THE ECONOMICS OF AN ALTERNATIVE BIO-ENERGY FEEDSTOCK – THE CASE OF *JATROPHA CURCAS*

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ABSTRACT

Biofuels such as ethanol and biodiesel are looked upon as the future source of alternative energy. These biofuels will supplement the needs of the ever increasing demand for fuel. Bio-energy feedstock is in high demand and current bio-crude oil prices such as soybeans and palm oil are higher than fossil fuel crude oil prices. Unless the price of fossil fuel crude oil increases beyond that, it would not be economically viable to produce biofuels from these feedstock.

Jatropha curcas has been touted as the future of biodiesel. The seeds from the *Jatropha curcas* are crushed and processed using transesterification. The product of the chemical reaction results in bio-oil and glycerin.

The objective of this paper is to study the economics of *Jatropha curcas* as an alternative bio-energy feedstock. Comparisons are done on *Jatropha curcas* oil, soybean oil, and palm oil. The *Jatropha curcas* industry is at its infancy, and crude *Jatropha curcas* oil is either not available in the open market or extremely difficult to find in any significant amount. However, soybean oil and crude palm oil are traded commodities and their prices are dependent on their demand and supply pressures. Given these conditions, the approach adopted here involved the establishment of a vertically integrated company that grows and harvests the *Jatropha curcas* feedstock and crushes the seeds to obtain the crude oil, and finally processes it to obtain biodiesel and glycerin.

The financial analysis provided results that indicate that the *Jatropha curcas* has the potential to be a successful feedstock. The conclusion after conducting net present value comparisons shows that the price per kilogram of the *Jatropha curcas* seed would be the determining factor in the success of this bio-fuel feedstock. As more work goes into the genetic selection of *Jatropha curcas* for high yield varieties, the feedstock's potential increases and its potential as a solution to the search for the competitive sources of biodiesel becomes more real.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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CHAPTER 1: INTRODUCTION

1.1 Introduction

Jatropha curcas is a crop that grows well on poor arable land and has been shown to be high in oils that can be easily processed into biodiesel for transportation and other energy. Being a non-food crop that does not compete with food crops means that the question of food versus fuels becomes moot. However, production is more than land allocation. It competes for labor and capital as well as management resources with all other production resources, as well as the opportunities to produce similar bio-energy solutions. In addition to all that, it also would compete with livestock production.

In order to make better investment decisions and ensure long-term shareholder value creation it is imperative that the economics of *Jatropha curcas* is evaluated within the context of alternative solutions. Many *Jatropha curcas* projects have been implemented without careful assessments of the risks and cost structures. Examples include the planting of large plantations with plant spacing error, where plants were grown too close or too far apart, not knowing the local impact for the crop where in some cases diseases and insect pressure have been a constant issue, and the lack of skilled labor within the area. Another example is from northern Kenya, where farmers were made to believe that *Jatropha curcas* was a drought-resistant crop that will do well without any moisture. Understanding the constraints associated with production of *Jatropha curcas* is important in helping make efficient decisions among alternative feedstock production for bio-fuel production.

Bio-fuel refers to fuel derived from renewable biological feedstock such as biomass from living plants, animals and/or their by-products. Traditional bio-fuel consists of animal dung, wood, saw dust and charcoal. These have been limited to producing cooking energy and home heating and continue to be important sources of energy in Africa and Asia, providing between 70 and 90 percent of rural energy (Kgathi and Zhou, 1995, Ramachandra *et al.*, 2004). New biofuels are being explored today for transportation and other uses, and these include energy from ethanol and bio-diesel. In recent decades, modern biofuels have become important sources of electricity and transport fuels in some parts of the world.

The seed of *Jatropha curcas* is the source of oil in the plant. This oil can be processed into biodiesel and its by-products processed into fuel pellets, fertilizer and soap products (glycerin). However, if *Jatropha curcas* is to be used as a source of bio-fuel successfully, then it has to be done responsibly. As a new feedstock, and given its agronomic flexibility in growing areas and requirements, its success will depend on careful assessment of its potential against competing feedstock and in the education of its supply chain from farmers to oil executives.

The use of food-based feedstock (e.g., corn and soybean) to produce biofuels such as ethanol and bio-diesel has become increasingly controversial. For example, it has been argued that the increase in corn prices in the last few years was due to the increased demand created by ethanol, and this price increase contributed to increasing food security risks in poor countries. However, there are counter arguments that the increase in commodity food prices was not caused by the derived demand for commodities by bio-fuel producers but simply due to the absurdly high prices of petroleum and the natural economic pressures that cause prices to go up.

It is possible to eliminate, or at least reduce, the connection between the pursuit of alternative energy sources and the food price fluctuations by searching for and introducing alternative feedstock that are non-food. Such is the case with *Jatropha curcas*. Being a non-food product which does well on poor lands and in low moisture environments, it has the potential to be a successful alternative to soybean oil, rapeseed oil, palm oil, castor oil, and cotton seed oil that are the primary feedstock in biodiesel production.

1.2 Research problem and research question

As a result of the controversy surrounding the use of food products in the production of bio-energy, many investors are jumping on the non-food sources of bio-fuel feedstock without careful assessment of their economic feasibility. This feasibility stretches from production economics through logistics and processing economics. It also encompasses the use economics, in the sense that the assumption of equal energy potential of products from all feedstock sources may be false, and hence must be evaluated. Additionally, there is a need for assessment of the organizations' structures to support the effective exploitation of an alternative feedstock.

Being a new feedstock, *Jatropha curcas* suffers from this lack of adequate information on its economics as a bio-fuel feedstock. This is, therefore, the problem that this research seeks to address, i.e., provide more information on the economics of *Jatropha curcas* as an alternative feedstock in the bio-fuel marketplace. The research question is as follows: What are the net economic advantages of *Jatropha curcas* over other feedstock for biodiesel production and are they large enough to warrant investment?

1.3 Objectives

The overall objective of this research is to conduct an economic analysis of *Jatropha curcas* as an alternative biodiesel feedstock. The specific objectives are as follows:

a) Evaluate the physical characteristics of *Jatropha curcas* and compare them to its principal feedstock competitors.

b) Analyze the economics of producing biodiesel from *Jatropha curcas* and compare it to that of selected alternative feedstock – oil palm and soybean.

1.4 Methods

The principal method for this thesis is Net Present Value (NPV) analysis, from primary production through processing to distribution levels of the supply chain. The analysis is based on the end-use value of the biodiesel produced. The research uses secondary sources and knowledgeable people in the industry are interviewed for critical perspectives on the *Jatropha curcas* as well as the biodiesel industry.

Econometric analysis is employed to determine the effect of certain production variables on the economic viability of *Jatropha curcas* vis-à-vis oil palm. This method allows for the assessment of the extent to which specific product characteristics and production variables create economic opportunities for alternative feedstock materials.

1.5 Thesis Outline

The next chapter presents the literature review encompassing discussion of what *Jatropha curcas* is, its agronomy, chemistry, and other scientific characteristics of *Jatropha curcas* compared to regular diesel as well as an overview of the diesel market.

In Chapter 3, the data, methods, models and hypotheses are, presented and discussed. The results of the analyses are presented and discussed in Chapter 4, and the final chapter focuses on providing a summary of the study, conclusions emanating from it and some recommendations on how to effectively introduce *Jatropha curcas* as an alternative feedstock in biodiesel production.

CHAPTER 2: LITERATURE REVIEW

In this chapter, an overview of the biodiesel market is presented, with specific focus on feedstock going into the production of renewable fuel products. The characteristics and agronomy of *Jatropha curcas* are also presented. The chapter also reviews the studies that have thus far been conducted on the economics of bio-fuel production, focusing on biodiesel products from feedstock such as soybean and palm oil.

2.1 *Jatropha Curcas* and its Uses

Jatropha curcas is a perennial plant belonging to the *Euphorbiaceae* family. It is commonly known as the physic nut. More common plants in the *euphorbiaceae* family include the rubber tree (*hevea brasiliensis*), cassava, castor oil plant, and the poinsettia plant. *Jatropha curcas* is native to Central America and the Caribbean. It has always been looked upon as a multipurpose plant that is drought resistant. Among the most common function of the *Jatropha curcas* is its use as fencing as it prevents animals from getting through when planted close together. If carefully planted, *Jatropha curcas* hedges not only protect gardens from hungry livestock but also reduce damage and erosion from wind and water (Henning, 1998).

According to Ochse (1980), "the young leaves may be safely eaten, steamed or stewed." They are favored for cooking with goat meat, said to counteract the peculiar smell. Though purgative, the nuts are sometimes roasted and eaten, a risk taken even with the knowledge of its toxicity. In India, pounded leaves are applied near horses' eyes to repel flies. The oil has been used for illumination, soap, candles, adulteration of olive oil, and making Turkey red oil. Nuts can be strung on grass and burned like candlenuts (Watt and Breyer-Brandwijk, 1962). Mexicans grow the shrub as a host for the lac insect or more commonly known as mealy bug. The secretions produced by the insect and the plant is then harvested and processed to obtain varnish or shellac type material. Ashes of the burned root are used as a salt substitute (Morton, 1981). Agaceta et al. (1981) conclude that it has strong molluscicidal activity. Duke and Wain (1981) list it for homicide, piscicide, and raticide as well. The latex was strongly inhibitory to watermelon mosaic virus (Tewari and Shukla, 1982). The bark may be used as a fish poison (Watt and Breyer-Brandwijk, 1962). In South Sudan, the seed as well as the fruit is used as a contraceptive (List and Horhammer, 1969–1979) and its sap stains linen, and can, therefore, be used for marking (Mitchell and Rook, 1979).

According to Hartwell (1971), the extracts of *Jatropha curcas* are used in folk remedies for cancer. Reported to be abortifacient, anodyne, antiseptic, cicatrizant, depurative, diuretic, emetic, hemostat, lactagogue, narcotic, purgative, rubefacient, styptic, vermifuge, and vulnerary, physic nut is a folk remedy for alopecia, anasorca, ascites, burns, carbuncles, convulsions, cough, dermatitis, diarrhea, dropsy, dysentery, dyspepsia, eczema, erysipelas, fever, gonorrhea, hernia, incontinence, inflammation, jaundice, neuralgia, paralysis, parturition, pleurisy, pneumonia, rash, rheumatism, scabies, sciatica, sores, stomachache, syphilis, tetanus, thrush, tumors, ulcers, uterosis, whitlows, yaws, and yellow fever (Duke and Wain, 1981; List and Horhammer, 1969–1979). Its latex may be applied topically to bee and wasp stings (Watt and Breyer-Brandwijk, 1962). It also has specific use in different cultures. For example, Mauritians massage ascitic limbs with the oil and Cameroonians apply the leaf decoction in arthritis (Watt and Breyer-Brandwijk, 1962). Colombians drink the leaf decoction for venereal disease (Morton, 1981) while Bahamans drink the decoction for heartburn. Costa Ricans poultice leaves onto erysipelas and splenosis and

Guatemalans place heated leaves on the breast as a lactagogue. Cubans apply the latex to toothache while Colombians and Costa Ricans apply the latex to burns, hemorrhoids, ringworm, and ulcers. Barbadians use the leaf tea for marasmus, Panamanians use it for jaundice and Venezuelans take the root decoction for dysentery (Morton, 1981).

Jatropha curcas seeds are used also for dropsy, gout, paralysis, and skin ailments (Watt and Breyer-Brandwijk, 1962). While its leaves are regarded as antiparasitic, applied to scabies; rubefacient for paralysis, rheumatism; also applied to hard tumors (Hartwell, 1971). Perry (1980) reports that its latex is used to dress sores and ulcers and inflamed tongues while its seed is viewed as aperient; the seed oil emetic, laxative, purgative, for skin ailments. Root is used in decoction as a mouthwash for bleeding gums and toothache. Otherwise used for eczema, ringworm, and scabies (Perry, 1980; Duke and Ayensu, 1984). Four antitumor compounds, including jatropham and jatrophone, are reported from other species of *Jatropha* (Duke and Ayensu, 1984). The crop is homeopathically used for cold sweats, colic, collapse, cramps, cyanosis, diarrhea, leg cramps.

2.2 Agronomy of the *Jatropha curcas*

The *Jatropha curcas* is a small tree with a gray bark which releases white watery latex when cut. Under perfect conditions the plant might grow to a height of 20 to 30 feet, but most commonly the plant would grow to 9 to 15 feet. The fruits may produce several crops during the year if conditions are right. The inflorescences yield a bunch of 10 or more ovoid fruits which have a fleshy exocarp which turns yellow and dries, the fruit matures and so does the seed. There are three to four seeds in the fruit and would eventually mature to dark oblong shaped seeds.

Jatropha curcas grows almost anywhere – even on gravelly, sandy and saline soils. It can thrive on the poorest stony soil. It can even grow in the crevices of rocks (Lele, 2006). The leaves shed during the winter months and form mulch around the base of the plant. The organic matter from shed leaves enhance earth worm activity in the soil around the root zone of the plants, which improves the fertility of the soil. Climatically, *Jatropha curcas* is found in the tropics and sub-tropics and likes heat, although it does well even in lower temperatures and can withstand a light frost. Its water requirement is extremely low and it can stand long periods of drought by shedding most of its leaves to reduce transpiration loss (Lele, 2006).

Jatropha curcas can be cultivated between latitude 30°N and 35°S, which is a much larger belt around the earth compared to that of oil palm which is only within the latitude of 4°N and 8°S (Jongschaap *et al*.,2007). The potential of the amount of ground that could be cultivated with *Jatopha curcas* is astounding and has the ability to change the socio economic conditions of those regions.

Figure 2.1: *Jatropha curcas* Plantation

Source: Jongschaap et al., 2007

Figure 2.2: *Jatropha curcas* Fruit and One Year Old Plant

Source: Beckford, 2009

Source: Beckford, 2009

Figure 2.3: ***Jatropha curcas*** **Seed**

Source: Jongschaap et al., 2007

2.2 Chemistry and Toxicity

Per 100 g, the *Jatopha curcas* seed is reported to contain 6.6 g H_2O, 18.2 g protein, 38.0 g fat, 33.5 g total carbohydrate, 15.5 g fiber, and 4.5 g ash (Duke and Atchley, 1983). Leaves, which show anti leukemic activity, contain □-amyrin, □-sitosterol, stigmasterol, and campesterol, 7-keto-□-sitosterol, stigmast-5-ene-3-□, 7-□-diol, and stigmast-5-ene-3 □, 7 □-diol (Morton, 1981). Leaves contain isovitexin and vitexin. From the nut, saccharose, raffinose, stachyose, glucose, fructose, galactose, protein, and an oil, largely of oleic- and linoleic-acids (List and Horhammer, 1969–1979), curcasin, arachidic-, linoleic-, myristic-, oleic-, palmitic-, and stearic-acids are also reported (Perry, 1980).

The poisoning is an irritant, with acute abdominal pain and nausea about 1/2 hour following ingestion. Diarrhea and nausea continue but are not usually serious. Depression and collapse may occur, especially in children. Two seeds are strong purgative. Four to five seeds are said to have caused death, but the roasted seed is said to be nearly innocuous. Bark, fruit, leaf, root, and wood are all reported to contain HCN (Hydrogen Cyanide) (Watt and Breyer-Brandwijk, 1962). Seeds contain the dangerous toxalbumin curcin, rendering them potentially fatally toxic.

2.3 Diesel

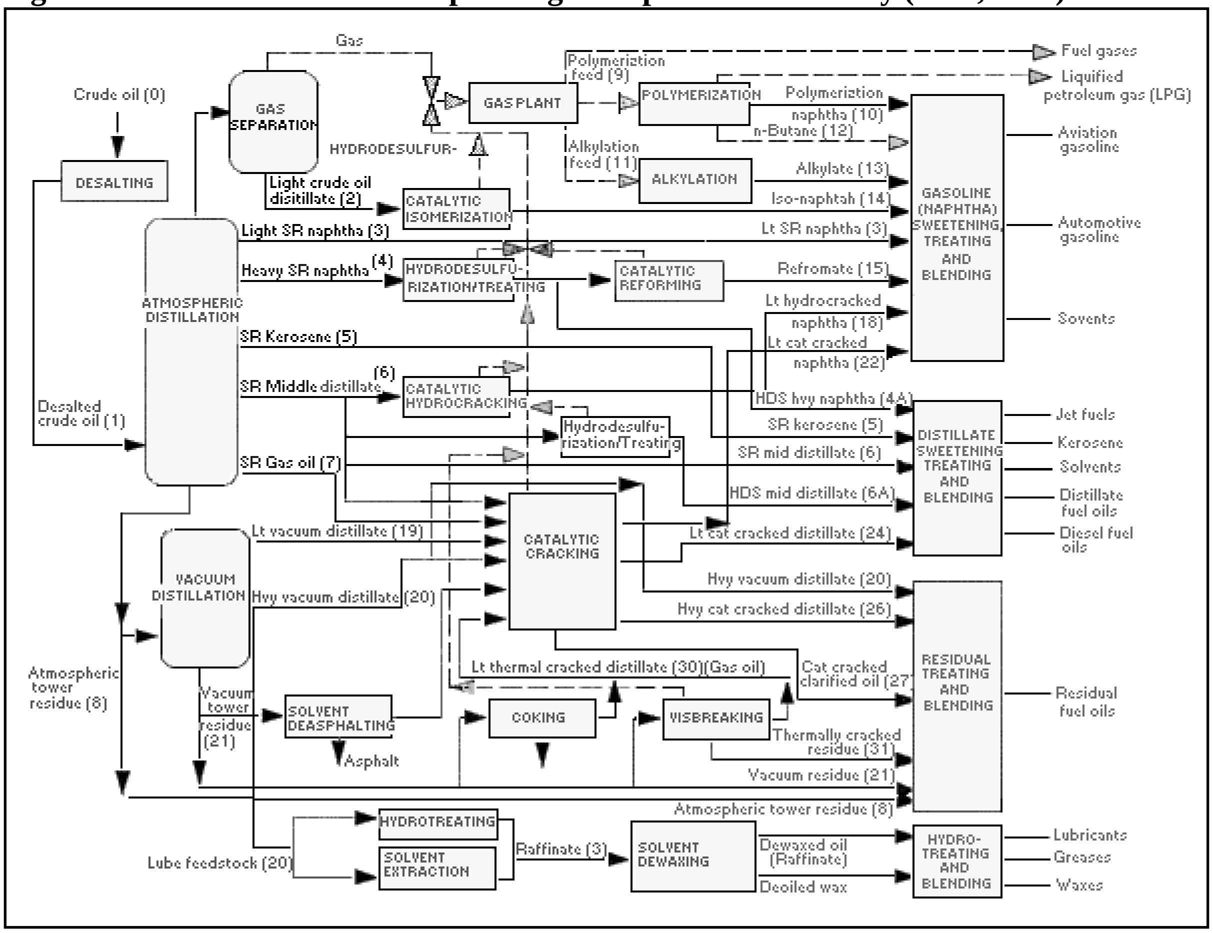
The "crude oil" pumped out of the ground is a black liquid called petroleum. This liquid contains aliphatic hydrocarbons, or hydrocarbons. The carbon atoms link together in chains of different lengths. Hydrocarbon molecules of different lengths have different properties and behaviors. For example, methane, a gaseous molecule, is a chain with just one carbon atom in it (CH_4) and is the lightest chain. Methane is a gas so light that it floats like helium. As the chains get longer, they get heavier. The first four chains -- CH_4 (methane), C_2H_6 (ethane), C_3H_8 (propane) and C_4H_{10} (butane) -- are all gases, and they boil at -161, -88, -46 and -1 degrees F, respectively (-107, -67, -43 and -18 degrees C). The chains up through $C_{18}H_{32}$ or so are all liquids at room temperature, and the chains above C_{19} are all solids at room temperature (HowStuffWorks.com, 2009).

