COMMERCIAL BIODIESEL PRODUCTION IN SOUTH AFRICA: A PRELIMINARY ECONOMIC FEASIBILITY STUDY

by

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Declaration of Originality

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature:______________________________ Date:____________________________

Abstract

Biodiesel, a fatty acid alkyl ester, derived from the transesterfication of vegetable oil, is considered a renewable fuel that can be used as a replacement for fossil diesel. The urgency for biofuel production in South Africa is motivated by the vulnerability of crude oil prices, high unemployment, climate change concerns and the need for the growing economy to use its resources in a sustainable manner.

The technical feasibility of biodiesel production has been proven and this study investigates its preliminary economic feasibility in South Africa by looking at the market, financial and agricultural feasibility of commercial biodiesel production.

The market feasibility

The potential market size for biodiesel in South Africa is about 1 billion litres if it is to replace 10% of its diesel consumption by 2010. However, governmental legislation and policies are needed to create a predictable and growing market for biodiesel in South Africa. These policies or regulations could be in the form of subsidising feedstock for biodiesel production, subsidising the biodiesel itself, using government purchasing power, mandatory blending legislation, tax incentives or price compensation agreements.

The financial feasibility

Calculations to asses the financial feasibility of commercial biodiesel production are based on a 2500 kg/h (22.5 million litres/annum) containerized plant. This size is based on findings of Amigun & von Blottnitz (2005) that the optimum biodiesel plant size in South Africa ranges between 1500 and 3000 kg/h. Two types of plants were considered, namely a seed extraction biodiesel production (SEBP) plant using locally produced oilseeds as feedstock and a crude oil biodiesel production (COBP) plant using imported crude vegetable oil as feedstock.

The capital investment for a SEBP plant ranges between R110 and R145 million while a COBP plant would require a capital investment of about R45 to R50 million. These amounts include a working capital of about R35 million due to money that is fixed in a 3 month stock supply.

The calculated biodiesel manufacturing costs of the two types of plants for various feed stocks at current prices (30 August 2006) are shown in Table 1:

Table 1: Manufacturing costs of biodiesel for various feed stocks

SEBP Plant		COBP Plant	
Local Feedstock	**Manufacturing Cost**	**Imported Feedstock**	**Manufacturing Cost**
Canola	R4.81/litre	Palm Oil	R6.62/litre
Sunflower seeds	R6.67/litre	Soybean Oil	R6.89/litre
Soybeans	R6.70/litre	Sunflower Oil	R7.48/litre
		Rapeseed Oil	R9.28/litre

Feedstock and raw material contribute to about 80% of the manufacturing cost while transport costs are the second biggest contributor. These results point to the fact that the plant location is very important in order to minimize production costs. Thus, commercial biodiesel production should not be centralized, but should rather happen through greater number of relatively small plants located in oilseed producing regions. (South Africa would require about 46 plants each producing 2500 kg/h to produce 10% of its diesel by 2010).

The sensitivity analyses showed that the manufacturing costs of a SEBP plant are very sensitive to changes in oilseed and oilcake prices while the manufacturing costs of a COBP plant are very sensitive to a change in crude vegetable oil price. The fluctuating nature of the agricultural commodity prices makes biodiesel manufacturing costs unpredictable. Soybean biodiesel costs are the most sensitive to price changes while sunflower biodiesel costs are the least affected.

An increase in glycerol price would decrease the manufacturing costs of biodiesel by about 12 cents/litre for every R1000/ton increase in price. Glycerol prices are currently too low to consider in the calculations due to a global oversupply as a result of biodiesel production.

The break even price of biodiesel is calculated by adding R1.01/litre fuel tax to the manufacturing cost, which means that biodiesel produced from oilseeds (except canola) will not be able to compete with the current price of fossil diesel (30 August 2006) without subsidies or legislation.

The agricultural feasibility

Producing 10% of South Africa's diesel using oilseeds would require a major production increase. Keeping the area ratio of the oilseeds constant during such an increase and using all 3 types of oilseeds for biodiesel production would have the following agricultural implications:

Table 2: Agricultural implication of producing about 1 billion litres of biodiesel

Thousand tons/ thousand ha	Current	Additional resources needed	Increase (-fold)
Sunflower Production	620	1900	4.0
Soybean Production	270	1500	6.4
Canola Production	44	100	3.3
Total Production	**934**	**3500**	**4.7**
Sunflower Area	460	1600	4.5
Soybean Area	150	900	7.7
Canola Area	40	100	3.6
Total Area	**650**	**2600**	**5.2**

Biodiesel production will also increase the local oilcake supply which means South Africa will change from being a net-importer of oilcake (730 thousand tons/year) to a net-exporter of oilcake (1.7 million tons/year).

Land availability for such a production increase is not a problem which means that the agricultural resources and potential market are available to produce and absorb 10% of the countries diesel in the form of biodiesel. However, at the moment the commercial production of biodiesel does not seem financially feasible without any government imposed legislation or subsidies.

Opsomming

Biodiesel, ‘n hernubare brandstof wat uit groente olie vervaardig word, is ‘n moontlike plaasvervanger vir petroleum diesel. Biodiesel vervaardiging in Suid Afrika word aangespoor deur hoë kru olie pryse, hoë werkloosheid syfers, toenemende bewustheid van klimaat veranderings en druk op ‘n groeiende ekonomie om sy bronne volhoubaar te gebruik.

Die vervaardiging van biodiesel is relatief maklik en hierdie studie is ‘n voorlopige ondersoek in die ekonomiese lewensvatbaarheid van komersiële biodiesel produksie in Suid Afrika deur te kyk na die mark, finansiële en landbou lewensvatbaarheid daarvan.

Die mark lewensvatbaarheid

Die potensiële grote vir ‘n biodiesel mark in Suid Afrika is omtrent 1 miljard liter indien dit 10% van sy petroleum diesel teen 2010 wil vervang, maar wetgewing sal nodig wees om ‘n voorspelbare en groeiende mark te skep. Hierdie wetgewing kan in die vorm van subsidies vir boere of biodiesel produsente wees, gebruik maak van regerings koopkrag, verpligtende inmeng maatreëls, belasting voordele of prys vergoeding ooreenkomste.

Die finansiële lewensvatbaarheid

Berekeninge om die finansiële lewensvatbaarheid te bepaal is op ‘n 2500 kg/uur (22.5 miljard liter/jaar) gedoen. Hierdie aanleg grote is gebaseer op inligting verkry deur Amigun & von Blottnitz (2005) wat sê dat die optimale grote biodiesel aanleg in Suid Afrika tussen 1500 en 3000 kg/uur is. Daar is na twee tiepe aanlegte gekyk, naamlik na ‘n saad ekstraksie biodiesel vervaardigings (SEBP) aanleg wat plaaslike oliesade as voer materiaal gebruik en ‘n kru olie biodiesel vervaardigings (COBP) aanleg wat ingevoerde groente olie as voer materiaal gebruik.

‘n SEBP aanleg het ‘n kapitale belegging van tussen R100 en R145 miljoen nodig terwyl ‘n COBP aanleg slegs tussen R45 en R50 miljoen nodig het. Hierdie bydrae sluit werkende kapitaal van omtrent R35 miljoen in wat vas is in 3 maande se voer materiaal kostes.

Die onderstaande tabel wys die vervaardigings kostes vir albei tiepe aanlegte en verskillende voer materiale.

SEBP Aanleg		COBP Aanleg	
Lokaale Voer Materiaal	**Vervaardigings Koste**	**Ingevoerde Voer Materiaal**	**Vervaardigings Koste**
Kanola	R4.81/litre	Palm Olie	R6.62/litre
Sonneblom saad	R6.67/litre	Sojaboon Olie	R6.89/litre
Sojabone	R6.70/litre	Sonneblom Olie	R7.48/litre
		Raapsaad Olie	R9.28/litre

Omtrent 80% van die kostes is voer materiaal terwyl vervoer kostes die tweede hoogste bydraer is. Hierdie resultaat wys na die feit dat die aanleg ligging ‘n baie belangrike rol speel om vervaardigins kostes te minimeer. Dus word die stelling gemaak dat komersiële biodiesel vervaardiging nie in ‘n paar sentrale aanlegte moet plaasvind nie, maar eerder in ‘n klomp verspreide relatief kleiner aanlegte moet plaasvind. Hierdie kleiner aanlegte sal in die oliesaad produserende streke versprei moet wees. (Suid Afrika sal omtrent 46 aanlegte nodig hê wat elk 2500 kg/uur produseer om 10% van sy diesel teen 2010 te kan vervaardig).

Die sensitiwiteits analiese het gewys dat die kostes van ‘n SEBP aanleg baie sensitief vir veranderings in oliesaad en oliekoek pryse is. Die kostes van ‘n COBP aanleg is baie sensitief vir veranderinge in groente olie pryse. Wisselvallige landbou pryse maak die kostes van biodiesel baie wisselvallig en onvoorspelbaar. Sojaboon biodiesel kostes is die sensitiefste vir prys veranderings terwyl sonneblom saad die minste geaffekteer word deur sulke prys veranderings.

Vir elke R1000/ton wat die glyserol prys styg sal die vervaardigings kostes van biodiesel met 12 sent/liter daal. Die glyserol prys is op die oomblik te laag om in ag te neem weens ‘n oormaat glyserol in die wêreld mark as gevolg van biodiesel produksie.

Die gelykbreek prys van biodiesel word uitgewerk deur R1.01/liter brandstof belasting by die vervaardigings kostes by te tel. Op die oomblik (30 Augustus 2006) kan biodiesel van oliesade (behalwe kanola) nie met die petroleum diesel prys meeding nie sonder enige subsidies of wetgewing.

Die landbou lewensvatbaarheid

Die landbou implikasies om 10% van die land se diesel uit oliesade te vervaardig word in die onderstaande tabel uiteengesit. Hierdie resultate is gebaseer op die feit dat al drie oliesade gebruik word vir biodiesel vervaardiging en dat die oppervlak verhouding van die drie oliesade konstant bly soos die produksie vermeerder.

Duisend ton/ duisend ha	**Huidiglik**	**Additionele bronne benodig**	**Vermeerder (-maal)**
Sonneblom saad Produksie	620	1900	4.0
Sojaboon Produksie	270	1500	6.4
Kanola Produksie	44	100	3.3
Totale Produksie	**934**	**3500**	**4.7**
Sonneblom Oppervlak	460	1600	4.5
Sojaboon Oppervlak	150	900	7.7
Kanola Oppervlak	40	100	3.6
Totale Oppervlak	**650**	**2600**	**5.2**

Biodiesel vervaardiging sal ook die plaaslike oliekoek produksie vermeerder sodat Suid Afrika sal verander van ‘n netto-invoerder (730 duisend ton/jaar) tot ‘n netto-uitvoerder (1.7 miljoen ton/jaar) van olikoek.

Land beskikbaarheid vir so ‘n vermeerderde produksie is nie ‘n probleem nie wat beteken dat Suid Afrika wel die landbou bronne en potensiële mark het om 10% van sy diesel te vervaardig en te absorbeer in die vorm van biodiesel. Uit `n finansiële oogpunt lyk dit egter asof die komersiële vervaardiging van biodiesel in Suid Afrika nie lewensvatbaar sal wees, sonder enige wetgewings of subsidies, nie.

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ASGISA	Accelerated and Shared Growth Initiative for South Africa
B05	Fuel blend containing 5% biodiesel and 95% fossil diesel
B10	Fuel blend containing 10% biodiesel and 90% fossil diesel
B100	Pure biodiesel
CEF	Central Energy Fund
CFPP	Cold filter plugging point
COBP	Crude oil biodiesel production
DME	Department of Minerals and Energy
FAME	Fatty acid methyl ester (Biodiesel)
FAPRI	Food and Agricultural Policy Research Institute
FFA	Free fatty acid
FOB	Free on board
FOR	Free on rail
GAIN	Global Agricultural Information Network
GHG	Greenhouse-gas
RORI	Rate of return on investment
SABA	Southern African Biofuel Association
SAGIS	South African Grain Information System
SARS	South African Revenue Service
SEBP	Seed extraction biodiesel production
VAT	Value added tax

Chapter 1

Introduction

Vegetable oils and their derivatives (such as methyl esters), commonly referred to as biodiesel, are prominent candidates as alternative diesel fuels. They have advanced from being purely experimental fuels to initial stages of commercialization in a number of countries. The use of vegetable oil in diesel engines is not a new concept; Rudolf Diesel, reportedly used groundnut (peanut) oil as a fuel for demonstration purposes in 1900 (Nitske & Wilson, 1965). There are however, a number of problems associated with using straight vegetable oil as a fuel for diesel engines such as high viscosity, injector coking and engine deposits. These problems can be solved to a certain degree by converting the vegetable oils into their methyl esters. This is done by means of the transesterfication reaction and the resulting product, fatty acid methyl ester (FAME), is also commonly known as biodiesel.

Biodiesel is technically competitive to conventional fossil diesel but relatively cheap fossil diesel prices have made the technology economically unfeasible for almost a century. However, recent high and rising world crude oil prices and claims that the world oil reserves are diminishing and environmental and political pressure have caused an urge in the development of the technology of biodiesel production.

1.1 Project Motivation

In view of the rising crude oil prices, forecasted shortages of fossil fuels, climate change, and the need for new income and employment opportunities in rural areas, biofuels have taken centre stage in policy debates in South Africa. The technical feasibility of biodiesel production has proven to be viable as biodiesel markets are currently growing exponentially in a number of countries. However, the question remains whether commercial biodiesel production will be economically feasible in South Africa?

1.2 Project Objective

A great deal about biodiesel has been said in the South African media. Many reports welcoming biodiesel as the fuel of the future while others have warned that the future of biodiesel does not look as promising as made out to be.

The objective of this study is to give an unbiased view of the following topics concerning biodiesel production in South Africa:

1. Is there a market for biodiesel in South Africa or can a market be created?
2. The costs involved with biodiesel production using various feed stocks at their current prices. These costs are based on an optimal sized commercial production plant.
3. Can biodiesel compete with the price of fossil diesel or should its market be driven by legislation?
4. Does South Africa have the agricultural resources to produce 10% of its diesel in the near future from oilseeds or would it be cheaper to import feedstock for biodiesel production?

1.3 Project Definition and Scope

This project is a preliminary economic feasibility study looking into the commercial production of biodiesel in South Africa. It is defined as a preliminary study due to the fact that biodiesel production is still in its initial stages in South Africa and that commercial production has yet to start.

The economic feasibility is narrowed down by examining the market, financial and agricultural feasibility of commercial biodiesel production in South Africa.

The market feasibility looks at the potential size of the biodiesel market in South Africa and possible legislation to create such a market in South Africa. It also looks at the role of the government in the development of the biodiesel industry.

The financial feasibility looks at the capital and manufacturing costs associated with biodiesel production. Cost calculations are based on two types of plants with a production capacity of 2500kg/h. The choice of this size of plant is explained in section 4.2.3. A SEBP plant produces biodiesel from oilseeds and a COBP plant uses crude vegetable oil, obtained from oilseeds crushers, as feedstock. The section also compares the cost of biodiesel production from the three main oilseeds in South Africa, namely sunflower seeds, soybeans and canola. Cost calculations are based on the current commodity prices (30 August 2006) and the results of price fluctuations are incorporated into the sensitivity analyses (-25% to +25%). The financial feasibility also includes profitability calculations and results based on various biodiesel selling prices.

Finally the ***agricultural feasibility*** investigates whether South Africa has the agricultural resources to support commercial biodiesel production. It also looks at the effects and benefits of biodiesel production on the local agricultural sector.

This study defines commercial production of biodiesel as 10% of the fossil diesel consumption in South Africa. This definition is based on discussions that the government might enforce a mandatory blend of 10% biodiesel into its fossil diesel (B10). Even if this figure is lower, at about 5% (B05), it is assumed that biodiesel from so called 'backyard-producers' will inevitably enter the market. This assumption is based on the fact that the tax regime excludes small scale producers from all fuel tax and levies if they produce less than 300000 litres per annum. This tax regime would make it more profitable for farmers to produce their own biodiesel on their farm.

For the purpose of this study, biodiesel is considered a methyl ester produced from vegetable oil by means of transesterfication. This is the same definition that the South African Standard SANS 1935 Automotive diesel fuel standard gives for biodiesel.

It is also assumed that all the stakeholders involved in the biodiesel production chain operate on an independent basis: The commercial biodiesel producer buys its feedstock from farmers or crushers at the market price and sells its product to the distributors in order to make a profit. This means that farmers producing biodiesel from their own crops are not considered in this study because it looks at the biodiesel industry as a whole.

1.4 Thesis Structure

A mind map used to approach this study is seen in Figure 1.

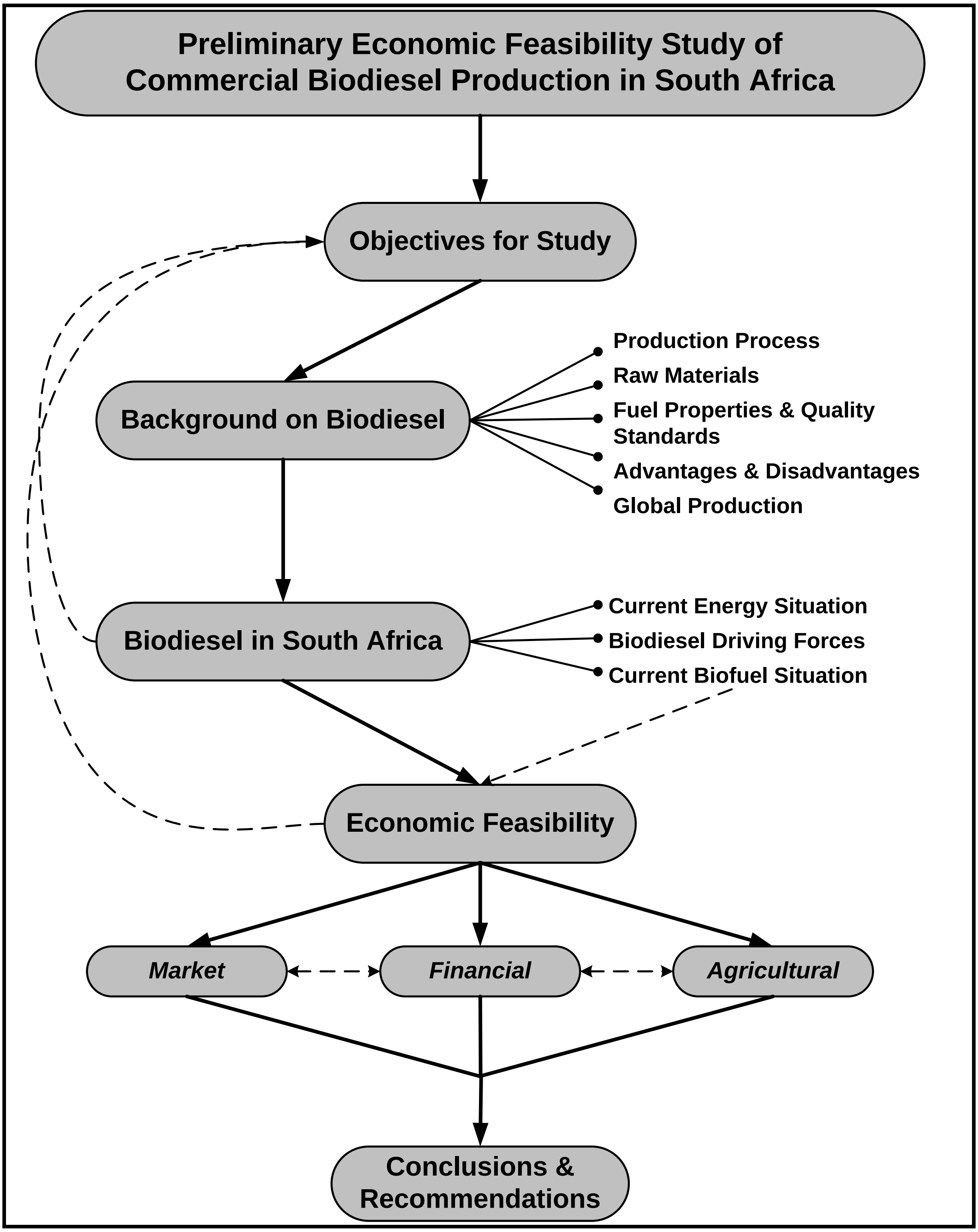


Figure 1: Mind map showing a broad overview of the study

Below is a very brief outline of the thesis:

Chapter 1 gives an introduction and broad outline of the study and defines it and its objectives.

Chapter 2 gives a brief background on biodiesel; discussing the production process, possible raw materials, the properties of biodiesel and the advantages and disadvantages of its use. The final section of this chapter looks at the global biodiesel production.

Chapter 3 looks at the driving forces of biofuels and the current biodiesel situation in South Africa.

Chapter 4 is an initial investigation into the economic feasibility of commercial biodiesel production in South Africa. The chapter is divided into three sections, namely the market feasibility, the financial feasibility and the agricultural feasibility of commercial biodiesel production.

Chapter 5 concludes all the findings of the study.

Chapter 6 has some recommendations based on the findings of this study.

Chapter 2

Background on Biodiesel

2.1 Definition

According to Friedrich (2003), biodiesel is defined as the fatty acid alkyl ester derived from the transesterfication of vegetable oils or animal fats. Thus it is the product obtained when a vegetable oil or animal fat (triglyceride) reacts with an alcohol in the presence of a catalyst. Glycerol is produced as a by-product (Figure 2).

In South Africa biodiesel is restricted by the SANS 1935 automotive standard to being a fatty acid methyl ester (FAME) derived only from vegetable oils (The South African Bureau of Standards, 2006). This means that either oilseeds or their subsequent crude vegetable oil can be used for the production of biodiesel or FAME (fatty acid methyl ester) in South Africa.

CH_2-O-COR | CH-O-COR | CH_2-O-COR	+	3 CH_3OH	⟷	CH_2-OH | CH-OH | CH_2-OH	+	3 R-$COOCH_3$
Triglyceride		**Methanol**		**Glycerol**		**Methyl Ester (Biodiesel)**
1 mol 10 litres		3 mol 1 litre		1 mol 1 litre		3 mol 10 litres

Figure 2: Reaction mechanism for transesterfication of triglycerides with methanol

2.2 Production Process

The vegetable oil used to make biodiesel has to be extracted from its oil crop and in some cases pre-treated before it can undergo transesterfication to produce a mixture of biodiesel and glycerol. These products and unreacted reactants have to be separated and purified to obtain the final product of biodiesel.

Figure **3** is a simplified schematic presentation of the 'earth to engine process'. The processes involved are discussed in greater detail in the following sections.

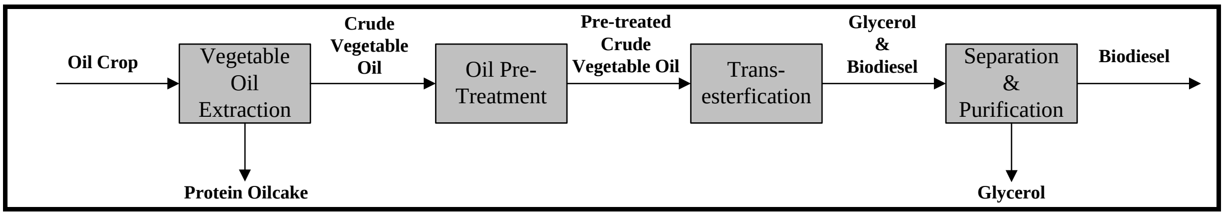


Figure 3: Schematic presentation of the 'earth to engine' process

2.2.1 Vegetable Oil Extraction

Vegetable oil extraction from oilseeds can be done by either chemical or physical extraction. Chemical extraction uses solvent extracts while physical extraction uses a number of different types of mechanical extraction methods such as expeller, screw or ram press. Chemical extraction produces higher yields, is quicker and less expensive and is used for large scale extraction processes (Wikipedia, 2006). Oil extraction of oilseeds also produces an oilcake (or meal) which is considered a valuable livestock feed product.

2.2.2 Oil Pre-treatment

Most crude vegetable oils, with the exception of palm and soybean oil, can be fed directly to the transesterfication process without any pre-treatment. Due to their high phosphatides content, palm and soybean oil need to be **degummed**. This refers to the removal of phosphatides (Mittelbach and Remschmidt, 2005). Phosphatides raise the level of phosphorous in the fuel which could cause the deactivation of the exhaust catalyst (Tyson et al., 2004). Oils with a high free fatty acid (FFA) content, >5%, need to undergo **deacidification** (Mittelbach and Remschmidt, 2005). This entails the removal of excessive free fatty acids in the oil to less than 1mg KOH/g equivalent. These free fatty acids reduce the catalyst, especially alkaline, activity and hinder the glycerol and biodiesel separation process. The degumming and deacidification processes can be conducted concurrently by adding an alkali catalyst such as NaOH which reacts with the FFA to form soap and in the presence of hot water causes the phosphatides to swell (Tyson et al., 2004). Both these products can be precipitated. If the acid number of the oil is very high, such as in waste vegetable oils, an acid catalyzed pre-esterfication of the free fatty acids with methanol or ethanol is recommended (Mittelbach and Remschmidt, 2005).

The final pre-treatment step is **dehydration**, to remove all traces of water in the oil. Traces of water in the oil decrease the conversion of alkaline catalyzed transesterfication and harm the acid catalyzed reaction. Dehydration is done either by low pressure distillation or by passing a stream of nitrogen through the oil (Mittelbach and Remschmidt, 2005).

2.2.3 Transesterfication

Transesterfication is the chemical reaction whereby the glycerine is removed from the triglyceride (vegetable oil) by reacting it with an alcohol to form an ester (biodiesel) and glycerol as by-product. If methanol is used in the reaction, the resulting product is a methyl ester and ethanol will produce an ethyl ester. Figure 2 illustrates the typical transesterfication reaction of triglyceride and methanol. The approximate proportion of each reactant and product is also shown (Biodiesel Education, 2006).

An excess of alcohol shifts the equilibrium to the right hand side of the reversible reaction. Methanol is the preferred alcohol used for the reaction on large scale; this statement is discussed in section 2.3.2.

Regardless of which alcohol is used, some form of catalyst has to be present to achieve high yields under relatively mild conditions. The two most common process options are either acid or alkali catalysed transesterfication reaction. Table 3 gives a comparison of the two different processes (Mittelbach and Remschmidt, 2005).

Not surprisingly, alkaline catalysis is by far the most commonly used reaction type for biodiesel production (Mittelbach and Remschmidt, 2005). It is very important for the reaction mixture to be homogenized during the initial stages of the process so that the transesterfication can proceed properly. This can be achieved by either vigorous mixing, low frequency ultrasonic irradiation or by using a common solvent. Once a sufficient amount of methyl esters and partial glycerides has been formed, they serve as a common solvent for alcohol and oil; this is no longer a problem (Mittelbach and Remschmidt, 2005).

Table 3: Comparison between alkali and acid catalysed transesterfication

Catalysis	**Alkaline**	**Acid**
Example	• KOH, NaOH, LiOH	• H_2SO_4
Advantages	• Lower alcohol:oil ratio 3-5:1 (mol) • Lower reaction temperature & pressure for high yield • Faster reaction time • Less corrosive to equipment means lower capital costs	• Not sensitive to free fatty acids in feedstock
Disadvantages	• Very sensitive to free fatty acids in feedstock – needs more pre-treatment of waste oils	• Requires higher temperature, pressure & volume of alcohol • Slower reaction times • Corrosive material • Very sensitive to water in feedstock

2.2.4 Separation and Purification

After the transesterfication step the glycerol layer has to be separated form the reaction mixture. **Phase separation** occurs spontaneously if methanol is used in alkali catalyzed transesterfication. To accelerate the phase separation one of the following might prove helpful: Adding water, extra glycerol or hexane to the mixture, cooling the reaction mixture or extraction of the esters by centrifugation. Once the glycerol and ester phases have been separated, each phase needs to be purified.

Methanol is recovered from the ester phase by vacuum distillation.

Removal of glycerol and partial glycerides from the ester phase is achieved by water or acid solution washing. However, this method is not recommended by Mittelbach and Remschmidt (2005) because of ester losses due to hydrolysis. They state that glycerol and glycerides should be removed by converting into triglycerides with the reverse transesterfication reaction. These triglycerides can then be easily removed from the ester phase and recycled back to the feed of the transesterfication reactor. This reverse reaction is achieved by adding an alkaline catalyst and heating the mixture to a temperature of 80 to 100°C. The methanol released during the reaction can be recovered by distillation.

Removal of free fatty acids from the ester phase, if necessary, is done by distillation as methyl ester has a lower boiling point than FFA. Due to the catalyst's solubility in water, it is removed during the water washing stage. However, if traces of catalyst remain in the ester phase, Mittelbach and Remschmidt (2005) suggest contacting the ester phase with cation exchange resin under anhydrous conditions to **remove the catalyst from the ester phase** or alternatively adsorbents such as silica gel or synthetic magnesium silicate can be added.

Purification of the glycerol phase also needs to take place due to the fact that the glycerol phase contains fatty acids, soaps and traces of the desired FAME. The first step is to add phosphoric acid to decompose the soaps into FFA which are insoluble in glycerol and form a separate phase which is then separated (Mittelbach and Remschmidt, 2005). If KOH was used as a catalyst during transesterfication, potassium dihydrogen phosphate is produced which can be used as fertilizer (Mittelbach and Remschmidt, 2005). Otherwise the resulting separated solids have to be considered as waste products. The resulting FFA can either be esterfied with sulphuric acid and ethanol or contacted with FAME and alkaline glycerol for two hours at 200°C to produce triglycerides. Both these products can be recycled back into the feed of the transesterfication reactor (Mittelbach and Remschmidt, 2005). A schematic diagram of biodiesel production process according to Mittelbach and Remschmidt (2005) is seen in Figure 4.

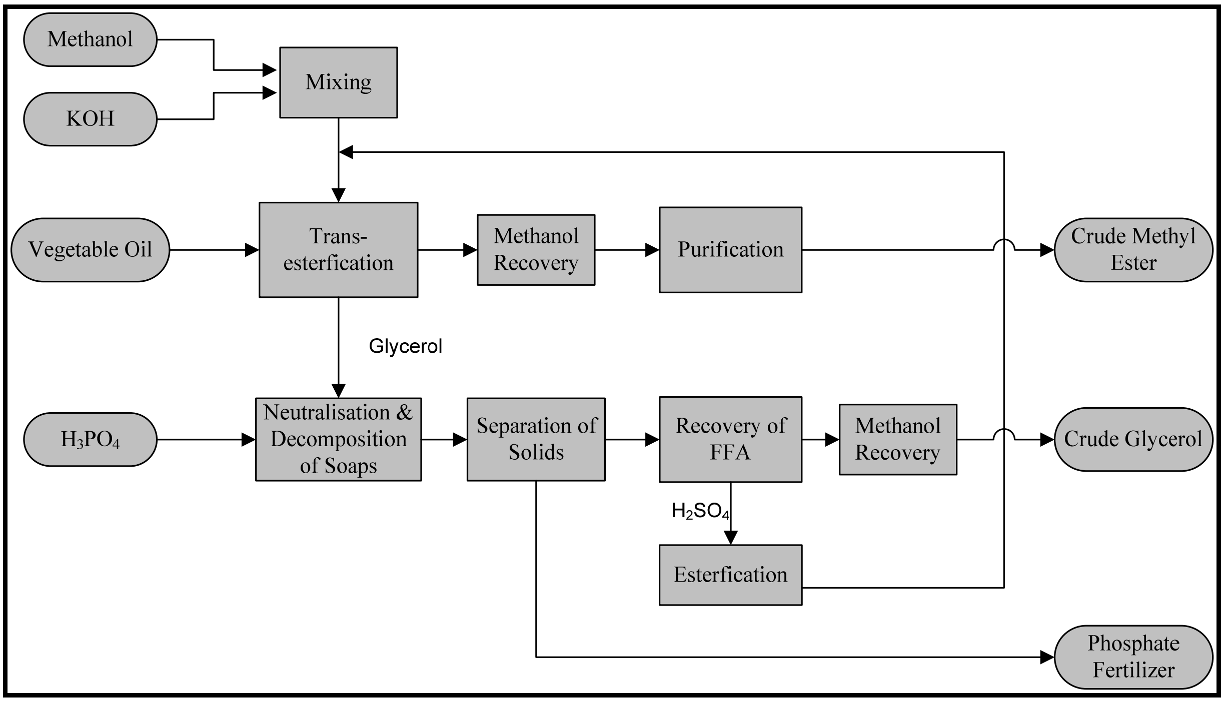


Figure 4: Typical biodiesel production process according to Mittelbach (2005)

2.3 Raw Materials

2.3.1 Oil Crops and Vegetable Oils

Any type of oilseed or its subsequent vegetable oil can be processed into biodiesel. Waste vegetable oil (WVO) is also a commonly used feedstock, but due to its high FFA content it is normally pre-mixed with a low FFA content crude vegetable oil or has to undergo pre-treatment. WVO is not considered for commercial biodiesel production as there is no secure supply of this feedstock for commercial biodiesel production.

Table 4 shows the major crops that are produced in South Africa with their 2005/06 production, harvest area, yield (SAGIS, 2006) and potential oil yield per hectare.

Results show that groundnuts have the highest oil yield per hectare but due to the low annual production and the high price of groundnuts, they are not an ideal oilseed for commercial biodiesel production. The canola production is lower than groundnut production in South Africa but a lower canola price may make it a potential crop for biodiesel production, even though it would only be able to contribute to a small part of the necessary feedstock. Sunflower seeds show a decent oil yield per hectare and are currently the main oilseed produced in South Africa which makes it the primary candidate for commercial biodiesel production. Soybeans have a lower oil yield per hectare but are also produced on large enough scale to be considered for biodiesel production. Based on the facts above, the cost of biodiesel production is examined for the following oilseeds: **Sunflower seeds, soybeans and canola.**

Table 4: South Africa's major crops

Crop	**Oil Yield**	**Area Harvested**	**Production**	**Yield**	**Oil Yield**
	kg/ton	***Thousand Ha***	***Thousand Tons***	***Tons/ha***	***kg/ha***
Maize	50	3,223	11,716	3.63	182
Wheat	-	805	1,905	2.37	-
Sunflower	**380**	**460**	**620**	**1.35**	**513**
Soy beans	**180**	**150**	**272**	**1.82**	**328**
Sorghum	-	260	86	3.01	-
Dry beans	-	48	72	1.5	-
Groundnuts	**420**	**40**	**64**	**1.6**	**672**
Canola	**400**	**44**	**40**	**1.1**	**440**
Cotton seed	130	23	32	1.36	177

The main crude vegetable oils used for biodiesel production in the world at the moment are soybean oil (USA), rapeseed oil (Europe) and palm oil (Mittelbach and Remschmidt, 2005).

As the properties of the different oils differ, so do the properties of their succeeding methyl esters. Section 2.4.1 gives a brief overview of the properties of the most common vegetable oil methyl esters.

2.3.2 Alcohol

Methanol is the most common alcohol used for transesterfication because of its low price and high reactivity compared to longer chain alcohols (Mittelbach and Remschmidt, 2005). Alkali catalyzed methanolysis can be conducted at moderate conditions to obtain a high yield. Another advantage that methanol has over ethanol is that it can easily be obtained in its pure form. This is of great importance as even traces of water drastically affect the reaction rate of the transesterfication reaction.

The stoichiometry of the reaction requires 3 mol of alcohol per 1 mol triglyceride (see equation in Figure 2), but in order to shift the equilibrium of the reaction to the right hand side, an excess amount of alcohol is used. Usually the suggested molar ratio of 6:1 methanol to vegetable oil in alkali catalysis is not exceeded (Mittelbach and Remschmidt, 2005). Acid catalysis however, requires molar ratios of methanol to vegetable oil of up to 30:1.

Although ethanolysis is considered more environmentally friendly, as ethanol can be produced by fermentation, and gives the biodiesel a higher cetane number, it is more energy consuming and creates problems for the product separation process.

