Bio-ethanol Production from Wheat in the Winter Rainfall Region of South Africa: A Quantitative Risk Analysis

James W. Richardson*

Wessel J. Lemmer

Joe L. Outlaw

*The authors are, respectively, Regents Professor and TAES Senior Faculty Fellow in the Department of Agricultural Economics at Texas A&M University, Senior Economist at Grain South Africa, and Professor and Extension Economist in the Department of Agricultural Economics at Texas A&M University.

Addresses:
Dr. James W. Richardson -- Department of Agricultural Economics, TAMU, College Station, Texas 77843 jwrichardson@tamu.edu

Mr. Wessel Lemmer -- P.O. Box 88, Grain South Africa, Bothaville, 9660, South Africa wessel@grainsa.co.za

Dr. Joe L. Outlaw -- Department of Agricultural Economics, TAMU, College Station, Texas 77843 joutlaw@tamu.edu

Contact Author:
Dr. James W. Richardson -- Department of Agricultural Economics, TAMU, College Station, Texas 77843 jwrichardson@tamu.edu 979-845-5913 / 979-845-3140 fax

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Executive Summary

Contrary to developments in other parts of the world, South Africa has not developed a bio-ethanol industry. In spite of interest from government, financial institutions and investors, there are no bio-ethanol plants supported by grains as feedstock established yet. Public and private players expect the national government to issue an investment incentive dispensation for the bio-ethanol industry. In the mean time the government needs a better understanding of the risks and prospects for the industry.

The objective of this paper is to quantify the risks and economic prospects that influence the profitability of bio-ethanol production from wheat in the winter rainfall region of South Africa.

A Monte Carlo simulation model of the economic activity for a bio-ethanol plant in the region is developed and simulated for 10 years to quantify the risk that investors will likely face. Under the Base scenario a 103 million liter bio-ethanol plant would not offer a reasonable chance of being economically viable. Average NPV was –R88.5 million and average ROI was -8.4 percent, and there was more than a 97 percent chance that NPV would be negative.

Alternative price enhancing policies were analyzed to determine the type of policy changes needed to make a bio-ethanol plant economically viable in the winter rainfall region of South Africa. The policy scenario which showed the most promise for making wheat bio-ethanol economically viable is to implement a price floor of R3.325/liter that is tied to inflation and to increase the reimbursement on the fuel levy to 70 percent.

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Abstract

Contrary to developments in other parts of the world, South Africa has not developed a bio-ethanol industry. The objective was to quantify the risks and economic viability of a wheat based bio-ethanol plant in the winter rainfall region of South Africa. Monte Carlo simulation of a bio-ethanol plant was used to quantify the risk that investors will likely face. Under the Base scenario a 103 million liter bio-ethanol plant would not offer a reasonable chance of being economically viable. Alternative price enhancing policies were analyzed to determine policy changes needed to make a bio-ethanol plant economically viable in the region.

Key Words: Biofuels, Ethanol, Risk Analysis, Simulation, Economic Viability, Simetar, SERF

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Introduction

Contrary to developments in other parts of the world, South Africa has not developed a bio-ethanol industry. In spite of interest from government, financial institutions and investors, there are no grain based bio-ethanol plants operating in the country. Public and private role-players, involved with the bio-ethanol supply chain developments in South Africa, expect an official investment incentive dispensation from the national government for the successful introduction of bio-ethanol to the on-road fuels market. Furthermore, the provincial government and future supply chain members who consider promoting the production of bio-ethanol from wheat as a feedstock need to acquire a better understanding of the risks and prospects involved. While currently limited, increased knowledge on the extent of the risks and economic viability for the industry will enhance the ability of the national and provincial government to assertively prepare investment incentives to finalize the draft bio-fuels industrial strategy.

The Western Cape Provincial Governments see the possible developments of the bio-ethanol industry as an opportunity to address socio-economic development. An annual gross income and revenue stream from a bio-ethanol industry is expected to create employment throughout the province, thus addressing unemployment long term in addition to the jobs created during construction. The introduction of a local bio-ethanol plant may create an economic spin off that will indirectly involve the creation of additional jobs in the economy. Benefits will accrue to all input sectors, particularly to wheat producers if the price of wheat is increased.

Wheat that is currently exported to other provinces could be used for bio-ethanol production and thus create new jobs at the provincial level and in rural areas. The provincial surplus of wheat produced in the Western Cape Province is sufficient to supply six percent of the total petroleum demanded.

However, the current surge in feedstock prices, lack of incentives to encourage development, and a general notion to evaluate the potential of the industry on point estimates (average, best-case, worst-case) reduces the confidence of investors. It is generally believed that the bio-ethanol industry is a break-even industry. Given the risks associated with feedstock price and availability, investors are cautious. They are demanding risk based economic feasibility analyses prior to investing.

New interest has been raised by the draft national bio-fuels industrial strategy. But, given the recommendations made in the draft strategy the bio-fuels industry would, according to the South African Biofuels Association, not be lucrative enough to attract investment. According to financial institutions investors require a real rate of return on investment of 19 percent (nominal 25 percent). At this point a risk-based study of the economic feasibility for a wheat bio-ethanol plant in the Western Cape Province is needed to estimate the probability of success given the required return on investment by investors.

The objective of this paper is to quantify the risks and economic prospects that influence the profitability of bio-ethanol production from wheat in the winter rainfall region of South Africa. Specific objectives are to: quantitatively assess risks that influence the income of potential bio-ethanol developments, and identify possible public policy that could be used to enhance the economic viability of bio-ethanol developments.

Procedures

The objectives will be achieved by simulating the economic activity associated with a proposed wheat bio-ethanol plant in the Western Cape Province for 10 years under alternative policy assumptions. The alternative policy assumptions are based on the Draft Biofuels Industrial Strategy of the Republic of South Africa (2006) and comments submitted by SABA (2007), the Western Cape Task Team on Renewable Fuels (WCTT, 2007), as well as the latest corporate tax policy (SARS, 2006).

A Monte Carlo simulation model of a bio-ethanol plant was developed using the framework provided by Richardson, Herbst, Outlaw and Gill (2007). Data to describe the input and output relationships for the Western Cape plant will come from Lemmer (2006). Historical data (1989-2006) for defining the probability distributions of the stochastic variables affecting the plant will come from the Abstract of Agricultural Statistics. (2006), Food and Agricultural Policy Research Institute (2006), Grain South Africa (2007), South African Reserve Bank (2007), Statistics South Africa (2007), South African Revenue Services (2006) and The Bureau for Food and Agricultural Policy (2006).

A Monte Carlo simulation modeling approach is used because it is the best methodology for estimating the probability distribution of unknown variables such as rate of return on investment for a business. Monte Carlo simulation has been used extensively in agricultural economics to analyze riskiness of proposed projects (e.g., Richardson and Mapp (1976), Reutlinger (1970), Aven (2005), Hardaker, Huirne, Anderson and Lien (2004)) and to analyze the riskiness of ethanol plants (e.g., Richardson et. al. (2007), Herbst (2003), Gill (2002), Lau (2003)). The methodology is flexible and can be applied to the analysis of ethanol plants in many different parts of the world.

The steps for developing a Monte Carlo simulation model are described by Richardson (2006). First the objective of the model must be established -- in this case it is to determine the probability that the rate of return to investment is greater than 25 percent and that the business will be an economic success. Second one must define all of the equations necessary to calculate the key output variables (KOV) and then identify the stochastic variables necessary to simulate the equations.

Parameters to define the probability distributions for the random variables must be estimated and used to simulate the random variables. Before the model can be built, the simulated values for each of the random variables must be validated. Validation must rely on standard statistical tests to insure that the stochastic variables statistically reproduce their assumed means and the variability is the same as observed over the historical period.

Once the stochastic component of the model is developed and validated, the analyst can program the equations necessary to simulate the variables required to calculate the KOVs. In the case of a Monte Carlo feasibility model for an ethanol plant, the equations are fairly straightforward. The equations for the model are the equations found in the pro-forma financial statements, namely: income statement, cash flow statement, and balance sheet statement. The equations for the Western Cape wheat bio-ethanol model are presented in the next section to provide an abstract description of how the model simulates the KOVs.

