Alternatives to Petroleum Based Fuel for Marine Vessels

Final Report

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Executive Summary

Biodiesel: An Alternative Fuel for Great Lakes Marine Vessels, Process Enhancement; Engine Test Data

We investigated use of transesterified vegetable oils – biodiesel – as an alternative fuel for marine vessels. The project goals were to determine technical and economic viability of using biodiesel, investigate cheaper ways to produce it, and study engine performance using biodiesel. In addition, we studied the possibility of using fuel cells to enhance the energy efficiency of biodiesel and to reduce the adverse impact of ships to the marine environment.

Our investigation has led to the following findings:

1. Technically, biodiesel production has become routine. A continuous, economically efficient, production process is used by all the large volume producers. Smaller producers use batch reactors that allow flexibility in operation and use of raw materials.

   Unfortunately, like any other agri-based energy source, biodiesel requires some form of federal or state subsidy to be competitive with petroleum based fuel. Minnesota State Statute 239.77, which was adopted on March 15th, 2002, mandates 2% biodiesel fuel by volume in all diesel fuel sold or offered in Minnesota. The mandate officially took effect on September 30th, 2005, when sufficient biodiesel production within the state of Minnesota was available to support the mandate.

2. An enzyme – lipase – can be used as a catalyst in the production process instead of the usual catalyst, sodium hydroxide. Although more expensive, lipase holds the promise of faster reaction rate and more economical biodiesel production. Further investigation into the enzymatic production of biodiesel is recommended.

3. The use of biodiesel blends in diesel engines lowers overall engine emissions when compared to petroleum-based diesel. In addition, biodiesel is a renewable energy source, has better lubricity than diesel fuel, is nontoxic and biodegrades faster than diesel fuel, and can be used in current diesel engines with little or no modification. Environmental concerns, legislative measures, and continued research into improved methods of producing biodiesel are among the many factors contributing to the increased use of biodiesel. Both legislative and industrial efforts point to the use of up to 20% biodiesel blends (B20) in the near future.

4. The tendency of biodiesel to act as a solvent and its higher cold flow properties can lead to problems during operation. Individual ship systems should be reviewed to identify potential cold weather and material compatibility problems prior to the adoption of high biodiesel content blends as a fuel. There is a potential for fuel gelling problems in Great Lakes vessels over the winter lay up period due to long-term (2 month) storage of biodiesel blends at low temperatures. The development

of a long-term low-temperature storage test to verify that separation of the blend and preferential gelling of the biodiesel component does not occur is recommended.

5. Our study also indicates that although ship-board use of fuel cells using biodiesel is energy efficient and environment friendly, is very capital intensive and highly unlikely to be economical.

Biodiesel: An Alternative Fuel for Great Lakes Marine Vessels; Economic Analysis; Supply and Demand; Economic Impact Model

Volatile production and pricing associated with dynamic changes make modeling the biodiesel industry challenging. For instance, for business planning, a break-even analysis usually calculates a break-even point based on fixed costs, variable costs per unit of sales, and revenue per unit of sales. Business planning at the level of individual enterprise is suggested as further research, and assumptions of per-unit revenue and per-unit cost as well as assumption of other fixed costs would be estimated through a detailed sales forecast as well as profit and loss data from the industry. Given the aforementioned volatility of this market, as seen in the supply and demand trends in the foregoing data tables, average sales and costs may not be representative. Analysts predict, however, that costs will come down and prices will rise, making the break-even point a moving target. The variation in feedstock producers, type of feedstock, the possibility of increased demand from Great Lakes maritime fleets, “fixed” costs such as legislated incentives and regulations which can be amended or removed, and the technological advances in chemical processing and operations and end-use engineering can introduce new variables at any stage of the business model.

For the industry sector, it can be assumed that eventually the low cost producers will able to force the independent producers out of the industry and capture market share. Changes in the industry sector will have impacts for the regional economy.

An estimate of economic impacts to the Great Lakes region from the introduction of more biodiesel production is provided. The use of biodiesel fuel by Great Lakes commercial fleets is expected to increase in the future. By the end of the decade, the demand for biodiesel could be over 30 million gallons. Although over 23 million gallons of diesel sales were disclosed by two Great Lakes suppliers for this report, other Great Lakes producers would not reveal sales volume. Therefore total Great Lakes sales or production could not be reported. However, it is possible to assume that a new 30 million gallons biodiesel facility could be supported as the Great Lakes fleets convert to biodiesel usage. Data show that there was total domestic demand for 2.1 billion gallons of distillate fuel oil for vessel bunkering in 2004. Great Lakes states maritime commerce consumes about 170 million gallons of diesel fuel. Based on soybean production in 2005 it would only take about 9% of the states’ soybean production to satisfy demand for converted biodiesel maritime use. How quickly vessels will convert to biodiesel is unknowable, but some of this demand could be supplied by increased biodiesel production. To meet this increased demand a new Great Lakes Biodiesel Plant, of typical production capacity of 30 million gallons per year, should be feasible. Our assumptions as inputs to these models are constrained to projections for commercial maritime diesel consumption.

With the completion of the construction phase it is estimated that the biodisel plant project will have spent a total of approximately $33.9 million on construction, and that the Biodiesel Plant Project will have generated $64.5 million in spending across the Great Lakes Region over two years.   The Value Added economic impact of the $14.3 million in expenditures for construction are expected to produce an impact of a total of $33.9 million for region. In Year 1 of construction, the Great Lakes Biodiesel Plant is expected to directly employ 172 workers for construction projects, which will result in the creation of 365 jobs in the Region. In Year 2 the plant is expected to directly employ 86 workers for construction projects, which will result in the creation of 182 jobs in the region.

When operations for the biodiesel plant reach typical year capacity, it is estimated to generate $48.4 million in direct spending across the Great Lake states. The indirect spending adds $22.5 million and $8.1 million (in induced spending). The total $79 million in expenditures occurs annually for the life of the facility.

During a typical year of operations, Great Lakes Biodiesel Plant will create over 194 full-time, part-time, and temporary jobs in the region by directly employing nearly 37 people.

■

Chapter 1: Overview

1.1 Introduction

This project was proposed in two parts: The first part presents engineering aspects of biodiesel fuel use for maritime commerce. This alternative fuel can be used as renewable energy in current diesel engines. The literature suggests that biodiesel fuel has similar energy content to diesel and little impact on performance; the fuel has better lubricity than petro-diesel and it compensates for Ultra Low Sulfur Diesel (ULSD); and that biodiesel can use the current distribution infrastructure, with some modifications for cold weather. It is also noted that biodiesel biodegrades faster than petro-diesel, and produces reduced emissions. Part two follows this chapter and offers an economic impact analysis.

1.2 Research Questions

Given these justifications for using biodiesel fuel in maritime operations, this project proposed to study the fuel production process and engine test data, and specifically, the operational issues associated with using biodiesel fuel and blends for Great Lakes maritime commerce. Researchers pursued the questions: What are the process enhancements issues for biodiesel fuel in the maritime setting? What are the cold weather recommendations? What are the engine conversion issues?

In a second part of this project, this report presents a review of supply and demand market data for the biodiesel industry, a review of legal mandates and incentives, as well as economic impact modeling for increased production of biodiesel fuel for maritime use. The larger question of costs and benefits for a maritime fuel conversion is outlined and suggested for further research in the recommendations of Chapter 5 of this report.

1.3 Report Organization

Chapter 1: Overview. A general overview of the project and a description of the organization of the report, including:

- Introduction
- Research questions

Chapter 2: Alternatives to Petroleum Based Fuels for Marine Vessels. Chapter 2 is divided into the following sections:

- Introduction
- Background, including B100 and blends; production of B100
- Process improvement, including potential improvements, including identified enzymatic catalyst (lipase), potential problems; and next step/s to be taken.
- Review of available engine test data: performance; emissions; power/torque/fuel economy including general issues with usage; potential issues for maritime applications; next step/s to be taken.

Chapter 3: Economic Impacts, Supply and Demand. Chapter 3 is divided into the following sections:

- Introduction, including the definition of the research issue, background, relevant literature, methodology, and report organization.
- Economics of the suggested conversion, including supply and demand (national picture, Great Lakes specifics); Duluth-Superior Fleet/Murphy Oil, inputs; status quo picture, petro-diesel, bio-diesel (b2); pricing, production data, storage, transportation; incentive programs; by-products; risk analysis.

Chapter 4: Potential Economic Impacts of a Biodiesel Fuel Plant for Great Lakes Maritime Fuel. This chapter contains our focus on impact modeling including the introduction of a biodiesel production plant to a Great Lakes state economy, including:

- The I/O model assumptions.
- Estimations of industry output, employment (all measures, all effects).
- Economic projections.

Chapter 5: Conclusions and Recommendations

- Engineering conclusions and recommendations, including a discussion of likely use of up to B20; legislative/economic environment promotes usage; potential to improve production process; summary of next step/s.
- Economic conclusions, a summary of the economic impact of the research findings, recommendations regarding cost benefit analysis and analysis of carbon credit trading, among other strategies.

The report includes a reference section which includes citations for all sources mentioned in the body of the report. The report includes one appendix of demand and supply supporting data. Tables and figures are listed separately in the contents pages as List of Tables and List of Figures and follow chapter numbers.

Chapter 2: Biodiesel: An Alternative Fuel for Great Lakes Marine Vessels

2.1 *Introduction*

Biodiesel is a renewable fuel that can be used in current diesel engines with little or no modification, and is therefore an attractive alternative to the significant volume of #2 diesel fuel used by vessels that operate on the Great Lakes. The following discussion presents some background on biodiesel, its definition, its properties, a description of the production process, and the current mandates and incentives for its use. The production process is investigated in detail and recommendations for potentially reducing biodiesel costs through process improvements are presented. Finally, engine performance and operational issues are explored and a new test for cold weather operation is proposed.

2.2 *Background*

The increased use of biodiesel and blends of biodiesel and petroleum-based diesel fuel has been motivated by several factors including; higher fuel prices, concern over emissions, and the uncertainty associated with foreign sources of oil. The production of biodiesel is unlikely to ever reach a level where it would completely replace petroleum-based diesel in the commercial fuel supply. However, the use of higher percentage biodiesel blends to extend limited oil supplies appears to be a foregone conclusion given the current political environment. Whether it is used as the primary fuel, or as part of a blend, biodiesel offers several attractive advantages:

- It is a renewable energy source.
- It can be used in current diesel engines.
- It has similar properties to diesel fuel.
- It has better lubricity than diesel fuel.
- The combustion of biodiesel produces fewer harmful emissions.
- It requires no major changes in the current distribution infrastructure.
- It is nontoxic and biodegrades faster than diesel fuel.

In addition to the above advantages, there are several legal mandates and incentives at both the state and federal level that encourage the use of biodiesel.

2.2.1 *Definition of Biodiesel and Blends*

Biodiesel is defined as “a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated B100” [1]. Biodiesel in its pure form is designated as B100 to indicate that the mixture consists of 100% (by volume) biodiesel. Blends of biodiesel and distillate fuel (e.g. #2 diesel) are designated by the letter “B” followed by the volume percentage of biodiesel contained in the mixture; for example, B20 refers to a blend of 20% biodiesel and 80% distillate fuel. The “distillate fuel” used in the blend can consist of a single distillate (e.g. #1 diesel, #2 diesel, fuel oil, etc.) or a mixture of more than one distillate, with the use of #1 and #2 diesel being the most common.

Biodiesel, as discussed in this report, should not be confused with straight vegetable oil (SVO) or the "home-brew" product described by authors such as Tickell [2]. In general, homemade versions of "biodiesel" often utilize different stock and catalysts than commercially produced biodiesel and have considerable variability in methanol and glycerin content in the final product. This variability is undesirable in the fuel supply as a standard fuel specification is desired for both predicting performance and designing engines to run efficiently on B100 and its blends. The variability in biodiesel supply has led to problems with the use of biodiesel and contributed to skepticism within certain communities (for example the trucking industry) about the incorporation of biodiesel blends in the commercial fuel supply.

The international standard that delineates the properties and testing procedures for B100 is ASTM D6751 [1]. Table provides a summary of the ASTM D6751 standard for grade S15 (sulfur content of less than 15 ppm) biodiesel. There is a separate standard for diesel fuel (ASTM D975 [3]) which includes testing procedures for both oxidation (long term) (ASTM D2274 [4] and ASTM D4625 [5]) and thermal (ASTM D6468 [6]) stability. Thermal and oxidation stability tests are accurate when used with diesel fuels and ASTM D6468 [6] testing indicates that B100 has good thermal stability. However, as the literature review provided by Waynick [7] shows, the oxidation tests are not reliable for predicting the oxidation stability of B100 and biodiesel blends. Westbrook [8] discussed combining a modified ASTM D2274 test with kinematic viscosity and acid number tests. The results show promise for characterizing B100 oxidation stability, but the limited amount of data is insufficient to specify stability limits. The problem of defining oxidation stability for biodiesel blends is further complicated by a lack of any standard for biodiesel blend properties. A standard for B20 is currently being defined by ASTM [9] in coordination with OEM engine manufacturers.