Diesel fuel is about 18 percent heavier than gasoline and consists mainly of hydrocarbons that range from C10 to C24. Gasoline, on the other hand, is usually in the C7 to C11 range, while kerosene, used for jet engine fuel, is in the C12 to C15 range.

The petroleum refining industry converts crude oil into more than 2500 refined products, including liquefied petroleum gas, gasoline, kerosene, aviation fuel, diesel fuel, fuel oils, lubricating oils, and feedstock for the petrochemical industry. Petroleum refinery activities start with receipt of crude for storage at the refinery, include all petroleum handling and refining operations, and they terminate with storage preparatory to shipping the refined products from the refinery. The petroleum refining industry employs a wide variety of processes. A refinery's processing flow is largely determined by the composition of the crude oil feedstock and the chosen slate of petroleum products. The example refinery flow scheme presented in Figure 2.4

shows the general processing arrangement used by refineries in the United States for major refinery processes. The arrangement of these processes will vary among refineries, and few, if any, employ all of these processes (EPA, 1995).

Figure 2.4: Schematic of an example integrated petroleum refinery (EPA, 1995).



Listed below are five categories of general refinery processes and associated operations (in reference to Figure 2.4):

1. Separation processes: involves atmospheric distillation, which is made up of (a) vacuum distillation and (b) light ends recovery (gas processing). These steps of refinery separation processes separate these crude oil constituents into common boiling point fractions.

2. Petroleum conversion processes, encompassing cracking (thermal and catalytic), reforming, alkylation, polymerization, isomerization, coking, and visbreaking. Cracking, coking, and visbreaking processes are used to break large petroleum molecules into smaller ones. Polymerization and alkylation processes are used to combine small petroleum molecules into larger ones. Isomerization and reforming processes are applied to rearrange the structure of petroleum molecules to produce higher-value molecules of a similar molecular size.

3. Petroleum treating processes involving hydrodesulfurization, hydrotreating, chemical sweetening, acid gas removal, and deasphalting. The first 4 processes in this step remove undesirable elements such as sulfur, nitrogen, and oxygen. Deasphalting, is employed primarily for the separation of petroleum products.

4. Feedstock and product handling comprises of storage, blending, loading, and unloading. These steps involve the logistical handling of the feedstock and product.

5. Auxiliary facilities utilizing boilers, waste water treatment, hydrogen production, sulfur recovery plant, cooling towers, blow-down system, and compressor engines. All these auxiliary processes and equipments are necessary for crude oil refining as are they for collecting by-products. [1]

[1] A barrel of crude oil consists of 42 U.S gallons. According to the Department of Energy (DOE), a barrel of crude oil yields between 44 and 45 gallons of petroleum products. A barrel of crude oil yields 10.31 gallons of diesel, 4.07 gallons of jet fuel, 18.56 gallons of gasoline, 1.38 gallons of heating oil, 1.72 gallons of liquefied petroleum gases (LPG), 1.68 gallons of heavy fuel oil, and 7.01 gallons of other petroleum products .

2.4 Biodiesel

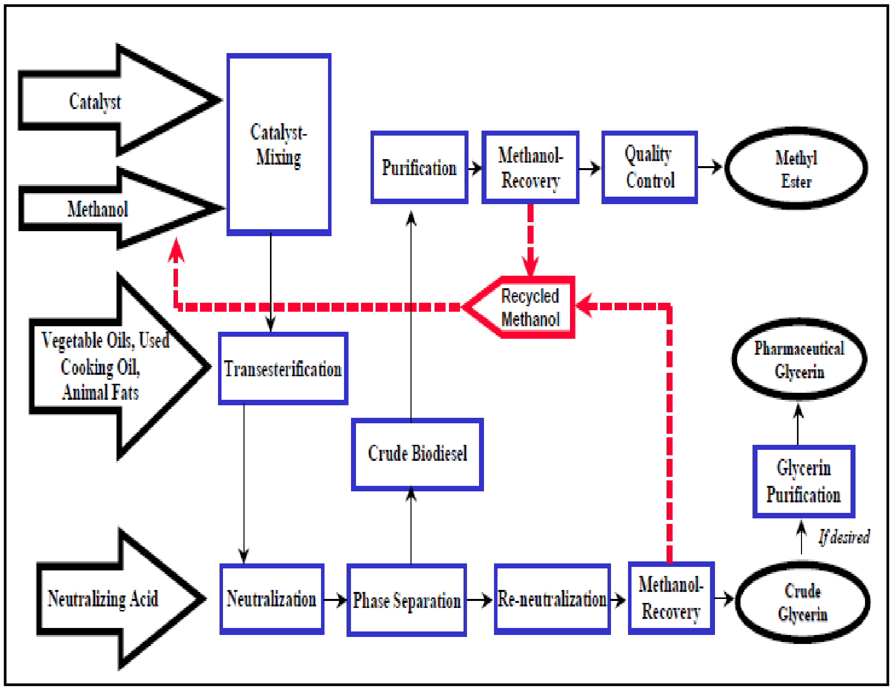
Biodiesel is obtained from the transesterification of vegetable oils. While this process has been around since early 1800s and the first biodiesel was obtained from peanut oil, the first use in an internal combustion engine was not until the Paris World Fair in 1900 (Nitske and Wilson, 1965). Biodiesel is actually very simple to make. It is made by chemically altering the molecular structure of any organic oil through the use of a chemical catalyst and an alcohol.

Technological improvements and better understanding of the transesterification processes have led to improvements in efficiency in the production of biodiesel. The raw materials options for its production have changed and increased.

The search for carbon neutral inputs makes the biodiesel increases the importance of plant sources of feedstock, such as vegetables, because they release no more than the amount of carbon they have and planting them absorbs the carbon again. Furthermore, their emissions are said to be reduced by 60 percent compared to fossil-based diesel oil (Stockmangrassfarmer.com).

Virgin oil is vegetable oil that is usually grown and processed to produce biodiesel. Among the types of virgin oils are soybean oil, rapeseed oil, mustard seed oil, algal oil, palm oil, and *Jathropa curcas* oil. Recycled oil that had been used by restaurants as cooking oils can also be used to make biodiesel. Yellow grease can also be used and it consists of used restaurant grease and animal fats.

Figure 2.5: Biodiesel production process



Source: National Biodiesel Board

The based catalyzed production of biodiesel generally occurs using the following steps (National Biodiesel Board):

- Mixing of alcohol and catalyst: The catalyst is typically sodium hydroxide (caustic soda) or potassium hydroxide (potash). It is dissolved in the alcohol using a standard agitator or mixer.

- Reaction: The alcohol/catalyst mix is then charged into a closed reaction vessel and the oil or fat is added. The system from here on is totally closed to the atmosphere to prevent the loss of alcohol. The reaction mix is kept just above the boiling point of the alcohol (around $160°F$) to speed up the reaction. Excess alcohol is normally used to ensure complete conversion of the fat or oil to esters.

- Separation: Once the reaction is complete, two major products exist: Glycerin and Biodiesel. Each has a substantial amount of the excess methanol that was used in the reaction. The reacted mixture is sometimes neutralized (if needed). The glycerin and biodiesel can be separated by gravity with glycerin being drawn off the bottom of the vessel. A centrifuge can also be used.

- Alcohol Removal: Once both the products are separated, then the excess alcohol in each phase is removed with a flash evaporation process or distillation. It is then re-used.

- Glycerin Neutralization: The glycerin by-product contains unused catalyst and soaps that are neutralized with an acid and sent top storage as crude glycerin. In some cases the salt formed during this phase is recovered for use as fertilizer. In more sophisticated operations, the glycerin is distilled to99% or higher purity and sold into the cosmetic and pharmaceutical markets.

- Methyl Ester Wash: Once separated from the glycerin, the biodiesel is sometimes purified by washing gently with warm water to remove residual catalyst or soaps, dried and sent to storage. In some processes this step is not needed. This is normally the end of the production process resulting n a clear amber-yellow liquid with a viscosity similar to petro-diesel. In some systems the biodiesel is distilled in an additional step to remove small amounts of color bodies to produce a colorless biodiesel.

2.5 Bio-fuel Feedstock Comparisons

Bio-fuels can be derived from various sources of feedstock and each one has a different cost of production and also amount of energy inputs and outputs differ too. Depending on whether the product is ethanol or biodiesel, it will always be compared to fossil fuels.

Table 2.1: Relative Costs of Biofuels from Various Feedstock

	Estimated cost per barrel of fuel
FEEDSTOCK	**COST/Barrel**
Cellulose	$305
Wheat	$125
Rapeseed	$123
Soybean	$122
Sugar beets	$100
Corn	$83
Sugar cane	$45
Jatropha	$43

Source: Goldman Sachs via Wall Street Journal (Aug 24, 2007)

Table 2.1 shows a comparison of various feedstock which are used to obtain biofuels. It is clear that cellulosic ethanol is very expensive to produce, and that *Jatropha curcas* is the cheapest to produce among the alternatives.

According to Bourne (2007), for every unit of energy from fossil fuel used or input needed, 1.3 units of energy are available for output if ethanol from corn is used. While for ethanol from sugarcane, for every one unit of input of fossil fuel, eight units of energy output are available. For biodiesel in general, for every one unit of input of fossil fuel, two and a half units of energy output are available. Whereas for cellulosic ethanol, for every one unit of fossil fuel input, a range of two to thirty six units of energy output are available. In this case the variability due to various production methods. Finally, for biodiesel from algae, the research is ongoing and no specific number is available, but theoretically an acre of algae can produce 5000 gallons of biodiesel a year.

Bourne (2007), adds that greenhouse gas emissions which accounts for the production and use of that particular fuel is promising for the bio-fuel candidates. Gasoline produces 20.4 pounds of carbon dioxide emissions per gallon of fuel. Corn ethanol emits 16.2 pounds per gallon which is 22% lesser than gasoline, sugarcane ethanol emits 9 pounds per gallon which is 56% less, biodiesel emits 7.6 pounds per gallon which is 68% less, and finally cellulosic ethanol produces 1.9 pounds per gallon, which is 91% less.

Finally, Bourne (2007) also adds that when gasoline was at the average price of $3.03 per gallon (July 2007), Ethanol (E85) was at $2.63 and that in order to get the equivalent amount of energy output from one gallon of gasoline, 1.41 gallons of E85 would need to be consumed which would bring the dollar value to \$3.71. Cane ethanol in order to match Brazil's average retail price of \$4.91 for 1 gallon of gasoline with 25% ethanol mixed in, would require 1.26 gallons of cane ethanol to produce the equivalent amount of energy which would bring the value to \$3.88 which is still substantially lower than the gasoline-ethanol mix. In Germany, the biodiesel is sold at a higher price than the fossil fuel diesel. In June 2007, the average price was \$6.15 a gallon for fossil fuel diesel and \$6.80 for biodiesel. To produce the equivalent amount of energy of 1 gallon of fossil fuel diesel, 1.01 gallons of biodiesel is required at a value of \$6.73.

The purpose of developing these products is to use them as fuel in internal combustion engines. But these engines are not well-suited for burning oil directly. The high viscosity of the oil causes coking of the injectors on the pistons and on the engine head which causes incomplete combustion of fuel. This leads to excessive carbon deposits on the pistons, eventually causing excessive wear on the engine. Therefore, the *Jatropha curcas* oil, like all the other oils, has to be processed into biodiesel through the transesterification process discussed above.

There are three important variables to focus on in processing oil into diesel: flash point, caloric value and cloud point. For efficient energy release, the fuel must have a low flash point and cloud point and high caloric value. Table 2.2 illustrates the differences between fossil diesel and *Jatropha curcas* oil and biodiesel, soybean biodiesel, and palm oil biodiesel. It shows that fossil diesel has higher caloric value, and the lowest flash and cloud point (except for soybean biodiesel) compared to *Jatropha curcas* oil, *Jatropha curcas* biodiesel, soybean biodiesel and palm oil biodiesel. However, *Jatropha curcas* biodiesel is not too different from fossil diesel where the density, viscosity, and caloric value are very much similar. The cloud point is not too far off compared to fossil diesel while the flashpoint is 125°C higher. The implication is that *Jatropha* *curcas* oil can possibly replace fossil diesel and could also be blended with fossil diesel to have caloric value, cloud and flash point properties that are more suitable. The same can be said of soybean biodiesel and palm oil biodiesel. The conclusion here is that, all three sources of feedstock, soybean, palm oil and *Jatropha curcas* are suitable replacements or complements for fossil diesel.

Table 2.2: Fuel Properties of *Jatropha curcas* Oil, *Jatropha curcas* Biodiesel and Fossil Diesel

Properties	*Jatropha curcas* Oil	*Jatropha curcas* Biodiesel	Soybean Biodiesel	Palm Oil Biodiesel	Fossil Diesel
Density, g/ml	0.920	0.865	0.880	0.870	0.841
Viscosity @ 40 ^{o}C, Cst	3.5	5.2	1.9 to 6	4.4	4.5
Calorific value, MJ/kg	39.7	39.2	32	37.8	42.0
Flash point, ^{o}C	240	175	130	182	50
Cloud point, ^{o}C	16	13	-1	15.2	9

Sources: Ramesh *et al.* (*Jatropha Curcas* and fossil diesel), Mekalilie *et al.* (Soybean), and journeytoforever.org (Palm Oil)

2.6 Bio-fuel Geo-politics

The European Union (EU) has been very critical of the United States in recent months for exporting subsidized biodiesel to the EU. This act, according to the EU Commission, has contributed to the "killing off" of biodiesel producers in Europe.

Germany has recently removed all subsidies for biodiesel production, causing its local biodiesel producers to be un-competitive against the US imports. At the other end of the spectrum, Spain, another EU nation continues to have subsidies, but local producers there too are unable to compete as loop holes in the current biodiesel system allows imports to receive subsidies too. This has created a general dissatisfaction that US biodiesel producers are getting “double” subsidies thus creating unfair competition.

European Trade Commissioner to the US, John Bruton (bioenergy-business.com) is quoted as saying,

> "What we are witnessing here is US taxpayers effectively subsidizing European motorists to the tune of around $300m last year, and that figure is set to be even higher this year - all while Americans themselves are suffering at the pump" (bioenergy-business.com).

The United States has been subsidizing biodiesel production at USD$1.00 per gallon for blended biodiesel. This has caused another issue where countries such as Malaysia and Indonesia have been exporting their biodiesel, predominantly palm oil, to the US and blending them with petroleum diesel in the US to qualify for the subsidies and then exporting the blended fuel to Europe to collect the EU subsidy. This has made it even more difficult for EU biodiesel producers to be competitive. The European Biodiesel Board (EBB) says that the fuel can be sold in the EU for less than EU producers pay for their raw materials (bioenergy-business.com).

The European Commission has threatened to bring the issue to the World Trade Organization (WTO) and has also threatened legal action. There have also been proposals that subsidies for biodiesel into EU nations be removed for already subsidized imported biodiesel.

Argentina is another country that has been benefiting from these subsidies. The Argentinean biodiesel producers have also jumped on the bandwagon of getting its own subsidies and also double subsidies from the EU.

Loop holes in the trade agreements have been taken advantage off to the dismay of the European biodiesel producers. Measures were taken by the US Congress to change the Energy bill in regards to biodiesel, but when the Energy Bill was signed by President Bush, the biodiesel trade and subsidy remedies were left out. The problem continues and while the biodiesel subsidies are expiring by the end of 2008, it is expected to be extended (grainet.com).

The EU is currently working on setting trade barriers and regulations in relation to biodiesel. Limiting subsidies and setting environmental limits on the bio-diesel products are possibilities. The EU currently is looking into biodiesel producing countries, and is now stating that they might ban biodiesel that is produced by raw materials that could cause environmental issues such as deforestation to grow biodiesel crops.

At present, biodiesel production has an issue where the low cost supply of raw materials is not easily available. In the US, the raw materials available are not cost effective. For example, soybean is among the largest source of feedstock for biodiesel in the US, but according to Hoffstrand and Johanns (2009), based on their biodiesel cost data, soybean biodiesel is not cost effective unless government subsidies and in place. Currently, algae is said to have the greatest potential to be the largest source of biodiesel raw material (biodieselfuelonline.com), but that has yet to be proven as to production and also costs involved. Work is currently being done on *Jathropa curcas* as a possible low cost material. There is another issue where biofuels made from world's dominant energy crops, including corn, soy, and oil palm, may have worse environment impacts than conventional fossil fuels, reports a study published in the journal Science (news.mongabay.com).

The EU can also impose tariffs and quotas on imported biodiesel that are heavily subsidized. Of course this could possibly cause other trade issues, but could also create a comparative advantage where each trade group could effectively gain from this issue. As an example, maybe a possibility would be for the EU to try to get more bananas from the Americas as part of the bargaining process.

