The Growth and Direction of the Biodiesel Industry in the U.S.

Roger G. Ginder and Nick D. Paulson

Roger Ginder is a professor and Nick Paulson is a graduate student in the Department of Economics, Iowa State University, Ames, IA.

For questions or comments about the contents of this paper, please contact Nick Paulson, 79 Heady Hall, Iowa State University, Ames, IA 50011; Ph: 515-294-8897; E-mail: *paulson@iastate.edu*.

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The biodiesel industry in the US has seen significant growth over the past decade. Figure 1 reports the annual biodiesel production levels in the US over the past 7 years. Since 1999, annual biodiesel production in the US has increased from 0.5 million gallons (MMG) to 75 MMG produced in 2005. Plant size, as measured by the rated annual production capacity, has also changed significantly. Ginder reports that initially, plants were built to produce biodiesel in discrete production runs or batches. These smaller plants generally do not collect byproducts from the production process, increasing marginal operating costs. Continuous flow plants, which are becoming the industry norm, provide operating cost advantages over the batch plants through their ability to capture and reuse certain components in the production process. However, the continuous flow plants require a higher initial investment and larger plant scale creating problems for investment groups to obtain the necessary capital required to build a continuous flow plant.

Figure 2 shows the distribution of biodiesel production facilities across the US by plant size. Currently, there are 65 plants in production ranging in size from less than 0.5 MMG to 30 MMG of annual production capacity. Current production capacity of plants in production is equal to about 395 MMG annually. However, there are currently plants under construction or in planning stages with annual capacities of 60-85 MMG. Including plants under construction and in planning stages, the US production capacity for biodiesel could reach over 1.8 billion gallons per year in a total of 157 production facilities by the end of 2007.

The significant growth and transition to larger scale continuous flow production plants is attributed to many factors. Increasing energy costs coupled with large agricultural commodity surpluses and low prices have allowed the biodiesel industry to compete with petroleum based diesel fuel (Gustafson). Previous studies have estimated that biodiesel production costs range between $1.50 and $2.50 per gallon depending on the feedstock used in the production process. These costs exceeded the wholesale price of petroleum based diesel by anywhere from $0.20 to $0.82 per gallon depending on the time period when these studies were conducted (Haas et al.; Duffield et al.). In a study from 1997 Giampetro, Ulgiati, and Pimentel also estimate that large-scale production of biofuels, including biodiesel, is not feasible without heavy government subsidies which create significant market extortions and provide an inaccurate reflection of the true costs to society of the production of biofuels. However, with current retail diesel fuel prices approaching $3.00 per gallon the biodiesel industry has been able to better compete with petroleum based diesel fuels, even in the absence of government subsidy programs. Moreover, Tareen, Wetzstein, and Duffield show that due to the stochastic nature of petroleum based energy markets, the market for biodiesel can be supported even with higher costs of production relative to petroleum based diesel fuel sources.

Legislation at both the federal and state levels has also promoted growth in the biodiesel industry, with the aim of reducing dependence on foreign energy supplies and also environmental considerations. The American Jobs Creation Act of 2004 provides a $0.50 per gallon blenders credit for each gallon of biodiesel used in diesel fuel blends and a $1.00 credit for each gallon in diesel fuel blends for agricultural uses (Harl and McKowen). This program provides replacement for the Commodity Credit Corporation (CCC) payment program which expires in 2006. At the state level, Minnesota has enacted legislation which requires a minimum of a 2% blend of biodiesel in all diesel fuels (Tiffany).

There have been a significant number of studies which have analyzed the feasibility of biodiesel production in the US (Van Wechel, Gustafson, and Leistritz; Fortenberry; Haas et al.; Duffield et al.). However, these studies generally rely on engineering estimates to analyze operating costs, which may differ significantly from what is experienced in actual production scenarios. The contribution of this study is that it uses numbers from plants already in production at current plant scales. A Microsoft Excel based model developed by the authors projects the financial performance of a typical production plant with an annual capacity of 30 MMG. These results are then compared to the performance of a hypothetical 60 MMG plant using estimates from various industry sources. The scenarios are compared with respect to per gallon production costs and expected income and return on investment over the first 7 years of operation for the plant. ROI targeting and breakeven analyses are also provided. The 60 MMG plant scenario is estimated to provide returns to scale in the area of labor and capital costs, however input and output procurement as well as construction considerations may be a concern for plants of this scale. Moreover, the results for the 60 MMG plant scenario are based on estimates while the 30 MMG plant scenario is based on actual production experiences by plants currently in operation.

