said to have a neutral net energy balance and the energy return on investment value is 1. Values greater than 1 mean the biofuel contains more energy than the fossil energy inputs used to make it; conversely values less than 1 mean that more nonrenewable energy was consumed during the production than is contained in the final product.

According to a study by the Minnesota Department of Agriculture, biodiesel and ethanol have energy yields of 3.2 and 1.34, respectively, which means biodiesel has a net energy gain of 220% and ethanol 34%.[438] An analysis of six studies by the Natural Resources Defense Council found that corn-based ethanol has an energy return on investment of between 1.29 and 1.65.[439] A similar survey of the net energy balance of biodiesel produced from different feedstocks found a range of estimates, including one that shows a negative balance (see Table 13).[440]

TABLE 13: BIODIESEL NET ENERGY BALANCE (NEB)[441]

Feedstock and Co-Products	NEB	Study
Soybean	1.6	Hill (2006)
Soybean+ Soymeal+ Glycerine	1.93	
Sunflower	0.46	Pimentel and Patzek (2005)
Sunflower + Oil meal	0.57	
Soybean	0.76	
Soybean + Soymeal	0.94	
Oilseed rape	2.99	ADEME(2002)
Sunflower	3.16	
Oilseed rape	1.98	Shell (2002)

Oilseed rape + Oil meal Oilseed rape + Oil meal + Glycerine Oilseed rape + Oil meal + Glycerine + Straw	3.36 3.45 6.35	
Oilseed rape Oilseed rape + Oil meal + Straw	1.78 3.71	Levington (2000)
Soybean	3.22	USDA (1998)

6.4 SOIL EROSION, LAND CONSERVATION, INVASIVENESS & BIODIVERSITY

Biofuels crops may help to prevent soil erosion and reclaim marginal lands for agricultural use. Some crops, such as rapeseed, are commonly used as a rotational crop to provide soil cover in between other harvests, typically wheat. Other feedstocks, like jatropha and croton, can help to reforest degraded areas that can replenish soils and local hydrology over time. Semi-arid crops, like castor, sweet sorghum and jatropha can also aid in returning marginal lands to productive use, thus increasing the overall efficient use of the land.

Of course, depending on the crops and the scale of production, many of these potential gains in land use can just as easily be undone by, for example, the deforestation of tropical rainforests to make way for industrial-scale palm oil plantations. Agricultural operations related to biofuels crops, such as seedbed preparation (i.e. ploughing and harrowing) and tilling, may also lead to soil erosion.

Another fear about biofuels crops is that they could promote leaching of excess chemical nutrients, containing nitrogen or phosphorus, from agricultural fields to natural ecosystems contributing to eutrophication. This concern is no different from that of any agricultural crop, whereby the negative environmental impacts of different farming techniques can be increased or decreased, depending on the approaches chosen by the farmer and the community. All too often, short-term economic benefits of increased yield outweigh the long-term interests of preserving soil and preventing environmental degradation. Governmental and non-governmental agencies must work to educate farmers to appreciate the long-term interests when they are making more short-term decisions on which agricultural methods to employ.

Demand for biofuels can also cause massive destruction of tropical rainforest ecosystems as they are cleared for biofuels plantations.[442] Deforestation for agricultural purposes is one of the most severe forms of land-use change. It is highly correlated with loss of biodiversity, as forested land, which is shifted to cultivation, loses its ecological function as a habitat for native plant and animal species. Examples include vast areas of natural forests and savannahs in Brazil and Asia that have been cleared for soy and palm plantations.

The Indonesian government is considering turning vast areas of Borneo's remote and biodiverse rainforests into oil-palm plantations, which could destroy habitat for over 360 species of animals, including orangutans.[443] Large-scale monoculture plantations can also lead to an increase in pests and diseases, which in turn require the application of greater amounts of toxic pesticides and energy-intensive fertilizers. To avoid these problems in Kenya, it is imperative that the government study the long-term impacts of land-use change for biofuels and plan accordingly. The central government should play a strong role in this process in consultation with local governments, as local governments acting alone may not always consider the broader impacts of their decisions on ecosystems that include areas beyond their jurisdictions.

Certain biofuels feedstocks, such as castor and jatropha, are considered invasive in some parts of the world and naturalized in others.[444] The Invasive Species Council of Australia recently released a report recommending that castor and jatropha, as well as a number of other potential biofuels crops, not be allowed in the country.[445] Both castor and jatropha have grown in Kenya under cultivation and in the wild for decades, if not longer. However, the introduction of large plantations of either crop raises serious questions about potential impacts on native ecosystems and must be adequately studied for its ability to spread before such plantations are undertaken. The Ministry of Energy is working with KEPHIS to study the potential invasiveness of different biofuels crops and to take the necessary steps to control any problems that might otherwise arise.

In the 1980s, Kenya allowed the introduction of a tree called *Prosopis juliflora*, as it was seen as having high potential as a fast growing tree that could help to reforest parts of the country. The tree has spread as intended and maintains certain benefits, such as fuel wood, but has since raised many concerns regarding its affect on domestic animals and native vegetation. The government is now trying to control the spread by introduction of a beetle that is thought to eat the tree's seeds and slow its spread. These efforts have done little to assuage the concerns of many Kenyans, who have filed a lawsuit against the government claiming millions in damages.[446] However, it is important to note that all invasive species are not equally dangerous, and there is even debate over the costs and benefits of prosopis. Many common non-native trees in Kenya, such as jacaranda, calliandra and juniper, are considered highly invasive in some parts of the world.

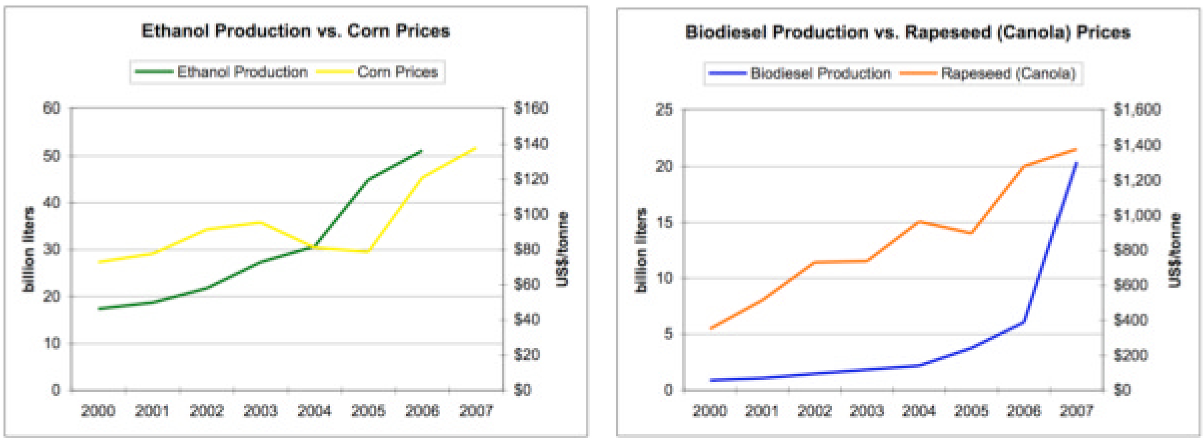
6.5 COMPETITION WITH FOOD

6.5.1 Debate & Facts on Biofuels and Food

Should edible crops be used for biofuels? As energy and food prices climb to record levels, this question is of the utmost importance, especially in countries like Kenya where approximately half of the population lacks access to adequate food.[447] While there are legitimate economic and ethical arguments on both sides of the debate, it is very difficult, if not impossible, to devise a universally applicable rule to guide decision makers in different parts of the world. The conflict between food and biofuels is certainly real. It is beyond dispute that food prices of major staples that are also being used as feedstocks for biofuels production have increased dramatically over the past several years as biofuels production has boomed (see Figure 10). What is not entirely clear is the causal link between the two.

On the one hand, the diversion of corn from food in the United States, which represents about 40% of global production,[448] and oilseeds in Europe and Southeast Asia *could be* a *main* driver for the rise in global commodity prices. World grain production has not kept up with consumption for six of the past seven years, and world grain stocks are at a 32-year low, down to about a 57-day supply.[449] Reductions in cheap corn exports to Mexico from the United States due to the increased demand for corn-based ethanol has led to increases in the price of tortillas, according news reports.[450] The debate has gotten so heated that a leading independent UN expert on the "right to food," Jean Zeigler, recently called the use of edible crops for biofuels "a crime against humanity" because of the impact higher food prices are having on the world's poor.[451]

FIGURE 10: ETHANOL & BIODIESEL PRODUCTION & FEEDSTOCK COMMODITY PRICES[452]



The UN Food and Agriculture Organization, which called Zeigler's remark "regrettable," has raised more scientifically-based concerns that the current biofuels boom may be threatening a hungrier world over the long term.[453] FAO's "Agricultural Outlook: 2007-2017" concludes:

> Currently strong world market prices for many agricultural commodities in international trade are, in large measure, due to factors of a temporary nature, such as drought related supply shortfalls, and low stocks. But, structural changes such as increased feedstock demand for biofuel production, and the reduction of surpluses due to past policy reforms, may keep prices above historic equilibrium levels during the next 10 years. Higher commodity prices are a particular concern for net food importing developing countries as well as the poor in urban populations, and will evoke on-going debate on the "food versus fuel" issue.[454]

Part of the problem is the fact that biofuels feedstock production is much more expensive in the United States and Europe than much of the developing world, yet large subsidies in the U.S. and Europe continue to prime the agricultural production pump, which helps maintain artificially high commodity prices.[455]

However, as the FAO report indicates, most short-term price increases in food are more the result of increased demand for food from many of the world's fastest expanding economies, like China and India, as well as the high price of petroleum, which affects everything from transport to the price of agricultural inputs like fertilizer and pesticides.[456] The head of the U.S. Department of Agriculture has put forth similar arguments.[457] Indeed, the fact that U.S. corn exports actually increased by about 26% from 2005 to 2006 makes it harder to direct blame at the U.S. ethanol program, in and of itself, causing the reduction in corn stocks worldwide that has increased prices.[458]

The success of sugarcane-based ethanol in reducing the price of fuel in Brazil may actually be helping to bring food prices lower.[459] Even UNEP Executive Director Achim Steiner is skeptical that higher food prices is simply the result of increased biofuels production:

> Global price fluctuations in the grain markets have always existed, although we are for some, like wheat, at historic highs at the moment. It would be somewhat premature to say that pasta costs more because there is biofuel grown in other parts of the world.[460]

6.5.2 Biofuels & Food in Kenya

One very important consideration when selecting potential feedstocks for biofuels production is whether current domestic production levels are sufficient to meet domestic demand for food and animal feed. Before considering whether the country should start producing biofuels from certain crops, it should evaluate whether doing so will put too much pressure on imports for food. It is likely to take at least a few years before the volume of production from jatropha, croton and castor are sufficient to begin large scale biodiesel production. However, some consumers are already eager to begin using locally produced biodiesel, and others would become interested if they begin to get accustomed to seeing it and hearing about it. The use of available feedstocks, such as coconut, cottonseed, rapeseed and sunflower, could be used to prepare the market for larger scale production that may take several years or longer to achieve.

