Biodiesel in Oregon:
Environmental Impacts and Economic Feasibility on the Columbia Plateau

Tristan Nuñez
Environmental Studies Senior Thesis
Lewis & Clark College
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I. Introduction

The search for alternatives to fossil fuels is a major environmental and political challenge facing industrialized society. Fossil fuels produce greenhouse gasses that cause global warming. They pollute the air with smog and toxic particulates. They cause dependence on foreign oil, leading to geopolitical instability, and they are running out. Yet they also are the lifeblood of our economy. Finding progress in the search for alternatives difficult the federal level, political pressure in the search for solutions has turned to the state and local level. Having the will, however, is different than knowing the way: feasible alternatives to fossil fuels are not readily apparent, making it difficult for decision-makers to take action.

Biodiesel (a diesel substitute made from vegetable or animal oils) is one of the leading alternatives to fossil fuels in transportation. Over its life cycle, the use of biodiesel releases 78% less carbon dioxide than regular diesel.[1] It also results in substantial reductions in most air pollutants that contribute to urban air problems. It can be produced domestically and provide needed markets and added value for agricultural producers. The Oregon Environmental Council, one of Oregon's leading environmental organizations, has started a project promoting biodiesel in Oregon, aiming to help develop the agricultural, industrial, and business base needed to develop a viable biodiesel industry in the state.[2]

In support of this effort, this thesis examines the environmental impact and economic feasibility of biodiesel in Oregon. Specifically, it seeks to answer the questions, "*What are the environmental impacts of making and using biodiesel? What are the economic hurdles to making biodiesel production a reality in northeastern Oregon*?"

I define environmental impact as the *range of actual and potential environmental changes caused by the implementation of a new technology*. I define economic feasibility as *the ability of market and regulatory forces to motivate the relevant economic actors to engage in production, processing, distribution, and consumption of the technology in question*.

The biodiesel field is incredibly complex. A local biodiesel expert who has been involved in the industry for over 20 years told me, “That’s what I like about it – one can never know everything that’s going on, and new things are constantly popping up.” Because a statewide feasibility study is beyond the scope of this thesis, I have chosen to focus on the biodiesel feasibility as it relates to the production and processing of oilseeds, specifically canola, on Oregon’s Columbia Plateau in the northeastern part of the state. The insights of this study are not directly applicable to the entire state, since regional agricultural and economic factors influence production costs significantly. However, this study provides a useful framework that could be applied to other areas.

I conclude that biodiesel’s environmental impacts are, on the whole, beneficial. It has benefits for air quality, reducing petroleum diesel use that contributes to cancer risk and other health problems. It significantly reduces greenhouse gas emissions on a lifecycle basis. The production process involves a simple chemical reaction with no emissions and inert waste products, though it may consume methanol derived from coal. On the agricultural side, it provides incentives for farmers to grow canola or similar oilseeds in a crop rotation, which improves soil quality, and by breaking disease cycles, can reduce the application of certain chemicals. There is little chance of new land coming under cultivation for rotation crops. Drawbacks include the application of some fertilizers and herbicides. Although the markets currently discourage genetically modified canola in the Northwest, if new varieties are developed that farmers find attractive, GMO proliferation may occur as well.

Economic feasibility is less clear, despite the fact that analysts, farmers, and agencies across the region have been examining it closely. The region lacks a large oilseed infrastructure, storing and crushing facilities, as well as operating biodiesel plants. The region also lacks a large market for biodiesel. The biodiesel industry will be a risky and uncertain endeavor at any scale in the Northwest.

As a result of constructing an economic model of a biodiesel plant in the Pendleton, Oregon area, I conclude that biodiesel is not likely to be economically feasible at present. The cost of growing canola is too high to provide the low-cost feedstock a biodiesel plant would need to compete with soybean-based biodiesel from the Midwest. However, the difference between Midwestern biodiesel and the costs of Pendleton-produced biodiesel is not large. By finding ways to increase the value of byproducts such as feed meal and glycerine, as well as reducing crushing costs, Pendleton-produced canola oil could be competitive. It is important to note that my model relied on several assumptions about canola prices and production levels that should be researched further and could significantly impact biodiesel's viability.

This report will first examine biodiesel feasibility studies conducted for other states or regions and apply their insights to Oregon's situation. Second, in the section on environmental feasibility, it will consider the impacts of growing, processing, and burning biodiesel. Third, it will consider the economic feasibility of producing canola and processing it into fuel in Northeastern Oregon. This examination of agricultural economics will focus on crop prices and production levels. The evaluation of processing economics looks at variable and fixed costs of production and the role of economies of scale. I present a rough economic model of biodiesel production to illustrate the economic challenges facing the industry. In conclusion I examine possible solutions to these challenges.

II. PREVIOUS ANALYSIS OF BIODIESEL FEASIBILITY

A. Introduction

No overarching study of biodiesel's feasibility in Oregon has yet been conducted. Brent Searle of the Oregon Department of Agriculture wrote an overview report, which examines land potentially available for biodiesel and incentives that might promote the industry in the state.[3] A feasibility study of a canola crusher has been conducted in Pendleton, but the results are proprietary.[4] A feasibility study of a biodiesel plant has just been completed for Columbia County in southern Washington, but the results have not yet been released.[5] The purpose of this literature review is to examine feasibility research conducted elsewhere. The major components found in these studies include economic (feedstock, processing, and market) aspects, political aspects (the agricultural lobby, regulations, national and state incentives), and technical concerns (regarding processing, transportation, and distribution infrastructure).

B. Feasibility Studies

Biodiesel feasibility studies have been conducted for Mississippi, Kansas, Missouri, the Southeastern U.S., North Dakota, British Columbia, Minnesota, Georgia, the Inland Pacific Northwest, and Seattle, WA. Further studies have been conducted on national and international levels, or have focused on specific topics such as emissions, production methods, and markets. Most of these feasibility studies were published since 2000. Considering that biodiesel was first commercially produced in Germany in 1991, and that petroleum prices have only recently pushed the U.S. market toward alternatives, this relatively large number of studies indicates biodiesel's timeliness. The field is still characterized by insufficient information. One recent report stated that "information on the economic feasibility of biodiesel is limited and unreliable" and that no feasibility studies "have addressed biodiesel in a comprehensive fashion." This results in reduced investor confidence, and industry expansion will be limited if this data remains unavailable.[6] I will examine a range of studies conducted, the factors they focused on, summarize their general findings and relate them to this study.

British Columbia

The Canadian consulting firm Wise Energy Co-op published a report in 2004 examining the feasibility of developing commercially viable biodiesel businesses in British Columbia. The report "is intended to be used as a guide [to help citizens] in assessing the potential of manufacturing biodiesel in their own community."[7] The report followed the following project phases: 1) biodiesel industry analysis, 2) analysis and projections of feedstock potential by type, 3) investigation of biodiesel processing technology options, 4) assessment of feedstock sourcing/collection/processing options, costs, and logistics, 5) preliminary assessment of market potential and development options, 6) assessment of potential environmental and social benefits, 7) and financial assessment for business start-up and financing. Regulatory considerations are examined relative to their impact on each of these areas. Due to British Columbia's climate, the report focuses almost entirely on the use of yellow grease (waste oil), rather than the agricultural production of oil feedstocks.[8]

North Dakota

The North Dakota State University Department of Agribusiness and Applied Economics published a report in 2002 examining the economic feasibility of biodiesel production in North Dakota. The study concludes that "with existing technology and no subsidy, biodiesel operation and investment costs for a North Dakota facility are not competitive with petroleum diesel," based on 2002 costs of petroleum diesel.[9] The study estimated production costs of $2.02 to 2.64 for biodiesel (depending on feedstock cost); in light of diesel market trends since the study was conducted, biodiesel may be more feasible. The study reviews biodiesel production basics, then examines diesel market segments, identifies market potential, economic profitability and investment costs, and develops a strategy for starting a production facility. The study also reviews relevant legislation and political considerations.

Kansas

In 2002 David Coltrain of Kansas State University's Department of Agricultural Economics examined whether Kansas agricultural producers should consider investing in biodiesel processing plants. Although the analysis was not extensive, he concluded that if soybean oil prices are low and government subsidies increase, Kansas soybean processors could produce profitable biodiesel. Coltrain considers inputs (feedstock price and availability), outputs (price of biodiesel, ethanol, and glycerol), and subsidies, and emphasizes the primary importance of feedstock price. Nelson et al., in a separate study, concluded that "constructing biodiesel plants in Kansas is feasible due to the anticipated increased demand for biodiesel as well as biodiesel incentives."[10]

Mississippi

Frazier, Barnes and Associates, a consulting firm, conducted a "Statewide Biodiesel Feasibility Study Report" for Mississippi in 2003. They characterize the biodiesel industry as "relatively new, but rapidly expanding … poised for significant growth over the next decade."[11] The report examines the national industry, biodiesel market segments, regional tax structures, licenses and permits, the financial market, and feedstock availability and cost. In contrast to the North Dakota study (VanWechsel et. al), Frazier, Barnes and Associates only look at state-level factors when examining state policy and feedstock availability; financing, markets, and industry trends are considered at the national level.

Georgia

Shumaker et al. conducted a “Study on the Feasibility of Biodiesel Production in Georgia” (2002). They examined feedstock availability, feedstock costs, the economics of biodiesel production (capital, production and breakeven costs), biodiesel competitiveness vis-à-vis petroleum, and conducted an economic impact analysis. The found biodiesel to be economically viable, provided that feedstock costs remained low (at around $0.10 per lb or $0.75 per gallon).

Tennessee

In 2002 the Agri-Industry Modeling & Analysis Group prepared a study on the economic feasibility of biodiesel production in Tennessee. The researchers began by examining the current market situation (for feedstocks, biodiesel, and tercerary products), the market outlook with relevance to policy, and then examined financial feasibility in Tennessee, and determined the best locations in Tennessee for a production facility.[12] The study found a stand-alone biodiesel plant of 13 million gallons per year to be profitable with best and baseline scenarios, but unfeasible under worst case scenarios.[13] These scenarios depended on both feedstock and biodiesel prices. The study focused exclusively on soybeans. Tax credits and public fleet use of biodiesel were considered significant in driving biodiesel demand both in the present and in the near future.[14]

Minnesota

University of Minnesota researcher Douglas Tiffany examined the impact of proposed state mandates requiring 2% biodiesel blends (B2) in 2001. He concluded that the mandate would “reduce the energy dependence of the state, improve air quality, provide fuels that reduce engine wear, and strengthen the local economy in a sustainable fashion with no budget exposure to the state of Minnesota.”[15] His report considered the effect of past mandates, federal and state mandates, the economic feasibility of production, and the mandates’ agricultural and overall economic impacts (through an IMPLAN analysis).

Seattle, WA

Graduate students at the University of Washington analyzed the Seattle market for its feasibility for biodiesel investment in 2003. They identified the following criteria for a successful venture: 1) abundant feedstock at a low price, 2) low upstream transportation cost, 3) few delivery points, 4) consumer affinity for biodiesel.[16] Using these criteria, they found Seattle to be an attractive location, with cheap feedstock, low transportation costs, large volume consumers, and a supportive environmental community.

Rapeseed in the Southeastern United States

Van Dyne and Raymer investigated rapeseed as a feedstock for biodiesel production in the southeastern U.S. in a 1992 report for the Tennessee Valley Authority. The report focused primarily on feedstock growing and costs and the production costs associated with a cooperative production facility. The report found that for rapeseed to be a sustainable economic endeavor, continued federal support for the crop would be needed.[17] Importantly, the report held that "any federal farm program costs will be offset by macroeconomic benefits of reduced imports, enhanced balance of payments, a more environmentally-friendly fuel, plus investment and employment in rural areas."

Canola-based production in the Inland Pacific Northwest

Withers and Noordam (1996) conducted an analysis of the feasibility of producing biodiesel from canola in the Inland Northwest. The report examined the costs of constructing a production facility, feedstock cost, markets (with a focus on an urban bus fleet), and site location.

Comprehensive studies

Bender examines twelve economic feasibility reviews in a 1999 study, and concludes that biodiesel is not economically feasible without tax credits and support. Bender reviews tax incentives, production economics (including economics of scale), differing feedstock components, byproducts, and considerations for agricultural cooperatives. These studies projected the cost of biodiesel from vegetable oil (US $0.54-0.62/L) and waste grease (US$0.34-0.42/L), uncompetitive compared to the 1999 petroleum diesel price of US$0.18/L.[18] Since diesel prices have doubled since that time, however, biodiesel is now far less unfeasible.

Ginder conducted a general evaluation of biodiesel as a value-added opportunity in a 2004 study, outlining key factors of concern in developing biodiesel markets, manufacturing, and feedstocks.[19] He does not examine biodiesel's national economic feasibility, but provides a good framework for doing so at the regional level. Feasibility studies appear less useful at scales larger than regions, since feedstock, processing, market, and government policy variables tend to vary significantly.

C. General Trends and Findings

Having reviewed the general approaches of feasibility studies that have been conducted in other regions, I turn to those findings relevant to an Oregon feasibility study. Though these topics overlap, I examine feedstock, processing, market and policy considerations separately. I use these findings to determine which factors to focus on in my research on biodiesel feasibility in Oregon.