2.3.3 Catalyst

The different catalyst options and their benefits and drawbacks have been discussed in section 2.2.3. The optimum concentration alkali catalyst is about 0.5-1.0% by weight of oil (Mittelbach and Remschmidt, 2005).

2.4 Fuel Properties and Quality Standards

2.4.1 Fuel Properties

Biodiesel and petroleum diesel vastly differ in their chemical composition. These differences give biodiesel different physical and chemical properties. The composition and properties of the biodiesel depend on the feedstock used in the manufacturing process.

The **cetane number** is an indication of a fuels readiness to auto ignite after it has been injected into the diesel engine. Diesel fuels are required to have a cetane number higher than 40 and most refineries produce diesel with cetane numbers between 40 and 45. Biodiesel has a higher cetane number between 46 and 60 (depending on the feedstock used) which shortens the ignition delay in the engine which improves the combustion characteristics (Biodiesel Education, 2006).

The **flashpoint** of a fuel is the temperature at which the vapour above the fuel becomes flammable. Petroleum-based diesels have flashpoints of 50°C to 80°C which makes them intrinsically safe. Biodiesel has a flashpoint of over 160°C which means that the fire hazard associated with transportation, storage and usage of biodiesel is much less than with other commonly used fuels (Biodiesel Education, 2006).

Lubricity can be defined as: “The property of a lubricant that causes a difference in friction under conditions of boundary lubrication when all the known factors except the lubricant itself are the same. Lower friction means higher lubricity" (Friedrich, 2003). Removing the sulphur from petroleum diesel, as required by recent world regulations, has decreased the lubricity of the fuel. Pure biodiesel and high level blends have excellent lubricity while even small amounts of biodiesel to fossil diesel has a dramatic effect on the lubricity of the fuel (Biodiesel Education, 2006).

The **sulphur content** of fossil diesel has to be below 50 ppm since the beginning of 2005 (SAPIA, 2006) as high sulphur contents in fuels have been associated with negative health effects and an increased service frequency on vehicles. Biodiesel is essentially seen as sulphur free when made from fresh vegetable oil. Biodiesel made from WVO might contain traces of sulphur and would have to be tested to fall into regulatory limits (Mittelbach and Remschmidt, 2005).

Cold temperature properties are measures of the behaviour of the fuel under low ambient temperatures. These are especially important in countries where the temperature is known to drop below 5°C. The **cloud point** denotes the temperature at which the first visible crystals are formed. The **pour point** is the lowest temperature to which the sample may be cooled while still retaining its fluidity. The **cold-filter plugging point (CFPP)** is considered a good indicator of operability limits of the fuel (Mittelbach and Remschmidt, 2005).

The **heating value**, also known as the **heat of combustion**, of biodiesel depends on the oil source. On a mass basis fossil diesel has a higher heating value; about 13% higher than that of biodiesel, but due to the higher **density** of biodiesel, the disadvantage of biodiesel is only about 8% lower on a volumetric basis. This means that for the same injection volumes, engines burning biodiesel have slightly lower power and torque. If injection volumes are changed for biodiesel, the same power and torque can be achieved. Flexi-fuel vehicles use intelligent motors which can detect the type of fuel being used (biodiesel, petroleum diesel or a blend) and automatically adjust the injection parameters (Mittelbach and Remschmidt, 2005). An increase of the injection volumes leads to a slightly higher **specific fuel consumption** when using biodiesel.

It is important to keep in mind that the above properties are those of pure biodiesel. If biodiesel is blended into fossil diesel at 5% or 10%, the properties of the fossil diesel would not be affected to a noticeable extend. It is only the 'lubricity' property of the biodiesel that has an effect even if used in very low blends; this property makes biodiesel an ideal additive for fossil diesel.

Table 5 illustrates the fuel properties (Mittelbach and Remschmidt, 2005) of petroleum diesel and the different vegetable oil methyl esters which are discussed in this study.

Table 5: Properties of petroleum diesel and biodiesel

		Fossil diesel	**Palm oil ME**	**Canola oil ME**	**Soybean oil ME**	**Sunflower oil ME**
Density	***[kg/m3] (T in °C)***	835 (15)	867 (15)	888 (15)	884 (25)	880 (25)
Kinematic viscosity	***[mm^2/s] (at 38 °C)***	2.7	4.3-6.3	3.50-5.00	3.05 - 4.08	4.20 – 4.40
Cloud point	***[°C]***	-15	13 to 16	-3 to 1	-2 to 2	0 to 3
Pour point	***[°C]***	-33	-	-15 to -9	-3 to -1	-3
CFFP	***[°C]***	-18	9 to 11	-19 to -8	-2	-3
Flash point	***[°C]***	50 - 80	155 - 174	153 – 179	141 - 171	164 – 183
Heating value	***[MJ/kg]***	42.7	41.3	40.07	39.8	39.71
Cetane number		47	52	56	50	53

2.4.2 Quality Standards

Quality standards are prerequisites for the commercial use of any fuel product. They serve as guidelines for the production process, guarantee customers that they are buying high-quality fuels and provide the authorities with approved tools for the assessment of safety risks and environmental pollution (Prankl, 2002).

Specifications for biodiesel require particularly close attention due to the large variety of vegetable oils that can be used for biodiesel production, and the variability in fuel characteristics that can occur with fuel produced from this feedstock. Numerous biodiesel standards are currently in force in a number of countries, including the EN 14214 in the European Union and the ASTM D 6751 in the USA (Mittelbach and Remschmidt, 2005).

South Africa currently uses the **SANS 1935 Automotive diesel fuel standard**. This is a voluntary standard for biodiesel which is a slight modification of the EN 14214. According to the South African Bureau of Standards (Manaka, 2006) the SANS 1935 has the following weaknesses:

- It has a narrow definition of biodiesel, as methyl esters derived only from vegetable oils. It excludes all ethyl esters and esters derived from other oils.
- It specifies the iodine number of the biodiesel that is aimed at excluding oils that have a higher value.
- Some of the requirements measured by correlated properties which makes the testing against the specifications expensive.
- It specifies the properties expected of biodiesel meant to be used directly as a pure fuel without blending. However, without taking into account the dilution effects of blends, it requires that the same requirements be applied to the biodiesel that is meant for blending.

With national standards being living documents that are continuously updated, this standard will most probably change in the near future.

2.5 Biodiesel Use

Biodiesel can be used in its pure form, also known as **neat biodiesel** or **B100**. This is the approach that provides the most reduction in exhaust particulates, unburned hydrocarbons, and carbon monoxide. It is also the best way to use biodiesel when its non-toxicity and biodegradability are important. Although neat biodiesel would not be expected to cause any operational problems, its solvent properties are at their highest intensity and may cause problems with loosening of varnish deposits in fuel tanks and lines, degradation of fuel lines because some elastomers are not compatible with biodiesel (such as BUNA rubbers), and cause paint removal near fuel fill ports (Biodiesel Education, 2006).

Biodiesel can also be used as a **blend**. Typically this can range from 5% to 50% biodiesel in 95% to 50% fossil diesel and is known as **B05, B10**, etc. depending on the blend. Blends reduce the cost impact of biodiesel while retaining some of the emissions reductions. Most of these reductions appear to be proportional to the percentage of biodiesel used (Friedrich, 2003).

Biodiesel can also be used as an **additive** (1%-2%) and is known as **B01** or **B02**. Tests for lubricity have shown that biodiesel is a very effective lubricity enhancer. Even as little as 0.25% can have a measurable impact and 1%-2% is enough to convert a very poor lubricity fuel into an acceptable fuel. Although these levels are too low to have any impact on the cetane number of the fuel or the emissions from the engine, the lubricity provides a significant advantage at a modest cost (Friedrich, 2003).

2.5.1 Advantages of biodiesel use

Using biodiesel has the following advantages for consumers (Journey to Forever, 1999):

- No engine modification is necessary. Most diesel engines manufactured after 1995 can run on either a blend or on pure biodiesel.
- Biodiesel is more environmentally friendly. It burns up to 75% cleaner than conventional fossil diesel as it substantially reduces unburned hydrocarbons, carbon monoxide and particulate matter and eliminates sulphur dioxide emissions in exhaust fumes. And its ozone-forming potential is nearly 50% less than fossil diesel fuel.
- Biodiesel is a renewable energy source as it is plant-based and adds no CO_2 to the atmosphere.
- Biodiesel is considered non-toxic and bio-degradable.
- Biodiesel has a high cetane rating which improves engine performance and is a much better lubricant than fossil diesel and can extend engine life.

2.5.2 Disadvantages of biodiesel use

Although the advantages make biodiesel seem very appealing, there are also several disadvantages to consider when using biodiesel (Beer and Grant, *year unknown*):

- Due to the high oxygen content, it produces relatively high NO_x levels during combustion. But these can be reduced to below fossil diesel fuel levels by adjusting engine timing and using a catalytic converter.

- Storage conditions of biodiesel must be monitored strictly as biodiesel has a lower oxidation stability and oxidation products that may be harmful to vehicle components, could be produced. Contact with humid air must be avoided due to its hygroscopic nature.

- The lower volumetric energy density of biodiesel means that more fuel needs to be transported for the same distance travelled.

- Biodiesel has a higher cold-filter plugging point temperature than fossil diesel which means it will crystallize into a gel at low temperatures when used in its pure form (see Table 5).

- It can cause dilution of engine lubricant oil, requiring more frequent oil change than in standard diesel-fuelled engines.

- Biodiesel is a strong solvent and scrubs out all the tars, varnishes, and gums left by fossil diesel in the fuel system which means that the fuel filter will have to be replaced a few times during the initial stages of biodiesel use.

- A modified refuelling infrastructure is needed to handle biodiesel, which adds to their total cost.

2.6 World Biodiesel Production

Biodiesel currently accounts for only 10% of the world biofuel production, with ethanol making up the rest. Global biodiesel production has expanded nearly fourfold between 2000 and 2005 (Figure 5) with the top five producers in 2005 being Germany, France, USA, Italy and Austria (Table 6) (World Watch Institute, 2006).

Considering the fact that biofuel, ethanol and biodiesel, production has more than doubled in the last 5 years while world oil production increased by only 7%, it might be thought that overall, biofuels have the potential to substitute petroleum fuels and increase energy security for many nations.

Table 6: Top five biodiesel producers in 2005

	Production (million litres)
Germany	1,920
France	511
United States	290
Italy	227
Austria	83

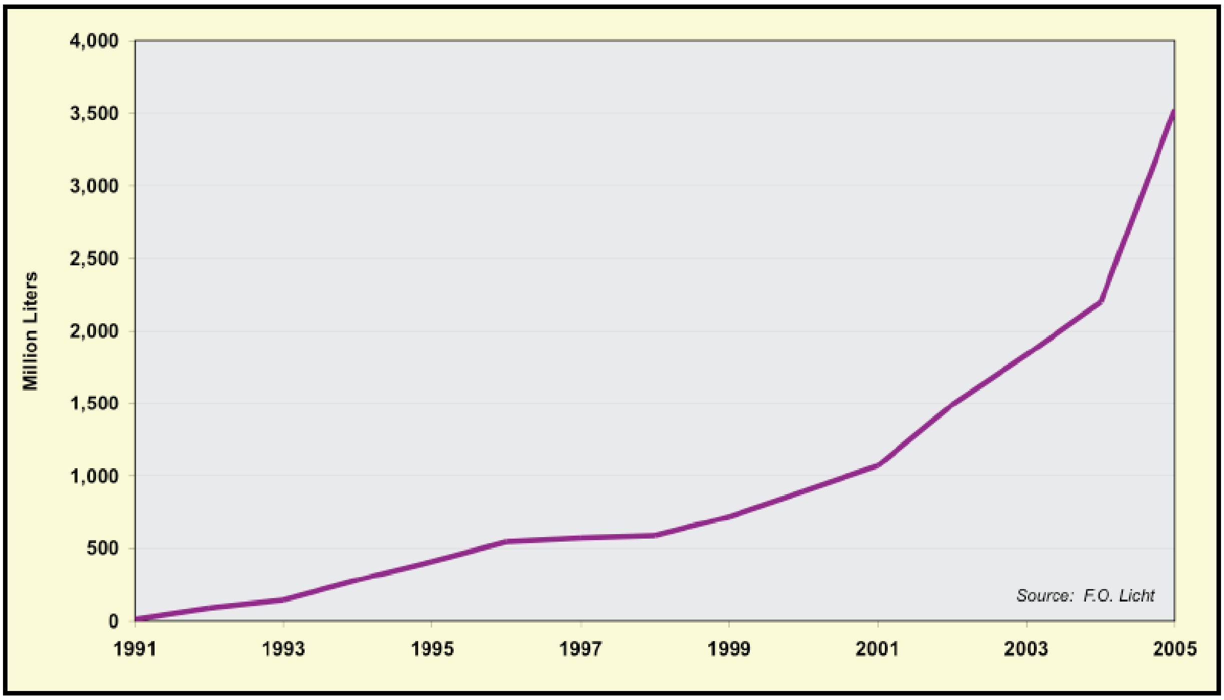


Figure 5: World biodiesel production, 1991 – 2005 (World Watch Institute, 2006)

Chapter 3

Biodiesel in South Africa

3.1 The Current South African Energy Situation

Approximately 14% of South Africa's total primary energy supply is imported in the form of crude oil. Furthermore South Africa's liquid fuels are manufactured by feedstock consisting of more than 50% imported crude oil, 30% coal, 10% domestic crude oil and 8% natural gas. This makes South Africa the largest emitter of greenhouse gasses in Africa and one of the top twenty carbon-intensive countries in the world (Wilson et al., 2005).

In 2005 South Africa consumed about 8.1 billion litres of diesel (SAPIA, 2006). This figure has been increasing at about 5% per annum since 2000. At an average annual increase of 5% per year, South Africa will be consuming about 10 billion litres by 2010 and about 17 billion litres by 2020 (See Appendix A). Diesel prices have reached new record heights selling at about R6.80/litre at the coast (2 August 2006) due to an all-time high global oil price caused by various political factors. Taking the volatile crude oil price and fluctuating Rand/Dollar exchange rate into account, a diesel pump price of R10.00 per litre does not seem that impossible in the foreseeable future.

3.2 Driving Forces of Biodiesel and Biofuels in South Africa

Biofuels could become part of the answer to the above mentioned problems as it would:

1. decrease South Africa's dependence on fossil fuels and imported oil,
2. promote renewable energy,
3. decrease pollution, and

4. assist South Africa in achieving the objectives of the White Paper on Renewable Energy, which states that by 2013, SA should be generating 10,000 GWh of energy from renewable sources (Wilson et al., 2005).

5. Ratification of the Kyoto Protocol by South Africa in 2002.

3.3 The Current Biofuel Situation in South African

According to the Department of Minerals and Energy (DME) former chief director of energy planning, Kevin Nasiep, South Africa will have a preliminary biofuels strategy by the end of 2006 and is looking at creating a market to use the end product and so reducing South Africa's reliance on imported oil (Engineering News, 25/04/2006). At a workshop held in June 2006 (a workshop aiming to establish the way forward for biofuels in South Africa) he stated that "the South African Biofuels Strategy Development has the following objectives: (i) avoidance of the adverse impact on Balance of Payments due to escalating crude oil prices, (ii) protection of the environment, and (iii) job creation potential of biofuels, particularly in the so-called second economy". The urgency of this initiative is motivated by the vulnerability of crude oil prices, high unemployment, climate change concerns, the need for the growing economy to use its resources sustainable and the potential integration of biofuel production into the Accelerated and Shared Growth Initiative of South Africa (ASGISA). ASGISA aims to halve unemployment and poverty by 2014 by stimulating economic growth.

Funding for projects and research on renewable energy has been set aside by organizations such as the Department of Minerals and Energy (DME) and the Department of Science and Technology (DST). The Southern African Biofuels Association (SABA) was established in April 2005 as a non-profit organization to support the development of a sustainable biofuel industry in Southern Africa. SABA is the largest biofuel association in Southern Africa and its members include biofuel producers (such as D1Oils Africa, De Beers Fuel and Ethanol Africa) equipment and technology suppliers (such as Shaval Bio Diesel, Praj Industries, Lurgi SA and Thyssen Krupp Engineering), academia (such as Wits University), agricultural producer associations (such as Grain SA, SA Cane Growers' Association and the Southern African Confederation of Agricultural Unions), financial institutions (such as Absa and Standard Bank), government departments (such as the DME), and state owned organisations (such as the Central Energy Fund). The government has established a task team to develop a biofuel strategy for South Africa by the end 2006. This task team consists of members from the Department of Agriculture, Environmental Affairs and Tourism, Land Affairs, Minerals and Energy, Trade and Industry, National Treasury and The Presidency.

Currently no blending mandates or incentives regarding the production or use of biofuels have been implemented by government. There is however, a voluntary fuel standard for biodiesel, the SANS 1935 Automotive diesel fuel standard, in South Africa (Section 2.4.2).

The South African Revenue Service (SARS) has stated that the fuel tax and levies on biodiesel are as follows: 60c fuel levy, 36.5c road accident fund and 4c customs and excise, which makes it R1.01/litre biodiesel. According to the South African Customs and Excise Act of 1964, Amendment DAR/19 scheduled with effect from 1 April 2006, biodiesel producers are considered commercial manufacturers, which need to register their business with SARS, if they produce more than 300000 litres biodiesel per year (SARS website, 2006).

Since the introduction of this tax regime, the demand for small scale biodiesel plants has increased; showing that producers rather opt for smaller production to decrease their production cost by avoiding the fuel tax and levies.

Friedrich (2003) describes a **three-stage biodiesel industry development** as follows:

- **Phase I** consists of the very first ideas and thoughts of biodiesel being used as a fuel until the actual adaptation of the ideas on the part of the decision maker who are then motivated to put these ideas into practice. The end of phase I (and beginning of phase II) is the political decision to invest money and other resources into biodiesel research.

- **Phase II** is characterized by research efforts, pilot projects, setting of frame conditions and financially supported technical trials.

- Countries in **phase III** show a biodiesel economy based primarily on a feasible economic production, distribution and use of biodiesel, and a self supportive biodiesel economy.

According to this classification, South Africa would be considered a “phase II-country”. In order to progress to phase III, the production of biodiesel will have to be economically feasible to all stakeholders in the industry; from the farmer to the consumer of biodiesel.

Chapter 4

The Preliminary Feasibility of Commercial Biodiesel Production in South Africa

The preliminary economic feasibility of commercial biodiesel production is investigated by examining the following:

1. ***The market feasibility of biodiesel in South Africa:*** examines whether there is a market for biodiesel in South Africa and how to successfully form and sustain an expanding biodiesel market by creating a regulation and policy environment.

2. ***The financial feasibility of biodiesel production:*** investigates the costs of biodiesel production in South Africa and the major factors affecting this. This is done by looking at two different optimal sized plants (Seed extraction biodiesel production and Crude oil biodiesel production) and examining their capital and manufacturing costs. The influence of agricultural commodity price changes on the manufacturing cost is also examined.

3. ***The agricultural feasibility:*** considers the current agricultural situation in South Africa regarding its oilseed production capacity, market prices and oil crop demand and considers whether the South African agriculture would be able to support commercial biodiesel production.

This study focuses solely on commercial biodiesel production. It is assumed that all the stakeholders operate on an independent basis: the commercial biodiesel producer buys its feedstock from farmers or oilseed crushers at the market price and sells its product to the distributors in order to make a profit. This study does not consider producers that produce less than 300000 litres per annum or produce biodiesel from their own oilseeds as it only looks at the biodiesel industry as a whole.

4.1 Market Feasibility

4.1.1 Potential biodiesel market size

The biodiesel market potential is defined by the size of the existing fossil diesel market. Although there is no principal technical limitation for replacing fossil diesel by biodiesel; feedstock availability in South Africa could become a limiting factor (See Section 4.3).

The number of diesel vehicles on South African roads has increased drastically the last few years and with that the South African diesel consumption has increased by more than 5.5% annually since 2002 (See Appendix A). By 2010 South Africa will be consuming about 10 billion litres of diesel per annum and by 2020 this will have risen to about 17 billion litres per year, assuming a conservative annual consumption increase of 5%.

South Africa would need to produce about 1 billion litres of biodiesel by 2010 to replace 10% of its fossil diesel consumption. 2010 can be seen as a reasonable goal seeing that the White Paper Act and AGISA targets are set for 2013 and 2014, respectively.

Table 7: Future biodiesel needed to replace fraction of fossil diesel in South Africa

Fraction of fossil diesel to be replaced	**Future prediction based on an annual 5% increase (million litres)**			
	2006	**2010**	**2015**	**2020**
1%	85	104	132	169
5%	426	518	661	844
10%	**852**	**1036**	**1322**	**1687**

Another criterion to define the market size of biodiesel is the amount of vehicles with given biodiesel warranties. The exact amount of these vehicles in South Africa is unknown but a guideline can be used, stating that vehicles manufactured after 1995 should be able to run on at least a blend of biodiesel. Although a blend of 10% biodiesel should not affect the running of a diesel car, vehicle owners would be very hesitant to use such a blend if their vehicle does not have a biodiesel warranty. This issue will have to be addressed by phasing in the use of biodiesel while ‘biodiesel-incompatible’ vehicles are gradually phased out.

It is clear that there is a definite potential market for biodiesel in South Africa but this is not all that the biodiesel industry needs to become a major player in the South African economy. In order to accelerate an expansion of biofuel production, the government should create policies which focus on creating a predictable and growing market for biofuels in South Africa.

4.1.2 Policies for developing the biodiesel market

The development of a biodiesel industry requires a framework of laws and regulations to stimulate demand. Possible laws and regulations that can be implemented by the government include:

- **Tax incentives.** These have been used effectively in Brazil, Germany and the United States to enhance biofuel production and reduce biofuel prices at the pump. To create a more competitive market for biodiesel in South Africa, the tax on biodiesel, for commercial producers, is currently 101.5 cents/litre while the tax on fossil diesel is 141.5 cents/litre. Only time will tell whether these tax incentives are enough for biodiesel to break into the competitive fuel market.

- **Use government purchasing power.** The enormous purchasing power of the government could be used to expand the biodiesel market by, for example, letting regional governments switch entire fleets (municipal, transport, etc.) to vehicles that run on biodiesel.

- **Setting and adhering to fuel quality standards.** South Africa currently has the SANS 1935 automotive diesel fuel standard in place which is at the moment still a voluntary standard for biodiesel producers. This standard needs to remain up to date with leading international standards, such as the EN 14214 and ASTM D 6751, and needs to be enforced at all levels of production. This is important for consumer confidence and will gain increased importance as international trade in biodiesel expands. Automakers also need assurance of consistent fuel characteristics so they can honour vehicle warranties. Strict enforcement of biodiesel regulations should also eliminate so called ‘cowboy-blenders’ which do great damage to the reputation of biodiesel.

- **Facilitate public-private partnerships.** Public-private partnerships have resulted in important technological breakthroughs in numerous countries and can play a vital role in advancing next-generation technologies.

- **Increase public awareness.** Consumer demand could be a powerful driver of the South African biodiesel market. Strategies to increase public awareness and comfort level with biodiesel need to be implemented. These could include various forms of public education, radio discussions, television advertising and signage along highways. Another option to follow could be to prohibit companies from advertising any fossil fuels. Public concerns regarding possible environmental impacts of biodiesel feedstock cultivation must also be addressed if biodiesel is to gain broad public acceptance.

- **Subsidies and blending mandates.** Policies regarding subsidies and blending mandates are still very controversial in South Africa at this stage. The problem with subsidies are that they are very difficult to discontinue once they have been created which means that should they be implemented, they need to be strategically phased out once the biodiesel industry has been established. Blending mandates could also become problematic as it is impossible to enforce a minimum percentage of biodiesel blends without knowing the production capacity of South Africa. By placing an upper limit on the percentage of biodiesel blend (for example 20%) one eliminates any negative effects of biodiesel that does not totally adhere to the quality standards, but at the same time restricts the biodiesel production industry. Mandatory blending policies would have to be coupled to a deadline set out by the government which could set aims such as a mandatory blend of 1% by 2009, 5% by 2015 and 10% by 2020.

- **Price compensation agreement.** Up to 1994 the government of South Africa had an agreement with SASOL that if the crude oil price went below a certain level and SASOL was unable to compete with the fuel prices in the country, the state would subsidise them, in order for them to continue production at a reasonable profit. If the crude oil price went above a certain level and SASOL was able to produce fuel for much less than the South African fuel price, SASOL would pay an agreed amount to the state for every litre sold. Such a ‘slide-scale’ agreement between the South African government and biofuel producers would develop its young biofuel market by reducing the risk involved and therefore creating a steady market amidst fluctuating feedstock and crude oil prices.

- **Kyoto Protocol 'carbon credit system'.** PriceWaterhouseCoopers recently became the first organization in Africa to be authorized by the United Nations to audit carbon credits under its Kyoto Protocol on climate change (Engineering News, 3/7/2006). Carbon credits are aimed at encouraging developing countries to reduce or lessen the effects of emission of greenhouse-gases, such as carbon dioxide, which is blamed for global warming. They are purchased by organisations in developed countries unable to meet the emission reduction targets committed to under the Kyoto Protocol. This not only limits the impact of emission cuts in the developed world, but also provides an incentive for developing countries to implement clean technologies. Carbon credits are based on organisations undertaking Clean Development Mechanism (CDM) projects. These CDM's involve a number of stakeholders, for example, in the case of biodiesel production this could include the farmer and biodiesel producer. The South African government has to approve all CDM projects via a Designated National Entity (DNE), which is housed in the Department of Minerals and Energy. Once a project is validated, registered and implemented, the actual emission reductions are verified and the credits are issued. These carbon credits can then be sold as a commodity and serve as a source of income to the company. Implementation of this policy should be advantageous to and attract numerous stakeholders into the South African biodiesel industry.

- **Import tariffs on biofuels.** As world biofuel production increases it will become an international commodity. Placing an import tariff on biofuels would protect the local market by preventing overseas countries from dumping their relatively cheap biodiesel in South Africa. Countries such as the USA can produce biodiesel for relatively cheap due to their farming subsidies and resulting low oilseed prices.

- **Rebate on the customs duty on imported feed stocks.** SASOL made a proposal that the import duty on soybeans be reduced so that imported feedstock can be used for biodiesel production. The reasoning behind this is to ensure that South Africa would have enough feedstock during the initial stages of biodiesel production. But the results of such a rebate might be more damaging than good to the South African agriculture as this would open the door for cheaper imported oilseeds. This would force down the local price and could even put a halt to local oilseed production. The import tariffs were implemented to protect the local farmers from cheap imported crops from countries such as the USA where farming is heavily subsidised. Biodiesel should be a totally local produced product for all its benefits to be realized. Even if this would take longer to reach certain production targets, it would at least benefit the total local economy.

4.1.3 The role of the government

Besides the frameworks of laws and regulations that can be implemented by the government to stimulate the biodiesel and biofuel market, it also needs to give the necessary financial support to research and development of energy from biomass technologies.

It is important that the government realises the role that biodiesel, and all biomass for that matter, play in the realisation of its goals set out in the White Paper Act on Renewable Energy, which states that by 2013, South Africa should be generating 10 000 GWh of energy from renewable sources (Wilson et al., 2005). Realising this and other benefits, biodiesel and biofuels should benefit from higher priority, of currently available renewable energy technologies, regarding policies and financing from the South African government.

Finally the South African government needs to realise the role it has to play to create a thriving and lasting biofuel industry in the country because nowhere in the world has a successful biofuels industry been established without the support of the government.

To have a successful start, the ‘infant’ biodiesel industry requires a ‘pulling-action’ from the government rather than a ‘pushing-action’ by the involved stakeholders. This ‘pulling-action’ can be summed up as follows:

Step 1: Removing confusion regarding biodiesel and biofuels and demonstrate government support to various technological and business plans.

Step 2: Implement policies and incentives to produce feedstock and facilitate an infant biofuel industry by creating a local market for these fuels.

Step 3: Accelerate the growth of an established biofuel industry and free biofuel market by phasing out all subsidies and keeping policies up to date with situations.

By releasing a biofuel strategy with certain objectives by the end of October 2006 and already funding some pilot research projects in the country, it seems that the government is starting to play its part in the establishment of a permanent biofuel industry in South Africa. Although this is essential, it is only the start and various other factors still play a major role in the economic feasibility of commercial production of biodiesel.

4.2 Financial Feasibility

On a national level the profitability of biodiesel production, especially during the early stages of the industry development, largely depends on legislation implemented by the state. But as the industry moves into a free market situation it needs to be able to maintain its profitability as subsidies and incentives are strategically withdrawn. It is at this stage that the production of biodiesel has to be financially feasible. Thus, firstly, would biodiesel be able to compete with the fossil diesel price or would mandatory blending legislation be necessary to create a forced market for biodiesel? And secondly, at what cost does biodiesel production become feasible for various types of feed stocks?

4.2.1 Basis and scope of calculation

The financial feasibility of biodiesel production is based on an optimum size biodiesel production plant in South Africa. The fixed capital cost and working capital for such a plant are calculated and discussed. The manufacturing costs and the profitability of biodiesel production from various types of feed stocks are also calculated, compared and discussed.

Two types of biodiesel production plants are considered for the calculations:

1. **Seed Extraction Biodiesel Production (SEBP) Plant:**
   The SEBP plant uses oilseeds for the production of biodiesel. This requires the biodiesel producer to buy oilseeds from local farmers at the market price, extracting the oil from the oilseeds and processing it into biodiesel. The oilcake resulting from the oil extraction is sold for livestock feed at market price depending on the protein content. Referring to section 2.3.1, the cost and profitability of biodiesel production using the following oilseeds are investigated:

Table 8: Potential oilseeds used for commercial biodiesel production

Oilseed	**Price (August 2006)**	**Source**
	R/ton	
Canola	1 900	Bester Feed & Grain Exchange
Soybeans	1 950	SAGIS
Sunflower seeds	2 220	SAGIS

These oilseeds are currently produced in South Africa and calculations are based on their current (August 2006) local prices (Appendix E). With oilseed prices varying greatly, results for different prices are included in the oilseed price sensitivity analyses.

2. **Crude Oil Biodiesel Production (COBP) Plant:**

The COBP plant produces biodiesel from crude vegetable oil. It is different from the SEBP plant in the way that it does not have a oilseed extractor and biodiesel producers would have to buy crude oil from oilseed crushers to produce biodiesel. This type of plant adds oilseed crushers as a link between the farmers and biodiesel producers into the production chain. World oilseed trade is in oil and oilcake and South Africa currently imports about two thirds of its vegetable oil (GAIN, 2006). If South Africa would not be able to produce the necessary feedstock, it would have to be imported in the form of crude vegetable oil meaning that more COBP plants would be necessary. Based on current world production and price, the following potential crude vegetable oils are investigated during this study to determine the costs and profitability of biodiesel production:

Table 9: Potential crude oils used for commercial biodiesel production

Oilseed	**FOB Price (August 2006)**	**FOR Price**	**Source**
	US$/ton	***R/ton***	
Palm Oil	468	5 220	Oil World & Ocean Freight
Soybean oil	502	5 500	Oil World & Ocean Freight
Sunflower oil	575	6 100	Oil World & Ocean Freight
Rapeseed oil	794	7 920	Oil World & Ocean Freight

Due to the fact that South Africa currently imports most of its vegetable oils, the calculations are based on imported crude oil prices (August 2006). This is done in order not to underestimate the cost of the feedstock and so that this study also compensates for a situation where the locally produced feedstock will not be enough to produce 10% of the country's diesel. This is not a pessimistic assumption but rather a worst case scenario consideration. Import prices include all costs associated to getting the feedstock to South Africa and onto a train in either Durban or Cape Town (Appendix E). Soybean and sunflower oil are imported from Argentina, palm oil from Malaysia and rapeseed oil from Europe. These are either vegetable oils that can be produced in South Africa or are used elsewhere in the world for biodiesel production. Results of fluctuating crude vegetable prices are included in the price sensitivity analyses.

A diagrammatic presentation of the production processes used in each type of plant is shown in Figure 6.

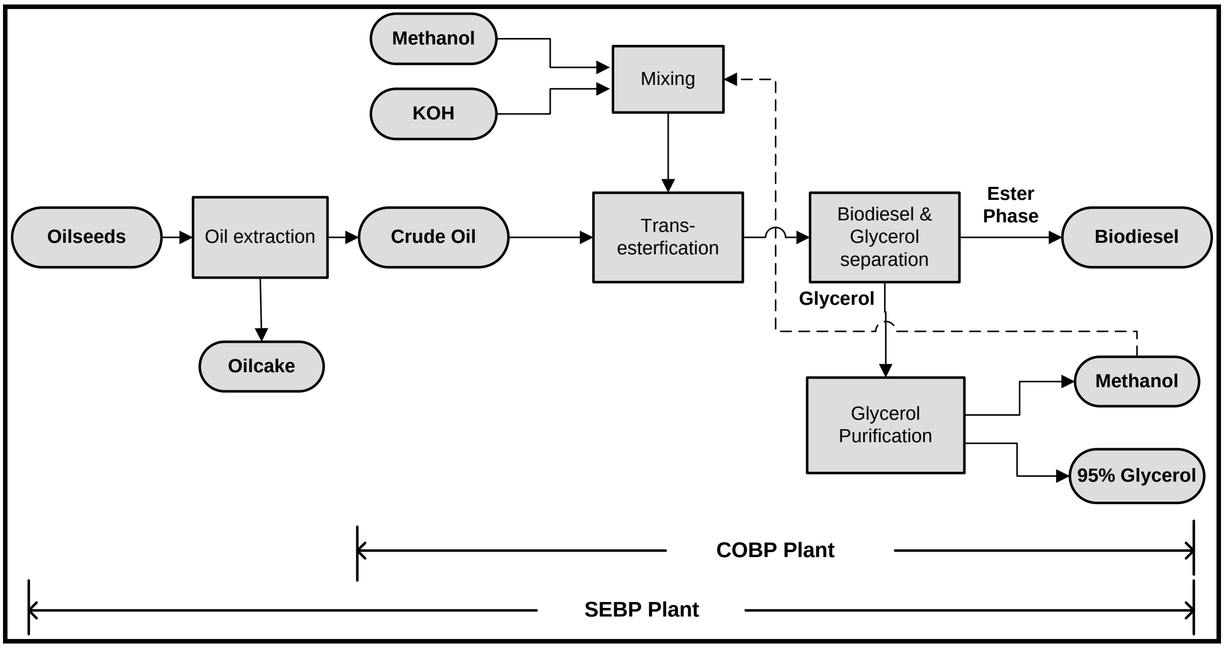


Figure 6: Biodiesel production processes for two types of plants

4.2.2 Assumptions

The calculations are based on the following assumptions:

1. Due to fluctuating nature of the commodity prices, all prices at the end of August 2006 are used. Although this might not reflect an annual average, the results for different feedstock prices can be obtained from the sensitivity analyses.

2. Exchange rates of 1US$ = R7.50 and 1 Euro = R9.50 are assumed. These are slightly higher than the average figures for most part of the year. No sensitivity analyses is done on the exchange rate as this figure only influences the capital investment and the manufacturing cost of a COBP plant using imported crude oil.

3. Plant operating hours of 7920/year, which means the plant runs for 330 days per annum.

4. A vegetable oil to biodiesel conversion in the transesterfication reactor of 95%.

5. Average densities of all liquids as seen in Appendix D.

6. Oil and cake yields of the different oilseeds are as follows:

Table 10: Oil and cake yields for hexane oilseed extraction

	% Oil	% Oilcake	% Extraction losses
Canola	40	55	5
Soybeans	18	77	5
Sunflower	38	57	5

7. Methanol recovered from the process is not recycled. The reason for this is that the recovered methanol is only 99.8% pure and might affect the reaction rate of the transesterfication reaction due to the sensitivity of the alkali catalyst to water. This is done not to underestimate the production costs. However, results showing the cost implication of recycling methanol are also shown in the calculations.

8. There is no market for glycerol and it cannot be sold as a by-product. This assumption is based on the fact that there is currently an over supply of glycerol in the world market. This over supply of glycerol can be ascribed to the global increase of biodiesel production. Since biodiesel production levels started to rise a few years ago, glycerol prices have dropped to their lowest levels which makes exporting glycerol not economically feasible at the moment to biodiesel producers in South Africa.

