ASSESSING THE ECONOMIC VIABILITY OF BIOFUEL PRODUCTION IN SOUTH AFRICA

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Abstract

Against the backdrop of rising fuel prices and increasing transport fuel demand, biofuel production, driven by the potential to contribute to energy security, climate change mitigation and rural development has experience rapid growth in recent years. Apart from a few private initiatives, South Africa has no commercialized biofuel industry to date. The concerns are that economic, environmental and socio economic issues can be a hindrance to the success of the industry. In response to these concerns this research intends to ascertain whether biofuel production could offer a viable economic alternative to fossil fuels in South Africa. For decision makers it is hard to find reliable reference material and solid guidance. Uncertainty over the potential risks and benefits has left potential investors unsure whether biofuel production could be a viable investment opportunity. The aim of this study was to determine if the benefits derived from biofuel production are significant enough to justify the substantial investment required.

The findings reveal that in the absence of clear government strategies and the availability of low cost feedstocks the production of biofuel cannot be viewed as viable. The results show that bioethanol from grain sorghum and sugarcane are not economically viable since the results turn out to be negative in terms of both net present values (NPV) and internal rate of return (IRR) calculations, thus rendering a viable payback (PBP) period as unattainable. Similarly, the NPV and IRR for biodiesel from soya beans and sunflower is negative and the PBP also unattainable. Sensitivity analyses indicate that these crops (except for sunflowers) could only become viable if there were to be a substantial reduction in feedstock prices. All other changes in parameters would not render any of the production plant viable.

CHAPTER 1

INTRODUCTION

1.1 Background of fossil fuels

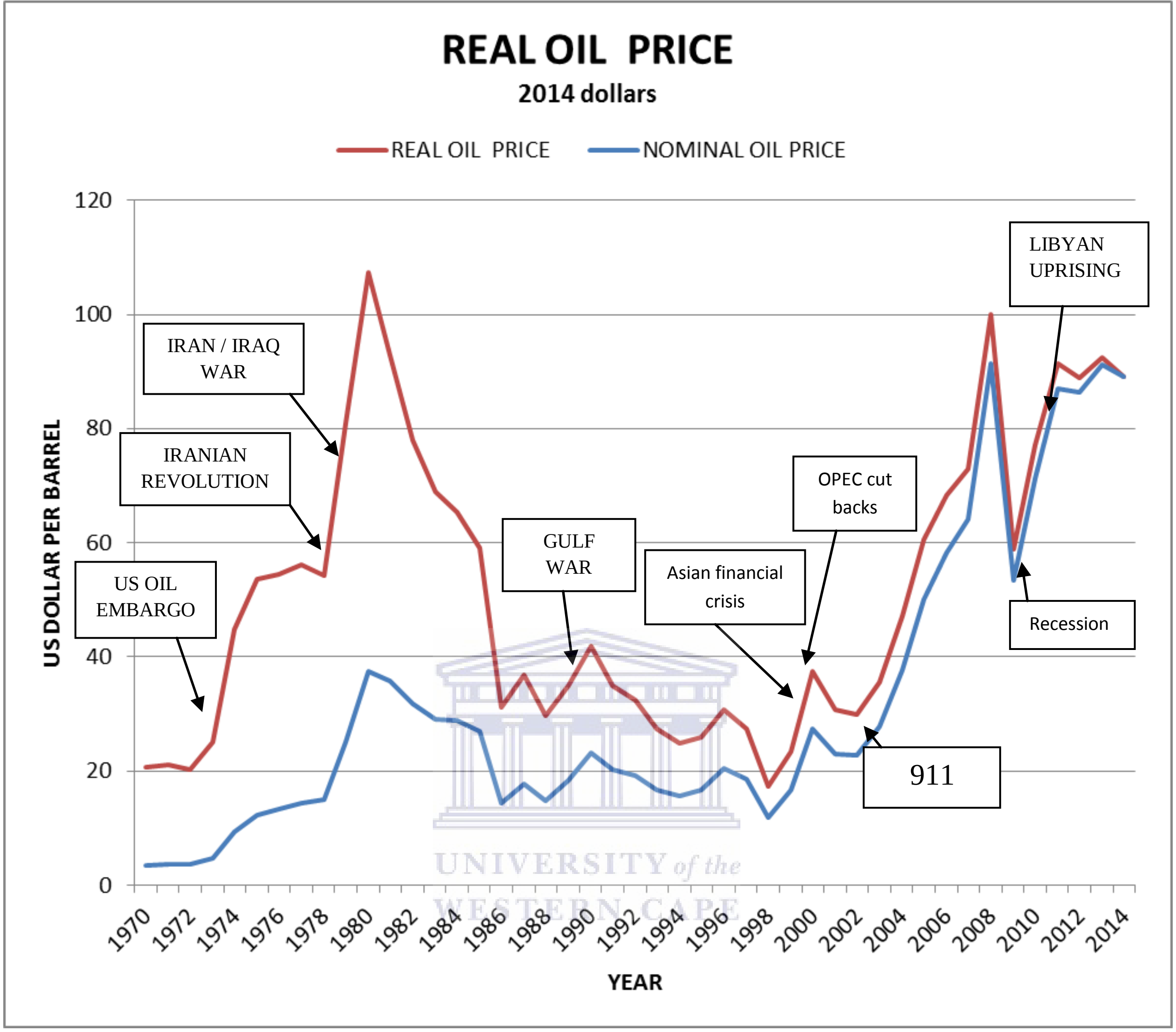
Since the early 2000s many countries have embarked on establishing alternative fuel energy sources to mitigate the effects of increasing global crude oil prices. Funke (2010: 1) argues that there is increasing fear in the world energy sector that fossil fuel reserves could dry up, placing the global economy in a predicament, with energy shortages and a lack of alternative energy sources. Goldthau and Sovacool (2012: 232) suggest that although the world faces daunting social, environmental, and political problems, energy needs require more attention. Energy plays such a key role in any given economy and the reliance on imported energy sources exposes countries to potential supply disruptions, thereby undermining growth and development. The evolution of world energy markets after 1970 has been dramatic and the impact on the world economy and on politics has been profound (Kasekende & Ibrahim, 2009: 14). This is evident in the worldwide ripple effect caused by the volatility of global energy sources such as oil and gas and their occasional spectacular price hikes and falls.

Oil is the most important energy source, accounting for more than one third of the world's energy mix (Mernier, 2007: 67). Oil has thus become a global commodity ever since industrial oil exploration started in Pennsylvania, USA in 1860. Prior to the development of a large-scale oil industry, crude oil was processed and sold by small-scale farmers and used as a light source, for protecting wounds, and for waterproofing purposes. The evolution of the industry has changed drastically since 1960, the year which marked the beginning of a new wave of globalisation

(Llewellyn Consulting, 2013). Total global oil consumption increased from about 21.4 to 46 billion barrels per day between 1960 and 1970.

Of all energy resources, oil enjoys the highest global demand, giving it a unique position as a price-setter in the global community, (Melaku, 2003: 1). Oil is largely concentrated in only a few regions. The political turmoil in the Middle East and North African (MENA) countries since December 2010 and the tightening of trade sanctions against Iraq in 2012 reignited energy security concerns about the region's reliability as a supplier (Fattouh & Mallinson, 2014: 1). The spreading instability in MENA countries created grave concerns amongst oil dependent countries about supply disruptions and further intensified the ever-recurring debate regarding energy security. The reliability of the region as oil supplier and the resilience of market mechanisms in coping with supply disruptions emerged as key aspects for consideration by policy makers. These concerns are justified since MENA countries account for 52% of the world's oil reserves and for 47% of global oil production (Fattouh & Mallinson, 2014: 2). Concerns about their reliability were further exacerbated by oil price shocks caused mainly by political tension in the MENA countries. Figure 1.1 below depicts various oil shocks where the price of crude oil almost doubled within a year or two.

Figure 1.1 Oil shocks



Source : www. inflationdata.com

The 1973-74 price shock was induced by the Arab-Israeli war that resulted in Arab oil producing nations putting an embargo on oil exports to the USA and Netherlands who were aligned with Israel. The Arab nations used oil as a weapon to achieve their economic goals. The real oil price increased from $25.06 in 1973 to $44.71 in 1974, as depicted by the graph. Those nations allied with the Arab nations during this period were not affected, but the embargo was later extended to include the Netherlands, Portugal, and South Africa (Ilie, 2006: 1). Furthermore the embargo caused a severe global economic recession.

The second post-war shock occurred during the Iranian Revolution and the subsequent war between Iraq and Iran in 1980, thereby causing Iranian oil exports to cease. Iran cut oil production and cancelled all export contracts with American companies. As indicated by the graph, the nominal oil price increased from $14.95 in 1978 to $37.43 in 1980. It pushed the American economy into recession when the USA Federal Reserve Bank increased interest rates to curb the growth in the dollar supply (Kutlu, 2015: 2).

The third oil shock was triggered by Iraq's invasion of Kuwait in August 1990 (Wakeford, 2006: 100). The nominal price increase from $14.87 in 1988 to $23.19 in 1990 placed policy makers in a quandary. The oil price increase, increased inflation and simultaneously curtailed economic growth (Khan & Hampton, 1990: 1). When policies were introduced to offset higher inflation rates due to higher oil prices, output suffered. Policies targeting offsets in output led to increased inflation. The fourth shock occurred between 2003 and 2008: this was triggered by China and other emerging countries' rapid increase in oil demand, while the supply pace slowed. Further niggling disruptions such as the on-going Iraqi conflict, political conflict in Nigeria, Hurricanes Katrina and Rita, and a leaking pipeline in Alaska contributed to the price spiral from $27.69 in 2003 to $91.48 in 2008 (Wakeford, 2006: 102).

The Libyan uprising was initiated by insurgency against the government. In the years prior to the uprising, events in Libya were characterised by civil conflicts, invasions, revolutions, and terrorist ~~s~~ acts, resulting in the loss of oil output and sharp increases in the price of oil (Fattouh & Mallinson, 2014). Given the importance of oil as an energy source, oil importing countries are especially vulnerable to price shocks that cause energy security concerns as any. Potential disruption in supply is viewed by many nations as a threat to their economic well-being. Energy security is viewed as dependent on the ability to maintain reliable sources of energy to meet one’s needs.

In the context of global oil price determinations, oil importing countries are considered to be much more vulnerable to oil price shocks and to supply disruptions. The extent of oil shocks can be broken down as follows: the magnitude of oil import dependence; the extent of oil resource dependence, and finally, the energy intensity levels of the economy. Developing countries tend to be more vulnerable to oil price increases than developed countries, especially where the primary sectors such as mining and resource exploration are relatively important sectors. According to Stefanski (2011) low- and middle income countries tend to spend a higher fraction of GDP and to be more oil-intensive than rich countries. South Africa is one of those developing countries that are especially vulnerable to international oil price increases.

South Africa relies heavily on imported crude oil (Nkomo, 2009: 20). Domestic oil production has fallen woefully short in terms of meeting demand requirements. Sasol produces 29% of domestic energy requirements from coal, while 71% must be imported. Dependence on imported oil makes South Africa vulnerable to price shocks, political fuel supply disruptions, and other external factors. According to the USA Energy Information Administration (2013), 74% of South Africa’s oil imports emanate from the Organization of the Petroleum Exporting Countries (OPEC), i.e. oil producing countries, including Saudi Aribia (50%) and Nigeria (24%), as shown in Table 1.1 below. The table also indicates the significant cost outlay South Africa makes to these countries to meet the demand for fossil fuel petroleum commodities.

Table 1.1 South African Import statistics 2013

Country	**Oil imports**	**Oil cost in billions (2013)**
Saudi Arabia	50%	R68.97
Nigeria	24%	R33.11
Ghana (Non-OPEC country)	5%	R6.90
Other	7%	R9.66

Note: Data are from January to November 2013.
Source: U.S. Energy Information Administration based on data from the Global Trade Atlas, the South African Revenue Service, and the Department of Trade and Industry

Even in recent times of low world oil prices the South African economy could not benefit fully due the devaluation of the rand and other domestic and international factors. Domestically, the value of the rand depreciated due to negative sentiments over electricity supply constraints, and internationally, due to the appreciation of the US dollar.

Figure 1.2 below indicates that since July 2014 crude oil prices have decreased by almost 50%, i.e. from approximately \$100 to \$50.50 in March 2015. Figure 1.3 shows that during the same time period the rand devalued from about R10.60 to currently R11.70 against the US dollar. The fuel pump price decreased from R13.84 (July 2014) to R10.86 (March 2015) for 93 unleaded petrol at the coast. This translates into a 27% decrease in the retail fuel price given a 50% decrease in the world oil price.

Figure 1.2 : Crude oil prices
Source: NASDAQ

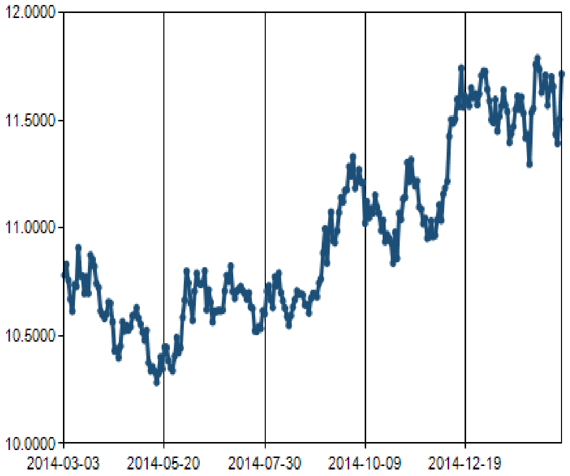
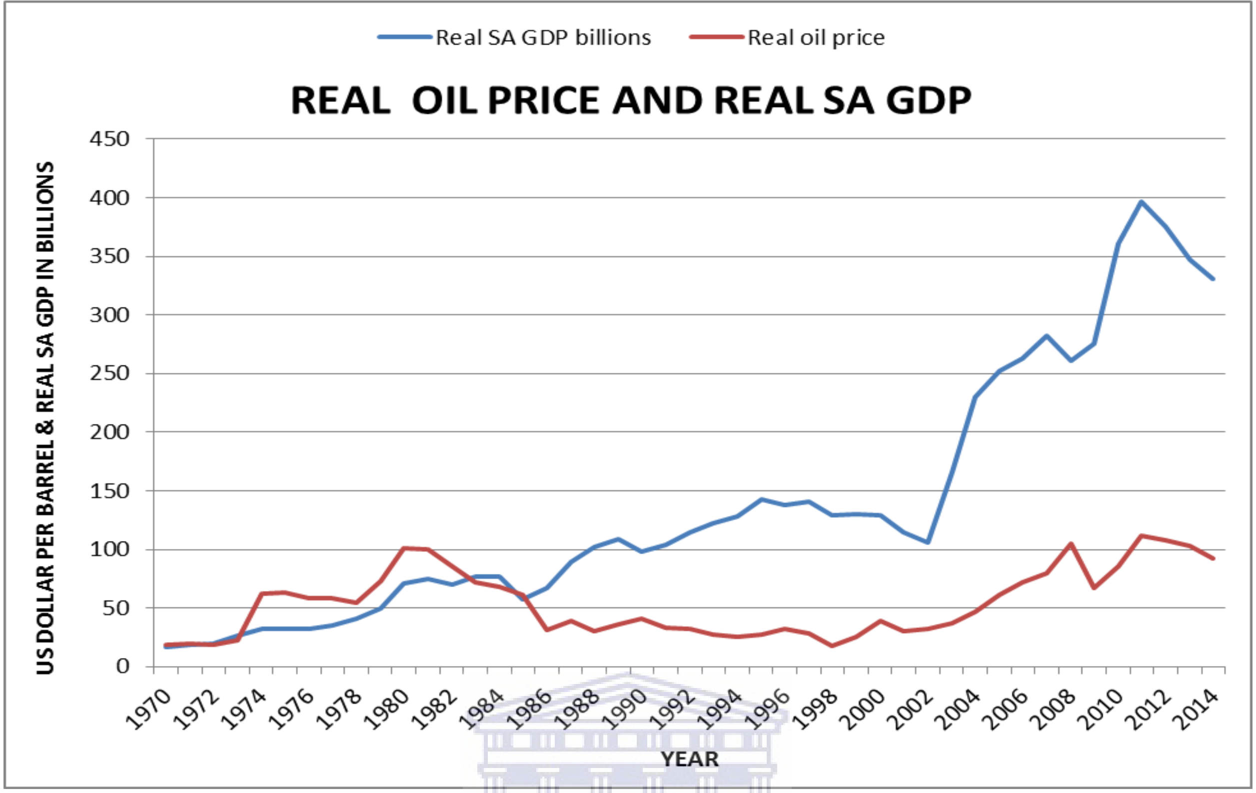


