



An Economic Assessment of Bioethanol Production from Sugar Cane: The Case of South Africa

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Abstract

The destabilising economic impact of South Africa's dependence on imported crude oil is a key motivation behind the country's drive to develop a biofuel industry. Much concern has been raised over the impact of biofuels production on price of food for the country's poor. It is this concern that has seen the prohibition of maize and the favouring of sugar cane as a feedstock in South Africa's Biofuels Industrial Strategy. This paper sets out to analyse the economic feasibility of producing bioethanol from sugar based on the industry's efforts to diversify its market base. The study suggests that bioethanol production is financially viable at an average US\$102/bbl for the period 2005-2015, based on estimates that producers typically pay the equivalent of US\$67/bbl for sugar cane feedstock, incur approximately US\$20/bbl in operating & maintenance costs and require the equivalent of US\$15/bbl to recoup capital investments. To kick-start the commercial production of fuel grade ethanol in South Africa, producers require mandated subsidisation. State support for bioethanol producers in the form of a guaranteed minimum selling price for bioethanol of 95 percent of the basic fuel price, exemption from fuel taxes in addition to specific capital investment allowances are required.

Keywords: Biofuels, Costing, South Africa

JEL Classification: Q42

1 Introduction

Most environmental activists argue that continued economic growth is incompatible with ecological safety (Burton, 2015). Furthermore, the decoupling of economic activity from the consumption of fossil fuels is seen by many as a desirable development in the pursuit of sustainable economic growth (Mulder & de Groot, 2004). The need for alternative sources of fuel to crude oil are persistent

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issues globally. Besides hydrogen, bioethanol and biodiesel are the only viable substitutes for mineral based transport fuels. These biofuels contribute approximately 2 percent of total global transport fuel (IEA, 2011). Bioethanol also known as ethyl or grain alcohol is a petrol substitute processed from the fermentation of starch based crops. These crops, namely: maize, barley, wheat, sugar cane, sugar beet and sorghum are well suited for use as vehicle fuels. Bioethanol and synthetic (petroleum based) ethanol are chemically indistinguishable in that they are both the same chemical compound, namely: C_2H_5OH . The only difference between the two is the isotopic composition of their carbon atoms.

Internationally, bioethanol is the most widely used vehicle fuel alternative to petroleum based on its popularity in the Americas. In Brazil, the successful establishment of the sugar cane to ethanol fuel industry resulted in the majority of motor vehicles there being fuelled from bioethanol derived from sugar. Bioethanol contributed to South Africa's liquid fuel resources between the 1930's and late 1960's, but ensuing cheap and abundant crude oil rendered the industry not viable (Cartwright, 2007). South Africa still produces small amounts of bioethanol by fermenting the molasses that it produces as a by-product of its sugar industry. This bioethanol is not, however, used in fuels but as an alcohol, in inks and paints, and by the pharmaceutical industry (Cartwright, 2007). Between 55 and 75 percent of this bioethanol is exported, mainly to African countries and to Europe. Estimates by the Ethanol Producers Association of Southern Africa (EPASA, 2013) suggest that up to 2 percent of South Africa's liquid fuel requirements, approximately 400 million litres could potentially be supplied from ethanol manufactured from sugar currently exported to world markets.

Whilst enthusiasm for increased biofuel production is countered by food security concerns (Braude, 2014) and ecological fears associated with the expansion of land and water intensive biofuel crops (Allouche, 2011), South Africa has nonetheless been party to the recent resurgent global interest in biofuels production (Brent, 2014). The renewed interest in 'cleaner' fuel alternatives is largely driven by international environmental concerns related to reducing carbon and other greenhouse gas (GHG) emissions (IEA, 2011). The substitutability of bioethanol for petroleum use presents crude oil dependent economies such as South Africa with the additional opportunity for greater energy security from the volatile price trends and supply-side uncertainties associated with the international crude oil market. This paper sets out to analyse the economic feasibility of producing bioethanol from sugar based on the South African sugar industry's efforts to diversify its product market base. Specifically the paper assesses the economic viability of a targeted approach by the sugar industry to redirect its annual sugar cane crop from producing sugar for the export market (where it faces increasing international competition from lower cost producers) toward bioethanol production for the local market. This diversification is important in ensuring the long-term financial survival of the sugar industry.

The rest of the paper is set out as follows. Section two provides an overview of the global production of biofuels, South Africa's liquid fuel requirements and biofuel policies. Section three undertakes an economic assessment of diversifi-

cation efforts by the South African sugar industry into bioethanol production based on world crude oil and international sugar market developments. Section four summarises the findings of the study and provides the reader with policy considerations in as far as promoting South African bioethanol production.

2 Background to South Africa's Bioethanol Production

According to the U.S. Energy Information Administration (EIA), the worldwide production of biofuels has grown constantly from about 1 billion litres (6,3 million barrels) in 1981 to over 120 billion litres (757.2 million barrels) in 2014 (Figure 1). Over this period, global production of fuel ethanol and biodiesel has increased by a staggering 10,458 and 26,335 percent, respectively. The global biofuel production is projected to reach 200 billion litres by 2020, with fuel ethanol and biodiesel shares of 75 percent and 25 percent, respectively (EIA, 2014). In 2014, biofuels provided around 4 percent of total fuel for road transportation worldwide and its projected share of world transport fuel by 2050 is estimated at 25 percent (IEA, 2011). The United States and Brazil are the top producers of biofuels globally whilst South Africa's share of global biofuel production is smaller than 0.01 percent.

