FEASIBILITY OF ON-FARM PROCESSING OF CANOLA, SOYBEAN AND SUNFLOWER INTO BIODIESEL

By

ARJUN BASNET

Bachelor of Science in Agriculture

Tribhuvan University

Rampur, Nepal

2005

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 2009

FEASIBILITY OF ON-FARM PROCESSING OF

CANOLA, SOYBEAN AND SUNFLOWER

INTO BIODIESEL

Thesis Approved:

Dr. Phil Kenkel

Thesis Adviser

Dr. Rodney Holcomb

Dr. Damona Doye

Dr. A. Gordon Emslie

Dean of the Graduate College

ACKNOWLEDGEMENTS

I would like to thank Dr. Philip Kenkel, my thesis advisor for accepting me as a graduate research assistant during my hard times and allowing me to work on this project. Sincere thanks go to him for his guidance, encouragement and the valuable time that he has provided to me during the preparation of this thesis. I would also like to thank my committee members Dr. Damona Doye and Dr. Rodney Holcomb for their continuous support and advice during the thesis work.

I would also like to remember my parents and thank them for their continuous support and for the burden they took to raise my academic career. I would also like to thank my sisters for their love and encouragement. I cannot forget my grandfather at this moment, without whom, I would not have reached at this position. Thanks also go to my girlfriend who continuously supported, encouraged and guided me whenever needed. I would also like to thank all the Nepalese friends and families in Stillwater, Oklahoma who made my stay in Stillwater as home away from home. I would also like to thank all my friends in the Department of Agricultural Economics from whom I have learned a lot and thanks to them for creating a friendly atmosphere.

Last but not the least, many thanks go to the entire staff and faculty in the Department of Agricultural Economics whose hard work and effort made my study in Oklahoma State University a success.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Problem Statement

Diesel fuel is one of the significant inputs used by farmers to run different farm machineries for daily farm operations. Oklahoma State University Enterprise Budgets, 2009 indicate that fuel and lubrications expenses are $44.85/acre for wheat production, $75.77/acre for cotton production, $34.44/acre for corn production and $54.44/acre for annual forage crops and as a percent of total operating expenses, fuel represents an estimated 23-41% of the total for these crops. Although the price of diesel fuel has declined in recent months, the pattern of the price paid by farmers for diesel fuel from 1998 to 2008 suggests that the price of diesel fuel will continue to increase in coming years (USDA, 2008). According to USDA statistics the price paid by farmers for diesel fuel increased by 192% from April 2003 to April 2008. Fuel price increases are a source of risk for Oklahoma producers. Because fuel represents a large portion of crop operating expenses and a risk factor for Oklahoma producers, many producers are interested in the feasibility of producing biodiesel for on-farm use.

Many farmers are interested in moderating the risk of increasing fuel prices by growing and processing small to moderate amounts of canola, sunflower, or other oilseed crops. Several Oklahoma producers have purchased small oil-seed screw presses and have constructed small biodiesel production units. However, reliable information on the feasibility of on-farm biodiesel production using oil seed crops is still largely unavailable. Previous studies of on-farm biodiesel production (Kingwell and Plunket, 2006) are not applicable to Oklahoma's production environment. Thus, there is a need to evaluate the economic feasibility of on-farm oilseed processing and biodiesel production.

Objectives

The general objective of this research is to determine the economic feasibility of on-farm biodiesel production from canola, soybean and sunflower. The specific objectives are:

To analyze cost and returns of a baseline scenario which involved processing canola,

To perform similar analysis for scenarios involving other oilseed feedstocks,

To determine sensitivity of the profitability of the on-farm biodiesel production facility to the scale of operation and changes in prices for various input and output factors.

Rationale for On-farm Oil Processing

Oilseeds have a relatively low value as a raw commodity but when the seed is processed into oil and meal it adds value to the crop (Grubinger, 2007). Oil produced from various oilseed crops like canola, soybean or sunflower has been used by human beings for consumption for many years. The meal feed co-product produced from the oilseeds is used as a valuable source of feed to livestock. In recent years the oil is being used as a raw material to make biodiesel. According to Bachmann (2004) most oil processing in the U.S. is done on a large, industrial scale using proprietary processes. But in recent years, interest in farm-scale extraction technologies has increased which might be the result of rise in fuel and feed costs and increasing interest of producers in making biodiesel and feed from oilseeds (Stebbins, 2008).

Farmers are continually looking for value added opportunities. As the price of energy increased, they started exploring ways to cope up with the increasing cost. According to Kenkel and Holcomb (2008) oilseed crushing and biodiesel production are not technically complex and can be conducted at farm level. So, it is possible that farmers can make their own fuel from agricultural products or byproducts, including waste vegetable oil or virgin oil from crops that can be grown locally. There are several benefits of producing biodiesel on-farm. If the biodiesel is used on-farm it eliminates transportation and retailing costs for both the fuel and the feed co-products. The biodiesel produced on-farm can reduce the fuel costs required for operating farm machineries. The meal feed co-products produced from oilseed processing can be used in livestock operations or they can also be sold in the local markets. The farm infrastructure which is already in existence could be used as farm-scale oilseed processing/biodiesel production facility substantially reducing the production cost. If excess biodiesel is produced, it can be sold directly to end-users in the "off-road" market—for use in farm, construction, heating or running diesel generators without being subject to fuel taxes (Stebbins, 2008).

Despite the loss of scale economies, farm scale oilseed processing has some unique economic efficiencies. There is substantial variation in the local basis for oilseed crops. A producer's opportunity cost for diverting oilseed crops to a processing operation may therefore be substantially below the national or regional price level (Kenkel and Holcomb, 2008). On-farm processing also eliminates marketing and transportation costs and issues with low local basis. Beside all the economic benefits mentioned above, it is equally beneficial to rotate some acreage into oilseed crops from some agronomic standpoint. The crop rotation improves the soil nutrients, controls pest and disease and helps in increasing the crop yield.

Oilseed Crop Production

Oilseed crops are those crops grown primarily for the oil contained in their seeds. The most common oilseed crops are soybean, canola or rapeseed, sunflowers, flax, mustard, cottonseed, peanuts, and castor beans. This study will consider soybean, canola and sunflower as a major feedstock to be used for on-farm processing because these are the most important and common oilseed crops produced in the southern plains in the US. Table 1 summarizes the basic characteristics of these three oilseed crops.

Table I-1: Basic Characteristics of Soybean, Canola, and Sunflower

Attribute	**Soybean**	**Canola**	**Sunflower**
Pounds per bushel (Avg)	60	50	28–32
Bushels per ton (Avg)	33	40	62.5-71
Yield/acre	1–1.1 tons	0.85 tons	1–1.1 tons
	35–40 bushels	32–35 bushels	66–73 bushels
Oil content	13–18% oil	40% oil	39–49% oil
Oil yield/acre	48 gallons	127 gallons	102 gallons
Oil yield/bushel	1.5 gallons	2.8 gallons	1.7 gallons
Biodiesel/acre	56 gallons	70 gallons	70 gallons

(Source: Stebbins, 2008)

Soybeans are typically sold by the bushel while canola is sold by the ton and sunflower is sold by the hundredweight. The meal from all three crops is typically sold by the ton while the oil is sold by the pound.

Soybean

Soybean is one of the most important commodity crops grown widely in the upper midwest in the United States. This crop accounts for about 90 percent of the U.S. oilseed crop production (Ash, Livezey and Dohlman, 2006). Though the oil content in soybean is low compared to sunflower and canola, the meal from the soybean is an important end product. Soybean meal is by far the world's most important protein feed, accounting for nearly 65 percent of world protein feed supplies and about two thirds of total US consumption of vegetable oils is dominated by soybean oil (Ash, Livezey and Dohlman, 2006). Soybean has also the advantage of growing with little or no nitrogen which makes it advantageous for the production of biodiesel, reducing significant cost in fertilizers (Pimentel et al, 2005)

Canola

The history of producing canola dates back to 1970's when some Canadian plant breeders developed Canola from rapeseed. The aim was to remove the anti-nutritional components (erucic acid and glucosinolates) from rapeseed to assure its safety for human and animal consumption. So, "Canola" takes its name from "Can" (for Canada) and "ola" (for low oil acid). Now, canola is one of the largest agricultural commodities of Canada and the US is its largest customer importing approximately 500,000 tons of canola oil, 255,000 tons of seed, and 1.1 million tons of meal from Canada each year (Canola Council of Canada, 2007). Stebbins, 2008 reports that the canola seed contains about 40% oil while other study reports that the oil content ranges between 40-43%. The canola oil has a very low level of saturated fat, and the meal is processed into livestock feed which has low level of toxin glucosinolates.

Sunflower

Sunflower is an important agricultural crop choice for US producers in the northern plains in the Dakotas to the panhandle of Texas (National Sunflower Association, 2009). According to the Thomas Jefferson Agricultural Institute (2009), sunflower was not seen as a vegetable oil source in US until the last 50 years and its use as a vegetable oil really began about 25 years ago. The oil content in sunflower ranges from 39% to 49% depending on the varieties and about 90% of the sunflowers grown in the US are of oilseed type. The sunflower oil is considered as a premium oil because of its light color, high level of unsaturated fatty acids, and lack of linolenic acid, bland flavor, and high smoke points (Stebbins, 2008). The cake produced as a byproduct of processing sunflower is used as a livestock feed which has high fiber and is lower in lysine. The protein percentage of sunflower meal ranges from 28% for non-dehulled seeds to 42% for completely dehulled seeds (Putnam et al, 1990).

Oil Seed Crushing

Solvent extraction and mechanical methods are the two popular methods of oil seed processing in US and Canada. In solvent extraction, a chemical such as hexane is used to extract the oil. A high proportion of oil (up to 99%) can be removed by using chemicals but precautions are always needed because the solvent used for extraction is highly flammable. Solvent extraction is suitable for larger systems when large quantities of oilseed are processed. For on-farm and small scale processing, mechanical extraction is used. Mechanical extraction technologies include simple expellers (often called cold press), pre-heated expellers, and extruder-expellers systems (Kenkel and Holcomb, 2008). The cold press uses no external heat applied during the expeller pressing and it has a lower oil extraction rate. In preheated steam expellers, steam is used to heat the cracked seeds while the extruder-expeller systems uses heat supplied by friction in the extruder eliminating the need for steam generation equipment. The raised temperature in pre-heated and extruder-expeller systems increases oil extraction and deactivate the enzymes, destroy micro-organisms which improves the protein quality of the meal. The heated seeds are then processed in a continuous screw press to force the oil from the seed. The pre-heat expeller has a higher extraction rate compared to the cold press, but is impractical for on-farm processing due to the need for steam generation equipment.

In extruder-expeller systems, the oilseed is compressed to a high pressure using friction as a source of heat inside the extruder which is then processed to an expeller. The expeller has a screw which rotates inside a perforated cylindrical cage and is driven by a motor. The screw progressively compresses the material as it moves on towards the discharge end of the cylinder. The gradually increasing pressure in the screw releases the oil from a small outlet called the choke provided in the barrel. The cake continues to move in the direction of the screw towards a discharge gate installed at the other end of the expeller. The extruder-expeller also has an improved extraction rate relative to the cold press. Because the heat is generated from friction, it is self-contained and suitable for on-farm or small scale processing. In addition, because the seed is subject to heat for a very short duration of time, the quality of the residual meal is preserved. In large scale operations the crude oil produced from the extraction is usually degummed, refined or deodorized. This process removes the impurities contain in the crude oil such as lecithin, free fatty acids and undesirable, color and odor.

Biodiesel Production

Biodiesel can be produced by chemically combining several types of natural oils or fats with an alcohol to form alky-esters of fatty acids (Ryan, 2004). The most common production process for biodiesel is base catalyzed trans-esterification, a relatively simple process which has a conversion yield of around 98% (Kenkel and Holcomb, 2008). In the trans-esterification process, the vegetable oil or animal fat (triglyceride) is reacted with alcohol (methanol or ethanol) in the presence of a catalyst (sodium hydroxide or potassium hydroxide) to yield biodiesel (mono-alkyl esters) and glycerol. The alcohol reacts with the fatty acids to form the biodiesel (mono-alkyl esters) and crude glycerol.

The general conversion of feedstock (oil) to biodiesel is:

87% Oil+12% Alcohol+1% Catalyst ➔ 87% Biodiesel+9% Glycerine+4% Other residue

The biodiesel making process is not difficult to master and the equipment is relatively affordable to use (Stebbins, 2008) and therefore, biodiesel can be produced in small batches for on-farm use. The system can be customized or a ready-made biodiesel processor can be purchased. The basic elements in a biodiesel processor are different sized tanks which are linked by piping, pumps, and valves. The tanks are used for producing and settling the biodiesel, mixing the methanol, and storing oil, glycerine, and finished biodiesel. Heating elements are sometimes included, and the system often includes electrical controls and switches. Other miscellaneous items include a filtration system to remove impurities from the finished product, safety equipments, spare part kits and titration supplies etc.

The first step in the biodiesel production process is to mix the alcohol and the catalyst in a tank. In another tank (reactor vessel), the oil is added using pumps. At the same time, the mixture of alcohol and catalyst is agitated and then transferred to the closed reactor vessel or processing tank. The temperature of the reaction mix is kept just above the boiling point of the alcohol (around 160°F) to speed up the reaction and the system is totally closed to the atmosphere to prevent the loss of alcohol (Kenkel and Holcomb, 2008). The results of the reaction are the production of glycerine and biodiesel as shown in the above equation. Since both these products are in the same vessel, the next step is to separate them which can be done by using gravity as these products differ in their densities. After separating biodiesel from glycerin, the biodiesel is gently washed with warm water to remove any remaining residuals (catalyst or soaps). After washing it is dried and then sent to storage for further use. Glycerine is the impure commercial product and glycerol is the pure chemical element which indicates that it is an alcohol. Glycerine is used in making soap, beauty products, pharmaceuticals and others. Kenkel and Holcomb, 2008 emphasize that prior to use as a commercial fuel, the finished biodiesel must be analyzed using sophisticated analytical equipment to ensure that it meets any required specifications.

Figure I-1. Flowchart of an Oilseed Crusher and a Biodiesel Processor

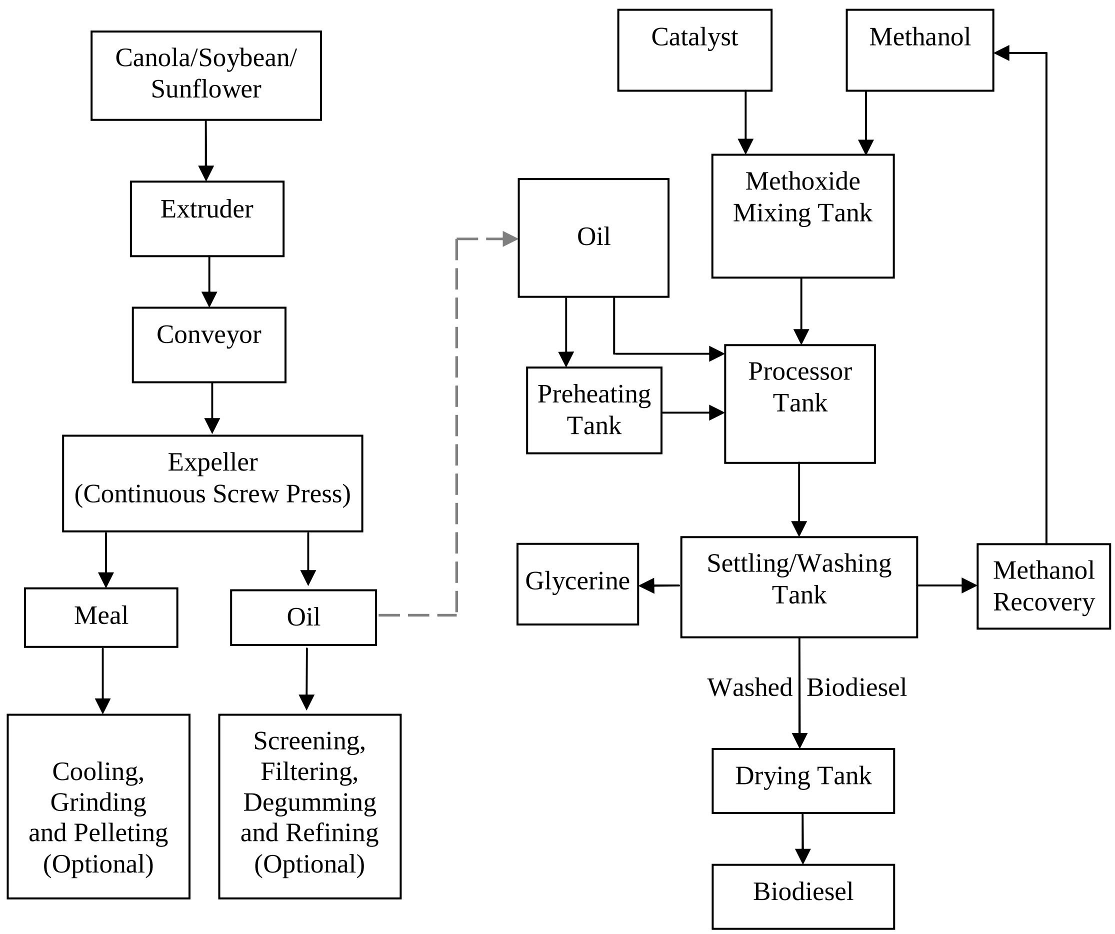


Figure: Oilseed Crusher
(Kenkel and Holcomb, 2006)

Figure: Typical Biodiesel Processor

Description of a Typical On-farm Processing System

Biodiesel can be produced on a larger scale (cooperative scale) for commercial purposes or on a smaller scale for private use. Biodiesel produced on-farm can be used for farm purposes or, if additional regulatory and quality control steps are undertaken, could be sold outside the farm. The on-farm production system generally uses oil produced from the farm to make biodiesel. Sometimes outside oil can be purchased when demand arises. An on-farm biodiesel production system would typically be housed on-farm in an existing building that could include both the oil processing unit and the biodiesel processor. An on-farm biodiesel production system would typically use straight vegetable oil extracted from oilseeds like canola, soybean and sunflower. Based on the scale of production, the on-farm biodiesel processing facility can be classified as-small scale, medium scale or community scale. Several manufacturers are available in the markets who sell different sized screw presses and biodiesel processors. Unlike the commercial biodiesel production, a small-scale biodiesel producer will not use some of the equipment and steps involved in large, commercial biodiesel production system because of the costs and scale of operation.

