The Case for Biodiesel

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Executive Summary

Biodiesel is a renewable, environmentally friendly substitute for petroleum-based diesel fuel. It is produced from vegetable oils, animal fats, or waste cooking oils and fats, and can be used in existing diesel engines without any expensive modifications. Biodiesel can also be added to petroleum diesel to create a biodiesel blend with favorable performance attributes and environmental benefits roughly proportional to the biodiesel fraction. Biodiesel is safe, nontoxic, biodegradable, and reduces the emissions of many harmful compounds associated with the combustion of petroleum-based diesel. Because biodiesel is produced from domestically produced plant oils or waste fats, switching from petroleum-based diesel to biodiesel decreases dependence on foreign petroleum, reduces net greenhouse gas emissions, and provides tangible benefits for the domestic economy.

The potential benefits associated with biodiesel have driven national, state, and local governments to adopt policies that mandate or make it financially beneficial to produce and use biodiesel. The limited supply of fossil fuels and the increasing level of global environmental consciousness suggest that additional incentives and mandates are likely in the future. The most important federal mandates affecting biodiesel demand are EPAct, which requires specific levels of alternative fuel usage in federal fleets, and the Clean Air Act, which will require all diesel fuel sold for on-road use to be ultra-low sulfur by 2006. Biodiesel incentive programs can be delineated into two main categories—production and consumption. Both types of incentives lower the cost of biodiesel, eroding the price differential that currently prevents its widespread adoption. Two new Washington State laws, which passed by a wide margin in the state legislature, also provide state-level incentives for biodiesel production. It appears that there may be significant public policy momentum for biodiesel in the near future that combines local, state, and federal mandates and incentives into a sustainable business opportunity.

The market size for diesel in the US is approximately $47 billion, making even a small market share attractive as a potential business opportunity. When we look deeper into the inherent advantages for biodiesel over petroleum-based diesel fuel, we see that biodiesel has the potential to provide a more stable, regionally specific diesel source because of the wide variety of feedstock options available for producing biodiesel. The key issues for a start-up biodiesel business opportunity in an urban market are: abundant feedstock at an attractive price, minimized transportation cost, few delivery points, and a high customer value for bodiesel attributes. In urban areas, yellow grease currently provides the lowest cost sourcing option, but a cost comparison reveals that even biodiesel derived from yellow grease is still more expensive than petroleum-based diesel. In the Seattle area, 20% of Metro King County's diesel needs for ferry and Metro bus operation (approximately 1.8 million gallons) could be met by converting the 9-11 million gallons of yellow grease produced by Seattle restaurants each year into biodiesel. However, there are currently several barriers to entry into this market, most importantly that current EPAct mandates do not recognize biodiesel as an ultra-low sulfur diesel.

In other regions of the United States (and possibly on a longer time horizon in Washington State), and also in India and China, biodiesel produced from agricultural feedstocks grown in rural areas could provide a significant fraction of diesel fuel needs. Several companies in China are already producing large quantities of biodiesel from virgin rapeseed oil, and the climate of India might be favorable for producing substantial quantities of biodiesel from a native tree that produces large quantities of inedible oil. Future technological or political developments could potentially make all of these markets attractive, especially for a company with experience producing, distribution, and marketing biodiesel in a regional setting.

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1. Introduction

Vegetable oils have long been promoted as possible substitutes for diesel fuel. In fact, Rudolph Diesel, the inventor of the diesel engine, reportedly used peanut oil in his original engine designs around the turn of the century. Interest in vegetable oils as transportation fuels continued in various parts of the world for several decades, until the relative abundance of inexpensive fossil fuels after the conclusion of World War II made research into diesel substitutes unnecessary. The OPEC embargo of the 1970s revived interest in alternative fuels, including vegetable oils as fuel for diesel engines, although interest in alternative energy subsequently waned in the United States and, to a lesser extent, other industrialized nations.

Recently, environmental and political concerns have prompted a resurgence in the use of biodiesel and other alternative fuels. In 1991, the European Union placed severe restrictions on the sulfur content of transportation fuels and proposed a 90% tax deduction for the use of biodiesel. Subsequently, many biodiesel manufacturing plants were built to convert rapeseed oil, the most common oilseed plant grown in Europe, into low-sulfur biodiesel fuel. European motorists currently consume over a quarter billion gallons of biodiesel fuel annually. Interest in biodiesel is also growing in the United States thanks to recent public policy decisions that mandate increased alternative fuel usage and require on-road diesel fuel to meet ultra-low sulfur requirements by 2007. Several demonstration programs are currently using biodiesel to fuel buses, trucks, construction and mining equipment, and motor boats, and Minnesota recently passed legislation requiring that all diesel fuel sold for on-road use include at least two percent biodiesel. However, the total volume of biodiesel produced in the United States remains only a small percentage of total diesel consumption, and significant political and economic hurdles must be addressed before biodiesel can provide a significant fraction of domestic diesel fuel consumption.

In this paper, we describe the biodiesel production process, analyze the social, political, and economic factors that have prompted people to consider replacing petroleum-based diesel with biodiesel, and explore the potential for biodiesel adoption in three broad markets: the United States, China and India. Public and private fleet vehicles represent a particularly attractive market for biodiesel, especially in the United States, although future demand is dependent on public policy decisions. Since one of the key values provided by biodiesel is the regional nature of its production, we have also chosen to look specifically at the market potential for biodiesel in Seattle and Washington State.

Value Proposition

Biodiesel provides immediate environmental and economic benefits to regions willing and able to adopt its use, and offers an attractive business opportunity in regions with abundant feedstocks, high diesel prices, and a favorable political climate. As discussed in detail in Sections 6 and 7, producing biodiesel from yellow grease and selling it to public and private fleets could represent an immediate business opportunity in both the Seattle area and several Chinese provinces, while producing biodiesel from agricultural feedstocks and/or developing a distribution network for biodiesel could represent an excellent long-term business venture in Washington State or in India. However, barring any radical changes in feedstock technology, the viability of biodiesel as an alternative fuel depends crucially on the price of petroleum-based diesel competitors and political developments at the local, national, and international levels.

Why does biodiesel represent an attractive business opportunity?

- Large Potential Market – Estimated diesel use in the United States was 36 billion gallons in 2001, which corresponds to a market size of approximately $47 billion, and includes a wide cross-section of economic activities. China and India also have large diesel markets.
- Environmental Benefits – Biodiesel reduces or eliminates tailpipe emissions of sulfur, hydrocarbons, carbon monoxide, particular matter, and other hazardous compounds, and also reduces net greenhouse gas emissions, which offers an incentive for cities with air quality problems, countries/regions concerned with global warming, or businesses concerned with either of these problems to adopt biodiesel
- Economic and Security Benefits – Replacing petroleum-based diesel with biodiesel decreases our dependence on foreign oil and promotes national energy security; using agriculturally-based transportation fuels also directly benefits the domestic economy by reducing outlays for foreign petroleum and providing new markets for agricultural products.
- Low switching costs – Virtually all diesel engines can use biodiesel, the biodiesel production process is well developed, it can be blended with conventional diesel fuel in any fraction, and the low toxicity and safety of biodiesel means that infrastructure and distribution costs would be lower than for many other alternative transportation fuels.

2. Background

2.1 Biodiesel production technology[1]

The high viscosity of vegetable oils and animal fats, which results in poor fuel atomization and fuel injector blockage, makes them best used as a transportation fuel after conversion to mono-alkyl esters of long chain fatty acids, which are commonly referred to as biodiesel. In the United States, fuel-grade biodiesel conforms to ASTM D6751 and is registered with the Environmental Protection Agency as a legal motor fuel. Biodiesel can also be blended with conventional petroleum-based diesel in any fraction; the resulting blend is referred to as "BXX", where "XX" is the percentage biodiesel.

Biodiesel can be produced from a variety of oil or fat feedstocks using several well-known industrial processes, the most common of which is base catalyzed transesterification with alcohol. In the most common implementation of the transesterification process, 7.4 pounds of fat or oil are reacted with methanol in the

[1] Unless otherwise noted, the material in this section was obtained from the Biodiesel Board: www.biodiesel.org

presence of a sodium or potassium hydroxide catalyst to produce one gallon of biodiesel and ten ounces of glycerine. It is worth noting that glycerine is a valuable by-product can be sold for use in soap production, and that both the catalyst and any excess methanol can be recovered for reuse, so that nothing is wasted in the production process (see Figure 1). The base catalyzed reaction is also more economical than other production methods because the reaction has a very high conversion rate (98%), generally requires only a single production step, and proceeds quickly at relatively low pressure (20 psi) and temperature (150 F).

The feedstocks commonly used for biodiesel production include rendered animal fats, recycled cooking oils and fats, and several different oilseed crops. Most of the biodiesel produced in the United States is made using soybean oil. Rapeseed oil, a close cousin of canola oil, dominates the biodiesel industry in Europe. Only a small amount of biodiesel is produced using waste cooking fats and oils, although many rendering companies and state and foreign governments have recently started investigating biodiesel production from yellow grease and animal tallow (Judd 2002; Groschen 2002; Fred Wellons, personal interview). We examine yellow grease in more detail in Sections 4 and 5.

Recent advances in biodiesel feedstock research have focused on the mustard plant and bioengineered algae strains. Mustard seeds have a very high oil content and require less water and agrochemicals to produce than conventional feedstocks, are not consumed by animals or humans (an important consideration when considering the economics of feedstock supplies), and the unused portions of the mustard seeds can be used as an organic crop fertilizer, which could make mustard seeds an attractive dedicated feedstock for biodiesel production in the future (Tyson et al., 2002). Biodiesel can also be produced from algae strains that have been engineered to have a high oil content and grown using high-density aquaculture (which would reduce the displacement of other agricultural products from arable farmland), but interest in algal biodiesel has waned because bioengineed algae is much more expensive to grow and process than traditional oilseed crops (DOE Report, 1998).

One of the major strengths of biodiesel compared to other alternative fuels is that it can be produced from a wide variety of feedstocks, which gives biodiesel producers and suppliers temporal and spatial flexibility in production. Different feedstocks could be used in different regions or at different times of year depending on price and availability.