Simulation Model for Wheat Bio-ethanol

The stochastic variables for the model are: bio-ethanol price, wheat price, DDGS price, petroleum price, electricity price, prices paid inflation rate, and operating interest rate. These random variables are simulated in the model using the multivariate empirical (MVE) probability distribution suggested by Richardson, Klose and Gray (2000). A MVE distribution was used to insure that the random variables are correlated the same as they have been in the past. Parameters for the MVE distribution were estimated by detrending the data and expressing the residuals as fractions of trend (S_i) and cumulative probabilities ($F(S_i)$). The parameters for the stochastic variables were estimated, and the model was simulated, using the Simetar add-in for Excel (Richardson, Schuman, and Feldman 2006). This method of estimating the parameters/simulation insures that the coefficient of variation (CV) for the simulated random variables will equal the CV from the historical data even though the projected means may differ considerably from their historical counterparts. (Note all stochastic variables are denoted in bold.) The equations for simulating the random variables are:

1) **Bio-ethanol Price**[1] $_{\mathbf{t}}$ = (0.95 * **BFP**$_t$[2] + 0.315 * Fuel Levy$_t$) * [1 + MVE (S_i F(S_i), C_7)]

2) **DDGS Price**$_{\mathbf{t}}$ = Mean Price$_t$ * [1 + MVE (S_i F(S_i), C_6)]

3) **Wheat Price**$_{\mathbf{t}}$ = Mean Price$_t$ * [1 + MVE (S_i F(S_i), C_5)]

4) **Petroleum Price**$_{\mathbf{t}}$ = Mean Price$_t$ * [1 + MVE (S_i F(S_i), C_4)]

5) **Electricity Price**$_{\mathbf{t}}$ = Mean Price$_t$ * [1 + MVE (S_i F(S_i), C_3)]

6) **Inflation Rate**$_{\mathbf{t}}$ = Mean Rate$_t$ * [1 + MVE (S_i F(S_i), C_2)]

7) **OP Interest Rate**$_{\mathbf{t}}$ = Mean Rate$_t$ * [1 + MVE (S_i F(S_i), C_1)]

8) **Down Time**$_{\mathbf{t}}$ = GRKS (minimum, middle, maximum)

The C_i values in equations 1-7 represent the correlated uniform standard deviates that insure that random variables are appropriately correlated. An independent stochastic variable was added to simulate the number of days the bio-ethanol plant is not operating due to repairs. The down time variable (8) was defined as the number of days the plant is closed and was simulated as a GRKS (10, 20, 30) distribution. The parameters indicate that the minimum down time is 10 days, the middle is 20 and the maximum is 30 days. However, there is a 2.5 percent chance that the plant could be closed less than 10 days and the same chance it could be closed more than 30 days. The finite end points for the distribution are 5 and 35 days.

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[1] Names of stochastic variables are denoted in bold. Variables that are calculated as a function of stochastic variables become stochastic variables themselves and are denoted in bold.
[2] BFP stands for the Basic Fuel Price.

Following the steps for building a Monte Carlo simulation model, the stochastic variables were simulated for 500 iterations and the resulting sample was used to validate the simulation process. Student–t tests were performed on each of the correlation coefficients for the seven stochastic variables in the MVE distribution (down time is an independent random variable). The t-tests failed to reject the null hypothesis that the MVE distribution appropriately correlated all of the random variables at the 95 percent level of significance. The Box's M test was used to test the covariance matrix for the simulated data vs. the covariance observed for the historical data. At the 95 percent level of significance, we failed to reject the null hypothesis that the covariance matrices were equal. Individual Student–t tests were performed to test if the simulated means for the 10-year planning horizon were statistically equal to their assumed means. In all cases the null hypothesis that the means were equal was rejected at the 95 percent level of significance.

Economic Feasibility Model

Equations to simulate the pro-forma financial statements using the stochastic variables as exogenous variables are described in this section. The section is separated into four parts, each pertaining to a pro-forma statement/function.

Income Statement

Annual receipts for the wheat bio-ethanol plant (14) are the sum of receipts for bio-ethanol, DDGS, and CO_2[3]. Bio-ethanol receipts (12) equal the product of stochastic bio-ethanol production and stochastic bio-ethanol price. Bio-ethanol production (9) is based on plant production capacity per day times the number of days the plant operates. Gross bio-ethanol sold (11) is equal to bio-ethanol production plus denaturant (5 percent petroleum) added. Receipts for

[3] Receipts from CO_2 were calculated using a constant price to account for the product but uncertainty about the industry prevented modeling the byproduct further.

DDGS (13) is the product of stochastic DDGS price and DDGS produced, which is a linear relationship to wheat used.

9) **Bio-ethanol Production$_t$** = Maximum Production per Day$_t$ * (365 – **Down Time$_t$**)

10) **Bio-ethanol Denaturant$_t$** = **Bio-ethanol Production$_t$** * 0.05[4]

11) **Denatured Bio-ethanol Production$_t$** = **Bio-ethanol Production$_t$** + **Bio-ethanol Denaturant$_t$**

12) **Bio-ethanol Receipts$_t$** = **Denatured Bio-ethanol Production$_t$** * **Bio-ethanol Price$_t$**

13) **DDGS Receipts$_t$** = **Wheat Used$_t$** * DDGS per bu Wheat * **DDGS Price$_t$**

14) **Total Receipts$_t$** = **Bio-ethanol Receipts$_t$** + **DDGS Receipts$_t$** + **Interest Earned$_t$**

Cash expenses for the plant are the sum of the cost for wheat, denaturant, electricity, interest, and other inputs (enzymes, labor, etc.). Wheat cost (16) is a function of the quantity of wheat used and the local price for wheat.

15) **Wheat Used$_t$** = **Bio-ethanol Production$_t$** / Conversion Rate

16) **Wheat Cost$_t$** = **Wheat Used$_t$** * **(Wheat Price$_t$ + Western Cape Province Price Wedge$_t$)**

Petroleum (17) cost for denaturant is a function of its stochastic price and the stochastic production of bio-ethanol. Electricity cost (18) equals electricity use times the price of electricity per kWH. Other production cost (19) equals the inflation adjusted cost of other inputs per liter times the total denatured bio-ethanol production. Similar formulas are used to simulate electricity (18) and other (19) production costs. Total variable costs (20) is the sum of all these cash costs.

17) **Petroleum Cost$_t$** = **Petroleum Denaturant$_t$** * **Petroleum Price$_t$**

18) **Electricity Cost$_t$** = **Denatured Bio-ethanol Production$_t$** * 3.553 * **Electricity Price$_t$**

[4] Petroleum is generally used to denature alcohol and when used it expands the volume of bio-ethanol about 5 percent. An option to be evaluated in South Africa is the use of paraffin as a denaturant. The cost is R0.01/liter and is assumed to add no volume to total bio-ethanol produced.

19) **Other Costs$_t$** = VC/liter$_{t-1}$ * **(1 + Inflation Rate$_t$)** * **Denatured Bio-ethanol Production$_t$**

20) **Total Variable Cost$_t$** = **Wheat Cost$_t$** + **Petroleum Cost$_t$** + **Natural Gas Cost$_t$** + **Electricity Cost$_t$** + **Other Costs$_t$**

The cost of operating interest expense (21) is simulated using the stochastic interest rate, total variable costs, and the fraction of the year operating capital is borrowed.

21) **Operating Interest$_t$** = **Total Variable Cost$_t$** * **OP Interest Rate$_t$** * Fract. of year

The interest cost to finance the proposed plant (22) is a deterministic value based on the amount financed (principal owed$_t$), the interest rate, and the number of years financed.

22) Plant Debt Interest$_t$ = Principal Owed$_t$ * Fixed Interest Rate$_t$

In the event the business has a cash flow deficit an equation is included to calculate the interest for a one-year loan to cover the cash flow deficit.

23) **Carryover Loan Interest$_t$** = **Cashflow Deficits$_{t-1}$** * **OP Interest Rate$_t$**

Total interest expenses (24) for the business is the sum of interest expenses in 21-23.

24) **Total Interest Expense$_t$** = Plant Debt Interest$_t$ + **Operating Interest$_t$** + **Carryover Loan Interest$_t$**

Depreciation (25) was calculated assuming an accelerated depreciation schedule that recapture the original capital cost in 3 years (50, 30, and 20 percent) for the original investment plus the depreciation for annual capital expenses for improvements.

25) Depreciation$_t$ = Plant Cost * fraction$_t$ + Capital Replacement$_t$ * fraction$_t$

Total expenses (26) is the sum of total variable expenses, interest expense, and depreciation. Net returns (27) to the plant equals total receipts minus total expenses and net cash income (28) is total receipts minus variable costs and interest expenses.

26) **Total Expenses$_t$** = **Total Variable Cost$_t$** + **Total Interest Expense$_t$** **+** Depreciation$_t$

27) **Net Returns$_t$** = **Total Receipts$_t$** – **Total Expenses$_t$**

28) $\textbf{Net Cash Income}_t$ = $\textbf{Total Receipts}_t$ – $\textbf{Total Variable Costs}_t$ – $\textbf{Total Interest Expense}_t$

Cash Flow Statement

Cash flows of an investment are often more critical to the success or failure than the return on investment (Richardson and Mapp 1976). Annual cash flows for the proposed plant are calculated using equations 29-35. The cash flow calculations start with interest earned on cash reserves from the previous year (29). Total cash inflows (30) is the sum of net cash income generated during the year plus positive cash reserves on January 1st and interest earned.