Oilseed Crusher (Extruder and Expeller)

Different capacities of extruders and expellers are available in the market. This study uses two different combinations of extruders and expellers: one with the smaller capacity which can crush 0.3 ton of oilseeds in one hour and the other with the larger capacity which can crush 1 ton of oilseed in one hour. The energy consumption for the smaller capacity crusher is 50 HP for the extruder and 12 HP for the expeller. Similarly, the energy consumption for the larger capacity crusher is 125 HP for the extruder and 30 HP for the expeller. The heat which is generated inside the extruder through friction cooks, sterilizes, stabilizes, texturizes, and dehydrates the products (InstaPro, 2009). The extruded material in meal form is then transferred to the horizontal press through an inclined conveyor as shown in the diagram below. Inside the extruder barrel, the cells are ruptured, including the oil cells because of the shear, temperature, and pressure, which allows for better and more efficient separation of the oil from the horizontal screw press (Insta-Pro, 2009).

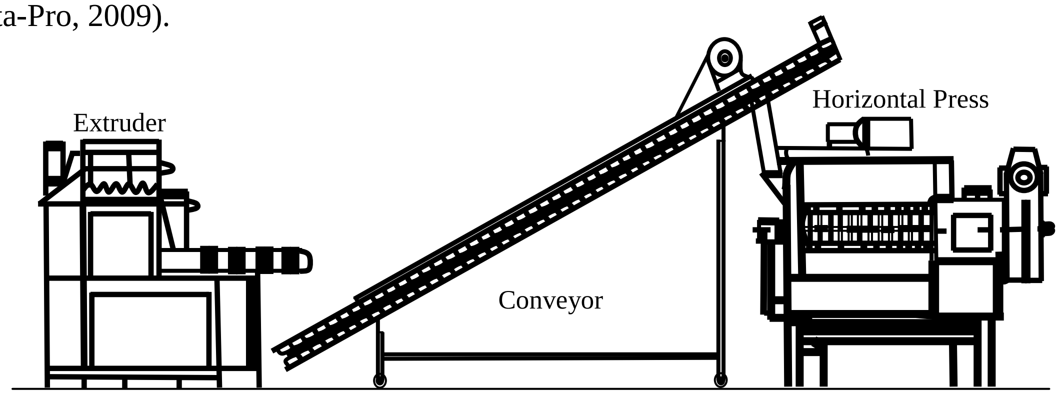


Figure I-2. Diagram of an Oilseed Crusher

Biodiesel Processor

Early producers attempted to make their own biodiesel processing facility by combining their own tanks, pipes and others. In recent years integrated biodiesel processors have been developed with turnkey operations. These biodiesel processors produce biodiesel from refined or pre-processed or raw vegetable oil. It includes several tanks: settling/washing tanks, processing tank, methoxide mixing tank, optional preheating tank or drying tank and pipes and fittings. The whole system comes in one set and is therefore called integrated. The biodiesel processor comes in different sizes and capacities. It has several pipes and fittings, control panel, digital temperature monitoring, ball valves, water wash system, processor pump, fuel filter and fuel polishing system, etc.

The oil is brought to the processing tank using the pump. Then the oil is heated using the inline heater & heating pump. At the same time, methoxide can be mixed while the oil is being heated. After heating the oil, methoxide is added to the oil in the processing tank and it is allowed to run. Then the biodiesel is transferred to the first settling and washing tank after the first batch finishes. Then another batch is started in the processing tank and sent to the settling and washing tank. The same process is continued until all settling/washing tanks have been filled. One more batch can also be processed and left in the processor to settle and be washed in the processing tank as the processor is also plumbed to settle and wash the biodiesel. After some hours, the biodiesel can be drained off the glycerine and then washed and dried. The whole process may take some time depending on how many hours a day it is attended to. After that, another batch can be started. Generally, one batch is completely reacted, washed, and dried in about 2-3 days but it depends on the size of the processor.

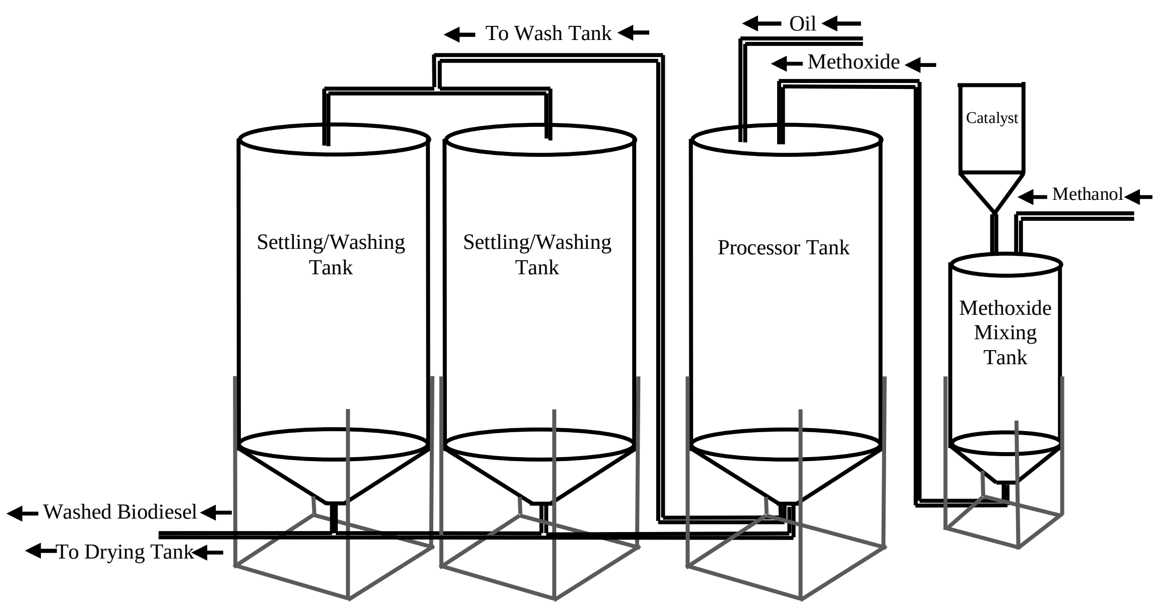


Figure I-3. Diagram of an Integrated Biodiesel Processor

Biodiesel Production Facilities

In this study, the on-farm biodiesel production facilities have been classified into three scales based on their production capacities. The purpose of this classification is to project the cost and returns for three different scales. The details for each of the scales are discussed below:

Small Scale

This system will make approximately 55,000 gallons of biodiesel annually. The capacity of press for this production facility is 0.3 tons per hour or 600 lbs per hour and the capacity of the biodiesel processor is 24 gallons per hour. Other equipment required in this production facility is almost the same as in other production facilities, only their capacities and the energy requirements vary.

Medium Scale

The capacity of press (oilseed crusher) for this production facility is almost twice the capacity of the small scale, i.e. 0.6 tons per hour or 1200 lbs per hour. The integrated biodiesel processor has the capacity to make 55 gallons of biodiesel in one hour and therefore, it will make approximately 125,000 gallons of biodiesel annually. The cost of equipment will be higher for this production facility than the equipment in the smaller scale.

Cooperative Scale

The capacity of press for the cooperative scale is 1 ton per hour or 2000 lbs per hour and the capacity of the integrated biodiesel processor is 110 gallons of biodiesel per hour. So, its annual production capacity is approximately 250,000 gallons. More labor may be required for this production facility as compared to the other production facilities and the cost of equipment is also higher. The cooperative scale is considered as the baseline equipment size and is used in most of the estimations.

CHAPTER II

REVIEW OF LITERATURE

Biodiesel is a name given to a fuel that is comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats (National Biodiesel Board, 2007). According to Esclaera et al, 2008, the U.S. consumes about 20.5 million barrels of petroleum fuels every day, 60% of which is imported from foreign sectors. Although biodiesel is an alternative to diesel fuel, it is not a complete solution to the current problems; instead, it is one of the ways to offset demand for fossil fuels while making use of locally produced resources (Haase et al, 2004).

Several previous studies have computed the economic feasibilities of biodiesel production ranging from oilseed crops (English et al, 2002; VenWechel et al 2002; Bender, 1999), fish oil (Sustainable Community Enterprises, 2008) to algae (Putt, 2007). Most of the feasibility studies have been done for larger/commercial scale (English et al, 2002; Frazier Barnes and Associates, 2003, VenWechel et al, 2002) and very few studies are done for smaller or on-farm scale (Bender, 1999; Haase et al, 2004; Whittington, 2006). To project the economic feasibilities, different methodologies have been employed. The most commonly used methods are the capital budgeting methods which make use of spreadsheets to project the costs and returns.

Previous Feasibility Studies of Biodiesel Production

Large level extensive financial projections have been done for establishing biodiesel production facility at various regional levels. English et al (2002) and Frazier Barnes and Associates (2003) performed a pro forma financial projections for an industrial level (13 million gallons per year) standalone and integrated biodiesel production facility in Tennessee and Mississippi respectively over a ten-year period using soybean as a feedstock. According to English et al (2002), for a stand-alone facility, the estimated internal rate of return (IRR) was 36% for baseline scenario, 103% for the best case scenario and negative for the worst case scenario. The estimated IRR for an integrated facility was 25% for baseline scenario, 108% for best scenario and negative for worst scenario. The relevant prices for the best and worst case scenarios were calculated by adjusting by their historical coefficients of variation. In the worst case scenarios tax credits were removed. All the estimations were made for a ten year period. They concluded that 10-15 million gallons per year biodiesel production facility is most efficient. Frazier Barnes and Associates (2003) used feasibility level pro forma financial projections for a ten year period for a stand-alone biodiesel plant and an integrated processing facility. The result indicated that with federal subsidy stand-alone plant had positive NPV and 20% IRR and with no federal subsidy it had negative NPV and negative IRR. The integrated processing facility with federal subsidy had positive NPV and 31% IRR and with no federal subsidy it had positive NPV and 21% IRR.

VanWechel et al (2002) evaluated the feasibility of establishing a standalone biodiesel production facility in North Dakota for a 5 million gallon per year biodiesel production facility using annual production costs. The expenses and revenues estimated in this study were derived from a variety of sources which were based on a compilation of industry data and contacts with producers. The cost per gallon of biodiesel was estimated to be $2.64 for a plant located in southeastern North Dakota and assuming a soybean oil price of 25 cents/gal. The authors report that this price is expensive when compared to the wholesale price of regular diesel in the Fargo area, which was $0.91 in late 2002.

Small Scale and On-Farm Production

In 1999, Bender reviewed 12 community-scale farmer cooperatives to examine economic feasibility of biodiesel production on a smaller scale. The results showed that the projected costs for biodiesel or animal fats were in a range of $1.13 to $2.60 per gallon which included meals and glycerine credits and assumption of reduced capital costs by having crushing/esterification facility added to an existing grain or tallow facility. When compared to the U.S. price for pre-tax biodiesel of $0.68/gallon in 1994, he concluded that biodiesel was not economically feasible as this price was not economically competitive with highway diesel. The study indicated that the costs for capital and operation for canola and sunflower are lower than for soybean, mainly due to the lower capacity needed for the extruder and oilseed press. The lower press capacity related to the higher oil content of canola and sunflowers which has on average 40% oil content relative to soybeans which has on average only 20% oil content. Bender emphasizes that biodiesel cooperatives can be successful when both crop and livestock are diversified, especially in regions where a large spreads exists between the price that farmers receive for their oilseed and the price they pay for protein meal.

In 2004, Haase et al examined the economic viability of building and producing biodiesel using a small-scale production system for a batch size of approximately 40 US gallons. The author pointed out several advantages of a small scale production process. The point of production is nearer to the point of consumption which enables it to be more efficient from an energy standpoint, it can be initiated with relatively low start-up cost that is within the reach of many diesel fuel consumers and it can be tailored to the size of the demand by building in flexibility and modularity. The system described by Haase et al used waste cooking oil and fat obtained from several restaurants and a university cafeteria as a feedstock which was considered free of cost. Many of the materials used were obtained from salvaged or surplus items greatly reducing the overall implementation cost. The authors did not provide rate of return data on the small scale biodiesel production because of the difficulties encountered in the production of ethyl esters in their study. However, they have reported that if estimates are correct and the procedure can be optimized, it is reasonable to assume that biodiesel can be produced in a small scale setting for approximately the same cost as buying petroleum based diesel. The estimated value per gallon of biodiesel was $1.63 per gallon which the author report is close to the average consumer price of diesel fuel from 02/02/04 to 05/10/04 of $1.60 per gallon.

In 2006, Whittington performed an economic evaluation of a farm based biodiesel plant in Australia using canola as a feedstock. He estimated simple budgets for 5,000 L (1,322 gal) batch processor with annual production of 40,000 L (10,582 gal) using canola grown on the farm but contract crushed by a commercial processor. The author indicated that the cost of capital would vary widely depending on what existing infrastructure is used, how much biodiesel is produced and how much oilseed is crushed on-farm, versus the same task done by a contractor where a fee per liter is charged but requires less capital outlay. Based on the reported costs and his investigations, the final cost to produce biodiesel in small plants was $1.43/L or $5.40/gal. Finally, he points out that it is critical to ensure that biodiesel is a cost effective alternative to mineral diesel.

In 2006, Sexton et al conducted a Pilot Production of Biodiesel from Canola in New England with a plant capacity which processed 18 tons per day and a small batch system biodiesel processor which processed 189 liters (49 gallon) per batch. A simple budget was created and they estimated the total capital cost of $1,010,000 and an interest expense assumption of $75,000 which would be repaid over an 8 year period at an interest rate of 8%. The final cost per gallon of canola oil was estimated to be $2.31 and the breakeven cost per gallon of biodiesel was estimated to be $3.07.

In 2007, Nowatzki et al conducted an economic analysis for a batch size of approximately 50 gallons. In their analysis they assumed that the on-farm small scale biodiesel producer already has storage and moving equipment for oilseed and they have a building to house the oilseed press and biodiesel processing equipment. They did not calculate fixed costs for these items and no cost or benefit from the unrefined glycerol byproduct was assumed. They estimated the cost for oilseed press, biodiesel processor and other associated equipment to be $13,000 and created a simple budget. From their analysis the cost of making biodiesel per gallon was $3.77 which was $1.37 more per gallon than the price of No. 2 petroleum diesel if diesel was valued at $2.40/gallon (excluding excise taxes). They say that biodiesel production would become profitable at certain levels of oilseed and diesel prices. For example, biodiesel production would break even at a canola price of $1.05 per pound if the price of diesel (excluding excise taxes) was $3.0 per gallon. When both the fixed costs and the costs for labor are excluded, the direct cost for producing biodiesel would be $2.89 which is still greater than the price of No.2 diesel purchased at that time.

Similarly in year 2007, Grubinger conducted a study for on-farm oil seed production and processing at the University of Vermont. He estimated both the cost of cultivating oilseeds and processing them into biodiesel. The estimated average net return for producing either canola or sunflower would be $250/acre prior to making biodiesel. The estimated total cost per gallon of biodiesel would be $3 for a plant size of 25,000 gallons per year, $2.6 for a plant size of 50,000 gallons per year and $2.48 for a plant size of 100,000 gallons per year.

In 2008, Jaeger and Siegel conducted a study on the economics of oilseed crops and their biodiesel potential in Oregon's Willamette Valley. They evaluated in detail the costs and returns from feedstock production, oilseed crushing, and biodiesel processing. When government subsidies were omitted, they estimated the cost of biodiesel per gallon to be $6.84 for winter canola and when federal and state subsidies were included, they estimated additional revenue of $2.30 to $3.10/gallon. They however say that only for winter canola and only if it were grown and processed on a large scale would subsidies achieve a breakeven point. In their study, they show that the cost per gallon for small-scale crushing and processing are significantly higher than for larger operations. They say that the cost per gallon would be $1 higher for a processing facility at or below 0.5 million gallons/year than for operations of 5 or 10 million gallons/year.

The cost of biodiesel reported by most of the authors exceeds the retail prices of diesel fuel compared to the study year except the one reported by Hasse et al (2004). The lower cost reported by them may be due to the feedstock and the materials they used. Their feedstock was waste grease and oil which they obtained free of cost from restaurants and cafeteria. Similarly, many of the materials they used were obtained from salvaged or surplus items greatly reducing the implementation cost. Though most of the studies discussed here report that biodiesel is not economically feasible, it is important to note as mentioned by Dagher et al (2003) that biodiesel production from animal fats or grease can be feasible for a smaller plant size when it is located within a 50 mile radius of the feedstock.