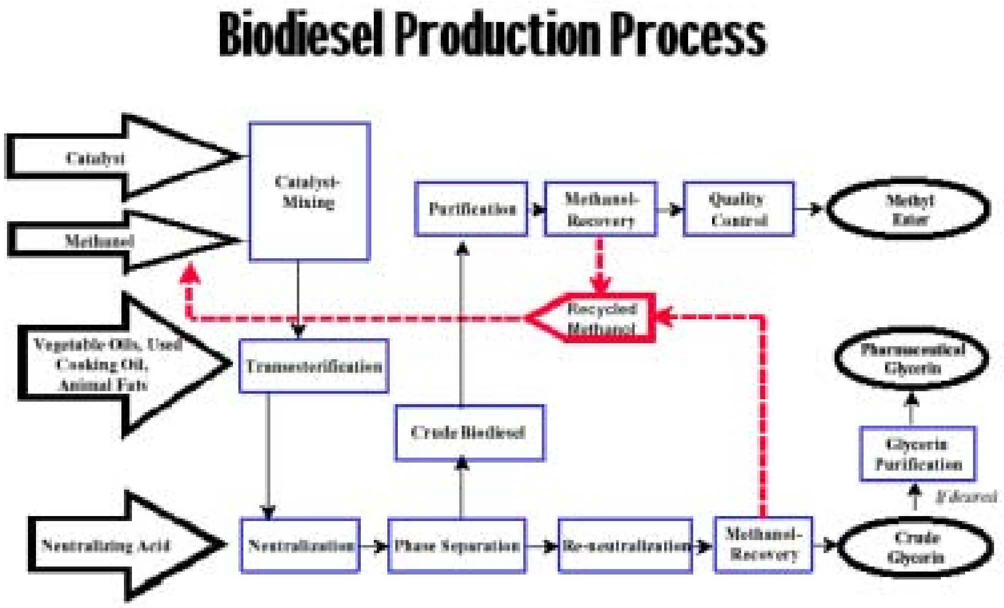

Figure 1: Schematic illustrating the biodiesel production process[2]

2.2 United States biodiesel production statistics

According to the National Biodiesel Board, biodiesel has been growing strongly since 1999 with production quantities reaching an estimated 10-15 million gallons in 2002 (Figure 2).

There are currently more than a dozen companies actively producing and marketing biodiesel in the United States, the majority of which is produced using virgin soybean feedstocks and is used for biodiesel blends, the most common of which is B20 (20 percent biodiesel). It has been estimated that the current production capacity for biodiesel from oilseed feedstocks is between 60-80 million gallons, although most biodiesel production facilities are modular, so production capacity could be doubled or tripled in less than 12 months if there were a significant increase in biodiesel command. There are also approximately 200 million gallons on excess capacity available within the oleochemical industry that could theoretically be used to produce biodiesel from waste oils and fats or other feedstocks that do not require mechanical separation of oils from seeds.

[2] Adapted from an untitled report found at www.biodiesel.org

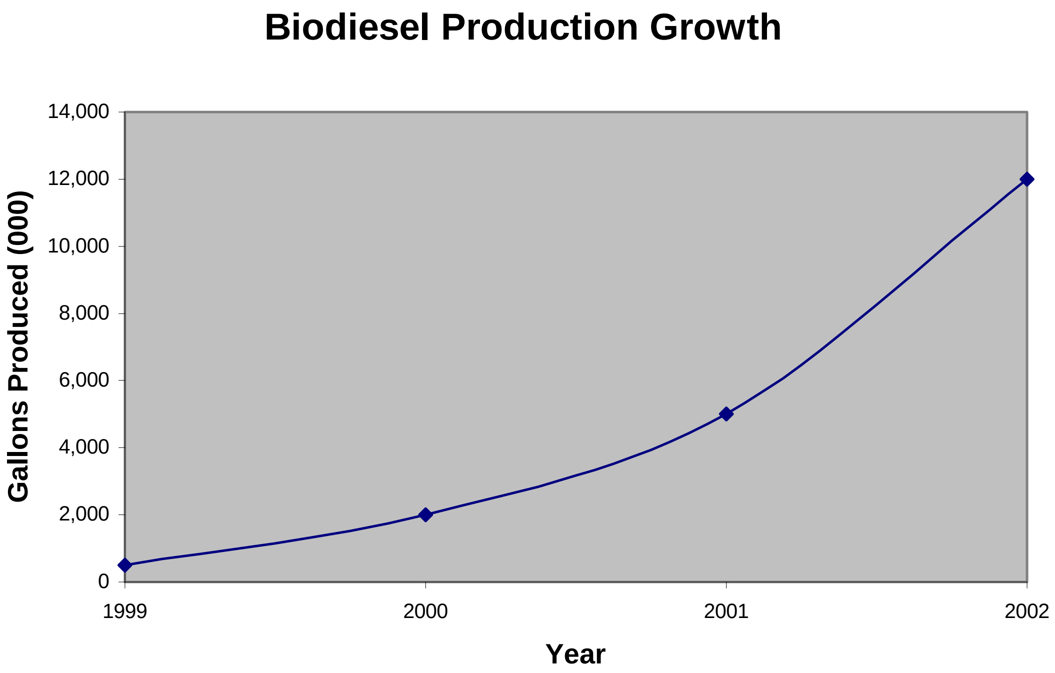

Figure 2: Growth in United States biodiesel production, 1999-2002[3]

2.3 Environmental benefits of biodiesel [4]

There is a large body of literature describing the environmental benefits obtained when petroleum-based diesel is replaced with biodiesel for use as a transportation fuel. The exact reduction in emissions obtained by switching from petroleum-based diesel to biodiesel is dependent on a number of factors, including the engine type and age, the operating conditions, the feedstock used to produce the biodiesel, the percentage of biodiesel in the blend, and the characteristics of the crude oil use to produce the conventional diesel that is being replaced; in most cases the differences between different fuels, engines, etc. are not very large, and the statistics below reflect the average environmental benefits reported. It should also be noted that the emission benefits associated with a biodiesel blend are generally roughly proportional to the percentage biodiesel in the blend (i.e. using B20 yields approximately one-fifth of the benefit obtained using pure B100 biodiesel).

Biodiesel is the only alternative fuel to successfully complete the EPA's Tier I and Tier II Health Effects testing under Section 211(b) of the Clean Air Act. The Tier I testing demonstrated significant reductions in most currently regulated exhaust emissions, in addition to many unregulated emissions, while the Tier II testing demonstrated that biodiesel is safe and nontoxic for humans (it is less toxic and safer to transport than

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[3] Personal interview with Austin McKeehan of the National Biodiesel Board.
[4] All of the statistics cited in this section were obtained from EPA Draft Technical Report 420-P-02-001 or USDA/DOE Report NREL/SR-580-24089

table salt). There have also been several "lifecycle" analyses of biodiesel that document substantial improvements relative to petroleum-based diesel in terms of the amount and type of wastes generated by the production and consumption of each fuel.

Biodiesel contains zero sulfur, so sulfate and sulfur dioxide (the two largest contributors to acid rain) are completely eliminated from the tailpipe emissions of vehicles using pure (B100) biodiesel. The tailpipe emissions of pure biodiesel also have 67% fewer unburned hydrocarbons (including 80% fewer polycyclic aromatic hydrocarbons, which are potentially carcinogenic, and 50% fewer speciated hydrocarbons, which contribute to smog formation), 48% less carbon monoxide (which is toxic), and 47% less particulate matter (which causes respiratory problems) than those of low-sulfur (#2) petroleum-based diesel. These benefits are even larger when biodiesel is compared to regular diesel fuel, which is not affected by the 1990 Clean Air Act ammendments and is commonly used in boats, farm equipment, and off-road vehicles. Biodiesel does produce a slight increase (10%) in nitrous oxide (NOx) tailpipe emissions relative to conventional diesel fuel, but the total smog forming potential is much lower for biodiesel and the absence of sulfur dioxide from biodiesel exhaust is expected to allow NOx control technologies (similar to the catalytic converter) to be adapted to diesel engines.

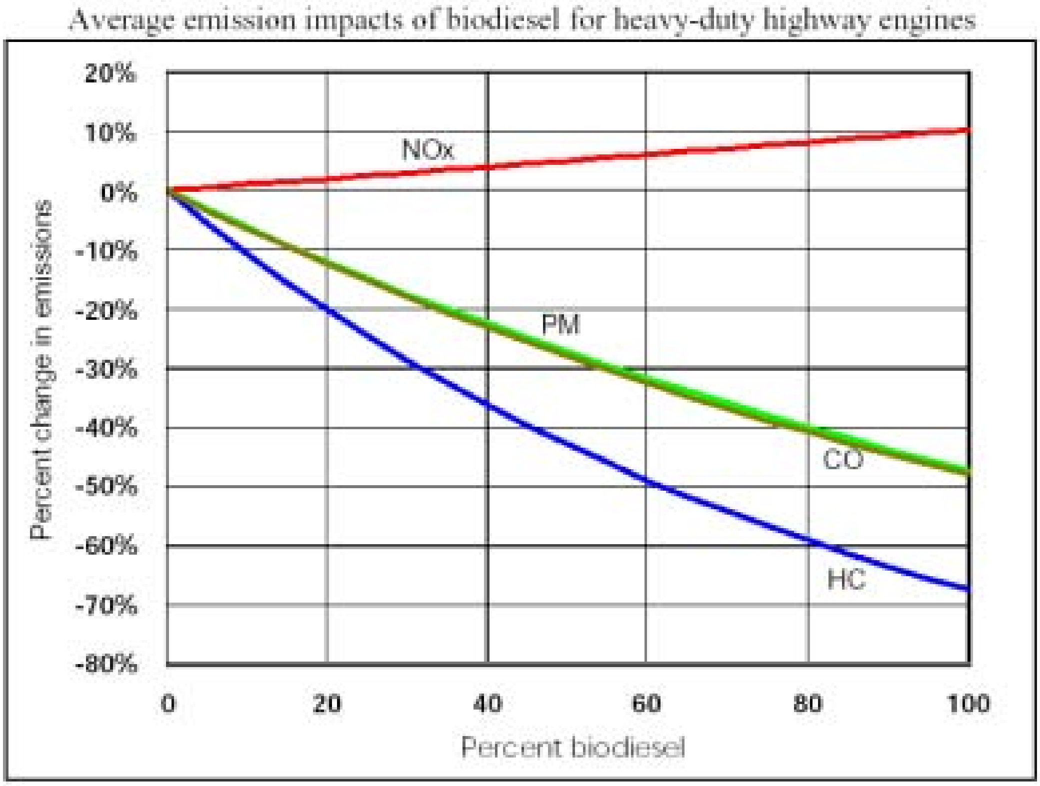


Figure 3: Biodiesel emission changes relative to petroleum-based diesel[5]

[5] EPA Draft Technical Report 420-P-02-001

Lifecycle analyses indicate that biodiesel also offers substantial "cradle-to-grave" environmental benefits relative to petroleum-based diesel. Biodiesel and conventional diesel are almost identical in terms of their efficiency converting a raw energy source (i.e. petroleum or soybean oil) into a fuel product. However, the production and consumption of pure (B100) biodiesel uses 95% less petroleum than the production and consumption of conventional diesel (the remaining 5% accounts for the natural gas used to produce the methanol used in the biodiesel production process and petroleum-based fuels used to power the farm equipment, transportation vehicles, and production equipment used to grow, transport, and transform the biodiesel feedstocks into fuel-grade methyl esters). Expressed in terms of fuel energy produced per unit of fossil fuel energy consumed, pure biodiesel yields 3.2 units of fuel energy for every unit of fossil fuel energy consumed over its life cycle, compared to 0.83 units for petroluem-based diesel, which highlights the "renewable" nature of biodiesel.

