Bio-ethanol production in South Africa
An objective Analysis

November 2005

bureau for food and agricultural policy

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Preface

Commodity price uncertainty within the agricultural sector has led to a search for alternative uses of these commodities. This report attempts to analyse one of such alternatives, namely the feasibility of the ethanol production process with specific focus on the maize sector. In the process of analysing the feasibility of the ethanol production from maize a number of scenarios have been designed and simulated, using the Bureau for Food and Agricultural Policy's (BFAP) econometric models. The simulation results produced by the models should only be considered together with the scenario assumptions under which they were run. As, Henri Theil, a great master of econometric modelling, once said: "*Models are to be used, not believed*."

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Executive Summary

Introduction

High oil prices and uncertainties regarding future reserves as well as the phenomenon of global warming have led to countries considering alternative means of energy generation. As the South African economy is highly dependent on oil, and since much of the agricultural sector has been suffering from low commodity prices, the question of the viability of ethanol production from agricultural crops, has surfaced. This report does not try to answer this question directly but rather attempts to analyse the impacts some of the critical factors influencing ethanol production, will have on its viability.

The outline of the report

The report is structured into three sections, section 1 gives a short background on the world's trends towards renewable energy, section 2 contains some extensive information on the ethanol production processes whilst the final section, section 3, contains a detailed discussion on the assumptions and scenario results that were used and produced in the simulation process.

Main findings of the report

The report contains a set of three different scenarios. Scenario 1 titled "*The new baseline"* represents the impact that a single ethanol plant has on the South African maize sector when holding all other baseline assumptions constant. Scenario 2, on the other hand, is designed to represent the likely success or failure of the ethanol plant in an environment in which the world's economies are growing and higher oil prices are the norm. The third and final scenario represents the opposite, a cooling down of the world's economies and a continual decrease in the oil price. Given these scenario assumptions the BFAP Sector Model has simulated a number of possible maize prices for the period 2007 up until 2010. Results are given from 2007 onwards, as it is assumed that ethanol production will commence then. These simulated prices and other assumptions are then fed into a stochastic simulation model, which is representative of a single ethanol production plant. It seems that in times of lower world economic growth and lower oil prices, ethanol production from maize might be an unrealistic option. Higher world economic growth and higher oil prices do, however, seem to have a positive effect on the plant's profitability.

1. Bio-ethanol in South Africa: An Introduction

1.1 Background

A new era in world energy markets started with new attention being paid to bio-fuel production. Since the industrial revolution, the world's primary energy supply has been based on fossil fuels i.e. oil, coal, petroleum and natural gas because of their relatively low prices and seemingly infinite stock. An oil crisis in the 1970's however, sent shockwaves across the globe, causing countries to start investigating alternative fuels to lower their dependency on oil from OPEC countries.

Brazil has been the leader in ethanol fuel production since the 1980's, and is still the largest supplier in the world, producing 3989 million gallons in 2004. The United States is the runner up with 3535 million gallons produced per annum and blending in 30% of the gasoline sold (Renewable Fuels Association, 2005). China has also entered the market, having built the largest ethanol plant in the world. Member states of the European Union are also on the moving towards renewable resources as they too have to reduce their emissions to 8% below their 1990 emission levels (Depledge & Lamb, 2003).

World crude oil demand is estimated to be growing at an annualised compound rate of 2%, and world crude oil production is 'expected to peak in the year 2037 with a volume of 53.2 billion barrels per day', as depicted in Figure 1 (Wood, Long & Morehouse, 2005). Although the day that oil supplies run out is still some uncertain distance away, many economic and environmental factors are driving the investigation and use of biologically derived sustainable fuels.

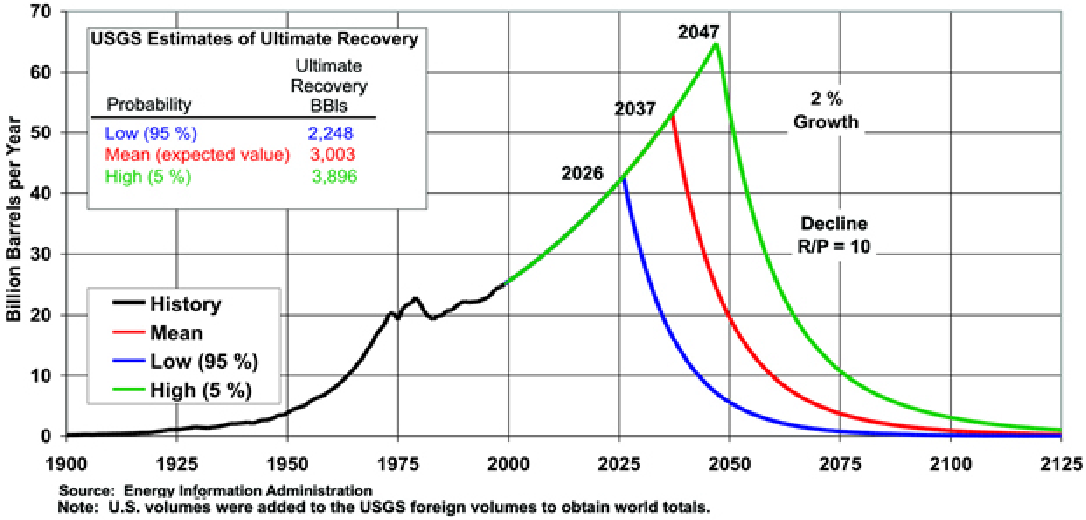

Figure 1: Annual production scenarios for oil

1.1.1 Purpose

The intention of this document is to provide the agricultural sector with an objective and unbiased view of some of the recent prospects surrounding bio-ethanol production in South Africa. Much speculation has joined the debate and the need has arisen for an impartial analysis to be written by an independent research institution.

1.1.2 Objectives

The objective of section 1 is to provide a broad overview of the renewable energy market in South Africa, and the different institutions and mechanisms that govern it. Particular attention will be given to bio-fuel production in this section. Section two focuses specifically on the ethanol production process and which types of agricultural commodities can be used to produce it. The third and final section of the report presents the assumptions and simulation results for two ethanol from maize production scenarios. The focus is to give relevant and objective feedback.

1.2 Government's stance towards renewable energy.

South Africa ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1997 and the Kyoto Protocol in 2005. These international treaties are the main agreements which address the global community's concerns regarding climate change and air pollution.

Due to South Africa's energy intensive economy, it is by far the largest emitter of Green House Gasses in Africa, with approximately 8 tons of CO_2 per capita annually (White Paper, 2003). Although South Africa is a non-annex 1 country in terms of the Kyoto Protocol, with no emission reduction targets until 2012, South Africa has voluntarily opted to reduce its dependency on fossil fuels and promote bio-fuels.

The South African government's medium-term (10-year) goal regarding renewable energy is '*10 000 GWh (0.8 Mtoe [Million tons of oil equivalent]) renewable energy contribution to final energy consumption by 2013, to be produced mainly from biomass, wind, solar, and small-scale hydro'* (White Paper, 2003). The renewable energy is to be utilised for electric power generation and non-electric technologies such as solar water heating and bio-fuels. In an effort to support this process, the government has granted a fuel levy tax reduction of 30% for bio fuels.

1.3 Benefits of ethanol fuel and other environmental considerations.

The possible impacts of bio-fuel development do not only affect the socio-economic domain, but also influence the state of our environment and natural resources. It is essential to look at what the consequences of implementing bio-fuel plants will have on the environment, and highlight the possible disadvantages and benefits resulting from it.

The two main advantages of using bio-ethanol as opposed to fossil fuels are its renewability and lower pollution levels. Because bio-ethanol is derived from biological plants, it is in essence a renewable source as long as favourable climatic conditions prevail and soils remain productive. Bio-ethanol can be blended into fuels to oxygenate it, which results in a cleaner and more thorough burning fuel. This reduces smog and air pollution and makes for efficient energy utilisation. Currently, a cheaper liquid oxygenate called MTBE (methyl tertiary-butyl ether) is used in South Africa despite its being recognised as a ground water contaminator. Ethanol offers compelling advantages. With its one-third oxygen content, it allows engines to run longer and cleaner, with 20% less carbon monoxide, resulting in reduced ground-level ozone (Mazza, 2003). According to Argone National Laboratory in the United States, 10% ethanol blends reduce greenhouse gas emissions by 12-19%.

It is however important to take care not to shift environmental burdens from one environment to another. Whilst we might lower carbon emissions by producing bio-fuels, it might negatively affect the agricultural environment that has to bear the burden of the possible increase of intensified production of crops. This would only serve to aggravate an existing environmental problem, as according to Mannion (1997), statistics indicate that 50 % of all soil erosion is due to agriculture. In South Africa, the annual soil losses are calculated at about 300-400 million tons (van Zyl, Kirsten, Binswanger 1996). South Africa's commitment to sustainable development, thus does not allow for an unprecedented intensification of agricultural practices.

It is also important to note that the fossil fuel industry disturbs the earth in the processes of exploration, drilling and refining. They may clear away many hectares of virgin forest, and disrupt the earth's soil structure. During the production of the crops utilised for making bio-fuels, on the other hand, the natural environment need not be damaged in this way.

