WPS6499

Policy Research Working Paper 6499

Are Biofuels Economically Competitive with Their Petroleum Counterparts?

Production Cost Analysis for Zambia

Thomson Sinkala
Govinda R. Timilsina
Indira J. Ekanayake

The World Bank
Development Research Group
Environment and Energy Team
June 2013

Policy Research Working Paper 6499

Abstract

With increased global interest in biofuels, Zambia, a Sub-Saharan African country that entirely depends on imports for its petroleum supply, is planning to implement blending mandates for biofuels. But, a large number of issues—including production costs of biofuels, land requirements to meet the mandates, and environmental benefits—have not yet been explored. This study aims to contribute in filling this gap. It finds that depending on feedstock type, costs of ethanol production range from US$0.360 a liter to US$0.680 a liter while the costs for biodiesel production range from US$0.612 a liter to US$0.952 a liter. Even if lower energy contents of biofuels are taken into account, the analysis shows that biofuels are cheaper than their petroleum counterparts. Considering the cost advantage of these biofuels over petroleum products and the availability of surplus agricultural land, Zambia is likely to benefit from the development of a biofuel industry. Biofuels is expected to reduce Zambia's petroleum import bill, which currently stands at more than US$700 million, enhance food security by providing incentives to increase yields, and increase affordability and accessibility to modern energy in the country where 77 percent of the population still lacks access to modern energy. It could also stimulate rural employment and development.

This paper is a product of the Environment and Energy Team, Development Research Group. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at gtimilsina@worldbank.org.

Are Biofuels Economically Competitive with Their Petroleum Counterparts? Production Cost Analysis for Zambia

Thomson Sinkala, Govinda R. Timilsina and Indira J. Ekanayake

Key words: Zambia, Biofuels, Production costs

JEL Classification: Q18, Q28, Q42, Q48

Sector: Energy and Mining, Agriculture and Rural Development

Are Biofuels Economically Competitive with Their Petroleum Counterparts? Production Cost Analysis for Zambia[1]

1 Introduction

The major sources for energy supply in Zambia include fuel wood, hydropower and petroleum products. Fuel wood accounts for about 70% of the nation's energy needs while hydropower contributes about 14%. The latter has an estimated resource potential of 6,000 MW of which 1,715.5 MW has been already installed. Hydroelectric plants that provide 99% of electricity in the country are located in Kafue Gorge, Kariba North Bank and Victoria Falls. Petroleum products, which account for 12% of the total energy mix, are all imported and transported through the TAZAMA pipeline from Dar-Es-Salaam in Tanzania to Ndola in Zambia, and the Oil Marketing Companies from mainly South Africa and Tanzania.

Considering the large and burdensome fuel import bill in Zambia, lack of indigenous petroleum production and the country's available vast arable land suitable for growing energy crops, all political parties in Zambia – whether they are in the government or in the opposition – seek to promote renewable energy such as biofuel in the country (Patriotic Front, 2011). The government has already revised its energy policy to introduce biofuels into the national fuel mix (MEWD, 2010). A Statutory Instrument No 42 of 2008, which lawfully recognizes biofuels in the national mix, has also been issued. The National Energy Policy of 2008 provides for the following policy measures for biofuels: (i) expansion of the role of biofuels in the national fuel mix; (ii) ensuring security of supply and stable prices of fuels by the promotion of the use of bio-fuels for transport as an alternative to petroleum; (iii) ensuring availability of data and information on market demand, resource assessment and applicability of biofuels; (iv) providing a legal and institutional framework for the biofuels sub- sector ; and (v) supporting investment in the biofuels industry through appropriate incentives, standards and research.

In April 2011, the government issued B5 and E10 blending targets up to 2015. Zambia is not alone in Sub-Saharan Africa to introduce biofuel mandates. Other African countries have also implemented blending targets or mandates. For example, Ethiopia (for Addis Ababa) and Malawi (but depends on availability) have each implemented a 10% blend mandate into gasoline while Nigeria has a bioethanol

[1] Tsinkala is a researcher based in Lusaka, Zambia and a retired professor, University of Zambia (tsinkala@gmail.com). Ekanayake is a senior agriculturist, World Bank Country Office, Lusaka Zambia (iekanayake@worldbank.org). Timilsina (corresponding author) is senior economist, Environment and Energy Unit, Development Research Group, The World Bank, Washington, DC (gtimilsina@worldbank.org). The authors wish to thank Ms. Mary Chipili, Director of Agriculture and her staff at the Department of Agriculture, Ministry of Agriculture and Livestock, Zambia National Farmers Union, the Board of Biofuels Association of Zambia and Mr. Roger Sherriff of Black Power Investment for providing data access and feedback. We also acknowledge the Knowledge for Change (KCP) Trust Fund for financial support. The views and findings are those of the authors and do not necessarily reflect those of the World Bank. All remaining errors are our own.

blending target of 10% (Sinkala, 2011b; Mtomba, 2011; Biofuels digest, 2011). South Africa has introduced a 2% mandate for bioethanol and 5% for biodiesel.

The Energy Regulations Board (ERB) of Zambia issued standards ZS E100 (for bioethanol) and ZS B100 (for biodiesel) in May 2008, and has put in place a biofuels framework with specific licenses for production/refining, storage facility, blending facility, distribution and retail (with on-site testing facilities). ERB has also introduced a captive license for own electricity generation. To help producers optimize their plans and production systems and to minimize their start-up costs for agro-suitability assessments, the Zambian government sought help of the Brazilian government to undertake a feasibility study for biofuels and food production in Zambia (FGV Projetos, 2011). A number of private companies explored production of biodiesel in Zambia including Zampalm focusing on oil palm in Mpika district in Muchinga Province, at an estimated investment of US$41 million[2], and Man Ferrostaal specializing in Jatropha in Mpika at an estimated investment of US$500 million[3], and Kaidi Biomass Zambia Limited which targeted multiple biofuels feedstocks in several parts of Zambia at an estimated investment of US$6 billion[4]. The latter has pulled out investment from the country because of the Zambian government's decision to initially sub-lease 4,000 hectares instead of the total of about 80,000 hectares identified for the project[5]. In the early stages of the industry, foreign companies including D1 and Oval biofuels were also active, largely through outgrower systems. The companies have since folded up largely due to the 2009 economic turmoil. Some small to medium scale producers today make up the largest area of production around 10,000 hectares.

For ethanol, the likely turn-key production can come from existing sugar producing companies including Zambia Sugar (14.3 million liters), Consolidated Farming Ltd (4.7 million liters) and Kalungwishi Estate (0.3 million liters) based on molasses (Pope and Chitembo, 2009). Assuming these companies decided to go into anhydrous bioethanol, this could give a total annual potential of 19.3 million liters at present and a projected total of 32.9 million liters in 2015.

