Economic Feasibility of Sustainable High Oilseed-Based Biofuel Production: The Case for Biodiesel in North Carolina

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Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Birmingham, AL, February 4-7, 2012

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Abstract

We assess the economic feasibility of a 10 MMGY biodiesel plant using a Monte Carlo Cash Flow model programmed in Excel using @Risk, a simulation and risk analysis software. The model incorporates stochastic components to capture uncertainty in the analysis. The stochastic components are mainly variables that may exhibit risk, such as input prices, output prices, and expected revenues, and these are assigned probability distributions in the model. The model is programmed with three output variables: stream of revenues, profits/loss, and the resulting net present value (NPV) over ten year forecast period.

Results from the cash flow analysis show that average expected revenues from the sale of biodiesel and co-products will be $48.5 million and total operating costs of $42.05 million per year. The economic feasibility of this biodiesel production plant is determined from the model calibration and sensitivity analysis. Using a discount rate of 7.5%, the simulated average NPV is $16.8 million and since this is positive, it indicates the project may be economically feasible subject to model assumptions. We find that the likelihood of the NPV greater than zero is 61% on average. Sensitivity and scenario analysis show that the NPV is most affected by fluctuations in biodiesel price, canola seed price, and the price of seed meal.

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Introduction

Much of the renewable fuel produced in the U.S. is ethanol, although biodiesel production has been increasing rapidly in the past decade (Outlaw et al., 2007). Both ethanol and biodiesel have experienced significant increases in number of plants in operation or under construction in response to the passage of the Renewable Fuel Standard (RFS) and Energy Independence and Security Act (EISA) of 2007. Corn-based ethanol production is becoming less profitable due to rising corn prices. At the current rate, ethanol production from corn is expected to more than double from the current 6.5 billion gallons to 15 billion gallons by 2015 (BR&DB, 2008). This level of ethanol production would require about 42% of 2007 corn crop to be devoted to ethanol production (WASDE, 2008). This would fuel more corn price increases, making ethanol production from corn less competitive. Currently, over 97 percent of ethanol production in the U.S. uses corn (BR&DB, 2008), representing about 20% of the U.S. corn crop.

While ethanol remains the leading biofuel produced in the U.S., there is potential for biodiesel production to catch-up or outpace ethanol production, especially as corn price continues its upward trajectory. Ethanol production increased from 3.4 billion gallons in 2004 to 8.9 billion gallons in 2008, representing an increase of 161%. In the same period, biodiesel production increased from 23 million gallons to 691million gallons, a whopping increase of 2,900%.

Among first generation biofuels, biodiesel production from oilseeds such as soybean, canola (also known as rapeseed), sunflower and other vegetable oils is gaining popularity.

Second generation biofuels, mainly cellulosic sources such as corn stovers, rice and wheat straw, wood biomass, and energy grasses (e.g.switchgrass and miscanthus), are equally gaining traction, albeit with a higher per unit production cost than ethanol production using corn.

Objective

We assess the economic feasibility of a proposed biodiesel plant in North Carolina that uses canola seeds as primary feedstocks. Our analysis is based on a 10 million gallon per year (MMGY) operating capacity. We perform a stochastic Monte Carlo financial simulation using historical data on biodiesel and seed meal prices, as well as costs of feedstocks, to determine the economic feasibility of the proposed plant.

Canola Seeds as feedstocks

Biodiesel production in the State of North Carolina relies on eight small-scale plants that use mainly waste vegetable oils (WVOs) and animal fats as feedstock (Table 1). The plant with the largest production capacity in the state is Patriot Biodiesel LLC, located in Greensboro, North Carolina. With a capacity of 6.5 MMGY, this plant uses multi-feedstock, but waste vegetable oils from restaurants form the major feedstock. Several plants, capacity ranging from 5 to 15 MMGY, are either under construction or being planned in the state. Soybean, one of the major oil-seeds for biodiesel production, is grown in the state, albeit not by any means large enough to feed the planned increases in biodiesel production. As a result, canola (**Can**adian **o**il **l**ow **a**cid), so named because of its low erucic acid content, has become a candidate oil-seed crop for biodiesel production in North Carolina. Canola is an improved cultivar from cross-breeding of four main *Brassica* oil-seed species, namely, rapeseed (*Brassica napus*), field mustard (*B. rapa*), Indian mustard (*B. juncea*), and Ethiopian mustard (*B. carinata*).

Nationally, there are 5 biodiesel plants that use canola oil as feedstock—these include, Archer Daniels Midland Co. of North Dakota (with operating capacity of 85 MMGY), Double Diamond Energy Inc. of Texas (operating capacity 30 MMGY), Inland Empire Oilseeds of Washington (operating capacity 8 MMGY), and Sun Power Biodiesel LLC of Wyoming (capacity 5 MMGY). Many other plants use some combination of multi-feedstocks that include canola, soy oil, and other vegetable oils. Agrigold Renewables in Texas uses sunflower oil and yellow grease to operate its 2 MMGY plant. According to data on plant capacity and utilization provided by the National Biodiesel Board (2008), soybean oil is the predominant feedstock choice for most of the biodiesel plants in the U.S. accounting for about 40% of biodiesel feedstock. Canola accounts for about 5% and recycled and waste vegetable oils make up less than 1 percent of feedstock. Canola and sunflowers have an oil content of 40%, while soybeans have 20%, thus capital and operational costs for the former oilseeds are lower (they require less extruder and press capacity) than the latter (Bender, 1999). However, soybean byproduct—meal cake—has a higher monetary value than canola and sunflower meals.

Canola oil has been proven to be an excellent feedstock for biodiesel production (George et al., 2008). EPA (2010) cleared canola oil as an approved biodiesel pathway; in its findings, the EPA states that canola oil biodiesel pathway creates a 50 percent reduction in greenhouse gas emissions compared to conventional diesel fuel baseline. The EPA study conducted a life cycle analysis on biodiesel production from canola oil and found canola oil has high conversion efficiencies compared to biodiesel produced from soy bean oil. They found that a pound of canola produces 0.40 pounds of oil compared to 0.18 pounds from soy beans. Moreover, canola biodiesel has a higher cetane number than soy biodiesel and petroleum-based diesel (56, 47, and 43, respectively). The higher cetane number of canola biodiesel gives better engine efficiency such as easier starting, quieter engine operation and lower engine temperatures (George et al., 2008). Thus canola oil now meets the standard as an advanced biofuel under the Energy Independence and Security Act of 2007.

