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The Growth and Direction of the Biodiesel Industry in the United States

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Abstract

The biodiesel industry in the United States has realized significant growth over the past decade through large increases in annual production and production capacity and a transition from smaller batch plants to larger-scale continuous producers. The larger, continuous-flow plants provide operating cost advantages over the smaller batch plants through their ability to capture co-products and reuse certain components in the production process. This paper uses a simple capital budgeting model developed by the authors along with production data supplied by industry sources to estimate production costs, return-on-investment levels, and break-even conditions for two common plant sizes (30 and 60 million gallon annual capacities) over a range of biodiesel and feedstock price levels. The analysis shows that the larger plant realizes returns to scale in both labor and capital costs, enabling the larger plant to pay up to \$0.015 more per pound for the feedstock to achieve equivalent return levels as the smaller plant under the same conditions. The paper contributes to the growing literature on the biodiesel industry by using the most current conversion rates for the production technology and current price levels to estimate biodiesel production costs and potential plant performance, providing a useful follow-up to previous studies.

Keywords: biodiesel, biofuels, feedstock, production costs, return on investment.

Introduction

The biodiesel industry in the United States has seen significant growth over the past decade. The growth in the industry is composed of both a large increase in the levels of production and production capacity and a transition in plant technology from smaller plants producing biodiesel in discrete production runs (batch plants) to plants operating continuously (continuous flow) with much larger annual production capacities. Ginder reports that initially plants were built to produce biodiesel in discrete production runs or batches. These smaller plants generally do not collect co-products or recover inputs for reuse in 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 co-products and reuse certain components in the production process. However, the continuous-flow plants are generally larger-scale plants, which require greater initial investment. This may introduce potential problems for investment groups in obtaining the necessary capital, through debt or equity sources, required to build a continuous-flow plant.

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). A number of recent studies have analyzed the feasibility of biodiesel production in the United States (Van Wechel, Gustafson, and Leistritz; Fortenbery; Haas et al.; Duffield et al.). The 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.

Giampietro, Ulgiati, and Pimentel estimated that large-scale production of biofuels, including biodiesel, would not be feasible without heavy government subsidies, which create significant market distortions and provide an inaccurate reflection of the true costs to society of the production of biofuels. However, with recent diesel fuel prices approaching, and at times exceeding, biofuel production costs, both the biodiesel and ethanol industries have been better able to 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 could be supported even with higher costs of production relative to petroleum-based diesel fuel sources.

The previous studies have generally relied on engineering estimates to analyze operating costs that may differ significantly from what is experienced in actual production environments. The main contribution of this article is the reporting of operating costs and conversion rates being realized at plants already in production and at current plant scales. We use a simple spreadsheet-based model to project the financial performance of a typical production plant with an annual capacity of 30 million gallons. These results are then compared to the performance of a hypothetical 60 million gallon plant. We estimate the production cost for the 30 (60) million gallon plant to be \$2.233 (\$2.219) per gallon of biodiesel. Moreover, we estimate that for every \$0.10 per gallon increase (\$0.02 per pound decrease) in the price of biodiesel (the feedstock), the expected return-on-investment (ROI) for the plant increases (decreases) by 2.2% (3.5%). Various industry sources¹ have confirmed the practicality of expanding the current technology up to 60 million gallon capacities.

The two plant size scenarios are compared with respect to per gallon production costs and expected income and return on investment over the first seven years of operation for the plant.

ROI targeting and break-even analyses are also provided. The 60 million gallon plant scenario is estimated to provide returns to scale in the area of labor and capital costs; however, input and output procurement, the ability to attract equity financing, and construction considerations may be a concern for plants of this scale. Moreover, the results for the 60 million gallon plant scenario are based on estimates while the 30 million gallon plant scenario is based on actual production experiences by plants currently in operation. Furthermore, our analysis assumes that the plant runs at full capacity. The scale economies of labor and capital estimated for the 60 million gallon plant would quickly be eroded away if the plant was unable to run at capacity.

The next section provides an overview on the biodiesel industry in the United States. Then, the model is discussed, followed by a section reporting a summary of the model results for the 30 and 60 million gallon plant scenarios under various feedstock and biodiesel price conditions. The final section provides some conclusions and comments on areas for further research.

Industry Overview

The National Biodiesel Board (NBB 2007) reports that biodiesel can be produced through 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 catalyzed. The base catalyzed method is the most commonly used since it is the most economical. Nearly three units of energy are reportedly gained per unit of energy input into the process. As a comparison, the same ratio for ethanol production is much lower at about 1.25. Using a life-cycle accounting approach, Hill et al. estimate a net energy balance ratio of 3.67 for biodiesel produced from soybean oil and 1.25

for corn-based ethanol. However, when co-products are included in the analysis the ratio falls to 1.93 for biodiesel but remains unchanged for ethanol produced from corn.

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 methyl esters (biodiesel), glycerin, and filter cakes, which can be used in animal feed rations. A portion of the alcohol is also collected as a co-product and can be cycled through the process again. Fatty acids may also be collected as co-products when a raw form of feedstock is used, such as animal fats.

These raw feedstocks may require additional pretreatment and can affect biodiesel and co-product yields but generally result in overall savings to the plant because of 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 provides 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 million gallon plant, compared to a plant using 100% vegetable oil.