It should be noted that these numbers are based on national averages for petroleum consumption and soybean oil production and conversion, so actual improvements might be even higher for regions with low transportation costs and/or high levels of renewable energy usage. It should also be noted that lifecycle analyses indicate smaller "cradle to grave" reductions in the specific pollutants mentioned in the tailpipe emission inventory above; this is mainly because fossil fuels are used to generate the energy used in the production, processing, and transportation of biodiesel and its feedstocks, and also because current oilseed feedstock processing technologies also fail to capture hydrocarbon emissions. Presumably, if biodiesel is adopted on a widespread basis, improvements in biodiesel production facilities and diesel engine design could mitigate some of these problems, and the use of renewable energy sources for electricity generation would further increase the improvements noted above.

Using biodiesel derived from plant oils also yields a substantial improvement in the net amount of carbon dioxide released to the environment, as well as a smaller reduction in methane emissions. Carbon dioxide and methane are greenhouse gasses that contribute to global warming. Unlike fossil fuels, which only add carbon dioxide to the atmosphere, soybeans and other plant feedstocks for biodiesel recycle carbon dioxide from the atmosphere via photosyntheses. Lifecycle analyses indicate that replacing petroleum-based diesel with B100 biodiesel yields a net 78% reduction in carbon dioxide emissions and a 2-3% reduction in methane emissions. Although no comprehensive lifecycle analyses have been performed for biodiesel producted from yellow grease or other recycled feedstocks, it is expected that biodiesel produced from waste oils and fats would also yield a net decrease in carbon dioxide emissions (since ultimately these fats and oils were derived from photosynthetic activity), although these reductions are probably lower than those obtained using virgin oil feedstocks.

2.4 Biodiesel performance[6]

Biodiesel has a higher cetane number[7] and offers similar power, torque, and fuel economy characteristics to low-sulfur (#2) petroleum-based diesel fuel without major engine modifications. Biodiesel also provides significant lubricity[8] improvement over petroleum diesel fuel, even for very low blends (e.g. B01 or B02), which is an important consideration since low-sulfur petroleum-based diesel has very low lubricity and generally requires a lubricity additive.

The two main performance problems reported with using biodiesel in diesel engines are cold weather performance and rubber degradation. Cold weather can cloud or even gel any type of diesel fuel, and these problems seem to be particularly acute when using *either* low-sulfur diesel or biodiesel. The most practical solutions to these problems are to blend the fuel with conventional (#1) diesel or a cold flow additive, use dedicated fuel heaters to keep the fuel above the cloud point, and/or store vehicles and fuel in or near a building when the weather is cold. Additional research is needed in this area before biodiesel can be adopted on a widespread basis in cold-weather climates.

Methyl esters can also soften and degrade certain kinds of elastomers and natural rubber compounds over time, so using biodiesel could impact fuel system components (most notably fuel hoses and fuel pump seals) over time. Most vehicles made after the 1990 Clean Air Act amendments (which mandated the use of low-sulfur diesel—see the following section) use components that are compatible with biodiesel, but owners of older vehicles should have their engine components regularly inspected or replaced after switching from petroleum-based diesel to biodiesel. Methyl esters can also dissolve fuel tank deposits in older vehicles, which can clog the fuel filter, although this is an inexpensive part that is easy to replace during regularly scheduled vehicle maintenance.

Property	Biodiesel	Petroleum Diesel
		(CARB low- sulfur diesel)
Cetane Number	51 - 62	44 - 49
Lubricity	Much greater than diesel comparable to all lubricants	Low- Sulfur fuel has very low lubricity factor
Biodegradability	Readily biodegrades	Poor biodegradability
Toxicity	Essentially non- toxic	Highly toxic
Oxygen	Up to 11% Free Oxygen	Very low
Aromatics	No aromatic compounds	18-22%
Sulfur	None	0.05%
Cloud Point	Slightly worse than diesel	
Flash Point	300-400 Deg. F	125 Deg. F
Spill Hazard	None	High
Material Compatibility	degrades natural, butyl rubber	No effect on natural, butyl rubber
Shipping	Shipped as non- hazardous and non- flammable material	Hazardous
Heating Value	2- 8% higher than diesel	
Renewable Supply	Renewable Fuel	Non- Renewable
Supply	U.S. est 2 billion gallons/yr	Limited
Energy Security	Domestic raw materials	Mix of domestic and imports
Alternative Fuel	Yes	No
Production Process	Chemical Reaction	Reaction + Fractionation

[6] All of the material in this section was obtained from EPA Draft Technical Report 420-P-02-001
[7] cetane is the diesel equivalent of octane
[8] lubricity describes the "slipperiness" of the fuel; higher lubricity decreases engine wear and promotes longer engine life, although biodiesel has not been used long enough for this effect to be documented

Figure 4: Summary of the differences between biodiesel and petroleum-based diesel[9]

3. Public Policies Affecting Biodiesel

The environmental and public health benefits associated with the production and use of biodiesel has driven national, state, and local governments to adopt policies that mandate or strongly encourage biodiesel. There are currently two specific federal mandates within the United States that support the business case for biodiesel production. One directly focuses on getting biodiesel into the fuel tanks while the other forces current petroleum-based diesel producers to deliver ultra low sulfur diesel (ULSD) to the pump. Additional efforts at the state and local level to move society away from global warming inducing fossil fuels point to potential future mandates. A well-planned local biodiesel production facility may be uniquely positioned to fulfill the demand for alternative fuels that result from these regional mandates.

3.1 Energy Policy Act (EPAct)

The 1992 *Energy Policy Act* (EPAct) seeks to accelerate the use of alternative fuels in the transportation sector. The U.S. Department of Energy's (DOE) primary goals are to decrease the nation's dependence on foreign oil and increase energy security through the use of domestically produced alternative fuels. According to the legislation, DOE's mission was to replace 10% of petroleum based motor fuels by the year 2000, and then increases the goal to 30% by 2010.

EPAct covers only specific subsets of the cars currently operated within the United States. The policy covers fleet vehicles that satisfy specific criteria. The criteria include:

- Fleets must be federal, state and fuel provider (utilities and alternative fuel suppliers) fleets that own, operate, lease or control at least 50 light-duty vehicles (8,500 lbs or less);
- Of the fleet vehicles, 20 or more must be operating primarily within any affected area; and
- The vehicles must also be centrally fueled or capable of being centrally fueled.

Affected areas are delineated by Metropolitan Statistical Area (MSA) and Consolidated Metropolitan Statistical Area (CMSA) definitions. These are cities or areas that had a population of at least 250,000 at the time of the 1980 U.S. census. Although municipal and private fleets have been considered for mandates, to date no final rule has been issued for these segments.

The fleets covered under EPAct may attain compliance by demonstrating they have met targets for alternative fuel vehicle purchases. Vehicles qualify if they are

[9] www.oceanairenvironmental.com

enabled to use several specific types of alternative fuels. Biodiesel is used in traditional diesel engines, requiring additional stipulations that qualify use of the cleaner burning fuel under the act. A mandated fleet can meet up to one-half of its vehicle purchase requirements through the use of biodiesel or biodiesel blends containing a minimum of 20 percent biodiesel. For every 450 gallons of biodiesel purchased for use in vehicles weighing in excess of 8,500 lbs, a fleet is allocated one alternative fuel vehicle acquisition "credit" under EPAct. The following table lists the vehicle purchasing requirements according to the EPAct:

Year	Federal (% or Number of AFVs)	State (% of AFVs)	Fuel Provider (% of AFVs)
1993	5,000 AFVs		
1994	7,500 AFVs		
1995	10,000 AFVs		
1996	25%		
1997	33%	10%	30%
1998	50%	15%	50%
1999	75%	25%	70%
2000	75%	50%	90%
2001	75%	75%	90%
2002	75%	75%	90%
2003	75%	75%	90%
2004	75%	75%	90%
2005	75%	75%	90%
2006	75%	75%	90%

Table 1: EPAct purchasing requirements for federal fleets

3.2 Highway Control of Air Pollution From New Motor Vehicle

In January 2001 the EPA issued final rules (66 FR 5063) that require oil refiners to reduce sulfur content in highway diesel fuel by 97% to a level no greater than 15 ppm by June 2006. To smooth transition to the new fuels and avoid inefficient capital investment, the rules allow for refiners to produce up to 20% of their highway diesel fuel at the 500 ppm level until June 2010, at which time 100% of the fuel must meet the 15 ppm standards. The fuel controls are coupled with the required installation of advanced control technologies on heavy-duty diesel vehicles in 2007. EPA believes that this rule, written under the administrative authority of the Clean Air Act, will lower emissions of particulate matter and NOx by 90 and 95% respectively.