WTO negotiations generally take a long time to materialize and possible preferential trade agreements between these countries would probably happen in order to solve this issue. As these geo-political issues are discussed and decided on, the work towards a source of feedstock for biofuel continues. *Jatropha curcas* has been marketed and publicized heavily as the future of bio-diesel with very little thought or planning in the agronomy and logistical issues involved. Currently, the second wave of *Jatropha curcas* investors is moving in with more research and information and with the hope and perseverance that this time it will be more successful. There is no doubt that subsidies do help, but it would be so very helpful for this very young industry that the countries involved with or whom are within their political influence to work out the geo-political issues to help start an industry that could very well change the political climate around the world.

2.7 Bio-fuel Economics

As the world's population become more dependent on the motorized vehicle and with markets such as India and China grows, so does the demand for fuel. Biofuels will play a critical role in providing the supply with the increased demands. The use of biofuels is not new but just needs to be streamlined in terms of production and logistics. The production of biofuels will also in turn take advantage of the earth's most valuable assets, its population and land availability. Creating and taking advantage of human skills such as farming would be a socio economic event where villages to countries can be more independent. With large swaths of land currently with poor arable soil, with its millions of inhabitants in these areas, such a crop such as *Jatropha curcas* would be able to provide a significant socio economic impact.

All these need for other forms or sources of energy and with bio-fuel being one of the major candidates, the processes used and capital spent may not always be necessarily financially viable. According to Tao and Aden (2009), with the current process economics for commercial bio-fuels for corn ethanol, sugarcane ethanol, and soybean biodiesel, the feedstock cost is a major contributor to the overall production cost, while the overall capital costs are not particularly large when compared to other processes or industries. Tao and Aden (2009) also added that future biofuels that require cellulosic processes and other advanced biofuels processes, such as butanol, would not only still face the high cost of feedstock but also the high capital costs needed for the deconstruction of these materials.

2.8 Summary

Whether ethanol or biodiesel is used, it is a move in the right direction. The ever changing climate and the constant degradation of the environment, provides us with a choice to look at greener ways to power our engines. Hydro power has been used. Solar and wind power has also been used and getting popular. However, the majority of our power plants and from the smallest of engines to the largest, fuel is needed. Bio-fuel will not completely replace the fossil fuels, as of yet, but will definitely complement our current resources.

CHAPTER 3: DATA, ASSUMPTIONS, METHODS, HYPOTHESES AND MODELS

3.1 Introduction

The purpose of this chapter is to present the data used in this study and present the overview of the methods applied to address the objectives. The chapter also presents the models used in the analysis and provides the hypotheses that are tested from the analyses. Scenarios are evaluated to compare soybean, palm oil and *Jatropha curcas*. The comparisons involve farm level production to biodiesel processing for *Jatropha curcas*, and biodiesel processing with crude vegetable oil for soybeans and palm oil. The financial statements of the scenarios will be evaluated. These financial numbers are obtained from secondary sources and especially for *Jatropha curcas*, there will be some assumptions made. Soybean oil and palm oil prices will be obtained from the market, and as for *Jatropha curcas*, since it is not a commodity as of yet, I will be using data from secondary sources.

3.2 Net Present Value (NPV) and Internal Rate of Return (IRR)

Net Present Value is a financial tool that indicates how much value an investment or project adds to a firm. It is the present value of a series of cash flows and it is a method where the time value of money is used to appraise long-term projects. This ensures that the investor incorporates the time effect on the value of money into the analysis of the investment. The difference between a project's present value of cash inflows and outflows generated and its cost of the initial investment is its Net Present Value (NPV). Companies can best help their shareholders by investing in projects with a positive NPV and rejecting those with a negative NPV (Brealey, Myers and Allen 2006). Another financial tool that can be used is Internal Rate of Return (IRR). The IRR of an investment is the discount rate, *r*, which causes NPV to equal zero. The same equation below can be used to solve for the discount rate, *r*. A project with a substantially higher IRR value than other options would still provide a much better chance of strong growth. It can also be explained as the interest rate at which the costs of the investment lead to the benefits of the investment.

$$NPV = I_0 + \frac{I_1}{1+r} + \frac{I_2}{(1+r)^2} + \ldots + \frac{I_n}{(1+r)^n}$$

The I's are net income amounts for each year. The subscripts are the year numbers, starting with 0, which is the year capital investment is made. The discount rate *r*, also described as the opportunity cost of capital, which is assumed to be constant (but does not have to be) in the future and *n* is the number of years the investments lasts. IRR is basically an indication of the yield of an investment while NPV is more an indicator of the value or magnitude of an investment.

3.3 Data

Jatropha curcas is a non-traded feedstock, unlike soybeans or oil palm. Therefore, the project was envisioned producing *Jatropha curcas* and processing it into biodiesel. This process was compared to (soybean/palm oil) but because these are traded, they were purchased as crude oil and processed.

Operating costs for the respective financial models were collected from secondary sources. They were either historical data or forecasts. A Monte Carlo approach was used to generate the future numbers based on the historical mean and standard deviation of these data. Cost of management to general labor was used in the financial analysis for both models, but here too some assumptions were used within a random range to provide for cost of living increases. A simulation of the production of *Jatropha Curcas* feedstock over a period of 34 years was applied. The reason 34 years was used for *Jatropha curcas* was for the initial gradual planting per year for up to five years and arriving at full production from year nine onwards, and the removal of older less productive plants from year 26 onwards to which the complete planting cycle ends at year 30 but gets back in full production from year 34 onwards (Appendix 1). A total area of one hectare was used to look at production values for soybeans, oil palm and *Jatropha curcas*. For *Jatropha curcas*, the one hectare data was then increased to 50,000 hectares which was used for the sake of simulation.

Historical data (from 1997 to 2008) on soybeans were obtained from USDA and used as the foundation data for the analysis while oil palm information were obtained from the Malaysian Palm Oil Board (Azman, 2003) (Appendix 2).

The biodiesel processing data and costs was obtained from Hofstrand and Johanns (2009), and was presented as per the sources. Since the biodiesel data provided by Iowa State University (Hofstrand and Johanns, 2009), is of a 30 million gallon biodiesel processing facility, with all the costs involved included, the same operational capacity was used for the analysis in this thesis.

3.4 Assumptions

At the farm level, soybean is farmed and produced annually, while *Jatropha curcas*, once planted will not produce or more accurately is not harvestable in the first year. The first harvest begins from Year 2 onwards and will reach its maximum yield capacity from Year 5 onwards. This information is very varied, and many claims are out there stating that the yield of the plant is very high. However, there are also claims that the yield is also very low. Because *Jatropha curcas* has only recently received significant research attention, this situation is not unexpected because of variability in measurements and, agronomic and horticultural conditions. For this research, yield data are assumed to be stochastic with a mean of 6382 kilograms per hectare and a standard deviation of 3037 kilograms per hectare (from Year 2 onwards). The basis of the numbers used is the United Nation's (2007) study on *Jatropha curcas* as a source of liquid bio-fuel in the Sub-Saharan regions of Africa (Table 3.1).

Table 3.1: *Jatropha curcas* yield per plant by age

Year of Planting	Average Yield Per Plant (in kilogram)
1st year	0
2nd - 3rd year	0.5 to 1
4th year	1.5 to 2.5
5th - 10 th year	2.5 to 5.0

Source: United Nations (2007)

As noted earlier, *Jatropha curcas* does not have a market where the seeds may be purchased like soybeans or oil palm. Therefore, the plan is to acquire 50,000 hectares in Indonesia or Malaysia for *Jatropha curcas* production. It has been assumed in this study that 2500 plants will be planted per hectare and 10,000 hectares will be cultivated per year in the first five years.

The perennial production of *Jatropha curcas* requires a rather high initial capital investment. This involves lots of land, ground work, nursery, planting and/or buying of young plants, replanting of young plants if any that were planted did not survive the field conditions, training of plants to shape them a certain way to help in harvesting purposes, infrastructure such as irrigation and pump system, farm buildings, machinery and offices. Palm oil production is rather similar with *Jatropha* *curcas* with high initial capital investments with no income the first few years while soybean would still require the capital investment of machinery, land, and management, the income starts the same year and repeats annually.

The cost of production for *Jatropha curcas* were sourced from Green Gold Ray Energies, Incorporated (GRYE). GRYE operates as a biodiesel, green technology, and alternative-renewable energy company in the Philippines and the United States. It primarily engages in the manufacture of biodiesel and alternative renewable fuel derived from *Jatropha curcas*. The company's product portfolio includes biodiesel oil and biofuels. It is also cultivating agricultural oil-based mineral resources from sugarcane, coconut, *Jatropha curcas*, sweet sorghum, and other crops. GRYE was incorporated in 1982 and is based in Corpus Christi, Texas. GRYE indicates that production costs per hectare is at USD$92.57. A stochastic factor is incorporated into this to yield the costs employed in the estimations and the analyses (Appendix 3). For example, the total operating costs from Years 7 to 10, a range of USD$34 to USD$50 per hectare is used, and from years 11 to 16 it ranges from USD$38 to USD$54, and from years 17 to 25 the range is from USD$42 to USD$58 per hectare. As for overhead costs, it ranges from USD$60 to USD$80, USD$64 to USD$84, and USD$68 to USD$88 respectively. This brings the total production costs to between USD$114 to USD$128, USD$112 to USD$135 and USD$96 to USD$782 (replanting starts again after 25 years) respectively. In the first year, the initial cost of custom operations of $700 per hectare is sourced from Lele (2006). This brings the total production cost for the first year to USD$782, where the production cost of USD$92 is incorporated into the total. From Year 2 to 6, production costs were sourced from GRYE.

In the 50,000 hectare estimation for *Jatropha curcas*, for the first 5 years, according to the total hectares planted that year and in this case 10,000 hectares a year, will cost between the range of USD$600 per hectare to USD$1500 per hectare. This will repeat again in the reverse from years 26 to 30 as removal of the older plants begins. However, between years 26 to 30 the cost is doubled as the action of planting and re-planting is happening in tandem (Appendix 1). From Year 5 onwards, plants that are five years and older will have higher yields than younger plants. For example, it is assumed yield ranges from two kilograms to five kilograms for this group of plants (Appendix 4).

The biodiesel price data is from Iowa State University over a period from April 2007 and August 2009. The mean is $4.64 per gallon and the standard deviation is $2.83. The biodiesel cost data is obtained from Iowa State University. The price of soybean oil and crude palm oil is from historical data. Assumptions include the production capacity, where *Jatropha curcas* is dependent on the 50,000 hectare plantation and production fluctuates while soybean oil and palm oil is operated at maximum capacity of 30 million gallon per year. The cost data is shown in Table 3.2:

Table 3.2 Biodiesel Cost Data

Fixed Costs	**Cost per Gallon (**¢/gallon)
Depreciation	0.00
Interest	6.46
Labor & Management	5.37
Marketing & Procurement	4.00
Property Taxes, Insurance, etc.	1.17
Total Fixed Costs	17.00
Other Variable Costs	
Chemicals	
Chemicals and Ingredients	5.7
Total Chemical Cost	5.7
Other Direct Costs	
Repairs & Maintenance	12.11
Transportation	10
Container	5
Water	0.7
Electricity	3
Other	3
Total Other Costs	33.81
Total Other Variable Cost	39.51

Source: Iowa State University (Hofstrand and Johanns, 2009)

In addition to the chemicals and ingredients cost (USD$0.057 per gallon), other production costs include feedstock, natural gas, and methanol.

Iowa State University cost data is also used with *Jatropha curcas* biodiesel simulation. In addition to that, the other assumptions include the price of the feedstock, the crushing cost at 8 percent of the variable cost, the startup cost of USD$47 million (USD$17 million in Year 0 and USD$30 million in Year 1) and the initial start up cost of the plantation is absorbed by the processing division (Appendix 5). The crushing cost at 8 percent was obtained from industry experts that did not want to be referenced and the startup capital cost of USD$47 million was available from Hofstrand and Johanns (2009).

Some specific conversions will be used, and is summarized in Appendix 6. Standard unit conversions are used and as for soybeans and *Jatropha curcas*, the conversions were from secondary sources. More specifically, 1 bushel of soybeans is converted to 1.49 gallons of biodiesel (Iowa State University) or 27.22 kilograms of soybeans to 1.49 gallons of biodiesel or 18.27 kilograms of soybeans to 1 gallon of biodiesel. It is assumed that a gallon of *Jatropha curcas* oil may be produced from between 9.46 kilograms to 15.14 kilograms of *Jatropha curcas* seeds. This range is defined by GRYE's and jatrophacurcasplantations.com out of Australia claims My research indicates that 1 gallon of *Jatropha curcas* oil is equivalent to 0.8 gallons (Lele, 2006) of biodiesel whereas 1 gallon of soybean oil is processed to 1 gallon (Hofstrand and Johanns, 2009) of biodiesel but due to insufficient sources for credible conversion for *Jatropha curcas,* we will use the same conversion as soybean oil.. The price information of *Jatropha curcas* seed is sourced from GRYE at USD$0.04 per kilogram and simulated to USD$0.20 per kilogram.

3.5 Hypothesis

The purpose of the thesis is to evaluate the economic and financial feasibility of producing biodiesel from *Jatropha curcas* and compare them with similar analyses conducted on soybeans and oil palm. To this end, the hypothesis that *Jatropha curcas* presents a higher NPV than the alternatives is proposed. This hypothesis is based on the fact that *Jatropha curcas* is a non-food product and hence does not command the high food prices. Additionally, it is argued that its higher oil yield offers it a production advantage.

CHAPTER 4: DATA AND RESULTS

4.1 Data

In this chapter, the results from the analyses proposed in Chapter 3 are presented using the data described above. The results encompass feedstock production of soybean, *Jatropha curcas*, and oil palm which then leads to the biodiesel production originating from these sources of feedstock.

4.2 Feedstock Production

The production of feedstock between soybean, *Jatropha curcas*, and oil palm were varied. Soybean is an annual crop, while *Jatropha curcas* and oil palm is a perennial crop. The data showed the annual cost of production for soybeans which also brought in the income for that year and for oil palm the data presented the production of a mature plantation that had trees that were maximum in yield. As for *Jatropha curcas*, the data encompassed the implementation of the plantation and the consequent years of production.

4.2.1 Soybean Feedstock Production

Data from the USDA indicated that in 2008 the average soybean producer had a yield of about 2863.35 kilogram per hectare. This translates to the gross revenue of $1103.18 per hectare. The total operating costs was at $329.42 per hectare. Operating costs consists of seeds, fertilizer, chemicals, custom operations, fuel, lube, electricity, repairs, purchased irrigation water and interest on the operating capital. While the allocated overhead costs, which consist of hired labor, opportunity cost of unpaid labor, capital recovery of machinery and equipment, opportunity cost of land, taxes, insurance, and general farm overhead, came to a total of $622.09 per hectare. With the operating costs and overhead costs combined, the net value of soybean production calculated to

$151.67 per hectare (Appendix 2). Data from the USDA, which did not include government subsidies, indicated that from 1997 to 2008, soybean farmers averaged a loss of USD$36.87 per hectare (Appendix 2).

4.2.2 Jatropha Curcas Feedstock Production

Because it is a new initiative, the *Jatropha curcas* production involves capital investments for production of seeds which is the feedstock for the oil production. These investments have been assumed in Chapter 3 to last more than 25 years. For *Jatropha curcas*, the producer or plantation company would have to invest in a large amount of capital into the initial investment to start a *Jatropha curcas* plantation. Once completed, the *Jatropha curcas* plant will remain there for up to 40 years, but for the purpose of harvesting from efficiently producing trees, we will harvest the plants for up to 25 years. The assumed maximum yield is achieved from 5 to 10 years of its life. This yield would continue on till an expected age of 25 years after which the yield is said to gradually decrease.

According to Green Gold Ray Energies, Inc. in the Philippines (GRYE), the annual cost of the plantation is about $92.57 per hectare. Refer to Appendix 3 where it states that the plantation cost is $92,570 per 1000 hectares. As mentioned earlier, the initial setup cost for the *Jatropha curcas* plantation would require capital. Lele (2006), states that it would require about 30,000 rupees (~USD$700) per hectare for the setup year. At best estimation, for the first year, with no revenue, the initial setup cost would be estimated at $782.60 per hectare. One thousand hectares would cost $782,600.00. As the value of production increases over the coming years, the expected Return on Investment (ROI) would begin between the fifth and sixth year. At the tenth year, the gross value of production less total costs would be estimated at $381.60 per hectare or $381,600.00 per 1000 hectares. This would, of course with fluctuations depending on weather, price, and other factors, maintain till the trees reach the age of 25 years. The assumptions made with references:

1) Plantation Cost of minimum USD$92.57 per hectare (Appendix 3)
2) Harvesting yield begins on the second year of production at 2500 kilograms per hectare to a maximum yield of 12,500 kilograms per hectare from the 5th year onwards (Appendix 7)
3) 2500 plants per hectare.
4) The yield expectations as per quoted by United Nations study (2007). Also refer to Table 3.1.
5) Seed price ex-farm to refinery is at $0.04 per kilogram (Appendix 3).

However, as we extrapolate the *Jatropha curcas* data to a higher number of hectares, the scenario changes. It is easy and straightforward when we look at the one hectare production numbers, but as the acreage significantly increased, so does the complexity of the planting schedule and production numbers. For the sake of simulating a large plantation, 50,000 hectares is used. When a production this large is undertaken, all 50,000 hectares cannot be planted in a single year. A 5 year planting schedule will be used, where 10,000 hectares would be planted every single year for the next 5 years, and replanting would start again from years 26 to 30 where 25 year old plants would be removed and replanted with a fresh start of trees at a rate of 10,000 hectares each. Which means the cost of custom operations, which includes planting and removal, would double when compared to the first 5 years. Yield too is not so straightforward with such a big plantation. The yield for the first 8 years would gradually increase until all the plants in the plantation are 5 years or older which is planned for the 9th year. As the plants mature and reaches maximum production, the yield is set to fluctuate between two kilograms to five kilograms per plant per year. At year 26, the removal and replanting begins for another five years and reaches maximum production again in year 34 for another cycle of maximum yield (Appendix 1).

The production results indicate that, the annual profit/(loss) for the first five years will be negative and only in the sixth year a positive profit/(loss) of USD$1,580,000 is achieved. At the end of year 34, even with double production costs from years 26 to 30 and a loss of yield from years 26 to 33, the annual profit/(loss) at year 34 is at USD$2,275,000 and the net accumulated profit/(loss) over the 34 years would bring in USD$107,590,000 (Appendix 4).