Despite government's policy initiatives and private sectors interest to respond to the policies, Zambia's faces several cross-cutting challenges and barriers. These include lack of readily available data on cost of production, impact of biofuels on national economy, lack of low cost investment fund for biofuels, lack of incentives to attract investment in biofuels industry, the slower pace in processing land acquisition applications, inadequate supportive regulations, inadequacy of information on biofuels, lack of understanding of environmental/energy tradeoffs, and absence of an effective inter-ministerial committee

---

[2] http://www.palmoilhq.com/PalmOilNews/zampalm-invests-in-palm-oil-plantation-in-zambia/
[3] http://business.globaltimes.cn/world/2009-06/436578.html
[4] http://www.times.co.zm/news/viewnews.cgi?category=6&id=1269073856
[5] http://allafrica.com/stories/201303111698.html

to oversee the development of the biofuels industry. In addition, there are a number of gaps in crucial physical infrastructure and incentives that are essential for a meaningful and vibrant biofuels industry in Zambia.

One of the key knowledge pieces that is essential for the development of biofuel sector but still missing is a comprehensive analysis of economics of biofuels in the country. The economic viability of biofuels depends on a number of factors, including the type of feedstock and its associated impact on natural resources (water, land, etc.), the impact of biofuels on other sectors of national economy, the prevalent prices of competitor (fossil and other) fuels, and the contribution to socio-economic development of a country. To the authors' knowledge, comprehensive analysis on production costs of biofuels and its impacts on other economic sectors have not been done yet for Zambia. A limited analysis has been carried out for other Sub-Saharan countries (see e.g., Mitchell, 2010). These studies are, however, mostly focused on single feedstocks, notably *Jatropha curcas* for biodiesel and sweet sorghum for bioethanol (BAZ, 2011). For example, Mitchell (2010) focuses on biodiesel from Jatropha in Malawi, Tanzanian and Zambia. Other studies present generalized costs based on experiences elsewhere on biodiesel production from Jatropha, soybeans and sunflower (Yamba, 2011) and on ethanol production from sugarcane (Mitchell 2010; Yamba 2011; Walimwipi 2008), cassava (Walimwipi 2008), and sweet sorghum and maize (Yamba, 2011). Although the agro-climatic conditions of Zambia are able to accommodate most of the popular liquid biofuel feedstocks, only sweet sorghum and Jatropha have been studied relatively significantly so far. University of Zambia has undertaken both agronomic and processing studies on sweet sorghum (Matsika *et al.* 2006; Barley, 2009) where results have indicated good potential. Various researchers have also studied Jatropha for bioenergy in Zambia but not specifically on economics (Sinkala and Chitembo, 2007; Freim, 2008).

This paper therefore aims to fill some of the aforementioned research gaps. We analyze production costs of both ethanol and biodiesel that can be produced in Zambia from various feedstocks. It also addresses required financial support including the potential role of carbon finance to promote biodiesel. It also highlights need for public policy and finance for biofuels significant take off. Key concerns of biofuels, particularly conflict with food security are also discussed.

2 Production Costs of Biofuels in Zambia

A number of crops grown in Zambia can be used as feedstock for ethanol; they include sugarcane, cassava, sorghum, pineapple, and sweet potato. Agave is also available in Zambia but is currently grown as a fence or ornamental plant and not in large scale. Oil crops grown in Zambia that can be used as biodiesel feedstock include soybeans, oil palm, castor, cotton, Jatropha, cashew nut, moringa, sunflower and groundnuts. Our cost estimates, however, focus on those feedstocks which are popularly grown in Zambia.

2.1 Data Sources for Estimating Production Costs

2.1.1 Data for Production Costs of Feedstock

For soybeans, Jatropha, groundnuts, sunflower, sugarcane and partially sweet sorghum, feedstock production costs were obtained locally from the Ministry of Agriculture and Livestock, Zambia National Farmers Union (ZNFU, 2010/2011), SEED-CO (2010 – 2011), and the Biofuels Association of Zambia (BAZ). Production costs for other feedstocks were estimated based on data obtained from other countries, as follows: palm oil (Malaysia, Indonesia and Nigeria), sweet sorghum (Philippines, EU and USA), castor (India), cassava (Nigeria and Thailand), and Agave (Australia and Mexico).

Although sugarcane and cassava are popularly grown in Zambia, no information on production costs are readily available. Oil palm is grown at small scale in Luapula Province and also in Mpika in Northern Province where a Zambian company Zamanita has so far established 3,500 Ha plantation out of a planned 20,000 hectares. University of Zambia has undertaken research activities on sweet sorghum, but there is no commercial production yet (Remvos, 2011). Jatropha is wide-spread at small scale in Zambia. Information on this crop was assembled from the Biofuels Association of Zambia including the main author of this article. Agave is grown only as an ornamental crop in Zambia although the country's climate and agronomic conditions are conducive to grow it in a large-scale. Agave is therefore also included in our analysis.

2.1.2 Data for Biofuels Processing Costs

Since no commercial production of biodiesel and bioethanol exist in Zambia, biofuels processing costs are obtained from a study carried out by APEC (Asia Pacific Economic Cooperation) in December 2010 (APEC Secretariat, 2010) for Brazil, Malaysia and the USA. The APEC study estimated processing costs over 10 years and found that the costs are relatively stable over the period.

2.1.3 Assumptions for Cost Estimation

We made the following assumptions to estimate production costs of biofuels:

- Existing agriculture lands would be used for feedstocks unless the feedstocks have not commercially grown in Zambia (e.g., palm and Jatropha). This means that there would be no additional costs for acquiring and clearing the lands. For crops which have not been produced commercially in Zambia, such as Palm and Jatropha, the annual costs would be 0.02 to 0.06 US$/liter over the first 10 years.
- The costs indicated above are average and indicative. The actual costs will vary among producers, depending on location, agronomic conditions, efficiency of operation, and the production technology used.
- Overhead costs are assumed to be 15% of the total variable costs, in place of the 30% of Total variable cost plus Interest used by ZNFU as Fixed Cost. This assumption for Zambia is largely because the overhead costs are likely to be distributed over several byproducts, such as electricity, fertilizer and pharmaceuticals. In the USA, for example, the overhead cost is about 5% (Shumaker et al., 2007).
- The cost of finance (i.e., lending is 16%), as announced by various banks in Zambia in November 2011 after pressure from the government. A 10% financial charge is also considered for comparison.
- The processing is assumed to occur at bioenergy crop farm, so that the costs reflect farm/refinery gate production cost. Although this looks unrealistic as not every farm can afford to have a processing plant, there is no alternative to this in the absence of knowledge for potential sites for processing plants across the country.

2.2 Estimation of Production Costs

Table A1 to A4 in the Appendix presents details of the estimation of production costs of ethanol and biodiesel from various feddstocks in Zambia.

2.2.1 Ethanol

At a 16% lending rate, ethanol production costs are US$0.542/liter for sugarcane, US$0.545/liter for sweet sorghum, US$0.360/liter for cassava, and US$0.680/liter for Agave *tequilana* (Tables A1 and A2 in the Appendix). The current price of gasoline in the retail market (petrol pump) is S$1.870/liter (K9,910/liter). If ethanol prices are expressed in term of gasoline equivalent unit[6]; the production costs of

[6] Ethanol has 32% lower energy content compared to gasoline; in other word, ethanol provides 32% less mileage than gasoline. Therefore ethanol prices are divided by 0.68 to calculate gasoline equivalent prices.

ethanol turn out to be US$0.797/liter, US$0.801/liter, US$0.529/liter and US$1/liter, respectively, form sugarcane, sweet sorghum, cassava and agave. Since these costs are plant gate costs they do not include taxes and subsidies. The retail prices of gasoline include taxes and charges, therefore we need to use wholesale price for better comparison. The current wholesale price of gasoline is US$0.99 per liter. The detailed structure of petroleum product pricing in Zambia is presented in Table A5 in the Appendix.