There are two disadvantages to ultra-low sulfur diesel fuel that increase the attractiveness of biodiesel—ULSD's higher cost per gallon compared to current highway diesel and increased fuel pump and injector wear. According to the Equipment Manufacturers Institute (EMI), the higher pump price for ULSD will make a 20 percent biodiesel blend (B20) - which typically costs 20 to 40 cents more per gallon than conventional No. 2 diesel - more cost-competitive. In addition, wear and tear on a vehicle's engine can substantially increase the total cost of ownership. Fleets with a large number of vehicles will need an efficient method for mitigating ULSD fuel pump and injector wear. Augmenting conventional diesel and ULSD fuel with just one or two percent biodiesel can effectively restore its lubricity, according to tests by Stanadyne Automotive Corp., the nation's largest independent fuel injection manufacturer. Several biodiesel-based diesel supplements are made for that purpose.

The Washington State legislature is aware of the ULSD mandate and creating biodiesel programs that take advantage of the momentum for alternative fuels. For example, HB 1243 directs the Superintendent of Public Instruction to "conduct a pilot project using biodiesel in school buses in communities with poor air quality during the 2004 school year." According to the law, at least seventy percent of the buses fueled with ultra low sulfur diesel during the 2003 school year must be fueled with B20. Although this sounds more like a mandate, the law goes onto to stipulate that the project must be funded through federal and state grants and cannot use state general funds. Without a designated funding source, this pilot project has the feel of a mandate, if an unfunded one.

3.3 Regional Global Warming Initiatives

Global warming trends dominate environmental policy debates in many governments outside of the United States. Recent efforts by the European Union and other environmentally progressive countries indicate that international agreements, like the Kyoto Protocol, will not begin the adoption of global carbon reducing policies; smaller jurisdictions, (multi-national, national, state, and municipal) are taking up the challenge to fight global warming in advance of ratification of an international treaty. In the United States, the current national political leaders, in both the executive branch and Congress, have demonstrated that they are unwilling to ratify Kyoto and would prefer to develop a policy "less harmful to the economy." Feeling the pressure from a vocal segment of the U.S. population, regional and state initiatives have begun developing the program infrastructure to support carbon reduction efforts without a federal mandate. Locally, a "Washington Climate Action Registry" was debated in Olympia this year. This voluntary registry is designed to support the trading of carbon reductions between private companies, lowering their cost of reducing their impact on the atmosphere.

According to a study done in 2000 by Energy Division of the Washington State Department of Community, Trade and Economic Development, 100 million tons of carbon dioxide are released each year into the atmosphere from sources within our state. Approximately 54 percent of those emissions come from tailpipes of cars and trucks. Local governments are beginning to take responsibility for their contribution by implementing steps to lower emissions from fleets they control. For example, Governor Locke signed a law encouraging all state fleets to use a fuel blend of 20% biodiesel and 80% petroleum diesel (B20) for use in diesel-powered vehicles. In addition, by June 1, 2006, state agencies complying with the ultra low sulfur diesel mandate of the U.S. Environmental Protection Agency, will use least 2% biodiesel as an additive to ULSD for lubricity. However, the law stipulates that biodiesel use is required provided that this is warranted and that performance and cost are comparable with other available lubricity additives.[10]

Within the Puget Sound area, local leaders are also pushing biodiesel. City of Seattle Mayor Greg Nickels and the Seattle City Council recently introduced a new initiative entitled 'Clean Green Fleet Action Plan.' The plan strives to reduce petroleum fuel use, increase the use of alternative fuels, reduce vehicle emissions, and improve the fuel efficiency of the City's fleet. The City's stated intent is to acquire a 100% clean and green fleet of vehicles that are the most fuel efficient, low emission vehicles available to meet the needs of City operations while relying on clean fuels. The specific measures called for in the plan include:

- Beginning in 2003, ensure at least 50% of new compact cars purchased each year are either alternative fuels or achieve at least 45 miles per gallon;
- By 2005, reduce annual fleet fuel use by 5% compared to 1999;
- *By the end of 2003, use a fuel blend of 20% biodiesel with 80% ultra-low sulfur diesel in the 902 on-road and off-road diesel vehicles*;
- By the end of 2004, complete the emission control retrofit project to install emissions control equipment on 400 existing heavy-duty diesel trucks.

3.4 Current Incentives Driving Biodiesel Production

Many different levels of government actively use incentives to expand the biodiesel market. Incentives can be delineated into two different categories—incentives focused on biodiesel production and incentives focused on biodiesel consumption. In essence, both categories lower the cost of biodiesel, eroding the price differential that currently prevents more widespread use. Depending on the level of government and the entity's commitment to biodiesel, the incentives can have a tangible and direct effect on its market viability, or they can be token in nature and indirect. The following two sections list some of the incentives. Not exhaustive, these incentives appear regularly in the literature and websites concerned with biodiesel production and use.

3.5 Federal Incentives Influencing Biodiesel Production and Consumption

Commodity Credit Corporation (CCC) Bioenergy Program

Under United State Department of Agriculture's (USDA) Commodity Credit Corporation Bioenergy Program, the CCC annually provides $150 million in cash payments to bioenergy (ethanol and biodiesel) producers in the U.S. that increase their purchases of agricultural commodities over the previous fiscal year's purchases and convert that commodity into increased bioenergy production. To be eligible, producers must produce and sell the fuel commercially and have authority from the Bureau of Alcohol, Tobacco and Firearms. Eligible commodities include barley, corn, grain sorghum, oats, rice, wheat, soybeans, sunflower seeds, canola, crambe,

[10] Washington State HB 1242, 2003

rapeseed, safflower, sesame seed, flaxseed, mustard seed, and cellulosic crops (such as switchgrass and short rotation trees).

In practice, the CCC Bioenergy Program results in completely defraying the cost of inputs for the marginal use of eligible commodities used in production. This potentially substantially reduces the early adoption market risk for biodiesel producers as they can build market share with subsidized production. Economies of scale become attainable with increased demand. The weighted average cost of production from year to year will remain below actual costs and allow producers the breathing room needed to compete against diesel's current dominance in sales and control of distribution channels.

At this time, production of biodiesel with a yellow grease feedstock is not currently eligible for the CCC Program. Grease rendering companies have begun to lobby for similar subsidies. Although renderers have a less powerful lobby compared to the agricultural interests that dominate some federal decisions, they believe the environmental benefits associated with recycling the oil, originally derived from agricultural crops, merit serious consideration. If such a subsidy materializes, it will allow yellow grease biodiesel to compete favorably with ULSD and petroleum based diesel in markets able to collect enough volume.

Congestion Mitigation and Air Quality (CMAQ) Improvement Program

The 1990 Clean Air Act (CAA) Amendments were designed to speed America's progress towards achieving compliance with the National Ambient Air Quality Standards (NAAQS). The amendments required lower permitted tailpipe emissions, initiated more stringent control measures in areas failing to attain the NAAQS (non-attainment areas), and attempted to tie transportation and air quality planning. The following year, Congress passed the Inter-modal Surface Transportation Efficiency Act (ISTEA), authorizing the CMAQ program, and providing $6 billion for surface transportation projects that contribute to air quality improvements and reduce congestion. Together, the CAA amendments, ISTEA and the CMAQ program realign the focus of transportation planning towards a more inclusive, environmentally-sensitive, and multimodal approach to addressing transportation problems.

In 1998, the CMAQ program funding was reauthorized under the Transportation Equity Act for the 21st Century (TEA-21). The TEA-21 CMAQ program provides over $8.1 billion dollars in funds to State DOTs, MPOs, and transit agencies for projects that reduce criteria air pollutants regulated from transportation-related sources over a period of six years (1998-2003). The TEA-21 CMAQ program features greater flexibility, several new program options, and an expansion of eligible activities available for funding. Biodiesel production facilities and distribution programs may be eligible. Any grant would lower the cost of production and distribution and make the fuel more cost-competitive.

Tax Deduction for Clean Fuel Infrastructure

EPAct includes mandates, regulations, and incentives. In addition to the alternative fuel vehicle program, the act also provides incentives designed to deliver a supply of fuel to meet the needs of the fleets choosing to reach compliance by using biodiesel. Under EPAct a tax deduction of up to $100,000 per location is available for qualified clean fuel refueling property. As stipulated in the act, the equipment must be used in a trade or business. There are no substantial costs to including biodiesel in an established retail setting if installed equipment is used to dispense biodiesel. Realization of the tax deduction would likely require the acquisition of new property or equipment. This credit is currently scheduled to expire on December 31, 2004.

Clean Fuels Formula Grant Program
The Clean Fuels Formula Grant Program is designed to accelerate the deployment of advanced bus technologies. The program offers an opportunity to incorporate low-emission vehicles into the mainstream of the nation's transit fleets and supports the FTA's efforts to advance emerging clean-fuel technologies. Additionally, this program was developed to assist transit systems in purchasing low emissions buses and related equipment, constructing alternative fuel fueling facilities, modifying existing garage facilities to accommodate clean fuel vehicles and assisting in the utilization of biodiesel fuel.

Public transit operators in CAA non-attainment or maintenance areas may apply for funding. Grants are made on a matching basis with federal funds match local funds on a 4-to- basis. Federal dollars must be used to purchase or lease clean fuel buses, construct or lease clean fuel electrical recharging facilities, improve existing facilities to accommodate clean fuel buses, re-power pre-1993 engines with clean fuel technology and retrofit or rebuild of pre-1993 engines if before a mid-life rebuild. Under this program, funds are allocated according to a legislative formula based on the number of vehicles in the bus fleet and the number of bus passenger miles as weighted by severity of non-attainment for either ozone or carbon monoxide.

3.6 State Incentives Influencing Biodiesel Production and Consumption

Two new Washington State laws provide incentives for biodiesel production. Their wide margin of passage may or may not indicate deep support for biodiesel in this state. The representatives from rural parts of the state may see biodiesel as a potential new market for crops, while the left leaning urban center representatives can demonstrate to environmental voters they are taking steps to improve air quality and fight global warming. This alliance between two polarized groups potentially bodes well for other future incentives, although mandates will be tougher.

HB 1240 provides tax incentives for biodiesel and alcohol fuel production. This is an attempt to lower the risk associated with committing capital to new production facilities. HB 1241 takes a different approach, providing tax relief to companies trying to sell or distribute alternative fuels. As noted on the Seattle Clean Cities website, "Beginning July 1, 2003, a tax deduction is available for the sale or distribution of biodiesel or alcohol fuel (comprised of at least 85% alcohol fuel by volume). Additionally, fuel delivery vehicles and machinery, equipment, and related services that are used for the retail sale of a biodiesel or alcohol fuel are exempt from state retail fuel sales and use taxes."