The rest of this paper is organized as follows. The next section briefly discusses the biodiesel production process and the characteristics of biodiesel. The following section discusses feedstock considerations for biodiesel production facilities. Next the Excel based model is discussed, followed by a section reporting results from the model for 30 MMG and 60 MMG plant scenarios. The final section to the paper provides conclusions and areas for further research.

Biodiesel Production and Characteristics

The National Biodiesel Board (NBB) reports that biodiesel can be produced by three main processes. The first is base catalyzed transesterification of the feedstock with alcohol. The second is direct acid catalyzed esterification with methanol, and the third is conversion of the oil to fatty acids and then to alkyl esters through acid catalyzation. The base catalyzation method is the most commonly used since it is the most economical. Roughly 3.2 units of energy are gained per unit of energy input into the process. As a comparison, the ratio for ethanol is much lower at about 1.25 to 1.

The process is carried out at fairly low temperatures with high conversion rates with minimal side reactions and reaction time. The conversion to methyl ester (biodiesel) is direct, and no exotic materials are necessary. The fat or oil is reacted with an alcohol, usually methanol, and a catalyst to produce glycerin, methyl esters (biodiesel), and filter cakes which can be used in animal feed rations. Alcohol is also a byproduct and is cycled through the process again, and there is a small amount of fertilizer also produced as a byproduct. Fatty acids are also collected as byproducts when a raw form of feedstock is used, such as animal fats. These raw feedstocks require additional pretreatment and effect output and byproduct yields, but generally result in overall savings to the plant due to their lower cost per pound compared to refined feedstocks. Industry sources estimate that a feedstock blend of 70% vegetable oil, such as soy oil, and 30% animal fats provide a savings of roughly $0.033 per pound of processed feedstock. This results in a savings of over $2 million per year for a 30 MMG plant.

The advantages of biodiesel compared to petroleum based diesel fuel, as reported by the NBB, include better lubricity characteristics and environmental benefits from lower emission levels of unburned hydrocarbons, carbon monoxide, carbon dioxide, and particulate matter. Engine modifications are generally not required to burn biodiesel. A reduced dependence on foreign energy sources and increased farm incomes from higher commodity prices are also cited as benefits of biodiesel production (NBB; Eidman). Disadvantages include potentially increased emissions of nitrous oxides and inferior cold flow properties compared to petroleum based diesel fuel.

Feedstocks Considerations

There are a wide variety of feedstocks available for the production of biodiesel. Soybean oil has historically been the most available feedstock in the US due to its high market share in the oil industry (Campbell). Rapeseed oil, more commonly referred to as canola in the US, has been the main feedstock in Europe. Figure 3 shows the distribution of feedstocks used by biodiesel plants in the US. Of the 65 plants currently operating, 54% (35) of them use soybean oil as the feedstock. 29% (19) are equipped to handle multiple types of feedstock, although the majority of these plants use soybean oil as the major feedstock in the production process. The remaining 17% (11) of the plants currently production biodiesel use other feedstock sources including recycled cooking oils, canola oil, and tallow. When plants under construction and in planning stages are included the relative market shares of the feedstock types continue to hold.

Other feedstock sources which will be used in plants under construction or in planning stages include yellow grease, trap grease, poultry fat, and sunflower oil. However the plants which are planning on using feedstocks other than soybean or canola tend to be smaller than 12 million gallons. However, since these alternative feedstocks tend to be byproducts of other production processes, the potential for further growth may be limited (Eidman; Ginder). Ginder also emphasizes that due to its relatively large market share in the U.S. fat and oil market, soybean oil provides the best potential for further expansion as a biodiesel feedstock. Moreover, virgin oil sources such as soybean and canola oil require less pretreatment and biodiesel of a more consistent quality relative animal based or recycled feedstock sources (see Ginder, Fig. 3).