9. Mittelbach and Remschmidt (2005) suggest that a potassium phosphate fertilizer can be produced by reacting phosphoric acid with the crude glycerol. This step is not considered in the study as there is not a definite known market for this fertilizer.

Thus, by not over estimating the possible income generated by the plant the prudence concept applied.

10. All fixed capital is depreciated at 10% per annum straight line method.

4.2.3 Plant size and location

Size optimization on biodiesel plants in South Africa has been done by Amigun and von Blottnitz (2005). Although they used Jatropha Curcas as the feedstock in their calculations, their model can be adapted to any type of feedstock. Their results generally show a near flat profile around the optimum plant size (biodiesel cost vs. plant capacity), which agrees with results reported by Kumar et al. (2002) and Jenkins (1996). Bender (1999) also confirms this by stating that operational costs of biodiesel production do not reflect an economy of scale which means that smaller or larger than optimum plants can be built with only a minor cost penalty. Amigun and von Blottnitz (2005) found that the optimum biodiesel plant size in South Africa varies between 1500 kg/h and 3500 kg/h and for the purpose of this study **the optimum biodiesel plant size is chosen as 2500 kg/h.**

The plant location is one of the most important factors determining the feasibility of a biodiesel plant due to the high transport costs of the feedstock and biodiesel to and from the processing plant. **South Africa would need about 46 plants, each producing 2500 kg/h to supply 10% of its diesel by 2010** (See Appendix B). Thus, biodiesel production in South Africa should be regionally based rather than a few very large centralised plants, due to the absence of economies of scale and the high cost of transport.

SEBP plants should be as close to the source (farms) of the feedstock as possible. This is due to the fact that the mass and volume of the oilseeds is 2.5 to 5 times more than the vegetable oil or biodiesel produced from it. This means that SEBP plants would have to be in the close vicinity of oilseed producing regions.

COBP plants would need to find a compromise on their location, between the feedstock supplier and biodiesel market, seeing that the volumes of the vegetable oil and biodiesel being transported are the same. The oilseed crushers would be located in the oilseed farming regions to buy the seeds from the farmers and sell the crude oil to the biodiesel producers and the oilcake to the livestock farmers.

4.2.4 Biodiesel plant description

BioKing® is a Dutch company specialising in the manufacture of biodiesel equipment for various production capacities. They manufacture two different sizes of containerized biodiesel production plants. Their largest containerized plant is the BK 18-ST (Appendix C) which has a production capacity of 2640 kg/h. Their BK-95 glycerol purifier uses batch distillation to separate and purify the glycerol and methanol mixture.

This containerized plant type has the following advantages:

1. Being a containerized plant, it relatively small and mobile.

2. It makes use of a continuous transesterfication reactor which shows high yields and fast reaction times.

3. Centrifuges are used for biodiesel/glycerol separation and biodiesel washing instead of settling and washing tanks. This speeds up the whole process and saves space and equipment costs.

4. It is a turnkey plant which is very simple to operate and not labour intensive.

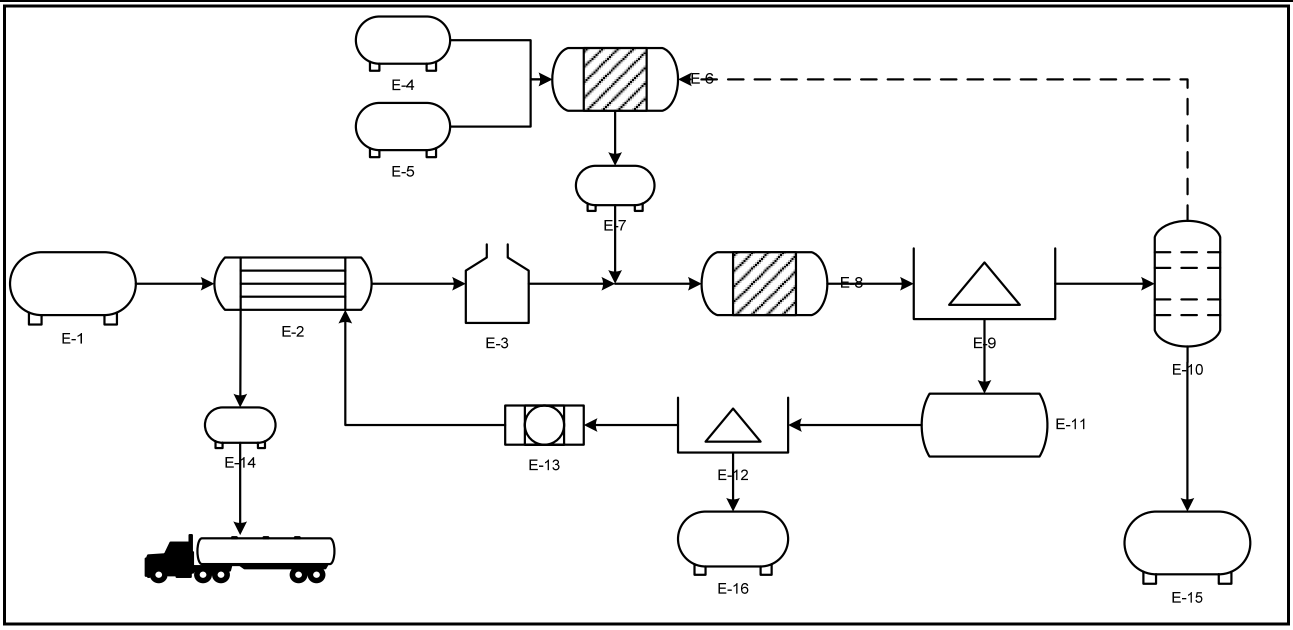
5. It uses no electricity as the generator and burner used in the plant are run on biodiesel and glycerol produced by the plant.

6. It can run on any type of vegetable oil and even animal fat.

7. The biodiesel produced is of high quality and meets international standards such as ASTM D-6751 and EN 14214.

8. The methanol that is obtained from the BK-95 glycerine purifier can be recycled to reduce costs.

The COBP plant discussed in this study consists of the BK 18 – ST containerized plant, BK-95 glycerol purifier and additional feedstock and product storage tanks. A simplified process flow diagram of this plant is shown in Figure 7 and Appendix C and a brief description and mass balance of the biodiesel production process follows.



COBP Plant: Equipment List

E1	External Crude vegetable oil storage	E9	Centrifuge (contaminated biodiesel & crude glycerol)
E2	Heat Exchanger 35°C	E10	BK-95 glycerol purifier
E3	Burner 60°C	E11	Continuous dry wash system
E4	KOH storage	E12	Centrifuge (biodiesel & magnesium waste)
E5	Methanol storage	E13	Filter
E6	Methoxide reactor	E14	Biodiesel buffer storage
E7	Methoxide storage	E15	External glycerol Storage
E8	Transesterfication reactor (continuous)	E16	External magnesium waste storage

Figure 7: A simplified process flow diagram of a COBP plant

Crude vegetable oil feedstock is pumped out of the external storage at 2743 kg/h. The feedstock is heated instantly with warm biodiesel to 35°C. After this the feedstock is heated further with the burner (running on glycerol and biodiesel) to 60°C. The potassium methoxide is formed in the methoxide reactor by reacting 466 kg/h methanol and 15 kg/h potassium hydroxide (KOH) catalyst in the methoxide reactor and stored in the internal temporary storage. Methoxide is added automatically and continuously in adjustable doses to the feedstock. The mixture is fed to the transesterfication reactor where an assumed conversion of 95% vegetable oil to biodiesel takes place. Crude glycerol (glycerol, KOH, water, soap and methanol) is separated from the biodiesel with centrifuges. Contaminated biodiesel is cleaned with magnesium silicate in a continuous dry wash system. The magnesium and absorbed particles, water and methanol are separated from the biodiesel with a self-discharging centrifuge. The biodiesel is filtered and passed through a heat exchanger to be cooled before going into the buffer storage for quality verification. After cooling to room temperature the biodiesel is pumped into the main storage.

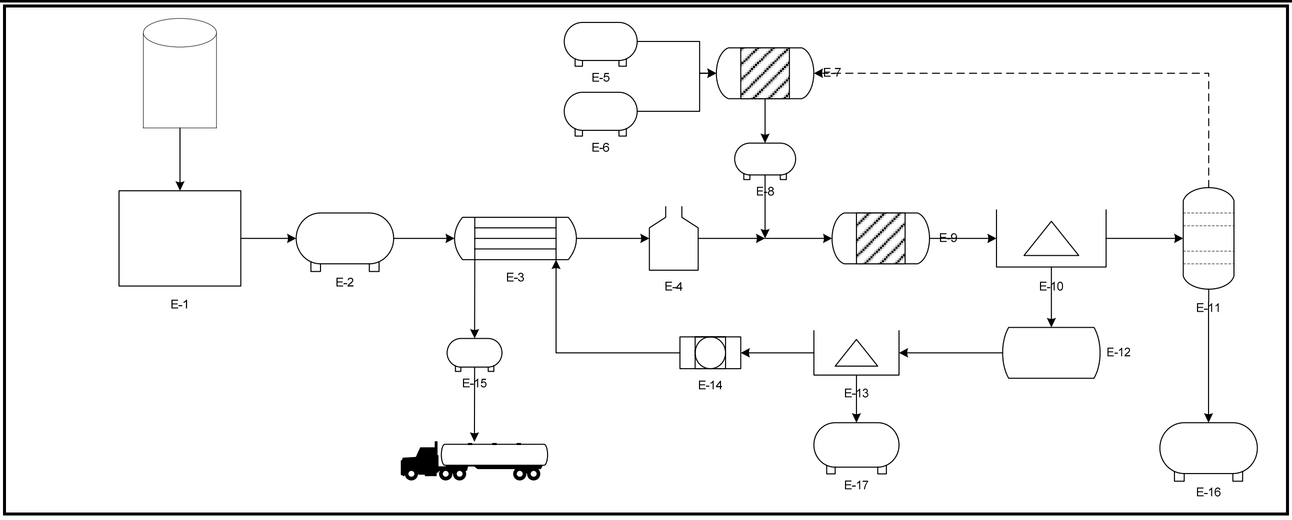
The crude glycerol is fed into the BK-95 batch distillation column where 99.8% pure methanol and 95% pure glycerine are recovered. The methanol could possibly be recycled to save costs. Flow rates and a basic mass balance of the different components entering and leaving the plant are shown in Table 11.

Table 11: Mass balance of the 2,500 kg/h biodiesel production plant using crude oil

		Litres/hour	*Kg/hour*	*Tons/annum*
IN	Crude Vegetable Oil	2991	2742	21725
	Methanol	589	466	3693
	Potassium Hydroxide		15	118
	Total		***3223***	
OUT	Biodiesel	2841	2500	19800
	95% Glycerine	314	345	2732
	99.8% Methanol	290	230	1822
	Catalyst, FFA, Soaps		148	1188
	Total		***3223***	

The SEBP plant discussed in this study consists of a 20 ton/hour hexane oilseed extractor, the BK 18 – ST containerized plant, BK-95 glycerol purifier and additional feedstock and product storage tanks. Most of the seed pressing companies in South Africa currently use hexane extraction but this size of extractor is larger than any extractor currently in operation. (This means that if South Africa is to produce biodiesel using COBP plants, the oilseed crushing capacity of the country would need to increase drastically.)

The oilseeds are fed from their storage into the extractor from where the resulting crude oil is fed to the oil processing part of the plant. The oil processing part of the plant is identical to the COBP plant described above. A simplified process flow diagram of an SEBP plant is shown in Figure 8 and Appendix C.



SEBP Plant: Equipment List

E1	Hexane extractor	E10	Centrifuge (contaminated biodiesel & crude glycerol)
E2	External Crude vegetable oil storage	E11	BK-95 glycerol purifier
E3	Heat Exchanger 35°C	E12	Continuous dry wash system
E4	Burner 60°C	E13	Centrifuge (biodiesel & magnesium waste)
E5	KOH storage	E14	Filter
E6	Methanol storage	E15	Biodiesel buffer storage
E7	Methoxide reactor	E16	External glycerol Storage
E8	Methoxide storage	E17	External magnesium waste storage
E9	Transesterfication reactor (continuous)		

Figure 8: A simplified process flow diagram of a SEBP plant

A mass balance for the different oilseeds is shown in Table 12. The balances do not reconcile due to the assumption that 5% of the oilcake is lost during extraction. The extractor is seen as a closed unit with only seed entering and crude oil and oilcake leaving. All hexane and other utilities used are included in the operation costs (per ton seed) and are not included in the mass balance.

Table 12: Mass balance of the 2,500 kg/h biodiesel production plant using oilseeds

		Canola		Soybeans		Sunflower seeds	
		Kg/hour	*Tons/annum*	*Kg/hour*	*Tons/annum*	*Kg/hour*	*Tons/annum*
IN	Seeds	6855	54292	15233	120648	7216	57149
	Methanol	466	3692	466	3692	466	3692
	Potassium Hydroxide	15	118	15	118	15	118
	Total	***7336***		***15714***		***7697***	
OUT	Biodiesel	2500	19800	2500	19800	2500	19800
	Oilcake	3770	29860	11730	92899	4113	32575
	95% Glycerine	345	2732	345	2732	345	2732
	99.8% Methanol	230	1822	230	1822	230	1822
	Catalyst, FFA, Soaps	148	1172	148	1172	148	1172
	Total	***6993***		***14953***		***7336***	

4.2.5 Capital investment of a SEBP and COBP plant

Fixed capital cost represents the cost of constructing a new biodiesel production plant. Generally, fixed capital cost consists of three parts: total bare module capital cost, contingencies and fees and costs associated with auxiliary facilities.

Total bare module capital cost is the sum of the cost of each piece of equipment in the process which in this case would be the containerized BK 18-ST plant, BK-95 glycerine purifier and the storage tanks for the feed materials and products. For the SEBP plant, the hexane oilseed extractor necessary for oilseed extraction is also included in this cost.

By using the technology of the BK 18-ST plant, the bare module cost of the total plant is simplified and more accurate. The costs of the BK 18-ST plant and BK-95 glycerine purifier are given online and were confirmed via email by the manufacturing company BioKing® (www.bioking.nl, 2006).

The South African company, Velo SA (Sieberhagen, 2006), was approached for pricing of storage tanks. The storage tanks are made from 304 stainless steel and each have a size of 100 m^3. This is the largest possible size that can be transported and does not have to be constructed on site. On site construction only becomes more economical for tanks larger than 10000m^3 (Sieberhagen, 2006). The amount of tanks is based on the volume needed for 3 weeks of storage of all feed material and products. The volume and price calculations are shown in Appendix B.

The cost of a 20 ton/hour is an estimate obtained from Sabie Management Services (Victor, 2006). It is an estimate as no such size extractors are currently operating in South Africa.

Contingencies and fees are defined as a fraction of the total bare module capital cost (e.g., 18% was used in the present study) to cover unforeseen circumstances and contractor fees (Turton et al. 2003).

Expenses of auxiliary facilities include items such as the purchase of land and installation of electrical and water systems. Auxiliary costs of both types of processes are calculated as 15% of the bare module cost of only the COBP plant. The reason for this is that the hexane oilseed extractor is a major contributor to the capital cost of the SEBP plant but does not really influence the auxiliary costs of such a plant seeing that the extractor will be able to use all the facilities installed for the crude oil processing part of the plant.

According to the definition of capital cost estimation provided by Turton et al.(2003), the economic estimation in this study is classified as a "study estimate". This study estimate has a range of expected accuracy from +30% to -20%. The capital costs for SEBP and COBP plant are presented in Table 13.

Table 13: Fixed capital cost for a biodiesel production plant

Description	**SEBP Plant**		**COBP Plant**	
	Cost		***Cost***	
	Thousand Euro	***Thousand Rand***	***Thousand Euro***	***Thousand Rand***
Hexane extractor		45000		
BioKing 18-ST containerized plant	329	3126	329	3126
BioKing 95 glycerine purifier	120	1140	120	1140
Storage		15000		4375
Total Bare Module Cost, C_{BM}		**64266**		**8641**
Contingency Fee, $C_F = 0.18C_{BM}$		11568		1555
Auxiliary facility costs, $C_{AC} = 0.15C_{BM}$		1296		1296
Fixed Capital Cost, $C_{FC} = C_{TM} + C_{AC}$		**77129**		**11492**

The fixed capital cost for a SEBP plant is about R80 million while this figure is much lower at about R12 million for a COBP plant. Results show that a SEBP plant requires almost seven times the amount of fixed capital compared to a COBP plant. This is due to the high cost of the hexane oilseed extractor and the additional storage cost necessary to accommodate larger volumes of oilseeds.

Working capital is the additional investment needed, over and above the fixed capital, to start up the plant and operate it to the point when income is earned. A number of methods to calculate working capital as a percentage of fixed capital are available but these are not suitable for a biodiesel plant, due to the high cost and throughput of raw materials. With a creditor turnover period of 90 days and a debtor's payment period of 30 days, the cost of raw materials for a three month period are taken as the working capital. The calculations to obtain the working capital for each type of feedstock and process are shown in Appendix B. These results are shown in Table 14.

Table 14: Working capital for different feed stocks for a SEBP and COBP plant

Plant Type	Feedstock	Thousand rand
SEBP Plant	Canola	31858
	Soybeans	67888
	Sunflower seeds	38327
COBP Plant	Soy oil	36300
	Sunflower oil	39854
	Rapeseed oil	50633
	Palm oil	34642

The working capital is about R35 million for most of the different types of feed stocks. The working capital for soybeans however, is almost double that (at about R70 million) due to the large volumes of beans needed for the same amount of crude oil. The reason for relative high amount of working capital needed for a rapeseed COBP plant is the simple fact that imported rapeseed oil is much more expensive than the other imported crude vegetable oils.

The **total capital investment** needed for the start up of a biodiesel plant is the total fixed capital added to the working capital as seen in Table 15.

The total capital investment needed for a 22 million litre/annum SEBP plant is about R115 million when using either sunflower or canola as feedstock and about R145 million for a plant using soybeans as feedstock.

For a COBP plant these figures look relatively more attractive to investors at about R50 million depending on the type of vegetable oil to be used.

Table 15: Total capital investment for biodiesel plants in South Africa

Plant Type	Feedstock	Fixed Capital *Thousand rand*	Working Capital *Thousand rand*	Capital Investment *Thousand rand*
SEBP Plant	Soybeans	77129	67888	**145018**
	Sunflower seeds	77129	38327	**115456**
	Canola	77129	31858	**108988**
COBP Plant	Rapeseed oil	11492	50633	**62125**
	Sunflower oil	11492	39854	**51346**
	Soy oil	11492	36300	**47792**
	Palm oil	11492	34642	**46134**

These results also show that more than half of the total capital investment consists of working capital which is tied up in three months of feedstock. Care must be taken when calculating the capital needed for such a plant not to assume that the working capital will be a percentage of fixed capital. This would result in a much lower and inaccurate figure for the necessary capital needed to start up a biodiesel production plant.

Figure 9 is a more illustrative diagram comparing the fixed capital, working capital and total capital investment of a biodiesel plant for the different types of feed stocks

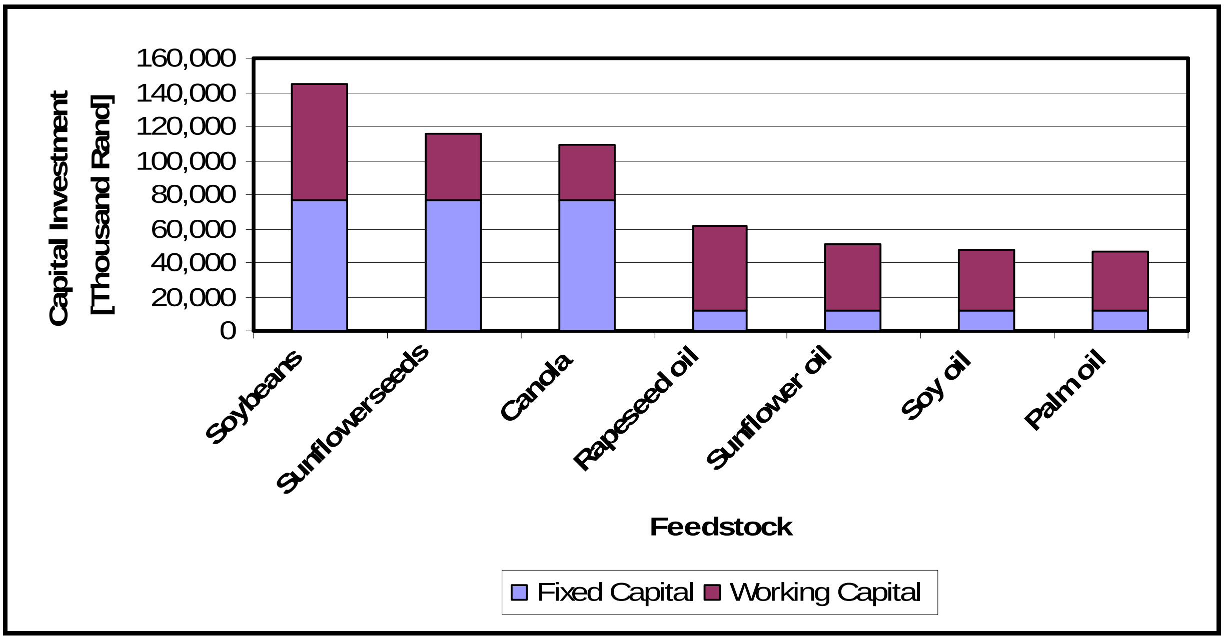


Figure 9: Graph showing the capital investment needed for a biodiesel plant

4.2.6 Manufacturing costs of a SEBP plant

Total manufacturing cost refers to the cost of the day-to-day operation of a biodiesel plant and is divided into two categories: variable manufacturing costs and indirect manufacturing costs & general expenses (or fixed manufacturing cost) (Turton et al. 2003).

Variable manufacturing costs consist of raw material cost, extraction cost, catalyst cost, operating labour fees, supervisory and clerical labour fees, utilities, transport cost, maintenance and repairs, operating supplies and laboratory charges.

Oilseed, methanol and catalyst costs are calculated from the mass balance and current (30 August 2006) local prices obtained form various sources (Appendix E). The extraction cost of R250 per ton is based on an average quoted rate obtained from various sources in the industry (Appendix E). All costs associated with the oilseed extraction part of the plant, such as labour, utilities, etc., are included in this amount. It is assumed that the oil processing part of the SEBP plant needs about 2 operators per shift which are paid an average wage of R50/hour. This assumption is based on the fact that the containerized oil processing plant is easy to operate and not labour intensive. The supervisory and clerical labour costs are estimated at about R100000 per month. Water is the only utility needed by the plant seeing that it generates its own electricity and heat by using a generator and burner running on biodiesel and glycerol. Transport cost calculations shown in Appendix B are based on indicative rail prices from Spoornet SA (Swart & Maree, 2006). Maintenance & repair costs, operating supplies and laboratory charges are calculated by multiplying with related factors obtained from Turton et al.(2003).

Indirect manufacturing costs and general expenses include overheads, insurance, administrative cost, research and development and depreciation. These are all calculated by multiplying with related factors, which are commonly applied to economic assessments according to Turton et al. (2003). The fixed capital of the plant is depreciated at 10% per annum, straight line method.

All the prices used in the calculations, further referred to in this study as the current prices (30 August 2006) and are shown in Table 16 and together with their sources in Appendix E.

Appendix F shows the detailed calculated manufacturing costs of a 2500kg/h SEBP plant for the different types of feed stocks, canola, soybeans and sunflower seeds. A summary of these costs for each type of feedstock is shown and discussed below. The total annual costs are given as well as each cost per litre of biodiesel. The percentage contribution of each cost item to the total manufacturing cost is also included to show the relevant importance of the accuracy of the price used for the calculations. For example it is important to have an accurate figure of a cost item if it contributes to about 50% of the total cost, whereas an estimate of a cost item could be justified if it only contributes to about 10% of the total cost.

Table 16: Current commodity prices used for cost calculations of SEBP plant

Item	**Local Price**
	R/ton
Soybeans	1950
Sunflower seeds	2220
Canola	1900
Soybean oilcake	1800
Sunflower oilcake	1170
Canola oilcake	1830
Methanol	3450
Potassium Hydroxide	7800

A 2500kg/h canola SEBP plant has an annual manufacturing cost of about R113 million which results to R4.80/litre biodiesel. Table 17 shows a summary of the manufacturing costs of such a plant. The complete cost calculations are shown in Appendix F.

Table 17: Manufacturing costs of a SEBP plant using canola as feedstock

Manufacturing Cost	***Annual***	***Cost/litre***	***Percentage***
	Thousand rand	***cent/litre***	***%***
Oilseed + Extraction cost - Oilcake credit	62088	279	58%
Methanol & Catalyst	13660	61	13%
Transport	9705	44	9%
Other variable manufacturing costs	7446	33	7%
Indirect manufacturing costs & General expenses	14085	63	13%
Total	**106984**	**480**	

A 2500kg/h soybean SEBP plant has an annual manufacturing cost of about R150 million which results to R6.69/litre biodiesel produced. Once again only a summary of all the costs in Appendix F is shown in Table 18.

Table 18: Manufacturing costs of a SEBP plant using soybeans as feedstock

Manufacturing Cost	***Annual***	***Cost/litre***	***Percentage***
	Thousand rand	***cent/litre***	***%***
Oilseed + Extraction cost - Oilcake credit	98215	441	66%
Methanol & Catalyst	13660	61	9%
Transport	15761	71	11%
Other variable manufacturing costs	7446	33	5%
Indirect manufacturing costs & General expenses	14061	63	9%
Total	**149143**	**669**	

A 2500kg/h sunflower SEBP plant has an annual manufacturing cost of about R150 million which results to R6.66/litre biodiesel produced. Once again only a summary of all the costs in Appendix F is shown in Table 19.

Table 19: Manufacturing costs of a SEBP plant using sunflower seeds as feedstock

Manufacturing Cost	***Annual***	***Cost/litre***	***Percentage***
	Thousand rand	***cent/litre***	***%***
Oilseed + Extraction cost - Oilcake credit	103053	463	69%
Methanol & Catalyst	13660	61	9%
Transport	9966	45	7%
Other variable manufacturing costs	7446	33	5%
Indirect manufacturing costs & General expenses	14329	64	10%
Total	**148454**	**666**	

The results above and in Figure 10 show that canola would currently be the cheapest feedstock for the production of biodiesel on a commercial scale. This statement is based solely on the cost of biodiesel production and does not consider any agricultural production issues at this stage. It is clear from the figure that the difference in manufacturing costs can be ascribed to a major difference in feedstock costs. The figure and above mentioned tables all show the **'net feedstock cost'** which is the cost of the seed added to the extraction cost and subtracting the value of the resulting oilcake. Figure 11 shows the 'net feedstock cost' per ton biodiesel of canola, soybeans and sunflower seeds.

Although the seed and extraction costs of canola and sunflower can be compared, the lower value of the sunflower oilcake makes its **'net feedstock cost'** about R5200/ton biodiesel which is much higher than that of canola at R3150/ton biodiesel. The slight difference in seed and extraction costs of canola and sunflower is due to the higher price of sunflower seeds which currently trade at R2220/ton which is about R300/ton higher than canola or soybeans. The value of the sunflower oilcake (R1170/ton) is about 65% of that of either soybean or canola oilcake because of its lower protein and higher fibre content. There is not a great demand for sunflower oilcake in the agricultural sector because of its lower nutritional value to the livestock. Sunflower oilcake consumption contributes to about 24% of the total oilcake consumption of South Africa as seen in Appendix I (GAIN, 2006).

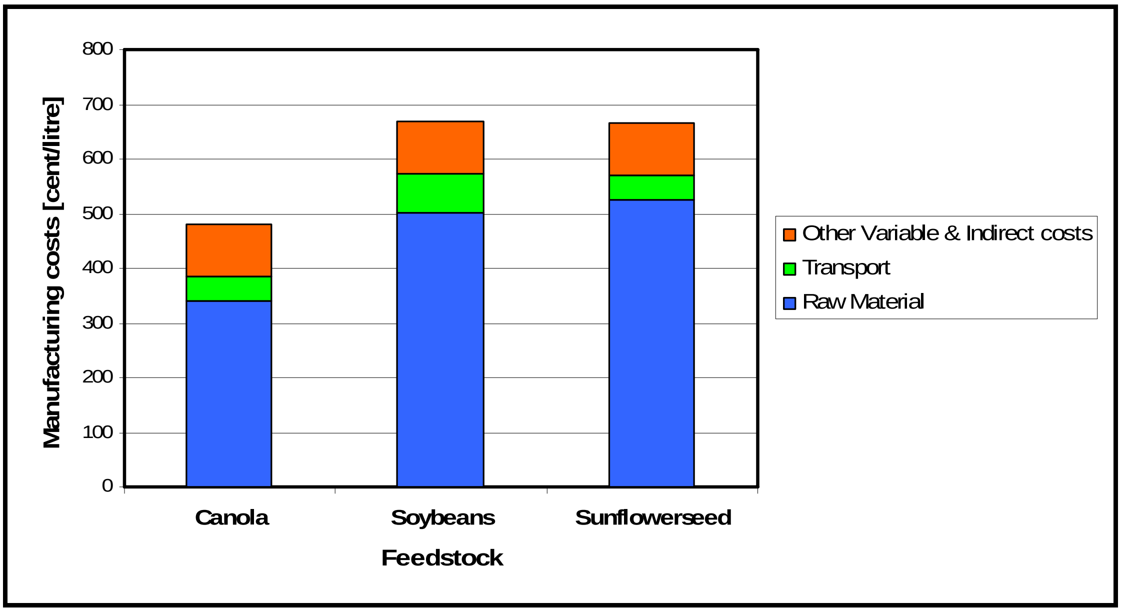


Figure 10: Manufacturing costs of a SEBP plant using different feed stocks

The **'net feedstock cost'** per ton biodiesel of soybeans compares to that of sunflower seeds at R5000/ton biodiesel. Soybean oilcake is as valuable as canola oilcake and contributes to about 60% of the South African oilcake consumption as seen in Appendix I (GAIN, 2006). Of the annual 740000 tonnes of soybean oilcake that is consumed, almost 90% is imported. The large amount of soybeans needed for biodiesel production because of its low oil content, raises the feedstock and extraction costs to such a level to cause the 'net feedstock cost' to be about R5000/ton biodiesel. This is about R200/ton biodiesel less than sunflower but R1800/ton biodiesel more than canola.

Thus looking at the results above, the major factors affecting the 'net feedstock cost' and consequently the manufacturing costs are the seed price, its oil content and the value of its resulting oilcake.

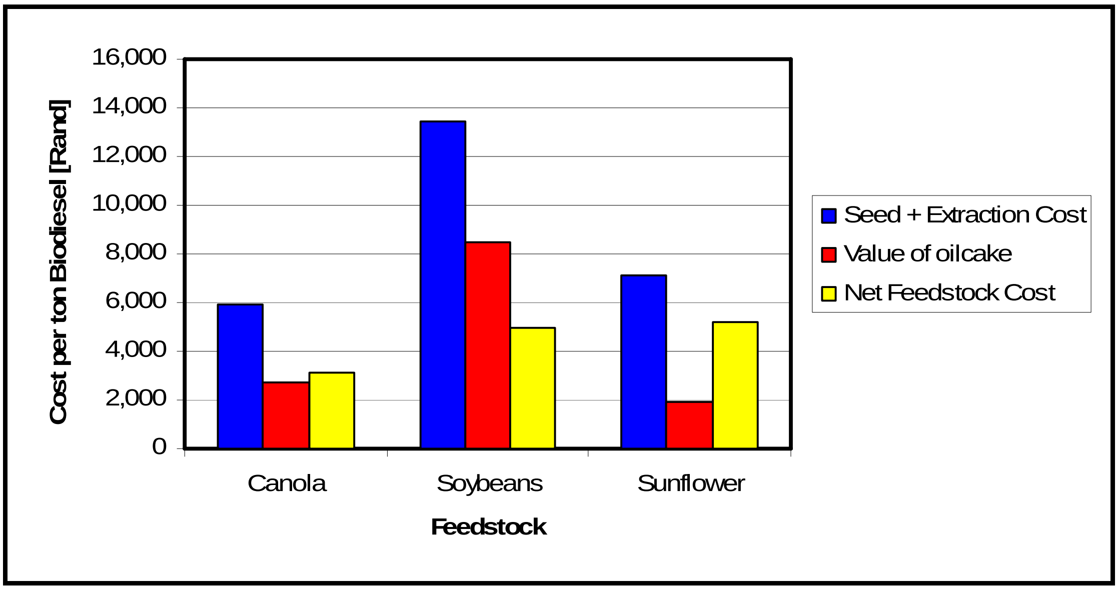


Figure 11: 'Net feedstock costs' per ton biodiesel of the different feed stocks

Transport cost is the second biggest single item contributing to the manufacturing costs which once again points to the fact that plant location is a very important fact to consider when thinking about biodiesel production. The transport costs are the highest for soybeans when comparing them to the other feed stocks. Once again this is due to the fact that more than double the volume of soybeans needs to be transported to the SEBP plant than either canola seeds or sunflower seeds.

The results in Figure 12 show that about 90% of the costs associated with biodiesel production are direct manufacturing costs while only about 10% of the costs are fixed. The relatively low indirect costs and general expenses prove that there is no major economy of scale advantage involved in biodiesel production which indicates that a different size plant will not endure any major cost penalty.

Another important result to note is that the transport costs are about just as much as the fixed costs of a SEBP plant. This result indicates that the plant location is a very important factor determining the economic feasibility of biodiesel production. With annual transport costs being between R10 and R15 million, depending on the feedstock, a SEBP plant should be as close as possible to the source of the feedstock in order to minimize these costs.

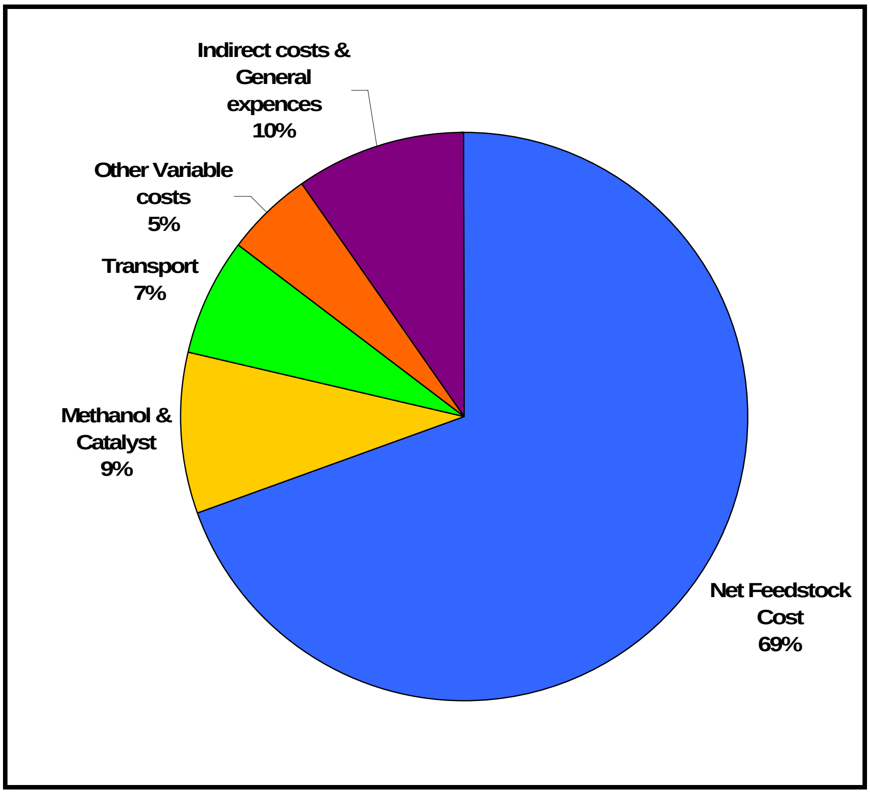


Figure 12: Pie chart showing cost contribution to total manufacturing cost of a SEBP plant

All the calculations so far have assumed that the recovered methanol is not recycled. This assumption was based on the fact that the recycled methanol is not 100% pure and might influence the activity of the catalyst. So in order not to underestimate costs, only fresh methanol is used for cost calculations of biodiesel production. If however, this 230kg/h methanol could be recycled without affecting the reaction rate, it would reduce the manufacturing cost for any type of feedstock by 28 cents/litre biodiesel.