There are older incentives on the books in Washington State. For example, qualifying high technology businesses are exempt from state sales and use taxes. The definition of high technology businesses includes developers of alternative energy resources.

The exemption is 100% with no limit and expires on July 1, 2004[11]. In another law, matching grant allowances were established under the Washington Clean Air Act of 1991 to facilitate the economic development based on clean fuel technology. Under this law, the grants can be used to:

- assist in the purchase and operation of clean fuel public transit vehicles;
- establish programs at vocational-technical institutes to certify clean-fuel vehicle mechanics; and
- further the establishment of clean fuel refueling infrastructure.

At the time of this report, it appears that no funds have been appropriated for these programs[12].

4. Market Overview

On the surface biodiesel and petrodiesel appear to be very similar. As discussed above, switching costs to the consumer are minimal, and replacing conventional diesel fuel with biodiesel yields many environmental, social, and economic benefits. However, an analysis of the market factors associated with biodiesel production and consumption reveals some strong differences between biodiesel and petroleum based diesel. These differences create both market and public policy opportunities for the near-term expansion of biodiesel.

4.1 Total Market Potential

Before we discuss the differences between petrodiesel and biodiesel from a market and economic perspective, we need to determine how big the market potential is for biodiesel in the US. Both on-road, and offroad diesel use has increased steadily over the last few years (see Figure 5). If we assume an estimated fuel cost of $1.30 per gallon, this yields a total market size for on-highway and off-highway diesel of approximately $46.5 billion. Biodiesel is exciting as a business proposition because establishing even a 0.1% market share results in a $46 million business. However, as shown below in detail, there are significant barriers to entry into the marketplace.

[11] RCW 82.63
[12] RCW 70.94.960

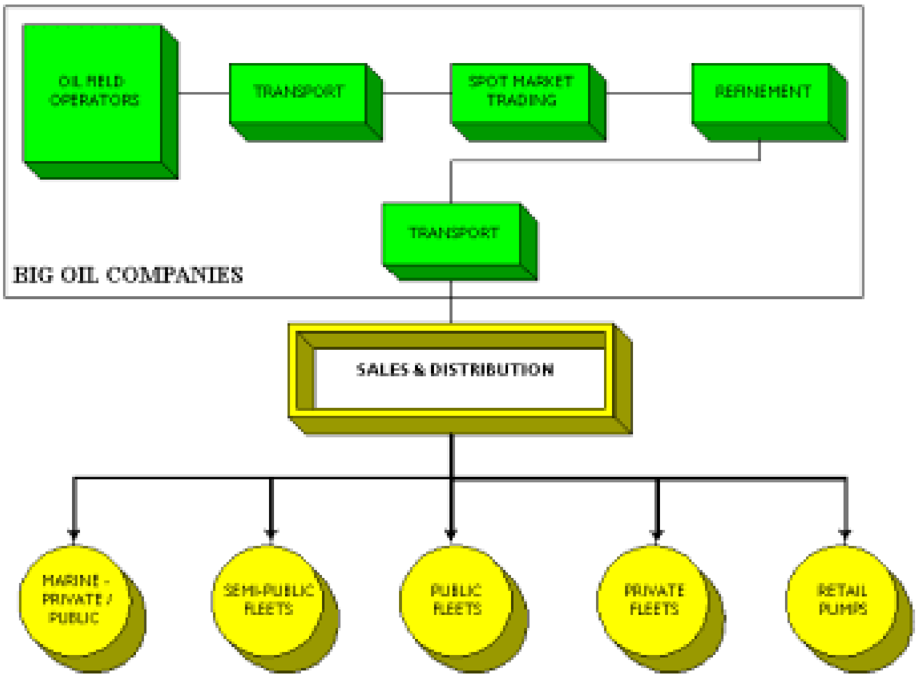
Table 13. Adjusted Sales of Distillate Fuel Oil by Energy Use in the United States: 1997-2001
(Thousand Gallons)

Energy Use	Distillate Fuel Oil				
	1997	1998	1999	2000	2001
U.S. Total	**52,665,438**	**53,063,934**	**54,758,718**	**57,217,230**	**58,971,486**
Residential	6,487,768	5,633,409	5,847,762	[R]6,123,946	[P]6,263,440
Commercial	3,218,497	3,044,495	3,003,653	[R]3,324,687	[P]3,505,057
Industrial	2,167,169	2,258,248	2,170,075	[R]2,117,531	[P]2,323,797
Oil Company	632,595	585,174	576,997	[R]671,170	[P]620,321
Farm	3,304,531	3,033,405	2,899,222	[R]3,122,416	[P]3,427,343
Electric Power	646,778	962,921	912,807	[R]1,139,740	[P]1,510,273
Railroad	3,067,400	2,833,276	2,789,926	[R]3,026,147	[P]2,951,631
Vessel Bunkering	2,107,561	2,125,568	2,064,590	[R]2,041,433	[P]2,093,252
On-Highway Diesel	28,614,022	30,150,191	32,082,447	33,129,664	33,215,320
Military	337,390	277,688	288,926	[R]227,998	[P]346,060
Off-Highway Diesel	2,081,728	2,179,560	2,142,313	[R]2,292,486	[P]2,514,791

Figure 5: Distillate fuel oil use in the United States[13]

4.2 Value Chain: Petrodiesel vs. Biodiesel

The figure below shows the petrodiesel supply chain:



[13] Reference: http://www.eia.doe.gov/oil_gas/petroleum/info_glance/petroleum.html.

Figure 6: Petrodiesel supply chain

It is interesting to note that the big oil companies control much of the upstream supply chain. Although the Petrodiesel supply chain looks relatively simple, in truth there are many complexities and subtle intermediaries adding value (and cost), due to the nature of the product and the vast number of users. The big oil companies trade significantly on the spot crude market to hedge risk. In addition, they will frequently own a specific portion of the value chain for a given location, such as refining in the Pacific Northwest. A rough breakdown of the various costs of petrodiesel is shown in the section below entitled Cost Comparison. A more in-depth look at petrodiesel reveals the following additional intermediaries:

- Vessel Operators:
- Ship Brokers:
- Pipeline Operators
- Commodity Brokers
- Inspectors
- Terminal Operators

The list of intermediaries like the one above is typical of a mature, commodity product. The key piece of information to gain from this analysis is that the petrodiesel supply chain, while mature, is still fraught with inefficiencies due to the nature of the required supply chain. The end-user's fuel may have originated from a number of locations (Alaska, Middle East, Gulf of Mexico, etc) but only one of chains would have resulted in the most cost effective route. And this route can change based on world events like wars, oil spills, and bad or good luck in finding oil!

In contrast, the biodiesel supply chain looks like this:

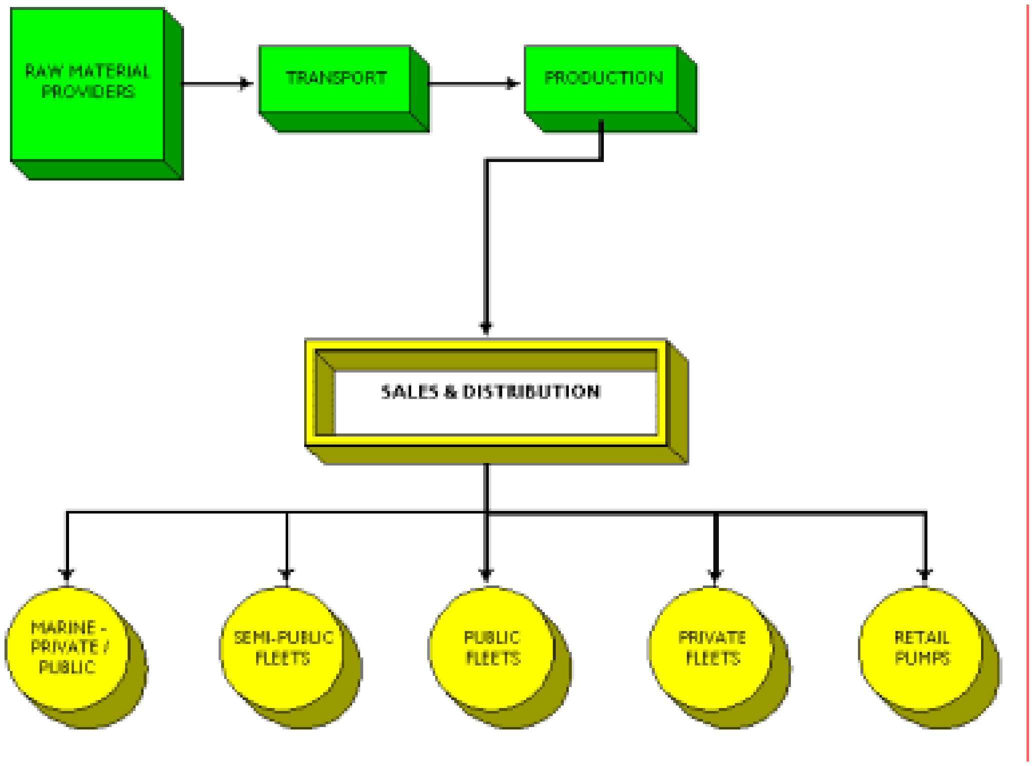


Figure 7: Biodiesel supply chain

You'll notice that the supply chain's themselves are not dramatically different. However, the stability of the supply itself and the ability for wider variation in raw materials from a much larger number of locations creates a very different "feel" to the supply chain. For example, if one were to use yellow grease feedstock from the Puget Sound Area, the variation in supply is not likely to vary greatly over time. While supply chain stability is difficult to measure in financial terms, if it results in price stability, it has real value to the end user over time.