Property	Test Method	Grade S15 Limits
Flash point	D 93	130°C min
Water and sediment	D 2709	0.05 % volume max
Kinematic viscosity	D 445	1.9-6.0 mm^2/s
Sulfated ash	D 874	0.02 % mass max
Sulfur	D 5453	0.0015 % mass (ppm) max
Copper strip corrosion	D 130	No. 3 max
Cetane number	D 613	47 min
Cloud point	D 2500	Report
Carbon residue	D 4530	0.05 % mass max
Acid number	D 664	0.80 mg KOH/g max
Free glycerin	D 6584	0.02 % mass
Total glycerin	D 6584	0.24 % mass
Phosphorous content	D 4951	0.001 % mass max
Distillation temperature	D 1160	360°C max

Table 2.1: Biodiesel (B100) requirements from ASTM D6751 [1].

2.2.2 *Properties of Biodiesel*

The properties of biodiesel vary slightly based on the vegetable oil used as the feedstock. In general, the properties of biodiesel are similar to #2 diesel fuel which allows it to be used directly in diesel-powered vehicles. The kinematic viscosity and density of biodiesel are close to that of #2 diesel, resulting in only minor changes in fuel delivery characteristics. The energy content of B100 is only slightly lower than that for #2 diesel and has little impact on engine power, torque, and fuel economy. As previously discussed, the use of biodiesel has several advantages over #2 diesel. Biodiesel is nontoxic and biodegradable, reducing fuel handling requirements. It has better lubricity than diesel fuel which reduces wear on fuel system parts such as injectors and pump bearings. Biodiesel could be used as an additive to ultra low sulfur diesel which suffers from low lubricity. The combustion of biodiesel produces fewer harmful emissions overall. Unburned hydrocarbon (HC), carbon monoxide (CO), and particulate matter (PM) emissions from combustion of biodiesel are significantly lower than those from burning #2 diesel.

Biodiesel also exhibits some less desirable properties that can cause operational problems. It acts as a solvent and will remove paint from surfaces and degrade some elastomers and rubber parts (e.g. fuel pump seals). Biodiesel has a tendency to gel at higher temperatures than #2 diesel. The increase in cold flow properties (tendency to gel) associated with biodiesel is quantified using cold filter plugging point, cloud point, and pour point tests. The cloud point, which is the temperature at which solid crystal first appear, has an average value of 3 deg. F for #2 diesel and 32 to 40 deg F for B100. Thus, B100 is not suited for use in cold climates if fuel system components are exposed to the environment. However, tests have shown that the cloud point for a B20 blend with #2 diesel is approximately 7 deg F. Solutions for the problems associated with the use of biodiesel will be addressed later in this report.

2.2.3 *Production of B100*

There are three general methods for producing biodiesel; base catalyzed transesterification of oil with alcohol, direct acid catalyzed esterification of oil with methanol, and conversion of oil to fatty acids, and then to alkyl esters with acid catalysis. The first of these methods has several advantages and is the most widely used; it is a low temperature and pressure process, it has high conversion efficiency, it has a short reaction time, and it does not require exotic construction materials.

The transesterification process involves the mixing of vegetable oil with an alcohol and a catalyst as shown in Figure 2. The vegetable oil is usually soybean or canola oil and the most commonly used alcohol is methanol. The catalyst for the reaction can be sodium hydroxide (NaOH), potassium hydroxide (KOH), or sodium methylate ($NaOCH_3$). Initial mixture fractions by volume are approximately 87%, 12%, and 1% for the vegetable oil, methanol, and catalyst respectively. The reaction takes place in either a batch or continuously stirred reactor and has a 98% conversion efficiency resulting in 86% methyl ester (biodiesel), 9% glycerin, 4% alcohol (unreacted), and 1% fertilizer by volume. The by-product glycerin has a higher density than biodiesel and may be removed via settling tank or centrifugal separator. The unreacted methanol may also be recovered for reuse.

The increased demand for biodiesel has led to the construction of several plants across the nation. According to the National Biodiesel Board (NBB), there are currently 86 biodiesel plants in the U.S. with annual capacities ranging from 50,000 to 30,000,000 gallons [10]. The three states with the largest biodiesel production capacity are Iowa, Texas, and Minnesota. Biodiesel is produced at three main plants within Minnesota: the Minnesota Soybean Processors (MNSP) plant in Brewster [11], the SoyMor plant in Albert Lea [12], and the Farmers Union Marketing and Processing Association (FUMPA) plant in Redwood Falls [13]. Biodiesel producers ship the B100 to refineries, such as the Flint Hills Resources' Pine Bend refinery in Rosemount, MN [14] or the Murphy Oil refinery in Superior, WI [15], where it is blended with diesel fuel.

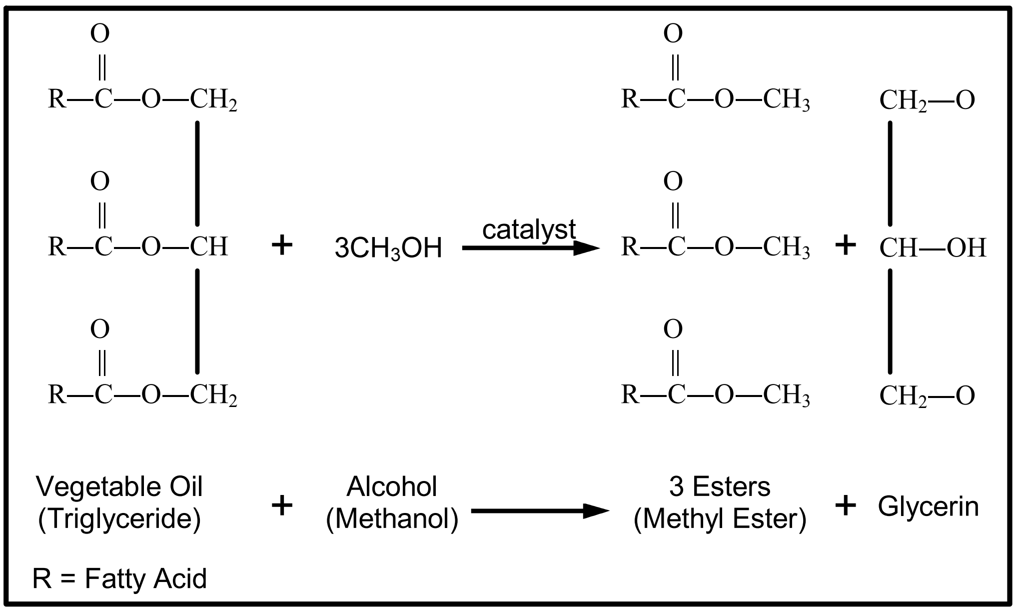

Figure 2: Transesterification process.

2.2.4 *Legal Mandates and Incentives*

Several pieces of biodiesel legislation have been enacted over the past five years at both the state and federal levels. For example, Minnesota State Statute 239.77, adopted on March 15th, 2002, mandates 2% biodiesel content in all diesel fuel sold in Minnesota. This mandate, which officially took effect on September 30th, 2005, has supported the development of three biodiesel plants in the state of Minnesota. There are currently 38 states that have legal incentives and/or usage mandates for biodiesel. On the federal level, B20, which is a mixture of 20% biodiesel and 80% petroleum diesel, was approved as an alternative fuel for use by federal, state, county and utility company vehicles under the Energy Policy Act of 1992 (EPACT). More recently, in response to the 2005 EPACT, the EPA has specified that a minimum of 2.78% of all fuel used nationwide will be renewable fuels (e.g. ethanol and biodiesel) [16]. The EPA also recognizes the use of biodiesel in emissions reduction strategies as part of their Clean Diesel [17] and Clean Ports USA [18] Programs.

2.3 *Process Improvement*

In general, the biodiesel production process can be described as esterification of vegetable oils by the process of alcoholysis [19,20]. For either batch (low production) or continuous (production rate > 1 million gal/year) production, a vegetable oil is reacted with methanol and a solvent (to promote mixing) in the presence of sodium catalyst (to reduce reaction activation energy). The reaction may be represented by,

$$CH_5O_2RO_2R'O_2R'' + 3CH_3OH \longleftrightarrow$$
$$CH_5(OH)_3 + CH_3OOR + CH_3OOR' + CH_3OOR''$$

where R , R' and R'' are primarily 16, 17, and 18 carbon chains. The triglycerides from vegetable oil in this process are converted to three separate methyl esters.

2.3.1 *Biodiesel Production Economics*

A preliminary technical and economic feasibility study of biodiesel production using soybean oil and the method described above was studied for this project. The recent findings of Haley et al. [21] are adapted for this purpose. For a 10 million gallon/year production facility, the total capital investment required is about $9.5 million dollars and the production cost is about $2.50/gal. Considering inflation, the production cost for biodiesel for 2006 would be about $2.75/gal. Thus, biodiesel is not competitive with petroleum-based diesel unless indirect (mandated use) or direct incentives are provided by the federal, state, or local government.

Our efforts to improve the economics of biodiesel production led us to thoroughly investigate an enzymatic catalyst that has the promise of increasing the esterification rate and decreasing effective production cost.

2.3.2 *Enzymatic Catalyst*

Our investigation into more efficient production of biodiesel from soybean oil led us to lipase, an enzymatic catalyst, to replace sodium hydroxide (NaOH) in the esterification reaction of soybean or other vegetable oils. Lipase is much more expensive than NaOH. In spite of its cost, lipase could potentially reduce production cost because it is recyclable and because it eliminates a separation step in the traditional base catalyzed process. P.flouroscens is a widely used variety of lipase. Other varieties include T. langinosa, R.miehei, and Candida Antarctica (Novozym 435). Candida Antarctica has a number of interesting properties that make it a candidate for further investigation.

Esterification using lipase as a catalyst generally requires it to be immobilized on some type of carrier particle allowing collection of the catalyst after the reaction is completed.

A few simple "cleansing" steps are required for the catalyst to be reused. The reaction is essentially similar to the traditional process in that the raw feed (vegetable oil) is reacted with a primary alcohol (usually methanol) to produce methyl esters and a by-product glycerol.

2.3.3 *Potential Problems and Solutions*

Using the more expensive enzymatic catalyst in place of NaOH poses a few potential problems. These problems are briefly described below.

- Methanol (used for esterification) is known to deactivate the lipase, greatly hindering its catalytic capabilities.
- Lipases are expensive, and must be reusable to be cost effective.
- Glycerol, the by-product of esterification reaction, seems to reduce the conversion of methyl esters, possibly due to unwanted side reactions.
- No reliable continuous process of esterification using lipase has been developed yet. A continuous process for biodiesel production is highly desirable to keep production costs low.

To improve the economics of biodiesel production using a lipase as the catalyst we are looking into the following process improvements:

- A step-wise addition of methanol to reduce the deactivation of the lipase by the alcohol. This may be done in a three part process; one molar equivalent being added every few hours a total of three times, resulting in the required 3:1 methanol to oil ratio. While this is effective, catalyst deactivation tends to be inevitable at some point. A good process seems to run about 10 batches before noticeable deactivation occurs.
- Different "carriers" of the lipase have been investigated to maximize conversion. One common carrier is polypropylene 100EP for P.flouroscens.
- Glycerol adsorbing compounds have been investigated to consume the glycerol and allow for a higher conversion. This incurs the loss of a valuable by-product and may require additional steps to deal with the additives.
- Alternate alcohols have been used to improve miscibility and/or lower the deactivation rate of the lipase caused by methanol.

2.3.4 *A Novel Biodiesel Production Method*

We believe that a new biodiesel production process, based on the work of Xu et al. [22] that addresses the above-mentioned problem areas, could significantly increase the fuel's competitiveness. In this process, methyl acetate is used as the reacting alcohol with soybean oil, and immobilized Candida Antarctica as the lipase catalyst. Methyl acetate has negligible effect on the catalyst. The main by-product, triacetylglycerol (instead of glycerol), is not absorbed on the catalyst surface, alleviating the catalyst deactivation problem. In addition, the recent work of Cortright [23] shows the promise of low cost hydrogen production from triacetylglycerol [24].

2.4 *Engine Test Data*

Summaries of the available literature for engine tests using biodiesel can be found on the NBB [25] and EPA [26] websites. The majority of engine test data for on-road diesel engines. While these engines are not precisely the same as those used on maritime vessels, most of the results can be generalized to any diesel engine. The available literature provides useful guidance for incorporating biodiesel in the fuel supply. Of particular interest are the effects of biodiesel on both direct performance measurements, such as power, torque and fuel economy, and the environmental impact via emissions.

2.4.1 *Power/Torque/Fuel Economy*

Biodiesel has slightly lower energy content per unit volume (average of approximately 33 MJ/L) than #2 diesel (36 MJ/L) which tends to cause a corresponding reduction in maximum power, maximum torque, and fuel economy. The reduction in performance decreases with the percentage of biodiesel in a blend. The engine testing results of Rakopoulos et al. [27] show that, within the range of experimental uncertainty, B10 and B20 blends exhibit similar performance to #2 diesel fuel. However, performance results using biodiesel blends are affected by the specific engine used, the percentage load at which the engine is operated, and the vegetable oil used in producing the biodiesel [27].

