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

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Abstract

We assess the economic feasibility of a 10 million gallon per year biodiesel plant that uses canola seeds as feedstock. A Monte Carlo Cash Flow model is programmed using @Risk simulation software. 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. The study finds that the likelihood of the NPV greater than zero is 63% on average. This indicates that the plant may be economically feasible, subject to model assumptions. Sensitivity and scenario analyses show that the NPVs were most affected by fluctuations in biodiesel price, canola seed price, and the price of seed meal. Indeed, over the long-term, feedstock price and biodiesel subsidies remain the major determining factors of profitability in biodiesel production. Historically, feedstock prices have been characterized by high volatility. The profitability of the biodiesel plant hinges to a large extent on the assumption that feedstock prices remain low and regular gasoline prices, especially petroleum diesel, remain stable over the forecast horizon. Moreover, the analysis assumes that the current biodiesel subsidy at $1.00/gallon remains in effect over the period of the study. Thus, removal of the subsidy would also render biodiesel production unprofitable given current feedstock prices.

Keywords: biodiesel, economic feasibility, Monte Carlo Simulations, risk analysis, Sensitivity Analysis.

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Introduction

Environmental concerns and geopolitical considerations are beginning to shape energy policies in the United States and other developed countries. The dependence on petroleum fuels not only pollute our environment but also raises questions concerning national security since much of the U.S. oil consumption is imported from politically unstable countries. Biodiesel and ethanol have become two competing candidates to substitute for petroleum fuels. However, the cost-competiveness of these renewable energy types, particularly biodiesel, has been called into question (Fore et al. 2011; Hill et al. 2006). Besides cost considerations, the food versus fuel debate has also picked up steam especially in the wake of the global food crises of 2008-2009 (Abott et al. 2008; Mitchell 2008). Pimentel and Patzek (2005) have questioned the moral and ethical basis of diverting corn from human consumption to fuel production, which has the tendency to cause food price inflation. Pimental et al. (2009) noted that ethanol production from corn in the U.S. increases the price of beef, chicken, pork, eggs, bread, cereals, and milk by about 10% to 30%.

Much of the renewable fuel produced in the U.S. is ethanol, although biodiesel production has been increasing rapidly in recent years (Pradhan et al. 2008). Until the 2008 economic downturn, biodiesel production was growing at a faster pace than ethanol production. Beginning in 2011, biodiesel production started to recover from the economic recession, surpassing its peak level in 2008. Both ethanol and biodiesel have experienced significant increases in the 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 (Outlaw et al. 2007). At the current rate, ethanol production from corn is expected to increase from the current 14 billion gallons in 2011 to more than 15 billion gallons by 2015. In 2011, the U.S. produced 12,358 million bushels of corn, of which 5,050 million bushels went into ethanol production, representing 41% of the 2011 corn crop (USDA-NASS, 2012). This level of ethanol production could fuel more corn price increases, making ethanol production from corn less competitive.

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 prices continue their upward trajectory. Ethanol production increased from 3.4 billion gallons in 2004 to 13.9 billion gallons in 2011—representing an increase of about 300% (Figure 2). In the same period, biodiesel production increased from 28 million gallons to 967 million gallons, a whopping increase of 3,300% (Figure 3). Given that soybean production, the largest biodiesel source, is not huge enough to fulfill the biodiesel mandate, other oilseeds such as canola can play an immense contribution to this effect. Canola biodiesel production, while a novel concept in North Carolina, is nonetheless one with a huge potential to be successful. Experimental trials on canola production conducted since 2000 have demonstrated that it can be profitably grown in North Carolina. The environmental conditions in North Carolina and the Southeastern U.S. in general are well-suited for the production of canola.

Among first generation biofuels, biodiesel production from oilseeds such as soybean, canola (a hybrid of rapeseed), sunflower and other vegetable oils is gaining popularity. Second generation biofuels, mainly cellulosic sources such as corn stover, 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.

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 (million gallons per year), 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. Soybeans, one of the major oil-seeds for biodiesel production, are grown in the state, although it is not nearly 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 five 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-feedstock that includes 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 (NBB 2011), 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 (EPA 2010).

Experimental trials have shown that canola can 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). Additionally, 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.

The objective of this study is to assess the economic feasibility of a biodiesel plant in North Carolina that uses canola seeds as primary feedstock. 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 feedstock, to determine the economic feasibility of the proposed plant. Our study seeks to contribute to filling the gap in scientific knowledge regarding biofuel feedstock alternatives in North Carolina. Moreover, it is apparent that the U.S. EPA renewable fuel mandate of 36 billion gallons by 2022 cannot be met by ethanol alone, which is why the U.S. EPA has expanded its renewable fuel mandate to include biodiesel. This means that other feedstock options have to be investigated, as we move toward the goal of achieving the renewable fuel mandate. To this end, the findings of the present study can help inform agribusiness managerial decision making towards investing in canola biodiesel production in North Carolina.

Table 1. North Carolina Biodiesel Plants.

Plant Name	**City**	**Feedstock**	**Capacity (MMGY)**
Blue Ridge Biofuels	Asheville	Multi-feedstock	1.2
Carolina Biodiesel LLC	Durham	[a]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

Sources. National Biodiesel Board and Biodiesel Magazine: [a] Waste Vegetables oils

Data and Methods

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).

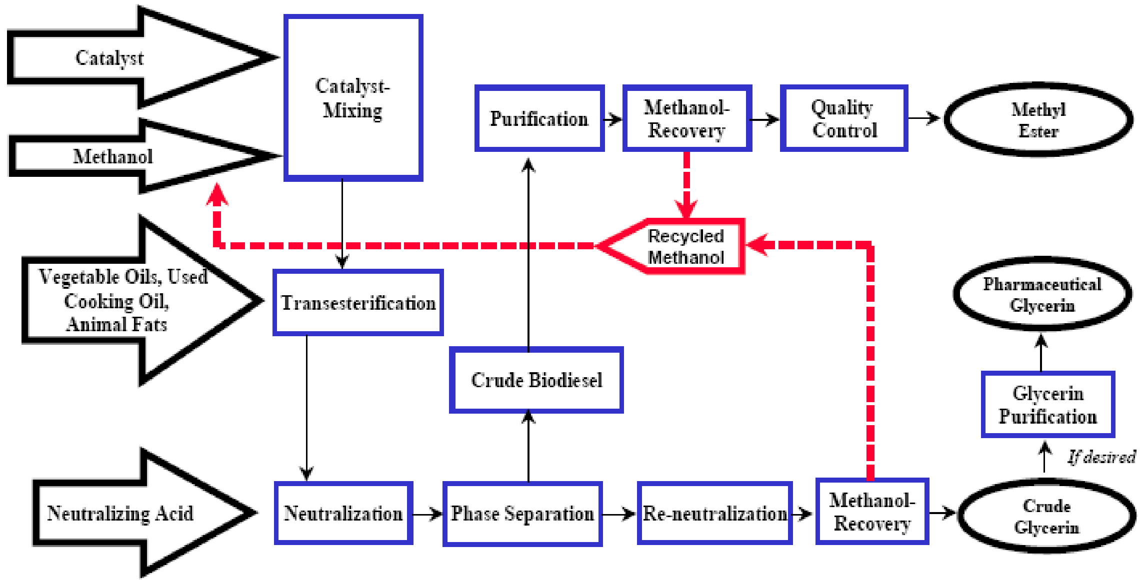

Figure 1. Biodiesel Production Process (Adapted from National Biodiesel Board 2011)

The reaction process may be summarized as follows;

$$(1)\quad \underset{(100\ parts)}{Methanol} + \underset{(1015\ parts)}{Vegetable\ Oil} \xrightarrow{NaOH} \underset{(1000\ parts)}{Methyl\ Ester} + \underset{(100\ parts)}{Glycerin} + Free\ Fatty\ Acid + Waste$$

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 3 shows the trends in biodiesel production in the U.S. from 2001 to 2011, while Figure 4 provides a comparison of monthly biodiesel production and consumption in the U.S. from 2005 to 2011. Biodiesel production suffered a sharp decline in 2008-2010. Although the economic downturn may have contributed to this decline, two major factors explain the near collapse of the biodiesel industry: First, biodiesel feedstock prices increased by more than 200% during that period, thus, rendering biodiesel production unprofitable relative to petroleum diesel. Secondly, exports of U.S. biodiesel to the European Union increased during this period in response to high prices there. However, the EU, sensing a threat to their biodiesel industry from the imports, imposed higher tariffs on U.S. biodiesel which curtailed the growing imports. This, coupled with a recovering economy and a new biofuel mandate (RFS2) led to the rebound in biodiesel production starting in 2011. In Figure 4, the production and consumption of biodiesel curves are in virtual lockstep, 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).