2.2.2. Biodiesel

Production costs for biodiesel at 16% lending rate are US$0.655/liter for soybeans, US$0.612/liter for palm, US$0.677/liter for Jatropha, US$0.761/liter for groundnuts, US$0.792/liter for castor, and US$0.952/liter for sunflower (Tables A5 and A6). If biodiesel prices are expressed in term of diesel equivalent unit[7]; the production costs of biodiesel turn out to be US$0.762/liter, US$0.712/liter, US$0.787/liter, US$.885/liter US$.921/liter and US$1.107/liter, respectively, for soybeans, palm, Jatropha, groundnuts, castor and sunflower. The current retail price of diesel in Zambia is US$1.56/liter (K7,566/liter). The wholesale price of diesel is US$1.16/liter. The prices of biodiesel are thus competitive to diesel price in Zambia.

The 16% cost of finance (i.e., commercial bank interest charge) is very expensive in Zambia. This might drop down if competition across commercial banks increases in the country. If the cost of finance decreases from 16% to 10%, the production costs decrease by 3% and more for most of the feedstocks. It is therefore important that the Zambian government sets up a low interest dedicated fund for the biofuel industry to overcome the financial barrier.

3 Land Requirement for Meeting Zambia's Biofuel Demand

Land is not a constraint for biofuel production in Zambia as it is a small market for petroleum products by international standards. In 2010, the country consumed about 215 million liters of gasoline and about 460 million liters of diesel and 22 million liters of kerosene (Energy Regulation Board, 2011). We estimate how much lands would be required if these fuels are substituted with domestically produced biofuels (please see Table A6 for the details of the estimation). We find that if the current consumption of diesel is entirely replaced with biodiesel, it would require 96,000 Ha (if palm is feedstock) to 940,000 Ha (if castor is feedstock). Similarly, if the current consumption of gasoline is replaced with domestically produced ethanol, it would require 21,500 Ha (if agave is the feedstock) to 120,000 Ha (if sweet sorghum is the feedstock). If current consumption of kerosene is replaced with Jatropha oil it would require about

[7] Ethanol has 32% lower energy content compared to gasoline; in other word, ethanol provides 32% less mileage than gasoline. Therefore ethanol prices are divided by 0.68 to calculate gasoline equivalent prices.

12,000 Ha. For the B5 and E10 blending targets announced in April 2011 by the government (MEWD, 2011), the land requirements range from 4,800 Ha (palm) to 47,000 Ha (castor) for biodiesel and from 2,000 Ha (agave) to 12,000 Ha (sweet sorghum) for bioethanol. In reality, a combination of feedstocks would be used depending on conditions in the locations of biofuels producers, so that land requirements would be somewhere between the lower and upper margins. If the molasses from existing sugarcane industry (Nakambala, Kafue and Kalungwishi) were used, more than 19 million liters of bioethanol would be produced without additional land requirement.

Zambia's land ratio currently at 5.79 hectares per person is relatively high, and is in fact higher than all industrialized and emerging economics, including Brazil. But the country has high poverty level and the lowest GDP among those. If Zambia were to use, for example, 20 million hectares for biofuels, the country would still remain with 4.25 Ha/person, higher than for industrialized and emerging economics whose areas per person range from 0.01 to 4.23 Ha. Meanwhile Zambia would earn more than US$100 billion annually from mainstream biofuels products alone, giving the country a biofuels per capita of US$7,700 per person. The country would also make savings from petroleum import bills. Therefore the land requirements for various consumption levels presented above, and beyond, can adequately be accommodated.

4 Potential for Zambia to Export Biofuels

As outlined in government policy (MEWD, 2008a) and strategy (MEWD, 2008b), the production of biofuels in Zambia would basically be for meeting domestic demand, particularly to meet the demand created by the mandates. However, considering availability of surplus agriculture lands and increasing international prices of biofuels, Zambia could produce biofuels for export if it is more economically attractive compared to direct exports of feedstocks.

The government might want to consider investigating the economics of exporting biofuels vs. exporting feedstocks directly (MEWD, 2008b). Note that such a comparison should include employment benefits created by biofuel processing industry, which would be missed if feedstock is exported directly. Moreover, producing biofuels within the country would have additional benefits such as bi-products of processing plants which could have market values and would help Zambia to maximize revenues from the industry as well as increase the industrial base, taking into account the considerable up/downstream industry that biofuels could spur.

In Zambia, biofuels can be processed using available technologies/accessories. Production or assembling these products can further spill over to the economy. However, to be biofuel exporter, Zambia needs strengthening existing infrastructure or building new infrastructure, such as tankers and pipelines. For example, Zambia could upgrade the Tanzania Zambia Mafuta (TAZAMA) pipeline to also house biofuel pipelines. The current petroleum pipeline is 1,706 Km from Ndola in Zambia to Dar-Es-Salaam in Tanzania. Due to land and water resources availability, frost distribution considerations and currently preferred locations of intending major investors in biofuels, most biofuels production is likely to take place in Northern and Luapula Provinces of Zambia. This should cut the current pipeline distance to Dar-Es-Salaam by about 500 to 600 Km. Brazil has taken a similar approach and is building pipelines from inland to ports on the east coast (Rennó, *Undated*).

The immediate external market for Zambia's biofuels is the Southern African Development Community (SADC) Region. At a blending ratio across the board of 5% where engine modification is not necessary, the annual market is about 2.2 billion liters, with the biggest being South Africa at more than 1.5 billion liters (Sinkala, 2011). Applying the Zambian gasoline to diesel consumption ratio of 1:2.14 to SADC consumption for E5 (700 million liters) and B5 (1.5 billion liters), corresponding land requirements would range from 70,000 Ha (agave) to 390,000 Ha (sweet sorghum) for bioethanol and 312,000 Ha (palm) to 3,070,000 Ha (castor) for biodiesel. For detail estimation please see Table A7 in the Appendix.