4.2.7 Price sensitivity analyses of a SEBP plant

Agricultural commodity prices such as those of oilseeds and soybeans vary greatly not only from year to year but also from month to month. Their prices are determined by the import parity and local stock supply. Biodiesel production costs and profitability are influenced by the feedstock cost and with great variation in these feedstock prices, it is important to establish to how sensitive the production costs are to feedstock price variations.

Appendix G shows the full sensitivity analyses of the effect of varied feedstock prices on the manufacturing costs of biodiesel. The feedstock costs are varied from -25% to +25% of the current trading price to include the fluctuations mentioned above. Manufacturing costs for each feedstock are presented in cents/litre and the percentage change is based on the cost in current conditions. All other prices and costs are held constant while varying the price of the feedstock. Figure 13 gives a graphical representation of the results shown in Appendix G by plotting the change in manufacturing costs (%) against the change in feedstock price (%).

The results illustrate a direct linear relationship between feedstock price and manufacturing cost. The gradient of canola price change is about 1 which means that the manufacturing cost will increase 1% for every 1% increase in the canola price. Sunflower has a gradient of less than 1 (0.86) which means that an increase in sunflower price will not have as great effect on the manufacturing cost. Soybeans on the other hand have a gradient of 1.6 which means that the manufacturing costs will increase 1.6 times more than the increase in soybean price. This means that the manufacturing cost of a soybean SEBP plant is the most sensitive to any fluctuations in feedstock prices. The reason for this is due to the large volume of soybeans needed for biodiesel production due to their lower oil content. This is also illustrated by the high oil yielding crops, canola and sunflower, whose manufacturing costs are less sensitive to crop price changes.

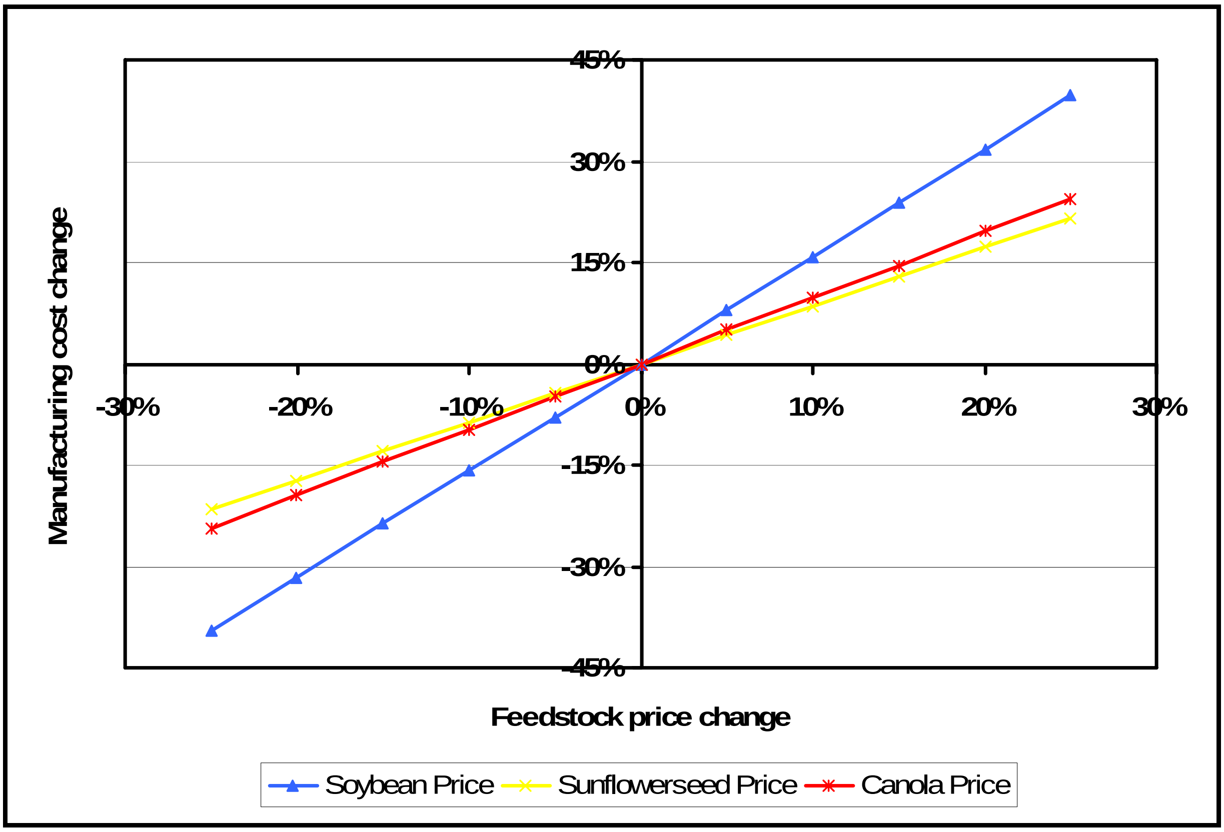


Figure 13: Manufacturing cost sensitivity to the feedstock prices

Considering the fluctuating and uncertain nature of agricultural commodity prices, the sensitivity of manufacturing cost against these would also illustrate the risk involved for using certain crops for biodiesel production. Based on these figures it would be a lot more risky using soybeans for the production of biodiesel as the manufacturing cost increase 1.6 times the price increase. Whereas the risk when using sunflower seeds and canola is considerably less with a one to one percentage increase of manufacturing cost against an increase of seed prices.

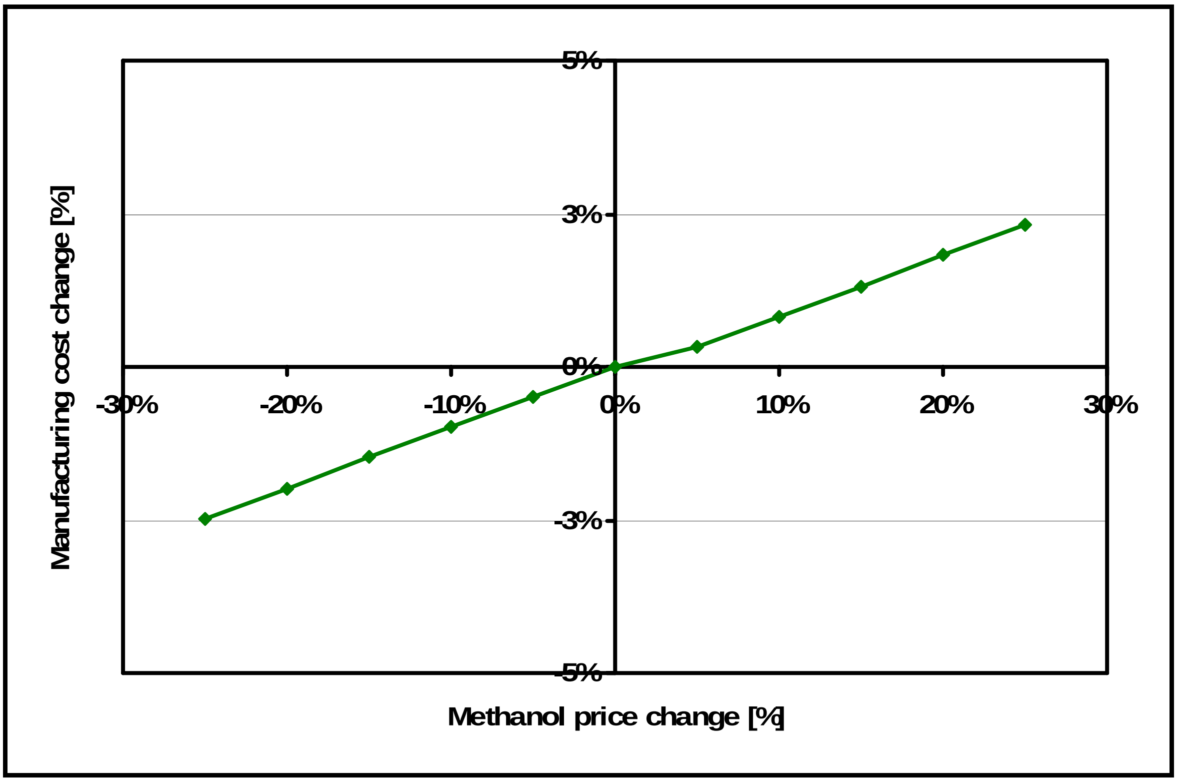


Figure 14: Manufacturing cost sensitivity to the methanol price

Methanol is one of the major chemical commodities traded internationally and is widely used as a chemical intermediary or solvent. The international methanol price has increased from about US$290/ton to US$360/ton in the last 6 months and it is believed that an increase in global biodiesel production might apply further upward pressure to the price of methanol. SASOL is the main supplier of methanol in South Africa and they currently sell their methanol in bulk at R3450/ton (VAT included). SASOL believes that an increase in biodiesel production in South Africa might push up this price (Rasool, 2006) and it is thus important to evaluate how sensitive the manufacturing cost of biodiesel is to an increase in the price of methanol. Figure 14 gives a graphical representation of the results shown in Appendix G by plotting the change in manufacturing cost (%) against the change in methanol price (%). The manufacturing cost considered for this sensitivity analyses is the average cost of canola, soybeans and sunflower seeds. The results indicate a change of less than 3% in manufacturing costs of a SEBP plant for a methanol price change of 25%. Thus, even at a methanol price R1000/ton greater than the current one (R3450/ton) the manufacturing cost of a SEBP plant would only be about 3% higher than at the current price. Comparing these to the sensitivity of feedstock price changes, it is safe to say that a methanol price increase would not have that drastic effect on the financial feasibility of biodiesel production.

Glycerol is used in a variety of grades to a wide range of applications, including resins, polyols, food, cosmetics, drugs, explosives, tobacco, paper making, adhesive and textiles. It is therefore a complex market with many countries having some level of manufacturing capability although overall world levels of production are not great in the context of the international chemical industry, being less than one million tonnes annually (Duncan, 2003). Prices have significantly been affected by the production of biodiesel driven by low crude vegetable oil prices; the resultant oversupply of glycerol caused a sharp reduction in its price (Duncan, 2003). This indicates that glycerol prices are sensitive to supply, a factor of particular relevance for biodiesel production as the volumes of by-product glycerol are high relative to most other production sources. If forty five SEBP plants would produce enough biodiesel to replace 10% of South Africa's diesel by 2010, about 123000 tons of 95% pure glycerine would be produced annually. This could push the price down to such a level that it would be cheaper to dispose of it than transporting it to the buyer. It is for this reason that this study assumes no market for the glycerol for all the cost calculations in order not to underestimate production costs. However, with intense research being conducted worldwide about alternative cost effective uses for glycerol, a breakthrough might trigger an increase in global demand for glycerol and its price may rise accordingly. It is for this reason that the affect of various glycerol price levels on the manufacturing cost of biodiesel is investigated.

Table 20: Influence of glycerol selling price on the manufacturing cost

Glycerine Selling Price ***R/ton***	**Manufacturing cost reduction** ***cent/litre biodiesel***
250	3
500	6
1000	12
2000	23

A single SEBP plant produces about 345kg/h of 95% pure glycerine of which 15kg/h is used as fuel for the burner which means a net glycerine production of 330kg/h. Table 20 shows the influence that the glycerol selling price has on the manufacturing cost.

The results reveal that the manufacturing costs will decrease by about 12cents/litre for every R1000/ton increase in the price of glycerol.

The SEBP plant is considered as an extraction plant added to a COBP plant. The **extraction costs** used in the cost calculations include every cost associated with the extraction part of the plant. Appendix E shows that an average extraction cost was used after consulting three different parties in the oilseed crushing industry (Nel, 2006; Victor, 2006; Becker, 2006; Nola Oil, 2006). The extraction costs obtained from the different parties varied between R150/ton to R350/ton. This is quite a large variance and it is important to determine how different extraction costs would influence the manufacturing costs of a SEBP plant. Figure 15 is a graphical representation of how the average manufacturing cost (canola, soybeans and sunflower seeds) varies as the extraction cost is changed.

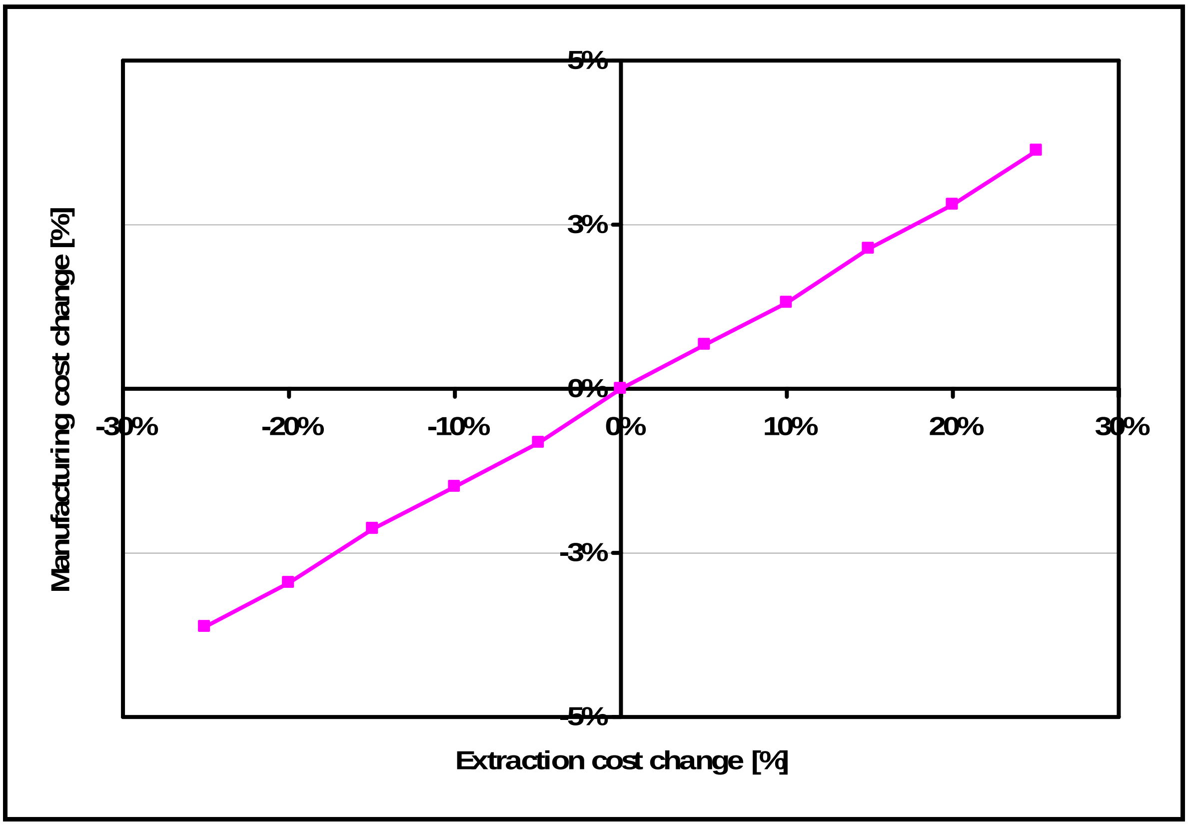


Figure 15: Manufacturing cost sensitivity to the extraction cost

Figure 15 shows that the manufacturing cost changes by about 4% if the extraction cost is varied by 25%. This means that the total manufacturing costs are still reliable even when an average extraction cost is taken for the calculations. This implies that if the costs of the extraction part of the plant were to increase it would not have a major influence on the total manufacturing cost.

Oilcake is another valuable product obtained from a SEBP plant. Being an agricultural commodity used for livestock feed, its price also varies quite substantially over time. Oilcake prices depend on its protein content and import parity. As already mentioned, canola and soybean oilcake are more valuable than sunflower oilcake due to their higher protein content and resulting nutritional value for livestock feed. All oilcake prices are correlated and some agriculturalists predict a drop in prices due to a possible global oversupply of oilcake resulting from an increase in biodiesel production from oilseeds (Griessel, 2006). Such a price drop would imply that canola and soybean oilcake might be looking at a price closer to R1500/ton compared to its current price of R1900/ton and sunflower oilcake prices could drop from R1170/ton to below R1000/ton. Such an event would obviously influence the financial feasibility of biodiesel production as the value of the oilcake directly influences the 'net feedstock cost' and thus the manufacturing costs of a SEBP plant.

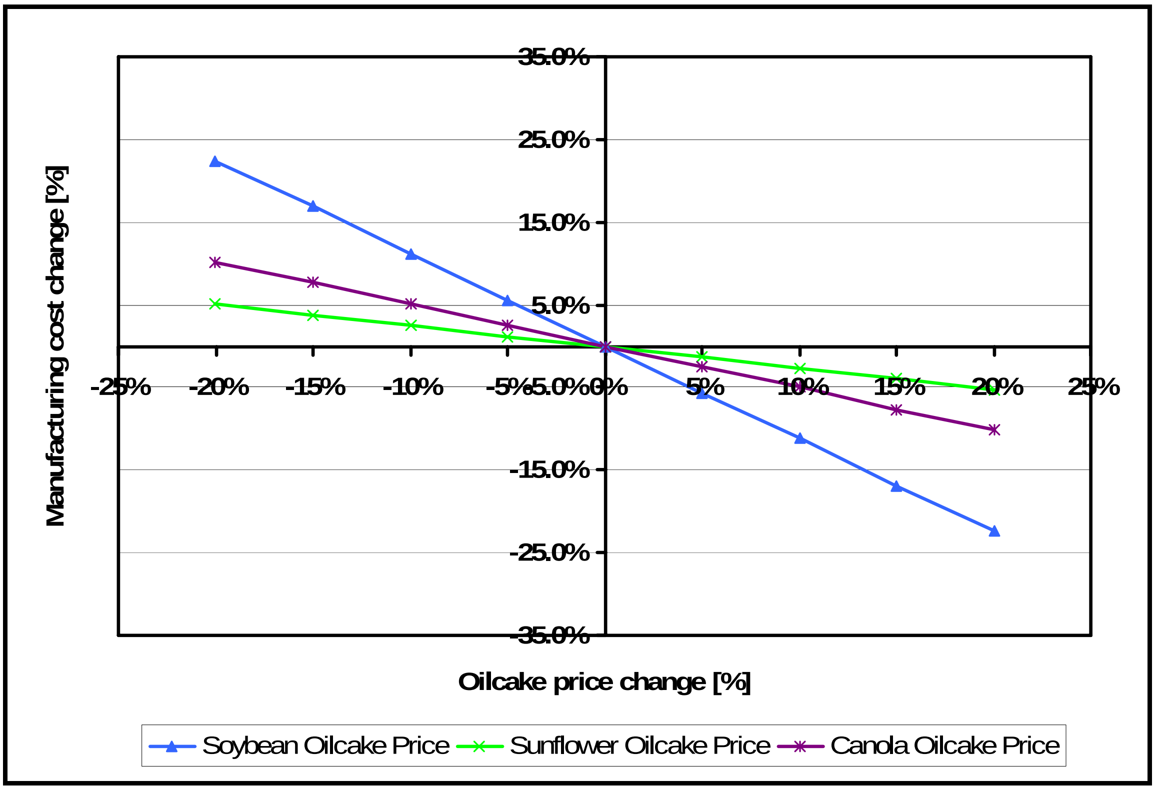


Figure 16: Manufacturing cost sensitivity to the oilcake prices

Figure 16 shows that the manufacturing cost of a soybean SEBP plant are very sensitive to the change in the price of soybean oilcake. The graph shows a gradient of about -1 which means that for every 1% decrease in the price of soybean oilcake, the manufacturing costs increase by about 1%. This can be attributed to the large amount of soybean oilcake produced, which is more than five times the amount of biodiesel produced. Thus, a decrease in the price of oilcake, as predicted by some, will have a major affect on the production cost of a soybean SEBP plant. Oilcake price fluctuations will not affect the canola and sunflower SEBP plant as much, with gradients of -0.5 and -0.25, respectively. The reason for this being that these plants only produce about 1.5 times more oilcake than biodiesel which is about a third of what a soybean SEBP plant produces. These lesser volumes of oilcake cause a lower sensitivity of manufacturing cost to oilcake prices. The slightly higher influence that the canola oilcake price has on its manufacturing cost compared to sunflower is due to the relatively higher value of canola oilcake and its resulting greater influence on manufacturing cost. Looking at these results it is evident that a soybean SEBP plant runs the highest risk for changes in oilcake prices while the lowest risk lies with the sunflower SEBP plant.

4.2.8 Profitability of a SEBP plant

The saying, “money makes the world go round”, implies that biodiesel will only be produced if a profit can be generated from its sales. One of the key factors which determine whether biodiesel production will be profitable is the biodiesel selling price. Although the price of fossil diesel fuel is not a direct component of the costing of biodiesel production, it provides the baseline against which the cost of biodiesel must be compared. This means that the world crude oil price also has a direct effect on the financial feasibility of production.

The previous section shows the manufacturing cost of the different SEBP plants. To obtain the **break-even cost** per litre biodiesel for these plants, a biodiesel tax of R1.01/litre has to be added to the manufacturing cost. This fuel tax is only applicable to commercial biodiesel producers that produce more than 300000 litres per year (SARS website, 2006). Figure 17 shows the break-even prices of the different biodiesels and compares them to fossil diesel.

The fossil diesel price is based on a selling price of R6.80/litre at the coast (30 August 2006), which means that the basic manufacturing cost includes the basic diesel price plus the transport and service fees. Duties and taxes of fossil diesel amount to R1.41/litre. The 40 cents/litre dealer margin is not included in this figure. The basic fossil diesel price in South Africa depends on the world crude oil price and the US$ exchange rate.

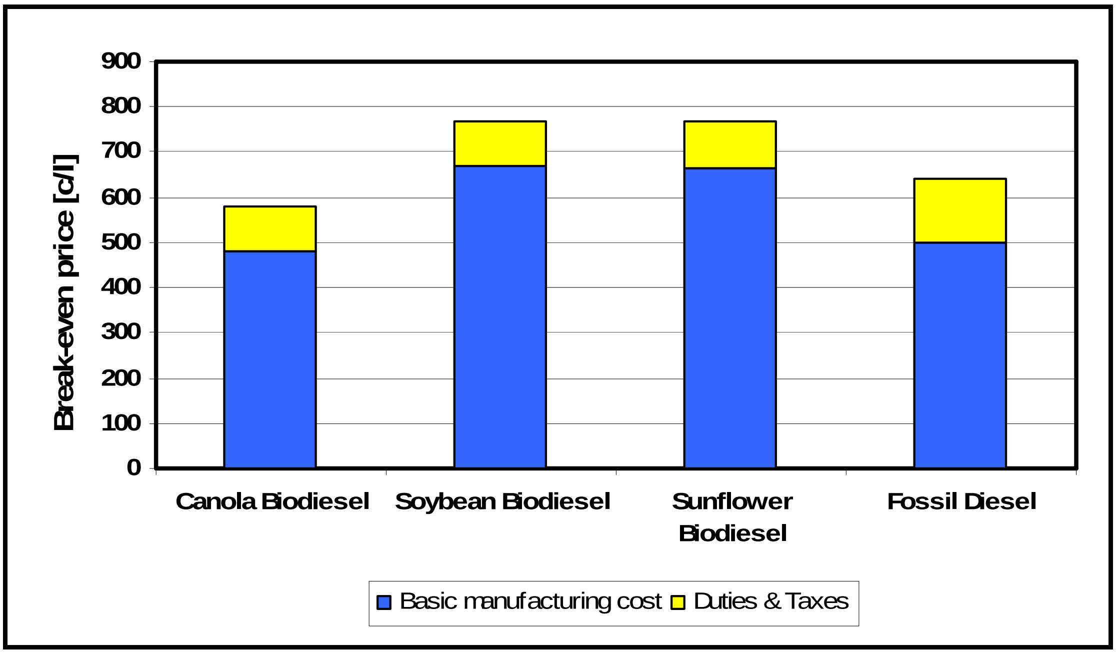


Figure 17: Break-even price of biodiesel compared to fossil diesel

The break-even price of the biodiesel and the factors affecting it has been discussed in section 4.2.6 and will not be repeated here. Fuel tax for biodiesel is 40 cents/litre less than that for fossil diesel. This legislation was passed by the government in order to make biodiesel more competitive against fossil diesel (Booysen, 2006).

Figure 17 shows that canola biodiesel is currently the only one that can compete with the price of fossil diesel. However, it must be kept in mind that these figures could change drastically over a month or so, depending on the feedstock, oilcake and crude oil price and US$/Rand exchange rate.

Looking at the recent fall in crude oil price and the relatively high oilseeds prices, the comparison between the fossil diesel and biodiesel price seems rather unfair. Biodiesel should not compete with the price of fossil diesel to enter the fuel market in South Africa, but rather establish its own niche market based on its fuel properties and environmental benefits. The creation of such a market would not lie in the hands of the biodiesel producers but rather rely on legislation passed by the government. This statement has been discussed in greater detail in section 4.1.2, but one example would be that if biodiesel blending into fossil diesel became mandatory, it could be sold at a price that would allow profitable biodiesel production.

This section of the study investigates the profitability of the different SEBP plants at various biodiesel selling prices. The results can be used to either see at what fossil diesel price biodiesel would start being competitive in a free market, or to see how the profitability is influenced by different selling prices of biodiesel. After seeing that the manufacturing costs of the SEBP plants are most sensitive to feedstock and oilcake prices, the section also looks at how these would influence the profitability of the different SEBP plants at various biodiesel selling prices.

A 2500 kg/h SEBP plant will use about 237600 litres of biodiesel per annum for its power generator. This means it will be able to sell about 22.3 million litres per year. This amount is used to calculate the potential net profit or loss for such a plant at various biodiesel selling prices. Firstly the profit per litre biodiesel is calculated as this is a good indication for this type of business. A company tax rate of 29% (this is standard in South Africa since 2006) is used for the net profit after tax calculation. Finally a rate of return on investment (RORI) is also shown for possible investors. The RORI is assumed at a fixed biodiesel selling price but can give a broad idea at what prices such a biodiesel plant would be a good investment. It is important to keep in mind that all the current prices (30 August 2006) of feed stocks and products are used and kept constant except the price of the biodiesel, which is varied for the calculations. Complete calculations and results are shown in Appendix H. The summarized results for each type of feedstock are shown in the tables below.

A canola SEBP plant requires a capital investment of about R110 million. Canola biodiesel production becomes financially feasible at a biodiesel selling price of around R5.90/litre. Its relatively low break-even cost (Figure 17) makes it profitable to produce biodiesel which sells around R6.50/litre, showing a RORI of 10%. Table 21 shows all the results for the various selling prices of biodiesel.

Table 21: The profitability of a canola SEBP plant for various biodiesel selling prices

Biodiesel Selling Price	Profit per litre before tax	Net Profit after 29% income tax	Rate of Return on Investment
R/litre	*R/litre*	*Thousand Rand*	*%*
6.50	0.69	10906	10%
7.00	1.19	18810	17%
7.50	1.69	26713	25%
8.00	2.19	34616	32%
8.50	2.69	42519	39%

A soybean SEBP plant requires a capital investment of about R145 million. It has a higher break-even cost than canola biodiesel which means that a soybean biodiesel only becomes financially feasible at a selling price of about R7.80/litre. And only showing a RORI of 9% at a price of R8.50/litre. Table 22 shows all the results for the various selling prices of biodiesel of a soybean SEBP plant.

Table 22: The profitability of a soybean SEBP plant for various biodiesel selling prices

Biodiesel Selling Price	Profit per litre before tax	Net Profit after 29% income tax	Rate of Return on Investment
R/litre	*R/litre*	*Thousand Rand*	*%*
6.50	-1.20	-18,968	-13%
7.00	-0.70	-11,064	-8%
7.50	-0.20	-3,161	-2%
8.00	0.30	4,742	3%
8.50	0.80	12,645	9%

A sunflower SEBP plant requires a capital investment of about R115 million. Its biodiesel has about the same break-even cost as soybean biodiesel which means that it will also only be financially feasible to commercially produce sunflower biodiesel at about R7.80/litre biodiesel. Table 23 shows all the results for the various selling prices of biodiesel

Table 23: The profitability of a sunflower seed SEBP plant for various biodiesel selling prices

Biodiesel Selling Price	Profit per litre before tax	Net Profit after 29% income tax	Rate of Return on Investment
R/litre	*R/litre*	*Thousand Rand*	*%*
6.50	-1.17	-18,493	-16%
7.00	-0.67	-10,590	-9%
7.50	-0.17	-2,687	-2%
8.00	0.33	5,216	5%
8.50	0.83	13,119	11%

Figure 18 gives an indication of the profitability of each type of SEPB plant at various selling prices for biodiesel. As already mentioned, a canola SEBP plant would be the only plant that would be financially feasible if biodiesel were to be sold at the current fossil diesel price. But being a borderline case, a slight drop in world crude oil prices, a stronger South African Rand or an increased canola price could cause canola biodiesel production to become financially unfeasible overnight.

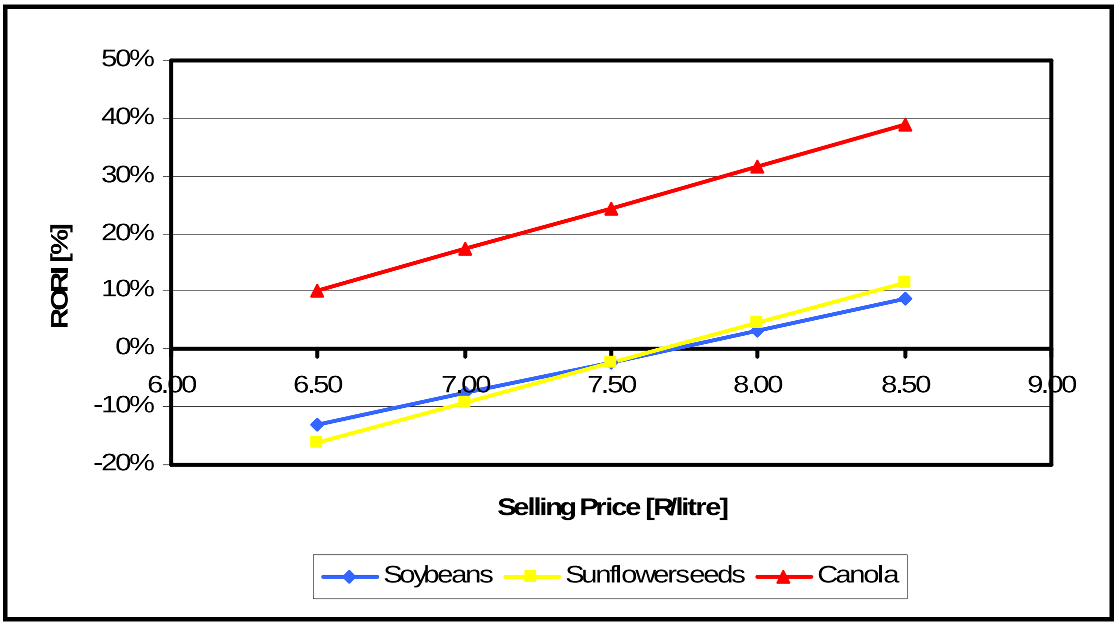
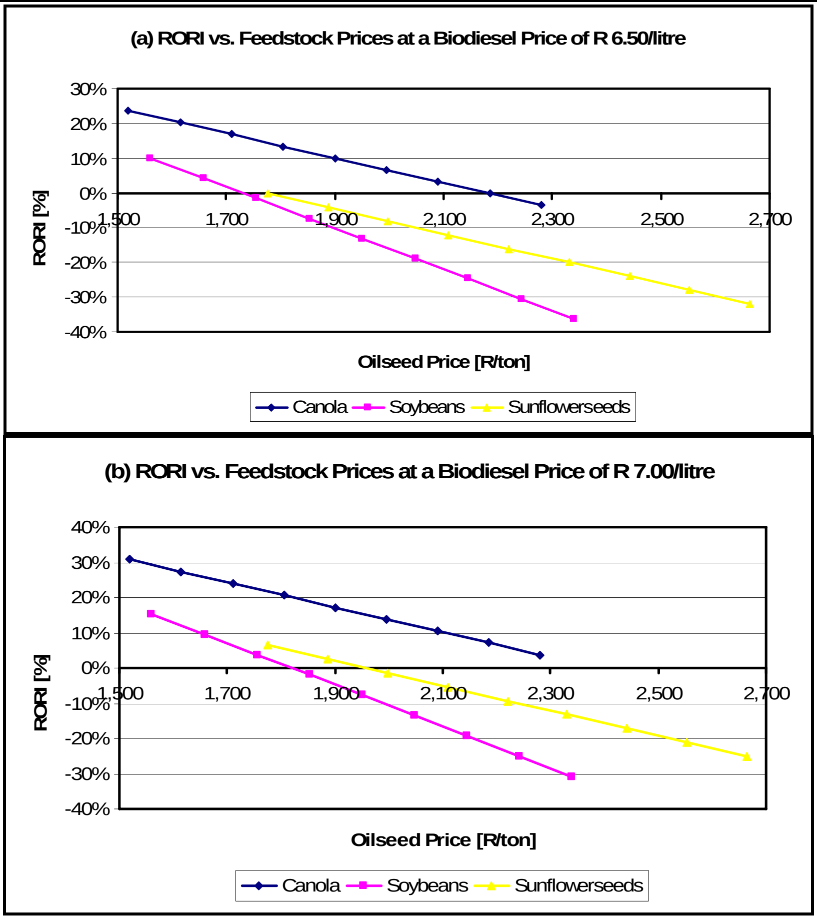


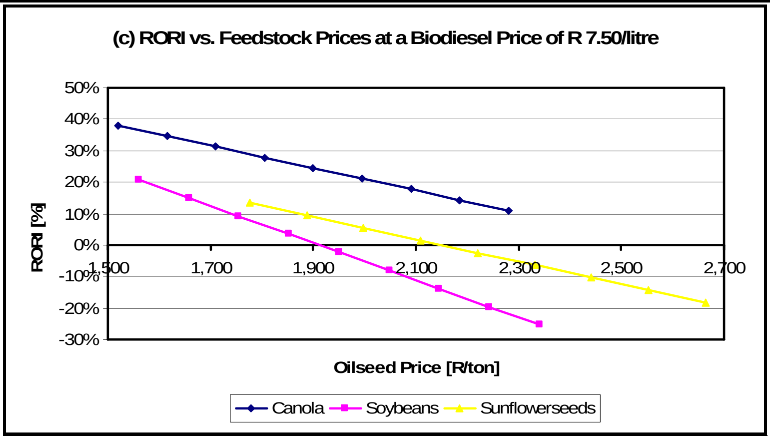
Figure 18: RORI vs. Biodiesel selling price for various feed stocks

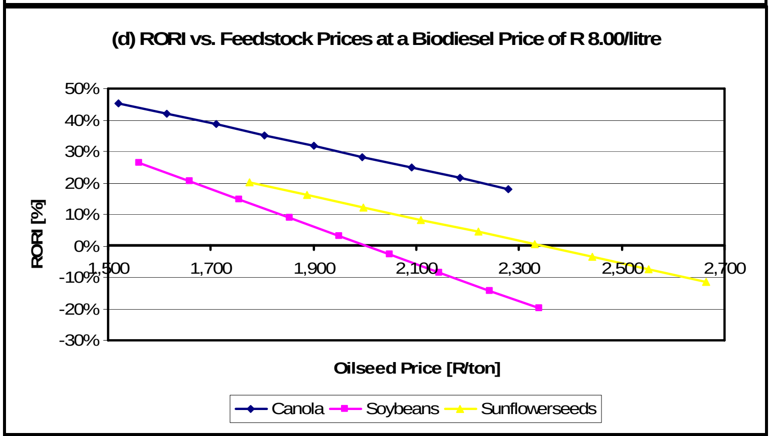
At the moment sunflower and soybean biodiesel cannot compete with the price of fossil diesel, but could potentially become financially feasible if the price of fossil diesel increased by at least R1.00/litre (currently at R6.80/litre). Although it is not impossible for the fossil diesel price to increase by R1 or even R2/litre, it is highly undesirable to directly connect the profitability of a biodiesel plant to external factors such as the world crude oil price and the US$/Rand exchange rate.