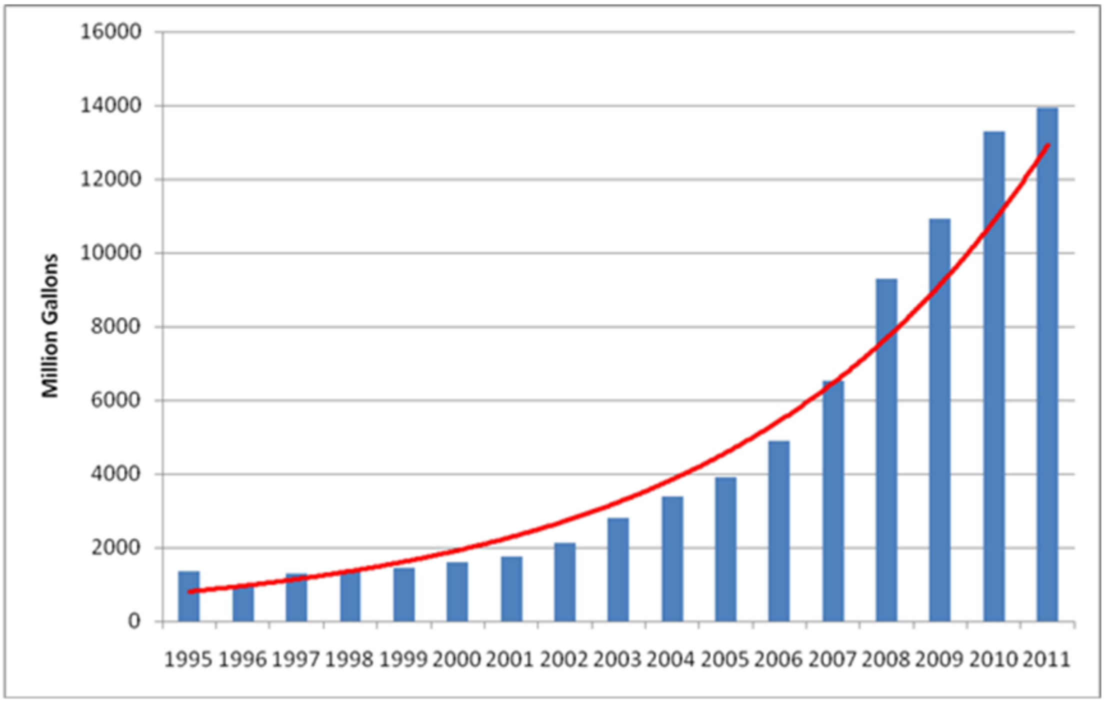

Figure 2. U.S. Ethanol production
Source. U.S. Energy Information Administration, Monthly Energy Review

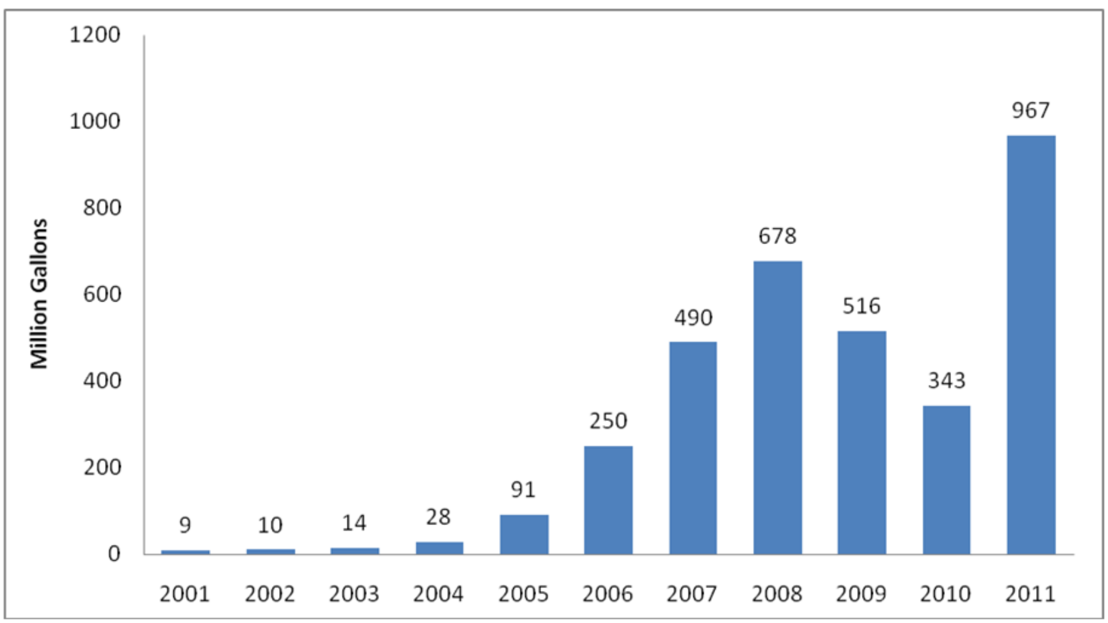

Figure 3. Annual Biodiesel Production, million gallons
Source. U.S. Energy Information Administration, Monthly Energy Review

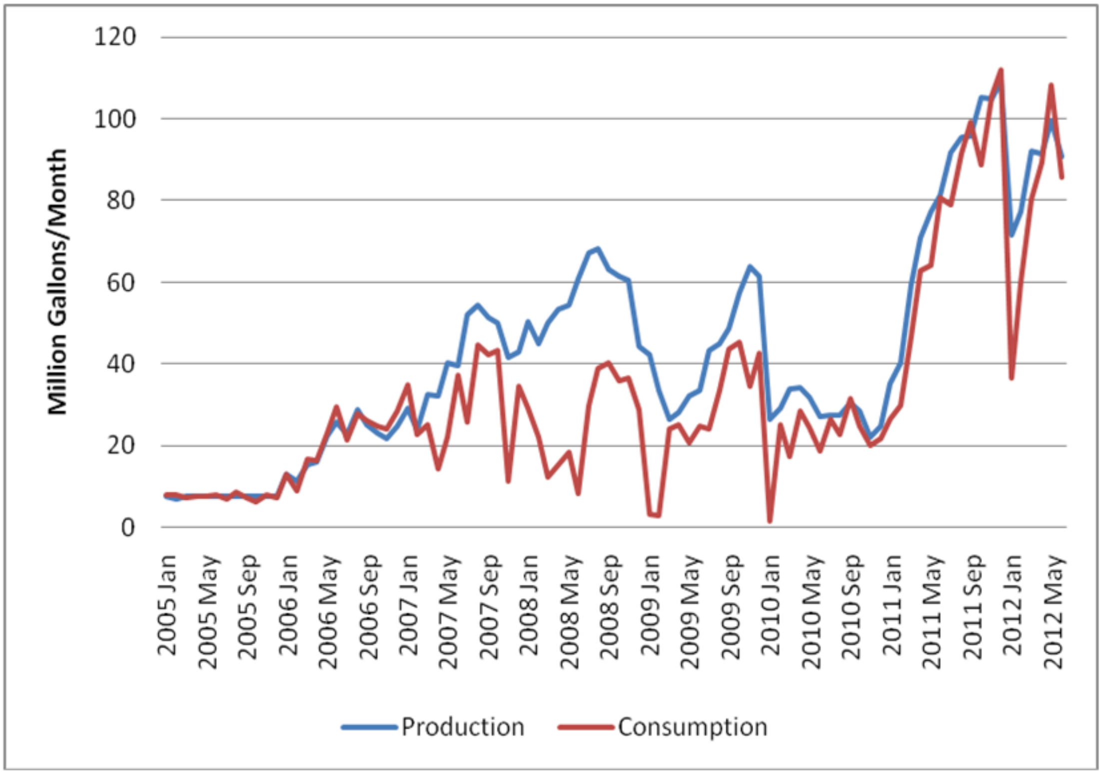

Figure 4. U.S. Biodiesel production and Consumption (monthly)
Source. U.S. Energy Information Administration, Monthly Energy Review