2. Ethanol production in South Africa:

The various options available

2.1 The current situation

Maize is the most important grain crop in South Africa, as it is both used for animal feed purposes and human consumption. Maize is the staple food of the majority of South Africans and during the 2003/2004 marketing year it was responsible for the second largest contribution to the gross value of agricultural production with a gross value of R 8.32 billion (NDA, Abstracts of Agriculture 2005). The 2004/2005 production year has received sufficient rainfall, resulting in a crop of 12.18 million tons (National Crop Estimates Committee, 2005), seeing that local market only consumes around 8 million tons, the country will be left with a surplus. The previous two marketing seasons have resulted in a surplus. During 2002/2003 a total amount of 9.7 million tons had been harvested whilst the 2003/2004 experienced a total production of 9.4 million tons. These values are sums that include both white and yellow maize production.

Basic economic principles tell us that if a good is in over supply the result will be a low price and if there is a shortage of a good then a high price will be the result. This is the exact situation in which the South African maize industry finds itself at the moment in an over supply of a commodity and a resultant low price. The current production season has a 2.9 million ton carry over surplus of maize from the previous season and the final estimate of the National Crop Estimates Committee stands at 12.1 million tons for the current production season (National Crop Estimates Committee, 2005). This results in a total of approximately 15 million tons available for consumption. The market can realistically absorb an average of 9 million tons. The final effect will be markets with 4.6 million tons carry over stock for the next season that, depending on the area planted for the new season, could apply price pressure in the maize market.

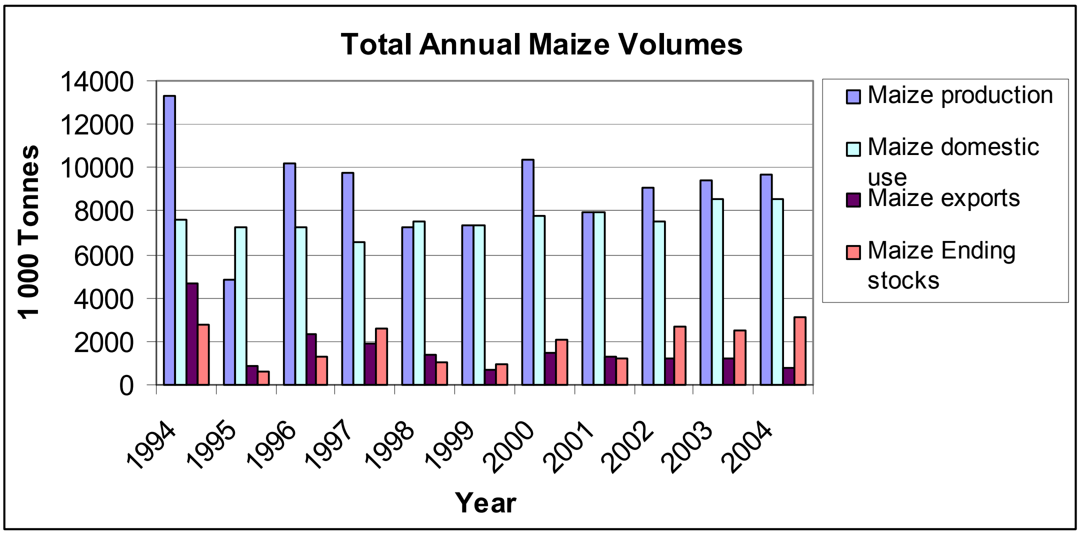

Figure 2: Total annual maize production and ending stocks.

Figure 2 indicates the carry over stock that is the result of a big crop for the past few years. As mentioned previously, the country can consume a maximum of 9 million tons, of this the remaining 4.6 million will be carried over to the next season. This, depending on that crop's size, can result in another surplus and with that a lower price.

2.2 Alternatives available to farmers

Various institutions advise farmers to know their costs of producing a ton of maize and in so doing they can more easily decide if they should plant maize in the coming season or not. Some advise that farmers should make use of a contract and thereby fix a price, before the production season starts, at levels above the cost of producing a ton of maize. To hedge the price on SAFEX at levels above the cost of producing a ton of maize is also an option. The result of such a strategy will be a profitable price for at least two-thirds of the farmer's crop (Standard Bank, 2005). Such hints and tips are fine for the individual farmer, but do they apply to the entire sector? What needs to be addressed is how to make the production of maize profitable in the long term and at the same time supply consumers with affordable food products produced from maize. The fact that the South African market is free and that it can only consume a maximum of 9 million tons is likely to force role players to find alternative uses of maize in order to deal with a low maize price.

Alternative uses for maize can be categorized into two groups. The one group would involve the moving of the actual crop to different locations, by means of exports whilst the other would involve the transformation of the crop into a secondary product, such as the production of ethanol from maize.

South Africa's competitiveness in the export market is hampered by the surplus production of developed nations, which in turn is constantly fuelled by direct and indirect subsidies.

Exports to SADC countries are taking place. The only problem might be that the price of the maize is too high and as a result most of South Africa's poorer neighbours cannot afford such a good. They would then rather rely on local production, which has been insufficient during the past year due to a drought, and also on food aid, which the world food program mostly supplies. Table 1 represents South Africa's whole maize exports to the SADC region for the 2004 / 2005 marketing season.

Table 1: South African whole grain exports, 2004/2005 (1st May – 30th April).

	2004 / 2005 Marketing Season		
	White (tons)	Yellow (tons)	Total
Zimbabwe	186,529	657	187,186
Mozambique	48,044	0	48,044
Namibia	43,452	12,500	55,952
Botswana	110,862	8,205	119,067
Swaziland	16,689	28,434	45,123
Lesotho	111,046	6,712	117,758
Madagascar	2,382	0	2,382
Angola	25,575	430	26,005
Kenya	112,251	0	112,251
Congo	216	0	216
Total	**657,046**	**56,938**	**713,984**

Source: *SAGIS, 2005.*

As the Table 1 indicates, a total of 714 thousand tons of grain have so far been exported to other African countries. The exports during the 2003 / 2004 marketing season were a bit larger as the total exports for both white and yellow maize amounted to 1.1 million tons (SAGIS, 2005), a small percentage of the entire crop.

For the current marketing season (04/05) maize exports increased sharply from May up until October 2005. Reasons for this increase in the exports can be partly contributed to the decrease in the local maize price, which in turn made our exports more competitive internationally (NDA, 2005).

The result of a relatively small percentage of exports has contributed to a large surplus of maize still in circulation and with those lower prices. This has given rise to the search for alternative uses of maize and with the world's leading countries moving towards renewable energy sources the production of ethanol from maize is under the spotlight.

2.3 The maize to ethanol production process

2.3.1 The dry milling process

The first phase of the production process involves the hammer mills, which grind the maize kernels into a fine meal. Thereafter water and the enzyme alpha amylase are added to the meal. The mash is then poured into the cookers. The cookers are heated to liquefy the starch. The cookers have a high temperature stage of 120 –150 degrees Celsius and a lower temperature period of 95 degrees Celsius. These high temperatures reduce the amount of bacteria that are contained within the mash. The process of adding water and enzymes is called the liquefaction. The mash from the cookers is cooled and the secondary enzyme, gluco-amylase is added to convert the starch into sugars. This process is called saccharification. Fermentation takes place when yeast is added to the mash to ferment the sugars, producing ethanol and carbon dioxide. The mash stays in the tanks for 50 hours. During these hours efforts must be made to reduce the heat, which is released from the fermentation process. The pH levels vary constantly and also have to be regulated. It is during this phase of the production cycle that CO_2 is captured and sold as a by-product for the use of gasification in the soft drink industry (Corn Refiners Association, 2005).