Model

The model was built in Microsoft Excel, and projects the financial performance of a continuous flow biodiesel plant over a 7 year period. Model inputs regarding the production technology, operating expenses, and capital costs are used to generate an income statement and a cash flow statement on a quarterly basis, and a balance sheet on an annual basis, over the 7 year analysis period. For the purposes of this study two scenarios were considered. The first is a continuous flow biodiesel plant with 30 MMG annual capacity using a feedstock blend of 70% soybean oil and 30% animal fats. The second scenario considers a plant with 60 MMG of annual production capacity using the same type of feedstock. Various industry sources were consulted to come up with values for the inputs to the model. The model inputs for the 30 MMG plant are based on both projections and actual production numbers from plants currently in production. There are currently no plants in production at the 60 MMG capacity scale. Thus, industry projections and estimates were used for these model inputs.

Table 1 reports values for all of the model inputs used in the analysis. The production technology variables are the same for each plant size scenario. Output yields are entered on a pound per pound of processed feedstock basis for biodiesel, glycerin, fatty acids, and filter cakes. Similarly, input requirements are entered on a pound per pound of processed feedstock basis for acids, catalysts, and alcohol required for the transesterification process.

Operating expenses are entered as the cost in dollars per gallon of biodiesel produced by the plant for power, fuels, supply and repairs, as well as a category for other miscellaneous operating expenses (i.e. water). Also included with operating expenses are variables for selling wages and expenses, labor, benefits, and quality control measures. Labor and benefits are the only operating expenses where the 30 and 60 MMG plant scenarios differ. Industry sources project that a 60 MMG plant will require the roughly the same amount of labor and benefits as a 30 MMG, which results in a cost per gallon which is half that of the 30 MMG plant scenario. For all operating expense variables where a range was reported in table 1, the average value over the range was used for the analysis in this paper.

Capital costs include a measure of base investment on a dollars per gallon basis, which includes all construction costs. Increasing returns to scale are assumed for the 60 MMG plant scenario with a lower base investment cost of $1.00 per gallon compared to the cost of $1.33 per gallon for the 30 MMG plant. A conservative estimate for land costs assumes 25 acres at $10,000 per acre for each plant scenario, and a 10% contingency is built into the total capital required for each plant scenario yielding a total cost of $1.47 ($1.10) per gallon for the 30 (60) MMG plant. A 50% equity financing structure was assumed with an interest rate of 8.75% for borrowed capital based on conversations with lenders in the industry. Industry sources suggested discount rates in the range of 10-20% to capture market risk, depending on the extent to which the plant develops procurement contracts for both production inputs and outputs. For this analysis, a discount rate of 15% was assumed. Assets were assumed to depreciate according to a straight line schedule over a period of 10 years, while a tax rate of 35% was assumed.

Results

Operating Costs

Under each plant capacity scenario, current output and input prices were used to assess the potential profitability of a biodiesel plant under current operating conditions. Current prices were obtained from various industry sources. A price of $3.00 per gallon was used for biodiesel. Co-product prices for glycerin, fatty acids, and filter cakes were set a $0.05 per pound as a baseline. Input prices were set equal to $0.25 per pound for the feedstock, and acids, $0.35 per pound for catalysts, and $0.15 per pound for alcohol. The output and input prices and technology assumptions used in the baseline case, along with the estimates for other operating expenses results in a production cost for biodiesel of $2.20 per gallon for a 30 MMG plant and $2.18 per gallon for a 60 MMG plant. The feedstock cost represents the most significant portion, 85%, of total operating costs. These production costs are slightly higher than the estimates reported by Haas et al. for a 10 MMG plant, Fortenbery mainly due to higher energy costs and lower contributions from the byproduct credit of glycerin due to lower prices. Fortenbery estimates production costs of about $2.86 per gallon for a 4 MMG soy based plant indicating significant returns to scale from increasing production for 4 MMG to 30 or 60 MMG, however a $0.33 per pound price for soybean oil was used in that analysis. Van Wechel, Gustafson, and Leistritz estimate an operating cost of about $2.62 per gallon for a 5 MMG plant in

North Dakota using soybean oil at $0.25 per pound. A comparison of our results to their study provides further evidence for increasing returns to scale in the biodiesel industry.

