



Cape Peninsula
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**Techno-economic evaluation of using maize for
bioethanol production compared to exporting it
from South Africa**

by

Ayanda Lawrence Ndokwana

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Management**

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Supervisor

S. Fore

Cape Town Campus

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ABSTRACT

Capital investment in bioethanol production requires sound economic feasibility studies. This study investigated the economic feasibility of using maize as a feedstock to produce bioethanol in South Africa. There is a huge opportunity to use dedicated underutilised arable land to grow maize which can be used for both consumption and bioethanol production. The study used 200 000 ton/year of maize that could have been exported to SADC countries to size a plant that produces 80 million litres per year of bioethanol. An advanced bioethanol processing technology that separates the fibre/bran which is burnt in a steam boiler to produce process steam was selected owing to advantages such as low energy consumption and capital expenditure on fermentation and distillation equipment.

This study employed a combination of qualitative and quantitative methods to gather data. The findings from a qualitative instrument indicated that a majority of respondents were in favour of the decision of excluding maize made by the South African government. Putting security of food at risk and uncertainty in the profitability of a maize-fed bioethanol plant in the South African context, were two of the primary reasons the respondents opted for an explicit exclusion of maize as a feedstock. Findings from quantitative analysis revealed that the profitability of the bioethanol plant was largely influenced by the prices of feedstock and bioethanol. The 2016 fiscal year indicated the worst case scenario in terms of economic viability of the bioethanol. The astronomically high price of maize due to drought (R5000/ton) rendered the project unprofitable as all of the economic indicators were negative. In the same marketing year, however, the trade balance of maize was positive, indicating a surplus. The study recommended that all of the surplus maize should be exported because it is not economically viable to build a bioethanol plant.

The 2011 fiscal year indicated the best case scenario in terms of the economics of the project. This was due to the decrease in price of maize (R1726/ton) and a slight increase in the price of bioethanol. All of the economic indicators were positive, suggesting the benefits of investing in bioethanol production. It was recommended that under normal conditions of maize production in South Africa, a bioethanol plant can be operated simultaneous to maize exportation to other countries without compromising food security, because a maize-fed bioethanol plant uses only a small proportion of maize (14.3%) from the total volume of maize that is exported. Furthermore, it generates more revenue (99.9%) compared to the maize export revenue. It was recommended that sensitivity analysis should be conducted in a holistic manner whereby all variables in the economic model must be adjusted to assess the impact of each on the overall project profitability.

This study also recommended the importance of performing probabilistic economic feasibility studies (the Monte Carlo Simulation) on maize-fed bioethanol plants in South Africa. These studies quantify the risk that is associated with price fluctuations of raw materials and products for a project helping policy makers and investors to make informed decisions.

The study concluded by qualifying the need to produce bioethanol from the maize cultivated in available arable soils in South Africa, thus alleviating the cost burden of importing oil and obnoxious environmental effects.

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ABBREVIATIONS AND ACRONYMS

AAP	Average Annual Profit
BFAP	Bureau for Food and Agricultural Policy
BFP	Basic Fuel Price
CAPEX	Capital Expenditures
CEPCI	Chemical Engineering Plant Cost Index
CO ₂	Carbon Dioxide
DAFF	Department of Agriculture, Forestry and Fisheries
DDGS	Dried Distillers Grain and Solubles
DNA	Deoxyribonucleic Acid
DoE	Department of Energy
DPP	Discounted Payback Period
EBITDA	Earnings Before Interest, Tax Depreciation and Amortization
FCI	Fixed Capital Investment
FDI	Foreign Direct Investment
FFV	Flexi-Fuel Vehicles
FV	Future value
GDP	Gross Domestic Products
Hi-Pro DDGS	High Protein Dried Distillers Grain and Solubles
IRR	Internal Rate of Return
MESP	Minimum Ethanol Selling Price
NBTT	National Biofuels Task Team
NPV	Net Present Value
OPEC	Organization of Petroleum Exporting Countries
OPEX	Operating Expenditures
PES	Probability of Economic Success
PV	Present Value
R _d	Cost of Debt
R _E	Cost of Equity
ROA	Return On Assets
ROI	Return On Investment

SADC	Southern African Development Community
SAFEX	South African Futures Exchange
SAGIS	South African Grain Information System
STEPP	Social, Technological, Economic, Environmental and Political
T_c	Corporate Tax
TCI	Total Capital Investment
TVM	Time Value of Money
USA	United States of America
WACC	Weighted Average Cost of Capital
WCI	Working Capital Investment
WVO	Waste Vegetable Oil

CHAPTER 1

INTRODUCTION

1.1 Background

The rapid industrialization of many economies around the world and the population growth over the past two decades have increased the demand of fossil fuels such as crude oil, coal and natural gas needed to meet the energy demands (Shahir *et al.*, 2015:6). Both developed and developing countries have been relying on fossil fuels for centuries to derive energy, a critical input for economic growth, and sustainable development. Nowadays, some of the most critical challenges facing the world with regards to fossil fuels are reserves depleting at an alarming rate, volatile oil prices, food crises, greenhouse gas emissions, human-induced climate change (evidenced by rising temperatures), stringent emission regulations and the rapid growth of population which outstrips supply (Basavaraj, Rao & Reddy, 2012:1). There is an urgent need to find alternative energy sources to replace fossil fuels. These sources must have infinite reserves; they must be renewable (i.e. their sources must be reproducible); they must not emit greenhouse gases such as carbon dioxide which pollute the environment; and the technology that is used to harness them must be feasible from an economic point of view.

Bioethanol, produced by the fermentation and distillation of sugars and starch-rich crops such as maize, has been identified as one of the leading candidates to replace a fraction of liquid fuels derived from oil such as gasoline. It can be blended with gasoline up to 10%, and used as a motor fuel without any engine modification required. It can also be used in high blends of 85% with gasoline to fuel flexi-fuel vehicles (FFV), vehicles having an internal combustion engine that is designed to run on more than one fuel, usually gasoline blended with bioethanol or methanol. Bioethanol fuel can also be used in a pure state as 100% in specially designed engines (Shahir *et al.*, 2015:64).

Both Brazil and the United States of America (USA) are the leading producers of bioethanol in the world, accounting for 89% of the total global production (Nasterlack, Blottniz & Wynberg, 2014:2). Brazil produces bioethanol from sugarcane and USA from maize. In China and Europe, cereals such as wheat and triticale are used as raw materials for bioethanol production. Amigun, Musango, and Stafford (2010:1362) indicate that in Africa, the production of bioethanol is stalling in lengthy legislation with no large scale commercial manufacturing plant which has been commissioned yet. In a poverty stricken continent such as Africa, using staple food crops such as maize, wheat and sugar for bioethanol production

is a significant issue as many countries continue to struggle yearly to produce sufficient crops to feed the expanding population. Africa houses the largest portion of arable land in the world, enough to produce crops for human consumption and production of biofuels. Uncertainty in policy frameworks for leveraging such an abundant resource by many African countries has been identified as one of the leading causes of the inadequate development of the biofuel industry (Amigun *et al.*, 2010:1363).

Although bioethanol is the leading candidate to replace gasoline, challenges such as food security and land use for agriculture will result in bioethanol replacing gasoline by a very small proportion. The transport sector in the world already consumes about 3.8 trillion litres of liquid fuel per annum (Morales *et al.*, 2014:1350). Research efforts on biofuels reveal that using second generation raw materials to produce bioethanol can be sustainable (Morales *et al.*, 2014:50). Second generation feedstock include crop residues such as rice husk, cane bagasse, sorghum bagasse, pulp, corn stover, wheat straw, barley straw, hardwood, soft wood and cellulose waste. The challenge pertaining to the use of this feedstock is a lack of an environmentally friendly and economically viable processing technology.

In South Africa, the production of bioethanol is still at an infancy stage characterised by the development of numerous policies that lack definitive implementation strategy (Pradhan & Mbohwa, 2014:1089). In 2007, the South African government approved the Biofuel Industrial Strategy compiled by the National Biofuels Task Team (NBTT). The aim of the strategy was to promote the local production of biofuels such as bioethanol and biodiesel using agricultural crops. These fuels have the potential to supplement the current fuel pool of South Africa which is comprised of fossil fuels (South Africa, Department of Energy, 2007). In this way the country will slash reliance on imported oil, reduce pollution levels, diversify its fuel supply and create many employment opportunities in rural farming. The Biofuel Industrial Strategy ratified the use of crops such as sugarcane, sorghum and sugar beet as feedstock to produce bioethanol. But the South African government has excluded maize as a potential feedstock for bioethanol production, citing concerns about food security, possible spike in the food prices and environmental concerns (Pradhan & Mbohwa, 2014:1092). Therefore, this study is aimed at performing an economic assessment of a bioethanol production process that utilises maize as a feedstock in South Africa, and a comparative analysis between the profitability that is generated by the maize exports to SADC countries and the bioethanol plant.

1.2 Problem statement

Maize as a potential feedstock for bioethanol production was excluded in the Biofuels Industrial Strategy approved by the South African government in 2007. However, there is no research conducted in South Africa with findings that support the concerns that the government has about using maize for bioethanol production. The lack of data on techno-economic studies for using crops, such as maize, that are produced in large quantities is one of the reasons the development of the biofuel industry in South Africa is faltering. Surpluses of maize can be used to assess the possibility of producing bioethanol in South Africa as compared to exporting it, whereby the monetary value generated from bioethanol production will be compared to the monetary value generated from the exported maize. This information can be studied by the South African Government to make informed decisions on mandatory policies of biofuels.

The previous aim of the Biofuels Industrial Strategy was to penetrate 2% of biofuels into the current fuel pool of South Africa by 2013, equivalent to 400 million litres per annum. However, the fact that the current status of the biofuel industry in South Africa is still at the introductory stage with no large scale commercial manufacturing plant commissioned yet, evidences the failure of the strategy to achieve its set goals in the projected time frame, such as the creation of 25 000 jobs in rural farming, energy supply diversification, enhanced energy security and reduced greenhouse gas emissions. Other reasons for this failure include the incomplete biofuel pricing framework and the delayed mandatory policy for blending biofuels (Pradhan & Mbohwa, 2014:1092).

1.3 Objectives of the study

- ❖ to describe the maize industry of South Africa;
- ❖ to analyse the maize production trends from 2011 to 2015 in South Africa;
- ❖ to analyse the domestic and export markets of maize;
- ❖ to use a 200 000 ton/year bioethanol plant as a reference size to assess profitability;
- ❖ to use profitability indicators such as discounted payback period, net present value and return on investment to assess the economics of the bioethanol production process; and
- ❖ to perform a comparative analysis between the value of the maize generated from exportation and the value generated from maize converted into bioethanol.

1.4 Rationale

The rationale of this study is to assess the possibility of using maize as one of the feedstocks for producing bioethanol in South Africa, and to bridge the gap created by the lack of techno economic data on maize to bioethanol production processes in South Africa. This data will also be used in conjunction with some of the existing techno economic data about sugar cane and sorghum conversion to bioethanol, which has already been employed as a point of reference in decision making when biofuel policies were structured in an effort to strengthen the biofuel industry in South Africa.

1.5 Research questions

In this study the following questions are addressed:

- ❖ What is the size of the South African maize industry?
- ❖ What conclusion can be drawn from maize production trends from 2011 to 2015 in South Africa?
- ❖ During this period how many tons of maize were allocated for the domestic and export markets, respectively?
- ❖ What size of the maize to bioethanol plant is profitable in South Africa?
- ❖ Which methods of determining profitability of the project are intended for use?
- ❖ Will the monetary value generated during bioethanol production be enough to justify use of maize for production of fuel instead of exporting it?

As part of this study, investigation will include the following hypothesis:

- ❖ Tentatively, it can be suggested that the reasons from which the conclusion of excluding maize as a feedstock for producing bioethanol were drawn are merely speculative, as evidenced by the dearth of studies addressing the feasibility of producing bioethanol fuel from maize in South Africa.

1.6 Scope of study

The scope of this research is limited to the study of bioethanol and excludes biodiesel and biogas. The study will focus more on starch-rich first generation feedstock for bioethanol production such as maize. The discussion around other prominent starch-rich first generation feedstock of bioethanol such as wheat, triticale, rye and barley will be presented. Only sugarcane and sorghum will be discussed as sugar-rich bioethanol feedstock. A brief examination will also be presented on second generation feedstock such as cellulose and

cane bagasse due to their potential to be sustainable sources after an effective processing technology has been established.

The focus will be on the South African maize export markets in the SADC countries. The economic feasibility study on bioethanol production is deterministic as opposed to a probabilistic study, implying that a deterministic study ignores uncertainty in prices and costs of process variables over a given period, and neglects to address risk. Finally, the processing technology chosen for this study is an advanced bioethanol plant, where fibre fractionation isolates the bran which is burnt in steam boilers to produce process steam (Amigun, Petrie & Gorgens, 2011:3179).

1.7 Deliverables

The following deliverables will emanate from this project:

- ❖ project proposal;
- ❖ dissertation (this study);
- ❖ an article to be published in an academic journal;
- ❖ dissertation oral presentation; and
- ❖ International Conference on Biodiesel and Biotechnology (ICBB) Cape Town 2016 Conference paper.

1.8 The division of chapters

This study is comprised of six chapters, discussed below:

- ❖ **Chapter 1:** Introduction

This chapter provides an overview of the global state of the biofuel industry, with emphasis on bioethanol production in different countries of the world as relevant to this study. The chapter highlights the advantages of investing in bioethanol commercial production processes and the pertinent challenges such as debates on food versus fuel, ineffective policy frameworks for bioethanol production by many African countries and insufficient economic data on bioethanol production for stimulating investor confidence in countries like South Africa. The chapter concludes by stating the study's major objective which is to evaluate profitability of the bioethanol plant in South Africa using maize as a feedstock, and to compare this with the profitability generated from maize exported to SADC countries.

❖ **Chapter 2:** Literature review

The literature study focuses on the analysis of the South African maize industry and the SADC countries as the maize export market. Genetic modification is described as a potential method of increasing maize yields. The implications of severe drought in South Africa in the 2015 and 2016 market years are analysed as some of the most significant challenges that can impede the production of bioethanol in the country. The implications of using maize to produce bioethanol in South African instead of exporting it elsewhere for human consumption are addressed from social, technological, economic, environmental and political points of view. The reasons why South Africa must make a considerable investment in the development of the biofuel industry are elaborated. Alternative feedstock for bioethanol production is discussed. Moreover, this chapter presents an analysis of the state of bioethanol production in Africa. Different economic feasibility studies concerning bioethanol production using other feedstock in South Africa will be explored. The chapter concludes by describing, at great length, the advanced bioethanol plant, where fibre fractionation isolates the bran which is burnt in steam boilers to produce process steam.

❖ **Chapter 3:** Research methodology

This chapter will highlight the reason for opting for a mixed method approach comprised of qualitative and quantitative techniques. The lack of bioethanol commercial manufacturing production processes in South Africa presents a challenge for acquiring quantitative data in real time so that economic feasibility studies can occur. To overcome this shortcoming, this study has relied on relevant literature as a point of reference and a base from which to conduct the feasibility study.

❖ **Chapter 4:** Economic feasibility study

This chapter assesses the profitability of a bioethanol plant that uses maize as a feedstock in South Africa by employing common capital budgeting metrics such as net present value, return on investment, discounted payback period, internal rate of return and return on assets. Sensitivity analysis is done on process variables that have a major impact on the overall profitability of the plant. Finally, a comparative analysis between the revenue generated from the bioethanol plant and the maize export revenue is offered.

❖ **Chapter 5:** Interpretation of results

The discussion of results is twofold: first, the findings from qualitative instruments such as a questionnaire are interpreted with the specific focus of highlighting the major objective of

each question to the respondents from the targeted organisations in South Africa. The general sentiments revealed by the respondents are explained. Secondly, the interpretation of findings is on quantitative data, whereby many economic models are used to generate the results. The meaning of these figures from an economic perspective will be assessed.

❖ **Chapter 6: Conclusions and recommendations**

This chapter compares the results of the study to those found in literature. The bottlenecks resulting in slow progress in the development of the bioethanol industry in South Africa are detailed. The prospects and challenges of the bioethanol industry are also reiterated. The recommendations for building a profitable bioethanol industry in South Africa and Africa at large are delineated. Finally, an indication of the areas which still require further study within the bioethanol production in South Africa are highlighted.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Depleting reserves of fossil fuels and global warming have triggered interest among biofuel industry practitioners, policy makers and investors from many countries for exploring alternative energy sources such as bioethanol in the transportation sector (Amigun *et al.*, 2011:1386). The major driver of bioethanol production by many developed countries is the reduction of the carbon footprint, whereas in developing countries the drivers are energy security, job creation, rural agricultural development and slashing reliance on imported crude oil.

Leiter and Lindorfer (2015:193) emphasise that the production of bioethanol on a commercial scale relies heavily on massive outputs of starch-rich crops such as maize and sugar-rich crops such as sugarcane from the agricultural sector. This is because there is often a strain exerted on these crops as they must satisfy food consumption and energy production aspects (Morales *et al.*, 2014:52). The availability of arable land and adequate water resources are two of the most important factors which determine the success and sustainability of the bioethanol production facility. South Africa has an abundance of arable land which has been identified for biofuel crops. A study by Pradhan and Mbohwa (2014:1094) also indicates that the 2% from biofuels (equivalent to 400 million litres per annum required to supplement the current fuel pool in South Africa) will require 1.4% out of the 14% total arable land which is underutilised. This means that biofuels crops can be produced without creating a shortfall in food for humans.

However, in a water-scarce country like South Africa, utilising the available land to grow crops to accommodate food and fuel is still an intricate challenge, especially under the current conditions of a near country-wide severe drought in the agricultural sector. This chapter will analyse the South African maize industry, as the probability of economic success of a maize-to-bioethanol plant depends on it.

2.2 The South African maize industry

Maize is the most important staple food crop that is produced in substantial quantities in South Africa. Normally, 60% of the maize produced in the country is white and used primarily for human consumption, while the remaining 40% of the maize produced is yellow and used for animal feed and other industrial applications (South Africa, Department of

Agriculture, Forestry and Fisheries. 2014). The 2015 marketing year yielded maize at 47% white and 53% yellow. The revenue that is generated by the maize industry depends on the amount of maize harvested in a specific season and the producer price applicable in that season. Maize was the largest contributor to the total revenue of field crops in South Africa, contributing 47% of the total revenue, followed by sugarcane (13.6%), wheat (9.9%), soya beans (7.65%) and hay (7.3%) (DAFF, 2015:8). The total revenue generated by maize in the 2014/2015 season was R23.236 billion. This revenue has declined as compared to the 2012/2013 season where it climbed to almost R25 billion, as depicted in Figure 1.