Increasing imports of some foods due to increased biofuels production also may not be such a bad thing, especially if the domestically produced crop can fetch more value as a biofuels feedstock than a food crop and the local food market can meet demand at affordable prices. However, gender and health issues must be taken into account. Traditionally, women are not in direct control of household assets including income, regardless of which family members are doing the work. This can often lead to negative impacts on the family, especially if they are no longer growing food that is readily available for the family to consume. A recent brief from the International Food and Policy Research Institute (IFPRI) synthesizing research findings on gender and food security made the following findings:

- Targeting women in agricultural technology dissemination can have a greater impact alleviating poverty than targeting men.
- Equalizing agricultural inputs between men and women results in significant gains in agricultural productivity.
- Raising a woman's status dramatically improves the health, longevity and productivity of her children.[461]

Another reason for considering using an edible crop for biofuels is if the domestic cost of production for that crop cannot compete in global or regional markets. Kenyan sugarcane is a good example of this phenomenon, as the current ex-factory price of a tonne of sugar produced in Kenya is about twice the price of imported sugar from other COMESA countries (see Section 3.1 for more detailed information on the reasons for this).[462] Restrictive tariffs on imported sugar – a new four-year extension was recently approved by COMESA – have been the key tool used by the Kenyan government to prevent the sugar industry from the catastrophic consequences of having to compete in regional and global markets. However, such tactics are unsustainable, as the day is likely to come when Kenya can no longer convince its trading partners to accept these measures. Another effect of current sugar policy is that the average consumer is paying more in Kenya for food products containing Kenyan sugar than they otherwise would if more cheap sugar was imported.

As long as Kenyan sugar companies enjoy protective tariffs that enable them to charge about twice the price for imported sugar – Ksh 53,540 per tonne compared with Ksh 28,874 per tonne for imported sugar – then it makes more economic sense to continue producing sugar as the primary product, with the molasses by-product used for ethanol. However, at COMESA prices, Kenyan sugar companies could make more money foregoing sugar production in favor of full-scale ethanol. At the current production level of about 71 tonnes of sugar per hectare, about 7.1 tonnes of sugar and 710 liters of ethanol can be produced per hectare. At Kenyan prices of Ksh 53,540 per tonne of sugar and the current wholesale price of about Ksh 50 per liter of ethanol, one hectare of processed cane yields Ksh 415,634. By contrast, if the entire production went towards ethanol production, then about 4,970 liters of ethanol could be produced per hectare of cane for a total of about Ksh 248,500. At high protectionist prices for sugar, sugar and ethanol makes more sense than ethanol alone. However, if and when protective tariffs disappear, then ethanol alone could make more economic sense as the amount of income per hectare for the co-production of sugar and ethanol would drop to Ksh 240,505 compared with Ksh 248,500 for ethanol alone (see Table 14).

TABLE 14: COMPARISON OF INCOME FROM CO-PRODUCTION OF SUGAR & ETHANOL VS. INCOME FROM ETHANOL ONLY AT CURRENT DOMESTIC & IMPORTED SUGAR PRICES[463]

	DOMESTIC SUGAR PRICES (KSH 53,540 PER TONNE)		IMPORTED SUGAR PRICES (KSH 28,874 PER TONNE)	
PRODUCTS	SUGAR + ETHANOL	ETHANOL	SUGAR + ETHANOL	ETHANOL
1 Ha Cane	71 tonnes	71 tonnes	71 tonnes	71 tonnes
Sugar Produced	7.1 tonnes		7.1 tonnes	
Sugar Income	380,134		205,005	
Ethanol (Cane Juice)		4,970 liters		4,970 liters
Cane Juice Ethanol Income		248,500		248,500
Ethanol (Molasses)	710 liters		710 liters	
Molasses Ethanol Income	35,500		35,500	
TOTAL INCOME (KSH)	415,634	248,500	240,505	248,500

The Managing Director of Muhoroni Sugar agreed that "we should be making ethanol instead of sugar, if it's more efficient."[464] It is important to note, however, that ethanol sold for Ksh 50 per liter would not be competitive with petrol at current prices unless there was a roughly Ksh 10 per liter reduction in fuel taxes. However, the markets for potable alcohol and methylated spirit would support a pre-tax price of about Ksh 50.

Increased income from biofuels could also provide the economic incentives for farmers to invest in more efficient agricultural production methods. Irrigation could vastly improve yields for both food and biofuels crops, thus increasing farm incomes and food security. However, the initial capital investment in an irrigation system is too high for most small farmers. Opportunities for growing lucrative cash crops could change the equation, thus enabling significant breakthroughs in agricultural production throughout Kenya. Of course, the most vulnerable smallholders, who are struggling to survive on extremely modest plots, are probably not the best candidates for experimenting with cash crops in lieu of their food crops. The income generated from such small plantations would probably not suffice to buy enough food.

6.6 INTERNATIONAL SUSTAINABILITY STANDARDS PROTECTING THE POOR AND THE ENVIRONMENT

The environmental sustainability of biofuels is at the center of a global debate over whether they are as green as first advertised. The thirst for feedstock is increasing pressure on agricultural lands, which can have the dual effect of raising food prices and pushing agriculture into undeveloped areas, such as tropical rainforests and grasslands. The release of carbon from this large-scale land-use change can negate, or at least diminish, the climate benefits of burning biofuels instead of fossil fuels. However, these and other impacts can be minimized through the use of strict standards that guarantee the sustainability of the production process and maximize the positive environmental and development benefits the fuels have to offer. This section provides an overview of the design and implementation of sustainability standards that are specifically designed for biofuels.

Various standards have been developed by different organizations with similar features, although no unifying global standard has yet been adopted. The German Ministry for Cooperation and Development provides the following environmental, social, and economic criteria for ensuring that biofuels projects in developing countries are conducted sustainably:[465]

Environmental Criteria:

- Conservation of natural ecosystems (e.g., avoiding the clearing of old-growth forests for cultivation of energy crops);
- Preservation of at least 10% for biotope networks and protection corridors;
- Preservation of genetic diversity, including a minimum number of species, as well as structural diversity within energy crop plantations;
- Ensuring sufficient recirculation of nutrients into cultivated soils and woodlands;
- Avoiding the negative impacts of pesticide and fertilizer use, as well as air pollutants;
- Avoiding water pollution and critical irrigation needs in semi-dry and dry regions;
- Avoiding soil erosion and degradation.

Social/Economic Criteria:

- Giving priority to food security;
- Avoiding negative health impacts from energy crop cultivation;
- Integrating, rather than displacing, landless people in energy cropping systems;
- Processing energy crops locally;
- Preservation and development of jobs in rural areas;
- Equitable distribution of economic benefits of biofuels;
- Local, informed participation in decision-making.

UNEP has identified a number of areas for measuring the sustainability of bioenergy projects: energy services for the poor, agro-industrial development and job creation, health and gender, food security; government revenues; trade, foreign exchange balances, and energy security; biodiversity and natural resource management; and climate change.[466]

Laws promoting biofuels can also help to ensure sustainability. For example, the Energy Act passed in the United States in December of 2007 actually mandates that biofuels that are used to meet the renewable fuels standard reduce lifecycle GHG emissions by at least 20% compared with the petroleum based fuels they are replacing.[467] Importantly, the definition for "lifecycle GHG emissions" includes both direct and indirect emissions, such as those caused by land-use change:

> The term 'lifecycle greenhouse gas emissions' means the aggregate quantity of greenhouse gas emissions (including direct emissions and significant indirect emissions such as significant emissions from land use changes), as determined by the Administrator, related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution, from feedstock generation or extraction through the distribution and delivery and use of the finished fuel to the ultimate consumer, where the mass values for all greenhouse gases are adjusted to account for their relative global warming potential.[468]

The method of accounting indirect emissions from land-use change, especially if that change is occurring in another part of the world, is extremely important to ensuring that all emissions are captured and quantified.

The EU, which has set an ambitious goal of 5.75% biofuels by the end of 2010, is now considering banning biofuels derived from crops grown on recently cleared forests, wetlands or grasslands.[469] The European Commission is drafting legislation that would mandate a minimum of 35% savings in GHG emissions over fossil fuels, although the details for measuring life cycle emissions will have to be developed.[470] The general idea behind the new rules is to verify that biofuels meet the new standards by tracking all biofuels from origin to market. Individual countries, like Germany and Switzerland are beginning to design their own standards to ensure the sustainability of the biofuels that may qualify for subsidies and that will count towards their national consumption targets.[471] The Netherlands says that it will no longer subsidize the importation of palm oil, claiming that much of it is being grown on Asian plantations created from drained peat lands.[472]

Brazil has also taken the following steps to reduce the negative environmental impacts of the biofuels it produces:[473]

- Burning of crops before harvest has been prohibited in the state of Sao Paolo, which accounts for the largest share of Brazil's sugarcane production. This has resulted in significant environmental benefits including the reduction in air emissions and reduced risks of forest fires.
- Efforts have been made to expand sugarcane plantations towards degraded or poor sites and 'dirty fields' instead of forested areas.
- Improved land-use management intended to reduce the risk of competition for land between food production and biomass resources.

Notwithstanding these efforts, the rapid expansion of palm oil and soy plantations has had many adverse effects on tropical ecosystems throughout the world. From 1990 to 2002, global oil palm plantations increased by 43% to 10.7 million hectares, while soy plantations have increased by 26% to 77.1 million hectares during the same period.[474] Most of this growth has occurred primarily in Indonesia and Malaysia (for oil palm) and in Argentina, the United States and Brazil (for soy).

In Brazil, soy expansion is causing massive soil erosion and loss of biodiversity in the bush savannah. In the last decade alone, millions of hectares of Argentine Chaco and Brazilian Cerrado have been converted to soy plantations.[475] In Malaysia and Indonesia, clear-cutting of tropical rainforests for palm oil plantations is one of the major threats to biodiversity. In Sumatra and Borneo, the palm oil industry has set up 6.5 million hectares of palm oil plantations and it is estimated to be responsible for the destruction of 10 million hectares of rainforest.[476] These plantations pose one of the greatest threats to the survival of many species, including orangutans, which have lost at least half of their habitat between 1992 and 2003.[477] A group known as the Roundtable on Sustainable Palm Oil is trying to stem these losses and improve the image of palm based biodiesel by establishing its own standards for ensuring sustainability.[478] Although, like all similar efforts described above, the success of the program will depend on making tough decisions that could increase cost of production and prohibit the use of some areas currently being considered for exploitation.

As discussed in detail above, the competition between biofuels and food is a key determinant of whether biofuels are indeed sustainable. Several countries have adopted policies that reduce or eliminate this conflict. For instance, the Indian Biodiesel Programme is promoting the rehabilitation of degraded lands by use of jatropha, which it hopes will actually allow some of these lands to return to food production in the future.[479] Countries like Tanzania, with so much unused arable land (55 million hectares by one estimate) could become a lead player in producing sustainable biofuels crops.[480]

While most of the efforts towards more sustainable biofuels discussed above are laudable and much needed, many hurdles remain to their successful adoption and implementation. First, like other similar standards, the devil is in the details. For example, a standard requiring a 40% reduction in GHG emissions may sound promising, but the results depend on precisely how the measurements are calculated, especially emissions from indirect land-use change. Verification, compliance and enforcement are also keys to success. Without verifiable assurances that the standards are being adhered with regard to specific batches of biofuels delivered and consumed, then the standard itself is meaningless. Biofuels sustainability standards in Kenya and the rest of the world would do well to copy many of the mechanisms that have been developed for other similar processes, such as the Forest Stewardship Council's system for certifying wood products and the Gold Standard for verified GHG emissions reductions.

6.7 HIV/AIDS

HIV/AIDS is an epidemic that challenges all aspects of development. It depletes the agricultural labor pool due to premature death and re-occurring periods of illness. This can incapacitate agricultural production and rural livelihoods. HIV/AIDS affects agriculture both directly and indirectly at the household level, changing supplies of labor, assets, patterns of farming, and other activities.[481] The relationship between biofuels and HIV/AIDS is no different than that of agriculture in general. However, as biofuels feedstocks comprise the largest portion of production costs, the availability and reliability of farm labor is a very significant issue. Some of the most suitable geographic regions for biofuels production also happen to have some of the highest rates of HIV/AIDS in Kenya (see Table 15).