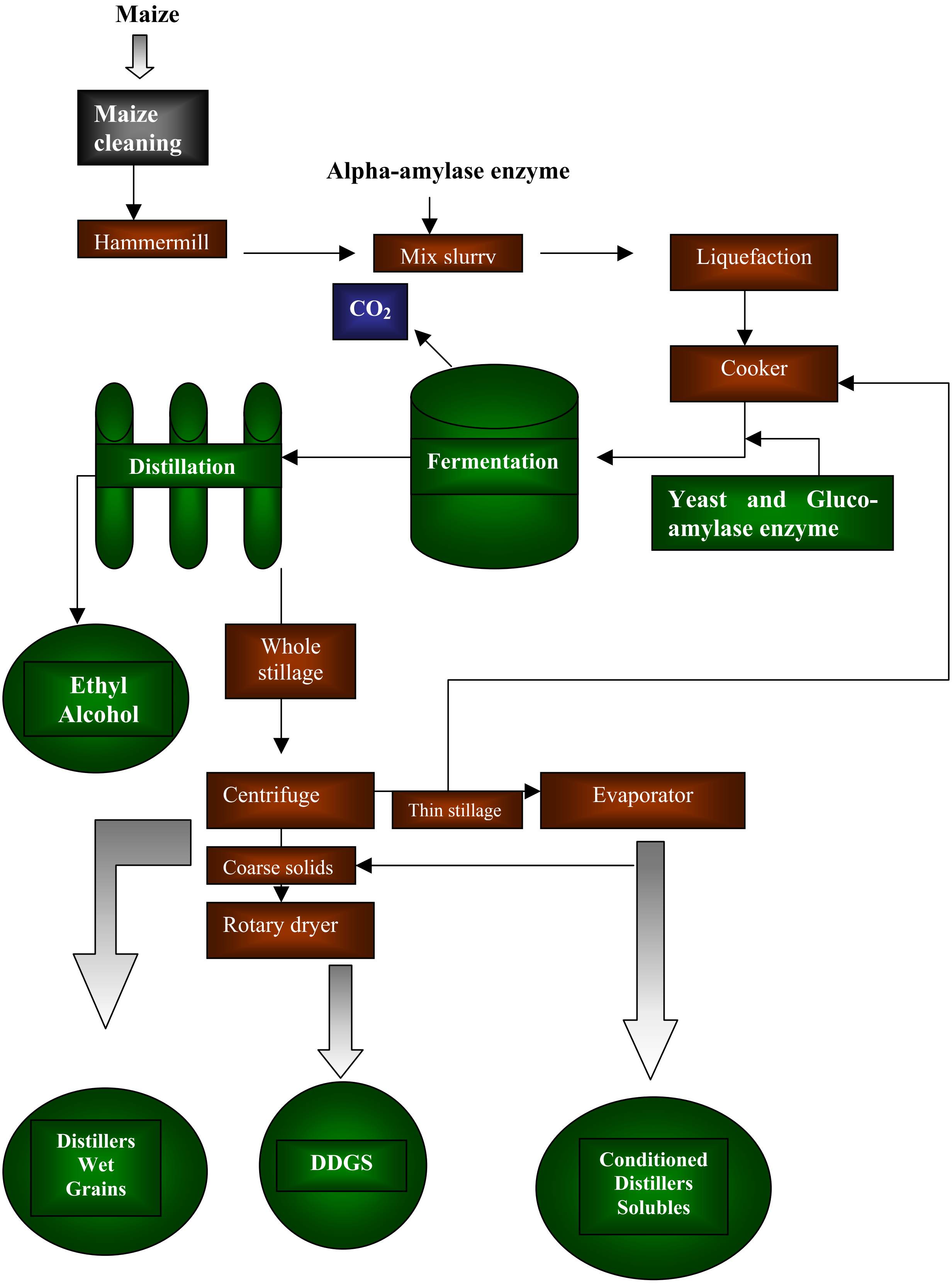

Figure 3: Maize dry-milling process overview
Source: *University of Minnesota, 2003.*

The distillation process, that follows next, is the process during which the alcohol is removed from the water and solids. This leaves the top of the final column 95% pure and a residual mash and the stillage is then transferred from the bottom of the distiller to the centrifuge where it is then processed further.

During dehydration all of the excess water is removed from the solution. This is achieved by installing molecular sieves in the system that capture the remaining water and let the vaporized ethanol solution pass by. The ethanol is then denatured through the addition of gasoline. Gasoline is often used as it is relatively cheaply available and because this lower octane substance can be blended with the high-octane ethanol. Once ethanol has been produced, the residual mash is centrifuged to separate the liquid from grain residues. The liquid is then heated to remove water and concentrate the soluble materials. The grain residues or distillers grains can then be sold and fed wet to cattle within a short period of time, or be dried in rotary drum driers and together with concentrated syrup, be sold as livestock feed better know as Dried Distillers Feed with Solubles, or DDGS (Corn Refiners Association, 2005).

2.3.2 The wet milling process

The wet milling process involves the corn kernel being pre-soaked and then milled to produce three streams of germ, fibre and starch. The germ is then extracted to produce maize oil, the most important co-product of the wet milling process. Depending on the cultivars that have been planted, a bushel (25.4012 kg) of maize can have an average yield of 1.6 pounds (0.7257 kg) of maize oil (Corn Refiners Association, 2005). The fibre portion includes seed pericarp and the bran, which has a composition of 70% xylose, 23% cellulose and 0.1% lignin. The starch fraction undergoes a centrifugation and saccharification process to produce wet cake and in the end yields 2.5 pounds (1.13398 kg) of maize gluten meal. The maize gluten meal is the second most valuable product in the process. The ethanol is then distilled leaving a thin stillage, when dewatered, leaves condensed distiller's soluble with containing 20% carbohydrate and 18% protein. Consequently a condensed distiller's soluble can be sprayed onto the maize fibres and fermented to produce 13.5 pounds (6.12349kg) of maize gluten feed. A bushel (25.4012 kg) of maize yields about 31.5 pounds (14.288kg) of starch, which can be further processed into 33 pounds of sweetener (a high fructose maize syrup) or 2.5 gallons (9.55litres) of ethanol (Corn Refiners Association, 2005).

2.4 By-products of the dry milling ethanol production process

When maize is used for the production of ethanol, a number of by-products are produced as a result. The by-products of the dry mill process are carbon dioxide, CO_2, and a mid level protein feed commonly known as dried distillers feed with solubles or DDGS.

2.4.1 Carbon dioxide

Carbon dioxide is captured during the fermentation process. Fermentation takes place once the mash, together with yeast and gluco amylase enzymes is placed into the fermentation tank. This by-product is used in the soft drink industry and represents about 1% of the dry mill's revenue.

2.4.2 Dried distillers grains with solubles

Dried distillers grains with solubles, also know as DDGS, is said to be an excellent mid-level protein feed, with a slight deficiency in amino acids and a lower energy content, as a result of the removal of starch which takes place during the ethanol production process (Tiffany, 2002). It has been found that DDGS is approximately made up of 26% crude protein, 10% crude fat, 12% crude fibre and 11% moisture (Tiffany *et al*, 2003). The nutritional content of DDGS often varies according to the production process, the types of cultivars used, environmental factors and the level of technology employed.

Table 2: Nutritional content variations of DDGS.

Contents	%
Protein	25.5-30.7
Fat	8.9-11.4
Fiber	5.4-6.5
Calcium	0.017-0.45
Phosphorus	0.62-0.78
Sodium	0.05-0.17
Chloride	0.13-0.19
Potassium	0.79-1.05
Amino Acids	**% total amino acid**
Methionine	0.44-0.56
Cystine	0.45-0.60
Lysine	0.64-0.83
Arginine	1.02-1.23
Tryptophan	0.19-0.23
Threonine	0.94-1.05

Source: *University of Minnesota, 2003.*

Table 2 represents the average nutritional values as taken by a number of different ethanol production plants throughout the USA. The University of Minnesota investigated these as part of a study. They found that the quantities mentioned, varied within the given range depending on the source, the technology used as well as the area of production. Table 3 compares the amino acids as a percentage of protein as part of different types of feed ingredients. The types of feed ingredients include maize, canola, soybean meal and DDGS.

Table 3: Ingredient amino acids (% of protein), as part of different feed ingredients

Amino Acids	Soyabean meal	Maize	Canola	DDGs
Methionine and Cystine	2.6	4.6	4.5	3.7
Lysine	6.2	3.0	5.6	2.8
Arginine	7.3	5.0	6.0	3.6
Tryptophan	1.6	0.9	1.3	0.7
Threonine	4.0	3.4	4.4	3.4

Source: *University of Minnesota, 2003.*

Table 3 clearly indicates that DDGS is deficient in all major amino acids compared to other ingredients used in feeds. Experiments conducted in the USA have however indicated that DDGS can be mixed into the diets of all major livestock feeds without having any negative side effects. Experiments conducted by numerous institutions advise that a concentration of up to 15% can be added to the feed without causing any negative side effects (University of Minnesota, 2003).

The utilisation of DDGS does pose some problems. Firstly the product is very bulky and as a result the transport thereof is expensive. It is therefore preferable if the end consumers of the product are in close vicinity of the ethanol plant. Another reason why being in close proximity to the ethanol plant is preferable, is that wet DDGS is of a better nutrient value but only has a short shelf life, making the time period of delivery crucial.

Price sensitivity of the feed industry is also a factor that needs to be taken into account when considering the sales of DDGS. A comprehensive report, written by Loutjie Dunn of Senwesko Feeds analyses the possible inclusion rates and impacts of DDGS on the formal feed market based on different prices and quality. The report is called "*The value of DDGS to the formal feed industry in South Africa*". BFAP made use of the assumptions in Mr. Dunn's report to include realistic assumptions on the replacement ratio (RR) of maize equivalents for DDGS in the South African animal feed market. For the purpose of this study one can distinguish between two different quality levels of DDGS. The one being a higher quality products, containing a higher level of proteins and the other a lower quality product, containing a lower amount of proteins. When taking the quality into account and then observing the price sensitivity, it becomes clear that at R300 / ton, the higher quality DDGS might see inclusion levels of 6% in the normal feed rations of livestock while the average quality DDGS might see inclusion levels at around 3% to 3.5% in the normal feed rations (Dunn, 2005).

2.5 The sugar – to - ethanol production process

2.5.1 The South African Sugar Industry

Sugar producing areas in South Africa are generally located in Kwazulu-Natal, a small part in Mpumalanga and also in the Eastern Cape. The industry is made up of approximately 50 000 registered growers who together produce 27 million tons of sugarcane. Of these 50 000 growers, approximately 48 000 are small scale, of whom 28 600 delivered cane producing around 13% of the total crop (SA sugar association, 2005). The other 2000 are the large-scale commercial growers who produce 75% of the total crop. The milling companies produce the remaining 12% of the total crop. These 12% are mostly produced on sugar estates that the company owns.

World market prices for raw sugar have rallied strongly over the month of June, extending the gain of $11 / ton posted during the second half of May by a $7 / ton. These surges in prices can be attributed to sudden Chinese and Malaysian buying as well as better than expected Russian imports (SA Sugar Journal, 2005). The market is currently, during July, at 9.00c/lb this is 42c down from its previous high of 9.42c/lb during March (SA Sugar Journal, 2005). It seems that production in other parts of the world is subject to some uncertainty, India for example has producers who are needing 40% recovery on their 2004 crop just to meet expectations. India's production will depend largely on the rains that the monsoon will bring. Brazil's sugar producers saw a disappointing end to their crop mainly due to ethanol production enjoying the lion's share of the available sucrose.