According to the Biodiesel Magazine (2012), 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. 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 (thousand barrels)

Year	Production	Imports	Exports	Net Imports	Consumption
2001	204.203	78.277	39.318	38.96	243.162
2002	249.620	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	2,161.586	206.707	205.756	0.95	2,162.536
2006	5,962.838	1,069.194	827.659	241.535	6,204.374
2007	11,662.501	3,342.057	6,477.025	-3134.97	8,527.531
2008	16,145.380	7,501.598	16,128.03	-8,626.44	7,518.947
2009	12,054.161	1,843.594	6,332.165	-4,488.57	7,536.871
2010	7,365.773	545.526	2,503.392	-1,957.87	5,446.908

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 $4.60 to produce a gallon of biodiesel from soybean oil compared to $1.65 to produce ethanol from corn. However, corn ethanol production requires high capital expenditure: estimates show that construction costs for a new ethanol plant averages about $1.05 to $3.00 per gallon of ethanol (Shapouri and Gallagher 2005). In the EU, it will cost $3.52 to produce a gallon of biodiesel using rapeseed. Conventional diesel and gasoline production costs per gallon are $1.65 and $1.38, 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[1] (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%. In a more recent study, Fore et al. (2011a) estimated that when feedstock is valued at production cost, canola-based biodiesel production will cost anywhere from $0.94/*l* to $1.13/*l* ($3.55/gal to $4.27/gal), while the cost of biodiesel production from soybean ranges from $0.40/*l* to $0.60/*l* ($1.51/gal to $2.27/gal). However, they also determined that when the feedstock is valued at market price (which would seem more appropriate since producers of the feedstock have to sell at market price) the cost of canola-based biodiesel is cheaper than soybean biodiesel production.

Numerous studies have compared the energy efficiency of biofuel production from different feedstocks. Several measures have been used to describe the energy efficiency of different renewable fuel production: the commonest are net energy balance (NEB) and net energy ratio (NER). Net energy balance is defined as the difference between the energy output and energy input in the production of a renewable energy (energy output-energy input), whereas net energy ratio is the energy output divided by the energy input (energy output/energy input) (Hill et al. 2006; Pradhan et al. 2008). Fore et al. (2011b) define a positive net energy balance as the situation in which there is a net gain of energy; which is to say that more energy is produced than consumed in the production of the biofuel. On the other hand, a net negative energy balance results when more energy is consumed than actually produced. A number of studies have found that ethanol production from corn and biodiesel production from soybean and canola have a negative net energy balance (Pimentel and Patzek 2005; Pimentel et al. 2008; Pimentel et al. 2009). Other researchers however found a positive net energy balance for these same biofuel sources. For example Hill et al. (2006) found that ethanol production yields a net positive energy balance of 25% while biodiesel production from soybeans yields 93% more energy than actually used in producing it. Fore et al. (2011b) estimates the NEB of canola biodiesel to be 0.66 MJ MJ^{-1} compared with $0.81 MJMJ^{-1}$ for soybean biodiesel. Similarly, they found the NER to be 1.78 and 2.05 for canola biodiesel and soybean biodiesel, respectively Insofar as energetic productivity is concerned, Fore et al. note that canola is a more productive biodiesel feedstock than soybean, because of its higher oil content.

[1] Estimates based on 2006 dollars

Bender[2] (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 showed that the cost of canola feedstock was \$0.32/*l* biodiesel. This translated 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.

Table 3. Cost of Biofuel production from selected feedstock

Biofuel/Country	Feedstock	Feedstock Cost (% of total)	Total production costs
Biodiesel		Percent	\$ per gallon
United States	Soybean Oil[a]	80-85	4.60
Malaysia	Palm Oil	80-85	2.23
EU	Rapeseed	80-85	3.52
India	Jatropha	80-85	2.13
Diesel			
United States	Diesel	75	1.65
Ethanol			
United States	Corn	39-50	1.65
United States	Cellulosic sources	90	2.88
Brazil	Sugarcane	37	1.05
EU	Wheat	68	2.39
EU	Sugar beets	34	3.08
Gasoline			
United States	Gasoline	73	1.38

Sources. Iowa State University Ag Marketing Resource Center (2012); Biomass Research and Development Board (2008). [a] U.S. producers of biodiesel receive a \$1.00 per gallon subsidy under the American Jobs Creation Act of 2004, extended through 2008 by the Energy Policy Act of 2005.

Graboski and McCormick (1998) analyzed the technical and economic feasibility of a 10 million gallon biodiesel facility using fats and oils as feedstock. Their calculations showed that the joint cost of feedstock and its conversion to biodiesel would be \$0.57/*l* or \$2.15/gal (\$0.81/*l*, \$3.04/gal in 2012 dollars). They concluded that the price of feedstock was 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 (in

[2] Estimates based on 1999 dollars

2012 dollars these would be \$3.22/gal to \$5.81/gal). Noordam and Withers also 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.

Net Present Value

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) described the net present value (NPV) as a good measure for determining the overall economic feasibility of a proposed investment.

Richardson and Mapp (1976) described 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 outlined 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. Data on biodiesel and electricity prices are obtained from the U.S. Energy Information Administration (EIA, 2011), canola price data are obtained from the Oil Crops Yearbook (ERS-USDA 2011), while other input prices such as methanol, caustic, labor, and glycerin are estimated based on the literature. 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 determined that the historical price of canola seeds follows a log-logistic distribution, based on Kolmogorov-Smirnov Statistics. Price of biodiesel follows a triangular distribution (based on chi-squared statistics) with three parameters; minimum (\$3.08/gal), mean (\$3.93/gal), and maximum (\$5.57/gal). Prices of seed meal, glycerin co-product, methanol, and other inputs are approximated by normal distributions. 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 (NCF) 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 (Palma et al. 2011).

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

$$(2)\ NPV = -(InitialEquity\ Investment) + \sum_{n=1}^{10} \frac{NCF_n}{(1+i)^n} + \frac{EndingNetWorth}{(1+i)^{10}}$$

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;

$$(3)\ NCF = \left(\tilde{P}_{bd} * Q_{bd}\right) + \left(\tilde{P}_m * Q_m\right) + \left(\tilde{P}_g * Q_g\right) - Capital\ Expenses - Operating\ Costs$$

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. The capital budgeting analysis assumes a 50% equity financing. The interest rate on debt financing is assumed to be 7.5% computed at the going commercial lending rate plus processing charges. A tax rate of 25% is also assumed and incorporated in the computation of operating expenses of the plant.