The advantages of biodiesel compared to petroleum-based diesel fuel, as reported by the NBB (2007), include improved lubricity characteristics² 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 2007; Eidman). Disadvantages include potentially increased emissions of nitrous oxides and inferior cold-flow properties compared to petroleum-based diesel fuel.

Production Capacity versus Actual Production

Figure 1 shows the distribution of biodiesel production facilities across the United States by plant size as of January 2007. Currently, there are 105 plants in production ranging in size from less than 0.5 million gallon to 30 million gallons of annual production capacity. Total production capacity of the plants that are currently operating is equal to about 864 million gallons annually. However, there are currently plants under construction or in planning stages with anticipated annual capacities of 60-100 million gallons. Including plants under construction and in planning stages, the U.S. production capacity for biodiesel could reach over 2.3 billion gallons per year in more than 180 production facilities by the end of 2007 (NBB 2007).

Figure 2 reports estimated biodiesel sales³ in the United States from 1999 through 2006. Annual biodiesel production in the United States increased from 0.5 million gallons in 1999 to an estimated 25 million gallons produced in 2004. Estimated production and sales tripled from 2004 to 2005, reaching 75 million gallons, and then more than tripled from 2005 to 2006 to reach 250 million gallons. Although biodiesel plant capacity was nearly 400 million gallons in 2006, actual production and sales of biodiesel were estimated to be only 250 million gallons (NBB 2007), implying that the industry was operating at just over 60% of capacity. Actual production has historically lagged total capacity for several reasons. First, many of the existing plants currently in operation are batch plants that, by definition, do not run continuously. The maximum capacity of these facilities will overstate actual production if they do not continually operate. For example, the production schedules for some batch plants that use recycled cooking oils may be dependent on a flow of feedstocks that does not permit them to run batches on a continuous basis.

Another factor that may create disparity between the actual level of production in a biodiesel plant and nameplate capacity is the plant's capability to meet the quality standards some larger-scale purchasers of biodiesel are now beginning to require. Small-scale "splash blenders" in many cases have less rigorous quality standards than larger-scale "rack blenders." An increasing proportion of buyers are now requiring process verification under the BQ-9000 quality standard.⁴ Plants that have not adopted this standard may be excluded from this growing part of the market and as a consequence may not run at full capacity.

A third factor that creates potential for disparity between production capacity and actual production is the fact that not all plant capacity that could potentially produce biodiesel is dedicated to fuel production. Some plants that can produce methyl ester can also produce other ester-based products, including ingredients for soap, shampoo, and Olestra cooking oil. While the plant may produce methyl ester for fuel part of the time, other products may be produced when it is advantageous. According to our industry sources, of the approximately 20 biodiesel plants with production capacities greater than 10 million gallons in mid-2006, fewer than 10 were fully dedicated to fuel production.

Biodiesel-Related Policy

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 because of environmental considerations. The American Jobs Creation Act of 2004 provides a \$0.50 blender credit for each gallon of biodiesel used in diesel fuel blends and a \$1.00 credit for each gallon of blended agri-biodiesel, or biodiesel produced from virgin feedstock sources (Harl and McKowen). Eligibility for the blender credit requires that biodiesel used in blends must be

registered as fuel through the Environmental Protection Agency and meet the ASTM D 6751 standard.

The Energy Policy Act of 2005 provides a \$0.10-per-gallon income tax credit on the first 15 million gallons produced by a plant each year and extends the blenders credit through 2008. However, production plants with annual capacities exceeding 60 million gallons are ineligible for the income tax credit (USDOE). The 2005 act also includes a Renewable Fuels Standard, which mandates the use of 4 billion gallons of renewable fuels by 2006 and 7.5 billion gallons by 2012 (Carriquiry). Other federal sources of industry subsidy have come from the Commodity Credit Corporation payment program, which expired in June of 2006.

At the state level, Minnesota has enacted legislation that requires a minimum of a 2% blend of biodiesel in all diesel fuels sold throughout the state (Tiffany). Moreover, many states offer different types of tax incentives and support for the building of infrastructure to aid in the adoption of biodiesel as a fuel source. For example, Iowa offers a three-cent income tax credit for each gallon of biodiesel used in fuel blends with at least 2% biodiesel to qualified retailers, as well as 50% cost-share infrastructure grants for up to \$50,000 for biodiesel-related projects (NBB 2006). Other states, especially throughout the Midwest, offer similar tax incentives and assistance for improving infrastructure, while state-level fuel blend mandates similar to those in Minnesota are also being considered (USDOT).

Feedstock 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 United States because of its high market share in the oil industry (Campbell). Rapeseed oil, more commonly referred to in the United States as canola, has been the main feedstock used in Europe. Figure 3 shows the distribution of

feedstocks used by U.S. biodiesel plants. Of the 93 plants currently operating that reported their feedstock source to the NBB, 43% (40) use soybean oil as the feedstock; 45% (42) 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 12% (11) of the plants currently producing biodiesel use other feedstock sources, including recycled cooking oils, canola oil, and tallow.

Fifty-three percent (39) of the plants currently under construction are being built to handle multiple feedstock while 43% (31) of these plants are being built to use soybean oil exclusively. Only 4% (3) of the plants currently under construction are planning to use another type of feedstock. One of these plants being constructed in North Dakota has a planned production capacity of 85 million gallons using canola oil. The other two plants are reportedly planning to use recycled cooking oils as the feedstock and will have production capacities of 4 and 5 million gallons.