The impact of high rates of HIV in the community is exacerbated by the fact that those affected are disproportionately between the ages of 15 and 49, the heart of the labor force. The loss of such a significant block of the labor force leaves children and the elderly to tend to their farms, which limits their ability to expand beyond the growth of basic subsistence crops. FAO predicts that AIDS could kill up to 17% of Kenya's agricultural labor force over the next 10-20 years.[483] HIV/AIDS also has an indirect impact on labor by increasing the nutritional needs of those affected. Both direct and indirect impacts will have massive repercussions for the country's agricultural sector, including its ability to increase production of biofuels crops.

TABLE 15: HIV PREVALENCE IN SELECT AREAS, 2006[482]

Province	District	Prevalence	Individuals
Coast	Taita Taveta	4.1%	5,757
Coast	Kwale	3.4%	8,904
Coast	Kilifi	1.9%	6,050
Coast	Malindi	3.4%	5,816
Eastern	Isiolo	4.9%	2,999
Eastern	Mwingi	3.8%	5,459
Eastern	Kitui	3.9%	9,598
Eastern	Machakos	3.4%	14,512
Rift Valley	West Pokot	3.2%	5,134
Rift Valley	Kajiado	2.8%	7,976
Rift Valley	Laikipia	5%	11,199
Rift Valley	Baringo	3.3%	7,876
Rift Valley	Samburu	6.1%	4,492
Western	Bungoma	5.1%	41,561
Western	Busia	5.9%	8,428
Western	Butere/Mumias	5.7%	15,632
Western	Kakamega	5.7%	12,237
Western	Teso	5.3%	8,842
Nyanza	Bondo	7.8%	6,203
Nyanza	Gucha	2.8%	6,527
Nyanza	Homa Bay	21%	40,052
Nyanza	Kisii Central	3%	11,516
Nyanza	Kisii North	2.9%	6,999
Nyanza	Kuria	3.1%	3,107
Nyanza	Migori	8.2%	28,519
Nyanza	Siaya	7.6%	11,948
Nyanza	Suba	21%	22,863

The introduction of biofuels cash crops to agricultural communities affected by HIV/AIDS could have many positive impacts. For example, increased income from the sale of biofuel feedstocks as cash crop could reduce the need for woman to engage in unprotected sex in exchange for food and money. Increased wealth could also enable better access to education, testing and treatment. The intensity of the labor required to grow various feedstocks is an important factor in determining which crops may be most compatible with communities with high prevalence rates. Biofuels policies should be sensitive to this reality and recommend crops that the local labor force is most capable of growing.

7. ROADMAP & RECOMMENDATIONS

With the right combination of governmental support, private sector entrepreneurship and NGO outreach, Kenya could become the biofuels powerhouse of East Africa and beyond. Within five years, Kenya could be blending 10% ethanol (E10) and 2% biodiesel (B2), plus providing surplus production for stationary power and exports. Biofuels could revitalize rural areas, like Nyanza and Western Provinces, and provide an engine of growth throughout the country. Such a program could also provide a model for the sustainable production of biofuels to counter the increasingly unsustainable models being pursued by large industrialized countries.

The Ministry of Energy's recently released biodiesel strategy makes a number of prudent recommendations to promote and develop the biodiesel industry in Kenya. Several key aspects of the following roadmap incorporate these recommendations from the Ministry, including the production of certified seeds, the establishment and upgrading of blending facilities, myriad aspects of research and development, and the creation of pilot biodiesel production plants. The authors of this study appreciate the Ministry's input and support.

7.1 ENVISIONING E10 & B2 BY 2013

Achieving targets of E10 and B2 by 2013 would require the production of about 93 million liters of ethanol and 32 million liters of biodiesel. This would produce close to 1,000 new non-farm jobs at production plants, blending facilities and for transport. Thousands of new farm jobs would also be created throughout the country. At $90 per barrel of oil, Kenya would save about $71 million in foreign currency from flowing out of the country if it produced 10% of its petrol and 2% of its diesel from biofuels.

A combination of feedstocks would be required to achieve these targets. For ethanol, the logical choices based on availability of land, yield and economics are sugarcane and sweet sorghum. Over 35 million liters of ethanol could be produced if 15,000 hectares of suitable new land (land that is not currently being used to grow food or other cash crops) were cultivated with sugarcane and the cane was used exclusively for ethanol. Another 22.9 million liters could be produced if half of the cane currently being crushed at four of the worst performing sugar factories were diverted for ethanol and power production over the next five years.[484] As discussed in Section 6.5.2 above, the latest protective COMESA exemption is scheduled to expire in 2012. If these factories cannot compete with import tariffs in place, it is highly unlikely that they will be able to when they disappear. A shift to ethanol and power production could aid these factories, or the ones that take their place, to turn their balance sheets around.

About 24.7 million hectares of new land would be required for enough sweet sorghum to produce the remaining 34.6 million liters of ethanol to achieve an E10 blend by 2013. These are very ambitious targets because this is a new crop for Kenya. The Ministry of Agriculture, through its research and extension services, will be crucial to the success of a large campaign to begin sweet sorghum plantations. The two ethanol companies, who have already begun field trials, will also need to play a key role in contracting and organizing farmers to produce for them. Extension services provided by NGOs and research by ICRISAT will also be very important to success.

Cassava is not included due to the currently prohibitive cost of feedstock. Both sugarcane- and sweet sorghum-based ethanol will require support from the government in terms of tax incentives unless the price of petrol rises significantly. A reduction in the fuel tax on every liter of ethanol from Ksh 20 to Ksh 10 could provide the type of incentive to galvanize the private sector into production (every liter of petrol is currently taxed about Ksh 30, but due to the fact that ethanol has about two-thirds of the energy content of petrol, three liters of ethanol will be required to replace every liter of petrol, so the equivalent tax on ethanol would be about Ksh 20, or two-thirds of that on petrol). Such a tax reduction could be payed for by a slight Ksh 1.67 per liter increase in the fuel tax on petrol. This would result in the same revenues for the government and the same overall pump price for the consumer because each liter sold would contain 10% ethanol at the reduced tax rate and 90% petrol at the slightly increased rate.

The combination of feedstocks to produce about 32 million liters of biodiesel is more difficult to discern. We have selected a combination of edible and non-edible crops, as well as a mix of annual crops and trees that take longer to mature, but reap many other ecological and long-term economic benefits. Castor, which will begin producing at full yields (about 1 tonne per hectare) within nine months of planting, could contribute enough oil for about 10 million liters. This would require 22,300 hectares of new castor plantations throughout the country. Fortunately, this is equivalent to less than one-half of one percent of potentially suitable areas for castor that are outside of food and cash crop growing areas.

It is envisioned that jatropha, which is likely to play a larger role in the long-term, will not have matured to the point of full production by 2013. However, if we calculate a reduced production of 833 kilograms per hectare, which would be expected of trees that are about three to four years old, instead of 2,500 kilograms at full maturity, then enough oil could be produced from 17.9 thousand hectares for about 5 million liters of biodiesel. As these plantations mature fully, they should produce roughly two to three times the oil.

Seeds from existing croton trees could be used to supply enough oil for two million liters.[485] This would require coordination and linkages with farmers who are already growing croton around their farms, and others who are willing to collect croton seeds growing wild. However, at Ksh 15 per kilogram, nearly Ksh 90 million would flow into rural communities for seeds that have heretofore only had limited, if any, value. We also envision another five million liters being produced from newly planted croton trees that have not yet fully matured; hence, the larger acreage requirements for a smaller amount of biodiesel compared with that from existing trees. Similar to jatropha, when these new croton trees are fully matured (in about 10 years), they will reap even greater quantities of oil.

According to a recent study, the coconut subsector in Kenya is only being exploited by 25% of its capacity.[486] Considering current coconut production is about 61,000 tonnes, we estimate that improving the exploitation rate to about 35% would produce enough copra to make about 4 million liters of biodiesel. New coconut plantations on an additional 3,400 hectares, or about 10% of suitable lands for coconut that are not currently under food or cash crop production, would add an additional 2 million liters per year.

An additional one million liters could be produced from a mix of cottonseed, rapeseed and sunflower. Although these edible crops should be prioritized for food production, producing enough oil for one million liters should have a negligible effect on overall edible oil supplies. For example, about 2,550 tonnes of rapeseed would be required to produce one million liters of biodiesel. At two tonnes per hectare, about 1,275 hectares would be required, which would amount to less than one percent of suitable unfarmed land. In fact, hundreds of thousands of hectares of currently unfarmed land that would be suitable for these crops exist throughout the country. Thus, if biofuels can bring a tiny portion of this land into production, it is likely to have an overall positive impact on food supplies, especially as newly-planted croton and jatropha trees begin to mature and yield increasingly more oil over the next 10 years.

TABLE 16: FEEDSTOCKS, LAND & INCOME FROM E10 & B2 PRODUCTION BY 2013			
Ethanol (93 mly)	Ethanol (m. liters)	Total Land ('000 ha)	% Suitable New Land
Sugarcane (new)	35.5	15	16.5%
Sugarcane (existing)	22.9	9.8	n/a
Sweet Sorghum (new)	34.6	24.7	1%
Ethanol Totals	93	49.5	n/a
Biodiesel (32 mly)	Biodiesel (m. liters)	Total Land ('000 ha)	% Suitable New Land
Castor (new)	10	22.3	0.3%
Jatropha (new)	8	28.6	0.4%
Croton (existing)	2	2.4	n/a
Croton (new)	5	29.5	4.5%
Coconut (existing)	4	6.7	n/a
Coconut (new)	2	3.4	10%
Cotton/Rape/Sunflower	1	n/a	n/a
Biodiesel Totals	32	50.2	n/a

7.2 EMPOWERING SMALLHOLDER BIOFUELS COOPERATIVES

In addition to scaling up production for transport biofuels blends, another area of opportunity is the small-scale and dispersed production and consumption of biofuels for domestic and community uses like cooking, lighting and rural electrification. Kerosene, charcoal and firewood are the current fuels of choice for many rural people throughout Kenya. These fuels are expensive, unhealthy and lead to massive deforestation on already denuded land. The introduction of oilseed crops on private and communal land, along with the establishment of community biodiesel processing facilities, would provide a viable, healthier and more sustainable alternative to the current fuel supply. The development of community owned cooperatives to help establish plantations and to process and sell the biodiesel and associated co-products could empower smallholders to become more energy independent, improve their local environment and to provide much-needed income and jobs to their communities.

7.3 DEVELOPING THE VALUE CHAIN

Various models of production will be needed to increase biofuels production in Kenya. Support from different stakeholders will be required to develop the value chain. For example, vast amounts of sweet sorghum, a crop that is barely grown in Kenya, will be required to significantly increase ethanol production. Ethanol companies are ready to support outgrowers who begin growing sorghum and farmers are interested in new crops as long as they are confident in the market for them. Agronomic expertise and extension services are the missing links to making sweet sorghum a reality in Kenya. ICRISAT, which has been developing sweet sorghum varieties for over a decade, and has a mandate to expand its sorghum work in Kenya, could be extremely helpful in making high yielding seeds available and in training extension workers in the nuances of growing the crop successfully. Education and outreach is key, but it must work its way down to the farm level.

The Ministry of Agriculture, along with the Ministry of Environment and Natural Resources and others, should take the lead coordinating efforts to expand agricultural production of biofuels feedstocks. KARI, KEFRI and KEPHIS could also play important roles in training farmers, providing extension services, and testing, certifying and distributing seeds. As discussed above in Section 3.2, myriad private businesses, NGOs and governmental institutions are beginning to plant jatropha and the Ministry of Energy's National Biodiesel Committee has proposed a strategy that focuses almost entirely on jatropha. Comprehensive provenance and silvicultural trials must be launched for jatropha and other new biofuels crops before large-scale production can begin. KEFRI is one of the few that has begun these important tests. Others, such as ICRAF and DEG, are planning similar trials. These and other similar efforts are key to achieving the level of production from these feedstocks that some are already counting on.