4.3 Vertical Market Segmentation

The end-user market can be segmented in an infinite number of ways, but for the purposes of this study, we have chosen 5 different vertical segments as shown in each of the supply chains above. The table below compares each segment on how they value the fuel they use in their diesel engine:

	Marine Private / Public	Semi-Public Fleets	Public Fleets	Private Fleets	Retail Pumps
Examples	Ferries, Ships, tugs, naval vessels	Garbage, construction	School Busses, metro busses	Private Busses, construction	Cars, trucks

Power Needs	Medium	Medium	High	Med	Low
Environmental Concern	Public – High Private - Low	High	High	Low - Moderate	Low (except for small segment)
Price Volatility Concern	High	High	High	High	Low
Lubricity / Performance	High	High	High	Med	Med
Fill Location Needs	Few	Few	Few	Few - Many	Many
Price Sensitivity	High	Moderate	Moderate - High	High	Moderate

Table 2: Biodiesel market segmentation comparison

The ideal customer for a large initial investment in biodiesel would be one with

- Low Power Needs: Busses and construction vehicles have frequent and large power needs while passenger cars have lesser power needs. Biodiesel has slightly less energy per volume of fuel. This makes pure biodiesel a concern for some users.
- High Environmental Concern: Public and semi-public fleets like school busses, public busses, ferries, and garbage trucks can be mandated to reduce pollution and net carbon creation while this is more difficult for private cars and trucks.
- High Price Volatility Concern: Large users of diesel fuel are more sensitive to the volatility associated with petrodiesel because fuel frequently makes up a larger portion of their expenses when compared to a single private car. In addition, larger users may be sophisticated enough to value price volatility in actual dollar terms.
- High Value for Lubricity: A large fleet buyer that is able to quantify the value of increased lubricity on average engine life over a fleet of vehicles can adjust its buying patterns and value lubricity in net present value terms. A single retail consumer is not likely to calculate this value explicitly for comparison.
- Few Number of Fill Locations: Single retail consumers will fill their vehicles at thousands of different locations over the life of their car's life while a public bus may only use one or two different fill locations. For an initial investor

looking to minimize risk, the best option is to lock in a single large consumer with minimal pump location needs.

- Low Price Sensitivity: All users are sensitive to price, but single retail consumers tend to be less sensitive to fuel prices than large users like marine operators who's margins depend on a low fuel price.

The analysis above clearly shows that the two best options for biodiesel from a customer segmentation perspective are public and semi-public fleets and marine vehicles. To the extent that sub-segments of the categories above have significantly higher value in some of the differentiating characteristics biodiesel provides, they may be attractive segments. However, the least expensive segments to serve from a start-up capital perspective are also public/private fleets and public marine fleets.

4.4 Cost Comparison

The differences in cost associated with various stages in the value chain are significant to uncovering the potential market opportunities for biodiesel. The chart below shows a breakdown of various costs and the total price for each "at the pump":

	Petrodiesel	Yellow Grease Biodiesel	Virgin Soy Biodiesel
Taxes	$0.48	$0.48	$0.48
Sales / Dist / Mktg	$0.27	$0.25 - $0.60	$0.25 - $0.60
Processing	$0.19	$0.55	$0.35
Feedstock	$0.77	$0.50 - $0.70	$1.00 - $1.50
Glycerin	-	$-0.10	$-0.10
Wholesale		$1.80 - $2.35	$2.00 - $2.85
Retail	$1.71	N/A	$2.77*

*Based on Dr. Dan's Fuelwerks in Seattle, WA. Cost to Dr. Dan's is approx $2.00 per gallon.

Table 3: Diesel fuel cost comparison[14]

As you can see, the increased price for biodiesel is driven mainly by input costs and processing costs. In an effort to more fully explain the differences in input costs, the

[14] Yellow grease information is based on an interview with Fred Wellons, employee for Baker Commodities, a rendering service. Petrodiesel breakdown is derived from http://www.eia.doe.gov/oil_gas/petroleum/info_glance/petroleum.html.

figure below shows the differences in price between the various feedstock products[15].

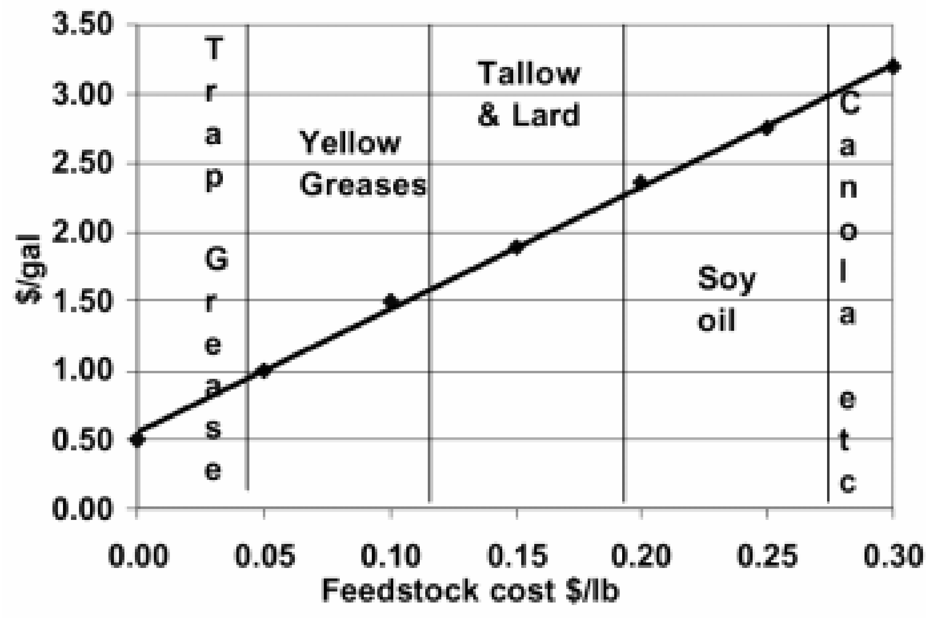


Figure 8: Differences in feedstock prices[16]

One obvious suggestion for biodiesel adoption is to develop better technology for biodiesel production. Biodiesel production already makes use of nearly 100% of the feedstock for useful output products (either biodiesel or glycerin for soap). Still, when comparing the tremendous economies of scale associated with petrodiesel to current biodiesel production, one can see obvious room for decreases in biodiesel cost. However, unless someone is willing to assume the monumental financial risk associated with developing both large-scale production facilities and competing retail locations, growth in biodiesel should be initially based on one key benefit: *reduced transportation costs*. The feedstocks for biodiesel can vary from yellow grease to pure virgin oilseeds. Unlike petrodiesel, these sources for biodiesel are not restricted to areas containing hidden oil reserves. Production plants can be located near sources of feedstock, which in turn, can be located in or near population centers. This can reduce transportation costs for both raw material input and distribution of output.

Due to these key differences, the economics surrounding the use of biodiesel vary dramatically by region. It should also be noted that this is simply a cost comparison. Other benefits and externalities (cleaner air, national economic benefits, etc) are not included in this comparison. Valuation and ability to translate externalities into policy

15 Yellow grease is animal feed grade. Trap grease is grease collected from restaurant sewer systems. Its considerably less clean and less abundant.
16 Coltrain, David, *Biodiesel: Is it worth considering?*, 2002 Risk and Profit Conference, Kansas State University, Dept of Agricultural Economoics.

drivers also varies dramatically by region, adding further to the variation in regional attractiveness.

The total current production of vegetable and animal oil and fat is still insufficient to provide enough biodiesel to serve the entire diesel industry. In fact, according to the table below, total production is approximately 10% of the total diesel needs. It seems unlikely that we could convert enough agricultural land to biodiesel production if the goal were to replace petrodiesel completely.

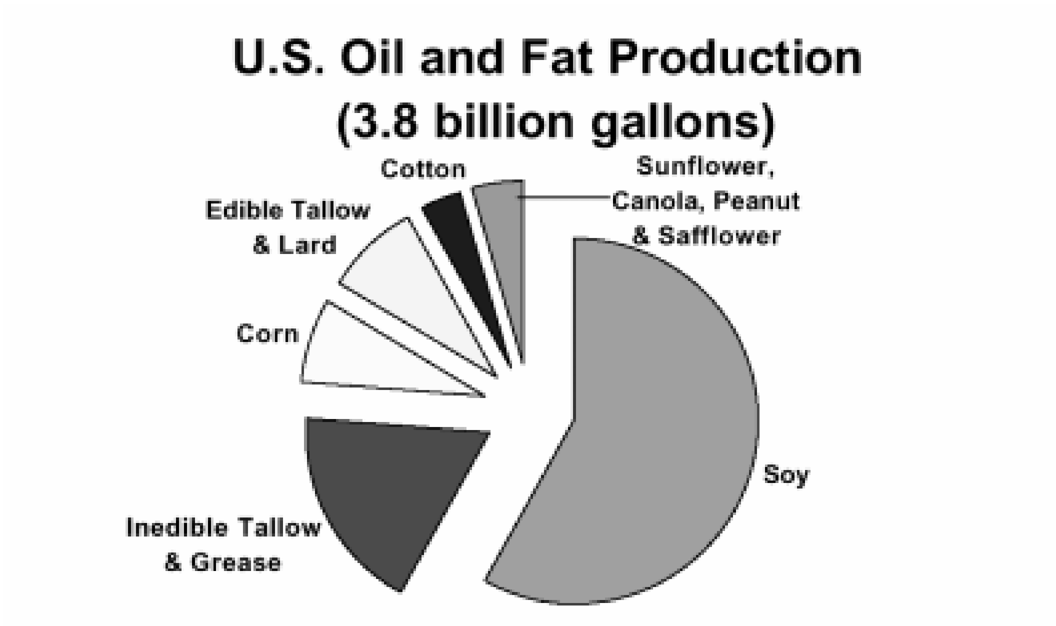


Figure 9: Oil and fat production in the United States[17]

Dr. Dan's Fuelwerks provides an interesting data point. Dr. Dan's is an alternative fuel station in the Ballard District of Seattle. In discussing the biodiesel pumping portion of his business, he mentioned that the business is only marginally profitable. He started his biodiesel pumping business in part because of the EPAact. However, due to limited compliance with the EPAact, his business has been limited to individual retail customers. For the most part, these are diesel car owners with strong environmental and anti-war values. Currently, Dr. Dan's is selling between 7,000 – 9,000 gallons / month compared to a regular gas station which may sell 40,000 gallons a week. Even though this may be a small market segment, there are other factors leading to the slow sales growth. The location for Dr. Dan's is very difficult to find and he has done little to market the product other than the development of a website. Even if Dr. Dan's was to sell from a better location and provide a more robust marketing effort, success is difficult on the cutting edge of a market and lacking any large customers makes it especially difficult.