CHAPTER III

METHODOLOGY

Baseline Model Assumption

The baseline model includes several assumptions which are discussed in detail in the following sub-headings.

Capital Investment

The plant property and equipment was assumed to be financed with 50% debt and 50% owner equity. Debt financing was assumed to be in the form of a 10 year loan at 7.5% annual interest rate. Start up and contingency expenses were assumed to be 20% of the total cost of plant, property and equipment (PPE). A short term loan (working capital) of $100,000 plus 2% of annual sales at an annual interest rate of 7.5% was assumed for medium and cooperative scale but for small scale a working capital of only 2% of annual sales was assumed. The working capital requirements were based on the need to finance feedstock purchases and cover operating expenses for the period of time between the initiating of seasonal operations and the receipt of income from biodiesel sales. This assumption likely over estimates the working capital requirements for a farm scale operation where the producer would be providing the oilseed feedstock. Property tax was assumed to be 0.5% of the total cost of plant, property and equipment (PPE). The land value was not considered. The percentage of payroll tax to salaries was assumed to be 5%

of salary expense, and the percentage of retirement tax to salaries was assumed to be 15% of salary expense. State tax credit was assumed to be $0.20/gallon for the first five years and federal tax credit was assumed to be $0.10/gallon only for the first year of production. Insurance was estimated to be 1% of total plant, property and equipment (PPE). Inflation for expense factor and final products was estimated at 1%. Ten percent discount rate was used for net present value (NPV) calculation. No trucking cost was assumed although the template has the option to calculate the trucking expenses.

Table III-1: Summary of Capital Investment

Particulars	Small Scale	Medium Scale	Cooperative Scale
Total Installed Plant and Equipment	$ 111,423	$ 216,556	$ 297,439
Plant Capacity	0.3 ton hour oilseed crusher and 24 gal/hour biodiesel processor	0.6 ton hour oilseed crusher and 55 gal/hour biodiesel processor	1 ton hour oilseed crusher and 110 gal/hour biodiesel processor
Start up and Contingency	20% of PPE	20% of PPE	20% of PPE
Working Capital	2% of annual sales with short term interest rate of 7.5%	$100,000 plus 2% of annual sales with short term interest rate of 7.5%	$100,000 plus 2% of annual sales with short term interest rate of 7.5%
Debt	50% at 7.5% interest rate for 10 years	50% at 7.5% interest rate for 10 years	50% at 7.5% interest rate for 10 years
Property Tax	0.50% of PPE	0.50% of PPE	0.50% of PPE
Inflation Rate	1%	1%	1%
Discount Rate	10%	10%	10%

Feedstocks and Crop Mix

Canola, soybean and sunflower were considered as the major feedstock of the facilities. Because it is impossible to perfectly match the output of a complement of oilseed crushing equipment with a complement of biodiesel production equipment, some additional oil was assumed to be purchased to maintain the selected biodiesel plant at full capacity. Five different input combinations of feedstocks were analyzed for sensitivity analysis. These included 100% canola, 100% soybean, 100% sunflower, a blend of 50% soybean and 50% canola, and a blend of 50% canola and 50% sunflower. A blend of 50%-50% scenario was used considering that the production systems involving both winter and summer oilseed crops could be attractive to some producers as they spread the harvest window and reduce the need for storage. Feasibility measures and sensitivity analysis are compared for each scenario. The baseline yield for canola, soybean and sunflower was assumed to be 2000 lbs/acre (20cwt), 1272 lbs/acre (21.2 bushel) and 1500 lbs/acre respectively based on the Oklahoma State University enterprise budgets, 2009. The yields are taken for Major County, Oklahoma. The baseline oil content of canola is assumed to be 38.22% which is based on the average value of the oil content for Enid, Goodwell, Perkins and Tipton, Oklahoma as presented in "2008 National Winter Canola Variety Trial Report". The oil content of soybean is assumed to be 18.7% which is based on the average value of soybean oil content from 1986 to 2008 for U.S. as reported in "2008 U.S. Soybean Quality Report". The oil content of sunflower is assumed to be 43.6% which is based on the "2008 U.S. Sunflower Crop Quality Report". Canola is considered as the baseline crop and is used for most of the estimations.

Table III-2: Summary of Baseline Crop Yield and Oil Content

Crop	Yield	Oil Content
Canola	2000 lbs/acre (20 cwt)	38.2%
Soybean	1272 lbs/acre (21.2 bushel)	18.7%
Sunflower	1500 lbs/acre	43.6%

(Canola is the baseline crop)

Raw Materials and Final Product Prices

Farm gate values for oilseed crops, meal and additional vegetable oil purchases would vary with local conditions. For the purpose of the baseline scenarios seed, meal and oil prices for canola, soybean and sunflower were obtained from the USDA's Oil Crops Outlook Handbook (2009) and it was averaged from October 2008 to March 2009 to obtain the most recent values. Canola grain price was calculated to be $17.40/cwt or about $0.16/lb, soybean grain price was calculated to be $9.53/bu. or $0.17/lb, and sunflower grain price was calculated to be $23.69/cwt or $0.24/lb. The meal price for canola was calculated to be $232.34/ton, for soybean it was calculated to be $282.13/ton, and for sunflower it was calculated to be $153.11/ton respectively. Excess oil from the crushing operation was valued at $0.38/lb for canola, $0.31/lb for soybean, and $0.49/lb for sunflower. Biodiesel can be manufactured from a variety of vegetable and animal oil feedstocks and many oilseed crushing/biodiesel operations supplement their oil supply with the most cost effective feedstock. The price of additional oil feedstock purchased was assumed to be $1.80/gallon ($0.23/lb). The additional oil feedstock was not intended to reflect a particular product but rather represent a producer's opportunity to complement farm produced oilseed with feedstocks available in their local area. In some market environments, oilseed producers are able to purchase lower cost oil feedstocks such as animal fats, to supplement their on-farm production and decrease their total feedstock costs. The price of biodiesel sold or value of biodiesel purchases replaced with the on-farm production was assumed to be $3.50 per gallon. For point of reference the long term (2006-2030) price forecast for diesel fuel prepared by the U.S. Energy Information Administration (2009) indicates an average price of $3.30/gallon and the current biodiesel price according to U.S. Department of Energy is $3.08/gal as of July, 2009. The price of methanol was assumed to be $5.80 per gallon, the price of sodium hydroxide (NaOH) was assumed to be $2.99/lb and the price of glycerine was assumed to be $0.19/lb.

Table III-3: Summary of Baseline Price or Cost Assumptions

Consumables	**Price/Cost**
Biodiesel Price (gal)	$3.50
Glycerine Price (lb)	$0.19
Methanol Price (gal)	$5.80
NaOH Price (lb)	$2.99
Soybean Oil Price (lb)	$0.31
Canola Oil Price (lb)	$0.38
Sunflower Oil Price (lb)	$0.49
Additional Oil Price (lb)	$1.80
Soybeans Meal Price (ton)	$282.13
Canola Meal Price (ton)	$232.34
Sunflowers Meal Price (ton)	$153.11

Utilities

The cost for electricity was assumed to be $0.11/KW. Similarly, the natural gas cost and water was assumed to be $1.2/CCF and $2.00/1000 gallons respectively. The cost of telephone was estimated to be $2000 per year. The costs assumed are consistent with the regional cost level (U.S. Energy Information Administration, 2009). Five percent maintenance cost was estimated as a percentage of total plant, property, and equipment. The table presented below shows a summary of the baseline cost assumptions for utilities used in the models.

Table III-4: Summary of Utility Cost Assumptions

Utility	Cost
Natural Gas Cost/CCF	$1.20
Electricity Cost/KW	$0.11
Water Cost (Per 1000 gallon)	$2.00

Production Facilities

The study is based on three different on-farm biodiesel production facilities and was classified as small scale (approx. 55,000 gallons), medium scale (approx. 125,000 gallons) and cooperative scale (approx. 250,000 gallons). Details on each of the production facilities have already been explained in the introductory section.

A comparative study of each of these three production facilities are provided in the tables that follow:

Annual Production Capacities of the Oilseed Crusher and Biodiesel Processor

Table III-5 shows the capacities of each of the production facilities, tons of oilseed they can crush, oil produced, extra oil required and biodiesel produced. The calculations assume canola as the feedstock for this example. For modeling purposes one employee is assumed for the operation with some input from the farm manager. In practice, it is likely that producers may hire two more part time workers. The extraction efficiency of the oilseed crusher is assumed to be 80% with an uptime percentage of 95.

Table III-5: Summary of Annual Production Capacities

Categories of the System	Oilseed Crushed (Tons)	Oil Produced (Gallons)	Oil Purchased (Gallons)	Excess Oil Produced (Gallons)	Biodiesel Produced (Gallons)
Small Scale	855	68,108	0	13,388	54,720
Medium Scale	1,710	136,216	0	10,816	125,400
Cooperative Scale	2,850	227,027	23,773	0	250,800

(Estimated for canola)

The capacity of the oilseed crusher for small scale production facility as shown in the table above is 0.3 ton/hr and it can crush 855 tons of oilseeds in one year producing 68,108 gal of oil when it is operated 10 hours per day and 300 days per year. The capacity of the biodiesel processor for small scale production facility is 24 gal of biodiesel in one hour. So, if this processor is operated 8 hours per day and 300 days per year, it would produce 54,720 gal of biodiesel. Considering this fact, the biodiesel processor will not use all the oil produced by the oilseed crusher and there would be an excess oil of 13,338 gal of oil.

The medium scale uses 2 oilseed crushers each with a capacity of 0.3 ton/hr. Therefore, it will require 1,710 tons of oilseeds and would produce 136,216 gal of oil. The capacity of the biodiesel processor for this facility is 55 gal of biodiesel in one hour. So, if it is operated 300 days a year and 8 hours a day, it will produce 125,400 gal of biodiesel. This processor will not utilize all the oil produced by the oilseed crusher and therefore there would be an excess oil of 10,816 gal of oil.

The cooperative scale is the largest of the system modeled in this study. It has an oilseed crusher with a processing capacity of 1 ton/hr. When it is operated in its fullest capacity and according to our baseline assumption of 10 hours per day and 300 days per year it will require 2,850 tons of oilseeds and would produce 227,027 gal of oil. The biodiesel processor for this system processes 110 gal of biodiesel in one hour and would make 250,800 gal of biodiesel. The oil produced by the oilseed crusher does not meet the full feedstock requirement for the biodiesel processor if it is operated in its fullest capacity of 8 hours per day and 300 days per year. So, it will require 23,773 gal of additional supplemental oil.

Acres Required for Full Capacity of Oilseed Crusher

Table III-6 summarizes different acres of land needed to be grown for each of the production facilities with different combinations of the feedstocks. The extraction efficiency of the oilseed crusher is assumed to be 80% with an uptime percentage of 95.

Table III-6: Summary of Acres Required for Full Capacity of Oilseed Crusher

Categories of the System	Acres to be grown				
	100 % Canola	100% Soybean	100 % Sunflower	50% Canola 50% Soybean	50% Canola 50% Sunflower
Small Scale	855	1,344	1,140	1,099	997
Medium Scale	1,710	2,688	2,280	2,199	1,995
Coop. Scale	2,850	4,481	3,800	3,665	3,325

For 100% crushing scenarios and all three production facilities, more acres are required for soybean crushed scenario and less acres are required for canola crushed scenario. For 50%-50% crushing scenarios and for all three production facilities, more acres are required for soybean and canola scenario and less acres are required in the canola and sunflower scenario. This is because of the variation in the oil content in those oilseeds. Soybean bears less oil than canola and canola bears less oil than sunflower.

Summary of Production Costs

The table presented below presents a summary of producing oilseed crops per acre, the cost of oilseed produced per lb and the cost of oil extracted per lb. This is calculated for 100% canola scenario, 100% soybean scenario and 100% sunflower scenario.

Table III-7: Summary of Production Cost Per Acre and Cost Per Lb

Cost of Production	Oilseed Crop Scenarios		
	100% Canola	100% Soybean	100% Sunflower
Crop production cost	$214.89/acre	$118.38/acre	$169.12/acre
Cost of oilseed produced	$0.10/lb	$0.09/lb	$0.11/lb
Cost of oil extracted	$0.35/lb	$0.67/lb	$0.35/lb

The crop production cost per acre is based on the cost estimation for individual crops by Oklahoma State University Enterprise Budgets, 2009. The cost of oilseed per lbs is estimated by dividing the total cost of production by the total quantity of oilseed produced. The cost of oil extracted is estimated by dividing the total cost of production by the total quantity of oil extracted from the oilseed crusher. The extraction efficiency of oilseed crusher in this study is assumed to be 80% and is same for all the crops.

Summary of Equipment Costs

The table presented below shows the list of all the equipments which are required for three different production facilities along with their cost estimations. The integrated biodiesel processor includes settling/washing tanks, processing tanks, methoxide mixing tank and pipes and fittings which are not shown in the table. Additional equipment if required can be added in the miscellaneous section. The costs of equipment presented in the table are based on the review of price quotes from several manufacturers of oilseed crushers and biodiesel processors. The pre cleaner was assumed to be used only for cooperative scale. The storage bins were assumed to store grains (oilseeds) for 2 weeks. The oil storage tanks and biodiesel storage tanks have the capacity to store oil and biodiesel for 1-1.5 months. Meal storage tanks have the capacity to store meal for 1-2 weeks and glycerine storage tanks have storage capacity of 1-2 months. Beside the cost of the equipments and other required accessories, ten percent of the total cost of equipment is added for installation and freight.

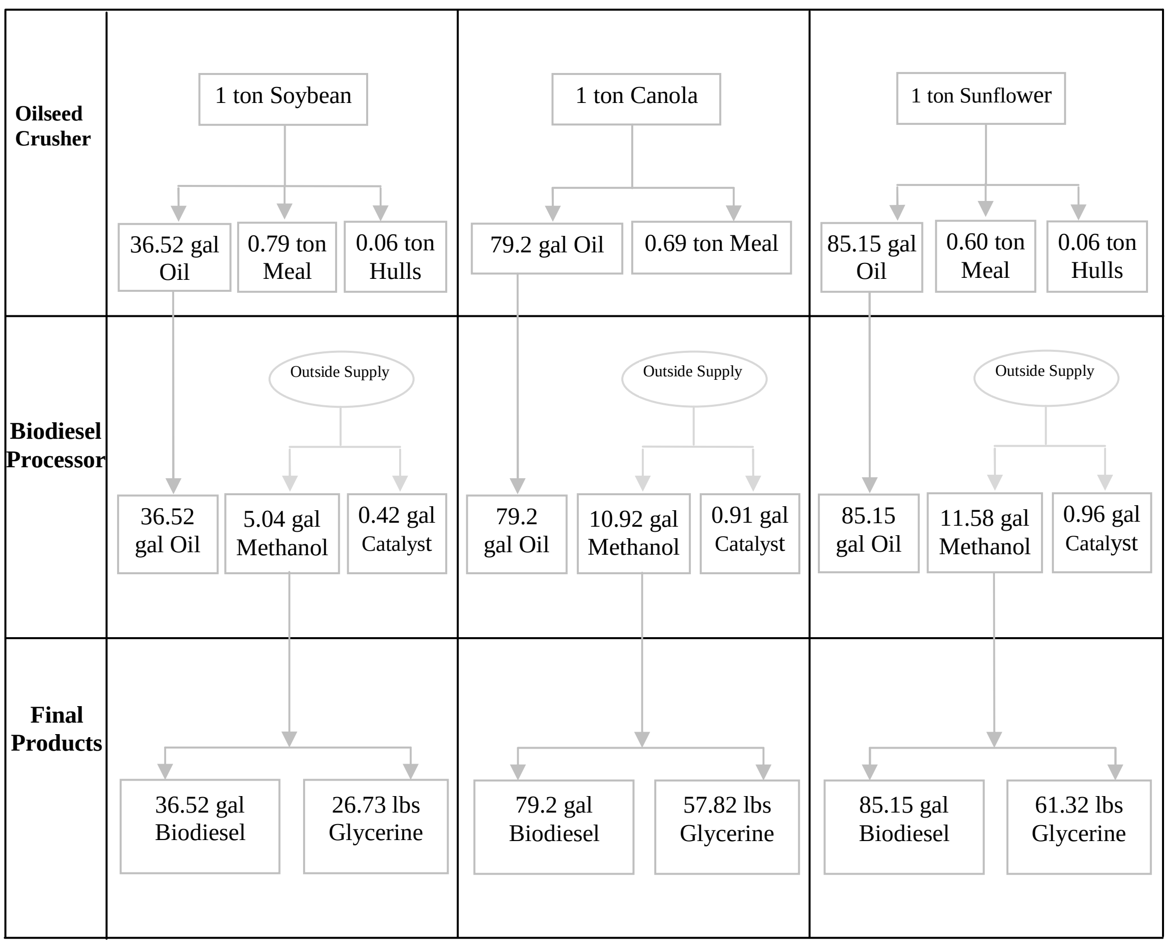
Table III-8: Summary of Equipment Costs for three Different Production Facilities