5 Biofuels under Climate Change Mitigation in Zambia

In Zambia, the cost of lending at 16% is relatively high and the biofuels industry is very new to local banks so that the industry faces investment hurdles. Government policy intervention would be needed to reduce this financial hurdle (as mentioned above). While the government could set up a dedicated fund to support new and emerging industries, other option that does not cost the government is to find a market for carbon mitigated through the use of biofuels. In the latter case, clean development mechanism (CDM)[8] facility could be exploited to help alleviate the financial barrier. Note however that there are difficulties in obtaining carbon credits for biofuel production because of rigorous project requirements established by the CDM Executive Board, the lack of approved methodologies, the high abatement costs of biofuel projects, and the difficulty of proving additionality and calculating the GHG emission reductions of a given project (Mitchell, 2010) plus low capacity and lack of experience in processing carbon credits by potential biofuel producers. At present, the only approved methodology for production of biofuels is AM0047, "*Production of biodiesel from waste oils and/or waste fats from biogenic origin and/or biodiesel from oil seeds grown on unutilised, or marginal lands which had uneconomical agricultural productivity (if any)*" (UNFCCC, *undated*). The relevant feedstock input are oil seeds from

[8] CDM is a market based instrument designed under the Kyoto Protocol to develop GHG mitigating projects in developing countries to "offset" developed countries GHG emissions. So far, majority of CDM projects have been implemented in Asia and Latin America (Menne *et al*., 2011). Africa, to date has implemented relatively few CDM projects.

crops, bushes or trees that when crushed release an oil that can be transformed into biodiesel. The diesel-biodiesel blends must comply with national regulations or with suitable international standards. The blended biodiesel must be supplied to consumers within the host country whose existing stationary installations or vehicles, that actually combust the blend, are included in the project boundary. There exist no biodiesel CDM projects in Africa.

In Zambia, CDM projects could be developed in areas including the over 250,000 hectares mine dump degraded lands in the Copperbelt, the over-grazed degraded areas in Southern Province, and the degraded forest areas due to shifting cultivation and charcoal production mainly in Northern Province. The beneficiaries in those areas are likely to be small biofuels producers since, due to existing settlements, large producers are not likely to operate in these areas.

The potential value of carbon credits at current carbon prices of approximately US$20 per ton of carbon or equivalent GHGs is about US$0.04–$0.05 per liter of ethanol (Mitchell, 2010). The price could rise to several times this value if carbon prices rise. The potential value of electricity cogenerated from sugarcane bagasse produced while extracting 1 liter of ethanol would be approximately US$0.028 per kilowatt-hour at carbon prices of US$20 per ton or equivalent GHGs.[9] On the assumption that agave, sweet sorghum and cassava would give similar results, estimates for bioethanol production costs show that CDM credits can reduce the cost of production by 13% for sugarcane, 17% for sweet sorghum, 14% for cassava and 9% for agave when money is borrowed at 16% interest. These are significant amounts for both producers and consumers of biofuels.

In the case of biodiesel, seed and oil from Jatropha are likely to dominate the oil-based biofuels production under CDM in Zambia because of its attributes; it is non-food plant would be preferred CDM candidate for production of biodiesel. Our study shows that an inefficient small scale crushing yield of 117 Kg oil (6,840 MJ) from one ton of Jatropha seed would save about 444 Kg of CO_2e if replacing diesel while the remaining cake (15,577 MJ) would save 1495 Kg of CO_2e if replacing coal (Louw and Andrews, *undated*). For a 6 tons yield of Jatropha per hectare, this translates into about US$232.68 per hectare, or US$0.13/liter, of CDM. This is about 19%, and is a significant credit to reduce the cost of production.

CDM is therefore important to reduce financial barriers to biofuels in developing countries including Zambia. A CER price of equivalent to US$0.040/liter for ethanol and an associated US$0.028/liter of electricity equivalent, totaling US$0.068/liter, would be required for a 100% substitution of Zambia's current annual gasoline consumption of 215 million liters; this would generate about US$21.5 million

[9] For efficient boilers, 125 KWh electricity can be generated per ton of sugarcane (BNDES and CGEE, 2008). At 80 litres of ethanol per ton of sugarcane, this translates to US$0.028 CDM revenue per litre of ethanol.

CDM revenue for Zambia. Similarly, a 100% substitution of Zambia's current annual diesel consumption of 460 million by Jatropha based biodiesel would generate around US$70 million CDM revenue. .

Table A8 in the Appendix estimates the total investment required to produce biofuels only for a 100% substitution of what Zambia consumed in 2010. It is as US$534 million, based on sugarcane and Jatropha as feedstocks. This amount does not include support for infrastructure development for the industry.

6 Factors Affecting Feedstock Selection

The factors important for biofuels feedstocks in Zambia include ownership of the biofuels wealth at national and individual levels, appropriate production technology and costs, job creation, resilience against external disturbances, diversity of products, size of investment, market access, land and water requirements, food security, environmental footprints. These factors help determine to what extent the biofuels industry would be sustainable in Zambia. Below are some of the considerations that may determine choice of feedstocks for biofuels in Zambia:

Production cost: Based on production costs indicated in tables A1 to A4, all feedstocks cost less than 1 US$, with the most expensive being sunflower (US$0.952/liter) for biodiesel and Agave *tequilana* (US$0.680) for ethanol. The more expensive the feedstock, the less attractive it is from both government's (due to reduced tax revenues) and producers' (due to low profit margins) perspectives. However, the government policy in support of a feedstock may target more than just direct tax revenues, as other issues may play larger effects. Therefore, a broad view including impact of a feedstock production on upstream and downstream socio-economic activities in the country is important.

Production size: The degree of participation in feedstock production depends on a number of factors. For example, sugarcane (1500 to 2500 mm per crop) and oil palm (5 mm/day) which require large amounts of water favor only those people with access to water resources and large capital to invest in irrigation facilities. These feedstocks are exclusive in this sense. Government support policies may however be attracted by high biofuels yields (8,800 l/Ha sugarcane and 4,800 l/Ha oil palm) and therefore less land used, and also the diversified economy due to valuable byproducts including food, feed, bioelectricity, fertilizer and building material.

Socioeconomic (pro-poor / low-input feedstock): The government policy under Policy Measures on Biomass, Section 5.2.2.2 item (viii) on Biofuels Programme states (MEWD, 2008): "*Facilitating funding to local investors and farmers to promote equity participation in the biofuels programme*". This means feedstocks such as sweet sorghum, agave, cassava, Jatropha and castor which are low capital, low management, low water and low fertilizer feedstocks. These feedstocks are therefore highly participatory by all socio-economic strata of society so that their promotion would reduce poverty in rural areas. Sorghum, cassava, Jatropha and castor are already being grown by rural communities. Policies should therefore strongly support these feedstocks while investing in developing their high yield varieties to reduce on land requirements.

Revenue diversification: Feedstocks with highly diversified byproducts (Tables A4 and A6) are good for spurring upstream and downstream industries. Evidence in Brazil and the USA shows that biofuels industry also results in significant related upstream and downstream industries. In 2009 the U.S. ethanol industry contributed over $53 billion in GDP to the economy while the Canadian industry added over $3 billion to the economy and created over 14,000 new direct and indirect jobs (GRFA, 2010). When in 2009 the US government delayed in extending incentives, the biofuels industry there reduced production which led to a decline in output throughout the entire economy. Consequently, real GDP was reduced by US$879 million (2009$), household income was reduced by US$485 million, and 8,900 out of 21,300 jobs were lost throughout 2010 (Urbanchu, 2011). In Brazil an economic assessment of the sugar cane sector in 2008 recorded huge gains in upstream, mainstream and downstream industries. The sector alone grossed US$ 86.83 billion based on 8.49 million hectares used in the country, netting an average of US$10,227/hectare (Neves et al., 2010).