Canola has been trialed and found to grow well in North Carolina as a winter annual crop. Its production practices are much similar to winter wheat, and thus, farmers who already grow winter wheat in the state could grow canola. The soil and fertilizer requirements of canola are similar to those of winter wheat (George et al., 2008). Besides, canola is a good choice for biodiesel production because it gives a better oil yield per acre, more than twice that of soybean (approximately 110 gallons per acre versus 45 gallons per acre). A proposed canola farmers' cooperative association is under formation by researchers at North Carolina A&T State University. The proposed canola farmers' cooperative will grow canola to feed a 10 MMGY biodiesel plant.

Table 1: North Carolina Biodiesel Plants.

Plant Name	**City**	**Feedstock**	**Capacity (MMGY)**
Blue Ridge Biofuels	Asheville	Multi-feedstock	1.2
Carolina Biodiesel LLC	Durham	WVOS	0.5
Evans Environmental Energies	Wilson	Animal fats/soy oil	3
Filter Specialty Inc.	Autryville	Soy oil/yellow grease	1
Foothills Bio-Energies LLC	Lenoir	Multi-feedstock	5
Patriot Biodiesel LLC	Greensboro	Multi-feedstock	6.5
Piedmont Biofuels Industrial LLC	Pittsboro	Multi-feedstock	1.4
Triangle Biofuels Industries Inc.	Wilson	Soy oil/ yellow grease	5

Source: National Biodiesel Board, 2011

Biodiesel Production

Biodiesel, an alcohol ester, is a renewable fuel produced from vegetable oils or animal fats (Bender, 1999). Biodiesel is made through a chemical process called transesterification (Figure 1), in which methanol/ethanol reacts with triglycerides resulting in methyl/ethyl esters (Barnwal and Sharma, 2004). As Figure 1 indicates, the process of producing biodiesel is to transesterify triacylglycerols in vegetable oils or animal fats with an alcohol (commonly methanol), in the presence of an alkali or acid catalyst (Zhang et al., 2003). The commonest alcohol used in biodiesel production is methanol owing to its lower cost. The resulting products are methyl ester (biodiesel), a co-product (crude glycerin), and some waste. The commonest used catalyst is either sodium hydroxide (NaOH) or potassium hydroxide (KOH).

The reaction process maybe summarized as follows;

$$\underset{(100\,parts)}{Methanol} + \underset{(1015\,parts)}{Vegetable\ Oil} \xrightarrow{NaOH} \underset{(1000\,parts)}{Methyl\ Ester} + \underset{(100\,parts)}{Glycerin} + Free\ Fatty\ Acid + Waste$$

Biodiesel production in the U.S. received a boost under the Energy Act of 2005 and the Energy Independence and Security Act of 2007. Production of biodiesel increased sharply from less than 2 million gallons in 2000 to about 802 million gallons in 2011 (NBB, 2011). Figure 2 shows the trends in biodiesel production in the U.S. from 2005 to 2010, while Figure 3 provides a comparison of monthly biodiesel production and consumption in the U.S. from 2001 to 2011. In Figure 3, the production and consumption curves closely match each other, indicating a high demand for biodiesel. At present, U.S. international trade in biodiesel or biofuels in general, is minimal. In 2001, U.S. imported 78 thousand barrels of biodiesel and exported 39 thousand, implying net imports of 38.9 thousand barrels (Table 2).

According to the Biodiesel Magazine (2011), 188 biodiesel plants were in operation with a total operating capacity of 2,882.71 million gallons per year and 13 other plants are under construction as of November 2011. This could bring the total potential operating capacity to more than 3.2 billion gallons of biodiesel per year. As the production of biodiesel increases in the country, exports are beginning to increase too. By 2007, the U.S. was already a net exporter—exporting 6,477 thousand barrels and importing 3,342 thousand barrels (Table 2).

Table 2: U.S. Production, Consumption, and Trade in Biodiesel

Year	**Biodiesel Production (Thousand Barrels)**	**Biodiesel Imports (Thousand Barrels)**	**Biodiesel Exports (Thousand Barrels)**	**Biodiesel Net Imports (Thousand Barrels)**	**Biodiesel Consumption (Thousand Barrels)**
2001	204.203	78.277	39.318	38.96	243.162
2002	249.62	190.893	55.549	135.344	384.964
2003	338.322	93.641	109.759	-16.118	322.204
2004	666.237	97.256	123.543	-26.287	639.95
2005	2161.586	206.707	205.756	0.95	2162.536
2006	5962.838	1069.194	827.659	241.535	6204.374
2007	11662.5	3342.057	6477.025	-3134.97	8527.531
2008	16145.38	7501.598	16128.03	-8626.44	7518.947
2009	12054.16	1843.594	6332.165	-4488.57	7536.871
2010	7365.773	545.526	2503.392	-1957.87	5446.908

Source: U.S. Energy Information Administration

Biodiesel Production Costs

Estimates show that biodiesel production using oilseeds is more costly than ethanol production from corn and cellulosic sources (Table 3). In the U.S. it costs $2.50 to produce a gallon of biodiesel from soybean oil compared to $1.50 to produce ethanol from corn. In the EU, it will cost $3.29 to produce a gallon of biodiesel using rapeseed. Conventional diesel and gasoline costs per gallon are $1.50 and $1.29 respectively. Haas et al. (2006) in their study of a medium-sized industrial biodiesel production facility estimated that the cost per gallon ranges from $1.48 (if degummed soybean cost 33 cents per kg) to $2.96 (if degummed soybean costs 77 cents per kg). For their 10 MMGY plant, estimated investment costs were $11.5 million ($1.12 per gallon), operating cost of 27.1 cents per gallon, and capital cost of 15 percent rate of return, assuming a 10-year life span. The co-product, glycerin, priced at 33 cents per kg, would provide a credit of 12.8 cents gallon, which could reduce production costs by about 6%.

Bender (1999) reviewed 12 studies on the economic feasibility of biodiesel production. Estimated cost of production (including cost of feedstock and conversion to biodiesel) ranged from $0.30/*l* ($1.14/gal) for biodiesel from soybeans to $0.69/*l* ($2.62/gal) for biodiesel produced from rapeseed. Bender also reviewed the economics of biodiesel from canola and sunflower, through a farmers' cooperative in Austria that has 290 members and grows about 430 ha of canola and sunflowers with an average yield of 3 t/ha. This is a government subsidized cooperative which enables farmers to grow canola on set-aside lands. At a canola price of $106/t, and 3000 kg of canola required to produce 1000 *l* of biodiesel, Bender's calculations show that the cost of canola feedstock was $0.32/*l* biodiesel. This translates into a capital and operating cost of $0.86/*l* ($3.26/gal) of biodiesel. At these costs, Bender concluded that biodiesel production from these oilseeds was not economically feasible, unless the government subsidized the entire cost of production, or technological development substantially reduces the cost of production.