Many countries worldwide have established biofuel targets and adopted mandatory biofuel policies in an attempt to mitigate the effects of global climate change and address energy security concerns related to fossil fuel dependency. The bulk of these biofuel mandates are for countries within the European Union (EU), where the Renewable Energy Directive (RED) had initially specified a 10 percent renewable content by 2020, this directive has since been scaled back to between 5 and 7.5 percent (Lane, 2014). Thirteen countries in the Americas have biofuel targets in place or under consideration, twelve in the Asia-Pacific region, eleven in Africa and the Indian Ocean, and two from non-EU countries in Europe (Lane, 2014). Besides those within the EU, the major blending mandates that influence worldwide demand and hence production in biofuels, are those set in the United States, China and Brazil. These countries have set targets (or as in the case of Brazil, has already attained a level) in the 15 to 25 percent range by 2020. Over the years, South Africa has tabled several biofuel policies, the most recent of which is the Biofuels Industrial Strategy. The strategy aims to promote the manufacture and use of renewable fuels, attract investment into rural agricultural development, and create additional employment in the country (DME, 2007).

South Africa consumes 0.7 percent of global petroleum, 0.4 percent of global diesel and 0.3 percent of global crude oil [EIA, 2014]. Viewed in a global context, South Africa's relatively low consumption of crude oil is as a result of the country's synthetic oil from coal production capacity. According to Chamdimba (2009), synthetic fuels in South Africa evolved from the political sanctions in the apartheid era that promoted the production of second generation, non-

renewable fuels from coal. Thirty percent of South Africa's liquid fuel requirement is produced in this manner by the former state owned company, SASOL. South Africa's proven oil reserves are about 2.4 billion litres (15096 thousand barrels) whereas the country's oil production was 28,9 million litres (182 thousand barrels) per day at the end of 2014 (BP, 2014). Based on these numbers, South Africa has limited crude oil reserves and imports a significant amount of oil to meet its domestic oil requirements. The country has an estimated reserve to production ratio of 0.23 years. This reserve to production ratio is the number of years for which the current level of production of fuel can be sustained by the country's crude oil reserves (Feygin & Satkin, 2004). South Africa's annual vehicle fuel consumption ranges between 20 and 25 billion litres and accounts for approximately a quarter of the country's total energy consumption in energy units yet 65 percent by value (DoE, 2014a). In 2014, expenditure on liquid fuels was the equivalent of 5 percent of the nation's US\$ 350 billion GDP value, tallying an amount of US\$ 48 million per day. Slightly less than 65 percent of South Africa's total liquid fuel consumption and 14 percent of the country's total energy consumption is derived from imported crude oil (DoE, 2014b). The bulk of these crude oil imports are from OPEC countries, with about half imported from Saudi Arabia followed by Nigeria (24 percent), Angola (14 percent), Ghana (5 percent), and small volumes from various producers (7%). Over 60 percent of products refined locally are produced from the imported crude oil and about 36 percent of the demand is met by coal and gas based synthetic fuels in addition to a very small amount of domestic crude oil (DoE, 2014c).

Crude oil is South Africa's most significant import item and at a value of US\$ 16 to 18 billion accounts for between 15 to 20 percent of total imports by the country per annum (SARB, 2009). In recent years South Africa's inflation rate has tracked changes in international oil prices, with inflation rising and remaining above the South African Reserve Bank's (SARB) mandated target of 6 percent for the twelve month period starting July 2007 till July 2008 when the crude oil price peaked at US\$ 132,83/bbl (SARB, 2009). This development necessitated a period of monetary policy contraction that saw the SARB hike the interest rate on eight sequential occasions. The country's fragile economic growth and employment creation efforts were dealt a severe blow during this period. According to Nkomo (2009), South Africa's high level of dependence on imported crude oil exposes the economy to potential events that interrupts supply and leads to higher oil prices that undermine economic growth and development. The most recent period of high crude oil prices in 2011 to mid 2014 (see Figure 2) has been cited by Wakeford (2013) as a contributing factor responsible for South Africa's widening trade deficit, higher rates of producer and consumer price inflation, lower growth in real GDP, falling employment and real wages, and greater poverty and inequality. The negative economic developments associated with South Africa's dependence on imported crude oil are without doubt a significant motivation behind the country's renewed efforts to develop a biofuel industry. South Africa is in dire need of alternative fuel sources to help it cope with energy security concerns and global emission commitments. Renewable fuels, such as biofuels, provide an opportunity to expand and diversify

South Africa's energy supply thereby reducing her foreign exchange expenditure and dependence on crude oil imports whilst at the same time reducing the size of the economy's carbon footprint.