Plants that are currently using or planning to use feedstock other than soybean or canola oils tend to be smaller than 12 million gallons. Moreover, since these alternative feedstocks tend to be by-products of other production processes, the potential for further growth may be limited (Eidman; Ginder). Ginder also emphasizes that because of 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, oil sources such as soybean and canola oil require less pretreatment and produce biodiesel of a more consistent quality relative to other virgin sources such as animal fat, or non-virgin sources such as recycled cooking oils (see Ginder, Fig. 3).

Model

The capital budgeting model was built using Microsoft Excel and projects the financial performance of a continuous-flow biodiesel plant over a seven-year period. Model inputs regarding the production technology (conversion rates), operating expenses, and capital costs are used to generate quarterly income and cash flow statements and an annual balance sheet over the seven-year analysis period. For the purposes of this study, two plant scenarios are considered.⁵ The first is a continuous-flow biodiesel plant with 30 million gallons annual capacity using a feedstock blend of 70% soybean oil and 30% animal fat. The second scenario considers a plant with 60 million gallons of annual production capacity using the same type of feedstock.⁶ Various industry sources were consulted to determine values for the inputs to the model. The model inputs for the 30 million gallon plant are based on actual production numbers from plants currently in production. As of January 2007, there were no plants in production at the 60 million gallon 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 based on pound per pound of processed feedstock for biodiesel, glycerin, fatty acids, and filter cakes. Similarly, input requirements are entered based on pound per pound of processed feedstock for acids, catalysts, and alcohol required in the (base-catalyzed) transesterification process.

Operating expenses are input as the cost in dollars per gallon of biodiesel produced by the plant for power, fuels, supplies and repairs, as well as a category for other miscellaneous operating expenses (e.g., 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 in which the scenarios for the 30 and the 60 million gallon plants differ

on a per gallon basis. Industry sources project that a 60 million gallon plant will require roughly the same amount of labor as a 30 million gallon plant, resulting in a 50% reduction in per gallon costs for labor and benefits. For all operating expense variables in which a range was reported in table 1, the average value over the range was used for this analysis.

Capital costs include a measure of base investment on a dollars per gallon basis, including all construction costs. Increasing returns to scale are assumed for the 60 million gallon 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 million gallon plant. Additionally, budgeted working capital was assumed to equal 15% of projected annual sales. A conservative estimate for land costs assumes 25 acres at \$10,000 per acre for each plant scenario. A contingency fund equal to 10% of the base investment was also assumed, resulting in an initial total capital cost (base investment) of \$2.00 (\$1.63) per gallon for the 30 (60) million gallon plant.

A 50% equity financing structure was assumed with an interest rate of 8.75% for borrowed capital based on conversations with lenders to 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, with a marginal income tax rate of 35%. We abstract from any tax credits, as they will vary by the region in which the plant is located. It is assumed throughout that the plant will be operating at full nameplate capacity. All prices used in the analysis are assumed to be the net price paid or received at the plant.

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 baseline operating conditions. Baseline prices were obtained from various industry sources and reflect market conditions in the summer of 2006. A baseline price of \$3.00 per gallon was used for biodiesel. Co-product prices for glycerin, fatty acids, and filter cakes were set at \$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, result in an estimated production cost for biodiesel of \$2.233 per gallon for a 30 million gallon plant and \$2.219 per gallon for a 60 million gallon plant. The feedstock cost represents the most significant portion, resulting in roughly 85% of total operating costs for both plant sizes. The total annual cost per gallon is equal to \$2.351 (\$2.315) for the 30 (60) million gallon plant when the amortized annual cost of (debt-financed) capital is included.

These production costs are slightly higher than the estimates reported by Haas et al. for a 10 million gallon plant, mainly because of lower contributions from the co-product credit of glycerin due to lower prices. Fortenbery estimates production costs of roughly \$2.86 per gallon for a 4 million gallon soy-based plant, indicating significant returns to scale from increasing production from 4 million gallons to 30 or 60 million gallons. However, it should be noted that a \$0.33 per pound price for soybean oil was used in that analysis. With an oil price of \$0.33 per pound, we estimate operating costs to increase by roughly \$0.60 to \$2.833 (\$2.819) per gallon for a 30 (60) million gallon plant. Van Wechel, Gustafson, and Leistritz estimate an operating

cost of about \$2.62 per gallon for a 5 million gallon 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 by increasing plant size beyond 10 million gallons. As plant size increases from 5 to 10 million gallons or more, a portion of these scale returns is most likely due to the use of continuous-flow versus batch technologies.

Return on Investment and Internal Rate of Return

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 over a long-term horizon. Tables 2a and 3a report average annual discounted ROI⁷ levels over a range of biodiesel and feedstock prices for the 30 and 60 million gallon plant scenarios, respectively. Prices for the co-products and other inputs were fixed at the baseline levels reported in the previous section. For the baseline case of \$3.00 per gallon for biodiesel and a feedstock price of \$0.25 per pound, a 30 million gallon plant can expect an average ROI of 10.2%, while a 60 million gallon plant can expect annual return to its investors of just over 14%. The difference between the plant size scenarios is driven by both the reduction in labor costs as well as the estimated savings in capital costs per gallon for the larger 60 million gallon plant. The sensitivity of plant performance to the feedstock price is illustrated by the fact that an increase of \$0.02 per pound in the price of the feedstock effects the expected ROI by more than 3.5% at a given biodiesel price. Feedstock prices exceeding \$0.30 per pound require biodiesel prices in excess of \$3.00 per gallon to achieve marginally positive return levels for both plant sizes.