29) $\textbf{Interest Earned}_t$ = $\textbf{Positive Cash Reserves}_{t-1}$ * CD Interest Rate_t

30) $\textbf{Cash Inflows}_t$ = $\textbf{Net Cash Income}_t$ + $\textbf{Positive Cash Reserves}_{t-1}$ + $\textbf{Interest Earned}_t$

Cash outflow (34) is the sum of several expenditure categories, namely: dividends (31), principal payments (32) for the original plant loan, scheduled capital replacements, repayment of cash flow deficit loans, and income taxes (33).

31) $\textbf{Dividends}_t$ = Maximum [0.0, $\textbf{Net Returns}_t$ * 0.25]

32) Principal Payment_t = Fixed Annual Payment – Plant Debt Interest_t

33) $\textbf{Income Taxes}_t$ = $\textbf{Positive Net Cash Income}_t$ * Income Tax Rate

34) $\textbf{Cash Outflows}_t$ = Principal Payment_t + $\textbf{Repay Cashflow Deficit}_{t-1}$ + Capital Replacement_t + $\textbf{Dividends}_t$ + $\textbf{Federal Income Taxes}_t$

Annual ending cash reserve (35) is the difference between cash inflows and cash outflows.

35) $\textbf{Ending Cash}_t$ = $\textbf{Cash Inflows}_t$ – $\textbf{Cash Outflows}_t$

Ending cash balances can be positive or negative due to the variability of production, input costs and product prices. If it is positive it is an asset and if it is negative a one-year cash flow deficit loan is obtained and it appears as a liability.

Balance Sheet Statement

The balance sheet for the wheat bio-ethanol model contains three equations: assets (36), liabilities (37), and net worth (38).

36) $\textbf{Assets}_t$ = Land Value + Book Value Plant_t + $\textbf{Positive Ending Cash}_t$

37) $\textbf{Liabilities}_t$ = Plant Debt_{t-1} – Principal Payments_t + $\textbf{Negative Ending Cash}_t$

38) $\textbf{Net Worth}_t$ = $\textbf{Assets}_t$ – $\textbf{Liabilities}_t$

Financial Ratios

The financial ratios and KOVs to summarize the economic viability of the bio-ethanol plant are calculated in the last part of the model. Net present value or NPV (39) is calculated as the difference between beginning net worth on the present value of retained earnings and dividends which leave the business.

39) $\textbf{NPV} = -\text{ Beginning Net Worth} + \sum (\textbf{Dividends}_i + \Delta\textbf{Net Worth}_i) / (1+0.25)^i$

The present value of ending net worth or PVENW (40) is calculated using a 25 percent discount rate to reflect the investor's specified minimum rate of return on investment.

40) $\textbf{PVENW} = \textbf{Net Worth}_{10} / (1+0.25)^{10}$

Return on investment or ROI (41) is calculated each year as the sum of net returns plus interest cost divided by the initial investment in the plant.

41) $\textbf{ROI}_t = (\textbf{Net Returns}_t + \textbf{Total Interest Cost}_t) / \text{Initial Plant Cost}$

Wheat Bio-ethanol Assumptions

The assumptions used to model a 103 million liter (ML) (27 million U.S. gallon) bio-ethanol plant are summarized in Table 1. This size of plant is consistent with average quantities of wheat that have been exported from the region for the past seven years. With the addition of a 5 percent petroleum denaturant total bio-ethanol production is 108.4 million liters of denatured

Table 1. Input Assumptions for a Western Cape Wheat Base Ethanol Plant.

Total Annual Production of Alcohol (Liters)	102,973,680
Cost per Liter to Build a Plant	3.93
Bio-Ethanol Production from Wheat (Litres/Ton)	360
Add: Denaturant (%)	0.05
Cost of a Bio-Ethanol Marker (Rand/Liter)	0.01
DDGS per ton of wheat	0.333
CO2 Extracted lquid tons per ton wheat	0.333
CO2 Price (Rand per ton liquid CO2)	109.2
Fract Year Operating Loan Borrowed	0.3
Electricity kW-Hours per Liter	3.55
Enzymes (Rand per Liter)	0.0860
Yeasts (Rand per Liter)	0.0393
Other Proc. Chem. & Antiobiotics (Rand per Liter)	0.0359
Boiler and Cooling Tower Chemicals (Rand per Liter)	0.0088
Water cost (Rand / Liter)	0.0045
Maint. & Repairs Costs R / Liter / year	0.0223
Labor cost (Rand / den. Liter)	0.0806
Management and Qual. Control (Rand / den. Liter)	0.0244
Real Estate Taxes (Rand / den. Liter)	0.0034
Licenses, Fees and Insurance (Rand / den. Liter)	0.0074
Miscellaneous Expenses (Rand / den. Liter)	0.0244
Fraction of Plant Debt Financed	0.5
Length of Loan to Build Plant	25
Fixed Interest Rate	0.145
Year Loan is Orginated	2007
Annual Change in the Value of the Plant	-0.05
Beginning Cash Reserves	0
Fixed Interest Rate for Cash Reserves	0.087
Discount Rate for NPV	0.25
Minimum Desired ROI for Investors	0.25
Dividends as Fraction of NCI	0.25
Days the Bio-Ethanol Plant Does Not Produce	0
Minimum Days	10
Middle Days	20
Maximum Days	30

ethanol. In a fermentation/distillation bio-ethanol plant, wheat produces 360 liters (95 U.S. gallons) of bio-ethanol, about 333 kg of DDGS per metric ton, and 333 kg of CO_2 (Rueve 2005).

The cost of a 103 ML bio-ethanol plant was estimated at R404.7 million, based on an average 2006 exchange rate of R6.77 to $1 U.S. and a R3.93 per liter ($2.20/gallon) turn key construction cost in the United States. Half of the cost of the plant would be financed at the current long-term interest rate of 14.5 percent over 25 years. The remaining cost of the plant will be covered by a shared financing arrangement with a government agency. The agency will provide the funds in return for an annual return equal to the prime interest rate charged on long term debt plus 4 percentage points. Private investors require a return on bio-ethanol and infrastructure investment of 19 percent real interest rate and 25 percent nominal interest rate (SABA, 2007).

The petroleum pricing mechanism, known as the Basic Fuel Price (BFP) Formula represents the landed cost of petroleum. The formula links the domestic retail prices to international crude oil prices by using a benchmark based on spot prices published by Platts. In the simulation model the BFP is stochastic based on its historical variability and the stochastic bio-ethanol price is calculated using the appropriate pricing formula (equation 1). An alternative set of parameters for the pricing formula are tested in the results section.

According to Akayezu, Linn, Harty and Cassidy (1998) the crude protein content of DDGS from wheat is considerably higher than corn DDGS, Linn and Chase (1996) also indicated that the nutrient content of distiller's grains is about three times more concentrated than the nutrients in the original feedstock before fermenting. As a result the price of DDGS is assumed to be 13 percent greater than the price of wheat on a ton basis.

Affordable energy is needed for the successful operation of dry mill ethanol plants. Energy generation in the Western Cape Province is however limited and industrial plants are powered by electricity from the national grid which is supplied by power lines from inland coalfields. Meredith, as cited in Jacques, Lyons & Kelsall (2003) indicate that wheat is virtually identical to corn (maize) in energy requirements for making bio-ethanol and requires 3.55 kW-Hours per liter. The average consumer cost of electricity is R0.24/kW-hr. The costs per liter for inputs in Table 1 such as enzymes, yeast, the processing chemicals and antibiotics is given by

Tiffany and Eidman (2003) and translated into Rand by the current U.S.-dollar exchange rate. The price for the commercial use of water was R4.51 per kiloliter in 2005. The ethanol plant will use approximately use 593.4 million liters of water annually.

The maintenance and repair per year is estimated at 1 percent of the total capital cost. The labor, management and quality control cost as well as economic circumstances and real estate taxes and license, fees and insurance cost corresponds to the assumptions made by Tiffany and Eidman (2003) after conversion to rand.

Projected prices, interest rates and rates of inflation used for the 2007-2016 analysis are summarized in Table 2. These prices are the mean prices for the stochastic variables in the model. Linear trend was used to project prices for BFP, which were used to calculate the average prices for bio-ethanol and the price of petroleum denaturant. The annual percentage change in the BFP was used to calculate the mean electricity prices. Simple trend least square regression was used to project the mean annual rates of inflation and interest rates. FAPRI (2007) projections of world wheat prices were used to calculate the mean price for wheat, given adjustments for location and grade of wheat proposed for use in a bio-ethanol plant. As indicated earlier DDGS price is a linear function of wheat price.