2.5.2 Ethanol from sugar and bagasse

The sugarcane to sugar production process is of a rather complicated nature. The process starts when the sugarcane is burnt to remove excess leaves and other organic matter after which it is then harvested on the field and transported to the sugar mill. At the mill the cane is crushed and the juice extracted, the byproduct of this process is known as bagasse. The juice is then further modified to form crystals after which two products, namely molasses and Sugar result. The sugar is then graded and divided into two separate categories, namely the export market and the domestic market.

Studies have indicated that 100 tons of sugarcane produces approximately 13 tons of sugar and 15 tons of bagasse (Purchase, 2005). The sugar to ethanol conversion process is estimated at around 44% meaning that of the 13 tons of sugar, 5,7 tons of ethanol can be produced. This would entail that approximately 5500 litres of ethanol can be produced from one hectare of sugar cane. Figure 4 represents this process graphically.

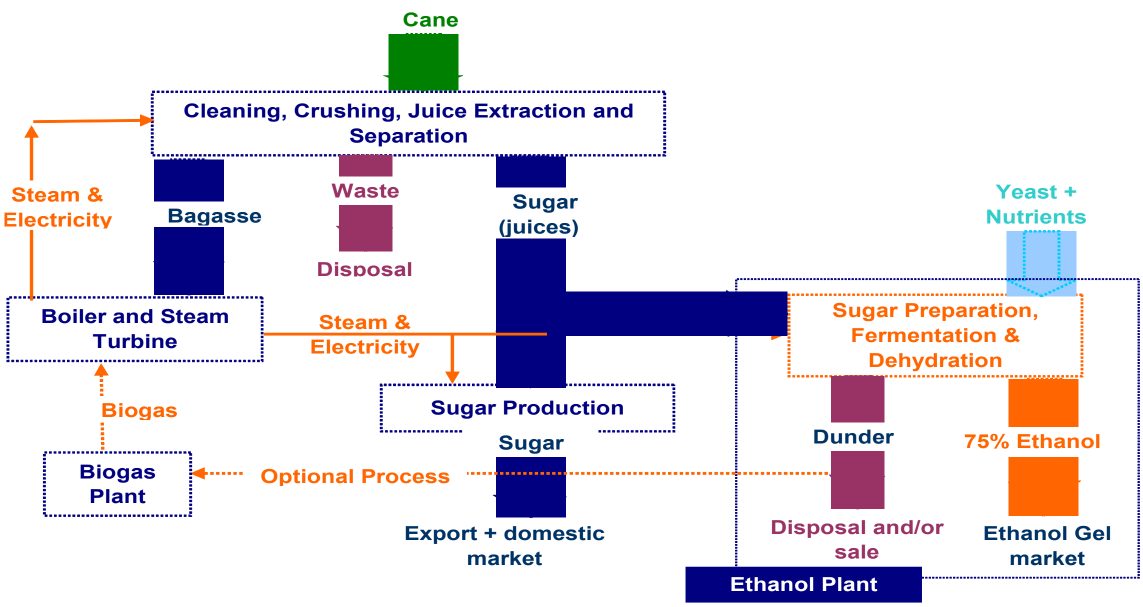

Figure 4: Graphical representation of the sugar to ethanol production process.
Source: *le Roux, 2004.*

As the above figure shows, cane is used as the raw material. The cane is then processed into three main categories, these are Bagasse, waste products and sugar juices. A process of cleaning, crushing, juice extraction and separation achieves these results. In this example the produced bagasse is used to power a boiler and steam turbine. Bagasse is not only a waste product, it can also be used to produce ethanol. The yield for this type of production is however not that high and therefore it might not be so profitable. The bagasse to ethanol process is discussed in the next section of this report. The sugar juices are divided into two categories, namely the high quality sugar, which is crystallised and then used for human consumption and exports, and the lower quality sugar, used for the production of ethanol. The production of ethanol from sugar then involves adding yeast and nutrients to the sugar solution. Then by a process of preparation, fermentation and dehydration the sugar solution is transformed into a 75% ethanol mixture that can be transformed into bio-ethanol gel and dunder which is some sort of energy resource that can be used to fuel the biogas plant, be disposed of or sold.

Bagasse, which is a by product of crushing sugarcane, is not a completely wasted product as it, with its starch content, can also converted to ethanol. Diagram 2 will represent this process more clearly. The bagasse to ethanol ratio is not that high. The conversion ratio is estimated at around 22,66% meaning that 15 tons of bagasse produce around 3,4 tons of ethanol (Purchase, 2005). The result is that bagasse yields a lower percentage of ethanol than sugar.

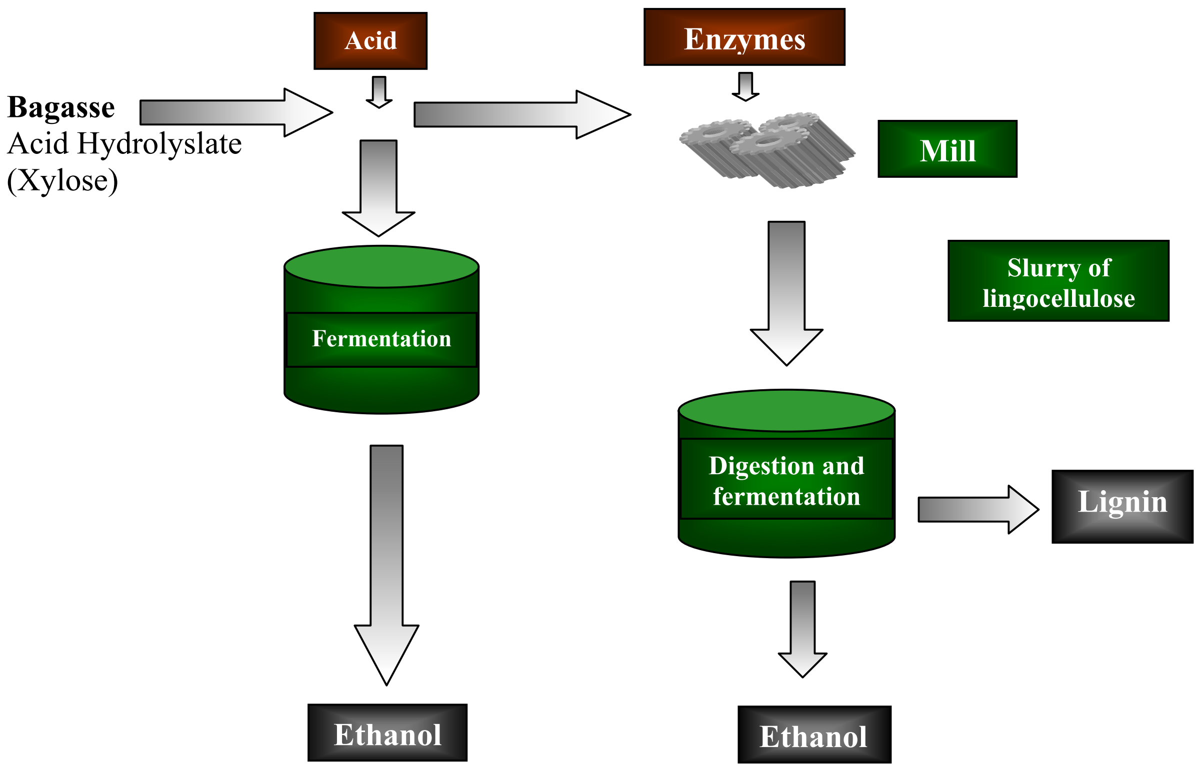

Figure 5: Bagasse - to - ethanol process

Source: *Purchase, 2005.*

The bagasse to ethanol production process, as depicted in figure 5, makes use of various chemical substances to get the final result. The first and simpler method involves adding acid to the bagasse. This slurry is then fermented and the final product is known as ethanol. Another process is the one where the bagasse is milled at first, then enzymes are added and the slurry of lignocellulose is added to a container or basin in which the digestion and fermentation process takes place. The products are lignin and ethanol (Purchase, 2005).

In early times lignin or lignosulfonates were used for leather tanning and dye baths, since then lignosulfates have been used in food products. Lignosulfates serve as emulsifiers in animal feed and are used as a raw material in vanillin. Vanillin is widely used as an ingredient in food flavours as well as in pharmaceuticals and a fragrance in some perfumes.

2.6 The Sorghum – to – ethanol production process

2.6.1 The South African Sorghum Industry

The South African Sorghum industry has seen a slight increase in the area of sorghum planted, but has experienced a dramatic increase in the total quantity of Sorghum harvested. This could mean that higher average yields have been realised over much of the production area. Sorghum production in South Africa reached a 10 year low during 2001/02 season when producers cultivated approximately 80 000 hectares. The areas cultivated increased steadily during the following season when 100 000 hectares were planted in 2002/2003 with a total production of just over the 200 000 tons (NDA, 2005). During the 2003/2004 planting season approximately 120 000 hectares of land had been cultivated with a harvest of around 340 000 tons. This has shown a substantial increase in the yield per hectare (Grain SA, 2004). The local prices of Sorghum have fallen rather steadily during the 2003/2004 harvesting season. The reason for this is that the crop's size was a lot larger than expected and that a low maize price has a negative effect on the sorghum price. Grain SA estimated that the price from the end of 2003 up until middle 2004 was around R 1350 per ton. The average price for 2004 was estimated to be around R900/ ton, this declined significantly to reach a value of around R450 – R470 /ton during the 2005 harvesting year (NDA, 2005).