ROI Targeting

Another concern to potential investors may be what kind of price realization is required to earn a target level of return. Table 4 reports the maximum feedstock price allowable to achieve a given level of ROI over a range of biodiesel prices for the 30 and 60 million gallon plants. Again, by-product 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 \$0.251 per pound for a 30 million gallon plant or \$0.274 per pound for a 60 million gallon plant. In general, increasing target returns by 5% requires the feedstock price to decrease by roughly \$0.035 per pound and \$0.028 per pound for the 30 and 60 million gallon plant, respectively. These results again illustrate the large role the price of the feedstock plays in the financial performance of a biodiesel facility. The 60 million gallon plant is estimated to be able to pay \$0.015 more per pound of feedstock to achieve the same return level as its 30 million gallon counterpart.

Break-Even Analysis

Investors may also be concerned with break-even feedstock prices that would induce the shutdown of the plant. Table 5 reports break-even feedstock prices over a range of biodiesel prices for the 30 and 60 million gallon plant scenarios, respectively. The break-even feedstock price is reported for the operating margin⁸ (OM), earnings before interest and taxes⁹ (EBIT), earnings before taxes (EBT), and net income (NI). For the 30 million gallon plant and baseline price of \$3.00 per gallon for biodiesel, the break-even feedstock price ranges from \$0.344 per pound for the OM to \$0.314 for NI. For the 60 million gallon plant and baseline biodiesel price case, the break-even feedstock prices range from \$0.346 per pound for the OM to \$0.322 for NI. Table 5 also implies that a \$0.10 increase in the price of biodiesel is roughly equivalent to a

decrease in the price of the feedstock of \$0.013 per pound for both 30 and 60 million gallon plants.

Conclusions

The biodiesel industry in the United States has shown significant growth and structural change over the past seven years. Total production has exploded from 0.5 million gallon in 1999 to an estimated 250 million gallons in 2006. Current production capacity is about 864 million gallons, with the potential to exceed 2.3 billion gallons by the end of 2007 if all proposed capacity is actually built. Since 2004, most of the production capacity has shifted from small batch-type facilities to larger continuous-flow plants with production capacities exceeding total annual production levels for the entire industry prior to 2005. Thus, the industry now consists of two rather distinct groups of plants: a group of smaller-scale plants typically using batch technology and a group of much larger plants typically using continuous-flow processes to operate at or slightly above nameplate capacity. The rapid industry growth that has occurred in the last two to three years can be attributed to many factors, including high energy prices and large, readily available supplies of agricultural commodities for use as feedstock.

The rapid growth of the industry has caused many of the previous studies of 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 environments for the currently typical plant sizes. Specifically, operating costs and financial performance for 30 and 60 million gallon plant sizes are estimated. The 30 million gallon plant scenario utilizes production technologies from actual experience, while the 60 million gallon plant scenario is based on extrapolating the technology of the current

30 million gallon plant configuration. The 60 million gallon scenario utilizes estimates from various industry experts and is believed to be practical. Larger plant sizes remain untested at this time and may or may not be practical using current configurations.

The results imply increasing returns to scale in increasing plant sizes from 30 million gallons to 60 million gallons. The larger plant size is estimated to achieve a production cost per gallon of biodiesel that is \$0.014 lower than that of the smaller plant, while being able to pay \$0.015 more per pound for the feedstock to earn equivalent return levels. 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 million gallons to 30 and 60 million gallons. Additional analysis also illustrates the sensitivity of expected ROI to varying feedstock and biodiesel prices. Expected internal rates of return and break-even conditions are reported over a range of biodiesel and feedstock prices for both plant sizes.

As the industry continues to grow, the increasing returns to scale may provide the larger-scale plants with an important competitive advantage in bidding for scarce high-quality virgin feedstock. Since biodiesel production has an exceptionally high feedstock cost share of total operating expenses (~85%), the impact of feedstock cost on a plant's profitability is magnified. The ability of a plant to successfully bid for feedstock ultimately determines whether the plant can continue producing or must shut down. At the margin, when available feedstock supply becomes very tight and feedstock prices approach break-even levels, smaller-scale biodiesel plants with higher variable operating costs will reach shutdown points earlier.

However, because there are currently no plants in operation at the scale of 60 million gallons, the estimates must be interpreted with care. Many variables must be considered,

including potential problems with construction timelines for very large plants and the ability to attract the required equity financing, as well as the input and output procurement aspects of producing 60+ million gallons of biodiesel per year at a single facility.

While 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 that is still widely considered to 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 simulation analysis that 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 would be extremely valuable for all market participants, including potential investors and lenders.

Endnotes

¹ The authors were asked to keep the identities of the plants that shared information on conversion rates and operating and capital costs confidential.

² The removal of sulfur reduces the lubricity of diesel fuel and can lead to engine wear. Recent mandates from the Environmental Protection Agency requiring lower sulfur levels in diesel fuels may help to boost demand for biodiesel because of its improved lubricity characteristics.

³ The NBB uses estimated sales figures as an estimate of actual production for any given time period. We adopt the same convention throughout the paper.