Figure 1.3 Rand/Dollar exchange rate :
Source : SA Reserve Bank

Higher oil prices create uncertainty about inflation, and about interest and exchange rates. In the context of the production process in which the output is measured in terms of GDP, energy resources are one important factor (Yeager, 2012: 388). Rising production costs due to higher oil costs create a lower employment demand and output. Figure 1.4 indicates the real oil price and South Africa's real GDP. Although the correlation is not decisive, a case can be made for the possibility that South Africa's GDP figure was reduced in subsequent periods due to the rise in the oil price. The 1980 international oil price shock caused the real GDP to decrease in subsequent periods (1981-2). The same situation was repeated with the 1990 oil price increase as the real GDP decreased.

Figure 1.4 Real oil price and SA Real GDP figures



Source : www. inflation**data**.com

Given the limitations that fossil fuels impose on the development of the global economy, biofuels are seen by many as catalysts for economic development. Von Maltitz and Brent (2010: 2) describe biofuels as a mechanism for achieving both greater energy security and less reliance on imported fossil fuels. Additionally, biofuels have potential for increasing national economic growth, with high proportions of development possible in rural areas. Biofuels are the most feasible alternatives to fossil fuels as they can be easily converted from existing energy structures at minimal cost and with few technological adjustments (Strydom, 2009: 8).

Chetty (2007: 2) points out that while countries are generally reluctant to respond to global energy warnings, Brazil and the USA have nevertheless established successful biofuel sectors in the last 40 years. The USA, with support from considerable government subsidies, produces 40% of global maize production, and 45% of this production is converted into biofuel production. Brazil has significant agricultural potential and the country has been producing biofuel mainly from sugarcane since 1970 (Gustavo, 2010: 87). For example, from the early 2000s, Brazil has channelled approximately 35% of its food crops into ethanol production. As the leading producer of biofuel, Brazil is likely to continue leading the way in substituting fossil fuel with biofuel. Currently Brazil has the world's most substantial and comprehensive biofuel industrial strategy, thereby ensuring that biofuel production is available for commercial consumption.

The USA ethanol industry is highly subsidised. The USA Energy policy (2005) has adopted a Renewable Fuels Standards (RFS) policy that aims to make the economy less dependent on fossil fuels, and more environmentally friendly, thereby creating an additional market for both the agricultural sector and for its labour market. The impact of the RFS has been estimated to reduce oil imports by an estimated 2 million barrels, creating more than 200 000 jobs, thereby adding to the Gross Domestic Product, supplementing housing incomes, and earning an additional $6 billion in investments (Funke, 2010).

South Africa is the world's 14th highest CO^2 emitter, and kick-starting its own biofuel programme can contribute to the reduction of greenhouse emissions and improved environmental conditions according to Gustavo (2010: 86) who further proposes biofuels as an alternative energy source to fossil fuels so as to contribute to the reduction in CO^2 emissions. Additionally, biofuel would provide added advantages, e.g. increases in agricultural activities and job creation, especially for the vulnerable poor.

The South African government promulgated the National Biofuel Industrial Strategy in 2007, outlining the policy, regulations, and incentives for the industry (Bekunda, Palm, de Fraiture, Leadley, Maene, Matinelli, Mcneely, Otto, Ravindranath, Victoria, Watson & Woods 2009: 251).

According to Funke, PG Strauss & Meyer (2009: 223) the government wishes to achieve social and economic objectives in rural areas, and additional markets for agricultural products through its South African biofuel industrial strategy. Additionally, secondary objectives for promoting locally produced fuels aim to ease the pressure of the balance of payments, to add to the renewable fuel pool, to provide cleaner energies, and to create a more secure overall energy environment.

To further ensure that food security is not at risk, the South African biofuel industrial strategy has decided to exclude maize as potential feed stocks for biofuel production. The strategy proposes the use of sugarcane and sugar beet for ethanol, and canola and soya beans for biodiesel production. The aim is to strike a balance between previously disadvantaged farmers and commercial farmers, as well as to create opportunities for new and emerging farmers.

However, according to Makaudze, Gelles & Takavarasha (2016, forthcoming) despite optimism surrounding biofuel as a viable alternative energy source, there are still obstacles such as controversies, uncertainties, and conflicts. In short in the South African context there are certain challenges confronting the industry. First, one must ask whether sufficient land and water resources are available in order to expand biofuel production. Second, there is heated debate as to whether or not food crops could be used for biofuel production. Diverting agricultural resources (land, water, fertilizer etc.) away from food production might contribute to food shortages and increase price levels (Adeyemo & Wise, 2009: 94). Doubtless the impact on the South African agricultural industry would be widespread given an expansion of the biofuels industry. It would lead to marginal increases in production of milk (7.5%), chicken (9.6%), and eggs (2.5%) by 2015 (Adeyemo & Wise, 2009:94). These issues are discussed comprehensively in Chapter 2.

1.2 Problem Statement

As discussed earlier, as with many other countries in sub-Saharan Africa, South Africa is highly dependent on imports of fossil fuels. The high imported price is transferred to consumers who are already burdened with other inflationary pressures that impede economic growth. There is still no workable biofuel project in South Africa, despite plans for projects, workshops, and debates promulgated over the last couple of years (Funke, 2010). The blame for this failure to ensure biofuel production can be ascribed mainly to the absence of the governments' policy determination and to the threat to food security. This is despite South Africa being a net exporter of maize, grain sorghum and soya beans (Agristats, 2013): moreover in recent years sufficient land has been available to meet the biofuel strategy requirements. As previously mentioned, biofuels have the potential to assist the transport sector to be less dependent on fossil fuels: in addition biofuels have the potential to help improve environmental conditions, to promote rural job creation, and to create new markets for agricultural produce. Certainly the 2% penetration level might not initially make a notable difference to the transport sector. However, it could create valuable benefits like job creation, agricultural development and better environmental conditions.

The success of Brazil and USA in producing biofuels from sugarcane and maize respectively has provided South Africa with a model and sufficient impetus to explore its own biofuel production options. For example, Brazil enacted a policy to ensure that sugar farmers contribute significant amounts of sugarcane to sustain the industry (Funke, 2010: 7). Additionally, the demand side was stimulated to absorb the additional supply by entering into agreements with large automobile manufacturers to produce cars running on 100% ethanol.

1.3 Research question

Given the problems that fossil fuels have imposed on the South African economy and concomitant controversies with regard to biofuel production, the fundamental question is whether or not fuels derived from agricultural crops can provide a viable alternative to fossil fuels.

For the purpose of investigating this fundamental question, the study intends to quantify all the costs and benefits of biofuel production. It will be projected over a 15 year period. Using appropriate economic viability tools it will seek to determine whether biofuels can offer an attractive investment opportunity for investors. If it turns out that the sum of the benefits exceeds the costs this would point to the viability of the biofuel project.

1.4 Study Objectives

The study seeks to:

- Provide basic insights into the background of a bioenergy alternative by reviewing recently published literature.
- Review viability assessment models and select the appropriate tools for the assessment.
- Quantify the costs and benefits of biofuel production stemming from grain sorghum and sugarcane feedstocks.
- Quantify the costs and benefits of biodiesel production from soya beans and sunflower feedstocks.
- Complete baseline assessments and to conduct sensitivity analysis so as to account for risks and uncertainties.

- Draw conclusions and summarize the results of this study.

1.5 Structure of the Study

This study is presented in six chapters, as follows:

Chapter 1 provides a motivation for the study, with the focus on the problem statement, rationale, and the outcomes to be achieved, as well as to outline potential benefits to be derived from the production of biofuels.

Chapter 2 provides an insight into the background and history of biofuel production. It especially emphasizes the factors underlying global biofuel production and the contribution of leading producers, e.g. Brazil and the USA. The chapter also reviews the South African Biofuel Industrial Strategy and the controversies surrounding biofuel production in South Africa.

Chapter 3 reviews different economic and financial viability models used in the assessment of commodities – as outlined in recently published literature. The literature review section ensures that the appropriate tools are selected in order to assess the viability of the bioenergy strategy in this study.

Chapter 4 constitutes the research methodology section, calculating the net present value (NPV), internal rate of return (IRR) and payback period (PBP) to assessment viability.

Chapter 5 presents the findings of this study.

Chapter 6 draws conclusions and suggests policy options: in addition it outlines recommendations for future research.

CHAPTER 2

BACKGROUND AND HISTORY OF BIOENERGY

2.1 Introduction

This Chapter provides a brief overview of issues involving production of biofuels and biodiesel and is structured as follows: (i) it provides an overview of the major bioenergy producing countries in the world (e.g. Brazil and USA); and (ii) it reviews South Africa's biofuel policy, including controversies and opportunities associated with biofuel development as an alternative source of energy for South Africa.

2.2 Overview of Global Biofuel Production and Consumption Trends

As indicated earlier, the over-dependence on fossil fuels as a dominant energy source has encouraged many countries to search for alternatives (Murillo, 2013: 166). An alternative energy source has been identified in the form of renewable bio-fuels such as ethanol, and biodiesel. According to The British Petroleum Statistical Review (2014), global energy consumption grew by 1.8% in 2012 and 2.3% in 2013. Non-renewable fossil fuels accounted for almost one third of energy consumption at 32.9% of total global energy consumption. The review further indicates that oil consumption grew by 1.4 million bpd (or 1.4%) in 2013. However, global oil production did not keep pace with the increase in consumption, as it grew by 550 000 bpd (or 0.6%), which is significantly less that the 1.4 million bpd. Renewables continued to increase in 2013, reaching a record of 2.7% of global energy consumption, and therefore up from 0.8% a decade ago. Global biofuel production grew by 6.1% (or 80 000 bpd) driven chiefly by Brazil (+16.8%) and the USA (+4.6%), the world's two largest producers.

2.2.1 Brazil

Brazil has been producing ethanol derived from sugarcane since the 1970's. For several decades, the sugarcane industry has been one of the main sectors in the Brazilian economy, but by mid-1970 the industry had been transformed in order to focus on ethanol production as well. After the 1970's oil crisis, Brazil developed several short-term policies to reduce the impact of high oil prices on the economy.

The Brazilian government entered into agreements with automobile manufacturers that ensured large-scale manufacture of vehicles capable of using the E100 pure ethanol fuel. This agreement ensured that the supply and demand side of the industry created sustainable markets to ensure the success of the venture.

The Brazilian government was proactive in entering into agreements with Petrobras (a state oil company), commercial car manufacturers, and sugar manufacturers in order to ensure both a constant supply of biofuels and also sustained demand by producing cars that run on biofuels, (Meyer et al., 2013). The Brazilian policy framework therefore supports an established agroindustry that contributes to economic growth and energy security.

Even with these challenges to the Brazilian biofuel programme, the success of the industry correlates strongly with the price of fossil fuels. According to Sorda, Banse & Kemfert (2010: 6981) the low oil price in the early 1980s led to a contraction of the industry as sales of ethanol powered vehicles plummeted and ethanol production costs rose sharply due to the overvalued Brazilian dollar.

2003 and subsequent years with high fossil fuel prices provided renewed interest in the industry as ethanol became cheaper relative to fossil fuels. The resurgence was justified by new flex fuel technology that enabled cars to run on both gasoline and biofuels. According to Sorda et al (2010) 83% of cars sold in 2006 were flex fuel cars, and by 2015 this fleet could comprise 43% of the total fleet. The importance of the success of the Proálcool is reflected in that sugar and ethanol have contributed significantly to the overall growth of the economy. The two industries when combined contribute 3.6 million jobs and 3.5 % of Brazil's GDP. There are no subsidies for ethanol production: however the ethanol option is given support by the absence of duties on it.

2.2.2 The USA

The USA is the largest biofuel producer with the government determined to move beyond a fossil fuel-based economy and diversify its energy base to include renewable energy supplies (Makaudze et al 2015, forthcoming). According to Funke (2010: 2), the American biofuel programme indicates that correct policy measures could sustain the industry.

US federal policy has played an important role in establishing the biofuel industry (Schnepf & Brent, 2013: 1). Policy measures have included setting of minimum renewable fuel requirements; blending production and usage tax credits; import tariffs; loans guarantees, and research grants. The US Congress established the Renewable Fuel Standards (RFS) when the Energy Policy Act of 2005 was enacted. The initial RFS (called RFS1) mandated a minimum of 4 billion gallons in 2006, rising to 7.5 billion by 2012. In 2007, the Energy Security Act of 2007 amended biofuel mandates to 2022.

The amended minimum requirements expanded to RFS2 required a minimum of 9 billion gallons by 2008, and 36 billion gallons to be produced by 2022 (Oladosu & Kline, 2010: 1). The federal government provided financial incentives for ethanol production before and beyond RFS1, and implemented a federal tax credit of between 40 and 60 cents for the amount of ethanol blended with gasoline. In the period 2005 to 2008, the tax credit was 51 cents for gasoline blending, equating to 5c for E10. Since 2009 the tax credit has been reduced to 45 cents.

The USA biofuel market is driven by maize-based ethanol production. Hoekman (2008: 2) states that although further increases in maize-based ethanol production are predicted, it is being constrained by problems stemming from insufficient land availability and water resources, and also by the food vs. ethanol debate. Babcock (2011: 9) conducted studies on the expansion and viability of ethanol production in the US and concluded that high initial profit margins were essential for expansion in biofuel production. His study investigated whether the high profit margins were due to subsidies or high crude oil prices. His findings were that during times of high oil prices in 2002/3, profit margins in 2005/6 would still be high, even without subsidies in place.

