ANALYSIS OF THE SOCIAL, ECONOMIC, AND ENVIRONMENTAL EFFECTS
OF REPLACING PETROLEUM-BASED FUELS
WITH BIODIESEL FUELS

by
Shirley Johnson

An investigative project submitted to
Sonoma State University
in partial fulfillment of the requirements
for the degree of

MASTER OF ARTS

in
Hutchins School of Liberal Studies Action for a Viable Future
Interdisciplinary Master's Program

Dr. Robert H. Girling, Chair

Dr. Debora Hammond

Dr. Ervand Peterson

4-24-08
Date
AUTHORIZATION FOR REPRODUCTION 
OF MASTER'S PROJECT

I grant permission for the reproduction of parts of this project without further authorization from me, on the condition that the person or agency requesting reproduction absorb the cost and provide proper acknowledgement of authorship.

DATE: 5-1-2008

Signature

Street Address

City, State, Zip
ANALYSIS OF THE SOCIAL, ECONOMIC, AND ENVIRONMENTAL EFFECTS OF REPLACING PETROLEUM-BASED FUELS WITH BIODIESEL FUELS

Project by
Shirley Johnson

ABSTRACT

Purpose of the Study:

Biofuels are a category of alternative fuels derived from organic matter. Biodiesel, a lipid oil-based biofuel, is produced from oilseed crops. Biodiesel and ethanol use different feedstock. Ethanol, a grain alcohol, is produced from grain crops. The expansion of biofuels production using food crops as a source of feedstock has caused concern regarding its impact on land, food supplies, and biodiversity.

The purpose of this study is to determine the viability of biodiesel as a sustainable alternative transportation fuel.

Procedure:

To determine the sustainability of biodiesel, this project examined the aspects of the social, economic, and environmental responses to biodiesel production and use. Biodiesel was compared and contrasted with ethanol. Most of the information was collected over two years of observations within sustainable biofuel groups, books addressing alternative fuels, and magazines published in relation to the biodiesel market. The information was then organized to address current issues regarding the biofuels industry.

Findings:

Biodiesel was found to be a renewable alternative fuel; it has lower carbon dioxide emissions than regular diesel fuel. Biodiesel made from soybeans are less erosive on soil than corn ethanol. Both biodiesel and ethanol compete for food supplies. Ecologically sensitive areas need extra consideration when determining available areas for feedstock cultivation.
Conclusions:

Biofuels made from food crops are not desirable as a long-term resource for feedstock. Biodiesel should transition from food crops, and utilize feedstock that can be grown on arid soil using little water. Next generation transportation fuels should be implemented to fit each community's environmental, social, and economic needs. Energy conservation is the best immediate solution for emission reductions.

Chair:

Signature

MA Program: Hutchins School of Liberal Studies
*Action for a Viable Future*
Interdisciplinary Master's Program
Sonoma State University

Date: **May 1, 2008**
ACKNOWLEDGEMENT

It took a community to accomplish this project. I would like to thank all the people who helped/inspired me along this journey. The ongoing effort it took to gather knowledge in order to evaluate the nature of biodiesel was exciting and exhausting. I relied on my community; it helped to bounce ideas off others and get honest and kind feedback.

First I would like to thank Dr. Francisco Vázquez, the director of my program, for his guidance and approachability. Furthermore, I am so thankful to my committee members for whom I would not have been able to begin this project if they had not made themselves available—Professors Robert Girling, Debora Hammond, and Erv Peterson.

I would to thank the ladies who both personally and professionally helped with my writing skills, Cinnamon Cruz and K8. Months of intense studying and writing were manifested in my relations with my close circle of family and friends. I appreciate the support by—The Norwitts, The Halls, The Foells, and the women friends.