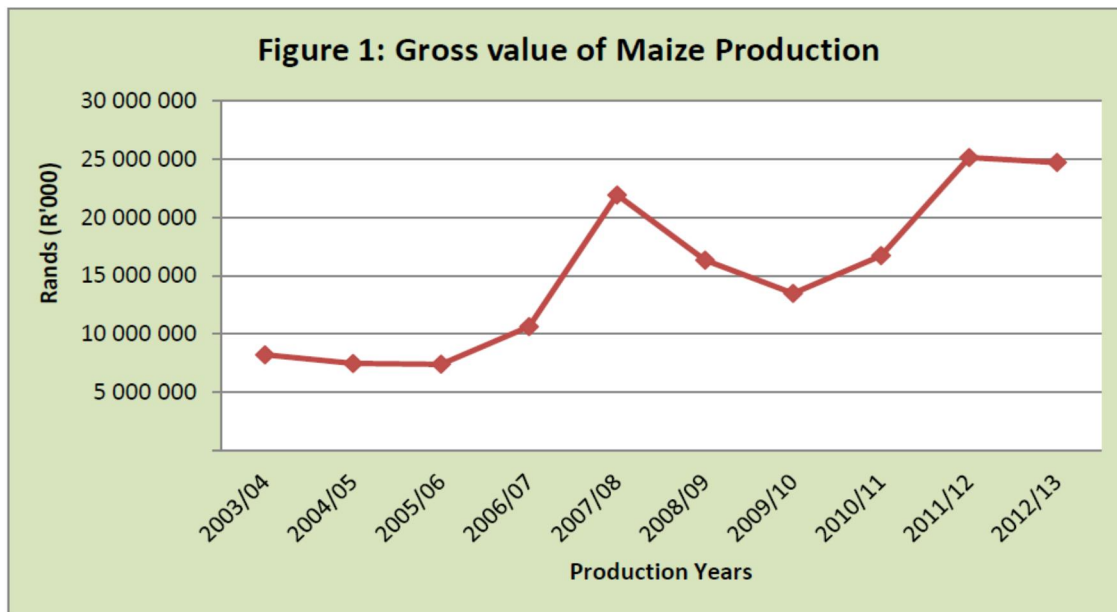


Figure 1: Revenue of maize in 2012 and 2013 (South Africa, Department of Agriculture, Forestry and Fisheries, 2014:1)

This discrepancy can be explained in terms of a higher production output during the 2012/2013 season. The decline in production output in the 2014/2015 season was due to a drought which primarily affected the Free State, Mpumalanga and North West, the three largest maize producing provinces in South Africa. Figure 2 and Figure 3 compare the production output of maize by provinces, also indicating the extent of decrement experienced by the three major producing provinces. In 2014/2015, the largest producing province in the country, the Free State, experienced a 3% drop in yield as compared to the 2012/2013 season. Mpumalanga, the second largest producer, gained 2% in yield, while North West also lost 3%. In the 2015/2016 season, the decline in production of these provinces was significant, resulting in a shortfall of the total production that was then supplemented with imports from other nations.

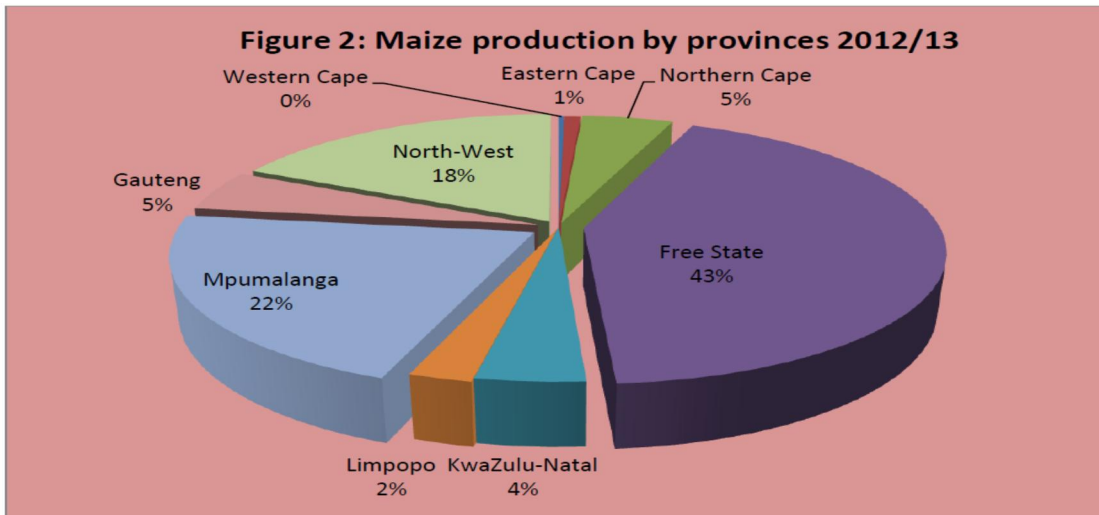


Figure 2: Maize production by provinces in 2012 and 2013 (South Africa, Department of Agriculture, Forestry and Fisheries, 2014:2)

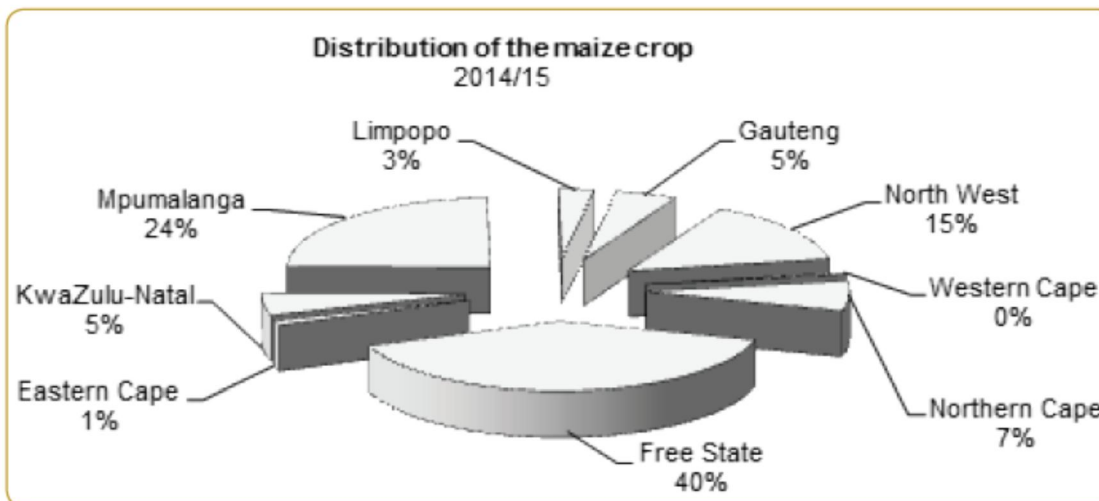


Figure 3: Maize production by provinces in 2014 and 2015 (South Africa, Department of Agriculture, Forestry and Fisheries, 2015:8)

2.2.1 Seasonal yield of maize

Table 1 illustrates how the total output of maize in South Africa has declined over five consecutive seasons. South Africa has 9 000 commercial maize farmers and an unknown number of developing farmers. The table shows that for the 2014/2015 season, the production of maize in South Africa dropped by 30.2% from 14.250 million tons achieved in the 2012/2013 season to 9.942 million tons achieved in the 2014/2015 season. As was already indicated, the drought resulted in the decrease in production output. The 2014/2015 yield was the second lowest after 7.125 million tons achieved in the 2006/2007 season over the past decade. This small output was a precursor of the global economic recession which affected many sectors of the economy, including the South African agricultural industry.

Table1: Maize production trend from 2011 to 2015 (DAFF, 2015:9)

Season	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015
Plantings (ha)	2 372 300	2 699 200	2 781 200	2 688 200	2 652 850
Production (tons)	10 360 000	12 120 656	11 810 600	14 250 00	9 941 650
Yield (ton/ha)	4.37	4.49	4.25	5.3	3.75

2.2.2 Producer prices

The total revenue generated by the maize industry in South Africa depends on the prices charged by producers per ton. The trend of the producer price is guided primarily by the following two factors (DAFF, 2015:9):

- ❖ **The period of surplus supply:** The price of maize in this period is determined in terms of export parity price. This is the price of maize on the international market, minus transport cost and other costs, multiplied by the exchange rate.
- ❖ **The period of a shortfall in supply:** In this period, the producer price is determined in terms of import parity price, which is the international price plus transport cost and other costs, multiplied by the exchange rate. Table 2 shows producer prices for the past five seasons in South Africa.

Table 2: Maize producer prices (DAFF, 2015:10)

Season	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016
Producer price (R/ton)	1 726	2 112	2 186	2 228	2 844	5 000

The dramatic increase of the producer price from R2844/ton in 2014/2015 season to R5000/ton in 2015/2016 is an indication of a severe shortfall in the total output of maize as a result of drought, constraining the country to rely heavily on imported maize from countries like USA.

The following factors also influence the producer price of maize:

- ❖ international maize prices;
- ❖ local production;
- ❖ local consumption;
- ❖ climatic conditions;
- ❖ production levels in SADC countries (South Africa is the major supplier of these countries); and
- ❖ international and domestic stock levels of maize.

2.2.3 Domestic market

The domestic market of maize is comprised of three sectors (Bureau for Food and Agricultural Policy, 2015). About 50% of the total maize production is further processed by companies (the millers) such as Tiger Brands, Premier Foods and FoodCorp, to produce food derivatives for human consumption. About 40% is used in animal feed, with top feed manufacturers including AFGRI, Bokomo, Meadow Feeds and Nova Feeds. The rest is used for seed and industrial applications (coatings, textile and paper, for example) (BFAP, 2015).

2.2.4 The SADC Export market

The industry exports mostly to ten SADC countries like Botswana, Lesotho, Namibia, Swaziland, Zimbabwe, Zambia, Malawi, Angola, Mozambique and Democratic Republic of Congo (DAFF, 2015:11).

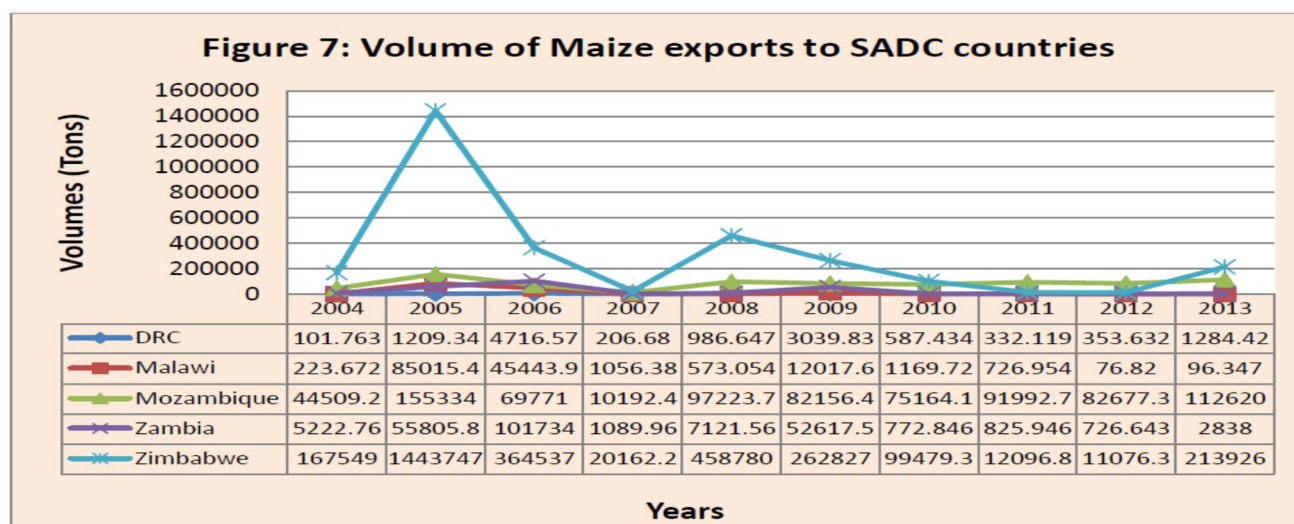


Figure 4: Volume of maize export to SADC countries (Quantec Data, 2014)

Figure 4 shows that a great proportion of maize exported to SADC countries in the past 12 years was allocated to Zimbabwe, due to food shortages in the country caused by political instability. The highest (1 443 747 tons) was exported in 2005 and the lowest (11 076.3 tons) was exported in 2012.

2.2.5 Trade balance

Trade balance is the difference between the country's exports and imports for a given period. The deregulation of the South Africa agricultural market in 1996 meant that maize producers have the liberty to sell locally or export. The decision to import maize is also determined by the exchange rate among foreign currencies. When the rand is weak against

other currencies, the price of maize will be expensive as import parity pricing will be applied, forcing millers to buy maize locally. The local producers will consider the export market when millers are unwilling to pay the prevailing market price locally.

2.2.6 Global production of maize

The USA is the largest producer of maize in the world, followed by China, Brazil and Europe. In the 2015/2016 season, USA produced 972.63 million tons, a figure that is 0.1% less than the volume of 1.009 billion tons it had produced during the 2014/2015 season. It contributed 35.4% of the world's total production, followed by China (23.1%), Brazil (8.2%) and Europe (6%). The remaining 27% was made up by Ukraine, Argentina, Mexico and South Africa (DAFF, 2015:11).

2.3 The implications of drought on maize production

Willemse, Strydom and Venter (2015) predicted the following implications on the South African production of maize from 2016 going forward:

- ❖ Grain imports will increase substantially from 4.1 million tons to 5.67 million tons. The harbour, railway and road logistics will experience severe pressure and there are doubts that South Africa will be able to move such a near-record quantity of grain inland, given the weak railway system and poor road logistics. This could result in supply bottlenecks and product shortages from time to time.
- ❖ Calculations indicate that grain imports will require roughly R25- R30 billion of foreign currency in the next year. This excludes the losses of grain farmers, estimated to be close to R10-R12 billion for 2015 alone.
- ❖ Yellow maize imports will increase from 900 000 tons to 2.2 million tons. International export markets will be lost for yellow maize, export markets which were fought hard for and which will take great effort and time to rebuild. The contrast is that South Africa exported 2.2 million tons of yellow maize annually, before the drought.
- ❖ White maize crop is expected to be less by at least 500 000 tons on domestic demand during 2016/2017 marketing year.
- ❖ The second week in December 2015, prices jumped to a record high of nearly R4000/ton. With very limited supplies available internationally, prices are expected to increase even further in coming months.
- ❖ Millers report that sales of white maize meal have dropped by 10-15% due to high prices, indicating strain on the lower income groups. Various reports suggest that hunger and malnutrition is increasing, posing a serious threat to political stability.

2.4 The implications of producing bioethanol instead of exporting maize

- ❖ **Socially:** Many countries in Africa retain the perception that bioethanol production will improve their standard of living through job creation. However, the debate on food versus fuel still weighs heavily and is a huge social concern which cannot be ignored (Amigun *et al.*, 2010:1363).
- ❖ **Technologically:** Capital investment in bioethanol plants will stimulate the evolution of advanced technologies. These are self-sufficient technologies in terms of energy consumption and efficiency.
- ❖ **Economically:** An abundant supply of bioethanol in the fuel pools of many countries that do not have oil reserves will save heavy import costs. However, there is still a gap in sound economic evaluation of using food crops for bioethanol production, especially in South Africa (Richardson, Outlaw & Lemmer, 2007).
- ❖ **Environmentally:** Tapping into bioethanol production commercially has attractive benefits, one of which is sustaining a cleaner environment as bioethanol has no carbon footprint. Land use change to accommodate crops for bioethanol remains a concern in South Africa.
- ❖ **Politically:** Diverting a portion of maize for bioethanol production that could have been exported to SADC countries could sabotage international relationships. Economists have identified this scenario as being similar to “islanding”, which occurs when a country cuts ties with other countries in terms of trade and chooses to exist in isolation.

2.5 Genetic modification of maize

A study conducted by Torney, Moeller, Scarper and Wang (2007:193) showed that maize has a great potential to be used as a feedstock for bioethanol production because it provides both the starch (derived from seeds) and cellulosic material (derived from stover) which can be used for bioethanol production. The fact that maize also finds many applications, such as a source of staple food for humans, animal feed, industrial applications (e.g. paper making) and fuel production, places immense strain on the crop. This suggests that traditional methods of growing maize need to be modified by genetic engineering approaches.

Rotolo, Francis, Craviotto and Ulgiati (2015:48) defined *genetic engineering* as a process which involves the isolation, characterisation and reintroduction of DNA into cells or

organisms through recombinant DNA technology. The common methods of modifying maize production include the following:

- ❖ conventional breeding;
- ❖ molecular marker assisted breeding; and
- ❖ genetic engineering.

Two methods of modifying maize production through genetic engineering have been used:

- ❖ modifying biomass properties to reduce processing cost; and
- ❖ increasing biomass yield and reducing agricultural impacts.

2.5.1 Genetic engineering to modify maize properties

According to Torney *et al.*, (2007:195) two key parts of the maize can be converted to bioethanol: 1) the kernel which is mainly made of starch, and 2) the stover which is predominantly made of lignin and cellulosic components. To convert these effectively into fermentable sugars of ethanol production, two strategies are used. One strategy is to modify the properties of starch or 'lignocellulose' so that they can be converted more readily into the desirable products. The other strategy is to introduce biomass conversion enzymes into plants so that they can assist the conversion process more effectively.

2.6 Alternative Bioethanol feedstocks

The advantage of bioethanol is its ability to be derived from a wide range of crops ranging from starch to sugar containing crops. Second generation feedstocks derived from non-food parts of the crop such as cane bagasse from sugar cane also have the potential of being used as a bioethanol feedstock.

2.6.1 Other bioethanol starch-rich feedstocks

An economic feasibility study conducted by Amigun *et al.* (2011:3181) classified starch-rich crops as those which contain 60-70% fermentable starch that can be used to produce bioethanol. This is because the profitability of the production plant that processes such feedstock improves in terms of the product and by-product yield. Maize and wheat contain 65% of fermentable starch and can output an average of 400 litres of bioethanol yield per ton of grains. Triticale has 66.4% of starch and can output an average of 436 litres of bioethanol per ton of grain.

❖ Barley

Barley is another potential bioethanol feedstock. The advantage of using barley for bioethanol production is that it can be harvested over short periods of time ranging from three to five weeks after plantation. This enhances the potential to produce the crop in high yields. In South Africa, barley is used mainly in the beer making industry.

❖ Wheat

Wheat is the third largest crop produced in South Africa for human consumption and animal feed. It is one of the potential feedstocks of bioethanol because it is grown extensively in South Africa and contains an appropriate proportion of starch (Richardson *et al.*, 2007). But the challenge of drought in South Africa is also diminishing yields of wheat whereby imports are advanced to supplement the local demand. The shortage of wheat in South Africa is one of the reasons the food inflation has hiked, resulting in low-income earners struggling to cope.

❖ Triticale

Triticale is a hybrid crop of wheat and rye (DAFF, 2015:9) grown extensively in Western Cape, it is advantageous because it has 66.4% of starch and 12.7% of protein. With a cheaper price than maize and wheat, triticale is used as an animal feed and as a ground cover in agriculture.

❖ Rye

Rye bears a lower starch content of 5%. However, when mixed with wheat it produces triticale, a hybrid crop which has beneficial qualities as an animal feed and bioethanol feedstock.

2.6.2 Sugar-rich feedstocks

An analysis by NBTT (2007) on the potential bioethanol feedstock in South Africa shows that sugar cane and sweet sorghum are the leading candidates. The advantage of using these crops is that they are grown abundantly in South Africa, as the country is one of the largest net exporters of them in the world.

❖ Sugar cane

In South Africa, large corporates such as Tongaat Hullet, Illovo and TSB are responsible for the production of sugar to meet both the local and international demand (South Africa,

Department of Agriculture, Forestry and Fisheries, 2014:3-6). Similar to the maize industry, the sugar industry in South Africa is consistently producing and exporting surplus sugar while posing less risk on the food security. Large quantities of sugar are produced in Kwazulu Natal and about 40% of the sugar that is locally produced is exported. Another attractive feature of sugar as a bioethanol feedstock is its valuable by-product called molasses which contains about 60% of fermentable sugar which can also be used to produce bioethanol fuel (Pradhan & Mbohwa, 2013:1095).

❖ Sweet sorghum

Another study conducted by the Department of Energy revealed that sweet sorghum has the potential of becoming a sustainable feedstock for bioethanol production owing to its drought-resistance and that it grows in large parts of South Africa (South Africa, Department of Energy 2012:3). South Africa used to blend bioethanol produced from sugar with petrol during the 1920s. However, the plummet in crude oil price increased the rate of import and directly led to the substitution of bioethanol as a blending component in the 1960s.