The Biofuels Industrial Strategy approved by the South African government in November 2007, was largely responsible for the resurgent economic interest in the country's biofuel industry. The draft bill initially prescribed a target of 4.5 percent of liquid road transport fuel market penetration by 2013. This represented approximately half of South Africa's renewable energy target at that point in time. The strategy proposed statutory blending so as to ensure E10 blends for petrol and B5 blends for diesel. This mandate would have resulted in net market penetration rates of 8 percent for petrol and 2 percent for diesel (NBTT, 2006). In December 2007 on implementation of the Biofuels Industrial Strategy, the South African authorities however made a substantial and unanticipated adjustment to its biofuel ambitions. The revisions to the bill included lower mandated substitution targets of 2 percent of liquid fuels for all biofuels by 2013, equivalent to approximately 400 million litres per annum (DME, 2007). Whilst the Biofuel Industrial Strategy effectively enforced the introduction of biofuels into the South African fuel mix, the strategy focused on the country's poverty alleviation efforts rather than on specifically reducing dependence on crude oil imports (Brent, 2014). The South African Department of Minerals and Energy (DME) indicated that during the initial phases of the biofuel production programme it anticipated the creation of 25,000 additional jobs in rural farming. The strategy aimed at achieving a number of intended objectives including attracting investment in rural areas and promoting agricultural development through supporting previously disadvantaged farmers and communities. The strategy recommended sugar cane and sugar beet as feedstock for ethanol production; and sunflower, canola and soybeans for biodiesel production. The strategy however explicitly excluded maize as a potential biofuel feedstock citing concerns relating to food security and potential adverse impacts of possible price hikes in this staple food item of the country's poor (DME, 2007).

Motivated by its poverty alleviation efforts and agricultural employment creation target, the South African government recognised the need to subsidise the biofuels industry under the Biofuel Industrial Strategy (Brent, 2014). According to Braude (2014), mandated state support included, a 100 percent exemption from fuel taxes in the case of bioethanol production whereas biodiesel manufacturers were to receive a rebate of 50 percent on the general fuel levy. Various other criteria have since been published by the Department of Energy (DoE), in particular criteria for the granting and issuing of a biofuel manufacturing licence, and criteria to be met to become eligible for the respective biofuel production subsidies. In the South African Government Gazette (GG) 35623 of 23 August 2012 (DoE, 2012a), the government yet again revised regulations regarding the mandatory blending of biofuels with fossil fuels, allowing for 5 percent blending of biodiesel with diesel and a range of between 2 and 10 percent blending of ethanol with petrol. With the higher blending target of 10 percent, government hoped it could create about 125,000 direct jobs mainly

based in rural areas. In essence the revisions required the petroleum industry to purchase all of the biofuel produced from licensed biofuel producers, as from a specified implementation date at a regulated price. It was indicated that the latter would be published monthly and based on the Basic Fuel Price and certain other considerations. In Government Notice R 719 (GG 36890) the mandatory blending implementation date was published, as 1 October 2015 (DoE, 2013). This deadline has since been breached due to lack of timeous progress in the biofuel regulatory process and policy enactments of the DoE.

What is evident from a review of the literature is that the constraint relating to government's lack of regulatory certainty is a key factor retarding the commercial production of biofuels in South Africa. This finding is confirmed in studies by Van Zyl and Prior (2009) and Braude (2014). Indeed, Letete and Von Blottnitz (2012) highlight that no commercial biofuel plants have been established since the introduction of the country's Biofuels Industrial Strategy in 2007. According to Brent (2014), only biodiesel is currently being produced for the transport market by the more than 200 small-scale initiatives that use recycled vegetable oil, most of which were established long before the strategy was released in 2007. It is clear that in spite of the depth of the capital market and investment muscle of various sectors in the South African economy, the private sector has not felt sufficient certainty to invest in commercial biofuels production. South Africa's minister of energy alluded to this fact in early 2013, when he noted that incentives such as the respective 50 and 100 percent fuel tax exemptions for biodiesel and bioethanol manufacturers had been insufficient to lure investments into the biofuels sector. Furthermore it is noted in Fechter (2013) that government sees the need to establish a more enabling and supportive regulatory framework owing to the fact that biofuels projects in the country are not seen to be financially attractive at prevailing feedstock, crude oil and liquid fuel prices (Fechter, 2013). A supporting regulatory framework for renewable fuels is certainly not an irregularity as globally the liquid fuels market is highly regulated.

Bioethanol Production from Sugar Cane

According to the DoE (2012b) the analysis of potential commercial ethanol feedstocks in South Africa reveals that grain sorghum, maize and sugar cane are the leading contenders. Maize and sugar cane are among the country's most important agricultural crops. Sorghum on the other hand used to be cultivated extensively in South Africa, but production has declined in recent years along with local market demand. Typically, South Africa manages to export three million tons of maize over and above the eight million tons that are consumed locally every year (FAOSTAT, 2007). This maize surplus is however dependent on weather conditions and not guaranteed. The use of agricultural feedstock for the production of chemicals and fuel is a complex issue in the light of food security. In South Africa, it is accepted that biomass for industry should not compete with food crops (CeBER, 2016). The utilisation of bio-based feedstocks that are traditionally considered sources of food is generally met with skepticism globally and remains a controversial issue (see Murphy et al., 2011 and Stecher et al., 2013 in this regard). Given the importance of the annual maize crop

to the country's food security its use as a feedstock in ethanol production is currently banned under the country's mandated Biofuels Industrial Strategy. According to the U.S. Department of Energy (2014) only the biomass residues of maize may be considered as a feedstock for the production of biofuel and bio-based chemicals in most African countries. It is for this reason, that the assessment that follows is based on the use of sugar cane as the feedstock for the proposed commercial biofuel production in South Africa.