Finally, I would like to thank my son Ryan, teenagers Sarah and JJ, and my granddaughter Rylee for giving up quality time for my studies. I am forever grateful and blessed for the steadfast reassurance from my patient and loving partner Jason.
# TABLE OF CONTENTS

## Part I.

A. Review of Literature—Viability of Biodiesel as an Alternative Transportation Fuel ................................................................. 1

B. Methodology ................................................................................. 20

C. Glossary of Terms ........................................................................... 21

D. Analysis of the Social, Economic, and Environmental Effects of Replacing Petroleum-based Fuels with Biodiesel Fuels .................. 25

E. Policy Recommendations ................................................................. 42

## Part II.

A. Social Justice ............................................................................... 44

B. Ecological Issues ........................................................................... 45

C. Psychological and Moral Dimensions to Change ............................. 45

## Part III.

Appendix A—Biodiesel GHG Savings ......................................................... 46

Appendix B—Biodiesel Feedstocks ......................................................... 47

Appendix C—National Biodiesel Board Fact Sheet ................................. 48

References ......................................................................................... 50
LIST OF TABLES OR FIGURES

Table 1—Primary Energy Requirements for the Petroleum
Life Cycle ................................................................................................................. 5

Table 2—Fossil Energy Requirements for the Petroleum
Diesel Life Cycle .......................................................................................................... 6

Table 3—Primary Energy Requirements for Biodiesel
Life Cycle ..................................................................................................................... 7

Table 4—Fossil Energy Requirements for the Biodiesel
Life Cycle ..................................................................................................................... 8

Table 5—Fossil Energy Balances of Biodiesel .............................................................. 9

Table 6—Biodiesel Emission Benefits ......................................................................... 10

Figure 1—Projected biodiesel production costs, compared with recent (pre-tax) diesel prices ........................................................................................................ 15

Table 7—Economic Comparisons of Multiple Feedstocks ........................................... 16

Table 8—Food Gap, 2016: Baseline vs. Price-Shock Scenario ....................................... 18

Table 9—World Biofuels Production, 2006 .................................................................. 32

Table 10—Palm Oil-Producing Countries Top 10 List .................................................. 35

Table 11—Feed Grain Database: Yearbook Table ......................................................... 37
Viability of Biodiesel as an Alternative Transportation Fuel

The purpose of this review is to critically analyze the published body of knowledge that has been part of my education through summary, classification, and comparison of prior research studies, reviews of literature, and theoretical articles.

This reviewing of the body of knowledge will focus on what makes biodiesel a worthy alternative to fossil fuel. Replacing fossil fuel with an alternative fuel must meet a range of positive objectives: (a) produces net energy gain, (b) have limited environmental impacts, (c) be economically competitive to fossil fuels, and (d) not compete with food supplies.

Renewable Transportation Fuels

What good is replacing one bad idea with another? Fossil fuel used for transportation purposes seemed like a good idea close to a century ago but now it is does not. The residual effects of fossil fuel use such as greenhouse gas (GHG), and the rising cost of crude oil per barrel, cause severe environmental, social, and economic hardships. An attractive characteristic of a replacement fuel would be one that does not contribute to climate change, thus mitigating the other hardships of weather changes, severe storms, and food shortages due to erratic weather patterns.

The earth is continually in a state of renewal. Carbon cycles are part of that renewal. The sun helps carbon-based plants grow and absorb carbons, and when the plants eventually die, the carbon is returned to the soil or to the atmosphere though respiration. In contrast with biofuels, fossil sourced fuel, is least renewable because it took millions of years to form.
Various methods are available to determine how renewable a transportation fuel is. Life cycle energy inputs (LCI), also known as “well-to-wheels” have a sequence of steps that are part of the calculations: feedstock production, feedstock transportation, fuel production, fuel distribution, and lastly vehicle use. Net energy balance (NEB) also referred to as energy returned on energy invested (EROEI), has some of the same inputs and outputs as LCI.

The basic formula for life cycle energy efficiency is the ratio of fuel product energy to total primary energy. Energy is measured in units of joule in this context the fuel contains millions of joules or mega-joule (MJ). The fuel product energy is energy that will do work in an engine, it is the final fuel product. The total primary energy is all the resources extracted from the environment such as feedstock, plus energy needed for processing such as coal, and natural gas. Life cycle energy efficiency is a way to measure how much energy remains after the process of fuel production.