Graboski and McCormick (1998) analyzed the technical and economic feasibility of a 10 million gallon biodiesel facility using fats and oils as feedstocks. Their calculations show that the joint cost of feedstock and its conversion to biodiesel would be \$0.57/*l* (\$2.15/gal). They concluded that the price of feedstock is the major determining factor in the production and consequently price of biodiesel.

Noordam and Withers (1996) determined the economic feasibility of producing biodiesel from canola in the inland Northwest, specifically eastern Washington and northern Idaho, assuming a 2.7 MMGY operating capacity. Total production costs ranged from \$2.19/gal to \$3.96/gal. Noordam and Withers (1996) determined that the economic feasibility analysis of biodiesel production using canola must also factor in the value of the meal and glycerin by-products. Canola seed meal is a good substitute for soybean meal in livestock rations while glycerin has various industrial uses, including soap manufacturing, pharmaceutical formulations, and in the food industry. The value of canola meal and glycerin can help offset the cost of biodiesel production using canola seeds.

Table 3: Cost of Biofuel production from selected feedstocks

Biofuel/Country	Feedstock	Feedstock (% of total)	Total production costs
Biodiesel		Percent	$ per gallon
United States	Soybean Oil	80-85	2.50
Malaysia	Palm Oil	80-85	2.04
EU	Rapeseed	80-85	3.29
India	Jatropha	80-85	1.99
Diesel			
United States	Diesel	75	1.50
Ethanol			
United States	Corn	39-50	1.50
United States	Cellulosic sources	90	2.69
Brazil	Sugarcane	37	0.98
EU	Wheat	68	2.23
EU	Sugar beets	34	2.88
Gasoline			
United States	Gasoline	73	1.29

Source: IMF, 2007; BR&DB, 2008

Data and Methods

In analyzing project returns under conditions of uncertainty, Reutlinger (1970) proposed the use of probability distributions to estimate the net present value of an investment. Monte Carlo simulations have become one of the preferred methods for analyzing investments under conditions of risk and uncertainty (Richardson and Mapp, 1976). In Monte Carlo analysis, stochastic variables that affect the investment's returns are assigned objective or subjective probability distributions, so that during the simulations, random values are drawn repeatedly from these distributions to determine the probability distribution of the net present value of the investment. Outlaw et al. (2007) describe the net present value (NPV) as a good measure for determining the overall economic feasibility of a proposed investment.

Richardson and Mapp (1976) describe the probability of economic success as the probability that the NPV is greater than zero, with the reason that if the NPV>0, then the investment will yield a return (IRR) that exceeds the investor's discount rate or opportunity cost of capital. For example, if the probability that the NPV>0 from an investment is found to be 90% at a discount rate of 5%, it means that there is a 90% chance that the project will be economically successful and will generate a rate of return exceeding 5%. Richardson and Mapp further outline the steps involved in a Monte Carlo simulation model to generate probabilistic cash flows for business decision-making.

The simulation model we use in this paper is an annual Monte Carlo Cash Flow model which is calibrated to historical data of biodiesel prices, input prices, and other operating expenses. Where there is no data on these variables for North Carolina, we use comparable national averages as proxies. Our Monte Carlo Cash Flow model is programmed in Excel using @Risk (http://www.palisade.com/risk/), a simulation and risk analysis software that is an add-in to excel. The model incorporates stochastic components to capture uncertainty or risk in the analysis. The stochastic components are variables that may exhibit risks, such as input and output prices. The risky variables are assigned probability distributions in the model based on objective (using historical data) or subjective judgment of the researchers (Table 4).

Using @Risk distribution fitting tools, we determine the historical price of canola seeds follows a logistic distribution. Price of biodiesel follows a triangular distribution with three parameters; minimum ($3.08/gal), mean ($3.74/gal), and maximum ($5.07/gal). Prices of seed meal and glycerin co-products are assumed to be normally distributed. The model is programmed with three output variables— stream of revenues over ten years, stream of profits/loss over ten year period, and the resulting net present value (NPV). The NPV is computed as the average discounted net cash flows (DCF) less the initial equity investment, as defined below. An NPV value greater than zero indicates that the project can be economically feasible subject to model assumptions (Table 5). The most important output variable in this simulation analysis is the NPV which determines the economic viability of the proposed plant (Richardson and Mapp, 1976; Palma et al., 2011).

The spreadsheet model is programmed to compute the NPV as follows;

$$NPV = -Initial\ Equity\ Investment + \sum_{n=1}^{10} \frac{NCF_n}{(1+i)^n}$$

Where NCF refers to net cash flow, and *i* is the discount rate, assumed to be 7.5%. The model is programmed for a 10-year operating period. The NCF is derived from the revenues/incomes that accrue to the plant from the sale of biodiesel, and two co-products— seed meal and glycerin.

For this reason the NCF is computed as;

$$NCF = (\tilde{P}_{bd} * Q_{bd}) + (\tilde{P}_m * Q_m) + (\tilde{P}_g * Q_g) - Capital\ Expenses - Operating\ Costs$$

Where tildes indicate stochastic variables, P_{bd} and Q_{bd} are price and quantity of biodiesel, P_m and Q_m are price and quantity of seed meal, P_g and Q_g are price and quantity of glycerin, respectively. Capital expenses include equipment and construction costs, operating costs include costs of inputs such as canola seeds, methanol, caustic (NaOH or KOH) used as catalyst in the transesterification process. Other operating expenses are labor, electricity, steam, repairs and maintenance, and overhead costs. Table 4 presents the summary statistics of these variables.

Results and Discussion

The Monte Carlo model is programmed under assumptions presented in Table 5. The 10 MMGY canola biodiesel plant is assumed to have a daily crushing capacity of 320 tons. With an annual crushing capacity of 97,280 tons, oil extraction rate of 44%, and efficiency of 90%, the plant is expected to produce 38,523 tons of oil, which yields 10 M gallons of biodiesel per year. The production of biodiesel will generate two co-products, seed meal and glycerin. Under the assumed operating capacity, 54,477 tons of seed meal, and 3,500 tons of glycerin will be produced per annum. These co-products are expected to add to the revenues generated from the sale of biodiesel.

Mean values for estimated revenues and costs of production are summarized in Table 6. For our 10MMGY canola biodiesel plant, we estimate initial equipment and construction costs (one-time investment cost) of $20.03 million ($2/gal), while annual operating cost will average about $42.05 million. Total revenues from sale of biodiesel will average $37.5 million per year, sale of seed meal will average $9 million per year, and sale of glycerin will bring in $2 million per year. Thus, the average total revenues per year will amount to about $48.5 million (Table 6). This implies a net income of $6.45 million per year.