Table 2. Assumed Mean Prices, Interest Rates and Rates of Inflation for the Base Scenario.

	Price of BFP	Price of Wheat	Price of Bio-Ethanol	Price of DDGS	Price of Electricity Price	Annual Change PPI	Interest Rate
	(R/Liter)	(R/Ton)	(R/Liter)	(R/Ton)	(R/kWH)	(Fraction)	(Fraction)
2007	2.33	1223.49	2.55	1382.55	0.25	4.06	0.12
2008	2.46	1214.07	2.68	1371.89	0.27	4.91	0.11
2009	2.58	1223.96	2.81	1383.07	0.28	5.22	0.11
2010	2.71	1234.47	2.94	1394.95	0.29	5.46	0.10
2011	2.83	1239.04	3.08	1400.11	0.30	5.62	0.10
2012	2.96	1244.24	3.21	1405.99	0.32	5.65	0.09
2013	3.09	1241.55	3.34	1402.95	0.33	5.82	0.09
2014	3.21	1239.44	3.47	1400.57	0.34	6.09	0.08
2015	3.34	1241.71	3.61	1403.13	0.35	6.21	0.08
2016	3.46	1245.30	3.74	1407.19	0.36	6.02	0.07

Results

The Monte Carlo simulation model for a proposed wheat based bio-ethanol plant in the Western Cape Province of South Africa was simulated for 10 years, 2007-2016. The results of the Base scenario to quantify the risks inherent in bio-ethanol production in the study area are presented in detail. Alternative policy scenarios are presented to investigate the types of policy scenarios where bio-ethanol production in the study would be profitable.

The alternative scenarios analyzed are summarized as:

- Base scenario assumes an accelerated depreciation method, use of a bi-ethanol marker as a denaturant, 50 percent shared financing with a government agency, bio-ethanol price calculated using 95 percent of the BFP and 31.5 percent reimbursement on the fuel levy (as proposed in the draft National Biofuels Industrial Strategy). The shared financing requires an 18.5 percent annual return to the investor.
- In the second scenario, a price subsidy of R1.03/liter of denatured bio-ethanol is added to the Base scenario.
- In the third scenario a higher bio-ethanol price resulting from a policy change to price bio-ethanol at 100 percent of the BFP plus 100 percent reimbursement on the fuel levy is added to the Base scenario.
- The fourth scenario adds a price floor for bio-ethanol of R3.325/liter that is linked to the annual percentage change in the inflation rate to the Base scenario.
- The fifth scenario is the Base scenario plus a price floor of R3.325/liter and increasing the reimbursement on the fuel levy to 70 percent.

The five scenarios are compared in terms of the summary statistics for the proposed bio-ethanol plant's key output variables (KOVs): net present value (NPV), present value of ending net worth (PVENW), return on investment (ROI), annual net cash income (Net Inc), annual ending cash reserves (Cash Res), and annual dividends (Dividend). Probabilities are reported for the probability that NPV is negative, probability ROI is less than 25 percent, probability PVENW is less than zero, probability of annual net cash income being negative, probability of annual ending cash reserves being negative, probability of annual dividends equaling zero. Fan graphs of the annual net cash income and ending cash reserves are presented to show how the variability of these variables changes over time.

The results for the Base scenario are summarized in Table 3 and Figures 1 and 2. The firm's NPV averages –R88.5 million and ranges from –R230 to R64.6 million. The average ROI is -8.4 percent and there is a 99 percent chance that average ROI over the planning horizon will be less than the investor's minimum value of 25 percent. Average annual net cash income is negative every year ranging from –R99 million in 2007 to –R109 million in 2012. The variability around the average net cash income grows over time as evidenced by the coefficient of variation (CV) increasing from 77 percent in 2007 to 132 percent in 2016, due to higher and higher interest expenses from refinancing cash flow deficits. The increased variability of net cash income is demonstrated in Figure 1, based on the widening of the 5 and 95 percentiles about the mean. Due to negative net cash income the firm's average ending cash reserve is negative and the risk of negative ending cash grows over the period. There is more than an 87 percent chance of negative ending cash reserves in each year. Average annual dividends are less than R3 million each year and the probability of a zero dividend is 79 to 87 percent over the planning horizon.

A subsidy of R1.03/literof bio-ethanol was used for the second scenario. This level of subsidy was arrived at by experimentation to find the subsidy which provided a 90 percent

Table 3. Base Scenario for a Western Cape, South Africa Wheat Based Bio-Ethanol Plant, 2007-2016.

	NPV (M.Rand)	PVENW (M.Rand)	ROI (Percent)							
Mean	-88.53	-92.24	-8.43%							
StDev	48.50	45.44	14.52%			**P(NPV<0)**	97%			
CV	-54.79	-49.26	-172.20			**P(ROI<0.25)**	99%			
Min	-230.65	-230.65	-56.57%			**P(PVENW<0**	98%			
Max	64.67	38.70	34.01%							
	Net Inc 2007 (M.Rand)	**Net Inc 2008** (M.Rand)	**Net Inc 2009** (M.Rand)	**Net Inc 2010** (M.Rand)	**Net Inc 2011** (M.Rand)	**Net Inc 2012** (M.Rand)	**Net Inc 2013** (M.Rand)	**Net Inc 2014** (M.Rand)	**Net Inc 2015** (M.Rand)	**Net Inc 2016** (M.Rand)
Mean	-99.13	-100.81	-105.07	-106.49	-108.75	-109.03	-105.65	-99.76	-95.94	-91.54
StDev	77.22	82.17	84.91	93.88	100.64	98.65	102.26	117.32	120.13	121.58
CV	-77.89	-81.50	-80.81	-88.16	-92.55	-90.48	-96.79	-117.60	-125.21	-132.82
Min	-307.92	-281.33	-289.27	-378.13	-342.23	-342.67	-356.95	-437.40	-421.36	-391.43
Max	132.81	123.58	156.38	151.79	203.41	209.94	204.19	223.06	263.19	284.00
P(NCI<0)	87.5%	87.6%	87.6%	85.4%	83.8%	86.6%	84.1%	80.0%	79.0%	79.5%
	Cash Res 2007 (M.Rand)	**Cash Res 2008** (M.Rand)	**Cash Res 2009** (M.Rand)	**Cash Res 2010** (M.Rand)	**Cash Res 2011** (M.Rand)	**Cash Res 2012** (M.Rand)	**Cash Res 2013** (M.Rand)	**Cash Res 2014** (M.Rand)	**Cash Res 2015** (M.Rand)	**Cash Res 2016** (M.Rand)
Mean	-100.87	-203.17	-310.13	-419.30	-531.78	-644.17	-754.01	-859.79	-962.21	-1,061.57
StDev	75.68	117.44	150.68	187.55	232.88	268.94	306.55	349.42	388.69	423.20
CV	-75.03	-57.80	-48.59	-44.73	-43.79	-41.75	-40.66	-40.64	-40.39	-39.87
Min	-308.95	-507.60	-644.32	-885.02	-1,141.54	-1,396.11	-1,589.35	-1,899.42	-2,111.54	-2,350.55
Max	115.18	182.98	119.87	218.81	282.03	161.36	120.45	124.12	150.21	157.95
P(EC<0)	87.7%	96.2%	98.0%	99.1%	99.1%	99.3%	99.2%	99.5%	99.7%	99.6%
	Dividend 2007 (M.Rand)	**Dividend 2008** (M.Rand)	**Dividend 2009** (M.Rand)	**Dividend 2010** (M.Rand)	**Dividend 2011** (M.Rand)	**Dividend 2012** (M.Rand)	**Dividend 2013** (M.Rand)	**Dividend 2014** (M.Rand)	**Dividend 2015** (M.Rand)	**Dividend 2016** (M.Rand)
Mean	0.70	0.74	0.74	1.11	1.27	1.00	1.30	2.01	2.16	2.46
StDev	2.41	2.39	2.64	3.30	3.74	3.36	3.71	5.28	5.51	6.05
CV	342.94	325.29	359.04	297.46	293.48	334.05	284.97	262.64	255.28	246.13
Min	-	-	-	-	-	-	-	-	-	-
Max	16.60	15.45	19.55	18.97	25.43	26.24	25.52	27.88	32.90	35.50
P(Div=0)	87.4%	87.4%	87.6%	85.4%	83.6%	86.6%	84.0%	80.0%	78.8%	79.4%

Figure 1. Base Scenario Fan Graph for Annual Net Cash Income (M. R.)