Results and Discussion

Table 4 presents the summary statistics of variables used in the analyses. In Figure 5 we compare monthly biodiesel prices with ethanol and regular gasoline prices. The gasoline price data are obtained from U.S. Energy Information Administration while biodiesel and ethanol prices are obtained from Iowa State University Center for Agricultural and Rural Development (CARD). A gallon of biodiesel in 2012 averages about \$4.60, lower than the 2011 average of \$5.70. Due to significant volatility in the price of biodiesel, the overall mean price of biodiesel in the dataset is \$3.93 (Table 4). 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 $43.01 million. Total revenues from sale of biodiesel will average $39.3 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 $50.5 million (Table 6). This implies a net income of $7.47 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 $18 million with 62.7% probability of a positive NPV (Figure 6: panel A), and a rate of return of 38%. Regression analysis coefficients (shown in Figure 6: 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 (or $88.50/ton) increase in the price of canola seeds will decrease the NPV by 0.81 standard deviations (or $1.8 million). On the other hand, a one standard deviation (or $0.75/gal) increase in the price of biodiesel will increase the NPV by 0.53 standard deviations (or $1.2 million) while a one standard deviation (or $52/ton) increase in seed meal price will increase the NPV by 0.27 standard deviations (or $626,586).

Additional caution should be exercised in order not to appear too bullish about the prospects of investment in canola biodiesel production. The high volatility of the feedstock implies that small changes in its price can significantly alter the results. As such, these findings need to be interpreted with caution, considering the fact that the model is quite sensitive to small changes in the feedstock price. The results are also subject to a continuation of $1.00/gal biodiesel subsidy. Removal of the subsidy will invalidate the conclusions drawn from the model.

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

Variable	**Mean**	**Std Dev**	**Distribution**
Price of			
Canola Seeds ($/ton)	304	88.5	Log-logistic
Biodiesel ($/gal)	3.94	0.47	Triangular
Seed Meal (S/ton)	164	47.24	Logistic
Glycerin ($/ton)	585	58.5	Normal
Methanol ($/gal)	1.5	0.15	Normal
Caustic ($/ton)	430	30.9	Normal
Electricity ($/ton of biodiesel)	8.19	0.82	Normal
Labor ($/ton of biodiesel)	5.11	0.51	Normal

Sources. Energy Information Administration (www.eia.gov) and Center for Agricultural and Rural Development (CARD), Iowa State University (www.card.iastate.edu). Distributions are determined based on the best fit for the data or normal approximations.

Most investors would prefer at least a 90% probability of success to invest in a project, and while the 62.7% probability of success (Figure 6) for this 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.

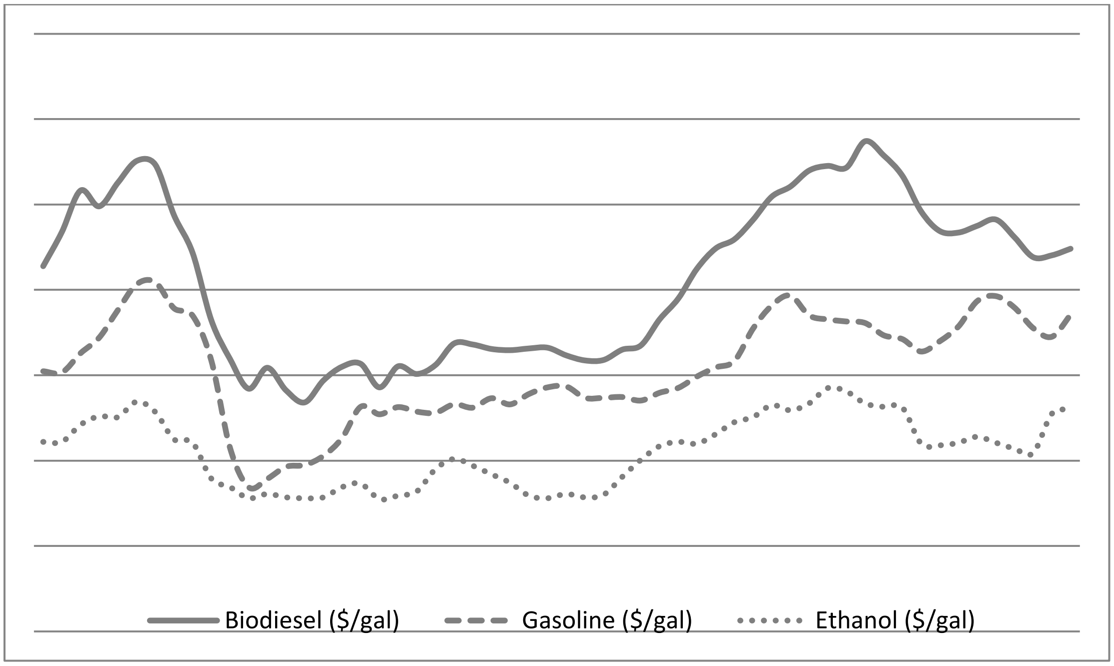

Figure 5. Monthly Prices of biodiesel, ethanol, and gasoline
Sources. Center for Agricultural and Rural Development (CARD), Iowa State University (www.card.iastate.edu), and Energy Information Administration (www.eia.gov).

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
Subsidy	$/gal	$1.00

Note. These assumptions are based on a 10 million gallon/year operating capacity. The analysis and conclusions drawn are subject to these assumptions. Any change in the assumptions will alter the results presented.