For purposes of determining the economic viability of the project, we performed Monte Carlo simulations with 1000 iterations using the model assumptions. The simulations were programmed over a ten year project operating period. The simulation results indicate an average

NPV of $16.8 million with 61% probability of a positive NPV (Figure 1: panel A), and a rate of return of 35%. Regression analysis coefficients (shown in Figure 1: panel B) indicate that the NPV is most sensitive to the price of the feedstock (canola seeds), biodiesel price, and the price of the seed meal. Increases in the price of canola seeds decrease the NPV, while increases in the prices of biodiesel, seed meal, and glycerin increase the NPV. The regression coefficients show that a one standard deviation increase in the price of canola seeds will decrease the NPV by 0.86 standard deviations. On the other hand, a one standard deviation increase in the prices of biodiesel and seed meal will increase the NPV by 0.40 and 0.29 standard deviations, respectively.

Table 4: Summary Statistics of Data and Distribution of Stochastic Variables

Variable	Mean	Std Dev	Distribution
Price of			
Canola seeds ($/ton)	296	78.5	Logistic
Biodiesel ($/gal)	3.74	0.47	Triangular
Seed Meal ($/ton)	166.34	47.24	Normal
Glycerin ($/ton)	585	58.5	Normal
Methanol ($/gal)	1.5	0.15	Normal
Caustic ($/ton)	430	30.9	Triangular
Electricity ($/ton of biodiesel)	8.19	0.82	Normal
Labor ($/ton of biodiesel)	5.11	0.51	Normal

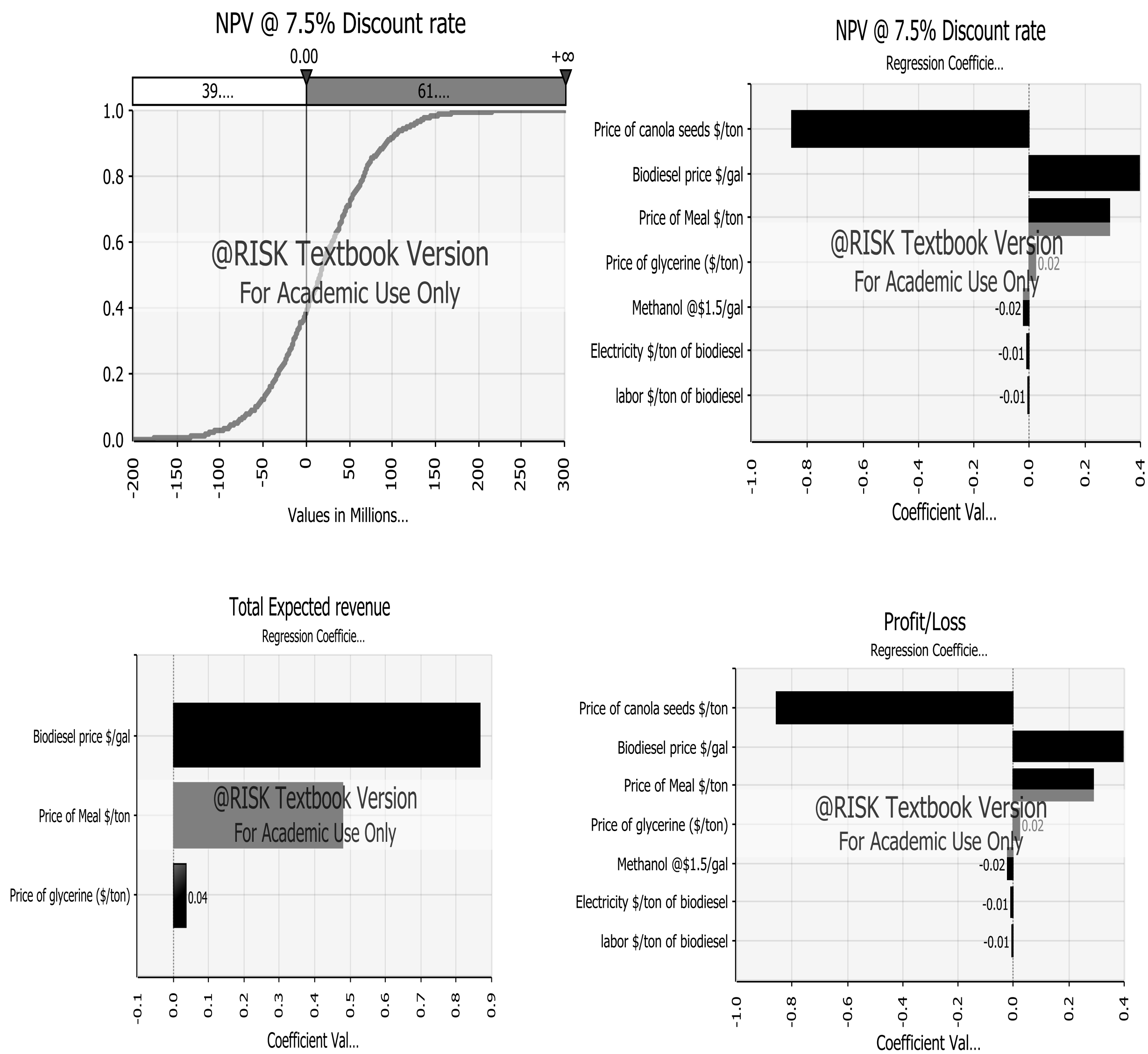
Table 5: Model Assumptions for 10 MMGY Biodiesel Plant

Variable	Unit	Value
Crushing plant capacity/hr	tons	20
Operating time/day	hours	16
Seeds pressed/day	tons	320
Production days/year	days	304
Annual tonnage pressed	tons	97,280
Oil extraction rate	percentage	44%
Extraction efficiency rate	percentage	90%
Oil output per annum	tons	38,523
No. of gallons/ton of oil	gallons	260
Biodiesel produced/year	gallons	10M
Seed meal output/year	tons	54,477
Glycerin output/year	tons	3,500

Most investors would prefer at least a 90% probability of success to invest in a project, and while the 61% probability of success (Figure 1) for the current project is not as great, it certainly indicates the project is more likely to succeed than to fail. Decreases in feedstock price (canola seeds) or increases in product prices (biodiesel, seed meal, and glycerin) could increase the probability of success. Sensitivity analyses (discussed in the next section) show that it is possible to obtain a probability of success greater than 90% under conditions of increased biodiesel prices or decreased feedstock costs.

Figure 1: Economic profitability of 10 MMGY Biodiesel Plant

a. b.



c. d.