As can be observed from the various criteria above, it is clear that Zambia is likely to take a combination of factors to maximize benefits from the industry. High yielding but water demanding feedstocks should be promoted within the allowable resources which take into account competing interests. Pro-poor / participatory feedstocks should also be promoted country-wide to develop rural areas, reduce poverty and improve access to modern forms of energy.

From the private sector perpective, however, medium to large scale investors are likely to target high-yielding but low cost feedstocks such as sugarcane, cassava and Agave for bioethanol and palm for biodiesel to maximize returns on investments. Soybeans may also be of interest due to its internationally sought-after meal for livestock and poultry industries.

7 Biofuels and Food Security in Zambia

One of the key concerns related to the large-scale expansion of biofuel is its conflict with food supply. However, Zambia is among the few countries which may not be impacted with this issue as the country does not have constraint on availability of productive agriculture lands (see Section 3 for more discussion). In Zambia, there are a number of people able to feed themselves but not able to, for instance, pay for school for their children and health care for their household, nor to participate in greater national economy. Although the country passes 45 years after its independence, 64% of the population is still below poverty line despite the rich resources that the country possesses (World Factbook, 2012). The farming infrastructure is poorly developed, and the costs of farming inputs (other than labor) increase with distance away from urban centers while prices of rural agricultural produce decrease with distance away from these centers (Cortez, et al. 2010).

The conditions as described above are markedly different from especially industrialized countries where it does not matter where foods and other goods and services are produced, they will generally reach the rest of the country efficiently and the costs of those foods, goods and services will generally be the same throughout the country. This is one very important factor which makes biofuels versus other competing interests a location specific issue rather than a global issue.

Globally, there is a direct link between petroleum prices and the food prices (GRAF, 2011). This is true in Zambia too -- increases in prices of food and other commodities whenever there are increases in petroleum prices (Chanda, 2011). The impacts of increased petroleum prices can be shielded if petroleum products are substituted with domestically produced biofuels. It is expected that biofuels industry could enhance household/national income in Zambia, especially for rural communities where feedstocks are to be grown. If the expenditure on petroleum imports is spent on domestic biofuel industry, it would significantly spill over throughout the economy, particularly, rural and low income households (Urbanchu, 2011; Neves *et al*., 2010).

Production of biofuels not necessarily decreases food supply is also demonstrated in other countries. Take an example of Brazil where productions of food as well as biofuels are ever increasing since 1990. The FAO crop statistics show that Brazil ranks top in producing several food crops. The development of biofuels industry in Zambia should learn from Brazilian experience (Sinkala and Mulenga, 2008; Pioneer, 2007).

8 Conclusions and Final Remarks

Zambia's climatic and agronomic conditions can accommodate a large number of tropical and sub-tropical crops which can be exploited for production of biofuels without negatively affecting food supply. This study shows that production of biofuels is economically attractive compared to imported gasoline and diesel in Zambia. The production costs of biofuels from most feedstocks are competitive to current prices of petroleum products in Zambia. Another comparative advantage of Zambia on biofuels is that the country does not have land constraints. A small fraction of agriculture lands could produce biofuels to meet the entire national demand thereby substituting petroleum products which is entirely imported otherwise.

The production of biofuels could enhance rather than reduce food security by increasing productivity through changing farming practices. It could enhance local economy by generating jobs to local population and markets to agriculture commodities which do not have market access at present.

The high cost of finance (16% or more) is one of the key barriers to the development of any new and emerging industries in Zambia. One option to reduce the financial barriers is to find markets for bi-products of biofuel industry. One of the bi-products is GHG mitigation through the substitution of petroleum products with biofuels. For example, if GHG mitigation caused by increased production of biofuels in Zambia could be sold to carbon market at a price of US$20/t$CO_2$, the total investment required by biofuel industry could be offset by more than 15% irrespective of the type of feedstock used for biofuels.

Regarding the selection of feedstock for biofuels in Zambia, several factors may influence depending upon the diverse interests of market participants. Medium to large scale investors are likely to target high yielding feedstocks such as sugarcane and oil palm to maximize earnings, while small scale participants are likely to engage in low input drought tolerant feedstocks such as sweet sorghum, cassava, Jatropha and castor which can grow in most parts of Zambia. Small scale participation might have a better fit to rural development policy of the Zambian government which “seeks to increase access to affordable energy in rural areas to reduce poverty and promote economic growth”.

References

Asia-Pacific Economic Cooperation (APEC) (2010). Biofuel Costs, Technologies and Economics in APEC Economies. www.biofuels.apec.org/pdfs/ewg_2010_biofuel-production-cost.pdf

Asia-Pacific Economic Cooperation (APEC) (2010). A Study of Employment Opportunities from Biofuel Production in Asia Pacific Economic Cooperation (APEC) countries. www.biofuels.apec.org/pdfs/ewg_2010_biofuels_employment.pdf.

Barley D.A. (2009). “The viability of sweet sorghum as a bioenergy crop in Zambia”. MSc. Thesis, Faculty of Engineering, Imperial College London, SW7 2AZ, UK.

Biofuels Association of Zambia (BAZ) (2011). Information from various BAZ documents and meetings. (2006 – 2011).

Bio-Era (2009). “U.S. Economic Impact of Advanced Biofuels Production”. February.

Banco Nacional de Desenvolvimento Econômico e Social of Brazil (BNDES) and Centro de Gestão e Estudos Estratégicos of Brazil (CGEE) (2008). “Sugarcane-Based Bioethanol – energy for sustainable development”. 1st Edition. November. www.sugarcanebioethanol.org

Chanda, G. (2011). "Expert predicts rise in fertiliser prices". Article published in the Post Newspaper. Tuesday 29th March. http://www.postzambia.com/post-read_article.php?articleId=19369

Cortez L, Leal MRLV and Sinkala T. (2010). "Why biofuels are important". In "Food versus Fuel – an informed introduction to biofuels", Frank Rosillo-Calle and Francis X. Johnsson (Eds.), Zed Books, London and New York, ISBN 978—1-84813-383-9.

Freim, L-O. (2008). "How will small scale farmers in Zambia benefit from growing of Jathatropha?". MSc. Thesis. Norwegian University of Life Sciences/Noragric/Development studies. http://www.umb.no/noragric/article/masters-theses-2008/.

FGV Projetos (2011). "Feasibility study for biofuels and food production in Republic of Zambia". A progress presentation. http://fgvprojetos.fgv.br/en/publicacoes

Global Renewable Fuels Alliance (GRFA) (2010). "Al Gore's Flip Flop on Biofuels". Press Release, November 24. http://www.globalrfa.com/pr_112410.php.

Global Renewable Fuels Alliance (GRFA) (2011). "Qatar's Comments on Biofuels are Self Serving: GRFA". Press Release, September 27. http://www.globalrfa.com.

International Energy Agency (IEA) (2011). "Technology Roadmap - biofuels for transport". www.iea.org/papers/2011/biofuels_roadmap.pdf.

International Energy Agency (IEA) (2011b). "World Energy Outlook 2011 Factsheet". International Energy Agency. http://www.iea.org/weo/docs/weo2011/factsheets.pdf.