Return on Investment

While estimates of operating costs provide a measure of how competitive a biodiesel plant may be with alternative industries (petroleum), it lacks information regarding the plant's ability to generate positive income for its investors while consistently meeting its financial obligations by generating adequate cash flows. Tables 2 and 3 report annual discounted ROI levels over a range of biodiesel and feedstock prices for the 30 and 60 MMG plant scenarios, respectively. Prices for the byproducts and other inputs were fixed at the baseline levels reported in the previous section. For the baseline case of $3.00 per gallon biodiesel and soybean oil at $0.25 per pound a 30 MMG plant can expect a ROI of 29%, while a 60 MMG plant can expect annual return to its investors of nearly 43%. The difference between the plant size scenarios is driven by both the reduction in marginal labor costs as well as the estimated savings in capital costs per gallon for the larger 60 MMG plant. ROI estimates range from a low of -11% with a biodiesel (soybean oil) price of $2.70 per gallon ($0.29 per pound) to a high of nearly 60% with a biodiesel (soybean oil) price of $3.20 per gallon ($0.21 per pound) for the 30 MMG plant. For the 60 MMG plant scenario, ROI estimates range from -7% to over 82% under the same pricing scenarios. The sensitivity of plant performance to the feedstock price is illustrated by the fact that a change of $0.02 per pound in the price of feedstock effects the expected ROI by more than 10% at a given biodiesel price.

ROI Targeting

Another concern to potential investors may be what kind of price realization is required to earn a target level of return. Tables 4 and 5 report the maximum feedstock price allowable to achieve a given level of ROI over a range of biodiesel prices for the 30 and 60 MMG plants, respectively. Again, byproduct and other input prices were set equal to the baseline case discussed previously. For the baseline case of $3.00 per gallon for biodiesel, a target ROI of 10% requires soybean oil prices below $0.28 per pound while a target ROI level of 50% requires soybean oil prices below $0.20 per pound. In general, shifting target returns by 10% requires the maximum feedstock price to change by $0.015 to $0.03 per pound. These results again magnify the large role the price of the feedstock plays in the financial performance of a biodiesel facility. The 60 MMG plant is estimated to be able to pay $0.02-0.03 more per pound of feedstock to achieve a target return level compared to the 30 MMG plant.

Breakeven Analysis

Investors may also be concerned with breakeven or shutdown prices for the feedstock to the production process. Tables 6 and 7 report breakeven feedstock prices over a range of biodiesel prices for the 30 and 60 MMG plant scenarios, respectively. The breakeven feedstock price is reported for the operating margin (OM), earnings before taxes (EBT), earnings before interest and taxes (EBIT), and net income (NI). For the 30 MMG plant and baseline price of $3.00 per gallon for biodiesel, the breakeven feedstock prices range from $0.34 per pound for the OM to $0.31 for NI. For the 60 MMG plant and baseline biodiesel price case, the breakeven feedstock prices range from $0.35 per pound for the OM to $0.32 for NI. Tables 6 and 7 also imply that a $0.10 increase in the price of biodiesel is roughly equivalent to a decrease in the price of soybean oil of $0.015 per pound for both 30 and 60 MMG plants.

Conclusions

The biodiesel industry in the US has shown significant growth and structural change over the past decade. Total production has exploded from 0.5 MMG in 1999 to 75 MMG in 2005. Current production capacity is about 395 MMG, with the potential to exceed 1.85 billion gallons by the end of 2007. Production plants have shifted from small batch type facilities to larger continuous flow plants with production capacities exceeding total annual production levels for the industry from only a year ago. Industry growth can be attributed to many factors, including high energy prices and large surpluses of agricultural commodities.

The rapid growth of the industry has caused many of the previous studies on the industry to become obsolete within months of their completion. In an attempt to keep up with the industry, this study provides estimates of operating costs and plant performance under current price scenarios and lending environment for the latest plant sizes. Specifically, operating costs and financial performance for 30 and 60 MMG plant sizes are estimated. The 30 MMG plant scenario utilizes production technologies from actual experience, while the 60 MMG plant scenario utilizes estimates from various industry experts.