Globally, the sugar industry has seen a significant trend toward diversification of the sector (Illovo Sugar Ltd., 2014). The end result of such diversification is a situation where the sugar mill is transformed into a bio-energy complex producing ethanol and electricity in addition to sugar. The sugar sectors in Brazil (the world leader), Thailand, Australia and Mauritius have all been party to this diversification trend. This is not the end of the story as recent research on the sugar cane plant, has identified many additional bio-technology products which can be derived through the process of converting the sugar cane based bio-energy complex into a bio-refinery. The identified outputs of the bio-refinery process include the production of bio-butanol, bio-chemicals (utilised in the production of bio-plastics), polymers, cellulosic ethanol and furfural (Fechter, 2013). This move to diversify the production base of the sugar cane plant is seen as a commercial imperative for sugar producers. Rising production costs in the last few decades (associated with higher labour, fuel, chemicals and fertilizer input costs) are largely responsible for the decreasing returns from sugar sales globally. Additionally government measures have distorted and contributed to the volatility of global sugar market prices (Illovo Sugar Ltd., 2014). It is no surprise therefore that the use of sugar for bioethanol production as a percentage of global sugar output has doubled from around 11 percent in 2000 to around 22 percent in 2012 whilst the number of countries engaged in commercial ethanol production has risen from just 10 in 2002 to over 60 in 2013 (BP, 2013).

Johnson (2007) identifies sugar cane as amongst the most energy efficient biofuel feedstocks (see Table 1 for details). One ton of sugar cane in South Africa is documented by (Fechter, 2010) to produce 80 litres of ethanol, or the energy equivalent of 1.2 barrels of crude oil.

This compares favourably with international bioethanol yields of 85 litres and 74 litres respectively from one ton of sugar cane in the case of Brazil and the United States (USDA, 2006).

South Africa is the largest producer of sugar cane in Africa, 350,000 hectares of sugar cane are cultivated every year of which three quarters is suitable for harvest (USDA, 2016). Six milling companies produce this sugar, with 14 sugar mills operating in South Africa's cane-growing regions. Typically the industry produces an average of 2.2 million tons of sugar a season of which approximately 65 percent is destined for the local market and the remainder of which is exported to the rest of Africa, Asia and the United States (USAD, 2016). According to the South African Sugar Association (SASA) the country's \$1bn sugar industry is looking to diversification to increase its revenue and arrest the shrinking margins of growers and millers and in so doing improve the long term viability of the industry (SASA, 2007). According to the feasibility study on

the bio-based chemicals landscape of South Africa by CeBER (2016), an opportunity exists for value addition in the sugar industry and this is being actively pursued owing to the industry's large export fraction into low priced markets. The South African sugar industry is well established and has significant investments within the local economy and Southern African Development Community (SADC) region. Sugar cane and sugar production is one of South Africa's key agro-industrial activities. This presents the sector with a significant advantage relative to other potential ethanol feedstocks in terms of its ability to raise capital and to develop and implement financing mechanisms. This is important, as the inability to raise capital has been cited as the single biggest constraint to the development of commercial biofuel production facilities in the country. Additionally, the results of research undertaken by Fechter (2012b) suggest that ethanol from sugar cane has a lower capital cost requirement than fuel from a crude oil refinery or even a gas-to-liquids plant. See Table 2 in this regard.

Despite its relative production efficiencies, the South African sugar industry battles at times to export profitably to the global market, as the international sugar price is substantially undermined by overproduction in major sugar-producing countries as a result of government subsidisation (Illovo Sugar Ltd., 2014). Market access for raw and refined sugar is furthermore restricted by high tariffs and preferential trade arrangements in the form of tariff rate quotas. These global market distortions threaten the maintenance of a profitable and sustainable sugar price on the domestic market. SASA has noted that there has been a significant decline in sugar cane production in South Africa since 2000. This according to the association has been further aggravated by a decrease in the land under cane cultivation and lower yields attributable respectively to the country's land reform efforts and persistent drought situation (SASA, 2007).

The South African sugar industry's diversification plans include amongst other strategies that of using sugar cane to produce bioethanol and to generate renewable electricity. In addition, the sugar cane feedstock can further be used to produce a range of platform chemicals, such as a range of carboxylic acids and alcohols, as well as fine chemicals with value in the food, chemical, biomaterial and pharmaceutical industries (CeBER, 2016). According to SASA if bioethanol production in South Africa were to achieve the DoE's mandated 2 percent blend level, the sugar industry would require between 20,000 and 30,000 hectares of available sugar cane land. In the case that the sugar industry sought to increase bioethanol production so as to achieve a 5 percent to 8 percent biofuel blend it would need at least another 17,200 hectares of further land in rural areas for sugar cane production. SASA indicated that the making of biofuel would not take away from the industry's ability to service the domestic market with sugar. The ability however to service the export market would be affected as any excess sugar cane produced annually would be used to produce bioethanol. SASA estimates suggest that if diverted to the production of bioethanol, the sugar cane surplus could produce an estimated 274 million litres of bioethanol; enough to supply more than half of the 400 million litres (E8) target that is mandated in the Biofuel Industrial Strategy. A ton of exported sugar cane currently earns South African growers approximately US\$35 in sugar revenues

compared to an average of US\$43 over the last 15 year period. Estimates by Illovo Sugar, Africa's top sugar producer suggest that the same ton of sugar cane could generate US\$41 for growers if converted into bioethanol, or substitute the need for US\$45 worth of petrol imports. This estimate is based on the assumption of 80 litres of bioethanol production per ton of sugar cane and 95 percent of the prevailing basic fuel price being paid for ethanol (Cartwright, 2007).