Life Cycle Energy Efficiency = Fuel Product Energy/Total Primary Energy

The fossil energy ratio helps determine the degree of which a fuel is or is not renewable. This equates to the ratio of the fuel product energy to the amount of fossil fuel used to make the final fuel product. A small ratio tending towards zero indicates a fuel is completely non renewable. As the ratio approaches infinity the fuel requires no fossil fuel input at all and considered a “completely renewable fuel” (Sheehan et al. 11).

Fossil Energy Ratio = Fuel Energy/Fossil Energy Inputs

Fossil Energy Ratio > 1 deems the fuel renewable.
A well known environmentalist, David Pimentel coauthored a paper with Tad Patzek, “Ethanol Production Using Corn, Switchgrass, and Wood; Biodiesel Production Using Soybean and Sunflower.” Their study claims biodiesel has a negative energy balance. The methods used to come to this conclusion are being questioned among the specialists in the field of energy balance research. The issue of biodiesel’s low energy balance has been countered in several research papers. University of Idaho Professors Jon Van Gerpen and Dev Shrestha published a study that shows Pimentel and Patzek’s claim as erroneous, and that biodiesel provides much more energy than is consumed in its production (Biodiesel Energy Balance).

Calculating energy balance is not straightforward. Some methods of calculation use different energy contents of biodiesel while in the process of production. Not all of the energy used in farming and crushing soybeans is dedicated to producing biodiesel; two bi-products also have caloric value, soybean meal and glycerin. These three energy imbedded portions of biodiesel production cause confusion in net energy balance calculations. An article in Biodiesel Magazine, by Shrestha and Van Gerpen, shows a simplified version of how three energy ratios were derived, using three different methods, one by National Renewable Energy Laboratory (NREL), a second by Pimentel, and a third by Jason Hill. Below is an illustration how discrepancies could happen.

Energy inputs and outputs should be defined as:

- $E_{f1}$ is the fraction of the energy input of meal
- $E_{f2}$ is the fraction of the energy input for biodiesel
- $E_{f3}$ is the fraction of energy input for glycerin
Assigning fractions to the end products:

Em is the energy equivalent to meal
Eb is the energy equivalent to biodiesel
Eg is the energy equivalent to glycerin

Energy Ratio as calculated by NREL definition = \( \frac{Eb}{Ef2} = 3.2:1 \)

Energy Ratio as calculated by Pimentel and Patzek definition = \( \frac{Eb}{E-Em} = 1:1 \)

(They subtracted the energy contained in the meal (Em) from the total input energy which could be problematic if the meal energy content exceeds the input energy content)

Energy Ratio as calculated by Hill definition = \( \frac{(Eb+Em+Eg)}{E} = 1.1:1 \)

Note: These numbers could change given different scenarios, which may add confusion. For example, reintroducing a byproduct such as biodiesel as part of the input energy alters the energy ratio significantly.

Misquotes and miscalculation have led to misunderstanding about biodiesel energy balance. Leveraging NREL’s study and misinterpreting the data causes Pimentel to misquote Sheehan when he claims biodiesel having a “negative energy return.” Adding to the confusion is the so-called dialogue regarding EROEI in the summer 2006 issue of YES! Magazine. The author refers to a 2005 study as showing a negative EROEI. The study does indeed state, “A negative energy return” which is leveraged from NREL, “1MJ of biodiesel requires an input of 1.24 MJ of primary energy” (Pibel, Pimentel 72). According to Sheehan, “Pimentel once again confuses total energy and fossil energy” (Biofuels 15). Pimentel used the energy numbers in a different context than was intended. Sheehan and others were showing and comparing the primary energy demand of each stage of biodiesel life cycle. Sheehan and his team of researchers calculated both
efficiency and fossil energy ratios using data from the stages of fuel production for petroleum diesel and biodiesel. The stages supply a better comprehensive picture when tabulated by units of energy as shown in tables 1-4.