2.6.2 Ethanol from sorghum

There are three different types of sweet sorghum harvesters. One is the conventional forage chopper, the second is the 'pith combine', which consists of a conventional forage chopper, modified to collect the pith fraction and to drop the rind leaf fraction back on the field. The third type of harvester is the pull type harvesters that will cut whole stalks and replace them in a windrow in the field (Rains *et al*, 1993). When producing ethanol from sorghum there seems to be a slight disadvantage in using the forage chopper. According to the research done by Rains, the passing of chopped whole stalk through the press reduces press capacity and reduces juice yield. Little juice is contained in the fibrous leaf and rind, but it absorbs juice, thus reducing the total juice that can be expressed.

Studies have revealed that sweet sorghum can produce quantities of both readily fermentable carbohydrate and fibre for conversion via enzymatic hydrolysis on a per hectare basis. In fact, some studies have found that sweet sorghum produces more carbohydrate per unit land area than maize, in certain areas of the United States (Parrish *et al*, 1985). Another difference between sorghum and maize is that sorghum does not concentrate the carbohydrates in the grain, but stores them in the stalk. Another advantage of sorghum is that the harvest season is relatively shorter than other crops, ranging between 4 to 6 weeks. Researchers believe that the challenge is to harvest the crop, separate it into juice and fibre and then to utilise each constituent for year round ethanol production (Rains *et al*, 1993).

Currently, some wet milling plants in the USA use sweet sorghum to produce ethanol. Figure 6 represents the sorghum to ethanol production process graphically. There are three product types, originating from sorghum production, which can be used for ethanol production. These products types are the grains, the sugar juice extract and the bagasse. The grains are fermented to produce ethanol and have as a by-product, dried distiller's grain. The sugar juice is fermented to produce ethanol, the bagasse can be burnt and as a result of the heat, electricity can be generated. Another use for bagasse may be the production of paper.

When using sweet sorghum in the ethanol production process, the by-product can be used as a feed ration for animals. The composition of this by-product is relatively unknown as the sorghum to ethanol process has not been done before. It is however estimated that no modifications need to be done to the dry milling plant, so that sorghum can be used as the input.

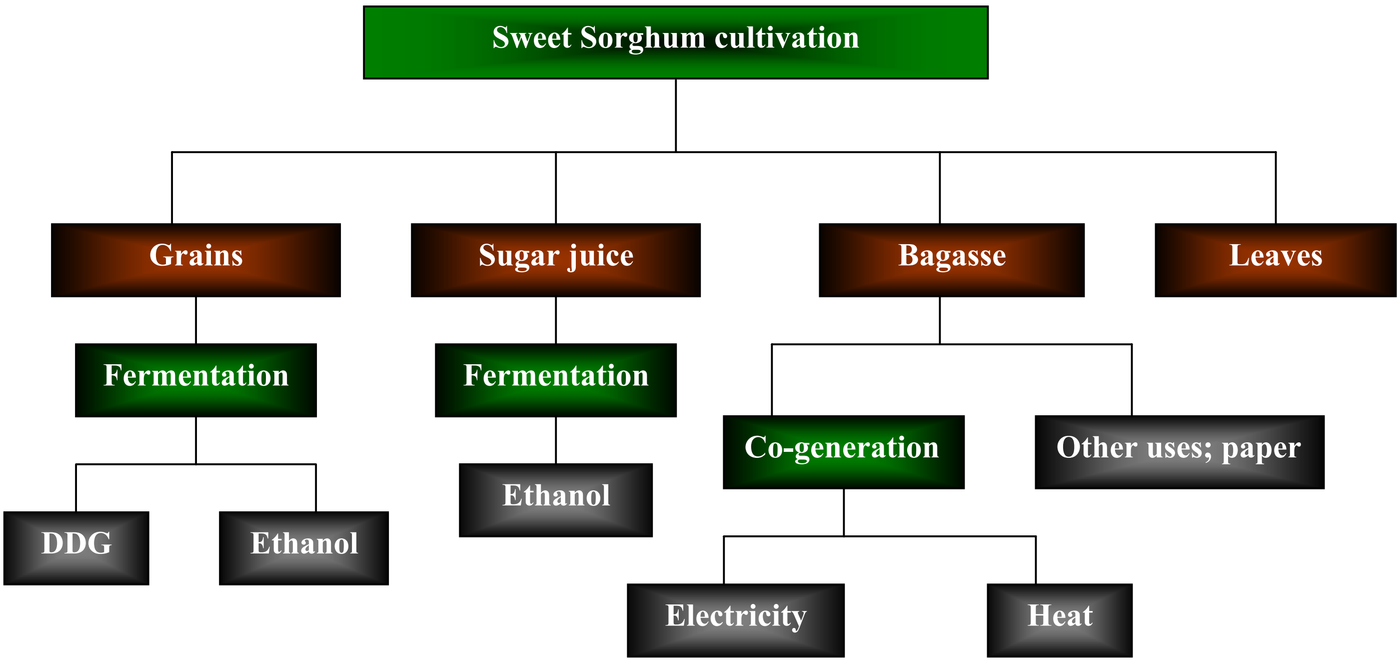

Figure 6: Graphical representation of the Sorghum to ethanol process

Source: *Chiaramonti et al, Energia Trasporti Agricoltura.*

3. Simulating the introduction of one dry mill maize-to-ethanol plant in the South African agricultural sector

3.1 Background to the simulation process

The simulation process is conducted by using the BFAP Grain, Livestock and Dairy Sector Model and BFAP's ethanol plant model. The Sector model simulates a baseline, which is a projection of future values under a specific set of policy and macroeconomic assumptions. The BFAP Grain, Livestock and Dairy Sector Model is an econometric, recursive, partial equilibrium model. Identified drivers of supply and demand for the various commodities included in the model are used to simulate equilibrium by means of balance sheet principles where demand equals supply.

This section of the report is not a forecast but rather a set of scenarios based on a number of assumptions. As the agricultural industry is filled with risk and uncertainty, future planning should address a variety of possible events or scenarios. Many of these scenarios can be quantitatively simulated using BFAP's Sector Model and BFAP's ethanol plant model. The Sector model's simulation results are then plugged into the ethanol plant model, which will simulate possible cash flow surpluses or deficits that the ethanol plant might experience given the specific scenario. By running these simulations possible risks that might influence the net cash flow of the proposed ethanol plant are highlighted. The results presented in this section can by no means be stated as absolute future predictions, but possible future situations given the historic behaviour of the sector and the assumptions made in the simulation process.

3.2 Assumptions

3.2.1 Baseline assumptions

The baseline projections are grounded on a series of assumptions about the general economy, agricultural policies, weather and technological change. Macroeconomic assumptions are based on forecasts prepared by a number of institutions like Global Insight, the Food and Agricultural Policy Research Institute (FAPRI) at the University of Missouri, ABSA bank and the Actuarial Society of South Africa (for projections on population). Table 4 and 5 present the baseline projections for key economic indicators and world commodity prices in the model.

Table 4: Economic indicators - Baseline projections:

Item		2005	2006	2007	2008	2009	2010
Crude Oil Persian Gulf: fob	$/barrel	55.00	56.03	57.07	58.10	59.13	60.16
Population	Millions	47.49	47.64	47.68	47.65	47.54	47.39
Exchange Rate	SA c/US$	595.98	640.09	681.69	722.59	763.78	805.79
Real per capita GDP	R/capita	16049.48	16627.26	17192.59	17759.95	18346.03	18896.41
CPIF	Index ('00)	137.94	143.87	149.91	155.16	161.83	168.47

Source: Global Insight, FAPRI, Actuarial Society, ABSA

Table 5: World Commodity Prices - Baseline projections:

Item		2005	2006	2007	2008	2009	2010
Yellow maize, US No.2, fob, Gulf	US$/t	104.19	107.17	108.16	109.16	110.15	111.14
Wheat US No2 HRW fob (ord) Gulf	US$/t	148.75	150.39	153.44	155.50	158.21	160.52
Sorghum, US No.2, fob, Gulf	US$/t	104.00	103.00	104.00	105.00	106.00	106.00
Sunflower Seed, EU CIF Lower Rhine	US$/t	315.80	330.49	339.05	339.05	340.28	340.28
Sunflower cake(pell 37/38%) , Arg CIF Rott	US$/t	117.40	119.66	123.04	125.30	126.43	125.30
Sunflower oil, EU FOB NW Europe	US$/t	705.00	727.63	743.48	745.74	748.00	750.26
Soya Beans seed: Arg. CIF Rott	US$/t	278.00	290.81	304.90	311.31	311.31	312.59
Soya Bean Cake(pell 44/45%): Arg CIF Rott	US$/t	235.00	238.81	240.08	245.16	246.43	246.43
Soya Bean Oil: Arg. FOB	US$/t	490.00	502.25	514.50	521.65	521.65	525.73
World fishmeal price: CIF Hamburg	US$/t	659.00	669.69	673.25	687.50	691.06	691.06
Nebraska, Direct fed-steer	US$/t	1831.00	1773.00	1742.00	1694.00	1645.00	1612.00
Chicken, U.S. 12-city wholesale	US$/t	1478.00	1392.00	1360.00	1352.00	1348.00	1351.00
Hogs, U.S. 51-52% lean equivalent	US$/t	1058.00	874.00	906.00	983.00	1067.00	1031.00

Source: FAPRI. Outlook 2005

The most important assumptions and deterministic baseline results can be summarized as follows:

- *The new FAPRI 2005 Agricultural Outlook* is used for the projections of world prices. This outlook was published in March 2005.
- It is generally assumed that current agricultural policies will be continued in South Africa and other trading nations.
- The exchange rate for 2005 is 595.98 SA cents per US $ after which it depreciates gradually to reach a level of 805.79 SA cents per US $ in 2010.