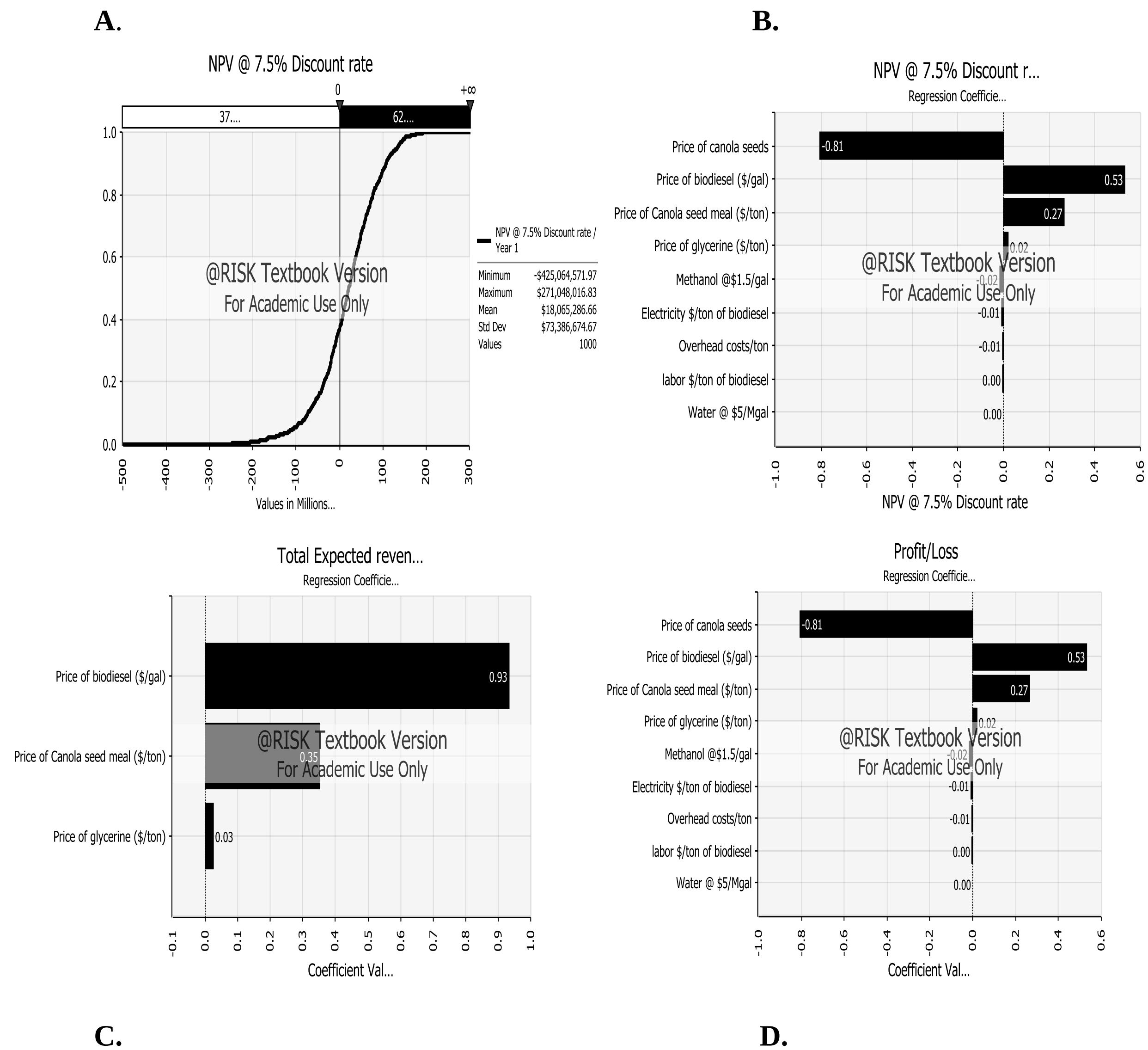

Figure 6. Economic profitability of 10 MMGY Biodiesel Plant

Regression coefficients for the responses of expected revenues and profits to changes in feedstock and product prices follow similar patterns as for the NPV (panels C and D in Figure 6). 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 (or $0.75/gal) will increase revenues by 0.93 standard deviations (or $237,552), and 0.35 standard deviations (or $89,401) for one standard deviation (or $52/ton) increase in the price of seed meal. Furthermore, a one standard deviation (or $88/ton) increase in canola seed price decreases profit by 0.81 standard deviation (or $273,854), while a one standard deviation increase in biodiesel price or seed meal price would increase profit by $179,188 and $91,284, 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@$304/ton	29,573
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		**43,011**
Total Revenues		
Biodiesel	10 mmgals@$3.93	39,376
Seed meal	54,477@$166/ton	9,061
Glycerin	3,500@$585/ton	2,047
Total Revenues		50,484

Note. Estimates are based on the data and author computations

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 baseline simulation results that three variables (biodiesel, canola seeds, and seed meal prices) are the most significant determinants of the NPV. Thus, we now 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 prices is $18 million, with a 62.7% probability of positive NPV. If we assume a 10% increase in canola seed price from the baseline price ($304.9/ton) to $335.4/ton, the average

NPV becomes negative (-$2.2 million), and probability of positive NPV decreases to 44.5%. Repeating this over different scenarios, the simulations show that as canola seed price increases, the mean NPV and probability of positive NPV decrease. On the other hand, decreasing the price of canola seeds increases the NPV as well as the probability of a positive NPV. At a canola price of $213.4/ton (30% decrease from the baseline price), the project is almost guaranteed to be successful (98.7% probability of success).

Table 8 presents the sensitivity of NPV to biodiesel price changes. As biodiesel price increases, the NPV increases and so does the probability of a positive NPV. A 10% increase in biodiesel price ($4.32/gal) from the baseline biodiesel price of $3.93/gal increases the probability that the plant will be economically viable to 77%; while at a price of $5.11/gal (30% increase from the baseline price) there is a 89.8% chance of success. Conversely, if the biodiesel price were lower, say $2.75/gal (a 30% decrease from the baseline) there is only a 26% 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 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 an average NPV of $18 million at a discount rate of 7.5%. Cash flow analysis shows that the plant could generate average annual revenue of $39.4 million from biodiesel sale, $9 million from seed meal, and $2 million from glycerin. Total revenues ($50.5 million) exceed total operating cost ($43.01 million) resulting in a net cash flow of $7.47 million per year. The probability of a positive NPV using the baseline data is 62.7%. 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 $304.9/ton, there is a 62.7% probability of a positive NPV, while a canola price of $213.4/ton, would imply an almost 99% chance of profitability. As biodiesel price increases, the NPV increases and so does the probability of a positive NPV. At the baseline biodiesel price, there is a 62.7% chance that the plant will be economically successful while at a price of $5.11/gal (a 30% increase from the baseline price) there is a 90% chance of success.

Given the above results, a couple of caveats are warranted: Historically, feedstock prices have exhibited a high volatility that makes it difficult to predict the direction of movement. Additionally, the results presented are subject to a $1.00/gal subsidy on biodiesel production. Thus, removal of the subsidy renders the investment in biodiesel plant unprofitable.

Managerial Implications: The renewable fuel standard of 36 billion gallons of biofuels by 2022 present investment opportunities for agribusiness managers. It is now clear that this mandate cannot be fulfilled by conventional feedstocks alone. This calls for more research on the profitability of alternative feedstocks. The U.S. Environmental Protection Agency conducted a life cycle analysis of canola biodiesel and found that it meets the requirements of an advanced biofuel. Canola biodiesel has a higher superior quality than soybean biodiesel (based on cetane number rating). Canola also has a higher energetic productivity than soybean due to its higher oil content (40% compared to 20% for soybean).

The present study is relevant to the agribusiness industry of North Carolina in that it informs managerial decision-making regarding investment in canola biodiesel production in the state. We analyze the returns to investment in a biodiesel plant that has an annual production capacity of 10 million gallons. The study assesses under different scenarios, the riskiness involved in investing in such a biodiesel production enterprise. The risk analysis controls for factors outside the control of the decision maker by developing probability distributions of key input and output variables. The study finds that the main drivers of profitability of an investment in a canola biodiesel processing plant are; price of biodiesel, price of canola seeds, and prices of co-products like seed meal and glycerin. Like in any forecasting process, the caveat remains that the analyses herein presented are based on the assumptions of the model and outcomes are subject to change depending upon changing economic conditions. Most importantly, future changes in prices of the feedstock (canola seeds) and major products (biodiesel, seed meal and glycerin) are likely to impact the profitability of biodiesel production. Furthermore, changes in government policies, such as an increase or decrease in the current $1.00/gallon subsidy on biodiesel production could affect the industry.

It also merits mention that while canola is relatively new in North Carolina, experimental research has shown that it has a good potential as a winter annual. North Carolina farmers who already grow winter wheat could also grow canola since both crops have very similar requirements. Thus, the availability of feedstock (a major determining factor to invest in biodiesel production) depends on whether farmers will have a ready market if they choose to grow canola. This may also have implications on acreage allotment to other crops like wheat and soybean—two major crops currently grown in North Carolina. Currently, soybean is by far the largest feedstock for biodiesel production not only in North Carolina but the U.S. as a whole. Achieving a nationwide B2 target (2% biodiesel blend in diesel transportation fuel) would require about 2.8 million metric tons of vegetable oil or 30% of the U.S. soybean crop (BM&BR, 2008). The biodiesel mandate, obviously, cannot be met by soybean alone. This underscores the need to supplement with other feedstock alternatives such as canola.