⁴ The National Biodiesel Accreditation Program (NBAP) is a cooperative and voluntary program for producers and marketers of biodiesel fuel meeting the BQ-9000 standard. The standard is a combination of the ASTM D 6751 quality standard for biodiesel fuel and a quality assurance program outlining standards for storage, sampling, testing, blending, shipping, distribution, and management practices for biodiesel fuel. As of January 2007, only 14, or 13.3%, of operating plants were *certified producers* under the BQ-9000 standard. Fuel marketers can also be accredited through the NBAP to become *certified marketers* (NBB 2007).

⁵ It should be noted that the model can easily be used to consider a wide variety of scenarios for plant size, technologies, and operating and capital costs. We chose the 30 million gallon and 60 million gallon plant scenarios to reflect the current industry environment.

⁶ The most common plant size for recently constructed plants has been 60 million gallons. This may be due to the eligibility requirements on the federal tax credit for biofuel plants. However, there are a handful of plants either being constructed or in planning stages with capacities exceeding 60 million gallons.

⁷ The reported annual ROI was calculated based on discounted quarterly net income using a 15% discount rate. Given the 50% debt-to-equity ratio for the plant, the annual return on equity is roughly double the reported annual ROI.

⁸ For the purposes of this analysis, the operating margin was defined as sales revenue from biodiesel, including co-product credits, less inputs costs and operating and labor expenses.

⁹ EBIT is equal to the operating margin less depreciation.

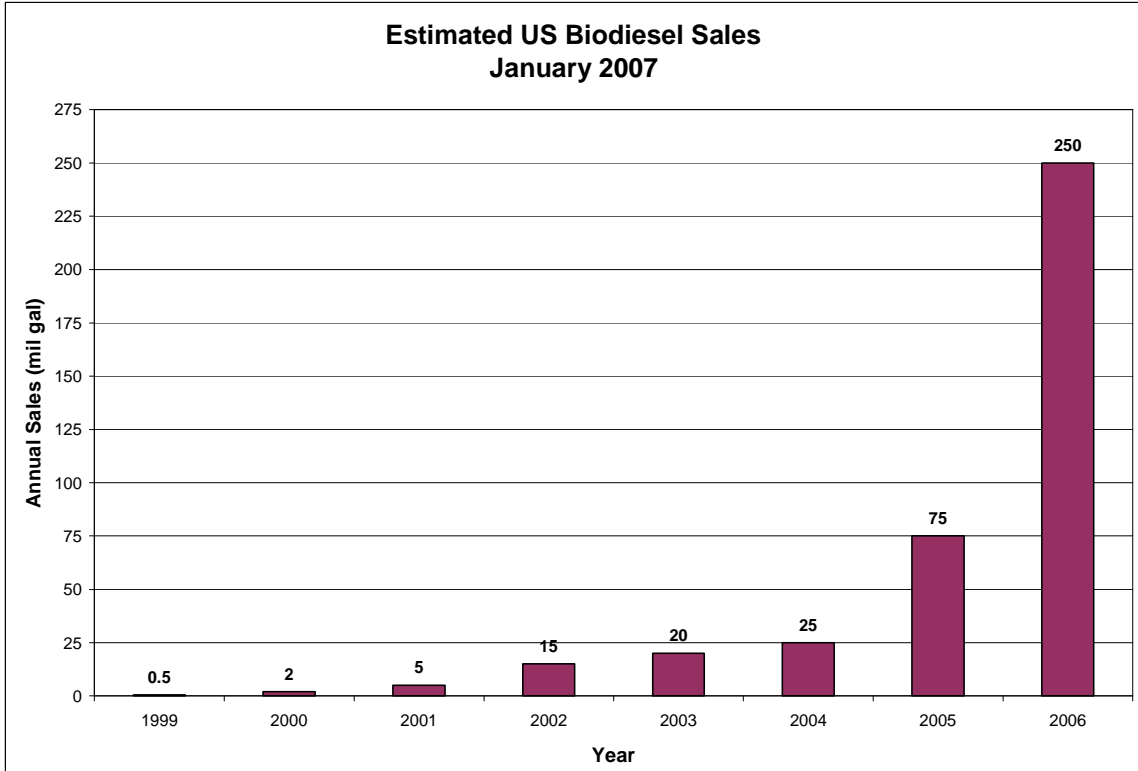


Figure 1. Estimated biodiesel sales in the United States
Source: National Biodiesel Board