- Rainfall is split into the rainfall that influences the area planted and the rainfall that influences the production or yield of each summer crop, which is included in the model. The average rainfall for the past 30 years, for specific months influencing the area planted and the production is used as the assumed value. The latest published rainfall statistics have been included in the model. This implies that the actual rainfall for the summer crop production season 2004/05 has been included in the model.

3.2.2 Assumptions regarding the ethanol production process

The assumption that are used for the simulation of the ethanol production process have their roots in reports gathered from the University of Minnesota as well as a report compiled by Mr. Loutjie Dunn from Senwesko feeds.

The ethanol plant model that BFAP has developed, with help of an example from the University of Minnesota, is a stochastic simulation model. The format of the model contains a complex set of equations, which are all based upon historical data, correlation matrices and valuable feedback from professionals. The model is designed specifically for a dry milling ethanol plant equipped to handle an input of around 370 000tons maize annually and produce an output of around 150 000 000 litres of ethanol, depending on the starch content of the maize used. Exogenous factors that have been identified as being critical to the ethanol production process include, the oil price, as the ethanol price is likely to be a function thereof, the exchange rate, the maize producer price, rainfall and the price that the feed market is willing to pay for DDGS.

The assumptions used in the simulations of this report are as follows:

- One ethanol plant uses 370 000 tons of maize to produce 111 000 tons of DDGS of average quality;
- Mr. Dunn’s calculations show that at an average price of R300/ton, 297 170 tons of DDGS will replace 98 789 tons of other feed products. The main products that will be replaced are maize, gluten feed, hominy chop and gluten meal. Thus, according to Mr. Dunn, 297 170 tons of DDGS will replace 322 492 tons of maize equivalents in the feed market.

- In this report the impact of only one ethanol plant that produces 111 000 tons of DDGS is analysed. Using a RR of 0.428 this plant is simulated to replace 47 508 tons of maize in the South African feed market.

Table 6: Net increase in maize demand for 1 ethanol plant – DDGS at R300/ton

Item	Tons
Maize usage by 1 ethanol plant	370 000 tons
DDGS tons produced by 1 ethanol plant	111 000 tons
Maize equivalents replaced in feed market (0,428 RR)	47 508 tons
DDGS consumption in market	111 000 tons
Surplus DDGS in domestic market	0 tons
Net increase in demand for maize in domestic market as result of ethanol plant	322 492 tons

Table 6 indicates that the net effect in terms of an increase in demand for maize because of ethanol production is likely to be 322 492 tons (370 000 tons – 47 508 tons). The increase in the demand of maize will, in the simulation, be split equally between white and yellow. Meaning that the demand for these commodities will each increase with 161 000 tons respectively.

The introduction of DDGS into the feed market, not only has implications for maize and maize products, but also for feed ingredients such as wheaten bran, fullfat soya, soyabean meal, sunflower meal, fish meal and cottonseed meal. Table 7 lists the impacts of DDGS on these products in the feed market.

Table 7: The impact of 111 000 tons DDGS on the feed market

Product	Impact on market (tons)
Maize	-47508.00
Wheaten bran	-19796.7
Fullfat soya	-5229.3
Soyabean meal	20170.3
Sunflower meal	-19049.7
Fishmeal	-1494.1
Cottonseed meal	-1867.6

Source: Dunn, 2005.

3.3 Scenarios

3.3.1 Scenario 1: "The new baseline"

The assumptions for this scenario include that an additional 322 490 tons of maize are taken out of the maize market. This is the maize equivalent that will be taken out of the market given the assumption mentioned in part 3.2.2 of this report. Furthermore the model has been adjusted as to compensate for this increase in demand of maize, keeping all of the original baseline assumptions constant. This results in the model simulating a new equilibrium, given the reduced supply. For accurate results the increased demand has been split equally between the yellow and white maize sectors. Table 8 represents the increase in price from the original baseline's assumption, given the changes. (BL = Baseline, SCE = Scenarios)

3.3.1.1 The sector model's results

Table 8: BFAP model output given scenario 1

Item		2007	2008	2009	2010
White maize production (BL)	1000t	5375.5	5565.6	5662.8	5987.6
White maize production (SCE)	1000t	5375.48	5708.06	5744.48	6096.57
White maize production (change)	1000t	0	142.46	81.68	108.97
White maize producer price (BL)	R/ton	1009.3	1061.9	1113.7	1087.0
White maize producer price (SCE)	R/ton	1069.26	1095.1	1157.87	1126.28
White maize producer price (change)	R/ton	59.96	33.2	44.17	39.28
Yellow maize production (BL)	1000t	3639.1	3926.2	3883.4	3998.6
Yellow maize production (SCE)	1000t	3639.1	4076.52	3964.44	4084.29
Yellow maize production (change)	1000t	0	150.32	81.04	85.69
Yellow maize producer price (BL)	R/ton	993.3	907.5	931.9	924.7
Yellow maize producer price (SCE)	R/ton	1089.45	952.60	983.85	981.39
Yellow maize producer price (change)	R/ton	96.15	45.1	51.95	56.69
Total maize production (BL)	1000t	9014.6	9491.8	9546.2	9986.2
Total maize production (SCE)	1000t	9014.6	9784.58	9708.91	10180.86
Total maize production (change)	1000t	0	292.78	162.71	194.66

As can be seen from Table 8 that the production of both white and yellow maize increased by approximately 142 460 tons and 150 320 tons, during 2008, respectively. As a result of the higher demand for both commodities, both experience increases in their producer prices. The white maize producer price for 2007 is simulated at R 1069.26 per ton, R59.96 higher than the baseline's projections, whilst the yellow maize producer price is simulated at R 1089.45 per ton, R96.15 per ton higher than the baseline's projection. The increase in the producer price moderated somewhat for the following years as the effect of the increased demand played them out. The simulation for 2010 for example, showed that the white maize producer price only changed by R39.28 per ton from the baseline.

From here onwards all simulations are run and compared to the "new baseline". This means that the assumptions of one ethanol plant becoming fully operational in 2007 resulting in a net increase in maize demand of 322 490 tons holds for all of the scenarios that follow.

3.3.1.2 The ethanol plant model's results

Taking all of these factors into account exactly as they appear in the original BFAP baseline and using the average producer price, as calculated from the values in Table 9, the ethanol plant model gives an output that represents the likely cash-flow, under the given set of assumptions. For simplicities sake the likely cash-flow has been simulated for the years 2007 and 2010, with the likely cash flows per ton maize ground, per litre of ethanol produced and the total presented in Table 9 below. Profits are preceded by a + whilst losses are preceded by a -.

Table 9: Profit for the ethanol plant given the assumptions of scenario 1

Description	2007	2010
Profit/loss per ton ground	-R 461.89	-R 420.02
Profit/loss per denatured litre	-R 1.23	-R 0.98
Total profit/loss of the plant	-R 195 324 851.45	-R 139 313 239.86

The results that are represented in Table 9 indicate just how sensitive the ethanol production process will be with respect to the critical drivers that were mentioned previously. The figures that are given in the table represent the annual total profit or loss for a specific plant. These simulations were done with the assumption that the ethanol price is R 2.72 per litre in 2007 and R 3.12 per litre in 2010. The DDGS prices that were used as inputs were R 462 per ton for 2007 and R 508 per ton for 2010. The reason for choosing a higher ethanol price in 2010 is that the baseline assumes the oil price moves to around $60 per barrel during that year, and since the ethanol and oil price are assumed to be correlated this conclusion is made.

3.3.2 Scenario 2: " Oil prices rise due to demand pull from a strengthening world economy"

Is this scenario it is assumed that the oil price increases, as has been witnessed during the past two years, at a constant rate of 5% to reach $69.37/barrel in 2010. The Rand/dollar exchange rate weakens to a low of R8.50/US$ in 2008, where after it again appreciates to R7.00/US$ in 2010.

Large maize harvests in the USA are assumed to lead farmers to use land that was previous planted under maize for soya bean cultivation. At the same time Argentina is assumed to experience a drought in 2007, which in turn reduces their production. As the world economy is still growing at a good rate, the demand for maize grows and world prices rise by 10% from the baseline to $118.98/ton in 2007.This gives the South African ethanol industry no option but to source local maize.

Rainfall is one of the factors that affects the South African maize production the most. In this scenario it is assumed that, on average, the South African maize producing areas experience good rainfall early in the 2005/2006 production season and as a result farmers decide to plant maize as opposed to other crops. The second half of the season, is however somewhat drier resulting in the yields of both yellow and white maize being reduced by 10% from the baseline. The exact opposite is assumed for the 2006/2007 season. The planting season is dry, resulting in fewer plantings whilst the second half of the season is wetter resulting in yields being 10% higher than in the baseline.

3.3.2.1 The sector model's results

In 2006 producer prices rise above those of the baseline where they remain until 2010. In this scenario the average producer prices for the period 2007-2010 are R1156.597/ton for white maize and R1019.29/ton for yellow maize. The dip in producer prices below baseline levels in 2010 could be due to the appreciation of the exchange rate in that year.

For the period 2007-2010, the level of white maize area planted and production increases to an average of 2.5% above the baseline, while yellow maize increases by an average of 0.5% above the baseline. White maize reaches a high of 6 158 251 tons in 2010 after a gradual annual increase. Yellow maize production reaches o high of 4 097 015 tons in 2008 following the highest yellow maize producer price of the period at R1130.80/ton in 2007.

Interestingly with one active ethanol plant, white and yellow maize ending stocks gradually increase over the period 2007-2010 to reach 1 601 183 tons and 1 131 307 tons in 2010.