Table 1

Primary Energy Requirements for the Petroleum Life Cycle

<table>
<thead>
<tr>
<th>Stage</th>
<th>Primary Energy (MJ per MJ of Fuel)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Crude Production</td>
<td>0.5731</td>
<td>47.73%</td>
</tr>
<tr>
<td>Foreign Crude Oil Production</td>
<td>0.5400</td>
<td>44.97%</td>
</tr>
<tr>
<td>Domestic Crude Transport</td>
<td>0.0033</td>
<td>0.28%</td>
</tr>
<tr>
<td>Foreign Crude Transport</td>
<td>0.0131</td>
<td>1.09%</td>
</tr>
<tr>
<td>Crude Oil Refining</td>
<td>0.0650</td>
<td>5.41%</td>
</tr>
<tr>
<td>Diesel Fuel Transport</td>
<td>0.0063</td>
<td>0.52%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1.2007</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>


Petroleum Diesel’s LCI:

Life Cycle Energy Efficiency = Fuel Product Energy/Total Primary Energy

\[ = \frac{1 \text{ MJ}}{1.2007 \text{ MJ}} \]

\[ = .8328 \text{ or } 83.28\% \]
Petroleum Diesel’s renewable ratio:

Fossil Energy Ratio = Fuel Energy/ Fossil Energy Input

= $1\text{MJ}/1.11995 \text{MJ}$

= 0.8337

Table 2

Fossil Energy Requirements for the Petroleum Diesel Life Cycle

<table>
<thead>
<tr>
<th>Stage</th>
<th>Fossil Energy (MJ per MJ of Fuel)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Crude Production</td>
<td>0.572809</td>
<td>47.75%</td>
</tr>
<tr>
<td>Foreign Crude Oil Production</td>
<td>0.539784</td>
<td>45.00%</td>
</tr>
<tr>
<td>Domestic Crude Transport</td>
<td>0.003235</td>
<td>0.27%</td>
</tr>
<tr>
<td>Foreign Crude Transport</td>
<td>0.013021</td>
<td>1.09%</td>
</tr>
<tr>
<td>Crude Oil Refining</td>
<td>0.064499</td>
<td>5.38%</td>
</tr>
<tr>
<td>Diesel Fuel Transport</td>
<td>0.006174</td>
<td>0.51%</td>
</tr>
<tr>
<td>Total</td>
<td>1.19952</td>
<td>100%</td>
</tr>
</tbody>
</table>

Biodiesel’s LCI:

Life Cycle Energy Efficiency = Fuel Product Energy/Total Primary Energy

\[ \frac{1\text{MJ}}{1.24\text{MJ}} \]

= 80.55%

Biodiesel’s renewable ratio:

Fossil Energy Ratio = Fuel Energy/Fossil Energy Inputs

\[ \frac{1\text{MJ}}{0.3110\text{MJ}} \]

= 3.215

Table 3

Primary Energy Requirements for Biodiesel Life Cycle

<table>
<thead>
<tr>
<th>Stage</th>
<th>Primary Energy (MJ per MJ of Fuel)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean Agriculture</td>
<td>0.0660</td>
<td>5.32%</td>
</tr>
<tr>
<td>Soybean Transport</td>
<td>0.0034</td>
<td>0.27%</td>
</tr>
<tr>
<td>Soybean Crushing</td>
<td>0.0803</td>
<td>6.47%</td>
</tr>
<tr>
<td>Soy Oil Transport</td>
<td>0.0072</td>
<td>0.58%</td>
</tr>
<tr>
<td>Soy Oil Conversion</td>
<td>1.0801</td>
<td>87.01%</td>
</tr>
<tr>
<td>Biodiesel Transport</td>
<td>0.0044</td>
<td>0.35%</td>
</tr>
<tr>
<td>Total</td>
<td>1.2414</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