Feedstock Considerations

Since the majority of studies have focused on soybeans as the feedstock for biodiesel, the amount of economic information available on using *brassicas* (canola, rapeseed, or industrial mustard) as a feedstock is limited and somewhat dated. A review of the European biodiesel industry should prove useful here but was beyond the scope of this study. Research at the University of Idaho has focused on canola, but has examined on technical rather than economic aspects.[20] Feedstocks merit central attention in any feasibility study, since they contribute 75% to 80% of total cost to the production facility.[21]

The Pacific Northwest cannot support soybean cultivation, but is well suited for *brassicas.* Canola and rapeseed tend to be more expensive feedstocks. Prices cited in the literature vary, ranging from \$0.25 per pound to \$0.16 per pound of oil.[22] According to Coltrain, research into mustard seed indicates very competitive price (\$0.10 per lb.) if combined with a secondary market in seed meal.[23] Wise Energy consultants echo this, noting that mustard seed has agricultural advantages over canola as well.[24] Mustard seed viability is highly contingent on the development of a secondary market for the meal (which may be used as a pesticide). Uncertainty with this market is high. An alternate feedstock for Oregon would be yellow (waste) grease from the state's urban centers. Yellow grease is one of the cheapest feedstocks.[25] However, it is currently used in animal feed, so a biodiesel production facility would have to compete with other yellow grease users.

Concerns raised by VanWechel et al. regarding feedstock sourcing in North Dakota soybeans are important. Agricultural products are frequently subject to long-term contracts, limiting the availability of products. Some canola in the PNW is grown under contract, but since it is a rotation crop, long-term contracts are impractical and not likely to be found in the region.

Dyne and Raymer emphasize the importance of federal price support for rapeseed crops to be profitable as a biodiesel feedstock in the Southeast.[26] Withers and Noordam emphasize the relative profitability of raising canola as opposed to peas and feed barley, which are alternate crops in the inland Northwest. The report concluded that on average, canola was less profitable than peas and barley, and would only be produced in areas with higher yields or with agricultural subsidies.[27] Notably, the canola production costs used by the authors differ substantially from costs in Northeastern Oregon.

Processing Considerations

Feasibility reports that reviewed biodiesel processing emphasized economies of scale, the development of new technologies, and the importance of secondary products in production economics. Shumaker et al. analyzed four differently sized biodiesel facilities, concluding that economies of scale are realized at a plant that produces 15 million gallons per year.[28] This finding was echoed by the Agri-Industry Modeling & Analysis Group's Tennessee analysis. Coltrain found that total cost for transesterification is $.52 per gallon, with overhead contributing $.33 per gallon. He cited other studies which have estimated total operating costs at 30-60 cents per gallon.[29] An industry rule of thumb estimates that capital and start-up costs come to $1 per gallon, so that a 10 million gallon per year facility will cost around $10 million.[30] Virtually all studies concluded that biodiesel is not competitive with petroleum diesel at current prices. Shumaker et al. added that with low feedstock costs biodiesel could be competitive if marketed as a blend, if petroleum diesel prices rise, or State or Federal tax incentives reduce costs and increase demand.[31]

The reports uniformly found that existing processing technology is sufficiently technically feasible to produce biodiesel. Two different production formats exist, the batch method (suited to smaller operations), and the continuous-feed method (best for operations processing more than 2 million gallons per year). Continuous feed operations are more efficient, but require a substantially higher cost outlay. Several studies raised the distinction between stand-alone plants (which bought vegetable oil as the primary input from a mill) and integrated plants, which used raw soybeans and produced both meal for secondary markets and oil for refining.[32] Since the extraction of oils from *brassicas* produces meal as well, this same dilemma will face a biodiesel plant in Oregon. Coltrain, Mixon et al., and VanWechel et al. raised the importance of transportation costs in siting processing facilities. Regionally, transportation adds $0.07 per gallon, and to ship biodiesel from the Midwest to coastal regions, it adds $0.17 per gallon.[33]

Biproducts of biodiesel production include meal from oilseeds and glycerine from biodiesel refining. Seed meals play an important role in driving profitability the *brassicas,* particularly with industrial mustardseed. Mustardseed varieties are being developed that could be used as a bioinsecticide, and canola produces a feed meal used by livestock. Glycerine is of less importance, since an expected boom in production associated with biodiesel is expected to saturate the market.[34] Of these economic factors, in my study I examine economics of scale, variable and fixed costs, and the structure of production and distribution.

Market and Policy Considerations

Typically, feasibility studies examine the current diesel market for to evaluate biodiesel market potential. Biodiesel is generally over $1.00/gal more expensive than petroleum diesel. The diesel market is not uniform, and public and semi-public fleets are seen as the primary market for biodiesel in the near future, since public fleets can meet federal alternative fuel mandates under the 1992 EPAct by using biodiesel.[35] Certain sectors of the public, particularly the agricultural and marine sectors, are likely to pay a premium for biodiesel. Rural cooperatives which provide diesel to farmers are some of the primary retail distributors of biodiesel. Retail pumps, especially in the trucking industry, are generally considered to be least feasible for finding customers willing to pay a premium. Unfortunately, this sector uses the largest proportion of diesel.

This has led the biodiesel lobby to press for government mandates requiring all diesel fuel to contain a percentage of biodiesel, or to provide tax breaks for biodiesel. These measures have been enacted in Minnesota and Illinois, and are being proposed in other states as well. Several feasibility studies examined the macroeconomic impacts of these measures, concluding they had a positive effect on the economy. Coltrain cites an Iowa State University economic study that concluded that the total incremental cost of operating the entire Iowa state fleet on B20 would be more than offset by the predicted increase in tax revenues.[36] A study in Illinois found that a state sales tax exemption passed in 2003 would boost the state's economy more than $22.5 million by increasing soybean prices $.05 per bushel.[37] Shumaker et al. found that the construction of a 15 million gallon per year plant would result in the addition of 132 jobs to the economy and over $2 million in tax revenue.[38] A Minnesota Department of Agriculture report in 2002 examined the economic impact of using biodiesel blends in the state. It reviewed the impact on the agricultural, processing and export sectors, and concluded that with a 5% blend ratio, the state's biodiesel industry would contribute $527 million to the economy.[39] These analyses provide an important argument in support of government intervention in support of rural economies. On the other hand, a study in Indiana found that mandating biodiesel blends in Indiana would lead to an economic loss as farmers shifted from corn to soy beans, since corn production brings more economic returns to the economy as a whole.[40] Although market and policy considerations are important, I will not examine them in detail due to the restricted scope of this study.

Conclusion

I have reviewed feasibility studies conducted in other parts of the U.S. to provide a framework for determining if biodiesel is feasible in Oregon. A feedstock needs to be developed that is financially and agriculturally attractive to farmers, yet cheap enough to provide a cheap feedstock for processors. Optimal processing plant size, location, and design need to be determined. A distribution network must be established that mediates between proximity to feedstock and markets. Markets should be targeted carefully to "triple-bottom-line" fleets that have non-economic reasons for using biodiesel, or legislation mandating a biodiesel blend should be passed. Although there not enough clear economic information about biodiesel production feasibility, synthesizing other reports provides a clear idea of central trends, opportunities, and obstacles in the industry. Biodiesel is not competitive at open market prices, but significant spillover benefits (rural economic development and environmental) exist to justify mandated biodiesel blends and tax credits. With these incentives, biodiesel production facilities are more likely to be profitable.

III. ENVIRONMENTAL IMPACTS

Evaluating the environmental desirability of a new technology like biodiesel is difficult, as there are frequently benefits in some areas but harms in others. To remedy this, one should examine the different environmental changes (both beneficial or detrimental) the use of a technology can or might cause throughout its life cycle. In this section I will examine the environmental consequences of producing canola, processing canola oil into biodiesel, and burning the fuel.

A. Agricultural impacts

As will be described in detail in the analysis of economic feasibility section below, canola is grown as a rotation crop with wheat in the Columbia Plateau region of north-central and northeastern Oregon. It can also be grown as a rotation crop with grass seed production areas in the Willamette basin. Rotation crops are beneficial to agriculture primarily by breaking weed and insect infestation cycles, which helps reduce pesticide use. Furthermore, rotation improves soil quality and increases species diversity in a region characterized by wheat monocultures.

Canola is a relatively hardy plant, but growers usually apply pesticides and fertilize when planting. Weed and insect damage can affect spring canola production at an economically significant level, while only insects are of concern for winter canola. Insecticides are applied to seeds rather than to fields, reducing environmental impact.[41] Insecticides used by canola growers have a "very low impact on beneficial insects and non-target species."[42] One potential danger is that once canola production begins on a large scale, new pest and disease cycles will break out that will have to be controlled with the application of a larger amount of chemicals than is currently required.[43] Fertilizer is applied, at a rate of 80 lbs of nitrogen and 15 lbs of sulfur per acre.[44] Another source recommends 100 to 150 lbs of nitrogen and 25 lbs of phosphorus per acre.[45] Since canola is grown in rotation, it displaces wheat production. For this reason, fertilizer inputs are not likely to change much, since they would also be used in wheat production.

Genetically modified (GMO) spring canola does exist and has been produced for a number of years, but has been "largely rejected" by the U.S. agricultural market. [46] Non-GMO hybrids are replacing GMO varieties in much of the U.S. In northeastern Oregon, no GMO canola is grown, since there are no GMO winter canola varieties yet, and winter canola is the predominant variety grown.[47] Farmers' concern for preventing seed contamination by GMO plants will likely remain high, but the development of new GMO varieties specific to the region, or a change in market pressures, could lead to the introduction of GMO canola. Thus far, only "Roundup Ready" (pesticide resistant) canola varieties have been produced commercially, which are of less ecological concern than "Bt" varieties, which contain a natural insecticide that affects non-target species.[48]

B. Production Impacts

A significant portion of biodiesel's environmental emissions and energy demand results from the crushing and refining process. There are various production methods, with different environmental impacts, making it difficult to accurately characterize biodiesel's processing impact in general. Unless otherwise noted, the information used here is based on an analysis of soybean-based biodiesel, which may differ from canola-based biodiesel.

Hexane and Crushing

Most commercial biodiesel is produced using hexane as a solvent to extract oil from soybeans during crushing. Hexane is a toxic, flammable chemical that emits substantial amounts of hydrocarbons (THC). Although tailpipe emissions of THC from biodiesel are 37% lower than diesel, biodiesel produces 35% more THC over its lifecycle. Petroleum diesel generates roughly five times as much wastewater flow as biodiesel, and biodiesel (B100) produces 96% less hazardous waste compared to the petroleum diesel life cycle.[49] These results are based off of soybean biodiesel, which relies on the use of hexane oil extraction. Large canola crushers in Canada also use hexane extraction. In the Northwest, the crushers under consideration are all cold screw presses, which do not emit pollutants. Cold screw press technology produces a higher quality feed meal, improving the meal byproduct, but raises crushing costs.[50] Hexane extraction requires large, high-volume crushers that are costly to build and consume more canola seed than the inland Northwest is expected to produce.[51] For this reason, hexane emissions from oilseed crushers are less of an environmental danger in the region than elsewhere.

Processing Considerations

Small-scale "homebrew" producers of biodiesel must be very careful to properly ventilate the fumes produced from the production process, which, especially if methanol is used in the production process, are toxic and flammable.[52] Wastewater used in washing the biodiesel must also be disposed of, and contains caustic chemicals, but no significantly toxic ones. For large Midwestern producers, processor solid waste is categorized as "oil and grease" for disposal purposes, and wastewater consists of small amounts of methanol, phosphatides, unsaponifiable matter, soap, and glycerides.[53] The caustic chemicals can be neutralized so that they can be disposed of through sewage systems.[54] Recently constructed commercial facilities (over 1 million gallons per year of capacity) are sealed so that emissions are substantially reduced. These facilities capture excess methanol, automatically neutralize excess caustics, and recycle their wastewater.[55,56] Some have raised concerns regarding the disposal of glycerine that contains methanol and caustics remaining from the production process.[57] The technology providers and producers contacted for this study, however, indicated that the glycerine was free of harmful contaminants.[58] Pollution resulting from the biodiesel production process is minimal, especially at commercial levels of production.

Input Considerations

The essential inputs are energy, an alcohol, a caustic catalyst, oil, wash water, and phosphoric acid used to neutralize the caustic and fatty acids. The cheapest alcohol to use is petroleum or coal-based methanol, which is sold as racing fuel and is similar to gasoline in nature. The fossil fuels from which methanol is made are environmentally unsustainable, entailing resource extraction and pollution from refining. Dewatered ethanol made from grains may also be used as a catalyst, but it is several times more expensive.[59] If Oregon develops a cellulose-based ethanol industry and prices drop, ethanol could become an affordable alcohol for biodiesel reactions. Since 10% of the volume of the biodiesel comes from the alcohol this is a significant amount. The most common catalysts are potassium hydroxide or sodium hydroxide, commonly used household chemicals, which contains the same constituents as wood ash, only in a more concentrated form. The reaction requires only a small amount of catalyst.

Energy (electricity and heat used in processing) constitutes only 1% of the total cost of producing biodiesel; biodiesel is not an energy intensive industry. For example, one model that produces 1,000 gallons per hour, consumes 7.5 kw/hr.[60] Marginal energy consumption in the Northwest is likely to come from coal or natural gas fired plants, contributing to regional pollution and energy consumption. Biodiesel and petroleum diesel consume roughly the same amount of energy in processing from the crude oil or vegetable oil.[61] Assuming that biodiesel will offset petroleum diesel production, the net effect is probably still environmentally positive, although more research needs to be done. Biodiesel processing, like any industrial process, is not environmentally perfect, but compared to the toxic emissions of petroleum diesel processing it is still environmentally attractive.