As discussed at length above, improvements could be made in sugarcane yields with the introduction of irrigation and fast growing varieties. The Kenya Sugar Board and the Sugarcane Growers Association could dramatically improve the competitiveness of the Kenyan sugar industry, as well as provide more feedstock for ethanol, with a program designed for improving yields. Investments should also me made in improving the road infrastructure in Western Kenya to accommodate the more efficient transport of feedstocks from farm to factory.

Another important component of expanded ethanol production would be to restructure the flow of feedstocks. Ethanol is currently produced at plants that are separate from the sugar factories that supply them with molasses. As pointed out in Section 4.4, this leads to unnecessary duplication of administrative costs and, perhaps more importantly, prevents the ethanol producers from using bagasse to reduce their considerable power costs. Ethanol from the limited supplies of molasses should be produced at the same facility as the cane is crushed, as is being planned by Mumias, to harness the synergies between the different products of sugarcane. The two existing ethanol plants should focus more of their attention on the production and use of sweet sorghum (as they are beginning to do) and make investments to utilize the bagasse from the sorghum stalk for power generation.

Unlike ethanol, which has a relatively high capital cost, biodiesel can be produced at different scales, from the farm to a large commercial plant. Biodiesel will also likely depend on a wider variety of feedstocks than ethanol. Large commercial farms with the capacity to grow their own feedstock, such as castor, rapeseed and sunflower, could integrate biodiesel production into their operations or outsource the processing to a dedicated biodiesel producer. Farmers could also aggregate their efforts into a cooperative business model. If production is high enough, farms may decide to increase the blend or transition some machines and vehicles over to B100.

At larger commercial scales of production, biodiesel manufacturers will have to secure sufficient feedstocks in much the same way that ethanol producers and other cash crop processors currently do. Maintaining a central plantation that is either owned outright or contracted for a number of years would provide an important hedge against the volatility of the market for oilseeds. This is especially true for new feedstocks like croton and jatropha, where growing costs and yields are not well established. The cost of oilseeds from a central plantation will likely be lower than those purchased from outgrowers, although the operational management much more demanding.

Another important issue in the biodiesel value chain is the location of the plant vis-à-vis the source of the feedstock and the market for the products (including co-products like glycerin). Given the state of the infrastructure in Kenya and the concomitant high cost of transport, it makes sense to locate biodiesel plants as close to the feedstock as possible, especially because moving relatively bulky seed is more expensive than transporting finished biodiesel. The availability of processing technology that can be scaled up can also help to maintain a production capacity that closely matches the quantities of feedstock available in the immediate vicinity. KIRDI, which is experimenting with biodiesel processing equipment, should be supported in developing cost-effective and efficient biodiesel reactors that can be distributed to different key processing hubs throughout the country.

The market for stationary power instead of transport could alter the business model and the scale of production. The use of higher blends of biodiesel, neat biodiesel (B100), or possibly even straight vegetable oil (SVO), in generators is an attractive alternative to blending biodiesel into the national petroleum distribution network. Individual companies with large diesel demands, like Safaricom and Celltel, could contract farmers directly and produce biodiesel themselves, or hire an outside firm to do the same. Testing the compatibility of diesel generators with different blends of biodiesel and SVO is an important first step in the process and could be assisted by KIRDI. Safari companies with large diesel fleets and the need to power remote lodges might also find this model attractive.

7.4 DESIGNING AN APPROPRIATE REGULATORY & FISCAL FRAMEWORK

A national strategy on biofuels must establish the policy framework that first lays out specified goals for biofuels in Kenya, such as an E10 mandate by 2013. Once the goals are established, then the regulatory and fiscal regime governing biofuels must be updated to ensure the goals are achieved. The primary objective should be the establishment of a lead institution that has the power to coordinate disparate government agencies and enable the government to speak with a unified voice on biofuels.

The Energy Act provides a mandate to the Ministry of Energy to take the lead on defining a national biofuels policy, which it has already begun to do through the formation of the NBC. The Energy Act also empowers the newly formed ERC to regulate biofuels in addition to more traditional sources of energy. The Ministries of Agriculture and Environment & Natural Resources are essential to the sustainable production of biofuels feedstocks and must continue to be involved at the highest levels of government. All other potentially affected government agencies, representatives from the business community, NGOs and development partners should also be consulted thoroughly. For example, farmers and biofuels project developers should have at least as much of a voice as NGOs and petroleum interests currently do within the NBC. A similar committee should be established to chart the course on ethanol.

Both committees should be provided explicit guidance from the Ministries of Energy, Agriculture and Environment & Natural Resources on the expected outputs and the structure of the recommendations that they are to produce. A national goal for ethanol and biodiesel, such as E10 and B2, should form the basis of the policy that is developed. Specific crops should be selected as primary feedstocks based on detailed and quantitative economic, agronomic, social and environmental criteria and analysis. A comprehensive programmatic EIA, including full public notice and opportunity to comment, must be conducted before the government formally adopts the new policy.

The vast majority of those interviewed for this study, including the Kenya Sugar Board, Kenya Sugarcane Growers Association and PIEA, agree that the logical lead agency should reside within the Ministry of Energy. However, because biofuels implicate many sectors that fall under the mandates of a number of government bodies outside of the Ministry of Energy, it makes sense to establish a high-level task force of the various interested ministries, including Agriculture, Environment & Natural Resources, Lands, Water and perhaps others. The most sensible place to locate the National Biofuels Programme is where it currently resides within the within the Renewable Energy Department, or alternatively, in a newly-created National Biofuels Authority within the Ministry of Energy.

Regulatory and fiscal reforms should then be crafted to achieve the desired objectives and to ensure consumers, workers, communities and the environment are not only protected, but benefit from the new industry. There is widespread support for the use of governmental policies to promote biofuels, even from the head of the Petroleum Institute of East Africa (PIEA), George Wachira, who said that the government's "responsibility to uplift the poor" could be realized through support programs and/or subsidies for farmers growing biofuels crops.[487]

The following policies should be considered as part of this process:

<u>Blending Mandate or Goals</u> – A national goal of the amount of ethanol and biodiesel that should or must be blended by a certain date or dates. Many stakeholders, especially those in the sugar and ethanol industry, agree that a blending law is a prerequisite to a successful biofuels program. One official expressed doubt that such an objective was politically possible given the lack of interest from the "oil dealing monopoly." One sugar executive explained that biofuels blending is comparable to allowing independent power producers to sell electricity into the power grid. Just as it makes no sense to restrict domestic electricity production from benefiting the nation at a time of energy shortages, it also makes no sense to limit the blending of domestically grown fuels.

As described above, E10 and B2 could serve as reasonable preliminary goals. Importantly, PIEA agrees with the idea of government-mandated standards for blending, but thinks they should be limited to no more than 10%. Until there is enough supply of biofuels to meet a national blending mandate, PIEA suggests that the standard be applied only to select industries or regions. For example, it does not make sense to initiate an E10 mandate in Nairobi or Mombasa if there is only enough ethanol being produced to supply 10% of Kisumu with ethanol. One way of achieving a blending mandate is through a renewable fuel standard (RFS) that requires refiners and petroleum distributors to meet blending mandates or, if they cannot do so, to purchase credits from those distributors who have exceeded their own requirements. This system has been used in the United States since 2005, but would require a good deal of government oversight and coordination, which may not be feasible in Kenya. Germany has used a tax incentive to promote biodiesel production, although is phasing that out in favor of a mandatory blending standard. Under the new arrangement, petroleum distributors will be required to blend a certain percentage of biodiesel, or pay a fine for each liter they fall short.

Fuel Quality & Blending Standards – KEBS must establish or revise fuel quality and blending standards for both ethanol and biodiesel based on the blending mandate and existing standards in Kenya and internationally.

Priority Feedstock Crops – Based on economic, agronomic, social and environmental criteria and analysis, optimal crops should be selected for biofuels. For ethanol, sugarcane and sweet sorghum seem to make the most sense; and for biodiesel, castor, coconut, croton, jatropha, rapeseed and sunflower should be considered. KEPHIS, KARI and/or KEFRI should be responsible for identifying, testing and certifying high yielding seeds that are adapted to the different agro-ecological zones in which they might be grown.

Licensing – Licensing requirements along the entire biofuels value chain should be reviewed and revised where necessary to protect consumers, workers, communities and the environment. PIEA has concerns about "rogue" biofuels producers who could sell biofuels of varying degrees of quality and undercut the established fuel companies. As explained below, the requirements of production and blending licenses that already exist in the law, should be sufficient to eliminate the threat of unregulated sales of biofuels in much the same way unregulated petroleum are quashed. If possible, the licensing requirements under the various laws and regulations discussed above should be integrated, thus eliminating unnecessary and onerous regulation. The following should be considered:

- Production License – Commercial producers should be licensed under the Energy Act by the Energy Regulatory Commission to ensure compliance with KEBS fuel quality standards. The license requirement under the Factories Act should be integrated to avoid unnecessary duplication. Licenses should not be required for home and farm production and consumption of biofuels given the fact that consumers do not face a risk of being harmed from biofuels that are not being sold.
- Blending License – Petroleum distributors blending biofuels should be licensed under the existing requirements of the Petroleum Act in accordance with the blending standards adopted by KEBS.
- Transport & Handling Licenses – Various health and safety requirements for the transport and handling of petroleum products exist under the Energy and Petroleum Acts. These should be updated for the specific chemical characteristics of ethanol and biodiesel.
- Occupational Safety and Health Services Registration – Biofuels producers likely have to register with the Director of Occupational Safety and Health Services to ensure worker safety.
- Environmental Licenses – A license may be required under either the Pharmacy and Poisons Act or the Use of Poisonous Substances Act, or both, for the import, sale and use of hazardous chemicals, such as methanol or hydrochloric acid. Water and air quality standards must be complied with and an EIAL must be obtained from NEMA prior to commencement of production. NEMA should streamline the environmental licensing requirements to ensure compliance with various water, air and waste disposal standards, as well as the assessment of environmental impacts.
- Fertilizer & Foodstuffs License – A license may be required for the production of fertilizers and animal feed from the byproducts of biofuels production.

Fiscal Policies, Fees & Incentives – Tax incentives are an attractive alternative or complement to regulatory mandates promoting biofuels. Opportunities to promote biofuels exist in the following categories:

- Fuel Taxes – As discussed in Sections 4.2 and 5.9 fuel taxes can make or break the feasibility of biofuels. Some combination of tax exemptions or subsidies will almost certainly be required to promote the industry. If fuel taxes were to apply fully to ethanol, sugarcane-based ethanol would be marginally feasible, but both sweet sorghum- and cassava-based ethanol would be prohibitively expensive to produce for fuel. No biodiesel crop would be economically feasible without a reduction in fuel taxes or some other subsidy.

  If fuel taxes do apply to biofuels, they must at least be proportional to the energy content of the fuel. For example, ethanol, which has about two-thirds the energy of petrol, should have no more than two-thirds the tax that an equivalent volume of petrol would have. (The economic feasibility analysis in Section 4.2 discusses this issue in more depth.) Additionally, farm-scale production, where the fuel being produced is not being sold, should also be exempt from fuel taxes. As Section 4.2 demonstrates, the cost of production of biodiesel at the farm-scale would be prohibitively expensive if taxed fully. If fuel taxes are determined to apply to biofuels, then another idea is to fix the tax based on the scale of production, so small producers are able to compete with larger ones.

  PIEA believes that tax reductions or exemptions on certain fuels are satisfactory as long as the social and economic benefits to the country are clear. For example, the reason why the tax on kerosene is less than that on diesel, which in turn is less than that on petrol, is the need to enable poor Kenyans to better afford cooking and lighting oil. The purpose is to alleviate the burdens on the customers of those fuels. A similar reduction or elimination of the fuel tax on biofuels would enable Kenyan farmers and entrepreneurs the chance to reap some of the economic benefits of petroleum dollars that are now flowing overseas.