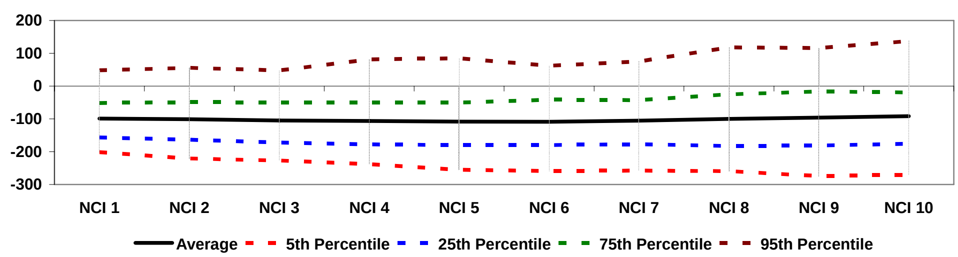
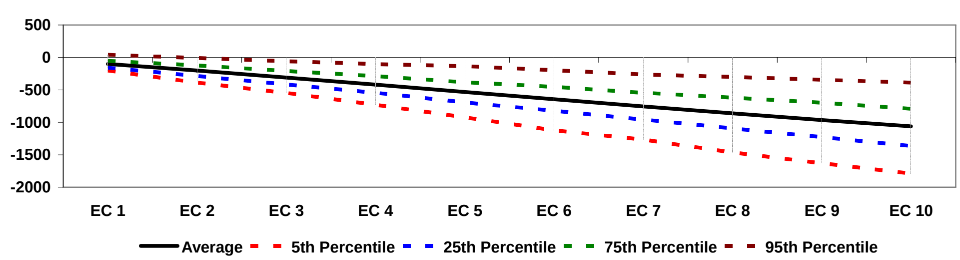


Figure 2. Base Scenario Fan Graph for Annual Ending Cash Reserves (M.R.)



chance that ROI is greater than 25 percent (Table 4 and Figures 3 and 4). The cumulative distribution function for ROI in Figure 4 shows the amount of variability in ROI and the relative position of the distribution to the investor's preferred minimum. The probability of a negative NPV is 5 percent so the business has a high probability of being an economic success, based on Richardson and Mapp's (1976) rule that economic success is a return greater than the discount rate, i.e., a positive NPV. Average annual net cash income ranges from R6 million in 2007 to R81 million in 2016. The probability of negative annual net cash income is 53.6 percent in 2007 and 27.5 percent in 2016. The fan graph shows that annual net cash income faces expanding variability over time, but has much less variability than under the Base scenario (Figure 3). The probability of negative ending cash reserves declines from 54.5 percent in 2007 to 18.7 percent in 2016. Average annual dividends ranges from R4.1 to R11.5 million, the probability of annual dividends equaling zero is 53.6 percent in 2007 and declines steadily to 27.4 percent in 2016.

In the third scenario the mean bio-ethanol price was increased by a favorable adjustment to allow 100 percent reimbursement in the fuel levy and allowing bio-ethanol to be valued at 100 percent of the BFP. Average ROI is 46.4 percent and average NPV is R80.7 million for this scenario, slightly higher than the price subsidy scenario (Table 5 and Figures 5 and 6). The probability of ROI less than the desired 25 percent level is 12.8 percent and the probability of a negative NPV is 9.2 percent. Average annual net cash income increases over the planning horizon from –R5.3 million in 2007 to R101.2 million in 2016. The probability of negative annual net cash income is more than 50 percent for 2007-2010, but improves to 30 percent in the last year. The average ending cash reserves is positive every year after 2010 and the probability of negative ending cash reserves decreases from 60 percent in 2007 to 27 percent in 2016. The

Table 4. Price Subsidy of R1.03/Liter for a Western Cape, South Africa Wheat Based Bio-Ethanol Plant, 2007-2016.

	NPV (M.Rand)	PVENW (M.Rand)	ROI (Percent)							
Mean	77.35	55.12	43.67%							
StDev	46.35	36.27	14.53%			**P(NPV<0)**	5.01%			
CV	59.92	65.80	33.28			**P(ROI<0.25)**	10.20%			
Min	-70.12	-71.12	-4.92%			**P(PVENW<0**	6.60%			
Max	232.86	168.71	85.91%							
	Net Inc 2007 (M.Rand)	**Net Inc 2008** (M.Rand)	**Net Inc 2009** (M.Rand)	**Net Inc 2010** (M.Rand)	**Net Inc 2011** (M.Rand)	**Net Inc 2012** (M.Rand)	**Net Inc 2013** (M.Rand)	**Net Inc 2014** (M.Rand)	**Net Inc 2015** (M.Rand)	**Net Inc 2016** (M.Rand)
Mean	6.28	13.38	18.22	26.29	33.37	41.28	52.36	63.55	72.18	81.12
StDev	77.31	81.55	84.07	91.77	96.60	95.37	97.55	108.51	108.70	111.87
CV	1,230.07	609.73	461.48	348.99	289.48	231.02	186.30	170.75	150.59	137.90
Min	-204.79	-164.50	-152.21	-232.62	-180.94	-179.36	-176.89	-197.60	-170.26	-148.32
Max	238.07	246.25	288.49	274.77	332.36	337.92	330.35	362.19	393.44	411.04
P(NCI<0)	53.6%	47.9%	46.3%	47.0%	40.6%	37.1%	35.2%	33.8%	28.3%	27.5%
	Cash Res 2007 (M.Rand)	**Cash Res 2008** (M.Rand)	**Cash Res 2009** (M.Rand)	**Cash Res 2010** (M.Rand)	**Cash Res 2011** (M.Rand)	**Cash Res 2012** (M.Rand)	**Cash Res 2013** (M.Rand)	**Cash Res 2014** (M.Rand)	**Cash Res 2015** (M.Rand)	**Cash Res 2016** (M.Rand)
Mean	1.07	10.76	26.06	44.65	65.47	94.24	133.58	182.84	241.49	310.89
StDev	71.34	109.68	138.69	165.26	197.76	223.21	248.54	280.63	310.28	337.79
CV	6,690.24	1,018.92	532.10	370.11	302.06	236.85	186.05	153.48	128.49	108.65
Min	-205.82	-286.14	-292.51	-398.76	-458.10	-516.25	-648.77	-779.14	-794.20	-864.83
Max	205.55	364.31	422.74	600.20	760.87	785.08	893.43	1,032.67	1,202.17	1,368.74
P(EC<0)	54.5%	47.9%	43.2%	42.8%	39.2%	34.0%	29.2%	27.4%	22.4%	18.7%
	Dividend 2007 (M.Rand)	**Dividend 2008** (M.Rand)	**Dividend 2009** (M.Rand)	**Dividend 2010** (M.Rand)	**Dividend 2011** (M.Rand)	**Dividend 2012** (M.Rand)	**Dividend 2013** (M.Rand)	**Dividend 2014** (M.Rand)	**Dividend 2015** (M.Rand)	**Dividend 2016** (M.Rand)
Mean	4.19	4.96	5.41	6.22	6.95	7.62	8.53	9.86	10.70	11.52
StDev	6.62	7.01	7.50	8.68	9.27	9.26	10.05	11.50	11.66	12.40
CV	158.04	141.38	138.58	139.64	133.35	121.45	117.79	116.64	108.98	107.62
Min	-	-	-	-	-	-	-	-	-	-
Max	29.76	30.78	36.06	34.35	41.55	42.24	41.29	45.27	49.18	51.38
P(Div=0)	53.6%	47.8%	46.2%	46.8%	40.6%	37.0%	35.0%	33.8%	28.2%	27.4%

Figure 3. Price Subsidy Scenario Fan Graph for Annual Net Cash Income (M. R.)

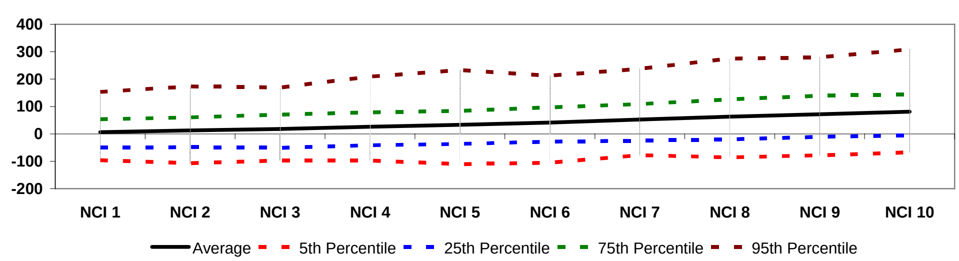


Figure 4. Cumulative Dsitribution Function of the ROI and the Minimum ROI (fraction)

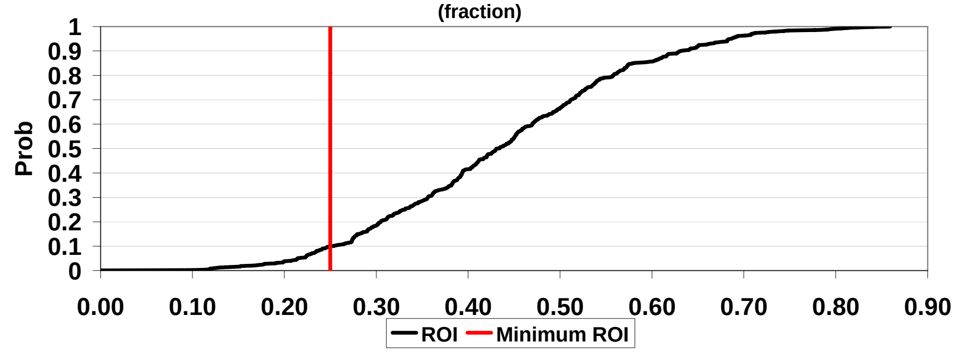


Table 5. More Favorable Bio-Ethanol Price Formula Scenario for a Western Cape, South Africa Wheat Based Bio-Ethanol Plant, 2007-2016.