Energy Regulation Board of Zambia (PRB) (2011). "Petroleum Industry Statistics". http://www.erb.org.zm/content.php?viewpage=erffs

Lungu L.H. (2011). "Government Renewable Energy Programmes". A Presentation at Renewable Energy Forum, Intercontinental Hotel, Lusaka. 24-25 August 2011.

Louw, R. and Andrews, J. (undated). "Exploring CDM Opportunities in Biofuels". www.ascension-publishing.com/BIZ/4ABAndrews.ppt

Matsika, E., Yamba, F., Munyinda, K. (2006). Harnessing sweet sorghum for bio-energy in Zambia. Energy for Renewable Development, 19 (3).

Menne, W., Gilbertson, T., Anderson, T., Maina, A. and Smolker, R. (2011). "The CDM and Africa: Marketing a new land grab". Briefing by the African Biodiversity Network, Biofuelwatch, Carbon Trade Watch, the Gaia Foundation and the Timberwatch Coalition. February.

Ministry of Energy and Water Development (MEWD) (2008a). "National Energy Policy". MEWD, Government of the Republic of Zambia, Lusaka.

Ministry of Energy and Water Development (MEWD) (2008b). "Zambia National Energy Strategy: 2008-2030". MEWD, Government of the Republic of Zambia, Lusaka.

Ministry of Energy and Water Development (2011). "Press Statement on Government Programme for Blending of Biofuels with Petroleum Products". Ministry of Energy and Water Development (MEWD), Government of the Republic of Zambia.

Mitchell, D. (2010). Biofuels in Africa: Opportunities, Prospects, and Challenges. World Bank, Washington, DC. http://africaknowledgelab.worldbank.org/akl/node/67.

Mtomba, V. (2011). "Ethanol Rules Outlined". In Newsday. 8th December. http://www.newsday.co.zw/article/2011-12-08-ethanol-rules-outlined/.

Neves, M.F., Trombinb V.G. and Consolic, M.A. (2010). "Measurement of Sugarcane Chain in Brazil". International Food and Agribusiness Management Review 13 (3): 37-54.

Okyere et. al. (2011). "Understanding the interaction between farm labor productivity, and health and nutrition: a survey of the evidence". Journal of Development and Agriculture Economics 3(3): 80-90.

Patriotic Front (2011). "Patriotic Front 2011 – 2016 Manifesto". The Manifesto of the party in Government for the period September 2011 to August 2016.

Petrobras (2008). "Petrobras´Strategy on Biofuels". Presented at the Deutsche Bank meeting. Sao Paolo, Brazil.

Pioneer (2007). "Food, Feed, Fuel and Fiber: meeting the challenge for increased grain production". Pioneer Hi-Bred International, Inc. January. http://www.pioneer.com/pv_obj_cache/pv_obj_id_E308B85B73E59A89E5AC7B039215C7FFD0EA0B00/filename/ProdChallenge.pdf

Pope, A. and Chitembo, A. (2009). "Report on deliberations of the workshop for the "Establishment of the Zambia National Sugar Strategy". Presentation in a Conference held at the Cresta Golfview Hotel, Lusaka on 11th March 2009.

Radich A. *(Undated).* "Biodiesel Performance, Costs and Use". Energy Information Administration of the USA. http://www.eia.gov/oiaf/analysispaper/biodiesel/.

Remvos N. (2011). "Potential for bioethanol production in Zambia". November 10. http://esse-community.eu/articles/potential-for-bioethanol-production-in-zambia/

Rennó M. *(Undated).* "Overview of the pipeline industry in Brazil: capturing pipeline opportunities". Pipeline committee, Brazilian petroleum, gas, and biofuels institute. http://www.braziltexas.org/attachments/contentmanagers/767/Capturing-Pipeline-Opps-in-Brazil.pdf

Sustainable Energy Africa (SEA) (2009). "Waste to Energy, South Africa". SEA. http://www.cityenergy.org.za/files/resources/implementation/08Waste.pdf.

SEED-CO. (2010). "Agricultural Crop Planner: *2010 – 2011 Season*". Published by SEED-CO, Box 35310 Lusaka, Zambia.

Shumaker, G., McKissick, J.C. and Smith, N. (2007). "Economics of Peanuts for Biodiesel Production". The University of Georgia, Center for Agribusiness and Economic Development, College of Agricultural and Environmental Sciences. Center Report # CR-07-04. February 2007.

Sinkala, T. (2011a). "The Current Status and Development of Biofuels Industry in Zambia". Presented at the Renewable Energy Forum organized by the Energy Regulations Board, Intercontinental Hotel, Lusaka, Zambia. August 24 – 25.

Sinkala, T. (2011b). "Biofuels Development in Africa: *Technology Options and Related Policy and Regulatory Issues*". United Nations Economic Commission for Africa - Regional Integration, Infrastructure and Trade Division. Addis Ababa, Ethiopia.

Sinkala, T. (2011c). "Biofuels potentials, market opportunities and barriers". Presented at the United Nations Economic Commission for Africa Conference on Strategy for Promoting Renewable Energy in Southern Africa. Birchwood Hotel, Johannesburg, South Africa. 28 - 29 November 2011.

Sinkala, T. and Chitembo, A. (2007). "An analysis of the global Jatropha industry and an in-depth case study of the value chain for jatropha in Zambia". International Labour Organisation (ILO). Geneva, Switzerland.

Sinkala, T. (2008). "Liquid Biofuels as a Viable Alternative to Fossil Fuels". Working paper for the Global Renewable Energy Forum, a joint activity of the United Nations Industrial Development Organization and the Brazilian Ministry of Mines and Energy, Foz do Iguaçu, Brazil. 18-21 May. For the United Nations Industrial Development Organization.

Sinkala, T. and Mulenga, C. (2008). "Report of the Tour of Liquid Biofuels Industry in Brazil". Joint report by the Ministry of Energy and Water Development and Biofuels Association of Zambia. Lusuka.

Strauss, J. (1986). "Does better nutrition raise farm productivity?" The Journal of Political Economy 94 (2): 297 – 320.

The Independent (2012). "Ethanol fuel prices explained". http://www.theindependent.co.zw/local/35439-ethanol-fuel-prices-explained.html?

United Nations Framework Convention on Climate Change (UNFCCC) (2007). "Approved baseline and monitoring methodology AM0047 *'Production of biodiesel from waste oils and/or waste fats from biogenic origin and/or biodiesel from oil seeds grown on unutilised, or marginal lands which had uneconomical agricultural productivity (if any)'* ". AM0047 / Version 02 Sectoral Scopes: 01 and 05 EB 3.

http://cdm.unfccc.int/filestorage/7/4/S/74SY45R4IJ904NOKQQURIAKY4GR0UP/Draft%20AM.pdf?t=SkN8bHU3ZmE1fDD-vgRbX2r5CZAR1DBof6zG.

Urbanchu, J.M. (2011). "Economic impact of removing the Biodiesel Tax Credit for 2010 and implementation of RFS2 targets through 2015". www.biodiesel.org/news/pressreleases/supporting_docs/20110615_Economic%20Impact.pdf.

Varming, S. and Dutschke, M. (2008). "CDM is Promoting Sustainable Palm Oil". Guest commentary in Point Carbon Newsletter, CDM & JI Monitor 14 May. http://www.ytl-svcarbon.com/news.php?newsID=19.