The greatest percentage deviations from the baseline take place in exports and imports. White maize exports increase by an average of 11% above the baseline, while yellow maize exports increase to an average of 1.3% above the baseline for the period. Imports of white maize decline to reach an average of 81% below the baseline. Yellow maize imports decline by an average of 6% below the baseline.

Figures 7, 8 and 9 show the projected baseline and scenario producer prices and volumes for both white and yellow maize over the period 2007-2010.

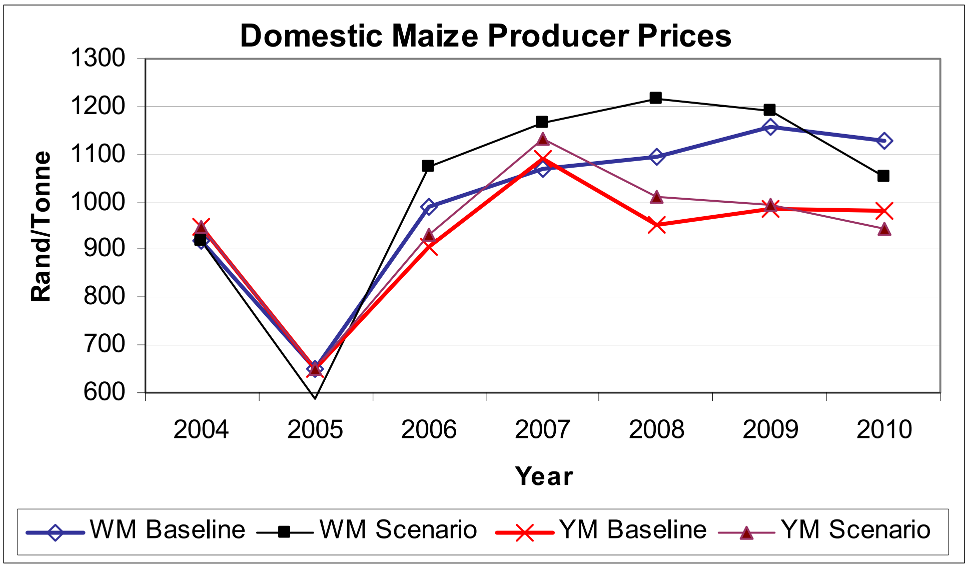

Figure 7: Domestic maize producer prices for scenario 2.

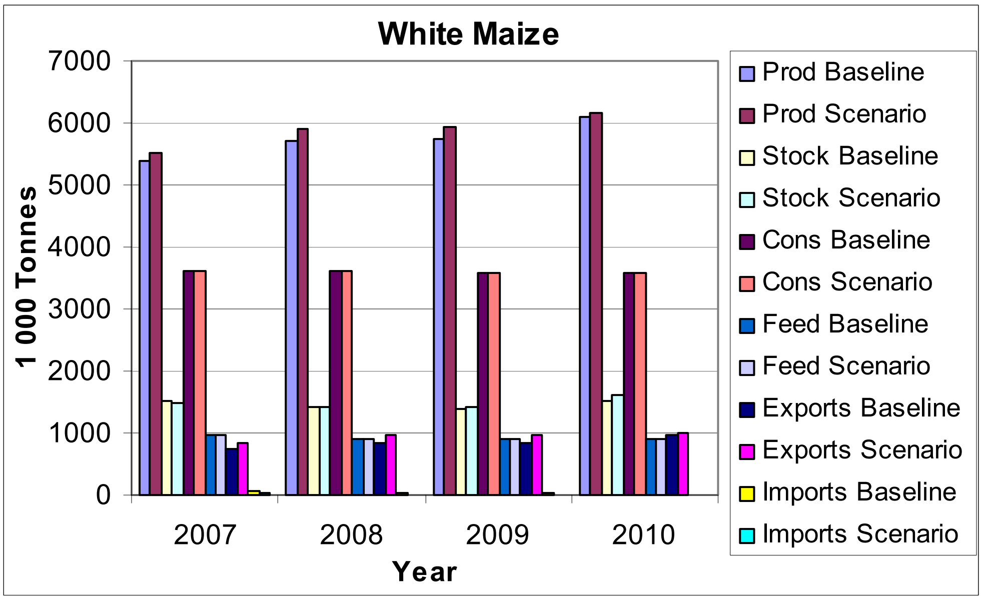

Figure 8: White maize baseline and scenario 2 volumes.

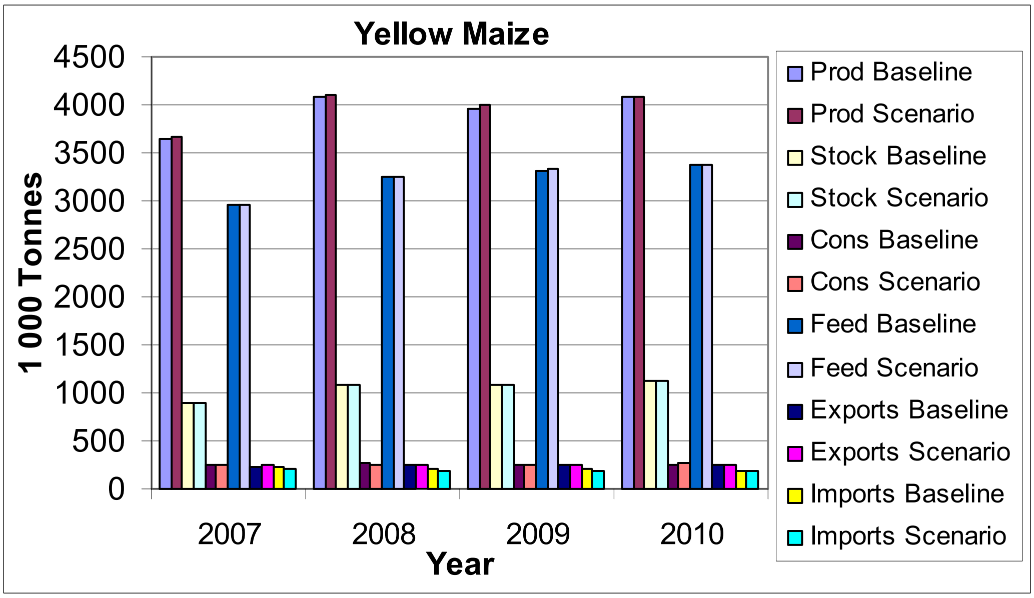

Figure 9: Yellow maize baseline and scenario 2 volumes

3.3.2.2 The ethanol plant model's results

The assumptions, exactly as they appear in section 3.3.2 are plugged into the ethanol model together with the relevant results, which have been simulated by the BFAP sector model. In short the scenario represents more favourable conditions for the trend toward renewable energy. The oil price is assumed to at a rate of 5% from 2006 up until 2010 and it is believed that this is mainly driven by the growth of the major world economies. The exchange rate weakens at first but then strengthens again towards 2010, creating some leeway for the ethanol plant to make positive profits. The results of the simulation are represented in Table10 , below.

Table 10: Profit for the ethanol plant given the assumptions in scenario 2

Description	2007	2010
Profit/loss per ton ground	-R 668.23	+ R 89.26
Profit/loss per litre	-R 1.70	+ R 0.14
Total profit/loss of plant	-R 231 034 530.32	+ R 21 151 938.75

Scenario 2 represents a more positive picture. This, on the back of a increasing oil price and a strengthening Rand and a somewhat lower maize price, as simulated by the BFAP sector model. Again some correlation between the oil price and the ethanol price is assumed and as the oil price moves towards $70 per barrel, over the 4-year period, the ethanol also moves into its upper ranges. An ethanol price of R2.85 per litre is assumed for 2007 while an ethanol price of R 3.12 per litre is assumed for 2010. Furthermore 2007 is simulated with a DDGS price of R 491 per ton whilst the DDGS price in 2010 is assumed to be around R 556 per ton. The simulation results indicate that the ethanol plant is likely to make a loss at first but then turns favourable, as the economic conditions for renewable energy improve.

3.3.3 Scenario 3: "Lower oil prices and a weakening world economy"

In this scenario it is assumed that the world economy is cooling down. This leads to lower oil demand and the average oil price decreasing annually with $5/barrel. The price of crude oil falls from $45/barrel during 2006 to $25/barrel in 2010. The lower oil prices result in lower freight rates of all major shipping lines. The slow down also results in the, average exchange rate weakening annually by R0.50 /US$. This means that the value of the Rand drops from R6.40/US$ in 2005 to an average of R9.00/US$ in 2010.

The world grain prices are assumed to increase by 10% to $118.98/ton. This is equivalent to the assumption made, regarding world grain prices in scenario 2.

The 2006/07 production season starts off with some good rainfall but then has a slightly drier year, resulting in a 20% lower yield being realised. 2007/08 experiences a similar situation, good rainfall at first and then a weaker rainfall period in the second half of the season, again resulting in 20% below baseline average yields. 2008/09 experiences the opposite to the previous two years, normal rainfall during the first half of the season and then above normal rainfall during the second half of season resulting in a 20% increase in the yield for both white and yellow maize.

3.3.3.1 The sector model's results

White maize producer prices remain above those of the baseline from 2005 to 2009 after which they drop below the baseline in 2010. Yellow maize producer prices increase until 2007 when they drop and seem to level off and then start declining. The movements of the baseline and scenario prices are best seen in Figure 10. The average simulated white maize price during 2007-2010 is R1159.39/ton while the average yellow maize is over the same period is R983.58/ton for this scenario.

