# POTENTIAL OF SUSTAINABLE BIOMASS PRODUCTION IN DEVELOPING COUNTRIES CASE STUDY KENYA

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ABSTRACT: 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. 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. Considering the destruction of rainforests and the use of staple food crops like maize for ethanol, impacts on ecosystems and food supplies have grown. This has challenged the overall value of biofuels as a solution to global warming and tight oil supplies. Developing 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. This study is intended to support these efforts with an analysis of latest information on agronomy, economics, law and policy, and environmental and social impacts of biofuels in Kenya.

Keywords: Developing countries, biomass resources, bio-energy strategy

## 1 BIOMASS FEEDSTOCK

### 1.1 Ethanol

Ethanol is a liquid fuel that can be produced from a variety of sugar crops, such as sugarcane and sweet sorghum; grains, such as corn and wheat; and cellulosic crops, such as switchgrass, although the latter is not yet economically viable for commercial production.

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.

The following ethanol feedstocks are considered in the study: cassava, sugar cane 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. In collaboration with the World Agroforestry Centre's (ICRAF's) GIS laboratory, suitability maps for each feedstock were designed showing where they can grow and where they would compete with existing food and cash crops.

### 1.2 Biodiesel

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 and sunflower.

Biodiesel 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 considers the following biodiesel feedstocks: castor, coconut, cotton, croton, jatropha, rapeseed and sunflower.

## 2 CURRENT STATUS OF BIOFUELS IN KENYA

Kenya's present-day ethanol industry, which includes Agro-Chemical and Food Company 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. Realizing both ethanol plants to run at full capacity 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 production methods. Planning to integrate the production of sugar, ethanol and power, Mumias Sugar Company targets 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 currently 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 sugar cane, 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 sugar cane, however more practical research needs to be done to maximize its economic potential in Kenya.

At the current growth rate in 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 present production of 20 million liters. 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 governmental agencies, NGOs and the private sector indicate great potential. The vast majority of current or planned biodiesel projects involve jatropha as the main feedstock, although projects involving other feedstocks like castor, croton and coconut, are also being discussed.

Many of these projects and organizations have started 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 Ministry of Agriculture holds 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 should take the lead in research for tree crops, like jatropha and croton, as well as for 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, working on the implementation of a recently released national strategy on biodiesel. 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.

## 3 ECONOMIC ANALYSIS

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. Even if only a portion of this money was 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. Thus, the study determines potential land availability for feedstock production.

A status quo feedstock production analysis 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.

A potential biofuel feedstock production scenario calculates the amount of each crop that could be grown at current yields if half of all suitable areas were planted. 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.

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).

The type of sorghum traditionally grown in Kenya does not contain a sweet stalk, as it is primarily grown for food. The cultivation of high-yielding sweet sorghum varieties could produce both grain for food and sugar for ethanol. Hence, over 8 billion liters of ethanol could be produced from sweet sorghum and alternatively more than 3 billion liters from cassava.

Depending on which biodiesel feedstock is used, between 125 million to over 5 billion liters could be produced.

**Table I:** Potential Biofuel Production Scenario

| | Av. Yield [t/ha] | Pot. Land [Mha] | Pot. Biofuel [Mltr] |
|---|---|---|---|
| Ethanol | | | |
| Cassava | 9.6 | 2.08 | 3,395 |
| Sugar cane | 33.4 | 0.09 | 30 |
| Sw. sorghum* | 35.0 | 5.90 | 8,260 |
| Biodiesel | | | |
| Castor | 0.23 | 6.82 | 703 |
| Rapeseed* | 2.00 | 0.16 | 125 |
| Sunflower | 0.92 | 3.48 | 1,325 |
| Jatropha* | 2.50 | 6.26 | 5,258 |

* Currently underexploited but prospective high potential biofuel feedstock crops

Sweet sorghum provides 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, the difficulty of growing sunflower due to pests, as well as its competing food uses, make these feedstocks appear somewhat less attractive. Castor and rapeseed could provide large quantities of feedstock in the near term, with castor maximizing more semi-arid areas and rapeseed being grown as rotational crop in conjunction with wheat, barley and other staples.

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.

An optimized feedstock production capacity requires the implementation of state-of-the-art agricultural input methods, such as high-yielding varieties under irrigation, to achieve maximum yields for each crop. The lesson is that both available land and increased yield are important factors in producing adequate supply of biofuel feedstock to support a domestic industry.