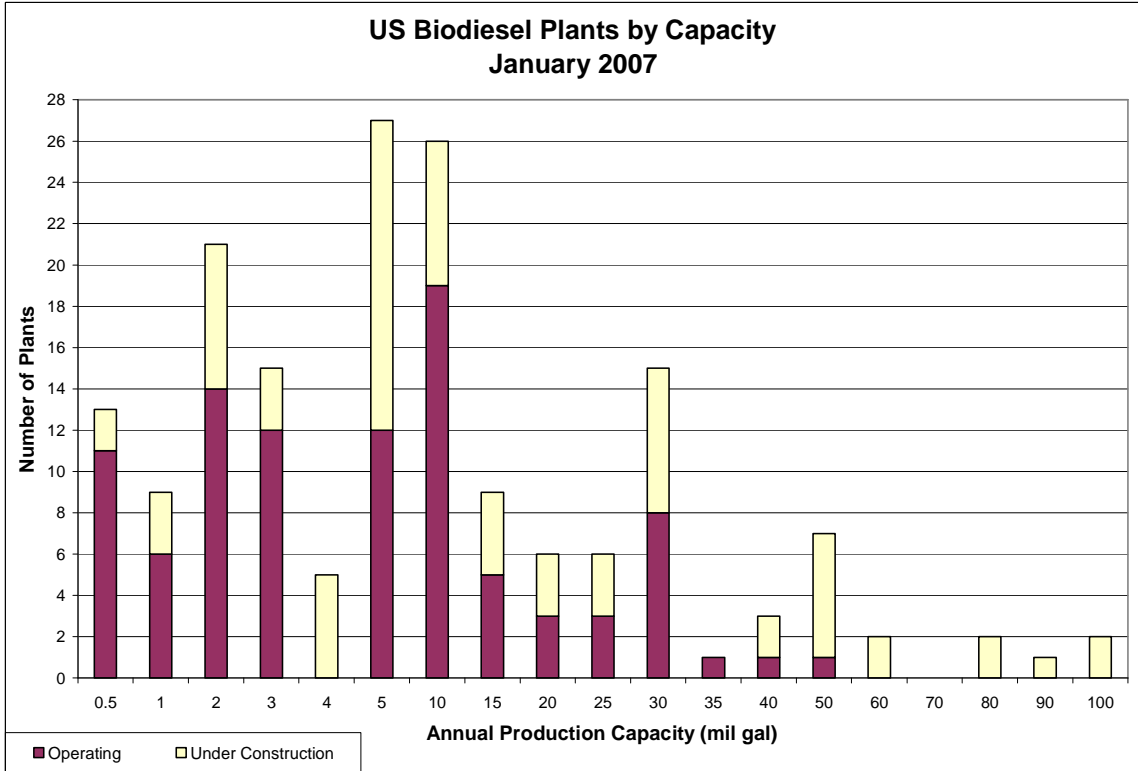


Figure 2. U.S. biodiesel plants by annual production capacity
Source: National Biodiesel Board

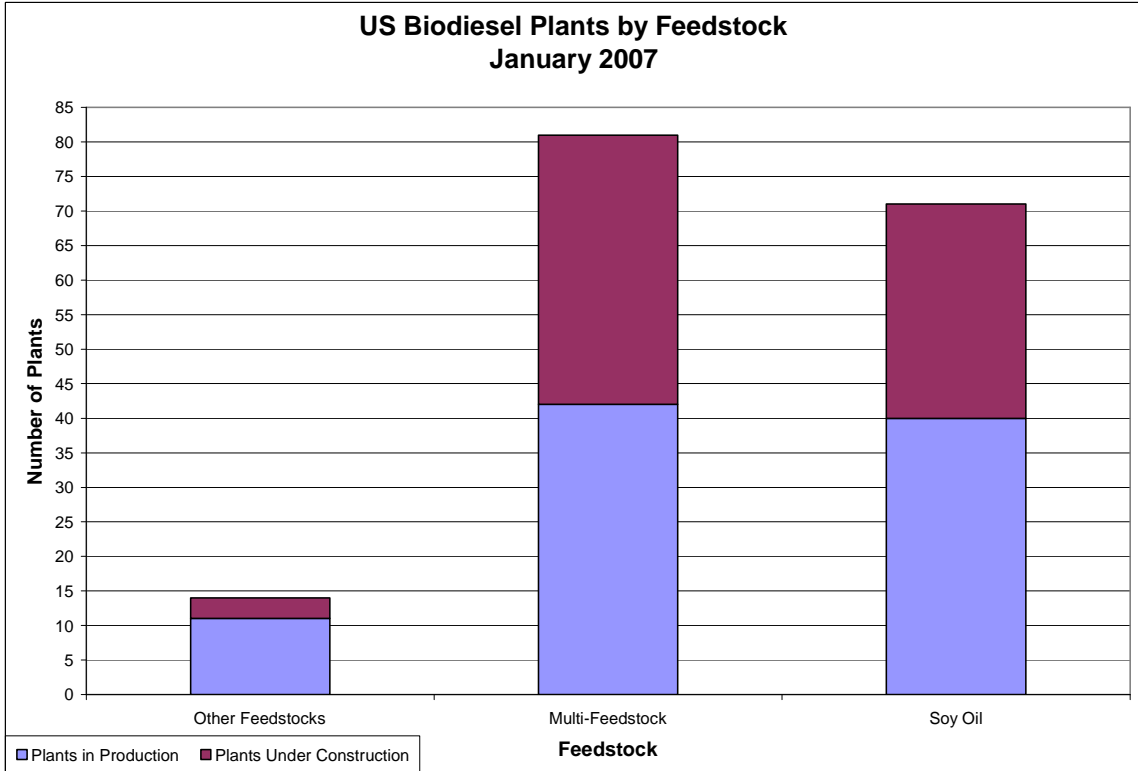


Figure 3. U.S. biodiesel plants by feedstock
 Source: National Biodiesel Board

Table 1. Technology, operating expenses, and capital costs for 30 and 60 million gallon plants