C. Biodiesel Emissions

Tailpipe pollutants from biodiesel have been thoroughly researched due to interest in the fuel as a method of reducing toxic urban pollution from diesel vehicles. Biodiesel "significantly reduces emissions of carbon monoxide, particulate matter, unburned hydrocarbons and sulfates"[62] and is less likely to cause cancer than petroleum diesel. However, it may increase nitrous oxide and tailpipe carbon dioxide emissions. The EPA and the National Renewable Energy Laboratory (NREL), among others, have synthesized the results of various studies on biodiesel emissions. Because many factors influence emissions (including fuel type and quality, as well as combustion and exhaust control technology), studies have resulted in a range of estimates. Despite variations, the studies all indicate that biodiesel as a technology effectively addresses air pollution and climate change, as it reduces many health-related air pollutants and greenhouse gasses.

Air Pollutants: Lifecycle Emissions

Lifecycle emissions (total emissions from the production, distribution, and use of the fuel) differ substantially from tailpipe emissions (what comes out of the exhaust pipe). For example, sulfur dioxide tailpipe emissions are eliminated with biodiesel, but lifecycle emissions are only reduced by 8% due to electricity from coal used in processing the diesel. Lifecycle emissions information for soybean biodiesel is summarized in Table 1. [63] Biodiesel fuel is generally analyzed as a blend with petroleum diesel (most often at 20% biodiesel, or B20), or as pure biodiesel, B100:

Table 1. Relative Change in Life Cycle Air Emissions for Fuels Containing 20% and 100% Biodiesel (Based on Soybean Production with Hexane Crushing Technology).

Pollutant	B20	B100
CO	-6.90%	-34.50%
PM	-6.48%	-32.41%
HF	-3.10%	-15.51%
SOx	-1.61%	-8.03%
CH_4	-0.51%	-2.57%
NOx	2.67%	13.35%
HCl	2.71%	13.54%
HC	7.19%	35.96%

National Renewable Energy Laboratory, 1998

Lifecycle emissions from *Brassica*-based, waste grease, and animal fat biodiesel are likely to be different due to different production methods and yields and the use of different energy sources in transportation and processing. For example, electricity produced in the Pacific Northwest from hydroelectric sources used in processing biodiesel would not contribute to sulfur dioxide emissions. No study has been conducted of lifecycle emissions for these sources.[64]

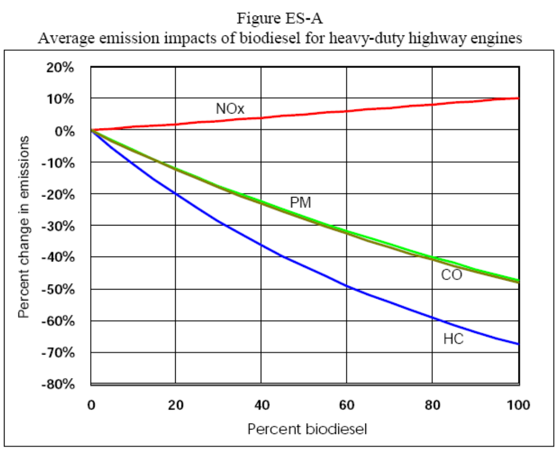
Tailpipe Emissions

The majority of research has been conducted on tailpipe emissions from large engines. According to the NREL, the use of 100% biodiesel (B100) eliminates sulfur dioxide emissions, reduces particulate matter (PM10, or particulate matter less than 10 microns) by 68%, hydrocarbons by 37%, and carbon monoxide by 46%. [65] Nitrous oxide emissions are increased by 8.89% with B100.[66] Illustrative of the range of emissions data, Table 2 summarizes the National Biodiesel Board's analysis of tailpipe emissions for EPA-required testing of the health effects of biodiesel:[67]

Table 2: Tailpipe Emissions (National Biodiesel Board, 1998).

Pollutant (tailpipe emissions)	**B100 vs. Diesel (2D)**	**B20 vs. Diesel (2D)**
Hydrocarbons	-80% to -90%	-20% to -30%
Carbon Monoxide	- 40% to -50%	-10% to -20%
Particulate Matter	-30% to -50%	-5% to -15%
Nitrous Oxides	+ 12%	+4%
Smog forming potential	-50%	-
Sulfur oxides and sulfates	-100%	-
PAH (aromatic compounds)	-75% to -85%	-
NPAH (aromatic compounds)	-90%	-

Graph 1 (EPA, 2002).



This EPA graph (Graph 1) illustrates the reductions in particulates, carbon monoxide, hydrocarbons, and the increase in nitrous oxides with various blends of biodiesel.[68]

Specific pollutants

<u>Hydrocarbons</u>: Hydrocarbons are a byproduct of fuel combustion and are a precursor, along with nitrogen oxides, to ground-level ozone, which causes smog and health problems. A range of results indicates substantial reduction with biodiesel. The NREL found that with B100, hydrocarbons were reduced by 37 percent. EPA health effects

testing (contracted by the National Biodiesel Board) found an 80 to 90 percent reduction. EPA data indicates an average of a 68 percent reduction in hydrocarbon emissions (see Graph 1 above) with B100, and 21 percent reduction with B20, based on numerous studies.[69]

Particulate Matter: Particulate matter consists of particles that cause irritation and health problems. EPA health effects testing found a reduction in particulates overall of 30 percent, and a reduction of particulate matter capable of entering human lungs and causing health problems of under ten microns (PM10) of 80 percent.[70] The NREL study found that "tailpipe emissions of PM10 are 68% lower for urban buses." Furthermore, biodiesel emits 83.6% less soot, which has been linked with cancer, than petroleum diesel.[71] The EPA comprehensive study found that particulate matter was reduced by 48%.[72] Biodiesel particulate matter has 20% less toxicity than diesel PM.[73]

PAH, NPAH, and other aromatics: Polycyclic aromatic hydrocarbons (PAH) and nitrated polycyclic aromatic hydrocarbons (NPAH) are a group of over 100 different chemicals that are formed during the incomplete burning of fuel and are carcinogenic. The EPA comprehensive study found that the exhaust emissions for PAH and NPAH compounds are substantially reduced for biodiesel compared to diesel. Most PAH compounds were reduced by 75% to 85%. All NPAH compounds were reduced by at least 90%.[74] A British Columbian study found an 80% reduction in PAH.[75] Tests from Europe illustrate the dramatic reduction in PAH with biodiesel in Table 3:[76]

Table 3 (MARC-4 Consulting, 2004).

Gaseous PAH levels of diesel fuel and a 50% biodiesel blend.

	Diesel		50% Biodiesel
		—- *µg/cycle* ---	
Naphthalene	331,654		384
Methyl-2 Naphthalene	10,289		329
Fluorene	1,864		368
Anthracne	4,301		873

Mutagenicity: A primary health concern with petroleum diesel is its carcinogenic exhaust. Test results have documented that the use of biodiesel reduced the Ames mutagenicity of diesel particulate matter (DPM) by 50% over conventional diesel fuel. Other sources have noted up to a 90% reduction in cancer-causing potential.[77] A study examining the likely impact of using B20 only in the heavy-duty diesel engine fleets in

Southern California found that it would result in a 5% reduction in risk associated with air toxics would result.

Carbon monoxide: Carbon monoxide contributes to smog. According to the NREL, use of 100% biodiesel reduces carbon monoxide (CO) by 34.5%.[78] The 2002 EPA study estimates a 48% reduction.[79] The EPA comprehensive study found a 50% reduction.[80] Lindhjem and Pollack found a 42% reduction in CO.[81]

Sulfur Dioxide: Sulfur Dioxide contributes to acid rain. Since Biodiesel contains no sulfur, it eliminates sulfur dioxide emissions. B100 reduces sulfur dioxide by 100%, and B20 reduces it by 20%.[82]

Nitrous Oxide: Nitrous oxide emissions, along with hydrocarbons, are a contributing factor to ozone. Studies of nitrous oxide emissions from biodiesel show increases in emissions over petroleum diesel by 13.2% (Lindhjem and Pollack),[83] 12% (Tier I Study),[84] 10% (BC Study),[85] and 5.2% (NREL 1998);[86] because the amount of NOx emitted is a function of engine design, research has shown that changes in engine timing and the composition of the base fuel for biodiesel blends can eliminate these NOx increases.[87] Despite the increase in NOx from biodiesel, the overall ozone-creating potential of biodiesel exhaust is 50% less than petroleum diesel.[88]

Greenhouse Gasses

Tailpipe emissions of carbon dioxide, the primary greenhouse gas, from biodiesel are 4.7% more than petroleum diesel due to biodiesel's more complete combustion and corresponding reduction in other carbon-containing emissions.[89] However, since greenhouse gasses collect at a global level, lifecycle CO2 emissions are of concern in addressing global warming, not tailpipe emissions. According to the National Renewable Energy Laboratory, lifecycle CO2 emissions from biodiesel are **78.45%** less than diesel.[90] Methane, another important greenhouse gas, is reduced by 2.57% and 0.51% for B100 and B20, respectively, compared to petroleum diesel, on a lifecycle basis.[91]

Table 4: Tailpipe Contribution to Total Lifcycle CO2 for Petroleum Diesel and Biodiesel (NREL, 1998).

Table 7: Tailpipe Contribution to Total Life Cycle CO_2 for Petroleum Diesel and Biodiesel ($g\ CO_2/bhp\text{-}h$)

Fuel	Total Life Cycle Fossil CO_2	Total Life Cycle Biomass CO_2	Total Life Cycle CO_2	Tailpipe Fossil CO_2	Tailpipe Biomass CO_2	Total Tailpipe CO_2	% of Total CO_2 from Tailpipe
Petroleum Diesel	633.28	0.00	633.28	548.02	0.00	548.02	86.54%
B100	136.45	543.34	679.78	30.62	543.34	573.96	84.43%

B. Lifecycle and Energy Analysis

The process of lifecycle analysis involves examining the sequence of steps involved in making and using the fuel, from the extraction of all raw materials involved in production to the emissions from combustion. In evaluating the overall environmental impact of a technology, it is important to use lifecycle analysis. In 1998 the National Renewable Energy Laboratory (NREL) conducted a lifecycle analysis comparing biodiesel produced from soybeans to petroleum diesel. Lifecycle emissions of greenhouse and criteria air pollutants are examined below. Biodiesel reduces most types of pollution compared to petroleum diesel; soybean-based B100 increases emissions of hydrochloric acid by 13.54%, due to coal combustion used in electric power generation, and biodiesel emits 35% more total hydrocarbons.[92]

Alternative fuels are frequently evaluated for their energy balance, that is, the amount of energy required to produce them in relation to the amount of energy they release when burned. According to the NREL study, “biodiesel yields 3.2 units of fuel product energy for every unit of fossil energy consumed in its life cycle,” and this ratio could be increased even more if non-fossil sources such as ethanol are used in refining instead of methanol.[93] Siting production of biodiesel close to the location of use substantially increases its relative efficiency.[94] Biodiesel’s energy balance exceeds that of ethanol, petroleum diesel and gasoline, as seen in Table 5. The amount of energy used in processing each raw material (crude oil or vegetable oil) is equivalent. The use of 100% biodiesel results in a 95% reduction in fossil fuel use compared to petroleum diesel.[95]

Table 5 (Minnesota Department of Agriculture, 2004).

Fossil Fuel Energy Balance/Energy Life Cycle Inventory

Fuel	Energy yield	Net Energy (loss) or gain
Gasoline	.805	(19.5 percent)
Diesel	.843	(15.7 percent)
Ethanol	1.34	34 percent
Biodiesel	3.20	220 percent

From http://www.mda.state.mn.us/ethanol/balance.html

F. Conclusion

The likely environmental impacts of biodiesel production in Oregon are mixed. Because it is a rotation crop, it is likely to have beneficial effects on agriculture. The inputs used in production involve energy as well as fossil fuel consumption. The industry will not result in a degradation of the environment or agricultural land, and it has the potential to reduce the amount of harmful air pollutants and greenhouse gas emissions. Biodiesel is not perfect, yet it represents an improvement over petroleum diesel.

IV. ECONOMIC FEASIBILITY

A. Defining Economic Feasibility

In examining economic feasibility of the biodiesel industry in Oregon, the central question is, "Do sufficient incentives exist for the necessary economic players to engage in production?" In other words, for each step of the production chain (from farmer to consumer) do the expected *economic* benefits outweigh the costs? Furthermore, what is the opportunity cost of producing biodiesel?

Even if biodiesel is profitable, if there are more lucrative alternatives, actors will not pursue it. This analysis focuses on quantifiable economic costs and benefits driven by markets, since few production decisions in competitive agricultural and fuels markets are driven by non-market logic. Situations in which non-economic considerations might influence production decisions are noted.

Table 6 considers the regional actors required to realize biodiesel production. Factors influencing economic feasibility for the agricultural producer, crushing facility and biodiesel processor are considered in this section. The focus of this analysis is on the production of biodiesel from canola grown in rotation with wheat in northeastern Oregon; different conditions elsewhere in the state may make biodiesel production more or less feasible elsewhere.

Table 6: Regional Actors in Biodiesel Production.