[17] Coltrain, David, *ibid.*

4.5 Summary of Marketplace: Opportunity Identification

The analysis above shows that the most likely opportunity for a successful venture in biodiesel is based on very localized regional attributes. The key issues are as follows:

- Abundant Feedstock at Attractive Price
- Minimized Upstream (to production facility) Transportation Cost
- Few End Delivery Points
- Customers Value for Key Biodiesel Attributes

Due to the regional nature of our research and high potential attractiveness, we chose to review the Seattle market as a likely candidate for biodiesel investment.

5. Seattle Biodiesel Business Intelligence

Based on the current experience of Dr. Dan's Fuelwerks, we can say with some certainty that the private retail market for soy-based biodiesel is not a very attractive opportunity. However, Seattle presents a potentially attractive business opportunity in other segments because of the following reasons:

- Feedstock: Seattle has a well established yellow grease market as most US cities do.
- Minimal Upstream Transportation Cost: Locating a plant at Harbor Island near the mouth of the Duwamish River will minimize logistical transportation costs
- Few End Delivery Points: Establishing a local contract with a big user like Washington State Ferries or Metro King County would require few end delivery points. In addition, locating on Harbor Island allows for biodiesel blending with either #2 petrodiesel or ULSD.
- Customers Value for Key Biodiesel Attributes: The Puget Sound is generally known for its strong environmental and anti-war views. Local politicians are likely to push government agencies like Washington State Ferries and Metro King County to adopt alternative fuel sources. In addition, Seattle air quality has worsened in recent years and we face potential EPA non-attainment in the near-term.

5.1 Seattle Market Opportunity

The factors listed above generally describe an attractive market opportunity for Seattle biodiesel. A more detailed review of this market opportunity reveals more business intelligence and some significant barriers.

Feedstock Supply: The most attractive near-term feedstock for the Seattle region is Yellow Grease. Yellow grease (used cooking oil) is a well-established commodity market with uses in animal feed, and overseas cooking oils. In discussing the market with Fred Wellons, an employee with Baker Commodities rendering service, he stated that his company collects approximately 5 million gallons of yellow grease annually in Seattle. He estimates total yellow grease collection of 9 – 11 million gallons. The current price for buying yellow grease is $0.95 / gallon (this seems to be a peak in the yellow grease price as it is generally less expensive). Currently, none of the grease is wasted, so adding a new, potentially large buyer of yellow grease will raise the price according to economic theory. However, the given the limited transportation costs, yellow grease is an attractive option. In addition, it requires little new logistical infrastructure. We can simply buy yellow grease from a Seattle renderer like Baker Commodities.

In the long run, mustard seed from Eastern Washington has a high potential as an economically viable feedstock. The feedstock could be shipped to our production facility or an additional production facility could be located in Eastern Washington. Mustard Seed is not currently produced, however, and the best near-term feedstock is yellow grease.

Production Facility: There are a number of attractive subsidies in place to ease the financial burden of the capital expenditure. Most notable is the USDA's bioenergy program seeking to expand industrial consumption of agricultural commodities for bioenergy use. Current subsidies include a $1.50 per gallon for every gallon of biodiesel produced in the 1st year for virgin soy production and $0.95 per gallon for yellow grease based biodiesel. The subsidy tapers off each year following the first year of production. Based on our discussion with Fred Wellons, initial start-up costs for a high efficiency plant are approximately $1.00 per gallon. To provide 20% of Metro KC's fuel needs, we would need a production facility producing 1.8 million gallons at a cost of approx. $1.8 million dollars.

Customers: The most attractive customers in the area are Washington State Ferries and Metro King County. The Washington State Ferry System uses approx. 12 million gallons of diesel a year while Metro KC uses 9 million gallons. Of the two customers, Metro is more attractive for two reasons. First, it is controlled by local legislation as opposed to state legislation for WSF. Local Seattle legislators have already mandated Metro KC to switch to ULSD. Second, Metro KC's fuel is supplied completely by the Harbor Island Fuel Depot. If we locate a production plant on Harbor Island, we can blend the biodiesel product with petrodiesel or ULSD on-site and make use of existing local sales and distribution trucks.

Metro KC recently reviewed biodiesel for possible alternative fuel use. When we discussed this review with Jim Boon, Metro KC maintenance manager, he mentioned several reasons why they have not chosen to use biodiesel:

1. Distribution Difficulties: Their review looked at virgin soy biodiesel. The only delivery method available was 50 gallon drums. Metro KC operates 8 fueling sites that receive full tank trucks of fuel nearly every day. 50 gallon drums is simply not an option. However, by locating a yellow grease biodiesel plant on Harbor Island, this problem is eliminated.

2. Mandate: They have been mandated to use ULSD by 2006. This mandate does not allow them to use biodiesel. This problem could be solved by pooling information on the problems associated with low sulfur diesel (carbon & particulate emissions, and reliance on foreign oil) and effectively lobbying local, state and national governmental agencies to allow biodiesel to compete with ULSD.

3. Emissions: Metro KC busses are already outfitted with advanced converter systems reducing emissions dramatically. A biodiesel blend with #2 petrodiesel would actually have a worse emissions profile compared to ULSD. The gold standard for fuel use would be ULSD mixed with biodiesel to create an ULSD B20. However, this would increase cost for fuel significantly.

4. Power: Metro busses require large power needs from the fuel. Pure biodiesel would have reduced power resulting in poorer performance. As we have already noted above, even converting ALL of the Seattle yellow grease to biodiesel production would result in marginally enough fuel for the Metro KC fleet. However, this would completely replace the existing yellow grease market and drive the price up dramatically. The best production scenario would be to blend biodiesel with ULSD at the Harbor Island fuel transfer facility.

Conclusion: Although biodiesel appeared initially to be an attractive potential opportunity in Seattle, there are significant barriers currently in place nearly eliminating it as a possibility. It would take a significant change in local political policy to make biodiesel attractive for the region. Most notably, our local politicians would need to find a value in our reduced dependence on foreign oil sources. If biodiesel is not allowed to compete with petrodiesel because of the mandate issue, the opportunity for biodiesel is much riskier and therefore less attractive.

6. Biodiesel Opportunities in China

6.1 Diesel supply and demand in China

The demand for diesel is high in China, with an annual consumption of 18-21 billion tons, and is growing very fast, with annual increases around 4%. If this trend continues, the demands of Chinese diesel will be 30 billion gallons by 2010. This is a significant fraction of current global diesel production, so the continued growth of the Chinese economy (which has averaged 9.4% per year over the past decade) is expected to have a large impact on global diesel supply and prices.

Currently, Chinese diesel production only meets 1/3 of domestic demand, and China is one of the largest oil importers in the world. If China does not adjust its energy production or consumption patterns, the country will depend increasingly on international petroleum exports as its economy continues to grow. This creates a serious challenge to Chinese energy security, and Chinese leaders take this challenge very seriously.

Two thirds of the cities in China regularly experience air pollution at levels that exceed national standards (which are called “Grade II”). Tailpipe exhaust from automobiles is one of the main sources of this pollution. Thus, reducing automobile emissions represents an important way to control environmental pollution in China, and the widespread adoption of biodiesel offers a way to achieve these reductions while benefiting the domestic economy. In addition, farmers are generally very poor in China due to the low prices paid for these crops, and creating an additional market for these products would help a large number of Chinese citizens living in rural areas.

6.2 Biodiesel development in China

The Ministry of Science and Technology of China, the China State Reform and Development Commission, and the China Engineering Academy rank biodiesel research and production as *the* priority of the Chinese energy industry. Bio-liquid-fuels are cited in the Tenth Five Years Development Policy and Regulation as a major future direction for new Chinese industrial development. Chinese researchers have also made advances in the fields of raw materials filtering, production techniques, and biodiesel additives.

Currently, most of biodiesel produced in China is made from virgin rapeseed oil. However, every year China uses 70 million tons of cooking oil, most of which is not reused, and China also has a huge annual agricultural production that includes large amounts of soybean, rapeseed, peanut and corn oils. Thus, there are a large number of potential feedstocks available in China for biodiesel production. Chinese experts estimate that 900 million gallons of biodiesel could potentially be produced from waste cooking oil alone.

Vice Professor Ji Xing at the University of Petroleum notes that the level of Chinese biodiesel production is actually between that of Europe and the United States, and notes that the Chinese petrochemical industry has supported biodiesel production from the very beginning, which could be one reason why the production level is higher than in the United States.

There are currently fewer than five companies producing biodiesel in China, the three largest being Hainan Zhenghe Bio Energy, Sichuan Gushan Grease Chemical, and Fujian Zhuoyue New Energy Development. Sichuan Gushan Grease Chemical, which is based in the Sichuan Province, uses virgin rapeseed oil to produce 3 million gallons of biodiesel per year that meets National Standard Q/72979019-0·1-2001 (which is similar to the ASTM D6751 standard used in the United States and a similar standard used in Europe). Testing by the Sichuan Automobile Protection Test Center has indicated that this biodiesel has performance characteristics similar to conventional diesel and has very positive environmental attributes. Hainan Zhenghe Bio Energy Company has invested $5 million (US) in a new factory that will be able to produce 15 million gallons of biodiesel per year from waste cooking oil in Changping, Beijing, with production coming online by the end of 2003.

6.3 Biodiesel price in China

Sichuan Gushan Grease Chemical reports a production cost of about 2800 yuan per ton to produce biodiesel from rapeseel oil. This biodiesel is sold to gas stations at a price of 3000 yuan per ton, which sell it at a retail price of 3500 yuan per ton, or about 3.1 yuan per litre ($1. 414 US per gallon). This price is similar to, but slightly higher than, the price of diesel in Sichuang province ($1.208 US per gallon). The other two large biodiesel production companies in China (Hainan Zhenghe Bio Energy and Fujian Zhuoyue New Energy Development) produce biodiesel using yellow grease (waste cooking oil), which has a controlled production cost of 2300 yuan per ton ($1.049 US per gallon), and thus can be sold at a lower price than conventional diesel (and for a higher profit).

Fuel Type	*Gasoline	*Petrodiesel	**Rape Biodiesel	*** YG Biodiesel
Regular (90)	2.63¥/liter = $1.20/gallon	2.65¥/liter = $1.208/gallon	3.1¥/liter = $1.414/gallon	2.3¥/liter = $1.049/gallon

Table 4: Price of petroleum products in China

* Price in Beijing market on May 10th, 2003
** Price provided by Mr. Chen Gonghao, Vice manager of Sichuan Gushan Grease Chemical, on May 22, 2003, for biodiesel produced from virgin rapeseed oil.
*** Price provided by Dr. Ji Xing, Associate Professor of University of Petroleum (Beijing) on May 29, 2003, for biodiesel produced from waste cooking oil.