  Importantly, government revenues can be protected even as taxes are reduced or eliminated for biofuels by accounting for the increased revenue from new biofuels businesses and/or marginally increasing the existing fuel tax on petroleum products to make up for exempted biofuels. For example, a Ksh 0.42 per liter increase in the roughly Ksh 20.5 fuel tax on diesel would cover the loss of revenue if biodiesel were completely exempted from fuel taxes up to a national B2 blend. A similar increase of Ksh 3.28 on each liter of petrol would offset the loss of revenue from 93 million liter of ethanol required for an E10 blend. Neither consumers nor the government would be affected by the change, although biodiesel production would become a much more attractive investment for project developers and farmers alike.
- Environmental Impact Assessment License Fee – NEMA imposes a fee of 0.1% of the total project cost to obtain an EIAL. The law does not distinguish between either the type or scale of the project when assessing the fee. Environmentally friendly projects, such as biofuels reforestation ones, should not be treated equally to environmentally-detrimental ones, such as industrial manufacturing involving toxic materials. Reducing or eliminating this fee for biofuels projects should be considered.
- Equipment Import Taxes – Both CIF and excise taxes apply to machinery and equipment that would be necessary for biofuels production in Kenya. Taken together, these taxes can

increase the cost of equipment by 20% or more. The 2007 Finance Bill considered exempting biofuels equipment, although ultimately abandoned the idea due to concerns over identifying items that could only be used for biofuels. This initiative should be revisited.

- Seed Taxes – Seeds are currently taxed upon import and with a VAT. Removing at least a portion of these taxes would promote the growing of biofuels crops and reduce the cost of feedstock.

7.5 ENSURING ENVIRONMENTAL SUSTAINABILITY

If strict sustainability standards were adhered to, the Kenyan biofuels industry could be one of the most environmentally sound in the world. The use of various crops that can grow in semi-arid areas combined with sophisticated mapping to minimize conflicts with existing food production areas, would enable large quantities of biofuels feedstocks to be produced in addition to, rather than at the expense of, existing food production. Increased farm income and the development of new agricultural areas would enrich rural areas with employment and new sources of income. This influx of capital could then be used to invest in irrigation and better management practices, which would in turn increase yields of all crops, including those grown for food.

The reliance on tree crops like croton and jatropha could be combined with reforestation and afforestation projects, as well as efforts to reclaim marginalized lands. The GHG benefits of relying on tree crops and growing feedstocks in semi-arid areas would also be greater than mimicking the biofuels production model used in most of the industrialized world, whereby staple food crops grown in arable lands or recently cleared rainforests are shipped around the world before they are converted to biofuels.

Many environmental and socio-economic risks of a large biofuels industry in Kenya would remain. For example, unchecked development and misguided subsidies could encourage massive monoculture plantations on arable lands that would reduce potential employment and local income benefits and threaten greater environmental harm than existing land uses. Different models of production that have been developed for other cash crops, such as coffee, tea, sugarcane and pyrethrum should be borrowed from where applicable. For example, the combination of nuclear plantations and outgrowers should be encouraged.

Another potential threat is increased air and water pollution from unregulated biofuels production facilities. It is essential that any regulatory review of existing air and water quality standards look closely at the emissions and effluents that could be released by such plants and implement strict rules for minimizing or eliminating adverse impacts. As is discussed in the regulatory analysis in Section 5, air and water quality standards, or the laws authorizing them, already exist. The key to a sustainable biofuels industry must include the development of reasonable requirements to protect air and water resources and an effective program of enforcement to ensure compliance.

7.6 PILOT PROJECTS & AREAS OF FURTHER RESEARCH

There are many research projects that would greatly help the development of a biofuels industry in Kenya, including in the areas of agronomy, fuel and blending standards, production technology and processing, markets and consumer use. As discussed above, provenance and silvicultural trials for croton, jatropha and perhaps other potential biofuels crops should be better coordinated and fully funded. Private farmers and agricultural companies stand ready to participate in these trials, offering land and labor in exchange for premium planting materials and scientifically rigorous analysis and advice. Pilot projects that demonstrate the viability of community based biofuels production clusters, such as the one in Mpeketoni and the project involving the Aga Khan Foundation's Coastal Rural Support Programme, should also be encouraged and supported. KARI, KEFRI, ICRAF and ICRISAT should coordinate their research into biofuels and develop a program of work that addresses some of these needs.

Research into fuel quality and compatibility with different applications is also important, especially given the varied feedstocks that may be used to produce biofuels in Kenya. KEBS should work closely with KIRDI and the private sector to carry out tests and to determine appropriate standards for fuel quality and blending. KIRDI could also provide assistance to the private sector in evaluating different biofuels processing technologies and developing the local capacity to produce and maintain such equipment.

Finally, research should be conducted into consumer behaviors and attitudes pertaining to biofuels, with the goal of developing public education campaigns to sensitize people to the benefits of producing and using biofuels in Kenya.

7.7 Informing & Creating Awareness Amongst Decision Makers & The Public

A coordinated biofuels policy and associated legislation or regulations are important, however, it is equally important that the government agencies charged with implementing the biofuels programs have strong institutional capacity to follow through. Public education and participation in the process is also very important as any comprehensive biofuels program will have broad impacts on land use, agriculture and energy throughout Kenya.

Workshops, trainings and public events should be held to inform and capacitate various stakeholders and the general public. In particular, special events should be organized for parliamentarians and other government officials, possibly through existing mechanisms such as the GTZ-sponsored Parliamentarian Network on Renewable Energy and Climate Change (PANERECC). The success of public education campaigns on public health issues, such as HIV/AIDS, could also serve as a model for public outreach on biofuels.

7.8 Conclusion

Kenya stands on the cusp of a tremendous opportunity to fuel economic growth with sustainably produced biofuels. A favorable climate combined with decades of experience as a producer of world-class agricultural products like coffee and tea makes Kenya well suited to the challenge of developing a new biofuels industry. But to reap the many benefits biofuels could offer Kenya, a focused effort will be required to develop and implement a framework that encourages investment, while also protecting consumers, communities and the environment.

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[284] The following notes correspond to the footnotes in the table:

[+] The type of sorghum currently grown in Kenya does not contain a sweet stalk, as it is primarily grown as a food grain. The sweet sorghum varieties that can be used for ethanol can produce much higher yields, according to studies conducted by ICRISAT in India and Thailand, and can also produce grain for food and sugar for ethanol simultaneously. The four "potential" scenarios use production numbers for sweet sorghum varieties being developed by ICRISAT in other parts of the semi-arid tropics that are compatible with agro-ecological zones in Kenya.

[++] Croton and jatropha are just beginning to be planted for commercial purposes, so no market for seeds or oil has yet been established.

[+++] Only negligible quantities of rapeseed are grown in Kenya, mostly near Laikipia, Nakuru, and Eldoret.

[a] Regarding Cassava, information on consumption and trade of cassava was unavailable to distinguish how much, if any, surplus of current production could be available for ethanol without competing with food. Average yields for 2006 from Kenya Ministry of Agriculture, *Economic Review of Agriculture: 2007*, 23.

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[g] At roughly 3,000 nuts per tonne of coconut and about 6,000 nuts per tonne of copra, approximately 2 tonnes of nuts are required for every tonne of copra. With a 65% oil content and 1,120 liters of oil per tonne, each tonne of copra will produce about 728 liters of biodiesel. Beatrice Gambo, personal communication; District Agricultural Officer, Kilifi, personal communication.

[h] At roughly 13% oil content and 1,120 liters of oil per tonne of seed, each tonne of cottonseeds will yield about 146 liters of biodiesel. Andrew Okello, personal communication.

[i] With a 37% oil yield and 1,120 liters of oil per tonne of oil, each tonne of sunflower seeds will yield about 414 liters of biodiesel. Evergreen Biofuels.

[j] With a 30% oil yield and 1,120 liters of oil per tonne of oil, each tonne of croton seeds will yield about 336 liters of biodiesel. Thijssen.

[k] With a 30% oil yield and 1,120 liters of oil per tonne of oil, each tonne of jatropha seeds will yield about 336 liters of biodiesel. K.S. Pant et al., "Seed Oil Content Variation in Jatropha curcas in Different Altitudinal Ranges and Site Conditions in H.P. India," LYONIA, vol. 11(2) (December, 2006), <http://www.lyonia.org/downloadPDF.php?pdfID=390.487.1http://www.lyonia.org/downloadPDF.php?pdfID=390.487.1> (3 January 2008).

[l] With a 35% oil yield and 1,120 liters of oil per tonne of oil, each tonne of rapeseed will yield about 392 liters of biodiesel.

[285] The following notes correspond to the footnotes in the table:

[+] The type of sorghum currently grown in Kenya does not contain a sweet stalk, as it is primarily grown as a food grain. The sweet sorghum varieties that can be used for ethanol can produce much higher yields, according to studies conducted by ICRISAT in India and Thailand, and can also produce grain for food and sugar for ethanol simultaneously. The four "potential" scenarios use production numbers for sweet sorghum varieties being developed by ICRISAT in other parts of the semi-arid tropics that are compatible with agro-ecological zones in Kenya.

[a] Average yields for 2006 from Kenya Ministry of Agriculture, *Economic Review of Agriculture: 2007*, (2008) 23.

[b] The reported yield for sugarcane in 2006 was 70.89 tonnes per hectare. However, the amount of sugarcane produced is not a factor of yield times acreage because of the fact that Kenyan varieties typically take 18-24 months to mature. In 2006, 147,730 hectares were planted with sugarcane and 4,932,839 tonnes were harvested, meaning that on average each hectare under production produced 33.39 tonnes. Irrigated sugarcane varieties can mature much faster. The sugarcane yield is the same for non-food and food competing; the conversion factor is what differs depending on whether sugar and molasses is produced, or just ethanol. Kenya Sugar Board, *Year Book of Sugar Statistics: 2006*, (2007).

[c] 30-40 tonnes of sweet stalk estimated over two harvests per year per hectare without irrigation. Bekele Shiferaw, ICRISAT, personal communication.

[d] 2005 data from FAOSTAT. Data for coconuts and cotton is from the Kenya Ministry of Agriculture, *Economic Review of Agriculture: 2007*, 32.

[e] Assuming 25 kg/tree, and 100 trees per hectare at 10x10 spacing equals 2,500 kg. Thijssen.

[f] Assuming 1.5 kg/tree after 7 years of growing, times 1,666 trees per hectare with 2x3m spacing. Tewari, 49.

[g] Assuming 1.5-2.5 tonnes per hectare unirrigated. KARI, Njoro Field Office.

[h] From GIS mapping conducted by ICRAF based on agronomic parameters for each feedstock, as well as data sets showing where food crops are currently being grown in Kenya.

[i] 1 tonne of fresh cassava will yield between 160-180 liters of ethanol. Shelty, 673.

[j] About 10 liters of ethanol can be produced per tonne of sugarcane if the ethanol is derived from the molasses byproduct of sugar production. About 70 liters per tonne can be produced if the entire production is dedicated towards ethanol production. Jack Opondo, Assistant Production Manager, Mumias Sugar Company, personal communication, 5 December 2007.

[k] Assuming 40 liters per tonne of sweet stalk. Reddy.

[l] With a 40% oil yield and 1,120 liters of oil per tonne of oil, each tonne of castor beans will yield about 448 liters of biodiesel. "Purple-Coloured Castor (Ricinus communis L.) – A Rare Multiple Resistant Morphotype," CURRENT SCIENCE, vol. 88, no. 2 (25 January 2005): 215, <http://www.ias.ac.in/currsci/jan252005/215.pdf> (3 January 2008).

[m] At roughly 3,000 nuts per tonne of coconut and about 6,000 nuts per tonne of copra, approximately 2 tonnes of nuts are required for every tonne of copra. With a 65% oil content and 1,120 liters of oil per tonne, each tonne of copra will produce about 728 liters of biodiesel. Beatrice Gambo, personal communication; District Agricultural Officer, Kilifi, personal communication.