Actor	**Need**	**Benefits**	**Problems**	**Alternatives**
Farmer	Rotation crop for wheat with value added use	Good rotation crop; breaks disease cycles	Market price below breakeven cost	Growing barley, peas, lentils
Crusher	Seed to crush; market for oil and meal	n/a	Crushing loses money; no crushers in region	Involvement in another ag enterprise
Meal User	Regional alternative to soybean meal for livestock feed	Canola can be grown in region; high quality feedstock; good for dairies	Can't use more than 12% canola meal in feed	Importing soybeans, cotton seed, or other meals
Biodiesel Processor	Cheap, regional vegetable oil	Oil feedstock; low pour point	No crushers; canola production low	Processing oil for biolubricants (potentially more lucrative)
Blender/ Distributor	Meet market demand for Biodiesel	Tax credit; environmental image; lubricity concerns; easily blended	Minimal economic incentive to expand storage facilities	Synthetic lubricity additives probably cheaper
User	Alternative fuel; certified safe for warranties; environmental image	Regional fuel source	Engine warranties; price increase; limited retail market	Petroleum diesel

B. Agricultural Economic Feasibility

General

Economic feasibility for the agricultural producer is a basic prerequisite for creation of a biodiesel industry in Oregon. The primary oil crop grown in Oregon is canola (primarily *Brassica napus* and *Brassica rapus)*. Industrial rapeseed, yellow mustard, and industrial mustard are other potential oil crops that have been grown in the state in far smaller amounts, and researchers at Oregon State University are researching the feasibility of meadowfoam and other non-traditional crops as potential oil sources.[96] This analysis focuses on canola, since it has a proven production history in the state, and interested parties (farmers, researchers, and entrepreneurs) are focusing on canola at this time.

What will motivate farmers to produce canola? As any other economic actors, farmers must believe that they will make money by growing the crop. Canola is not the primary crop that farmers grow; rather, it is a rotation crop used in cultivation of wheat. It can also be used as a rotation crop for grass seed, which is grown in the Willamette valley. This analysis looks only at canola's use as a rotation crop with wheat. Farmers evaluate the crop's profitability (or lack thereof) against that of alternative rotation crops such as barley, peas, or lentils. In order for farmers to plant, economic returns must be greater than those of alternate uses of the land. Additionally, there are other considerations that can lead to production even if numbers do not "pencil out," such as the need to mitigate losses during rotation on land used to grow more lucrative crops, or the agronomic benefits of raising canola as a rotation crop. This section will examine the non-economic benefits of canola as a rotation crop, the cost of production and the relationship between yield and production decisions, history and trends in canola prices, and contrast canola to alternate rotation crops, and evaluate Oregon's production potential. It concludes that a price of \$0.13 to \$0.14/lb of canola seed would substantially increase canola production. The development of local markets for canola seed might result in this price level. However, developing these markets is difficult since there is relatively little canola currently grown in the region.

Canola as a rotation crop

Canola is primarily grown as a rotation crop with wheat in the Columbia Plateau region of north-central and northeastern Oregon. Canola, a broadleaf, breaks weed (e.g. downy brome and crabgrass) and insect infestation cycles in cereals, since it changes crop type and permits farmers to use herbicides they cannot use on wheat.[97] It also improves soil quality, since it has a deep taproot that increases soil depth and permeability.[98] The use of canola in rotation following a fallow increases the following year's wheat yield in the northeast Oregon region by 10% on average (studies show increases from 0% to 25%, depending on rainfall).[99] Canola is an annual dryland crop grown in areas that receive 13 inches to 24 inches of rainfall per year, with rainfall greatly influencing the level of production per acre.[100] Canola may also be grown as a rotation crop on irrigated land for disease control purposes.[101] There are two types of canola: spring, planted in the spring months and harvested in September and October, and winter, which is planted in the early fall and harvested from June to July.[102] Winter canola is currently the most common in the region. A four year rotation for winter canola is typical, in the pattern of a summer fallow followed by winter canola, another summer fallow, and then winter wheat. Summer fallows are necessary in the region in order to build soil moisture. In areas with rainfall above 16 to 17 inches per year, spring canola can be grown in a three-year rotation of spring canola, spring cereal, and winter wheat.[103] These rotation patterns can vary substantially depending on rainfall and demand for various crops at a particular time. Canola itself cannot be grown more than two years in a row due to diseases that attack repeated cultivation.[104] It is unknown what large acreages in canola would do to disease and insect cycles, since there is no regional experience, but increased acreage would probably reduce overall yield and increase pest problems.[105]

Costs of production

Breakeven price

Producers make production decisions based on a "breakeven price," the level at which their returns on a crop will cover their expenses. Agricultural researchers compile "enterprise budgets" which estimate costs associated with producing crops in a particular region. These are based on the consultation of knowledgeable producers. The most recent enterprise budget for Oregon canola was compiled by the Oregon State University Extension Service and examined costs in north-central Oregon in 1998.[106] The 1998 budget found a breakeven price of $0.09 per lb to cover cash (variable) costs, and $0.12 per lb for total (variable and fixed) costs (for yields of 2,000 lbs per acre).[107] The breakeven price has most likely risen since that time, due to rising fuel and fertilizer costs. In comparison, a 1995 budget for the Pendleton area found a breakeven price of $0.07 per pound for variable costs, and $0.12 per lb for total costs (for yields of 2,500 lbs per acre).[108] Enterprise budgets are based on estimates of input costs, and actual costs may vary depending on yield rate and other factors. According to OSU Extension agronomist Don Wysocki, the yields assumed in the studies are high for the regional average, and lower yields would raise the breakeven price.[109] Despite the generalizations they are based on, the OSU budgets appear relatively accurate, as currently area producers communicate that breakeven price is around $0.13 to $0.14 per lb, at the farm gate.[110] Another source estimates that the breakeven price may be slightly lower, depending on yield and other factors.[111] In 2003, Washington State University Cooperative Extension examined the costs incurred by actual producers in producing canola in eastern Washington and north-central Idaho, regions similar to northeastern Oregon.[112] For canola produced in the 15-20 inch rainfall zone (most similar to northeastern Oregon), breakeven prices were $0.14, $0.09, $0.11 cents per lb, and for the less than 15 inches/year rainfall zone, breakeven prices were $0.16 and $0.14 cents per lb. At market prices ($0.11/lb), yields would have had to be between 1,400 and 1,650 lbs per acre to reach breakeven cost. The large disparities between breakeven prices were largely due to differences in land costs for different producers. Although these results vary, they reinforce estimates of average production costs between $0.12 and $0.14 per lb.

<u>Inputs</u>

The factors determining the costs of production are outlined in Table 7, based on the OSU enterprise budgets:

Table 7: Costs of winter canola production, 1998 (OSU Enterprise Budgets, Corp et al., 1999).

Variable Costs	$ 174.53/ac	Percent of total cost
Summer Fallow	$ 39.03/ac	16%
Crop Production (seeding, fertilizer, etc.)	$ 65.12/ac	27%
Harvesting Operations (labor, transport, fuel)	$ 48.12/ac	19%
Other (crop insurance, etc.)	$ 22.51/ac	9%

Fixed Costs: (land, depreciation, insurance)	$ 66.10/ac	27%
Total Costs	$ 240.63/ac	-

The primary inputs to canola production are pesticides and fertilizer, machinery, labor, and the cost of the land. Canola seed can be harvested, stored and transported using the same equipment used to harvest wheat (a conventional dryland combine), so no major new capital investment is required to produce it.[113] Adding specialized equipment can increase the efficiency of harvest since some canola seeds fall out of holes in the machinery more easily than wheat. Farmers are not expected to buy new equipment due to high machinery cost.[114] Farmers could conceivably share equipment to reduce costs, but since canola must be harvested within a short window of time to have the appropriate moisture content, equipment sharing is not likely to be feasible. Farmers must also cover the cost of delivery to the buyer, usually a grain elevator or broker in the region. For the 1998 enterprise budget, hauling charges constitute 10% of total cost, at $1.28 per ton.[115]

Yield and Price

Yield plays an important role in determining whether a crop is attractive to farmers, and is a determinant of the breakeven price. For example, if the 1995 budget cited above had used a yield of 2,000 lbs per acre, the variable and fixed breakeven costs would have been $0.09 and $0.15 per lb, respectively, rather than $0.07 and $0.12/lb. With higher yields, farmers can make more money and the breakeven price goes down. With lower yields, the breakeven price goes up. Average yields for the counties in which the data is available are listed in Table 8, for the time period of 1993-2003 (some years are unavailable due to confidentiality concerns; these are averages of available statistics):

Table 8: Average yield, 1993-2003 (OAIN Database, 2004).

County	**Yield (lbs/ac)**
Baker	2110
Gilliam	1143
Morrow	2258
Umatilla	2033
Union	1145
Total Average	1677

According to Dwight Robanske, a county commissioner involved in developing a biodiesel facility in Columbia County, Washington, a rule of thumb for dryland canola yield in the Pendleton, Oregon is 1,500 lbs per acre.[116] A Washington State University study estimated an average of 2,000 lbs per acre for eastern Washington,[117] and the Oregon State University enterprise budgets cited above used estimates of 2,000 and 2,500 lbs per acre. However, for use as an average for the region, it appears that this estimate is excessively high. These studies assume canola is grown on summer fallow on the best land. If most available wheat acreage were rotated into canola, yields would be lower. According to Don Wysocki, a better average would be 1,000 lbs per acre.[118] This average would be the result of varying yields from the 3 growing niches for canola:

1. fall planted on summer fallow (2000-3000 lb); most consistent yields
2. fall planted on recrop or stubble (1200-2000 lb)
3. Spring planted (200-1800 lb/acre).[119]

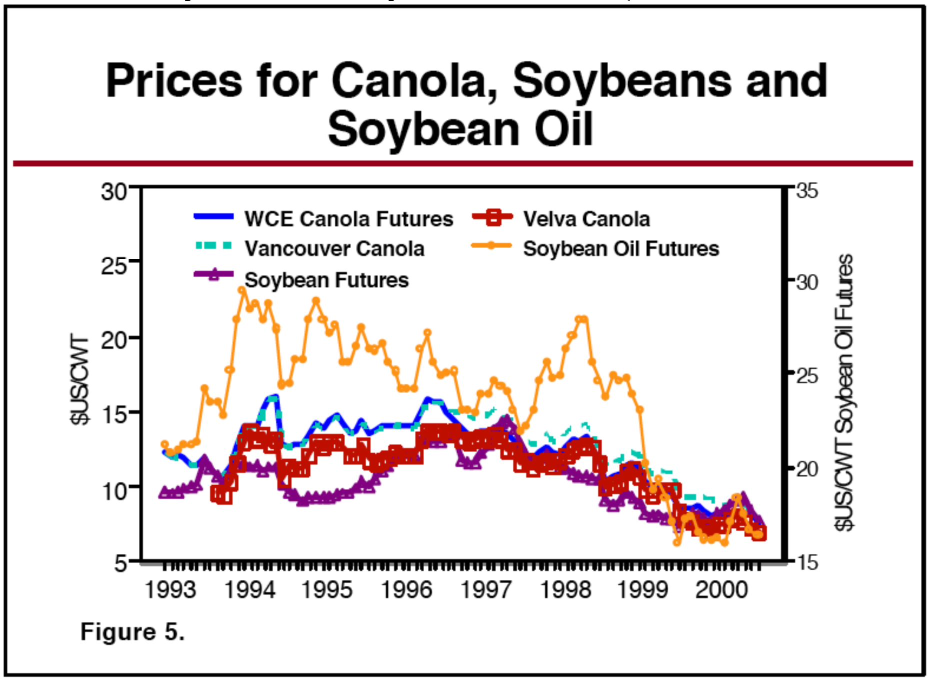
It is not clear what proportion of land is or could be put into each type of growing niche, which makes general estimates of canola yield tentative.

Because yield levels will vary from farm to farm, as market price approaches breakeven price, farmers with more productive land will begin producing canola before the average farmer. For this reason, some producers will grow canola even though the market price is below the average breakeven price. After prices continue to rise, producers with more marginal land will start producing, since the increased price per acre will allow them to meet the breakeven price specific to their acreage. This follows the basic economic principle of diminishing marginal returns. Average yield will go down as more marginal lands are brought into production. On the whole, according to the analysts interviewed and the data examined, a price of 12 to 14 cents appears a reliable estimate of what is needed to motivate the market. The possible production levels at each price are examined below.

Determinants of market price

Due to the competitive structure of agricultural markets, the open commodities markets set the prices farmers receive for their products. The soybean market largely influences canola price; soybeans are the predominant oilseed. Because oilseeds are largely interchangeable goods, buyers can switch between soybeans, cottonseed, canola, and other oilseeds, causing these commodity prices to follow similar trends. For example, feed brokers use the general rule of thumb that canola meal is 65% to 75% the cost of soybean meal.[120] Soybean prices, in turn, are driven by demand from livestock and human food markets for soybean meal and oil. These are international markets also open to intense competition, and prices have been driven down by increased overseas production. Oregon canola prices are shown in Graph 2 in the section on price and production levels.

Graph 2: Canola, Soybeans, and Soybean Oil Prices (Flaskerund et al., 2000).