	30 Million Gallon Plant	60 Million Gallon Plant
Output Yield (lbs/lb of feedstock)		
Biodiesel	0.982	0.982
Co-Product Yields (lbs/lb of feedstock)		
Glycerin	0.137	0.137
Fatty Acids	0.034	0.034
Filter Cakes	0.041	0.041
Total Co-Product Credit (\$/gal)	\$0.080	\$0.080
Input Requirements(lbs/lb of feedstock)		
Feedstock	1	1
Acids	0.0123	0.0123
Catalysts	0.0314	0.0314
Alcohol	0.1007	0.1007
Total Input Cost (\$/gal)	\$2.097	\$2.097
Operating Expenses (\$/gal)		
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
<i>Salaries</i>	<i>0.02-0.028</i>	<i>0.011-0.015</i>
<i>Benefits</i>	<i>0.006-0.008</i>	<i>0.003-0.004</i>
Quality Control	0.003-0.004	0.003-0.004
Total Operating Expenses (\$/gal)	\$0.217	\$0.202
Total Production Cost (\$/gal)	\$2.233	\$2.219
Capital Costs		
<i>Base Investment (\$/gal)</i>	<i>1.33</i>	<i>1.00</i>
Contingency (% of base)	10%	10%
Land	\$250,000	\$250,000
Working Capital (% of annual sales)	15%	15%
<i>Total Base Investment (\$/gal)</i>	<i>\$2.00</i>	<i>\$1.63</i>
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%
Amortized Capital Cost (\$/gal)	\$0.118	\$0.096
Total Cost (\$/gal)	\$2.351	\$2.315

Source: Various industry sources

*The co-product credit and input costs are based on the reported conversion rates and baseline price levels. The density of biodiesel was assumed to be equal to 7.40 lbs/gal.

Table 2a. Average long-term ROI, 30 million gallon plant

	Feedstock Price (\$/lb)						
	\$0.21	\$0.23	\$0.25	\$0.27	\$0.29	\$0.31	\$0.33
Biodeisel Price (\$/gal)							
\$2.40	5.02%	2.21%					
\$2.50	6.86%	4.03%	1.25%				
\$2.60	8.68%	5.84%	3.05%	0.32%			
\$2.70	10.51%	7.65%	4.85%	2.10%			
\$2.80	12.32%	9.45%	6.63%	3.88%	1.17%		
\$2.90	14.13%	11.25%	8.42%	5.64%	2.93%		
\$3.00	15.94%	13.04%	10.20%	7.41%	4.68%	2.00%	
\$3.10	17.73%	14.82%	11.97%	9.17%	6.42%	3.73%	
\$3.20	19.52%	16.60%	13.74%	10.92%	8.16%	5.46%	2.81%
\$3.30	21.31%	18.37%	15.50%	12.67%	9.90%	7.18%	4.52%
\$3.40	23.08%	20.14%	17.25%	14.41%	11.63%	8.90%	6.22%
\$3.50	24.85%	21.90%	19.00%	16.15%	13.36%	10.61%	7.92%

Table 2b. Internal rate of return, 30 million gallon plant

	Feedstock Price (\$/lb)						
	\$0.21	\$0.23	\$0.25	\$0.27	\$0.29	\$0.31	\$0.33
Biodeisel Price (\$/gal)							
\$2.40	-2.30%	-15.60%					
\$2.50	4.15%	-7.05%	-22.14%				
\$2.60	10.18%	0.14%	-12.41%	-30.93%			
\$2.70	15.94%	6.27%	-4.47%	-18.20%			
\$2.80	21.53%	12.06%	2.37%	-9.58%	-25.16%		
\$2.90	27.02%	17.63%	8.26%	-2.10%	-14.86%		
\$3.00	32.46%	23.06%	13.84%	4.39%	-7.02%	-20.93%	
\$3.10	37.88%	28.41%	19.23%	10.13%	0.09%	-11.97%	
\$3.20	43.32%	33.71%	24.51%	15.52%	6.28%	-4.68%	-17.38%
\$3.30	48.80%	39.01%	29.72%	20.75%	11.89%	2.12%	-9.35%
\$3.40	54.33%	44.33%	34.91%	25.89%	17.11%	8.04%	-2.52%
\$3.50	59.66%	49.70%	40.09%	30.98%	22.20%	13.56%	3.99%

Note: Assumed discount rate of 15%.

Table 3a. Average long-term ROI, 60 million gallon plant

	Feedstock Price (\$/lb)						
	\$0.21	\$0.23	\$0.25	\$0.27	\$0.29	\$0.31	\$0.33
Biodeisel Price (\$/gal)							
\$2.40	7.78%	4.19%					
\$2.50	10.09%	6.48%	2.96%				
\$2.60	12.39%	8.76%	5.22%	1.77%			
\$2.70	14.68%	11.03%	7.47%	4.00%			
\$2.80	16.96%	13.29%	9.71%	6.22%	2.81%		
\$2.90	19.23%	15.54%	11.94%	8.43%	5.00%	1.65%	
\$3.00	21.49%	17.78%	14.16%	10.63%	7.18%	3.82%	
\$3.10	23.73%	20.01%	16.37%	12.82%	9.35%	5.97%	2.66%
\$3.20	25.97%	22.23%	18.57%	15.01%	11.52%	8.11%	4.79%
\$3.30	28.19%	24.44%	20.77%	17.18%	13.68%	10.25%	6.91%
\$3.40	30.40%	26.63%	22.95%	19.34%	15.82%	12.38%	9.02%
\$3.50	32.60%	28.82%	25.12%	21.50%	17.96%	14.50%	11.12%