Walimwipi. 2008. "Biofuels development in Africa". Compiled for the ICS-UNIDO 6-month training, on attatchment to the German Biomass Research Centre, Torgauer Straße 116, 04347 Leipzig, Germany.

Yamba F.D. (2011). "Integrated approach for well-informed biofuels policy and business decisions". Presented at the Renewable Energy Forum organized by the Energy Regulations Board, Intercontinental Hotel, Lusaka, Zambia. August 24 – 25. http://www.erb.org.zm.

Zambia National Farmers Union (ZNFU) (2011). "Enterprise Budgets". ZNFU, Lusaka. www.znfu.org.zm.

Appendix

Table A1: Bioethanol Feedstock Costs with and without CDM credits

ITEM	**AMOUNT (US$/Ha)**			
	Sugar cane	**Sweet sorghum**	**Cassava**	**Agave *tequilana***
VARIABLE COSTS				
Land preparation			62.61	
Seeds/Seedlings/Cuttings	1,200.00	12.37	112.70	1,949.85
Hand planting seedlings / cuttings	130.00	123.48	25.04	
Herbicides / Weedcides Insecticide	12.00		87.65	
Fertilisers	800.00	251.94	165.91	
Weeding			62.61	
Harvesting			109.57	
Water Management	155.00			
Labor	113.40	41.24		
Operational Expenses				2,454.23
Insurance	38.50	11.20	32.47	28.00
Transport in-field (US$0.2/Km, 5Km average)	110.00	40.00	25.00	
Repair and maintenance	90.00	65.72	41.24	
Total Variable Costs (TVC)	**2,648.90**	**545.96**	**524.45**	**4,432.07**
Overhead (Mgt + Other) costs: 15% of TVC	397.34	81.89	78.67	221.60
Sub-Total	**3,046.24**	**627.85**	**603.12**	**4,653.67**
Interest on borrowed money (10% of Sub-Total)	304.62	62.79	60.31	465.37
TOTAL Cost Per Ha	**3,350.86**	**690.64**	**663.43**	**5,119.04**
Cost @ 16% interest NO CDM, (US$/Litre) =	**0.542**	**0.545**	**0.360**	**0.680**
Cost @ 10% interest NO CDM, (US$/Litre) =	**0.521**	**0.524**	**0.353**	**0.652**
Price reduction, (%) =	**4**	**4**	**2**	**4**
Cost @ 10% interest WITH CDM, (US$/Litre) =	**0.453**	**0.43**	**0.301**	**0.594**
Contribution by CDM credit, (%)	*13*	*18*	*15*	*9*
Cost @ 16% interest WITH CDM, (US$/Litre) =	**0.473**	**0.455**	**0.309**	**0.622**
Contribution by CDM credit, (%)	***13***	***17***	***14***	***9***

Table A2: Production costs for BIOETHANOL from various sugar/starch crops in Zambia

Cost Item	Sugarcane	Sweet sorghum	Cassava	Agave Tequilana
Feedstock unit cost, US$/Litre	0.381	0.384	0.09	0.512
Capital cost + interest, US$/Litre	0.000	0.000	0.06	0.000
Chemicals/enzymes, US$/Litre	0.060	0.060	0.02	0.060
Energy/Utility, US$/Litre	0.020	0.020	0.09	0.020
Operations / Maintenance, US$/Litre	0.040	0.040	0.03	0.040
Unforeseen, US$/Litre	0.020	0.020	0.02	0.020
Total, US$/Litre @ 10% interest =	**0.521**	**0.524**	**0.353**	**0.652**
Total, US$/Litre @ 16% interest =	**0.542**	**0.545**	**0.360**	**0.680**
Total, US$/Litre @ 10% interest, CDM =	**0.453**	**0.434**	**0.301**	**0.594**
Total, US$/Litre @ 16% interest, CDM =	**0.473**	**0.455**	**0.309**	**0.622**
Yield, (Metric Tons/Ha)	110	40	25	80
Yield, (Litres/Metric Ton)	80	45	200	125
Yield, (Litres/Ha)	8,800	1,800	5,000	10,000
Water Requirement, mm	1500 - 2500	450 to 700	400 - 750	500
Fertilizer Requirement, Kg/Ha	300 basal & 250 kg urea	N 75-150 P 30-60, K 60-120.	NPK N20:P10:K10, 9 (50 kg) bags	150 – 350 Kg Urea (if necessary)
Gestation Period, (months)	12 - 14	4 – 4.3	10	60 - 72
Immediate Revenue Diversification	Food, Cogen, Fertiliser	Food, Cogen, Fertiliser	Food, Feeds, Biogas, Cogen	Food, Biogas, Cogen, Fertiliser

SOURCES:

http://www.keralaagriculture.gov.in/htmle/irrigation/criticalgrowthstg.html
http://www.fao.org/docrep/S2022E/s2022e02.htm
http://www.tabef.or.tz/wp-content/uploads/2011/10/Sugar-cane-outgrower-publication-WWF_Final_low-res.pdf

Table A3: Biodiesel Feedstock Costs with and without CDM credits

ITEM	AMOUNT (US$/Ha)					
	Soy	**Palm**	**Jatropha**	**Groundnut**	**Castor**	**Sunflower**
VARIABLE COSTS						
Seeds/Seedlings/Cuttings	180.12	120.00	41.24	37.11	9	46.19
Hand planting seedlings / cuttings		274.00	20.62			
Herbicides / Weedcides Insecticide	383.12		78.35	165.17		54.02
Fertilizers + applications	255.67	116.95	51.55	835.09		255.05
Weeding		57.48	20.62			
Pruning		27.63				
Replacement of dead palms		12.99				
Road maintenance		27.38				
Harvesting and collection	171.69		556.70			
Harvesting tools	12.86					
Water Management						
Fuels/Oils	42.89		62.68	139.79	15.67	131.96
Combine / tractor hire	85.00				164.95	85.00
Electricity	36.75					
Labor	65.98			301.03	259.79	220.61
Transport on-farm (US$0.2/Km, 5Km average)	6.27	121.67	6.27	6.27	6.27	6.27
Repair & maintenance	7.84					
Insurance	13.25	33.33	6.93	32.47	5.60	2.60
Total Variable Costs (TVC)	**1,126.48**	**975.98**	**844.95**	**1,516.94**	**461.28**	**863.24**
Overhead (Mgt + Other) costs: 15% of TVC	**168.97**	**146.40**	**126.74**	**227.54**	**69.19**	**129.49**
Sub-Total	**1,295.45**	**1,122.37**	**971.69**	**1,744.49**	**530.47**	**992.72**
Interest on money (10% of Sub-Total)	129.55	112.24	97.17	174.45	53.05	99.27
TOTAL Cost Per Ha	**1,425.00**	**1,234.61**	**1,068.86**	**1,918.93**	**583.52**	**1,092.00**
Cost @ 16% interest, (US$/Litre) =	**0.655**	**0.612**	**0.677**	**0.761**	**0.792**	**0.952**
Cost @ 10% interest, (US$/Litre) =	**0.635**	**0.594**	**0.669**	**0.741**	**0.772**	**0.918**
Cost reduction, (%) =	3	3	1	3	3	4