2.4.2 *Emissions*

Table 2 shows a summary of "average" biodiesel energy content and emissions results [28] obtained from reference [29]. The table shows that the use of biodiesel and biodiesel blends results in reductions in most regulated emissions. Total unburned hydrocarbons (THC), carbon monoxide (CO), and particulate matter (PM) emissions decrease significantly with biodiesel usage, while oxides of nitrogen (NOx) emissions increase moderately. It should be stressed that these are "average" emission results, and may not reflect actual conditions obtained using a specific engine and "type" of biodiesel used in the blend. However, the large reductions in THC, CO, and PM indicate that a reduction can be expected in these emissions regardless of the engine or "type" of biodiesel used. The slight increase in NOx emissions shown in Table 2 may or may not be present for a specific engine and/or "type" of biodiesel. For example, the test results of Rakopoulos et al. [27] show a slight reduction in NOx emissions when comparing results using #2 diesel to results using B20 blends produced from five different "types" (cottonseed oil, soybean oil, sunflower oil, rapeseed oil, and palm oil methyl ester) of biodiesel.

Table 2 also shows the "average" emissions results for some non-regulated pollutants. Emissions of sulfates, polycyclic aromatic hydrocarbons (PAH's), nitrated PAH's (nPAH), and hydrocarbon species that can react to form smog, are greatly reduced with the use of biodiesel. Since B100 is derived from vegetable oil, it contains no sulfur compounds, and thus sulfate emissions are reduced in proportion to the percent volume of biodiesel in the blend. The primary concern over sulfur emissions is the potential to produce acid rain. The reduction of sulfur emissions is currently being addressed via the introduction of ultra low sulfur diesel (ULSD) in the fuel supply. Polycyclic aromatic hydrocarbons and nPAH's have been identified as potential cancer causing compounds [28] and are precursors to soot (particulate matter) formation. Smog is a form of air pollution in which certain emissions react to produce several irritating and oxidizing compounds, the most prominent of which is ozone. Nitrogen oxides, hydrocarbons, and sunlight are required to form smog. The reaction of certain hydrocarbons with nitrogen oxide (NO) contributes to the formation of ozone. The tendency of hydrocarbon emissions to contribute to ozone formation is described as the ozone potential of speciated hydrocarbons. Even though the last four pollutants in Table 2 are currently unregulated, the reduction in these pollutants is clearly desired.

Biodiesel Content	**B100**	**B20**
Energy Content/Gal	-8%	<-2%
Emission		
Regulated		
Total Unburned Hydrocarbons	-67%	-20%
Carbon Monoxide	-48%	-12%
Particulate Matter	-47%	-12%
NOx	+10%	+2%
Non-Regulated		
Sulfates	-100%	-20%
PAH (Polycyclic Aromatic Hydrocarbons)	-80%	-13%
nPAH (nitrated PAH's)	-90%	-50%
Ozone potential of speciated HC	-50%	-10%

Table 2.2: Energy content and emissions for B100 and B20 [28,29].

2.4.3 *Issues with Usage*

The advantageous and potentially problematic properties of biodiesel were introduced in an earlier section (***2.2.2 Properties of Biodiesel***). The issues associated with biodiesel usage stem primarily from two properties; biodiesel acts as a solvent, and biodiesel has higher cold flow properties than #2 diesel. Several solutions to the issues associated with biodiesel usage are presented in the U.S. Department of Energy's "2004 Biodiesel Handling and Use Guidelines" [30]. These issues and solutions are discussed below.

The fact that biodiesel acts as a solvent leads to both fuel handling and operational issues. The least critical of these issues is that biodiesel spills on painted surfaces should be cleaned up immediately to prevent paint removal. A larger concern is B100's tendency to soften and degrade certain rubber and elastomer compounds. These compounds are often used in fuel hoses and fuel pump seals, particularly on older engines. Prior to using B100 in an engine, the OEM engine manufacturer should be consulted to determine if the fuel system components are compatible with B100. Compatibility issues can be resolved by replacing fuel system components with synthetic hoses and seals that are resistant to oxygenated fuels. For example, parts made with Viton® are compatible with B100. Newer engines that are manufactured to operate using ULSD will, in general, have parts that are compatible with B100. Even if a newer ULSD compatible engine is used, the

OEM manufacturer should be consulted to verify compatibility and ensure engine warrantees will be honored. Biodiesel blends up to B20 have been used in older engines without any observed fuel system component degradation. However, a prudent course of action would be to upgrade fuel system components if B20 is to be used. Because it is a solvent, B100 will remove deposits left in the fuel system by petroleum diesel, which can lead to clogged fuel filters. When switching directly from petroleum diesel to B100, fuel filters should be checked and cleaned frequently until the fuel system deposits are removed. Blends as high as B20 have not shown the same tendency to remove fuel system deposits, however, more frequent checking and cleaning of the fuel filters should still initially be performed.

Engine operation in cold weather can be problematic due to the higher cold flow properties associated with B100. As a precaution, B100 should not be used without heated fuel tanks and fuel lines if the temperature is below 40°F. This is a conservative estimate since the "average" cloud point of B100 is 32°F as compared to 3°F for #2 diesel. Blends up to B20 can be used in environments with temperatures approaching the operational temperature for the distillate used in the blend. For example, the cloud point of #2 diesel is 3°F, and when B20 is produced with #2 diesel, the cloud point is approximately 7°F. The solutions for avoiding fuel gelling when using B100 or a biodiesel blend (such as B20) are the same as those for #2 diesel. Namely, blend with #1 diesel, use a fuel line heater, keep the engine and fuel lines in an environmentally controlled space, and use cold flow enhancing fuel additives.

2.4.4 *Maritime Usage*

Biodiesel blends up to approximately B20 can be used as direct replacements for diesel powered equipment on maritime vessels that utilizes #2 diesel with little or no modification to current systems. The use of a B20 blend will allow for measurable reductions in emissions with no noticeable decrease in fuel economy. Many OEM engine manufacturers currently certify the use of up to B5 in their engines as long as both the biodiesel and the distillate portion of the blend meet ASTM specifications. ASTM International is currently working with OEM engine manufacturers to create a B20 standard for engine certification tests. Main engines that operate on heavy fuel oils or Bunker C are not candidates for the use of B20.

Examples of ship board systems that currently use #2 diesel include, the main engines on ships with EMD diesels, diesel-generator sets, emergency generators, and deck crane power packs. The specific engines that power these systems, as well as the makeup of the systems themselves, vary from ship to ship. Some components, such as the deck crane power packs, have fuel systems exposed to ambient weather conditions, while other components, such as the diesel-generator sets, have fuel system components in environmentally controlled spaces. As a result, no single set of rules for converting to B20 usage can be delineated, and the general rules for dealing with the issues discussed in the preceding section should be applied to each system on each ship.

A potential problem with maritime operation that has not been addressed in the literature is that of the long-term stability of biodiesel blends in cold weather. As discussed earlier in this report, stability tests address both the thermal [6] and oxidation [4,5] stability. These tests use a slightly elevated temperature to simulate long-term storage (greater than 4 to 6 months). This is unlikely to be a problem with vessels on the Great Lakes, which refuel often. The exception to frequent refueling occurs during the winter lay up period (2 months), when the portions of the main fuel tank below the waterline are at approximately 0°C (32°C) and portions above the waterline may be at temperatures slightly below freezing. Auxiliary systems may have components exposed to below freezing temperatures. The available stability tests do not address this potential cold weather problem. The 2004 Biodiesel Handling and Use Guidelines [30] recommends that blends should be stored at 5 to 10°F above the cloud point of the blended fuel, which suggests that distillate portion of a B20 blend should consist of "winter diesel" (a mix of #1 and #2 diesel). Given that this is done, it is still unclear if prolonged exposure of a B20 (or lower) blend to low temperatures causes any separation and preferential gelling of the biodiesel component.

2.4.5 *Cold Weather Storage Test*

There is currently no test specification for extended storage of biodiesel blends at low temperatures. However, the 2004 Biodiesel Handling and Use Guidelines [30] present a test to check for stratification of biodiesel blends. We plan to modify this test to visually check for biodiesel crystallization and determine if any stratification occurs under low temperatures for extended periods. Such a test would provide useful information to potential biodiesel users on the Great Lakes.

2.5 *Conclusions and Recommendations*

The preceding discussion suggests that biodiesel is an attractive alternative to petroleum-based diesel. The shift to increased biodiesel usage is being driven by, among other factors, environmental concerns, legislative measures, and continued research into improved methods of producing biodiesel. Based on both legislative trends and the efforts of OEM engine manufacturers, it appears likely that B20 will become the standard blend in the diesel fuel supply sometime in the foreseeable future, much as E10 has become a standard fuel in the Midwestern states gasoline fuel supply.

Investigations into possible improvements in the biodiesel production process led to the potential use of a lipase as a replacement for the currently used catalyst sodium hydroxide. The commercial development of a lipase-based process could lower fuel costs and would represent a novel approach to biodiesel production. Hydrogen gas could be extracted from the primary by-product (triacetylglycerol) of the new process to produce energy via either direct combustion or a fuel cell. Investigation into the development of a commercially viable lipase-based production process should be continued.

A review of the literature addressing engine performance and operational issues shows that, while biodiesel has several advantages, such as reduced emissions, the use of biodiesel and its blends in cold weather conditions presents some problems. The guidelines for conversion from petroleum-based diesel to the use of biodiesel blends like B20 suggest that a review of current individual ship systems to identify potential cold weather and material compatibility problems should be performed. This can be accomplished proactively since mandated biodiesel content will likely increase in a step-wise manner over time, for example, from B2 to B5 to B10, and finally to B20. A particular concern for marine vessels on the Great Lakes is potential fuel problems due to storage of biodiesel blends at the low temperatures present during the winter lay up period. It is recommended that a long-term low-temperature test be developed to verify that separation of the blend and preferential gelling of the biodiesel component does not occur.

Chapter 3: Biodiesel: An Alternative Fuel for Great Lakes Marine Vessels; Economic Analysis, Demand and Supply

3.1 Introduction

In the past application of biodiesel for merchant ship propulsion on a large scale has not been seen as an option because of the unavailability of fuel. Background literature has shown a 2% blend of biodiesel is estimated to increase the cost of diesel by 2 or 3 cents per gallon, which includes the fuel, transportation, storage, and blending costs. The following tables quantify demand and supply for biodiesel fuel, review incentives and risk including by-products as market risk.

Research issue. The Labovitz School proposes to quantify the economic impact of fuel conversion from current petroleum based fuel to biodiesel fuel as presented in the research findings for the Great Lakes Maritime Research Institute project by the UMD Departments of Chemical and Industrial Engineering.

Financial and economic scenarios for conversion will be modeled.

This study was contracted for by the Great Lakes Maritime Research Institute.

The contract for this study has the following project description:

> *The economic analysis will include modeling of supply and demand for biodiesel fuel.*
>
> *Great Lakes shipping requirements will be highlighted; an overview of federal and Great Lake states regulations and biofuel subsidies will be completed.*
>
> *Comparisons between the U.S. and Great Lakes Region for the modeling, regulations, and subsidies will be reported.*

Background. The advantages of using biodiesel include supporting domestically produced fuel that helps the agriculture sector and drastically decreases in the amount of polluting emissions. Biodiesel is the only alternative fuel to have fully completed the health effects testing requirements of the Clean Air Act. The use of biodiesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide, and particulate matter compared to emissions from diesel fuel. In addition, the exhaust emissions of sulfur oxides and sulfates (major components of acid rain) from biodiesel are essentially eliminated compared to diesel. Soybean oil is currently the leading source of virgin vegetable oil used for biodiesel feedstock in the United States.[31]

Biodiesel tax credits are available so it will make it competitive with petroleum. [32] General business credit requires certification and eligibility for selling or using biodiesel (not in a mixture) as a fuel. The biodiesel fuel credit consists of a straight biodiesel fuel credit and a biodiesel mixture credit. Certification must identify the product produced and the percentage of biodiesel and agric-biodiesel in the product. [Currently, the credit is not allowed for biodiesel (or agric-biodiesel) used as a fuel in a trade or business if that biodiesel (or agric-biodiesel) was sold in a retail sale for circumstances described by the IRS.]

The U.S. Department of Agriculture announced in January 2001 the implementation of the first program providing cost incentives for the production of 36 million gallons of biodiesel. Bills supporting the use of biodiesel and ethanol were also introduced to the U.S. Congress in 2003, including one that would set a renewable standard for fuel in the U.S. and one that would give biodiesel a partial fuel excise tax exemption. More than a dozen states have passed favorable biodiesel legislation. [See: 2005 Federal Energy Bill Provisions; and MN State Energy Legislation 2005.] [33]

Biodiesel is known to have a solvent effect that may release deposits accumulated on tank walls and pipes from previous diesel fuel storage. This affect is much more dramatic with B100 than with biodiesel blends like B20.