4.2.3 Oil Palm Feedstock Production

Oil palm plantations are set up with long term in mind. It is similar to that of *Jatropha curcas* plantations. According to Azman (2003), smallholders and the estate sector were compared, and showed that the smallholders had costs of USD$506.42 per hectare and a net income of USD$346.22 per hectare while estate holders had costs of USD$649.61 and due to higher yields had a net income of USD$388.62 per hectare. The data is then used for 50,000 hectares, the net income of estate holders adds up to over USD$19 million per year (Appendix 8). These data is based on a fixed yield per hectare on established plantations and based on the given prices. We will use the estate holder's income to compare with *Jatropha curcas* plantation income and upon comparing the data, it indicates that *Jatropha curcas* has the ability to match oil palm, if the yield does not fluctuate greatly and if the price continues to increase, it would be as good or better investment than oil palm.

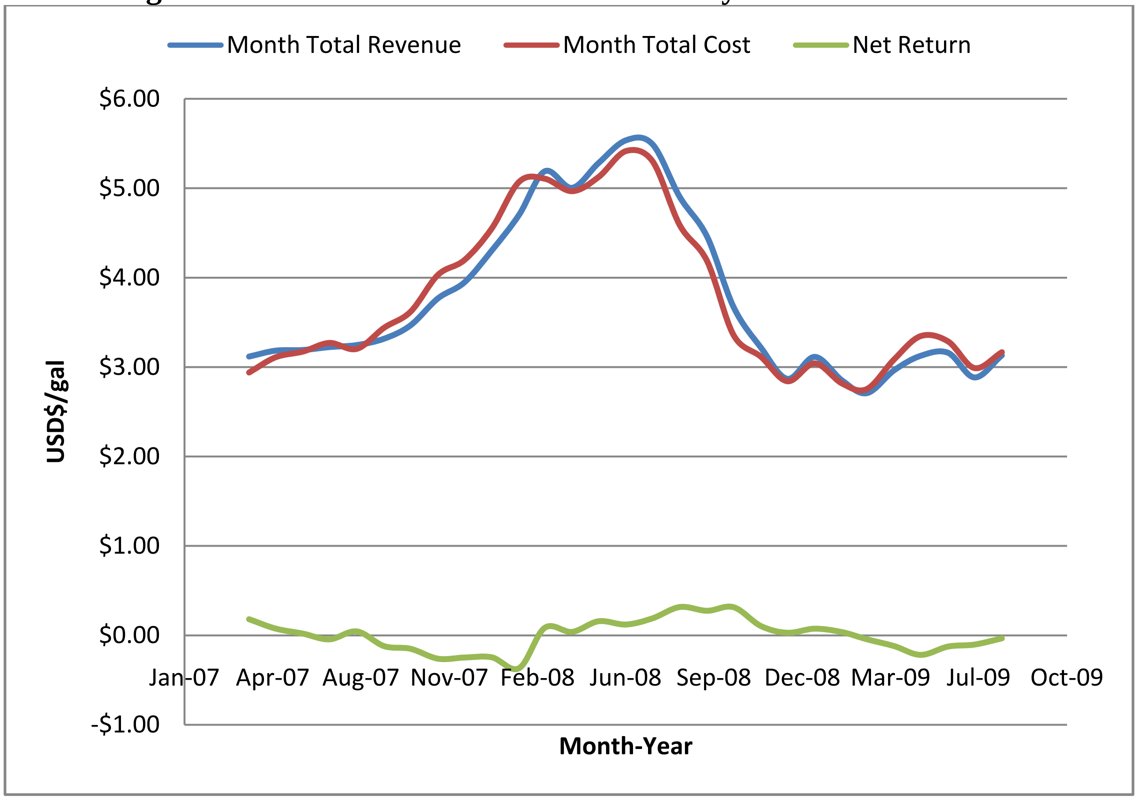
4.3 Results- Biodiesel Production

As mentioned in Chapter 3, the comparisons are that of *Jatropha curcas* seed being bought in and crushed and finally processed while soybean oil and crude palm oil are purchased to be processed to biodiesel.

4.3.1 Soybeans – Biodiesel Production

Data obtained from Iowa State University (Hofstrand and Johanns, 2009), from April 2007 to August 2009, indicates that at varied prices of biodiesel, the revenue for a 30 million gallons per year biodiesel facility, ranged from as low as USD$2.71 per gallon to USD$5.54 per gallon. The total cost of production varied from USD$2.75 per gallon to as high as USD$5.42 per gallon. The net return per gallon after all costs ranged from as low as at a loss of USD$0.37 per gallon to a profit of USD$0.18 per gallon (Figure 4.1).

Figure 4.1: Monthly Total Revenue, Cost, and Net Return (USD$ per gallon) from April 2007 to August 2009 for Biodiesel Production from Soybean as a Feedstock.



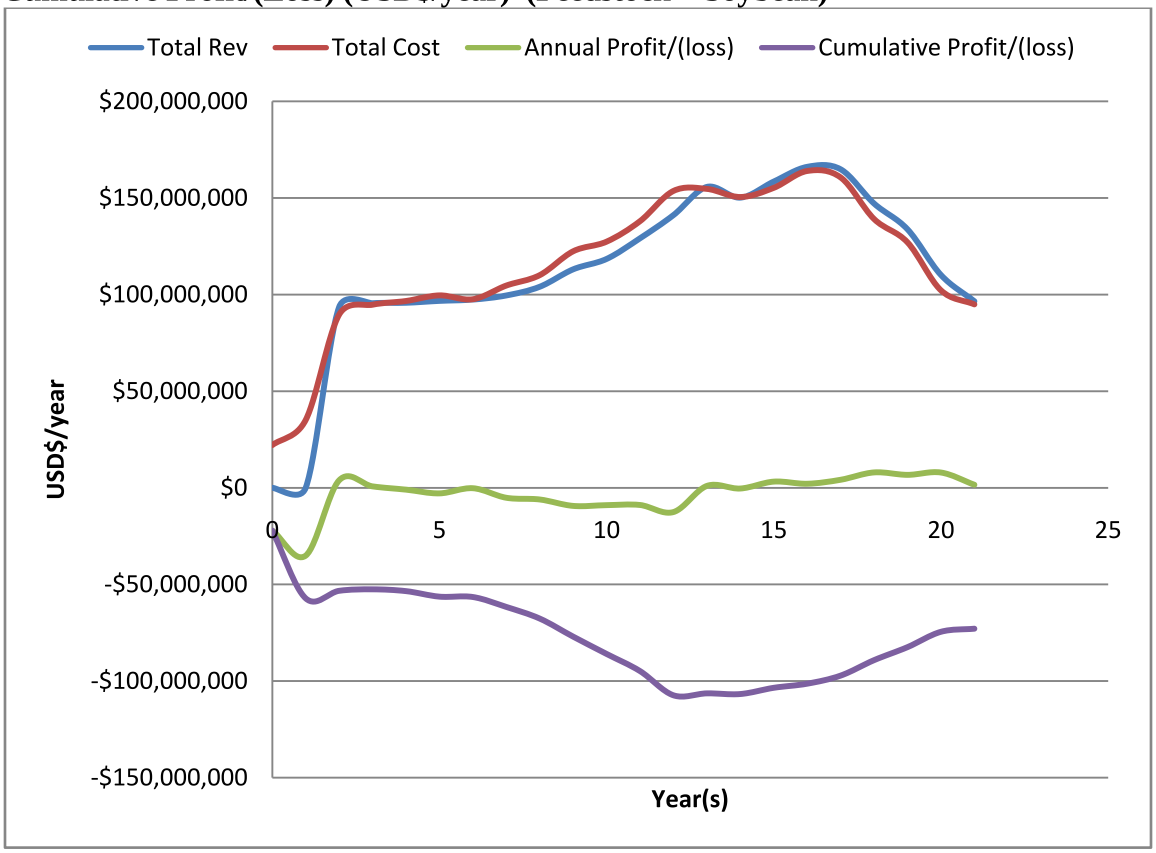
Source: Hofstrand and Johanns, (2009)

Over that period of time, assuming that the biodiesel facility had been producing at capacity (2.5 million gallons per month or 30 million gallons per year) , the cumulative income would be at a loss of just over USD$80,000 (Appendix 9).

However, a 21 year projection of production at maximum capacity is done in order to provide a fair comparison with that of *Jatropha curcas* and palm oil. The data was based on historical prices of soybean oil (Appendix 10), and assumed biodiesel prices. It also had the capital input of USD$47 million from Year 0 to Year 1. With no changes to fixed costs, and some variable cost changes, the facility has a cumulative loss over a period of 21 years of just over USD$70 million

(Appendix 11)(Figure4.2) and a negative NPV of over USD$63 million at a discount rate of 8 percent.

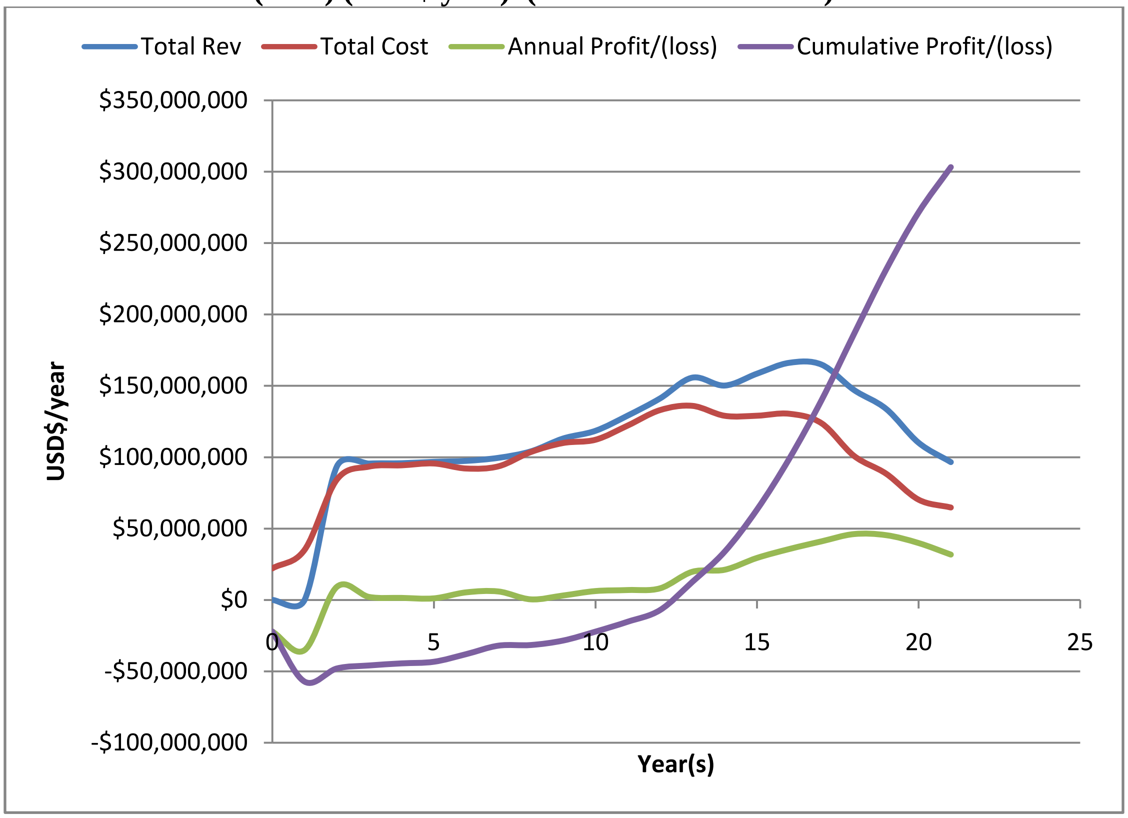
Figure 4.2: Trend of Projected Biodiesel Cost, Revenue, Annual Profit/(Loss) and Cumulative Profit/(Loss) (USD$/year) (Feedstock = Soybean)



4.3.2 Oil Palm - Biodiesel Production

With the same cost data used on soybean biodiesel and *Jatropha curcas* biodiesel (Hofstrand and Johanns, 2009), crude palm oil prices will be incorporated into the analysis. The crude palm oil prices are actual monthly closing prices that are averaged out to obtain an average yearly price. With crude palm oil prices ranging from USD$1.40 to USD$3.70 per gallon and with all the costs incurred, the cumulative income from Year 0 to Year 21 showed an amount of over USD$300 million (Appendix 13) with a NPV of about USD$50 million at a discount rate of 8 percent (Appendix 13) (Figure 4.3).

Figure 4.3: Trend of Projected Biodiesel Cost, Revenue, Annual Profit/(Loss) and Cumulative Profit/(Loss) (USD$/year) (Feedstock = Palm Oil)



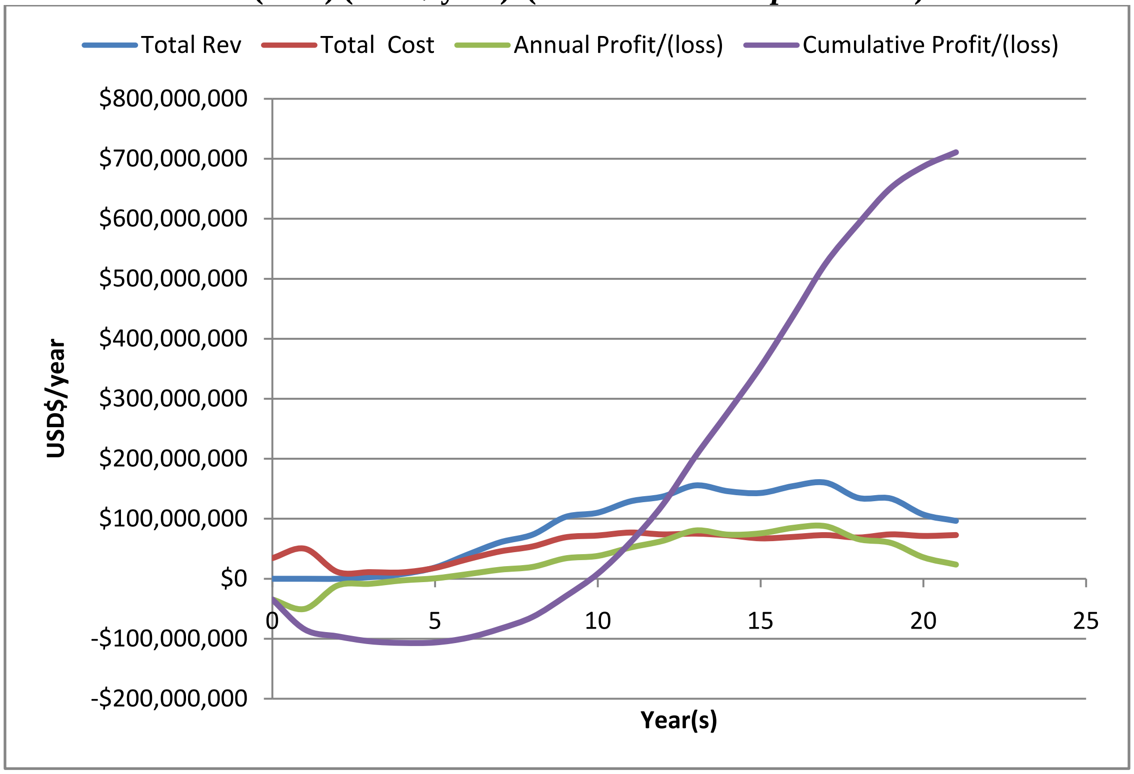
4.3.3 Jatropha Curcas - Biodiesel Production

The *Jatropha curcas* biodiesel data obtained from GRYE shows the 5-year projected profit and loss statement. In this model the processing output started with just over 1 million gallons of biodiesel and ends with just under 40 million gallons in Year 5. Year 1 showed a significant loss of USD$876,938 and year 2 to 5 was profitable. Year 5 brought in an income of over USD$115 million at the price of USD$7.51 per gallon and also includes the by-products of seed cake for fertilizer and glycerin (Appendix 12).

However, *Jatropha curcas* data was not the same. As discussed previously, the assumption that *Jatropha curcas* seed was purchased as an internal transfer from the plantation by the processing plant, a vertically integrated company, at the internal transfer seed feedstock price of USD$0.04 to USD$0.20 per kilogram and with the seed oil efficiency between 9 kilograms to 15 kilograms of seed to a gallon of oil. These two variables and its ranges will be used for the NPV analysis.

For comparison, an assumed base of USD$0.10 per kilogram of seed and 15 kilograms of seed to a gallon of oil is used. The yield transferred from the plantation, was simulated 20 times using the Monte Carlo method with yields per plant ranging from two to five kilograms per tree. This assumption is only used on plants that were five years old or older. With the assumed base, over a period of Year 0 to Year 21, with the first years absorbing losses from the plantation and the capital expenditure of the processing facility, the *Jatropha curcas* biodiesel facility would have had a cumulative profit of just over USD$700 million with a NPV of over USD$164 million and IRR of 18% at a discount rate of 8 percent (Appendix 5) (Figure 4.4).