	NPV	PVENW	ROI							
	(M.Rand)	(M.Rand)	(Percent)							
Mean	80.74	54.04	46.42%							
StDev	61.11	48.09	19.34%			**P(NPV<0)**	9.26%			
CV	75.69	88.98	41.66			**P(ROI<0.25)**	12.82%			
Min	-109.25	-109.77	-16.42%			**P(PVENW<0**	13.56%			
Max	290.08	207.96	102.25%							
	Net Inc 2007	**Net Inc 2008**	**Net Inc 2009**	**Net Inc 2010**	**Net Inc 2011**	**Net Inc 2012**	**Net Inc 2013**	**Net Inc 2014**	**Net Inc 2015**	**Net Inc 2016**
	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)
Mean	-5.34	3.68	11.47	22.94	32.90	44.24	59.55	75.27	87.83	101.22
StDev	103.12	108.03	111.64	121.82	127.30	126.64	129.64	144.44	143.81	147.93
CV	-1,930.39	2,931.72	973.62	531.11	386.91	286.23	217.71	191.88	163.73	146.14
Min	-259.87	-212.44	-211.83	-299.07	-239.70	-227.28	-215.56	-256.16	-216.53	-199.97
Max	293.59	304.46	351.86	350.57	415.56	426.31	419.13	464.38	504.45	526.04
P(NCI<0)	59.9%	50.8%	50.1%	50.3%	45.0%	42.0%	39.0%	37.5%	31.8%	30.4%
	Cash Res 2007	**Cash Res 2008**	**Cash Res 2009**	**Cash Res 2010**	**Cash Res 2011**	**Cash Res 2012**	**Cash Res 2013**	**Cash Res 2014**	**Cash Res 2015**	**Cash Res 2016**
	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)
Mean	-11.41	-11.89	-4.73	7.66	25.05	53.03	94.93	150.22	218.30	300.78
StDev	95.25	146.16	184.53	219.85	263.10	297.99	331.69	374.61	412.70	447.83
CV	-834.73	-1,229.36	-3,905.07	2,868.39	1,050.49	561.91	349.40	249.38	189.05	148.89
Min	-260.90	-390.43	-406.18	-603.27	-672.42	-759.43	-916.59	-1,075.68	-1,108.04	-1,224.82
Max	240.04	429.31	499.13	720.48	941.77	989.48	1,119.79	1,298.27	1,518.93	1,734.29
P(EC<0)	60.2%	54.8%	52.8%	50.5%	48.7%	42.8%	39.0%	35.1%	30.5%	27.0%
	Dividend 2007	**Dividend 2008**	**Dividend 2009**	**Dividend 2010**	**Dividend 2011**	**Dividend 2012**	**Dividend 2013**	**Dividend 2014**	**Dividend 2015**	**Dividend 2016**
	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)
Mean	4.86	5.70	6.39	7.49	8.35	9.29	10.54	12.32	13.46	14.62
StDev	8.34	8.77	9.47	11.13	11.89	11.99	13.04	15.06	15.24	16.31
CV	171.49	153.89	148.36	148.49	142.32	129.03	123.71	122.19	113.26	111.56
Min	-	-	-	-	-	-	-	-	-	-
Max	36.70	38.06	43.98	43.82	51.95	53.29	52.39	58.05	63.06	65.75
P(Div=0)	59.8%	50.6%	50.0%	50.2%	44.8%	42.0%	39.0%	37.4%	31.8%	30.2%

Figure 5. Use an Alternative Price Formula Scenario Fan Graph for Annual Net Cash Income (M. R.)

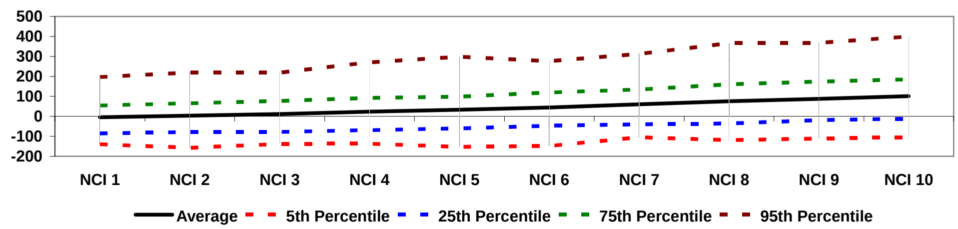
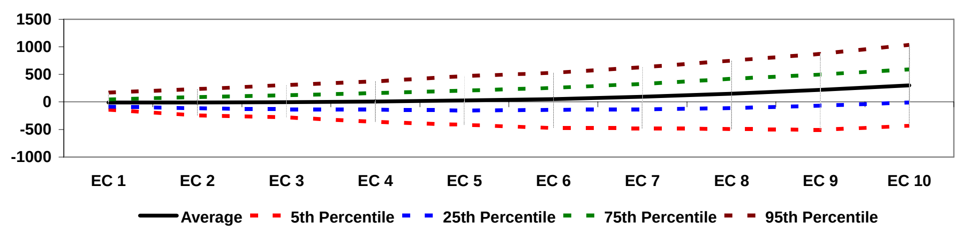


Figure 6. Use an Alternative Price Formula Scenario Fan Graph for Annual Ending Cash Reserves (M.R.)



fan graph for ending cash reserves shows the improvement in the probability of positive cash reserves (Figure 6).

Instituting an inflation adjusted minimum price for bio-ethanol at R3.325/liter in the fourth scenario improves the economic viability of the proposed bio-ethanol plant over the Base scenario (Table 6 and Figures 7 and 8). Average ROI is 47 percent, a significant increase over the -8 percent for the Base scenario. The probability that ROI will be less than 25 percent is less than one percent for the price floor scenario. Average annual net cash income is positive each year after 2008 and increases from –R14.0 million in 2007 to more than R140 million in 2016. The probability of negative net cash income is 66 percent in 2007 and decreases to zero in the last year. The presence of a minimum price for bio-ethanol reduces the downside risk on net cash income. This result is best seen by comparing the fan graphs for net cash income between the Base (Figure 1) to the fan graph for the minimum price scenario (Figure 7). Dividends average R7.1 million over the 10 years period and the probability of a zero dividend is less than 25 percent after 2011.

The last scenario combines a minimum price of R3.325/liter with a 70 percent reimbursement on the fuel levy (Table 7 and Figures 9 and 10). Average NPV is R100.5 million and there is almost a 100 percent chance of a positive NPV; the average ROI is 56.1 percent and there is a near zero chance that ROI will be less than the minimum desired level of 25 percent. Average annual net cash income increases over the period from R1.5 million at the outset to more than R158 million in 2016. The probability of net cash income being less than zero decreases from 57 percent to zero over the period (Figure 9).

A side-by-side comparison of the five scenarios is provided in Table 8. Based on the mean values for the KOVs, the most profitable scenario is the fifth scenario which provides a

Table 6. Minimum Price Floor Scenario for a Western Cape, South Africa Wheat Based Bio-Ethanol Plant, 2007-2016.