	List of Equipments	Small Scale	Medium Scale	Community Scale
Oilseed Crusher	Grain storage bin 1 (30 ton)	$3,500	0	0
	Grain storage bin 2 (75 ton)	0	$8,750	0
	Grain storage bin 3 (150 ton)	0	0	$17,500
	Pre cleaner	0	0	$10,000
	Extruder 1 (600 lbs/hr)	$28,298	$56,596	0
	Expeller 1 (600 lbs/hr)	$31,434	$62,868	0
	Extruder 2 (2500 lbs/hr)	0	0	$62,344
	Expeller 2 (2500 lbs/hr)	0	0	$62,869
	Conveyor	$4,659	$9,318	$4,659
	Filter	$1,000	$1,000	$1,000
	Drum strainer	$40	$40	$40
	Oil storage tank 1 (1000 gal)	$1,781	0	0
	Oil storage tank 2 (2000 gal)	0	$2,633	0
	Oil storage tank 3 (5000 gal)	0	0	$5,952
	Meal storage tank 1 (25 ton)	$105	0	0
	Meal storage tank 2 (50 ton)	0	$196	0
	Meal storage tank 3 (100 ton)	0	0	$369
	Spare parts kit	$500	$500	$500
	Installation and Freight	$6,439	$12,878	$12,987
	Sub-total	$77,756	$154,779	$178,220
Biodiesel Processor	Titration pipe supplies	$100	$100	$100
	Lab glass ware	$100	$100	$100
	Purchased oil storage tank 1 (750 gal)	$1,074	0	0
	Purchased oil storage tank 2 (1500 gal)	0	$2,207	0
	Purchased oil storage tank 3 (3000 gal)	0	0	$3,195
	Methanol tank 1 (250 gal)	$370	0	0
	Methanol tank 2 (350 gal)	0	$611	0
	Methanol tank 3 (1000 gal)	0	0	$1,073
	Biodiesel processor 1 (24 gal/hr)	$24,500	0	0
	Biodiesel processor 2 (55 gal/hr)	0	$47,000	0
	Biodiesel processor 3 (110 gal/hr)	0	0	$94,000
	Biodiesel storage tank 1 (1000 gal)	$1,781	0	0
	Biodiesel storage tank 2 (2000 gal)	0	$2,633	0
	Biodiesel storage tank 3 (5000 gal)	0	0	$5,952
	Glycerine tank 1 (1000 gal)	$1,397	0	0
	Glycerine tank 2 (2000 gal)	0	$2,531	0
	Glycerine tank 3 (4000 gal)	0	0	$3,504
	Biodiesel test kit	$200	$200	$200
	Scale	$50	$50	$50
	pH meter	$45	$45	$45
	Safety equipment	$500	$500	$500
	Drum strainer	$100	$100	$100
	Spare part kits	$500	$500	$500
	Pipes and fittings	$500	$500	$500
	Installation and Freight	$2,450	$4,700	$9,400
	Sub-total	$33,667	$61,777	$119,219
	Grand Total	$111,423	$216,556	$297,439

Example: Input-Output Flow

This gives an idea of how much biodiesel and other by-products are produced from 1 ton of oilseed. This also gives an idea of what quantity of other inputs are required to make biodiesel from 1 ton of oilseed crops. The extraction efficiency of the oilseed crusher was assumed to be 80%. The oil content of soybean, canola and sunflower was assumed to be 18.7%, 38.2% and 43.6% respectively. The calculation on the biodiesel aspect assumes that to make 100% of the input content in the biodiesel processor we will require 87% oil, 12% alcohol and 1% catalyst. If we have inputs in this proportion we would get output as 87% biodiesel, 9% glycerine and 4% other residues.

Figure III-1: Example: Input-Output Flow



(Calculation made for Coop. Scale)

The flow chart presented above shows that 1 ton of soybean would produce 36.52 gal oil, 0.79 ton meal and 0.06 ton hulls. If this oil goes into biodiesel processor, it will require 5.04 gal methanol and 0.42 gal catalyst to process into biodiesel. The final product would be 36.52 gal biodiesel and 26.73 lbs glycerine along with other residual matters. The same explanation would apply for 1 ton of canola and 1 ton of sunflower.

Summary of Daily Capacities and Outputs

The table presented below shows the inputs required and outputs produced for each of the three different production facilities on a daily basis and for all three feedstocks.

Table III-9: Summary of Daily Capacities and Outputs

Inputs/Outputs Per Day			**Small Scale**	**Medium Scale**	**Cooperative Scale**
Oilseed Crusher	Input	Grain	2.85 ton	5.7 ton	9.5 ton
	Output	Oil Produced	104 gal (Soybean) 227 gal (Canola) 243 gal (Sunflower)	209 gal (Soybean) 454 gal (Canola) 487 gal (Sunflower)	348 gal (Soybean) 757 gal (Canola) 811 gal (Sunflower)
		Meal	2.25 ton (Soybean) 1.96 ton (Canola) 1.71 ton (Sunflower)	4.51 ton (Soybean) 3.92 ton (Canola) 3.45 ton (Sunflower)	7.51 ton (Soybean) 6.53 ton (Canola) 5.75 ton (Sunflower)
		Hulls	0.17 ton (Soybean) 0.17 ton (Sunflower)	0.34 ton (Soybean) 0.34 ton (Sunflower)	0.57 ton (Soybean) 0.57 ton (Sunflower)
Biodiesel Processor	Input	Oil from Oilseed Crusher	104 gal (Soybean) 182 gal (Canola) 182 gal (Sunflower)	209 gal (Soybean) 418 gal (Canola) 418 gal (Sunflower)	348 gal (Soybean) 757 gal (Canola) 811 gal (Sunflower)
		Extra Oil Required	78 gal (Soybean) 0 gal (Canola) 0 gal (Sunflower)	209 gal (Soybean) 0 gal (Canola) 0 gal (Sunflower)	488 gal (Soybean) 79 gal (Canola) 25 gal (Sunflower)
		Methanol	16 gal	38 gal	75 gal
		Catalyst	14 lbs	32 lbs	64 lbs
	Output	Biodiesel	182 gal	418 gal	836 gal
		Glycerine	134 lbs	306 lbs	613 lbs

The calculation is based on the assumption that the oilseed crusher is operated 10 hours a day and the biodiesel processor is operated 8 hours a day. The other assumptions are that one ton of soybean will produce 36.52 gallon of oil, 0.79 ton of meal and 0.06 ton hulls; one ton of canola will produce 79.2 gal of oil and 0.69 ton of meal; and one ton of sunflower will produce 85.16 gal of oil, 0.60 ton of meal and 0.06 ton hulls. The calculation assumes that the oilseed crusher for small scale, medium scale and cooperative scale can crush 2.85 tons, 5.7 tons and 9.5 tons of oilseeds respectively in one day. Similarly, the calculation assumes that the biodiesel processor for small scale, medium scale and cooperative scale facilities can make 182 gal, 418 gal and 836 gal of biodiesel respectively in one day. If 2.85 tons of oilseeds are supplied for small scale to crush, 104 gal of oil is produced from soybean, 227 gal of oil is produced from canola and 243 gal of oil is produced from sunflower. The quantities of meal and hulls produced from these feedstocks will also vary. When all the oil produced by crushing the oilseed in small scale is supplied to the biodiesel processor some additional oil of 104 gal is required if soybean is used as a feedstock. But no additional oil is required if canola or soybean is used as a feedstock. The additional oil is required to meet the full biodiesel production potential of the small scale biodiesel processor of 182 gal in one day. Beside 182 gal of biodiesel produced in one day from the small scale facility, 134 lbs of glycerine and other residual matters are also produced. The similar explanation is applicable for the medium scale and cooperative scale facility. In each of the facilities, the additional oil required is more for soybean scenario than for canola and sunflower scenario. This is because the oil content of soybean is comparatively less than the oil content of canola and sunflower.

Summary of Energy and Processing Time Estimations

The following table provides an idea of the quantities of electricity in kilowatts or water in gallons used to process 1 ton of oilseeds into biodiesel. This gives an idea of the utility costs and KWs used to operate different scales of oilseed crushers to process 1 ton of oilseed. This also gives an idea of the utility costs, KWs and water (Gal) used by different scales of biodiesel processors to process the oil produced from 1 ton of soybean, canola and sunflower.

Table III-10a: Small Scale: Energy and Processing Time Estimations

Energy and Processing Time for 1 ton		Soybean	Canola	Sunflower
Oilseed Crusher	Time to process	3.51 hr	3.51 hr	3.51 hr
	HP	71	71	71
	KW	199	199	199
	Utilities	$21.93	$21.93	$21.93
Biodiesel Processor	Time to process	1.6065 hr	3.475 hr	3.702 hr
	KW	26.39	57.08	60.8
	Water	1,575 gal	1,662 gal	1,673 gal
	Utilities	$6.05	$9.60	$10.03
	Total Cost	$27.98	$31.53	$31.96

The table above indicates that it will take 3.51 hour to crush 1 ton either of soybean, canola or sunflower. A total of 71 HP is calculated which is based on the sum of HPs for extruder, expeller and conveyor which are 50 HP, 20 HP and 1 HP respectively for each of them. The KW calculation is based on 80% connected HP multiplied by the hours and days of operation. The total utility cost is calculated to be approximately $21.93 which is obtained by multiplying the total KWs by the electricity cost of $0.11 per KW. So, $21.93 is the electricity cost to crush 1 ton of oilseed for small scale.

The operating time calculated for the biodiesel processor is based on the quantity of oil produced from each of the three oilseed crops. One ton each of soybean, canola and sunflower will produce approximately 37 gallons, 80 gallons and 85 gallons of oil respectively. Therefore, as less oil comes from soybean, less time is used to process soybean compared to canola and sunflower. Canola will require more time to process than soybean while sunflower will require even more time than canola. The KW calculation for biodiesel processor is based on the total BTUs required per gallon and it depends on the BTUs calculated for the reactor and the oil-methanol condenser. The calculated BTUs per gallon of biodiesel for the simplest biodiesel reaction and methanol recovery system were 2,398 BTUs. This value was converted to KWs supplementing with the fact that 1 KW/hr would produce 3,412 BTUs. Most of the calculated electricity as shown in the table above would be used to heat the required quantity of the biodiesel and some fraction of this energy would be used to operate processor pumps and other similar equipment if necessary. The water usage is based on the assumption that 2 gallon of water is required for each gallon of biodiesel plus an additional 500 gallons of water for drinking and 1000 gallons for wash or cleanup. A water rate of $2 per 1000 gallon is used to calculate the cost of water. Finally, the total utility cost for operating biodiesel processor is calculated by summing the cost for electricity and water usage. This cost is summed up with the total cost of operating the oilseed crusher to obtain the final total utility cost. The same explanation follows for table III-7b and table III-7c which are presented below.

Table III-10b: Medium Scale: Energy and Processing Time Estimations

Energy and Processing Time for 1 ton		**Soybean**	**Canola**	**Sunflower**
Oilseed Crusher	Time to process	1.755 hr	1.755 hr	1.755 hr
	HP	141	141	141
	KW	198	198	198
	Utilities	$21.78	$21.78	$21.78
Biodiesel Processor	Time to process	0.701 hr	1.5163 hr	1.6155 hr
	KW	26.31	56.91	60.63
	Water	1,575 gal	1,662 gal	1,673 gal
	Utilities	$6.04	$9.58	$10.02
	Total Cost	$27.82	$31.36	$31.8

Table III-10c: Cooperative Scale: Energy and Processing Time Estimations

Energy and Processing Time for 1 ton		Soybean	Canola	Sunflower
Oilseed Crusher	Time to process	1.053 hr	1.053 hr	1.053hr
	HP	156	156	156
	KW	131	131	131
	Utilities	$14.46	$14.46	$14.46
Biodiesel Processor	Time to process	0.3505 hr	0.7582 hr	0.80775 hr
	KW	26.02	56.29	59.97
	Water	1,575 gal	1,662 gal	1,673 gal
	Utilities	$6.01	$9.52	$9.94
	Total Cost	$20.47	$23.98	$24.4

Description of the Feasibility Template

An economic feasibility template was constructed using Microsoft Excel to project the cost and return of on-farm processing of canola, soybean and sunflower into biodiesel. Data was collected from several sources to create spreadsheets used in this feasibility study. The structure of the feasibility template was based on a previous biodiesel feasibility template developed by Drs. Bowser, Kenkel and Holcomb at Oklahoma State University. The template contains eleven different worksheets for inputs and outputs. Five worksheets require input information which are basic capital structure, biodiesel production size and capacity, production costs, equipment scheme and personal expenses. The user-supplied information and assumptions made for the model is used in financial calculations. The calculations include market and expense projections, loan amortization, operation summary, and return on investment which were calculated for a ten year period. A separate user’s manual will be developed for the use of the template. The detail on each of the sheets is explained below.

Input Value

The “input value” is the first sheet which takes several input information. The cells colored in green are used to fill the input information which is carried to other worksheets for the required calculations. The users will have the option to enter the basic information like the no. of oilseed crushers or the biodiesel processors to be used along with their capacities from the dropdown list or can enter their own value. Other information like the oilseed crops to be used and their proportionate use can be given. When these informations are entered, the annual biodiesel production (gallons), oilseed crushed (tons), oil produced (gallons) or any excess oil/purchase oil (gallons) are calculated by the template. There are other input cells as well for capital structure like debt, loan term, interest rate, working capital and so on. Other input cells include tax information, biodiesel tax credit and transportation. There are also input cells for raw and final product prices, utilities, inflation, and other. There are also cells for adjusting the values for the selected crops. All the values entered in the input cells in this sheet are used for calculation on other sheets.

Cost of Production

The cost of production sheet includes simple calculations for producing soybean, canola and sunflower. The cost per acre for each of the crops is determined from the values entered for seed, fertilizer, pesticide, insurance, operating capital, custom hire, machinery fuel, lube and repair and some other expenses. The total cost for each of the crops is calculated by multiplying the total acres grown for each of the crops. The basic expense data for producing these crops per acre are obtained from Oklahoma State University’s Enterprise Budgets (2009).

Equipment

The equipment sheet includes cost estimation for the oilseed crusher and biodiesel processor. This sheet includes the list of all necessary equipments and their accessories. For the oilseed crusher, this includes pre-cleaner, extruder, expeller, conveyor, filters, tanks (for meal and oil storage), spare part kits and miscellaneous items. Similarly, different capacities of the integrated biodiesel processor, tanks for methanol, glycerol and biodiesel and other accessories are included for the biodiesel processor. This sheet also has the option to include the number of pieces of oilseed crushers and biodiesel processors or their accessories. Beside this, it also has the option to include their cost and other specifications like the horse power (HP) and electricity (KW/hr) used by the equipment or the horse power (HP) and electricity (KW/hr) used by its accessories during oilseed crushing or biodiesel processing.

Utilities

This sheet includes detailed cost estimation for electricity, heat exchanger and water. It also includes cost estimates for sewage disposal and telephone. The cost for electricity is based on the HP or KW/hr used which comes from the equipment sheet. The calculation for natural gas consumption is based on the total BTUs estimation required per gallon of biodiesel for the simplest biodiesel reaction and methanol recovery system. Users will have opportunity to use either electricity or natural gas for heat exchanger. The total water required is calculated by assuming that one gallon of biodiesel production will require two gallons of water. Total utility per year and total utility per gallon are calculated using the summed cost estimation from electricity, natural gas, water usage, telephone and waste disposal.

Personnel Expenses

This sheet includes adjustable variables for personnel expenses. The sheet includes details for the employees who work in the administration section and those who work in the production section. The variables in this sheet include the information for employee position, their number, salary, benefits and overtime percentage. On the basis of this information, the total personnel expenses are determined.

Capital Assets

This sheet calculates depreciation on a yearly basis. The depreciable assets used for calculation includes buildings, special purpose buildings, equipment and heavy rolling stock, and light trucks and vehicles. Buildings are depreciated on a 39 year straight line. Special purpose buildings are depreciated on a 10 year straight line. Equipment and heavy rolling stock are depreciated on a 7 year life using MACRS (Modified Accelerated Cost Recovery System) and light trucks and vehicles are depreciated on a 5 year life using MACRS.

Market Projection

This sheet includes information on annual tons of oilseed processed for each crop, the yearly prices per lb for three crops, the prices for meal, hull and the additives. Other details included are the yearly sales for meal, hulls, oil, glycerol and biodiesel in terms of tons or gallons and in dollars. This sheet also includes the purchase volume and the dollars spent for the purchase of additional oil, methanol and catalyst. The gross margins for each year are also calculated.

Loan Amortization

This sheet is used to calculate loan principal and interest payments. The data used for calculation in this sheet are obtained from input value sheet. Working capital is amortized on this sheet. The sheet provides details on interest expenses on an annual basis.

Expense Projection

This sheet projects yearly expenses for ten year periods which are based on the information provided in the earlier worksheets. Total variable expenses are calculated by summing the sub-totals for personnel expenses, trucking expenses, expenses for utilities, and cost of production for the oilseed crops. Similarly, the expenses for maintenance, insurance, property tax and others are summed to get the fixed expenses. Finally, other miscellaneous expenses are included to obtain the total expenses.

Operation Summary

This sheet summarizes the total income and expenses for a ten year period. The sheet uses the market projection sheet to obtain the gross sales and cost of goods sold and expense projection sheet to obtain the expenses. This sheet shows simple projections of cash flows which are made by adjusting annual after tax profits for depreciation expenses and loan principal payments. Net costs per gallon of biodiesel for each production period are also calculated in this worksheet.