Figure 4.4: Trend of Projected Biodiesel Cost, Revenue, Annual Profit/(Loss) and Cumulative Profit/(Loss) (USD$/year) (Feedstock = *Jatropha curcas*)

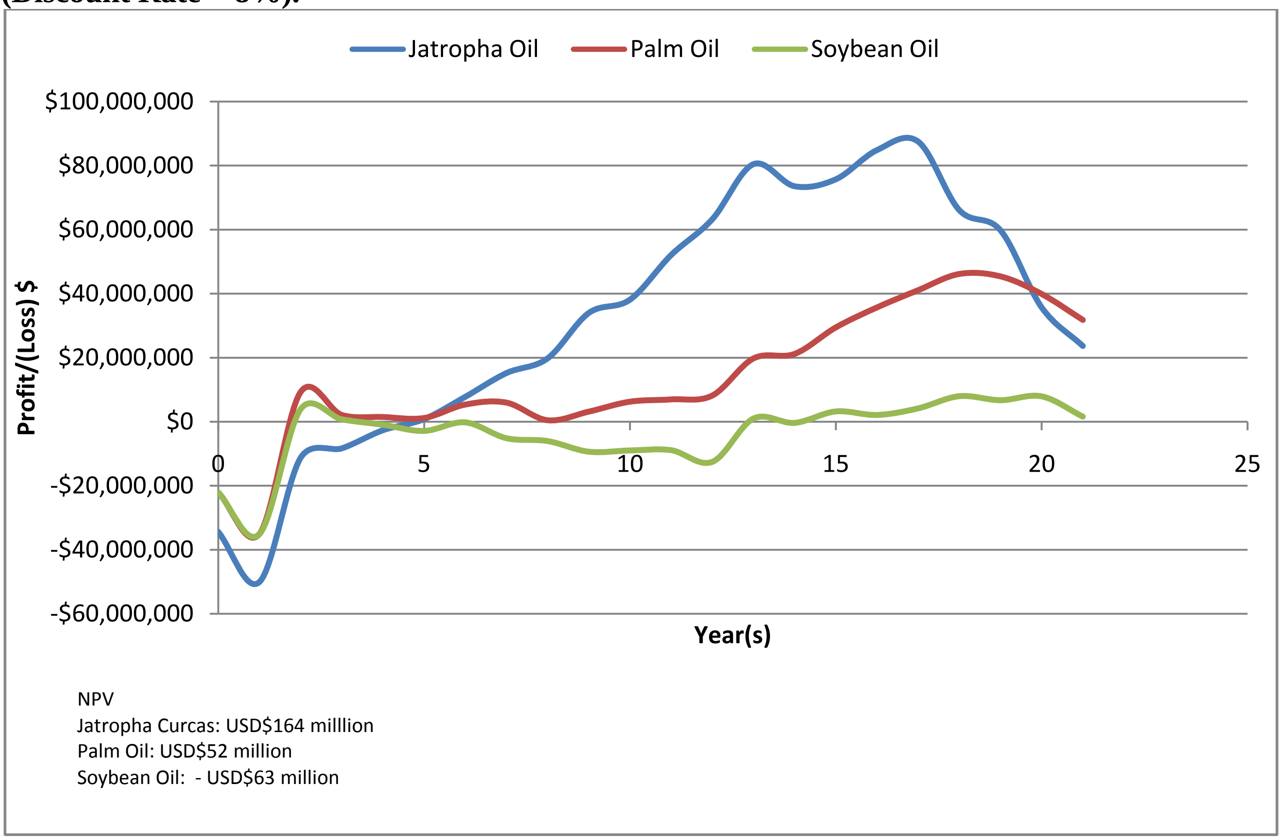


4.4 NPV Results and Analysis

A summary of the results are presented in Appendix 14 where it shows the biodiesel data for soybean, palm oil and *Jatropha curcas* as the source of feedstock. From Year 0 to Year 1, the capital inputs of a total of USD$47 million were included and for *Jatropha curcas* the added cost from the losses of the plantation division. The results showed that at a fixed discount rate of 8 percent *and Jatropha curcas* extraction rate of 15 kilograms of seed per gallon of oil and USD$0.10 per kilogram of seed, soybeans as a feedstock is not a feasible option since its NPV is negative. However, both palm oil and *Jatopha curcas* are feasible feedstock options because of their positive NPVs. The analyses show that the NPV for soybean over the 21-year time frame was –USD$63 million while that of oil palm was USD$52 million and finally *Jatropha curcas* posted an NPV of over USD$164 million which was higher than both alternatives. This was in spite of the fact that its production involved investments in primary production and processing compared to soybean and palm oil feedstock being purchased without the heavy primary production investments.

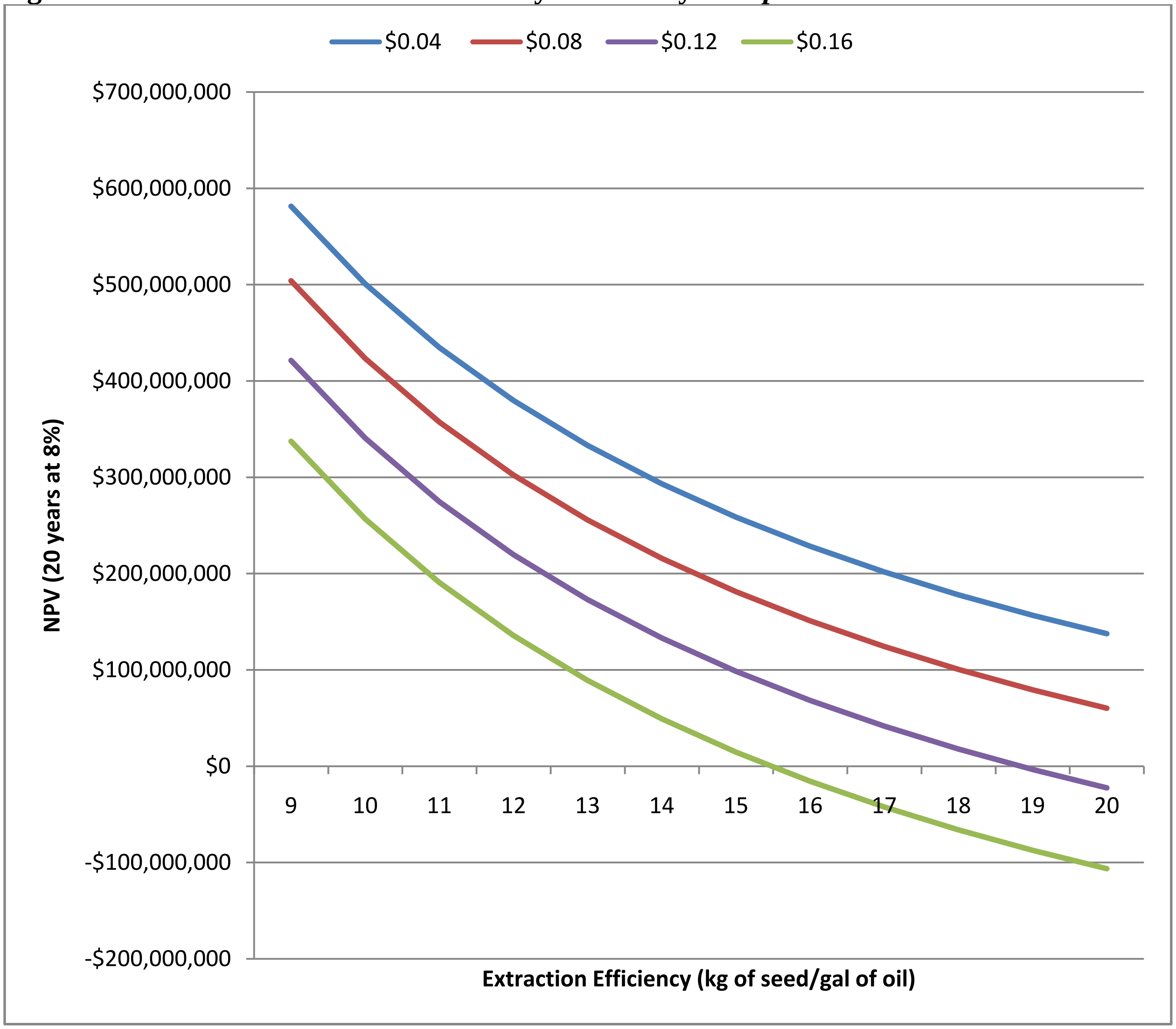
Figure 4.5 shows the profit and loss trend lines for *Jatropha curcas*, palm oil, and soybean oil. The data of the annual profit and loss leads to the NPV conclusion as stated above. For the purpose of this thesis, since the NPV for *Jatropha curcas* was higher than soybean and palm oil, further analyses of the NPV results will just focus on the data for *Jatropha curcas*.

Figure 4.5: Projected Annual Net Income Situation for Alternative Biodiesel Feedstock (Discount Rate = 8%).



As expected, oil extraction efficiency influences the profitability and feasibility of the processing facility. Additionally, the cost of seeds also influences the results. Figure 4.6 shows the results of sensitivity of the NPV model to feedstock price given oil extraction efficiency for *Jatropha curcas* at a constant discount rate of 8 percent. The results indicate that the project becomes infeasible if the *Jatropha curcas* seed price exceeds $0.16 per kilogram and oil extraction rate goes above 16 kilogram of seed per gallon of oil. This implies that management of the *Jatropha curcas* plant must pay careful attention to the cost of production of seeds and their oil extraction efficiency - the lower their cost of seeds and the higher their oil extraction efficiency, the more profitable their operations. Given that they have full control on their feedstock compared to soy or oil palm, this strategic effort must help them focus in enhancing their competitive position in the biodiesel market.

Figure 4.6: Effect of oil extraction efficiency on NPV by *Jatropha curcas* Procurement Price



4.4.1 Sensitivity Analyses

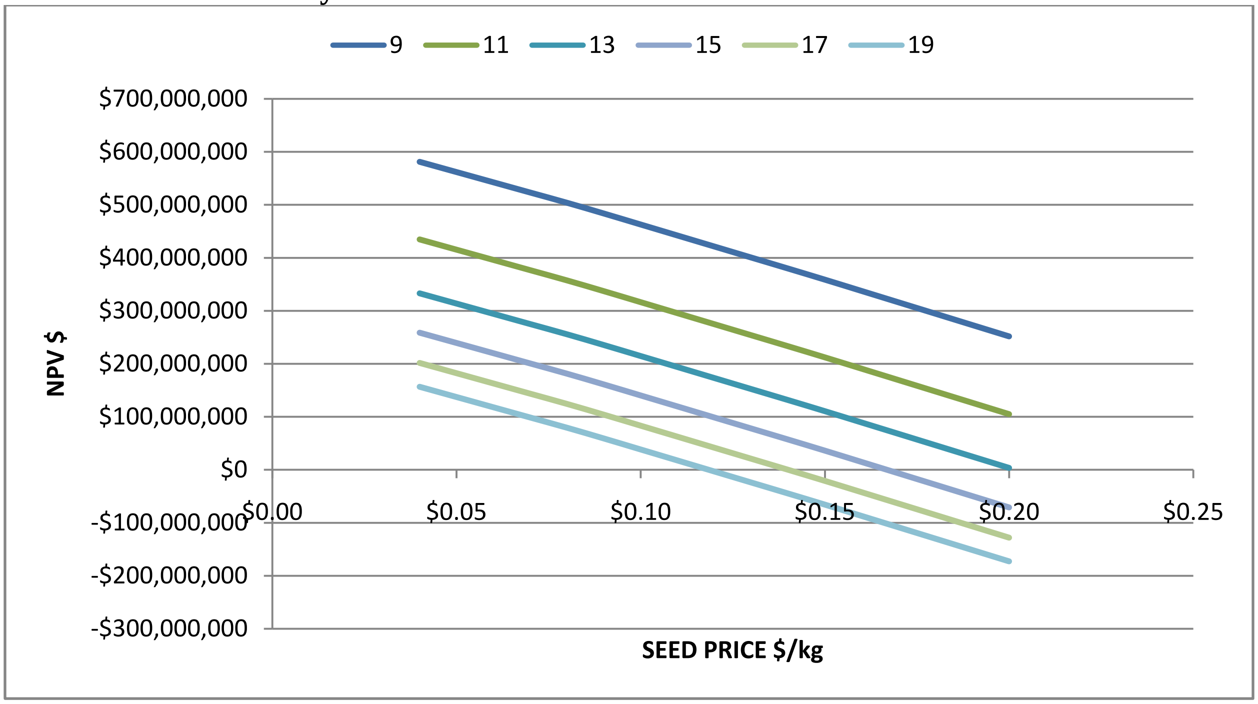
The NPV results are sensitive to seed cost, discount rate, and extraction rate. The higher the seed cost the lower the NPV, and thus extraction efficiency rates becomes more crucial, and need to be more efficient to improve the investment. The discount rate obviously affects the NPV – the higher the discount rate, the lower the NPV.

The foregoing analyses have been conducted under specific assumptions about discount rates, extraction rates and seed costs. However, these are all subject to change. For example, the macroeconomic environment can have direct effect on the cost of capital, affecting the interest rate and production costs will directly affect the internal transfer price for *Jatropha curcas* seeds from the farm to the biodiesel processing plant. Based on the reality of these potential changes, the sensitivity of the foregoing results to changes in these variables are presented and discussed. The reference point for the ensuing sensitivity analyses is the discount rate, seed cost and extraction efficiency used in the base analysis.

4.4.2 Effect of Seed Cost on NPV

To evaluate the benefits of focusing on these transfer seed price and extraction efficiency, Figure 4.7 presents the change in performance (NPV) given changes in seed costs for different extraction efficiencies. This indicates that a high extraction efficiency and low seed price positively affects the NPV. This is obvious at the point when the extraction efficiency was poor at 19 kilograms of seed per gallon of oil, the NPV was low and continues to get worse as price continues to increase. In this case, USD$0.12 was the limit of feasibility of the project if the extraction efficiency was at 19 kilograms of seed per gallon of oil.

Figure 4.7: NPV Change by *Jatropha curcas* Seed Price with 15 kilograms per gallon as Base Oil Extraction Efficiency



CHAPTER 5: SUMMARY AND CONCLUSIONS

Biofuels, particularly biodiesel will possibly be an integral source of energy in the near future. European nations have already been aggressively using biodiesel and it will not be long before the rest of the world catches up. It would most likely not replace fossil fuels, but would complement the existing sources of fuel.

This thesis compares the two available feedstock, soybean and palm oil, to the *Jatropha curcas* oil. It begins with the farming side where soybean is farmed annually, and oil palm and *Jatropha curcas* is farmed perennially with long term plantations in mind. Data is presented to show the difference in profitability for the farming sector. The results can be summarized to that of soybean being the least profitable (unless government subsidies are involved), and with palm oil and *Jatropha curcas* the profitability is substantial and sustainable. Due to soybean oil and crude palm oil being traded, the biodiesel processing part of the enterprise will purchase these bio crude oils and process them to biodiesel. However, the *Jatropha curcas* processing would procure the seeds from the plantation as an internal transfer of a vertically integrated company, crushes the seed to get the crude oil, and finally processing the *Jatropha curcas* crude oil to biodiesel. The profitability for processing of the soybean oil again does not show any great profitability and unless government subsidies are used, it is not a sustainable enterprise. The biodiesel processing for both palm oil and *Jatropha curcas* show profitability. *Jatropha curcas* being the better investment even though it had crushing costs and losses absorbed from the plantation division.

Net Present Value (NPV) analysis for bio-fuel production was conducted on all three feedstock – soybean, palm oil, and *Jatropha curcas* at a discount rate of 8 percent and it clearly shows that

Jatropha curcas and palm oil were consistent on the profitability and thus a positive NPV, USD$164 million and USD$52 million respectively, while soybean although profitable in some years was not as consistent and thus a negative NPV at –USD$63 million (Figure 4.5).

Net Present Value (NPV) analysis was also conducted on the *Jatropha curcas* biodiesel financial data with a fixed extraction efficiency of 15 kilograms of seed per gallon of oil, and although the data shows that price of seed and extraction efficiency may be the determining factor for the success of this new feedstock, continued research into newer higher yielding varieties will help compensate for the increasing prices of the *Jatropha curcas* feedstock and other variable and fixed costs. Figure 4.7 shows that at the extraction efficiency of 15 kilograms of seed per gallon of oil, the price of seed can go no higher than USD$0.165 per kilogram of seed.

This thesis does not fully show the potential of *Jatropha curcas*. In the time of writing this thesis, *Jatropha curcas* processing for biodiesel has turned out several other by-products other than glycerin. The seed cake can be used to obtain fertilizer, bio-gas, and animal feedstock (after processing). The fertilizer and bio-gas products have been said to be very promising and if that is true, then *Jatropha curcas* biodiesel may one day be the by-product. Future research is needed in these areas and analyzed to show the greater potential of *Jatropha curcas*.

In conclusion, NPV and IRR analyses suggested that *Jatropha curcas* is a feasible feedstock in the production of biodiesel and potentially more profitable than both soy and oil palm as feedstock alternatives. The results may help guide investments in the *Jatropha curcas* industry with careful attention to cost of production of *Jatropha curcas* seeds and the extraction technology that is adopted at the oil processing stage of biodiesel manufacturing. The research did not incorporate the potential social benefits from the development of a *Jatropha curcas* project into the analysis (employment, economic development, new industries, etc.) for a country such as Indonesia or Malaysia. It also did not identify some of the inherent challenges and opportunities in breeding, multiplication and crop production husbandry. These must all be analyzed by future research in order to develop a more complete economic picture of this feedstock. But in the end, the research shows that there is indeed a feedstock that can contribute to addressing the current energy challenges facing the global market without sacrificing food products that meet the nutrition and food security needs of a majority of the globe's population who live in poor countries.

REFERENCES

Agaceta, L.M., Dumag, P.U., and Batolos, J.A.,“ Studies on the control of snail vectors of fascioliasis: Molluscicidal activity of some indigenous plants”. In: Bureau of Animal Industry, Manila, Philippines, NSDB Technology Journal: Abstracts on Tropical Agriculture 7 (1981). 38008; 6: 2: 30–34.

Azman Ismael, Mohd. Arif Simeh, and M. Mohd. Noor, “The production Cost of Oil Palm Fresh Fruit Bunches: the case of independent Smallholders in Johor”, Malaysian Palm Oil Board 2003.

Beckford, R.,”Competitiveness of Jatropha, Utilization Routes, and Ecological Effects” ,University of Florida, IFAS Extension, Jatropha World Conference, Miami, Florida, 2009.

Bioenergy Business, January 16, 2008, “EU ambassador hits out at US subsidy for biodiesel exports”, http://www.bioenergy-business.com/index.cfm?section=lead&action=view&id=11007

Biodieselnow, “The Basics of Biodiesel Production 101”, http://www.biodieselnow.com/blogs/methods/archive/2007/01/27/the-basics-of-biodiesel-production-101.aspx

Biodiesel Fuel Online, http://www.biodieselfuelonline.com/Biodiesel_Algae.html

Bourne, J.K., “Green Dreams”, National Geographic, October 2007: 38-59

Cynthia Ann Peterson. "Jatropha: The next big thing in bio-fuel?" Malaysian Business, 1 Apr. 2008

Duke, J.A. and Atchley, A.A. Proximate analysis. In: Christie, B.R. (ed.), “The handbook of plant science in agriculture”. CRC Press, Inc. (1984), Boca Raton, FL.

Duke, J.A. and Ayensu, E.S. “Medicinal plants of China”. Reference Publications (1985), Inc. Algonac, MI.

Duke, J.A. and Wain, K.K.,” Medicinal plants of the world”, 1981.

Department of Energy, http://tonto.eia.doe.gov/energyexplained/index.cfm?page=oil_home

EPA.GOV (1995), http://www.epa.gov/ttn/chief/ap42/ch05/final/c05s01.pdf

Grainnet, “European Biodiesel Board Threatens Legal Action Against US Biodiesel Subsidies”, http://grainnet.com/articles/European_Biodiesel_Board_Threatens_Legal_Action_Against_U_S__Biodiesel_Subsidies-49733.html, October 23, 2007.