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%
	($213.4)	**($243.9)**	**($274.4)**	**($304.9)**	**($335.4)**	**($365.9)**	**($396.4)**
†Mean NPV	79.2	58.8	38.5	18	-2.2	-22.5	-42.9
†Min NPV	-32.3	-52.6	-73	-287	-113	-134	-154
†Max NPV	230	209	189	191	148	128	107
Pr (NPV>0)	98.7%	94.3%	79.5%	62.7%	44.5%	28.7%	18.3%

† 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%
	($2.75)	**($3.14)**	**($3.54)**	**($3.93)**	**($4.32)**	**($4.72)**	**($5.11)**
†Mean NPV	-42.5	-22.4	-1.7	18	38	59	79
†Min NPV	-420	-400	-380	-287	-339	-139	-299
†Max NPV	83	103	124	191	164	185	205
Pr (NPV>0)	26%	40.7%	56%	62.7%	77.1%	85.5%	89.8%

† 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%
	($114.9	**($131.3)**	**($147.7)**	**($164)**	**($180.5)**	**($196.9)**	**($213.4)**
†Mean NPV	-0.27	5.8	12	18	24	30	36
†Min NPV	-384	-377	-371	-287	-359	-353	-347
†Max NPV	185	191	197	191	210	216	222
Pr (NPV>0)	54.2%	59%	62.7%	62.7%	69.6%	71.9%	75.1%

† Values in $ Million, computed from simulations

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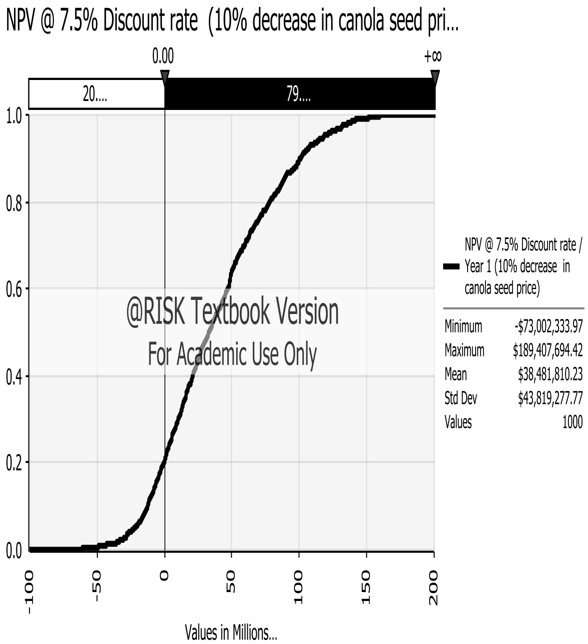
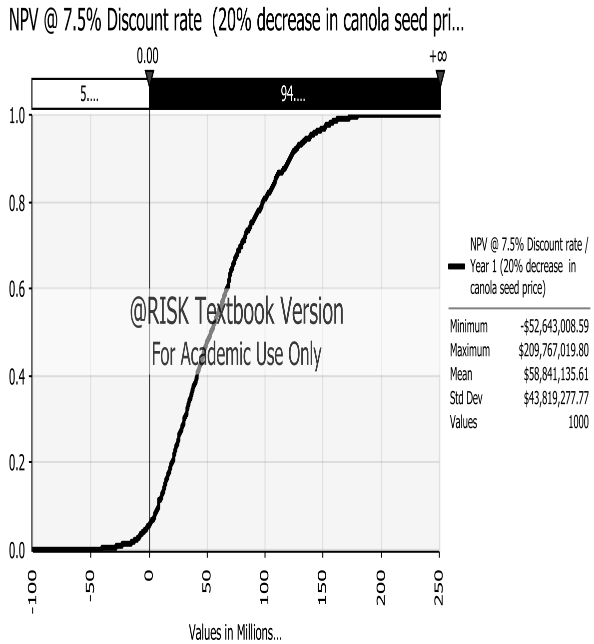
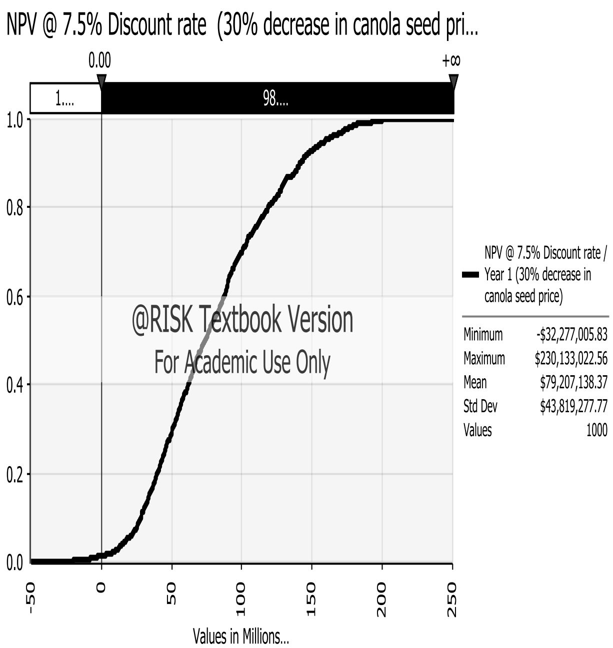
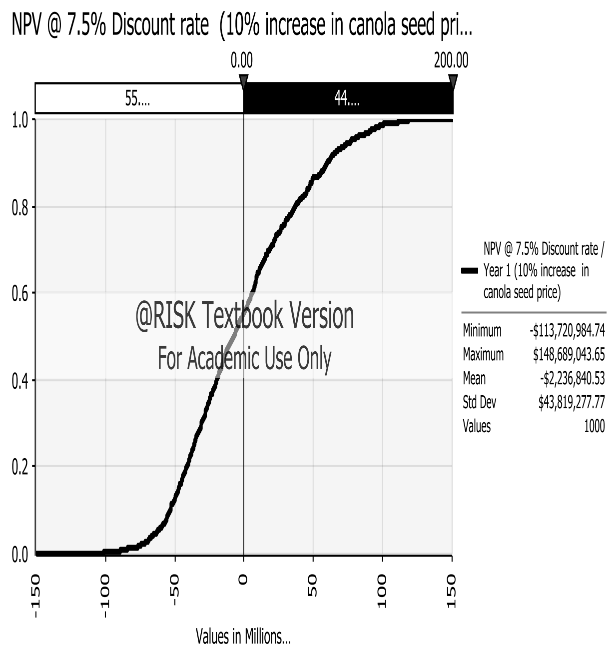
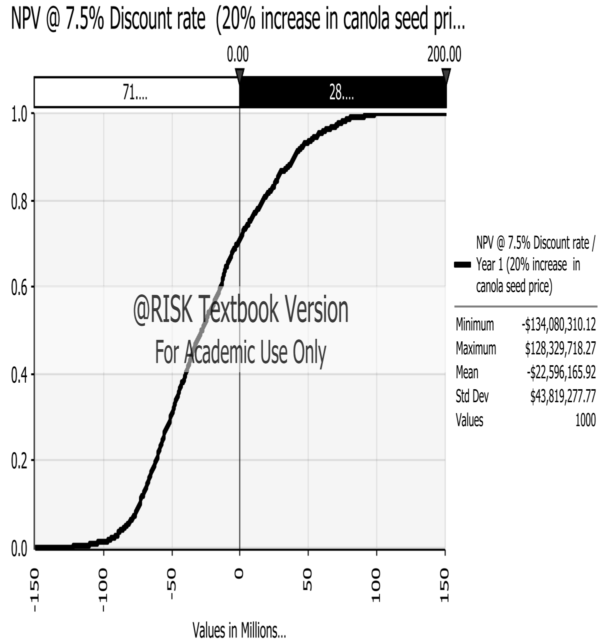
Appendix 1. Sensitivity Analysis of NPV to Changes in Canola Seed Prices (Pr NPV > 0)