Return on Investment

This is the most important sheet as it summarizes the feasibility of the biodiesel production facility. The feasibility measures used for calculation are internal rate of return (IRR), net present value (NPV), return on assets (ROA), return on equity (ROE) and payback period. All five measures are determined by using the standard formula for calculations. The six measures test the feasibility of the on-farm biodiesel production. For all the scenarios, feasibility measures were computed and are summarized on the "Return on Investment" sheet in the feasibility template.

The Internal Rate of Return (IRR) is an interest rate at which the cost of investment leads to the benefits of the investment or it is an interest rate for an investment which will turn the net present value (NPV) to zero. The IRR is generally a compounded return from the project and is a measure of what the company could be earning had they invested elsewhere. It is generally better to invest in projects where rates of return are higher than the firm's required rate of return. The generally acceptable rate of return is 7-8%.

The Net Present Value (NPV) is a sum of the difference between the present value of cash inflows and the present value of cash outflows. NPV compares the dollar value of a project today to the value of that same dollar in the future at a given discount rate. It is similar to IRR in that it considers cash flows and adjusts for the time value of money. A positive NPV is generally acceptable for a project.

The Return on Assets (ROA) measures how profitable a firm is relative to its asset. It gives an idea of how efficiently management is using its assets to earn profits. But ROA does not provide a perfect measure of profitability because it is impacted by depreciation and other tax issues and the owner's return is also impacted by the firm's use of debt and equity capital.

The Return on Equity (ROE) measures how profitable a firm is relative to the owner's equity. It measures how much profit a firm generates to the money invested by the shareholders. Like ROA, it is also impacted by depreciation and other tax related issues. Compared to NPV or IRR, ROE is less useful in evaluating a potential project although it is widely accepted measure of firm performance because ROE is impacted by the amount of leverage, two firms with different ratios of debt and equity in their capital structure would project different ROEs for an identical project (Kenkel et al, 2005).

The last measure is the payback period which measures the length of time which is required to cover the cost of an investment. There is no general benchmark for an acceptable payback period however three years or less is generally accepted.

In the return on investment sheet, sensitivity analysis was performed using all the five financial measures discussed above. This was done by varying the corresponding values by certain percentage and measuring the financial measures. The sensitivity analysis for biodiesel prices and additional purchased oil prices was performed for all the five scenarios. The sensitivity for the impact of the scale of the production facility, oil content, cost of equipment, cost of production, cost of maintenance, cost of electricity and interest rate are performed only for the baseline (100% canola) scenario. Other sensitivity performed is for crop yield and for soybean meal price. The sensitivity analysis was performed using macros feature in Excel.

CHAPTER IV

RESULTS AND SENSITIVITY ANALYSIS

The term sensitivity analysis refers to the process of performing budget computations or feasibility projections multiple times, each with a different set of prices or yields (Kay et al, 2008). This study uses sensitivity analysis to study the impact of changes in the values of oilseed crop inputs, biodiesel and oilseed meal outputs, type of crop used as input, oilseed yield and scale of production and various cost factors on the returns to the integrated oilseed processing and biodiesel processing venture. The sensitivity analysis includes projections for a 100% canola scenario, 100% soybean scenario, 100% sunflower scenario, 50% soybean-50% canola scenario and 50% canola-50% sunflower scenario. The sensitivity for 50% soybean-50% sunflower was not performed since they both are the summer crops. The 100% canola scenario is considered as the baseline scenario and the cooperative scale is considered as the baseline equipment size. The feasibility template constructed in MS Excel was used to estimate the returns on investment for each of the scenarios. The internal rate of return (IRR), net present value (NPV), return on assets (ROA), return on equity (ROE) and payback period were computed as measures of return on investment. For breakeven analysis, an IRR of 0% was considered a break even return. In some scenarios involving negative returns it was not possible to calculate the internal rate of return. The sensitivity of the return on investment to the scale of the production facility, cost of equipment, cost of production, oil content, cost of maintenance, cost of electricity and interest rate were performed for the baseline (100% canola) scenario. The sensitivity for biodiesel price and purchased oil price was performed for all the five scenarios and sensitivity for yield was performed for three 100% scenarios. Details of the analysis and results are discussed below.

Results for Baseline (100% Canola Crushed) Scenario

For the baseline scenario, 100% canola was used as the feedstock. The equipment in the “input value sheet” was set to the baseline i.e. cooperative scale (1 ton/hr for the oilseed crusher and 110 gallon/hr for the biodiesel processor). The oilseed crusher was operated 10 hours/day and the biodiesel processor was operated 8 hours/day. When operated in its fullest capacity, the oilseed crusher would supply 227,027 gallons of oil. So, 23,773 gallons of additional oil was required to meet the full production potential of the biodiesel processor which would finally make 250,800 gallons of biodiesel annually. The result for this scenario is presented in the table below:

Table IV-1: Measures of Return at Baseline for the 100% Canola Scenario

Economic Variables	Values at Baseline
IRR	25.16%
NPV	$250,423
ROA	14.94%
ROE	39.45%
Payback Period	7^{th} Year

The results at baseline values showed that for 100% canola the IRR would be 25.16%, NPV would be $250,423 and the payback period would be 7 year. This means that the 100% canola scenario would be profitable under baseline assumptions and prices and the generated cash flows can cover the expenses of the project.

Several sensitivity analyses were performed for this scenario. The impact of biodiesel price, additional purchased oil price, the scale of the oilseed crusher and the biodiesel processor, the yield of the crop, the canola oil content, the total cost of the equipment, the total cost of production, the interest rate, the cost for electricity and maintenance cost were performed by varying the corresponding values and the changes in measures of return were calculated. The details of the sensitivity analyses for this scenario are presented and discussed below.

<u>Impact of Biodiesel Price-Baseline Scenario</u>

The price of biodiesel was allowed to vary by 5 cents and all other variables were kept constant at baseline values. Then return on investment measures such as internal rate of return (IRR), net present value (NPV), return on assets (ROA), return on equity (ROE) and payback period were calculated for each of the changes in the biodiesel prices. The table presented below shows the changes in sensitivity measures for each of the biodiesel prices.

Table IV-2: Impact of Biodiesel Price on ROI for the Baseline Scenario

Economic Variable	Biodiesel Price					
	$3.20	$3.25	$3.30	$3.35	$3.40	**$3.50**
IRR	-7.60%	-0.66%	5.31%	10.70%	15.25%	**25.16%**
NPV	-$228,848	-$148,970	-$69,091	$10,787	$82,715	**$250,423**
ROA	-11.22%	-6.86%	-2.50%	1.86%	5.78%	**14.94%**
ROE	-13.40%	-4.59%	4.22%	13.03%	20.96%	**39.45%**
Payback Period	>10 Year	>10 Year	>10 Year	10th Year	9th Year	**7th Year**

(Baseline biodiesel price is $3.50/gal, Sensitivity performed for Coop. Scale)

The results in table IV-2 show that the breakeven biodiesel price is between $3.25 and $3.30. An increment in the biodiesel price by 5 cents per gallon would increase the

IRR by approximately 5% and similarly it would increase the ROA by approximately 4%, and ROE by approximately 8%. The net present value (NPV) for the baseline biodiesel price was calculated to be $250,423. This value indicates that at the selected baseline biodiesel price and discount rate, the scenario of crushing canola and manufacturing biodiesel will generate sufficient cash flow to cover expenses and cover the 10% opportunity cost of the invested capital. The positive projected cash flows of $250,423 at biodiesel price of $3.50 per gallon show that the project's income can cover the cash expenses and loan payments of the project. The payback period would be seven years from the investment year for the baseline biodiesel price.

Impact of Additional Purchased Oil Price-Baseline Scenario

As discussed previously, operating both the oilseed processing equipment and biodiesel processing unit at full capacity requires some additional oil to be purchased from outside sources. This feedstock represents approximately 10% of the total oil processed. The price of the additional oil was allowed to vary by 10 cents while keeping all other variables constant at baseline values. Then return on investment measures were calculated for each of the change in the purchased oil prices. The table presented below shows the changes in return on investment measures for each of the additional purchased oil prices.

Table IV-3: Impact of Purchased Oil Price on ROI for the Baseline Scenario

Economic Variable	Purchased Oil Price					
	$1.7	**$1.8**	$1.9	$2.0	$2.1	$2.2
IRR	31.63%	**25.16%**	18.44%	11.32%	3.46%	-5.83%
NPV	$365,512	**$250,423**	$135,334	$20,245	-$94,844	-$209,933
ROA	21.22%	**14.94%**	8.66%	2.37%	-3.91%	-10.19%
ROE	52.14%	**39.45%**	26.76%	14.07%	1.38%	-11.32%
Payback Period	5th Year	**7th Year**	8th Year	10th Year	>10 Year	>10 Year

(Baseline purchased oil price is $1.8/gal or $0.23/lb, Sensitivity performed for Coop. Scale)

Results indicate that the breakeven price of additional oil is between $2.1 and $2.2 per gallon. A 10 cent decrease in the price of additional purchased oil results in approximately 7% increase in IRR, approximately 6% increase in ROA and approximately 13% increase in ROE. The net present value (NPV) for the baseline purchased oil price would be $250,423 and the payback period would be 7 years.

<u>Impact of Scale of Oilseed Crusher and Biodiesel Processor-Baseline Scenario</u>

The sensitivity for the impact of the scale of the production facilities (oilseed crusher and biodiesel processor) was examined. The working capital for medium and cooperative scale operations was set to 2% of annual sales plus $100,000 while the working capital of the small scale was set just to 2% of annual sales with no other amount. The full capacity volumes of the various scales of oilseed presses were not perfectly aligned with the maximum capacities of the various scales of biodiesel processors. Because of this mis-match the price assumption for the outside oil purchases or excess oil sales interfered with the examination of scale economies. If the assumed price for outside oil purchased was low relative to the value of biodiesel then an equipment complement where the biodiesel processor capacity exceeded the oilseed press capacity appeared more profitable. Similarly when the value of excess oil was high relative to the biodiesel value then scenarios where the oilseed press capacity exceeded the biodiesel processor appeared more profitable. To isolate the impact of scale economies, the ratio of oil supplied by the crusher to the amount purchased from outside sources was held constant across the facilities. This made it necessary to vary the assumed hours of operation of the crushing systems from the 10 hour/day baseline assumption. The crushing system was assumed to operate 7.27 hours/day for the small scale system, 8.33 hours/day for the medium scale and 10 hours for the cooperative scale. By doing so, the oilseed crusher supplied approximately 90% of the oil and approximately 10% of the oil had to be purchased from outside sources for each scale of operations.

Table IV-4: Impact of Scale of Production on ROI for the Baseline Scenario

Economic Variable	**Small Scale** Oil Produced: 49,515 Oil Purchased: 5,205	**Medium Scale** Oil Produced: 113,468 Oil Purchased: 11,932	**Cooperative Scale** Oil Produced: 227,027 Oil Purchased: 23,773
IRR	Neg	Neg	**25.16%**
NPV	-$441,427	-$301,842	**$250,423**
ROA	-62.51%	-21.09%	**14.94%**
ROE	-117.81%	-34.34%	**39.45%**
Payback Period	>10 Year	>10 Year	**7^{th} Year**

(Cooperative scale is the baseline equipment size)

The result showed that both the medium and small scale has negative returns and only cooperative scale has positive returns. The small scale facility has higher values of negative returns compared to the medium scale. The labor cost per gallon and the capital cost per gallon were significantly higher for small scale when compared with the cooperative scale. This shows that smaller the scale of production the larger will be the negative returns reflecting the economies of scale. Since the cooperative scale appears most profitable, this scale of production would likely exceed the oilseed crop production of a single producer but would be obtainable by a small group of producers or a small scale cooperative.

<u>Impact of Canola Yield-Baseline Scenario</u>

Canola yield impacts the per-acre return from producing canola and processing it into biodiesel. The acres required to produce canola depends on the capacity of the oilseed crusher and the yield of the crop. When the canola yield is higher, less acres of land is needed to produce canola and vice-versa. Table IV-5 summarizes the changes in measures of return when the yield of the canola is allowed to vary by 5% of the baseline yield holding all other baseline assumptions constant at baseline values.

Table IV-5: Impact of Canola Yield on ROI for the Baseline Scenario

Economic Variable	Canola Yield (lbs/acre)					
	1700	1800	1900	**2000**	2100	2200
IRR	Neg	-1.86%	13.33%	**25.16%**	35.30%	44.32%
NPV	-$413,661	-$167,704	$52,363	**$250,423**	$429,620	$592,526
ROA	-21.40%	-7.94%	4.10%	**14.94%**	24.74%	33.66%
ROE	-33.22%	-6.30%	17.78%	**39.45%**	59.06%	76.89%
Payback Period	>10 Year	>10 Year	10th Year	**7th Year**	5th Year	4th Year

(Baseline canola yield is 2000 lbs/acre, Sensitivity performed for Coop. Scale)

Results indicate that the breakeven yield of canola is between 1800 lbs/acre and 1900 lbs/acre. An increase in yield per acre by 5% of the baseline yield increases the IRR and ROA by approximately 10% and ROE by approximately 20%. The net present value (NPV) for the baseline canola yield is $250,423 and the payback period is 7 year.

Impact of Canola Oil Content-Baseline Scenario

Canola oil content varies among varieties and the methods of extraction. Some varieties of canola yield a high percentage of oil while others yield very low. Similarly, some methods of extraction can extract a very high quantity of oil per lb while other methods cannot. Therefore, an increment of 0.2% of the canola oil content was made and measures of return on investment were noted. All other baseline assumptions were held constant. Table IV-6 summarizes the results of the changes in measures of return.

Table IV-6: Impact of Canola Oil Content on ROI for the Baseline Scenario

Economic Variable	Canola Oil Content					
	37.2%	37.4%	37.6%	37.8%	38.0%	**38.2%**
IRR	Neg	-0.5%	6.7%	13%	19%	**25.16%**
NPV	-$243,468	-$146,627	-$49,785	$47,056	$143,897	**$250,423**
ROA	-12.02%	-6.74%	-1.45%	3.84%	9.12%	**14.94%**
ROE	-15.01%	-4.33%	6.35%	17.03%	27.70%	**39.45%**
Payback Period	>10 Year	>10 Year	>10 Year	10 Year	8th Year	**7th Year**

(Baseline canola oil content is 38.2%, Sensitivity performed for Coop. Scale)

Results indicate that the measures of return are highly sensitive to canola oil content. When the canola oil content is increased just 0.2% above the baseline, IRR increases approximately by 6%, ROA increases approximately by 5%, and ROE increases approximately by 10%. The breakeven canola oil content is approximately 37.4%.

Impact of Cost of Equipment-Baseline Scenario

The sensitivity of the return on investment to the cost of equipment was measured by varying the cost of equipment by 20% of the baseline cost while all other variables were kept constant at baseline values. Table IV-7 summarizes the results of changes in measures of return.

Table IV-7: Impact of the Cost of Equipment on ROI for the Baseline Scenario

Economic Variable	Cost of Equipment					
	$297,439	$356,927	$416,414	$475,902	$535,390	$594,878
IRR	**25.16%**	23.66%	22.13%	20.58%	18.99%	17.38%
NPV	**$250,423**	$223,387	$196,351	$169,315	$142,279	$115,244
ROA	**14.94%**	8.81%	4.44%	1.15%	-1.40%	-3.44%
ROE	**39.45%**	26.37%	17.03%	10.02%	4.57%	0.21%
Payback Period	**7th Year**	8th Year	10th Year	10th Year	>10 Year	>10 Year

(Baseline equipment cost is $297,439, Sensitivity performed for Coop. Scale)

The results indicate that the measures of return are not very sensitive to the cost of equipment. When the cost of equipment is increased by 20%, IRR decreases by approximately 2%, ROA decreases by approximately 4% and return on equity decreases by approximately 6%. In this result, it is surprising to note that the IRR is still positive when the cost of equipment is almost increased by 80% or even by 100%.

Impact of Cost of Production for the Oilseed Crop-Baseline Scenario

The crop production directly affected the return on investment since the system is integrated with crop production, oilseed crushing and biodiesel processing. In this case, the cost of production for canola is allowed to vary by 5% of the baseline cost and all other variables are kept constant at baseline. Table IV-8 summarizes the results of the changes in measures of return in this case.

Table IV-8: Impact of the Cost of Production for Canola on ROI for the Baseline Scenario

Economic Variable	Cost of Production					
	$551,190	$581,811	**$612,434**	$643,055	$673,677	$704,298
IRR	46.20%	35.80%	**25.16%**	13.95%	1.33%	Neg
NPV	$626,737	$438,580	**$250,423**	$62,266	-$125,891	-$314,048
ROA	35.53%	25.23%	**14.94%**	4.64%	-5.65%	-15.95%
ROE	80.63%	60.04%	**39.45%**	18.86%	-1.73%	-22.32%
Payback Period	4th Year	5th Year	**7th Year**	10th Year	>10 Year	>10 Year

(Baseline total cost of producing canola is $612,434, Sensitivity performed for Coop. Scale)

The breakeven production cost underlying the base scenario was between $673,677 and $704,298. Results show significant positive returns for most of the range of the production costs. Lowering the cost by 5% increases the IRR by approximately 10%, ROA by approximately 11% and ROE by approximately 21%. This shows that the measures of return are sensitive to the cost of canola.

<u>Impact of Interest Rate (Short Term and Long Term)-Baseline Scenario</u>

In this case both the short term and long term interest rate were varied by 4% and the impacts on returns were measured. All other variables under baseline assumptions are kept constant. Table IV-9 summarizes the results of the sensitivity for this case.