2.6.3 Second generation feedstocks

This cluster of feedstock is derived from non-food parts of the crop. The interest to pursue them as alternative bioethanol feedstocks comes from the large amount of fermentable starch and sugar contained within. The major challenge of using lignocellulose biomass (straw, bagasse, woodchip, etc.) to produce bioethanol is that it is generally quite expensive, and the economics are dependent on electricity co-production and sales. Capital costs are typically US\$300 million for a commercial scale plant of this nature. Wastes from paper and pulp processes, such as spent sulphite liquor and primary sludge, are probably the best options. These processing residues from lignocellulose can be converted into bioethanol with relatively simple and smaller-scale processes.

Table 3 lists the quantities of agricultural and forestry biomass available in South Africa, as well as the energy output which can be derived when they are harnessed.

Table 3: Second generation feedstock (Littlewood, Murphy & Wang, 2012:293)

Biomass	Quantity in million tons/year (Mt/yr)	Energy output in pico joules/year (PJ/yr)
From agriculture		
Maize stover	6.7	118
sugarcane bagasse	3.3	58
wheat straw	1.6	28
From forestry industry		
Sawmill dust	0.9	16
Paper and boardmill dust	0.1	2

2.7 The global outlook of biofuel production

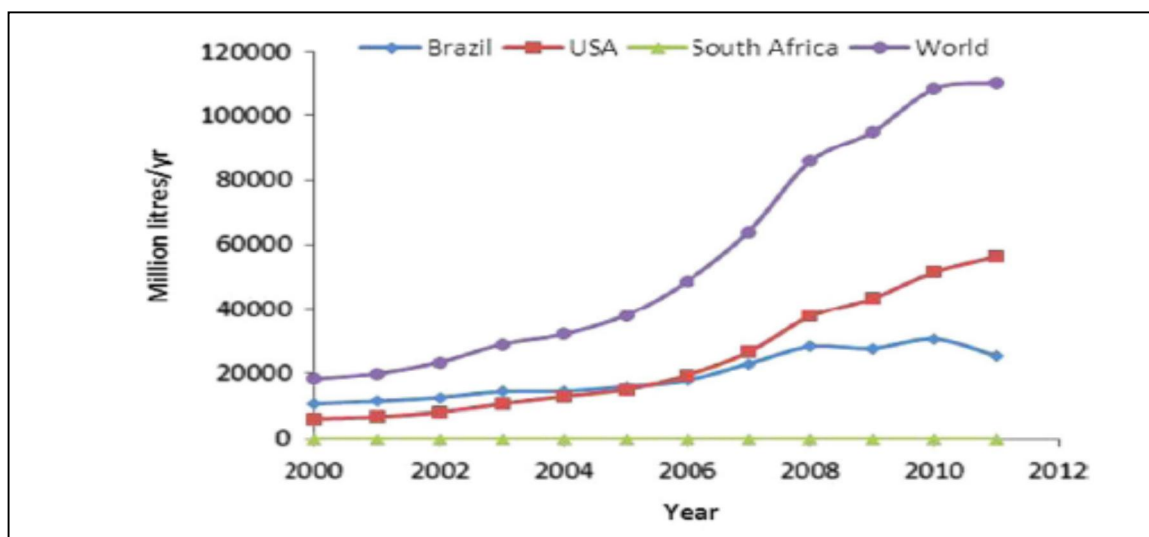


Figure 5. Comparison of biofuel production (Pradhan & Mbohwa, 2013:1090)

Figure 5 depicts worldwide production of biofuels whereby USA and Brazil have been the major production countries over the past thirteen years. The graph also shows that South Africa’s contribution on the global scale has been insignificant over this period, with a contribution less than 0.01%. The global biofuel production has been increasing steadily from about 20 billion litres (125 million barrels) in 2001 to over 110 billion litres (692.5 million barrels) in 2011. During this period, both bioethanol and biodiesel were the major biofuels, both with substantial increments in production. With the current increase in the world energy demand, the biofuel production is projected to reach about 222 billion litres in 2021. The transport sector is the largest consumer of biofuels. In 2011, biofuel production provided

about 3% of the total road transportation worldwide. It is projected that by 2050, about 27% of the transportation fuel will be provided by biofuels (Pradhan & Mbohwa, 2013:1090).

2.8 The reasons South Africa must invest in biofuels

South Africa is not part of the Organisation of Petroleum Exporting Countries (Non-OPEC) on the African continent, suggesting that it is one of the countries in Africa with little or no crude oil reserves. In order to meet the nation's oil needs, a significant amount of oil must be imported annually. However, relying on imported oil means that the country suffers from heavy foreign exchange. Investing in the development of the biofuel industry will alleviate the burden of incurring heavy cost of imported oil because biofuels such as bioethanol are derived from renewable sources (crops) which can be grown locally on readily available land.

- ❖ South Africa is the largest consumer of energy in Africa

This is one of the compelling reasons a substantial investment in the development of biofuels is required in South Africa. The BP Statistical Review of World Energy in 2013 cited that South Africa accounted for about 31% of the total primary energy consumption in Africa in 2012. The transport sector was the largest consumer, accounting for about 25% of the total energy.

- ❖ South Africa is the leading carbon dioxide emitter in Africa

In 2011, South Africa contributed 40% of Africa's emissions and was responsible for 1.4% of global carbon dioxide, making it the leading emitter in Africa and the 14th largest in the world. This can be attributed to South Africa's reliance on fossil fuels that have a substantial carbon footprint.

- ❖ There is enough arable land for renewable feedstock

In 2007 the Biofuel Industrial Strategy formulated by the Department of Energy in South Africa, recommended that 2% of biofuels which are required to supplement the current fuel pool in South Africa would require about 1.4% of arable land to produce renewable feedstock for bioethanol and biodiesel commercial manufacturing. This is attainable because approximately 14% of South Africa's land is underutilised. The good news is that the 2% target can be met without compromising food security.

- ❖ To attract foreign investment

Europe is another continent that is drifting away from utilising fossil fuels to meet the energy demand due to environmental concerns, such as increased levels of air pollution, resulting in adverse phenomena such as acid rain and global warming. Biofuels are considered to be the only medium-to-long term sustainable sources of energy which have the potential to replace the fossil fuels while posing no harm to the environment. Currently, the European Union has a target of 5.7% share of biofuels in transport. By 2020, this number is anticipated to be 10%. However, the constraint of limited agricultural land in Europe will present an intricate challenge in achieving these targets. That is why many European countries, Germany for one, are keen to build a biofuel production base in Africa. Thus many African countries such as South Africa, Malawi and Kenya, the net importers of oil, will benefit significantly from Foreign Direct Investment (FDI).

- ❖ To slash imported crude oil

According to the BP Statistical Review of World Energy in 2013, the total crude oil consumption in South Africa was 98.8 million litres (609 000 barrels/day) in 2012. Of this total, about 68 million litres (428 000 barrels/day) which equals about 70% of the oil consumption, was imported. Biofuels have the potential of rescuing South Africa from the burden of heavy foreign exchange spent on imported oil.

- ❖ To achieve the Biofuel Industrial Strategy objectives

The Biofuel Industrial Strategy was formulated primarily to promote production of biofuels using renewable crops such as sugar cane, sorghum, sugar beet, soybean, sunflower and canola. In this way, rural agricultural investment leading to job creation would be enhanced. Other objectives of the strategy include import substitution of oil, reduction of pollution levels, supplementing the current fuel pool and energy security diversification.

- ❖ Biofuels can be produced from a wide range of feedstocks

Unlike fossil fuels such as diesel and petrol, which can only be derived from non-renewable sources such as crude oil and natural gas, the feedstock options of producing biofuels such as biodiesel and bioethanol are plentiful and renewable. Biofuels can be produced from first and second generation classes of feedstock derived from agricultural crops. The first generation feedstocks include the food parts of the crop such as oil seeds from which vegetable oils like sunflower or canola oil can be extracted and processed to produce biofuels. The second generation feedstocks include the non-food parts of the crop such as

cellulosic biomass of the crop (e.g. woody material, straws and grasses). From the cellulosic biomass, fermentable starch is the required component which can be extracted and processed further to produce biofuels. However, the Biofuel Industrial Strategy of South Africa stipulates that the production of biofuels from second generation feedstock will occur only after first generation production has been fully developed.

Biodiesel can also be produced from waste vegetable oil (WVO) collected from fast foods outlets, food manufacturers, restaurants and hospitality outlets (Apostolakau, Kookos & Marizioti, 2008:1023). Many small scale biodiesel manufacturers in South Africa use WVO as a potential feedstock because the equipment and machinery involved have low acquisition costs, simple designs and ease of operation. Another advantage of using WVO as a feedstock is that it does not compete with food or agricultural land. The disadvantage of WVO plants, however, is that production rates are considerably low due to batch reactors that owners prefer over continuous reactors.

Bioethanol can also be produced from molasses. This is a valuable by-product produced during sugar manufacturing from sugar cane and is used in animal feed production. Molasses contains approximately 60% of fermentable sugar which can be further concentrated to about 99%, making it a suitable feedstock for bioethanol production.

- ❖ The scope for technological advancement is large for biofuels

Littlewood *et al.* (2012) articulated that there is plenty of room for developing the existing technology of producing biofuels. Their ability to be derived from renewable sources allows them to take the centre stage, so to speak, in the advancement of the existing technology. Most countries throughout the world perceive biofuels as a medium to long term solution to all the threats posed by fossil fuels (Morales *et al.*, 2014:1354). There is little scope for technological innovations in the already matured petroleum industry which is characterised by depleting reserves of crude oil and natural gas, resulting in the current global volatile fuel and food prices.

2.9 The exclusion of maize

In South Africa, the government has explicitly banned the use of maize as a bioethanol feedstock, highlighting concerns such as the risk of jeopardising food security. But the decision of excluding maize has been heavily criticised by most South Africa maize farmers, with farmers arguing that a steady growth in production of maize over the preceding years, and the fact that maize is drought-resistant in a water-scarce country, is evidence that there is more than enough of this crop to accommodate both human

consumption and energy production. However, these sentiments were expressed by the South African maize farmers prior to the challenge of drought which is unfortunately decreasing present maize yields.

2.10 The state of bioethanol production in South Africa

The state of the biofuel development in South Africa is still at the introductory stage characterised by many governmental plans and policy statements, with no large scale commercial plant yet commissioned. Table 4 lists bioethanol projects on the commercial scale which are on the pipeline in South Africa.

Table 4: Bioethanol projects in South Africa (adapted from Pradhan & Mbohwa, 2014:1092)

Name	Type (feedstock)	Capacity (million litres/year)	Location
Arengo 316. Ltd.	Ethanol (sorghum)	90	Cradock, Eastern Cape
Mabele Biofuels	Ethanol (sorghum)	158	Bothaville, Free State
Ubuhle Renewable Energy	Ethanol (sugar)	50	Jozinin, KZN
E10 Petroleum Africa CC	Ethanol	4.2	Germiston, Gauteng

A delay in the implementation of the mandatory policy for blending biofuels by government meant that not even a single company in Table 4 managed to commission a bioethanol plant.

2.11 The Biofuel Industrial Strategy

The Biofuels Industrial Strategy was published in 2007 by the NBTT which was appointed by the cabinet in 2005 with the mandate of developing a Biofuels Industrial Strategy targeted at creating employment and diversifying sources of energy in South Africa.

The aim of the Biofuels Industrial Strategy was to penetrate 2% of biofuels into the current fuel pool of South Africa by 2013, equivalent to 400 million litres per annum. The following is a list of goals the Strategy aimed at achieving:

- ❖ energy diversification;
- ❖ attracting investment in rural agriculture;
- ❖ poverty alleviation;
- ❖ slashed reliance on imported oil;
- ❖ reduction of greenhouse gas emissions; and
- ❖ creation of 25 000 jobs in rural farming.

The strategy also highlighted infant-industry incentives, such as exemption on fuel tax, in an effort to support manufacturers. It was stipulated that bioethanol is 100% exempt from fuel tax which amounts to R 2.21 per litre.

2.12 Bioethanol production in Africa

Africa has been identified as a potential investment destination for the production of biofuels, bioethanol and biodiesel in particular, by the European Union. This is due to the fact that the continent is a significant bearer of natural resources such as arable land and water resources for biofuel crops. If unutilised arable land can be leveraged by numerous African countries to grow crops for biofuels, the contribution of the continent towards the global production of biofuels will be substantial. However, a study conducted by Amigun (2010:1362) on biofuels and sustainability in Africa showed that the development of the biofuel industry in many African countries is still in the first phase of development. This is the 'idea generation' phase by decision makers. The second phase would be political decisions to invest money into the research and the development of ideas, pilot projects and establishing frame works such as policies and regulations. The third phase involves concrete implementation after informed decisions from feasibility studies arise. The economic development of many African countries, though, is impeded by their lack of adequate energy sources (Amigun *et al.*, 2010:1361).

2.12.1 Bioethanol producers in Africa

Forty-two African countries are net oil importers. Egypt, Nigeria, Algeria and Libya are the only four countries in Africa that are energy exporters because they have proven reserves of crude oil and natural gas. This implies that a majority of African countries suffer from heavy foreign exchange incurred during the importation of oil.

Bioethanol is the most promising biofuel product that can be produced from different raw materials in many African countries. Table 5 shows a list of countries with projects on the pipeline to produce bioethanol from various feedstocks.

Table 5: Bioethanol projects in Africa

Country	Feedstock	Capacity in (million liters per year)
Benin	Cassava	20
Burkina Faso	Sugar cane	20
Ivory Coast	Molasses	20
Guinea Bissau	Cashew	10
Mali	Molasses	20
Malawi	Molasses	146
Kenya	Molasses	413
Ethiopia	Molasses	80
Nigeria	Sugar cane	70
Sudan	Molasses	408
Swaziland	Molasses	480
Senegal	Molasses	15
Tanzania	Molasses	254
Uganda	Molasses	119

Bioethanol producers in Africa (Amigun *et al.*, 2010:1361)

The interest to invest in bioethanol production by many African countries is propelled by opportunities for job creation, economic development, climate change, new research and technological advances. Many countries such as China, Germany, Sweden, Brazil, Norway, Britain and Netherlands are already flocking into many African countries, acquiring huge pieces of land for biofuel crop plantation. However, many countries are continuing with developments without policies or regulatory frameworks in place.

2.13 Different feasibility studies of bioethanol production

Many studies on the economic assessment of bioethanol production technologies using various feedstocks have been conducted in South Africa.

2.13.1 A feasibility study using sorghum and sugar cane as feedstocks

In 2007, the National Biofuels Task Team conducted a feasibility study whereby two bioethanol plants using sorghum and sugar cane were analysed for profitability. It was discovered that a 118 500 ton/year bioethanol plant that used sorghum as feedstock was profitable and would need a capital investment of R2.131 billion. Another plant that produced bioethanol from sugar cane as a feedstock with a capacity of 75 050 ton/year, requiring a capital investment of R1.973 billion, was also declared profitable. The study concluded that an average level of support needed from the South African Government would be 563 cent/litre (or R5.63/l) to yield a targeted return on assets (ROA) of 15%.

2.13.2 A feasibility study using triticale as a feedstock

Amigun (2011:3179) conducted an economic risk assessment study on advanced bioethanol production technologies in South Africa using the Monte Carlo Simulation Technique. The study did a comparative analysis on three different technologies for producing bioethanol in the Western Cape Province of South Africa. A reference plant capacity of 200 000 ton/year was chosen to determine two profitability indicators: net present value (NPV) and return on investment (ROI). Triticale grains were used as a feedstock. Triticale is a hybrid crop of wheat and rye with a starch content of 53-64%. Triticale, wheat and barley are grown abundantly in Western Cape.

To attract investment on biofuels, sound probabilistic feasibility studies on production processes are necessary. Probabilistic feasibility studies can take into consideration (quantify) risk factors associated with the inputs of a production plant (such as the price of the feedstock, inflation, electricity and labour) and measure the probability of the outputs (such as price for product). Deterministic feasibility studies ignore this and assume that everything will be fixed. This is not true in constantly changing business environments. The Monte Carlo Simulation Technique assesses the economic risk of a project by converting uncertainty in input variables into probability distributions. By iterating the simulated model repeatedly, the probability of the outputs is quantified. NPV and ROI are used to indicate the probability of economic success.

This study used the following production technologies:

- ❖ **Scenario 1:** A conventional dry-mill bioethanol plant;
- ❖ **Scenario 2:** An advanced bioethanol plant, where fibre fractionation isolates the bran which is burned in a steam boiler to produce process steam; and
- ❖ **Scenario 3:** An integrated starch and cellulose fermentation plant, where the fibre from fractionated grain is pre-treated and hydrolysed with enzymes before being fermented to bioethanol.

All of the three plants used the same processing capacity of 200 000 ton/year. The results of the study showed that scenario 2 was the preferable processing technology, achieving 98% probability of economic success and NPV greater than zero. Scenario 3 was the second preferred technology, with 96% probability of economic success and NPV greater than zero. Scenario 1 was the least preferred technology, with 93% probability of economic success and NPV greater than zero. The conclusion drawn was that without governmental

support in the form of subsidies and incentives, the probability of economic success is only 19%.

2.13.3 A feasibility study using wheat as a feedstock

Richardson *et al.* (2007:181-204) also conducted a feasibility study on a conventional dry-mill ethanol plant that uses wheat as a feedstock in Western Cape, also using the Monte Carlo Simulation Technique. The study also discovered that economic success of such a plant depends greatly on the government subsidy.

2.13.4 Advanced bioethanol plant using maize as a feedstock

The present study will perform a deterministic economic assessment of an advanced maize-fed bioethanol plant with a fractionator that isolates the bran which is burned in a steam boiler to generate process steam. This technology was selected specifically because previous studies which have used other starch-rich crops in South Africa such as wheat and triticale to assess bioethanol plant profitability, have found that it is more profitable as compared to a conventional dry-mill bioethanol plant (Leitner & Lindorfer, 2015:195). This can be attributed to the fact that bioethanol plants employing this technology are self-sufficient in terms of energy. Coal-based electricity is the second largest operational cost after the feedstock for the bioethanol plant. So the use of biomass (fractionated bran) as a source of fuel enhances the potential of the plant to be economical. The fibre/bran is used as a fuel in steam boilers that produce steam for the process plant. In this way, expensive coal-based electricity for running the boilers is substituted. In terms of being energy self-sufficient, this plant can be compared to a sugar cane-to-bioethanol plant, which uses bagasse as a source of fuel. Bagasse is a solid residue remaining after sugar juice is extracted. (Brent, Blottinitz & HietKamp, 2010:20).