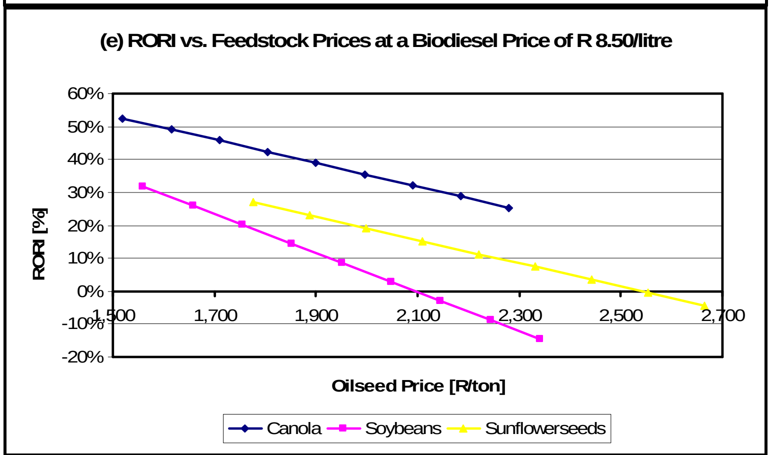
Although canola can be considered a borderline case, overall the commercial biodiesel from oilseeds seems financially unfeasible in South Africa when competing purely with the price of fossil diesel. However, if a separate market can be created for biodiesel, and certain take off is guaranteed to producers, large scale biodiesel production would take off in South Africa. For example if high enough minimum prices are set for biodiesel in South Africa, it would minimize the risk for producers and a lot more players would invest in SEBP plants. This could create a healthy competition in the biodiesel market and possibly lower manufacturing costs, making it even more financially feasible to produce biodiesel in South Africa. As already mentioned in section 4.1.2, this type of market can only be generated by legislative regulative forces initiated by the government.

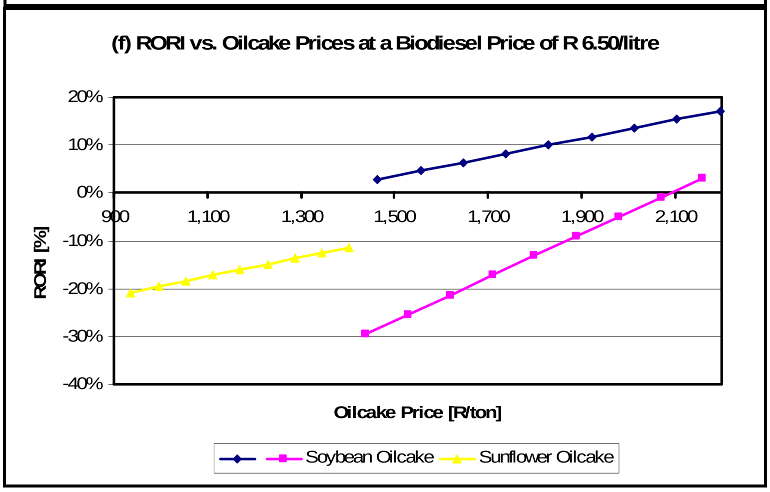
The sensitivity analyses in section 4.2.7 revealed that feedstock and oilcake price changes have the biggest influence on manufacturing costs of biodiesel. These two would then obviously also have the biggest influences on the profitability of a SEBP plant. Figure 19 (a) – (e) show the RORI for a canola, soybean and sunflower SEBP plant for different feedstock prices at a set biodiesel selling price as indicated. The oilcake price for all these is held constant at its current value. Figure 19 (f) – (j) show the RORI for the different plants for the different oilcake prices at a set biodiesel price. The feedstock prices are held constant at their current value.




(c) RORI vs. Feedstock Prices at a Biodiesel Price of R 7.50/litre
RORI [%]
50%
40%
30%
20%
10%
0%
-10%
-20%
-30%
1,500
1,700
1,900
2,100
2,300
2,500
2,700
Oilseed Price [R/ton]
Canola
Soybeans
Sunflowerseeds


(d) RORI vs. Feedstock Prices at a Biodiesel Price of R 8.00/litre
RORI [%]
50%
40%
30%
20%
10%
0%
-10%
-20%
-30%
1,500
1,700
1,900
2,100
2,300
2,500
2,700
Oilseed Price [R/ton]
Canola
Soybeans
Sunflowerseeds


(e) RORI vs. Feedstock Prices at a Biodiesel Price of R 8.50/litre
RORI [%]
60%
50%
40%
30%
20%
10%
0%
-10%
-20%
1,500
1,700
1,900
2,100
2,300
2,500
2,700
Oilseed Price [R/ton]
Canola
Soybeans
Sunflowerseeds


(f) RORI vs. Oilcake Prices at a Biodiesel Price of R 6.50/litre
RORI [%]
20%
10%
0%
-10%
-20%
-30%
-40%
900
1,100
1,300
1,500
1,700
1,900
2,100
Oilcake Price [R/ton]
Soybean Oilcake
Sunflower Oilcake

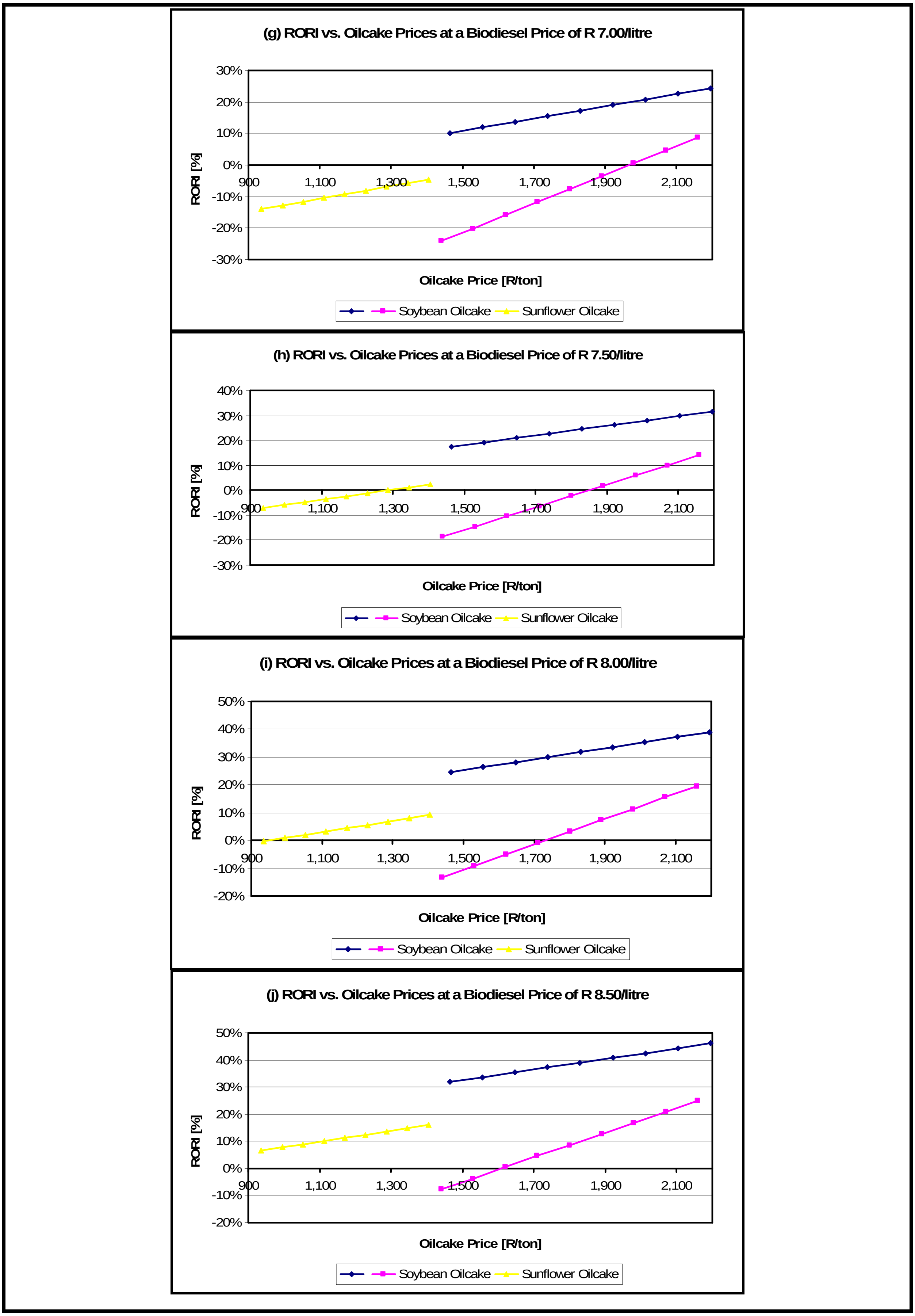


Figure 19: Profitability of biodiesel at various oilseed and oilcake prices

The results show what the expected RORI on investment would be at various feedstock and oilcake prices for certain biodiesel selling prices. These results can be used as an indication at what oil crop, oilcake and biodiesel prices, biodiesel would be profitable and financially feasible.

The value of the glycerol can also have an affect on the profitability as it can decrease manufacturing costs and increase profits. Refer to section 4.2.7 for these results and implications.

4.2.9 Manufacturing costs of a COBP plant

Total manufacturing cost refers to the cost of the day-to-day operation of a biodiesel plant and is divided into two categories: variable manufacturing costs and indirect manufacturing costs & general expenses (or fixed manufacturing cost) (Turton et al., 2003).

Variable manufacturing costs consist of raw material cost, catalyst cost, operating labour fees, supervisory and clerical labour fees, utilities, transport cost, maintenance and repairs, operating supplies and laboratory charges.

Crude oil, methanol and catalyst costs are calculated from the mass balance (section 4.2.4) and current (August 2006) local and international prices obtained form various sources (Appendix E). It is assumed that the COBP plant needs about 2 operators per shift which are paid an average wage of R50/hour. This assumption is based on the fact that the containerized oil processing plant is easy to operate and not labour intensive. The supervisory and clerical labour costs are estimated at about R100000 per month. Water is the only utility needed by the plant seeing that it generates its own electricity and heat by using a generator and burner running on biodiesel and glycerol. Transport cost calculations shown in Appendix E are based on indicative rail prices from Spoornet SA (Swart & Maree, 2006). Maintenance & repair costs, operating supplies and laboratory charges are calculated by multiplying with related factors obtained from Turton et al. (2003).

Indirect manufacturing costs and general expenses include overheads, insurance, administrative cost, research and development and depreciation. These are all calculated by multiplying with related factors, which are commonly applied to economic assessments according to Turton et al. (2003). The fixed capital of the plant is depreciated at 10% per annum, straight line method.

Prices used in the calculations, further referred to in this study as the current prices and are shown in Table 24 and together with its sources in Appendix E. As already mentioned in section 4.2.1, prices of imported crude oils are used for the calculations. These would present the costs involved if South Africa were to import its feedstock for biodiesel. These prices are higher than local vegetable oil prices but are assumed as a worst case scenario due to an absence of large scale local vegetable oil production.

Table 24: Current commodity prices used for cost calculations of COBP plant

Item	FOB Price	FOR Price
	US$/ton	R/ton
Soybean oil (Argentina)	502	5500
Sunflower oil (Argentina)	575	6100
Palm oil (Malaysia)	468	5220
Rapeseed oil (Europe)	794	7920
Methanol		3450
Potassium Hydroxide		7800

Appendix F shows the detailed calculated manufacturing costs of a 2500kg/h COBP plant for the different types of crude oils. The only difference, concerning this study, between these crude oils is their price. A summary of these costs for the different types of crude vegetable oil are shown in Table 25 and Table 26 and discussed below.

The only difference in the manufacturing costs of the different types of feedstock COBP plants are the vegetable oil feedstock costs. The annual vegetable feedstock costs and cost/litre biodiesel for the different types of COBP plants are shown in Table 25.

Table 25: Vegetable oil feedstock costs for a COBP plant

Feedstock Cost	*Annual*	*Cost/litre*
	Thousand rand	*cent/litre*
Palm oil	113370	509
Soybean oil	119451	537
Sunflower oil	132482	595
Rapeseed oil	172010	713

These oil feedstock costs are added to the costs shown in Table 26, which are the same for any type of feedstock COBP plant, to give the total manufacturing cost.

Table 26: Remaining manufacturing costs of a COBP plant

Remaining Manufacturing Cost	*Annual*	*Cost/litre*
	Thousand rand	*cent/litre*
Methanol & Catalyst	13660	61
Transport	13623	61
Other variable manufacturing costs	2855	13
Indirect manufacturing costs & General expenses	4020	18

The indirect cost shown in Table 26 is an average of the 4 different types of feedstock plants shown in Appendix F. These amounts only differ slightly due to a few factorial amounts based on the different direct manufacturing costs.

The comparative results of the manufacturing costs of the different types of COBP plants are shown in Figure 20.

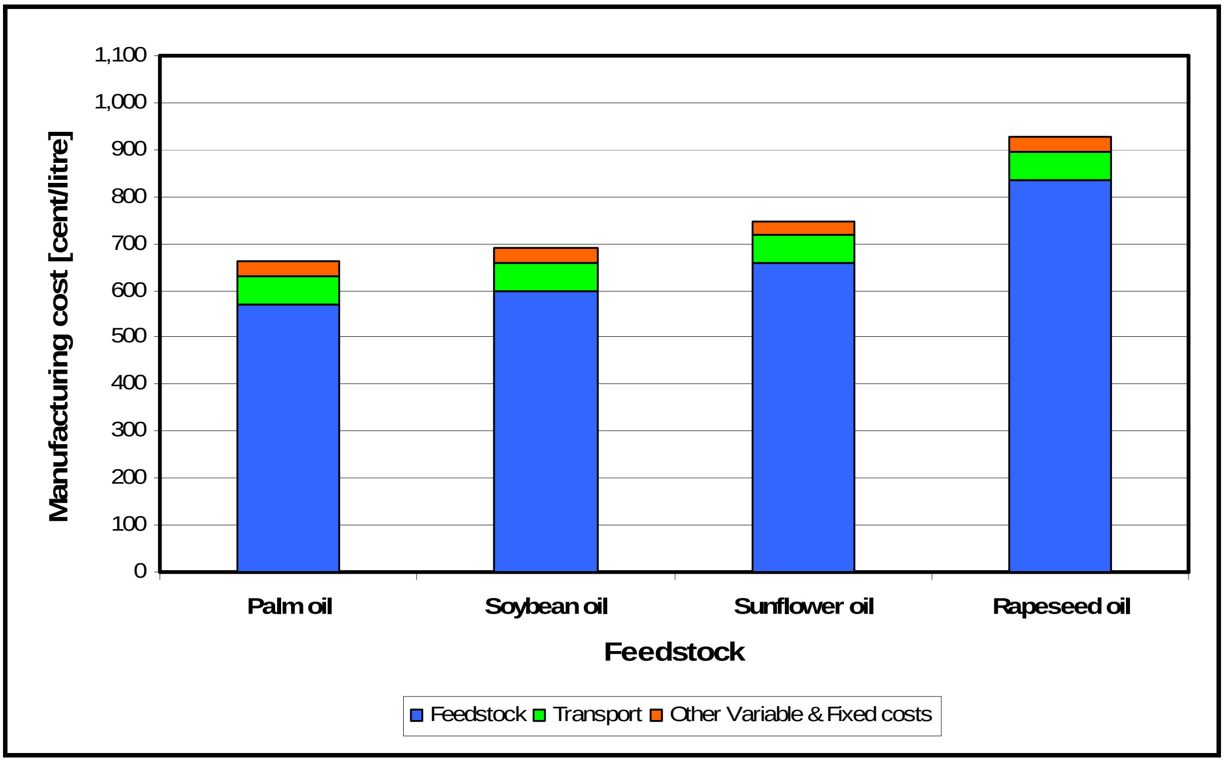


Figure 20: Manufacturing cost for different feed stocks used in a COBP plant

Results show that biodiesel manufactured from Malaysian imported **palm oil** can be manufactured for about R6.60/litre. Palm oil is currently one of the cheapest vegetable oils and its international trade has increased since global biodiesel production started to take off. South Africa cannot produce palm oil as it does not have the ideal climate to grow these trees. Although palm oil biodiesel does have some undesirable cold properties, if blended at ratios below 20% biodiesel these would not have an affect on the fuel.

Soybean oil biodiesel made from Argentinean imported soybean oil can be produced for about R6.90/litre. This is slightly higher (20 cents/litre) than the cost for producing biodiesel from locally produced soybeans in a SEBP plant.

Biodiesel can be produced at R7.50/litre from imported **sunflower oil**. Sunflower oil is mainly used for cooking purposes and its international price is higher than that of soybean oil and palm oil. This is about 80 cents/litre more than sunflower biodiesel produced by a SEBP plant using locally produced sunflowers.

The international price of **rapeseed oil** cannot be compared to other vegetable oils as it is almost one and a half times the price of soybean oil. European biodiesel is mainly made from rapeseed oil which has excellent fuel properties. But its high price makes it a very uneconomical feedstock for biodiesel in South Africa. At current prices it would cost about R9.30 to produce one litre of biodiesel. For this reason it is no longer regarded as a possible feedstock for biodiesel production in South Africa at this stage.

Results show that feedstock costs contribute even more to the total manufacturing cost in a COBP plant than in a SEBP plant. This and the fact that feedstock costs are about the only varying manufacturing cost, suggest that the cheapest vegetable oil will most likely be able to produce the cheapest biodiesel as its COBP plant would the lowest manufacturing costs.

Transport cost, as seen in Figure 21, is the second largest contributor after raw material cost to the manufacturing cost of a COBP plant.

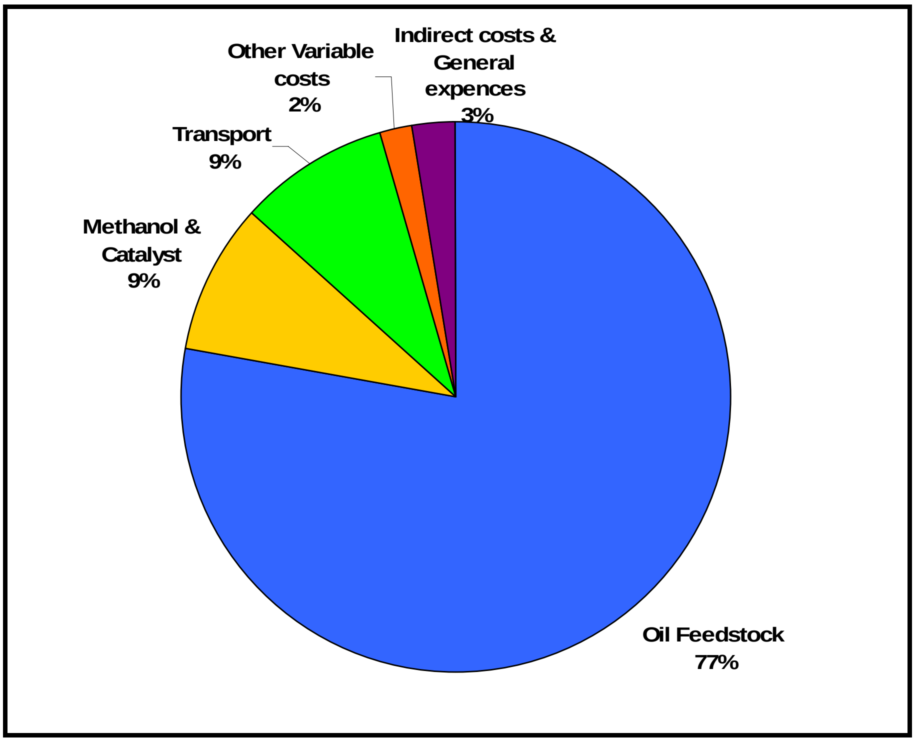


Figure 21: Pie chart showing cost contribution to the total manufacturing cost of a COBP plant

4.2.10 Price sensitivity analyses of a COBP plant

A sensitivity analyses on the manufacturing costs of a COBP plant is done on the price of crude vegetable oil and methanol. This choice is based on the fact that both these items are internationally traded commodities whose prices fluctuate and might increase even more as the global biodiesel production increases further.

For the sensitivity of the manufacturing cost on the crude vegetable oil price, the current price of imported soybean oil, R5500/ton, is selected as standard. A -25% (R4125/ton) to +25% (R6875/ton) of the crude vegetable oil price sensitivity was calculated during which all the other prices and costs were held constant. This range of analyses includes all the prices that the different vegetable oils have traded for the last year and also the current prices for locally produced vegetable oils. It also covers prices on the upside which experts predict the average vegetable oil price could reach due to a growing biodiesel market (FAPRI, 1995). The results are shown graphically in Figure 22 while calculations are shown in Appendix G.

The impact that a methanol price change would have on the manufacturing cost was also calculated and is presented in Figure 22.

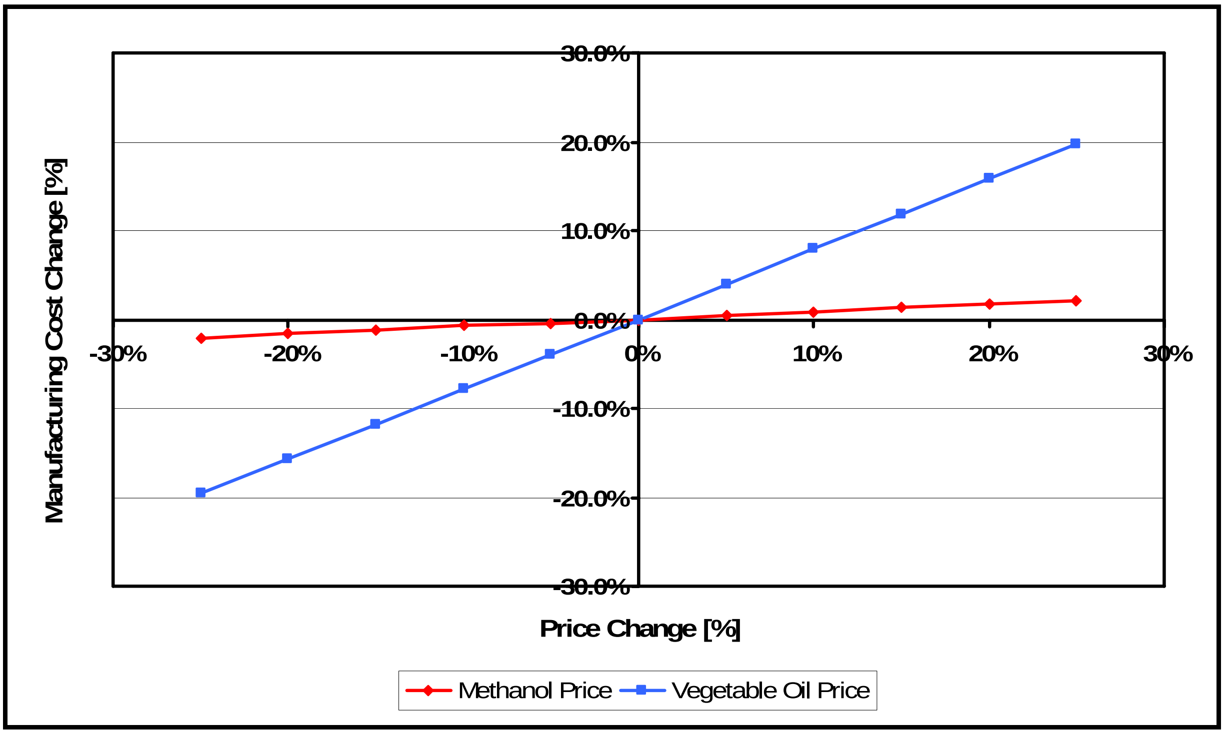


Figure 22: Manufacturing cost sensitivity of COBP plant to vegetable oil and methanol prices

The results show that the manufacturing costs of a COBP plant are not sensitive to changes in the methanol price. Manufacturing costs change by about 2% if the methanol price changes by 25%. Thus, a methanol price change would not hold great risk to the production of biodiesel in a COBP plant.

The manufacturing costs of a COBP plant are sensitive to a change in the crude vegetable oil price. Results show a change of about 20% in manufacturing costs if vegetable oil prices change by 25%. With the unpredictable fluctuating nature of vegetable oil prices it means that such a plant runs the risk of higher manufacturing costs and lower profits in times of increased vegetable oil prices.

4.2.11 Profitability of a COBP plant

The same factors affecting the profitability of a SEBP plant also play a role in determining the profitability of a COBP plant. This section investigates first of all whether it would be profitable to produce biodiesel from imported vegetable oil when comparing the biodiesel selling price to that of fossil diesel. Secondly it also determines at what crude vegetable oil selling prices, biodiesel production would become profitable.

Section 4.2.9 shows the manufacturing costs of the different COBP plants. To obtain the **break-even cost** per litre biodiesel for these plants, a biodiesel tax of R1.01/litre is added to the manufacturing cost. This fuel tax is only applicable to commercial biodiesel producers that produce more than 300000 litres per year (SARS website, 2006). Figure 23 shows the break-even prices of the different biodiesels produced from imported crude vegetable oils and compares them to the price of fossil diesel. As already mentioned, crude rapeseed oil has been omitted due to its high price and subsequent high manufacturing cost.

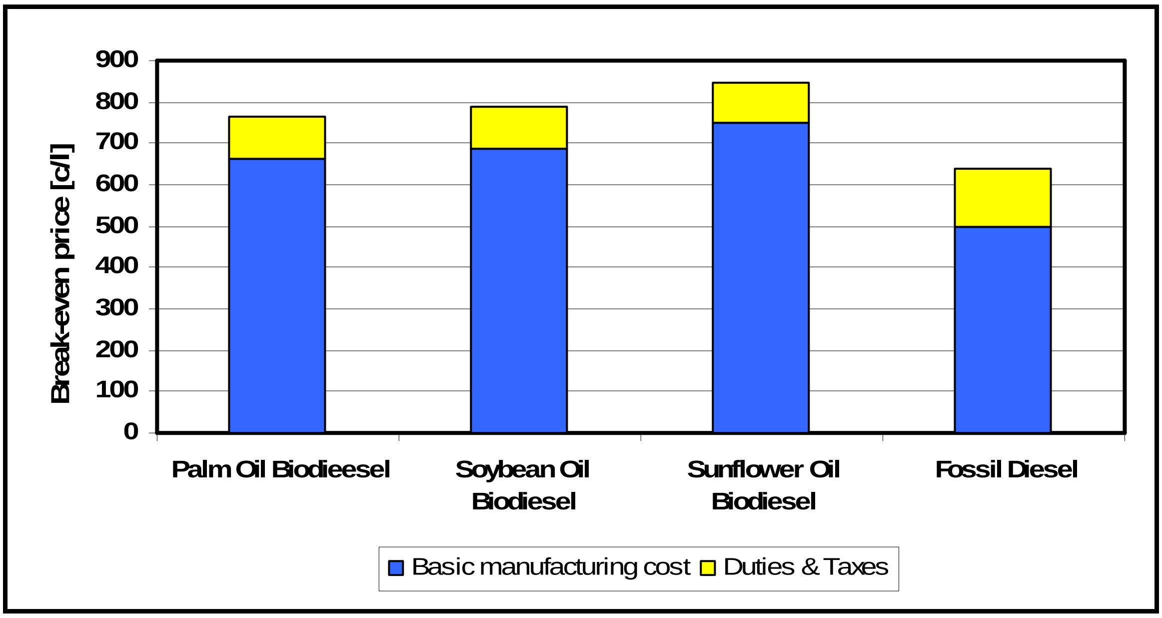


Figure 23: Break-even costs of various imported crude vegetable oils biodiesel

Break-even costs show that currently the price of biodiesel, produced from imported crude oil, cannot compete with the fossil diesel price (R6.80/litre pump price at 30 August 2006). Palm oil biodiesel, currently the cheapest to manufacture, would only become profitable if it is sold at about R7.70/litre. Soybean oil biodiesel would be profitable at a selling price of about R7.95/litre while sunflower biodiesel would have to be sold for R8.50/litre in order for production to be profitable.

So at what crude vegetable oil price would biodiesel become competitive with fossil diesel? Or how profitable would biodiesel production be at various vegetable oil and biodiesel prices? Appendix J shows the profitability of the imported vegetable oils, palm oil, soybean oil and sunflower oil. These results just expand on the results shown in Figure 23 and calculate the RORI of a COBP plant assuming various biodiesel prices (R6.50/litre – R8.59/litre). A graphical summary of these results can be seen in Figure 24.

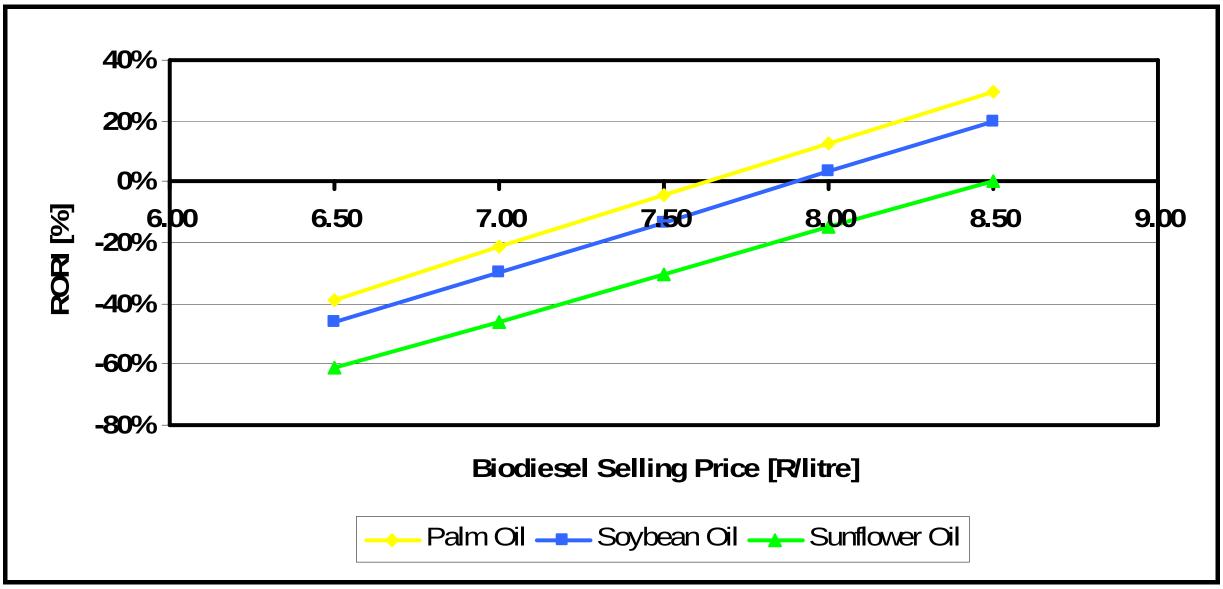


Figure 24: RORI of different feedstock COBP plants at various biodiesel selling prices

Currently a COBP plant using any type of imported oil will not be profitable if the biodiesel selling price is below R7.50/litre. Palm oil and soybean oil plants will start showing a good RORI when biodiesel can be sold between R8.00/litre and R8.50/litre. A sunflower oil COBP plant will have a positive RORI at a biodiesel selling price of R8.50/litre. Once again these results show that at the moment biodiesel cannot compete with fossil diesel on a selling price basis.

All the results of the COBP plant are based on imported feedstock. These costs could possibly be lowered if local feedstock were to be used. Figure 25 shows data that would help to asses the potential profitability of biodiesel production by means of a COBP plant. For example that crude oil will have to be bought for about R4000/ton to produce biodiesel which can compete with the price of fossil diesel (R6.50/litre).

The data in Figure 25 can also be used as a tool to compare the cost of producing biodiesel from oilseeds to that of using its crude vegetable oil. Assuming South Africa starts producing vegetable oil on a large scale, this data can be compared to the data in Figure 19 (section 4.2.8: profitability of biodiesel at different oil crop and oilcake prices), and used to decide on what type of plant , SEBP or COBP, would be more profitable at certain oil crop, oilcake, vegetable oil and biodiesel prices.

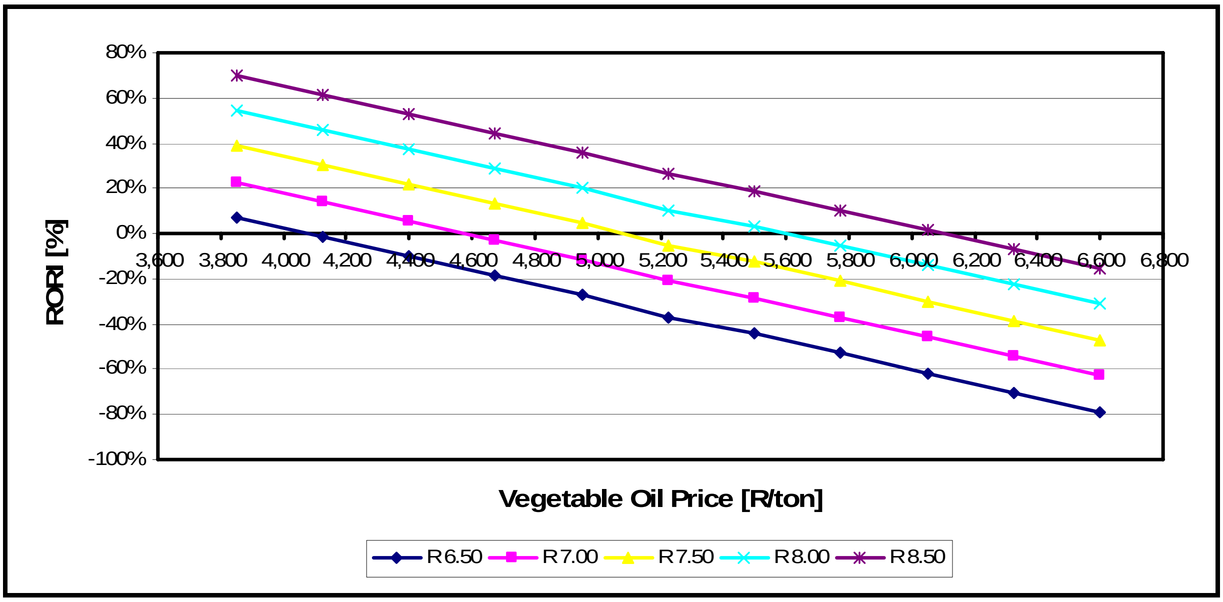


Figure 25: Profitability of biodiesel for different vegetable oil prices

4.2.12 SEBP plant vs. COBP plant

The financial feasibility of commercial biodiesel production in South Africa can be summed up by saying that under current (August 2006) conditions and prices, biodiesel would not be able to compete with the price of fossil diesel. Thus, at the moment, commercial biodiesel production is financially unfeasible without a legislative regulatory forced market. This, however, does not mean that commercial biodiesel production is not feasible at all in South Africa. It simply means that production will need to be financially feasible and profitable for the necessary players to engage in it. This could happen through rising fossil diesel prices, lower oilseed or vegetable oil prices or governmental legislation and policies. These policies or regulations could be in the form of subsidising feedstock for biodiesel production, subsidising the biodiesel itself, using government purchasing power, mandatory blending legislation, tax incentives or price compensation agreements.

When it does become financially feasible to produce biodiesel from crude vegetable oil, it can be done by either a SEBP plant or a COBP plant. Details and costs of these two types of production plants have been discussed in this section and are summarized in Table 27.