Table IV-9: Impact of Interest Rate on ROI for the Baseline Scenario

Economic Variable	Interest Rate					
	3.50%	**7.50%**	11.50%	15.50%	19.50%	23.50%
IRR	26.82%	**25.16%**	23.49%	21.80%	20.10%	18.37%
NPV	$279,324	**$250,423**	$221,522	$192,620	$163,719	$134,818
ROA	18.00%	**14.94%**	11.76%	8.49%	5.14%	1.71%
ROE	45.16%	**39.45%**	33.52%	27.39%	21.08%	14.63%
Payback Period	6th Year	**7th Year**	7th Year	8th Year	9th Year	10th Year

(Baseline short term and long term interest rate is 7.5%, Sensitivity performed for Coop. Scale)

The results indicate the measures of return are not sensitive to both the short term and long term interest rate for an integrated oilseed crushing and biodiesel production venture. There will be positive returns at interest rates of 23.5% or lower. Only when interest rate exceeds 25% were the returns on assets negative and the payback period exceeded 10 years. Increasing interest rate by 4% lowers IRR by approximately 2%, ROA by approximately 3% and ROE by approximately 6%.

Impact of Maintenance Cost-Baseline Scenario

In the baseline scenario, the annual costs of maintaining and repairing the oilseed crushing and biodiesel facility were assumed to be 5% of the total equipment costs. The maintenance cost was varied by 2% increment to investigate its impact on the project returns, and the changes in measures of return were calculated. All other baseline assumptions were kept constant. Table IV-10 summarizes the changes in measures of return in this case.

Table IV-10: Impact of Maintenance Cost on ROI for the Baseline Scenario

Economic Variable	Maintenance Cost					
	3%	**5%**	7%	9%	11%	13%
IRR	27.45%	**25.16%**	22.82%	20.43%	17.96%	15.40%
NPV	$292,320	**$250,423**	$208,525	$166,628	$124,730	$82,833
ROA	17.17%	**14.94%**	12.71%	10.48%	8.25%	6.02%
ROE	44.22%	**39.45%**	34.69%	29.92%	25.15%	20.39%
Payback Period	6th Year	**7th Year**	7th Year	8th Year	8th Year	9th Year

(Baseline maintenance cost is 5%, Sensitivity performed for Coop. Scale)

Results show that there are positive returns for most of the ranges in maintenance cost. It means the measures of return are not sensitive to the maintenance cost. When maintenance cost is increased by 2%, IRR, ROA and ROE decreases by approximately 2%, 2% and 5% respectively.

Impact of Electricity Cost-Baseline Scenario

The cost of electricity was varied by 2 cents per KW and all other baseline assumptions were held constant. Then changes in measure of return were calculated. Table IV-11 summarizes the changes in measures of return for the impact of the electricity cost.

Table IV-11: Impact of Electricity Cost on ROI for the Baseline Scenario

Economic Variable	Cost of Electricity (Per KW)					
	$0.11	$0.13	$0.15	$0.17	$0.19	$0.21
IRR	**25.16%**	21.08%	16.88%	12.51%	7.90%	2.93%
NPV	**$250,423**	$179,921	$109,420	$38,919	-$31,581	-$102,082
ROA	**14.94%**	11.09%	7.24%	3.39%	-0.46%	-4.30%
ROE	**39.45%**	31.68%	23.90%	16.13%	8.35%	0.58%
Payback Period	**7th Year**	8th Year	9th Year	10th Year	>10 Year	>10 Year

(Baseline electricity cost is $0.11 per KW, Sensitivity performed for Coop. Scale)

Results show that the returns are positive up to $0.17/KW for electricity cost. Negative returns on assets and net present value are observed at electricity cost of $0.19 per KW. IRR, ROA and ROE decrease by approximately 4%, 4% and 8% respectively when the electricity cost is increased by 2 cents per KW.

Summary of Sensitivity Analysis-Baseline Scenario

The chart presented below summarizes the results of the sensitivity performed for different prices and cost factors for baseline (100% Canola) scenario. The chart was made by estimating the IRR when the corresponding values were changed by 1.5% from the baseline and keeping all other variables constant at baseline. The percentage of canola oil content is the most sensitive to the measures of internal rate of return (IRR) when compared to all other factors under study. An increase in canola oil content just by 1.5% increased IRR by almost 15%. Other sensitive factors to the measures of return are biodiesel price, cost of producing canola, canola yield and purchased oil price. Cost of equipment and cost of electricity were slightly sensitive. Interest rate and maintenance cost were not sensitive at all.

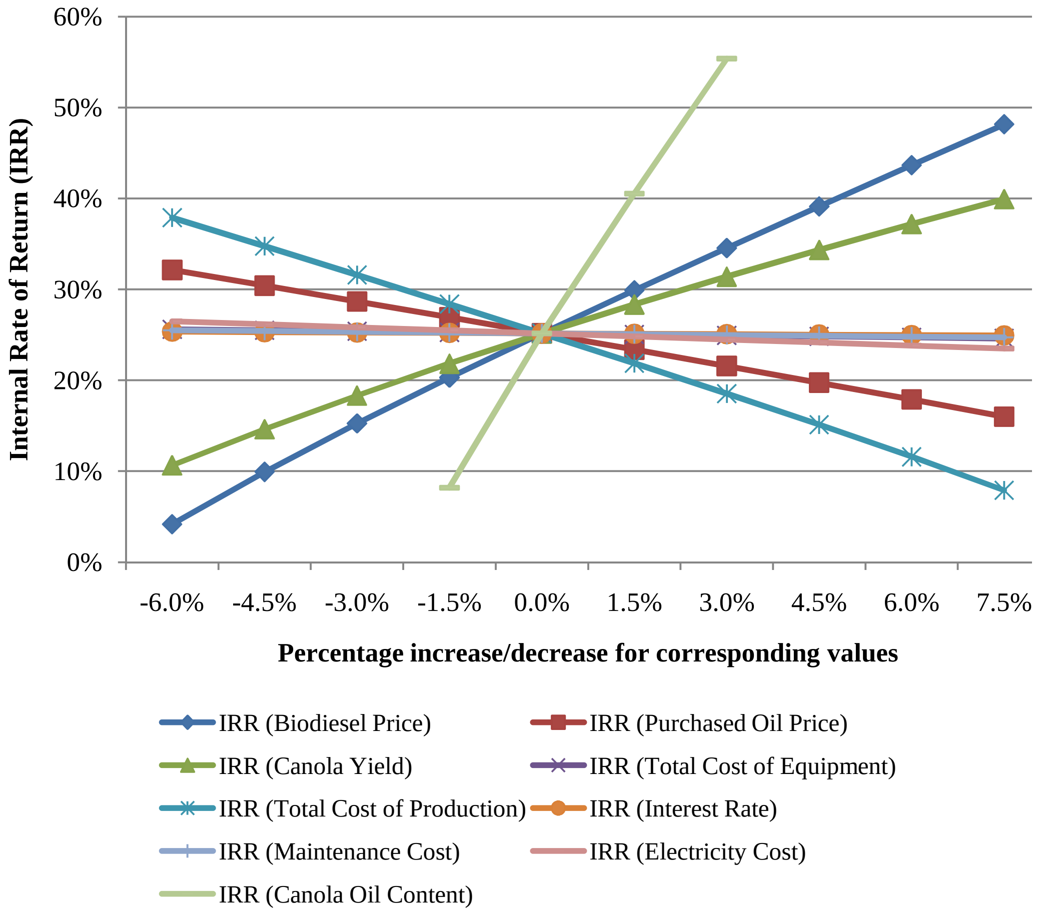


Figure IV-1: Impact of various prices and cost factors on IRR for the baseline scenario

Results for 100% Soybean Crushed Scenario

The sensitivity analysis for the 100% soybean crushed scenario was performed by changing the feedstock used to 100% soybean in the feasibility template and keeping all other variables as in the baseline scenario. The scale of the equipment was set to the cooperative scale which is assumed to be the baseline equipment scale for all the sensitivity. The biodiesel price was assumed to be $3.50/gallon, the price of additional purchased oil was assumed to be $1.80/gallon and the soybean yield was assumed to be 1272 lbs/acre. The oilseed crusher was operated 10 hours per day and the biodiesel processor was operated 8 hours per day. Both the oilseed crusher and the biodiesel processors were operated for 300 days per year. Target biodiesel production was 250,800 gallon per year and 4481.13 acres of land were required to keep the crushing unit at full capacity. The crushing operation produced 104,346 gal of oil and 146,454 gal of additional oil was purchased. A higher proportion of oil was required to be purchased relative to the 100% canola scenario because soybeans have less than half of the oil content of canola. The results for this scenario are presented in the table below:

Table IV-12: Measures of Return at baseline for the 100% Soybean Scenario

Economic Variable	Values at Baseline
IRR	Neg
NPV	-$8,659,498
ROA	-471.35%
ROE	-943.56%
Payback Period	>10 Year

The results of this scenario show that the 100% soybean scenario has unacceptable negative returns at baseline values and assumptions. This is because soybean has less oil content and therefore produces less oil because of which a large sum of money is spent on purchasing additional oil (more than half of its production) to operate the biodiesel processor in its fullest capacity.

Four different sensitivity analyses were performed for this scenario. The impact of biodiesel price, the impact of additional purchased oil price, the impact of soybean yield and the impact of soybean meal was performed by varying the corresponding values and calculating the changes in measures of return. The details of the sensitivity analysis are presented below.

Impact of Biodiesel Price-100% Soybean

The impact of changes in the price (or on-farm value) of biodiesel on return on investment for the integrated crushing and biodiesel processing operation were calculated by systematically varying the prices of the biodiesel by 5 cents/gallon increments while holding all other baseline assumptions constant. Table IV-13 summarizes the changes in measures of return when biodiesel prices are allowed to vary for this scenario.

Table IV-13: Impact of Biodiesel Price on ROI for 100 % Soybean Scenario

Economic Variable	Biodiesel Price					
	$3.40	$3.45	**$3.50**	$3.55	$3.60	$3.65
IRR	Neg	Neg	**Neg**	Neg	Neg	Neg
NPV	-$8,827,448	-$8,744,733	**-$8,659,498**	-$8,575,504	-$8,499,510	-$8,419,516
ROA	-480%	-476%	**-471.35%**	-466%	-462%	-458%
ROE	-962%	-952%	**-943.56%**	-934%	-925%	-917%
Payback Period	>10 Year	>10 Year	**>10 Year**	>10 Year	>10 Year	>10 Year

(Baseline biodiesel price is $3.50 per gallon, Sensitivity performed for Coop. Scale)

Results indicate that there are unacceptable returns on investment at most of the biodiesel prices which were significantly above the baseline biodiesel price. The price of biodiesel required to achieve approximately 10% IRR with the 100% soybean scenario was $8.92 per gallon. The low yield per acre of soybeans (which is based on the OSU enterprise budgets, 2009) and its low oil content contributed to the unfavorable return on investment. Since there is low oil coming from the oilseed crusher, a large quantity of additional oil has to be purchased which increases the expenses for the inputs.

Impact of Additional Purchased Oil Price-100% Soybean

The price of additional purchased oil was allowed to vary by 15 cents per gallon increments and all other baseline assumptions were held constant. Table IV-14 summarizes the measures of return for this case.

Table IV-14: Impact of Purchased Oil Price on ROI for 100 % Soybean Scenario

Economic Variable	Purchased Oil Price					
	$1.35	$1.5	$1.65	**$1.8**	$1.95	$2.1
IRR	Neg	Neg	Neg	**Neg**	Neg	Neg
NPV	-$5,464,374	-$6,529,415	-$7,594,457	**-$8,659,498**	-$9,724,540	-$10,789,581
ROA	-296%	-355%	-413%	**-471.35%**	-529%	-587%
ROE	-591%	-708%	-826%	**-943.56%**	-1061%	-1178%
Payback Period	>10 Year	>10 Year	>10 Year	**>10 Year**	>10 Year	>10 Year

(Baseline purchased oil price is $1.8/gal or $0.23/lb, Sensitivity performed for Coop. Scale)

The result indicated that there are no positive returns for a range of additional purchased oil prices when the purchased oil prices are lowered by 15 cents. All the economic variables are negative and the payback period is more than 10 year. This means the project will not generate sufficient cash flows to cover the projected expenses.

Impact of Soybean Yield-100% Soybean

The yield of the soybean per acre is allowed to vary by 144 lbs/acre (10% of baseline yield) increments while all other variables are kept constant to measure the changes in return. Table IV-15 summarizes the impact of changes in soybean yields on the rate of return measures.

Table IV-15: Impact of Soybean Yield on ROI for 100 % Soybean Scenario

Economic Variable	Soybean Yield (Lbs/acre)					
	1144	**1272**	1399	1526	1653	1780
IRR	Neg	**Neg**	Neg	Neg	Neg	Neg
NPV	-$9,021,673	**-$8,659,498**	-$8,363,173	-$8,116,236	-$7,907,289	-$7,728,192
ROA	-491%	**-471.35%**	-455%	-441%	-430%	-420%
ROE	-983%	**-943.56%**	-911%	-884%	-861%	-841%
Payback Period	>10 Year	**>10 Year**	>10 Year	>10 Year	>10 Year	>10 Year

(Baseline soybean yield is 1272 lbs/acre, Sensitivity performed for Coop. Scale)

The results indicate that the rate of return remained unacceptable even at soybean yields 100% above the baseline level. The important factor for the unacceptable rate of return is the low oil content of soybean of just 18.7%. Under the current baseline yield of 1272 lbs/acre, an increment of 100% in the baseline soybean oil content had to be made to 38.02% and at this percentage of oil content, an approximately 10% IRR would be achieved.

Impact of Soybean Meal-100% Soybean

The soybean meal price per ton is allowed to vary by 10% increments and all other variables are kept constant at baseline value. Then measures of return were calculated which are summarized in the table below.

Table IV-16: Impact of Soybean Meal on ROI for 100 % Soybean Scenario

Economic Variable	Soybean Meal ($/ton)					
	$253.92	**$282.13**	$310.34	$338.56	$366.77	$394.98
IRR	Neg	**Neg**	Neg	Neg	Neg	Neg
NPV	-$9,065,157	**-$8,659,498**	-$8,253,839	-$7,848,181	-$7,442,522	-$7,036,863
ROA	-493%	**-471.35%**	-449%	-427%	-404%	-382%
ROE	-988%	**-943.56%**	-898%	-854%	-809%	-764%
Payback Period	>10 Year	**>10 Year**	>10 Year	>10 Year	>10 Year	>10 Year

(Baseline soybean meal price is $282.13/ton, Sensitivity performed for Coop. Scale)

The results indicate that the measures of return remained unacceptable at wide ranges of soybean meal price. Only at soybean meal price of $885 per ton, a 10% IRR was achieved.

Results for 100% Sunflower Crushed Scenario

The sensitivity for 100% sunflower crushed scenario was performed by changing the feedstock used to 100% sunflower in the feasibility template and keeping all other variables as in the baseline scenario. The scale of the equipment was set to cooperative scale, the biodiesel price was assumed to be $3.50/gallon, the price of additional purchased oil was assumed to be $1.80/gallon and the sunflower yield was assumed to be 1500 lbs/acre. The oilseed crusher was operated 10 hours per day and the biodiesel processor was operated 8 hours per day. The oilseed crusher and the biodiesel processor were operated 300 days per year. Target biodiesel production was 250,800 gallon per year, 3,800 acres of land was required, 243,288 gal of oil was produced and 7,512 gal of additional oil was purchased. The results for this scenario are presented in the table below:

Table IV-17: Measures of Return at Baseline for the 100% Sunflower Scenario

Economic Variable	Values at Baseline
IRR	25.95%
NPV	$266,173
ROA	15.77%
ROE	41.35%
Payback Period	6^{th} Year

The results at baseline values showed that for 100% sunflower, the IRR would be 25.95%, NPV would be $266,173 and the payback period would be 6 year. This means that the 100% sunflower scenario would be profitable under baseline assumptions and prices and the generated cash flows can cover the expenses of the project.

Three different sensitivity analyses were performed for this scenario. The impact of biodiesel price, the impact of additional purchased oil price and the impact of sunflower yield was performed by varying the corresponding values and the changes in measures of return were calculated. The details of the sensitivity analysis are presented below.

Impact of Biodiesel Price-100% Sunflower

The impact of biodiesel price and changes in measures of return was calculated by varying the biodiesel price by 5 cents/gal increments while holding all other baseline assumptions constant. Table IV-18 summarizes the measures of these changes.

Table IV-18: Impact of Biodiesel Price on ROI for 100 % Sunflower Scenario

Economic Variable	Biodiesel Price					
	$3.20	$3.25	$3.30	$3.35	$3.40	**$3.50**
IRR	-5.91%	0.68%	6.44%	11.71%	16.17%	**25.95%**
NPV	-$213,098	$133,220	-$53,341	$26,536	$98,465	**$266,173**
ROA	-10.39%	-6.03%	-1.67%	2.69%	6.62%	**15.77%**
ROE	-11.51%	-2.70%	6.11%	14.92%	22.85%	**41.35%**
Payback Period	>10 Year	>10Year	>10 Year	>10 Year	9th Year	**6th Year**

(Baseline biodiesel price is $3.50/gal, Sensitivity performed for Coop. Scale)

Results indicate that the breakeven biodiesel price per gallon is about $3.25. When the biodiesel price per gallon is increased by 5 cents, internal rate of return (IRR) increases approximately by 5%, return on assets (ROA) increases approximately by 4% and return on equity (ROE) increases approximately by 9%. Payback period would start to fall from 10 years at biodiesel price between $3.35 and $3.40 per gallon.