Regression coefficients for the responses of expected revenues and profits to changes in feedstock and product prices follow similar patterns as for the NPV (See panels C and D in Figure 1). Total expected revenues increase with increases in product and co-product prices, as expected, but decreases with increasing feedstock price. A one standard deviation increase in biodiesel price will increase revenues by 0.87 standard deviations, and 0.48 standard deviations for one standard deviation increase in the price of seed meal. A one standard deviation Increase in canola seed price decreases profit by 0.86 standard deviation, while a one standard deviation increase in biodiesel price or seed meal price would increase profit by 0.40 and 0.29 standard deviations, respectively.

Table 6: Estimated Annual Production costs and Revenues for a 10 MMGY Biodiesel Plant

Item description	Quantity/Unit	Value (thousands)
Equipment/construction	$	20,031
Operating cost		
Canola seed	97,280@$294/ton	28,607
Methanol	1.167mgal@$1.50/gal	1,750
Caustic	35.8 tons@$430/ton	15
Steam	0.25mm btu/hr	10
Water	$/mm gal	50
Utilities	$/ton	796
Labor	$/ton	497
Repairs/maintenance	1% of equipment cost	200
Interest payment on 50% debt	7.5%	751
Income tax	25% rate	9,369
Total operating expenses		**42,045**
Total Revenues		
Biodiesel	10 mmgals@$3.74	37,476
Seed meal	54,477@$166/ton	9,061
Glycerin	3,500@$585/ton	2,047
Total Revenues		**48,584**

Sensitivity Analysis

Determining the economic feasibility of an investment is a very uncertain adventure owing to the difficulty of predicting economic variables. A case in point is the bankruptcy filing of Solyndra Corporation, a Solar Manufacturing firm, barely two years after it was found to be economically viable and received $535 million of Federal funding. The reason for this unfortunate situation, as in many failed business investments, is that changes in stochastic variables (factors outside the control of the decision-maker), will change the outcome (profitability or loss) of the investment. In the case of Solyndra, plummeting prices of solar panels rendered the business unprofitable. Because of this difficulty of pinning-down economic outcomes, it is often necessary to perform sensitivity or "what if" analysis to determine how outcome variables will change given changes in the input variables.

In the present case, our aim is to determine how economic feasibility of the biodiesel plant, measured by the NPV, will change given changes in crucial variables in the investment decision process. In other words, sensitivity analysis helps to determine what factors significantly affect the probability of economic success as measured by the NPV. It has already been indicated in the initial simulation results that three variables (biodiesel, canola and seed meal prices) are the most significant determinants of the NPV. Thus, we simulate the sensitivity of the NPV to changes in these three variables.

Table 7 presents the sensitivity of the NPV to changes in canola seed price. We simulate how the NPV changes given increases in the canola seed price (10%, 20%, and 30%) and decreases in canola seed prices (-10%, -20%, and -30%). The mean NPV after 1000 iterations, using the baseline canola seed price of $296/ton, is $15 million, with a 67.5% probability of positive NPV. If we assume a 10% increase in canola seed price ($325.6/ton), average NPV becomes negative (-$4.3 million), and probability of positive NPV decreases to 45%. Repeating this over different scenarios, the simulations show that as canola seed price increases, the mean NPV and probability of positive NPV decreases. On the other hand, decreasing price of canola seeds increases the NPV as well as the probability of a positive NPV. At a canola price of $207.2/ton (30% decrease from the baseline price), the project is almost guaranteed to be successful (99.9% probability of success).

Table 8 presents the sensitivity of NPV to biodiesel price. As biodiesel price increases, the NPV increases and so does the probability of a positive NPV. At the baseline biodiesel price of $3.74/gal, there is a 64.4% chance that the plant will be economically viable, while at a price of $4.48/gal (30% increase from the baseline price) there is a 92% chance of success. Conversely, if the biodiesel price were lower, say $2.62/gal (a 30% decrease from the baseline) there is only a 21% chance of economic success. If for some reason, such as political instability in the Middle East, petroleum prices were to go up, demand for renewable fuels would increase, and thus the price of biodiesel would increase, thus increasing the profitability of biodiesel production.

Similar analysis of the sensitivity of NPV to changes in the price of seed meal is presented in Table 9. Since the seed meal is a co-product, increases in its price will increase revenues, and by extension, the NPV and probability of positive NPV would increase. Graphical depictions of these sensitivity analyses can be found in the appendixes 1-3. Appendix 1 shows graphs of the probability of positive NPV given changes in the price of canola seeds. Appendixes 1 and 2 show similar cases for biodiesel and seed meal.

Summary and Conclusion

This paper investigates the economic feasibility of producing biodiesel from canola seeds in the State of North Carolina. The 10 MMGY plant will have an annual crushing capacity of 97,280 tons, generating 10M gallons of biodiesel, and two co-products of economic value, namely, seed meal and glycerin. Assuming a project lifespan of ten years, the plant can generate a NPV of $16.8 million at a discount rate of 7.5%. Cash flow analysis shows that the plant could generate average annual revenue of $37.5 million from biodiesel sale, $9 million from seed meal, and $2 million from glycerin. Total revenues ($48.5 million) exceed total operating cost ($42 million) resulting in a net discounted cash flows of $6.45 million per year. The probability of a positive NPV using the baseline data is 61%. Three factors are found to significantly affect the NPV, i.e. feedstock price (canola seeds), biodiesel price, and seed meal price. Regression analysis indicates that the NPV is most responsive to changes in the feedstock cost than to the other factors.

A sensitivity analysis is performed to ascertain the responsiveness of the NPV to fluctuations in the prices of canola seeds (feedstock), biodiesel, and seed meal. The simulations show that as the price of the feedstock increases, the mean NPV and probability of positive NPV decrease, and vice versa for decreases in feedstock price. At the baseline canola seed price of $296/ton, there is a 67.5% probability of a positive NPV, while a canola price of $207/ton, would imply almost 100% chance of profitability. As biodiesel price increases, the NPV increases and so does the probability of a positive NPV. At the baseline biodiesel price of $3.74/gal, there is a 64.4% chance that the plant will be economically successful while at a price of $4.48/gal (30% increase from the baseline price) there is a 92% chance of success.

Table 7: Sensitivity Analysis of the Impact of Canola Seed Price on the Probability of Success (NPV>0), Canola seed price ($/ton).