Hartwell, J.L. “Plants used against cancer. A survey”. Lloydia (1971), 30-34.

Henning R.K. (1998) Use of *jatropha curcas* L:A household perspective and its contribution to rural employment creation. Experiences of the Jatropha Project in Mali, West Africa, 1987 to 1997

Hofstrand, D., Johanns, A., Ag Marketing Resource, Biodiesel Profitability, Iowa State University, University Extension, 2009

HowStuffWorks.com. “What's the difference between gasoline, kerosene, diesel, etc?" 01 April 2000. http://auto.howstuffworks.com/fuel-efficiency/alternative-fuels/question105.htm> 11 July 2009.

Imelda V Abano. "FOOD VERSUS FUEL IN THE PHILIPPINES", Contemporary Review 1 Jul 2008: 151-153.

INFORM. **“**Consequences of jatropha emphasis in Myanmar/Burma”, International News On Fats, Oils, and other Related Materials: (1 Jun 2008): 386-387

Jongschaap, R.E.E., W.J.Corre, P.S. Bindraban and W.A.Brandenburg, 2007. Claims and Facts on Jatropha Curcas L. Global Jatropha Curcas evaluation, breeding and propagation programme. Plant Research International B.V., Wageningen, the Netherlands, Report 158,

Journeytoforever.org, “Oil yields and characteristics”, http://www.journeytoforever.org/biodiesel_yield2.html#fuelfats

Kgathi,D.L. and Zhou, P.,” Bio-fuel use assessments in Africa: implications for greenhouse gas emissions and mitigation strategies”. *Environmental Monitoring and Assessment 38* (1995), 253-269.

Kondor, L., BioDiesel Technologies GmbH, Vienna, Austria. Asia Biodiesel Conference , Singapore, 13-14 November 2007

Lele, S.,”Biodiesel and Jatropha Cultivation”, Agrobios (2006), India.

List, P.H., Horhammer, L. “Hager's handbuch der pharmazeutischen praxis”, vols 2–6. Springer-Verlag (1969–1979), Berlin.

Little, E.L., Jr., Woodbury, R.O.,Wadsworth, F.H. “Trees of Puerto Rico and the Virgin Islands”, vol. 2. Ag. Handbook 449 (1974) , USDA, Washington, DC.

Mekalilie, B.B.,Bhattacharya,T.K.,Mohammed,H.I., “Studies on compatible fuel properties of soybean ethyl ester and its blends with diesel for fuel use in compression ignition engines”, http://www.sustech.edu/staff_publications/file.pdf

Mitchell, J.C., Rook, A. “Botanical dermatology”, Greenglass Ltd. (1979)., Vancouver.

Morton, J.F.,"Atlas of medicinal plants of middle America. Bahamas to Yucatan". C.C. Thomas (1981), Springfield, IL.

Magretta, J., "Why business models matter", Harvard Business Review, May 2002

Mongabay.com,"EU may ban palm oil biodiesel", January 15, 2008, http://news.mongabay.com/2008/0115-biofuels.html

National Biodiesel Board, http://www.biodiesel.org/pdf_files/fuelfactsheets/prod_quality.pdf

Nitske, W.R., and C.M. Wilson, "*Rudolf Diesel, Pioneer of the Age of Power*", University of Oklahoma Press, Norman, Oklahoma, 1965.

Ochse, J.J.,"Vegetables of the Dutch East Indies", (1931) Reprinted 1980. A. Asher & Co., B.V. Amsterdam.

Perry, L.M.,"Medicinal plants of east and southeast Asia". MIT Press (1980)., Cambridge.

Peterson, C.A. "Jatropha: The next big thing in bio-fuel?" Malaysian Business, 1 Apr. 2008: 27.

Ramachandra, T.V., Krishna, S.V. and Shruthi, B.V., "Decision support system to assess regional biomass energy potential". International Journal of Green Energy 1 (2004), 407-428.

Ramesh, A.*, Samapathrajan, A.,Venkatachalam, P., Production of biodiesel from *jatropha curcas* oil by using pilot biodiesel plant, Agrl. Engg. College & Research Institute Tamil Nadu Agricultural University Coimbatore, Tamil Nadu, India

Stockmangrassfarmer.net,"Bio-fuel subsidies actually subsidize confinement stocker cattle production". http:/stockmangrassfarmer.net/cgi-bin/page.cgi?id=671

Studenmund, A., "Using Econometrics: A practical guide". New York: Addison-Wesley, 2006

Tao, L., Aden,A., "The economics of current and future bio-fuels". NREL report, In Vitro Cell.Dev.Biol, The society for In Vitro Biology, 45:199-217, 2009

Tatsuji Koizumi and Keiji Ohga, "Biofuels Polices in Asia: Trade effects on World Agricultural and Biofuels Trade," presentation at the 2007 Agricultural Forum, Arlington, Virginia, March 2007.

Tewari, J.P. and Shukla, I.K." Inhibition of infectivity of 2 strains of watermelon mosaic virus by latex of some angiosperms",. Geobios. Jodhpur, India. 9(3) (1982).:124–126.

United Nations, "Small Scale Production and Use of Liquid Biofuels in Sub-Saharan Africa: Perspective for Sustainable Development," May 2007

Watt, J.M. and Breyer-Brandwijk, M.G. "The medicinal and poisonous plants of southern and eastern Africa", 2nd ed. E.&S. Livingstone, Ltd. (1962), Edinburgh and London.

Wisegeek.com, . "What is diesel fuel?", http://wisegeek.com/what-is-diesel-fuel.htm

APPENDIX 1: *JATROPHA CURCAS* PLANTING SCHEDULE

50,000 Hectare *Jatropha curcas* Planting Schedule

			HECTARES	PLT SCHEDULE					
JC Planting schedule - 'ooo			50	5	Yield - Hectares				
	Production activities in Hectares			Hectares	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5 and up
Year (s)	Planted	Removed	Total Planted	Harvestable	0	0.5	1	2	(2,5)
1	10	0	10	0	10	0	0	0	0
2	10	0	20	10	10	10	0	0	0
3	10	0	30	20	10	10	10	0	0
4	10	0	40	30	10	10	10	10	0
5	10	0	50	40	10	10	10	10	10
6	0	0	50	50	0	10	10	10	20
7	0	0	50	50	0	0	10	10	30
8	0	0	50	50	0	0	0	10	40
9	0	0	50	50	0	0	0	0	50
10	0	0	50	50	0	0	0	0	50
11	0	0	50	50	0	0	0	0	50
12	0	0	50	50	0	0	0	0	50
13	0	0	50	50	0	0	0	0	50
14	0	0	50	50	0	0	0	0	50
15	0	0	50	50	0	0	0	0	50
16	0	0	50	50	0	0	0	0	50
17	0	0	50	50	0	0	0	0	50
18	0	0	50	50	0	0	0	0	50
19	0	0	50	50	0	0	0	0	50
20	0	0	50	50	0	0	0	0	50
21	0	0	50	50	0	0	0	0	50
22	0	0	50	50	0	0	0	0	50
23	0	0	50	50	0	0	0	0	50
24	0	0	50	50	0	0	0	0	50
25	0	0	50	50	0	0	0	0	50
26	10	10	50	40	10	0	0	0	40
27	10	10	50	40	10	10	0	0	30
28	10	10	50	40	10	10	10	0	20
29	10	10	50	40	10	10	10	10	10
30	10	10	50	40	10	10	10	10	10
31	0	0	50	50	0	10	10	10	20
32	0	0	50	50	0	0	10	10	30
33	0	0	50	50	0	0	0	10	40
34	0	0	50	50	0	0	0	0	50

APPENDIX 2: SOYBEAN FEEDSTOCK PRODUCTION DATA 1997 - 2010

Source:
Economic Research Service, U.S. Department of Agriculture,
http://www.ers.usda.gov/data/costsandreturns/testpick.htm

U.S. soybean production costs and returns per planted **hectare**, excluding Government payments, 1997-2008 with 2009 and 2010 forecasts

													Forecast	Forecast
Item	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
		dollars per planted hectare					dollars per planted hectare			dollars per planted hectare				
Gross value of production														
Primary product: Soybeans	694.89	551.45	439.84	450.83	441.36	513.97	576.91	626.29	653.76	629.71	886.45	1103.18	`	
Total, gross value of production	694.89	551.45	439.84	450.83	441.36	513.97	576.91	626.29	653.76	629.71	886.45	1103.18		
Operating costs:														
Seed	48.73	50.56	47.57	47.39	55.82	62.89	67.75	73.41	80.60	79.81	98.26	109.59	143.52	155.99
Fertilizer	19.77	19.77	19.67	19.45	20.56	16.78	18.26	19.99	24.86	32.25	41.60	74.17	60.71	65.98
Soil conditioners	0.25	0.25	0.25	0.35	0.27	0.27	0.30	0.32	0.32					
Manure	2.13	1.98	1.95	2.08	2.69	0.99	1.14	1.19	1.48					
Chemicals	65.16	65.85	61.48	55.15	56.56	42.30	41.81	39.71	33.58	35.73	36.76	40.27	43.17	44.43
Custom operations	14.46	14.43	14.48	14.68	15.15	15.22	15.62	15.76	16.48	14.85	16.09	16.20	16.51	17.10
Fuel, lube, and electricity	17.64	14.75	14.58	21.25	21.47	17.25	21.57	23.33	33.66	33.38	37.62	49.76	34.15	40.28
Repairs	23.23	23.70	24.19	25.13	26.17	24.12	24.14	26.44	27.90	29.16	30.54	31.90	32.32	33.21
Purchased irrigation water	0.12	0.12	0.12	0.15	0.15	0.30	0.30	0.32	0.32	0.27	0.28	0.30	0.27	0.30
Interest on operating capital	4.89	4.60	4.32	5.34	3.36	1.51	1.01	1.58	3.71	5.36	5.85	7.22	1.51	4.32
Total, operating costs	196.37	196.00	188.61	190.96	202.20	181.62	191.90	202.05	222.91	230.82	267.00	329.42	332.15	361.61
Allocated overhead:														
Hired labor	4.79	4.89	4.97	5.02	5.04	4.55	4.69	5.04	5.02	4.40	5.55	6.42	6.60	6.77
Opportunity cost of unpaid labor	43.56	44.75	45.61	48.16	49.84	38.52	39.81	39.83	41.44	37.56	46.47	51.99	53.42	54.71
Capital recovery of machinery and equipment	122.59	125.18	127.45	132.47	137.76	106.99	107.32	117.35	123.97	149.20	183.15	205.05	217.84	225.03
Opportunity cost of land (rental rate)	189.62	191.90	197.04	197.98	202.57	199.51	202.45	207.27	214.19	212.93	259.88	287.29	298.55	306.87
Taxes and insurance	16.70	17.03	16.73	17.32	17.64	13.99	14.33	14.46	14.97	19.60	24.01	26.71	29.48	31.51
General farm overhead	33.80	31.97	34.92	35.98	37.49	28.10	28.81	29.31	30.81	32.67	40.21	44.62	45.79	47.05
Total, allocated overhead	411.08	415.72	426.72	436.92	450.34	391.65	397.41	413.25	430.40	456.34	559.27	622.09	651.68	671.94
Total costs listed	607.45	611.72	615.33	627.88	652.54	573.27	589.31	615.30	653.31	687.16	826.27	951.51	398.15	418.27
Value of production less total costs listed	87.45	-60.27	-175.49	-177.05	-211.18	-59.30	-12.40	10.99	0.46	-57.45	60.18	151.67		
Value of production less operating costs	498.52	355.45	251.23	259.88	239.16	332.35	385.01	424.24	430.85	398.89	619.45	773.76		
Supporting information:														
Yield (bushels per planted hectare)	106.25	106.25	98.84	101.31	106.35	98.84	87.94	111.84	115.10	113.67	111.55	105.23		
Price (dollars per bushedl at harvest)	6.54	5.19	4.45	4.45	4.15	5.20	6.56	5.60	5.68	5.54	7.95	10.48		
Enterprise size (planted hectares) 1/	543.62	543.62	543.62	543.62	543.62	662.23	662.23	662.23	662.23	748.71	748.71	748.71		
Production practices: 1/														
Irrigated (percent)	5	5	5	5	5	9	9	9	9	9	9	9		
Dryland (percent)	95	95	95	95	95	91	91	91	91	91	91	91		
HECTARES PLANTED														

APPENDIX 3: GRYE *JATROPHA CURCAS* FEEDSTOCK PRODUCTION DATA

Forecast	
Jatropha Plantation (Hectares)	1,000
Number of Plants per Hectare	2,500
	2,500,000
Total Seedling for 1000 Hectares	+ 5%
Quarterly Seed Production per Hectare (Tons)	3
Total Yearly Seed Production, 1000 hectares (Tons)	12,000
Weight of seed per liter Jatropha Crude Oil (kg)	2.5
Total Yearly Jatropha Crude Oil Produced (liters)	4,800,000
Total Yearly Jatropha Crude Oil Produced (gal)	1,268,026
I Liter of Jatropha Crude Oil after Transesterification	0.8 Liter Biodiesel
Total Yearly Jatropha Biodiesel produced (liters)	3,840,000
Total Yearly Jatropha Biodiesel produced (gal)	1,014,421
Price of Jatropha Crude oil (per gal)	$1.25
Biodiesel (B100) (per gal)	$1.94
Price of Jatropha Press Cake (per ton)	$4.00
Price of Jatropha Residual (per ton)	$60.00
Buying Price of seed (per kilogram)	$0.04
EXPENSES	
Planting Cost	$92,574
Oil Mill Cost	$770,191
Operating Cost	$596,272
TOTAL EXPENSES	$1,459,037
INCOMES	
Jatropha Biodiesel	$1,967,977
Jatropha Crude Oil @ $1.94/gal (B100) and $1.25/gal (Crude Oil)	$1,585,033
Jatropha Press Cake	$28,800
Glycerin (Jatropha Residual)	$230,400
TOTAL GROSS INCOME	$3,812,210
NET INCOME (per Year per 1000 Hectares)	$2,353,173

Jatropha Cultivation: Feasibility studies were done with a reference report from the JatrophaWorld showing that (1) Jatropha Oil Yield: Jatropha seeds yield 35% to 40% oil (2) Jatropha press cake = 60% per ton of seeds (3) Jatropha Residual or Glycerin = 15% to 20% per cubic meter of Jatropha crude oil (4) Jatropha Plant Life Span: Jatropha takes approximately 8 to 12 months from planting to first harvest, and the plant can thrive successfully up to 40 years.

Source: GreenGold Ray Energies, Inc. (GRYE)

APPENDIX 4: 50,000 HECTARE JATROPHA CURCAS FEEDSTOCK PRODUCTION

Yield Inc	price		
0%	$0.04	/kg	15 kg seed/gal oil

YIELD (Kg)	Yield - Kg	with	2500	plants per hectare						
'000	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5 and up	TOTAL	TOTAL REVENUE '000	TOTAL COST '000	ANNUAL PROFIT '000	NET ACCM'D PROFIT ' 000
Year (s)	0	0.5	1	2	(2,5)	YIELD				
1	0	0	0	0	0	0	$0	$12,296	($12,296)	($12,296)
2	0	12500	0	0	0	12500	$500	$16,252	($15,752)	($28,048)
3	0	12500	25000	0	0	37500	$1,500	$9,991	($8,491)	($36,539)
4	0	12500	25000	50000	0	87500	$3,500	$12,808	($9,308)	($45,847)
5	0	12500	25000	50000	125000	212500	$8,500	$17,725	($9,225)	($55,072)
6	0	12500	25000	50000	100000	187500	$7,500	$5,920	$1,580	($53,492)
7	0	0	25000	50000	225000	300000	$12,000	$5,350	$6,650	($46,842)
8	0	0	0	50000	200000	250000	$10,000	$5,800	$4,200	($42,642)
9	0	0	0	0	625000	625000	$25,000	$6,000	$19,000	($23,642)
10	0	0	0	0	250000	250000	$10,000	$5,700	$4,300	($19,342)
11	0	0	0	0	500000	500000	$20,000	$5,950	$14,050	($5,292)
12	0	0	0	0	250000	250000	$10,000	$5,600	$4,400	($892)
13	0	0	0	0	250000	250000	$10,000	$5,400	$4,600	$3,708
14	0	0	0	0	625000	625000	$25,000	$6,450	$18,550	$22,258
15	0	0	0	0	625000	625000	$25,000	$6,300	$18,700	$40,958
16	0	0	0	0	250000	250000	$10,000	$6,100	$3,900	$44,858
17	0	0	0	0	375000	375000	$15,000	$6,950	$8,050	$52,908
18	0	0	0	0	375000	375000	$15,000	$6,100	$8,900	$61,808
19	0	0	0	0	250000	250000	$10,000	$6,200	$3,800	$65,608
20	0	0	0	0	500000	500000	$20,000	$6,350	$13,650	$79,258
21	0	0	0	0	500000	500000	$20,000	$7,100	$12,900	$92,158
22	0	0	0	0	625000	625000	$25,000	$6,400	$18,600	$110,758
23	0	0	0	0	375000	375000	$15,000	$6,800	$8,200	$118,958
24	0	0	0	0	500000	500000	$20,000	$6,200	$13,800	$132,758
25	0	0	0	0	500000	500000	$20,000	$6,400	$13,600	$146,358
26	0	0	0	0	200000	200000	$8,000	$17,725	($9,725)	$136,633
27	0	12500	0	0	150000	162500	$6,500	$13,538	($7,038)	$129,595
28	0	12500	25000	0	100000	137500	$5,500	$11,371	($5,871)	$123,724
29	0	12500	25000	50000	125000	212500	$8,500	$18,112	($9,612)	$114,112
30	0	12500	25000	50000	100000	187500	$7,500	$14,776	($7,276)	$106,836
31	0	12500	25000	50000	250000	337500	$13,500	$18,112	($4,612)	$102,224
32	0	0	25000	50000	375000	450000	$18,000	$11,371	$6,629	$108,853
33	0	0	0	50000	200000	250000	$10,000	$13,538	($3,538)	$105,315
34	0	0	0	0	500000	500000	$20,000	$17,725	$2,275	$107,590