His finding suggests that biofuel production has become a more viable alternative whenever fossil fuel prices are increasing. The decline in profit margins during the later months of 2008 was a result of the decrease in fossil fuel prices and maize prices.

2.2.3 The European Union

According to Switzer and McMahon (2011: 713) the first major significance step in ensuring a coherent EU biofuel policy was the promulgated directive, 2003/30 which aimed to promote biofuels and other renewable fuels for transport. Initially, a non-binding target of 5.75% biofuel to be included in petrol and diesel for member states by 2010 was proposed. Since the results were mixed, the EU commission published the Renewable Energy Road Map in 2007, proposing a binding target of 20% renewable energy out of total energy consumption, and a 10% biofuel share in the transport sector in 2020. This binding mandate was subject to production becoming sustainable and commercially available and allowing for adequate levels of blending.

In April 2009, the commission adopted the Renewable Energy Directive 2009/28 that mandated that a 20% share of final energy consumption by EU member states be renewable energy by 2020, but allowing for differential contribution by members in accordance with their starting points.

The EU states that governments mainly supported biofuel producers through the mechanism of import protection and subsidies (Charles et al, 2013). Tax credits are commonly used as incentives in biofuel policy frameworks. These tax credits are given to blenders for each litre of biofuel blended into the fuel mix together with other fuels. Tax exemption instruments are used to stimulate the demand for biofuels and to increase the competitiveness of biofuels.

Funke (2010: 25) points out that the EU has an Energy Tax Directive that controls the minimum rate of taxation on energy products consumed for motor vehicle usage, heating, and for electrical consumption. The goal is to encourage more efficient use of energy resources and of imported energy products. Funke (2010) also noted that France and Germany are moving towards taxing biofuels when blending mandate ~~s~~ targets are in place, while the UK wants to make the industry more profitable by increasing tax incentives.

According to Flach, Bendz, & Lieberz (2014) the EU’s demand for biofuel and biodiesel surged between 2006 and 2011. In 2011 biofuel consumption peaked at 5.7 billion litres, of which 1.64 billion litres were imported. In 2013 the EU Energy Council (EC) succeeded in isolating the biofuel industry from major competitive suppliers by imposing anti-dumping duties for biofuel produced in the US. During 2013, 400 million litres of ethanol were imported with zero duty quotas: this import emanated mainly from Peru, Guatemala and Pakistan. In January 2014 the EC imposed further anti-dumping duties to restrict ethanol imports of E48 of US origin that had been blended in Norway. This represents a circumvention of EU anti-dumping duties on ethanol, originating from the US (Flach et al., 2014).

2.3 Review of Bio-fuel Policy Strategy in South Africa

The South African Biofuel strategy of 2007 adopted a plan to achieve a revised 2% penetration level of biofuels in the national liquid fuel supply: this would be down from an initial target of 4.5% (BIS, 2007). Based on the national fuel consumption of petrol and diesel of about 20 billion litres per annum, a 2% biofuel target (bioethanol and biodiesel) translates into approximately 400 million litres of liquid bioenergy fuels. The revised target from the initial draft proposal considered the challenges and controversies experienced during the development of the biofuel strategy. Achieving numerous objectives is what drives the Biofuel industrial strategy: these will be explained in the next section.

2.3.1 Opportunities and Controversies of Bio-fuel Production in South Africa

South Africa, for a middle-income country, has extremely high levels of absolute poverty. A significantly high number of South African households are food insecure and unemployed, especially in rural areas. This necessitates food security provision and poverty alleviation at national, provincial, and local levels. Agricultural development has been seen as one avenue to improve rural development and to enhance rural livelihoods. According to the BIS (2007), biofuel production seeks to create opportunities for rural development by creating a market for produce that would otherwise not be planted (BIS, 2007). Since most of the poor and unemployed reside in rural areas, especially in the former homelands, these areas are mostly earmarked for biofuel production opportunities.

2.3.2 Promote Climate-smart Environmental Strategies

According to the National Research Foundation (2010) biofuels are developed as a more environmentally friendly alternative energy source to alleviate the dependency on limited and finite fossil fuels. Biofuels from maize, grain sorghum and soya beans can significantly reduce greenhouse gas (GHG) emissions compared to fossil fuel emissions. According to the Food and Agricultural Organisation (FAO), the reduction of carbon dioxide emissions is one of the explicit goals for policy measures that can support the production of biofuels

2.4 Issues Involved

At market level, the biofuel industrial strategy aims to create a reliable market for biofuels. The mooted 2007 strategy proposed that biofuels be used in petrol and diesel production, with a B2 or 2% biodiesel and an E8 or 8% bioethanol blend. However Funke et al. (2009) deviate from this, and propose rather that biofuels should be blended in accordance with the South African National Standards (SANS) (2006) guidelines, thereby limiting biofuel content to 5% for biodiesel and 10% for petrol. These constraints will ensure that the appropriate blends ensuring quality of biofuels and other fuels are produced. As a fuel, ethanol differs from petrol in energy content and is more corrosive, requiring engine modification to prevent damage. Ethanol only has 70% of the energy content of petrol: it requires 30% more fuel to cover distances, and reduces engine performance (Von Maltitz & Brent, 2009:1). An ethanol blend of 10% requires no engine modification, but anything beyond this requires duel fuel cars in order to run normally.

2.4.1 Agriculture

According to Adeyemo and Wise (2009: 95), biofuel production could stimulate rural agriculture, attracting more resources into agriculture and positively affecting food security. Pingali, Raney & Wiebe (2008) state that to prevent conflict between fuel and food, agricultural productivity growth is essential.

In addition, South Africa has been fortunate to enjoy bumper crops in recent years. Von Maltitz and Brent (2009: 3) state that commercial farmers are keen to establish a biofuel industry to boost agricultural production. They have the capacity to produce crops substantially beyond food and animal feed requirements, but overproduction reduces prices substantially, thereby creating lower profit margins. However, since the Biofuel industrial strategy required feedstocks mainly from designated areas, small-scale farmers must be developed so as to become producers. Table 2.2 below indicates that South Africa is a net maize, grain sorghum and soya beans exporter. Although the government has stipulated that maize could not be used as an input for biofuel production, South Africa has consistently produced surplus maize. Therefore, biofuels create a market for agricultural produce, allowing farmers to produce without the risk of thereby depressing prices.

Table 2.2 Maize, grain sorghum and soya beans' exports: 2009 – 2013

YEAR	Maize	Grain sorghum	Soya beans
	1000 tons	1000 tons	1000 tons
2009/10	1 796	52	121
2010/11	2 194	24	43
2011/12	2 575	25	158
2012/13	1 946	19	15

Source : Agristats (2013)

2.4.2 Food security

Food stock crops are produced mainly for human consumption but could also be used for biofuels. Basic economic theory suggests that the increase in demand for biofuel will raise the price and in turn require larger areas of fertile land for fuel production instead of food crops. Adeyemo and Wise (2009: 95) define a nation's food security as a scenario where citizens have food readily available (locally produced or imported) at an affordable price; hence they propose three driving forces behind the notion of food security, namely food prices, and a demand for land and water. Rosegrant (2008: 1) states that biofuel policies have triggered a significant increase in food prices, with large volumes of food also produced.

2.4.3 Animal Feed

The BIS (2007) endorses feedstock for biofuels as this will increase food security by increasing the availability of by-products that could be absorbed by the animal feed market. Industry concerns regarding the danger of an over-supply of by-products were mitigated since a 2% penetration level would ensure that the price of by-products remains competitive. The animal feed market could thus become a major additional stream of income for biofuel plants.

2.4.4 Land Tenure Issues

Historically, indigenous South Africans were denied any tenure rights due to racial segregation (Lahiff, 2015). The historic Group Area Act demarcated people's domiciles based on race, thereby resulting in massive forced removals, especially to former homeland areas. Land ownership in the former homelands is still held mostly by parastatal trusts, referred to as communal or tribal land. By 1994, approximately 16 million South Africans resided in former homelands and were living in extreme poverty. Whites largely own agricultural rural land. Despite the current South African governments land redistribution policies, racial discrimination in terms of fragmented land tenure issues is difficult to dismantle. Since biofuel expansion is geared towards rural development for the poor, land tenure issues should be resolved at a more rapid pace in order to ensure that the marginalised benefit from it.

2.5 Current Biofuel Issues in South Africa

The South African government has identified biofuel production as a major source of employment and as a potential driver of economic development (Government Gazette, 2014: 9). However, despite the approval of the BIS of 2007, South Africa is still without a large biofuel player to date. According to the Government Gazette (2014) biofuel production is not considered a sufficiently attractive option at current prevailing feedstock and fuel prices. However the Department of Energy and a biofuel task team were mandated to oversee the implementation of a biofuel strategy through the implementation of a mandatory blending date and the licensing of potential producers.

These two issues were supposed to be preceded by a biofuel policy framework that never happened. In the Government Gazette No. 36890 of 30 September 2014, the Minister of Energy, Dikobe Martins, announced that the effective date for mandatory blending was to be 1 October 2015. The date was set since it was assumed that all outstanding issues of infrastructure to enable blending by 1 October 2015 would have been completed. Adhering to the regulations of the petroleum product specifications and standards, the minister promulgated a ruling that biodiesel could be blended under all specifications from 5% to as much as 100%: however bioethanol's range was set at 2% to 10% on a volumetric basis.

The mandatory blending rates required applications from and licensing of potential biofuel producers who would meet the 2% penetration level requirement. The table below indicates the license applications received up to January 2014.

Table 2.3 Biofuel contracts to SA businesses

Company Name BIOETHANOL	**Feedstock**	**Capacity (million litres)**	**Location**	**License status**
MabeleFuels	Sorghum	158	Bothaville, FS	Issued
UbuhleRenewable Energy	Sugarcane	50	Jozini, KZN	Issued
E10Petroleum Africa CC	Sugarcane and other crops	4.2	Germiston, Gauteng	Granted
Arengo316 (PTY) LTD	Sorghum and sugarbeet	180	Cradock, Eastern Cape (EC)	Granted
BIO DIESEL				
Rainbow Nations Renewable FuelsLTD	Soyabeans	288	PE, (EC)	Issued
Exol OilRefinery	Wastevegetable oil	12	Krugerdorp, Gauteng	Granted
PhytoEnergy	Canola	>500	PE, (EC)	Early stage of licensing
Basfour3528 (Pty) LTD	Soyabeans	170	Berlin, EC	Issued

Source : Government Gazette (January 2014)

These envisaged biofuel plans would boast a total capacity of about 1 260 million litres per year. If realised, this would exceed the 400 million (2%) penetration levels into the national fuel supply. Most notable is that none of these plants has yet been constructed, let alone commissioned to start biofuel production. Mabele Fuels, the largest proposed bioethanol facility, is forecast to become operational in 2017. All the other plants are still in the initial planning phase. The delays are said to be caused by the lack of a biofuel pricing mechanism.

It is obvious that the implementation of mandatory blending from 1 October 2015 was unattainable since issues such as the construction and licensing of biofuel plants had not been dealt with. The BIS (2007) provides that a licenced petroleum manufacturer may buy biofuel only from a licenced biofuel producer. Furthermore, when a licenced biofuel producer supplies a blending facility, it must be accompanied by a quality assurance certificate.

2.6 Cost and benefits of bioenergy

This study reflects mainly on the potential financial benefits of bioenergy production. However, Elbehri Segerstedt & Liu (2013 : 61) in their study mention additional external costs or benefits that include environmental, employment and security - and supply benefits. Environmental benefits have been achieved mainly by quantifying the reduction in GHG emissions driven by the price of carbon. Moreover the BIS (2007) estimates that 2% penetration levels of biofuels into the national fuel supply would create approximately 25 000 job opportunities. This would decrease the unemployment rate by 0.6% and GDP by 0.05%, i.e. ensuring a balance of payment saving of R1.7 billion and a greenhouse gas emission saving of R100 million per year. Furthermore the BIS (2007) estimates that the job-to-investment ratio is about 100 times higher than with crude oil. The employment benefit would lead to job creation and poverty relief opportunities mainly for poor farm workers. It is also an input cost into the production of biofuels, forming part of the plants' operating and maintenance costs.

2.7 Conclusion

Several authors have conducted research in order to assess the viability of an extended biofuel production programme in South Africa. For example Von Maltitz and Brent (2008), Chetty (2007), and Smith (2010) suggest that land, water, and food security issues are factors that must be considered when assessing biofuel development possibilities. Funke (2010) and Ademeyo and Wise (2009) argue that the lack of government policy directives are the major factors stifling biofuel development.

According to Von Maltitz and Brent's (2008) assessment of biofuel options for Southern Africa the region has the potential to engage in biofuel projects that can be sustained by means of careful planning. The region's motivation to expand biofuel production is based on energy security rather than aiming at a reduction in global warming. However, the authors state that although the region has great biofuel potential, alternative land use options for biofuel could be earmarked for further research.

Chetty (2007) conducted research through primary source interviews in order to assess the factors influencing the success potential of biofuels in the South African liquid fuel industry. The key findings were that ethanol is a suitable alternative only if it is blended with conventional fuel at up to 10%. Additionally, issues involving government support, land, water, and security concerns are more important factors than the suitability issue. Smith (2010) provides a multiple scenario analysis of the potential of biofuels derived from maize, using the initial 4.5% penetration of the biofuel industrial strategy into the national liquid fuel supply.

According to Adeyemo and Wise's (2009) a large-scale biofuel industry would provide South Africa with an opportunity to meet energy security, and also provide for job creation, and agricultural development objectives. Furthermore, they support the omission of maize as feedstock, based on its staple food characteristics. Sugar cane is proposed as a more reliable feedstock for biofuels, particularly since it is less threatening to food security. Funke et al. (2010) modelled the impact of the biofuel industrial strategy on the SA agricultural sector and found that at $150 per barrel of oil, ethanol from sugarcane could be more financially viable than the export of sugar.

Their conclusion is that with favourable macroeconomic conditions and government support, expanded biofuel production could become a highly viable option.

Funke (2010: 181) suggests that the lack of significant economic activity in the biofuel industry is due to government's failure to give policy direction and also its poor execution of the little direction that does exist. The author uses the Brazilian experience as an example of how government policy execution and direction have created a sustainable industry that contributes to fuel security.

In brief, this chapter has aimed to provide a review of biofuel development taking place in different countries around the world. This overview is important since it provides insights regarding biofuel policy and development strategies that other countries, like South Africa, could emulate. For instance, there is the example of how Brazil has adopted the policy of ethanol production from sugarcane and the USA from maize.

The South African biofuel programme is constrained by a lack of effective directive policies and the concern over food security that proposes the exclusion of maize as a potential feedstock. Although energy security is of grave concern for economic development, the dominant food versus fuel debate is largely responsible for the lack of significant economic activity in the industry. In addition, the biofuel programme needs to be driven by rural development and improvement of living standards, especially those of the poor. The expansion of biofuels in South Africa remains a controversial issue due largely to land and water constraints and food security issues.