Table 27: Comparison of a SEBP plant to a COBP plant

	SEBP Plant	**COBP Plant**
Explanation	• Uses oilseeds for the production of biodiesel.	• Uses crude vegetable oil for the production of biodiesel.
Implication	• Plant crushes oilseeds and obtains vegetable oil (biodiesel production) and oilcake (feed). • Resulting oilcake is an important source of income for the plant. • Would also be able to use crude oil but would be a waste of capital investment. • Should be closer to the farms than to biodiesel outlet as larger volumes of seeds need to be transported. • Feedstock will have to be locally produced.	• Plant will buy crude oil from large scale oilseed crushers. • A large scale oil crusher's network will have to be established in South Africa as it is non-existent at the moment. • Oil crushers will be in the seed producing areas. • Biodiesel plant can be situated anywhere between biodiesel outlet and vegetable oil suppliers as the volumes to be transported are the same. • Vegetable oil feedstock can be locally produced or imported from overseas.
Assumptions made for cost calculations	• Choice of feedstock based on oil content, local production and price. • All current (30 August 2006) prices and costs are used for the calculations. • Plant operates 7920h/year. • A vegetable to biodiesel conversion of 95%. • No market for the glycerol that is produced as by-product. • The recovered methanol is not recycled.	• Choice of feedstock based on international production and price. • The plant uses only imported feedstock. This is to asses a type of 'worst case scenario' where SA would not be able to produce enough feedstock locally. • All current (30 August 2006) prices and costs are used for the calculations. • Plant operates 7920h/year. • A vegetable to biodiesel conversion of 95%. • No market for the glycerol that is produced as by-product. • The recovered methanol is not

		recycled.
Feedstock	• Soybeans (18% oil, R1900/ton) • Canola (40% oil, R1,950/ton) • Sunflower seeds (38% oil, R2,220/ton)	• Palm oil (R5,220/ton) • Soybean oil (R5,500/ton) • Sunflower oil (R6,100/ton) • Rapeseed oil (R7,920/ton) - too expensive
Plant Description	• Hexane seed extractor. • Containerized 2,500kg/h plant. This was found to be in the range of an ideal sized plant. • Production of about 22.5 million litres biodiesel per annum.	• Containerized 2,500kg/h plant. This was found to be in the range of an ideal sized plant. • Production of about 22.5 million litres biodiesel per annum.
Capital Cost	• R110 million - R145 million depending on feedstock. • Large amount of working capital required to cover the cost of 3 months' feedstock. • Working capital about 40% of capital investment.	• R45 million – R50 million depending on feedstock. • Large amount of working capital required to cover the cost of 3 months' feedstock. • Working capital about 75% of capital investment.
Manufacturing Cost	• Feedstock cost about 70% • Other raw material, transport and indirect cost each about 9%. • Sensitive to price of oilseed and oilcake. • Soybean plant costs the most sensitive to these price changes. • Sunflower plant most robust to these price changes. • Costs can be decreased by 12c/l for every R1000/ton increase in glycerol price. • Costs can be reduced by 28c/l if	• Feedstock cost about 80% • Other raw material and transport cost each about 9%. • Sensitive to price of vegetable oil. • Depend mostly on the price of the crude vegetable oil. • Costs can be decreased by 12c/l for every R1000/ton increase in glycerol price. • Costs can be reduced by 28c/l if methanol is recycled.

	methanol is recycled	
Biodiesel Break-even Price	• R1.01/litre fuel taxes added to manufacturing cost to give a break-even price for each type of feedstock. • Canola R5.81/litre • Soybeans R7.70/litre • Sunflower seed R7.67/litre • Locally produced oilseeds show lower break-even costs due to high cost of imported crude vegetable oil	• R1.01/litre fuel taxes added to manufacturing cost to give a break-even price for each type of feedstock. • Palm oil R7.63/litre • Soybean oil R7.90/litre • Sunflower oil R8.49/litre • Locally produced oilseeds show lower break-even costs due to high cost of imported crude vegetable oil.
Profitability	• Depends on biodiesel selling price. • Lower break-even costs result in higher profitability. • Canola is the only feedstock that can compete with price of fossil diesel at the moment. But this is also only marginal.	• Depends on biodiesel selling price. • No imported crude oil can produce biodiesel which can compete with the price of fossil diesel at the moment. • Potential profitability would be increased if locally produced vegetable oils can be obtained at a lower cost.

Results show that locally produced feedstock shows a potentially higher profitability than imported feedstock. Be it locally produced oilseeds or their subsequent vegetable oil that could potentially be bought at a lower cost than imported vegetable oil. Assuming for a moment that biodiesel does become profitable, which ever way, and the necessary players become involved in commercial production. The next question then becomes whether the South African agricultural sector will be able to supply the required resources for commercial biodiesel production from vegetable oil, keeping in mind that production is more economical when using locally produced feedstock?

4.3 Agricultural Feasibility

The previous section mentions two different types of biodiesel plants, SEBP and COBP, which can be used for biodiesel production in South Africa. The SEBP plant uses oilseeds while the COBP uses crude vegetable oil as feedstock. The latter means that the oilseeds are crushed elsewhere and the plant buys the vegetable oil from the oilseed crusher or farmer. Results also showed that biodiesel production is most economical when locally produced feedstock is used. So whether it is a SEBP plant that crushes the seeds on-site or a COBP plant that uses the vegetable oil of oilseeds crushed elsewhere, the oilseeds need to be planted and harvested in South Africa for biodiesel production to be economical without legislative help.

4.3.1 Oil crop production in South Africa

Sunflower and soybeans are the primary oil crops grown in South Africa. Minor oil crops that are also grown include canola, groundnuts and cotton seed. Of the 3 minor oilseeds, canola was also included in this study for reasons given in section 2.3.1.

The sunflower is an annual summer crop grown mainly in the provinces of Mpumalanga, Gauteng, North West, Limpopo and Free State. The planting season ranges from November to January while harvesting season is from April to June depending on the region (Leather, 2006). It is currently the primary oil crop planted in South Africa and the area planted to sunflower constituted about 70% of the total area planted to the main oilseeds in 2005 (SAGIS, 2006). Sunflower production, harvest area and yield data of South Africa for the last 10 years and an estimate for 2006/07 can be seen in Appendix I and Figure 26.

Sunflower is the main supply of local plant protein in South Africa and although production is on the increase, it is still short of the domestic demand. This makes South Africa a plant protein deficient country which means sources of plant protein have to be imported to satisfy the local demand. In 2005 South Africa imported about 6000 tons of sunflower seeds which amount to about 3% of the total supply (GAIN, 2006). This is not much, as the oilseed trade and consumption is in meal and oil, not so much seed.

Sunflower oil is the preferred edible oil in South Africa and the demand forces the country to import about 15% of its sunflower oil (GAIN, 2006). Argentina is the main supplier of this commodity. In 2004 South Africa imported 94000 tons of sunflower oil which is an equivalent to about 223000 tons of sunflower seed but this figure has decreased to about 36000 tons (equivalent to 95000 tons sunflower seed) in 2005 due the gaining popularity of soybean oil (GAIN, 2006). The sunflower oil production, imports and consumption in South Africa for the last 10 years is shown in Appendix I. Sunflower oil is the main product of the sunflower seed oil extraction process and is currently more expensive than soybean oil which is actually a secondary product of its oil extraction process.

Sunflower meal/oilcake is the other product of the oil extraction process. The use of sunflower meal as livestock feed is limited due to its high fibre and lower protein content (GAIN, 2006). Due to this fact, sunflower meal consumption is only about half the consumption of soybean meal in South Africa. South Africa currently imports less than 10% of its total sunflower meal consumption (Appendix I). Due to lower demand of the meal, the price of sunflower meal is much lower than that for soybean and canola meal.

The soybean is an annual summer crop grown mainly in the Mpumalanga, Gauteng and Free State regions. The planting season commences in October/November and the beans are harvested in April/May (Leather, 2006). The area planted soybeans currently constitutes about 30% of the total area planted to the main oilseeds in South Africa (GAIN, 2003). This figure has been growing the last two seasons as talks of biodiesel production started to look promising. Production, harvest area and yield data of the last 10 years can be seen in Appendix I and Figure 26.

South Africa, being a plant protein deficient country, has to import a large part of its total soybean supply. Soybean trading, like with sunflower is done in meal and oil. On average about 10-15% of the total soybean supply in South Africa is crushed, 10-15% is used for human consumption and 70-75% for animal feed and seeds.

Although sunflower oil is still the preferred edible oil in South Africa, **soybean oil** is growing in importance due to the fact that it is cheaper than sunflower oil and is denatured and blended with other oils in the final product (GAIN, 2006). South Africa has to import most of its soybean oil from Argentina and Brazil (GAIN, 2006). In 2005 South Africa imported soy oil equivalent to 975000 tons of soybeans. Previous years imports and consumption of soy oil can be seen in Appendix I.

Soybean meal/oilcake consumption in South Africa for 2004/05 was 740000 tons of which only 90000 was produced locally (GAIN, 2006). This means South Africa currently imports almost 90% of its total soybean meal supply which amounts to over 800000 tons of soybeans. The soybean meal is used for animal fodder and is ideal because of its high protein and low fibre content. Soybean meal imports and consumptions for previous years are seen in Appendix I.

Canola is a cultivar of the rapeseed plant and is grown mainly in the Western Cape. When compared to the production of sunflower and soybeans, canola production is barely noticeable, making up less than 5% of the total oilseed production in 2005 (SAGIS, 2006). Due to its low production, it is not a major traded commodity in South Africa. No canola or its subsequent products were imported in 2005, and the local production is mainly crushed for its oilcake which has a slightly higher value than that of soybean oilcake (Protein Research Foundation, 2006). The production, area planted and average yield of canola for the past 10 years is seen in Appendix I and in Figure 26.

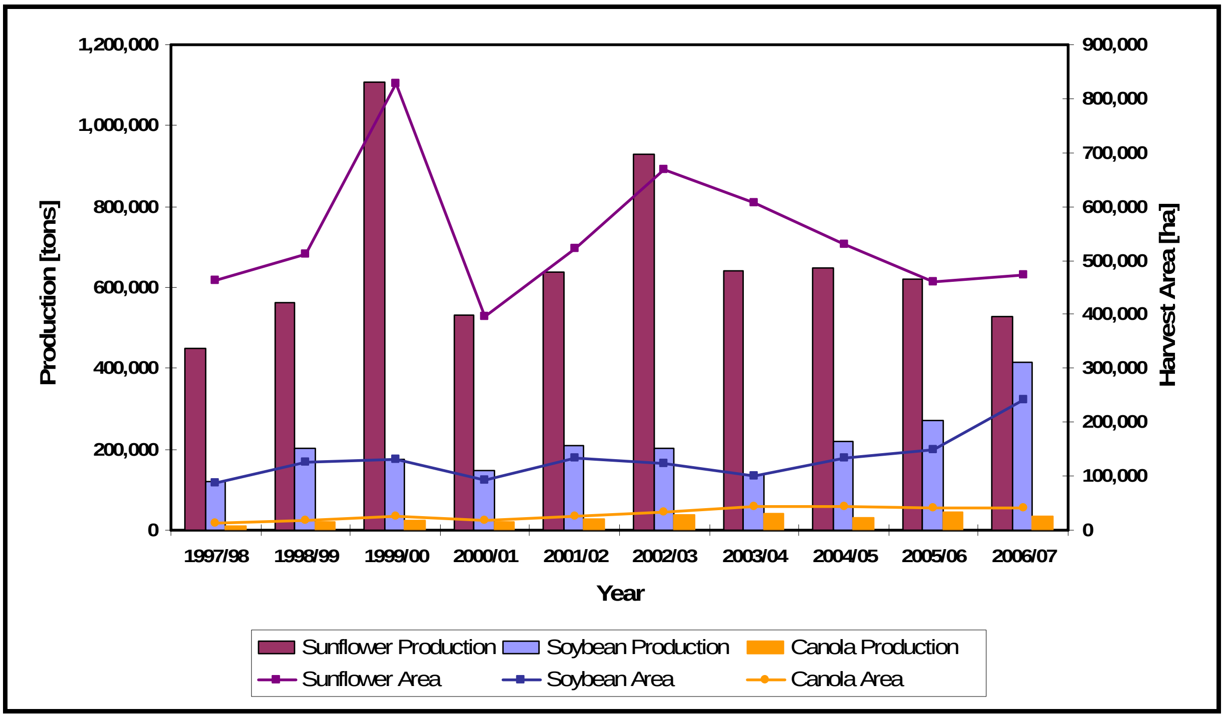


Figure 26: Historic production and planted area for sunflower, soybeans and canola in SA

In 1998 oilseeds constituted to about 10% of the total area planted to South Africa's main crops. This figure rose to about an estimated 22% for the 2006/07 season. This is due to the fact that the total area planted with crops has decreased drastically in the last decade while the area planted with oilseeds has remained fairly consistent. The production ratio of the different oilseeds has been relatively constant in the past at about 75% sunflowers, 22%

soybeans and 3% canola. But this has changed in the last two years to a predicted ratio in 2007 of about 54% sunflowers, 42% soybeans and 3% canola. Due to fairly equal yields, the area ratio is very similar to the production ratio at about 62% of the total oilseed area planted with sunflower, 34% planted with soybeans and 4% with canola. The recent increase in soybean production can be ascribed to the biodiesel buzz that has been in South Africa for the past year or so.

4.3.2 Agricultural resources required for commercial biodiesel production

Commercial biodiesel production, to replace 10% of the fossil diesel consumption, would have serious implications for the country's agricultural sector. The first and most important implication this would have is the increase in production to supply the necessary feedstock for 10% of the countries' diesel fuel.

Section 4.2 showed that the production costs for sunflower and soybean biodiesel in a SEBP plant are about the same at R7.70/litre, while it is almost R2.00/litre cheaper to produce biodiesel from canola in a SEBP plant. So it might seem that South Africa should try to produce all its biodiesel from locally planted canola. This would mean an annual canola production of about 2.5 million tons (by 2010) compared to the current production of 33000 tons. This on its own is already an impossible task not even mentioning that the area needed would be more than the available suitable area and the fact that canola is a very difficult crop to grow.

Thus the required oilseed production increase to produce 10% of South Africa's diesel by 2010 (1 billion litres) is illustrated using 3 different scenarios:

- **Scenario 1:** using only sunflower seeds
- **Scenario 2:** using only soybeans
- **Scenario 3:** using sunflower seeds, soybeans and canola in their current area ratio

These scenarios assume that the current production and demand for the oilseeds stays constant and that all the oilseeds necessary for biodiesel production will have to be produced additionally to the current production.

Scenario 1: The results showing the required sunflower production increase for commercial biodiesel production up to 2015 is shown in Table 28. An average yield of 1.15 ton/ha (as predicted by SAGIS for 2006) is assumed for the sunflower production to calculate the additional land needed.

Table 28: Sunflower production increase needed to supply 10% of South Africa's diesel

Year	Fossil Diesel	10% Biodiesel	Sunflower	Area needed
	Million litres	*Million litres*	*Thousand tons*	*Thousand ha*
2005	8115			
2006	8521			
2007	8947	895	2294	1995
2008	9394	939	2409	2095
2009	9864	986	2529	2199
2010	**10357**	**1036**	**2656**	**2309**
2011	10875	1087	2788	2425
2012	11419	1142	2928	2546
2013	11990	1199	3074	2673
2014	12589	1259	3228	2807
2015	13218	1322	3389	2947

Results show that an additional 2.7 million tons of sunflower seeds will have to be produced by 2010 to supply South Africa with 10% of its diesel. Adding this to the current production of about 620000 tons, a total sunflower harvest of about 3.3 million tons would be required. This is 5.3 times more than the current production. 3.3 million tons of sunflower seeds would require an area of about 2.9 million hectare which is almost 6 times as much as the current area planted with sunflowers. Crushing 3.3 million tons of sunflower seeds would result in about 1.9 million tons of sunflower oilcake. The demand for sunflower oilcake in 2004/2005 was about 300000 tons (Protein Research Foundation, 2006) which was all produced locally. That would leave South Africa with an excess of about 1.6 million tons of sunflower oilcake. A part of this oilcake would be taken up by local farmers as the demand for oilcake is said to increase (FAPRI, 1995) but a large part of the oilcake would have to be exported.

Scenario 2: The results showing the required soybean production increase for commercial biodiesel production up to 2015 is shown in Table 29. An average yield of 1.65 ton/ha (slightly lower than the yield of 1.7 ton/ha predicted by SAGIS for 2006) is assumed for the soybean production to calculate the additional land needed.

Table 29: Soybean production increase needed to supply 10% of South Africa's diesel

Year	Fossil Diesel	10% Biodiesel	Soybeans	Area needed
	Million litres	*Million litres*	*Thousand tons*	*Thousand ha*
2005	8115			
2006	8521			
2007	8947	895	4836	2931
2008	9394	939	5078	3078
2009	9864	986	5332	3231
2010	**10357**	**1036**	**5598**	**3393**
2011	10875	1087	5878	3563
2012	11419	1142	6172	3741
2013	11990	1199	6481	3928
2014	12589	1259	6805	4124
2015	13218	1322	7145	4330

Results show that an additional 5.6 million tons of soybeans will have to be produced by 2010 to supply South Africa with 10% of its diesel. Adding this to the current production of about 270000 tons, a total soybean harvest of about 5.9 million tons would be required. This is about 22 times more than the current production. 5.9 million tons of soybeans would require an area of about 3.6 million hectare which is almost 24 times as much as the current area planted with soybeans. This additional required area is more than 1 million hectare more than if only sunflower seeds were used for the same biodiesel production. Crushing 5.9 million tons of soybeans would result in about 4.5 million tons of soybean oilcake. The demand for soybean oilcake in 2004/2005 was about 750000 tons of which 650000 tons were imported (Protein Research Foundation, 2006). That would leave South Africa with an excess of about 3.7 million tons of soybean oilcake. A part of this oilcake would be taken up by local farmers as the demand for oilcake is said to increase (FAPRI, 1995) but a large part of the oilcake would have to be exported to a market that might already be oversupplied with soybean oilcake due to biodiesel production in countries such as the USA and Brazil.

Scenario 3: The results showing the required production increase for each type of oilseed (in their relative area ratio: 62% sunflower, 34% soybeans, 4% canola) for commercial biodiesel production up to 2015 is shown in Table 30. An average yield of 1.15 ton/ha for sunflower, 1.65 ton/ha for soybeans and 1.00 ton/ha for canola (as predicted by SAGIS for 2006) is assumed to calculate the additional land needed.

Results show that an additional 1.5 million tons of soybeans, 1.9 million tons of sunflower and 100000 tons of canola will have to be produced by 2010 to supply South Africa with 10%

of its diesel. This increase would result in a total **soybean** harvest of 1.8 million tons in 2010 which is about a 6 times increase on the harvest of 2005/06. An additional 1.9 million tonnes of **sunflower** seeds by 2010 would mean a 4-fold increase on the harvest of 2005/06. The current **canola** production would have to increase by about 3 times to achieve a total harvest of 150000 tons.

Table 30: Total oilseeds production increase needed to supply 10% of South Africa's diesel

			Soybeans		Sunflower		Canola		Total
Year	**Fossil Diesel**	**10% Biodiesel**	**Production**	**Area**	**Production**	**Area**	**Production**	**Area**	**Area**
	Million litres	***Million litres***	***Thousand tons***	***Thousand ha***	***Thousand tons***	***Thousand ha***	***Thousand tons***	***Thousand ha***	***Thousand ha***
2005	8115								
2006	8521								
2007	8947	895	1257	762	1606	1396	87	87	**2246**
2008	9394	939	1320	800	1686	1466	92	92	**2358**
2009	9864	986	1386	840	1770	1540	96	96	**2476**
2010	**10357**	**1036**	**1456**	**882**	**1859**	**1616**	**101**	**101**	**2600**
2011	10875	1087	1528	926	1952	1697	106	106	**2730**
2012	11419	1142	1605	973	2049	1782	111	111	**2866**
2013	11990	1199	1685	1021	2152	1871	117	117	**3009**
2014	12589	1259	1769	1072	2260	1965	123	123	**3160**
2015	13218	1322	1858	1126	2373	2063	129	129	**3318**

The 2005/06 harvest season produced a total oilseed (soybean, sunflower and canola) harvest of about 936000 tons (SAGIS, 2006). **If these 3 oilseeds had to produce 10% of South Africa's diesel by 2010, the total production would have to increase by 3.4 million tons.** Thus, a total required harvest of 4.4 million tonnes in 2010 would mean a 4.7-fold increase.

In 2005/06 a total area of 650000 hectare was harvested (SAGIS, 2006) for the three above mentioned oilseeds. **To supply the above mentioned production of oilseeds an additional area of 2.6 million would be necessary.** Thus, the total land planted to oilseeds by 2010 would be about 3.25 million hectare, a 5-fold increase of the current area.

Table 31 shows how an increase in oilseed production as in scenario 3 would affect the oilcake supply in South Africa. Results show a possible excess of about 1.7 million tons by 2010 assuming that the current demand for oilcake stays constant. Even if the demand doubles, South Africa would still become a net exporter of oilcake. Results show that scenario 3 affects each type of oilcake production less than either of the previous scenarios.

Table 31: Impact of scenario 3 on oilcake supply in South Africa

Oilcake Production	2004/05 Production	2004/05 Imports	Scenario 3 Potential Production	Potential Excess
	Thousand tons	*Thousand tons*	*Thousand tons*	*Thousand tons*
Sunflower	260	16	**1413**	1,137
Soybean	144	648	**1329**	537
Canola	26	0	**80**	54

Table 32 shows how the different scenarios would effect the current individual and total oilseed production. Scenario 1 would require a 5-fold increase of sunflower production compared to only a 4-fold increase in the sunflower production of scenario 3. The total oilseed production is affected the least by scenario 1 (about 4-fold increase) and the most by scenario 2 (about 7-fold increase). Scenario 3 has a 4.7-fold increase of the total oilseed production. Scenario 2 looks the least likely, stating that the current soybean production would have to increase by about 22 times to be able to supply South Africa with 10% of its diesel. Scenario 3 seems to have the balance between the impact of individual oilseed production increase and total oilseed production increase.

Table 32: Oilseed production comparison between the 3 scenarios

Oilseed Production	Current	Scenario 1 by 2010	Increase	Scenario 2 by 2010	Increase	Scenario 3 by 2010	Increase
	Thousand tons	*Thousand tons*		*Thousand tons*		*Thousand tons*	
Sunflower	620	**3276**	**5.28**	620	1.00	**2479**	**4.00**
Soybean	270	270	1.00	**5868**	**21.73**	**1726**	**6.39**
Canola	44	44	1.00	44	1.00	**145**	**3.30**
Total	**934**	**3590**	**3.84**	**6532**	**6.99**	**4350**	**4.66**

Table 33 shows how the different scenarios would affect the areas planted to individual and total oilseeds. Once again scenario 3 suggests the best balance between the total necessary area increase and the area increase of each individual oilseed.

In summary, South Africa should rather focus on a total and balanced increase of oilseed production. Not only focusing on a single oilseed but rather increasing the production of all the major oilseeds. Also seen from the results is that biodiesel would mainly be produced from sunflower seeds and soybeans on a large scale. Canola and possibly even other oilseeds would only make up a small fraction of the total feedstock required for the biodiesel production in South Africa.

Table 33: Oilseed area comparison between the 3 scenarios

Oilseed Area	Current	Scenario 1 by 2010	Increase	Scenario 2 by 2010	Increase	Scenario 3 by 2010	Increase
	Thousand Ha	*Thousand Ha*		*Thousand Ha*		*Thousand Ha*	
Sunflower	460	**2769**	**6.02**	460	1.00	**2076**	**4.51**
Soybean	150	150	1.00	**3543**	**23.62**	**1152**	**7.68**
Canola	40	40	1.00	40	1.00	**145**	**3.63**
Total	**650**	**2959**	**4.55**	**4043**	**6.22**	**3373**	**5.19**

The agricultural productivity and area will have to increase drastically to achieve the aim of commercial biodiesel production in South Africa. Scenario 3 suggests that South Africa would need an additional 2.6 million hectare planted to the main oilseeds. Now that the targets are known, the next question is whether these are reachable targets or impossible dreams?

Figure 27 shows that the total area planted with South Africa's main crops has decreased by about 40% in the last decade from about 6.4 million hectare to 3.7 million hectare (SAGIS, 2006). This is mainly due to the decrease in maize production as a result of the oversupply and weaker maize price in South Africa the past few years. The figure also shows that the area planted to oilseeds stayed fairly constant at about 800000 hectare but now constitutes to a larger part of the total area planted with crops in South Africa.

What these results show is that there is basically at least 2.7 million hectare of 'unused' land that used to be cultivated in South Africa. This figure could potentially be much larger as it does not consider agricultural statistics before 1997 and also does not consider any other fertile land that has not been cultivated previously. It must be kept in mind that the currently 'unused' agricultural land used to be mainly for maize. Sunflower and soybeans can easily be grown in the same type of soil as maize (Landbou Weekblad 01/09/2006) which makes them ideal candidates to be planted in the previously cultivated currently 'unused' areas.

Area planted with maize has dropped from above 4 million hectares to below 2 million hectares since 1997. Assuming that this figure could rise to about 3 million hectares in the next few years, South Africa would still be left with an 'unused' area of about 1.7 million hectares that was previously cultivated. Crop rotation of maize and soybeans is not only a way of sustainable farming but also promises to increase the yield and production of both crops (Landbou Weekblad 01/09/2006). This means that every year about half of the area that has previously been considered a maize producing area would be able to produce soybeans. This might seem unlikely presently but could be possible if controlled by all the regional agricultural authorities.

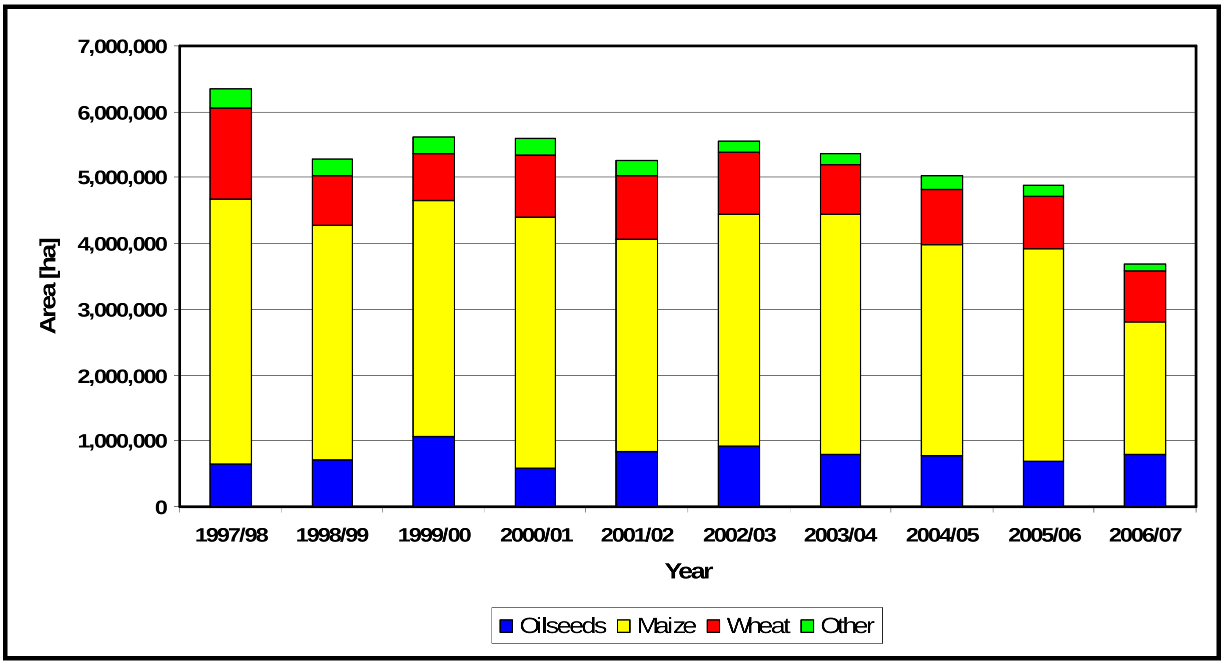


Figure 27: Total area planted to the main South African crops

Thus, looking at previously cultivated land which is presently 'unused', crop rotation and fertile land that still needs to be cultivated, **South Africa does have the potential to increase its oilseed production by at least 2.6 million hectares**. It will be a difficult and timely task increasing oilseeds to levels which will be able to supply the country with 1 billion litres of biodiesel and will require the efforts, planning and execution of all the players involved in the South African agriculture.

Farming is like any other business in the sense that it needs to be profitable, meaning that a certain crop will only be planted if it can generate sufficient profit for the farmer. This leads to the reality that the land availability is only the first step of the possible agricultural production and that farmers would still need to be motivated to start farming for biodiesel.

4.3.3 Farming for biodiesel

Seeing that the oilseed production targets for commercial biodiesel production are possible, the next task would be on how to achieve these targets.

Most importantly, the oilseed price needs to be high enough for farmers to plant it. As already mentioned, farming is a business and crops are only planted if they produce a high enough profit for the farmer. This creates a sort of difficult situation as biodiesel producers look for the cheapest possible feedstock but farmers want the highest possible price. This situation would have to reach equilibrium where both parties would be satisfied with the oilseed price seeing that they do depend on each other for business. Looking at the cost calculations in the previous section, it is clear that at current oilseed prices (sunflower and soybeans) the cost of biodiesel would exceed that of fossil diesel by quite a margin. This implies that only a forced biodiesel market such as mandatory blending or some sort of subsidies would ensure that the necessary oilseeds can be bought from the producers at a price that makes their production profitable.

Commercial biodiesel production would create a steady market for oilseeds in South Africa. This steady market would lower the risk involved for the farmer signing future contracts on their oilseeds with biodiesel producers. To further motivate farmers to achieve the required oilseed production levels, rewards could be offered for attaining certain production targets. Oilseed production for biodiesel production purposes needs to be planned in great detail. Biodiesel producers and oilseed crushers sit in the middle of the production chain and pressure from both sides, the farmer and biodiesel buyer, does not allow for great scope in any price or cost variations. Biodiesel producers would have to sit down with farmers ahead of the planting season discussing the production and price of oilseeds, taking into account things like crop rotation, rainfall, etc.

Biodiesel should not only serve as a replacement for fossil fuels, but also improving and reviving the agricultural economy of South Africa. This can be achieved in various ways of which one would be that if certain tax incentives are put in place for biodiesel, to make sure that they go back all the way to the farmer. The same could apply to the concept of carbon credits. If the biodiesel production industry would be approved to earn carbon credits, that part of the generated income be raked back to the farmers. Other benefits such as biodiesel at a lower price than fossil diesel to farmers that supply feedstock could also be used to motivate farmers to farm for biodiesel.

Farms supplying feedstock to large-scale (commercial) biodiesel production do not need to be commercial farms. Small or subsistence farmers, especially those from a previously disadvantaged background, could form cooperatives that would be able to utilise the benefits of the economies of scale offered by a central crusher or transport system to supply feedstock to a biodiesel production plant. Commercial biodiesel production should not be centralized but rather by smaller regional plants as discussed in section 4.2.3. Either in the form of SEBP plants between the farms or COBP plants that receive their supply of vegetable oils from oilseed crushers that are set up between farms. This means that although commercial oilseed producers would make up the largest part of the feedstock suppliers, there is a lot of room for small-scale producers to have a constant off-set for their crop. This secure and constant source of income could possibly up-lift rural communities and increase oilseed production on small-scale farms. Making farmer's shareholders in biodiesel production plants would increase their interest in this sector and improve cooperation between biodiesel producers and farmers.

Another question that needs to be asked by both farmers and biodiesel producers is how the increased demand for oilseeds caused by biodiesel production would affect the price of oilseeds? South Africa has a fairly free agricultural market which is sometimes a disadvantage to the farmers who have to compete with import parity from countries such as the USA were farmers are heavily subsidised. An increased demand for oilseeds would initially push up the price but only to the levels of the import parity. If farmers can produce crops profitably at these prices, a supply and demand equilibrium price will be established for oilseeds in South Africa which will be less than the import parity of either the oilseeds or the resulting vegetable oil. Thus, an initial price increase of local oilseeds can be expected but this will not be able to exceed import parity of oilseeds or equivalent vegetable oil. If this price is greater than the 'break-even' price for farmers they will produce to supply the demand. This means that the oilseed price in South Africa is not only affected by local demand, but also by international supply and demand which in turn affects the international price of these commodities. Appendix J shows how the import and export parity controls the South African crop price.

Biodiesel producers must also accept the fact that even if farmers start farming for biodiesel, the increase in oilseed production in South Africa will be gradual. 1 billion litres of biodiesel will not be able to be produced of totally local produced feedstock the first few years. Thus biodiesel production levels would either have to start out low and increase as crop production increases or the necessary feedstock would have to be imported to reach a target of about 10% of the countries diesel from the start. The former one would probably be the most likely to happen in South Africa and should go hand-in-hand with date targets set by the government.

Biodiesel should be seen as an agricultural commodity, meaning that production would vary from year to year depending on external factors such as annual rainfall and crop yields. Keeping this in mind biodiesel producers should always assess worst case scenarios before setting up plants. These risk analyses should be first and foremost be based on the fact that crop production is never guaranteed and depends mostly on the rainfall which is one of the most unpredicted elements of nature. Most agricultural commodities such as crops are seasonal which means biodiesel producers would have to take into account that the main oilseed supply would only be during certain times of the year and great planning from both the farmers and biodiesel producers will be necessary to have a constant supply of feedstock throughout the year.

4.3.4 Benefits of farming for biodiesel

Besides creating a steady market and price for local oilseeds, biodiesel production also holds in a number of other benefits for local farmers.

In 2005/06 South Africa consumed about 1.2 million tons of oilcake (Protein Research Foundation, 2006). Appendix I shows the detailed consumption of the different types of oilcakes for the past 3 years. Of these 1.2 million tons, about 700000 tons were imported. Soybean oilcake makes up more than 80% of these imports. Figure 28 shows how the total oilcake consumption for 2004/05 is split up between the different types. The sunflower and canola oilcake are mostly locally produced, but almost 90% of the soybean oilcake is imported.

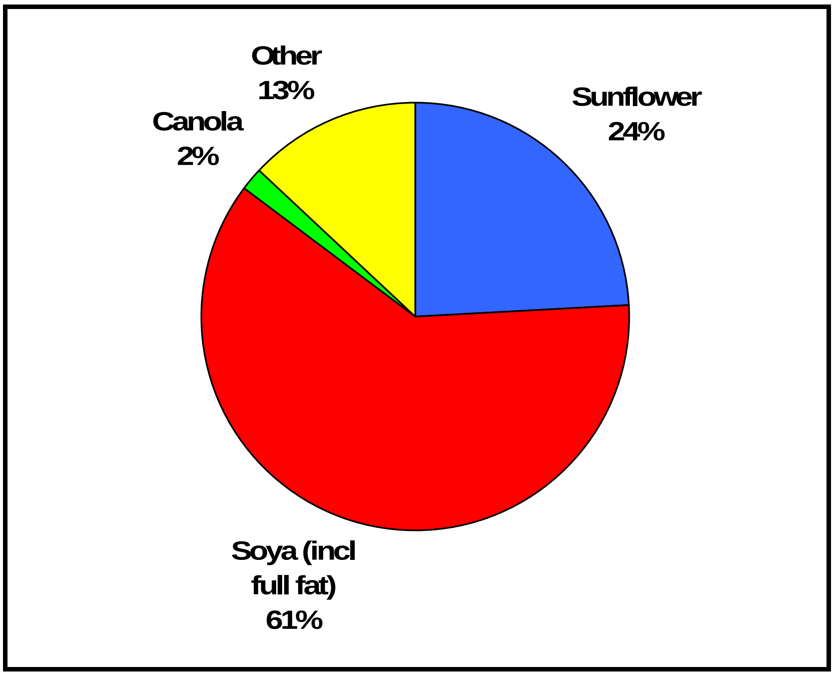


Figure 28: South African oilcake consumption in 2004/05

Assuming an increase in oilseed production in South Africa as in scenario 3 (section 4.3.2), the oilcake production would also increase drastically. Table 31 shows that South Africa would have an excess of 1.1 million tons of sunflower oilcake, 540000 tons soybean oilcake and 54000 tons canola oilcake based on the current demand. This would change South Africa from being a net-importer of oilcake to potentially a net-exporter of oilcake. Some of the excess oilcake production would be absorbed by the local market which will probably increase in the future (FAPRI, 1995). The remaining oilcake would have to find its way into the international market. The fact that South Africa would no longer have to import its oilcake (especially soybean oilcake) is good news to local livestock farmers as they would possibly obtain the locally produced oilcake at prices lower than import parity.