APPENDIX 5: *JATROPHA CURCAS* BIODIESEL DATA

8%

FROM 50 K Plantation **30 mil** **capacity**

Year	**Yield**	**kg per gal 15 gal**	**Biodiesel Price Per Gal**	**Biodiesel Rev**	**Glycerin Price Per Gal**	**Total Rev**	**Variable Cost**	**$0.10 price per Kg Total Fixed Cost**	**15 kg seed/gal oil Annual Profit/(loss)**	**Cumulative Profit/(loss)**
-1	0	0	$0	$0	$0	$0	$0	$34,394,750	-$34,394,750	-$34,394,750
0	0	0	$0	$0	$0	$0	$0	$50,100,750	-$50,100,750	-$84,495,500
1	0	0	$3.09	$0	$0.03	$0	$0	$11,339,750	-$11,339,750	-$95,835,250
2	12,500,000	833,333	$3.16	$2,631,250	$0.03	$2,653,750	$1,851,831	$9,156,750	-$8,354,831	-$104,190,081
3	37,500,000	2,500,000	$3.17	$7,912,500	$0.03	$7,980,000	$5,566,265	$5,098,750	-$2,685,015	-$106,875,095
4	87,500,000	5,833,333	$3.20	$18,652,083	$0.03	$18,809,583	$12,934,037	$5,098,750	$776,796	-$106,098,299
5	186,250,000	12,416,667	$3.22	$39,981,667	$0.03	$40,316,917	$27,464,374	$5,098,750	$7,753,793	-$98,344,506
6	275,000,000	18,333,333	$3.29	$60,339,583	$0.03	$60,834,583	$40,562,541	$5,098,750	$15,173,293	-$83,171,213
7	318,750,000	21,250,000	$3.44	$73,126,563	$0.03	$73,700,313	$48,834,387	$5,098,750	$19,767,176	-$63,404,038
8	410,000,000	27,333,333	$3.74	$102,281,333	$0.03	$103,019,333	$63,976,161	$5,098,750	$33,944,422	-$29,459,616
9	418,750,000	27,916,667	$3.92	$109,468,229	$0.03	$110,221,979	$67,031,041	$5,098,750	$38,092,188	$8,632,572
10	450,000,000	30,000,000	$4.28	$128,325,000	$0.03	$129,135,000	$71,990,266	$5,098,750	$52,045,984	$60,678,557
11	437,500,000	29,166,667	$4.68	$136,427,083	$0.03	$137,214,583	$68,897,581	$5,098,750	$63,218,252	$123,896,809
12	450,000,000	30,000,000	$5.16	$154,912,500	$0.03	$155,722,500	$70,190,824	$5,098,750	$80,432,926	$204,329,734
13	437,500,000	29,166,667	$4.98	$145,213,542	$0.03	$146,001,042	$67,365,248	$5,098,750	$73,537,043	$277,866,778
14	406,250,000	27,083,333	$5.26	$142,350,000	$0.03	$143,081,250	$62,277,305	$5,098,750	$75,705,195	$353,571,973
15	418,750,000	27,916,667	$5.51	$153,820,833	$0.03	$154,574,583	$64,647,825	$5,098,750	$84,828,009	$438,399,981
16	437,500,000	29,166,667	$5.47	$159,468,750	$0.03	$160,256,250	$67,668,189	$5,098,750	$87,489,311	$525,889,293
17	412,500,000	27,500,000	$4.88	$134,117,500	$0.03	$134,860,000	$63,682,932	$5,098,750	$66,078,318	$591,967,611
18	450,000,000	30,000,000	$4.43	$132,975,000	$0.03	$133,785,000	$68,918,897	$5,098,750	$59,767,353	$651,734,963
19	437,500,000	29,166,667	$3.65	$106,312,500	$0.03	$107,100,000	$66,307,142	$5,098,750	$35,694,108	$687,429,071
20	450,000,000	30,000,000	$3.19	$95,737,500	$0.03	$96,547,500	$67,816,374	$5,098,750	$23,632,376	$711,061,447

IRR	18%
NPV	$164,358,919

APPENDIX 6: CONVERSIONS

1	Hectare	=	2.471	Acres	
1	gallon	=	3.785	liters	
1	ton	=	1000	kg	
1	metric ton	=	300.1964	gal Jatropha Curcas Oil	(density Jatropha Biodiesel = 0.88)
1	kg	=	1200	seeds (Jatropha Curcas)	
1	gal SoyOil	=	1	gal biodiesel	
1	bushel Soy	=	1.49	gal biodiesel	
2.5	kg Jcseeds	=	1	lit of JCOil	
1	liter JCOil	=	0.8	lit biodiesel	
1	gal JCOil	=	0.8	gal biodiesel	
1	galJCBioD	`	1.25	gal JC oil	
1	gal JCOil	=	9.4625	kg to	15.14 kg
1	hectare	=	165.6816	gallons	Soybean biodiesel
1	hectare	=	1321	gallons	Jatropha Curcas biodiesel

APPENDIX 7: *JATROPHA CURCAS* YIELD

Prod Yr	**yield/plt**	**2500.00**	**plts per hec**
1	0.0	0.00	kg per hec
2	1.00	2500.00	kg per hec
3	1.50	3750.00	kg per hec
4	2.50	6250.00	kg per hec
5	5.00	12500.00	kg per hec
10	5.00	12500.00	kg per hec

Source: United Nations (2007)

APPENDIX 8: PALM OIL FEEDSTOCK PRODUCTION DATA

PALM OIL PLANTATIONS

USD$1 = RM$3.50

SMALLHOLDERS		
COSTS	rm/hec	**usd/hec**
UPKEEP	385.14	**110.04**
FERT and APPL	358.99	**102.5685714**
HARVESTING	566.48	**161.8514286**
TRANSPORTATION	373.48	**106.7085714**
MISC	88.38	**25.25142857**
TOTAL (SMALLHOLDERS)	1772.47	**506.42**
YIELD/HEC (ton/hec)	15.85	**4.528571429**
PRICE/ Ton	188.28	**53.79428571**
INCOME PER HEC	2984.238	**852.6394286**
NET INCOME/HEC	1211.768	**346.2194286**
Net Income	**5000**	**hectares**
	$6,058,840.00	**$1,731,097.14**
	50000	**hectares**
	$60,588,400.00	**$17,310,971.43**

Source:Azman(2003)

ESTATE HOLDERS		
COSTS	rm/hec	**usd/hec**
UPKEEP	347.19	**99.19714286**
FERT and APPL	541.11	**154.6028571**
HARVESTING	461.41	**131.8314286**
TRANSPORTATION	490.94	**140.2685714**
JOINT ESTATE COSTS	509.38	**145.5371429**
MISC (dep)	-76.4	**-21.82857143**
TOTAL (ESTATE SECTOR)	2273.63	**649.6085714**
YIELD/HEC (ton/hec)	19.3	**5.514285714**
PRICE/ Ton	188.28	**53.79428571**
INCOME PER HEC	3633.804	**1038.229714**
NET INCOME/HEC	1360.174	**388.6211429**
Net Income	**5000**	**hectares**
	$6,800,870.00	**$1,943,105.71**
	50000	**hectares**
	$68,008,700.00	**$19,431,057.14**

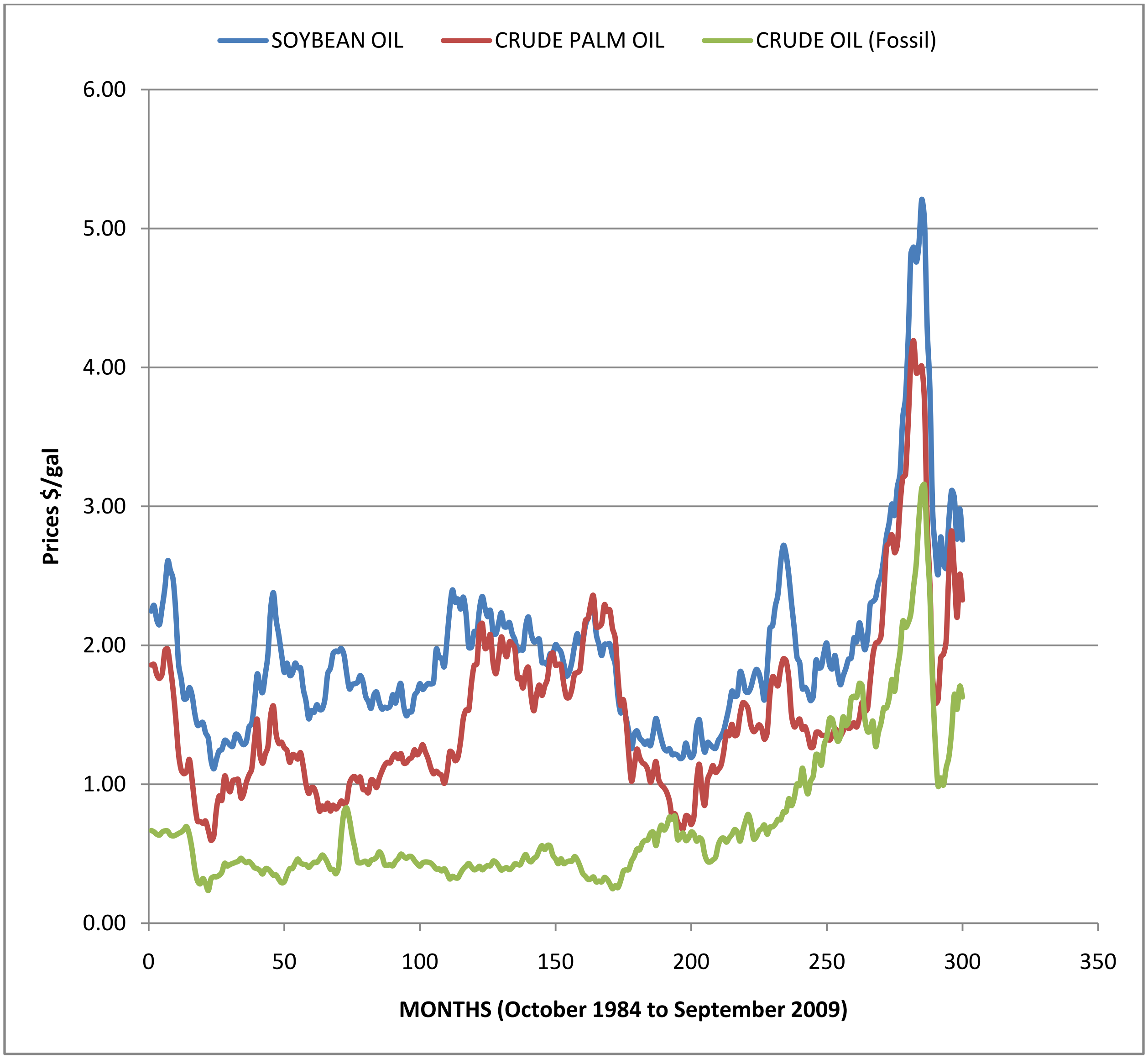
Source:Azman (2003)

APPENDIX 9: SOYBEAN MONTHLY BIODIESEL DATA

Monthly Costs and Returns per Gallon of Biodiesel Produced

	Prices				*Revenue per Gallon*			*Cost per Gallon*								*Net Return/Gal.*			
Month and Year	Biodiesel (gallon)	Soybean Oil (pound)	Natural Gas (000 cub. ft)	Methanol (pound)	Biodiesel Revenue	Glycerine Revenue	Total Revenue	Soybean Oil Cost	Natural Gas Cost	Methanol Cost	Other Variable Costs	Total Variable Costs	Fixed Costs	Total Cost	Biodiesel Break-even	` Variable Costs	Over All Costs	Profit/Loss 2,500,000	Cumulative Profit/Loss
Apr-07	$ 3.09	$ 0.30	$ 8.31	$ 0.15	$ 3.09	$ 0.03	$ 3.12	$ 2.26	$ 0.06	$ 0.11	$ 0.25	$ 2.68	$ 0.26	$ 2.94	$ 2.91	$ 0.44	$ 0.18	$ 450,287.89	$ 450,287.89
May-07	$ 3.16	$ 0.32	$ 7.75	$ 0.15	$ 3.16	$ 0.03	$ 3.18	$ 2.43	$ 0.05	$ 0.11	$ 0.25	$ 2.85	$ 0.26	$ 3.11	$ 3.08	$ 0.34	$ 0.08	$ 188,658.73	$ 638,946.62
Jun-07	$ 3.17	$ 0.33	$ 8.32	$ 0.15	$ 3.17	$ 0.03	$ 3.19	$ 2.49	$ 0.06	$ 0.11	$ 0.25	$ 2.91	$ 0.26	$ 3.17	$ 3.15	$ 0.28	$ 0.02	$ 47,377.48	$ 686,324.10
Jul-07	$ 3.20	$ 0.34	$ 8.34	$ 0.14	$ 3.20	$ 0.03	$ 3.22	$ 2.60	$ 0.06	$ 0.10	$ 0.25	$ 3.01	$ 0.26	$ 3.27	$ 3.24	$ 0.22	$ (0.05)	$ (113,284.22)	$ 573,039.88
Aug-07	$ 3.22	$ 0.34	$ 7.63	$ 0.14	$ 3.22	$ 0.03	$ 3.25	$ 2.54	$ 0.05	$ 0.10	$ 0.25	$ 2.94	$ 0.26	$ 3.20	$ 3.18	$ 0.30	$ 0.04	$ 109,222.03	$ 682,261.92
Sep-07	$ 3.29	$ 0.37	$ 7.25	$ 0.14	$ 3.29	$ 0.03	$ 3.32	$ 2.77	$ 0.05	$ 0.10	$ 0.25	$ 3.18	$ 0.26	$ 3.44	$ 3.41	$ 0.14	$ (0.12)	$ (302,956.51)	$ 379,305.41
Oct-07	$ 3.44	$ 0.38	$ 7.25	$ 0.26	$ 3.44	$ 0.03	$ 3.47	$ 2.87	$ 0.05	$ 0.18	$ 0.25	$ 3.36	$ 0.26	$ 3.62	$ 3.59	$ 0.11	$ (0.15)	$ (377,111.07)	$ 2,194.34
Nov-07	$ 3.74	$ 0.43	$ 8.27	$ 0.30	$ 3.74	$ 0.03	$ 3.77	$ 3.24	$ 0.06	$ 0.21	$ 0.25	$ 3.77	$ 0.26	$ 4.03	$ 4.00	$ (0.00)	$ (0.26)	$ (654,158.96)	$ (651,964.61)
Dec-07	$ 3.92	$ 0.44	$ 8.59	$ 0.38	$ 3.92	$ 0.03	$ 3.95	$ 3.35	$ 0.06	$ 0.27	$ 0.25	$ 3.94	$ 0.26	$ 4.20	$ 4.17	$ 0.01	$ (0.25)	$ (621,703.06)	$ (1,273,667.67)
Jan-08	$ 4.28	$ 0.49	$ 8.40	$ 0.38	$ 4.28	$ 0.03	$ 4.30	$ 3.71	$ 0.06	$ 0.27	$ 0.25	$ 4.29	$ 0.26	$ 4.55	$ 4.52	$ 0.02	$ (0.25)	$ (614,878.06)	$ (1,888,545.73)
Feb-08	$ 4.68	$ 0.56	$ 9.61	$ 0.32	$ 4.68	$ 0.03	$ 4.70	$ 4.26	$ 0.07	$ 0.22	$ 0.25	$ 4.81	$ 0.26	$ 5.07	$ 5.05	$ (0.11)	$ (0.37)	$ (919,223.13)	$ (2,807,768.86)
Mar-08	$ 5.16	$ 0.57	$ 9.67	$ 0.29	$ 5.16	$ 0.03	$ 5.19	$ 4.32	$ 0.07	$ 0.20	$ 0.25	$ 4.85	$ 0.26	$ 5.11	$ 5.08	$ 0.34	$ 0.08	$ 208,830.22	$ (2,598,938.64)
Apr-08	$ 4.98	$ 0.56	$ 10.30	$ 0.24	$ 4.98	$ 0.03	$ 5.01	$ 4.21	$ 0.07	$ 0.17	$ 0.25	$ 4.71	$ 0.26	$ 4.97	$ 4.94	$ 0.30	$ 0.04	$ 96,134.36	$ (2,502,804.28)
May-08	$ 5.26	$ 0.58	$ 10.47	$ 0.23	$ 5.26	$ 0.03	$ 5.28	$ 4.38	$ 0.07	$ 0.16	$ 0.25	$ 4.86	$ 0.26	$ 5.13	$ 5.10	$ 0.42	$ 0.16	$ 393,836.04	$ (2,108,968.23)
Jun-08	$ 5.51	$ 0.62	$ 11.38	$ 0.24	$ 5.51	$ 0.03	$ 5.54	$ 4.65	$ 0.08	$ 0.17	$ 0.25	$ 5.16	$ 0.26	$ 5.42	$ 5.39	$ 0.38	$ 0.12	$ 302,228.99	$ (1,806,739.25)
Jul-08	$ 5.47	$ 0.60	$ 11.95	$ 0.24	$ 5.47	$ 0.03	$ 5.49	$ 4.54	$ 0.08	$ 0.17	$ 0.25	$ 5.04	$ 0.26	$ 5.30	$ 5.28	$ 0.45	$ 0.19	$ 473,847.74	$ (1,332,891.51)
Aug-08	$ 4.88	$ 0.51	$ 11.38	$ 0.24	$ 4.88	$ 0.03	$ 4.90	$ 3.82	$ 0.08	$ 0.17	$ 0.25	$ 4.33	$ 0.26	$ 4.59	$ 4.56	$ 0.58	$ 0.32	$ 791,260.24	$ (541,631.27)
Sep-08	$ 4.43	$ 0.46	$ 8.94	$ 0.24	$ 4.43	$ 0.03	$ 4.46	$ 3.44	$ 0.06	$ 0.17	$ 0.25	$ 3.92	$ 0.26	$ 4.18	$ 4.16	$ 0.54	$ 0.27	$ 686,278.99	$ 144,647.71
Oct-08	$ 3.65	$ 0.35	$ 7.02	$ 0.23	$ 3.65	$ 0.03	$ 3.67	$ 2.63	$ 0.05	$ 0.16	$ 0.25	$ 3.10	$ 0.26	$ 3.36	$ 3.33	$ 0.58	$ 0.31	$ 786,836.04	$ 931,483.75
Nov-08	$ 3.19	$ 0.32	$ 6.84	$ 0.21	$ 3.19	$ 0.03	$ 3.22	$ 2.40	$ 0.05	$ 0.15	$ 0.25	$ 2.85	$ 0.26	$ 3.11	$ 3.09	$ 0.36	$ 0.10	$ 258,818.97	$ 1,190,302.72
Dec-08	$ 2.84	$ 0.29	$ 7.61	$ 0.15	$ 2.84	$ 0.03	$ 2.87	$ 2.17	$ 0.05	$ 0.11	$ 0.25	$ 2.58	$ 0.26	$ 2.84	$ 2.81	$ 0.29	$ 0.03	$ 71,368.54	$ 1,261,671.26
Jan-09	$ 3.09	$ 0.32	$ 7.94	$ 0.11	$ 3.09	$ 0.03	$ 3.12	$ 2.40	$ 0.06	$ 0.08	$ 0.25	$ 2.78	$ 0.26	$ 3.04	$ 3.01	$ 0.34	$ 0.07	$ 185,135.18	$ 1,446,806.44
Feb-09	$ 2.82	$ 0.29	$ 7.51	$ 0.11	$ 2.82	$ 0.03	$ 2.85	$ 2.17	$ 0.05	$ 0.08	$ 0.25	$ 2.55	$ 0.26	$ 2.82	$ 2.79	$ 0.30	$ 0.04	$ 88,847.68	$ 1,535,654.12
Mar-09	$ 2.68	$ 0.28	$ 7.01	$ 0.10	$ 2.68	$ 0.03	$ 2.71	$ 2.12	$ 0.05	$ 0.07	$ 0.25	$ 2.49	$ 0.26	$ 2.75	$ 2.73	$ 0.22	$ (0.04)	$ (110,655.05)	$ 1,424,999.07
Apr-09	$ 2.94	$ 0.33	$ 5.39	$ 0.09	$ 2.94	$ 0.03	$ 2.97	$ 2.47	$ 0.04	$ 0.06	$ 0.25	$ 2.83	$ 0.26	$ 3.09	$ 3.06	$ 0.14	$ (0.12)	$ (301,763.14)	$ 1,123,235.93
May-09	$ 3.10	$ 0.36	$ 4.66	$ 0.09	$ 3.10	$ 0.03	$ 3.13	$ 2.73	$ 0.03	$ 0.06	$ 0.25	$ 3.08	$ 0.26	$ 3.35	$ 3.32	$ 0.04	$ (0.22)	$ (547,431.89)	$ 575,804.04
Jun-09	$ 3.13	$ 0.35	$ 4.40	$ 0.09	$ 3.13	$ 0.03	$ 3.16	$ 2.68	$ 0.03	$ 0.06	$ 0.25	$ 3.03	$ 0.26	$ 3.29	$ 3.26	$ 0.14	$ (0.13)	$ (315,056.89)	$ 260,747.15
Jul-09	$ 2.86	$ 0.31	$ 4.40	$ 0.10	$ 2.86	$ 0.03	$ 2.89	$ 2.37	$ 0.03	$ 0.07	$ 0.25	$ 2.73	$ 0.26	$ 2.99	$ 2.96	$ 0.16	$ (0.10)	$ (259,046.09)	$ 1,701.05
Aug-09	$ 3.11	$ 0.34	$ 4.40	$ 0.11	$ 3.11	$ 0.03	$ 3.13	$ 2.54	$ 0.03	$ 0.08	$ 0.25	$ 2.91	$ 0.26	$ 3.17	$ 3.14	$ 0.23	$ (0.03)	$ (85,196.94)	$ (83,495.89)