2.1 The Economic and Financial Assessment

What follows is an assessment of the economic and financial viability of a base case bioethanol production scenario where commercial producers of bioethanol in South Africa receive no subsidies or any kind of assistance from government. This is not to suggest that government will not subsidise the industry if there is reason to do so based on social development objectives (Brent, 2014) and meeting the country's carbon emission reduction commitments. The South African Biofuel Industrial Strategy has since its conception been based on supporting bioethanol production through additional measures such as tax rebates which could be as high as 100%. Globally, support provided by government is a key factor influencing the sustainability of bioethanol production and a requirement for establishing a mandated market (see the studies by Braude, 2014 and Brent, 2014 in this regard). The level of support required is however crucially dependent on the combination of world sugar and crude oil prices. The successful establishment of the Brazilian bioethanol industry was undoubtedly aided by the huge difference witnessed during the mid 1970s between the global crude oil and international sugar prices. The 250 percent spike in global crude oil prices from a relative low of US\$3.29/bbl in 1973 to a high of US\$11.65/bbl in mid 1975 accompanied by a steep drop in international sugar prices from an all time high in November 1974 of US\$1.44/kg to a level below US\$0.44/kg the following year (see Figure 2) helped support the Brazilian government's mandated fuel substitution drive to replace relatively expensive crude oil imports with locally manufactured bioethanol.

Since ethanol is mandated as part of the South Africa's fuel basket, its selling price is determined by the import parity price of the country's petroleum products. This price is in turn driven by the world price of crude oil, and local crude oil refining margins. The world sugar price on the other hand is a good proxy for the price (cost) of the sugar cane based feedstock utilised in the ethanol production process. This is due to the fact that surplus sugar produced from the cane crop can either be exported or used as a raw material in the production of bioethanol. Whilst both the world crude oil and sugar prices are quoted in US dollars and fluctuate regularly, the South African rand to US dollar exchange rate has been deteriorating constantly over the years. This suggests that, even with the recent drop seen in global commodity prices, downward movements in the exchange rate of the South African rand will restrain the impact of these price changes on the import price of crude oil whilst cushioning the export price of sugar for the local industry.

2.1.1 Bioethanol Production Costs

Due to the limited opportunities to take advantage of economies of scale in production commercially produced bioethanol tends to be associated with higher production costs than conventional fuel types (STS, 2008). These production costs are however difficult to estimate as they are dependent on several factors, including the commodity price of the feedstock crop, the fuel processing method, and country specific variations in feedstock crop yields. The assessment of bioethanol production costs in South Africa is based on an assumed constant world sugar price of 29 US cents per kilogram (the average price witnessed over the last ten years). Historically the world sugar price has been much lower than this as is evident from Figure 2 and it could thus be argued that this assumption is perhaps too high. According to research by EPASA (2013), the international sugar market has in recent years been subject to structural change due to the fact that Brazil, the biggest producer and exporter of sugar (23 and 50 percent respectively of world production and exports), uses sugar on a large scale to produce bioethanol. Furthermore the ability of Brazil to switch its sugar cane crop from the export of sugar to the production of ethanol suggests they have the ability to stabilise the world price of sugar at a level higher than historical values (EPASA, 2013).

Taking an average world price of sugar of 29 US cents per kilogram for the period 2005 to 2015 and an average South African yield of 80 litres of ethanol per ton of sugar cane, the average feedstock crop cost incurred by bioethanol producers is 42 US cents per litre (or US\$67/bbl). International bioethanol cost estimates suggest that feedstock costs contribute between 60 to 65 percent of overall production costs whilst operating & maintenance costs are generally responsible for between 20 and 25 percent of total costs and the remaining 15 percent of costs are attributable to capital. Based on these percentages, the study estimates total average bioethanol production costs in South Africa of 68 US cents per litre (or US\$102/bbl) for the period 2005 to 2015 (See Table 3).

Figure 3 provides some indication as to how these production costs compare internationally.

South African costs of ethanol supply are similar to those in the United States, which are significantly (almost 50 percent) lower than production costs in EU countries, where wheat is the utilised ethanol feedstock. South African estimated ethanol production costs from sugar cane are however substantially higher than those in Australia, Thailand and Brazil. The main differences in production costs according to Fechter (2013) arise due to country variations in agricultural yields, efficiencies, support for agricultural (food) products and alternative land values. It should be noted however that the above figures for South Africa exclude tax reductions or other incentives that may reduce sustainable production costs.

2.1.2 Bioethanol Selling Price

The price of fuel is regulated in South Africa by the department of energy (DoE). The DoE's monthly, publicised figures for the "basic fuel price" (BFP) provide an estimation of the realistic costs of importing refined crude oil into South Africa. The regulated BFP establishes a notional import parity pricing guideline for the country's petroleum industry in the sale of its products. In order to compete with imported petrol on a cost basis, South African bioethanol would have to be cheaper than the "basic fuel price" (BFP). Since the world price of crude oil is quoted in US dollars, it is clear from Table 4 that the BFP in South Africa is highly dependent on exogenous movements in the country's exchange rate as well as global crude oil prices. Based on an average exchange rate value of 12 US cents per South African rand and an average crude oil price of \$82/bbl (\$0,51/litre) for the period 2005 to 2015, the study estimates a BFP of 72c per litre (US\$114/bbl).