2.14 The advanced bioethanol processing technology

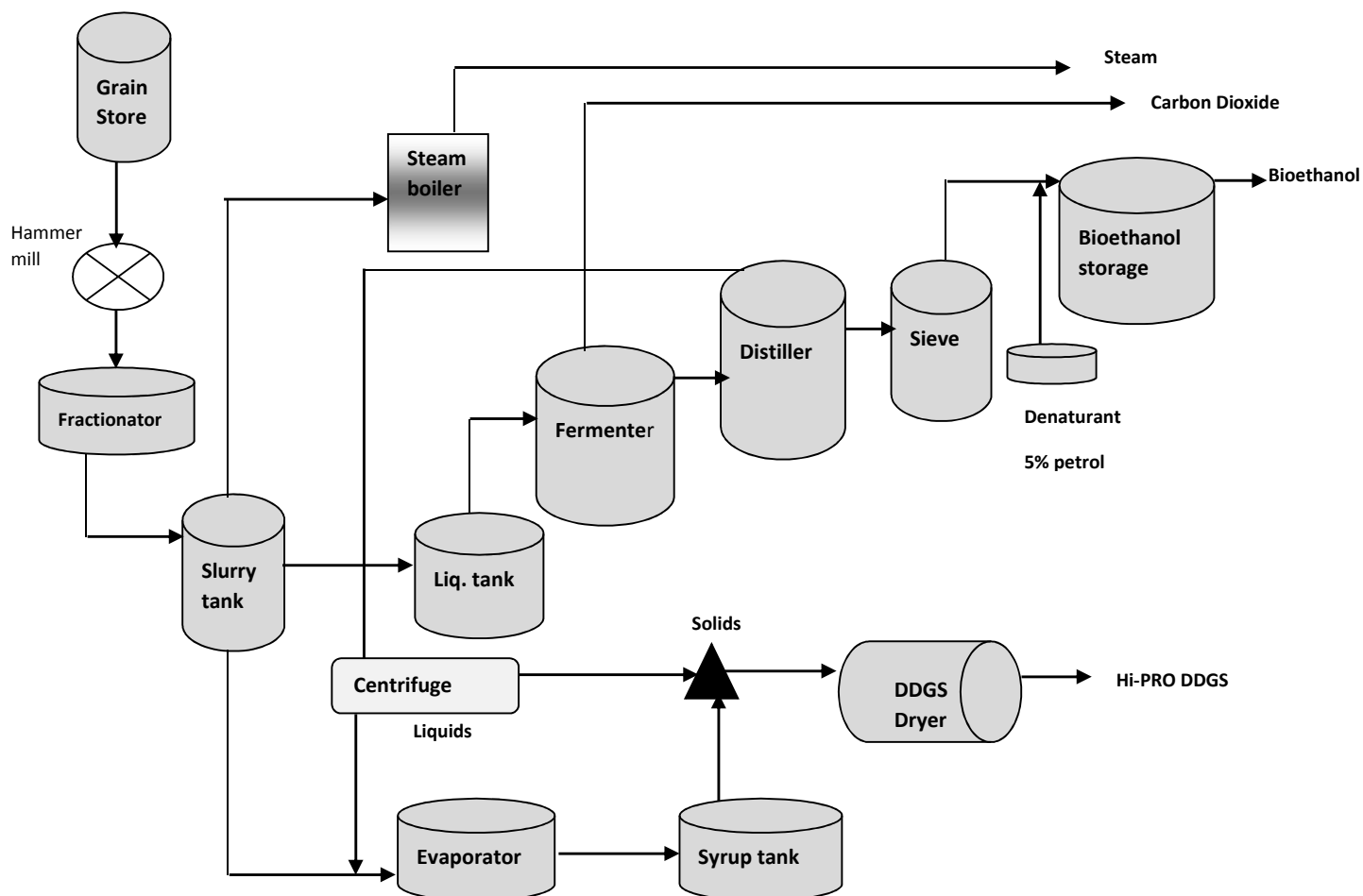


Figure 6: Advanced bioethanol plant (Amigum *et al.*, 2011:3180)

In an advanced bioethanol production technology shown in Figure 6, the maize grains from the storage tank enter a hammer miller which mills the grains to expose components like the germ, endosperm and bran. The fractionator is a unit that isolates the bran (fibre) and the endosperm (carbohydrates). The bran is fed in a steam boiler as a fuel to produce process steam. The mixture of endosperm and some of the bran is fed into the slurry tank where water and enzymes are added to form a mash/slurry for a process called *enzymatic hydrolysis*. Enzymatic hydrolysis converts the starch into dextrose, a simple sugar suitable for the fermentation process (Leitner & Lindorfer, 2015:195).

The mash is fed into fermenters where yeast and nutrients are added. During fermentation, carbon dioxide gas (CO₂) is released while ethanol in a form of beer is produced. Ethanol from fermentation is fed into a distillation column for purification and dehydrated in a sieve to produce 200 proof ethanol (99.5%). This is anhydrous ethanol because it has no water in it. It is then blended with 5% unleaded petrol, known as the denaturant, so that it may

not be consumed as beer. The blended bioethanol is sent to storage tanks and ready for transportation to filling stations. The CO₂ is piped to gas storage tanks and marketed to consumers that purify and bottle the gas for fire extinguishers and food and beverage preservative.

The third valuable by-product from this process, High Protein Dried Distillers Grains and Solubles (Hi-Pro DDGS), is used as animal feed (dairy, beef, poultry). It is produced from non-carbohydrate components (bran) that could not be fermented. DDGS produced from a conventional dry mill process contains about 35% protein. However, in an advanced bioethanol process, the protein content is improved to about 65% due to bran fractionation step. This enhances the value of DDGS to be on par to that of other protein-rich animal feeds such as soybean oilcake, which is currently in great demand in South Africa.

2.15 Bioethanol production in USA

The bioethanol industry is one of the most significant industries in USA. Currently, the industry encompasses over 200 production plants using conventional dry-mill technology and maize as a feedstock (Amigum *et al.*, 2010:1362). These plants have a combined contribution of about 13.5 billion gallons of bioethanol. The USA has advanced in bioethanol production from maize because 70% of the companies producing the fuel use dry-mill plants, with the other plants using advanced technologies whereby second-generation feedstocks such as grass straws and wood are also used. This means that in the USA, bioethanol is produced using starch (from grains) and cellulose (grass, wood components). The land for plantation of bioethanol crops as well as water resources for irrigation, do not compete for pieces of lands dedicated to producing food crops.

2.16 Bioethanol production in Brazil

Brazil has made advancements in the production of bioethanol from sugar cane as a feedstock over the past two decades, with the use of advanced energy self-sufficient technologies (bagasse as a fuel source) by many Brazilian corporations accounting for the industry success.

2.17 Conclusion

The global contribution of South Africa in the production of biofuels (which is less than 0.01%) is a clear indication of an industry that still warrants further consideration by government in terms of investing in it. South Africa needs to invest heavily in developing the biofuel industry as it is still at the introductory stage. Maize was banned as one of the

potential feedstocks by the South African Government in the 2007 Biofuels Industrial Strategy. However, if maize is to be used as one of the feedstocks to produce bioethanol, then conventional farming techniques must be modified by genetic engineering.

Grain sorghum and sugar cane are the leading candidates in that regard for producing bioethanol on a large scale. In the Western Cape, there is potential for growing triticale and wheat as feedstocks for bioethanol. Feasibility studies which have been conducted for production plants that will process these crops in South Africa show an acceptable level of economic success provided government support in terms of fuel tax exemption and subsidies for producers is available.

Many African countries are net importers of crude oil. Not having diversified energy sources has been identified as one of the limitations of economic development by these countries. As a result, a number of these countries have initiated projects to produce bioethanol on a large scale, taking advantage of readily available foreign investment from countries such as China and the European Union, countries which are keen to tap into the viable emerging renewable energy market in Africa. USA and Brazil thrive in the production of bioethanol because manufacturing corporations employ economy of scale strategies and invest in energy efficient advanced bioethanol production technologies (Estherhuizen, 2009).

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

Chapter two surveyed the literature at great length in terms of the South African maize industry and the challenge of the present drought affecting current yields of maize. More literature was reviewed in terms of the outlook of the biofuel production in the world; major reasons why South Africa needs to make considerable investment in the development of the biofuel industry; the state of the biofuel industry in South Africa; bioethanol production in Africa; economic assessment of the bioethanol plant in South Africa; and brief insight into the bioethanol production industry in the US and Brazil. Chapter three will focus on the research methodology required to accomplish the following research objectives.

3.2 Research objectives

- ❖ to describe the maize industry of South Africa;
- ❖ to analyze the maize production trends from 2011 to 2015 in South Africa;
- ❖ to analyze the domestic and export markets of maize;
- ❖ to use a 200 000 ton/year bioethanol plant as a reference size to assess profitability;
- ❖ to use profitability indicators such as discounted payback period, net present value and return on investment to assess the economics of bioethanol production processes; and
- ❖ to perform a comparative analysis between the value of the maize generated from exportation and the value generated when maize is converted into bioethanol.

3.3 Research method

This study will adhere to mixed qualitative and quantitative methods (Creswell, 2003), employing qualitative methods in the sense that instruments such as questionnaires will be used to gather opinions and experiences of respondents which will be analysed for pertinent conclusions, and quantitative methods in the sense that numerical data gathered from secondary sources (published literature) will be used to assess the profitability of the bioethanol plant.

❖ Limitations of the study

The study will be limited to gathering qualitative and quantitative data from three institutions (two public and one private). A questionnaire is the only qualitative instrument that will be used while five capital budgeting metrics (economic models) will be used as a quantitative instrument. Economic data will only be acquired from published literature owing to the lack of real time data from businesses operating bioethanol plants.

3.4 Scope of qualitative technique

Gathering data using a qualitative method approach will be limited to one research instrument, an administered questionnaire. A questionnaire is an appropriate instrument for this research because the organisations from which the respondents will be drawn are scattered geographically throughout three South African provinces, making it difficult if not impossible, to collect the data by visiting these locations in person. The questionnaire is structured in such a way to elicit opinions and insights about the reasons the biofuel industry is stalling in South Africa, as well as insightful recommendations for developing the industry. Relevant government departments and emerging private companies must play a crucial role in achieving this.

3.5 Sources of data

- ❖ The Department of Energy of South Africa
- ❖ The Department of Agriculture in Western Cape
- ❖ Three private companies producing biofuels in South Africa:
 - ✓ Mabele Fuels (Pty) Ltd. operating in Johannesburg, Cape Town and Bothaville (Free State)
 - ✓ Greentech Biofuels (Pty) Ltd. operating in Port Elizabeth
 - ✓ Green-Diesel (Pty) Ltd. operating in Cape Town
- ❖ Maize Market Value Chain Profile for 2014, compiled by the Department of Forestry and Fisheries of South Africa
- ❖ Published literature on how to evaluate profitability indicators such as payback period, net present value and return on investment of a manufacturing plant

3.6 Sample size

In each of the seven branches of the Department of Energy, a stratified random sampling technique will be used whereby five respondents will be sampled. The population further consists of the Business Planning and Strategy branch within the Department of Agriculture in Western Cape, Executive Management of Mabele Fuels, Greentech Biofuels and Green-Diesel. This is summarised in the sampling table below.

- ❖ Department of Agriculture in Western Cape: a sample of three officials within the Business Planning and Strategy branch
- ❖ Mabele Fuels: a sample of three Directors
- ❖ Greentech Biofuels: a sample of three Directors
- ❖ Green-Diesel: a sample of two Directors

Table 6: Population and the sample size

Department of Energy Branches	Location	No. of respondents	Contact Number
Energy Policy and Planning	Pretoria	5	012 406 8000
Petroleum and Petroleum Products Regulation	Pretoria	5	012 406 8000
Nuclear Energy	Pretoria	5	012 406 8000
Clean Energy	Pretoria	5	012 406 8000
Energy Programs and Projects	Pretoria	5	012 406 8000
Corporate Services	Pretoria	5	012 406 8000
Financial Management Services	Pretoria	5	012 406 8000
Department of Agriculture in Western Cape branch			
Business Planning and Strategy	Cape Town	3	021 808 5191
Biofuels Private Companies in South Africa			
Mabele Fuels	Cape Town and Johannesburg	3	021 418 4490
Greentech Biofuels	Port Elizabeth	3	041 451 1834
Green-Diesel	Cape Town	2	021 919 2166
TOTAL		46	

- ❖ Permission letters

Appendix B of the study illustrates five permission letters which were sent to the five institutions where data for the study will be sourced. The reason for requesting consent prior to data collection from these institutions, was to address ethical considerations such as gaining informed consent, confidentiality, privacy, anonymity, Copy right, ownership of data, use and misuse of data.

3.7 Sampling technique

A stratified random sampling technique will be employed (Golafshani, 2003). This technique involves dividing the population into homogeneous sub-groups and then taking a random sample in each sub-group. Stratified random sampling is appropriate for this study because the department is sub-divided into seven branches (Golafshani, 2003). So a simple random sampling method will be done in each branch whereby each respondent will be asked to complete a questionnaire. Again, using a questionnaire to gather qualitative data will be appropriate as the population from which the sample will be drawn is geographically dispersed. Alternatively, if a respondent that was requested to participate in the survey is unavailable, a suitably experienced respondent situated within the same stratum will be asked to participate.

3.8 The survey instrument

Table 7 (STEEP factors) presents a sample questionnaire for this study. The questionnaire is structured in a manner that addresses the STEEP factors previously discussed in Chapter 2: social, technological, economic, environmental and political factors. As the context of the study affects these factors, the survey instrument has incorporated them. Under each factor is a list of questions generated with the objective of eliciting opinions and thoughts of the chosen participants from the various organisations shown in Table 6. The ultimate goal of this instrument is to assess the opinions of the participants and evaluate if they help the study to attain its set objectives, research questions and hypothesis.

- ❖ **Social factors:** The objective of addressing this factor was to gain opinions on food versus fuel.
- ❖ **Technological factors:** This factor gauges insights on technologies for producing maize and bioethanol in South Africa.
- ❖ **Economic factors:** This factor intends to discover the revenue stream that is favoured between bioethanol production and maize exports.
- ❖ **Environmental factors:** This factor assesses the impact of bioethanol production on the environment.
- ❖ **Political factors:** This factor captures opinions on the effectiveness of government in policy making and support of bioethanol production, as well as the consequences on international relationships the use of maize for bioethanol production might have.

Table 7: STEEP factors

	STEER factors	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
Social Factors						
1	The South African maize industry is big enough to produce maize for both consumption and bioethanol production	1	2	3	4	5
2	Using maize to produce bioethanol will upset the country's food security	1	2	3	4	5
3	Maize is a major staple food crop for both domestic and export markets	1	2	3	4	5
4	More jobs can be created in rural agricultural farming of maize	1	2	3	4	5
5	Land use change to accommodate biofuel crops such as maize will not be accepted by the indigenous owners of land	1	2	3	4	5
Technological Factors						
1	A maize-to-bioethanol technology is capital intensive in South Africa	1	2	3	4	5
2	200 000 tons/year of a bioethanol plant will be profitable in South Africa	1	2	3	4	5
3	There is a big scope for advancing bioethanol technology in South Africa	1	2	3	4	5
4	The production of maize in South Africa on farms is well mechanized	1	2	3	4	5
5	Emerging maize farmers must be resourced with advanced farming implements	1	2	3	4	5
Economic Factors						
1	Discounted Payback Period, Net Present Value and Return On Investment are good economic indicators because they account for time value of money	1	2	3	4	5
2	Using maize to produce bioethanol will generate more revenue for the country	1	2	3	4	5
3	Bioethanol production will save heavy foreign exchange charged from government during the import of crude oil	1	2	3	4	5
4	Maize has more economic benefits as a bioethanol feedstock than Sugar cane	1	2	3	4	5
5	Bioethanol production will attract Foreign Direct Investment in South Africa	1	2	3	4	5
Environmental Factors						
1	Maize for bioethanol production should be genetically modified	1	2	3	4	5
2	There is enough underutilised arable land in South Africa	1	2	3	4	5
3	Bioethanol will reduce the carbon footprint because it is clean and renewable	1	2	3	4	5
4	Water resources are scarce in South Africa to grow maize for both food and fuel	1	2	3	4	5
5	Fossil fuels such as gasoline contribute to the effects of global warming	1	2	3	4	5
Political Factors						
1	Government support is essential in farming crops that produce bioethanol	1	2	3	4	5
2	Government needs an effective implementation strategy on bioethanol production	1	2	3	4	5
3	Using maize to produce bioethanol instead of exporting it will ruin international relationships that South Africa has with other countries	1	2	3	4	5
4	The Biofuel Industrial Strategy is one of the most effective policies in South Africa	1	2	3	4	5
5	Bioethanol production is stalling in legislation in South Africa	1	2	3	4	5

3.9 Scope of quantitative technique

The quantitative research method will be used to investigate numerical data from published literature on economic feasibility studies already conducted in South Africa to evaluate profitability of an advanced bioethanol production technology that uses maize as a feedstock. Profitability indicators such as payback period, net present value and return on investment will be employed to assess the economics of the bioethanol production process. Bioethanol production is still at the infancy stage in South Africa, a limitation which often means that acquiring real-time quantitative data from companies running the plants is virtually impossible. This study has relied on similar economic feasibility studies in South Africa that have investigated starch-rich crops other than maize.

3.9.1 Economic models

The study conducted by Amigun *et al.* (2011) on the economic feasibility of a bioethanol plant that used triticale grains as a feedstock in South Africa was applied as a 'base case' to perform economic evaluation of the current study.

❖ Cost capacity estimation

Amigun *et al.* (2008:8) followed the widely used model for estimating biofuel production plants:

$$C_2 = C_1 \left(\frac{Q_2}{Q_1} \right)^x$$

Where C_1 and C_2 are the costs associated with capacities Q_1 and Q_2 ; and X is the plant capacity cost factor. This model is explained in greater detail in Chapter 4.

❖ Chemical Engineering plant cost index

After the plant has been scaled up using the above model, it must be re-adjusted for inflation using relevant indexes. The application of the model is also illustrated in Chapter 4.

$$C_{2,Corrected} = C_2 \left(\frac{I_2}{I_1} \right)$$

I_2 is the chemical engineering plant cost index (CEPCI) in the year that the plant is built; while I_1 is the historical CEPCI corresponding to capital cost C_1 which was used for scaling up. Application of these indices is explained in chapter 4.

❖ Profitability indicators

Capital budgeting models such as NPV, ROI, DPP, IRR and ROA are discussed in Chapter 4.

3.10 Conclusion

One of the major drives for undertaking this study is to contribute to the development of the biofuel industry in South Africa which is unfortunately still stalling at the introductory stage. The study aims at contributing to the development of the industry by generating economic data on using crops that are produced in surplus quantities, specifically maize, for bioethanol production in South Africa. This is the data which can be considered by policy makers, industry development practitioners and investors to make informed decisions before capital investment goes into manufacturing plants.

A mixed method that incorporates both qualitative and quantitative research methods of gathering data was chosen as the appropriate approach. In order to successfully meet the objectives of the study, a combination of qualitative and quantitative data needs to be captured and analysed, and conclusions will be drawn from the findings. The qualitative research method employed a questionnaire as the relevant research instrument to the targeted organisations. The quantitative research method relied on published literature such as feasibility studies of other starch crops such as triticale and wheat which have already been conducted in South Africa.

CHAPTER 4

ECONOMIC FEASIBILITY STUDY

4.1 Introduction

Before an industrial plant can be opened for operation, a large sum of money must be supplied to purchase and install the necessary machinery and equipment (Sparks, Ortmann & Lagrange, 2010). Land and service facilities must be obtained, and the plant must be erected with proper piping, controls and services. The capital needed to supply the necessary manufacturing and plant facilities is called the *fixed capital investment*, while that necessary for the operation of the plant is termed the *working capital*. The sum of the fixed capital investment and the working capital is called the *total capital investment* (Sparks *et al.*, 2010).

4.2 Fixed capital investment (FCI)

Chemical plants are built to generate profit for the investors. That is why an estimate of the necessary investment and the cost of production is required before the profitability of a project can be accurately assessed (Sparks *et al.*, 2010). For a plant that processes 200 000 ton/year of maize to produce bioethanol in South Africa, the following economic assumptions were made.

Economic assumptions (Amigun *et al.*, 2011):

- ❖ The salvage value of the plant is 10% of the fixed capital investment.
- ❖ The working capital is 10% of fixed capital investment.
- ❖ 25% minimum return on investment desired by investors.
- ❖ Debt to equity ratio is 70:30.
- ❖ DDGS price is equal to the price of soya oil cake after grain fractionation which is R7000/ton.
- ❖ The price of maize is R5000/ton (SAFEX, 2016).
- ❖ The bank fixed interest rate for the loan to build the plant is 14.1%.
- ❖ Inflation rate is 6.3% (Statistics South Africa, 2016).
- ❖ Corporate tax levied on companies is 28% (South Africa Revenue Services, 2016).
- ❖ Straight-line depreciation is used to calculate depreciation of assets over 15 years.
- ❖ The life span of the plant is 15 years.