Relevant sources and literature. Secondary data sources include, but are not limited to, the U.S. Department of Energy, Energy Information Administration, for oil pricing trends; the MN Soybean Processors for producer data; Farmers Union Marketing and Processing Association (FUMPA) for producer data; U.S. Department of Transportation and the Census; the Bureau of Economic Analysis for commodity and industry tables; the National Biodiesel Board for trade association and industry data; and the Renewable Fuels Association for industry statistics. One of the fastest moving statistical sources for biodiesel data to date remains the National Biodiesel Board (nbdb.org).

Methodology. This economic analysis does not include assumptions from the wide ranging national discussion of biodiesel processes and its use as a fuel, nor does it develop arguments or contribute to many of the environmental and economic topics currently being pursued by interest groups.

This economic analysis looks briefly at the national picture, for perspective and comparisons but focuses on the regional industry impacts for the Great Lakes. The analysis presents for comparison measures of the petro-diesel supply chain, and compares the hypothetical B2 supply chain including financial considerations such as pricing, production data. Also presented on a local and regional basis are incentive programs, regulations, and subsidies from the federal government, the State of MN, and other Great Lakes regional agencies.

A larger economic perspective includes strategies such as carbon credits trading, as a business asset, which are one choice among many for fuel consumers to consider when planning for regulation compliance. Carbon credit trading is part of a larger incentive approach. The market gives consumers the opportunity to choose the most efficient means for reducing their carbon emissions. Benefit cost analysis presents a range of other compliance strategies, in some cases choices more efficient (less expensive, more productive) than mandating change to biodiesel fuel. This research includes: review of the economics of emissions regulation strategies (of which carbon credit trading is one); study of appropriate caps on emissions levels; quantifying the variety of incentives that encourage consumer compliance with regulatory caps; and comparing economic benefit and cost to various stakeholders. These strategies are taken up in Chapter 5: Recommendations to this report.

3.2 Demand and Supply for Great Lakes Maritime Biodiesel Fuel

The fuel tested for this study was specifically derived from soybean feedstock and blended as B2 fuel. Therefore the following discussion will present supply chain information based on these two attributes and generally constrained to the study area for Great Lakes maritime commerce.

The supply chain for biodiesel demand and supply production and delivery is made complicated by vertical integration of processes at various points in the supply chain. For instance, producers and distributors are often the same entity, as are distributors and retailers. This industry started with small independent entrepreneurs, with demand as a grass roots movement at large, however large and global scale production is growing, for instance the aggressive Brazilian project, so that the small players are destined to be subsumed into conglomerate structures. For our analysis, the changing nature of these structures, and the volatile production and pricing associated with these dynamic changes make modeling the industry in its infancy beyond the scope of this project. An analogy can be drawn with the computer industry, when the industry was first beginning there were many independent producers trying to meet growing demand. Eventually the low cost producers were able to force the independent producers out of the industry and capture more and more market share. Thus, the moving target of capturing data to show trends and industry structure, as we attempt to do below, is challenging.

3.2.1 Demand

Demand will be presented first from the larger national perspective, then from the Great Lakes and maritime perspectives. The national overview of transportation energy crude oil consumption is shown in the graphic below. Data from the Transportation Energy Data Book 2005 shows that U.S. marine petroleum demand was approximately 0.43 million barrels per day, or 157 million barrels per year in 2002, or 8.6 billion gallons of crude oil demand for the total domestic U.S. marine sector.

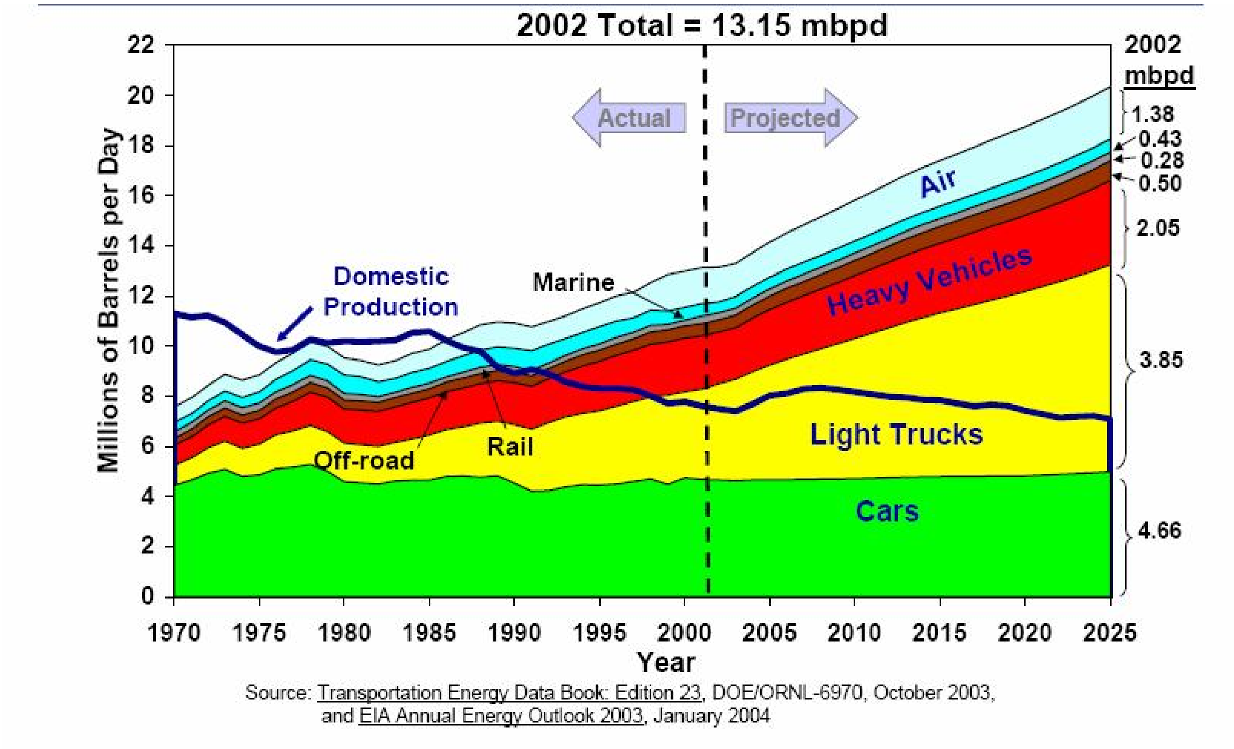

Figure 2: U.S. Diesel Demand

Moving again from the national demand to the U.S. domestic marine detail, vessel bunkering data from the US DOE, show that demand was 2.1 billion gallons in 2004. Note: Vessel bunkering includes sales for the fueling of commercial or private boats, inclusive to oil company vessels but excluding military vessels.

Table 3.1: Diesel Consumption: Vessel Bunkering, Sales of Distillate Fuel Oil by Energy Use in the United States: 2000-2004 (in thousands of gallons)

	Distillate Fuel Oil				
Energy Use	*2000*	*2001*	*2002*	*2003*	*2004*
U.S. Total	59,601,230	59,911,345	59,342,633	63,854,776	62,257,934
Vessel Bunkering	2,261,422	2,044,049	2,078,921	2,216,921	2,139,643

Source: DOE EIA http://www.eia.doe.gov/pub/oil_gas/petroleum/data publications/fuel_oil_and_kerosene_sales/historical/2004/foks_2004.html

From the U.S. domestic marine sector to the Great Lakes detail, we see vessel bunkering data by Great Lakes use as almost 170 million gallons in 2004.

Table 3.2: Diesel Consumption: Vessel Bunkering, Sales of Distillate Fuel Oil by Energy Use in the Great Lakes States: 2004 (in thousands of gallons)

Destination	*Vessel Bunkering 2004*	*% of Great Lakes*
New York	13,296	8%
Pennsylvania	22,964	14%
Illinois	107,110	63%
Indiana	7,289	4%
Michigan	8,792	5%
Minnesota	5,367	3%
Ohio	3,104	2%
Wisconsin	1,949	1%
Great Lakes Total	169,871	
U.S. Total	2,139,643	100%

Source: DOE EIA
http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/fuel_oil_and_
kerosene_sales/historical/2004/foks_2004.html
*Note: these data are used in the impact modeling for Chapter 4.

Biodiesel B20 prices increased from $1.23 in July in 2002 to a peak of $2.84 in September 2005. The price came back somewhat in February 2006.

Table 3.3: U.S. Biodiesel Prices October 2000 to February 2006

Date	*Petroleum Diesel ($/gal)*	*Biodiesel B20 ($/gal)*
10-Oct-00	1.44	
3-Jul-01	1.56	
22-Oct-01	1.33	1.47
11-Feb-02	1.13	1.27
15-Apr-02	1.31	1.25
22-Jul-02	1.30	1.23
28-Oct-02	1.46	1.60
10-Feb-03	1.65	1.48
8-Dec-03	1.45	1.55
8-Mar-04	1.59	1.65
14-Jun-04	1.66	1.73
15-Nov-04	2.10	2.09
21-Mar-05	2.20	2.18
15-Sep-05	2.77	2.84
09-Feb-06	2.56	2.64

Source: Biodiesel prices, DOE.gov

Demand Forecast. Table 3.4 below shows 2005 to 2015 projected consumption of highway diesel and B100 from soybeans and other feedstock. B100 demand is expected to increase almost nine-fold, rising from 75 million gallons in 2005 to 648 million gallons by 2015. It is unlikely that the Great Lakes maritime industry will experience these explosive growth rates, but this is an indication of the expected acceptance of biodiesel fuels.

Table 3.4: U.S. Diesel Fuel and Biodiesel Forecast

	Highway Diesel Use /1 (Bil gal)	***B100 Volume (Mil gal)***	***Biodiesel From Soybeans (Pct)***	*Biodiesel From Soybeans (Mil gal)*	*Biodiesel From other Feedstocks (Mil gal)*	*Soybean Oil Equiv /2 (Mil lb)*	*Soybean Equiv /3 (Mil Bu)*
2005	43.2	**75.0**	**91.5%**	68.6	6.4	51	46
2006	44.4	**150.0**	**90.8%**	136.1	13.9	1,021	92
2007	45.5	**172.5**	**90.0%**	15.3	17.3	1,164	105
2008	46.4	**215.6**	**89.3%**	192.4	23.2	1,443	130
2009	47.4	**269.5**	**88.5%**	238.5	31.0	1,789	161
2010	48.4	**323.4**	**87.8%**	283.8	39.6	2,129	191
2011	49.4	**388.1**	**87.0%**	337.7	50.5	2,533	227
2012	50.2	**465.8**	**86.3%**	401.7	64.0	3,013	270
2013	51.0	**535.6**	**85.5%**	457.9	77.7	3,435	308
2014	51.6	**589.2**	**84.8%**	499.3	89.8	3,745	336
2015	52.3	**648.1**	**84.0%**	544.4	103.7	4,083	367

Source: Forecast prepared by LECG, LLC
1. Annual Energy Outlook 2006. High Oil Price Case. Table 2.
Converted from btu at 138,690 btu/gal
2. Converted using 7.5 lb soybean oil = 1 gal biodiesel
3. Assumes 11.1 lbs sbo/bu soybeans

3.2.2 Supply

Following the data for soybean feedstock supply, we compare the Great Lakes states' ability to supply feedstock for biodiesel production of fuel for maritime commerce. The 1996-2006 production level trend for soybean production and prices for the U.S. is shown below. In 2006 production topped 3 billion bushels.

Table 3.5: U.S. Soybean Production and Price Trends 1996-2006

Year	*Area*	*Production (thousands of bushels)*	*Price($ per bushel)*
1996	U.S.	2,380,274	$7.35
1997	U.S.	2,688,750	$6.47
1998	U.S	2,741,014	$4.93
1999	U.S	2,653,758	$4.63
2000	U.S	2,757,810	$4.54
2001	U.S	2,890,682	$4.38
2002	U.S	2,756,147	$5.53
2003	U.S	2,453,665	$7.34
2004	U.S	3,123,686	$5.74
2005	U.S	3,086,432	$5.50
2006	U.S	3,092,970	

Source: USDA - National Agricultural Statistics Service

The detail in the U.S. trend for the Great Lakes states for 2005 shows the percent of U.S. The eight Great Lakes states produced 45% of the total U.S. soybean production.

Table 3.6: Great Lakes States Soybean Production and Price Trends 2005

Year	Area	Production *(thousands of bushels)*	Per Cent of US Total	Price *($ per bushel)*
2005	Illinois	439,425	14%	$5.50
2005	Indiana	263,620	9%	$5.50
2005	Michigan	76,615	2%	$5.55
2005	Minnesota	306,000	10%	$5.45
2005	New York	7,896	0%	$5.20
2005	Ohio	201,600	7%	$5.55
2005	Pennsylvania	17,220	1%	$5.55
2005	Wisconsin	69,520	2%	$5.50
2005	Totals	1,381,896	45%	$5.48

Source: USDA - National Agricultural Statistics Service; NASS - Data and Statistics - Quick Stats.
See: www.nass.usda.gov/Data_and_Statistics/Quick_Stats/

Great Lakes states' maritime commerce consumes about 170 million gallons of diesel fuel. Based on soybean production in 2005 it would take about 9% of the eight states' soybean production to satisfy total demand for converted biodiesel maritime use.