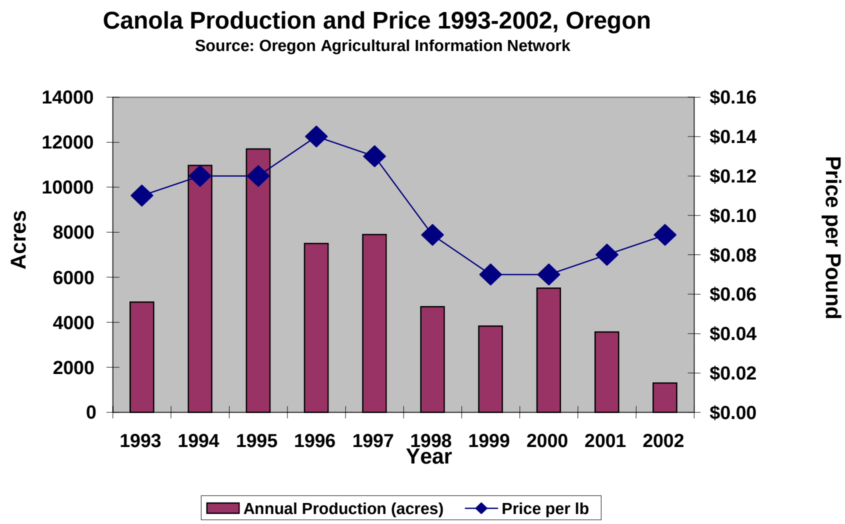
From http://www.ag.ndsu.nodak.edu/aginfo/cropmkt/pubs/Eb-75.pdf[121]

Transportation considerations

Agricultural commodities are very sensitive to transportation costs due to their bulk. Transportation of commodities over 100 miles by truck generally makes the economically unfeasible.[122] As noted above, transportation constitutes 10% of the farmer's production costs. Since there are no local markets for canola seed, regional prices are depressed because canola seed must be transported to a seed crusher outside of the region for processing. There are no commercial canola seed crushers in the Pacific Northwest; the nearest crushers are located in Great Falls, MT, and in Lethbridge, Alberta, Canada.[123] Canola seed produced in the region is either shipped to these crushers by rail or transported by barge to crushers in California or Japan.[124] Ironically, canola seed is shipped to these crushers, while meal is imported back into the region for use as livestock feed. Finding a way to reduce transportation costs, such as locating a crushing operation in the region, would result in a higher price for the producer and increase production.

Price and Production Levels: How much canola can northeastern Oregon support?

Graph 3: Production and Average Price of Canola in Oregon from 1993-2002 (OAIN Database, 2004).[125]



Although increasing prices would likely increase canola acreage, it is not clear to what level production could increase. Oregon contains only a limited amount of land used for the cultivation of wheat and other crops that need rotation, where the bulk of canola production could occur. Only between a third and a fourth of this land could be available for canola production at a time, since it is a rotation crop, and other crops may compete with canola. Wysocki estimates that of eastern Oregon's two million acres of cropland, about a quarter of that land would support canola production once in every three years, so that the region could probably support 160,000 acres of canola per year.[126] Wysocki estimated that a price of around $0.14 would motivate this level of production.

Wysocki also noted that irrigated land in central Oregon could also support canola as a rotation crop, but since canola does not have the high returns that other irrigated crops do, central Oregon production would not be significant. Another source indicated that for planning purposes, one should calculate that one tenth of arable land will be in canola each year.[127] For eastern Oregon, this figure (200,000 acres) corresponds roughly to Wysocki's estimate of 160,000 acres, or around 80,000 tons of canola seed per year (at a yield of 1,000 lbs/ac). A report by the Oregon Department of Agriculture more generously estimated that the northeast Oregon region could support up to 350,000 acres of canola. The same report estimated that up to 50,000 acres could be produced in the Willamette Valley.[128] Yield per acre in the Willamette Valley is higher than that in eastern Oregon, so a substantial amount of oil could be produced in the region.[129]

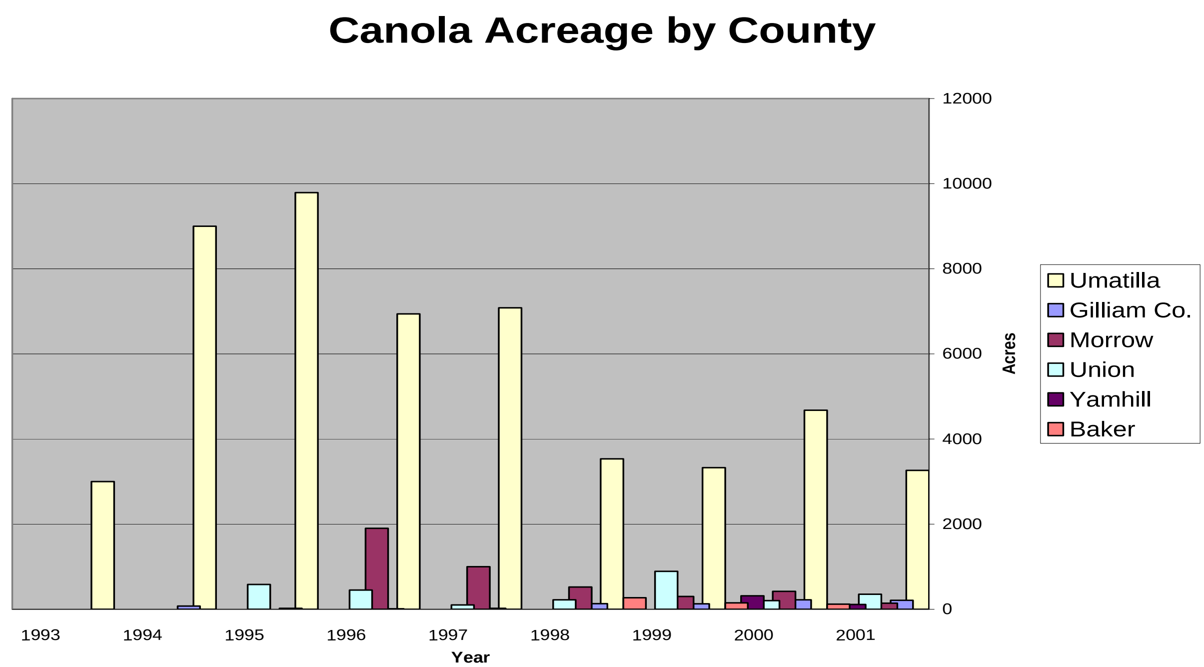
Importantly, there is also substantial dryland wheat production directly north of the Washington Oregon border, so that that area would also be important for making a plant feasible in the NE Oregon area. Quantifying the amount of land in Washington available is beyond the scope of this study, but could prove important in determining the size of a biodiesel plant sited in the region.

Canola production peaked in 1994-1995 when prices reached 14 cents per pound.[130] All relevant sources consulted felt that canola production would be price responsive, and that farmers would increase production if prices were to rise again.[131] Statewide production approached 12,000 acres in 1995 at a price of \$0.12 per lb. Prices crashed in the late 1990s causing production to decline; in 1999, prices fell to \$.07 per lb and production dropped below 4,000 acres.[132] What is unclear is whether the relationship between price and production is linear, so extrapolating from these prices is an uncertain undertaking.

Production Distribution

The bulk of past canola production in the state has taken place in Umatilla, Morrow, and Union counties, as indicated by Graph 4, below, with the vast majority of production in Umatilla County. Much of this crop data for the past decade is incomplete, however, due to confidentiality concerns in counties with few producers. Still, it demonstrates the dominance that northeastern Oregon has in canola production. Other areas of the state could conceivably support canola as well.

Graph 4: Canola Acreage in Oregon (OAIN Database, 2004).



Competing rotation crops

Barley, field peas, and lentils are the primary competing rotation crops to canola.[133] From the available data, it appears that the most common rotation crops, peas, barley, and lentils, are likely to be money-losers for farmers. For this reason, increasing the local price for canola will likely cause farmers to choose it over other rotation crops, unless other crops rise in price as well. Farmers may continue to include legumes in their rotation for non-economic reasons, for example, in order to fix nitrogen in the soil. For this reason, it is unwise to assume that farmers will automatically drop alternate rotation crops.

According to one source, "there is no money in barley."[134] Statistics support this assertion. The breakeven price to cover total costs for irrigated barley in southern

Oregon (no data are available for eastern Oregon) is $145 per ton.[135] Current market value is $86 per ton, resulting in a loss of $59 per ton, or a loss of $104 per acre, at the average yield of 1.77 tons per acre in 2003. Oregon has an average yield of approximately 2 tons per acre of barley from 1990 to 2003.[136] In Washington, cost per ton of producing barley with a 2 ton per acre yield is $106.61 per ton.[137] Market price in Oregon in 2003 was $86 per ton, and for the past decade, prices have averaged $77.64 per ton, resulting in a loss for barley production.[138] Dry field peas may be less disadvantageous, with an average production cost at $0.12 per lb for a 2100 lb per acre yield. The average market price since 1990 has been $0.10 per lb (and at a current price of around $0.08 per lb), however, so even at that yield level the crop would be a money loser. Information is unavailable for lentil production and yield in northeastern Oregon, but at the low yield level likely in the region (due to relatively lower rainfall), a loss of $5 per acre is reported in eastern Washington.[139] According to Wysocki, lentils and peas are currently grown at breakeven cost.[140]

Conclusion

In summary, agricultural producers are motivated to produce the rotation crop that benefits their main crop and provides the best returns. Canola is an excellent rotation crop for wheat in northeastern Oregon, and additionally provides diversification from the fluctuations of wheat prices. Competing rotation crops appear to be as unprofitable as canola currently is. Higher canola prices would most likely result in canola being chosen over lentils, peas, or barley. In the past, higher canola prices have resulted in substantially increased production of canola. A stable increase in canola prices to 13 or 14 cents per pound is expected to result in an increase in canola production.[141] Current market prices are determined by the open commodities market and are closely linked to the soybean market. However, regional prices are depressed by the costs of transportation to markets outside the region. By circumventing transportation costs through developing local markets for canola seed, regional prices could rise sufficiently to increase production. It is unclear how much local markets would be pay. However, a Catch-22 situation arises in which the development of local markets is inhibited by a lack of local feedstock, which doesn't exist because there is no local market. Overcoming this challenge is the central hurdle facing canola, and in turn, the state's nascent biodiesel industry. A concerted effort would be needed to support production of the crop that educated farmers about its economic viability and value as a rotation crop.

C. Crusher Economic Feasibility and Siting

After farmers grow seed, it must be crushed in order to extract oil and produce meal used for livestock feed. This section addresses the following question: Are the market prices of the input (seed) and the value of outputs (meal and oil) such that an economic actor – be it a farmer's cooperative or a biodiesel producer – can afford to pay the costs required to crush canola? This section will examine the logistics of the crushing process, address the lack of information regarding the cost of crushing and constructing a crusher, and examine the economies of scale involved in crushing. Due to a lack of data, I am unable to conclusively evaluate the economics of a crushing plant; however, anecdotal evidence from experts indicates that crushers are only economically feasible when built into another economic endeavor; in this case, either a feed mill that uses the meal, or a biodiesel plant that uses the oil.

Crushing Process

The canola seed is first cleaned through aspiration and screen separation. It is then heated, either through a rotary kiln heated by steam or with a grain dryer. The seed is flaked by passing through metal rollers. Then the seed is typically "cooked" at temperatures of 75-85 degrees Celsius for 20 to 40 minutes in order to adjust moisture content and cause the oil to coalesce.[142] The seed may also not be cooked at all, but cold-pressed. At this point there are two production options. The seed may pass through a mechanical screw press, which removes an estimated 80 to 90% of the oil, with outputs of finished meal and oil.[143] Alternately, after coming out of the screw press, the resulting "press cake" may be soaked in hexane, which dissolves the remaining oil. The oil-hexane mixture is heated, driving off the hexane. [144] Hexane is a highly flammable and toxic substance, and the EPA has been pressuring crushers in the Midwest to phase out its use.[145] Hexane residue in animal feed has been linked to animal fatalities.[146] When processed for food production, the raw oil is then "degummed" by combining it with small amounts of water or steam and centrifuging it.[147] Experience with soybean based biodiesel shows that biodiesel does not require degumming and bleaching, but benefits from it, as the resulting fuel has less free fatty acids and less phosphatides.[148] However, since canola oil has very few free fatty acids to begin with, degumming and bleaching are most likely not necessary.

Extraction of canola oil with the screw presses being considered in the Northwest would result in less efficient extraction. Outputs are 32-35% oil, and 65-68% meal by weight.[149,150] This is less efficient than the n-hexane process, which results in outputs of 40% oil and 60% meal.[151] However, because hexane extraction reduces the meal value of canola meal and requires a much larger capital outlay, economic actors in the Northwest are not considering hexane extraction. Hexane plants typically process over 365,000 tons/yr of seed, while plants being considered currently in the Northwest would process around 60,000 tons/yr.

Siting of Crushing Facilities

Typically, crushing facilities are located close to regions with large canola production in order to reduce the costs of transportation and handling. Since U.S. production is concentrated around northern North Dakota, there are several plants there and one in Culbertson, in eastern Montana. The Culbertson plant (over 1000 miles away from Pendleton, Oregon) currently supplies the Pacific Northwest with canola meal used for livestock.[152] The closest crusher to Oregon is located in Great Falls, Montana and is run by Montana Specialty Mills.[153] Other crushers that process Pacific Northwest canola include a plant in Lethbridge, Alberta that processes 1,200 metric tonnes per day and employs 170 workers.[154] For the past four years this plant has consumed all of the canola handled by Pendleton Grain Growers, the Pendleton, Oregon farmers' cooperative.[155] Canola crushers have been located primarily in Canada proximity to large stocks of canola seed as well as a favorable Canadian/U.S. exchange rate. There are seven canola processing plants in western Canada, yet none in the Northwestern U.S.[156] These plants are large, averaging between 1,000 and 2,000 metric tonnes per day.[157]

There are currently no commercial crushers operating in the Pacific Northwest, although one is being constructed in Creston, Washington by Columbia Oilseeds, LLC, which is partially owned by Advanced Protein Technologies (APT), a feed company. The crusher should be ready for the 2005 canola harvest. This plant is expected to handle 60,000 tons per year.[158] A small-scale, portable crusher may be on-line for crushing in the Lincoln County, WA area in the winter of 2004-2005.[159] Potential sites for crushing facilities in the Northwest, based on available agricultural acreage, are examined below.