4.2.1 Capital Expenditure (CAPEX)

The CAPEX of the plant is determined using the scaling up or down model illustrated below:

$$C_2 = C_1 \left(\frac{Q_2}{Q_1} \right)^x \quad [1]$$

Where C_1 is the cost of an existing plant capacity Q_1 ; C_2 is the cost of the considered plant capacity Q_2 ; and X is the scaling up or down factor equal to 0.6 for plant capacities from 80 to 160 million litres of bioethanol per year. The scaling up of a 200 000 ton/year maize-to-bioethanol plant will be based on a study of Amigun *et al.* (2011), the results of which are presented in Table 8.

Table 8: Triticale as a feedstock (Amigun *et al.*, 2011)

Feedstock type: Triticale grains	
Process parameters	Units
Plant capacity	200 000 ton/year
Yield	436 Litres/ton _{grain}
Bioethanol output	87.2 million litres per annum (MLpa)
CAPEX for bioethanol plant	R 5.31/L
Energy demand	2.842 kWh/L
DDGS output per ton of grains	0.25 ton/ton _{grain}
CO ₂ output per ton of grains	0.372ton/ton _{grain}
By product revenue	
DDGS	R 7000/ton
CO ₂	R 132/ton
Process operating expenses	
Enzymes	R 0.32/L
Yeasts	R 0.039/L
Other Process Chem & antibiotics	R 0.036/L
Bioler and cooling tower chem	R 0.009/L
Annual cost of water	R 0.038/L
Business operating expenses	
Maint. & Repair Costs	R 0.022/L
Labour Cost	R 0.087/L
Management & Qual.Control	R 0.03/L
Financing & business expenses	
Debt:Equity	70/30
Fixed interest on capital loan	14.1%
Depreciation method	MACRS
Average tax rate	28%
Discount rate for NPV	25%
Minimum desired ROI for investors	25%

The assumed process parameters for the plant capacity of this study that is using maize grains as feedstock are as follows:

Table 9: Maize as a feedstock

Feedstock type: Maize grains	
Process parameters	Units
Plant capacity	200 000 ton/year
Yield	400 Litres/ton _{grain}
Bioethanol output	80 million litres per annum (MLpa)
CAPEX for bioethanol plant	R 5.31/L
Energy demand	2.842 kWh/L
DDGS output per ton of grains	0.25 ton/ton _{grain}
CO ₂ output per ton of grains	0.372ton/ton _{grain}
By product revenue	
DDGS	R 7000/ton
CO ₂	R 132/ton
Process operating expenses	
Enzymes	R 0.32/L
Yeasts	R 0.039/L
Other Process Chem & antibiotics	R 0.036/L
Bioler and cooling tower chem	R 0.009/L
Annual cost of water	R 0.038/L
Business operating expenses	
Maint. & Repair Costs	R 0.022/L
Labour Cost	R 0.087/L
Management & Qual.Control	R 0.03/L
Financing & business expenses	
Debt:Equity	70/30
Fixed interest on capital loan	14.1%
Depreciation method	Straight line
Average tax rate	28%
Discount rate for NPV	20.9%
Minimum desired ROI for investors	25%

The next step is to estimate the CAPEX (C_2) of the maize processing plant using the CAPEX of the triticale processing plant (C_1) which is determined by multiplying the CAPEX for a litre of bioethanol (R5.31) and the plant capacity (87.2 MLpa), giving R463 032 000.

$$C_2 = 463032000 \left(\frac{80}{87.2} \right)^{0.6} = R439\ 698\ 625$$

The new CAPEX (C_2) is adjusted for inflation using the chemical engineering plant cost index. This figure is compared to R424 800 000, which is C_2 that is directly obtained from multiplying the CAPEX for a litre of bioethanol (R5.31) and its capacity (80 MLpa).

4.2.2 The chemical engineering plant cost

It is of utmost importance to adjust the calculated cost of the plant for inflation during the time period of scaling up or down. The adjustment is done by applying the chemical engineering plant cost indices according to Equation 2:

$$C_{2,Corrected} = C_2 \left(\frac{I_2}{I_1} \right) \quad [2]$$

C_2 is the corrected cost of the considered plant capacity Q_2 ; I_2 (567.5) is the chemical engineering plant cost index (CEPCI) in the year that the plant is built; while I_1 (585.7) is the historical CEPCI corresponding to capital cost C_1 which was used for scaling up in Equation 1.

$$C_{2,Corrected} = 439698625 \left(\frac{567.5}{585.7} \right) = R426\,035\,461$$

After the chemical engineering plant cost indexes have been factored, the resultant CAPEX is greater than R424 800 000. This means that Equation 1, which can be used for either scaling up or down for the new plant CAPEX, initiated the scaling up in this scenario.

4.2.3 Product revenue

Bioethanol is the major product of the process, while Distillers' Dried Grains and Solubles (DDGS) and carbon dioxide (CO_2) are the two by-products produced in significant quantities.

❖ Bioethanol price

The selling price of bioethanol is equal to the basic fuel price (BFP) times blending value of bioethanol, as indicated by Equation 3.

$$\text{Bioethanol price at refinery} = \text{BFP} \times \text{blending value} \quad [3]$$

This bioethanol price estimation at the refinery is only applicable provided the BFP is blended with 2% bioethanol where the blending value is 1 (Department of Energy, 2014). According to the Department of Energy in 2016, the BFP between July and August was 612.970 cent/litre (R6.13/litre)

Therefore bioethanol price at refinery = $6.13 \times 1 = R6.13/\text{litre}$

4.2.4 By-product revenue

❖ DDGS

The advanced bioethanol plant with a fibre fractionation step enriches the protein content of DDGS from 35% to about 65%, putting its market value on par to that of soya oil cake which is currently in great demand as the preferred animal feed in South Africa. The DDGS price was assumed to be R7000/ton for a plant that produces 0.25 ton of DDGS per ton of maize (BFAP, 2015).

❖ CO₂

Carbon dioxide is an odourless, colourless, non-toxic and non-flammable gas supplied as high pressure liquefiable gas in metal cylinders. In South Africa, CO₂ is marketed to Afrox, a large gas manufacturing company in Sub-Saharan Africa. The bioethanol plant that processes maize was assumed to produce 0.372 tons of CO₂ per ton of maize. The price of CO₂ based on the study by Amigun *et al.* (2011) was assumed to be R132/ton.

Table 10 summarises the revenue of products and by-products of the process.

Table 10: Revenue

Revenue			
Item	Yield	Unit price	Revenue per 80 million litres bioethanol
Bioethanol	80 000 000 litres/year	R6.13/litre	R490 400 000
DDGS	0.25 ton/ton _{maize}	R7000/ton	R 350 000 000
CO ₂	0.372 ton/ton _{maize}	R132/ton	R9 820 800
Total revenue			R850 220 800

It should be noted that the revenues of DDGS and CO₂ are calculated based on 200 000 ton/year of maize which is processed in the plant, rather than 80 000 000 litres/year of bioethanol produced. For every ton of maize processed, 0.25 tons of DDGS are produced, totalling 50 000 tons produced per annum. Using a unit price of R7000/ton, the annual revenue of R350 million is generated. Similarly, the revenue of CO₂ is based on the quantity of maize, whereby every ton of maize processed yields 0.372 tons of CO₂. This means that 74 400 tons of CO₂ are produced per annum, resulting in a revenue of R9 820 800.

4.3 Working capital investment (WCI)

Working capital is the investment necessary for the operation of the plant.

4.3.1 Operational expenses (OPEX)

The operational expenses for this study are divided into process and business operating expenses, according to Table 11.

Table 11: Expenses

Process operating expenses		
Item	Cost per liter of bioethanol	Total cost per 80 million litres of bioethanol
Maize	R 12.50	R 1 000 000 000
Enzymes	R 0.32	R25 600 000
Yeasts	R 0.04	R3 120 000
Antibiotics	R 0.04	R2 880 000
Boiler & cooling tower chem.	R 0.01	R 720 000
Annual cost of water	R 0.04	R3 040 000
Electricity	R 1.90	R152 320 000
Business operating expenses		
Item	Cost per liter of bioethanol	Total cost per 80 million litres of bioethanol
Labour cost	R 0.09	R6 960 000
Maint. & Repairs cost	R 0.02	R1 760 000
Management & Qual. Control	R 0.03	R2 400 000
Real estate & taxes	R 0.00	R 240 000
Licenses, fees & insurance	R 0.01	R 560 000
Miscellaneous expense	R 0.02	R1 920 000
Total OPEX		R1 201 520 000

From the table of operating expenses it must be noted that the total cost of feedstock, which is maize is quite large. Based on a typical assumption that 400 litres of bioethanol are formed per ton of processed maize, combined with the fact that maize costs R5000/ton, it can be seen that the unit cost of maize per litre of bioethanol (R12.5) is double the unit price of bioethanol (R6.13/litre), implying that the actual value of the economics of the project will be destroyed.

4.3.2 Total capital investment (TCI)

$$TCI = FCI + WCI$$

[4]

$$TCI = (R426\ 035\ 461 + R1\ 201\ 520\ 000) = R1\ 627\ 555\ 461$$

The total capital investment is not in accordance to the economic assumption that the working capital will be 10% of the fixed capital. Conversely, the fixed capital is 35% of the working capital. This can be attributed to the high cost of production, with feedstock and electricity contributing significantly to this cost. The feedstock is more valuable than the energy end product which is bioethanol. This means that converting maize into bioethanol affects the economics of the plant negatively.

4.4 Net present value (NPV)

Net present value refers to the calculation that compares the money received in the future to the money received today, while accounting for time and interest. It is based on the principle of time value of money which explains how time affects monetary value. The following equation illustrates the time value of money concept:

$$PV = \frac{FV}{(1 + i)^N} \quad [5]$$

Where:

- ❖ PV = Present value (the value of the sum of money today)
- ❖ FV = Future value (the value of the sum of money in the future)
- ❖ i = Interest rate or discount rate per period
- ❖ N = The number of periods

In the equation above, the plant life span is the only known parameter. The net annual cash flow generated by the project (future value) needs to be known so that the net present value can be determined. The net annual cash flow can be determined by subtracting the cash outflow of the project from the cash inflow on an annual basis. Depreciation of the plant also needs to be calculated as this is treated as an expense in the income statement for tax purposes, although it does not imply the physical movement of cash. Another important parameter that must be known is the discount rate i , determined by calculating the weighted average cost of capital (WACC). The plant depreciation and WACC calculations are summarised below.

4.4.1 Straight line depreciation

The straight line depreciation is a method of dividing the difference between the cost of an asset and its salvage value by the number of years it is expected to be used. The straight line depreciation is the preferred method because it is easy to use and the likelihood of errors is minimal because the same amount is expensed every accounting period. Other

asset depreciation techniques, such as double declining balance, are more complex, whereas the straight line depreciation method uses three variables: the asset value, the salvage value of an asset and the expected lifespan of an asset.

Asset value = R426 035 461

Salvage value = R42 603 546 (10% of fixed assets)

Lifespan = 15 years

Straight line depreciation = (asset value – salvage value)/number of years

$$= (426\,035\,461 - 42\,603\,546)/15$$

$$= R25\,562\,128$$

4.4.2 Weighted average cost of capital

The weighted average cost of capital is a combination of debt and equity used to finance the business. Corporate finance involves three activities of financial management decisions: capital budgeting, capital structure and working capital management. *Capital budgeting* occurs when a company chooses investment opportunities that will have high return on investment. *Capital structure* refers to the financing mix (grant, equity and debt) that is used to finance the investment. *Working capital management* deals with managing the day-to-day activities of a business such as receiving cash from customers and paying suppliers.

After an investment opportunity has been selected, deciding how to finance the investment becomes the critically important second aspect. The cost of capital used to finance differs from company to company and is dictated by factors such as creditworthiness, track record (operating history), liquidity and profitability. Generally, newly established business ventures will be offered a higher cost of capital as compared to older ones by financiers because they have not fashioned a solid track record for themselves in the market and have a high risk profile.

The following equation illustrates how WACC for this project is evaluated.

$$WACC = \frac{E}{V} R_E + \frac{D}{V} R_D (1 - T_C) \quad [6]$$

Where:

❖ R_E = Cost of equity

- ❖ R_D = Cost of debt
- ❖ E = Market value of equity
- ❖ D = Market value of debt
- ❖ V = Financing mix (debt + equity)
- ❖ T_C = Corporate tax rate

The bioethanol plant is financed by:

- ❖ R_E = 25% (minimum return on investment ROI desired by investors)
- ❖ R_D = 14.1% - the bank fixed interest rate for the loan to build the plant
- ❖ E = 30% of total capital investment (R488 266 638)
- ❖ D = 70% of total capital investment (R1 139 288 823)
- ❖ V = $E + D = (30 + 70) = 100$
- ❖ T_C = 28% tax levied on companies

$$WACC = \frac{30}{100} 25 + \frac{70}{100} 14.1(1 - 0.28)$$

$$WACC = 14.6\%$$

The investors would like to achieve a 25% return on their investment while the lenders are expecting 14.1% return on the money they have lent. This means that the project is expected to return a minimum of 19.6% on average per annum in order to satisfy both the debt and equity holders. So, 19.6% would be the expected WACC for the project. However, the calculated WACC is 14.6% and is less than the expected WACC, meaning the project will have a cash shortfall in satisfying the obligation of the investor and lender percentages they are expecting for the capital used to fund it. In monetary terms, this means that for the R488 266 638 that was invested, the investors are expecting a return of R122 066 660 (25%) per year while from R1 139 288 823 borrowed, the lenders are expecting a return of R160 639 724 (14.1%) per year. Therefore, the project will not meet the expectations of its investors and lenders.

4.4.3 Net annual cash flow

Table 12: Income statement

Profit or loss statement for the year ended in June 2016				
		R(million)	R (million)	
Sales				850.22
Less variable expenses				
	Maize	1000		
	Enzymes	25.6		
	Yeasts	3.12		
	Antibiotics	2.88		
	Boiler & cooling tower chem.	0.72		
	Annual cost of water	3.04		
	annual cost of electricity	<u>152.32</u>		
				<u>1187.68</u>
Contribution margin				-337.46
Less fixed expenses				
	Salaries	6.96		
	Maintenance	1.76		
	Quality control	2.4		
	Real estates	0.24		
	Licenses & insurance	0.56		
	Miscellaneous exp.	1.92		
	Depreciation	<u>25.56</u>		
Total fixed expenses				<u>39.402128</u>
Net loss				-376.86

The income statement above depicts the loss of R376 861 328 from what is generated by the project per annum. The negative contribution margin also indicates that the project will not be able to cover its variable and fixed expense, nor render any profit with what remains.

The annual cash flow is computed as follows:

Net loss = - R376 861 328

Add: Non-cash deduction for depreciation = R25 562 128

Net annual cash flow = -R351 299 000

4.4.4 NPV

The net present value of the project is calculated using a discounting rate of 14.6% (WACC) per year. Annual inflation is 6.3% (from economic assumptions). Therefore, the discount rate for the project is 14.6% + 6.3% = 20.9%.

Table 13: First trial of NPV

Project name: Bioethanol production from maize			
Year number	Present value factor at 20.9%	Project net income/loss [R]	Present value [R]
1	0.827	-351 299 000	-290 524 273
2	0.684	-351 299 000	-240 288 516
3	0.566	-351 299 000	-198 835 234
4	0.468	-351 299 000	-164 407 932
5	0.387	-351 299 000	-135 952 713
6	0.32	-351 299 000	-112 415 680
7	0.264	-351 299 000	-92 742 936
8	0.219	-351 299 000	-76 934 481
9	0.181	-351 299 000	-63 585 119
10	0.15	-351 299 000	-52 694 850
11	0.124	-351 299 000	-43 561 076
12	0.103	-351 299 000	-36 183 797
13	0.085	-351 299 000	-29 860 415
14	0.07	-351 299 000	-24 590 930
15	0.058	-351 299 000	-20 375 342
Total		-5 269 485 000	-1 582 953 294
Capital investment [R]	1 627 555 461		
NPV [R]	= PV(total) – Capital		
	-3 210 508 755		

Sample calculation for year 2:

$$PV = \frac{FV}{(1+i)^N} = \frac{-351299000}{(1+0.209)^2} = -R240\,288\,516$$

The project does not warrant a further consideration because of a negative net present value.

4.5 Return on investment

Return on investment (ROI) is another financial metric for evaluating the efficiency of an investment. ROI calculates the percentage of investment that is returned per year. This is achieved by first determining the average annual profit (AAP) and then dividing AAP which is the benefit (return) of an investment by the cost of an investment according the formulas below:

$$AAP = \frac{TotalGains - TotalOutlay}{NumberOfYears} \quad [7]$$

Where:

- ❖ Total gains = - R5 269 485 000
- ❖ Total outlay (original investment) = R1 627 555 461
- ❖ Number of years = 15 years

$$AAP = \frac{-5269485000 - 1627555461}{15} = -R459\,802\,697$$

The next step is to determine ROI as follows:

$$ROI = \frac{APP}{Investment} \times 100\% \quad [8]$$

$$ROI = \frac{-459802697}{1627555461} \times 100\% = -28.3\%$$

The negative percentage (-28.3%) implies a negative growth (specifically, a loss) in earnings of the project. When a project has positive returns on its investment, it means positive growth which is signified by higher earnings, productivity, expansion and ultimately an increase in share price of the company. Negative growth signifies a decline in sales, productivity output, wage growth, job losses, share price and even liquidation.

$$\text{Project growth rate} = \frac{\text{endingvalue} - \text{beginningvalue}}{\text{beginningvalue}} \times 100\% \quad [9]$$

$$= \frac{-5269485000 - 1627555461}{1627555461} \times 100\% = -424\%$$

This means that the project is experiencing 424% of negative growth rate every year.

4.6 Discounted payback period

The discounted payback period (DPP) is a capital budgeting procedure for evaluating the profitability of a project by determining the number of years that are required for a breakeven point to be reached. This is accomplished by discounting future cash flows of the project, taking into account the time value of money (TVM).

$$DPP = A + \frac{B}{C} \quad [10]$$

Where:

- ❖ A = Last period with a negative cumulative discounted cash flow
- ❖ B = Absolute value of discounted cumulative cash flow at the end of period A
- ❖ C = Discounted cash flow during the period after A

Table 14: First trail of DPP

Project name: Bioethanol production from maize				
Year number	Present value factor at 20.9%	Project cash flow [R]	Discounted cash flow [R]	Cumulative discounted cash flow [R]
0	1	-1 627 555 461	-1 627 555 461	-1 627 555 461
1	0.827	-351 299 000	-290 524 273	-1 918 079 734
2	0.684	-351 299 000	-240 288 516	-2 158 368 250
3	0.566	-351 299 000	-198 835 234	-2 357 203 484
4	0.468	-351 299 000	-164 407 932	-2 521 611 416
5	0.387	-351 299 000	-135 952 713	-2 657 564 129
6	0.32	-351 299 000	-112 415 680	-2 769 979 809
7	0.264	-351 299 000	-92 742 936	-2 862 722 745
8	0.219	-351 299 000	-76 934 481	-2 939 657 226
9	0.181	-351 299 000	-63 585 119	-3 003 242 345
10	0.15	-351 299 000	-52 694 850	-3 055 937 195
11	0.124	-351 299 000	-43 561 076	-3 099 498 271
12	0.103	-351 299 000	-36 183 797	-3 135 682 068
13	0.085	-351 299 000	-29 860 415	-3 165 542 483
14	0.07	-351 299 000	-24 590 930	-3 190 133 413
15	0.058	-351 299 000	-20 375 342	-3 210 508 755

In Table 14, the net project balance is a loss signified by negative values up until the end of its life span. Using 25% as the minimum return on investment anticipated by investors, the expected payback period for this project is four years. However, according to the table above, the net worth of the project on each year is a loss, meaning that the expected payback period will never be achieved. Generally, when the initial cash outlay is used to fund the project, there is a recession phase experienced during the first few years of inception, whereby the project illustrates the behaviour of a cash sink. During this phase, the project net balance is negative. The second phase is recovery. This is the breakeven point whereby the revenue generated by the project is equal to the expenses. After the recovery phase, the project starts to make profit for the investors. This project will never attain a phase where it will make positive returns for its financiers.

$$DPP = 14 + \frac{3190133413}{20375342} = 171 \text{ years}$$

By definition, the last period with a negative cumulative discounted cash flow is in year 14 (A) and the absolute value at the end of this period is -R3 190 133 314. The discounted cash flow after year 14 is -R20 375 342. It can be noted that this project will not be economically viable for investors as it will take forever to reach a period for a breakeven point to be achieved.