Table 3.7: Great Lakes States Soybean Production and Price Trends 2005 for Maritime

Year	Area	Production *(thousands of bushels)*	Possible total gallons from 2005 soybean production (thousands of gallons)*	Gallons forecast to achieve states' contribution to meet 2005 Great Lakes maritime demand
2005	Illinois	439,425	615,195	54,058
2005	Indiana	263,620	369,068	32,430
2005	Michigan	76,615	107,261	9,425
2005	Minnesota	306,000	428,400	37,644
2005	New York	7,896	11,054	971
2005	Ohio	201,600	282,240	24,801
2005	Pennsylvania	17,220	24,108	2,118
2005	Wisconsin	69,520	97,328	8,552
				170,000
2005	Totals	1,381,896	1,934,654	

*According to the US Department of Agriculture's (USDA) Farm Service Agency, one bushel of soybeans yields approximately 1.4 gallons of biodiesel.
Source: USDA - National Agricultural Statistics Service; NASS - Data and Statistics - Quick Stats. See: www.nass.usda.gov/Data_and_Statistics/Quick_Stats/; UMD BBER

3.2.3 Incentives

Federal Incentives. "The main drivers for increased biodiesel demand will be projected high energy prices and incentives provided by the EPACT05 and individual States. As indicated earlier, EPACT05 mandates that a minimum of 7.5 billion gallons of renewable fuels (ethanol and biodiesel) be used in the nation's motor fuel by 2012. The legislation provides other significant incentives, specifically: Extension of the biodiesel tax credit through 2008 at one cent per gallon for agri-biodiesel and ½ cent per gallon for biodiesel from other sources such as recycled fats and oils" [34]

Table 3.8: U.S. Biodiesel Tax Incentives

Biodiesel Tax Credit	Current rules: Excise tax credit of $1/gal agri-biodiesel & $0.50/gal waste-biodiesel owed on federal road taxes. Changes 1/1/06: 1¢/% biodiesel through December 31, 2008. IRS rules on changes have not been issued yet.
Biodiesel Station Tax Credit	Up to 30% of the total costs up to $30,000 of B20 (20% biodiesel) or greater fueling equipment installed as of January 1, 2006 through December 31, 2007. IRS rules have not been issued yet.

Source: www.biodiesel.org/news/taxincentive/

Table 3.9: U.S. Incentive Program Payments

Fuel	*Gallons Reported*	*Payments*
Q1 2006 Payment Information		
Ethanol Increase	178,906,818	$4,257,670
Biodiesel Increase	25,909,877	$4,252,737
Biodiesel Base	10,206,299	$0
Total Biodiesel	36,116,176	$4,252,737
Program Total	215,022,994	$8,510,407
Second Quarter, Fiscal Year (FY) 2006 Payment Information		
Ethanol Increase	202,515,048	$4,676,529
Biodiesel Increase	29,078,589	$3,834,885
Biodiesel Base	6,905,720	$0
Total Biodiesel	35,984,309	$3,834,885
Program Total	238,499,357	$8,511,414
Q3 2006 Payment Information		
Ethanol Increase	203,970,911	$5,029,630
Biodiesel Increase	50,273,774	$4,385,807
Biodiesel Base	14,380,439	$0
Total Biodiesel	64,654,213	$4,385,807
Program Total	268,625,124	$9,415,437
Cumulative 2006 Payment Information		
Ethanol Increase	580,996,189	$13,860,613
Biodiesel Increase	103,321,587	$12,165,625
Biodiesel Base	32,192,229	$0
Total Biodiesel	135,513,816	$12,165,625
Program Total	716,510,005	$9,415,437

Cumulative 2005 Payment Information		
Ethanol Increase	543,546,642	$65,947,726
Biodiesel Increase	50,922,590	$32,022,011
Biodiesel Base	15,263,152	$1,630,945
Total Biodiesel	66,185,742	$33,652,956
Program Total	609,732,383	$99,600,682

US Incentive Bioenergy Program Payments 2005-06
Source: http://www.fsa.usda.gov/FSA/webapp?area=home&subject=coop&topic=pai-be-05. See Programs and Initiatives; Bioenergy Program

Table 3.10: Great Lakes States Biodiesel Incentives

	MN	*WI*	*IL*	*IN*	*MI*	*OH*	*PA*	NY
Biodiesel Use Incentive		Yes						
AFV Acquisition Requirements	Yes	Yes	Yes			Yes	Yes	Yes
Blend Mandate	2%		2%					
Alternative Fuel Tax	Yes		Yes			Yes	Yes	
AFV Tax Deduction		Yes	Yes					Yes
Emissions Reduction Requirement	Yes						Yes	
LEV Acquisition Requirement		Yes						
Alternative Fuel Production Incentive				Yes	Yes			
Biodiesel Blending Credit				Yes				
Biodiesel Retailer Credit				Yes		Yes		Yes
Consumption Mandate								Yes

AFV = Alternative Fuel Vehicle LEV = Low Emission Vehicle

Source: U.S. DOE Energy Efficiency and Renewable Energy.
See: http://www.eere.energy.gov/afdc/laws/incen_laws.html

Minnesota incentives

Table 3.11: Minnesota Biodiesel Mandate

Biodiesel Blend Mandate	*Issue Date*	*Effect Date*	*Exemptions*	*Conditions to be met for the mandate*
Two Bills: H.F. 362 and S.F. 326. All diesel fuel sold or offered for sale in the state for use in internal combustion engines must contain at least 2% biodiesel fuel by volume.	2001	30-Jun-05	Jet fuel and aviation fuel	The state is able to produce more than eight million gallons of biodiesel fuel annually, or a federal action creates a $0.02 per gallon or greater reduction in the price of taxable fuel containing at least 2% biodiesel fuel sold in the state.

Source: U.S. DOE Energy Efficiency and Renewable Energy.
See: http://www.eere.energy.gov/afdc/laws/incen_laws.html

3.4.2 Risk

The following two tables highlight a simple SWOT analysis (strengths, weaknesses, opportunities and threats). The tables show both the producers (or suppliers) and the consumers (end-users). The SWOT analysis is typically used in the development of a feasibility study or business plan, and for marketing plans.

Producers:

Table 3.12: Producers' Risk Analysis

Strengths:	*Weaknesses:*	*Opportunities:*	*Threats:*
Less dependence on foreign oil	By-products from process of producing Biodiesel Glycerin	Many new opportunities will arrive for alternative fuel producers in the next couple of years with raising gas prices	Threat of higher up companies coming by and stealing business
High energy multiplier	Chemical and engineering skills are required	Rapidly emerging fuel	
Tax incentives			

Source: UMD BBER

Consumers:

Table 3.13: Consumers' Risk Analysis

Strengths:	*Weaknesses:*	*Opportunities:*	*Threats:*
Better lubricity	More expensive then petro-diesel	Alternative fuel choices	Better lubricity
Consumer incentives	Poor performance in cold temperatures (gelling)	Environmentally friendly	Higher prices

Source: UMD BBER

For the general economy of the U.S. (and the Great Lakes states) the strengths include reduction of dependence on foreign oil supplies, the benefits from reinvesting money in the U.S. and regional economy, stronger energy yield, and the advantage of net energy gain for biodiesel fuel compared to other fuels.

Table 3.14: Net Energy Gain (or loss) by Fuel

Fuel	Energy Yield	Net Energy (loss) or gain
Gasoline	0.805	(19.5 percent)
Diesel	0.843	(15.7 percent)
Ethanol	1.34	34 percent
Biodiesel	3.2	220 percent

Source: Energy Balance/Energy Life Cycle Inventory

By-products as market risk

Glycerol is a by-product from the transesterification process used in the formation of biodiesel. The glycerol produced during the transesterification process is about 50% pure. You can raise the purity level to 80%-90% by adding hydrochloric acid until the crude glycerol reaches a pH level that is acidic (around 4.5).

Market: Glycerol is a very common industrial product. Primary uses for glycerol include: food products, cosmetics, toiletries, toothpaste, explosives, drugs, animal feed, plasticizers, tobacco, and emulsifiers. There are color and odor standards for glycerol. Market pricing is based on glycerol that is 99.7% pure

The glycerol market will most likely become oversaturated in the next two years unless new uses for glycerol are discovered.

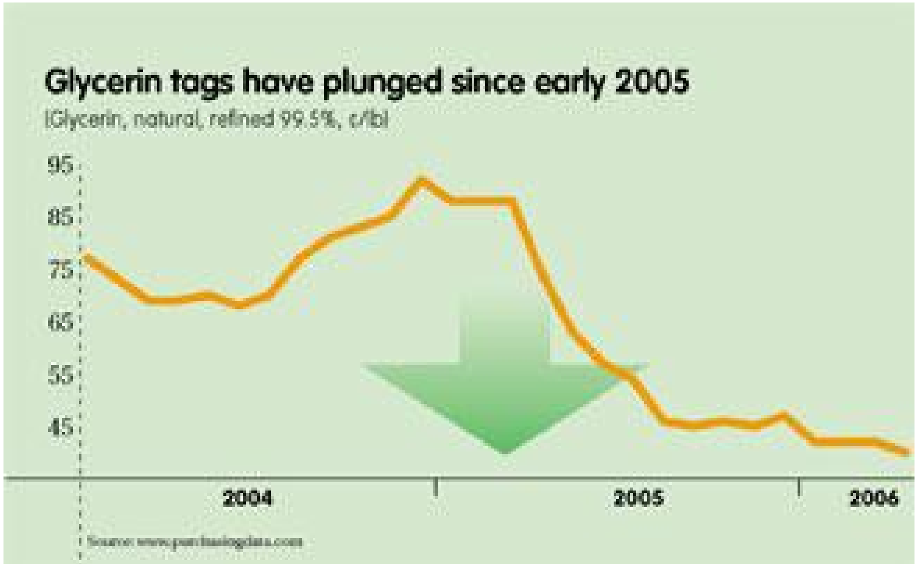

Figure 3: Glycerin as Market Risk
Source: "Glycerin Glut Sends Prices Plummeting," Gordon Graff. See www.purchasing.com/article/CA6341035.html

Summary. Volatile production and pricing associated with dynamic changes make modeling the biodiesel industry challenging. For instance, for business planning, a break-even analysis usually calculates a break-even point based on fixed costs, variable costs per unit of sales, and revenue per unit of sales. Business planning at the level of individual enterprise is suggested as further research, and assumptions of per-unit revenue and per-unit cost as well as assumption of other fixed costs would be estimated through a detailed sales forecast as well as profit and loss data from the industry. Given the aforementioned volatility of this market, as seen in the supply and demand trends in the foregoing data tables, average sales and costs may not be representative. Analysts predict, however, that costs will come down and prices will rise, making the break-even point a moving target. The variation in feedstock producers, type of feedstock, the possibility of increased demand from Great Lakes maritime fleets, "fixed" costs such as legislated incentives and regulations which can be amended or removed, and the technological advances in chemical processing and operations and end-use engineering can introduce new variables at any stage of the business model.

For the industry sector, it can be assumed that eventually the low cost producers will able to force the independent producers out of the industry and capture market share. Changes in the industry sector will have impacts for the regional economy. An estimate of economic impacts to the Great Lakes region from the introduction of more biodiesel production follows in Chapter 4.

Chapter 4: Potential Economic Impacts

Economic Impact Modeling: Great Lakes Biodiesel Plant

4.1 Biodiesel Plant Impact

The use of biodiesel fuel by Great Lakes commercial fleets is expected to increase in the future. By the end of the decade, the demand for biodiesel could be over 30 million gallons. Although over 23 million gallons of diesel sales were disclosed by two Great Lakes suppliers for this report, other Great Lakes producers would not reveal sales volume. Therefore total Great Lakes sales or production could not be reported. However it is possible to assume that a new 30 million gallons biodiesel facility could be supported as the Great Lakes fleets convert to biodiesel usage. We note from the previous chapter, data show that there was domestic demand for 2.1 billion gallons of distillate fuel oil for vessel bunkering in 2004. How quickly vessels will convert to biodiesel is unknown, but some of this demand could be supplied by increased biodiesel production. To meet this increased demand, a new Great Lakes Biodiesel Plant, of typical production capacity of 30 million gallons per year, should be feasible. Our assumptions as inputs to these models are constrained to projections for commercial maritime diesel consumption.

The following Great Lakes Biodiesel Plant is modeled to be a 30 million gallon production facility with a construction cost of $30.98 million. This study is not site-specific in that the findings are for a facility that can be located anywhere in the eight-state Great Lakes Region. There would be 37 workers employed at full capacity operations. These economic model specifications were selected to be conservative and well under estimated market demand. In reality, sales should be able to support additional Great Lakes plants to feed the expanding maritime demand. The economic impacts presented in this report are for a single plant.

The UMD Labovitz School research bureau (Bureau of Business and Economic Research) worked with biodiesel industry contacts in determining key assumptions in the development of the economic impact model. Regional and state data for the impact model for Value Added, Employment, and Output is supplied by IMPLAN. [35] From these data, Social Accounts, Production, Absorption, and By-products information are generated from the national level data and incorporated into the model.