CHAPTER 3

LITERATURE REVIEW

3.1. Introduction

The literature review section of this study aims to provide a broad overview of the concept of economic viability, the tools available to assess it and the empirical evidence from other studies to determine whether projects are viable or not. The tools used to assess other projects or enterprises provide the basis for identifying the appropriate tool to evaluate whether biofuels could be a viable option as an alternative or supplement to fossil fuels.

3.2. Defining Economic viability

Economic viability analysis is often perceived as a way of justifying decisions made in allocating scarce resources amongst various competing options, (Vila, 2009). The economic impact of proposed capital projects is identified, and where possible, the cost and benefits valued in monetary terms will assist investors to select projects that will provide maximum benefit to society. Economic viability analysis is thus concerned with assessing the net worth of a project and provides the means to rank projects in terms of efficiency in allocating and using resources.

The economic viability of engaging in a project is synonymous with levels of sustainability and growth that account for all resources used, whether human, technological or natural: furthermore it gauges both the values it generates for investors and the benefits gained by society (Hurst, 2013:8). The goal of all economic projects is profitability, considered either in terms of financial or economic viability. According to Schuhbauer and Sumaila (2014 : 1) financial viability occurs when economic profits are positive most of the time for privately owned projects (individuals or firms). Economic viability differs as it refers to profitability that benefits society at large. It is achieved when the benefits to society are deemed positive. However for society to benefit on a continuous basis, projects should also be sustainable.

Desai (1997) suggests that for projects to be sustainable they must provide sufficient incentives for producers; there must be availability of sufficient funds to maintain project operations; the projects must use the least cost means to obtain benefits; costs and benefits should be in line with the projects' objectives and environmental effects need to be included in the analysis process.

3.3 Economics and viability

3.3.1 Classical economics and viability

In his book, *Wealth of Nations*, Adam Smith writes that individual self-interest and free competition between economic actors can create a self-constraining system (Werhane, 2006:199). The system allows the 'invisible hand' to govern market transactions. Adam Smith thought that markets and competition are beneficial and in the public interest (Sandmo, 2014:6). He claims that entrepreneurs moving their capital from declining to expanding interest are to the benefit of society. Classical economics therefore assumes that individuals will pursue viable business opportunities where their own private benefits exceed private costs.

3.3.2 Neoclassical economics and viability

In most cases economic viability provides the basis for rational decision-making. Neoclassical economic theory is also based on the assumption of rationality. Thus being rational, decision-makers will supposedly choose the best option from a range of alternatives to maximize their profit opportunities. Hence neoclassical economists define viability as a firm's expected profits in an open, competitive market (Lin, 2005:4). If a normally managed firm can earn an acceptable normal profit in an open market situation, then the firm is seen to be viable.

In contrast, a firm is viewed as nonviable if in its continued operations, it relies on external subsidies or protection as support. Lin (2005:5) concludes that if a firm does not obtain acceptable profits in open markets then it should not have been set up in the first place. No investor will invest in a firm that cannot obtain an acceptable profit in open markets but has to be continually sustained via government subsidies.

3.4 Tools for assessing economic viability

Numerous tools are available to assess the economic viability of production activities. The most common methods are via the following instruments: the Cost-Benefit Analysis (CBA), Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PBP) and Return on Investment (ROI). However, since the costs and benefits are sometimes difficult to quantify in monetary terms, a Cost-Effective Analysis (CEA) approach is often used (Queensland Treasury, 1997). Cost-Effectiveness Analyses express the costs and benefits in physical numbers rather than monetary values if quantification in monetary values is difficult.

As a standard economic viability technique, Cost-Benefit Analysis (CBA) helps to assess the desirability of a project (Jorge-Calderón, 2013:10). Jorge-Calderón (2013) identifies CBA as a useful tool for clarifying the aims of a project. It provides a tool to estimate what will happen if the project is embarked upon.

In addition, CBA evaluates whether the project is the best option available, who gains and who loses from the project, and whether the project is financially sustainable: moreover it can help with informing investors if the project has value for society. However, CBA's weaknesses must be also considered before the method is selected for economic viability analysis. Depending on what one wants to assess, the data for analysis are not available to perform a comprehensive BCA and it should be replaced by a cost-effectiveness analysis. CEA is more appropriate in cases where costs and benefits are hard to quantify. If the ratio of benefits to cost exceeds one, the project is profitable whatever the outcomes of different evaluations might suggest. The CBA however can be summarized via two complementary evaluations, i.e. NPV and IRR which are especially useful where cash flows and returns vary over time.

NPV compares the current stream of value of benefits with the current stream of value of cost for a given timeframe. When an investment is made, the expected net future value (NFV) is projected against investing into another venture. The NFV is discounted over the planned time horizon of the project so as to estimate the NPV. The Net Present Value is the difference between future benefits and cost at a given discounted rate.

The NPV is given as:

$$\sum_{t=0}^{n} Btx\,(1+r)^{-t} \quad - \sum_{t=0}^{n} Ctx\,(1+r)^{-t}$$

B_{tx} = the present value of benefits at a discounted factor $(1+r)^{-t}$

C_{tx} = present value of cost at a discounted factor $(1+r)^{-t}$ of a project x.

During use of CBA, NPV provides a key decision-making criterion for viability. If the NPV is greater than zero, that is the total discounted benefits are greater than the total discounted cost, the project is viable. The project is acceptable as long as:

$NPV \geq 0$

Single NPV calculations might not be realistic and should be performed using different combinations of best and worst case scenarios. For viability analysis using NPV, a minimum set of key assumptions should be identified in order to render the project desirable or undesirable. If projects offer alternative solutions to problems the one with the highest NPV should be selected.

The IRR represents the rate of return of benefits that would cover all the costs of a project. It is the discount rate at which the present net benefits of the future values total zero. At the IRR the present value of the benefits' stream is equal to the present value of the cost stream. A project is acceptable if the IRR is equal to or exceeds the interest rate of capital usage. The discount rate is required for long term analysis of a project's viability. It is defined as the value of present value at the beginning of year one for $1 at the end of n years (Vila, 2009). The discount rate is presented as follows:

$$DF = \frac{1}{(1+r)^n}$$

Where:

n = number of years

r = interest rate

For the NPV = 0 and the CBA = 1 the IRR could be calculated as follows:

$$IRR = r_1 + \frac{(NPV_1) \times (r_2 - r_1)}{(NPV_1 - NPV_2)}$$

The IRR is useful when the investment comprises of a single outlay at the beginning, thereby providing a stream of benefits over time. However, for cash flows with multiple sign reversals, there might exist more than one IRR which is subject to various interpretations. PBP refers to the number of years it would take for the initial investment to recoup its original costs through the annual net revenues it generates (Walekhwa, Lars & Mugisha, 2014).

According to Botchkarev & Andru (2011:246) ROI provides a rationale for future investment decisions and for choice of viable acquisitions. ROI can calculate priorities for certain projects and justify investment therein. It provides the basis for informed decisions about which projects to pursue. ROI is used to evaluate existing systems and to consider what post-implementation decisions must be taken in order to remain viable. The result obtained from ROI calculations encourages cost efficiencies, and focuses on the main corporate metrics, namely profitability.

3.5 Review of Previous Studies Economic Viability Assessment

Tatsuya, Yoshihito, Mohd, Azhari, Nik, Alawi & Zainuri (2013) have assessed the economic viability of integrated biogas energy and compost production for sustainable palm oil mills' management in Malaysia. Their study proposed a new approach for this integrated technology project. The economic viability was evaluated based on changes of material flows and energy balance when a palm oil mill introduces new integrated technologies over a 10 year period: NPV, IRR, and PBP and sensitivity analysis were employed for this evaluation. The results of the study indicate~~s~~ that the introduction of the new integrated technology is viable as the IRR achieved after a 10 year period is 32%, compared to an initial developers' internal benchmark of 15%. The NPV and PBP are at $9.53 million and encompass about 3 years respectively. Sensitivity analysis that was conducted indicated fluctuations in the price of outputs between a -20% and +20% range. The change price of certain outputs therefore has a greater effect on NPV and IRR fluctuations.

A study conducted by Richardson, Johnson, Lacey, Oyler & Capareda (2014) evaluated the economic viability of harvesting and extraction technology contributions to Algae biofuels. The study compares two harvesting technologies and three extraction technologies, using a Farm-level Algae Risk Model in order to simulate the economic feasibility for farms via use of alternative technologies. The combination of the most promising harvesting and extraction systems indicates a 64% increase in NPV and 90% reduction in cost compared to the baseline. However, an estimated 64% increase in NPV still renders the project undesirable as the NPV is still below zero.

Albarelli, Ensinas & Silva (2014) evaluated product diversification as a method to enhance the economic viability of second generation biofuels in Brazil. After conducting economic viability assessment, the results indicate that second generation ethanol production processes are enhanced by product diversification. The second process integrated with the joint production presents a 2.3 year payback period compared to 4.7 years' payback from integration with the autonomous distillery - and even higher NPV and IRR.

Walekhwa, Lars & Mugisha (2014) evaluated the economic viability of biogas energy production from family-sized digesters in Uganda. The methods used to determine the results of the study included the payback period, NPV, IRR and sensitivity analysis. The empirical results indicated that given a 12% discounts' rate the PBP is 1.17, 1.08 and 1.01 years for 8m³, 12m³ and 16m³ plants, respectively. The results show that as the capacity of the plants increases from 8m³ to 16m³ the payback period increases. The lower PBP is attributed to lower installation, operation and maintenance costs that decrease as the size of the plant increases. The results of the PBP indicate that the 16m³ with the shortest period is the most economically viable. At the baseline discount rate of 12%, the NPV for the 8m³, 12m³ and 16m³ plants are all positive at $4535, $6998 and $9542, respectively. The slope of the change in NPV with the plant size depends on the discount rate. The analysis shows that the lower discount rate shows a greater change in NPV values. The smaller 8m³ plants are more sensitive to economic parameters, rendering the 16m³ plants more economically viable.

The results from the IRR analysis show that the IRR increases as the capacity of the plants increases. The scale of the plants contributes significantly to the change in the IRR rate. At the current discounted benefits and costs, the NPV would be zero for the 8m³, 12m³ and 16m³ plants at discounts rates of 36%, 37% and 39%, respectively. Interest rates lower than these three parameters would lead to positive NPV's, implying that the discounted benefits will exceed the discounted cost. The results show that the larger scale 16m³ plants with the higher IRR is the most economically viable. Sensitivity analysis was conducted with variations in discounts' rates, and with increases and decreases in capital costs and operating costs. The results show that increasing the discount rate from 12 to 24%, decreases the NPV, and therefore, the profitability, significantly. The increase in capital has a similar decrease in NPV effect as does the increase in discount rates. The results show that the increase in operation and maintenance costs of 50% at discount rates of 6 to 24% creates negative NPV and thus renders the plants unviable.

The common characteristics from all these empirical studies of economic viability used by researchers are NPV, IRR, PBP and sensitivity analysis. They provide a comprehensive view of the viability of production of different commodities and could therefore also be applied in biofuel production assessments. The study from Walekhwa, Lars & Mugisha (2014) on the economic viability of biogas energy production at different discount rates provides an analysis mode that encompasses all criteria for economic analysis that will be used in this study. Hence after quantifying and valuation of the benefits and costs of biofuel production, the economic viability using the payback period, NPV, IRR and sensitivity analysis, will be assessed as decision-making criteria.

CHAPTER 4

RESEARCH METHODOLOGY

4.1 Introduction

In selecting the methods used to evaluate the viability of biofuels, the need to quantify the costs and benefits of biofuel production plants is thus crucial. For it to be viable, it implies that the total benefits accruing from investing in biofuels should exceed the total cost of the production of biofuels. The fundamental question is thus: how economically viable is biofuels' production? Put differently, does biofuel production have lower cost relative to the associated benefits?

Inadequate information about the viability of biofuels could be a hindrance to potential investors: this could account for its low performance thus far in South Africa. This study therefore intends to provide adequate information to assist potential investors to make informed decisions about production of biofuels.

4.2 Materials and methods

The analysis for the Department of Agriculture, Forestry and Fisheries (DAFF, 2011) revealed that grain sorghum and sugarcane for biofuel production and soya beans and sunflower for biodiesel production are the leading contenders. Although maize is also a suitable feedstock it has been excluded due to food security concerns. This study is therefore limited in that it assesses only the viability of biofuel from grain sorghum and sugarcane and biodiesel from soya beans and sunflower as proposed feedstocks.

DAFF analysis indicates that large parts of South Africa are well suited for grain sorghum cultivation due to its drought resistant properties. Sugarcane is produced in large quantities in South Africa, especially in KwaZulu Natal and surplus production of approximately 40% is exported annually.

In this analysis a comprehensive cost estimation of two recommended plant capacities of 158 000m³/a in the case of grain sorghum and 95 000m³/a for sugar cane, was undertaken for biofuel production. For biodiesel the analysis includes a plant capacity of 113 000m³/a with either soya beans or sunflower as feedstocks.

This is followed by the economic evaluation of benefits accrued via these plants. The calculated costs and benefits were used to evaluate the viability of biofuel production. These tools include the Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Period (PBP). Finally sensitivity analysis through varying parameter values of cost and revenues of 158 000m³/a for grain sorghum, 95 000m³/a for sugar cane and 113 000m³/a for soya beans and sunflower were undertaken.