Impact of Additional Purchased Oil Price-100% Sunflower

The price of additional oil was allowed to vary by 20 cents per gallon increments while keeping all other variables constant. Then changes in measures of return were calculated for each of the changes in the purchased oil prices. Table IV-19 summarizes the changes in measures of return for this case.

Table IV-19: Impact of Purchased Oil Price on ROI for 100 % Sunflower Scenario

Economic Variable	Purchased Oil Price					
	$1.60	**$1.8**	$2.0	$2.2	$2.4	$2.6
IRR	30.03%	**25.95%**	21.79%	17.51%	13.06%	8.37%
NPV	$338,906	**$266,173**	$193,440	$120,706	$47,973	-$24,760
ROA	19.74%	**15.77%**	11.80%	7.83%	3.86%	-0.11%
ROE	49.37%	**41.35%**	33.33%	25.31%	17.28%	9.26%
Payback Period	6th Year	**6th Year**	7th Year	9th Year	10th Year	>10 Year

(Baseline purchased oil price is $1.80/gal or $0.23/lb, Sensitivity performed for Coop. Scale)

Results indicate that the purchased oil price is not sensitive to the measures of return. When the purchased oil is increased by 20 cents, IRR decreases approximately by 4%, ROA decreases approximately by 4% and ROE decreases approximately by 8%. Only when purchased oil price is $2.60 per gallon and above does net present value turn negative and payback period exceeds 10 years. All the measures of return would be positive when the additional purchased oil price is $2.4 per gallon and at this price the cash flows would be sufficient to cover the projected expenses.

Impact of Sunflower Yield-100% Sunflower

The impact of changes in sunflower yield on the return on investment was investigated by varying sunflower yield by 75 lbs/acre increments (5% of the baseline yield) while keeping all other variables constant. Table IV-20 summarizes the measure of these changes.

Table IV-20: Impact of Sunflower Yield on ROI for the 100 % Sunflower Scenario

Economic Variable	Sunflower Yield (Lbs/acre)					
	1350	1425	**1500**	1575	1650	1725
IRR	-2.09	13.67%	**25.95%**	36.51%	45.92%	54.45%
NPV	-$172,580	$58,342	**$266,173**	$454,209	$625,152	$781,230
ROA	-8.23%	4.40%	**15.77%**	26.06%	35.42%	43.96%
ROE	-6.67%	18.60%	**41.35%**	61.92%	80.63%	97.71%
Payback Period	>10 Year	10th Year	**6th Year**	5th Year	4th Year	3rd Year

(Baseline sunflower yield is 1500 lbs/acre, Sensitivity performed for Coop. Scale)

The results indicate that the breakeven yield of sunflower is between 1350lbs/acre and 1425 lbs/acre and yields of sunflower are very sensitive to the measures of return. An increase in yield per acre by 5% increases the IRR approximately by 12%, ROA approximately by 10% and ROE approximately by 21%. Any yield at baseline and above would give positive returns. A yield of 1405 lbs/acre would be required to obtain an IRR of approximately 10%.

Results for 50 % Soybean and 50% Canola Crushed Scenario

In this scenario, the feedstocks used are changed to 50% soybean and 50% canola in the feasibility template and all other assumptions were kept as in the baseline scenario. Total target biodiesel production was 250,800 gallons per year. Total acres of land estimated for this production was 3,665 acres for both soybean and canola. An estimated 165,686 gallon of oil was produced and an estimated 85,114 gallon of additional oil was purchased. The sensitivity for the impact of different biodiesel prices and the impact of different additional purchased oil price was performed in this case. The results for this scenario are presented in the table below:

Table IV-21: Measures of Return at baseline for the 50% Soybean and 50% Canola Scenario

Economic Variable	Values at Baseline
IRR	Neg
NPV	$4,201,784
ROA	-228.06%
ROE	-451.75%
Payback Period	>10 Year

The results of this scenario show that the 50%-50% combination of soybean and canola has unacceptable negative returns at baseline values and assumptions. This is because soybean has less oil content and therefore produces less oil because of which a large sum of money is spent on purchasing additional oil (about 25% of the total requirement) to operate the biodiesel processor in its fullest capacity.

Two different sensitivity analyses were performed for this scenario. The impact of biodiesel price and the impact of additional purchased oil price were performed by varying the corresponding values and the changes in measures of return were calculated. The details of the sensitivity analysis are presented below.

Impact of Biodiesel Price-50% Soybean and 50% Canola

In this case, the price of biodiesel was varied by 5 cents/gallon increments keeping all other baseline assumptions constant. Then changes in measures of return were calculated which are summarized in Table IV-22 below.

Table IV-22: Impact of Biodiesel Price on ROI for 50 % Soybean and 50% Canola Scenario

Economic Variable	Biodiesel Price					
	$3.40	$3.45	**$3.50**	$3.55	$3.60	$3.65
IRR	Neg	Neg	**Neg**	Neg	Neg	Neg
NPV	-$4,369,491	-$4,286,896	**-$4,201,784**	-$4,117,912	-$4,042,027	-$3,962,148
ROA	-237%	-232%	**-228.06%**	-223%	-219%	-214%
ROE	-470%	-461%	**-451.75%**	-442%	-434%	-425%
Payback Period	>10 Year	>10 Year	**>10 Year**	>10 Year	>10 Year	>10 Year

(Baseline biodiesel price is $3.50/gal, Sensitivity performed for Coop. Scale)

The results indicated unacceptable return on investment at different ranges of biodiesel price. There was an unacceptable return even when the price of biodiesel per gallon was increased to $3.65 which is 15 cents over the baseline price. To generate approximately 10% IRR, the price of biodiesel per gallon had to be set at $6.13. The negative returns in this case were the result of the low oil content of soybean and its low yield tending to less oil produced from the oilseed crusher and requiring a large sum of money for purchasing additional oil to run the biodiesel processor in its fullest capacity.

Impact of Additional Purchased Oil Price-50% Soybean and 50% Canola

The price of the additional purchased oil was allowed to vary by 15 cents per gallon increments and all other baseline assumptions were kept constant. Then the changes in measures of return were calculated (Table IV-23).

Table IV-23: Impact of Purchased Oil Price on ROI for 50% Soybean and 50% Canola Scenario

Economic Variable	Purchased Oil Price					
	$1.5	$1.65	**$1.8**	$1.95	$2.10	$2.25
IRR	Neg	Neg	**Neg**	Neg	Neg	Neg
NPV	-$2,965,648	-$3,583,716	**-$4,201,784**	-$4,819,852	-$5,438,410	-$6,057,372
ROA	-160%	-194%	**-228.06%**	-261%	-295%	-329%
ROE	-315%	-383%	**-451.75%**	-519%	-588%	-656%
Payback Period	>10 Year	>10 Year	**>10 Year**	>10 Year	>10 Year	>10 Year

(Baseline purchased oil price is $1.80/gal or $0.23/lb, Sensitivity performed for Coop. Scale)

No positive returns were observed, when the price of additional purchased oil was changed by 15 cents per gallon. All the economic variables were negative and the payback period was more than 10 years for a wide range of purchased oil prices.

Results for 50% Canola and 50 % Sunflower Crushed Scenario

In this scenario, the feedstock used was changed to 50% canola and 50% sunflower in the feasibility template and all other baseline assumptions were held constant. The target biodiesel production was 250,800 gallon per year. An estimated 3,325 acres of combined land for canola and sunflower was required, 235,157 gallon of estimated oil was produced and 15,643 gallon of estimated additional oil was purchased.

The sensitivity for the impact of different biodiesel prices and the impact of different additional purchased oil prices was performed in this case. The results for this scenario are presented in the table below.

Table IV-24: Measures of Return at baseline for the 50% Canola and 50% Sunflower Scenario

Economic Variable	Values at Baseline
IRR	25.56%
NPV	$258,298
ROA	15.36%
ROE	40.40%
Payback Period	7th Year

There were significant positive returns for the 50% canola and 50% sunflower scenario and the project appeared profitable. The results at baseline values for this scenario show that the IRR would be 25.56%, NPV would be $258,298 and the payback period would be 7 year. This means that the combination of 50% canola and 50% sunflower would provide an acceptable return under baseline assumptions and prices and the generated cash flows can cover the expenses of the project.

Two different sensitivity analyses were performed for this scenario. The impact of biodiesel price and the impact of additional purchased oil price were performed by varying the corresponding values and the changes in measures of return were calculated. The details of the sensitivity analysis are presented below.

Impact of Biodiesel Price-50% Canola and 50% Sunflower

The impact of biodiesel price in this case was performed by varying the price of biodiesel by 5 cents per gallon increments while holding all other baseline assumptions constant. Then changes in measures of return were calculated (Table IV-25).

Table IV-25: Impact of Biodiesel Price on ROI for 50 % Canola and 50% Sunflower Scenario

Economic Variable	Biodiesel Price					
	$3.20	$3.25	$3.30	$3.35	$3.40	**$3.50**
IRR	-6.74%	0.02%	5.88%	11.21%	15.71%	**25.56%**
NPV	-$220,973	-$141,095	-$61,216	$18,662	$90,590	**$258,298**
ROA	-10.81%	-6.45%	-2.09%	2.28%	6.20%	**15.36%**
ROE	-12.45%	-3.65%	5.16%	13.97%	21.90%	**40.40%**
Payback Period	>10 Year	>10 Year	>10 Year	10th Year	9th Year	**7th Year**

(Baseline biodiesel price is $3.50/gal, Sensitivity performed for Coop. Scale)

Results indicate that the breakeven price of biodiesel is about $3.25. When the biodiesel price is increased by 5 cents, IRR increases approximately by 5%, ROA increases approximately by 4% and ROE increases approximately by 8%. The payback period would start to fall at biodiesel price of $3.30 per gallon and above.

Impact of Additional Purchased Oil Price-50% Canola and 50% Sunflower

The price of the additional oil was allowed to vary by 15 cents per gallon increments while keeping all other variables constant at baseline. Table IV-26 presented below shows the changes in sensitivity measures for each of the different additional purchased oil prices for this scenario.

Table IV-26: Impact of Purchased Oil Price on ROI for 50 % Canola and 50% Sunflower Scenario

Economic Variable	Purchased Oil Price					
	$1.65	**$1.80**	$1.95	$2.10	$2.25	$2.40
IRR	31.92%	**25.56%**	18.97%	12.01%	4.38%	-4.50%
NPV	$371,889	**$258,298**	$144,706	$31,114	-$82,477	-$196,069
ROA	21.56%	**15.36%**	9.16%	2.95%	-3.25%	-9.45%
ROE	52.93%	**40.40%**	27.87%	15.35%	2.82%	-9.71%
Payback Period	5th Year	**7th Year**	8th Year	10 Year	>10 Year	>10 Year

(Baseline purchased oil price is $1.80/gal or $0.23/lb, Sensitivity performed for Coop. Scale)

Results indicate that the breakeven price of additional purchased oil is between $2.25 and $2.40 per gallon. A $0.15 decrease in the price of additional oil results in approximately 7% increase in the IRR, approximately 6% increase in ROA and approximately 13% increase in ROE. The payback period would be more than 10 years and returns would be negative when the additional purchased oil price exceeds $2.40 per gallon. The breakeven price for purchasing additional oil would be between $2.25 and $2.40. At that price level for additional oil the IRR would be 0%.

CHAPTER V

CONCLUSION

Large quantities of diesel fuels are used by farmers for operating different farm equipment and machinery in the field. The high price volatility of diesel fuel is a significant source of risk for agricultural producers. Biodiesel appears to be one of the viable options to combat any rise in the price of diesel fuel. It can be produced on-farm and used on-farm. Despite these advantages producers have difficulty determining whether the potential financial benefits from the on-farm biodiesel production outweigh the investment and operating costs. This research was conducted to project the financial feasibility of biodiesel production on-farm from oilseed crops. Canola, soybean and sunflower were considered as the major feedstock used in the biodiesel production.

An oilseed crusher and a biodiesel processor were assumed to be housed on-farm. Three different equipment sizes were considered. In each case, the biodiesel processor was assumed to be operated at full capacity and was matched with the most appropriate scale of oilseed crushing equipment. Surplus or deficit oil supplies were assumed to be sold or purchased, respectively. The feasibility analysis was performed for five different scenarios, three for each of the crops, one for the combination of canola and soybean and other for the combination of canola and sunflower. The 100% canola crushed scenario was assumed to be the baseline scenario. An MS Excel based feasibility template was constructed to perform the feasibility analysis. The template was used to input the basic financing information, prices of the inputs and outputs, details of the equipments and to project the cost and returns for a ten year period.

Specific Conclusions

The first objective of this research was to analyze cost and returns of a baseline scenario which involved processing canola, the second objective was to perform similar analysis for scenarios involving other oilseed feedstocks and the third objective was to determine the sensitivity of the profitability of the on-farm biodiesel production facility to the scale of operation and changes in prices for various input and output factors. The previously described feasibility template constructed in MS Excel was used to determine the objectives mentioned above. The template proved to be very helpful in projecting the costs and returns of the processing facilities.

Among the 100% scenarios, the baseline (100% canola) scenario appeared to be the most attractive. Under baseline assumptions, the return on investment for processing canola was only slightly below that of sunflower. Canola is a winter annual and is therefore easier to fit into a rotation with winter wheat which is Oklahoma's dominant crop. For producers who can fit a summer crop into their rotation, processing sunflower was also shown to have an acceptable return on investment with returns slightly exceeding those of canola. At the baseline biodiesel price, the IRR for the 100% canola scenario was 25.16% and the IRR for the 100% sunflower scenario was 25.95%. The least profitable scenario was the 100% soybean scenario which had unacceptable negative returns over a wide range of biodiesel prices. Among the combined 50% winter and 50% summer crop scenarios, the results indicated that a combination of canola and sunflower could provide acceptable returns but the returns from processing a canola and soybean mix was unacceptable. Processing a combination of a summer and winter oilseed crop would provide diversification and reduce the need for oilseed storage. The 50% canola and 50% sunflower scenario had positive returns at a biodiesel price of $3.35 per gallon and above while 50% canola and 50% soybean had unacceptable negative returns over a wide range of biodiesel prices. The negative returns in the 100% soybean scenario and negative returns in 50% canola-50% soybean scenario is because of the low oil content of soybean compared to other crops. Because of the lower oil content, large quantities of additional oil have to be purchased to operate the biodiesel processor in its fullest capacity. Under the baseline assumption of $1.80/gallon for outside oil purchased, sourcing the outside feedstock decreased the return on investment of the project. So, to summarize, 100% canola scenario, 100% sunflower scenario and 50% canola-50% sunflower scenario appear profitable under baseline assumptions and prices. However, when the breakeven prices of $3.20-$3.30 per gallon for these scenarios are compared with the current biodiesel price of $3.08 per gallon (U.S. Department of Energy, July, 2009), all the measures of return turn negative and the investment does not look profitable. The breakeven prices for these scenarios are not economically competitive with the current biodiesel price and therefore the investments are not economically feasible unless producers anticipate an increase in the biodiesel price in the future. On the other hand, the 100% soybean scenario and the 50% canola-50% soybean scenario appear least feasible under baseline assumptions as they had unacceptable negative returns over a wide range of input factors under study.

To determine how sensitive the return on investment of the baseline (100% canola) scenario was to other cost factors, ten different sensitivity analyses were performed. The result showed that the returns are highly sensitive to the oil content of canola. When the canola oil content is increased by 0.2%, IRR increases dramatically by 6%. It should be noted that the oil content is not affected by the oilseed crushing equipment but is likely impacted by crop genetics and production practices. Similarly, the measures of return were sensitive to the canola yield, total cost of production, purchased oil price, total cost of equipment and electricity cost. There was an increase in IRR by 10% when canola yield was increased by 5%. IRR turned negative when the total cost of producing canola was increased by 15% of the baseline estimated cost of production. Similarly, when purchased oil price was increased by 10 cents per gallon, IRR decreased approximately by 7%. When the total cost of equipment was increased by 20%, IRR decreased approximately by 2% and when the electricity cost was increased by 2 cents per KW, IRR decreased approximately by 4%.

The scale of the processing equipment also had a major impact on the return on investment. In order to separate the effect of equipment scale from the effect of outside oil purchases, the oil produced to oil purchased was set to 9:1 with 90% produced oil and 10% purchased oil. The working capital for the small scale operation was adjusted just to 2% of annual sales with no extra amount while the working capital for medium and small scale had $100,000 extra amount beside 2% of annual sales. This was done because the working capital of the small scale would be lower since the feedstocks are provided from the on-farm crop production while for the other two scales the feedstocks are required from the members. The results showed that there were significant negative returns for both the small and medium scale and only the cooperative scale enjoyed positive returns. While the returns on investment were negative in both cases, returns for the small scale equipment complement were slightly higher than the medium scale. Because of the economies of scale, producers considering on-farm oilseed and biodiesel production might be best served by combining operations in a small scale formal or informal cooperative. The other variables or factors examined for sensitivity are interest rates (short term and long term) and maintenance cost. The return on investment was not sensitive to these cost factors. There were positive returns at interest rates (short term and long term) of 23.5%. So, it is not very sensitive. Similarly, the IRR was 15.4% and all other measures of return were positive even when the maintenance cost was 13% which is an increment of 8% above the baseline.