<http://www.nrel.gov/docs/legosti/fy98/24089.pdf>
Table 4

Fossil Energy Requirements for the Biodiesel Life Cycle

<table>
<thead>
<tr>
<th>Stage</th>
<th>Fossil Energy</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean Agriculture</td>
<td>0.0656</td>
<td>21.08%</td>
</tr>
<tr>
<td>Soybean Transport</td>
<td>0.0034</td>
<td>1.09%</td>
</tr>
<tr>
<td>Soybean Crushing</td>
<td>0.0796</td>
<td>25.61%</td>
</tr>
<tr>
<td>Soy Oil Transport</td>
<td>0.0072</td>
<td>2.31%</td>
</tr>
<tr>
<td>Soy Oil Conversion</td>
<td>0.1508</td>
<td>48.49%</td>
</tr>
<tr>
<td>Biodiesel Transport</td>
<td>0.0044</td>
<td>1.41%</td>
</tr>
<tr>
<td>Total</td>
<td>0.3110</td>
<td>*100.00%</td>
</tr>
</tbody>
</table>

*Rounded up


Other biodiesel feedstocks are measured as well, see table 5, to assess if they fall into the renewable fuel category. Palm oil biodiesel ranks tops of the list in fossil energy balance followed by waste vegetable oil.
Table 5

Fossil Energy Balances of Biodiesel

<table>
<thead>
<tr>
<th>Fuel (feedstock)</th>
<th>Fossil Energy Balance (approximately)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biodiesel (palm oil)</td>
<td>~9</td>
</tr>
<tr>
<td>Biodiesel (waste vegetable oil)</td>
<td>5-6</td>
</tr>
<tr>
<td>Biodiesel (soybeans)</td>
<td>~3</td>
</tr>
<tr>
<td>Biodiesel (rapeseed, EU)</td>
<td>~2.5</td>
</tr>
<tr>
<td>Biodiesel (sunflower)</td>
<td>3</td>
</tr>
<tr>
<td>Biodiesel (castor)</td>
<td>~2.5</td>
</tr>
</tbody>
</table>


Nonetheless the consistency has much to be desired in evaluating the energy balances of feedstock. Policymakers need more coherence in the methodology of energy balance calculations.
Environmental Impacts

One attractive feature of biodiesel is its lower tailpipe emissions than that of petroleum diesel. Biodiesel blended with petroleum diesel produces different mixtures for transportation fuels. BXX denotes the percentage of biodiesel with petroleum diesel; for instance B20 means 20% biodiesel, 80% petroleum diesel, and B100 means 100% biodiesel. Reduction in tailpipe emissions varies as shown in table 6 with percentage of biofuels mixtures. A benefit to biodiesel use for transportation fuels is it does decreases carbon emissions.

Table 6
Biodiesel Emission Benefits

<table>
<thead>
<tr>
<th></th>
<th>CO</th>
<th>HC</th>
<th>PM</th>
<th>Toxics</th>
<th>NOx</th>
</tr>
</thead>
<tbody>
<tr>
<td>B2/B5</td>
<td>&lt;-5%</td>
<td>&lt;-5%</td>
<td>&lt;-5%</td>
<td>&lt;-5%</td>
<td>neutral</td>
</tr>
<tr>
<td>B20* Soy</td>
<td>-12%</td>
<td>-11%</td>
<td>-18%</td>
<td>-12 - 20%</td>
<td>+1.2%</td>
</tr>
<tr>
<td>B20**</td>
<td>-32%</td>
<td>-40%</td>
<td>-24%</td>
<td>-5%</td>
<td></td>
</tr>
<tr>
<td>B100*</td>
<td>-43%</td>
<td>-56%</td>
<td>-55%</td>
<td>-60 - 90%</td>
<td>+5.8%</td>
</tr>
</tbody>
</table>

*Source: Shaine Tyson, NREL Report, March 2001 based on test averages

** Source: Dr. Robert McCormick, NREL, May 2005 bus chassis dynamometer testing of conventional city buses with Cummins ISM 2000 engines–No EGR

a The top row includes gases that are considered GHG equivalents, carbon monoxide (CO) and hydrocarbons (HC). Also included on the top row is, the particulate matter (PM), and an ozone gas, mono-nitrogen oxides (NOx).
Greenhouse gases are released in the atmosphere by a myriad of sources; with biofuels they can be narrowed down a bit. Biofuel production and use emits carbon dioxide equivalents that contribute to climate change. Measuring the impact that biofuels have on the environment is one of the elements for acceptance as an alternative transportation fuel. Production of plant based biodiesel requires, cultivation, processing and transporting the biofuels to various locations. Soybean oil is the largest supply for biodiesel production, currently in America. Cultivation of soybeans has imbedded GHG potential from petroleum in the tractors, fertilizer, and from soil carbons.