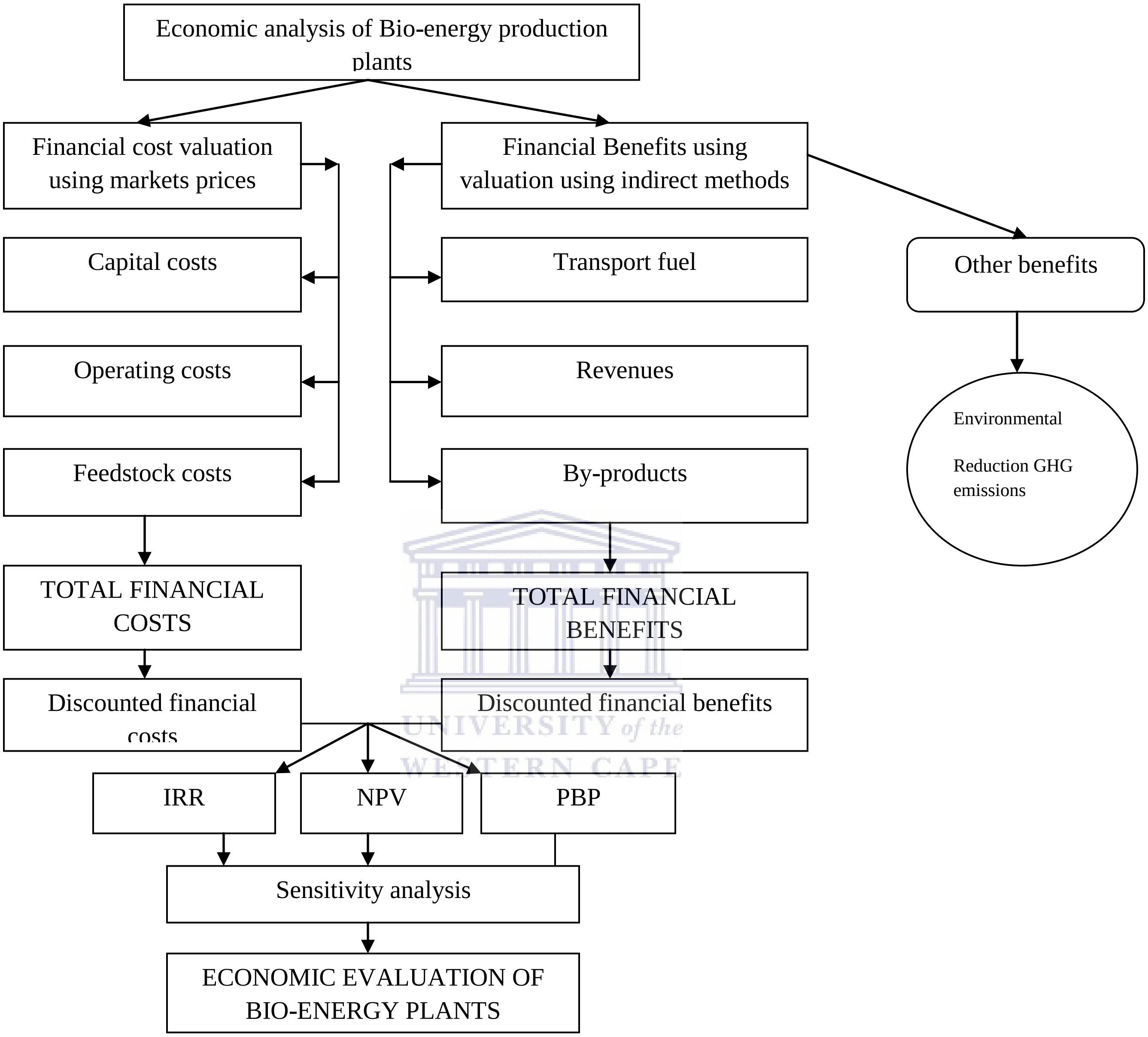


Figure 4.1 Framework for evaluation of economic viability of biofuel plants.

4.3 Framework for analysis of economic viability of biofuel from grain sorghum and sugarcane and biodiesel from soya beans and sunflower.

In evaluating the viability of biofuels in South Africa, the framework developed by Walekhwa et al (2014) to evaluate the viability of biogas in Uganda has been adopted with some modifications. The framework is presented in figure 4.1.

4.3.1 Cost of biofuel production in South Africa.

The costs of establishing a biofuel plant in South Africa depend on the specific type and size of the plant, together with the operating and maintenance costs (all variable), and also the costs of feedstocks and transportation.

4.3.1.1 Capital costs

Capital costs include the civil construction of a biofuel plant and installation costs. The Department of Agriculture, Forestry and Fisheries has estimated the initial investments in these plants: see table 4.1 below. These estimates depict 2011 prices.

Table 4.1 Capital investments into biofuel plants

	158 000m^3/a grain sorghum plant		95 000m^3/a sugarcane plant		113 000m^3/a soya beans plant		113 000m^3/a sunflower plant	
	2011	2016	2011	2016	2011	2016	2011	2016
	million	million	million	million	million	million	million	million
Capital costs	2.131	2.82	1.973	2.61	1.135	1.50	1.041	1.38

Source : Department of Energy (DoE) (2011)

Table 4.2 (see below) shows the average inflation rate from 2011 to September 2016 used to calculate the current setup costs.

Table 4.2 Average inflation rate 2011 -2016

Year	2012	2013	2014	2015	2016
Rate	5.75%	5.77%	6.13%	4.51%	6.5%

Source : Inflation.eu. WORLD INFLATION DATA

4.3.2 Operating costs

The operating cost includes the operational and maintenance expenses for the biofuel plants. It includes the costs of various inputs in the system, as well as the manpower required to operate the system. These costs can be divided into feeding and operation of the plant, regular maintenance, supervision, storage, utilities, labour, supplies and general work, consumables and the administration costs associated with running a biofuel plant. The Biofuel Industrial Strategy (2007) estimated that operational cost of a conventional biofuel production plant is approximately 15% of total production costs.

4.3.3 Feedstock costs

The main input costs into the production of conventional, first generated biofuels is the feedstock used. The Biofuel Industrial Strategy (2007) estimated that feedstock costs of a conventional biofuel production plant are approximately 70% of total production costs. Charles et al (2013 :31) in their study on the costs and benefits of EU biofuel policies estimate ~~s~~ feedstock costs at 90% for biodiesel and 70-80% for bio-ethanol of the total production costs.

Taking into account the capacity of each plant, the average grain sorghum, soya beans and sunflowers' SAFEX prices for the 2014/2015 production year were used for the assessment and are depicted in table 4.3 below. For sugarcane the average price for the harvesting season 2014/2015 was used.

Table 4.3 SAFEX price of feedstocks

Feedstock	Sugarcane	Grain sorghum	Soya beans	Sunflower
	R / ton	R / ton	R / ton	R / ton
SAFEX price	R433.90	R2 626.78	R5 549.36	R4 435.47

Source : Abstract of Agricultural Statistics (2016) & Cane Growers' Association

Brazil and the USA are at the forefront of biofuel production and are the leaders in conversion technology as presented in table 4.4 (see below). For the purpose of this study, the global conversion rates of the selected crops are shown in table 4.5.

Table 4.4 Biofuel global yield and conversion rates

CROP	WORLD NATIONAL ESTIMATES	BIOENERGY	CROP YIELD	CONVERSION EFFICIENCY	BIOFUEL YIELD
			(Tonnes / ha)	(Litres / tonne)	(Litres / ha)
Sorghum	World	Ethanol	1.3	380	494
Sugar cane	Brazil	Ethanol	73.5	74.5	5 476
Soyabeans	Unites States of America	Bio diesel	2.7	205	552
Soyabeans	Brazil	Bio diesel	2.4	205	491

Source: FAO (2008) The state of Food and Agriculture, Biofuels, Prospects, Risks and Opportunities

Table 4.5 Biofuel yield and conversion rates for selected crops

Feedstock	Sugarcane	Grain sorghum	Soya beans	Sunflower
	(Litres/tonne)	(Litres/tonne)	(Litres/tonne)	(Litres/tonne)
Conversion rates	70	380	205	398.5 (BFAP)

4.4 Benefits of biofuel plants

Quantifying the benefits of bioenergy (biofuel and biodiesel) production is an important step in calculating the economic valuation of biofuel and biodiesel production. The benefits are dual: i.e.

both monetary and environmental, as shown in figure 4.1. Monetary benefits are the revenues generated from delivering biofuels at the market price into the national fuel supply of South Africa and from the sales of by-products. The revenues earned from the sales of biofuels would represent the direct net return to investors. Net returns are monetary values after taxation. Taxes represent the benefits accruing to government: these would ultimately benefit society at large.

The most notable environmental benefits from biofuel production are the reductions in greenhouse emissions. Biofuels are clean-burning fuels produced from vegetable oil, animal fats and grease with lower toxic air emissions than fossil fuels (Shalaby, 2013 : 455). Biofuel can be used as a fuel in vehicles in its pure form or as a gasoline additive in order to increase octane and reduce carbon emissions. It is most widely used in Brazil and the USA. Biodiesel can also be used in diesel vehicles in its pure form, but is mostly an additive to fossil fuels in order to reduce particles, carbon monoxide and hydrocarbons in diesel cars.

4.4.1 Monetary benefits of biofuel production

4.4.1.1 Revenues

Since both bioethanol and biodiesel have a lesser energy content than petrol and diesel respectively, the biofuel price delivered to blenders was estimated at 95% of the basic fossil fuel price (Kohler, 2016 : 14). The basic fuel price is regulated in SA by the Department of Energy (DOE). According to the data from the National Department of Energy the average basic price of 95 unleaded petrol was R5.48 and 0.005% sulphur diesel was R5.12 between November 2015 and October 2016: this represents realistic costs in terms of importing oil into South Africa. In the USA and Brazil the equivalent discount to the basic fuel price has been 5% in the last five years (Kohler, 2016 : 11).

The different plant capacities therefore would generate revenues for investors from the quantities delivered to blenders at 95% of the current basic fuel price. The projected revenues per annum are presented in table 4.5 below.

Table 4.5 Projected annual revenues of biofuel plants from different feedstocks

	158 000m³/a grain sorghum plant	95 000m³/a sugarcane plant	113 000m³/a soya beans plant	113 000m³/a sunflower plant
	millions	millions	millions	millions
Revenues	822,55	494.57	549.63	549.63

4.4.1.2 By-products

Distillers' dried grains with solubles (DDGS) are the nutrient rich co-product of dry-milled ethanol production. According to Stroade, Martin & Conrad (2009: 3) that as the US ethanol industry expanded, distillers' grain solubles gained in importance as an ethanol output, as well as a livestock input. The gross margins for ethanol producers are thus the value of ethanol plus the value of DGGS, less the price of feedstocks.

In addition DDGS has risen in importance in the livestock industry due to increases in the price of animal feedstocks. According to Mabele Fuels, an ethanol plant in Bothaville, DDGS has three times the protein and the same energy level as the original grain feedstock. Since only the starch is converted to ethanol the residue contains a high protein used as animal feed.

The Bureau for food and agricultural policy analysis (2008) on the viability of biofuels suggests that for every litre of biofuel produced from sorghum, an additional 96c income from by-products is generated.

As biodiesel is a promising alternative fuel, increased production also increases the production of the principal co-product, glycerine. To offset the high production costs of biodiesel the utilization of glycerin is a promising option for lowering the costs. According to Fangxia, Milford & Runcang (2012:1) a 30 million gallon biodiesel plant will generate around 11 500 tons of pure glycerin per year. This estimation indicates that a 113 000m³/a plant produces 29.85 million gallons of biodiesel per year and 11 443 tonnes of glycerine per year. Fangxia, Milford & Runcang (2012) suggest that the price of glycerin in the USA is $0.05 per pound. Given the exchange rate, this amounts to about 72c per pound in South Africa. The Bureau for food and agricultural policy analysis (2008) on the viability of biofuels indicates that for every litre of biodiesel produced from soya beans and sunflower, an additional R14.64 and R2.40 income from by-products are generated, respectively.

4.4.2 Other non-monetary benefits

As described in chapter 2, South Africa could benefit from bioenergy production through the reduction of greenhouse gases. Although research shows that environmental factors are crucial factors in the production of biofuel, job creation and agricultural development are also significant potential beneficiaries.

4.5 Financial and Economic Model Analysis

After quantifying the various economic costs and benefits, the decision-making criteria discussed in chapter were used in the analysis of the viability of biofuels in South Africa.

The NPV is calculated as the average discounted net cash inflows, less the average net cash outflows, less the initial setup cost. The projected value of the investment can be modelled using NPV analysis to determine whether the project should be implemented when based on revenues and costs.

To gauge the economic and financial viability of biofuels from sugarcane and sorghum and biodiesel from sunflower and soya beans, the NPV model takes into account all inflows and outflows, minus the initial setup costs. It can be defined as follows:

$$\sum_{t=1}^{n=15} \mathrm{Btx}\,(1+\mathrm{r})^{-\mathrm{t}} \quad - \sum_{t=1}^{n=15} \mathrm{Ctx}\,(1+\mathrm{r})^{-\mathrm{t}} \; - S1$$

Investments with a shorter payback period are preferred. When the net cash revenues are constant over time it can be calculated as follows:

PBP = TI/NR

Here TI is the total amount of investment and NR is the net revenue, i.e. the annual gross profit, less operating costs. However, this study assumes that net revenues to recoup the initial investment are not constant. The payback period in years is where the sum of the net cash revenues are equal to the initial investment.

The IRR is a tool that estimates the interest rate at which the present values of net cash revenues are equal to zero. IRR represents the maximum interest rate at which an investment can be funded if the net cash flow generated is sufficient to repay the original capital outlay at the end of the project's life. IRR is calculated as:

$$\sum_{t=1}^{n=15} (\mathrm{Btx} - \mathrm{Ctx})(1+\mathrm{r})^{\bar{\mathrm{t}}} \; = 0$$

Sensitivity analysis is used to incorporate uncertainty into economic evaluations so as to determine results under different situations where parameters differ from the initial values. Parameters that can differ include the input costs of biofuel costs, interest rates, discount rates, technological developments and other factors.

4.6 General Assumptions for baseline projections

In assessing the viability of biofuel production the following was assumed for the model:

- A 15 year time period measurement. A 15 year analysis provides investors with adequate decision-making criteria to decide whether to invest in biofuels or not. According to the International Food and Agricultural Review (2013), government and private institutions make decisions based on a time period of at least (or greater than) 10 years for research involving long-term energy and fuel projects. Cason & Satishchandra (2015) in their study on the cost and benefits of biofuel production from maize adopted a 15 year period for their economic viability analysis.

- Future cash flow projections have been incremented by the average inflation rate of 5.36% for the period 2001 to 2015.

- The capital budgeting assumes 100% bond financing and 0% equity rate.

- The discount rate of 12.35% is based on the average interest rate for the period 2001- 2015.

- SAFEX prices for all feedstocks for the 2014/2015 production year were used for the assessment.

- The average basic fuel prices for the 2014/2015 year were used for the assessment.

- The biofuel and biodiesel prices are assumed to be 95% of the fossil fuel price.

- The model is simplified to estimate a single value of benefits and costs and generalize it to other situations.

- 100% of the biofuel plant capacities are absorbed into the national fuel supply of South Africa.

- All by-products from the production of bioenergy are absorbed into the other markets.

CHAPTER 5

ESTIMATIONS AND RESULTS

5.1 Introduction

This chapter sets out to determine the economic viability of biofuels in South Africa. This is done through a baseline viability assessment using the tools described in chapter 3. The baseline assessment results are based on current benefits and costs as described in chapter 4.

The benefits and cost data are used in determining the net present value (NPV), and also IRR and the payback period. Cost and benefits data have been entered into two internet calculators that generated the same results. The results from use of these tools form the basis of assessing whether investing biofuels could provide a viable business opportunity. Since capital projects evolve over time, three biofuel viability scenarios are used to reveal the inherent uncertainty in the model simulation.

5.2 Viability calculations using baseline projections

5.2.1 Total financial costs and benefits

The baseline projections were developed for comparison the results of the other three scenarios. Tables 5.1 and 5.3 represent the financial costs and benefits associated with the production of biofuels in South Africa. The total costs represent the total sum of the initial capital investment, and the operating and feedstock costs. The results from table 5.1 show that the bulk of the financial costs comprises of feedstock costs, with operating costs at approximately 15% of the total costs.

Table 5.2 indicates the projected baseline cost per litre bioethanol and biodiesel for the different feedstocks. The results indicate that it is more cost effective to produce biofuel from sugarcane and biodiesel from sunflower crops than grain sorghum and soya beans respectively. It also shows that bioethanol costs significantly less to produce given the current feed stock prices.