4.7 Internal rate of return (IRR)

The internal rate of return (IRR) is the discount rate which makes the present value of the net income to be equal to present value of the investment cost (i.e. NPV to be equal to zero). It is the interest percentage the company has to achieve in order to breakeven on its investment. Since the major objective of investing in a project is to achieve better than breakeven, companies consider this the minimum acceptable return on investment. Any project that has an IRR greater than the cost of capital will be profitable and is worth investing in it. IRR is calculated by trial and error using linear interpolation.

4.7.1 IRR versus NPV

IRR and NPV are popular capital budgeting techniques for evaluating project profitability. IRR gives a percentage of the minimum return on investment that must exceed the project's cost of capital, while NPV gives an indication of how much the present value of the future cash flows at a given cost of capital exceeds the initial investment.

IRR is calculated using the knowledge of NPV, whereby the value of the NPV decreases with an increase in discount rate (cost of capital). The trial and error process is initiated by estimating a discount rate that will give an NPV equal to zero (IRR). Depending on how far the new calculated NPV is from zero, the discount rate can be adjusted up or down (second iteration) using the knowledge that the higher the discount rate, the lower the NPV, and vice versa. The results are summarised in the following tables:

Table 15: First trial of NPV & IRR

Year number	Discount factor at 60%	Project cash flow [R]	Discounted cash flow [R]
1	0.625	-351 299 000.00	-219 561 875
2	0.391	-351 299 000.00	-137 357 909
3	0.244	-351 299 000.00	-85 716 956
4	0.153	-351 299 000.00	-53 748 747
5	0.095	-351 299 000.00	-33 373 405
6	0.060	-351 299 000.00	-21 077 940
7	0.037	-351 299 000.00	-12 998 063
8	0.023	-351 299 000.00	-8 079 877
9	0.015	-351 299 000.00	-5 269 485
10	0.009	-351 299 000.00	-3 161 691
11	0.006	-351 299 000.00	-2 107 794
12	0.004	-351 299 000.00	-1 405 196
13	0.002	-351 299 000.00	-702 598
14	0.001	-351 299 000.00	-351 299
15	0.001	-351 299 000.00	-316 169
total			-585 229 004
capital investment			1 627 555 461
NPV			-2 212 784 465

Table 16: Second trial of NPV & IRR

Year number	Discount factor at 300%	Project cash flow [R]	Discounted cash flow [R]
1	0.250	-351 299 000	-87 824 750.00
2	0.063	-351 299 000	-22 131 837.00
3	0.016	-351 299 000	-5 620 784.00
4	4.00E-03	-351 299 000	-1 405 196.00
5	9.70E-04	-351 299 000	-340 760.03
6	2.00E-04	-351 299 000	-70 259.80
7	6.00E-05	-351 299 000	-21 077.94
8	2.00E-05	-351 299 000	-7 025.98
9	9.50E-07	-351 299 000	-333.73
10	2.00E-07	-351 299 000	-70.26
11	5.00E-07	-351 299 000	-175.65
12	6.00E-08	-351 299 000	-21.08
13	2.00E-08	-351 299 000	-7.03
14	4.00E-09	-351 299 000	-1.41
15	9.00E-10	-351 299 000	-0.32
total			-117 422 300
capital investment			1 627 555 461
NPV			-1 744 977 761

Table 17: Third trial of NPV & IRR

Year number	Discount factor at 1000%	project cash flow [R]	Discounted cash flow [R]
1	0.091	-351 299 000	-31968209
2	8.00E-03	-351 299 000	-2810392
3	8.00E-04	-351 299 000	-281039.2
4	7.00E-05	-351 299 000	-24590.93
5	6.00E-06	-351 299 000	-2107.794
6	6.00E-07	-351 299 000	-210.7794
7	5.00E-08	-351 299 000	-17.56495
8	5.00E-09	-351 299 000	-1.756495
9	4.00E-10	-351 299 000	-0.1405196
10	4.00E-11	-351 299 000	-0.01405196
11	4.00E-12	-351 299 000	-0.001405196
12	3.00E-13	-351 299 000	-0.00010539
13	3.00E-14	-351 299 000	-1.0539E-05
14	3.00E-15	-351 299 000	-1.0539E-06
15	2.00E-16	-351 299 000	-7.02598E-08
total			-35 086 569
capital investment			1 627 555 461
NPV			-1 662 642 030

The trial and error method was done using three estimated discount rates: 60%, 300% and 1000%. The ascending order of these discount rates was chosen on the basis that the higher the discount rate, the lower the NPV. The aim was to find a discount rate that will yield the NPV that will be as close as possible to zero so that linear interpolation can be done. The three net present values calculated from the estimated discount rates show that for this project the minimum return on investment that must exceed the project's cost of capital is impossible to reach; hence, this project is not economically viable.

4.8 Required government subsidy using ROA

The required government subsidy for this project is determined by calculating the return on assets (ROA). According to the South African Department of Energy (2014), an

economically viable biofuel project is the one that can achieve a minimum of 15% ROA for investors. The 15% ROA is used as a point of reference in determining the amount of subsidy required from government to render the project profitable. The subsidy is used to bridge between the gap that may be created when a project generates actual market related earnings and the earnings required to the 15% ROA for the benchmark plant. The calculations are illustrated as follows:

$$ROA = \frac{EBITDA}{TotalAssets} \quad [11]$$

Where:

- ❖ EBITDA (Earnings before interest, tax, depreciation and amortization) = this is the actual cash flow generated from operations in the income statement for a specific fiscal year.
- ❖ Total assets = these are total assets in the statement of financial position (balance sheet) for the same fiscal year.

If ROA for a particular project is less than 15%, a subsidy value is added such that EBITDA plus the subsidy divided by the total assets yields 15%. If the value of ROA is greater or equal to 15%, no subsidy is required as the required minimum return on investment is achieved. ROA for this study is determined as follows:

EBITDA = R850 220 800 (revenue)

Total assets = R426 035 461 (fixed capital investment)

$$ROA = \frac{850220800}{426035461} \times 100\% = 200\%$$

In general terms, ROA indicates the potential of a project to convert the invested money to purchase assets into profit. The higher the value of ROA, the better it is for the project because it means its potential to convert every cent invested in assets into profit is also high. The 200% ROA means that for every rand that is invested in fixed assets, two rand (R2.00) is generated in profits for the 2016 fiscal year. For this project, if this metric is used alone to assess profitability, it can be misleading as it denotes economic success compared to other metrics which have already been evaluated. This is because the calculation of ROA does not factor in the expenses incurred in the project. For instance, the value of the NPV became negative because the project expenses were too high when compared to its revenue, resulting in a loss in net cash flow.

There is no government subsidy required for this project. This is because the minimum stipulated ROA of 15% by the Department of Energy is already achieved by a huge margin. If the subsidy was required, a reference sorghum manufacturing plant for all starch crops was going to be used (Department of Energy, 2014) to determine the required subsidy for the present study. The reference sorghum manufacturing plant, is a study that was done by NBTT, with a processing capacity of 158 million per annum and required a subsidy of 195 cent/litre (R1.95).

4.9 Minimum ethanol selling price

One of the most important factors that determine profitability of the bioethanol plant is its selling price as it has a direct impact on revenue that is generated. The minimum ethanol selling price (MESP) is another factor that is used to determine the amount of government subsidy required in a biofuel project. It is given by the formula below:

$$\text{MESP} = \text{Subsidy} + \text{BFP} \times \text{Blending value} \quad [12]$$

Where:

- ❖ BFP × Blending value is similar to one already determined in equation 3. For bioethanol that is blended with 2% and 95 unleaded petrol, its blending value is equal to 1. The basic fuel price (BFP) as determined by the Department of energy between July and August 2016 was R6.13/litre. Considering that there is no subsidy needed for this project the MESP is calculated as follows:

$$\text{MESP} = 0 + 6.13 \times 1 = \text{R}6.13/\text{litre}$$

MESP indicates the amount of subsidy required for the project by noting that if its value is greater than BFP × blending value, then a subsidy is required from government to adjust the project to be profitable. If it is less than this value no subsidy is required as a minimum of 15% ROA is achieved. For this project, MESP is equal to the BFP.

4.10 Sensitivity analysis

Sensitivity analysis was performed on factors that display a significant contribution on the project profitability. Two factors which are the basic fuel price and the feedstock price were chosen.

4.10.1 Basic fuel price

Figure 7 shows basic fuel prices listed by the Department of Energy from 2011 to 2016. Since the impact of BFP is to increase the revenue of the project and ultimately increase the profit, a year with the highest BFP value was chosen in order to perform sensitivity analysis. Year 2014 has the highest BFP value of 857.95 cent/litre (R8.58/litre). NPV, ROI, DPP, IRR and ROA of the project will be evaluated on this new BFP value. During this process, only BFP and feedstock price have been varied, the other factors remained constant.

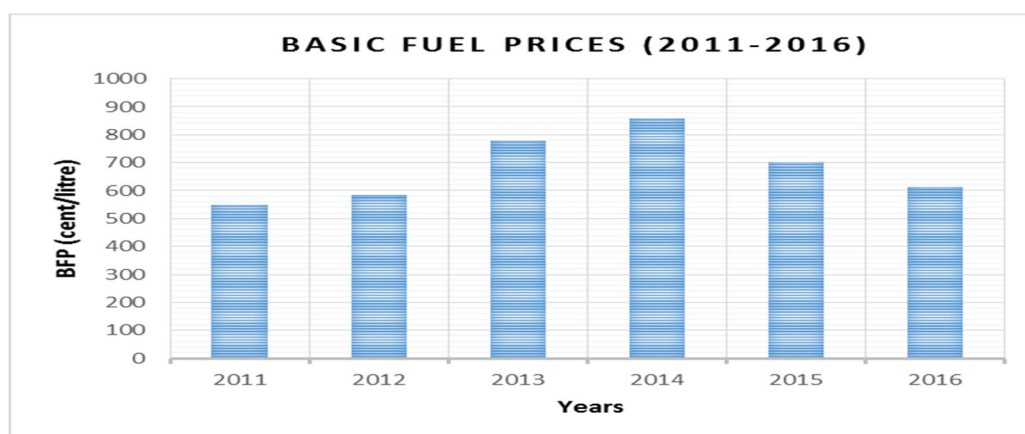


Figure 7: Basic fuel price from 2011 to 2016 (Department of Energy, 2016)

4.10.2 Feedstock price

The South African Grain Information System (SAGIS, 2016), shows historical trends of the white maize prices in South Africa from 2011 to 2016 as depicted in Figure 7. The impact of maize on this project is that it is an expense that decreases revenue and ultimately decreases the profit. A year with the lowest price of maize was chosen in order to perform sensitivity analysis. Year 2011 had the lowest price of white maize of R1726/ton.

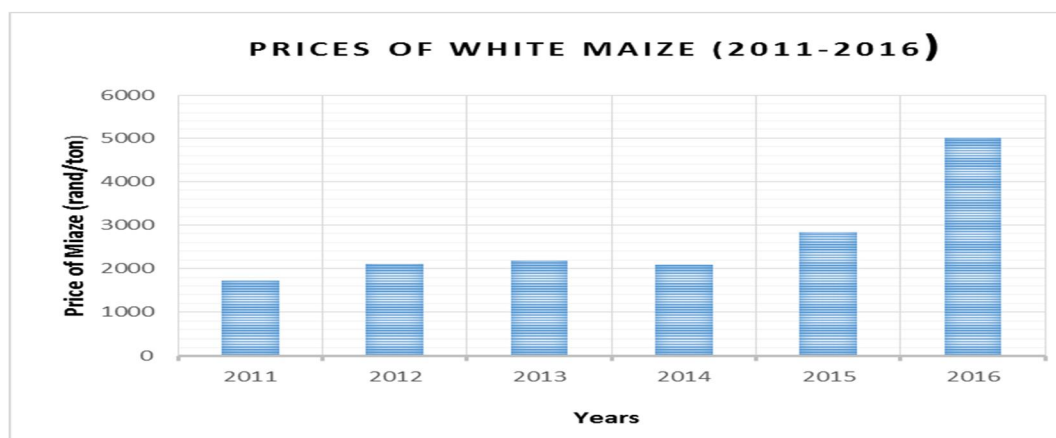


Figure 8: Prices of white maize from 2011 to 2016 (SAGIS, 2016)

4.10.3 NPV

❖ Revenue

The adjustment of the BFP by increasing it from R6.13/litre to R8.58/litre also increases the revenue from R850 220 800 to R1 046 220 800 respectively.

Table 18: Sensitivity analysis revenue

Revenue			
Item	Yield	Unit price	Revenue per 80 million litres bioethanol
Bioethanol	80 000 000 litres/year	R8.58/litre	R686 400 000
DDGS	0.25 ton/ton _{maize}	R7000/ton	R 350 000 000
CO ₂	0.372 ton/ton _{maize}	R132/ton	R9 820 800
Total revenue			R1 046 220 800

❖ OPEX

Using the assumption that every ton of maize processed yields 400 litres of bioethanol, by using the new price of maize of R1726/ton, the cost of maize per litre of bioethanol decreases significantly by 66% from R12.5 to R4.30.

Table 19: Sensitivity analysis expenses

Process operating expenses		
Item	Cost per liter of bioethanol	Total cost per 80 million litres of bioethanol
Maize	R 4.30	R 344 000 000
Enzymes	R 0.32	R25 600 000
Yeasts	R 0.04	R3 120 000
Antibiotics	R 0.04	R2 880 000
Boiler & cooling tower chem.	R 0.01	R 720 000
Annual cost of water	R 0.04	R3 040 000
Electricity	R 1.90	R152 320 000
Business operating expenses		
Item	Cost per liter of bioethanol	Total cost per 80 million litres of bioethanol
Labour cost	R 0.09	R6 960 000
Maint. & Repairs cost	R 0.02	R1 760 000
Management & Qual. Control	R 0.03	R2 400 000
Real estate & taxes	R 0.00	R 240 000
Licenses, fees & insurance	R 0.01	R 560 000
Miscellaneous expense	R 0.02	R1 920 000
Total OPEX		R 545 520 000

❖ Total Capital Investment

$$TCI = FCI + WCI$$

$$TCI = (R426\ 035\ 461 + R545\ 520\ 000) = R971\ 555\ 461$$

❖ Net annual cash flow

Table 20: Sensitivity analysis income statement

Profit or loss statement for the year ended in June 2016				
			R(million)	R (million)
Sales				1046.22
Less variable expenses				
	Maize		344	
	Enzymes		25.6	
	Yeasts		3.12	
	Antibiotics		2.88	
	Boiler & cooling tower chem.		0.72	
	Annual cost of water		3.04	
	annual cost of electricity		<u>152.32</u>	
				<u>531.68</u>
Contribution margin				514.54
Less fixed expenses				
	Salaries		6.96	
	Maintenance		1.76	
	Quality control		2.4	
	Real estates		0.24	
	Licenses & insurance		0.56	
	Miscellaneous exp.		1.92	
	Depreciation		<u>25.56</u>	
Total fixed expenses				<u>39.40</u>
Net Profit				475.14

Net profit= R475 137 872

Add: Non cash deduction for depreciation = R25 562 128

Net annual cash flow = R500 700 000

When determining the new NPV, the weighted average cost of capital and depreciation remained the same. The calculation of the new NPV is displayed in table 21.

Table 21: Sensitivity analysis NPV

Project name: Bioethanol production from maize			
Year number	Present value factor at 20.9%	Project net income/loss [R]	Present value [R]
1	0.827	500 700 000	414 078 900
2	0.684	500 700 000	342 478 800
3	0.566	500 700 000	283 396 200
4	0.468	500 700 000	234 327 600
5	0.387	500 700 000	193 770 900
6	0.32	500 700 000	160 224 000
7	0.264	500 700 000	132 184 800
8	0.219	500 700 000	109 653 300
9	0.181	500 700 000	90 626 700
10	0.15	500 700 000	75 105 000
11	0.124	500 700 000	62 086 800
12	0.103	500 700 000	51 572 100
13	0.085	500 700 000	42 559 500
14	0.07	500 700 000	35 049 000
15	0.058	500 700 000	29 040 600
Total		7 510 500 000	2 256 154 200
Capital investment [R]	971 555 461		
NPV [R]	= PV(total) – Capital		
	1 284 598 739		

A positive NPV indicates that the project will be profitable as this is evidenced by a positive net profit in the income statement.

4.10.4 ROI

$$AAP = \frac{\text{TotalGains} - \text{TotalOutlay}}{\text{NumberOfYears}}$$

Where:

- ❖ Total gains = R7 510 500 000
- ❖ Total outlay (new capital investment) = R971 555 461
- ❖ Number of years = 15 years

$$AAP = \frac{7510500000 - 971555461}{15} = R435\,929\,636$$

$$ROI = \frac{435929636}{971555461} \times 100\% = 45\%$$

This implies that with the new feedstock price, the project will be able to return 45% of the original investment annually, for the next fifteen years.

4.10.5 DPP

Table 22: Sensitivity analysis DPP

Project name: Bioethanol production from maize				
Year number	Present value factor at 20.9%	Project cash flow [R]	Discounted cash flow [R]	Cumulative discounted cash flow [R]
0	1	-971 555 461	-971 555 641	-971 555 461
1	0.827	500 700 000	414 078 900	-557 476 561
2	0.684	500 700 000	342 478 800	-214 997 761
3	0.566	500 700 000	283 396 200	68 398 439
4	0.468	500 700 000	234 327 600	302 726 039
5	0.387	500 700 000	193 770 900	496 496 939
6	0.32	500 700 000	160 224 000	656 720 939
7	0.264	500 700 000	132 184 800	788 905 739
8	0.219	500 700 000	109 653 300	898 559 039
9	0.181	500 700 000	90 626 700	989 185 739
10	0.15	500 700 000	75 105 000	1 064 290 739
11	0.124	500 700 000	62 086 800	1 126 377 539
12	0.103	500 700 000	51 572 100	1 177 949 639
13	0.085	500 700 000	42 559 500	1 220 509 139
14	0.07	500 700 000	35 049 000	1 255 558 139
15	0.058	500 700 000	29 040 600	1 284 598 739

$$DPP = A + \frac{B}{C}$$

- ❖ A = Last period with a negative cumulative discounted cash flow (second year)
- ❖ B = Absolute value of discounted cumulative cash flow at the end of period A (-R 214 997 761)
- ❖ C = Discounted cash flow during the period after A (R342 478 800)

$$DPP = 2 + \frac{214997761}{342478800} = 3 \text{ years}$$

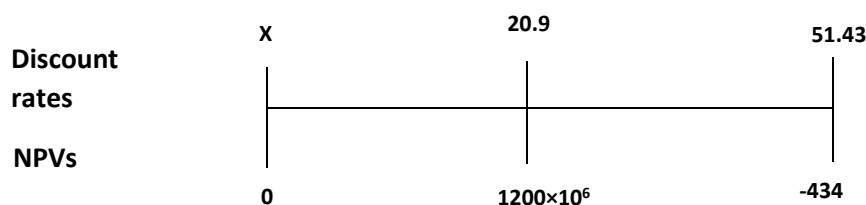
The cheaper price of maize and a slightly higher price of bioethanol have rendered the project to be profitable as this can also be observed in the determination of the new discounted payback period. It will take three years for the project to reach the breakeven point. This is the desired scenario considering the fact that the plant life span is fifteen years. Breaking even in the third year often means that the profit will be experienced over many years still to come by the investors.