	NPV	PVENW	ROI							
	(M.Rand)	(M.Rand)	(Percent)							
Mean	72.74	57.53	47.38%							
StDev	27.66	22.05	10.65%			**P(NPV<0)**	0.57%			
CV	38.02	38.33	22.49			**P(ROI<0.25)**	0.80%			
Min	-23.71	-24.07	9.72%			**P(PVENW<0**	0.63%			
Max	166.55	131.58	85.59%							
	Net Inc 2007	**Net Inc 2008**	**Net Inc 2009**	**Net Inc 2010**	**Net Inc 2011**	**Net Inc 2012**	**Net Inc 2013**	**Net Inc 2014**	**Net Inc 2015**	**Net Inc 2016**
	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)
Mean	-14.05	-7.12	1.20	17.10	31.32	47.97	68.23	93.36	114.64	140.99
StDev	38.22	40.38	42.75	47.14	49.91	47.28	50.75	54.39	55.85	57.78
CV	-271.97	-566.99	3,555.22	275.67	159.37	98.56	74.38	58.26	48.71	40.98
Min	-125.56	-117.20	-119.40	-119.55	-104.23	-89.38	-107.89	-98.25	-35.66	0.53
Max	132.81	145.61	180.30	174.26	222.83	228.75	214.21	256.62	285.11	305.75
P(NCI<0)	66.4%	59.3%	49.6%	35.1%	25.7%	13.2%	8.0%	3.3%	2.3%	0.0%
	Cash Res 2007	**Cash Res 2008**	**Cash Res 2009**	**Cash Res 2010**	**Cash Res 2011**	**Cash Res 2012**	**Cash Res 2013**	**Cash Res 2014**	**Cash Res 2015**	**Cash Res 2016**
	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)
Mean	-16.19	-25.36	-26.60	-14.07	4.66	36.32	81.89	146.46	228.58	333.29
StDev	36.31	54.36	70.53	89.08	104.39	116.75	135.01	155.08	177.72	205.37
CV	-224.28	-214.35	-265.15	-632.95	2,239.96	321.43	164.88	105.89	77.75	61.62
Min	-126.59	-236.53	-241.46	-307.18	-337.87	-331.71	-336.41	-437.31	-434.58	-426.63
Max	115.18	182.98	185.31	251.20	317.21	325.05	437.24	572.55	783.06	1,022.98
P(EC<0)	67.2%	69.9%	67.5%	55.1%	48.4%	37.7%	27.6%	18.7%	10.0%	4.8%
	Dividend 2007	**Dividend 2008**	**Dividend 2009**	**Dividend 2010**	**Dividend 2011**	**Dividend 2012**	**Dividend 2013**	**Dividend 2014**	**Dividend 2015**	**Dividend 2016**
	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)
Mean	1.11	1.52	2.06	3.43	4.81	6.34	8.84	11.79	14.38	17.62
StDev	2.47	2.86	3.43	4.35	5.06	5.38	5.71	6.52	6.86	7.22
CV	223.26	188.37	166.56	126.69	105.09	84.85	64.54	55.25	47.73	40.98
Min	-	-	-	-	-	-	-	-	-	0.07
Max	16.60	18.20	22.54	21.78	27.85	28.59	26.78	32.08	35.64	38.22
P(Div=0)	66.2%	59.2%	49.6%	35.0%	25.6%	13.2%	8.0%	3.2%	2.2%	0.0%

Figure 7. Minimum Price Floor Scenario Fan Graph for Annual Net Cash Income (M.R.)

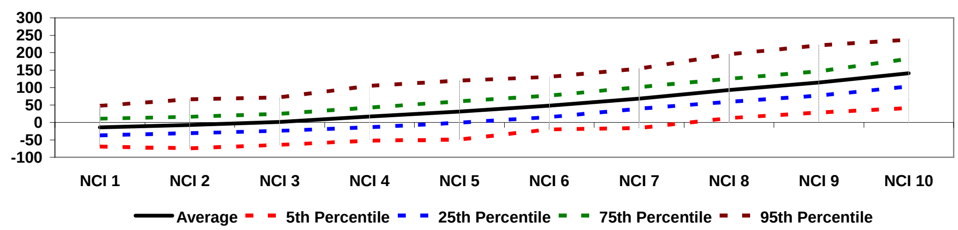


Figure 8. Minimum Price Floor Scenario Fan Graph for Annual Ending Cash Reserves (M.R.)

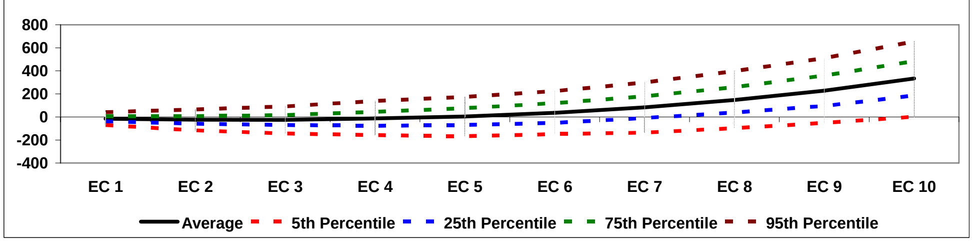


Table 7. Combination of Scenario for a Western Cape, South Africa Wheat Based Bio-Ethanol Plant, 2007-2016.

	NPV	PVENW	ROI							
	(M.Rand)	(M.Rand)	(Percent)							
Mean	100.59	78.36	56.18%							
StDev	34.88	26.58	11.86%			P(NPV<0)	0.43%			
CV	34.68	33.92	21.12			P(ROI<0.25)	0.57%			
Min	-21.29	-21.70	10.43%			P(PVENW<0	0.45%			
Max	207.86	158.42	93.94%							
	Net Inc 2007	Net Inc 2008	Net Inc 2009	Net Inc 2010	Net Inc 2011	Net Inc 2012	Net Inc 2013	Net Inc 2014	Net Inc 2015	Net Inc 2016
	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)
Mean	1.52	10.90	20.95	37.66	51.02	67.77	88.09	113.55	133.19	158.32
StDev	54.84	57.04	59.38	66.53	67.93	63.87	65.96	72.04	70.78	71.64
CV	3,596.70	523.18	283.42	176.67	133.13	94.25	74.88	63.45	53.14	45.25
Min	-125.56	-117.20	-119.40	-114.48	-103.61	-85.86	-73.86	-96.95	-35.66	5.00
Max	210.62	228.58	266.39	256.33	316.48	324.65	320.46	356.06	390.30	413.14
P(NCI<0)	57.6%	49.8%	39.8%	28.5%	18.7%	8.4%	5.3%	2.7%	1.7%	0.0%
	Cash Res 2007	Cash Res 2008	Cash Res 2009	Cash Res 2010	Cash Res 2011	Cash Res 2012	Cash Res 2013	Cash Res 2014	Cash Res 2015	Cash Res 2016
	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)
Mean	-2.09	5.92	24.14	54.61	90.70	140.43	205.79	292.33	397.73	527.33
StDev	50.27	75.58	95.92	117.46	137.26	152.12	171.21	195.87	220.58	247.59
CV	-2,405.34	1,276.34	397.36	215.10	151.33	108.32	83.20	67.00	55.46	46.95
Min	-126.59	-180.77	-188.76	-243.44	-291.33	-298.98	-318.29	-417.90	-414.08	-404.63
Max	183.27	319.92	323.33	490.35	632.17	639.31	730.42	843.27	1,062.92	1,272.87
P(EC<0)	58.0%	51.9%	44.7%	35.2%	28.3%	18.3%	10.4%	6.1%	2.9%	1.0%
	Dividend 2007	Dividend 2008	Dividend 2009	Dividend 2010	Dividend 2011	Dividend 2012	Dividend 2013	Dividend 2014	Dividend 2015	Dividend 2016
	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)
Mean	2.59	3.24	4.04	5.70	6.98	8.71	11.23	14.27	16.68	19.79
StDev	5.04	5.53	6.06	7.23	7.78	7.64	7.85	8.85	8.77	8.96
CV	194.75	170.45	150.11	126.96	111.55	87.66	69.88	61.98	52.60	45.25
Min	-	-	-	-	-	-	-	-	-	0.62
Max	26.33	28.57	33.30	32.04	39.56	40.58	40.06	44.51	48.79	51.64
P(Div=0)	57.4%	49.8%	39.8%	28.4%	18.6%	8.4%	5.2%	2.6%	1.6%	0.0%

Figure 9. Combination of Scenarios Fan Graph for Annual Net Cash Income (M. R.)