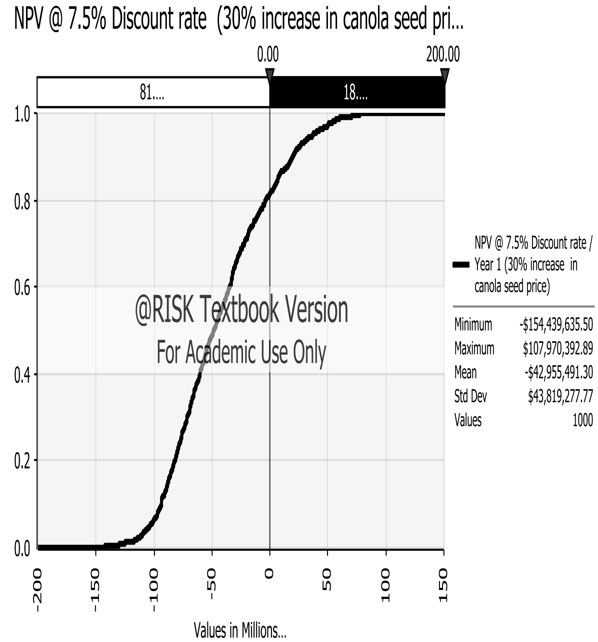




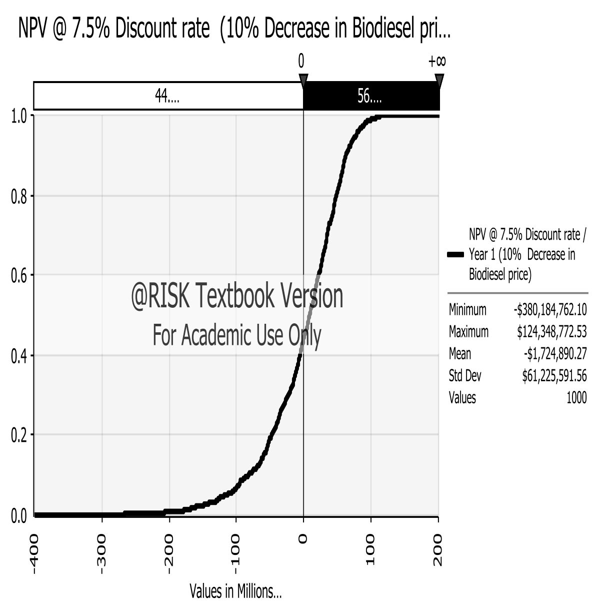


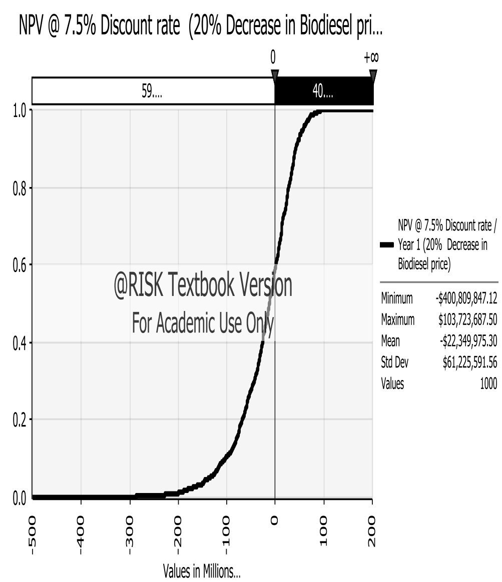


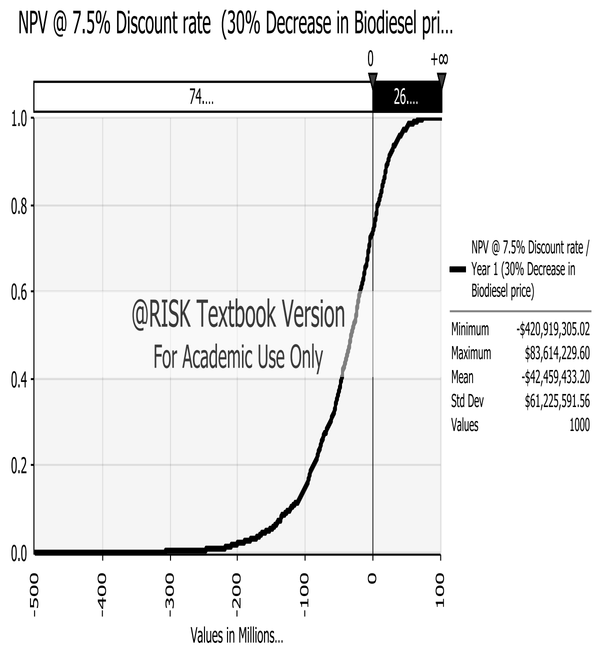




Appendix 2. Sensitivity Analysis of NPV to Changes in Biodiesel Prices (Pr NPV > 0)