Crushing Economics

According to an analyst for a Washington livestock feed firm that is developing canola crushing as part of its operation, "crushing is a money losing business" that has "lost money 14 out of the past 20 years."[160] This assertion is supported by recent trends, where Canadian canola crushers were operating at half capacity at a monetary loss in 2001 and 2002. Rising demand for canola meal and oil and depressed seed prices allowed them to be profitable in 2003.[161] Crushing suffers from low margins caused by downward pressures on prices caused by competition on both sides: farmers can sell their seed elsewhere or produce different crops if the crusher isn't paying enough, and buyers of meal and oil can import it from elsewhere or use alternatives such as soybean-based products.[162] Crushers essentially gamble that the difference between the market price of oilseed and the market price of the resulting oil and meal is large enough to cover their costs.

Costs and Returns: Evaluating industry margins

The costs of crushing are primarily equipment, labor, and energy. No information is available to determine these costs for plants being considered in the Pacific Northwest, since there are no existing facilities, and investors considering construction consider it proprietary.[163] Large canola crushing plants are expensive.[164] A plant constructed in 1995 in Saskatoon cost 53.6 million Canadian dollars with a 2,000 metric tonnes per day capacity, employing 50 people.[165] Capital costs are unavailable for the 60,000 ton/yr plant size being considered in the Northwest.

For large producers (over 1000 tons/day), crushing costs are around $30 per ton. For smaller producers around 60,000 tons/yr, costs are closer to $50 per ton. The Canadian Canola Board publishes a "Canola Board Crush Margin" which evaluates the difference between seed cost and oil and meal returns, and "is a measure of the trend in core processing returns," providing a general indicator of the economic well being of the canola processing sector.[166] The current crush margin is around $18 U.S. dollars per U.S. ton, but market forces cause this to vary substantially.[167] A University of Georgia study estimates per ton processing costs (over seed cost) of $30.47 for a 500 ton/day plant,

$19.89 for a 1000 ton/day plant, and $17.44 for a 1500 ton/day plant.[168] These figures are purportedly for a generic oilseed processing plant, but the numbers used are based on using soybeans as a feedstock. [169] As this shows, there are substantial economies of scale influencing whether a plant would be profitable; at current margins, only the 1500 ton/day plant would reach breakeven price.

Economies of scale and crusher siting in Oregon

On the one hand, economies of scale dictate that a crusher must be over the size required to meet breakeven costs. On the other hand, a crusher cannot be so large that it depletes local oilseed supplies, which would require trucking of oilseeds from farther away and excessively raise input costs. Evaluating the optimal size of a crusher for Oregon's canola production regions is beyond the scope of this paper. John Graff of APT estimates that a crusher must process 50,000 tons of canola per year in order to break even. Correspondingly, APT is basing its crushing plant siting and planning on estimating that each plant will process 60,000 tons per year.[170]

A 60,000 ton plant would require 60,000 acres of canola at yields of 2,000 pounds per acre, and 80,000 acres at yields of 1,500 pounds per acre. Using the latter, more conservative yield, and assuming that canola is planted once every four years, would require at least 320,000 acres of land in wheat/canola rotation. Graff recommends using a safety margin of requiring 10 times the amount of cultivatable land required for the annual consumption of the crushing plant. If a 50,000 ton per year crusher were to be sited in Umatilla County, it would require 66,666 acres per year of canola production, or 266,666 acres available for a four year rotation. In 2003 the county had 278,500 acres in wheat production in that year alone, indicating that it could support this level of production.[171] This level of production has remained steady for the past four years.[172] If 160,000 acres were in production at 1000 lbs/ac yield, the region could support an 80,000 ton/yr facility. A second factor that comes into play, in addition to acreage availability, is transportation distance to the crusher. Production of canola on cropland over 100 miles away from the crushing facility is uneconomical due to transport costs.[173] A production facility centrally located in northeastern Oregon would be well within 100 miles of the region's productive acreage.

Conclusion

This analysis shows that logistically speaking, the eastern Oregon region would be able to support a crushing facility large enough to reach breakeven costs. Crushing involves separating canola seed into meal and oil. Crushing plants are unprofitable since market forces on both sides drive margins down. As a "necessary evil" for the canola industry, a crushing plant in the region would reduce the costs involved with having to transport canola outside of the region for crushing. According to two Washington sources in enterprises related to crushing, a regional crushing plant would allow farmers to capture money that is currently spent transporting canola out of the region. If canola prices were high enough to bring 160,000 acres of canola into production, northeastern Oregon could support crushing facility that operated at break-even cost.

D. Biodiesel Processor Economic Feasibility

Introduction

The actual production of biodiesel from vegetable oil occurs in a biodiesel processing plant, in which the oil undergoes a chemical reaction called transesterification, creating a vegetable ester, "biodiesel," which has properties similar to petroleum diesel. This section addresses two closely related questions. First, can Oregon biodiesel plants produce biodiesel from regional feedstocks cheaply enough to outcompete biodiesel from the Midwest? Second, what size plant(s) and production structure (centralized versus decentralized) will optimize the industry's competitiveness? In order to answer these questions, I first examine the criteria that need to be met for the industry to be operational and competitive. Then I examine the influence of plant size and structure on economic efficiency. Prior to this analysis, however, I examine the general economic situation faced by the Northwest's biodiesel industry, especially the uncertainty it must overcome.

The situation faced by the Northwest's industry

The biodiesel industry in the U.S. is extremely young. In 2003, 30 million gallons of biodiesel were produced in the U.S.; in 1999, only 500,000 gallons were produced.[174] Biodiesel is produced primarily in large facilities that process soybean oil in the Midwest.[175] The Pacific Northwest currently imports all of its commercially available biodiesel (though a small amount of biodiesel is produced by individuals and cooperatives).[176] Midwestern biodiesel is produced from soybean oil, which is considered a byproduct by large soybean processing plants. These plants use biodiesel production to absorb excess oil when prices are low; if prices rise, they shift the oil into more profitable markets such as food products and lubricants.[177] Midwestern producers have a low-cost feedstock and established, large-scale production facilities, allowing them to produce biodiesel cheaply. Larger plants are under construction, and supply is expected to increase.

The challenge faced by a fledgling Oregon biodiesel industry is outcompeting the relatively low cost of Midwest biodiesel. Transportation costs raise the cost of biodiesel currently (by approximately $0.20 per gallon), which increases the price and reduces the quantity demanded.[178] Regional production of biodiesel would largely circumvent this cost. However, this does not mean that regionally-produced biodiesel would necessarily be more affordable. The costs of the inputs required for biodiesel production, combined with economies of scale in the industry, put Northwestern production at a disadvantage. This is compounded by a lack of concrete data on the cost of constructing and operating biodiesel facilities and the unpredictable nature of the commodity markets on which the industry relies.

Uncertainty and Risk

The biodiesel industry is characterized by substantial uncertainty. No one knows what trends will be in diesel fuel and in oilseed feedstock prices. Prices of oilseeds have fluctuated greatly, as shown in Graph 3 in the previous section. Correspondingly, feedstock availability and biodiesel demand are uncertain. Costs are also uncertain: it is not clear how much crushing and processing equipment and infrastructure will cost (since these are site-specific). Processing technology is continually evolving, and construction of a plant could “trap” an enterprise into an inefficient process that would make the firm vulnerable to competitors in the future. Only a relatively small amount of oilseeds are produced in the region, no crushing or refining facilities exist, there is limited biodiesel consumption; the industry must build from scratch. These factors combine to make the biodiesel industry in the Northwest relatively unattractive to the investors required to initiate production.

The Refining Process

The creation of biodiesel from vegetable oils, through transesterification, generally involves mixing vegetable oil with methanol or ethanol (in the proportion of 1:10) in the presence of a catalyst, usually sodium hydroxide or potassium hydroxide. The product reacts, forming glycerine (10 to 20%) and biodiesel (80 to 90%). The basic process of methyl esterification has changed little over the past 90 years.[179] Feedstock oils that contain a large amount of fatty acids (primarily waste oils) will also have a portion of the fatty acids "drop out" of the biodiesel.[180] The proportions at which biodiesel and glycerine are produced depend on the type of reactor used as well as the quality of the original feedstock.[181] Some processors have been developed which operate at high temperatures and pressures, which cause the transesterification of the oil without alcohol or a catalyst.[182]

As a chemical reaction involving flammable and toxic chemicals (the methanol used is explosive and must be treated with care), it is important that the plant be monitored frequently, in order to check the operation of the equipment. Even the most automated operations legally require 1 to 2 people to be present at all times to monitor the equipment. According to one plant designer, no skill level beyond a high school diploma is needed to monitor the basic operation of the plant.[183] However, another consultant stated that a skilled operator with general experience with running the processor would have to be present at all times, even if the plant was fully automated, due to safety concerns.[184] For safety reasons, two people should be attending the plant at all times.[185,186]

The plants do not have a large energy demand, and can be fueled by diesel or other heat sources to create steam, and by electric power for pumping, stirring, and ventilation. They do not take up much space relative to other agricultural processing equipment. A 1,000 gallon per hour (around 8 million gallons per year) processor has been designed that could fit within an 8' by 8' by 20' shipping container; fuel storage and office space would have to be added to this area. A complete plant in Hawaii that produces 400,000 gallons per year fits on half an acre of land.[187] Oregon Biofuels' plant site is situated in a small warehouse not more than 10000 ft^2.

What production size and structure will optimize the industry's competitiveness?

One can imagine biodiesel production being organized in various ways. Biodiesel can be produced using household ingredients in five gallon buckets; it can also be produced in plants that produce 30 million gallons per year. Between these extremes one can imagine a variety of different production structures. Farmers could produce seed, have a portable press come to their farms and press the oil, produce biodiesel on their farms with some of the oil and sell the excess. Alternately, they could haul their seed to a nearby, cooperatively owned crusher and processor, then produce biodiesel for their own use and sell the excess on the open market. Or they could sell their seed to a regional crusher and processor, which would sell biodiesel to metropolitan areas and meal to the local livestock industry. Metropolitan areas could produce biodiesel from waste grease, with similar variances of scale.

The methods that make most sense economically will likely be those that are implemented in the region. One system might increase employment and self-sufficiency most, for example, but if the biodiesel is to be traded on the open market, or compete with petroleum diesel, the system that most reduces costs will most likely be chosen be economic actors over the long run. However, because the industry will most likely require government intervention to initiate, that intervention could be shaped in a way that maximizes non-economic benefits (such as rural employment and self-sufficiency) while at the same time ensuring that the industry is competitive in the short to medium terms.

I will examine two areas that shed light on the economies of scale that were referenced in the section evaluating the potential competitiveness of northeastern Oregon's biodiesel. The following questions must be asked to determine which production structure is most effective. First, what are the costs involved in producing biodiesel, and are these costs sufficiently low to make biodiesel from the region competitive with biodiesel produced elsewhere? Second, are the costs distributed among inputs in such a way as to make one industry structure more advantageous than another? Specifically, do economies of scale exist that promote large, regional biodiesel plants over small, decentralized ones?

Table 9: Production Costs (University of Minnesota, 2003).

Biodiesel Production Costs for a Soybean-based plant in the Midwest, 15 million gallons per year				
	Units per gallon of biodiesel	average case	cost per gallon	Percent of total cost before interest and depreciation
Feedstock	7.5	0.2142	1.606	91.30%
Methanol (lb)	0.81	0.0679	0.055	3.13%
Catalyst - Sodium hydroxide	0.01	0.0575	0.001	0.06%
Power (kwH)	0.1	0.075	0.007	0.40%
Steam (lb)	5.66	0.0006	0.003	0.17%
Cooling water (ft3)	0.59	0.0022	0.001	0.06%
Wash water (ft3)	0.02	0.0037	0	0.00%
Fuel Oil for heat (gal)	0.01	0.8149	0.008	0.45%
sales and administration	n/a	0.038	0.038	2.16%
Number of Employees				
3 mga plant	13	0.2366		
9mga plant	21	0.1125		
15mga plant	28	0.0864	0.086	4.89%
21 mga plant	36	0.0772		
maintenance (% of capital cost per gallon)	2.50%		0.021	1.19%
Insurance	1%		0.008	0.45%
cost per gallon before interest, depreciation, and glycerine credit			1.836	
Crude glycerine (lb) (credit)	0.77	0.1	-0.077	-4.38%
cost per gallon before interest and depreciation			1.759	100.00%
from www.mda.state.mn.us/ams/biodiesel/tfm2003sep3item2.pdf				

Inputs

The primary variable inputs in producing biodiesel are the oil, the alcohol, the catalyst, power and heat, labor, and testing costs. Fixed capital costs include the price of the plant infrastructure and the actual operating equipment, including the processor, monitoring equipment, tanks, safety equipment, etc. Assuming that one is using the same feedstock, the cost of oil, alcohol and catalyst stays largely the same per gallon of biodiesel produced. Labor, testing, and fixed costs drop substantially as the number of gallons produced increases, leading to substantial economies of scale that will be discussed below. The relative portion of total operating costs of feedstock, capital, and labor vary depending on the size of the plant. Table 9 examines the costs involved in producing biodiesel in a 15mga plant.

Economies of Scale

For a small plant, labor is a significant portion of cost; for a large plant, this goes down significantly. According to one technology provider, "two people can push 2 million gallons a year through a processor in the same way they can push 10 million gallons a year through a plant."[188]

Table 10 considers the savings in labor cost from increasing production in an example from a technology provider; a 2mga plant would save $1,000,000 per year on labor if it were to expand production to 10mga.[189]

Table 10: Savings from Labor and Economies of Scale.