Biodiesel production will increase research conducted on oilseeds and agricultural methods. This research will lead to better farming techniques and sustainable management, improved crop yield and thus better and more efficient oilseed production areas that will benefit both the biodiesel producers and the agricultural sector in South Africa in the short and long run.

While biodiesel production itself is not labour intensive, it is estimated that biodiesel production in South Africa could create at least 38500 farm-level jobs (Engineering News, 20/10/2006 ‘Biofuel Feature’).

Commercial biodiesel production would stimulate rural development and generate an income for small scale farmers especially those from a previously disadvantaged background by giving them a guaranteed off-set and source of income for their oilseeds.

Although biodiesel is considered a sustainable fuel, care must be taken to ensure that this remains true. Oilseeds producers need to farm in a sustainable manner and additional land needs to be created in a sustainable way. This is to ensure that biodiesel production is sustainable throughout its production chain. Lessons can be learnt from countries such as Malaysia and Brazil where deforestation, to obtain more land for the production of crops for biofuels, has become a major concern.

Thus, concluding, South Africa does have the land available to produce the feedstock necessary for commercial biodiesel production but it will require great planning from everyone involved for the feedstock production to increase to such levels. Not only a single feedstock should be considered for biodiesel production, but both sunflower and soybean production should increase evenly in their current area ratios seeing that the cost of biodiesel production from these two feed stocks is about the same.

Chapter 5: Conclusion

World biofuel production is on the increase due to rising crude oil prices, decreasing fossil fuel reserves and environmental concerns. South Africa wants to join global biofuel producers as it would decrease its dependence on fossil fuels and imported oil, promote renewable energy, decrease pollution and help achieve the ASGISA aims which are to halve unemployment and poverty by 2014.

Biodiesel produced form vegetable oil is seen as the ideal candidate to replace fossil diesel in South Africa. The technology for biodiesel production is known and readily available but a question still hangs over its economic feasibility. The economic feasibility of commercial biodiesel production in South Africa depends on its agricultural, financial and market feasibility.

Sunflower seeds and soybeans are the primary oilseeds for biodiesel production in South Africa with canola being considered a secondary crop as it could also possibly contribute to a small part of the feedstock, especially in the Western Cape. The current production of these oilseeds is not nearly enough to supply South Africa with about 10% of its diesel. It was found that the best way of increasing crop production for biodiesel production was to increase all the oilseeds evenly, keeping the current area ratio between them constant. This is based on 2 reasons: Firstly, the production cost of sunflower seed and soybean biodiesel are about the same and even though the production cost for canola biodiesel is lower, a major increase in canola production is not feasible in South Africa. Secondly, this type of increase scenario has the least impact on each of the oilseeds when compared to using either only sunflower seeds or only soybeans to produce the country's biodiesel. Results show that a 4-fold production increase of sunflower seeds, 6-fold production increase of soybeans and 3-fold production increase of canola are required if South Africa is to produce 10% of its diesel using these 3 oilseeds. This oilseed production increase would require about 2.6 million ha of additional land. This area of land is available in South Africa in the form of unused previously cultivated land, unused previously uncultivated but fertile land and crop rotation of maize and soybeans.

Farming for biodiesel will require a great deal of planning from both the biodiesel producers and farmers. Biodiesel should be seen as an agricultural commodity implying that its seasonal availability and price might vary and that its production might often depend on external factors such as climate or rainfall. Biodiesel production can be very beneficial to local commercial and small-scale farmers as it would create a steady local demand for oilseeds. A potentially higher price for oilseeds is also expected along with the increased demand for oilseeds in South Africa. Although there would probably be an initial increase in oilseeds prices, these prices will not be able to increase above the import parities of either oilseeds or crude vegetable oil.

Importing feedstock for biodiesel production should not be considered for the following 2 reasons: First of all, high international oilseed prices and shipping costs combined with a weaker South African Rand currently make the production costs of biodiesel from imported crude vegetable oil to be higher than that produced form local oilseeds. Secondly, the local economy (especially the agricultural economy) will only benefit from biodiesel production if the feedstock is also produced locally.

The current (August 2006) break-even cost (manufacturing cost + R1.01/litre fuel tax and levies) of biodiesel, sunflower seeds (R7.67/litre), soybeans (R7.70/litre) and canola (R5.81/litre) cannot compete with the current pump price of fossil diesel (R6.80/litre). Although canola looks promising, its small-scale production and the recent dip in world oil price support the above made statement. As commodity prices change, this situation may change somewhere in the future, but for now, fossil diesel simply remains cheaper than biodiesel produced on a commercial scale.

Between 80% and 90% of the total manufacturing cost of biodiesel are feedstock and other raw materials which is an indication that there are no major economies of scale involved in the biodiesel production process. The second biggest cost item is transport (about 10%). The two above mentioned facts strongly point to the fact that commercial biodiesel production (if realized) in South Africa should not be centralized but rather happen through a greater number of relatively smaller plants all over South Africa. This would cause biodiesel production to be regionalized with oilseed regions having a greater density of such ‘smaller’ plants. This means that the main factor determining the size of a biodiesel plant in South Africa should be the availability of oilseeds or crude vegetable oil in that area.

An example of such a plant setup would be a hexane seed extractor with a 2500kg/h biodiesel plant. South Africa would require about 46 of these to produce enough biodiesel to replace 10% of the fossil diesel by 2010. The capital investment needed for such a SEBP plant would be between R110 and R 145 million depending on the type of oilseed used. This large amount is mainly due to the high cost of the hexane extractor and the working capital. The working capital is a real thorn in the side for potential biodiesel producers as between R30 and R70 million can be fixed into 3 months of stock necessary for smooth plant operation.

Biodiesel production costs of a SEBP plant highly depend on the price of the oilseeds and oilcake. The fluctuating nature of the prices of these agricultural commodities would greatly vary the biodiesel production costs. Such price fluctuations would have the greatest effect and risk on a soybean SEBP plant and the smallest effect and risk on a sunflower SEBP plant. The production costs of a COBP plant are highly dependant on the price of the crude vegetable oil. This type of plant would require oilseed crushers to be added into the production chain as link between the farmers and biodiesel producers.

An increase in the glycerol price would have positive implications on biodiesel production as every R1000/ton price increase would reduce manufacturing costs by 12 cents/litre. An oversupply of glycerol in the world due to increased biodiesel production has caused its price to drop considerably the last few years.

The profitability of biodiesel production in South Africa depends largely on the selling price of the biodiesel. If biodiesel would be considered an agricultural commodity, it would be unfair to compare it to the fossil diesel price which is directly linked to the world crude oil price and Rand/US$ exchange rate. Thus saying that biodiesel should not compete with fossil diesel to enter the South African fuel market but rather establish its own niche market based on its fuel properties and environmental benefits. Creating and sustaining such a market is not in the hands of biodiesel producers or farmers, but relies on legislation passed by the government. Such legislation and policies could be in the form of subsidising feedstock for biodiesel production, subsidising the biodiesel itself, using government purchasing power, mandatory blending legislation, tax incentives or price compensation agreements to stimulate a market for biodiesel in South Africa.

Thus, this study concludes that the economic feasibility of commercial biodiesel production in South Africa depends on government legislation, seeing that South Africa does have the agricultural capacity to produce the necessary feedstock, but the current break-even costs of biodiesel exceed the fossil diesel pump price meaning that a market can only be created and sustained by certain laws and regulations.

Chapter 6: Recommendations

Based on the findings in this study, the following recommendations are made by the author:

- A more extensive economic feasibility study should be conducted once the government’s biofuel strategy is released at the end of 2006.

- The South African government must realise its role in the development of a biofuel industry in the country and not be too ignorant to learn from countries with an already developed biofuel industries.

- All the stakeholders should be involved every step of the way for the development of a successful biodiesel industry.

- When it comes to biodiesel, commercial production does not necessarily mean a few huge centralized plants, one must not forget the small producers which could at the end of the day also contribute quite a bit to the production of renewable energy.

References

Amigun B., von Blottnitz. H., 2005, *Size Optimization of a biodiesel processing plant*, Environmental Process Engineering group, University of Cape Town, South Africa,

Becker, K., 2006, Southern Oil, personal communication via email,

Beer, T., Grant, T., year unknown, *Comparison of Transport Fuels*, Australian Greenhouse Office, 463 pages,

Bender, M., 1999: *Economic Feasibility Review for Community-Scale Cooperatives for biodiesel*, Scientific publication, The Land Institute (http://www.landinstitute.org/vnews/display.v/ART/1999/01/18/3e43e6b418401),

Biodiesel Education, 2004, http://www.me.iastate.edu/biodiesel [02-05-2006]

BioKing® Biodiesel Equipment Manufacturing: www.bioking.nl (25/06/2006),

Booysen, T., 2006, Biodiesel One, personal communication,

Duncan, J, 2003, *Costs of Biodiesel Production*, Energy Efficiency and Conservation Authority.

Engineering News, 3 July 2006, *SA reviewing 20-plus carbon credit projects*,

Engineering News, 20 October 2006, *Biofuels feature*, Vol. 26 no 40, page 56-64

Engineering News Website:http://www.engineeringnews.co.za/ (25/04/2006),

Food and Agricultural Policy Research Institute (FAPRI), 1995, *US and World Agricultural Outlook*,

Friedrich, S., 2003, *A world Wide Review of the commercial production of Biodiesel*, Schriftenreihe Umweltschutz und Ressourcenoekonomie, Global Agriculture Information Network (GAIN), *Republic of South Africa Oilseeds and Products 2006,*

Griessel, M, 2006, Protein Research Foundation, personal communication

Jenkins, B.M., 1996: *A comment on the optimal sizing of a biomass utilization facility under constant and variable cost scaling*, Biomass and Bioenergy, 13, 1&2, 1-9,

Journey to Forever, 1999, *Biodiesel*, http://journeytoforever.org/biodiesel,

Kirsten, J, Vink, N, 2002, Pricing Behaviour in the South African Agricultural Sector – Final Report, a report commissioned by the National Treasury,

Kumar, A., Cameron, J. B. and Flynn P.C., 2002: *Biomass power cost optimum plant size in western Canada*, Biomass and Bioenergy Volume 24, Number 6, June 2003, page 445-464,

Landbou Weekblad, 1 September 2006, 'Sojabone is die moeite werd',

Leather, H., 2006, Grain SA, Personal communication via email

Le Roux, E, 2006, Bester Grain & Feed Exchange, personal communication via email,

Manaka, A, 2006, South African Bureau of Standards – Chemical and Mining Standards, personal communication via email,

Mittelbach, M., Remschmidt, C., 2005, *Biodiesel - the Comprehensive Handbook*, 2nd Edition, Martin Mittelbach, 332 pages,

Nassiep, K.M., 07/06/2006, Department of Minerals and Energy - Chief Director of energy planning, Presentation to biofuels workshop at Stellenbosch,

Nel, R., 28/09/2006, South African Oilseed Crushers Association, personal communication,

Nitske, W.R., Wilson, C.M., 1965: *Rudolf Diesel: Pioneer of the Age of Power*, University of Oklahoma Press, 318 pages,

Protein Research Foundation, 20/08/2006, www.pns.net,

Prankl, H., 2002: *High Biodiesel quality required by European Standards*. European Journal of Lipid Science and Technology 104, page 371-375, Rasool, June 2006, SASOL sales manager, personal communication,

Sieberhagen, K., 29/08/2006: Engineer at Velo SA, personal communication,

South African Bureau of Standards, 2006, Chemical and Mining Standards, Personal communication via email,

South African Grain Information Service, 2006, www.sagis.org.za,

South African Petroleum Industry Association, 2006, www.sapia.co.za,

South African Revenue Service, 31 March 2006, Rules and Amendments, www.sars.co.za,

Swart, A., Maree, Z., 26/08/2006, Spoornet South Africa, personal communication,

Turton, R, Bailie, R.C, Shaeiwitz, J.A, Whiting, W.B, 2003: *Analysis, Synthesis and Design of Chemical Processes*, 2nd edition, Prentice Hall PTR,

Tyson, K.S., Bozell, J., Wallace, R., Petersen, E., Moens, L., 2004, *Biomass Oil Analysis – Research Needs and Recommendations*, National Renewable Energy Laboratory, US Department of Energy

Victor, S., August 2006, Sabie Management Services, personal communication

Wikipedia internet encyclopaedia, 2006, Vegetable oil entry, http://en.wikipedia.org,

Wilson, S. C., Matthew, M., Austin, G. & von Blottnitz, H. 2005. *Review of the Status of Biodiesel Related Activities in South Africa.* Report for the City of Cape Town, South Africa, 76 pages,

Worldwatch Institute, June 2006, Biofuels for Transportation Report.

Appendices

Appendix A: South African Diesel Consumption

Table A1: South African past and future diesel consumption (SAPIA, 2006)

Year	Fossil Diesel	1% Biodiesel	5% Biodiesel	10% Biodiesel
	Million litres	Million litres	Million litres	Million litres
1994	5110			
1995	5432			
1996	5759			
1997	5869			
1998	5959			
1999	5993			
2000	6254			
2001	6488			
2002	6831			
2003	7263			
2004	7679			
2005	8115			
2006	8521			
2007	8947	89	447	895
2008	9394	94	470	939
2009	9864	99	493	986
2010	10357	104	518	1036
2011	10875	109	544	1087
2012	11419	114	571	1142
2013	11990	120	599	1199
2014	12589	126	629	1259
2015	13218	132	661	1322
2016	13879	139	694	1388
2017	14573	146	729	1457
2018	15302	153	765	1530
2019	16067	161	803	1607
2020	16871	169	844	1687

*Assumed at an average annual increase of 5%

Appendix B: Calculations

Number of plants needed to supply South Africa with 10% of its diesel consumption:

By 2010 South Africa will be consuming 10,375,000 kilolitres of diesel at a constant increase of 5% per annum. In order to replace 10% of this diesel consumption, South Africa will need to produce 1,037,500 kilolitres of biodiesel.

Each optimum sized plant (as discussed in this study) produces 2,500 kg/h biodiesel. Thus at 330 days operation per year:

$$
\begin{aligned}
&2.5 tons \times 24 \times 330 \\
&= 19{,}500 tons / annum \\
&= 22{,}500 kilolitres / annum \\
&\therefore \frac{1{,}036{,}000}{22{,}500} \\
&= 46 \, plants
\end{aligned}
$$

Storage volume and cost calculations

- 3 weeks stock
- Tank size: 100m^2
- Tank cost: R125,000/tank (includes construction costs)
- Source: Velo South Africa (Sieberhagen, 2006)

Table B1: COBP plant storage volume & cost

Item	Flow rate	Total volume	No of tanks	Cost
	kg/h	m^3		Rand
Vegetable oil	2742	1507	15	1875000
Biodiesel	2500	1432	15	1875000
Methanol	466	297	3	375000
Glycerol	345	158	2	250000
Total Cost				**4375000**

Table B2: SEBP plant storage volume & cost

Item	Flow rate	Total volume	No of tanks	Cost
	kg/h	m^3		Rand
Oil seeds	15,235	10,197	100	12,500,000
Biodiesel	2,500	1,432	15	1,875,000
Methanol	466	297	3	375,000
Glycerol	345	158	2	250,000
Total Cost				**15,000,000**

Working capital calculations

Table B3: Raw material cost for 3 months

Item	Price	Oil content	Flow rates	Amount for 3 months	Cost for 3 months
	R/ton	%	kg/h	tons	Thousand rand
Soybeans	1950	18%	15233	32904	64163
Sunflower seeds	2220	38%	7216	15586	34601
Canola	1900	40%	6855	14807	28133
Soy oil	5500		2742	5923	32575
Sunflower oil	6100		2742	5923	36129
Rapeseed oil	7920		2742	5923	46908
Palm oil	5220		2742	5923	30917
Methanol	3450		466	1007	3473
KOH	7800		15	32	253

Transport cost calculations

- Assuming production is regional and plants are fairly evenly spread across South Africa
- Area of South Africa = 1.2 million km^2
- Thus each plant (of the 46) covers an area of about 26000 km^2
- A circle with an area of 26000 km^2 has a radius of about 91 km
- Above statements justify the following transport distance estimations:
    - Oilseed: 250 km from farm to SEBP plant
    - Crude vegetable oil: 1000 km from harbour to COBP plant (assuming worst case scenario of imported feedstock)
    - Biodiesel: 250 km from plant to regional distributor
    - Methanol: 1000 km from port to plant
- Distances are overestimated not to underestimate the transport cost
- Indicative pricing obtained from Spoornet SA (Swart & Maree, 2006)

Table B4: Indicative rates from Spoornet SA (Rand/ton)

Item	250km	500km	1000km
Oilseeds	91.25	140.62	230.00
Crude vegetable oil	161.35	274.55	408.50
Methanol	161.35	274.55	408.50
KOH	161.35	274.55	408.50
Biodiesel	161.35	274.55	408.50

Table B5: Transport costs for a soybean SEBP plant

Item	Amount	Average distance	Total
	Tons	*km*	*Thousand Rand*
Soybeans	120658	250	11010
Methanol	3691	1000	1508
KOH	119	1000	49
Biodiesel	19800	250	3195
Total			**15761**

Table B6: Transport costs for a sunflower seed SEBP plant

Item	Amount	Average distance	Total
	Tons	*km*	*Thousand Rand*
Sunflower seeds	57149	250	5215
Methanol	3691	1000	1508
KOH	119	1000	49
Biodiesel	19800	250	3195
Total			**9966**

Table B7: Transport costs for a canola SEBP plant

Item	Amount	Average distance	Total
	Tons	*km*	*Thousand Rand*
Canola	54292	250	4954
Methanol	3691	1000	1508
KOH	119	1000	49
Biodiesel	19800	250	3195
Total			**9705**

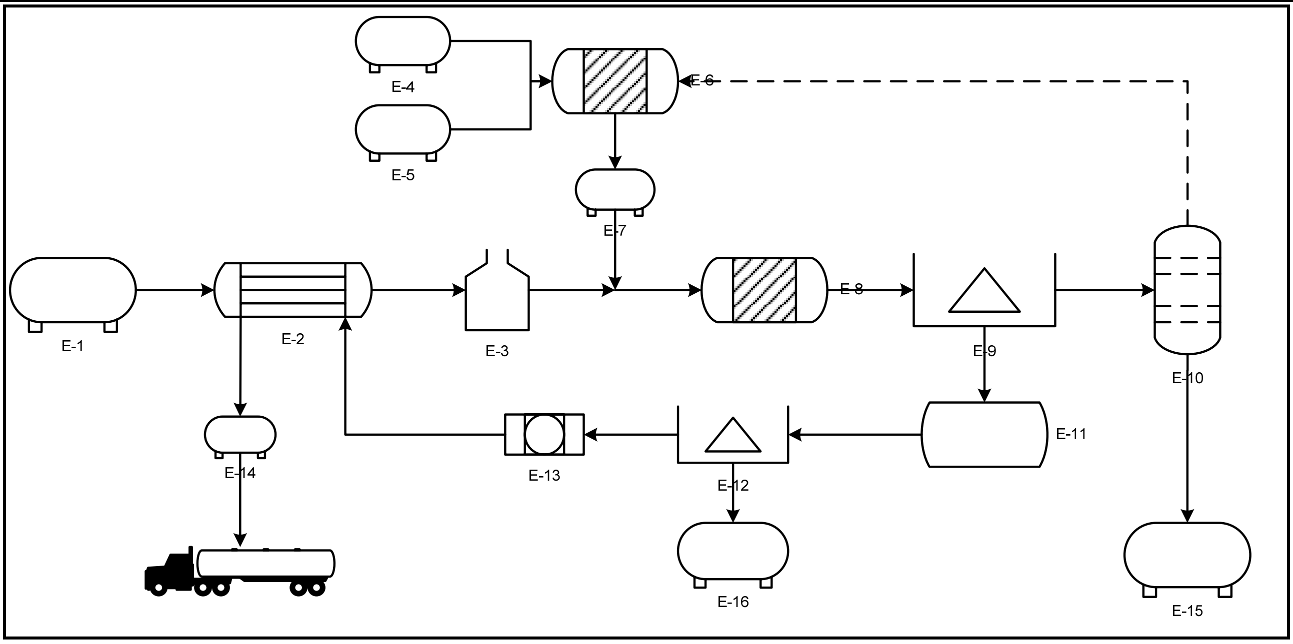
Table B8: Transport costs for a COBP plant

Item	Amount	Average distance	Total
	Tons	*km*	*Thousand Rand*
Crude oil	21718	1000	8872
Methanol	3691	1000	1508
KOH	119	1000	49
Biodiesel	19800	250	3195
Total			**13623**

Appendix C: Plant Description

Crude oil biodiesel processing (COBP) plant

The COBP plant discussed in this study consists of the BK 18 – ST containerized plant, BK-95 glycerol purifier and additional feedstock and product storage tanks. A simplified process flow diagram of the plant is shown below.



COBP Plant: Equipment List

E1	External Crude vegetable oil storage	E9	Centrifuge (contaminated biodiesel & crude glycerol)
E2	Heat Exchanger 35°C	E10	BK-95 glycerol purifier
E3	Burner 60°C	E11	Continuous dry wash system
E4	KOH storage	E12	Centrifuge (biodiesel & magnesium waste)
E5	Methanol storage	E13	Filter
E6	Methoxide reactor	E14	Biodiesel buffer storage
E7	Methoxide storage	E15	External glycerol Storage
E8	Transesterfication reactor (continuous)	E16	External magnesium waste storage

Figure C1: Process flow diagram of a COBP plant

Crude vegetable oil feedstock is pumped out of the external storage at 2743 kg/h. The feedstock is heated instantly with warm biodiesel to 35°C. After this the feedstock is heated further with the burner (running on glycerol and biodiesel) to 60°C. The potassium methoxide is formed in the methoxide reactor by reacting 466 kg/h methanol and 15 kg/h potassium hydroxide (KOH) catalyst in the methoxide reactor and stored in the internal temporary storage. Methoxide is added automatically and continuously in adjustable doses to the feedstock. The mixture is fed to the transesterfication reactor where an assumed conversion of 95% vegetable oil to biodiesel takes place. Crude glycerol (glycerol, KOH, water, soap and methanol) is separated from the biodiesel with centrifuges. Contaminated biodiesel is cleaned with magnesium silicate in a continuous dry wash system. The magnesium and absorbed particles, water and methanol are separated from the biodiesel with a self-discharging centrifuge. The biodiesel is filtered and passed through a heat exchanger to be cooled before going into the buffer storage for quality verification. After cooling to room temperature the biodiesel is pumped into the main storage.

The crude glycerol is fed into the BK-95 batch distillation column where 99.8% pure methanol and 95% pure glycerine are recovered. The methanol could possibly be recycled to save costs.

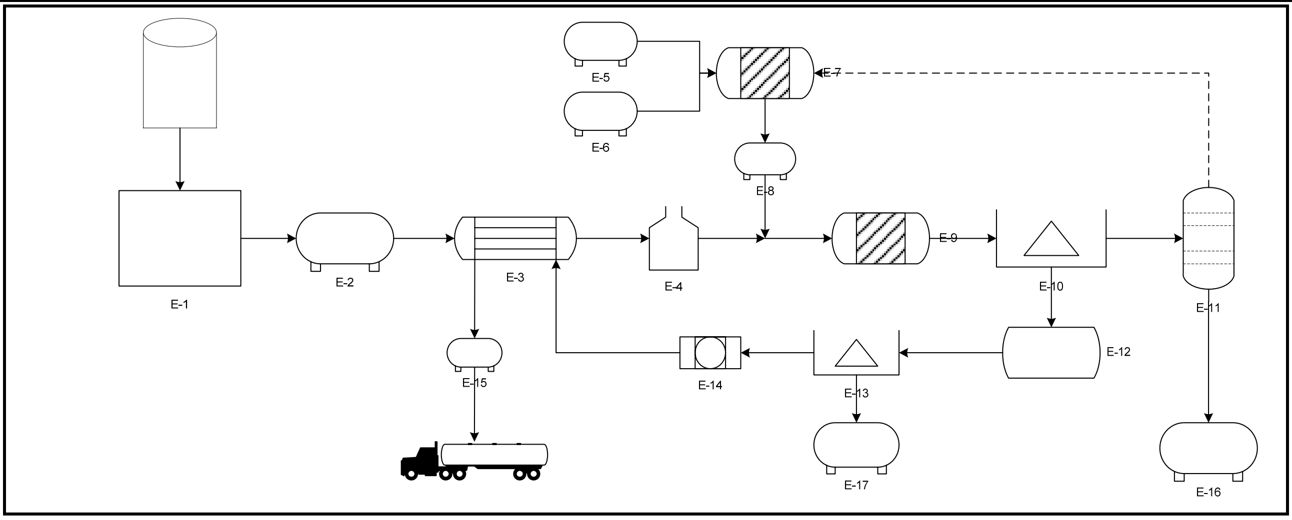
Flow rates and a basic mass balance of the different components entering and leaving the plant are shown below.

Table C1: Mass balance for a COBP plant

		Litres/hour	*Kg/hour*	*Tons/annum*
IN	Crude Vegetable Oil	2,991	2,742	21,725
	Methanol	589	466	3,693
	Potassium Hydroxide		15	118
	Total		***3,223***	
OUT	Biodiesel	2,841	2,500	19,800
	95% Glycerine	314	345	2,732
	99.8% Methanol	290	230	1,822
	Catalyst, FFA, Soaps		148	1,188
	Total		***3,223***	

Seed extraction biodiesel production (SEBP) plant

The SEBP plant discussed in this study consists of a 20 ton/hour hexane oilseed extractor, the BK 18 – ST containerized plant, BK-95 glycerol purifier and additional feedstock and product storage tanks. Most of the seed pressing companies in South Africa currently use hexane extraction but this size of extractor is than any extractor currently in operation. A simplified process flow diagram of the plant is shown below:



SEBP Plant: Equipment List

E1	Hexane extractor	E10	Centrifuge (contaminated biodiesel & crude glycerol)
E2	External Crude vegetable oil storage	E11	BK-95 glycerol purifier
E3	Heat Exchanger 35°C	E12	Continuous dry wash system
E4	Burner 60°C	E13	Centrifuge (biodiesel & magnesium waste)
E5	KOH storage	E14	Filter
E6	Methanol storage	E15	Biodiesel buffer storage
E7	Methoxide reactor	E16	External glycerol Storage
E8	Methoxide storage	E17	External magnesium waste storage
E9	Transesterfication reactor (continuous)		

Figure C2: Process flow diagram of a SEBP plant

The oilseeds are fed from their storage into the extractor from where the resulting crude oil is fed into the vegetable oil storage. The oil processing part of the plant is identical to the COBP plant described above.

Appendix D: Densities

Table D1: Densities of commodities

Item	Density
	kg/m^3
Vegetable oil (average)	917
Biodiesel (average)	880
Methanol	792
Glycerol	1100

Appendix E: Prices used in Calculations

Table E1: Local oilseed prices

Item	**Price**	**Source**
	R/ton	
Soybeans	1950	SAGIS
Sunflower seeds	2220	SAGIS
Canola	1900	Bester Feed & Grain Exchange

- FOB price: Free on board
- FOR price: Free on rail in South Africa
- FOB to FOR price calculations shown in costing sheet of Ocean Freight (Le Roux, 2006)

Table E2: International crude oil prices

Item	**FOB Price**	**FOR Price**	**Source**
	US$/ton	***R/ton***	
Soybean oil (Argentina)	502	5500	Oilworld & Ocean Freight
Sunflower oil (Argentina)	575	6100	Oilworld & Ocean Freight
Palm oil (Malaysia)	468	5220	Oilworld & Ocean Freight
Rapeseed oil (Europe)	794	7920	Oilworld & Ocean Freight

- Amounts ordered in largest possible quantity and prices include VAT

Table E3: Local chemical commodity prices

Item	**Price**	**Source**
	R/ton	
Methanol	3450	SASOL
Potassium Hydroxide	7800	Crest Chemicals

- Crude vegetable oil transported in 22 ton container
- Exchange rate of R7.50/US$ assumed

Table E4: Costing sheet calculating FOB to FOR prices (Le Roux, 2006)

CIF Cost US	Palm Oil	Soybean Oil	Sunflower Oil	Rapeseed Oil
FOB price (US$/ton)	**468**	**502**	**575**	**794**
Purchase Price (22 ton container)	10296	11044	12650	17468
Ocean Freight	2400	2400	2400	2400
BAF	385	385	385	385
War risk	0	0	0	0
Additional charges	83	83	83	83
Insurance (0.25%)	33	35	39	51
Purchase Price in ZAR	**98977**	**104601**	**116676**	**152901**
Documentation and Clearing Costs				
Freight Collection Fee	150	150	150	150
Cargo Dues*	1610	1610	1610	1610
Terminal Handling Costs	750	750	750	750
Carrier Haulage*	287	287	287	287
Agents Releas Fee	105	105	105	105
Port Health	90	90	90	90
CTO	100	100	100	100
Documentation Fee	600	600	600	600
Finance Fee	350	350	350	350
Bank Cost	200	200	200	200
VAT (marked with *)	560	560	560	560
Cartage*	1100	1100	1100	1100
Transport to Warehouse*	1000	1000	1000	1000
Custom Duties (10% on FOB for veg. oil)	7722	8283	9488	13101
Handling + Storage				
Unpack	650	650	650	650
Handling + Storage	615	615	615	615
Transport to Client	0	0	0	0
Total Costs (per 22 ton container)	**114865**	**121050**	**134330**	**174169**
Cost per Ton (R/ton)	**5221**	**5502**	**6106**	**7917**

Table E5: Extraction costs obtained from industry sources

Source	**Cost**
	R/ton seed
Southern oil	350
Crown Oil	300
Nola	220
Mr Victor (Sabie)	130
Average Cost	***250***

Appendix F: Manufacturing Cost Calculations & Results

Table F1: Manufacturing costs of SEBP plant: Canola

	Amount	Cost	Cost
		Thousand rand	cents/litre
ANNUAL COSTS			
Variable Costs			
Oilseeds (tons)	54,296	103,163	463
Extraction cost		13,574	61
Methanol (tons)	3,691	12,733	57
Catalyst (tons)	119	927	4
Operating Labour (hours)	15,840	792	4
Senior staff		1,200	5
Water (m^3)	4,499	13	0
Transport costs		9,705	44
Maintenance & repairs (6% of fixed capital)		4,628	21
Operating Supplies (15% of maintenance & repairs)		694	3
Laboratory charges (15% of operating labour)		119	1
Subtotal, A_{DME}		**147,547**	663
Indirect Costs & General Expenses			
Overheads (60% of sum of all labour & maintenance)		3,252	15
Insurance (0.5% of fixed capital)		771	3
Administrative costs (25% of overheads)		813	4
Research & development (1% of total manufacturing cost)		1,475	7
Depreciation (10% of fixed capital)		7,713	35
Subtotal		**14,025**	63
Total production costs		**161,572**	726
Less Oilcake credit	29,863	54,649	245
Total manufacturing costs		**106,923**	480

Table F2: Manufacturing costs of SEBP plant: Soybeans

	Amount	Cost	Cost
		Thousand rand	cents/litre
ANNUAL COSTS			
Variable Costs			
Oilseeds (tons)	120,658	235,283	1,057
Extraction cost		30,164	135
Methanol (tons)	3,691	12,733	57
Catalyst (tons)	119	927	4
Operating Labour (hours)	15,840	792	4
Senior staff		1,200	5
Water (m^3)	4,499	13	0
Transport costs		15,761	71
Maintenance & repairs (6% of fixed capital)		4,628	21
Operating Supplies (15% of maintenance & repairs)		694	3
Laboratory charges (15% of operating labour)		119	1
***Subtotal, A** $_{DME}$*		**302,314**	1,358
Indirect Costs & General Expenses			
Overheads (60% of sum of all labour & maintenance)		3,252	15
Insurance (0.5% of fixed capital)		771	3
Administrative costs (25% of overheads)		813	4
Research & development (1% of total manufacturing cost)		1,512	7
Depreciation (10% of fixed capital)		7,713	35
Subtotal		**14,061**	63
Total production costs		**316,375**	1,421
Less Oilcake credit	92,907	167,232	751
Total manufacturing costs		**149,143**	670

Table F3: Manufacturing costs of SEBP plant: Sunflower seeds

	Amount	Cost	Cost
		Thousand rand	**cents/litre**
ANNUAL COSTS			
Variable Costs			
Oilseeds (tons)	57,154	126,881	570
Extraction cost		14,288	64
Methanol (tons)	3,691	12,733	57
Catalyst (tons)	119	927	4
Operating Labour (hours)	15,840	792	4
Senior staff		1,200	5
Water (m^3)	4,499	13	0
Transport costs		9,966	45
Maintenance & repairs (6% of fixed capital)		4,628	21
Operating Supplies (15% of maintenance & repairs)		694	3
Laboratory charges (15% of operating labour)		119	1
Subtotal, A_{DME}		**172,242**	774
Indirect Costs & General Expenses			
Overheads (60% of sum of all labour & maintenance)		3,252	15
Insurance (0.5% of fixed capital)		771	3
Administrative costs (25% of overheads)		813	4
Research & development (1% of total manufacturing cost)		1,722	8
Depreciation (10% of fixed capital)		7,713	35
Subtotal		**14,271**	64
Total production costs		**186,513**	838
Less Oilcake credit	32,578	38,116	171
Total manufacturing costs		**148,397**	667

Table F4: Manufacturing costs of COBP plant: Palm oil

	Amount	Cost	Cost
		Thousand rand	cents/litre
ANNUAL COSTS			
Variable Costs			
Crude Vegetable Oil (tons)	21,718	113,370	509
Methanol (tons)	3,691	12,733	57
Catalyst (tons)	119	927	4
Operating Labour (hours)	15,840	792	4
Senior staff		1,200	5
Water (m^3)	4,500	14	0
Transport costs		13,623	61
Maintenance & repairs (6% of fixed capital)		690	3
Operating Supplies (15% of maintenance & repairs)		41	0
Laboratory charges (15% of operating labour)		119	1
Subtotal, A_{DME}		**143,508**	645
			0
Indirect Costs & General Expenses			0
Overheads (60% of sum of all labour & maintenance)		889	4
Insurance (1% of fixed capital)		115	1
Administrative costs (25% of overheads)		222	1
Research & development (1% of total manufacturing cost)		1,435	6
Depreciation (10% of fixed capital)		1,149	5
Subtotal		**3,810**	17
Total manufacturing costs		**147,318**	662

Table F5: Manufacturing costs of COBP plant: Soybean oil

	Amount	Cost	Cost
		Thousand rand	cents/litre
ANNUAL COSTS			
Variable Costs			
Crude Vegetable Oil (tons)	21,718	119,451	537
Methanol (tons)	3,691	12,733	57
Catalyst (tons)	119	927	4
Operating Labour (hours)	15,840	792	4
Senior staff		1,200	5
Water (m^3)	4,500	14	0
Transport costs		13,623	61
maintenance & repairs (6% of fixed capital)		690	3
Operating Supplies (15% of maintenance & repairs)		41	0
Laboratory charges (15% of operating labour)		119	1
Subtotal, A_{DME}		**149,589**	672
			0
Indirect Costs & General Expenses			0
Overheads (60% of sum of all labour & maintenance)		889	4
Insurance (1% of fixed capital)		115	1
Administrative costs (25% of overheads)		222	1
Research & development (1% of total manufacturing cost)		1,496	7
Depreciation (10% of fixed capital)		1,149	5
Subtotal		**3,871**	17
Total manufacturing costs		**153,460**	689