***NOTE**: The blank spaces shown under each feedstock are because either inputs are not applicable or costs were grouped into other cost centres by sources of information*

Table A4: Production costs for BIODIESEL from various oil crops in Zambia

Cost Item	Soy	Palm	Jatropha	Ground nut	Castor	Sunflower
Feedstock unit cost, US$/Litre	0.429	0.426	0.459	0.521	0.562	0.698
Capital cost + interest, US$/Litre	0.090	0.000	0.090	0.090	0.090	0.090
Chemicals/enzymes, US$/Litre	0.050	0.100	0.050	0.050	0.050	0.050
Energy/Utility, US$/Litre	0.010	0.020	0.010	0.010	0.010	0.010
Ops / Maintenance, US$/Litre	0.050	0.100	0.040	0.050	0.040	0.050
Unforeseen, US$/Litre	0.020	0.020	0.020	0.020	0.020	0.020
Total, US$/Litre @ 10% interest =	**0.635**	**0.594**	**0.669**	**0.741**	**0.772**	**0.918**
Total, US$/Litre @ 16% interest =	**0.655**	**0.612**	**0.677**	**0.761**	**0.792**	**0.952**
Yield, (Metric Tons /Ha)	3.5	15.8	6.0	5.0	1.0	2.0
Yield, (Litres/Metric Ton)	196	304*	300	522	489	398
Yield, (Litres/Ha)	686	4,803	1,800	2,610	489	796
Water Requirement, mm	450 - 700	3 – 5mm per day during hot-dry season	500 - 600	500 - 700	500-600	600 -1000
Fertilizer Requirement, (Per Ha)	250 Basal, 100 Urea	N170-230, P70-90, K220-310 per Year	2.5 t chicken / organic manure	200 Basal, 250 Gypsum	N40,P40, K20	200 Basal, 150 Urea.
Gestation Period, (months)	4.5 to 5	24 – 30	24 - 36	4.3 – 4.7	4 - 6	4.2 to 4.5
Immediate Revenue Diversification	Food, Feed	Food, Cogen, Fodder, Building, Furniture	Feed, Biogas, Cogen, Fertiliser	Food, Feed	Fertiliser	Food, Feed

** **PO** = Palm Oil = 239 Litres/t bunches, **PKO** = Palm Kernel Oil = 65 Litres/t bunches*
Density of vegetable oils is 0.92 gram/ml = 1,087 litres/ton of vegetable oil (Mitchell, 2010).

Table A5: Structure of petroleum prices in Zambia
(Unit: Local currency per liter unless specified otherwise)

	Cost element	Gasoline	Diesel	Kerosene
Wholesale Price	Feedstock cargo	3.77	4.44	4.07
	Others	0.11	0.12	0.11
	Finance charges	0.11	0.12	0.11
	TAZAMA pumping fee	0.21	0.25	0.23
	TAZAMA pipeline losses	0.05	0.06	0.06
	Import duty	0.21	0.25	0.23
	Refinery fee	0.26	0.31	0.28
	Refinery losses	0.52	0.62	0.57
Pump Price	Ndola Fuel Terminal	0.03	0.03	0.03
	Excise Duty + VAT	3.25	1.89	0.00
	Transporter's margin	0.24	0.26	0.21
	Oil Marketing Company margin	0.48	0.48	0.53
	Dealer/Retail marging	0.32	0.32	0.35
	ERB fees	0.06	0.06	0.05
	Strategic Reserves Fund	0.29	0.00	0.00
	UPP (Uniform Pump Pricing) pump price	**9.91**	**9.20**	6.83
	Wholesale price	**5.24**	**6.16**	**5.66**
	Wholesale price (US$/liter)	**0.99**	**1.16**	**1.07**

Source: http://www.erb.org.zm/reports/ERBStatusReportPetroleumSector.pdf; and http://www.erb.org.zm/press/statements/Fuel%20Price%20Adjustment%20Statement2013April.pdf

Table A6: Land requirements for different fuel substitutions in Zambia

Feedstock	Yield	Target Fuel	2010 Fuel Consumption	Land Required for 100% Substitution (Ha)	Land Required for B5 and B10 (Ha)
					B5 Land
Palm	4,803	Diesel	460,000,000	95,773	4,789
Groundnut	2,610	Diesel	460,000,000	176,245	8,812
Jatropha	1,800	Diesel	460,000,000	255,556	12,778
Sunflower	796	Diesel	460,000,000	577,889	28,894
Soy	686	Diesel	460,000,000	670,554	33,528
Castor	489	Diesel	460,000,000	940,695	47,035
					E10 Land
Agave	10,000	Gasoline	215,000,000	21,500	2,150
Sugarcane	8,800	Gasoline	215,000,000	24,432	2,443
Cassava	5,000	Gasoline	215,000,000	43,000	4,300
Sweet sorghum	1,800	Gasoline	215,000,000	119,444	11,944
Jatropha	1,800	Kerosene	22,000,000	12,222	***100% Replacement***

Table A7: Land ratio for SADC region as target market at B5 and E5

Feedstock	Yield/Ha	Target Fuel	B5/E5 Consumption (Litres)	Ha
Palm	4,803	Biodiesel	1,500,000,000	312,305
Groundnut	2,610	Biodiesel	1,500,000,000	574,713
Jatropha	1,800	Biodiesel	1,500,000,000	833,333
Sunflower	796	Biodiesel	1,500,000,000	1,884,422
Soy	686	Biodiesel	1,500,000,000	2,186,589
Castor	489	Biodiesel	1,500,000,000	3,067,485
Agave	10,000	Bioethanol	700,000,000	70,000
Sugarcane	8,800	Bioethanol	700,000,000	79,545
Cassava	5,000	Bioethanol	700,000,000	140,000
Sweet sorghum	1,800	Bioethanol	700,000,000	388,889

Table A8: Level of financial support for biofuel production only

100% substitution gasoline consumption of Zambia in 2010	215,million liters
Energy equivalent volume of ethanol needed (1 liter ethanol = 0.68 liter of gasoline in energy equivalent term)	316.2 million liters
Cost per litre of sugarcane based bioethanol	0.542 US$
Investment amount required, US$	**171.4 million US$**
CDM revenue per litre of ethanol at carbon price of US$20/t$CO_2$	0.068 US$
Total CDM revenue that can be generated	21.5 million US$
100% substitution diesel consumption of Zambia in 2010	460 million liters
Energy equivalent volume of biodiesel needed (1 liter biodiesel= 0.86 liter of diesel in energy equivalent term)	534.9 million liters
Cost per litre of Jatropha based biodiesel	0.677 US$
Investment amount required	**362.12 million US$**
CDM revenue per litre of biodiesel at carbon price of US$20/t$CO_2$	0.130US$
Total CDM revenue that can be received for biodiesel	69.53 million US$
TOTAL Investment for biofuels production ONLY, US$	**533.48 million US$**
TOTAL CDM revenue	91.03 million US$
CDM revenue as percentage of total investment	**17%**