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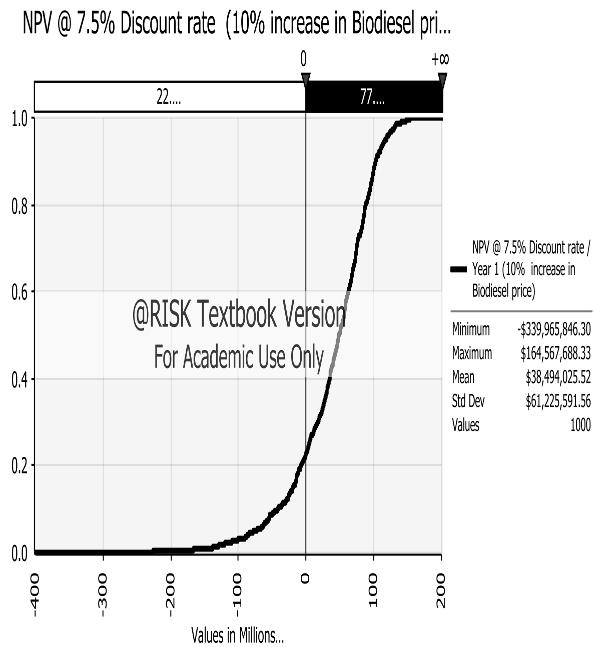
Values in Millions...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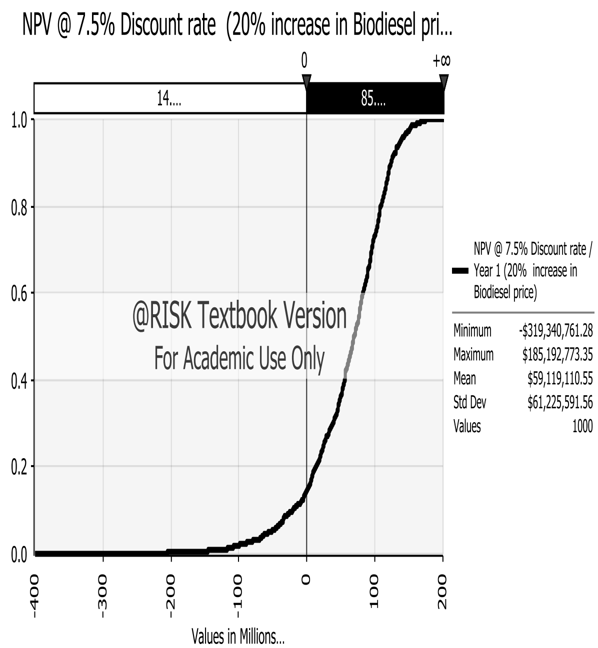
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Std Dev $61,225,591.56
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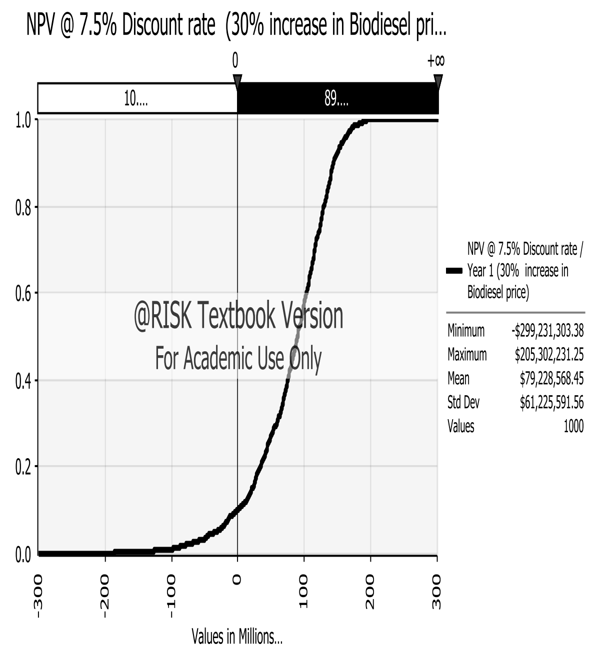
Values in Millions...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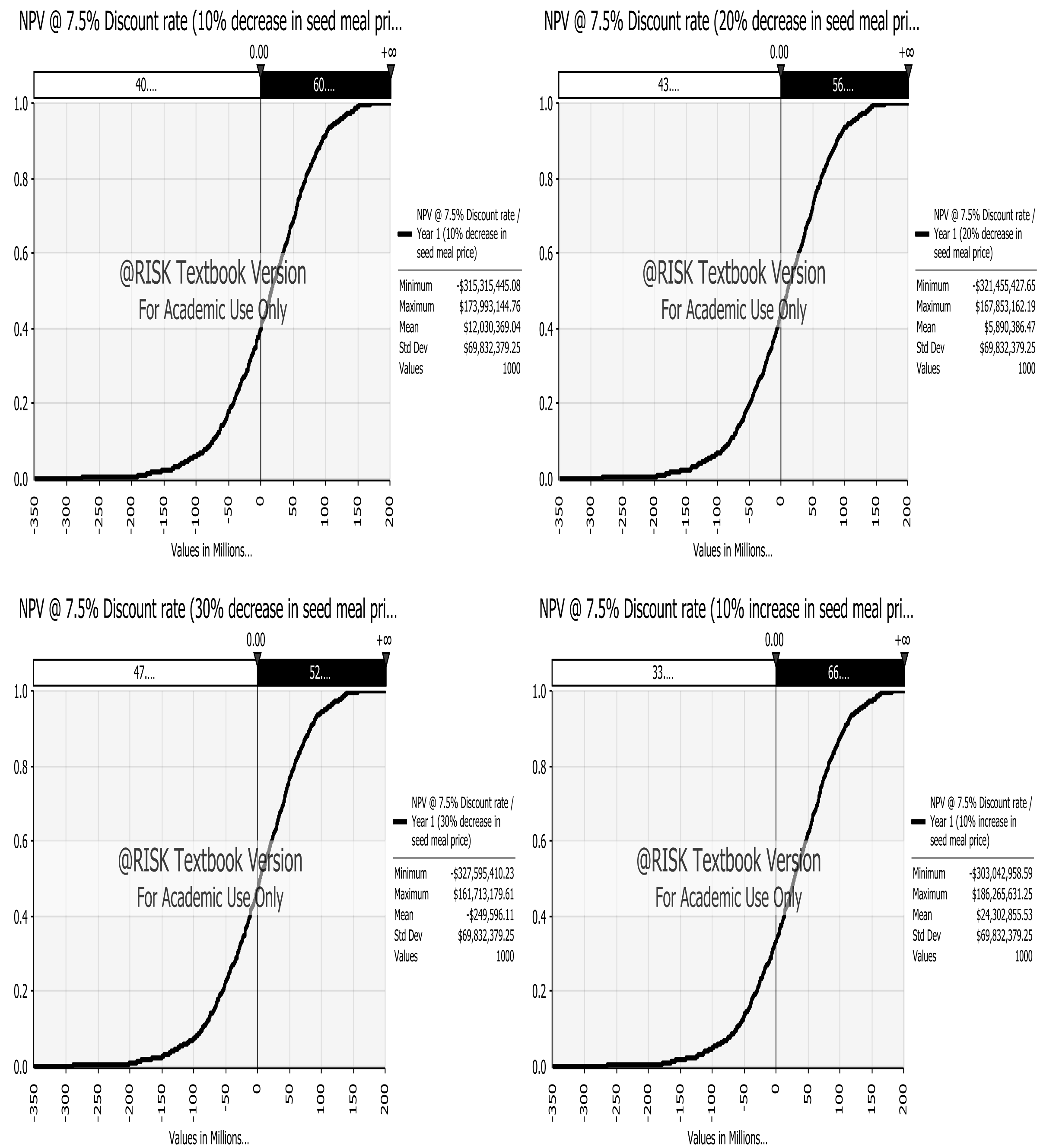
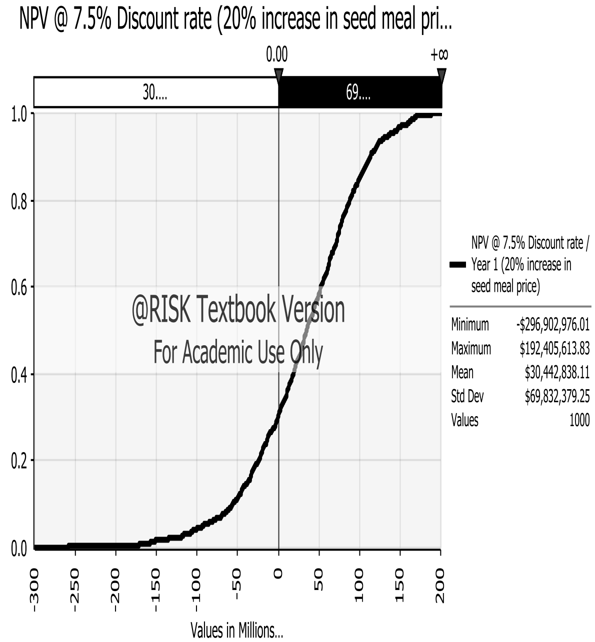
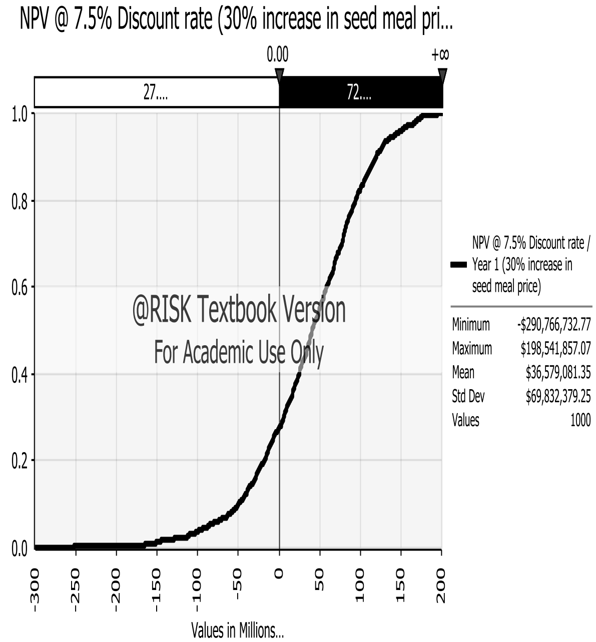
@RISK Textbook Version
For Academic Use Only
NPV @ 7.5% Discount rate / Year 1 (30% increase in Biodiesel price)
Minimum -$299,231,303.38
Maximum $205,302,231.25
Mean $79,228,568.45
Std Dev $61,225,591.56
Values 1000
Values in Millions...

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




NPV @ 7.5% Discount rate (20% increase in seed meal pri...
0.00
+∞
30....
69....
@RISK Textbook Version
For Academic Use Only
NPV @ 7.5% Discount rate / Year 1 (20% increase in seed meal price)
Minimum -$296,902,976.01
Maximum $192,405,613.83
Mean $30,442,838.11
Std Dev $69,832,379.25
Values 1000
Values in Millions...


NPV @ 7.5% Discount rate (30% increase in seed meal pri...
0.00
+∞
27....
72....
@RISK Textbook Version
For Academic Use Only
NPV @ 7.5% Discount rate / Year 1 (30% increase in seed meal price)
Minimum -$290,766,732.77
Maximum $198,541,857.07
Mean $36,579,081.35
Std Dev $69,832,379.25
Values 1000
Values in Millions...