Employees	Salary	Labor Cost	Production	Labor cost per gallon
4	$63,000/yr	$252,000	2 mga	$0.126
4	$63,000/yr	$252,000	10mga	$0.025
Savings per gallon: $0.10		Total savings: $1,000,000/yr		

Per gallon capital cost also varies according to plant size. For a 50 mga plant, economies of scale impacting capital and labor costs reduce total non-feedstock production costs to 5 to 7 cents per gallon.[190] Accurately determining capital costs within the range in Table 11 for a plant in Oregon is beyond the scope of this paper. The technology providers consulted avoided making general estimates. For plants producing over several million gallons a year, the industry "rule of thumb" used for a turnkey operation is that for each gallon of output, there will be $1.00 to $1.15 of capital costs involved.[191] For example, a 10 million gallon plant will cost 10 million dollars; a 30 million gallon plant, 30 million dollars.[192] However, this varies highly. For Midwestern plants, the addition of a crushing facility (presumably hexane) to the biodiesel processor will double or triple this cost.[193] It is unclear what the price would be for cold expeller pressing of canola. The increase in cost is apparent in the estimated cost for the 10 mga combined crushing and biodiesel plant being studied for Columbia Co., Washington; estimates for the plant's capital costs come to $30 million.[194] Site specific criteria largely influence the cost of a production facility. For example, if the plant is being constructed as part of an existing agricultural operation, infrastructure costs may go down.

Table 11: Capital Cost for a Biodiesel Plant. (Tyson et al., 2004).

Plant Size Million gallons per year[195]	Low MM$	High MM$
1.0	1.9	3.1
15.0	9.5	15.8
50.0	19.7	32.8

Testing is another fixed cost that influences the competitiveness of small plants. In order to sell biodiesel commercially, the fuel must be certified with the EPA as having met the EPA’s health standards. The cheapest way to achieve this certification is to join the National Biodiesel Board, which costs $2,500 per year. In addition, the fuel must be tested periodically at a cost of $500 to $900 per test.[196] It is unclear how often this testing must occur; one source believed it was required annually.[197] In addition, the producers would have to set up their own lab to test the fuel. Labs cost $150,000 to $200,000. A final element pushing plants toward a large size is uniformity of the resulting product. Larger plants can afford to have testing facilities at the plant, which can test the fuel quality, ensuring that the product is consistent. Portable plants are not economically feasible since they are too small and the constant shifting will prevent the creation of a fuel that meets ASTM standards.[198]

Actual experience

The experiences of biodiesel producers indicate that the industry is still serving a niche market. Small producers have done well in the market, depending on their source of feedstock, market, and subsidies. However, the expectation is that the biodiesel market will soon grow into a commodity market, where in the words of one source, “if you don’t watch every quarter cent, you will get beat out very quickly.”[199] The commercial biodiesel industry will be one that requires high volumes, high quality, and low cost. Large plants using cheap feedstocks best meet these criteria. Opinions on the smallest plant size that can competitively produce biodiesel vary. It is generally accepted that plants that use virgin oil must be larger than plants that use waste oil, due to the narrower margin between feedstock and finished product cost. Dwight Robanske of Columbia Co. feels that a 5 million gallon plant would be too small for economic viability in the region.[200] Kelly King of Pacific Biodiesel, a technology provider, estimated a minimum size of 3 million gallons per year.[201] According to Mike Marquardt, a different technology provider, 6 mga is a minimum for overcoming economies of scale.[202]

Other structural considerations: Stand-alone or combined with oil crusher?

Biodiesel processors can be "independent" or they can be situated at the same location as a crusher. Because people are interested in virgin oil feedstocks as a method of improving rural economies, the majority of actors interested usually are thinking of combining crusher and processor. The reason for this is that the enterprise can capture profits from both the sale of the meal and the sale of the oil, as well as share labor and equipment between the two operations.[203] Since biodiesel costs the same to transport as oil (they are approximately the same volume), transportation concerns do not effect the decision to have a stand-alone or combined facility. If the canola is crushed elsewhere, then the biodiesel processor would pay proportionately less for the oil than for the oilseed, since it will be unable to capture any profits to be had from meal sales.[204] Past a 100 mile radius from the processing plant hauling seed is economically prohibitive.[205] In this case it would make more sense for the oilseed to be crushed elsewhere and then trucked to the biodiesel plant.

Continuous or batch feed processors?

Processors can either be batch processors or continuous processors. For plants over 2 mga, continuous feed processors are more efficient than batch processors.[206] New plants constructed that produce over 2 mga will most likely be continuous processors.[207] The controls required for a large continuous feed processor cost several hundred thousand dollars; smaller plants do not produce enough fuel to justify this cost.

Processor location

As discussed above, the location of the oilseed crusher is largely determined by the availability of oilseed in the region: In the Northwest, it must be located within 100 miles of enough acreage of canola to overcome the economies of scale associated with oilseed crushing. For this reason, a biodiesel processor could be located as a stand-alone plant either in the city closest to the larges markets, or in the countryside in combination with the crusher. Locating the biodiesel plant in the countryside makes most sense from a practical and political perspective, as raw vegetable oil costs as much to transport as biodiesel. There are economies of scale to be realized by combining a crusher with a biodiesel plant (since labor, heat, and equipment can be shared between the two operations), so it makes most sense to build combined plants. This model has generally been followed in the Midwest for this reason. One of the chief justifications for supporting the industry is its potential to help revitalize rural economies and help farmers; locating the plant in the countryside will increase its chance of receiving funding and political support. This is especially true if the plant is being undertaken through a farmer's cooperative, as is being considered in Columbia County, Washington.[208] The structure envisioned by the Columbia Co. growers group is a centralized crushing and biodiesel facility, drawing on canola seed feedstocks within a 100-mile radius, which would be trucked to the facility.[209] The site will be chosen at a location that would give it highway, water, and railroad access.[210] The plant would consume canola from 125,000 acres of land annually, and the recently completed feasibility study found that the region could support that much canola.

E. A hypothetical model: Could a Pendleton, Oregon biodiesel plant be competitive?

For Oregon to have a viable biodiesel industry, the following criteria must be met:

1) enough feedstock must be available at a sufficiently low price;
2) the plant must be large enough to take advantage of economies of scale;
3) financing must be available to construct and operate a plant; and
4) there must be enough demand for biodiesel in the region
5) Oregon biodiesel must outcompete Midwestern biodiesel.

By examining available data and making using estimates for uncertain figures, I construct a model of possible costs and revenues faced by a Pendleton, Oregon biodiesel plant. First, I briefly examine the financing and market aspects.

Financing

Financing must be available that is sufficient to construct a biodiesel plant. Options available include forming a limited liability corporation and issuing stock, forming a farmer's cooperative, or to try to find venture capitalists to fund such an operation. A good example of how a biodiesel plant would be financed comes from a proposed $30 million dollar crushing/ biodiesel in Columbia County, Washington. The route that the Columbia Co. growers appear to be going is to form a cooperative funded in part by farmers and in part by grants and low interest loans. For the 30 million dollar plant, the farmers would have to raise 14 million dollars in equity. The primary organizer, Dwight Robanske, estimated that they could sell 14,000 shares at $1000 each, and with that equity would be able to get a loan for the remainder of the money out of low interest loans available through the Federal Farmers Credit banks.[211]

It appears that financing for these kinds of plants is available through grants and loans, if they have a business plan that shows they are viable. As of yet, however, only a handful of business plans have been conducted. Only one operation, a crusher that is part of American Premix Technologies' Quincy, Washington plant, has actually received financing.

Sufficient Demand and Price

Consumption in Oregon is currently around 500,000 gallons of biodiesel per year.[212] The general consensus among individuals interviewed is that the Federal Excise Tax credit of October 2004 will be sufficient to bring biodiesel blends to the same price level as petroleum diesel; the most recent information indicates B20 will be $0.10 higher than petroleum diesel.[213] At this cost, it is expected that demand for biodiesel will increase rapidly when the tax credit comes into effect in January of 2005. No specific predictions have been made for what projected consumption in Oregon will be; for this reason, it is difficult to assess if Oregon demand will be sufficient to absorb potential biodiesel production. Market forces outside of the region will determine biodiesel price levels, and it is outside the scope of this study predict price trends. For the purposes of this analysis, I have assumed that the market is constrained by supply, and that increased production in the region will be absorbed without price reduction. This may be inaccurate and should be investigated further.

The Model

Table 12: A Hypothetical: "Pendleton Biodiesel" Production Costs.

Canola price per lb	Acreage	Yield (lb/ac)	Tons Canola	Gallons of Oil	Raw canola oil cost (Crushing Cost = $50/ton)	With Meal Credit of $0.07 per lb of meal, or $0.973/gal
$0.10	5,000	2,000	5000	467290	$2.675	$1.702
$0.11	35,000	1,750	30625	2862150	$2.889	$1.916
$0.12	65,000	1,500	48750	4556075	$3.103	$2.130
$0.13	95,000	1,250	59375	5549065	$3.317	$2.344
$0.14	125,000	1,000	62500	5841121	$3.531	$2.558
$0.15	130,000	1,000	65000	6074766	$3.745	$2.772
$0.16	135,000	1,000	67500	6308411	$3.959	$2.986
	Biodiesel Production Costs: divide feedstock by number below	Biodiesel Cost with Glycerine Credit of $.75/gal glycerine	Transport costs $0.04 per gallon	Difference between Midwest B100 and Pendleton B100	Economically competitive?	
$0.10	0.7	$2.359	$2.399	$0.201	yes	
$0.11	0.75	$2.483	$2.523	$0.077	yes	
$0.12	0.8	$2.591	$2.631	-$0.030	borderline	
$0.13	0.8	$2.858	$2.898	-$0.298	no	
$0.14	0.8	$3.126	$3.166	-$0.566	no	
$0.15	0.8	$3.393	$3.433	-$0.833	no	
$0.16	0.8	$3.661	$3.701	-$1.101	no	

General

Table 12 represents an economic model of a biodiesel production plant located in northeastern Oregon. Pendleton was chosen for simplicity's sake, but the plant could be located elsewhere in the region, such as in Umatilla, which is closer to fuel terminals and barge transportation. Because of the importance of economies of scale, both the costs and volumes of production are included.

Canola price per pound

The table is arranged so that price per pound is the variable being examined. Canola is currently $0.09 per lb.[214] Production at this price is currently minimal, however, since it does not cover costs of production.

Acreage (assumed)

The acreage in production increases as price increases. The relationship of acreage produced at each price is arbitrarily assumed to be linear for lack of better information. A regional agronomist estimated that the NE Oregon region could support around 160,000 acres in canola, if prices were sufficiently high. This model uses a more conservative upper figure of 125,000 acres at $0.14/lb. On the low end, prices between $0.07 and $0.11 have resulted in production of around 4,000 to 5,000 acres per year. Due to a lack of information, a linear relationship between production and price was assumed for this model between $0.10 and $0.14, with a slower increase in production at $0.15 and $0.16/lb, assuming that less acreage would be available once production had reached that level. This is obviously a questionable assumption, but until detailed research is conducted on likely production, there is little alternative.

As Graph 3 (above, in the section on agricultural feasibility) shows, in real life, production is not directly responsive to price, probably since canola is grown as a rotation crop. It is unclear how reliable these statistics are as a guide of how large production would be if a sustained demand were maintained at a price level of $0.14/lb. It takes a period of time for farmers to get used to growing a particular crop; if prices were maintained high level, production would likely rise as producers grow to “trust” the crop.

Yield (assumed)

Wysocki estimates that an average yield for the region is 1,000 lbs per acre. One expects yield to decrease as the acreage and price increases. Since production costs per acre are relatively fixed, as prices rise, farmers can bring in less-productive land into production, due to decreasing marginal returns. Since yields in Umatilla Co, the primary canola producer currently, have averaged 2,000 lbs per acre, I have used this as a starting point. A linear relationship is again assumed, with yield decreases stopping at 1,000 lbs per acre at $0.14.

Production: Tons of canola (derived)

Production is derived from the assumed yield and acreage.

Crushing Cost per ton (assumed)

Crushing cost is a significant factor in determining economic feasibility. Crushing cost for average conventional small-scale (50,000 ton/yr) facilities is around $50/ton or $0.53 per gallon of oil.[215] Combining a crusher with another facility (for example, a feed mill or a biodiesel plant) and innovative crusher designs might reduce capital costs, so that crushing costs could be reduced substantially. This appears to be the approach being taken by American Premix in Creston, WA. The alternative model assumes $30/ton, or $0.32/gal for crushing costs. This is the average cost for large-scale (over 365,000 tons per year), hexane-based crushing facilities.[216]

Another simplifying assumption used here is that crushing costs remain the same regardless of volume. This is unlikely to be the case. Since I do not have a range of crushing costs relative to volume, I kept crushing costs the same for different volumes. In reality, volumes below 50,000 tons of canola seed per year (or 65,000 acres) will likely have a crushing cost of over $50/ton. Each $10/ton increase in crushing costs results in a $0.11 increase in feedstock oil cost (and a larger increase in biodiesel cost since production costs are derived from feedstock costs in this model).

Table 13: Influence of Crushing Costs on B100 Cost.

B 100 Cost, Delivered to Portland				
	Crush Cost			
Canola price per lb	$60/ton	$50/ton	$40/ton	$30/ton
$0.10	*$2.552*	*$2.399*	*$2.247*	*$2.094*
$0.11	**$2.665**	*$2.523*	*$2.380*	*$2.237*
$0.12	**$2.764**	$2.631	*$2.497*	*$2.363*
$0.13	$3.032	**$2.898**	$2.764	$2.631
$0.14	$3.299	**$3.166**	$3.032	$2.898
$0.15	$3.567	**$3.433**	$3.299	$3.166
$0.16	$3.834	**$3.701**	$3.567	$3.433
Bold text indicates likely, conventional crush costs; Italicized text indicates competitive pricing (below $2.60/gal).				