Table 5.1 Estimated ~~of~~ annual financial costs of biofuel production in South Africa

		Capacity of plant			
No	Component	158 000m³/year grain sorghum plant	95 000m³/year sugarcane plant	113 000m³/year soya beans plant	113 000m³/year sunflower plant
		millions	millions	millions	millions
1	Capital costs[1]	2.82	2.61	1.50	1.38
2	Operating costs[2]	193.24	104.4	540	222.2
3	Feedstock costs[3]	1 092.20	588.9	3 058.9	1 257.7
4	Total costs	1 288.26	695.94	3 600.4	1 481.28

Note : 1m³ = 1 000 litres
1 : Department of Energy (2011)
2 : Biofuel Industrial Strategy (2007)
3 : Daff (2016)

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Table 5.2 Unit cost of biofuel for different feedstocks

		Capacity of plant			
No	Component	158000m³/year grain sorghum plant	95000m³/year sugarcane plant	113000m³/year soya beans plant	113000m³/year sunflower plant
		millions	millions	millions	millions
1	Unit costs	R8.15	R7.33	R31.86	R13.11

Table 5.3 (see below) shows that the total benefits consist of the revenues from the sales of biofuel and the by-products generated from its production. Except for biodiesel production from soya beans the majority of the benefits are obtained from the revenues earned from the sales of biofuel.

Table 5.3 Estimated annual financial benefits of biofuel production in South Africa

		Capacity of plant			
No	Component	158000m³/year grain sorghum plant	95000m³/year sugarcane plant	113000m³/year soya beans plant	113000m³/year sunflower plant
		millions	millions	millions	millions
1	Revenues[1]	822.55	494.57	549.63	549.63
2	By-products[2]	151.6	0	1 654.3	271.2
3	Total benefits	974.15	494.57	2 203.93	820.83

Note 1: tonne = 2 204.62 pounds
1. Department of Energy (DoE) (2016)
2. Bureau of Food and Agricultural Policy (BFAP) (2008)

The results from table 5.3 have been used to estimate the potential income to be earned from the production and sales of one litre of bioethanol and biodiesel. Table 5.4 (see below) shows that the potential income generated from grain sorghum for bioethanol and from soya beans for biodiesel yield better results. This is mostly attributed to the difference in the income generated from the sales of by-products from the different feed stocks. However, for the results to be conclusive a merging of the costs and benefits results for financial and economic analysis is required.

Table 5.4 Potential Income benefit per litre biofuel produced from different feedstocks

		Capacity of plant			
No	Component	158000m³/year grain sorghum plant	95000m³/year sugarcane plant	113000m³/year soya beans plant	113000m³/year sunflower plant
		millions	millions	millions	millions
1	Revenue per litre	R6.17	R5.21	R19.50	R7.26

5.2.2 Financial and Economic Analysis

Table 5.5 simulates the NPV results obtained from cash inflow and outflow projections over a 15 year period. At the base discount rate of 12.35% the results for all plants turn out to have negative net present values: hence these are unviable options to pursue.

Although the NPV results show that bioethanol and biodiesel production from grain sorghum and sunflower render better results than from sugarcane and soya beans respectively, significant changes to inputs into the model are required to make any proposal viable. Since biofuel and biodiesel's prices are based on the basic fuel price, input costs should be significantly lower to make any project sufficiently viable.

The IRRs of the 4 plants shown in table 5.5 are all negative since the NPVs for the 4 plants are so largely negative that they are rendered insignificant for viability assessment. Since the requirement for viability is for the IRR to be larger than the interest rate (or discounted value), the negative IRRs render all projects unviable. The payback period is also not applicable as no profits could be realized in the initial and subsequent years to repay the initial investment for each plant.

Table 5.5 Net Present value for the base case scenario at a discount rate of 12.35% after 15 years

Biofuel plant capacity	Net present value	IRR	Payback period
	millions	%	Years
158 000m³/year grain sorghum plant	-R2 756.74	-24.22%	NA
95 000m³/year sugarcane plant	-R2 064.29	-28.67%	NA
113 000m³/year soya beans plant	-R14 473.9	-38.76	NA
113 000m³/year sunflower plant	-R6 838.84	-44.53	NA

The baseline assessment forms the basis to explore the net effect on the net present costs of systematic changes in individual parameters. Since the results of the baseline assessments provide such unviable results, parameter changes were limited to factors contributing to improving the viability of bioenergy production. Sensitivity analysis was thus performed by varying the feedstock cost price, basic fuel price and the discount rate for each proposed project. Market situation changes in demand and supply of biofuel production could lead to the reduction in feedstock and operating costs of biofuel plants.

5.3 Sensitivity Analysis

5.3.1 Change in feedstock prices

As mentioned earlier, feedstock costs represent the most significant contributor to the cost component in order to produce bioenergy. It is therefore also assumed that the change in the feed stock price could be a major contributing factor to deem biofuel projects viable or not. Hence, the change in feedstock prices would therefore be more sensitive than other parameters in viability assessments.

Since these bioenergy projects are assessed over an average period, feedstock prices were used in the assessments from 2001 to 2015. The Safex feedstock prices presented in table 5.6 are significantly lower than the baseline prices which could render the projects potentially viable. The estimated cost at the average Safex price is shown in table 5.7 – as used in the financial viability assessment.

Table 5.6. SAFEX price of feedstocks

Feedstock	Sugarcane	Grain sorghum	Soya beans	Sunflower
	R/ton	R/ton	R/ton	R/ton
SAFEX price	R247.85	R1 627.1	R2 969.06	R3 024.9

Source : Abstract of Agricultural Statistics (2016)

Table 5.7 Estimated of annual financial cost of biofuel production in South Africa

		Capacity of plant			
No	Component	158 000m^3/year grain sorghum plant	95 000m^3/year sugarcane plant	113 000m^3/year soya beans plant	113 000m^3/year sunflower plant
		millions	millions	millions	millions
1	Capital costs[1]	2.82	2.61	1.50	1.38
2	Operating costs[2]	119.89	59.82	289.08	151.61
3	Feedstock costs[3]	676.53	336.37	1 636.60	857.75
4	Total costs	799.24	398.80	1 927.18	1 010.74

Note : 1m^3 = 1 000 litres
1 : Department of Energy (2011)
2 : Biofuel Industrial Strategy (2007)
3 : Daff (2016)

The results from the model portrayed in table 5.8 suggest that all plants could be viable except with biodiesel production from sunflower plants. The positive NPV's from grain sorghum, sugarcane and soya beans imply that these could be economically viable. Based on the current stream of benefits and costs, the IRR results show that the NPV's for grain sorghum, sugarcane and soya beans plants would be equal to zero at discount rates (interest rates) of 22.25%, 24.69% and 14.44%, respectively. Discount rates beyond these percentages will render the NPV negative, implying that the costs stream will exceed the benefits stream. The results also show that biofuel from sugarcane and soya beans will be more economically viable due to higher IRR's for biofuel and biodiesel, respectively.

It also shows that the sugarcane plant has a lower, undiscounted payback period than grain sorghum, rendering biofuel production from it more viable. For biodiesel soya beans has a payback period of 6.05 years. Sunflower biodiesel production’s payback period is not applicable as profit streams are all indicated as negative.

Table 5.8 Net Present value for the change in feedstock prices’ scenario at a discount rate of 12.35% after 15 years

Biofuel plant capacity	Net present value	IRR	Undiscounted Payback period
	millions	%	Years
158 000m³/year grain sorghum plant	R1 841.32	22.25%	4.15
95 000m³/year sugarcane plant	R1 018.35	24.69%	3.78
113 000m³/year soya beans plant	R2 885.36	14.44%	6.05
113 000m³/year sunflower plant	-R1 957.2	-18.68%	NA

5.3.2 Change in Basic fuel price

Research into changes in the basic fuel price suggests that its movement depends largely on the changes in the world oil price. During 2015 the basic fuel price peaked at R7.03 and diesel at R6.46 in July when the world oil price was at its highest in the prior month.

Given the current costs and benefit streams, the NPV and IRR results shown in table 5.9 suggest that investing in any of the proposed bioenergy projects will not be viable due to negative results. Keeping the other parameters constant requires a more substantial increase in the basic fuel prices of petrol and diesel to render any of the projects viable as depicted in table 5.10. All NPV’s and IRR’s are negative, rendering the payback period not applicable as it cannot have a negative value.

Table 5.9 Estimated annual financial benefits of biofuel production in South Africa

		Capacity of plant			
No	Component	158000m³/year grain sorghum plant	95000m³/year sugarcane plant	113000m³/year soya beans plant	113000m³/year sunflower plant
		millions	millions	millions	millions
1	Revenues[1]	1055.20	634.46	693.48	693.48
2	By-products[2]	151.60	0	1 654.3	271.20
3	Total benefits	1 206.80	634.46	2 347.78	964.68

Note 1: ton = 2 204.62 pounds
1. Department of Energy (DoE) (2016)
2. Bureau of Food and Agricultural Policy (BFAP) (2008)

Table 5.10 Net Present value for the change in the basic fuel price scenario at a discount rate of 12.35% after 15 years

Biofuel plant capacity	Net present value	IRR	Payback period
	millions	%	Years
158 000m³/year grain sorghum plant	-R841.71	-6.12%	NA
95 000m³/year sugarcane plant	-R630.38	-8.5%	NA
113 000m³/year soya beans plant	-R13 352	-34.76%	NA
113 000m³/year sunflower plant	-R5 498.9	-34.81%	NA

5.3.3 Different discounted values

The South African prime interest rate is currently at historical lows and the average between 2011 and 2015 has been around 8.95% according to the South African Revenue Services. It is therefore 3.4% below the 15 year average of 12.35% used in the baseline assessment. Table 5.11 shows the NPV, IRR and payback period results for the discount rates of 3.4% below and above a 12.35% interest rate.

The variance of 3.4% below and above does not render any project viable. The results in table 5.11 indicate that at lower discount rates the results actually deteriorate. It also shows that extremely high discount rates are required to significantly improve the projections for each proposed project.

Table 5.11 Net Present value at different discount rates after 15 years

Biofuel plant capacity	NPV IRR 8.95%	NPV IRR 15.75%	IRR	Payback period
	millions	millions	%	Years
158 000m³/year grain sorghum plant	-R3 427.98	-R3 226.6	-24.22%	NA
95 000m³/year sugarcane plant	-R2 189.38	-R2 060.76	-28.67%	NA
113 000m³/year soya beans plant	-R15 351.4	-R14 449.5	-38.76	NA
113 000m³/year sunflower plant	-R7 253.42	-R6 827.3	-44.53	NA

5.4 Conclusion

The aim of this chapter was to ascertain whether biofuel and biodiesel production are economically viable from four selected crops using three financial assessment tools. The benefits and costs streams projected over a fifteen year period were inserted into the NPV, IRR and payback period equations in order to calculate the results.

The outcomes from the three models can provide the basis for investors to decide whether it is economically viable to pursue investments into any of the four projects. The baseline projections produced very pessimistic results as all proposed projects had negative NPVs and IRRs. This rendered the payback period unattainable as it cannot be presented as negative years.

A sensitivity analysis was performed and the results show that the most important sensitivity parameter is the price of the feedstock. Table 5.12 shows that a decrease in the sugarcane price of 42.8% leads to an increase in viability of 46.5%. The changes in the price of feedstocks therefore lead to a higher degree of variability in the modelled results.

The modelled results further indicate that the other parameters have little influence on the baseline projections. Variations in the basic fuel price and in the discount values still render all proposed projects as not being economically viable.

Table 5.12 Change in feedstock prices vs change in viability projections

Feedstock	Sugarcane	Grain sorghum	Soya beans	Sunflower
	R/ton	R/ton	R/ton	R/ton
SAFEX price	R433.90	R2 626.78	R5 549.36	R4 435.47
SAFEX price	R247.85	R1 627.10	R2 969.06	R3 024.90
Change in price	-42.8%	-38%	-46.5%	-31.2%
Change in viability	46.5%	53.36%	53.2%	25.85%

The outcomes of the model are summarized in appendix A at the end of this document. The tables indicate the projected future cash flows, the discount rate based on the average interest rate and the NPV values for each year.

CHAPTER 6

POLICY RECOMMENDATIONS AND CONCLUSIONS

6.1 Introduction

Since the release of the proposed South African Biofuel Industrial Strategy of 2007, little attempt has been made to create a commercialized biofuel sector. Criticisms regarding issues such as food security; water resources and land availability; and feedstock choices have stifled the development of biofuel production in South Africa. Significant changes to the draft strategy of 2006 have seen the target revised down from a 4.5% to a 2% biofuel penetration level into the national fuel supply. More importantly, sugarcane and sugar beet for biofuels and sunflower, canola and soya beans were proposed as potential feedstocks to biofuel production (DME, 2007:3). This study might be seen as also contributing to research into these crops as feedstocks.

The objective of this study was to estimate how economically viable biofuel and biodiesel production can be from grain sorghum, sugarcane, soya beans and sunflower as feedstocks. The overall objectives of this study were outlined in chapter 1. Subsequently chapter 2 set out to provide information on the recent history and background with regard to global biofuel production, especially emphasizing the roles of leading countries, Brazil and the USA. Chapter 3 provides insight into recently published studies and models used to assess the viability of different commodities. Different assessment tools were reviewed and economic viability study tools, NPV, IRR and payback periods were selected for this study. Relevant data were gathered for input into the models in chapter 4. The results were interpreted in chapter 5 and sensitivity analyses were performed in order to ascertain modelled results obtained when varying a few input and output parameters.

Chapter 6 draws important conclusions regarding the viability of biofuel production from grain sorghum, sugarcane, soya beans and sunflower in South Africa: it integrates the key findings and seeks to provide policy recommendations for stakeholders.

6.2 Key Findings

The key findings of this study are as follows:

- The current lack of economic activities in this field is justified as food security; water issues and land availability require further investigation before there can be expansion of the industry.

- The benefits and costs provide the basis for deciding to create a fully commercialized biofuel industry. The expected costs and benefits streams for 10-15 years should provide enough impetus to decide whether to invest into biofuel production or not.

- Four biofuel viability scenarios were formulated to assess the viability of biofuel and biodiesel from different feedstocks. The results of the analyses are summarized as follows:

  (i) The baseline scenario results show that biofuel and biodiesel are not viable under the aegis of current cost and benefit streams. The simulation results for the NPVs and IRRs are negative for all plants, rendering these unviable options to pursue at present.

  (ii) Sensitivity analysis performed indicates that biofuel production could become viable with a substantial reduction in feedstock prices. On diverting back to recent 15 year averages, the NPV and IRR turn out to be positive for all crops except sunflowers. The payback periods are short enough to receive a substantial return on investment.

(iii) The biofuel price is closely related to the basic fuel price. Even increases of 28% in the basic petrol and 26% in biodiesel prices render all the proposed projects not viable.

(iv) The change in the interest rate (discount rate) would have no significant impact on improving the baseline assessment results. The NPV and IRR values are all negative for all proposed plants and the payback period unattainable.

- The feedstock price is the most crucial factor to be considered in the appraisal of all biofuel projects. Since crop prices are volatile, movement in its prices must be carefully considered in order to evaluate biofuel and biodiesel viability.
- Benefit and cost projection streams are subject to uncertainty and might not provide substantially different results - as has been indicated in the study.