Four different sensitivity analyses were performed for 100% soybean scenario and three different sensitivity analyses were performed for 100% sunflower scenario. The sensitivity for 100% soybean scenario showed that all the returns were negative and unacceptable for a wide range of biodiesel prices, additional purchased oil prices, soybean meal prices and a wide range of soybean yield. This is mainly associated with the low oil content of the soybean which is almost half compared to the oil content of canola and sunflower. To achieve a 10% IRR, the biodiesel price had to be set at $8.92 per gallon or the oil content had to be increased to 38.02%. The 100% sunflower scenario showed better performance compared to the 100% soybean scenario. All the measures of return were positive at the baseline level. The results showed that it was highly sensitive to the sunflower yield and some to the purchased oil price. When the sunflower yield was increased just by 5%, IRR increased approximately by 12%. Similarly, when the purchased oil price was increased by 20 cents per gallon, IRR decreased approximately by 4%.

Two different sensitivity measures were performed each for the 50%-50% scenarios. There were unacceptable negative returns for the 50% canola-50% soybean scenario. For the 50% canola- 50% sunflower scenario, both the biodiesel price and the purchased oil price were sensitive to the measures of return. IRR increased by approximately 5% when the biodiesel price was increased by 5 cents per gallon and IRR decreased by approximately 7% when the purchased oil price was increased by 15 cents per gallon. So, both the biodiesel price and the purchased oil price are sensitive to the measures of return for 50% canola-50% sunflower scenario.

At the baseline assumptions, the 100% sunflower crushed scenario followed by combination of 50% canola-50% sunflower scenario and then 100% canola scenario appears to be the most attractive scenario of all the scenarios. The higher returns in case of 100% sunflower scenario are because of two factors - its high oil content associated with low production cost per acre. If the yield or oil content of any oilseed crop can be increased, or if the cost of production per acre can be lowered, there will be significant changes in the measures of return and any scenario can be more profitable than another. Since both canola and sunflower oil are used for food grade products, producers may also want to consider their opportunity costs for these alternative markets. The 100% soybean crushed scenario and its combination with canola did not perform better because its oil content was very low compared to the other two crops. With the current oil content, the returns would not be positive even if the yield is increased by 100% or the cost of production per acre is lowered significantly. In order to make the 100% soybean scenario a profitable venture, oil content would have to be doubled or meal co-product value would have to increase dramatically. The $3.20-$3.30 breakeven biodiesel price per gallon for baseline (100% canola) scenario seems to be close enough with the current nationwide average biodiesel price of $3.08 per gallon for B100 (100% Biodiesel). For on-farm production on a smaller scale, this price is a reasonable price for farmers to use it on-farm for farm purposes or use it as a fuel additive.

In conclusion, this research has shown that canola, sunflower or combination of either of these two would be the preferred feedstocks for on-farm biodiesel production at baseline assumptions and based on the Oklahoma State University's Enterprise Budgets for crop production cost per acre and yield. But since the breakeven prices are not competitive with the current biodiesel price, none of the scenarios are economically feasible. The on-farm processing of soybean and its combination with canola does not appear economically feasible even at baseline assumptions. The return on investment of an on-farm crushing and biodiesel operation for canola is sensitive to the oil content, price of biodiesel, yield of the crop, cost of production, purchased oil price and the scale of the equipment. Producers interested in on-farm oilseed and biodiesel production might be best served by combining operations in a small scale formal or informal cooperative because of the economies of scale and they should also consider the cost of outside feedstock. Access to a low priced feedstock such as used cooking oil or animal fat would improve the return on investment. Purchasing higher priced oil feedstocks to keep the biodiesel processor operating at full capacity reduces the project returns. The relative cost of outside oil purchases also highlights the need to match the capacities of the oilseed crushing and biodiesel equipment.

Limitations and Recommendations for Future Research

The feasibility template created for this study purpose has opened up an avenue for detailed financial analysis for on-farm biodiesel production using canola, soybean and sunflower. Several input and output prices, and other required assumptions were made to project the different economic variables. Most of the data used were historical data which were averaged over a range of time periods. As the grain and oilseed prices change over time the results of this study may not be suitable to reflect the economy for the next 2-3 years. Furthermore, the results of this study are highly dependent on several factors, most important being the oil content, yield of the crop, cost of crop production, biodiesel price, additional oil price and capacity of the equipment. So, with changes in these and other factors results will differ.

During the course of the study, it was very hard to find an exact match for the processing capacities of the oilseed crusher and the biodiesel processor. Sometime, the capacity of the oilseed crusher would be high and sometime the capacity of the biodiesel processor would be low and vice-versa. Therefore, an exact complement was hard to find to match both. Producers investing in on-farm biodiesel processing facility must work hard to find an exact match for the processing capacities of the oilseed crusher and the biodiesel processor. Similarly, an accurate cost of the biodiesel processor and the accurate cost of the oilseed crusher were also hard to determine. It was also hard to estimate the utilities cost for the biodiesel processor and the oilseed crusher. More information from the operating plant manufacturers can improve these estimates.

Based on the results of the study, on-farm or small scale cooperative processing feedstocks with higher oil content, high yielding crops and lower crop production cost can be economically feasible and is recommended. Choice can be made for those varieties which yield high and provide a large percentage of oil. Only one additional paid operator and input from farm managers for the processing operation was assumed. Therefore, an impact of the actual labor requirements for the on-farm processing operations or an integration of labor into the processing plant could be a good point of investigation for further research and is recommended.

REFERENCES

Ash, M., J. Livezey and E. Dohlman. 2006. Soybean Backgrounder. Electronic Outlook Report from the Economic Research Service. United States Department of Agriculture (USDA).

Bachmann, J. 2004. Oilseed Processing for Small-Scale Producers. ATTRA Publication #IP134, May. ATTRA (Appropriate Technology Transfer for Rural Areas) – National Sustainable Agriculture Information Service, National Center for Appropriate Technology (NCAT), Fayetteville, AR, USA.

Bender, M. 1999. Economic Feasibility Review for Community-scale Farmer Cooperatives for Biodiesel." *Bioresource Technology* 70(1999): 81-87.

Bowser, T., P. Kenkel and R. Holcomb. 2008. Oklahoma State University Biodiesel Feasibility Template. Available at http://www.fapc.okstate.edu/services/economics.html

Canola Council of Canada. Canola Quick Facts. A Major Canadian Export. Nov 1, 2005. Available at http://www.canola-council.org/factsexport.html

Dagher, M., R. Panicker, E. Myles and N. Bell. 2003. Mississippi Biodiesel Feasibility Study. Alcorn State University. Mississippi Small Farm Development Center. Alcorn State, Mississippi. Available at http://www.mississippi.org/assets/docs/library/alcorn_sec3_report.pdf

Doye, D. and R. Sahs. 2008. Oklahoma State University Enterprise Budgets for Canola, Soybean and Sunflower. Available at http://agecon.okstate.edu/budgets/

English, B., K. Jensen and J. Menard. 2002. Economic Feasibility of Producing Biodiesel in Tennessee. Agri-Industry Modelling and Analysis Group (AIM-AIG). Report Prepared for Tennessee Soybean Promotion Board, Tennessee Farm Bureau, Tennessee Department of Agriculture, USDA Rural Development, and Tennessee Valley Authority.

Escalera, E., J. Lee, J. Parsons, I. Rusangiza. 2006. Biofuels Production Systems Analysis. Proceedings of the 2008 IEEE Systems and Information Engineering Design Symposium, University of Virginia, Charlottesville, VA, USA.

Frazier Barnes and Associates. 2003. Statewide Biodiesel Feasibility Study Report for The Mississipi Biomass Council and The Mississippi Technology Alliance.

Giampietro, M., S. Ulgiatti, and D. Pimentel. 1997. Feasibility of Large-Scale Biofuel Production. Bioscience, Vol. 47, No. 9, PP. 587-600. American Institute of Biological Sciences.

Grubinger, V. 2007. On-farm Oil Seed Production and Processing. Final Report. A One Year Pilot Project. The University of Vermont Extension. Available at http://www.uvm.edu/vtvegandberry/.../Final%20Report%205-15-2007.pdf

Haas, M. J., A. J. McAloon, W. C. Yee and Thomas A. Foglia. 2006. A Process Model to Estimate Biodiesel Production Costs. Bioresource Technology 97, PP. 671-678.

Hasse, S., B. Craig and A. Goebel. 2004. An Economic Analysis of Small-Scale Biodiesel Production: Implementation of Ethyl Ester Production in a Job Shop Setting. Available at http://grad.mnsu.edu/research/urc/journal/URC2004journal/CraigHaase.pdf

InstaPro ExPress Process. Available at http://insta-pro.com/pdfs/Insta-ProExPressProcess.pdf

Jager, W. and R. Siegel, 2008. Economics of Oilseed Crops and Their Biodiesel Potential in Oregon's Willamette Valley. Oregon State University. Extension Service. Available at http://www.arec.oregonstate.edu/jaeger/energy/SR%201081%20Oilseeds.pdf

Kay, R.D., W.M. Edwards and P.A. Duffy. 2008. Farm Management. Sixth Edition.

Kingwell, R. and B. Plunkett. 2006. Economics of On-Farm Biofuel Production. Available at http://www.agric.wa.gov.au/content/SUST/BIOFUEL/200603_BFOnFarmEconomics.pdf

Kenkel, P. and R. Holcomb. 2008. Feasibility of On-farm or Small Scale Oilseed Processing and Biodiesel Production. Transition to a Bioeconomy: Integration of Agricultural and Energy Systems, Farm Foundation Press. Available at http://www.farmfoundation.org/news/articlefiles/378-FFbook6-12-08.pdf

Kenkel, P., R. Holcomb, N. Dunford and M. Dicks. 2005. Economic Feasibility of Producer-Owned Oilseed Processing Facility in Oklahoma. Oklahoma State University.

Kenkel, P., R. Holcomb, M. Dicks and N. Dunford. 2006. Feasibility of a Producer-Owned Winter Canola Processing Venture. Oklahoma State University.

Naeve, S.L., J.H. Orf and T. O'neill. 2008. Quality of the United States Soybean Crop: 2008. Available at http://www.soybeans.umn.edu/pdfs/2008/quality/2008USSoybeanQuality_Report.pdf

National Biodiesel Board. 2007. Biodiesel, Renewable Diesel and Co-processed Renewable Diesel. Available at http://www.biodiesel.org/pdf_files/fuelfactsheets/Co-Processing%20One%20Pager.pdf

U.S. Sunflower Crop Quality Report. Available at http://www.sunflowernsa.com/uploads/2008_CropQuality.pdf

National Winter Canola Variety Trial. 2008. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Available at http://www.ksre.ksu.edu/library/crpsl2/srp1009.pdf

Nesbitt, D.P. National Director of Sales, Insta-Pro International. Personal Communication.

Nowatzki, J., A. Swenson, D.P. Wiesenborn. 2007. Small-scale Biodiesel Production and Use. North Dakota State University. Extension Service. Available at http://www.ag.ndsu.edu/pubs/ageng/machine/ae1344.pdf

Ryan. 2004. Biodiesel – A Primer. ATTRA – National Sustainable Agriculture Information Service. Available at www.attra.ncat.org

Pimentel, D. and T.W. Patzek. 2005.Ethanol Production Using Corn, Switchgrass, and Wood; Biodiesel Production Using Soybean and Sunflower. Natural Resources Research, Vol. 14, No. 1.

Purcella, G. Owner, Summit Enterprises LLC. Manufacturer of the EZBiodiesel Processor. Personal Communication.

Putnam, et al, 1990. Sunflower. Alternative Field Crops Manual. Available at http://www.hort.purdue.edu/newcrop/afcm/sunflower.html

Putt, R. 2007. Algae as a Biodiesel Feedstock: A Feasibility Assessment. Center for Microfibrous Materials Manufacturing. Department of Chemical Engineering. Auburn University.

Sexton, et al. 2006. Pilot Production of Biodiesel from Canola in New England. Univeristy of Maine Cooperative Extension. Report available on request at http://www.sare.org/reporting/report_viewer.asp?pn=ONE05-048&ry=2006&rf=1&rtf=1

Stebbins, E.J. 2008. Homegrown Feed, Food and Fuel. The Market Potential of Farm-Scale Oilseed Crop Products in Vermont. Department of Community Development and Applied Economics. University of Vermont. Available at http://www.vsjf.org/biofuels/documents/FFP_Final_Report_2008.pdf

Sustainable Community Enterprises. 2007. A Feasibility Study for Fish Oil Biodiesel Production. Clayoquot Biosphere Trust. Available at http://www.clayoquotbiosphere.org/projects/2006/Biodiesel_Fesibility.pdf

Thomas Jefferson Agricultural Institute, Sunflower: A Native Oilseed with Growing Markets: Overview. Available at http://www.jeffersoninstitute.org/pubs/sunflower

U. S. Department of Agriculture, Economic Research Service. Oil Crops Outlook. April 2009. Available at http://jan.mannlib.cornell.edu/usda/ers/OCS//2000s/2009/OCS-04-10-2009.pdf

U. S. Department of Agriculture, National Agricultural Statistics Service. 2007 Crop Production Report. Available at http://www.nass.usda.gov

U. S. Department of Agriculture, National Agricultural Statistics Service. 2008. Available at http://www.nass.usda.gov/Statistics_by_State/Pennsylvania/Publications/Annual_Statistical_Bulletin/2007_2008/Prices_paid.pdf

U.S. Energy Information Administration. October, 2009. Available at http://eia.doe.gov/

U.S. Department of Energy. 2009. Clean Cities Alternative Fuel Price Report. Energy Efficiency and Renewable Energy. Available at http://www.afdc.energy.gov/afdc/pdfs/afpr_jul_09.pdf

Van Gerpen, J. 2005. Biodiesel Processing and Production. Fuel Processing Technology 86, No. 10, PP. 1097-1107.

Vanwechel, T., C.R. Gustafson and F.L. Leistritz. 2002. Economic Feasibility of Biodiesel Production in North Dakota. Agribusiness and Applied Economics Report No. 505. North Dakota State University.

Whittington, T. (2006). Biodiesel Production and Use by Farmers: Is it Worth Considering? Department of Agriculture and Food. Government of Western Australia. Available at http://www.agric.wa.gov.au/objtwr/imported_assets/content/sust/biofuel/onfarmbiodieselprod.pdf

VITA

Arjun Basnet

Candidate for the Degree of

Master of Science

Thesis: FEASIBILITY OF ON-FARM PROCESSING OF CANOLA, SOYBEAN AND SUNFLOWER INTO BIODIESEL

Major Field: Agricultural Economics

Biographical:

Education: Completed the requirements for the Master of Science in Agricultural Economics at Oklahoma State University, Stillwater, Oklahoma in December, 2009.

Experience: Graduate Research Assistant, Department of Agricultural Economics, Oklahoma State University, April 2008 to Present. Project Officer, LI-BIRD (Nepal), March 2006 to December 2007.Research Officer (Intern), LI-BIRD (Nepal), August, 2005 to February, 2006.

Professional Memberships: Agricultural and Applied Economics Association (AAEA)-Member, Gamma Sigma Delta-Member

Name: Arjun Basnet　　Date of Degree: December, 2009

Institution: Oklahoma State University　　Location: Stillwater, Oklahoma

Title of Study: FEASIBILITY OF ON-FARM PROCESSING OF CANOLA, SOYBEAN AND SUNFLOWER INTO BIODIESEL

Pages in Study: 82　　Candidate for the Degree of Master of Science

Major Field: Agricultural Economics

Scope and Method of Study: The high volatility of fuel prices has forced farmers to consider alternative sources of energy for daily farm activities. Therefore, farmers are contemplating purchase of small scale biodiesel processors for on-farm use. However, they are uncertain about the economic cost and benefits of processing oilseeds into biodiesel on-farm. They are interested in moderating the risk of the increasing fuel prices by growing and processing small to moderate amounts of canola, sunflower or other oilseed crops. Therefore, in order to provide more information to potential investors about their investments, a Microsoft Excel based feasibility template was constructed to form a budget and project the cost and return for determining the economic feasibility of on-farm biodiesel production from canola, soybean and sunflower. Five feasibility measures were calculated including internal rate of return, net present value, return on assets, return on equity and payback period which were compared for five different potential scenarios.

Findings and Conclusions: Three scenarios-100% canola, 100% sunflower and 50% canola-50% sunflower appeared profitable at baseline assumptions and prices. The breakeven biodiesel prices of $3.20-$3.30/gal for these scenarios at baseline were not competitive with the current biodiesel price of $3.08/gal at market. Therefore, the investments are not economically feasible unless producers anticipate an increase in the biodiesel price in future. Two scenarios-100% soybean and 50% canola-50% soybean had significant negative returns and did not prove profitable even at baseline assumptions and prices. The negative returns with soybean and its combination with canola was due to the low oil content of the soybean. Results of the sensitivity analysis show that the baseline scenario (100% canola) was sensitive to oil content, biodiesel prices, scale of equipment, canola yield, cost of production, cost of equipment, purchased oil prices and electricity cost. It was not sensitive to interest rates and maintenance cost. 100% sunflower and 50% canola-50% sunflower scenario were sensitive to biodiesel prices, purchased oil price and yield of the crops.

ADVISER’S APPROVAL: Dr. Phil Kenkel