Gallons of Oil (derived)

One gallon (7.5 lbs) of oil is extracted from 21.4 lbs of oilseed, along with 13.9 lbs of meal, assuming that 35% of the oilseed is extractable oil. This is an industry standard for expeller pressed canola. In turn, one gallon of oil is roughly equivalent to one gallon of biodiesel output.

Raw Canola Oil Price (derived)

(Price/lb seed cost) * (price/lb crushing cost) * 21.4 lbs oilseed/gal = price/gal

Meal Credit (supported estimate)

The meal credit is an important part of the production calculus. Commercial canola feed meal averaged $140/ton from 1990 to 2003 delivered to the region; sale at this price would result in a credit of $0.07 per lb of meal, or $0.973 per gallon of oil. Since regional crushers would most likely not use hexane, the canola meal would likely command a premium, since expeller pressed meal has more lipids and a higher food value. I have been unable to locate data to determine the size of this premium, however. If, hypothetically, this premium brought non-hexane canola meal prices to $180 per ton, the meal credit would rise to $1.25, which could significantly increase biodiesel's feasibility.

Biodiesel Production Costs (supported estimate)

These figures are based on general industry standards for the cost of producing biodiesel from virgin oil. For plants producing less than 1 million gallons per year (mga), feedstock costs are 70% of total costs; for plants between 2 and 3 mga, 75%; for plants around 5mga, 80%; and over 10 mga, 85%.[217] For extremely large plants proposed in the Midwest, feedstock costs are expected to rise to 90% of total costs; this size plant is unfeasible in the Northwest, however. This includes both variable (inputs and labor) and fixed (capital) costs.

Glycerine Credit (supported estimate)

Glycerine is a byproduct of biodiesel production; on average, for every 10 lbs of biodiesel, 1 lb of crude glycerine is produced. Crude (80-85%) glycerine can be sold for $0.50 to $1.00 per gallon *if* there is a market available for it.[218] Glycerine can be refined to food and pharmaceutical grade with a value of $8.00/gal, but this is only economical for a biodiesel plant with a capacity of more than 10 mga. The crude glycerine produced is neutralized and if not refined, can be sold as livestock feed sweetener or burned as fuel, or alternately used in soap making.[219] Assuming that the methanol is recovered and the glycerine is neutralized with phosphoric acid, both standard production procedures, glycerine is non-toxic and biodegradable.

I have used a glycerine credit of $0.75 per gallon of glycerine ($.072 per gallon of biodiesel), since the northeast Oregon region cannot support a biodiesel plant large enough to economically justify the glycerine refining equipment (this would require output of 10mga). Furthermore, increased biodiesel production is expected to flood the glycerine market, driving down the price of glycerine and reducing the value of the glycerine credit. If competitive small-scale refining technology were available and pure glycerine prices stayed at $8.00/gal, the gross glycerine credit would be $0.76/gal of biodiesel, indicating the substantial impact this would have on production costs.

Transport Costs (supported estimate)

If the fuel were produced in Pendleton, Oregon, it is likely that the majority of it would be transported to market in the Portland, Oregon area. Transportation could be by truck, rail, or barge. Tanker truck transportation at $0.04/gal appears the most feasible, as barging requires investment in holding tank infrastructure, and rail is economically prohibitive.

Barging from the Umatilla terminal to Portland is the most economical at around $0.03/gal, but requires a minimum load of 5,000 to 10,000 barrels (210,000 to 420,000 gal). This would require large investment in holding tanks with 10,000 to 15,000 barrels (420,000 to 630,000 gal) storage capacity.[220] For a production plant producing 5 mga, storage time between shipments would be 15 days. Given biodiesel's 6-month shelf life, this is logistically feasible, but the capital needed for tanks and the cumbersome nature of barge transport are likely hurdles to this approach.

Costs for rail on the Union Pacific line are $2,266 per tanker car from Pendleton to Portland. A tanker car can transport up to 27,000 gal, resulting in a transport cost of $0.084/gal. This does not include the cost of renting or owning a car, transporting the car back, which are additional.[221] I have been unable to find information on these costs.

Tanker truck transportation between Pendleton and Portland costs a total $0.08/gal, which covers the cost of transport for both ways.[222] If the tanker truck "backloaded" by transporting a load of biodiesel from Pendleton to Portland, and then hauled a load of diesel back to Pendleton, the per-gallon cost for biodiesel would be reduced in half to $0.04/gal. Tanker trucks have 10,000-gallon capacities, so the storage facilities needed at the plant would be minimal.

The Umatilla, Oregon petroleum terminal handles between 1 and 1.5 million barrels (42 to 63 million gallons) of diesel per year, delivered by barge.[223] With a state mandate requiring a 2% biodiesel blend, mixing at this terminal could absorb 840,000 to 1.26 million gallons of biodiesel per year. Biodiesel used at the Umatilla terminal would be most competitive since transportation costs would be minimal.

Comparison to Midwest Biodiesel

According to several sources, biodiesel in the Northwest is a supply-constrained market, meaning that as production goes up, consumption will go up as well.[224] It is unclear to what extent this is true, and another source indicated that one hurdle faced by the regional industry is the lack of guaranteed demand for the product.[225]

Currently, biodiesel delivered to the Portland area from the Midwest runs around $2.60.[226] The average U.S. price in October 2004 was $2.47, with prices as low as $2.20/gal in the Midwest.[227] This price has fluctuated somewhat over the past two years, with an upward trend continuing in the near future, but competition and increases in production are expected to drive prices down within the next several years.[228] If biodiesel is used to provide lubricity in ultra low sulfur diesel, increased demand could raise prices despite production increases.[229]

Due to these uncertainties, I have used the current price of delivered Midwest biodiesel ($2.60) as a basis for evaluating feasibility. If Oregon-produced biodiesel is cheaper, it is viable; if it is more expensive, it is not.

Weaknesses in Model

The lack of data on acreage in production at a given price is problematic, as explained above. If the relationship between price and acreage is not linear, then prices will have to rise to $0.13 to $0.14 for levels of production to occur that would support a biodiesel facility. If acreages are less than the model assumes, production costs will rise due to less economies of scale. Furthermore, the assumption of fixed crushing costs is misleading, since at low seed prices, low volumes will raise per ton crushing costs.

Hence, the per gallon values for canola seed prices of $0.11 to $0.10/lb are probably understated. Low volumes of biodiesel production appear competitive in the model, but the increases in crushing costs will probably make this level of production unfeasible. More research is needed to determine crushing costs at these levels of production.

Since developing a model of production costs for hypothetical plant is beyond the scope of this paper, production costs are derived from feedstock costs using an industry standard. As feedstock costs vary (due to different crushing costs, for example), the model will inaccurately amplify this variance (since feedstock costs influence production costs in this model, which would not be the case in reality). This amplification is around $0.05 for a raise in feedstock cost caused by a $20/ton increase in crushing cost at $0.12/lb of canola seed.

E. Economic Bottlenecks: Potential Solutions

The major influences on biodiesel production cost that could be varied are 1) crushing costs, 2) meal returns, 3) glycerine returns, 4) and the economies of scale involved with production costs. Finding ways to reduce these costs and optimize returns is imperative in making the biodiesel industry feasible in the Northwest. Finding new, low-cost technologies for small-scale, cheap crushing is imperative. Marketing the meal as a high value alternative to hexane-pressed canola meal is important; more rewarding may be growing industrial mustard, if a steady market can be found for using the meal as an insecticide. A glycerine refining technology that is affordable at smaller volumes is needed. Since the glycerine market is projected to be volatile in the near future, however, planners should not rely on glycerine to make a biodiesel project feasible.

Economies of scale involved with biodiesel production are perhaps the major hurdle. At feedstock prices low enough to make biodiesel affordable, the oilseed supply is too low to support a facility that has the economies of scale needed to be competitive with Midwestern biodiesel. The same is true for glycerine refining. One solution may be to have a regional biodiesel processor that draws oil from the southern Washington and northwestern Oregon regions. Crushers could be decentralized, reducing the high transport costs associated with trucking seeds, and providing meal to local livestock producers. The expelled oil could then be transported to the centralized crusher. Since the biodiesel has to be transported to market anyway, and raw oil and biodiesel cost the same to transport, transportation costs should not significantly increase. In this fashion, feedstock prices can remain low, but by consolidating production from the entire region, the biodiesel plant can still take advantage of economies of scale. The challenge facing this solution is making the sub-regional crushing operations affordable at lower levels of output.

Existing incentives

Incentives are frequently examined as a way that the State could promote biodiesel and help it overcome production hurdles. Incentives exist at the state level for investing in, producing, and using biodiesel in the form of tax credits and loans. These are administered by the Department of Environmental Quality. The Business Energy Tax Credit provides a 35% (of infrastructure investment) tax credit to alternative fuels investors. The Energy Loan Program offers low-interest loans for projects that develop alternative fuel infrastructure. Other incentives provided by Oregon include property tax exemptions such as the Enterprise Zone Exemption (which exempts increased property taxes). Oregon currently has an ethanol facility tax exemption (50% of assessed value for up to five years). The Oregon Environmental Council is promoting a similar tax exemption for biodiesel. As noted above, however, taxes are only a small part of production costs and would unlikely be decisive in making regional biodiesel affordable. Federal biodiesel incentives include competitive biorefinery grants, a biodiesel fuel education program, the Bioenergy Program (which pays producers for increasing output of biodiesel), federal procurement and testing funding, the Renewable Energy Development Loan and Grant Programs. The Energy Policy Act of 1992 provides an adjustment to gross income for the cost to purchase or convert a “clean fuel vehicle,” for which biodiesel qualifies, as well as a deduction of up to $100,000 for biodiesel refueling stations.[230] These existing incentives do not aid Oregon-produced biodiesel relative to Midwestern biodiesel. As a result, research and development of ways to reduce the costs of production may be the best way to make the industry feasible, with other government incentives becoming more important when Pendleton-produced biodiesel becomes more competitive.

F. Conclusion

It is difficult to draw a firm conclusion from this analysis since much of the data is assumed. More research is needed, although to some extent this is part of the inherent uncertainty in a developing industry. The model does illustrate several key lessons. First, feedstock cost is likely to be too high using current production technologies. At low seed prices, production levels are too low to make a plant competitive with large biodiesel plants. As seed price rises, production will go up and the plant may take advantage of economies of scale, but this raises feedstock cost too high for it to be competitive. By reducing crushing and production costs, or by finding higher value uses for meal or glycerine byproducts, biodiesel could likely become feasible. This will require innovation and the development of new markets on part of the firms involved.

V. CONCLUSION

This thesis has examined the likely environmental impacts and economic feasibility of using canola grown in northeastern Oregon to produce biodiesel. It has sought to answer the questions, "*What are the environmental impacts of making and using biodiesel? What are the economic hurdles to making biodiesel production a reality in northeastern Oregon?*"

As this report has shown, biodiesel has significant environmental benefits for reducing pollution from diesel burning vehicles. Furthermore, it appears environmentally neutral to positive in its agricultural impact as a rotation crop, requiring some chemical inputs but reducing others, and involving a low danger of proliferating genetically modified crops. It reduces greenhouse gas emissions and dependency on foreign oil supplies. The production process does involve fossil fuel (methanol) and energy inputs, but is virtually non-polluting if the proper technologies are used, providing a significant advantage over oil refineries. Biodiesel's environmental impacts are, on the whole, favorable.

This report is unable to come to any hard conclusions about biodiesel's economic feasibility as an industry on Oregon's Columbia Plateau. This is due to a lack of reliable data and the uncertainty involved in the industry, and more research is clearly needed. Examination of agricultural economics shows that farmers need $0.13 to $0.14 per pound of canola seed in order to produce enough of the crop to support a crusher and biodiesel processor. Crushing and processing costs are subject to economies of scale. These economies of scale allow large production plants in the Midwest, with which Oregon plants must compete, to produce biodiesel very cheaply. At the scales possible in northeastern Oregon, production costs are relatively high. Crushing and production costs are offset significantly by the sale of canola meal and glycerine. The fundamental question is, "*Given these factors, can northeast Oregon producers produce biodiesel from canola cheaply enough to compete with Midwestern biodiesel?*"

The "Pendleton Biodiesel" model provides insight into this question and illustrates the relative importance of various production factors. It is likely that the production of canola as an oilseed for the production of biodiesel is not economically feasible, due to the high price that would be required to encourage sufficient production of the crop. At lower levels of production, seed cost is sufficiently low, but since the biodiesel industry is structurally prone to economies of scale, smaller plants would most likely not be able to compete with imported biodiesel. These hurdles may be overcome with further research and innovation. Crushing and processing costs may be reduced as the technologies evolve and through combining them with other agricultural operations. Increasing the value of byproducts is an equally promising solution, and may be particularly important with feedstocks not examined in this analysis, such as industrial mustardseed used as an organic pesticide.

Enthusiasm for biodiesel in Oregon is very high, and the questions raised by this report will likely be answered through practice in the near future. Despite the economic hurdles that this thesis examines, they may be surmountable. Furthermore, different crops, as well as other regions of the state, may have different economic characteristics that would make the industry feasible. The benefits of biodiesel for the environment and agricultural communities merit continued pursuit of the fuel in Oregon.

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