NPV/Scenario	-30%	-20%	-10%	Baseline	10%	20%	30%
	($207.2)	($236.8)	($266.4)	($296)	($325.6)	($355.2)	($384.8)
†Mean NPV	74.7	54.9	35	15	-4.3	-24	-43
†Min NPV	-10	-30	-50	-70	-89	-109	-129
†Max NPV	166	147	127	107	87	68	48
Pr (NPV>0)	99.9%	98.3%	89%	67.5%	45%	20.6%	7.8%

† Values in $ Million, computed from simulations

Table 8: Sensitivity Analysis of the Impact of Biodiesel price on the Probability of Success (NPV>0), Biodiesel price ($/gal)

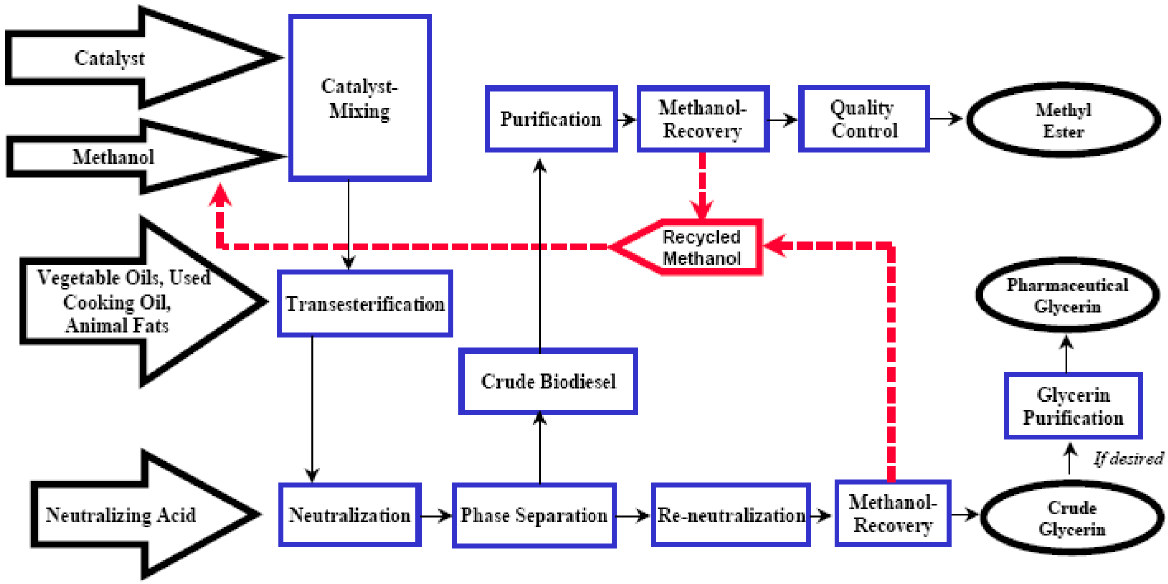
NPV/Scenario	-30%	-20%	-10%	Baseline	10%	20%	30%
	($2.62)	($2.99)	($3.36)	($3.74)	($4.11)	($4.49)	($4.48)
†Mean NPV	-41	-21	-2	16.7	35	55	74
†Min NPV	-274	-255	-235	-216	-197	-177	-158
†Max NPV	192	211	230	250	269	288	307
Pr (NPV>0)	21.2%	32.7%	47.8%	64.4%	76.5%	86.1%	91.9%

† Values in $ Million, computed from simulations

Table 9: Sensitivity Analysis of the Impact of Canola Seed meal price on the Probability of Success (NPV>0), Canola seed Meal price ($/ton).

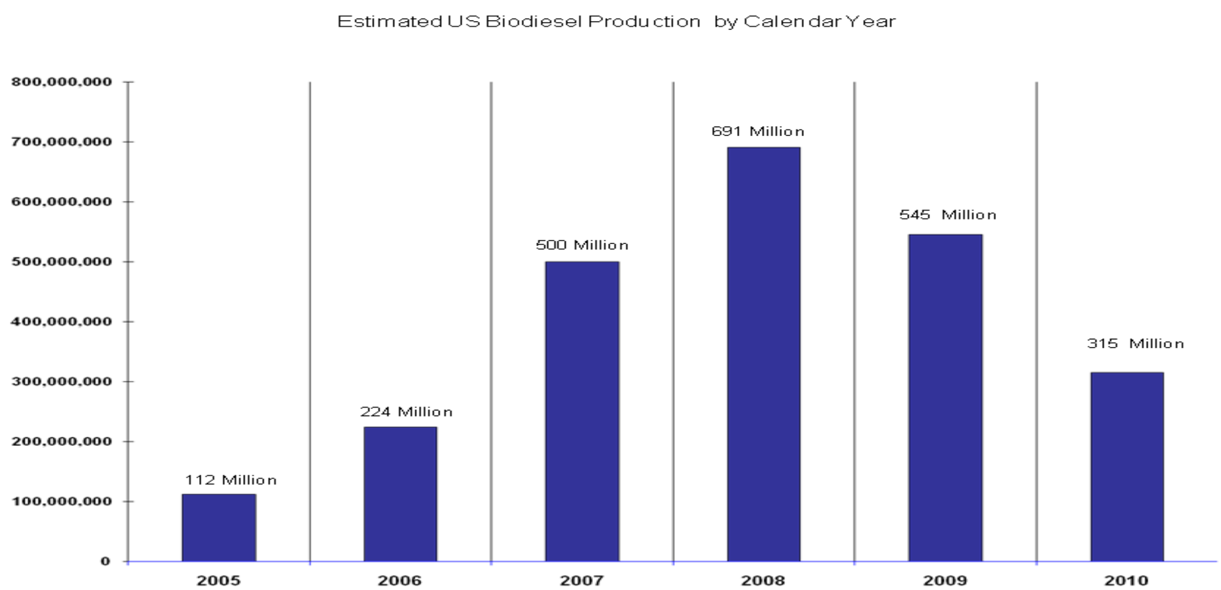
NPV/Scenario	-30%	-20%	-10%	Baseline	10%	20%	30%
	($116.45)	($133.09)	($149.72)	($166.36)	($182.99)	($199.63)	($216.27)
†Mean NPV	-1.9	4.2	10.4	16.7	22	29	35
†Min NPV	-289	-283	-277	-270	-264	-258	-252
†Max NPV	258	265	271	277	283	290	296
Pr (NPV>0)	48.4%	52.3%	56.3%	61.9%	65.7%	70.9%	74.1%