4.10.6 IRR

Table 23: Sensitivity analysis IRR

Project name: Bioethanol production from maize			
Year number	Present value factor at 51.43%	Project net income/loss [R]	Present value [R]
1	0.660	500 700 000	330 639 309
2	0.436	500 700 000	218 339 030
3	0.288	500 700 000	144 181 078
4	0.190	500 700 000	95 210 569
5	0.126	500 700 000	62 872 692
6	0.083	500 700 000	41 518 241
7	0.055	500 700 000	27 416 742
8	0.036	500 700 000	18 104 758
9	0.024	500 700 000	11 955 552
10	0.016	500 700 000	7 894 898
11	0.010	500 700 000	5 213 428
12	0.007	500 700 000	3 442 709
13	0.005	500 700 000	2 273 407
14	0.003	500 700 000	1 501 254
15	0.002	500 700 000	991 359
Total		7 510 500 000	971 555 027
Capital investment [R]	971 555 461		
NPV [R]	= PV(total) – Capital		
	-434		

The linear interpolation to calculate IRR is done as follows:



$$\frac{20.9 - X}{51.43 - 20.9} = \frac{1200 \times 10^6 - 0}{-434 - 1200 \times 10^6}$$

$$X = 51.43\%$$

The new IRR for the project exceeds the cost of capital. By trial and error, the starting guess was 51.43% yielding the NPV of -434. The Calculation shows that 51.43% is the minimum return on investment that the project must attain in order to be profitable.

4.10.7 ROA

$$ROA = \frac{EBITDA}{TotalAssets}$$

EBITDA = R1 046 220 800 (new revenue)

Total assets = R426 035 461 (fixed capital investment)

$$ROA = \frac{1046220800}{426035461} \times 100\% = 245\%$$

245% ROA means that for every rand that is invested in fixed assets, R2.45 is generated in profits for the 2016 fiscal year when the prices of maize and bioethanol are adjusted.

4.11 Comparative analysis

A comparative analysis between the value of the maize generated from exportation and the value generated when maize is converted into bioethanol is done by taking into consideration the revenues generated between 2011 and 2016 fiscal years in South Africa. The analysis on the bioethanol plant will focus mainly on the year which showed the best case scenario by having the highest revenue generated, as well as the year which showed the worst case scenario by having the lowest revenue generated. In terms of exported maize, revenue analysis is also done on maize that was exported to SADC countries between 2011 and 2016 marketing years from South Africa.

4.11.1 Bioethanol plant revenue

The economic assessment of the bioethanol plant that processes 200 000 ton/year of maize in South Africa shows two scenarios. The first scenario is a worst case scenario whereby the probability of economic success (PES) of the plant is destroyed by an exorbitant price of maize (R5000/ton) used as a feedstock. The economic assessment in this scenario was performed amid of the drought crisis in the South African agricultural sector, which has resulted in diminishing crop yields and high grain prices in the 2016 fiscal year. In this scenario, the impact of varying the basic fuel price on the project profitability was also explored. The second scenario is representative of the best case scenario whereby the price of maize was the lowest and the basic fuel price in the 2011 fiscal year was higher than 2016. The economic outlook of the two scenarios is summarised in Table 24.

Table 24: Worst case scenario of economics

Worst case scenario	
Fiscal year	2016
Price of maize (R/ton)	5000
Basic fuel price (R/L)	6.13
Revenue [R]	850 220 800
Operational expenses [R]	1 201 520 000
Net loss [R]	-376,861,328
NPV [R]	-3,210,508,755
ROI (%)	-28
DPP (years)	171

The project is not economically viable in the worst case scenario as this is characterised by negative profitability indicators such as NPV, ROI and DPP. The costly price of maize in South Africa was the most significant factor affecting the economic success of the project. Maize is the major grain crop which finds many applications such as human consumption, animal feed, industrial application and bioethanol production in other countries. The persistent drought conditions in South Africa have significantly decreased the yield of maize for the 2015 and 2016 marketing years, resulting in the import of millions of tons to supplement the local shortfall. The spike in the price of maize can also be linked to the heavy foreign exchange rate especially with the weaker rand against other major currencies such as the US dollar and the British pound.

Table 25: Best case scenario of economics

Best case scenario	
Fiscal year	2011
Price of maize (R/ton)	1726
Basic fuel price (R/L)	8.58
Revenue [R]	1 046 220 800
Operational expenses [R]	545 520 000
Net profit [R]	475 135 872
NPV [R]	1 284 598 739
ROI (%)	45
DPP (years)	3

The best case scenario is representative of a profitable project as this is evidenced by positive economic indicators in favour of the investors. This scenario indicates that this is the best time to build a bioethanol processing plant in South Africa.

4.11.2 Export maize revenue

Over the past five years, South Africa has produced an average of 10 million tons of maize. Out of this, an average of 8 million tons was used for local consumption, animal feed and production of other secondary products. About 2 million tons of surplus maize was exported to many different countries including SADC countries which account for approximately 70% of the total volume of maize exported from South Africa. About 2 million tons of surplus maize also generates R6 billion in export revenue. However, this study focuses on the export revenue that is generated from exporting to ten SADC countries during the 2011 and 2015/2016 marketing years.

The two marketing years were chosen for the purpose of direct comparison in terms of generated revenues between the bioethanol plant and maize exports. For instance, during

the economic evaluation of the bioethanol plant, two scenarios occurring in 2011 and 2016 were analysed. Maize export revenues achieved by South Africa in the same periods are also analysed as follows.

- ❖ South African maize exports and imports to SADC in the 2011 and 2015/2016 marketing years

Table 26: Trade balance

Country	2011 Export value [R]	2011 Import value [R]	2015/2016 Export value [R]	2015/2016 Import value [R]
Namibia	133 054	43	666 153	0
Botswana	300 652	1 201	482 060	89
Lesotho	260 996	1 028	272 866	89
Mozambique	174 321	266	242 527	723
Swaziland	185 035	3 545	233 192	1 535
Demacratic Republic of Congo (DRC)	5 299	1 560	52 866	51
Zambia	12 562	94 412	48 985	74 023
Zimbabwe	74 566	302	22 362	0
Angola	19 077	0	20 002	0
Tanzania	5 105	0	8 485	0
Total	1 170 667	102 357	2 049 498	76 510
Trade Balance	Exports - Imports		Exports - Imports	
	1 068 310		1 927 988	

If an average of 2 million tons of surplus maize are exported to various countries including SADC countries, and 70% of this volume is exported to SADC countries, it means that an average of 1.4 million tons was sent to SADC countries every year for the past five years. The export revenue for 2011 was R1 170 667 as shown in Table 26. This is very small compared to the revenue generated from the bioethanol plant in 2011 which is R1 046 220 800 (Table 25). When the operational expenses of R545 520 000 are factored out from the revenue, the net profit is positive, implying that the plant will be profitable.

From an economic point of view, under the given price conditions of feedstock (maize) and bioethanol in South Africa during the 2011 fiscal year, it would make sense to invest in a bioethanol plant during this period because it displays many economic merits such as positive NPV, high ROI and shorter payback period. Furthermore, the investment to the bioethanol plant can be done without postponing the export of maize to SADC countries. On average, a bioethanol plant uses only 14.3% per year of the total volume of maize that is exported to SADC countries and the 2011 analysis shows that it can still generate revenue that is 99.9% more than the revenue generated from maize exports to SADC countries. With the reputation of South Africa to be able to keep surplus stocks of maize

until the following production season, this would mean that having a bioethanol plant operating parallel to the maize exporting business, will equate to the increased total revenue derived from maize as well as creation of many employment opportunities in the country.

Table 26 also gives an indication of the trade balance which is the difference between the countries exports and imports for a given period. Trade balance is another important measure of the country's gross domestic products (GDP) as it can be used by economists as a statistical tool to understand the strength of the country's economy relative to other economies. When the trade balance is positive, it is called a trade surplus implying that the country exports more goods and services than imports. Trade surplus results from the country's credit items: exports, foreign spending in the domestic economy, and foreign direct investment (FDI) in the domestic economy. These items indicate an influx of money in the country. A negative trade balance is called a trade deficit. This occurs when there are more imports than exports. The trade deficit is a resultant of debit items such as imports, foreign aid, domestic spending abroad and investments abroad. The trade balance for the 2011 marketing year is illustrated below.

$$\text{Trade Balance} = \text{Exports} - \text{Imports} \quad [13]$$

$$\text{Trade Balance} = \text{R1 170 667} - \text{R102 357} = \text{R1 068 310 (trade surplus)}$$

A trade surplus is often an indication that the country will be able to pay for its imports. The bioethanol manufacturing plant and the export of maize to SADC countries in 2011, display a scenario of economic success.

The export revenue for 2015/2016 marketing years is R2 049 498. This is also relatively small compared to the total revenue of R850 220 800 that was generated by the bioethanol plant in 2016. However, when the operational expenses of R1 201 520 000 are factored out from the revenue, the result is a staggering net loss in profits of R376 861 328 experienced every year. This already signifies a de-motivation to invest in the bioethanol plant under the given feedstock and bioethanol prices. Table 26 also shows a trade surplus of R1 927 988 during the same year. Therefore during this period, due to negative economic indicators such as NPV, ROI and DPP, it will not be economically viable to invest in a bioethanol plant. The unfavourable climatic conditions such as severe drought, which decreased the output of maize and increased its selling price throughout South Africa, are amongst the reasons the construction of a bioethanol plant is undesirable from an economic perspective. The best decision in this scenario is to postpone bioethanol

production from maize and export all the surplus maize to SADC countries.

4.11.3 Conclusion

The economic evaluation of a bioethanol plant that processes maize which could have been exported to SADC countries should be performed holistically, taking into consideration the implications posed by social, political, technological and environmental factors on the final decision that is chosen. For instance, the government's decision to produce bioethanol with a portion of maize that could have been exported to a specific country in the SADC region that does not have any reserves, will affect the food security for that country by raising a food versus fuel debate which is a social aspect. International relationships may be ruined resulting in countries existing as islands. That is a political aspect.

Chemical plants are built to generate profit for investors. Year 2011 and 2015/2016 are the marketing years which were chosen to evaluate profitability of the bioethanol plant and export of maize in SADC countries. Owing to a lower price of maize and high bioethanol price during 2011, the bioethanol plant was more profitable than exported maize. In 2015/2016 years, the assessment showed that the bioethanol plant will not be profitable due to an expensive price of maize. The maize trade surplus was more for 2015/2016 compared to 2011.

CHAPTER 5

INTERPRETATION OF RESULTS

5.1 Introduction

In this chapter the interpretation of results will be done in two folds, which incorporate the analysis of the feedback from the questionnaire (qualitative) and the analysis of the results generated by economic models (quantitative).

5.2 Qualitative results

The respondents from which the questionnaire was addressed were categorised into:

- ❖ **National government (Department of Energy)** : First category
- ❖ **Provincial government (Department of Agriculture)**: Second category
- ❖ **Private sector (Mabele Fuels, Greentech Biofuels & Green-Diesel)**: Third category

The responses from each category are summarised in terms of the STEEP factors displayed in Table 7 of Chapter 3 as follows.

5.2.1 Social factors

On social factors, the majority of the respondents (30 out of 35) from the national government chose responses which strongly disagree with the idea of proposing the use of maize to produce bioethanol in the country. This echoes the concerns already made by government when maize was banned explicitly for being used as one of the bioethanol feedstocks in the Biofuel Industrial Strategy. Two out of three respondents from the provincial department also agreed with the majority of the national government. The Western Cape Provincial Department of Agriculture was also one of the victims of the prevalent drought in the country. The respondents voiced their concerns on implications bioethanol production from maize will have, as the country is already battling to retain sufficient stock levels of this crop to feed the nation.

A total of nine responses were obtained from three private companies. The opinions of respondents in this category strongly agreed with the concept of catering a portion of maize that could have been exported to bioethanol production. Some of their opinions state that drought which is affecting the yields of maize is usually a passing phase. They even made references to the 1992 drought which was also catastrophic in South Africa but managed to pass. The hope that these respondents still have on the bioethanol industry of South

Africa is the available land which is not utilised and the fact that if genetic modification is used, challenges such as water scarcity can be bypassed.

5.2.2 Technological factors

The national government responses expressed strong disagreement with factors such as the profitability of bioethanol production technologies. On the additional notes that they wrote on the margin of the questionnaire, they emphasize that bioethanol technologies are generally capital intensive as most of the equipment and machinery must be imported. Profitability will not be possible at all as huge government subsidies are required to render these projects profitable. The responses from provincial government showed a general strong agreement with regard to the big scope that is available for advancing the technology for producing bioethanol compared to the petroleum industry. They also added that the lack of advanced farming implements to emerging maize farmers is not the only pertinent challenge in South Africa, comprehensive support is required.

The responses of the private sector on technological factors agree with the fact that importing bioethanol plants will hike the fixed capital investment. They attributed the slow progress of the bioethanol production in South Africa to high start-up capital requirements, lack of government support and inability of businesses to produce bankable projects that can strengthen the confidence of financiers such as grants, loans and capital from investors.

5.2.3 Economic factors

The sentiments of the national government on the probability of bioethanol production to add more revenue in South Africa, agree strongly. This is because government knows that bioethanol production will significantly slash the nation's reliance on imported oil which is currently one of the country's astronomical costs. The provincial department agreed that maize is the largest net earner of foreign currency compared to sugarcane. Therefore deferring maize exports for bioethanol production with plenty of uncertainties does not make economic sense.

The private sector strongly agreed with the opinion of using some of the portion of exported maize for bioethanol production. They agree that bioethanol plants will generate more revenue than maize exports. However, this can be attained over a long period of time, not immediately. Due to uncertainties in this field, investors need good economic feasibility studies that will quantify risk.

5.2.4 Environmental factors

The majority of the views here were neutral. This is because there are differing views with regards to the bioethanol fuel actually reducing greenhouse gases. Life cycle studies on bioethanol production suggest that there is more carbon dioxide generated during its production when the holistic value chain is considered. Inputs such as electricity (for running the plant), fertilizers (crops) and transport contribute substantial volumes of CO₂ before the bioethanol is burnt as a fuel. The opinions from the provincial government also disagree with the fact that bioethanol will save the environment. The concluding remark here was that this will only be possible if the whole value chain is “green”. The private sector disagreed with bioethanol being a potential substitute of gasoline in the short to medium term. Some of the views on bioethanol are that it is an energy sink, meaning that the energy spent to produce the fuel is more than the energy that can be derived from the final product.

5.2.5 Political factors

Here, the national government strongly agreed that the support from government is needed to support farmers producing biofuel crops and subsidies to biofuel producers. The provincial government were neutral about the implications that may be caused by bioethanol evolution in South Africa such as maize export postponement to SADC countries resulting in sabotaged political relationships. The private sectors strongly disagreed with this view, stating that the historical production trends of maize in the country in the past ten years suggest that the amount of maize that was exported to SADC countries was drawn from a surplus which was carried over to the following seasons. This category acknowledges the current challenges of drought but suggest that in the long term when such a challenge has abated, there is a potential opportunity of the country to create a bioethanol revenue stream which studies also suggest that it surpasses that of the maize in terms of quantity.

5.3 Quantitative results

The second part of analysing results will focus on deducing the meaning of the answers which were derived from the economic models. These answers were divided into two sections. The first set of answers was derived from the input data of 2016. The second set was derived when two variables were converted from 2016 to 2011 input data (sensitivity analysis), to investigate the impact of changing them on the overall economics of the project.

5.3.1 Analysis of the first set of answers

❖ CAPEX

The estimated CAPEX of 80 million litres per year of a bioethanol plant using the scaling up model was within the range suggested by literature whereby it was stated that for capacities ranging from 80 to 160 million litres per year, the scaling factor of 0.6 can be used. The CAPEX was used to calculate the total capital investment required for the project.

❖ OPEX

The OPEX of the plant was estimated using the data from the base case which is illustrated in table 8 of Chapter 4. The prices of maize (R5000/ton) and electricity accounted for 83% and 13% respectively in the total value of the OPEX, destroying any chance for the plant to be profitable. As a result when the total capital investment was determined, the OPEX reversed the economic assumption that was made earlier that it will be 10% of the fixed cost, instead the fixed cost was 35% of the OPEX.

❖ NPV

The net cash flow was negative due to expenses exceeding the revenue. The principle of time value of money works by discounting future cash flow into present value using an appropriate discounting factor. This means that discounting a negative cash flow meant that the net present value of the project was going to be significantly low as shown in Table 13 of Chapter 4.

❖ ROI

In Chapter 4 it was briefly explained that a negative ROI indicates a substantial decline in growth of profits and productivity of the project.

❖ DPP

The determination of DPP indicated that under the economically unviable conditions, the project will take forever for the break-even point to be reached.

❖ IRR

Using trial and error, Tables 15, 16 and 17 show the selection of different discount rates to determine NPV that will be as close as possible to zero. These discount rates were chosen on the principle that NPV decreases with an increase in discount rate. The results indicate

that for this project it is impossible to attain a minimum return on investment to reach the required breakeven point.

❖ ROA

ROA was the only positive economic indicator for this section. This was attributed to the fact that the calculation of ROA does not factor expenses but only the revenue and asset value. In Chapter 4 it was explained that if this indicator is used in isolation it can be misleading as it signifies economic success. ROA for this project also shows that there is no government subsidy required as it is way beyond 15% ROA which is the minimum that a bioethanol plant must attain in order to be deemed profitable.

5.3.2 Analysis of the second set of answers (sensitivity analysis)

❖ Basic fuel price

A new basic fuel price for the 2011 fiscal year was chosen from the Department of Energy (2016) due to the fact that it was the highest compared to other years. The highest value of BFP was chosen with an understanding that it increases the revenue hence it was used to determine the new revenue to see if the difference in profitability will be created.

❖ Feedstock price

The lowest price of maize from the 2011 marketing year was also chosen from SAGIS (2016), also with an understanding that the price of maize affects the total expenses.

❖ NPV

The new NPV was positive indicating that a further consideration in terms of capital investment is warranted.

❖ ROI

The new ROI for the project was 45%. This exceeds the minimum ROI of 25% that was made on the economic assumptions in Chapter 4. The base case study by Amigun *et al.* (2011) from which most of the economic assumptions for the current study are derived, used 25% as a minimum ROI required by investors based on the discount rate of 25% which was also used. So in order for the project to be profitable it must be equal or greater than the discount or hurdle rate. The adjustment on the BFP and feedstock prices have contributed positively on the new ROI as it exceeds the required minimum by a huge margin (20%).

❖ DPP

The calculation of the DPP in the first set of answers of the economic evaluation of the plant indicated that the time to reach breakeven point for the project was not realistic (175 years). The new DPP of three years was more attractive from an investment point of view. This is due to the fact that if the estimated lifespan of the project is fifteen years, and after three years the project will have paid back the original capital outlay, then for the twelve years still to come the project will be generating profit.