Farming equipment used to be a horse and a plow but those days are quickly disappearing. Gone also are the small farmers. In 2002, farms on 1000 acres or more operated two thirds of all farm land in America (USDA). High technology farming is the norm instead of the exception as in other countries. Partnered with large farms are massive tractors, tilling, and large amounts of fertilizer which all contribute to GHG levels.

Industrialized agriculture uses enormous amounts of petroleum products for cultivation and harvest. Production costs, in both monetary and environmental terms, are high for most food crops. Petroleum costs come from the farming equipment and the transportation costs of shipping the crops. The huge amounts of fertilizer needed for high yields taxes the environment. Nitrogen fertilizer, a fossil fuel–derived product, is called a petrochemical because it is made from natural gas with ammonium nitrate as a byproduct. The fertilizer is rich in nitrogen, which is also considered a GHG. Ammonium nitrate, the major ingredient in explosives, became overabundant after World War II and was applied to cropland throughout the United States. Cleverly stated, Vandana Shiva the Indian
farmer activist says in her speeches, “We’re still eating the leftovers of World War II” (qtd in Pollan 41).

Originally, corn was not as dependent on additional nutrients; however, years of growing and producing hybrids have changed this. Mass produced hybrid corn depletes soil of nutrients in one season, thus necessitating the application of fertilizer. Unlike corn, soybeans require little fertilizer to grow; they replenish nitrogen in soils. The other advantage soybean has over corn is the requirement for less pesticides. Comparing lifecycle environmental effects of corn ethanol, soybean biodiesel uses, per unit of energy gained 1% of the nitrogen, 8.3% of the phosphorus, and 13% of the pesticide by weight (Hill et al.). David Pimentel has long been an advocate for decreasing fertilizer use. He warns of the environmental hazard from fertilizer use on farmlands and its influence in runoff, where billions of gallons are choking rivers and seas and creating dead zones. The moral dilemma from banning fertilizers is that it could cause starvation; food crops grown without fertilizers would reduce world food production an “estimated 40%” (Miller 232-234).

Until recently, tailpipe emissions, crop cultivation, and transportation were all that was needed to know about biodiesel production and its environmental effects. Carbons are appearing in unsuspected ways, such as when tilling land. Farmers were encouraged not to till because it creates land loss from runoff and wind displacement. Another disadvantage of tilling is it overturns soil and releases carbon trapped beneath the surface. Cultivating or disrupting lands that were not otherwise used returns the soil carbon to the atmosphere. Converting new or conserved land to farmland may contribute to an increase in GHG emissions through tilling the soil. Two studies recently released have concluded
that the positive effects of biofuels and carbon reduction can be adversely affected by using new croplands (Searchinger et al., Fargione et al.). The study solidifies the value of leaving rainforests and grasslands intact. Furthermore, non-tilling practices should remain rewarding for the farmer, and monoculture should be replaced by crop rotation.

Perennials like shrubs or trees can grow on degraded soil and may be a biofuel feedstock. Today more than 90% of U.S biofuel is grown in corn fields in the American Midwest, this provides an opportunity for new biofuel production from waste streams, cellulose crops and algae in the Northwest (Mazza). Soil carbons may be traceable and calculable through a tool called GREET (Greenhouse Gases, Regulated Emissions, and Energy use in Transportation). Argonne National Laboratory created this tool to model energy and emission impacts of new transportation fuels. Since the review of the carbon soil study, Michael Wang the developer of the GREET model, will update their models to "reflect indirect land use conversions (qtd. in Mazza).