Table F6: Manufacturing costs of COBP plant: Sunflower seed oil

	Amount	Cost	Cost
		Thousand rand	cents/litre
ANNUAL COSTS			
Variable Costs			
Crude Vegetable Oil (tons)	21,718	132,482	595
Methanol (tons)	3,691	12,733	57
Catalyst (tons)	119	927	4
Operating Labour (hours)	15,840	792	4
Senior staff		1,200	5
Water (m^3)	4,500	14	0
Transport costs		13,623	61
Maintenance & repairs (6% of fixed capital)		690	3
Operating Supplies (15% of maintenance & repairs)		41	0
Laboratory charges (15% of operating labour)		119	1
Subtotal, A_{DME}		**162,620**	730
			0
Indirect Costs & General Expenses			0
Overheads (60% of sum of all labour & maintenance)		889	4
Insurance (1% of fixed capital)		115	1
Administrative costs (25% of overheads)		222	1
Research & development (1% of total manufacturing cost)		1,626	7
Depreciation (10% of fixed capital)		1,149	5
Subtotal		**4,001**	18
Total manufacturing costs		**166,622**	748

Table F7: Manufacturing costs of COBP plant: Rapeseed oil

	Amount	Cost	Cost
		Thousand rand	cents/litre
ANNUAL COSTS			
Variable Costs			
Crude Vegetable Oil (tons)	21,718	172,010	773
Methanol (tons)	3,691	12,733	57
Catalyst (tons)	119	927	4
Operating Labour (hours)	15,840	792	4
Senior staff		1,200	5
Water (m^3)	4,500	14	0
Transport costs		13,623	61
Maintenance & repairs (6% of fixed capital)		690	3
Operating Supplies (15% of maintenance & repairs)		41	0
Laboratory charges (15% of operating labour)		119	1
Subtotal, A_{DME}		**202,148**	908
			0
Indirect Costs & General Expenses			0
Overheads (60% of sum of all labour & maintenance)		889	4
Insurance (1% of fixed capital)		115	1
Administrative costs (25% of overheads)		222	1
Research & development (1% of total manufacturing cost)		2,021	9
Depreciation (10% of fixed capital)		1,149	5
Subtotal		**4,397**	20
			0
Total manufacturing costs		**206,544**	928

Appendix G: Sensitivity Analyses Calculations & Results

Table G1: Manufacturing cost sensitivity analyses of a SEBP plant

Sensitivity on	**Methanol Price**										
Change	**-25%**	**-20%**	**-15%**	**-10%**	**-5%**	**0%**	**5%**	**10%**	**15%**	**20%**	**25%**
Price	2,588	2,760	2,933	3,105	3,278	**3,450**	3,623	3,795	3,968	4,140	4,313
Manufacturing cost (Average)	591	594	597	600	603	**606**	608	611	614	617	620
Change in manufacturing cost	-2.5%	-2.0%	-1.5%	-1.0%	-0.5%	0.0%	0.3%	0.8%	1.3%	1.8%	2.3%
Sensitivity on	**Soybean Price**										
Change	**-25%**	**-20%**	**-15%**	**-10%**	**-5%**	**0%**	**5%**	**10%**	**15%**	**20%**	**25%**
Price	1,463	1,560	1,658	1,755	1,853	**1,950**	2,048	2,145	2,243	2,340	2,438
Manufacturing cost	405	458	511	564	617	**670**	723	776	830	882	936
Change in manufacturing cost	-39.6%	-31.6%	-23.7%	-15.8%	-7.9%	0.0%	7.9%	15.8%	23.9%	31.6%	39.7%
Sensitivity on	**Sunflowerseed Price**										
Change	**-25%**	**-20%**	**-15%**	**-10%**	**-5%**	**0%**	**5%**	**10%**	**15%**	**20%**	**25%**
Price	1,665	1,776	1,887	1,998	2,109	**2,220**	2,331	2,442	2,553	2,664	2,775
Manufacturing cost	523	551	580	609	638	**667**	695	724	753	782	810
Change in manufacturing cost	-21.6%	-17.4%	-13.0%	-8.7%	-4.3%	0.0%	4.2%	8.5%	12.9%	17.2%	21.4%
Sensitivity on	**Canola Price**										
Change	**-25%**	**-20%**	**-15%**	**-10%**	**-5%**	**0%**	**5%**	**10%**	**15%**	**20%**	**25%**
Price	1,425	1,520	1,615	1,710	1,805	**1,900**	1,995	2,090	2,185	2,280	2,375
Manufacturing cost	363	387	410	433	457	**480**	504	527	550	574	597
Change in manufacturing cost	-24.4%	-19.4%	-14.6%	-9.8%	-4.8%	0.0%	5.0%	9.8%	14.6%	19.6%	24.4%
Sensitivity on	**Extraction Cost**										
Change	**-25%**	**-20%**	**-15%**	**-10%**	**-5%**	**0%**	**5%**	**10%**	**15%**	**20%**	**25%**
Price	188	200	213	225	238	**250**	263	275	288	300	313
Manufacturing cost (Average)	584	588	593	597	601	**606**	610	614	619	623	628
Change in manufacturing cost	-3.6%	-3.0%	-2.1%	-1.5%	-0.8%	0.0%	0.7%	1.3%	2.1%	2.8%	3.6%
Sensitivity on	**Soybean Oilcake Price**										
Change	**-25%**	**-20%**	**-15%**	**-10%**	**-5%**	**0%**	**5%**	**10%**	**15%**	**20%**	**25%**
Price	1,350	1,440	1,530	1,620	1,710	**1,800**	1,890	1,980	2,070	2,160	2,250
Manufacturing cost	858	820	783	745	707	**670**	632	595	557	520	482
Change in manufacturing cost	28.1%	22.4%	16.9%	11.2%	5.5%	0.0%	-5.7%	-11.2%	-16.9%	-22.4%	-28.1%
Sensitivity on	**Sunflower Oilcake Price**										
Change	**-25%**	**-20%**	**-15%**	**-10%**	**-5%**	**0%**	**5%**	**10%**	**15%**	**20%**	**25%**
Price	878	936	995	1,053	1,112	**1,170**	1,229	1,287	1,346	1,404	1,463
Manufacturing cost	709	701	692	684	675	**667**	658	649	641	632	624
Change in manufacturing cost	6.3%	5.1%	3.7%	2.5%	1.2%	0.0%	-1.3%	-2.7%	-3.9%	-5.2%	-6.4%
Sensitivity on	**Canola Oilcake Price**										
Change	**-25%**	**-20%**	**-15%**	**-10%**	**-5%**	**0%**	**5%**	**10%**	**15%**	**20%**	**25%**
Price	1,373	1,464	1,556	1,647	1,739	**1,830**	1,922	2,013	2,105	2,196	2,288
Manufacturing cost	542	529	517	505	492	**480**	468	456	443	431	419
Change in manufacturing cost	12.9%	10.2%	7.7%	5.2%	2.5%	0.0%	-2.5%	-5.0%	-7.7%	-10.2%	-12.7%

Table G2: Manufacturing cost sensitivity analyses of a COBP plant

Sensitivity on	Methanol Price										
Change	**-25%**	**-20%**	**-15%**	**-10%**	**-5%**	**0%**	**5%**	**10%**	**15%**	**20%**	**25%**
Price	2,588	2,760	2,933	3,105	3,278	**3,450**	3,623	3,795	3,968	4,140	4,313
Manufacturing cost	675	678	681	684	686	**689**	692	695	698	701	704
Change in manufacturing cost	-2.0%	-1.6%	-1.2%	-0.7%	-0.4%	0.0%	0.4%	0.9%	1.3%	1.7%	2.2%

Sensitivity on	Vegetable Oil Price										
Change	**-25%**	**-20%**	**-15%**	**-10%**	**-5%**	**0%**	**5%**	**10%**	**15%**	**20%**	**25%**
Price	4,125	4,400	4,675	4,950	5,225	**5,500**	5,775	6,050	6,325	6,600	6,875
Manufacturing cost	554	581	608	635	662	**689**	716	744	771	798	825
Change in manufacturing cost	-19.6%	-15.7%	-11.8%	-7.8%	-3.9%	0.0%	3.9%	8.0%	11.9%	15.8%	19.7%

Appendix H: Profitability Calculations & Results

- Same as manufacturing cost sheet with a income section added
- Price of biodiesel was varied to obtain different results – R8.00/litre in this example

Table H1: Example of SEBP plant profit calculation sheet

	Ammount	Cost	Cost
		Thousand rand	cents/litre
ANNUAL COSTS			
Variable Costs			
Oilseeds (tons)	120,658	235,283	1,057
Extraction cost		30,164	135
Methanol (tons)	3,691	12,733	57
Catalyst (tons)	119	927	4
Operating Labour (hours)	15,840	792	4
Senior staff		1,200	5
Water (m^3)	4,499	13	0
Transport costs		15,761	71
Maintanance & repairs (6% of fixed capital)		4,628	21
Operating Supplies (15% of maintanance & repairs)		694	3
Laboratory charges (15% of operating labour)		119	1
Subtotal, A_{DME}		**302,314**	1,358
Indirect Costs & General Expences			
Overheads (60% of sum of all labour & maintanance)		3,252	15
Insurance (0.5% of fixed capital)		771	3
Administrative costs (25% of overheads)		813	4
Research & development (1% of total manufacturing cost)		1,512	7
Depreciation (10% of fixed capital)		7,713	35
Subtotal		**14,061**	63
Total production costs		**316,375**	1,421
Less Oilcake credit	92,907	167,232	751
Total manufacturing costs		**149,143**	670
ANNUAL SALES			
Biodiesel Produced (litres)	22,500,000		
Less Biodiesel for generator (litres)	237,600		
Biodiesel for sale (litres)	**22,262,400**		
ANNUAL INCOME			
Selling Price of biodiesel (R/litre)	R 8.00		
Total Sales		178,099	
Less Total manufacturing costs		149,143	
Less Fuel tax (R1.01/litre)		22,485	
Profit (before income tax)		6,471	29
Income tax (29%)		1,877	
Net Profit		**4,595**	21

Table H2: Profit sensitivity to oilseed price change calculations of a SEBP plant

Profit Sensitivity to Canola Price Change

Selling Price	Oilseed Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 6.50	1,520	R 3.87	25,606	23%
	1,615	R 4.10	21,971	20%
	1,710	R 4.33	18,335	17%
	1,805	R 4.57	14,542	13%
	1,900	R 4.80	10,906	10%
	1,995	R 5.04	7,113	7%
	2,090	R 5.27	3,477	3%
	2,185	R 5.50	-158	0%
	2,280	R 5.74	-3,952	-4%
Selling Price	**Oilseed Price**	**Manufacturing cost**	**Net Profit After Tax**	**RORI**
R/litre	R/ton	R/litre	Thousand rand	%
R 7.00	1,520	R 3.87	33,509	31%
	1,615	R 4.10	29,874	27%
	1,710	R 4.33	26,238	24%
	1,805	R 4.57	22,445	21%
	1,900	R 4.80	18,810	17%
	1,995	R 5.04	15,016	14%
	2,090	R 5.27	11,381	10%
	2,185	R 5.50	7,745	7%
	2,280	R 5.74	3,952	4%
Selling Price	**Oilseed Price**	**Manufacturing cost**	**Net Profit After Tax**	**RORI**
R/litre	R/ton	R/litre	Thousand rand	%
R 7.50	1,520	R 3.87	41,413	38%
	1,615	R 4.10	37,777	35%
	1,710	R 4.33	34,142	31%
	1,805	R 4.57	30,348	28%
	1,900	R 4.80	26,713	25%
	1,995	R 5.04	22,919	21%
	2,090	R 5.27	19,284	18%
	2,185	R 5.50	15,648	14%
	2,280	R 5.74	11,855	11%

Profit Sensitivity to Soybean Price Change

Selling Price	Oilseed Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 6.50	1,560	R 4.58	14,384	10%
	1,658	R 5.11	6,006	4%
	1,755	R 5.64	-2,371	-2%
	1,853	R 6.17	-10,748	-7%
	1,950	R 6.70	-19,126	-13%
	2,048	R 7.23	-27,503	-19%
	2,145	R 7.76	-35,880	-25%
	2,243	R 8.30	-44,416	-31%
	2,340	R 8.82	-52,635	-36%
Selling Price	**Oilseed Price**	**Manufacturing cost**	**Net Profit After Tax**	**RORI**
R/litre	R/ton	R/litre	Thousand rand	%
R 7.00	1,560	R 4.58	22,287	15%
	1,658	R 5.11	13,910	10%
	1,755	R 5.64	5,532	4%
	1,853	R 6.17	-2,845	-2%
	1,950	R 6.70	-11,222	-8%
	2,048	R 7.23	-19,600	-14%
	2,145	R 7.76	-27,977	-19%
	2,243	R 8.30	-36,513	-25%
	2,340	R 8.82	-44,732	-31%
Selling Price	**Oilseed Price**	**Manufacturing cost**	**Net Profit After Tax**	**RORI**
R/litre	R/ton	R/litre	Thousand rand	%
R 7.50	1,560	R 4.58	30,190	21%
	1,658	R 5.11	21,813	15%
	1,755	R 5.64	13,435	9%
	1,853	R 6.17	5,058	3%
	1,950	R 6.70	-3,319	-2%
	2,048	R 7.23	-11,697	-8%
	2,145	R 7.76	-20,074	-14%
	2,243	R 8.30	-28,609	-20%
	2,340	R 8.82	-36,829	-25%

Profit Sensitivity to Sunflower Price Change

Selling Price	Oilseed Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 6.50	1,776	R 5.51	-316	0%
	1,887	R 5.80	-4,900	-4%
	1,998	R 6.09	-9,484	-8%
	2,109	R 6.38	-14,068	-12%
	2,220	R 6.67	-18,651	-16%
	2,331	R 6.95	-23,077	-20%
	2,442	R 7.24	-27,661	-24%
	2,553	R 7.53	-32,245	-28%
	2,664	R 7.82	-36,829	-32%
Selling Price	**Oilseed Price**	**Manufacturing cost**	**Net Profit After Tax**	**RORI**
R/litre	R/ton	R/litre	Thousand rand	%
R 7.00	1,776	R 5.51	7,587	7%
	1,887	R 5.80	3,003	3%
	1,998	R 6.09	-1,581	-1%
	2,109	R 6.38	-6,164	-5%
	2,220	R 6.67	-10,748	-9%
	2,331	R 6.95	-15,174	-13%
	2,442	R 7.24	-19,758	-17%
	2,553	R 7.53	-24,342	-21%
	2,664	R 7.82	-28,926	-25%
Selling Price	**Oilseed Price**	**Manufacturing cost**	**Net Profit After Tax**	**RORI**
R/litre	R/ton	R/litre	Thousand rand	%
R 7.50	1,776	R 5.51	15,490	13%
	1,887	R 5.80	10,906	9%
	1,998	R 6.09	6,323	5%
	2,109	R 6.38	1,739	2%
	2,220	R 6.67	-2,845	-2%
	2,331	R 6.95	-7,271	-6%
	2,442	R 7.24	-11,855	-10%
	2,553	R 7.53	-16,439	-14%
	2,664	R 7.82	-21,022	-18%

Table H2 (continued): Profit sensitivity to oilseed price change calculations of a SEBP plant

Profit Sensitivity to Canola Price Change

Selling Price	Oilseed Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 8.00	1,520	R 3.87	49,316	45%
	1,615	R 4.10	45,680	42%
	1,710	R 4.33	42,045	39%
	1,805	R 4.57	38,251	35%
	1,900	R 4.80	34,616	32%
	1,995	R 5.04	30,822	28%
	2,090	R 5.27	27,187	25%
	2,185	R 5.50	23,551	22%
	2,280	R 5.74	19,758	18%

Selling Price	Oilseed Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 8.50	1,520	R 3.87	57,219	53%
	1,615	R 4.10	53,583	49%
	1,710	R 4.33	49,948	46%
	1,805	R 4.57	46,154	42%
	1,900	R 4.80	42,519	39%
	1,995	R 5.04	38,725	36%
	2,090	R 5.27	35,090	32%
	2,185	R 5.50	31,455	29%
	2,280	R 5.74	27,661	25%

Profit Sensitivity to Soybean Price Change

Selling Price	Oilseed Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 8.00	1,560	R 4.58	38,093	26%
	1,658	R 5.11	29,716	20%
	1,755	R 5.64	21,339	15%
	1,853	R 6.17	12,961	9%
	1,950	R 6.70	4,584	3%
	2,048	R 7.23	-3,794	-3%
	2,145	R 7.76	-12,171	-8%
	2,243	R 8.30	-20,706	-14%
	2,340	R 8.82	-28,926	-20%

Selling Price	Oilseed Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 8.50	1,560	R 4.58	45,996	32%
	1,658	R 5.11	37,619	26%
	1,755	R 5.64	29,242	20%
	1,853	R 6.17	20,864	14%
	1,950	R 6.70	12,487	9%
	2,048	R 7.23	4,110	3%
	2,145	R 7.76	-4,268	-3%
	2,243	R 8.30	-12,803	-9%
	2,340	R 8.82	-21,022	-14%

Profit Sensitivity to Sunflower Price Change

Selling Price	Oilseed Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 8.00	1,776	R 5.51	23,393	20%
	1,887	R 5.80	18,810	16%
	1,998	R 6.09	14,226	12%
	2,109	R 6.38	9,642	8%
	2,220	R 6.67	5,058	4%
	2,331	R 6.95	632	1%
	2,442	R 7.24	-3,952	-3%
	2,553	R 7.53	-8,535	-7%
	2,664	R 7.82	-13,119	-11%

Selling Price	Oilseed Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 8.50	1,776	R 5.51	31,296	27%
	1,887	R 5.80	26,713	23%
	1,998	R 6.09	22,129	19%
	2,109	R 6.38	17,545	15%
	2,220	R 6.67	12,961	11%
	2,331	R 6.95	8,535	7%
	2,442	R 7.24	3,952	3%
	2,553	R 7.53	-632	-1%
	2,664	R 7.82	-5,216	-5%

Table H3: Profit sensitivity to oilcake price change calculations of a SEBP plant

Profit Sensitivity to Canola Oilcake Price Change

Selling Price	Oilcake Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 6.50	1,464	R 5.29	3,161	3%
	1,556	R 5.17	5,058	5%
	1,647	R 5.05	6,955	6%
	1,739	R 4.92	9,010	8%
	1,830	R 4.80	10,906	10%
	1,922	R 4.68	12,803	12%
	2,013	R 4.56	14,700	13%
	2,105	R 4.43	16,755	15%
	2,196	R 4.31	18,651	17%
Selling Price	Oilcake Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 7.00	1,464	R 5.29	11,064	10%
	1,556	R 5.17	12,961	12%
	1,647	R 5.05	14,858	14%
	1,739	R 4.92	16,913	16%
	1,830	R 4.80	18,810	17%
	1,922	R 4.68	20,706	19%
	2,013	R 4.56	22,603	21%
	2,105	R 4.43	24,658	23%
	2,196	R 4.31	26,555	24%
Selling Price	Oilcake Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 7.50	1,464	R 5.29	18,968	17%
	1,556	R 5.17	20,864	19%
	1,647	R 5.05	22,761	21%
	1,739	R 4.92	24,816	23%
	1,830	R 4.80	26,713	25%
	1,922	R 4.68	28,609	26%
	2,013	R 4.56	30,506	28%
	2,105	R 4.43	32,561	30%
	2,196	R 4.31	34,458	32%

Profit Sensitivity to Soybean Oilcake Price Change

Selling Price	Oilcake Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 6.50	1,440	R 8.20	-42,835	-30%
	1,530	R 7.83	-36,987	-26%
	1,620	R 7.45	-30,980	-21%
	1,710	R 7.07	-24,974	-17%
	1,800	R 6.70	-19,126	-13%
	1,890	R 6.32	-13,119	-9%
	1,980	R 5.95	-7,271	-5%
	2,070	R 5.57	-1,265	-1%
	2,160	R 5.20	4,584	3%
Selling Price	Oilcake Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 7.00	1,440	R 8.20	-34,932	-24%
	1,530	R 7.83	-29,084	-20%
	1,620	R 7.45	-23,077	-16%
	1,710	R 7.07	-17,071	-12%
	1,800	R 6.70	-11,222	-8%
	1,890	R 6.32	-5,216	-4%
	1,980	R 5.95	632	0%
	2,070	R 5.57	6,639	5%
	2,160	R 5.20	12,487	9%
Selling Price	Oilcake Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 7.50	1,440	R 8.20	-27,029	-19%
	1,530	R 7.83	-21,180	-15%
	1,620	R 7.45	-15,174	-10%
	1,710	R 7.07	-9,168	-6%
	1,800	R 6.70	-3,319	-2%
	1,890	R 6.32	2,687	2%
	1,980	R 5.95	8,535	6%
	2,070	R 5.57	14,542	10%
	2,160	R 5.20	20,390	14%

Profit Sensitivity to Sunflower Oilcake Price Change

Selling Price	Oilcake Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 6.50	936	R 7.01	-24,026	-21%
	995	R 6.92	-22,603	-20%
	1,053	R 6.84	-21,339	-18%
	1,112	R 6.75	-19,916	-17%
	1,170	R 6.67	-18,651	-16%
	1,229	R 6.58	-17,229	-15%
	1,287	R 6.49	-15,806	-14%
	1,346	R 6.41	-14,542	-13%
	1,404	R 6.32	-13,119	-11%
Selling Price	Oilcake Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 7.00	936	R 7.01	-16,122	-14%
	995	R 6.92	-14,700	-13%
	1,053	R 6.84	-13,435	-12%
	1,112	R 6.75	-12,013	-10%
	1,170	R 6.67	-10,748	-9%
	1,229	R 6.58	-9,326	-8%
	1,287	R 6.49	-7,903	-7%
	1,346	R 6.41	-6,639	-6%
	1,404	R 6.32	-5,216	-5%
Selling Price	Oilcake Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 7.50	936	R 7.01	-8,219	-7%
	995	R 6.92	-6,797	-6%
	1,053	R 6.84	-5,532	-5%
	1,112	R 6.75	-4,110	-4%
	1,170	R 6.67	-2,845	-2%
	1,229	R 6.58	-1,423	-1%
	1,287	R 6.49	0	0%
	1,346	R 6.41	1,265	1%
	1,404	R 6.32	2,687	2%

Table H3 (continued): Profit sensitivity to oilcake price change calculations of a SEBP plant

Profit Sensitivity to Canola Oilcake Price Change

Selling Price	Oilcake Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 8.00	1,464	R 5.29	26,871	25%
	1,556	R 5.17	28,767	26%
	1,647	R 5.05	30,664	28%
	1,739	R 4.92	32,719	30%
	1,830	R 4.80	34,616	32%
	1,922	R 4.68	36,513	34%
	2,013	R 4.56	38,409	35%
	2,105	R 4.43	40,464	37%
	2,196	R 4.31	42,361	39%

Selling Price	Oilcake Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 8.50	1,464	R 5.29	34,774	32%
	1,556	R 5.17	36,671	34%
	1,647	R 5.05	38,567	35%
	1,739	R 4.92	40,622	37%
	1,830	R 4.80	42,519	39%
	1,922	R 4.68	44,416	41%
	2,013	R 4.56	46,312	42%
	2,105	R 4.43	48,367	44%
	2,196	R 4.31	50,264	46%

Profit Sensitivity to Soybean Oilcake Price Change

Selling Price	Oilcake Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 8.00	1,440	R 8.20	-19,126	-13%
	1,530	R 7.83	-13,277	-9%
	1,620	R 7.45	-7,271	-5%
	1,710	R 7.07	-1,265	-1%
	1,800	R 6.70	4,584	3%
	1,890	R 6.32	10,590	7%
	1,980	R 5.95	16,439	11%
	2,070	R 5.57	22,445	15%
	2,160	R 5.20	28,293	20%

Selling Price	Oilcake Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 8.50	1,440	R 8.20	-11,222	-8%
	1,530	R 7.83	-5,374	-4%
	1,620	R 7.45	632	0%
	1,710	R 7.07	6,639	5%
	1,800	R 6.70	12,487	9%
	1,890	R 6.32	18,493	13%
	1,980	R 5.95	24,342	17%
	2,070	R 5.57	30,348	21%
	2,160	R 5.20	36,196	25%

Profit Sensitivity to Sunflower Oilcake Price Change

Selling Price	Oilcake Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 8.00	936	R 7.01	-316	0%
	995	R 6.92	1,106	1%
	1,053	R 6.84	2,371	2%
	1,112	R 6.75	3,794	3%
	1,170	R 6.67	5,058	4%
	1,229	R 6.58	6,481	6%
	1,287	R 6.49	7,903	7%
	1,346	R 6.41	9,168	8%
	1,404	R 6.32	10,590	9%

Selling Price	Oilcake Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 8.50	936	R 7.01	7,587	7%
	995	R 6.92	9,010	8%
	1,053	R 6.84	10,274	9%
	1,112	R 6.75	11,697	10%
	1,170	R 6.67	12,961	11%
	1,229	R 6.58	14,384	12%
	1,287	R 6.49	15,806	14%
	1,346	R 6.41	17,071	15%
	1,404	R 6.32	18,493	16%

- Same as manufacturing cost sheet with an income section added
- Price of biodiesel was varied to obtain different results – R8.00/litre in this example

Table H4: Example of COBP plant profit calculation sheet

	Amount	Cost	Cost
		Thousand rand	cents/litre
ANNUAL COSTS			
Variable Costs			
Crude Vegetable Oil (tons)	21,718	119,451	537
Methanol (tons)	3,691	12,733	57
Catalyst (tons)	119	927	4
Operating Labour (hours)	15,840	792	4
Senior staff		1,200	5
Water (m^3)	4,500	14	0
Transport costs		13,623	61
maintenance & repairs (6% of fixed capital)		690	3
Operating Supplies (15% of maintenance & repairs)		41	0
Laboratory charges (15% of operating labour)		119	1
Subtotal, A_{DME}		**149,589**	672
			0
Indirect Costs & General Expenses			0
Overheads (60% of sum of all labour & maintenance)		889	4
Insurance (1% of fixed capital)		115	1
Administrative costs (25% of overheads)		222	1
Research & development (1% of total manufacturing cost)		1,496	7
Depreciation (10% of fixed capital)		1,149	5
Subtotal		**3,871**	17
Total manufacturing costs		**153,460**	689
ANNUAL SALES			
Biodiesel Produced (litres)	22,500,000		
Less Biodiesel for generator (litres)	237,600		
Biodiesel for sale (litres)	**22,262,400**		
ANNUAL INCOME			
Selling Price of biodiesel (R/litre)	R 8.00		
Total Sales		178,099	
Less Total manufacturing costs		153,460	
Less Fuel tax (R1.01/litre)		22,485	
Profit (before income tax)		2,154	10
Income tax (29%)		625	
Net Profit		**1,529**	7

Table H5: Profit sensitivity to vegetable oil price change calculations of a COBP plant

Profit Sensitivity to Vegetable Oil Price

Selling Price	Vegetable Oil Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 6.50	3,850	R 5.27	3,477	7%
	4,125	R 5.54	-790	-2%
	4,400	R 5.81	-5,058	-10%
	4,675	R 6.08	-9,326	-19%
	4,950	R 6.35	-13,593	-27%
	5,225	R 6.66	-18,525	-37%
	5,500	R 6.89	-22,129	-44%
	5,775	R 7.16	-26,397	-53%
	6,050	R 7.44	-30,822	-62%
	6,325	R 7.71	-35,090	-70%
	6,600	R 7.98	-39,358	-79%

Selling Price	Vegetable Oil Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 8.00	3,850	R 5.27	27,187	54%
	4,125	R 5.54	22,919	46%
	4,400	R 5.81	18,651	37%
	4,675	R 6.08	14,384	29%
	4,950	R 6.35	10,116	20%
	5,225	R 6.66	5,184	10%
	5,500	R 6.89	1,581	3%
	5,775	R 7.16	-2,687	-5%
	6,050	R 7.44	-7,113	-14%
	6,325	R 7.71	-11,381	-23%
	6,600	R 7.98	-15,648	-31%

Selling Price	Vegetable Oil Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 7.00	3,850	R 5.27	11,381	23%
	4,125	R 5.54	7,113	14%
	4,400	R 5.81	2,845	6%
	4,675	R 6.08	-1,423	-3%
	4,950	R 6.35	-5,690	-11%
	5,225	R 6.66	-10,622	-21%
	5,500	R 6.89	-14,226	-28%
	5,775	R 7.16	-18,493	-37%
	6,050	R 7.44	-22,919	-46%
	6,325	R 7.71	-27,187	-54%
	6,600	R 7.98	-31,455	-63%

Selling Price	Vegetable Oil Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 8.50	3,850	R 5.27	35,090	70%
	4,125	R 5.54	30,822	62%
	4,400	R 5.81	26,555	53%
	4,675	R 6.08	22,287	45%
	4,950	R 6.35	18,019	36%
	5,225	R 6.66	13,088	26%
	5,500	R 6.89	9,484	19%
	5,775	R 7.16	5,216	10%
	6,050	R 7.44	790	2%
	6,325	R 7.71	-3,477	-7%
	6,600	R 7.98	-7,745	-15%

Selling Price	Vegetable Oil Price	Manufacturing cost	Net Profit After Tax	RORI
R/litre	R/ton	R/litre	Thousand rand	%
R 7.50	3,850	R 5.27	19,284	39%
	4,125	R 5.54	15,016	30%
	4,400	R 5.81	10,748	21%
	4,675	R 6.08	6,481	13%
	4,950	R 6.35	2,213	4%
	5,225	R 6.66	-2,719	-5%
	5,500	R 6.89	-6,323	-13%
	5,775	R 7.16	-10,590	-21%
	6,050	R 7.44	-15,016	-30%
	6,325	R 7.71	-19,284	-39%
	6,600	R 7.98	-23,551	-47%

Appendix I: South African Agricultural Statistics

Table I1: South African oilcake production, import & consumption 2003-2006 (Protein Research Foundation, 2006)

	Local Production (Ton)			Imported (Ton)			Total Consumption (Ton)		
Year	**2003/2004**	**2004/2005**	**2005/2006**	**2003/2004**	**2004/2005**	**2005/2006**	**2003/2004**	**2004/2005**	**2005/2006**
Oilcake									
Sunflower	336,000	277,200	260,400	24,379	16,073	*	360,379	293,273	*
Soya (incl full fat)	119,280	92,080	144,000	497,316	648,478	*	616,596	740,558	*
Canola	14,685	20,570	26,053	0	0	*	14,685	20,570	*
Other	19,448	26,886	41,768	110,354	131,346	*	129,802	158,232	*
Total	**489,413**	**416,736**	**472,221**	**632,049**	**795,897**	**727,779**	**1,121,462**	**1,212,633**	**1,200,000**

Source: Protein Research Foundation

* Data not available

Table I2: South African vegetable oil production, imports & consumption 2004-2005 (GAIN, 2006)

	Local Production (Ton)		Imported (Ton)		Total Consumption (Ton)	
Year	**2004**	**2005**	**2004**	**2005**	**2004**	**2005**
Oil						
Sunflower	275,000	239,000	94,000	36,000	369,000	275,000
Soya	2,000	3,000	176,000	220,000	178,000	223,000
Other	0	0	541,000	510,000	541,000	510,000
Total	**277,000**	**242,000**	**811,000**	**766,000**	**1,088,000**	**1,008,000**

Table I3: South African sunflower seed production, harvest area & yield 1997-2006 (SAGIS, 2006)

Period	Total Production	Total Area	Total Yield
	Tons	Ha	Tons/ha
1997/1998 (1997)	450,000	464,000	0.97
1998/1999 (1998)	562,067	511,000	1.10
1999/2000 (1999)	1,109,000	828,000	1.34
2000/2001 (2000)	530,625	396,350	1.34
2001/2002 (2001)	638,320	521,695	1.22
2002/2003 (2002)	928,790	667,510	1.39
2003/2004 (2003)	642,610	606,450	1.06
2004/2005 (2004)	648,000	530,000	1.22
2005/2006 (2005)	620,000	460,000	1.35
2006/2007 (2006)	527,720	472,480	1.12

Table I4: South African soybean production, harvest area & yield 1997-2006 (SAGIS, 2006)

Period	Total Production	Total Area	Total Yield
	Tons	Ha	Tons/ha
1997/1998 (1997)	120,000	87,000	1.38
1998/1999 (1998)	200,900	125,000	1.61
1999/2000 (1999)	174,800	130,500	1.34
2000/2001 (2000)	148,720	93,787	1.59
2001/2002 (2001)	209,705	134,150	1.56
2002/2003 (2002)	202,398	124,150	1.63
2003/2004 (2003)	136,520	100,130	1.36
2004/2005 (2004)	220,000	135,000	1.63
2005/2006 (2005)	272,500	150,000	1.82
2006/2007 (2006)	413,995	240,570	1.72

Table I5: South African canola production, harvest area & yield 1997-2006 (SAGIS, 2006)

Period	Total Production	Total Area	Total Yield
	Tons	Ha	Tons/ha
1997/98	11000	13000	0.85
1998/99	21000	17000	1.24
1999/00	23000	25000	0.92
2000/2001	20299	19145	1.06
2001/2002	25750	27000	0.95
2002/2003	37975	33000	1.15
2003/2004	40770	44200	0.92
2004/2005	32000	44250	0.72
2005/2006	44200	40200	1.1
2006/2007	33500	33500*	1*

* Estimate figure

Appendix J: Local crop prices vs. import and export parity

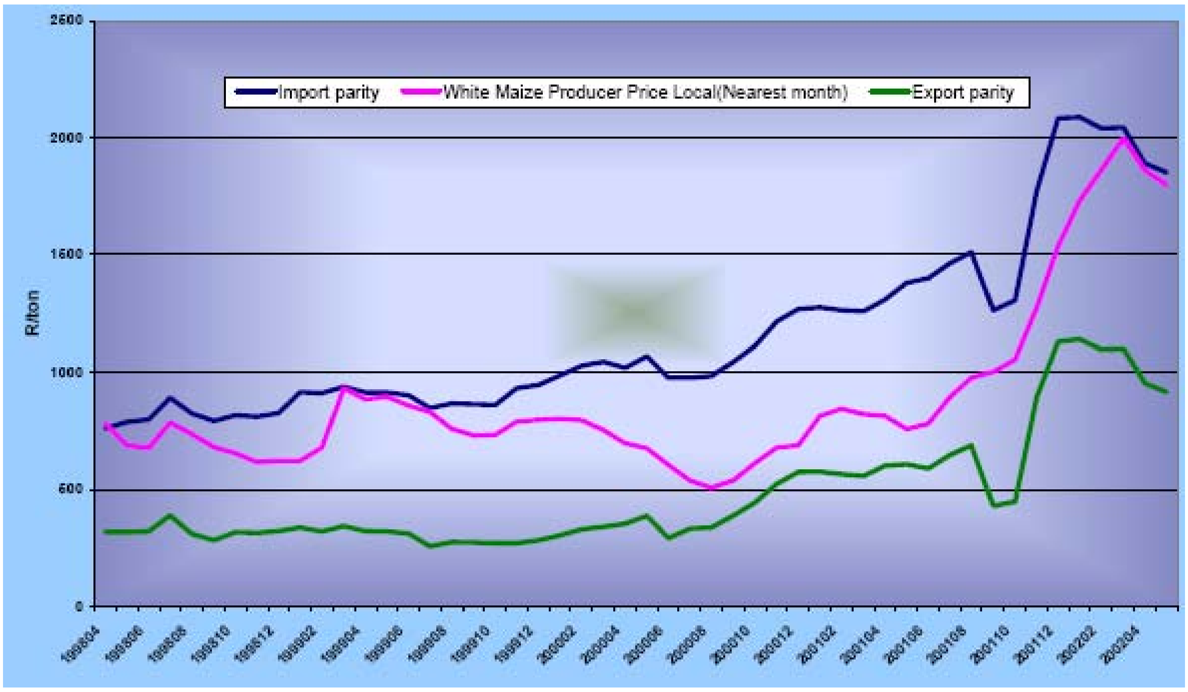


Figure J1: Illustration of how the local crop price fluctuates between import and export parity (Kirsten & Vink, 2002))