The Study Area. This report measured the economic impact of a Great Lakes Biodiesel Plant on the eight-state Great Lakes region. The study area includes the states of Minnesota, Wisconsin, Michigan, Ohio, Illinois, Indiana, Pennsylvania and New York.

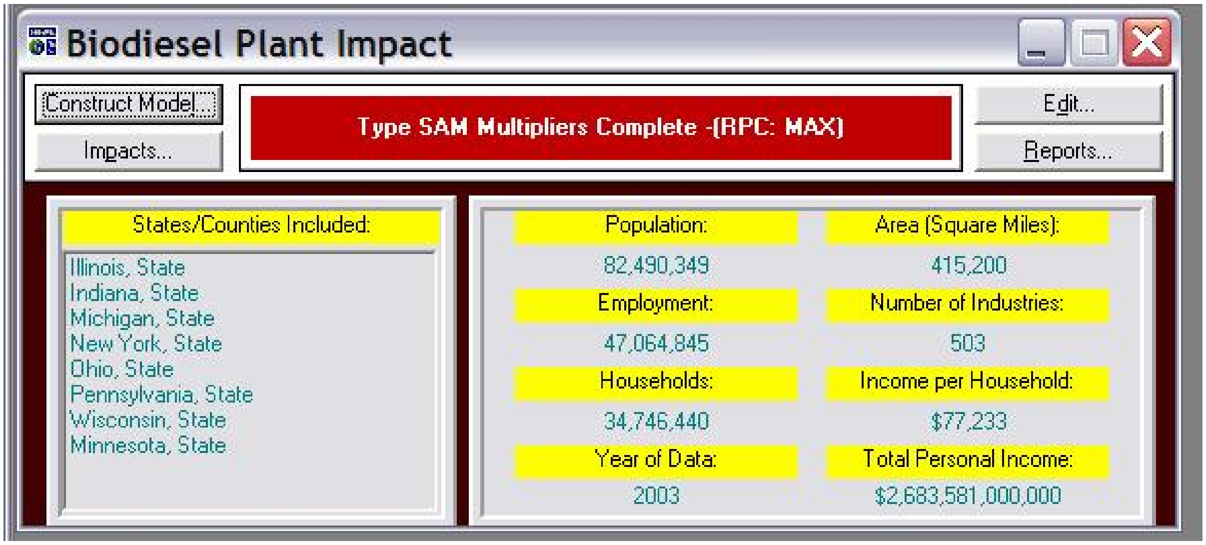

Figure 4: Great Lakes Region IMPLAN model information
Note: The most recent data available for modeling is year 2003. IMPLAN model deflators were used to report 2005 impacts.

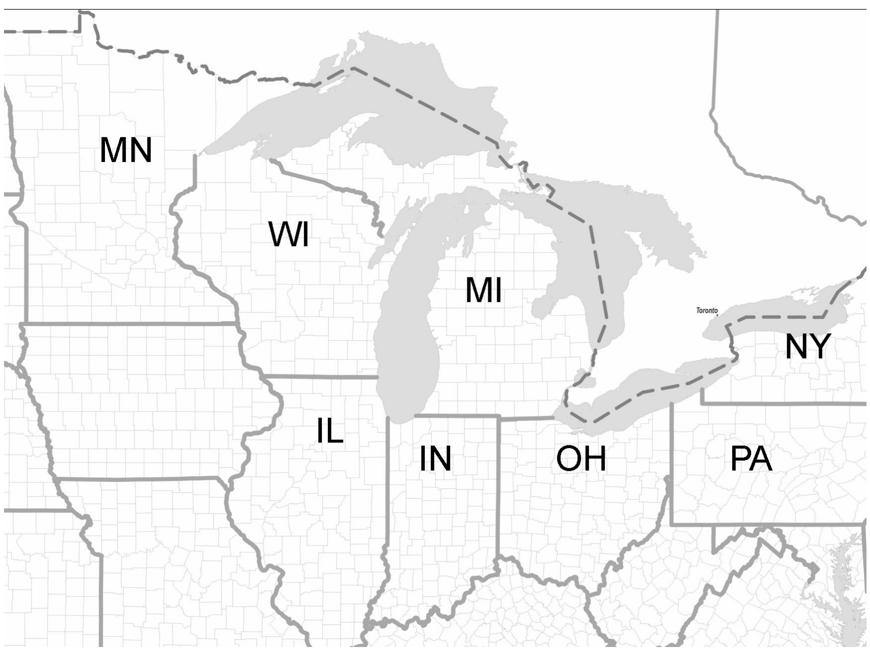

Figure 5: Great Lakes Study area including Illinois, Indiana, Michigan, New York, Ohio, Pennsylvania, Wisconsin, and Minnesota.
*Source:**www.amaps.com/,** by permission.*

Impact Procedures and Input Assumptions. There are two components to the IMPLAN system, the software and databases. The databases provide all information to create regional IMPLAN models. The software performs the calculations and provides an interface for the user to make final demand changes.

Comprehensive and detailed data coverage of the IMPLAN study areas by county, and the ability to incorporate user-supplied data at each stage of the model building process, provides a high degree of flexibility both in terms of geographic coverage and model formulation, in this case definition of the State of Minnesota and the eight-state Great Lakes Region study areas, and the definition of specific models for construction and operations. Using the IMPLAN software and data, BBER identified Great Lakes Biodiesel Plant's expenditures in terms of the sectoring scheme for the model, in producer prices, in historical dollars based on the year of the model, and applied those dollars spent within the two study area definitions given for the impact analysis.

Data:

IMPLAN data files use federal government data sources including:

- US Bureau of Economic Analysis Benchmark I/O Accounts of the US
- US Bureau of Economic Analysis Output Estimates
- US Bureau of Economic Analysis REIS Program
- US Bureau of Labor Statistics County Employment and Wages (CEW) Program
- US Bureau of Labor Statistics Consumer Expenditure Survey
- US Census Bureau County Business Patterns
- US Census Bureau Decennial Census and Population Surveys
- US Census Bureau Economic Censuses and Surveys
- US Department of Agriculture Crop and Livestock Statistics

IMPLAN data files consist of the following components: employment, industry output, value added, institutional demands, national structural matrices and inter-institutional transfers.

Impacts for these models use the most recent IMPLAN data available which is for the year 2003. The impact is reported in 2005 dollars, calculated with the built-in deflators of the modeling software.

Economic impacts are made up of direct, indirect, and induced impacts. The following cautions are suggested assumptions for accepting the impact model:

- IMPLAN input-output is a production based model
- Local or export based purchases that represent transfers from other potential local purchases are not counted.
- The numbers (from U.S. Department of Commerce secondary data) treat both full and part time individuals as being employed.
- Assumptions need to be made concerning the nature of the local economy before impacts can be interpreted.
- The IMPLAN model was constructed for the year 2003 (most recent data available). 2005 dollars are estimated by the model.

Definitions used in this report:

Measures

- **Gross Output** represents the value of local production required to sustain activities.
- **Value Added** is a measure of the impacting industry's contribution to the local community; it includes wages, rents, interest and profits.
- **Employment** estimates are in terms of jobs, not in terms of full-time equivalent employees. Hence, these may be temporary, part time or short term jobs.

Effects

- **Direct** – Initial new spending in the study area resulting from the project
- **Indirect** – The additional inter-industry spending from the direct impact
- **Induced** – The impact of additional household expenditure resulting from the direct and indirect impact.

Inputs provided for modeling the impact of the Great Lakes Biodiesel Plant

BBER modeled key assumptions to estimated expenditures for the proposed plant.

Construction

Materials: For the construction impact, BBER estimates the construction period is 18 months. Construction costs are estimated to be $20,654,014 for Year 1 and $10,327,007 in Year 2. For these dollars, percent of the total cost for materials, and the percent the eight-state region could supply of products and services for the project.

Labor: Costs for the 18 month timeline. IMPLAN model's estimates of wage rates and output per workers are used for labor costs.

Operations

For the operations impact, BBER provided estimates for such components as staffing and labor cost per year. BBER also projected the annual total output of the plant.

Industry sector adjustments

NAICS industry sector 311225 Fats and Oils Refining and Blending (IMPLAN sector 54) was used to model the potential Great Lakes Biodiesel Plant.

Production functions addressed in the gross absorption tables for the industrial sectors of the input-output modeling were adjusted to reflect estimates for the Great Lakes Biodiesel Plant construction and operations demand changes.

Benchmark (economic base) and impact (additional plant) models were constructed for the regional eight-state economy.

Employment

IMPLAN measures of direct, indirect, and induced employment follow from assumptions in the model concerning the estimation of permanent, temporary, and part-time employment.

Inflation

The most recent IMPLAN data available for modeling these impacts are for industry sectors in the year 2003. To more accurately represent costs and impacts 2003 impacts were then inflated to show 2005 dollars in the tables of this report, using the industry specific deflators from the IMPLAN model.

4.2 Findings: Construction Impacts and Operations Impacts

The following tables use the estimated values of Great Lakes Biodiesel Plant's direct expenditures on the Great Lakes Region as the original input for the model. Direct expenditures are listed in the column labeled, "Direct Effect." "Indirect Effect" measures the amount of increased spending between commercial, government and service industries, and "Induced Effect" measures the amount of increased spending by residential households. "Total Effect" is the sum of Direct, Indirect, and Induced Effects.

None of the tables that show Great Lakes Biodiesel Plant's yearly employment impacts add the total number of jobs-created across all 18 months of construction. Although IMPLAN required that each calendar year of construction be modeled as a separate event, each job created by construction activity may carry through all calendar years as the same job, and could thus be counted more than once. (For instance, the engineers, project managers, and installers that Great Lakes Biodiesel Plant will employ for Year 1 might still be employed by Great Lakes Biodiesel Plant in Year 2.)

Table 4.1: Summary
Great Lakes Biodiesel Plant Construction Impacts *Year 1 and 2*
(2005 Dollars)

Years	Value Added Totals $	Employment Totals	Output Totals $
Year 1	$22,606,772	365	$43,003,008
Year 2	$11,303,386	182	$21,501,504
Total	$33.910.158	N/A	$64.504.513

Construction. Table 4.1 summarizes the total effects of Great Lakes Biodiesel Plant's direct construction expenditures. The column on the right (labeled "Output Totals") shows that Great Lakes Biodiesel Plant's overall construction expenditure of $30.98 million (direct effect) is calculated to create an additional $34.5 million (indirect and induced effects) in further spending—resulting in economic activity totaling $64.5 million. The column on the left (labeled "Value Added Totals") measures the economic impact of the $14.3 million that the Great Lakes Biodiesel Plant is expected to use to pay for wages, rents, interest, and profits, and is estimated to result in an additional $19.7 million in commercial, government, services and consumer spending for a total of $33.9 million. The column in the center (labeled "Employment Totals") shows the total number of jobs that Great Lakes Biodiesel Plant will create in the Great Lakes Region by directly employing construction workers. The column shows that in Year 1 of construction, the Great Lakes Biodiesel Plant, which is expected to directly employ nearly 172 workers for construction projects, will result in the creation a total of nearly 365 jobs in the Region. In Year 2 the plant is expected to directly employ almost 86 workers for construction projects, which will result in the creation of more than 182 jobs in the region.

Table 4.2 shows the detailed impact of Great Lakes Biodiesel Plant's construction expenditures on the eight-state Great Lakes Region, over the 18 months of construction required to build Great Lakes Biodiesel Plant. As Table 4.2 illustrates, Great Lakes Biodiesel Plant expects to directly spend a total of $14.3 million on wages, rents, interest, and profits, which in turn will generate an additional $19.6 million in further spending (for a total of $33.9 million). Dividing total value added impact ($33.9 million) by direct -expenditures ($14.3 million) results in a value-added multiplier of 2.37. This means that for each dollar that Great Lakes Biodiesel Plant expends on wages, rents, interest, and profits related to construction, the economy will spend another $1.37.

Table 4.2: Value Added Impact from Construction, Great Lakes Region (2005 dollars)

Year	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
1	$9,515,959	$5,646,003	$7,444,810	$22,606,772
2	4,757,980	2,823,002	3,722,405	11,303,386
Total	$14,273,939	$8,469,005	$11,167,215	$33,910,158

Table 4.3 shows the economic impact of Great Lakes Biodiesel Plant's total output expenditures over two years of construction. Based on direct-expenditures of $30.9 million, Great Lakes Biodiesel Plant is expected to create $33.5 million in further spending activity in the region. The ratio of Total Effect to Direct Effect ($64.5 million to $30.9 million) gives us an output multiplier of 2.08 for the region.

Table 4.3: Output, Impact from Construction, Great Lakes Region (2005 dollars)

Year	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
1	$20,654,014	$9,989,732	$12,359,263	$43,003,008
2	10,327,007	4,994,866	6,179,631	21,501,504
Total	$30,981,021	$14,984,598	$18,538,894	$64,504,513

Table 4.4 shows the Great Lakes Biodiesel Plant's impact on employment in the eight-state Great Lakes Region, over the 18 months of plant construction. This table shows that every job that Great Lakes Biodiesel Plant creates during the construction period will result in the creation of additional jobs. Table 4.4 shows that the plant will create roughly 172 full-time, part-time, and temporary jobs during Year 1, which in turn will cause the creation of 193 jobs throughout other sectors. In Year 2 the Great Lakes Biodiesel Plant will create 86 new direct jobs and another 96 jobs will be created in the other sectors of the regional economy.