6.3 Policy Recommendations

Several policy options could be derived from this study. Since feedstock costs are the most crucial factor for potentially contributing to the viability of biofuel production, policy options are mostly directed towards it. This study reveals that biofuel producers require reliable, low cost feedstocks if plants are to become economically viable.

A decrease in feedstock prices could improve the profitability of plants significantly, as shown in the sensitivity analysis. This study assumes that feedstocks are sourced from commercial farmers and bought at the current market price. The BIS (2007) was promulgated to attract investment into rural areas and promote agricultural development.

While US and European biofuel production is highly subsidized, South African agricultural subsidies are limited. Support must thus be justified by maximising the benefits and minimising the costs. At farm-level programmes must be put in place to assist farmers to reduce the cost of crop production. The BIS (2007) suggests that emerging farmers organise themselves in cooperatives to maximise collective benefits and to participate fully or partially in the ownership of biofuel plants.

The development of biofuel production might help to ensure that the grain strategy objective (DAFF, 2012) of increasing the production of agricultural produce is met. The reduction in the price causes farmers to cut back on production when demand does not meet increases in supply. The strategy intends to ensure that the reduction in crop prices is not offset by farmers cutting back on agricultural production when supply does not met demand.

6.4 Areas for future research

In this study it is clearly indicated that future biofuel research should centre on alternative feedstocks for bioenergy production. Since the biofuel industry competes with the food market, non-food crops might produce more attractive prospects for potential investors. For example, Jatropha and switchgrass are non-food crops and could become leading contenders for biodiesel and bioethanol production purposes. According to Smith (2013:1) switchgrass shows promise as an effective source of ethanol. It has an advantage over corn crops as a conventional feedstock as it grows on marginal land and does not compete with food crop production.

Jatropha is a drought resistant, non-edible plant that can be grown on marginal land with limited water supply (Elbehri, Segerstedt & Liu, 2013 : 34). It is suitable for biodiesel production when extracted from the oilseed. The process of extracting biodiesel from jatropha is uncomplicated and presents low technological requirements. The by-products from the process are fertilizer and glycerin, approximately 10% of total output of biofuels (Elbehri et al, 2013 : 35).

Biofuel production remains controversial due to the food versus fuel debate. Until the issues are resolved, those views currently for and against biofuel production can each provide valid reasons as to why the industry must or must not be developed. This research indicates that measures should be put into place to ensure that biofuel production does not create food shortages. The results of research into biofuel production might even suggest that the development of the industry will increase food security in South Africa. Job creation is identified as one of the strong incentives for promotion of the biofuel industry. Future research could determine how many jobs could be created per million litres of biofuels.

6.5 Conclusion

The results of this study are conclusive. This study has shown that biofuel production cannot be viable given the current cost and the benefits levels derived from the production thereof. Bioenergy cannot compete with fossil fuels. Conventional petrol and diesel are produced from oil and sold at a significantly lower basic fuel price than the current cost of biofuels' production.

The biggest obstacle in the development of biofuels is the market price of feedstocks. For biofuel production to become economically viable a substantial reduction in the feedstock price is required. It requires substantial government support at either farm-level or biofuel production level. However, it is debatable whether the South African support could be sustained over a lengthy period of time.

To conclude, this research has highlighted the factors that contribute to the economic viability of bioenergy production in South Africa. Grain sorghum, sugarcane and soya beans plants might become viable if certain policy measures could ensure that the production costs of these feedstocks are reduced. Farmers require clear government direction to ensure that their participation is sustainable and able to remain~~s~~ viable over a period of sufficient time.

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APPENDIX A.1 : Detailed simulation results of baseline assessment

158 000m^3/a grain **SORGHUM** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE +5.36%	974.15	1026.36	1081.37	1139.33	1200.4	1264.74	1332.53	1404	1479.2	1558.49	1642.03	1730.04	1822.77	1920.47	2023.4	21599.24
DISCOUNT RATE 12.35%	1.1235	1.26225	1.41814	1.59328	1.79005	2.01112	2.2595	2.5385	2.852054	3.20428	3.60001	4.04461	4.54412	5.105321	5.7358	
NPV	867.067	813.118	762.527	715.084	670.595	628.873	589.747	553.05	518.6438	486.377	456.118	427.739	401.127	376.1703	352.77	8619.007
158 000m^3/a grain **SORGHUM** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST +5.36%	1288.26	1354.34	1426.93	1503.41	1583.99	1668.89	1758.34	1852.6	1951.89	2056.51	2166.74	2282.88	2405.24	2534.16	2670	28504.16
DISCOUNT RATE	1.1235	1.26225	1.41814	1.59328	1.79005	2.01112	2.2595	2.5385	2.852054	3.20428	3.60001	4.04461	4.54412	5.105321	5.7358	
NPV	1146.65	1072.96	1006.2	943.594	884.885	829.83	778.2	729.78	684.3805	641.801	601.87	564.425	529.308	496.3762	465.49	11375.75
95 000m^3/a **SUGARCANE** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE +5.36%	494.57	521.08	549.01	578.44	609.44	642.11	676.53	712.79	751	791.25	833.66	878.34	925.42	975.02	1027.3	10965.94
DISCOUNT RATE 12.35%	1.1235	1.26225	1.37522	1.49831	1.6324	1.77851	1.93768	2.1111	2.300047	2.5059	2.73018	2.97453	3.24075	3.530799	3.8468	
NPV	440.205	412.818	399.215	386.063	373.339	361.039	349.144	337.64	326.515	315.755	305.35	295.287	285.557	276.1471	267.05	5131.119
95 000m^3/a **SUGARCANE** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST +5.36%	695.94	730.49	769.64	810.89	854.35	900.14	948.39	999.22	1052.78	1109.21	1168.66	1231.3	1297.3	1366.84	1440.1	15375.25
DISCOUNT RATE 12.35%	1.1235	1.26225	1.37522	1.49831	1.6324	1.77851	1.93768	2.1111	2.300047	2.5059	2.73018	2.97453	3.24075	3.530799	3.8468	
NPV	619.439	578.72	559.647	541.204	523.369	506.122	489.446	473.32	457.721	442.639	428.052	413.948	400.308	387.1192	374.36	7195.413

APPENDIX A.2 : Detailed simulation results of baseline assessment

113 000m^3/a **SOYA BEANS** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE +5.36%	2203.93	2322.06	2446.52	2577.65	2715.81	2861.38	3014.75	3176.3	3346.59	3525.97	3714.96	3914.08	4123.87	4344.91	4577.8	48866.62
DISCOUNT RATE 12.35%	1.1235	1.26225	1.37522	1.49831	1.6324	1.77851	1.93768	2.1111	2.300047	2.5059	2.73018	2.97453	3.24075	3.530799	3.8468	
NPV	1961.66	1839.62	1779	1720.38	1663.69	1608.87	1555.85	1504.6	1455.009	1407.07	1360.7	1315.86	1272.5	1230.574	1190	22865.4
113 000m^3/a **SOYA BEANS** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST +5.36%	3600.4	3791.8	3995.04	4209.17	4434.78	4672.48	4922.92	5186.8	5464.8	5757.71	6066.32	6391.47	6734.05	7095	7475.3	79798.02
DISCOUNT RATE 12.35%	1.1235	1.26225	1.37522	1.49831	1.6324	1.77851	1.93768	2.1111	2.300047	2.5059	2.73018	2.97453	3.24075	3.530799	3.8468	
NPV	3204.63	3004	2905.01	2809.29	2716.72	2627.2	2540.62	2456.9	2375.951	2297.66	2221.95	2148.73	2077.93	2009.46	1943.2	37339.29
113 000m^3/a **SUNFLOWER** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE +5.36%	820.83	864.83	911.18	960.02	1011.48	1065.7	1122.82	1183	1246.41	1313.22	1383.61	1457.77	1535.91	1618.23	1705	18199.98
DISCOUNT RATE 12.35%	1.1235	1.26225	1.37522	1.49831	1.6324	1.77851	1.93768	2.1111	2.300047	2.5059	2.73018	2.97453	3.24075	3.530799	3.8468	
NPV	730.601	685.148	662.569	640.737	619.626	599.211	579.466	560.37	541.9062	524.051	506.783	490.084	473.936	458.3184	443.22	8516.024
113 000m^3/a **SUNFLOWER** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST +5.36%	1481.28	1559.22	1642.79	1730.84	1823.61	1921.36	2024.34	2132.8	2247.16	2367.61	2494.51	2628.22	2769.09	2917.51	3073.9	32814.27
DISCOUNT RATE 12.35%	1.1235	1.26225	1.37522	1.49831	1.6324	1.77851	1.93768	2.1111	2.300047	2.5059	2.73018	2.97453	3.24075	3.530799	3.8468	
NPV	1318.45	1235.27	1194.56	1155.2	1117.13	1080.32	1044.72	1010.3	977.0059	944.814	913.68	883.575	854.459	826.3031	799.08	15354.86

APPENDIX A.3 : Detailed simulation results of the change in feedstock prices

158 000m^3/a grain **SORGHUM** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE 5.36%	974.15	1026.4	1081.4	1139.3	1200.4	1264.7	1332.5	1404	1479.2	1558.5	1642	1730	1822.8	1920.5	2023.4	21599.2
DISCOUNT RATE 12.35%	1.1235	1.2623	1.3752	1.4983	1.6324	1.7785	1.9377	2.1111	2.3	2.5059	2.7302	2.9745	3.2408	3.5308	3.8468	
NPV	867.07	813.12	786.32	760.41	735.36	711.13	687.69	665.03	643.12	621.93	601.44	581.62	562.45	543.92	526	10106.6
158 000m^3/a grain **SORGHUM** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST 5.36%	799.24	839.11	884.09	931.48	981.41	1034	1089.4	1147.8	1209.3	1274.2	1342.5	1414.4	1490.2	1570.1	1654.3	17661.5
DISCOUNT RATE 12.35%	1.1235	1.2623	1.3752	1.4983	1.6324	1.7785	1.9377	2.1111	2.3	2.5059	2.7302	2.9745	3.2408	3.5308	3.8468	
NPV	711.38	664.77	642.87	621.69	601.21	581.39	562.23	543.71	525.79	508.46	491.71	475.51	459.84	444.69	430.03	8265.28
95 000m^3/a **SUGARCANE** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE 5.36%	494.57	521.08	549.01	578.44	609.44	642.11	676.53	712.79	751	791.25	833.66	878.34	925.42	975.02	1027.3	10965.9
DISCOUNT RATE 12.35%	1.1235	1.2623	1.3752	1.4983	1.6324	1.7785	1.9377	2.1111	2.3	2.5059	2.7302	2.9745	3.2408	3.5308	3.8468	
NPV	440.2	412.82	399.22	386.06	373.34	361.04	349.14	337.64	326.52	315.75	305.35	295.29	285.56	276.15	267.05	5131.12
95 000m^3/a **SUGARCANE** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST 5.36%	398.8	417.43	439.8	463.37	488.21	514.38	541.95	571	601.61	633.86	667.83	703.63	741.34	781.08	822.95	8787.24
DISCOUNT RATE 12.35%	1.1235	1.2623	1.3752	1.4983	1.6324	1.7785	1.9377	2.1111	2.3	2.5059	2.7302	2.9745	3.2408	3.5308	3.8468	
NPV	354.96	330.7	319.8	309.26	299.07	289.22	279.69	270.47	261.56	252.95	244.61	236.55	228.76	221.22	213.93	4112.77

APPENDIX A.4 : Detailed simulation results of the change in feedstock prices

113 000m^3/a **SOYA BEANS** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE 5.36%	2203.9	2322.1	2446.5	2577.7	2715.8	2861.4	3014.8	3176.3	3346.6	3526	3715	3914.1	4123.9	4344.9	4577.8	48866.6
DISCOUNT RATE 12.35%	1.1235	1.2623	1.3752	1.4983	1.6324	1.7785	1.9377	2.1111	2.3	2.5059	2.7302	2.9745	3.2408	3.5308	3.8468	
NPV	1961.7	1839.6	1779	1720.4	1663.7	1608.9	1555.9	1504.6	1455	1407.1	1360.7	1315.9	1272.5	1230.6	1190	22865.4
113 000m^3/a **SOYA BEANS** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST 5.36%	1927.2	2028.9	2137.7	2252.2	2373	2500.1	2634.2	2775.3	2924.1	3080.8	3246	3419.9	3603.3	3796.4	3999.9	42698.9
DISCOUNT RATE 12.35%	1.1235	1.2623	1.3752	1.4983	1.6324	1.7785	1.9377	2.1111	2.3	2.5059	2.7302	2.9745	3.2408	3.5308	3.8468	
NPV	1715.3	1607.4	1554.4	1503.2	1453.7	1405.8	1359.4	1314.6	1271.3	1229.4	1188.9	1149.7	1111.9	1075.2	1039.8	19980
113 000m^3/a **SUNFLOWER** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE 5.36%	820.83	864.83	911.18	960.02	1011.5	1065.7	1122.8	1183	1246.4	1313.2	1383.6	1457.8	1535.9	1618.2	1705	18200
DISCOUNT RATE 12.35%	1.1235	1.2623	1.3752	1.4983	1.6324	1.7785	1.9377	2.1111	2.3	2.5059	2.7302	2.9745	3.2408	3.5308	3.8468	
NPV	730.6	685.15	662.57	640.74	619.63	599.21	579.47	560.37	541.91	524.05	506.78	490.08	473.94	458.32	443.22	8516.02
113 000m^3/a **SUNFLOWER** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST 5.36%	1010.7	1063.5	1120.5	1180.5	1243.8	1310.5	1380.7	1454.7	1532.7	1614.8	1701.4	1792.6	1888.7	1989.9	2096.6	22381.6
DISCOUNT RATE 12.35%	1.1235	1.2623	1.3752	1.4983	1.6324	1.7785	1.9377	2.1111	2.3	2.5059	2.7302	2.9745	3.2408	3.5308	3.8468	
NPV	899.64	842.51	814.75	787.9	761.94	736.84	712.56	689.08	666.37	644.41	623.18	602.65	582.79	563.59	545.02	10473.2