[n] At roughly 13% oil content and 1,120 liters of oil per tonne of seed, each tonne of cottonseeds will yield about 146 liters of biodiesel. Andrew Okello, personal communication.

[o] With a 37% oil yield and 1,120 liters of oil per tonne of oil, each tonne of sunflower seeds will yield about 414 liters of biodiesel. Evergreen Biofuels.

[p] With a 30% oil yield and 1,120 liters of oil per tonne of oil, each tonne of croton seeds will yield about 336 liters of biodiesel. Thijssen.

[q] With a 30% oil yield and 1,120 liters of oil per tonne of oil, each tonne of jatropha seeds will yield about 336 liters of biodiesel. K.S. Pant.

[r] With a 35% oil yield and 1,120 liters of oil per tonne of oil, each tonne of rapeseed will yield about 392 liters of biodiesel.

[286] The following notes correspond to the footnotes in the table:

[+] The type of sorghum currently grown in Kenya does not contain a sweet stalk, as it is primarily grown as a food grain. The sweet sorghum varieties that can be used for ethanol can produce much higher yields, according to studies conducted by ICRISAT in India and Thailand, and can also produce grain for food and sugar for ethanol simultaneously. The four "potential" scenarios use production numbers for sweet sorghum varieties being developed by ICRISAT in other parts of the semi-arid tropics that are compatible with agro-ecological zones in Kenya.

[a] U.N. FAO, *The World Cassava Economy: Facts, Trends & Outlook*, Chapter 3.1, <http://www.fao.org/docrep/009/x4007e/X4007E04.htm#ch3.1> (3 January 2008).

[b] Based on the average yield per hectare of sugarcane in Brazil. F.O. Licht, *Ethanol Production Costs,* 77.

[c] Assuming 2 crops per year at 35 tonnes per crop. Reddy.

[d] Assuming a yield of 1.2 tonnes per hectare. Purdue University, Center for New Crops and Plants Database, "Ricinus Communis L," from James A. Duke, *Handbook of Energy Crops* (1982),

<http://www.hort.purdue.edu/newcrop/duke_energy/Ricinus_communis.html#Yields%20and%20Economics> (5 December 2007)

[e] Assuming 10,000 nuts per hectare with 100 nuts per tree and 100 trees per hectare. About 3 nuts per kilogram equals 3.33 tonnes per hectare. ABD-DANIDA, 10.

[f] Assuming 3 tonnes per hectare irrigated. Kenya Cotton Development Secretariat; Kenya Ministry of Agriculture, *Annual Report: 2006*.

[g] Assuming 3 tonnes irrigated. Kenya Ministry of Agriculture, *Technical Handbook for Field Crops*; Evergreen Biofuels.

[h] 25 kg/tree, and 100 trees per hectare at 10x10 spacing equals 2,500 kilograms. Thijssen.

[i] Irrigated estimate of 2.5 kilograms per tree after 7 years, times 1,666 trees per hectare with 2x3m spacing. Tewari, 49.

[j] Assuming 3-4 tonnes per hectare irrigated. Martin Dyer, personal communication; KARI, Njoro Field Office.

[k] 1 tonne of fresh cassava will yield between 160-180 liters of ethanol. Shelty, 673.

[l] About 10 liters of ethanol can be produced per tonne of sugarcane if the ethanol is derived from the molasses byproduct of sugar production. About 70 liters per tonne can be produced if the entire production is dedicated towards ethanol production. Jack Opondo, Assistant Production Manager, Mumias Sugar Company, personal communication, 5 December 2007.

[m] Assuming 40 liters per tonne of sweet stalk. Reddy.

[n] With a 40% oil yield and 1,120 liters of oil per tonne of oil, each tonne of castor beans will yield about 448 liters of biodiesel. "Purple-Coloured Castor (Ricinus communis L.) – A Rare Multiple Resistant Morphotype," CURRENT SCIENCE, vol. 88, no. 2 (25 January 2005): 215, <http://www.ias.ac.in/currsci/jan252005/215.pdf> (3 January 2008).

[o] At roughly 3,000 nuts per tonne of coconut and about 6,000 nuts per tonne of copra, approximately 2 tonnes of nuts are required for every tonne of copra. With a 65% oil content and 1,120 liters of oil per tonne, each tonne of copra will produce about 728 liters of biodiesel. Beatrice Gambo, personal communication; District Agricultural Officer, Kilifi, personal communication.

[p] At roughly 13% oil content and 1,120 liters of oil per tonne of seed, each tonne of cottonseeds will yield about 146 liters of biodiesel. Andrew Okello, personal communication.

[q] With a 37% oil yield and 1,120 liters of oil per tonne of oil, each tonne of sunflower seeds will yield about 414 liters of biodiesel. Evergreen Biofuels.

[r] With a 30% oil yield and 1,120 liters of oil per tonne of oil, each tonne of croton seeds will yield about 336 liters of biodiesel. Thijssen.

[s] With a 30% oil yield and 1,120 liters of oil per tonne of oil, each tonne of jatropha seeds will yield about 336 liters of biodiesel. K.S. Pant.

[t] With a 35% oil yield and 1,120 liters of oil per tonne of oil, each tonne of rapeseed will yield about 392 liters of biodiesel.

[u] From GIS mapping conducted by ICRAF based on agronomic parameters for each feedstock, as well as data sets showing where food crops are currently being grown in Kenya.

[287] Kenya Energy Regulatory Commission, "Current Electricity Tariffs," <http://www.erb.go.ke/tariffs_structure.htm> (5 January 2008).

[288] Anton Van Tonder, Plant Director, Spectre International, personal communication, 12 February 2008; Alan Mugera Andagalu, Marketing Officer, Agro-Chemical, personal communication 12 February 2008.

[289] Anton Van Tonder, Plant Director, Spectre International, personal communication, 12 February 2008; Alan Mugera Andagalu, Marketing Officer, Agro-Chemical, personal communication 12 February 2008.

[290] Overall production costs are calculated from data contained in F.O Licht, *Ethanol Production Costs,* 101-113. The capital, or fixed costs, are taken directly from the study, in cases where the cost has been broken down to a per liter amount. In cases where the capital cost is presented as an overall amount, like $10 million for an ethanol plant with a 20 million liter capacity, then the per liter cost is calculated based on a 50% debt (10 year loan at 10% annual interest), 50% equity financing (15% return on investment).

[291] F.O Licht, *Ethanol Production Costs,* 101-113.

[292] Anton Van Tonder, Plant Manager, Spectre International, personal communication, 12 February 2008.

[293] Jack Opondo, Assistant Production Manager, Mumias Sugar Company, personal communication, 5 December 2007.

[294] Overall production costs are calculated from data contained in F.O Licht, *Ethanol Production Costs,* 101-113. The capital, or fixed costs, are taken directly from the study, in cases where the cost has been broken down to a per liter amount. In cases where the capital cost is presented as an overall amount, like $10 million for an ethanol plant with a 20

million liter capacity, then the per liter cost is calculated based on a 50% debt (10 year loan at 10% annual interest), 50% equity financing (15% return on investment).
[295] F.O Licht, *Ethanol Production Costs,* 110-111.
[296] F.O Licht, *Ethanol Production Costs,* 110-111.
[297] Ministry of Agriculture, *Economic Review of Agriculture: 2007*, (2008) 23.
[298] The Kilifi and Bungoma District Guidelines place the per hectare cost of production at Ksh 31,700 and, according to FAOSTAT, the current yield for cassava in Kenya is 9.6 tonnes per year, which means the cost of production is Ksh 3,302 per tonne.
[299] Anton Van Tonder, Plant Director, Spectre International, personal communication, 12 February 2008; Alan Mugera Andagalu, Marketing Officer, Agro-Chemical, personal communication, 12 February 2008.
[300] Croton may be used as chicken feed, however, because there is no large-scale market for the product, we calculate the value of the seedcake as biogas rather than animal feed.
[301] The following notes explain how we calculated current cost of the different oilseed feedstocks and seedcake revenue. For inedible crops, like castor and jatropha, biogas is calculated at 150 cubic meters, or 113 kilograms, of liquid petroleum gas equivalent per tonne of seedcake and Ksh 40 per kilogram. Seedcake revenue for both biogas and animal feed is also a factor of oil yield, where low yielding seeds, like cotton, will produce more seedcake per tonne, compared with high yielding oilseeds, like coconut.

[a] FAOSTAT lists the import price for castor oil in 2005 at $1,247 per tonne, which would be roughly Ksh 72.4 per liter, much more than the Ksh 38.6 included here. However, FAOSTAT lists the price of castor beans in Kenya in 2005 at Ksh 11,727 per tonne and personal communication with farmers provided a price of Ksh 12,000-15,000 per tonne of seed, so we have used an estimated price of Ksh 20,000 per tonne of seed, which may be too low.

[b] This is the price of copra, not coconuts. The Ministry of Agriculture puts the cost of one tonne of nuts at Ksh 11,300. Ministry of Agriculture, *Economic Review of Agriculture: 2007*, 32. At approximately two tonnes of nuts for every tonne of copra, that means a tonne of copra will cost 22,600 plus processing of the copra, which we estimate at Ksh 2,000 per tonne, for a total price of copra of Ksh 24,600 per tonne. However, because much of the coconut subsector is currently underutilized, we have increased the price another Ksh 2,000 per tonne as an incentive for producers to deliver to the market. Including a 5% rate of inflation per year onto the total of 24,600, the 2008 price is estimated at Ksh 29,327 per tonne of copra. The price of seedcake is Ksh 4,856 per tonne, which is based on the 2005 year import price, according to FAOSTAT, multiplied times factor of two based on the average increase in oilseed products since 2005, as reported in U.S. Department of Agriculture, *Oilseeds: World Markets and Trade*, (February 2008), Tables 29-31, <http://www.fas.usda.gov/oilseeds/circular/2008/February/Oilseeds0208.pdf> (15 March 2008).

[c] The price is based on the average price from 2003 to 2006, according to Kenya Ministry of Agriculture, *Economic Review of Agriculture: 2007*, 30. The price of seedcake is based on personal conversations with oilseed crushing companies in Nairobi, as of March 2008.

[d] The price of croton seeds are estimated based on a survey of farmers and extension throughout areas where croton is grown.

[e] The price of jatropha is estimated based on a survey of farmers and extension throughout areas where croton is grown.

[f] The price of rapeseed is based on the import price of rapeseed oil in 2005, according to FAOSTAT, which was $1,255 per tonne, which equals about Ksh 73 per liter. Prices of rapeseed oil globally have risen significantly since 2005, with the price of canola oil in Rotterdam at $1,405 per tonne in January 2008, according to the U.S. Department of Agriculture, *Oilseeds: World Markets and Trade*, Table 31. However, KARI, Njoro cites a farm price of Ksh 18,000 per tonne as of the end of 2007. We have chosen to discount the price to the equivalent of $800 per tonne of oil, which is equal to about Ksh 46 per liter without accounting for pressing costs. The price of rapeseed cake is estimated at Ksh 12,000 per tonne, which is based on personal communication with oilseed processing companies in Nairobi as of March 2008.

[g] The price of sunflower seeds is based on the 2005 year price listed on FAOSTAT, multiplied times a factor of 1.8, which is the amount sunflower prices have risen on the world market over that period according to U.S. Department of Agriculture, *Oilseeds: World Markets and Trade*, Table 31. The price of sunflower seed cake is estimated at Ksh 16,000 per tonne, which is based on personal communication with oilseed processing companies in Nairobi as of March 2008.

[302] ABD-DANIDA, vii.
[303] F.O Licht, *World Biodiesel Markets*, 18.
[304] F.O. Licht, *Ethanol Production Costs*, 75.
[305] Personal communication, Anton Van Tonder, Spectre Chemical; personal communication, Agro-Chemical.
[306] F.O. Licht, *Ethanol Production Costs*, 91.