Table 3b. Internal rate of return, 60 million gallon plant

	Feedstock Price (\$/lb)						
	\$0.21	\$0.23	\$0.25	\$0.27	\$0.29	\$0.31	\$0.33
Biodeisel Price (\$/gal)							
\$2.40	4.91%	-10.25%					
\$2.50	12.43%	-1.00%	-17.24%				
\$2.60	19.31%	7.30%	-7.04%	-26.00%			
\$2.70	26.01%	14.60%	1.62%	-13.42%			
\$2.80	32.62%	21.23%	9.50%	-4.20%	-20.77%		
\$2.90	39.22%	27.71%	16.57%	4.01%	-10.12%	-30.37%	
\$3.00	45.85%	34.13%	23.03%	11.54%	-1.62%	-16.60%	
\$3.10	52.55%	40.55%	29.32%	18.35%	6.23%	-7.22%	-24.42%
\$3.20	59.36%	47.00%	35.56%	24.73%	13.44%	0.75%	-13.14%
\$3.30	66.32%	53.54%	41.81%	30.84%	20.02%	8.29%	-4.58%
\$3.40	73.06%	60.18%	48.10%	36.91%	26.34%	15.21%	2.94%
\$3.50	79.87%	66.96%	54.48%	43.00%	32.28%	21.59%	10.21%

Note: Assumed discount rate of 15%.

Table 4. Maximum feedstock prices (\$/lb) for target ROI level

	<u>Target ROI</u>										
	<u>30 Million Gallon Plant</u>					<u>60 Million Gallon Plant</u>					
	5%	10%	15%	20%	25%	5%	10%	15%	20%	25%	
Biodiesel Price (\$/gal)	\$2.40	\$0.210	\$0.176				\$0.225	\$0.198	\$0.171		
	\$2.50	\$0.223	\$0.188				\$0.238	\$0.21	\$0.184		
	\$2.60	\$0.236	\$0.201				\$0.251	\$0.223	\$0.196	\$0.170	
	\$2.70	\$0.249	\$0.214	\$0.179			\$0.264	\$0.236	\$0.208	\$0.182	
	\$2.80	\$0.262	\$0.226	\$0.192			\$0.277	\$0.248	\$0.221	\$0.194	\$0.168
	\$2.90	\$0.275	\$0.239	\$0.204	\$0.171		\$0.290	\$0.261	\$0.233	\$0.206	\$0.18
	\$3.00	\$0.288	\$0.251	\$0.216	\$0.183		\$0.303	\$0.274	\$0.245	\$0.218	\$0.191
	\$3.10	\$0.301	\$0.264	\$0.229	\$0.195		\$0.316	\$0.286	\$0.258	\$0.230	\$0.203
	\$3.20	\$0.313	\$0.277	\$0.241	\$0.207	\$0.173	\$0.329	\$0.299	\$0.270	\$0.242	\$0.215
	\$3.30	\$0.326	\$0.289	\$0.253	\$0.219	\$0.185	\$0.342	\$0.311	\$0.282	\$0.254	\$0.227
	\$3.40	\$0.339	\$0.302	\$0.266	\$0.231	\$0.197	\$0.355	\$0.324	\$0.295	\$0.266	\$0.239
	\$3.50	\$0.352	\$0.315	\$0.278	\$0.243	\$0.209	\$0.367	\$0.337	\$0.307	\$0.278	\$0.251

Table 5. Long-term break-even feedstock prices (\$/lb)

	<u>30 Million Gallon Plant</u>				<u>60 Million Gallon Plant</u>			
	OM	EBIT	EBT	NI	OM	EBIT	EBT	NI
\$2.40	\$0.266	\$0.249	\$0.240	\$0.237	\$0.268	\$0.255	\$0.247	\$0.245
\$2.50	\$0.279	\$0.262	\$0.252	\$0.250	\$0.281	\$0.268	\$0.260	\$0.258
\$2.60	\$0.292	\$0.275	\$0.265	\$0.263	\$0.294	\$0.281	\$0.273	\$0.270
\$2.70	\$0.305	\$0.288	\$0.278	\$0.275	\$0.307	\$0.294	\$0.286	\$0.283
\$2.80	\$0.318	\$0.301	\$0.291	\$0.288	\$0.320	\$0.307	\$0.299	\$0.296
\$2.90	\$0.331	\$0.314	\$0.304	\$0.301	\$0.333	\$0.320	\$0.312	\$0.309
\$3.00	\$0.344	\$0.327	\$0.317	\$0.314	\$0.346	\$0.333	\$0.325	\$0.322
\$3.10	\$0.357	\$0.340	\$0.330	\$0.327	\$0.359	\$0.346	\$0.338	\$0.334
\$3.20	\$0.370	\$0.353	\$0.343	\$0.339	\$0.372	\$0.359	\$0.351	\$0.347
\$3.30	\$0.383	\$0.366	\$0.356	\$0.352	\$0.385	\$0.372	\$0.363	\$0.360
\$3.40	\$0.396	\$0.379	\$0.369	\$0.365	\$0.399	\$0.385	\$0.376	\$0.373
\$3.50	\$0.409	\$0.392	\$0.381	\$0.378	\$0.412	\$0.398	\$0.389	\$0.385

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