APPENDIX A.5 : Detailed simulation results of the change in the basic fuel price

158 000m³/a grain **SORGHUM** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE 5.36%	1206.8	1271.48	1339.63	1411.4	1487.1	1566.8	1650.8	1739.3	1832.5	1930.7	2034.2	2143.2	2258.1	2379.1	2506.6	26757.58
DISCOUNT RATE 12.35%	1.1235	1.22405	1.33361	1.453	1.583	1.7247	1.879	2.0472	2.2304	2.4301	2.6476	2.8845	3.1427	3.4239	3.7304	
NPV	1074.14	1038.75	1004.52	971.41	939.4	908.45	878.52	849.57	821.57	794.5	768.32	743	718.52	694.84	671.95	12877.47
158 000m³/a grain **SORGHUM** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST 5.36%	1288.26	1354.34	1426.93	1503.4	1584	1668.9	1758.3	1852.6	1951.9	2056.5	2166.7	2282.9	2405.2	2534.2	2670	28504.16
DISCOUNT RATE	1.1235	1.22405	1.33361	1.453	1.583	1.7247	1.879	2.0472	2.2304	2.4301	2.6476	2.8845	3.1427	3.4239	3.7304	
NPV	1146.65	1106.44	1069.98	1034.7	1000.6	967.65	935.76	904.93	875.11	846.28	818.39	791.43	765.35	740.13	715.74	13719.18
95 000m³/a **SUGARCANE** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE 5.36%	634.46	668.47	704.3	742.05	781.82	823.73	867.88	914.4	963.41	1015.1	1069.5	1126.8	1187.2	1250.8	1317.9	14067.65
DISCOUNT RATE 12.35%	1.1235	1.22405	1.33361	1.453	1.583	1.7247	1.879	2.0472	2.2304	2.4301	2.6476	2.8845	3.1427	3.4239	3.7304	
NPV	564.717	546.112	528.117	510.71	493.88	477.61	461.87	446.66	431.94	417.7	403.94	390.63	377.76	365.31	353.27	6770.247
95 000m³/a **SUGARCANE** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST 5.36%	695.94	730.49	769.64	810.89	854.35	900.14	948.39	999.22	1052.8	1109.2	1168.7	1231.3	1297.3	1366.8	1440.1	15375.25
DISCOUNT RATE 12.35%	1.1235	1.22405	1.33361	1.453	1.583	1.7247	1.879	2.0472	2.2304	2.4301	2.6476	2.8845	3.1427	3.4239	3.7304	
NPV	619.439	596.78	577.112	558.09	539.7	521.92	504.72	488.09	472.01	456.45	441.41	426.87	412.8	399.2	386.05	7400.63

APPENDIX A.6 : Detailed simulation results of the change in the basic fuel price

113 000m³/a **SOYA BEANS** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE 5.36%	2347.78	2473.62	2606.21	2745.9	2893.1	3048.2	3211.5	3383.7	3565	3756.1	3957.5	4169.6	4393.1	4628.5	4876.6	52056.32
DISCOUNT RATE 12.35%	1.1235	1.22405	1.33361	1.453	1.583	1.7247	1.879	2.0472	2.2304	2.4301	2.6476	2.8845	3.1427	3.4239	3.7304	
NPV	2089.7	2020.84	1954.26	1889.9	1827.6	1767.4	1709.1	1652.8	1598.4	1545.7	1494.8	1445.5	1397.9	1351.8	1307.3	25052.81
95 000m³/a **SOYA BEANS** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST 5.36%	3600.4	3791.8	3995.04	4209.2	4434.8	4672.5	4922.9	5186.8	5464.8	5757.7	6066.3	6391.5	6734.1	7095	7475.3	79798.02
DISCOUNT RATE 12.35%	1.1235	1.22405	1.33361	1.453	1.583	1.7247	1.879	2.0472	2.2304	2.4301	2.6476	2.8845	3.1427	3.4239	3.7304	
NPV	3204.63	3097.74	2995.67	2897	2801.5	2709.2	2619.9	2533.6	2450.1	2369.4	2291.3	2215.8	2142.8	2072.2	2003.9	38404.53

113 000m³/a **SUNFLOWER** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE 5.36%	964.68	1016.39	1070.87	1128.3	1188.8	1252.5	1319.6	1390.3	1464.9	1543.4	1626.1	1713.3	1805.1	1901.8	2003.8	21389.6
DISCOUNT RATE 12.35%	1.1235	1.22405	1.33361	1.453	1.583	1.7247	1.879	2.0472	2.2304	2.4301	2.6476	2.8845	3.1427	3.4239	3.7304	
NPV	858.638	830.348	802.988	776.53	750.95	726.2	702.27	679.13	656.75	635.11	614.18	593.95	574.38	555.45	537.15	10294.03
95 000m³/a **SUNFLOWER** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST 5.36%	1481.28	1559.22	1642.79	1730.8	1823.6	1921.4	2024.3	2132.8	2247.2	2367.6	2494.5	2628.2	2769.1	2917.5	3073.9	32814.27
DISCOUNT RATE 12.35%	1.1235	1.22405	1.33361	1.453	1.583	1.7247	1.879	2.0472	2.2304	2.4301	2.6476	2.8845	3.1427	3.4239	3.7304	
NPV	1318.45	1273.82	1231.84	1191.2	1152	1114	1077.3	1041.8	1007.5	974.3	942.19	911.15	881.12	852.09	824.01	15792.9

APPENDIX A.7 : Detailed simulation results at discount rate 8.95%

158 000m³/a grain **SORGHUM** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE 5.36%	974.15	1026.4	1081.4	1139.3	1200.4	1264.7	1332.5	1404	1479.2	1558.5	1642	1730	1822.8	1920.5	2023.4	21599.24
DISCOUNT RATE 8.95%	1.0895	1.187	1.2932	1.409	1.5351	1.6725	1.8222	1.9853	2.1629	2.3565	2.5674	2.7972	3.0476	3.3203	3.6175	
NPV	894.126	864.66	836.17	808.61	781.97	756.2	731.28	707.19	683.88	661.35	639.56	618.49	598.11	578.4	559.34	10719.33
158 000m³/a grain **SORGHUM** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST 5.36%	1288.26	1354.3	1426.9	1503.4	1584	1668.9	1758.3	1852.6	1951.9	2056.5	2166.7	2282.9	2405.2	2534.2	2670	28504.16
DISCOUNT RATE 8.95%	1.0895	1.187	1.2932	1.409	1.5351	1.6725	1.8222	1.9853	2.1629	2.3565	2.5674	2.7972	3.0476	3.3203	3.6175	
NPV	1182.43	1141	1103.4	1067	1031.8	997.85	964.97	933.17	902.42	872.69	843.93	816.12	789.23	763.23	738.08	14147.31
95 000m³/a **SUGARCANE** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE 5.36%	494.57	521.08	549.01	578.44	609.44	642.11	676.53	712.79	751	791.25	833.66	878.34	925.42	975.02	1027.3	10965.94
DISCOUNT RATE 8.95%	1.0895	1.187	1.2932	1.409	1.5351	1.6725	1.8222	1.9853	2.1629	2.3565	2.5674	2.7972	3.0476	3.3203	3.6175	
NPV	453.942	438.99	424.52	410.53	397	383.92	371.28	359.04	347.21	335.77	324.71	314	303.66	293.65	283.98	5442.203
95 000m³/a **SUGARCANE** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST 5.36%	695.94	730.49	769.64	810.89	854.35	900.14	948.39	999.22	1052.8	1109.2	1168.7	1231.3	1297.3	1366.8	1440.1	15375.25
DISCOUNT RATE 8.95%	1.0895	1.187	1.2932	1.409	1.5351	1.6725	1.8222	1.9853	2.1629	2.3565	2.5674	2.7972	3.0476	3.3203	3.6175	
NPV	638.77	615.4	595.12	575.51	556.54	538.2	520.47	503.32	486.73	470.7	455.19	440.19	425.68	411.66	398.09	7631.581

APPENDIX A.8 : Detailed simulation results at discount rate 8.95%

113 000m³/a **SOYA BEANS** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE 5.36%	2203.93	2322.1	2446.5	2577.7	2715.8	2861.4	3014.8	3176.3	3346.6	3526	3715	3914.1	4123.9	4344.9	4577.8	48866.62
DISCOUNT RATE 8.95%	1.0895	1.187	1.2932	1.409	1.5351	1.6725	1.8222	1.9853	2.1629	2.3565	2.5674	2.7972	3.0476	3.3203	3.6175	
NPV	2022.88	1956.2	1891.8	1829.4	1769.1	1710.9	1654.5	1600	1547.2	1496.3	1447	1399.3	1353.2	1308.6	1265.5	24251.66
95 000m³/a **SOYA BEANS** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST 5.36%	3600.4	3791.8	3995	4209.2	4434.8	4672.5	4922.9	5186.8	5464.8	5757.7	6066.3	6391.5	6734.1	7095	7475.3	79798.02
DISCOUNT RATE 8.95%	1.0895	1.187	1.2932	1.409	1.5351	1.6725	1.8222	1.9853	2.1629	2.3565	2.5674	2.7972	3.0476	3.3203	3.6175	
NPV	3304.64	3194.4	3089.2	2987.4	2888.9	2793.7	2701.7	2612.6	2526.6	2443.3	2362.8	2284.9	2209.6	2136.8	2066.4	39603.02
113 000m³/a **SUNFLOWER** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE 5.36%	820.83	864.83	911.18	960.02	1011.5	1065.7	1122.8	1183	1246.4	1313.2	1383.6	1457.8	1535.9	1618.2	1705	18199.98
DISCOUNT RATE 8.95%	1.0895	1.187	1.2932	1.409	1.5351	1.6725	1.8222	1.9853	2.1629	2.3565	2.5674	2.7972	3.0476	3.3203	3.6175	
NPV	753.401	728.58	704.57	681.35	658.9	637.19	616.2	595.89	576.26	557.27	538.91	521.15	503.98	487.37	471.31	9032.325
95 000m³/a **SUNFLOWER** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST 5.36%	1481.28	1559.2	1642.8	1730.8	1823.6	1921.4	2024.3	2132.8	2247.2	2367.6	2494.5	2628.2	2769.1	2917.5	3073.9	32814.27
DISCOUNT RATE 8.95%	1.0895	1.187	1.2932	1.409	1.5351	1.6725	1.8222	1.9853	2.1629	2.3565	2.5674	2.7972	3.0476	3.3203	3.6175	
NPV	1359.6	1313.6	1270.3	1228.4	1187.9	1148.8	1110.9	1074.3	1038.9	1004.7	971.6	939.58	908.62	878.68	849.73	16285.75

APPENDIX A.9 : Detailed simulation results at discount rate 15.75%

158 000m^3/a grain **SORGHUM** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE 5.36%	974.15	1026.4	1081.4	1139.3	1200.4	1264.7	1332.5	1404	1479.2	1558.5	1642	1730	1822.8	1920.5	2023.41	21599.24
DISCOUNT RATE 15.75%	1.1575	1.2611	1.374	1.4969	1.6309	1.7769	1.9359	2.1092	2.2979	2.5036	2.7277	2.9718	3.2378	3.5276	3.84328	
NPV	841.6	813.86	787.04	761.11	736.03	711.78	688.32	665.64	643.71	622.5	601.99	582.15	562.97	544.42	526.48	10089.6
158 000m^3/a grain **SORGHUM** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST 5.36%	1288.3	1354.3	1426.9	1503.4	1584	1668.9	1758.3	1852.6	1951.9	2056.5	2166.7	2282.9	2405.2	2534.2	2669.99	28504.16
DISCOUNT RATE 15.75%	1.1575	1.2611	1.374	1.4969	1.6309	1.7769	1.9359	2.1092	2.2979	2.5036	2.7277	2.9718	3.2378	3.5276	3.84328	
NPV	1113	1073.9	1038.5	1004.3	971.23	939.23	908.28	878.35	849.41	821.42	794.35	768.18	742.87	718.39	694.716	13316.2
95 000m^3/a **SUGARCANE** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE 5.36%	494.57	521.08	549.01	578.44	609.44	642.11	676.53	712.79	751	791.25	833.66	878.34	925.42	975.02	1027.28	10965.94
DISCOUNT RATE 15.75%	1.1575	1.2611	1.374	1.4969	1.6309	1.7769	1.9359	2.1092	2.2979	2.5036	2.7277	2.9718	3.2378	3.5276	3.84328	
NPV	427.27	413.2	399.58	386.42	373.68	361.37	349.46	337.95	326.81	316.04	305.63	295.56	285.82	276.4	267.292	5122.488
95 000m^3/a **SUGARCANE** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST 5.36%	695.94	730.49	769.64	810.89	854.35	900.14	948.39	999.22	1052.8	1109.2	1168.7	1231.3	1297.3	1366.8	1440.1	15375.25
DISCOUNT RATE 15.75%	1.1575	1.2611	1.374	1.4969	1.6309	1.7769	1.9359	2.1092	2.2979	2.5036	2.7277	2.9718	3.2378	3.5276	3.84328	
NPV	601.24	579.25	560.16	541.7	523.85	506.59	489.89	473.75	458.14	443.04	428.44	414.33	400.68	387.47	374.706	7183.246

APPENDIX A.10 : Detailed simulation results at discount rate 15.75%

113 000m^3/a **SOYA BEANS** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE 5.36%	2203.9	2322.1	2446.5	2577.7	2715.8	2861.4	3014.8	3176.3	3346.6	3526	3715	3914.1	4123.9	4344.9	4577.8	48866.62
DISCOUNT RATE 15.75%	1.1575	1.2611	1.374	1.4969	1.6309	1.7769	1.9359	2.1092	2.2979	2.5036	2.7277	2.9718	3.2378	3.5276	3.84328	
NPV	1904	1841.3	1780.6	1722	1665.2	1610.3	1557.3	1506	1456.3	1408.4	1361.9	1317.1	1273.7	1231.7	1191.12	22826.94
95 000m^3/a **SOYA BEANS** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST 5.36%	3600.4	3791.8	3995	4209.2	4434.8	4672.5	4922.9	5186.8	5464.8	5757.7	6066.3	6391.5	6734.1	7095	7475.29	79798.02
DISCOUNT RATE 15.75%	1.1575	1.2611	1.374	1.4969	1.6309	1.7769	1.9359	2.1092	2.2979	2.5036	2.7277	2.9718	3.2378	3.5276	3.84328	
NPV	3110.5	3006.7	2907.7	2811.9	2719.2	2629.6	2543	2459.2	2378.1	2299.8	2224	2150.7	2079.8	2011.3	1945.03	37276.45
113 000m^3/a **SUNFLOWER** plant																
YEAR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED REVENUE 5.36%	820.83	864.83	911.18	960.02	1011.5	1065.7	1122.8	1183	1246.4	1313.2	1383.6	1457.8	1535.9	1618.2	1704.97	18199.98
DISCOUNT RATE 15.75%	1.1575	1.2611	1.374	1.4969	1.6309	1.7769	1.9359	2.1092	2.2979	2.5036	2.7277	2.9718	3.2378	3.5276	3.84328	
NPV	709.14	685.78	663.18	641.32	620.19	599.76	580	560.88	542.4	524.53	507.25	490.53	474.37	458.74	443.623	8501.7
95 000m^3/a **SUNFLOWER** plant	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
PROJECTED COST 5.36%	1481.3	1559.2	1642.8	1730.8	1823.6	1921.4	2024.3	2132.8	2247.2	2367.6	2494.5	2628.2	2769.1	2917.5	3073.89	32814.27
DISCOUNT RATE 15.75%	1.1575	1.2611	1.374	1.4969	1.6309	1.7769	1.9359	2.1092	2.2979	2.5036	2.7277	2.9718	3.2378	3.5276	3.84328	
NPV	1279.7	1236.4	1195.7	1156.3	1118.2	1081.3	1045.7	1011.2	977.9	945.68	914.52	884.38	855.24	827.06	799.809	15329