Table 4.4: Employment, Impact from Construction, Great Lakes Region, Year 1, Year 2

Year	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
1	172	80	113	365
2	86	40	56	182

Note: Employment impacts from construction cannot be summed for a total over the two year construction period.

(Note: Although each year of construction must be modeled as a separate event, each job created by construction activity can carry through all years, as the same job. For instance, engineers, project managers, and installers for year 1 can be in the same job in year 2.)

The following table, Table 4.5shows the employment impacts from construction for the Great Lakes Region comparing the two years of the construction period. Jobs are ranked by industry sector.

Table 4.5:, Employment Impacts from the Great Lakes Biodiesel Plant Construction, Great Lakes Region, Construction Year 1 and Year 2, by Industry Sector

Source: IMPLAN

YEAR 1	*Jobs*	*YEAR 2*	*Jobs*
Other new construction	171.6	Other new construction	85.8
Architectural and engineering services	19.5	Architectural and engineering services	9.8
Food services and drinking places	14.3	Food services and drinking places	7.2
Employment services	10.8	Employment services	5.4
Wholesale trade	9.4	Wholesale trade	4.7
Hospitals	5.7	Hospitals	2.8
Offices of physicians- dentists- and other health	5.5	Offices of physicians- dentists- and other health	2.7
Food and beverage stores	5.4	Food and beverage stores	2.7
General merchandise stores	5.0	General merchandise stores	2.5
Automotive repair and maintenance- except car wash	4.4	Automotive repair and maintenance- except car wash	2.2
Real estate	4.2	Real estate	2.1
Services to buildings and dwellings	3.7	Services to buildings and dwellings	1.9
Nursing and residential care facilities	3.6	Nursing and residential care facilities	1.8
Motor vehicle and parts dealers	3.4	Motor vehicle and parts dealers	1.7
Social assistance- except child day care services	3.0	Social assistance- except child day care services	1.5
Miscellaneous store retailers	2.8	Miscellaneous store retailers	1.4
Truck transportation	2.8	Truck transportation	1.4
Insurance carriers	2.6	Insurance carriers	1.3
Private households	2.6	Private households	1.3
Nonstore retailers	2.4	Nonstore retailers	1.2
Clothing and clothing accessories stores	2.4	Clothing and clothing accessories stores	1.2
Religious organizations	2.3	Religious organizations	1.2
Building material and garden supply stores	2.2	Building material and garden supply stores	1.1

Operations. Tables below show the economic effects that the Great Lakes Biodiesel Plant is expected to have on the Great Lakes Region during a typical year of operations. It is important to note that unlike the effects of Great Lakes Biodiesel Plant's construction expenditures, which are singular, this report assumes that the region will reap the benefits of the plant's typical-year operations expenditures annually for the life of the plant. The detailed operations impact findings below are reported for the study area, for the typical year, by measure, and by effect.

Table 4.6: Summary
Great Lakes Biodiesel Plant Operations Impacts
Typical Year (2005 Dollars)

Years	Value Added Totals $	Employment Totals	Output Totals $
Typical	$20,187,559	231	$79,035,226

Table 4.6 Summary shows the total economic effects of Great Lakes Biodiesel Plant's direct expenditures for operations on the Great Lakes Region. The right-most column (labeled "Output Totals") displays the economic effects that the plant's total expenditures for operations are expected to have on the region. In a typical year, the plant is expected to directly spend $48.4 million for operations, thereby generating a total of $79 million in economic activity across the region. The left-most column (labeled "Value Added Totals") shows the economic impact of the money that Great Lakes Biodiesel Plant expects to specifically use to pay for wages, rents, interest, and profits related to operations. During a typical year, it is predicted that the plant will directly expend $5.3 million to meet these costs, which should result in total spending of $20 million. The center column (labeled "Employment Totals") measures the number of jobs that Great Lakes Biodiesel Plant is likely to indirectly create by directly creating jobs in operations. Over a typical year, the plant is likely to employ 37 workers in operations, which should result in the creation of nearly 231 jobs in total across the Region.

Table 4.7 shows the detailed Value Added, Output, and Employment impacts for a typical year from operations activity related to the project. The Table shows that in a typical year, the plant is expected to directly spend around $5.3 million in value added expenditures, which should create a total of over $20 million in spending in the region.

Table 4.7: Impact from Operations, Great Lakes (2005 dollars)

	Direct Effect	*Indirect Effect*	*Induced Effect*	*Total Effect*
Value Added	$5,290,991	$9,988,629	$4,907,939	$20,187,559
Output	$48,409,100	$22,478,363	$8,147,766	$79,035,226
Employment	37	120	74	231

As illustrated by Table 4.7, the plant is expected to spend almost $48.5 million for operations in a typical year, which should result in a total of $79 million in spending region-wide. The economic multiplier is 1.63 ($79 million to $48.5 million).

Table 4.7 also shows the multiplier effect for employment, where the 37 direct employment jobs create related jobs in the larger economy totaling 194, and a total added employment in the region of 231. The following table, Table 4.8 shows Employment impacts from Operations for the Great Lakes Region broken out by industry sector. Total jobs are ranked by industry sector employment for the typical year.

Table 4.8: Employment Impacts from the Great Lakes Biodiesel Plant, Great Lakes Region Operations, Total Effect Ranked by Industry Sector

IMPLAN SECTOR	*Direct Effect*	*Indirect Effect*	*Induced*	*Total Effect*
Fats and oils refining and blending	36.9	0.3	0.0	37.2
Wholesale trade	0.0	16.8	2.2	19.0
Truck transportation	0.0	15.8	0.5	16.3
Food services and drinking places	0.0	3.4	7.1	10.5
Oilseed farming	0.0	6.1	0.0	6.1
Employment services	0.0	3.1	0.9	4.0
Real estate	0.0	1.9	1.7	3.5
Management of companies and enterprises	0.0	2.9	0.3	3.3
Automotive repair and maintenance- except car wash	0.0	1.8	1.4	3.2
Hospitals	0.0	0.0	2.9	2.9
Food and beverage stores	0.0	0.7	2.1	2.8
Offices of physicians- dentists- and other health	0.0	0.0	2.8	2.8
General merchandise stores	0.0	0.6	2.0	2.6
Monetary authorities and depository credit	0.0	1.5	0.6	2.2
Plastics plumbing fixtures and all other plastics	0.0	2.1	0.1	2.1
Nursing and residential care facilities	0.0	0.0	2.1	2.1
Rail transportation	0.0	2.0	0.0	2.1
Motor vehicle and parts dealers	0.0	0.5	1.5	2.0
Services to buildings and dwellings	0.0	1.3	0.6	1.9
Social assistance- except child day care services	0.0	0.0	1.7	1.7

4.3 Conclusions

This chapter applies an economic multiplier analysis and input/output model that was created in Minnesota by the Minnesota IMPLAN Group, Inc., and is used by other state governments and the USDA Forest Service, among others.

This economic analysis from the UMD Labovitz School's research bureau reports models for a Great Lakes Biodiesel production plant's direct effects, plus the additional spending effects that could be expected in the greater economy of the Great Lakes States.

With the completion of the construction phase it is estimated that the biodisel plant project will have spent a total of approximately $33.9 on construction, and that the Biodiesel Plant Project will have generated $64.5 million in spending across the Great Lakes Region over two years. The Value Added economic impact of the $14.3 million in expenditures for construction are expected to produce an impact of a total of $33.9 million for region. In Year 1 of construction, the Great Lakes Biodiesel Plant is expected to directly employ 172 workers for construction projects, which will result in the creation of 365 jobs in the Region. In Year 2 the plant is expected to directly employ 86 workers for construction projects, which will result in the creation of 182 jobs in the region.

When operations for the biodiesel plant reach typical year capacity, it is estimated to generate $48.4 million in direct spending across the Great Lake states. The indirect spending adds $22.5 million and $8.1 million (in induced spending). The total $79 million in new expenditures occurs annually for the life of the facility. During a typical year of operations, Great Lakes Biodiesel Plant will create over 194 full-time, part-time, and temporary jobs by directly employing nearly 37 people.

Special Considerations. Special considerations for interpreting these impact numbers: Regional indirect and induced effects are driven by assumptions in the model. One problem is that the assumptions can mask the true multiplier. This is especially true of the assumption of constant returns to scale: This assumption most affects induced effects and says that if I drink coffee, and my income increases, I will drink proportionally more than before. The amount of weight placed on the induced effects (the percentage of the total induced effect you would want to use) can be further analyzed with an in-depth impact study, involving much more specific data collection and more detailed analysis.

Construction costs may be larger due to commodity prices, banker's fees, and interest payments. Any differences would affect the estimates given here.

Readers are also encouraged to remember the BBER was asked to supply an economic impact analysis only. Any subsequent policy recommendations should be based on the "big picture" of total impact. A cost benefit analysis would be needed to assess the environmental, social, and governmental impacts.

4.4 Impact Comparisons

The comparison impacts provided in Table 4.9 show estimates for the impact of the Great Lakes Biodiesel Plant construction and operations on the U.S. as a whole, and the Great Lakes Region as discussed above.

Table 4.9: Great Lakes Biodiesel Plant Construction Totals Impact Comparisons, U.S., Great Lakes Region (2005 dollars); Year 1, Year 2

Source: IMPLAN

	Year	*1*	*2*	*Total*
United States	*Value Added Totals*	$33,169,760	$16,809,880	$49,979,640
	Employment Totals	529	265	NA
	Output Totals	$65,410,434	$32,705,217	$98,115,651
Great Lakes	*Value Added Totals*	$22,606,772	$11,303,386	$33,910,158
	Employment Totals	365	182	NA
	Output Totals	$43,003,008	$21,501,504	$64,504,513

Table 4.10: Great Lakes Biodiesel Plant Operation Totals Impact Comparisons, U.S., Great Lakes Region (2005 dollars); Typical Year

Source: IMPLAN	*Value Added*	*Employment*	*Output*
United States	$61,545,932	845	$181,918,066
Great Lakes	$20,187,559	231	$79,035,226

Chapter 5: Conclusions and Recommendations

Chemical and Mechanical Engineering conclusions

We investigated use of transesterified vegetable oils – biodiesel – as an alternative fuel for marine vessels. The project goals were to determine technical and economic viability of using biodiesel, investigate cheaper ways to produce it, and study engine performance using biodiesel. In addition, we studied the possibility of using fuel cells to enhance the energy efficiency of biodiesel and to reduce the adverse impact of ships to the marine environment.

Our investigation has led to the following findings:

1. Technically, biodiesel production has become routine. A continuous, economically efficient, production process is used by all the large volume producers. Smaller producers use batch reactors that allow flexibility in operation and use of raw materials. Unfortunately, like any other agri-based energy source, biodiesel requires some form of federal or state subsidy to be competitive with petroleum based fuel. Minnesota State Statute 239.77, which was adopted on March 15th, 2002, mandates 2% biodiesel fuel by volume in all diesel fuel sold or offered in Minnesota. The mandate officially took effect on September 30th, 2005, when sufficient biodiesel production within the state of Minnesota was available to support the mandate.
2. An enzyme – lipase – can be used as a catalyst in the production process instead of the usual catalyst, NaOH. Although more expensive, lipase holds the promise of faster reaction rate and more economic biodiesel production. An approach to further investigate this enzymatic production of biodiesel is outlined in the report body.
3. Our study also indicates that although ship-board use of fuel cells using biodiesel is energy efficient and environment friendly, but would be capital intensive and highly unlikely to be economical.
4. The use of biodiesel blends in diesel engines lowers overall engine emissions when compared to petroleum-based diesel. In addition, biodiesel is a renewable energy source, has better lubricity than diesel fuel, is nontoxic and biodegrades faster than diesel fuel, and can be used in current diesel engines with little or no modification. Environmental concerns, legislative measures, and continued research into improved methods of producing biodiesel are among the many factors contributing to the increased use of biodiesel. Both legislative and industrial efforts point to the use of up to 20% biodiesel blends (B20) in the near future.
5. The tendency of biodiesel to act as a solvent and its higher cold flow properties can lead to problems during operation. Individual ship systems should be reviewed to identify potential cold weather and material compatibility problems prior to the adoption of high biodiesel content blends as a fuel. There is a potential for fuel gelling problems in Great Lakes vessels over the winter lay up period due to long-term (2 month) storage of biodiesel blends at low temperatures. The development of a long-term low-temperature storage test to

verify that separation of the blend and preferential gelling of the biodiesel component does not occur is recommended.

Economic analysis conclusions

Volatile production and pricing associated with dynamic changes make modeling the biodiesel industry challenging. For instance, for business planning, a break-even analysis usually calculates a break-even point based on fixed costs, variable costs per unit of sales, and revenue per unit of sales. Business planning at the level of individual enterprise is suggested as further research, and assumptions of per-unit revenue and per-unit cost as well as assumption of other fixed costs would be estimated through a detailed sales forecast as well as profit and loss data from the industry. Given the aforementioned volatility of this market, as seen in the supply and demand trends in the foregoing data tables, average sales and costs may not be representative. Analysts predict, however, that costs will come down and prices will rise, making the break-even point a moving target. The variation in feedstock producers, type of feedstock, the possibility of increased demand from Great Lakes maritime fleets, "fixed" costs such as legislated incentives and regulations which can be amended or removed, and the technological advances in chemical processing and operations and end-use engineering can introduce new variables at any stage of the business model.