Figure 1. Biodiesel Production Process



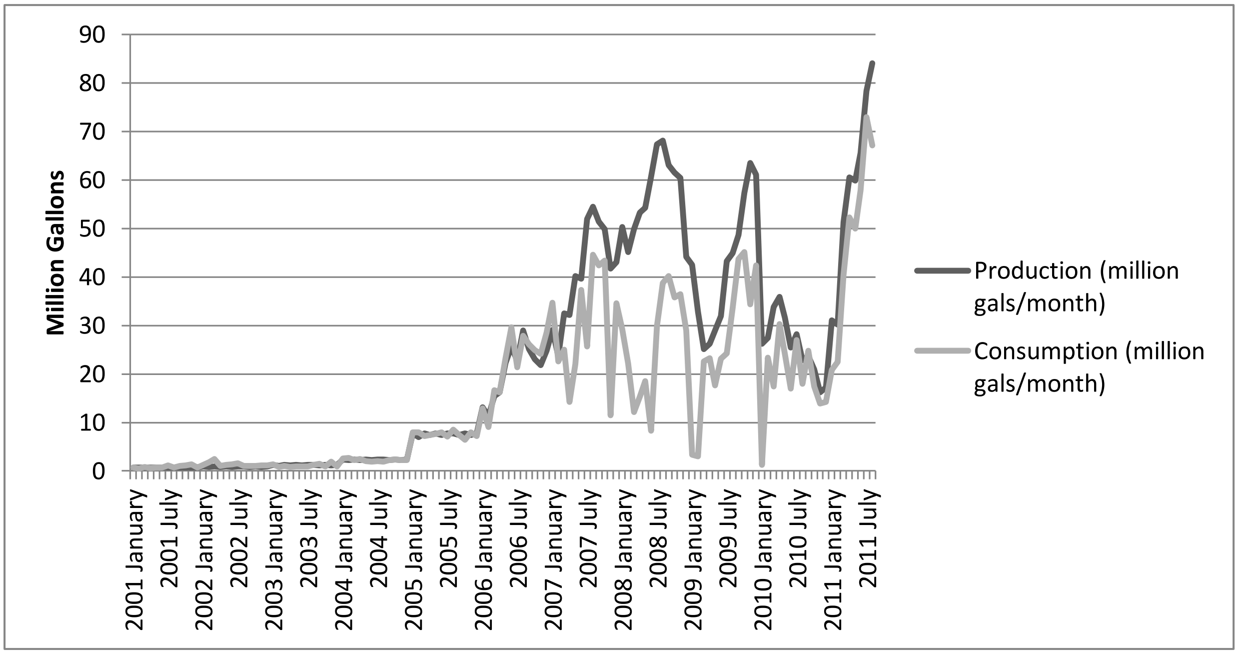
Source: National Biodiesel Board

Figure 2: Annual Biodiesel Production, million gallons



Source: National Biodiesel Board

Figure 3: U.S. Biodiesel production and Consumption



Data Source: U.S. Energy Information Administration

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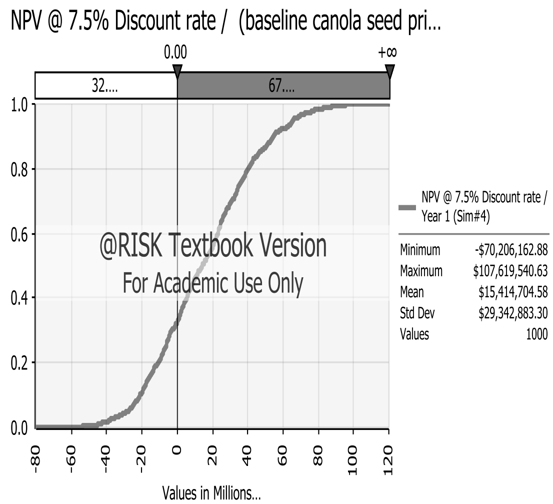
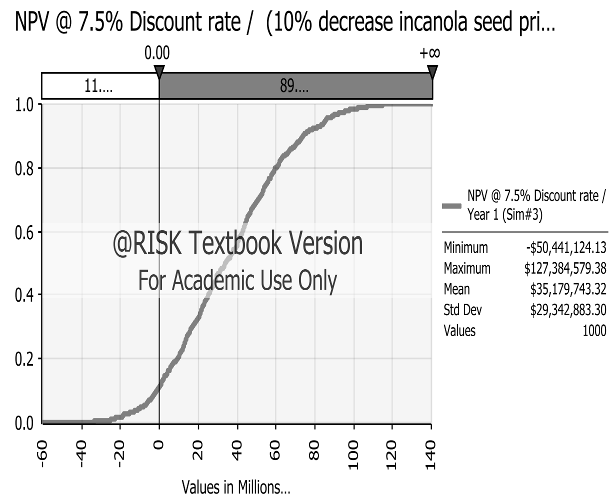
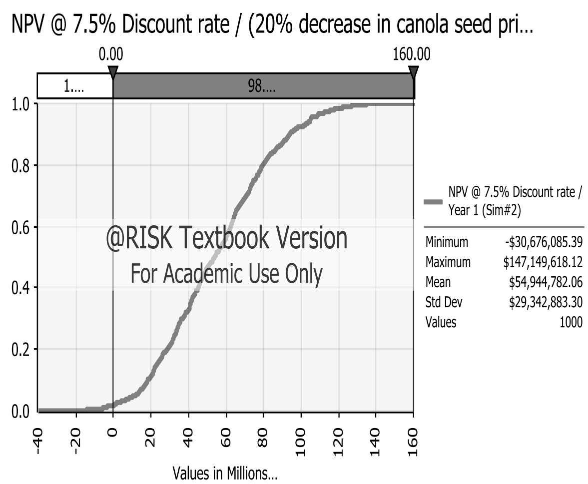
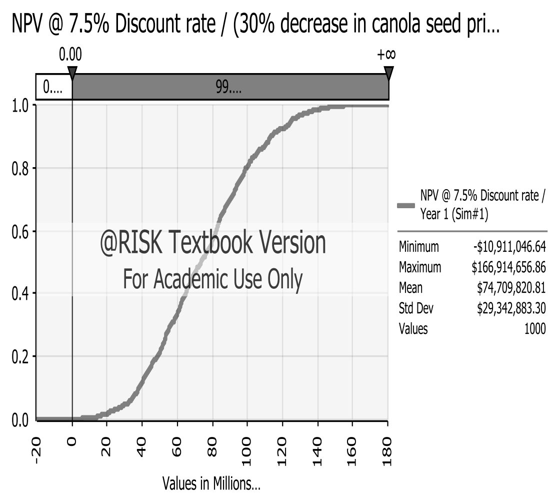
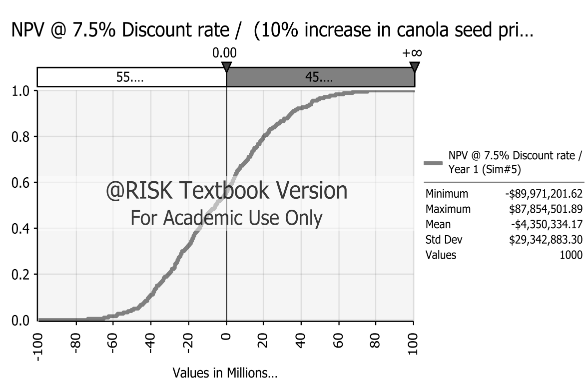
Appendix 1: Sensitivity Analysis of NPV to Changes in Canola Seed Prices (Pr NPV > 0)