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 high. 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 high operating costs in Kenya are poor infrastructure and the relative inefficiency of the Kenyan ethanol model.

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.

Three different scales of production were evaluated 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 price per tonne of oilseed, the percentage of oil that can be extracted from the seed (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 experience growing these 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 other crops considered. The next two cheapest feedstocks are coconut and castor.

To determine the overall feasibility, the cost of production including 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 publication. However, discounting for the lower energy value in biodiesel, the comparative price of petroleum diesel can be reduced by 7% to Ksh 74.4 per liter. Thus, at current retail prices, biodiesel production is not economically feasible at any scale of production, except perhaps for croton and jatropha at large commercial scale, 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. A 10% ethanol blend (E10) in Kenya would require approximately 93 million liters a year by 2013. 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 2% 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 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.

Kenya spent $983 million, or 5.6% of gross domestic product on 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).

## 4 REGULATORY & FISCAL ANALYSIS

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 farm-based operation consuming all of what it produced.

Health, safety and worker protection are also important considerations for biofuel producers or sellers, complying with associated laws or regulations. 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 import 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 laws and regulations in those areas. Implications of current fuel taxes applying to petrol (about Ksh 30 per liter) and diesel (about Ksh 20 per liter) for biofuels should be reduced or eliminated to promote the industry.

## 5 IMPACT ASSESSMENT

In general, impacts depend on the type of used feedstock as well as on 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 ($NO_x$) 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 was 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 on other air emissions, the climate benefit of a particular biofuel is dependent on the scale and mode of production, as well as on 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 forests 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 reduce their overall environmental benefits significantly. The use of waste materials, marginal lands and reforestation projects are essential to maximize 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 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 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 FAO reports, most short-term price increases in food are more the result of increased demand for food from 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 help 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 may also not be as bad, especially if domestically produced crops can fetch more value as a biofuels feedstock than a food crop and the local food market can meet demand at affordable prices.

Beyond, considering the use of edible crops for biofuels, domestic cost of crop production cannot compete in global or regional markets. As long as Kenyan sugar companies enjoy protective tariffs enabling to charge about twice the price for imported sugar, then it makes more economic sense to continue producing sugar as primary product, with by-product molasses used for ethanol. However, if protective tariffs disappeared, then 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.

Environmental sustainability of biofuels is at the center of a global debate 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 been adopted yet. 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 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. Such a program on sustainable biofuels production could develop rural areas throughout the country and provide a model in order to counter 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 was 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 the developing biodiesel industry in Kenya. Several key aspects of the following roadmap incorporate these recommendations from the Ministry, including a certified seed production, the establishment and upgrading of blending facilities, aspects of research and development as well as the creation of pilot biodiesel production plants.

- 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 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.
  - Establish a high-level task force of the various ministries referring to Energy, Agriculture, Environment and Natural Resources. Other affected government agencies, representatives from the business community, NGOs and development partners should also be consulted.
  - Create a transparent and inclusive process of defining the specific strategy and measures for encouraging the production and use of biofuels.
  - Implement policies that promote biofuels production and protect consumers, workers and the environment.
  - Adopt blending mandates that specify the amount of ethanol and biodiesel by certain dates.
  - Design fuel quality and blending standards for both ethanol and biodiesel based on Kenyan and international blending mandates and existing standards.
  - Designate priority in selection of optimal biofuels feedstock crops based on economic, agronomic, social and environmental criteria and analysis.
  - Identify and certify optimal seeds for selected priority feedstock crops adapted to the respective agro-ecological zones.
  - Review and revise all licensing requirements along the entire biofuels value chain to protect consumers, workers, communities and the environment eliminating redundant regulations.
  - Adopt incentives for tax exemptions or subsidies to promote the new biofuels industry.
- Develop and implement sustainability standards for biofuels that are stringent but achievable.
  - The use of crops that can grow in semi-arid areas combined with a sophisticated mapping to reduce food competing land-use conflicts would enable large quantities of additional biofuels feedstocks.
  - The reliance on tree crops like croton and jatropha could be combined with reforestation and afforestation projects, as well as with 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.

## 7 REFERENCES

The complete manuscript content of the underlying Case Study Kenya is based on

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