White maize production increases over the period to reach 6 181 270 tons. White maize production remains above the baseline at an average of 6%. After a spike in production to 4 084 410 tons in 2007 (a 12.24% deviation from the baseline), yellow maize production remains relatively constant for the rest of the period.

After the high of 1 801 610 tons of white maize ending stocks in 2005, they drop to 1 490 420 tons in 2006. During 2007-2010 stocks gradually increase to reach 1 741 940 tons (15% above the baseline level) in 2010. Yellow maize ending stocks follow a similar pattern with a spike in 2004 to 1 223 710 tons after which they decline to 815 750 tons in 2005. Yellow maize stocks then gradually increase to 1151 100 tons in 2010. As in scenario 1, the total maize ending stocks tend to increase over the period 2007-2010 despite ethanol production taking place.

White maize exports increase over the period 2007-2010 to an average of 21% above the baseline, with the highest volume of exports being 1 123 000 tons in 2009. After 2005 yellow maize exports also tend to increase in volume at levels above those of the baseline to reach 260 380 tons in 2010. White maize imports decrease to zero in 2009 and 2010. Yellow maize imports, on the other hand, increase to 214 150 tonnes in 2006 after which they begin to decline, reaching a level of 128 040 tons in 2010. Yellow maize imports remain below baseline levels for the period 2006-2010.

Figures 10, 11 and 12 show the projected baseline and scenario producer prices and volumes for both white and yellow maize over the period 2007-2010.

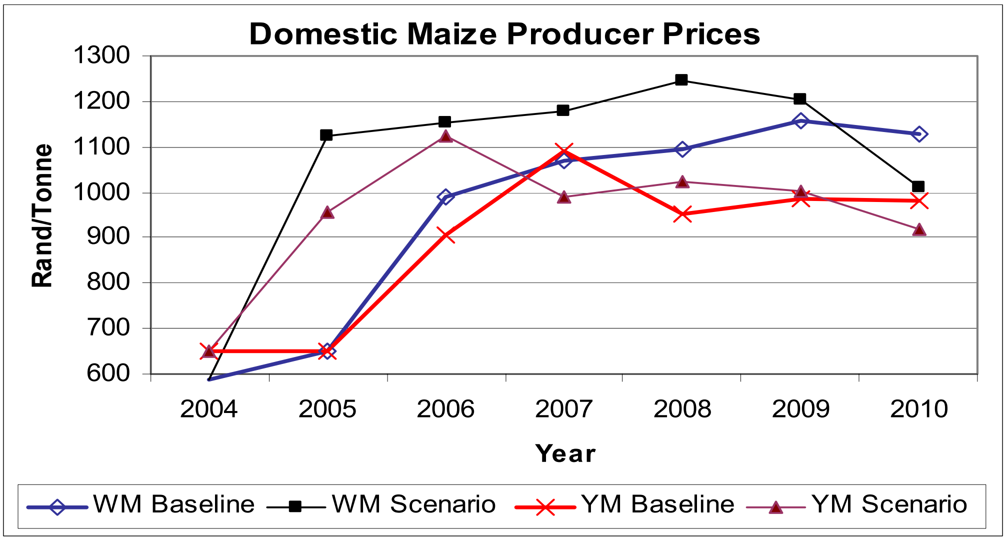

Figure 10: Domestic maize producer prices for scenario 3

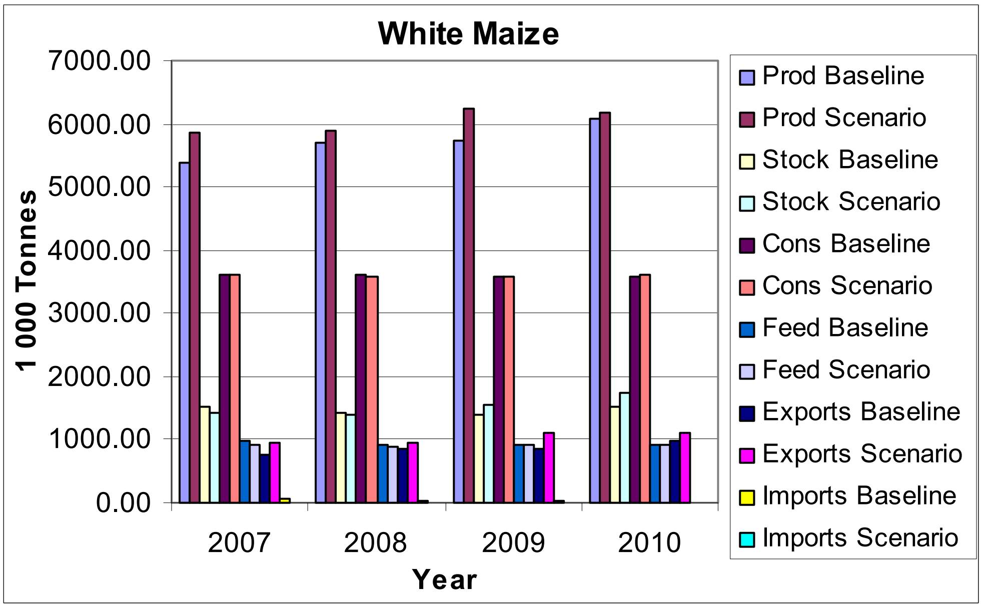

Figure 11: White maize baseline and scenario 3 volumes

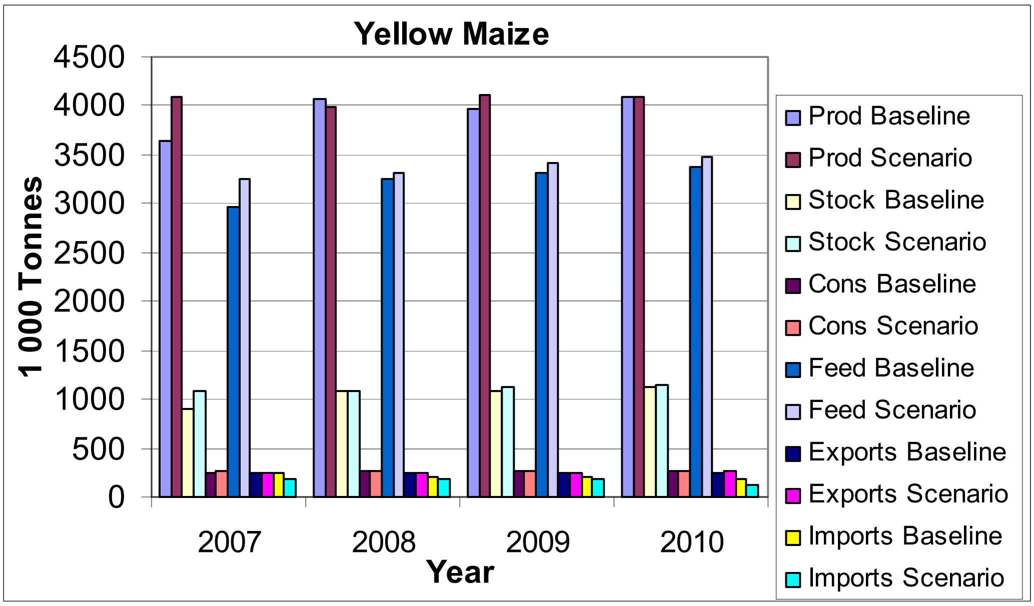

Figure 12: Yellow maize baseline and scenario 3 volumes

3.3.3.2 The ethanol model's results

With world economy slowing down and oil prices falling the conditions seem less than favourable for renewable energy sources. Furthermore the Rand depreciates as the South African economy moves into a recessive state, and with higher maize prices due to a drier production season the ethanol production process is likely to be less favourable. Table 11 represents the likely profitability given these assumptions.

Table 11: Profit of ethanol plant given the assumptions of scenario 3

Description	2007	2010
Profit/loss per ton ground	-R 550.72	-R 848.15
Profit/loss per litre	-R 1.24	-R 1.99
Total profit/loss of plant	-R 187 840 851.02	-R 297 846 036.38

Table 11 indicates that this scenario poses the greatest risks to the profitability of ethanol production. A low oil price and a slumping world economy together with a dry maize production season during 2007 result in an ethanol price of R 2.81 per litre given that the oil price is still at relatively high levels during that year. The ethanol price then falls as the oil price decreases and for 2010 a price of R 2.01 per litre is simulated given the oil price of $ 25 per barrel. The DDGS price is simulated at R 481 per ton for 2007 and R 471 per ton for 2010, again the drop in the price hangs together with the slump in the world economies and therefore a decline in demand.

4. Conclusion

With the world moving towards the use of renewable energy and the South African agricultural sector recently experiencing low average commodity prices, the establishment of an ethanol production plant has been put forward as a possible way to (1) increase domestic prices, (2) lower the country's dependence on international oil prices and (3) keep up with some of the latest developments in renewable energy use. This analysis was conducted to highlight some of the South African agricultural commodities that can be used to produce ethanol. Sets of scenarios were then designed to quantitatively investigate, through use of model simulations, what impacts these ethanol plants are likely to have on the maize sector. The scenarios focused mainly on the maize sector as a result of the amount of attention that this possibility has received in the last year as well as the availability of information on which to make assumptions

The model results clearly indicate that a higher oil price and a growing world economy are likely to favour the ethanol production in the longer term. It seems that the opposite is true for a lower oil price and a slowing world economy. One important conclusion that can be drawn from this is that the risks that the ethanol industry will face need to be clearly understood. The behaviour of factors like rainfall, the producer price of agricultural commodities, the exchange rate and the oil price will ultimately be the key to the success of ethanol production in South Africa.

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