The results imply increasing returns to scale in increasing plant size from 30 MMG to 60 MMG. These scale returns are estimated to come from savings in marginal labor costs and capital costs. A comparison of operating cost estimates to previous studies also indicates increasing returns to scale in moving from plants with production capacities of 4-5 MMG to 30 and 60 MMG.

However, the fact that there are currently no plants in operation at the scale of 60 MMG the estimates must be interpreted with care. Many variables must be considered, including potential problems with construction timelines for very large plants as well as the input and output procurement aspect of producing 60+ MMG of biodiesel per year at a single facility.

While the a mixture of soybean oil and animal fat was the only feedstock examined in this study, there are some industry concerns related to the use of non-virgin feedstock sources such as recycled cooking oils. The quality level of output produced from non-virgin feedstocks can be highly variable. This is a major concern for an industry which is still widely considered to still be in its infancy stages.

Additionally, this analysis examined scenarios in a static fashion, whereas prices fluctuate in actual practice. An area for further work is to perform simulation analysis which includes price volatility. This type of analysis would provide not only expected levels for income, cash flow, and returns, but also distributions and confidence intervals for these financial indicators around that mean. This type of information should have extremely high value for all market participants including potential investors and lenders.

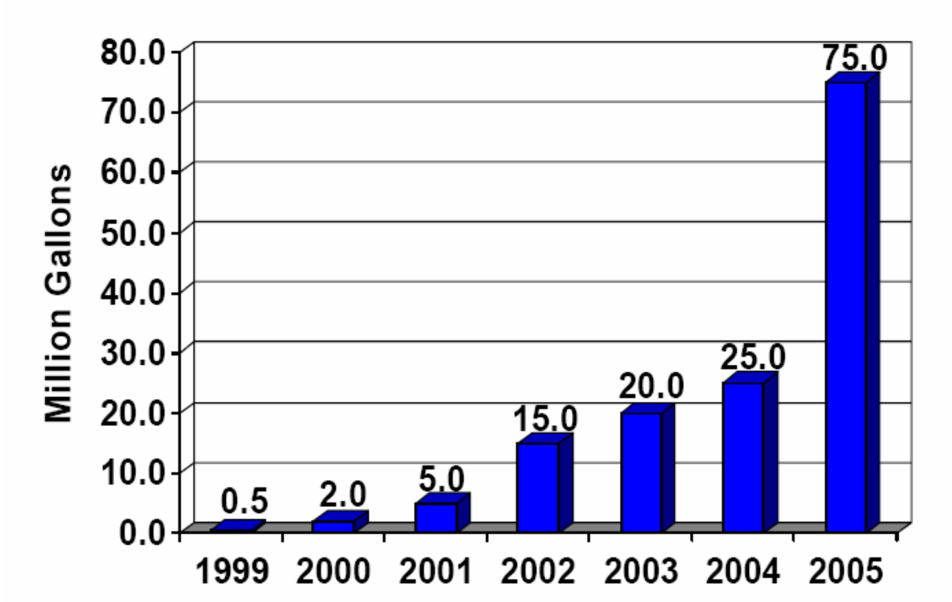

Figure 1. Biodiesel Production in the US
Source: National Biodiesel Board

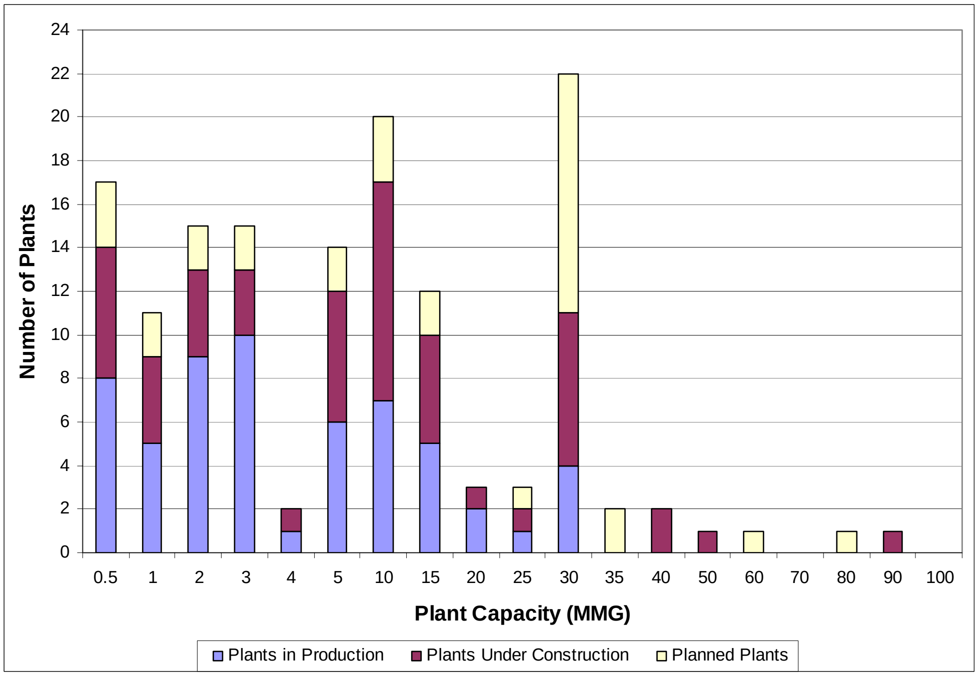

Figure 2. US Biodiesel Plants by Annual Production Capacity
Source: National Biodiesel Board

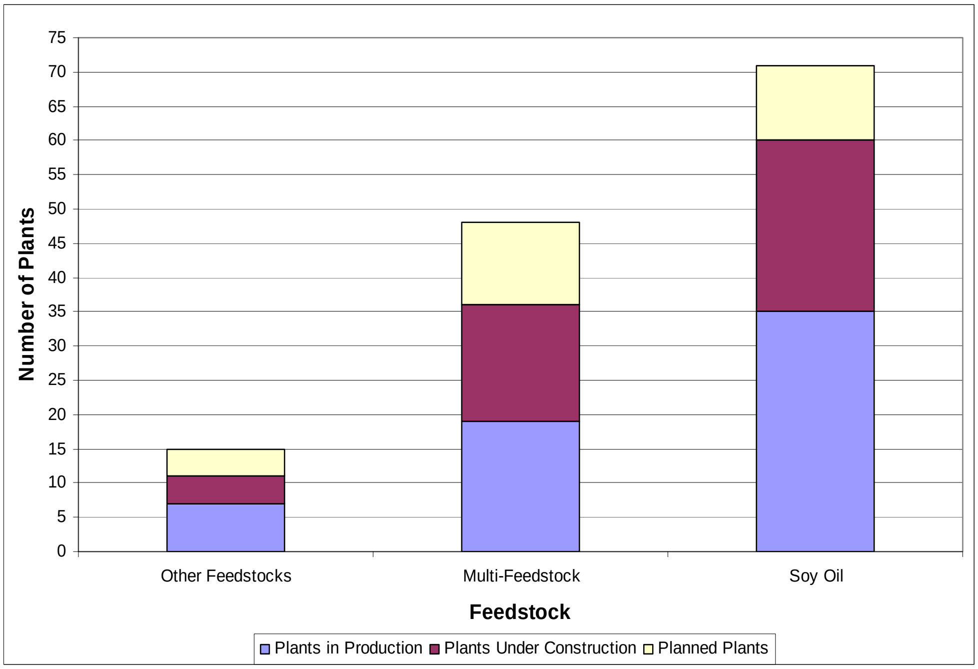

Figure 3. US Biodiesel Plants by Feedstock
Source: National Biodiesel Board

Table 1. Technology, Operating Expenses, and Capital Costs for 30 and 60 MMG Plants

	30 MMG Plant	60 MMG Plant
Output Yields (lbs/lb of feedstock)		
Biodiesel	0.980	0.980
Glycerin	0.113	0.113
Fatty Acids	0.034	0.034
Filter Cakes	0.041	0.041
Input Requirements(lbs/lb of feedstock)		
Acids	0.0123	0.0123
Catalysts	0.0314	0.0314
Alcohol	0.1007	0.1007
Operating Expenses ($/gal capacity)		
Power	0.011-0.016	0.011-0.016
Fuels	0.042-0.059	0.042-0.059
Supply and Repairs	0.022-0.031	0.022-0.031
Others	0.028-0.039	0.028-0.039
Selling Wages and Expenses	0.049-0.068	0.049-0.068
Salaries	*0.02-0.028*	*0.011-0.015*
Benefits	*0.006-0.008*	*0.003-0.004*
Quality Control	0.003-0.004	0.003-0.004
Capital Costs		
Base Investment ($/gal)	*1.33*	*1.00*
Land	$250,000	$250,000
Contingency (%)	10%	10%
Overall project cost ($/gal)	*1.47*	*1.10*
Interest Rate	8.75%	8.75%
Equity Financing	50%	50%
Useful Life (years)	7-15	7-15
Tax Rate	35%	35%
Discount Rate	10-20%	10-20%