❖ IRR

Sensitivity analysis indicates that the new IRR for the project is 51.43%. This means that the project can be accepted as it will be profitable. ROI and IRR are accepted based on whether they exceed the determined hurdle rate for the project. IRR also exceeded the hurdle rate of 20.9% justifying the need for capital investment on the project.

❖ Comparative analysis

The concerns that were raised by the South African government as major reasons for excluding maize as one of the bioethanol feedstocks were mainly of the social and environmental nature. The economic perspective was not explored hence this study has landed itself into performing a comparative analysis between the revenue generated by the bioethanol plant and the revenue generated by exporting maize. The analysis was done for 2011 and 2016. The results of the 2011 analysis showed that it was favourable to invest in bioethanol plant owing to an affordable price of maize then, and the basic fuel price which was high. The revenue generated during this period was very high compared to the revenue of the maize exports in the same period. The fact that a bioethanol plant also uses a very small portion of the total volume of the maize that is exported, also qualified the need to invest in the plant in 2011. The conclusion here was that the business of producing bioethanol from maize can be run parallel to the business of exporting maize without compromising the supply.

The analysis for 2016 showed the demerits to invest in a bioethanol plant in the sense that there is a net loss generated in the entire lifespan of the project. All the economic indicators were also negative due to extremely high price of maize in South Africa. Even though South Africa could not produce enough maize for the 2016/2015 marketing year due to drought, the government still made a commitment to export a substantial portion of maize to its neighbouring countries which also suffered from maize shortages because of a catastrophic

Drought. Conversely, the revenue generated from the exports of maize indicated that it is best to export all the surplus maize than to build a bioethanol plant.

5.4 Conclusion

Qualitative results from the three categories of respondents show answers which range from strong agreements which are in favour of social, environmental and political factors supporting exclusion of maize as a bioethanol feedstock and strong agreements in favour of economic factors which support the use of maize without postponing exports. Most of responses of the first category (national government) were in favour of banning the use of maize and focus on exporting. This category also showed strong agreements with the uncertainty of the profitability of the bioethanol plant in the South African context and the environmental changes this will bring. The second category (provincial government) expressed similar sentiments to the first category pertaining to banning the use of maize as a feedstock. Some of the comments they made on the questionnaire include lack of clear direction and good leadership of the current government to create effective policies that will cater for bioethanol production and maize exports, environmental concerns and jeopardising food security. The third category (private sector) expressed strong agreements that there is a great potential of using maize for bioethanol production. The category also expressed strong agreements on the need for governments' intervention by providing subsidies to render bioethanol projects profitable. The majority of their responses was disagreeing with excluding maize as a feedstock.

Quantitative results show that the price of maize and bioethanol have a significant influence on the overall profitability of the bioethanol plant. These two parameters were chosen to perform sensitivity analysis of the plant after it was observed that the price of maize plays a crucial role in determining the size of the overall expenses of the project while the bioethanol price a crucial role in determining the size of the project revenue. The results of the study show that the bioethanol plant will be profitable in 2011 as compared to 2016. This was attributed to the expensive price of maize in 2016 and lower selling price bioethanol. Therefore, a bioethanol plant could be run simultaneously to the export of maize. The 2016 results indicate that it is not profitable to invest in a bioethanol plant. The conclusion was that all of the maize must be exported.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

Chapter 5 provided answers of the research questions in Chapter 1 which served as the rationale to pursue this study. This chapter will integrate each question with the relevant answer provided by the results with the aim of verifying if the set objectives were attained. This chapter will also verify the outcome of the study if it nullifies or validates the decision of government to exclude maize as a feedstock. Lastly, the chapter will conclude by giving a brief summary of each chapter and the areas recommended for further study.

6.2 Revisiting the research questions and the hypothesis

The first question required the study to determine the size of the South African maize industry in terms of revenue, number of businesses operating in it and the yield of maize per annum. The study indicated that the revenue of the industry was R23.236 billion for the 2014/2015 marketing. This had declined from R25 billion which was attained the previous season. The study mentioned that the industry has about 9 000 commercial farmers and an unknown number of emerging farmers. Few major companies in the downstream sector were also mentioned. These are the companies that mill the maize and derive many food products for the domestic and export markets. The second question of the study was on the maize production trends over the past five years in South Africa. This was answered by the tabulated information from Department of Agriculture, Fisheries and Forestry (2015) in Table 1 of Chapter 2, where the trend shows that the volume of maize produced in the country was steady from 2011 to 2013 and increased sharply in 2014. In 2015 until the present moment the output of maize has dropped significantly because of drought as predictions suggest that even further declines in 2017 will be expected.

The third question required to find out the number of tons of maize allocated for the domestic and export market. The study gave an average of 10 million tons which is generally produced in South Africa, with an average of 8 million tons dedicated for the local market while an average of 2 million tons is exported every year except the 2016 whereby South Africa has committed itself to only export 700 000 tons of maize due to severe shortages in the country. The fourth question addressed the estimated size of the bioethanol plant that will be profitable in South Africa. The economic feasibility of this study was performed on a plant capacity that processes 200 000 tons of maize per annum and

yields 80 million litres of bioethanol (Chapter 4). The selection of this size was guided by the scaling up factor in a model derived by Amigun *et al.* (2011), whereby the minimum required plant size in order to scale up from a known capacity is 80 million litres per annum.

The fifth question focused on the methods of determining profitability of the bioethanol plant. The study chose a sample of prominent profitability indicators such as NPV, ROI, DPP, IRR and ROA. These were chosen based on the fact that they employ the principle of time value of money, enabling investors to make informed decisions on project selection. The final question required the study to compare the business of producing bioethanol from maize and the business of exporting from an economic perspective and recommend the best option. This analysis showed that the economics of the bioethanol plant are largely dictated by the feedstock price and the price of bioethanol. The results showed that during the marketing years when a ton of maize was less than R2000.00 (2011) and the bioethanol selling price greater than other years, the project is profitable. The 2016 analysis indicated the worst case scenario in the profitability of the bioethanol plant, emphasizing a negative impact that drought has on the price hike of maize and food inflation in general.

The study managed to achieve its set objectives by providing answers to all of the questions which triggered the need to undertake the project. The majority of respondents in qualitative results (questionnaire) are in favour of the decision of the South African government to exclude maize as a bioethanol feedstock. Meanwhile, the quantitative results (feasibility study) suggest that during seasons of high production yields (when producer prices are low) it is economically viable to invest in a bioethanol plant while exporting maize at the same time. This is due to the fact that the proposed plant size only uses a small proportion of the overall volume of maize that is exported. Moreover, the revenue that is generated by the plant exceeds the revenue generated from maize exports to SADC countries by a huge margin. Therefore, from a social and political point of views, the decision to exclude the maize can be qualified. However, from the economic, environmental and technological standpoints, the decision to exclude the maize as feedstock is nullified by the study.

6.3 Conclusion

❖ Chapter 1

This chapter provided the direction for the entire study by first indicating a gap in the existing body of knowledge in term of current problem identification. Key questions and hypothesis were addressed and it was in the best interest of this study to attain the objective of

providing answers to key questions. The chapter concluded by demarcating the scope of study.

❖ Chapter 2

This chapter focused on surveying literature at great lengths in terms of the production of maize in South Africa and its local and export markets. Implications of drought on maize production were addressed. Other bioethanol feedstocks were stated. The global outlook of the bioethanol industry was analysed with the specific focus to the current state of the industry in South Africa and the African continent at large. An advanced bioethanol plant with a bran fractionation step that is used as an additional fuel was chosen. It was concluded that South Africa needs to slash its entire reliance on imported fuels as this has heavy cost implication which results in many obnoxious environmental effects.

❖ Chapter 3

An integration of qualitative and quantitative methods was used to achieve the study objective. The qualitative method relied on a questionnaire as research instrument while the quantitative method relied on relevant published literature used as base case to acquire quantitative data. The sample of the study was divided into three categories comprising of the public sector (national government), another public sector of the smaller size (provincial government) and the private sector (private companies).

❖ Chapter 4

This chapter dwelled on the economic evaluation of the bioethanol plant, where many economic models were used. The input data was obtained from literature. This study was split into two sections. The first sections assessed the economics of the bioethanol plant using real time data of the present moment. The second section generated its results from changing specific major variables with an intention of gauging the impact of varying them on the overall profitability of the plant

❖ Chapter 5

Chapter five deduced the meanings of the results from qualitative and quantitative instruments. This paved the way for logical conclusions which were arrived at in Chapter 6. This chapter was also useful in refining the results and provided the answers to the study questions posed in Chapter 1.

6.4 Recommendations

The study recommended the following research areas:

- ❖ Sensitivity analysis of the economic feasibility of bioethanol plant that focuses on all the variables
- ❖ A probabilistic economic feasibility study of a bioethanol plant that uses maize as a feedstock in South Africa: A Monte Carlo Simulation
- ❖ A study that assesses the impact of using biomass (bran) as an alternative fuel on the overall economics of the bioethanol plant
- ❖ The impact of using a combined heat power plant (CHP) on the overall economics of the bioethanol plant
- ❖ A detailed lifecycle assessment of using all the starch-rich and sugar-crops to produce bioethanol in South Africa
- ❖ A detailed feasibility study that compares the value that is generated when maize is exported to all of the countries in the world and the value generated when maize is used as a bioethanol feedstock

Concluding remarks

The study concludes by stating that although the challenge of drought is still persistent in the country, there is an opportunity to grow large volumes of genetically modified maize in marginal soils and produce bioethanol in South Africa without upsetting the food security.

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APPENDICES

Appendix A: Permission letters



Dr Dirk Troskie
Director: Business Planning and Strategy
Email: DirkT@elsenburg.com
tel: 021 808 5190 fax: 021 808 5382

Reference:

WSSA (Pty) Ltd
C/O Baden Powell & Macassar Roads
Macassar
WESTERN CAPE
7134

Dear Mr Ayanda Ndokwana

REQUEST FOR APPROVAL TO CONDUCT RESEARCH WITHIN THE DEPARTMENT OF AGRICULTURE IN WESTERN CAPE FOR DISSERTATION PURPOSES

I refer to your letter dated 18 January 2016. Our understanding is that the full extent of your request is that:

- a) You will supply us with a questionnaire
- b) Three (3) of our officials will complete the questionnaire.

I hereby give approval for the completion of said questionnaire.

Kind regards



MS JS ISAACS
HEAD OF DEPARTMENT

11/2/16

DATE

31736 Nkcazo Street

Makhaza

7784

18 January 2016

Mr Muzi W. Mkhize

Chief Director: Hydrocarbons Policy

Department of Energy

Private Bag X96

Pretoria

0001

Tel: 012 406 7570/1; Email: muzi.mkhize@energy.gov.za

Dear Mr Mkhize

**REQUEST FOR APPROVAL TO ENGAGE THE DEPARTMENT OF ENERGY REGARDING MY
ACADEMIC RESEARCH PROJECT**

Our telephonic discussion regarding the above mentioned subject refers.

I herewith require your engagement as a senior official within the Department of Energy of South Africa (DoE) in conducting my academic research project. I am studying a Masters Degree of Business Administration in Project Management at Cape Peninsula University of Technology (CPUT). CPUT makes it mandatory for all post-graduate students to obtain permission before commencing with the research if the study participants are in a company or government department.

My Masters dissertation entails the "Techno-economic evaluation of using maize for bioethanol production compared to exporting it from South Africa". What has triggered an interest to conduct this research is the fact that the Government of South Africa has excluded maize from being used as a feedstock for biofuels in the Biofuels Industrial Strategy. Government has cited concerns about food security, noting that maize is a staple food crop. My research primarily



Ayanda Ndokwana | Plant Supervisor

WSSA (Pty) Ltd

c/o Baden Powell & Macassar Roads, Macassar, Western Cape 7134

Email: andokwana@wssa.co.za

Cell: 083 490 7957

Fax: +27 21 857 2224

Web: www.wssa.co.za

Date : 18 January 2016

To : The founders and Managing Partners of Green Diesel, Craig and Bettina

Dear Sir/Madam

REQUEST FOR APPROVAL TO CONDUCT RESEARCH WITHIN GREEN DIESEL FOR DESSERTATION PURPOSES

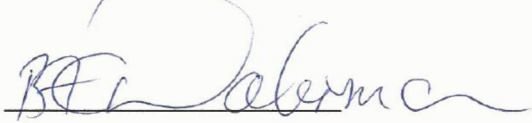
I would like to request for permission to conduct an academic research project within Green Diesel. I am currently studying a Masters Degree of Business Administration in Project Management at the Cape Peninsula University of Technology (CPUT). The University makes it mandatory for all the post graduate students to obtain permission before commencing with the research if the study participants are in a company or a government department so that an ethical clearance can be issued. I am also an employee of WSSA (Pty) Ltd as a Plant Supervisor in Cape Town.

The topic of my Masters' dissertation is on the **"Techno-economic evaluation of using maize for bioethanol production compared to exporting it from South Africa"**. What has triggered an interest to conduct this research is because of the fact that government of South Africa has excluded maize to be used as a feedstock for biofuels in the Biofuel Industrial Strategy. I am aware of the fact that your business focuses only on biodiesel production, However, my research is targeting to obtain information on both biodiesel and bioethanol emerging manufacturers in South Africa therefore I would like to get your opinions on this subject. My research will also focus on comparing the monetary value that is generated when maize is exported, and the monetary value generated when it is used to produce biofuels (bioethanol). To successfully attain the objectives of this study I will need to administer a short questionnaire. Published literature such journals, books and newspaper articles will be used to supplement gathered information.

The findings of this study will be strictly for academic purposes and will be treated with maximum confidentiality. A copy of the completed dissertation will also be sent to you.

Yours sincerely

Ayanda Ndekwana



APPROVED:

Craig: Green Diesel

DATE: 02/02/2016

COMMENTS:



Ayanda Ndokwana | Plant Supervisor

WSSA (Pty) Ltd

c/o Baden Powell & Macassar Roads, Macassar, Western Cape 7134

Email: andokwana@wssa.co.za

Cell: 083 490 7957

Fax: +27 21 857 2224

Web: www.wssa.co.za

Date : 18 January 2016

To : Mr Hayden

Dear Sir

REQUEST FOR APPROVAL TO CONDUCT RESEARCH WITHIN GREENTECH BIOFUELS FOR DISSERTATION PURPOSES

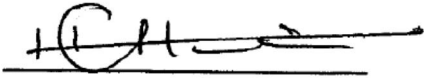
I would like to request for permission to conduct an academic research project within Greentech Biofuels. I am currently studying a Masters Degree of Business Administration in Project Management at the Cape Peninsula University of Technology (CPUT). The University makes it mandatory for all the post graduate students to obtain permission before commencing with the research if the study participants are in a company or a government department so that an ethical clearance can be issued. I am also an employee of WSSA (Pty) Ltd as a Plant Supervisor in Cape Town.

The topic of my Masters' dissertation is on the **"Techno-economic evaluation of using maize for bioethanol production compared to exporting it from South Africa"**. What has triggered an interest to conduct this research is because of the fact that government of South Africa has excluded maize to be used as a feedstock for biofuels in the Biofuel Industrial Strategy. I am aware of the fact that your business focuses only on biodiesel production, However, my research is targeting to obtain information on both biodiesel and bioethanol emerging manufacturers in South Africa therefore I would like to get your opinions on this subject. My research will also focus on comparing the monetary value that is generated when maize is exported, and the monetary value generated when it is used to produce biofuels (bioethanol). To successfully attain the objectives of this study I will need to administer a short questionnaire. Published literature such journals, books and newspaper articles will be used to supplement gathered information.

The findings of this study will be strictly for academic purposes and will be treated with maximum confidentiality. A copy of the completed dissertation will also be sent to you.

Yours sincerely

Ayanda Ndokwana



GREENTECH BIOFUELS

BIODIESEL MANUFACTURERS AND RETAILERS

P.O. Box 22337, Port Elizabeth, 6000
Unit 17, Old Dorbyl Complex, 20 Bennett Street,
Neave Industrial, Port Elizabeth
Cell: 082 378 5979 • Tel: 041 451 1834 • Fax: 086 599 3043
Email: info@biofuelsgt.co.za • Website: www.biofuelsgt.co.za

APPROVED:

Hayden: Greentech Biofuels

Comments:



Ayanda Ndokwana | Plant Supervisor

WSSA (Pty) Ltd

c/o Baden Powell & Macassar Roads, Macassar, Western Cape 7134

Email: andokwana@wssa.co.za

Cell: 083 490 7957

Fax: +27 21 857 2224

Web: www.wssa.co.za

Date : 18 January 2016

To : Mr Asogan Moodaly the Managing Director for Mabele Fuels (Pty) Ltd

Dear Sir

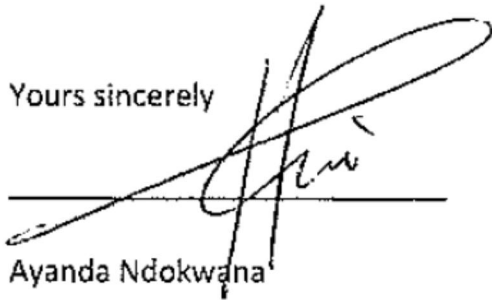
REQUEST FOR APPROVAL TO CONDUCT RESEARCH WITHIN MABELE FUELS FOR DESSERTATION PURPOSES

I would like to request for permission to conduct an academic research project within Mabele Fuels. I am currently studying a Masters Degree of Business Administration in Project Management at the Cape Peninsula University of Technology (CPUT). The University makes it mandatory for all the post graduate students to obtain permission before commencing with the research if the study participants are in a company or a government department so that an ethical clearance can be issued. I am also an employee of WSSA (Pty) Ltd as a Plant Supervisor in Cape Town.

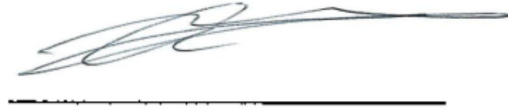
The topic of my Masters' dissertation is on the "**Techno-economic evaluation of using maize for bioethanol production compared to exporting it from South Africa**". What has triggered an interest to conduct this research is because of the fact that government of South Africa has excluded maize to be used as a feedstock for biofuels in the Biofuel Industrial Strategy. Since Mabele Fuels is one of the potential biofuel producer in South Africa, I would like to get views of the company on using crops such as maize to produce biofuels on the large commercial scale. My research focuses primarily on comparing the monetary value that is generated when maize is exported, and the monetary value generated when it is used to produce biofuels (bioethanol). To successfully attain the objectives of this study I will need to administer questionnaires and short telephone interviews to an appropriate sample size within the company. Published literature such journals, books and newspaper articles will be used to supplement gathered information.

The findings of this study will be strictly for academic purposes and will be treated with maximum confidentiality. A copy of the completed dissertation will also be sent to verify authenticity.

Yours sincerely



Ayanda Ndokwana



APPROVED:

MANAGING DIRECTOR: MABELE FUELS (PTY) LTD

DATE: 25/01/2016

COMMENTS:

Appendix B: Certificate of Authenticity

Certificate of Authenticity



084 618 2095
laurabudler@gmail.com
ChickPea Proofreading & Editing

CERTIFICATE: COA1901ALN

19 January 2017

To Whom It May Concern

This is to certify that “**Techno-economic evaluation of using maize for bioethanol production compared to exporting it from South Africa**” by AYANDA LAWRENCE NDOKWANA for CPUT has been professionally edited by Dr Laura Budler of ChickPea Proofreading and Editing Services for Students and Professionals.

Document:

Job Number	Document title
2112	Techno-economic evaluation of using maize for bioethanol production compared to exporting it from South Africa

Dr. Laura Budler
CEO ChickPea