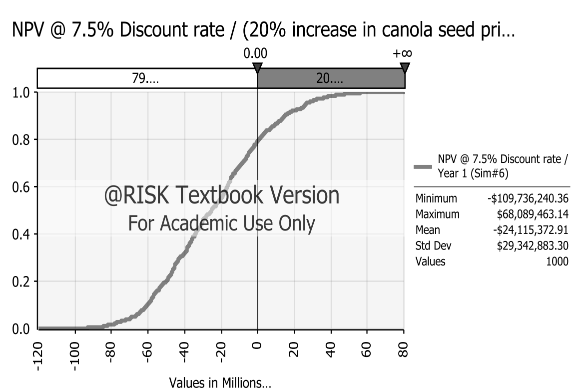




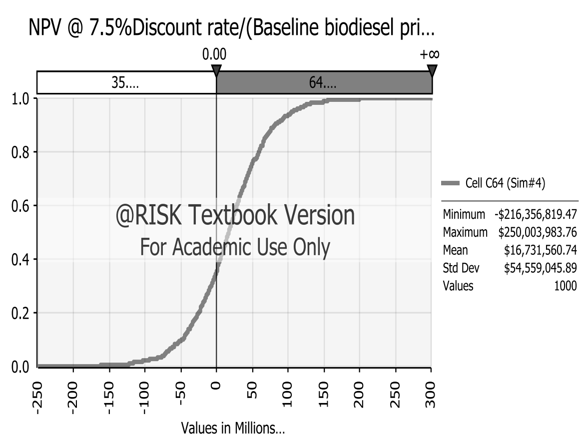


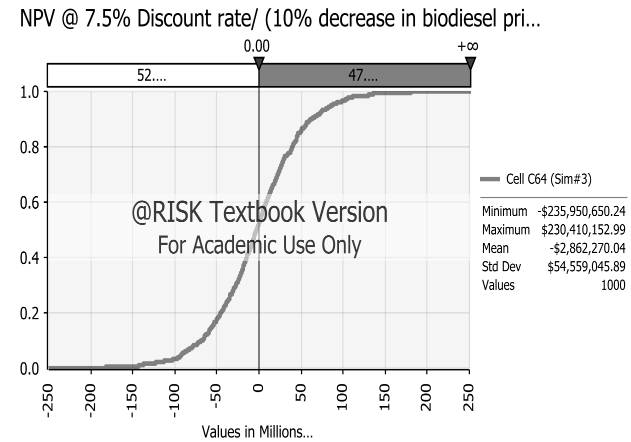


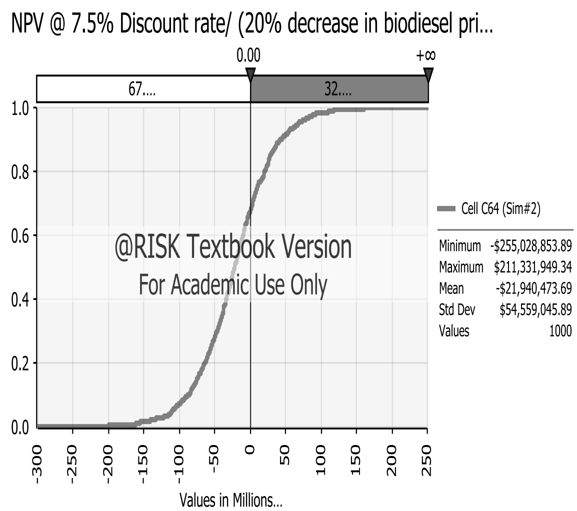


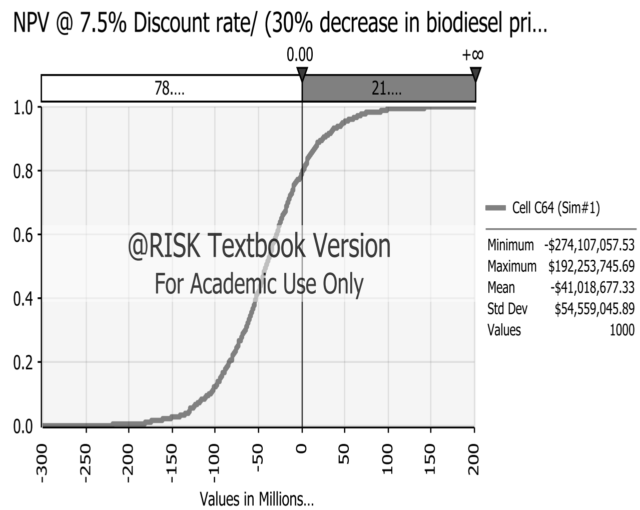


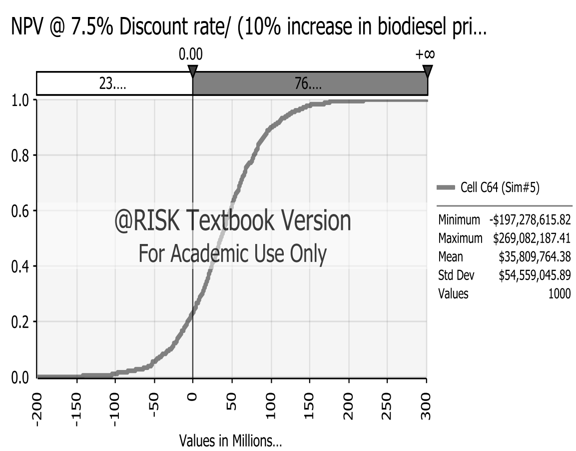
Appendix 2: Sensitivity Analysis of NPV to Changes in Biodiesel Prices (Pr NPV > 0)

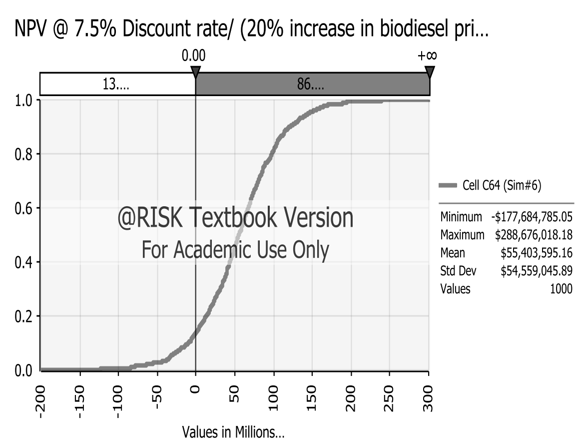












Appendix 3: Sensitivity Analysis of NPV to Changes in Canola Seed Meal Prices (Pr NPV > 0)