Source: Various Industry Sources

Table 2. Expected Return on Investment for 30 MMG Plant

		Biodiesel Price ($/gal)				
		2.70	2.85	3.00	3.10	3.20
Feedstock Price ($/lb)	$0.21	30.02%	38.70%	47.36%	53.12%	58.89%
	$0.23	20.82%	29.55%	38.24%	44.02%	49.79%
	$0.25	11.48%	20.33%	29.08%	34.88%	40.67%
	$0.27	1.72%	10.95%	19.83%	25.69%	31.51%
	$0.29	-10.93%	1.09%	10.41%	16.38%	22.27%

Table 3. Expected Return on Investment for 60 MMG Plant

		Biodiesel Price ($/gal)				
		2.70	2.85	3.00	3.10	3.20
Feedstock Price ($/lb)	$0.21	44.18%	55.74%	67.27%	74.96%	82.65%
	$0.23	31.93%	43.55%	55.13%	62.83%	70.52%
	$0.25	19.53%	31.29%	42.93%	50.67%	58.37%
	$0.27	6.72%	18.84%	30.63%	38.42%	46.17%
	$0.29	-7.63%	5.94%	18.13%	26.05%	33.88%

Table 4. Maximum Feedstock Prices ($/lb) for Target ROI Level, 30 MMG Plant

		Target ROI				
		10%	20%	30%	40%	50%
Biodiesel Price ($/gal)	$2.70	$0.245	$0.224	$0.202	$0.180	$0.158
	$2.80	$0.258	$0.237	$0.215	$0.193	$0.171
	$2.90	$0.271	$0.249	$0.228	$0.206	$0.184
	$3.00	$0.283	$0.262	$0.240	$0.218	$0.197
	$3.10	$0.296	$0.275	$0.253	$0.231	$0.209
	$3.20	$0.308	$0.287	$0.266	$0.244	$0.222

Table 5. Maximum Feedstock Prices ($/lb) for Target ROI Level, 60 MMG Plant

		Target ROI				
		10%	20%	30%	40%	50%
Biodiesel Price ($/gal)	$2.70	$0.265	$0.249	$0.233	$0.217	$0.200
	$2.80	$0.278	$0.262	$0.246	$0.229	$0.213
	$2.90	$0.290	$0.274	$0.258	$0.242	$0.226
	$3.00	$0.303	$0.287	$0.271	$0.255	$0.238
	$3.10	$0.315	$0.300	$0.284	$0.267	$0.251
	$3.20	$0.328	$0.312	$0.296	$0.280	$0.264

Table 6. Breakeven Feedstock Prices ($/lb), 30 MMG Plant

		OM	EBIT	EBT	NI
Biodiesel Price	$2.70	$0.302	$0.285	$0.272	$0.270
	$2.80	$0.315	$0.298	$0.285	$0.283
	$2.90	$0.328	$0.311	$0.298	$0.295
	$3.00	$0.341	$0.324	$0.311	$0.308
	$3.10	$0.354	$0.337	$0.323	$0.321
	$3.20	$0.367	$0.350	$0.336	$0.333

Table 7. Breakeven Feedstock Prices ($/lb), 60 MMG Plant

		OM	EBIT	EBT	NI
Biodiesel Price	$2.70	$0.310	$0.297	$0.286	$0.284
	$2.80	$0.323	$0.311	$0.299	$0.297
	$2.90	$0.336	$0.324	$0.312	$0.309
	$3.00	$0.349	$0.337	$0.324	$0.322
	$3.10	$0.362	$0.350	$0.337	$0.335
	$3.20	$0.375	$0.363	$0.350	$0.347

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