[307] F.O. Licht, *Ethanol Production Costs*, 105.
[308] F.O. Licht, *Ethanol Production Costs*, 91.
[309] FAOSTAT, reporting Uganda produced 1.95 million tonnes of sugarcane in 2006.
[310] Matthew Owen and John Saka, GTZ Programme for Biomass Energy Conservation in Southern Africa and Malawi Department of Energy Affairs, "The Gel Fuel Experience in Malawi," (2006).
[311] F.O Licht, *World Biodiesel Markets*, 80.
[312] Republic of South Africa, *Biofuels Industrial Strategy of the Republic of South Africa*, 10.
[313] The additional 93 million liter capacity would generate about Ksh 4.65 billion at ~ Ksh 50 per liter wholesale price. This does not account for the capital investments in the plants. One study estimated annual local economic benefits of about $1.48 per liter of ethanol produced in the United States. John M. Urbanchuk, *Contribution of the Ethanol Industry to the Economy of the United States* (21 February 2006) 6, <http://www.ethanolrfa.org/objects/documents/576/economic_contribution_2006.pdf> (15 January 2008) (estimating $115 million annual addition to the local economy for a 50 million gallon per year ethanol plant).
[314] Jack Opondo, Assistant Production Manager, Mumias Sugar Company, personal communication, 5 December 2007; Anton Van Tonder, Plant Director, Spectre International, personal communication, 4 December 2007; U.S. Department of Agriculture, Oak Ridge National Laboratory, *Biofuels and Agriculture: A Factsheet for Farmers*, (September 2001), <http://www1.eere.energy.gov/biomass/pdfs/farmerfactsheet.pdf> (3 February 2008) (estimating that a 100-million-gallon/year ethanol production facility would create 2,250 local jobs for a single community).
[315] Jack Opondo, Assistant Production Manager, Mumias Sugar Company, personal communication, 5 December 2007.
[316] Jack Opondo, Assistant Production Manager, Mumias Sugar Company, personal communication, 5 December 2007.
[317] Kenya Sugar Board, *Year Book of Sugar Statistics 2006*, Table 8.
[318] The following sources were used to calculate farm income:

[a] Cost of production and price is from the Bungoma and Kilifi District Guidelines. Yield is from the Ministry of Agriculture, *Economic Review of Agriculture: 2007*, 23.

[b] Yield is based on the average annual yield for sugarcane, which is about half of the current yield of about 70 tonnes per hectare due to the 18-24 month growing cycle. Kenya Sugar Board, *Year Book of Sugar Statistics: 2006*.

[c] Data on yields and the cost of production is taken from Reddy et al.

[319] New York State Energy Research and Development Authority, *Statewide Feasibility Study for a Potential New York State Biodiesel Industry, Final Report 04-02* (June 2003); George A. Shumaker et al., *A Study on the Feasibility of Biodiesel Production in Georgia* (estimating 18 direct and indirect jobs for a 1.8 million liter plant and 53 jobs for a 10.8 million a year plant).
[320] Projected yields under rainfed conditions were taken from Tewari, 49.
[321] Kenya Ministry of Energy, as submitted by Petroleum Marketers, "Kenya Inland Petroleum Sales."
[322] U.S. Department of Energy, Energy Information Administration, *International Energy Annual 2005*, <http://www.eia.doe.gov/emeu/international/oilconsumption.html> (1 February 2008); Kenya Ministry of Planning and National Development, Central Bureau of Statistics, "Facts and Figures of Kenya 2006;" Kenya Ministry of Energy, as submitted by Petroleum Marketers, "Kenya Inland Petroleum Sales."
[323] The following notes correspond to the lettered citations in the table:

[+] The type of sorghum currently grown in Kenya does not contain a sweet stalk, as it is primarily grown as a food grain. The sweet sorghum varieties that can be used for ethanol can produce much higher yields, according to studies conducted by ICRISAT in India and Thailand, and can also produce grain for food and sugar for ethanol simultaneously.

[a] 9.6 tonnes per hectare of cassava root, according to Ministry of Agriculture, *Economic Review of Agriculture: 2007*, 23. 1 tonne of fresh cassava will yield about 170 liters of ethanol, according to Shelty et al., 673.

[b] 70.89 tonnes per hectare of sugarcane, according to Kenya Sugar Board, *Year Book of Sugar Statistics, 2006*. At 70 liters of ethanol per tonne of cane if only ethanol is produced, and 10 liters per tonne of cane if molasses is used, the total ethanol production per hectare is about 4,962 liters per hectare from canejuice and 709 liters per hectare from molasses.

[c] 35 tonnes per hectare of sweet sorghum, according to personal communication, Bekele Shiferaw, ICRISAT, personal communication. At 40 liters of ethanol per tonne of sorghum stalks, about 1,400 liters of ethanol can be produced per hectare of sweet sorghum.

[d] 10% of 2006 petrol consumption in Kenya is 50.9 million liters. Discounting for the lower energy content in ethanol would require 77.12 million liters to replace 10% of petrol. Kenya Inland Petroleum Sales, Kenya Ministry of Energy, as submitted by Petroleum Marketers.

[e] Kenya Ministry of Agriculture, *Economic Review of Agriculture: 2007*, 23.

[f] Kenya Sugar Board, *Year Book of Sugar Statistics: 2006*, (2007).

[324] The following notes correspond to the lettered citations in the table:

[+] Croton and jatropha are just beginning to be planted for commercial purposes, so no market for seeds or oil has yet been established.

[++] Only negligible quantities of rapeseed are grown in Kenya, mostly near Laikipia, Nakuru, and Eldoret.

[a] We assume an average yield of 1 tonne per hectare. The current yield for castor in Kenya, 0.23 tonnes per hectare, is extremely low due to the lack of proper management and intercropping. The optimal yield of over 1 tonne per hectare. At a 40% oil yield, multiplied times 1.12 to account for the conversion from tonnes to liters, each tonne of castor will produce 448 liters of biodiesel.

[b] Current yield for coconut is 1.64 tonnes of nuts, or 0.82 tonnes of copra, per hectare, according to Kenya Ministry of Agriculture, *Economic Review of Agriculture: 2007*, 32. With a 65% oil content multiplied times 1.12 to account for the conversion from tonnes to liters, each tonne of copra will produce about 728 liters of biodiesel.

[c] Current yield for cottonseed is 0.6 tonnes per hectare, according to Kenya Ministry of Agriculture, *Economic Review of Agriculture: 2007*, 30. At roughly 13% oil content and 1,120 liters of oil per tonne of seed, each tonne of cotton seeds will yield about 146 liters of biodiesel.

[d] At 2.5 tonnes per hectare and a 30% oil yield, multiplied times 1.12 to account for the conversion from tonnes to liters.

[e] At 2.5 tonnes per hectare and a 30% oil yield, multiplied times 1.12 to account for the conversion from tonnes to liters.

[f] At 2 tonnes per hectare and 35% oil content, multiplied times 1.12 to account for the conversion from tonnes to liters.

[g] At 0.92 tonnes per hectare and 37% oil content, multiplied times 1.12 to account for the conversion from tonnes to liters.

[h] 2005 data from FAOSTAT. Data for coconuts and cotton is from the Kenya Ministry of Agriculture, *Economic Review of Agriculture: 2007*, 32.

[325] Kenya Ministry of Energy, as submitted by Petroleum Marketers, "Kenya Inland Petroleum Sales," (reporting a total of 13.65 million barrels of oil for petrol and automotive diesel combined); U.S. Department of Energy, Energy Information Administration, "This Week in Energy," (3 January 2008) <http://tonto.eia.doe.gov/oog/info/twip/twip.asp> (20 February 2008) (listing an average price of US$72 per barrel of oil in 2007); U.S. Central Intelligence Agency, "World Factbook, Kenya," <https://www.cia.gov/library/publications/the-world-factbook/geos/ke.html> (7 December 2007) (reporting US$17.5 billion GDP for Kenya in 2006).

[326] U.S. Central Intelligence Agency, "World Factbook, Kenya."

[327] U.N. Convention on Climate Change, "Production of Biodiesel Based on Waste Oils and/or Waste Fats From Biogenic Origin for Use as Fuel," AM0047.

[328] U.N. Convention on Climate Change, "Registered Projects by Region," <http://cdm.unfccc.int/Statistics/Registration/RegisteredProjByRegionPieChart.html> (25 January 2008).

[329] The laws of Kenya include the following: The Constitution of the Republic of Kenya and subject thereto, all other written laws, including certain Acts of Parliament of the United Kingdom as listed and modified in accordance with the first and Second schedules of the Judicature Act (Cap. 8) of the laws of Kenya; subject thereto and so far as those written laws do not extend or apply, the substance of the common law, the doctrines of equity and the statutes of general application in force in England on the 12th August 1897, and the procedure and practice observed in courts of justice in England at that date. However, the common law, doctrines of equity and statutes of general application shall apply so far only as the circumstances of Kenya and its inhabitants permit and subject to such qualifications as those circumstances may render necessary. Further, African customary law shall apply in civil cases in which one or more of the parties is subject to it or affected by it, so far as it is applicable and is not repugnant to justice and morality or inconsistent with any written law.

[330] The Energy Act, Kenya Gazette Supplement No. 96 (Act No. 12) of 2006, § 103 [hereinafter referred to as the "Energy Act"] (compelling the State to pursue and facilitate the production of biofuels).

[331] Energy Act, § 2.

[332] Energy Act, § 3 (stating that "[t]he provisions of this Act shall apply, as hereinafter specified, to every person or body of persons importing, exporting, generating, transmitting, distributing, supplying or using electrical energy; importing, exporting, transporting, refining, storing and selling petroleum or petroleum products; producing, transporting, distributing and supplying of any other form of energy, and to all works or apparatus for any or all of these purposes.")

[333] Energy Act, § 6 (providing the ERC with "all powers necessary or expedient for the performance of its functions under this Act," including: the issuance of licenses and permits; environmental, health and safety regulations for the energy sector; and the investigation and punishment of violations of the Act or any regulations made thereunder).

[334] Ministry of Energy, Biodiesel Strategy, 17.