For the industry sector, it can be assumed that eventually the low cost producers will be able to force the independent producers out of the industry and capture market share. Changes in the industry sector will have impacts for the regional economy. An estimate of economic impacts to the Great Lakes region from the introduction of more biodiesel production follows in Chapter 4.

Economic analysis recommendations

The environmental and economic challenge driving the presentation of alternative fuels for the Great Lakes maritime fleet includes consideration of strategies not part of the scope of this analysis. Discussion of these strategies often starts with consideration of carbon credit trading for maritime biodiesel fuel alternatives and further research is recommended. Carbon credits, as a business asset, are one choice among many for fuel consumers to consider when planning for regulation compliance. Carbon credit trading is part of a larger incentive approach. The market gives consumers the opportunity to choose the most efficient means for reducing their carbon emissions. Benefit cost analysis presents a range of other compliance strategies, in some cases choices more efficient (less expensive, more productive) than mandating change to biodiesel fuel.

This research includes: review of the economics of emissions regulation strategies (of which carbon credit trading is one); study of appropriate caps on emissions levels; quantifying the variety of incentives that encourage consumer compliance with regulatory caps; and comparing economic benefit and cost to various stakeholders.

Studying incentives for fuel emissions regulation compliance can include:

1) **Biodiesel incentives:** demand and supply analysis (as in this report); feasibility or cost comparisons for implementing emerging marine designs; differences in total costs structure; incentive for adopting new technology, early adopters and newer infrastructure/vessels gain the most, aged vessels encouraged attrition.

2) **Application of "textbook" models already in the literature such as:** $S0_2$ program; successfully regulates the sulfur emissions in the power generation market; note producers choose to cut compliance cost by changing inputs – switching to low sulfur coal – rather than install costly technology i.e. "scrubbers".

Types of economic regulation currently part of this kind of benefit cost analysis: Permits (including how permits are business assets, and can be flexible); Standards; Credits; TBE standards (technology based emission).

In short, the economics of studying how carbon credits might work in the business economy of Great Lakes carriers requires an approach broader than the narrow focus on one strategy – for instance, carbon credit trading. Economics of the market make researchers cautious about dictating a change to a new technology (for instance mandating the use of biodiesel fuel in marine vessels) as this kind of strategy has been shown to be more expensive and less productive for capping emissions. It is best to let the consumer figure out what will get the greatest compliance for the least money. The biodiesel alternative is presented as one choice.

Fischer-Tropes? "Diesel is going to be very different in the future. It will be highly refined or will be a gas-to-liquid procedure like Fisher Tropes that will take the sulfur out all together," according to Dr. Roberta Nichols, retired from Ford Motor Company and Alternative Fuel Consultant, Speaking on "Gasoline Today: Which Fuels Will You Sell Tomorrow?" At The Colorado-Wyoming Petroleum Marketers Association Convention and Trade Show Jackson Hole, Wyoming August 21-24, 1999

"Fischer-Tropes technology produces synthetic diesel fuel that is almost miraculous. The problem with Fischer Tropes diesel is it has a low lubricity factor, causing wear and tear on the equipment. That is solved by blending it with biodiesel. A 5 to 7 percent of blend biodiesel solves the cetene problem," [as identified at the 23rd Annual Wyoming Forum Wyoming Business Alliance/Wyoming Heritage Foundation "Infrastructure in Wyoming: Bucking the Tide or Directing the Future?"November 17-18, 2005 – Casper's Parkway Plaza]:

> "Now, one thing that was skipped here is that there is a possibility to use coal by converting it to syngas, a mixture of C0 and H2, that is then fed to a Fischer-Tropes Catalyst. This allows the generation of, in the crudest form, of a synthetic crude oil. Fischer used this technology in World War II to help keep the Nazi war machine running. (Sadly he was a true believer and destroyed much of his research so the Allies wouldn't get it.) Back when I [was] in graduate school, it

was considered the hot topic, very much like nano-technology is today. The emphasis was to get away from making synthetic crude and design catalysts to make specific ranges of molecules. The neat thing is Fischer used coal and we have lots of that in untapped reserves that, at current efficiencies, would last centuries. Especially if the car fuels and heating energy came from other sources." http://www.technogypsy.net/May2005.htm

Possible work plan for analysis of emission control for Great Lakes vessels might include:

- Identification/quantification of total emissions of selected pollutants (CO_2,CO, PM, NO_X, HC, etc.)
- Application of Benefit-Cost Analysis to establish total emission targets for each pollutant
- Cost-effectiveness Analysis of various types of economic regulations to attain emission targets
- Establishment of TDP markets
- Impact on emissions and the shipping industry

Details of this work plan might include:

1) Estimation of total current emissions
   - Emissions per source (vessel)
   - Number of sources
   - Future projections

2) Establishing total emission targets
   - Benefits (improved environmental quality)
   - Costs (abatement, compliance, enforcement)

3) Types of economic regulation of emissions:
   - TBES (Technology-Based Emission Standards)
   - CAC standards (Command-And-Control standards)
   - Emission Charges/Taxes
   - TDP (Tradable/Transferable Discharge Permits/credits)

4) Establishment of tradable discharge permit markets
   - Total emission target
   - Distribution of permit/credits (historical, auction, etc.)
   - Trading mechanisms
   - Examples of "Cap-And-Trade" Programs (CAP):
     - SO_2 emissions (1990 Clean Air Act Amendments)
     - NO_X emissions (Ozone Transport Committee)
     - VOM (Volatile Organic Material) emissions (Chicago)

5) Impacts of emission control

- Emissions reduction/improvement in environmental quality
- Cost to shipping industry
- Incentives created (new technologies including the use of biodiesel fuel/engines)

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Appendix A: Demand and Supply Supporting Data

Appendix tables include:

Table A-1: Great Lakes States Soybean Production and Price Trends 1996-2006

Year	*Area*	*Production (thousands of bushels)*	*Price ($ per bushel)*
1996	Wisconsin	32,190	$7.24
1997	Wisconsin	44,000	$6.38
1998	Wisconsin	51,700	$4.85
1999	Wisconsin	59,800	$4.70
2000	Wisconsin	60,000	$4.45
2001	Wisconsin	58,090	$4.31
2002	Wisconsin	66,880	$5.35
2003	Wisconsin	46,760	$7.11
2004	Wisconsin	53,475	$5.70
2005	Wisconsin	69,520	$5.50
2006	Wisconsin	68,040	
1996	Illinois	398,925	$7.55
1997	Illinois	427,850	$6.56
1998	Illinois	464,200	$5.01
1999	Illinois	443,100	$4.75
2000	Illinois	459,800	$4.62
2001	Illinois	477,900	$4.55
2002	Illinois	453,650	$5.66
2003	Illinois	379,620	$7.51
2004	Illinois	495,000	$5.84
2005	Illinois	444,150	$5.50
2006	Illinois	482,400	
1996	Indiana	203,680	$7.34
1997	Indiana	230,550	$6.59
1998	Indiana	231,000	$5.05
1999	Indiana	216,450	$4.71
2000	Indiana	252,080	$4.61

Table A-1: Great Lakes States Soybean Production and Price Trends 1996-2006

Year	*Area*	*Production (thousands of bushels)*	*Price ($ per bushel)*
2001	Indiana	273,910	$4.42
2002	Indiana	239,455	$5.55
2003	Indiana	204,060	$7.67
2004	Indiana	284,280	$5.66
2005	Indiana	263,620	$5.50
2006	Indiana	284,000	
1996	Ohio	157,150	$7.42
1997	Ohio	190,960	$6.49
1998	Ohio	193,160	$4.99
1999	Ohio	162,000	$4.72
2000	Ohio	186,480	$4.63
2001	Ohio	187,780	$4.46
2002	Ohio	151,040	$5.59
2003	Ohio	164,780	$7.20
2004	Ohio	207,740	$5.74
2005	Ohio	201,600	$5.55
2006	Ohio	201,480	
1996	New York		
1997	New York		
1998	New York	3,977	$5.10
1999	New York	4,736	$4.20
2000	New York	4,356	$4.55
2001	New York	5,214	$4.55
2002	New York	4,608	$5.85
2003	New York	4,830	$7.80
2004	New York	6,708	$5.40
2005	New York	7,896	$5.20
2006	New York	7,896	
1996	Pennsylvania	11,400	6.65
1997	Pennsylvania	13,690	6.8
1998	Pennsylvania	15,800	4.95
1999	Pennsylvania	10,150	4.6
2000	Pennsylvania	16,555	4.37
2001	Pennsylvania	13,825	4.26
2002	Pennsylvania	10,140	5.9
2003	Pennsylvania	15,375	7.33
2004	Pennsylvania	19,550	5.43
2005	Pennsylvania	17,220	

Table A-2: Minnesota Soybean Production and Price Trends 1996-2006			
Year	*Area*	*Production (millions of bushels)*	*Price ($ per bushel)*
1996	MN	224.20	$5.45
1997	MN	255.45	$5.90
1998	MN	285.60	$7.26
1999	MN	289.80	$5.42
2000	MN	293.15	$4.32
2001	MN	266.40	$4.38
2002	MN	306.85	$4.42
2003	MN	238.40	$4.65
2004	MN	232.65	$6.20
2005	MN	306.00	$7.26
2006	MN	288.00	

Source: USDA - National Agricultural Statistics Service

Table A-3: Number of Biodiesel Alternative Refuel Sites by Great Lakes State, 2005

State	Biodiesel sites
Ohio	15
Michigan	12
Indiana	10
Illinois	6
Pennsylvania	3
Minnesota	2
Wisconsin	1
New York	0

Source: U.S. Department of Energy, Alternative Fuels Data Center web site, www.eere.energy/cleancities/afdc/infrastructure/station_counts.html, September 2005. See http://cta.ornl.gov/data/chapter6.shtml

Table A-4: Minnesota Producers of Biodiesel Fuel, 2006

	FUMPA	*SoyMor*	*MN Soybean Processors*
Feedstock:	80% soy, 20% poultry fat	Soybean oil	Virgin soybean oil
Catalyst:	Sodium Methoxide	Sodium Methylate	Sodium Methylate
Methanol/Ethanol:	Methanol	Methanol	Methanol
Feedstock Supplier:	Degussa, Ashland, South Dakota Soy, CBI	Confidential	Confidential
Glycerine price:	0.12	$0.092/lb	Varies
Customers:	Confidential	Confidential	Confidential
B100 $/gallon:	Average of $2.95	2.5	2.6
B99.9 $/gallon:		2.5	
Sales:	3MM gallon	30MM gallon	30MM gallon
Employment:	10 direct	28	10 FTE

Source: UMD BBER, by phone to producers

Table A-5: Great Lakes States Private and Commercial Non-Highway Use of Gasoline-2004

Oct-05	*(Thousands of gallons)*	*Table MF-24*
State	Marine	Total All Uses
Illinois	-	135,960
Indiana	12,957	91,475
Michigan	64,693	171,076
Minnesota	33,789	97,607
New York	56,399	161,640
Ohio	32,985	159,386
Pennsylvania	23,610	110,385
Wisconsin	28,980	109,577
Great Lakes States TOTAL	253,413	1,037,106
U.S. Total	1,005,029	4,626,471

Source: United States Department of Transportation - Federal Highway Administration
Private and Commercial Non-highway Use of Gasoline - 2004 1/By state including marine
http://www.fhwa.dot.gov/policy/ohim/hs04/htm/mf24.htm

Table A-6: Marine Diesel Sales, Corunna Refinery, Ontario, Canada

Year	*Fuel*		*in cubic meters*
2005			
	Marine Diesel		
		Total	55,400 m3

Source: Shell Canada Limited

Table A-7: Biodiesel Fuel, Duluth/Superior Shipping Demand, 2005

Blend	Gallons	Month/year
B2	650,000 gallons per month	10 month season
B2	6.5 million	annual consumption

Source: Murphy Oil

Table A-8: U.S. Waterborne Traffic by State in 2004

(Millions of Short Tons)

Great Lakes States	Domestic tons
Ohio	100.60
Illinois	113.10
Pennsylvania	65.80
New York	55.60
Michigan	64.40
Indiana	73.00
Minnesota	40.20
Wisconsin	31.90

The U.S.Waterway System Transportation Facts. See www.iwr.usace.army.mil/ndc/factcard/fc05/factcard.pdf

Table A-9: U.S. Biodiesel Production and Consumption Trends

Year	**Production (millions of gallons)**	**Consumption (millions of gallons)**	**B20 Price**
2000	2.00	2.00	1.44
2001	5.00	5.00	1.56
2002	15.00	15.00	1.30
2003	20.00	25.00	1.50
2004	25.00	30.00	0.00
2005	75.00		2.48