The producer selling price of bioethanol is an issue of debate globally yet in most instances is determined by supply and demand conditions. This is typically the case in Brazil and the United States, the two largest producers of bioethanol. In the United States, the equivalent discount to the basic fuel price (BFP) has averaged 5 percent over the last five years (STS, 2008). Taking its cue from the United States, the Biofuels Task Team has suggested that the recommended transfer price of bioethanol from producers to the South African petroleum industry be regulated at 95 percent of the BFP (NBTT, 2006). Assuming bioethanol can be produced at the mandated E10 market penetration level, Table 4 then suggests an average regulated selling price for commercial producers of bioethanol in South Africa of US68c per litre (US\$108/bbl) in accordance with these recommendations. This regulated selling price allows potential bioethanol producers to breakeven over the 10 year period under investigation by just matching incurred production costs of 68c per litre (recall Table 3). Based on these cost estimates, the ability of South African bioethanol to compete with imported petrol is contingent upon oil prices higher than US\$82 per barrel and sugar prices below US\$290 per ton. Anticipated "learning-by-doing" could however help reduce bioethanol production costs over time. In Brazil, the cost of processing bioethanol has dropped by an estimated 10 percent a year over the past 5 years as a result of efficiency and scale enhancements in commercial production (STS, 2008). Provided such gains are not offset by hikes in the price of sugar cane feedstock they can be expected to enhance the financial viability of the bioethanol industry.

An important additional factor that requires consideration is the comparative technological energy efficiency of ethanol vis a viz petrol. According to the U.S. Energy Information Administration (EIA), a widely held misconception is that energy parity exists between these two fuel alternatives on a volumetric basis. This is untrue, as ethanol is substantially less efficient than petrol in terms of energy content (EIA, 2014). The efficiency of a fuel in terms of energy content can readily be measured in British Thermal Units (BTU). Scientifically it is the amount of heat (energy) required to raise the temperature

of 1 pound of water by 1 degree Fahrenheit. The BTU of regular petrol fuel is 114,100 BTU per gallon whereas ethanol's BTU is 76,100 BTU per gallon. Essentially, ethanol fuel requires one and a half times the volume of petrol to yield the same energy output or distance – in the case of transport. In order to compete unassisted with imported fuel, on an energy equivalent basis, South African bioethanol would thus have to be produced at an average US\$0.48 per litre under the assumption that ethanol is only 66.7 percent as efficient when compared to petrol. This production cost is considerably lower than the average BFP of US\$0.72 per litre (shown in Table 3).

Most established bioethanol producing countries have relied on state subsidies to support their industries, and according to Braude (2014) aspirant bioethanol producers in South Africa have lobbied government for the same support. The pricing of South Africa's liquid fuels is subject to a range of domestic and international levies that collectively comprise 41 percent of the retail price. The domestic levies include: "Customs and Excise Duties (0.3%), Fuel levy (16.2%), Equalisation Fund levy (0%), Road Accident Fund levy (7.2%), Incremental Inland Transport Cost Recovery levy (0.2%), Petroleum Products levy (0.01%), Demand Side Management levy (0.8%), Tracer Dye levy (0%)" (SAPIA, 2012). By providing the bioethanol industry with exemption from certain fuel taxes, South Africa would forego fiscal revenue but support the emergence of a local industry with the ancillary benefits of securing both greater energy security and a reduced carbon footprint for the economy (Braude, 2014). It is not in the South African Government's interests to undermine its oil refining capacity by placing producers under price pressure. The recommendations by the country's Biofuels Task Team (NBBT, 2006) supports the profits of the country's oil refiners by suggesting bioethanol producers sell ethanol to the petroleum industry at 95 percent of the BFP. This, however, makes the price paid to bioethanol manufacturers as volatile as the international crude oil price. Adopting such an approach would have seen bioethanol manufacturers paid an average US\$ 0.68 per litre for the period 2005-2015, which is substantially higher than that estimated by the Biofuels Task Team study. When compared to the prices that bioethanol manufacturers would pay for feedstock in order to sustain sugar cane farming activities (US\$ 0.42 per litre) this provides a sustainable margin for manufacturers. The estimated selling price does not however allow for the recouping of operating & maintenance costs or any capital expenditures incurred by bioethanol manufacturers. The latest position of the South African Cabinet with respect to the country's biofuels regulatory framework suggests however that government is only willing to waive fuel taxes, which compromises 16 percent of the retail price of fuels without stipulating a price at which bioethanol ought to be sold, as had been suggested by the Biofuels Task Team. These developments, namely a combination of reduced biofuel targets and limited fiscal support is likely to see most commercial bioethanol production activities in South Africa operate outside the domain of a state regulated market.