335 Energy Act, §§ 27, 80.
336 *See generally*, Energy Act, Part V (including no requirement on license or permit for any business regarding renewable energy).
337 The Industrial Alcohol (Possession) Act, Chapter 119 of the Laws of Kenya, *repealed* 10 October 2007 by the Licensing Laws (Repeal and Amendment) Act, No. 5 of 2007, § 4.
338 Energy Act, §§ 3, 103.
339 Energy Act, § 115 (emphasis added).
340 Kenya Bureau of Standards, KS 03-515:1990, "Specification for 10% Gasohol;" KS 03-382:1982, "Specification for Power Alcohol."
341 Energy Act, § 95.
342 The Environmental Management and Coordination Act [hereinafter referred to as the EMCA], No. 8 of 1999 of the Laws of Kenya, § 59(1); Environmental (Impact Assessment and Audit) Regulations [hereinafter referred to as the EIA Regulations], 2003, Kenya Gazette Supplement No. 56 (Legislative Supplement No. 31) Legal Notice No. 101.
343 EIA Regulations, §§ 17, 22.
344 The Petroleum Act, Chapter 116 of the Laws of Kenya, the Petroleum Rules.
345 The Factories and Other Places of Work Act, Chapter 514 of the Laws of Kenya, § 9(1)
346 The Factories and Other Places of Work (Risk Reduction) Rules, 2007.
347 The Employment Act, Kenya Gazette Supplement No. 107, Act No. 11 of 2007, § 15.
348 The Labour Relations Act, No. 14 of 2007, § 5.
349 The Labour Relations Act, §§ 48, 49.
350 The Work Injuries Benefits Act, No. 13 of 2007, § 11.
351 The Work Injuries Benefits Act.
352 This is if the accident was due to an act done by the employee for the purpose of, in the interests of or in connection with, the business of the employer despite the fact that the employee was at the time of the accident acting in contravention of any law or instructions by or on behalf of his employer or without any instructions from the employer. Even when the employee is being conveyed to work in a vehicle provided by the employer for that purpose, he is deemed to be in the course of his employment.
353 EMCA, § 57.
354 The National Environment Action Plan Committee (NEAP) is established under EMCA, § 37(1).
355 EMCA, §§ 37(2), 38(c).
356 The Seeds and Plant Varieties Act, Chapter 326 of the Laws of Kenya.
357 EMCA, Second Schedule, "Projects to Undergo Environmental Impact Assessment," as read with EMCA, § 58(1).
358 EMCA, §§ 2, 58.
359 EMCA, § 58(1).
360 EIA Regulations, § 48.
361 EMCA, §§ 58(8)-(9).
362 EMCA, § 59(1).
363 EIA Regulations.
364 EMCA, § 58(7).
365 EMCA, § 63.
366 These circumstances are where: there is substantial change or modification in the project or in the manner in which the project is being operated; the project poses environmental threat which could not be reasonably foreseen at the time of the study, evaluation or review; or it is established that the information or data given by the proponent in support of his/her application for an environmental impact assessment license under section 58 was false, inaccurate or intended to mislead. Any failure, neglect or refusal to comply with the directions of NEMA issued as above is an offence. EMCA § 64(1).
367 EMCA, §§ 65(2)-(3).
368 EMCA, § 42 (1): "No person shall, prior written approval of the Director-General given after an environmental impact assessment, in relation to a river, lake or wetland in Kenya, carry out any of the following activities Erect, reconstruct, place, alter, extend, remove or demolish any structure or part of any structure in, or under the river, lake or wetland; excavate, drill, tunnel or disturb the river, lake or wetland; introduce any animal whether alien or indigenous, dead or alive, in any river, lake or wetland introduce or plant any part of a plant specimen, whether alien or indigenous, dead or alive, in any river, lake or wetland; deposit any substance in a lake, river or wetland or in, on, or under its bed, if that substance would or is likely to have adverse environmental effects on the river, lake or wetland; direct or block any river, lake or wetland from its natural and normal course; or drain any lake, river or wetland."
369 EMCA, § 42.

[370] EMCA (Water Quality) Regulations, 2006, Legal Notice No. 120 (Kenya Gazette Supplement No. 68, Legislative supplement No. 36).
[371] The EMCA (Water Quality) Regulations contain precise and calculated standards in the schedules at the back of the text for water of different sources and for all uses. One can consult the text for specific information.
[372] EMCA (Water Quality) Regulations, 2006, rules 5, 11.
[373] An Effluent Discharge License is non-transferable. EMCA (Water Quality) Regulations, 2006, rules 11, 18.
[374] EMCA (Water Quality) Regulations, 2006, rule 14.
[375] EMCA (Water Quality) Regulations, 2006, rule 10.
[376] The Pharmacy and Poisons Act, No. 244 of 1990; The Use of Poisonous Substances Act, No. 247 of 1964.
[377] EMCA, § 94(b)
[378] EMCA, § 94(c)
[379] EMCA, § 94(g)
[380] EMCA, § 87(4)
[381] The Fertilizers and Animal Foodstuffs Act, Chapter 345 of the Laws of Kenya, §§ 8, 19(1). The said Act covers standards of composition, efficacy, fineness and purity of animal foodstuffs; the prohibition of certain substances and the limitation of percentages of certain substances in the foodstuffs; records and returns to be kept and furnished by manufacturers and sellers of the animal foodstuffs; as well as requirements as to the proper storage of fertilizers and animal foodstuffs.
[382] The Fertilizers and Animal Foodstuffs Act, § 5(1).
[383] EMCA (Waste Management) Regulations, 2006, Kenya Gazette Supplement No. 69, Legislative Supplement No. 37, Legal Notice No. 121.
[384] EMCA, § Section 87 (2)
[385] The Seeds and Plant Varieties Act, Chapter 326 of the Laws of Kenya.
[386] The Plant Protection Act, Chapter 324 of the Laws of Kenya.
[387] Kenya Ministry of Trade and Industry, *Handbook on Importing and Exporting*, 34.
[388] KEPHIS is a regulatory agency for quality control of agricultural input and produce whose mandate includes testing certification, quarantine control of seeds (including imported seeds) and planting materials and grading. The Minister for the time being in charge of Agriculture may make rules for the purpose of preventing and controlling the spread of pests or diseases via seed importation through quarantine after inspection. The Minister may order the quarantine of shipment vessels and seeds and order the disinfection, treatment, destruction and disposal of any unhealthy plant, or of any plant appearing to be infected with any pest or disease, or of anything else, whether of a nature similar to a plant or not, likely to infect any plant with any pest or disease. The Plant Protection Act, § 3.
[389] Kenya Ministry of Trade and Industry, *Handbook on Importing and Exporting*, 34.
[390] The Trade Licensing Act, Chapter 497 of the Laws of Kenya, § 5(1).
[391] A Trade Licensing Officer is appointed under the provisions of the Trade Licensing Act, Chapter 497 of the Laws of Kenya, § 6.
[392] KEPHIS was established in 1996 as a regulatory agency for quality control of agricultural input and produce. Its mandate includes testing certification, quarantine control of seeds and planting materials, grading. The Seeds and Plants Varieties Act, Chapter 326 of the Laws of Kenya, § 3c.
[393] Kenya Ministry of Trade and Industry, *Handbook on Importing and Exporting*, 72.
[394] The following seeds make up Schedule 1 seeds: Wheat, Barley, Oats, Beans, Millet (finger), Sorghum, Rice, Sunflower, Sugarcane (for the production of white sugar). The Agriculture Act, Chapter 318 of the Laws of Kenya.
[395] The Seeds and Plant Varieties Act, Regulation number 5.
[396] The Customs and Excise Act, Chapter 472 (2) Laws of Kenya, § 12.
[397] The Customs and Excise Act, §§ 6, 7, 12.
[398] The Value Added Tax Act, Chapter 476 Laws of Kenya at the Second Schedule.
[399] The Interpretations and General Provisions Act, Chapter 2 of the Laws of Kenya, § 2.
[400] The Governments Land Act, Chapter 280 of the Laws of Kenya; the Registration of Titles Act, Chapter 281 of the Laws of Kenya; the Land Titles Act, Chapter 282 of the Laws of Kenya; the Land Consolidation Act Chapter 283 of the Laws of Kenya; the Land Adjudication Act, Chapter 284 of the Laws of Kenya; the Registration of Documents Act, Chapter 285 of the Laws of Kenya; the Land (Group Representatives) Act, Chapter 287 of the Laws of Kenya; the Trust Land Act, Chapter 288 of the Laws of Kenya; the Trusts of Land Act, Chapter 290 of the Laws of Kenya; the Equitable Mortgages Act, Chapter 291 of the Laws of Kenya; the Wayleaves Act, Chapter 292 of the Laws of Kenya; the Distress for Rent Act, Chapter 293 of the Laws of Kenya; the Trespass Act, Chapter 294 of the Laws of Kenya; the Land Acquisition Act, Chapter 295 of the Laws of Kenya; the Rent Restriction Act, Chapter 296 of the Laws of Kenya; the Survey Act, Chapter 299 of the Laws of Kenya; the Registered Land Act, Chapter 300 of the Laws of Kenya; the

Landlord and Tenant (Shops, Hotels and Catering Establishments)Act, Chapter 301 of the Laws of Kenya; the Land Control Act, Chapter 302 of the Laws of Kenya; the Mortgages (Special Provisions) Act, Chapter 304 of the Laws of Kenya.

[401] The Registration of Titles Act, Chapter 281 of the Laws of Kenya, provides for the transfer of land by the registration of titles and defines land to include: "land and benefits to arise out of land or things embedded or rooted in the earth, or attached to what is so embedded for the permanent beneficial enjoyment of that to which it is so attached, or permanently fastened to anything so embedded, rooted or attached, or any estate or interest therein, together with all paths, passages, ways, waters, watercourses, liberties, privileges, easements, plantations and gardens thereon or thereunder lying or being, unless specifically excepted." The Land Consolidation Act, Chapter 283 of the Laws of Kenya, which "provides for the ascertainment of rights and interests in, and for the consolidation of, land in the special areas; for the registration of title to, and of transactions and devolutions affecting, such land and other land in the special areas; and for purposes connected therewith and incidental thereto," defines land to include "land covered with water, any estate or interest in land other than a charge, all things growing thereon and buildings and other things permanently affixed thereto." The Land Adjudication Act, Chapter 284 of the Laws of Kenya, which provides for the ascertainment and recording of rights and interests in Trust land, and for purposes connected therewith and purposes incidental thereto, defines land to include "things growing on land and buildings and other things permanently affixed to land." The Land Acquisition Act, Chapter 295 of the Laws of Kenya, which makes provision for the compulsory acquisition of land for the public benefit, defines land to include "all land, whether covered with water or not, and things attached to the land, or permanently fastened to anything attached to the land, and (where the meaning may be inferred) any estate, term, easement, right or interest in or arising out of land." The Land Control Act, Chapter 302 of the Laws of Kenya, which provides for controlling transactions in agricultural land (generally land that is not within a municipality or a township; or an area which was once a township or a trading centre under repealed laws) defines land to include "an estate, interest or right in land."

[402] Freeholds are divided into: fee simple, fee tail, life interest and estate par autre vie. A person who has a freehold right, has absolute ownership (indefeasible legal title) over land from the government of Kenya, and upon his demise or infirmity, the legal title over the land would by law pass on to his rightful heir(s) and if non are in existence, it would revert back to the government.

[403] Leaseholds can be categorized into the following: for a specific period, periodic tenancies, tenancies at sufferance and tenancies at will. A person who enjoys a leasehold title over any property possesses only conditional rights of ownership over the said property and the lease can either be determined by the effluxion of time or by some other condition precedent set within the lease agreement itself by the parties to the lease.

[404] Servitudes are rights in the soil of another. For example, easements or profits a prendre. They are referred to as "*rights in alieno solo*."

[405] Business means a concern carrying on the occupation of; a regulated trade; importing or exporting goods; commission agent or indent agent; manufacturer's representatives; produce dealer or produce broker; business broker or management consultant; insurance agent; estate agent; or any other occupation, whether similar to any of the foregoing or not, which the Minister may, declare to be an occupation for the purposes of definition. The Trade Licensing Act, § 2.

[406] The Trade Licensing Act, § 5.

[407] General business areas include most major urban areas in Kenya.

[408] The Trade Licensing Act, § 5.

[409] The Trade Licensing Act, § 5.

[410] The Investment Promotion Act, No. 6 of 2004. Investment means the contribution of local or foreign capital by an investor, including the creation or acquisition of business assets by or for a business enterprise and includes the expansion, restructuring, improvement or rehabilitation of a business enterprise.

[411] An investment certificate can be transferred by the holder to another person(s), but only with approval from Kenya Investment Authority. Equally, the certificate can be amended or revoked where need be.

[412] The KIA is continued under § 14 of the new Investment Promotion Act (from the repealed Investment Promotion Centre Act) and has been issued with the mandate of approving applications for and issuing investment certificates to investors.

[413] The Investment Promotion Act, §§ 12, 13.

[414] Kenya Revenue Authority, Petroleum Monitoring Unit, as of 18 December 2007.

[415] EMCA, § 57(1).

[416] EMCA, § 57(2)(b). Similarly under § 57(2)(c)-(d) the Finance Minister may recommend for tax disincentives to deter bad environmental behavior that leads to depletion of environmental resources or that cause pollution; or user fees to ensure that those who use environmental resources pay proper value for the utilization of such resources.

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[427] U.S. Environmental Protection Agency, *A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions* (October 2002).
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