APPENDIX 10: CRUDE SOYBEAN OIL, CRUDE PALM OIL, AND CRUDE OIL (FOSSIL) HISTORICAL PRICES – 25 YEARS (MONTHLY) FROM OCTOBER 1984 TO SEPTEMBER 2009



APPENDIX 11: SOYBEAN BIODIESEL DATA

8%

SOYBEAN OIL

30 mil capacity

Year	Production gal	Biodiesel Price Per Gal	Biodiesel Rev	Glycerin Price Per Gal	Glycerin Rev	Total Rev	Soybean Oil Cost	Soy Oil Per kg	Total Variable Cost	Facility Capital Input	Total Fixed Cost	Total Cost	Over All Costs Profit/(loss)	Cumulative Profit/(loss)
0	0	$0	$0	$0	$0	$0	$0	$0	$0	$17,000,000	$22,098,750	$22,098,750	-$22,098,750	-$22,098,750
1	0	$0	$0	$0	$0	$0	$0	$0	$0	$30,000,000	$35,098,750	$35,098,750	-$35,098,750	-$57,197,500
2	30,000,000	$3.09	$92,750,000	$0.03	$810,000	$93,560,000	$67,712,175	$2.26	$84,557,462	$0	$5,098,750	$89,656,212	$3,903,788	-$53,293,712
3	30,000,000	$3.16	$94,725,000	$0.03	$810,000	$95,535,000	$72,944,325	$2.43	$89,672,012	$0	$5,098,750	$94,770,762	$764,238	-$52,529,474
4	30,000,000	$3.17	$94,950,000	$0.03	$810,000	$95,760,000	$74,745,000	$2.49	$91,592,387	$0	$5,098,750	$96,691,137	-$931,137	-$53,460,611
5	30,000,000	$3.20	$95,925,000	$0.03	$810,000	$96,735,000	$77,904,675	$2.60	$94,495,327	$0	$5,098,750	$99,594,077	-$2,859,077	-$56,319,688
6	30,000,000	$3.22	$96,600,000	$0.03	$810,000	$97,410,000	$76,058,700	$2.54	$92,500,252	$0	$5,098,750	$97,599,002	-$189,002	-$56,508,690
7	30,000,000	$3.29	$98,737,500	$0.03	$810,000	$99,547,500	$83,125,500	$2.77	$99,583,895	$0	$5,098,750	$104,682,645	-$5,135,145	-$61,643,835
8	30,000,000	$3.44	$103,237,500	$0.03	$810,000	$104,047,500	$86,137,950	$2.87	$104,973,749	$0	$5,098,750	$110,072,499	-$6,024,999	-$67,668,835
9	30,000,000	$3.74	$112,260,000	$0.03	$810,000	$113,070,000	$97,304,400	$3.24	$117,320,824	$0	$5,098,750	$122,419,574	-$9,349,574	-$77,018,409
10	30,000,000	$3.92	$117,637,500	$0.03	$810,000	$118,447,500	$100,611,300	$3.35	$122,308,853	$0	$5,098,750	$127,407,603	-$8,960,103	-$85,978,512
11	30,000,000	$4.28	$128,325,000	$0.03	$810,000	$129,135,000	$111,256,800	$3.71	$132,914,453	$0	$5,098,750	$138,013,203	-$8,878,203	-$94,856,715
12	30,000,000	$4.68	$140,325,000	$0.03	$810,000	$141,135,000	$127,949,850	$4.26	$148,566,594	$0	$5,098,750	$153,665,344	-$12,530,344	-$107,387,060
13	30,000,000	$5.16	$154,912,500	$0.03	$810,000	$155,722,500	$129,625,950	$4.32	$149,617,454	$0	$5,098,750	$154,716,204	$1,006,296	-$106,380,764
14	30,000,000	$4.98	$149,362,500	$0.03	$810,000	$150,172,500	$126,262,425	$4.21	$145,419,804	$0	$5,098,750	$150,518,554	-$346,054	-$106,726,818
15	30,000,000	$5.26	$157,680,000	$0.03	$810,000	$158,490,000	$131,290,725	$4.38	$150,164,884	$0	$5,098,750	$155,263,634	$3,226,366	-$103,500,452
16	30,000,000	$5.51	$165,300,000	$0.03	$810,000	$166,110,000	$139,557,975	$4.65	$158,884,169	$0	$5,098,750	$163,982,919	$2,127,081	-$101,373,371
17	30,000,000	$5.47	$164,025,000	$0.03	$810,000	$164,835,000	$136,103,850	$4.54	$155,549,744	$0	$5,098,750	$160,648,494	$4,186,506	-$97,186,865
18	30,000,000	$4.88	$146,310,000	$0.03	$810,000	$147,120,000	$114,699,600	$3.82	$134,025,794	$0	$5,098,750	$139,124,544	$7,995,456	-$89,191,409
19	30,000,000	$4.43	$132,975,000	$0.03	$810,000	$133,785,000	$103,136,775	$3.44	$121,950,569	$0	$5,098,750	$127,049,319	$6,735,681	-$82,455,727
20	30,000,000	$3.65	$109,350,000	$0.03	$810,000	$110,160,000	$78,969,225	$2.63	$97,118,884	$0	$5,098,750	$102,217,634	$7,942,366	-$74,513,362
21	30,000,000	$3.19	$95,737,500	$0.03	$810,000	$96,547,500	$72,049,650	$2.40	$89,842,589	$0	$5,098,750	$94,941,339	$1,606,161	-$72,907,201
											NPV		-$63,564,411	

APPENDIX 12: *JATROPHA CURCAS* BIODIESEL DATA YEAR 1 TO YEAR 5 FROM GRYE (PHILIPPINES)

JATROPHA CURCAS BIODIESEL				Source : GRYE GreenRay Energy			
			met tons				
			3,840	18240	43200	54400	132800
		Price	850	1200	1500	1800	2000
			3264000	21888000	64800000	97920000	265600000
			JATROPHA CURCAS				
			Year 1	Year 2	Year 3	Year 4	Year 5
BIODIESEL OUTPUT (GAL)			1,014,423.67	4,818,512.46	11,412,266.34	14,371,002.06	35,082,152.09
JATROPHA PRESS CAKE (metric ton)			960.00	4,560.00	10,800.00	13,600.00	33,200.00
GLYCERIN (metric ton)			7,200.00	34,200.00	81,000.00	102,000.00	249,000.00
PRICE							
BIODIESEL (GAL)			3.22	4.54	5.68	6.81	7.57
JATROPHA PRESS CAKE (metric ton)			60.00	84.60	105.75	126.90	141.00
GLYCERIN (metric ton)			4.00	5.65	7.06	8.47	9.41
NET SALES							
BIODIESEL (GAL)			3,264,000.00	21,888,000.00	64,800,000.00	97,920,000.00	265,600,000.00
JATROPHA PRESS CAKE (metric ton)			57,600.00	385,776.00	1,142,100.00	1,725,840.00	4,681,200.00
GLYCERIN (metric ton)			28,800.00	193,230.00	571,860.00	863,940.00	2,343,090.00
TOTAL SALES			3,350,400.00	22,467,006.00	66,513,960.00	100,509,780.00	272,624,290.00
DIRECT COSTS			2,883,472.00	13,696,492.00	32,438,771.00	40,850,145.00	99,723,374.00
FACTORY OVERHEAD			599,108.00	844,743.00	1,055,929.00	1,267,115.00	1,406,497.00
ADMIN AND OP EXP			519,820.00	1,519,179.00	1,703,666.00	1,888,152.00	2,009,913.00
TOTAL COGS			4,002,400.00	16,060,414.00	35,198,366.00	44,005,412.00	103,139,784.00
GP BEFORE TAX AND DEP			-652,000.00	6,406,592.00	31,315,594.00	56,504,368.00	169,484,506.00
LESS : CORP INC TAX		32%	0.00	2,050,109.44	10,020,990.08	18,081,397.76	54,235,041.92
INCOME BEFORE DEP			-652,000.00	4,356,482.56	21,294,603.92	38,422,970.24	115,249,464.08
LESS DEP			224,938.00	224,938.00	224,938.00	224,938.00	224,938.00
NET INCOME/(LOSS)			-427,062.00	4,581,420.56	21,519,541.92	38,647,908.24	115,474,402.08

APPENDIX 13: PALM OIL BIODIESEL DATA

													8%	
	PALM OIL													
		30 mil	capacity											
Year	**Production gal**	**Biodiesel Price Per Gal**	**Biodiesel Rev**	**Glycerin Price Per Gal**	**Glycerin Rev**	**Total Rev**	Palm Oil Cost	Palm oil Per kg	**Variable Cost**	Facility Capital Input	**Total Fixed Cost**	**Total Cost**	**Over All Costs Profit/(loss)**	**Cumulative Profit/(loss)**
0	0	$0	$0	$0	$0	$0	$0		$0	$17,000,000	$22,098,750	$22,098,750	-$22,098,750	-$22,098,750
1	0	$0	$0	$0	$0	$0	$0		$0	$30,000,000	$35,098,750	$35,098,750	-$35,098,750	-$57,197,500
2	30,000,000	$3.09	$92,750,000	$0.03	$810,000	$93,560,000	$62,398,947	$2.08	$79,244,234	$0	$5,098,750	$84,342,984	$9,217,016	-$47,980,484
3	30,000,000	$3.16	$94,725,000	$0.03	$810,000	$95,535,000	$71,604,921	$2.39	$88,332,608	$0	$5,098,750	$93,431,358	$2,103,642	-$45,876,841
4	30,000,000	$3.17	$94,950,000	$0.03	$810,000	$95,760,000	$72,359,033	$2.41	$89,206,420	$0	$5,098,750	$94,305,170	$1,454,830	-$44,422,011
5	30,000,000	$3.20	$95,925,000	$0.03	$810,000	$96,735,000	$73,909,798	$2.46	$90,500,450	$0	$5,098,750	$95,599,200	$1,135,800	-$43,286,211
6	30,000,000	$3.22	$96,600,000	$0.03	$810,000	$97,410,000	$70,534,661	$2.35	$86,976,213	$0	$5,098,750	$92,074,963	$5,335,037	-$37,951,175
7	30,000,000	$3.29	$98,737,500	$0.03	$810,000	$99,547,500	$72,044,820	$2.40	$88,503,214	$0	$5,098,750	$93,601,964	$5,945,536	-$32,005,639
8	30,000,000	$3.44	$103,237,500	$0.03	$810,000	$104,047,500	$79,671,991	$2.66	$98,507,791	$0	$5,098,750	$103,606,541	$440,959	-$31,564,680
9	30,000,000	$3.74	$112,260,000	$0.03	$810,000	$113,070,000	$84,822,193	$2.83	$104,838,618	$0	$5,098,750	$109,937,368	$3,132,632	-$28,432,047
10	30,000,000	$3.92	$117,637,500	$0.03	$810,000	$118,447,500	$85,412,915	$2.85	$107,110,468	$0	$5,098,750	$112,209,218	$6,238,282	-$22,193,766
11	30,000,000	$4.28	$128,325,000	$0.03	$810,000	$129,135,000	$95,426,176	$3.18	$117,083,829	$0	$5,098,750	$122,182,579	$6,952,421	-$15,241,345
12	30,000,000	$4.68	$140,325,000	$0.03	$810,000	$141,135,000	$107,267,677	$3.58	$127,884,421	$0	$5,098,750	$132,983,171	$8,151,829	-$7,089,516
13	30,000,000	$5.16	$154,912,500	$0.03	$810,000	$155,722,500	$110,879,683	$3.70	$130,871,187	$0	$5,098,750	$135,969,937	$19,752,563	$12,663,047
14	30,000,000	$4.98	$149,362,500	$0.03	$810,000	$150,172,500	$104,752,035	$3.49	$123,909,414	$0	$5,098,750	$129,008,164	$21,164,336	$33,827,384
15	30,000,000	$5.26	$157,680,000	$0.03	$810,000	$158,490,000	$105,075,916	$3.50	$123,950,075	$0	$5,098,750	$129,048,825	$29,441,175	$63,268,558
16	30,000,000	$5.51	$165,300,000	$0.03	$810,000	$166,110,000	$106,000,188	$3.53	$125,326,381	$0	$5,098,750	$130,425,131	$35,684,869	$98,953,427
17	30,000,000	$5.47	$164,025,000	$0.03	$810,000	$164,835,000	$99,218,975	$3.31	$118,664,869	$0	$5,098,750	$123,763,619	$41,071,381	$140,024,807
18	30,000,000	$4.88	$146,310,000	$0.03	$810,000	$147,120,000	$76,549,192	$2.55	$95,875,386	$0	$5,098,750	$100,974,136	$46,145,864	$186,170,672
19	30,000,000	$4.43	$132,975,000	$0.03	$810,000	$133,785,000	$64,490,159	$2.15	$83,303,953	$0	$5,098,750	$88,402,703	$45,382,297	$231,552,969
20	30,000,000	$3.65	$109,350,000	$0.03	$810,000	$110,160,000	$47,025,685	$1.57	$65,175,345	$0	$5,098,750	$70,274,095	$39,885,905	$271,438,874
21	30,000,000	$3.19	$95,737,500	$0.03	$810,000	$96,547,500	$41,872,583	$1.40	$59,665,522	$0	$5,098,750	$64,764,272	$31,783,228	$303,222,102
											IRR		14%	
											NPV		$52,558,172	

APPENDIX 14: SUMMARY OF BIODIESEL PRODUCTION, ANNUAL PROFITS/(LOSS) AND NPV USING JATROPHA CURCAS, OIL PALM, AND SOYBEANS AT 30 MILLION GALLONS PER YEAR PRODUCTION

Discount Rate 8%

Year	Jatropha Oil	Palm Oil	Soybean Oil
0	-$34,394,750	-$22,098,750	-$22,098,750
1	-$50,100,750	-$35,098,750	-$35,098,750
2	-$11,339,750	$9,217,016	$3,903,788
3	-$8,354,831	$2,103,642	$764,238
4	-$2,685,015	$1,454,830	-$931,137
5	$776,796	$1,135,800	-$2,859,077
6	$7,753,793	$5,335,037	-$189,002
7	$15,173,293	$5,945,536	-$5,135,145
8	$19,767,176	$440,959	-$6,024,999
9	$33,944,422	$3,132,632	-$9,349,574
10	$38,092,188	$6,238,282	-$8,960,103
11	$52,045,984	$6,952,421	-$8,878,203
12	$63,218,252	$8,151,829	-$12,530,344
13	$80,432,926	$19,752,563	$1,006,296
14	$73,537,043	$21,164,336	-$346,054
15	$75,705,195	$29,441,175	$3,226,366
16	$84,828,009	$35,684,869	$2,127,081
17	$87,489,311	$41,071,381	$4,186,506
18	$66,078,318	$46,145,864	$7,995,456
19	$59,767,353	$45,382,297	$6,735,681
20	$35,694,108	$39,885,905	$7,942,366
21	$23,632,376	$31,783,228	$1,606,161
NPV	$164,358,919	$52,558,172	-$63,564,411