2.2 Environmental Motivation

As identified earlier, one of the key motivations behind the biofuel production initiatives in South Africa is the anticipated environmental dividend associated with lower green house gas (GHG) emissions when substituting the country's crude oil import requirements. The proposed domestic cultivation and processing of biofuels is however by no account carbon neutral (Cartwright, 2007). The production and use of fertilizers to support and promote biofuel feedstock crop yields is in itself energy intensive and responsible for the release of nitrogen gases. The Fertilizer Association of South Africa estimates that fertilizers currently account for 1.5 percent of the country's emissions, whereas the agricultural sector as a whole accounts for 12.5 percent of emissions – an amount that includes losses of soil carbon (FAOSTAT, 2007).

In the absence of any lifecycle analysis pertaining to emissions associated with South Africa's biofuel sector, studies for the United States (USDA, 2006) and Brazil (Macedo et al, 2004) suggest that in the case of bioethanol, the ethanol produced from sugarcane provides eight times the energy that is used in its cultivation and saves 2.07 tons of carbon dioxide equivalent per ton produced. Assuming that bioethanol has 80 percent of the energy content of mineral petrol, as suggested earlier in this study, this represents an emissions saving of 1.66 tons of carbon dioxide equivalent per ton of petrol equivalent that is replaced. Sugar cane's relative GHG efficiency is mainly due to the use of bagasse in generating the energy required by sugar refineries. A ton of cane in South Africa currently produces 30 kWh of energy from bagasse, although this could according to Johnson (2007) be increased to 200 kWh with the adoption of more efficient technologies. As Macedo et al (2004) points out, Brazil's emissions gains are self perpetuating, in that as more bioethanol enters the market, the larger are the opportunities for transporting cane without burning fossil fuels and the greater the availability of bagasse for cogeneration that can be used in agriculture and in processing. Based on the GHG emission numbers from the Macedo et al (2004) study, the proposed Biofuels Industrial Strategy target of 2 percent of vehicle fuels would result in roughly 500,000 tons of carbon dioxide equivalent being saved annually for South Africa. Whilst any reduction in South Africa's carbon footprint would be viewed as a positive development, this estimated reduction in GHG emissions represents less than 0.15 percent of the country's current emissions and is smaller than her annual incremental emissions increase. In terms of the reduction of GHG emissions, Johnson (2007) points out that replacing the synthetic fuels created by SASOL would deliver significantly greater emissions reductions than the proposed mandated bioethanol target.

3 Conclusions

South Africa's high level of dependence on imported crude oil exposes the economy to global events that impact on crude oil supply and prices. Given the country's vulnerability to global crude oil price shocks these events have the

potential to undermine South Africa's economic growth and development. The renewed efforts to develop a biofuel industry in South Africa are undoubtedly motivated by such concerns. The development of a national policy that promotes commercial biofuels production has however been countered by concerns relating to food security issues within South Africa. This concern has seen the prohibition of maize and the favouring of sugar cane as a feedstock in South Africa's Biofuels Industrial Strategy. The paper set out to analyse the economic feasibility of producing bioethanol from sugar based on the industry's efforts to diversify its product market base. The promotion of commercial bioethanol production in South Africa is seen not only as an opportunity to support the long-term financial survival of the country's sugar industry but also as an opportunity to promote social development within the country.

The results of this study suggest that the South African sugar sector has the potential to provide enormous promise in the development of the country's biofuels market. The key constraint to the country's commercial production of bioethanol is, however, the national regulatory environment. Without greater regulatory certainty and in the absence of government subsidisation, the work here concurs with the earlier findings of Van Zyl & Prior (2009) that investment in bioethanol production within South Africa's sugar sector will not take place. The study results suggest that costs associated with the production of bioethanol from sugar in South African are similar to those in the United States. These costs are significantly lower than those in EU countries, but somewhat 50 percent higher than production costs in Brazil (the lowest cost global producer). Furthermore it is established that South African bioethanol production is financially viable at US\$102 per barrel. This is based on estimates that producers typically pay the equivalent of US\$67 per barrel for sugar cane feedstock, incur approximately US\$20 per barrel on operating & maintenance costs and require the equivalent of US\$15 per barrel to recoup capital investments and secure a sustainable level of retained earnings.

It is clear from this study, that in the case of a bioethanol price equivalent to 95 percent of the basic fuel price, that returns to South African producers are likely to be negligible when crude oil prices are below US\$82 per barrel. If bioethanol production from sugar cane is to have any meaningful impact on South Africa's liquid fuels supply security, the financial support for biofuels producers needs to extend beyond the national Biofuels Task Team's mandated biofuel selling price. Indeed it needs to be acknowledged, that the South African sugar industry requires substantial subsidisation to kick-start the commercial production of fuel grade ethanol. The study's results concur with the findings of Braude (2014), that additional state intervention is required in the form of fuel tax exemptions that are linked to both the price of crude oil and the exchange value of the country's currency. Additionally, clear state mandated subsidies and capital investment allowances are needed for the successful establishment of the commercial production of bioethanol from sugar in South Africa. This state support is lacking to date as South African authorities have merely indicated that a nominal fiscal incentive of a few cents per litre of fuel is to be granted to assist potential bioethanol manufacturing plants with their initial capital cost

hurdles. The costs of the fiscal incentive will according to the authorities be recovered through a levy included in the monthly price determination of the country's petroleum products. At the last count, licences had been granted to four producers to manufacture bioethanol from sorghum. It is, however, still the case that only one sugar cane company has been granted a licence to commercially produce bioethanol in South Africa.