6.4 Obstacles to biodiesel adoption in China and their potential solutions

Given the size of the diesel market in China, domestic concerns about energy security and air pollution control, and the competitive price of biodiesel (especially when produced from waste cooking oil), it is somewhat surprising that Chinese biodiesel production is currently only 15-18 million gallons. Three factors may help to explain why this is the case:

The monopolization in the traditional oil-chemistry industry system. China Petroleum and Chemical Corporation (Sionpec) controls most of gas stations in China. Sinopec does not want to share this market with other companies, such as privately owned biodiesel producers, and refuses to share its distribution channels to provide biodiesel to a larger number of people. Thus, biodiesel producers have to look for direct consumers, such as transportation companies. In some small towns, biodiesel compnies are able to set up a partnership with local gas stations, such as San Tai County in Sichuan Province, where Sichuan Gushan Grease Chemical has set up such an arrangement. Breaking the monopoloization of the oil industry would allow more biodiesel companies to compete in the diesel market, especially foreign companies which might have more experience in developing biodiesel distribution networks.

Lack of national standards for biodiesel. China not only has not a national standard in place for biodiesel production quality, but also has not such standards have been issued for production techniques, distribution networks, or engine performance for biodiesel. If the government were to issue such standards it would promote faster biodiesel industrialization.

Lack of oversight for waste cooking oil collection. Currently, businessmen illegally collect and sell waste cooking oil as raw material to produce fresh cooking oil, making it more difficult for biodiesel producers to obtain yellow grease for use in biodiesel production. Making tougher rules to manage the collection of waste cooking oil and to prohibit waste cooking oil from re-entering the cooking oil market would help free up this feedstock for biodiesel production. Since the yellow grease recycling industry is not presently very well established in China, this is much easier to do than in countries where yellow grease recycling is a big business that would be adversely impacted by such regulations.

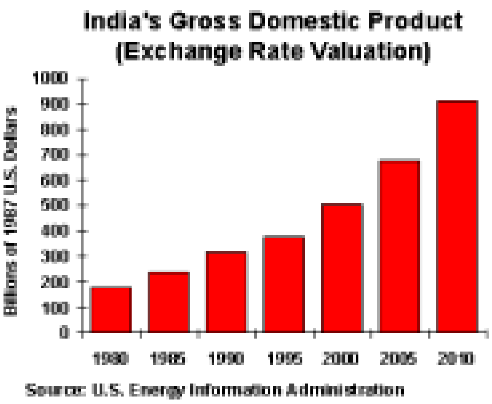
Finally, the Chinese government could help promote the adoption of biodiesel on a wide scale by adopting policies and regulations that encourage biodiesel production, sale, and consumption. As with the biodiesel market in the United States, favorable policies could greatly reduce initial market entry costs for biodiesel producers and drive down biodiesel prices.

7. Biodiesel Opportunities in India

7.1 Background

India is a rapidly expanding country in terms of both its population and its economy. According to the 2001 Census of India, country's population stood at 1,027,015,247 persons. Although India occupies only 2.4% of the world's land area, it supports over 15% of the world's population. Demographics indicate the population will grow because almost 40% of Indians are younger than 15 years of age and are likely to produce offspring. By 2050, United Nations' demographers project that India will have added another 530 million people for a total of more than 1.5 billion. If India continues on its projected demographic path, it will overtake China by 2045, becoming the world's most populous country.

Economic growth in India, as in many developing and developed countries, is currently correlated with increased energy consumption. The environmental issues often discussed in public policy debates in India arise because of two factors, the sectors responsible for energy use and where economic development is happening.



Although a large proportion of Indians (approximately 70%) live in 550,000 rural villages, urbanization levels have increased consistently since 1971. Many Indians have begun congregating in large cities as evidenced by the fact that cities with at least a million people increased from 12 in 1981 to 23 in 1991. The total population in these metropolitan areas accounts for nearly one-third of total urban population. Over 50% of the population of these metros lives in the five giant conglomerates- Mumbai (12.57 million), Calcutta (10.92 million), Delhi (8.38 million), Chennai (5.36 million) and Bangalore (4.09 million). In Delhi this has increased the number of registered vehicles to increase from 841,000 in 1985 to over 3.5 million in 2001.

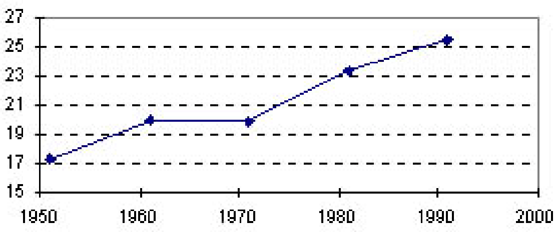


Figure 1.1 Urban population as % of total population

Despite the fact that 350 million Indians live on less than a dollar a day, the country as a whole has been experiencing material economic growth over the last few decades. A consequence of India's rapid economic growth has been severe air and water pollution, deforestation, water shortages, and carbon emissions. The country's carbon emissions are rising rapidly due to industrialization, transportation sector growth, and the wide-spread use of coal as a fuel. Between 1986 and 1995, India's carbon emissions rose 40 percent. Sulfur dioxide and the airborne particulate levels in many Indian cities greatly exceed international standards.

7.2 Health Problems and Policy Mandates

Rapid population growth, economic growth, and the increasing vehicle population within the large cities has had a material impact on air quality. As a result, the Indian Government has taken measures to reduce pollution in these metropolitan areas, including:

Table 16: Health costs of particulate pollution in Delhi

Costs	1991-92 [1]	1995 [2]
Annual premature deaths due to ambient SPM	7,491	9,859
Episodes of illness due to ambient SPM	39,48,923	51,97,018
Monetary losses resulting from premature deaths due to ambient SPM (in Rs crore)	651.0	856.7
Monetary losses from sicknesses requiring medical treatment due to ambient SPM (in Rs crore)	24.6	32.4
Monetary losses from minor illnesses	275.0	NA

Source:
1 Carter Brandon and Kirsten Hommann 1995, The cost of inaction: Valuing the economy-wide cost of environmental degradation in India. Asia Environment Division, World Bank. Washington DC. October 17, mimeo.
2 Centre for Science and Environment 1997, Death is in the air, in *Down To Earth*, Society for Environmental Communications, New Delhi, November 15.

- In 1995 unleaded gasoline was introduced in the cities of Delhi, Bombay, Calcutta, and Madras, followed by expansion to the entire country;
- In 1999 the level of permitted sulfur content was reduced from 0.5% to 0.25% (2,500 ppm). Some large cities, including Delhi, face tougher 2000 standards of 0.05%;
- Permitted benzene content has been reduced from 5% to 1%;
- In 1990 the Euro II emissions standards were implemented in Delhi, Bombay, Calcutta, and Madras, with a time schedule to tighten standards for two and three-wheelers to Euro II and Euro III standards in 2005 and 2010 respectively; and
- A Supreme Court mandated the use of compressed natural gas (CNG) by the Delhi bus fleet. Superior economics of CNG use compared to petroleum has resulted in a substantial number of private owners to convert their cars, taxis, and auto-rickshaws.

7.3 Why Biodiesel is Attractive in India

On top of the evolving policy mandates that require the use of cleaner fuels, biodiesel production in India is attractive for several other reasons. Petroleum diesel fuel has been sold at government-subsidized rates in India to keep the transport costs low and increase GDP. Currently, a liter of gasoline normally costs 2.5 times more than a liter of diesel fuel. Taking advantage of this cost differential, Indian car manufacturers have been investing heavily in the production of diesel vehicles. As such, there are a substantial number of vehicles on the road that demand diesel and would not require the relatively expensive retrofits needed to use CNG. According to the Program for Computational Reactive Mechanics report "Modeling

Anthropogenic Emissions from energy activities in India: Generation and Source Characterization," the ration of diesel usage to gasoline usage in India is 7:1.

India's economic surge has relied heavily on the use of imported, non-renewable energy sources. As reported by Clean Cities International:

- The share of India's energy derived from oil will increase from roughly 30% now to 70% in 2010
- India imports 60% of its oil, paying foreigners $12 billion US per year
- Projected energy needs will completely consume India's known oil reserves by 2012

The final factor making biodiesel production in India attractive is the potential to cultivate cheap feedstocks. India has a climate that is conducive to growing two species of trees, Jatropha Curcas and Pangomia Pinnata, that produce large quantities of non-edible oil. According to experts interviewed by the NGO Renewing India, one hectare of cultivated Jatropha can yield 5 MT of seeds from which 1.5 MT of oil and 3.5 MT of cake could be derived. The nitrogen, phosphorus, and potassium rich cake could be used as an organic fertilizer on plantation. This prolific oil-producing tree:

- has a wide environmental tolerance,
- grows in any type of soil,
- is easy to propagate through seeds or cuttings,
- requires minimal care;
- demonstrates a lower gestation period;
- is not susceptible to grazing by animals; and
- adapts well to various kinds of wastelands the government currently is trying to reclaim.

Pilot Jotropha plantation projects are underway. The adoption of large-scale biodiesel production and consumption potentially lowers India's dependence on foreign oil, helps improve air quality in major cities like Delhi, reclaims unusable wastelands, employs unemployed Indians, and keeps the country's economy on track for its planned 8% annual GDP growth over the next five years.

7.4 Best Opportunity for Market Entry in India

It appears that there are several drivers in place that make biodiesel development in India attractive. As investors in a foreign country, it may be challenge to find the proper entry into this market. Preliminary research does not indicate whether or not yellow grease would be an option in India. Much of the literature and "buzz" around biodiesel centers on agricultural feedstocks. If that is the case, India's agricultural industry will likely quickly take up the challenge of growing the feedstocks. The country already has a well established distribution system, with some major national and global players firmly entrenched. It appears that the most accessible link on the value chain may be biodiesel refining. A well-executed commitment of capital towards a refinery near Delhi, coupled with alliances with the major petroleum diesel distributors could prove help improve air quality in one of the most dirty urban areas on the planet and provide a reasonable return on the investment.

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