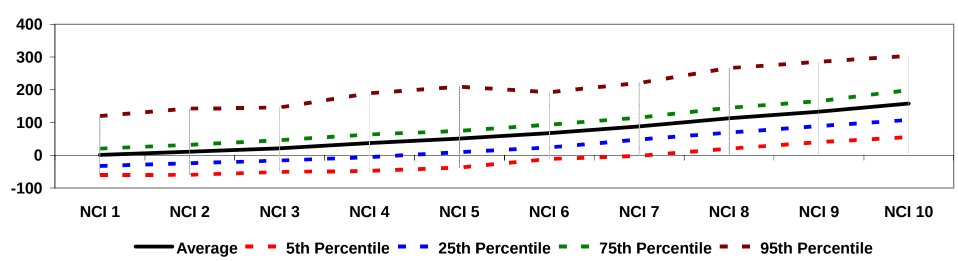
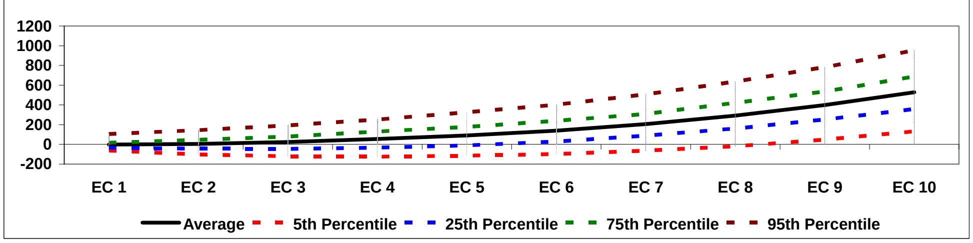


Figure 10. Combination of Scenarios Fan Graph for Annual Ending Cash Reserves (M.R.)



higher mean price and a price floor without a subsidy. The fifth scenario provides more than a 99 percent of economic success and of returning the investors a ROI greater than a 25 percent minimum. Based on the average ROI, NPV, net cash income, and dividends the second ranked scenario is scenario three, followed by the second scenario, a R1.03/liter bio-ethanol price subsidy.

Stochastic efficiency with respect to a function (SERF)[5] was used to rank the five estimated probability distributions for NPV (Figure 11)[6]. The five scenarios were analyzed across a wide spectrum of risk preferences, ranging from decision makers who are risk neutral to extremely risk averse (relative risk aversion coefficients of zero to 4.0. A Power utility function was assumed because the risky distributions represented both income and wealth changes over a multiple year planning horizon (Hardaker, Huirne, Anderson, and Lien). The SERF analysis showed that for decision makers representing all levels of risk aversion, the preferred is scenario five, followed by scenarios three, two, four and the least preferred scenario is the Base.

Conclusions

Investors in South Africa have not ventured into the field of bio-ethanol production although sufficient wheat is available in the winter rainfall region. Uncertainty about government policies and rates of return that can be earned from investing in bio-ethanol plants has been used to justify the delay. The objective of this paper was to quantify the risks and economic prospects that influence the profitability of bio-ethanol production from wheat in the winter rainfall region of South Africa. Specific objectives were to: quantitatively assess risks

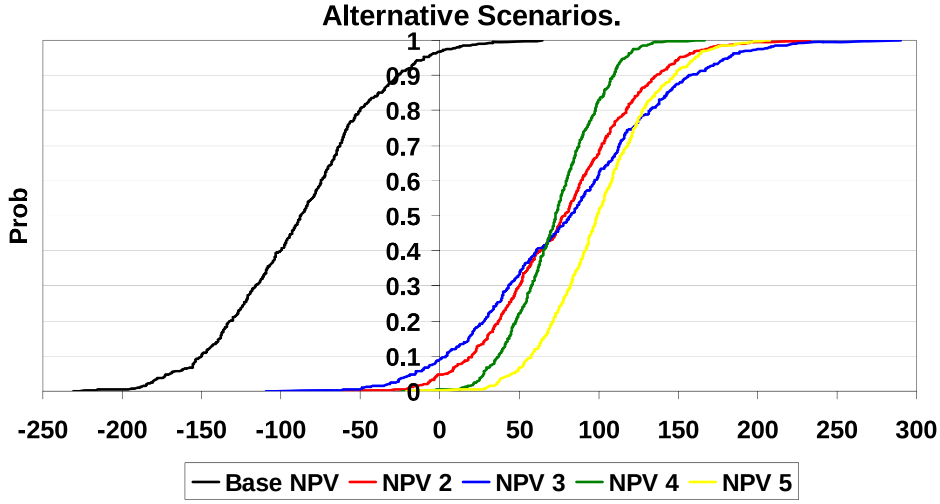
[5] SERF is a risk ranking procedure introduced by Hardaker, Richardson, Lien, and Schumann (2004) and provides an innovative approach for quantitatively ranking risky alternatives utilizing the full range of the distributions and decision maker's preference for income and risk.

[6] A CDF chart displays the probability of a risky variable, such as, NPV, being less than a particular value on the X axis. For example there is a 50 percent chance than NPV will be less than R100 million for scenario five.

Table 8. Comparison of a Western Cape, South Africa Wheat Bio-Ethanol Plant's Economic Viability Across Scenarios.

	Base	R1.03/Liter Subsidy	More Favorable Price Formula	Minimum Price Floor	Higher Price and Price Floor
Net Present Value (NPV)					
	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)
Mean	-88.53	77.35	80.74	72.74	100.59
StDev	48.50	46.35	61.11	27.66	34.88
CV (fration)	-54.79	59.92	75.69	38.02	34.68
Min	-230.65	-70.12	-109.25	-23.71	-21.29
Max	64.67	232.86	290.08	166.55	207.86
P(NPV<0)	96.79%	5.01%	9.26%	0.57%	0.43%
Rate of Return on Investment (ROI)					
	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)
Mean	-8.43%	43.67%	46.42%	47.38%	56.18%
StDev	14.52%	14.53%	19.34%	10.65%	11.86%
CV (fration)	-172.20	33.28	41.66	22.49	21.12
Min	-56.57%	-4.92%	-16.42%	9.72%	10.43%
Max	34.01%	85.91%	102.25%	85.59%	93.94%
P(ROI<0.25)	98.57%	10.20%	12.82%	0.80%	0.57%
Average Annual Net Cash Income					
	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)
Mean	-102.22	40.80	43.38	49.36	68.30
StDev	99.88	95.33	126.44	48.44	65.00
CV (fration)	-98.38	381.63	389.87	347.22	504.41
Min	-354.87	-180.75	-233.84	-91.66	-86.76
Max	195.23	321.49	405.64	214.62	308.30
Ending Cash Reserves in 2016					
	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)
Mean	-1061.57	310.89	300.78	333.29	527.33
StDev	423.20	337.79	447.83	205.37	247.59
CV (fration)	-39.87	108.65	148.89	61.62	46.95
Min	-2350.55	-864.83	-1224.82	-426.63	-404.63
Max	157.95	1368.74	1734.29	1022.98	1272.87
Average Annual Dividend					
	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)	(M.Rand)
Mean	1.35	7.60	9.30	7.19	9.32
StDev	3.84	9.39	12.12	4.98	7.37
CV (fration)	300.13	128.35	136.43	110.33	107.12
Min	0.00	0.00	0.00	0.01	0.06
Max	24.40	40.19	50.70	26.83	38.54

Figure 11. CDF of the NPV Probability Distributions for Alternative Scenarios.



that influence the income of potential bio-ethanol developments, and identify possible public policy that could be used to enhance the economic viability of bio-ethanol developments.

A Monte Carlo simulation model of the economic activity for a bio-ethanol plant in the region was developed and simulated for 10 years to quantify the risk that investors will likely face. Under the Base scenario a 103 million liter bio-ethanol plant would not offer a reasonable chance of being economically viable. Average NPV was –R88.5 million, average ROI was -8.4 percent, and there was more than a 97 percent chance that NPV would be negative. The risk for a bio-ethanol plant was considerably higher than most investors would be willing to accept given a CV of -54.8 percent.

Alternative pricing policies were analyzed to determine the type of policy changes that would be needed to make a bio-ethanol plant economically viable. Implementing a R1.03/liter subsidy for bio-ethanol would increase average NPV to R77.3 million and average ROI to 43.6 percent. With a subsidy there is significant reduction in the risk of a negative NPV, decreasing the chance from 97 percent for the Base to only 5 percent. A more favorable bio-ethanol price, due to pricing bio-ethanol at 100 percent of the BFP plus 100 percent reimbursement on the fuel levy, was analyzed. The more favorable pricing formula increased average NPV to more than R80 million and average ROI to 46 percent, and it reduced the risk of a negative NPV to 0.5 percent. Instituting an inflation adjusted price floor at R3.325/liter increased average NPV and ROI, but not as mush as the subsidy. The last policy scenario assumed a price floor of R3.325/liter and increasing reimbursement on the fuel levy to 70 percent. It provided the greatest increase in average NPV, ROI, net cash income, dividends, and ending cash reserves, and the largest reduction in relative risk for these KOVs.

A stochastic efficiency ranking of the risky alternatives showed that the last policy scenario (price floor of R3.325/liter and an increase in the reimbursement on the fuel levy to 70 percent) would be preferred by all classes of risk averse decision makers. Ranked second was the more favorable formula for computing the bio-ethanol price.

The results of this analysis demonstrate that bio-ethanol production from wheat in the winter rainfall region of South Africa is not likely to be profitable without significant involvement by the government. Policy assistance to enhance price and reduce risk can take on many different forms as demonstrated by the analysis. Any policy option should be analyzed thoroughly prior to implementation to avoid unintended consequences.

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