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Table 1
Comparison of biofuel yields

Crop	Seed yield (tons/ha)	Crop yield (tons/ha)	Biofuel yield (litre/ha)	Energy yield (GJ/ha)
Sugar cane	n/a	100	7,500	157.5
Palm oil	9,800	70	3,000	105.0
Sorgum	n/a	60	4,200	88.2
Maize	n/a	7	2,500	52.5
Jatropha	740	n/a	700	24.5
Soybean	480	n/a	500	17.5

[Source: Johnson, 2007]

Table 2
Ethanol's capital competitiveness
(Costs in US\$ per litre)

	Oil refinery	Gas to liquids	Ethanol (sugar)
Plant & equipment	1.19	3.16	0.79
Infrastructure	0.32	0.32	0.40
Exploration	1.19	0.79	0.00
Agricultural	0.00	0.00	0.40
Total costs	2.69	4.27	1.58

[Source: Adapted from Fechter, 2012]

Table 3:
Estimated Bioethanol production costs
(US cents per litre)

	2005	2015	Average
Feedstock price	32	44	42
O&M	12	16	16
Capital	7	10	10
Total	51	70	68

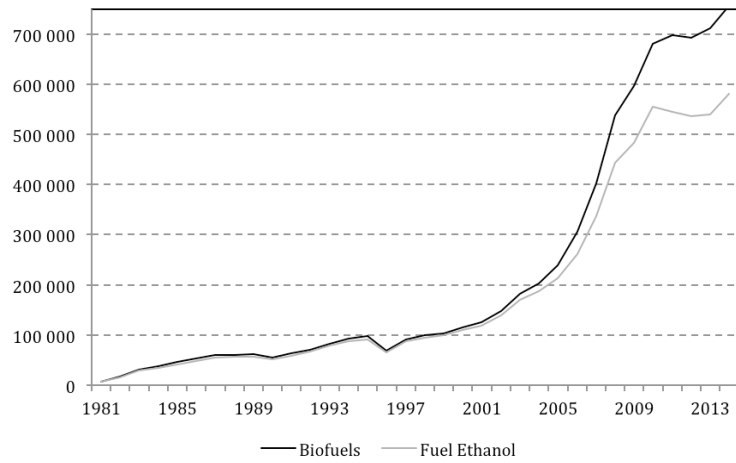
[Source: Authors own calculations based on yields by Fechter, 2010 and cost estimates by USDA 2006].

Table 4:
Suggested Bioethanol selling price
(US cents per litre)

	2005	2015	Average
Crude oil	34	33	51
US\$/ZAR	0,16	0,08	0,12
BFP (95 petrol)	46	46	72
Bioethanol	44	44	68

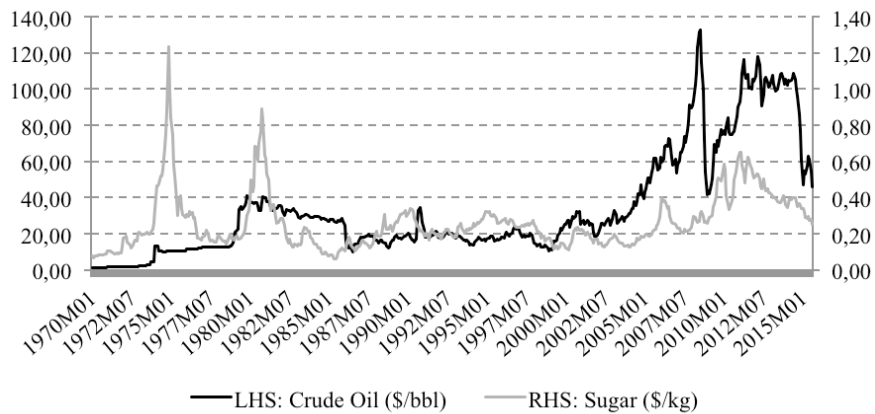
Source: Authors own calculations

Figure 1
Global Biofuel and Fuel Ethanol Production
(Thousand barrels)



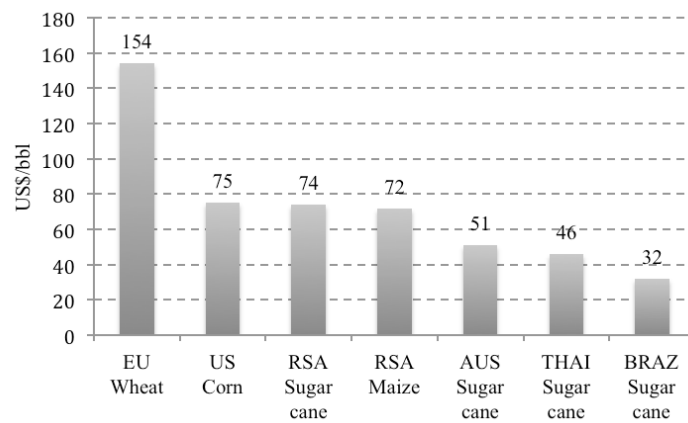
[Source: EIA, 2014]

Figure 2
Global Crude Oil and Sugar Price



[Source: World Bank, Pink Data Sheet]

Figure 3:
Bioethanol Production Costs, 2005
International Comparison



[Source: Moreira, 2006]