Not everything about agriculture is bad, but change is needed, and biofuel could be just that. The Worldwatch Institute makes clear the pros and cons of biomass for energy:

The large-scale cultivation and harvesting of photosynthetic energy brings with it a different set of challenges and concerns. While fossil fuels pose a greater threat to greenhouse gas concentrations, biomass fuels potentially pose a larger threat to wild ecosystems, soil quality and water use. At the same time, should biofuels be cultivated carefully, they might also bring net ecological benefits. Perennial crops, in particular, can bring advantages: they have a potential to sequester carbon, diversify the habitat
of old farmland, and maintain or restore the soils of degraded marginal lands. At best, the value of biomass will provide an economic motive for prudent ecosystem management. (97)

Biodiesel made from soybean has fewer negative effects on the environment than corn ethanol such as: GHG reduction in tailpipe emissions and has less fertilizer use impact. But it still is not the best choice for an alternative transportation fuel because of the environmental issues of tilling and water usage. Unfortunately, for right now, it is our only choice.

Economic Competitiveness

Biofuels are getting large subsidies that help with its cost competition with fossil fuels. The environmental cost of fossil fuels are not captured in market prices so it is fair to allow a level playing ground for biofuels that provide environmental benefits. Biodiesel subsidies are essential in the survival for competition with petroleum diesel, but as the price of oil rises it becomes more viable. Based on 2005 oil prices, the most prevalent feedstock available today vegetable oil and animal fat are more competitive with diesel than the Fischer Tropsch (FT) process (see fig. 1).
Fig. 1 Projected biodiesel production costs, compared with recent (pre-tax) diesel prices, adapted from report by Richard Doornbosch, Roundtable on Sustainable Development (2007) 21.

In 2005, the price comparison was not promising for biodiesel in comparison to the per energy equivalent liter (EEL) of diesel. Estimated soybean biodiesel production cost was $0.55 per diesel EEL, compared to diesel wholesale prices averaged at $0.46/liter. However, the United States federal government provides a $0.29 per EEL subsidy to qualified producers (Hill et al.). This equates to a subsidized cost of $0.26/liter or in more familiar terms, a gallon equals 3.785 liters so multiplied by $0.26 equals $0.98/gallon production costs and $2.07/gallon for unsubsidized production.
A study conducted in 1998, modeled a small biodiesel plant capable of processing 500,000 gallons. The model used various feedstock to determine production pricing without subsides. The prices are accurate for production costs back then because oil prices per barrel were much less in 1998. Soybean oil is the least expensive given the choices available today. Animal fats come in second, but currently the supply is limited. As indicated in table 7, canola oil is the third option but it is not a crop that thrives well in America.

Table 7
Economic Comparisons of Multiple Feedstocks

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>$/Gal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybeans</td>
<td>$1.26</td>
</tr>
<tr>
<td>Canola</td>
<td>$1.46</td>
</tr>
<tr>
<td>Sunflower</td>
<td>$2.35</td>
</tr>
<tr>
<td>Animal Fats</td>
<td>$1.35</td>
</tr>
</tbody>
</table>

Source: J. Alan Weber and Donald L. Van Dyne. “Cost Implications of Feedstock Combinations of Community sized Biodiesel Production.”

From a sustainable and economic standpoint biodiesel’s best feedstock choice would be used vegetable oil or animal fats. It is cost competitive, the most environmentally beneficial feedstock, and does not compete with food supplies. Rendered
animal fat takes more processing than vegetable oil but in the future supplies could increase given the ability to process all forms of fats.

Food Supplies

Higher grain prices are detrimental to the food supplies of import-dependent countries and poor countries. Such nations may not be able to afford the rising cost of imported oil or food. Countries whose food security is most at risk include those that are both poor and import dependent.

To identify countries at high risk of hunger due to grain shortages, the daily calorie intake and the percentage of import dependence are calculated. Of the six lowest-income countries—Eritrea, Liberia, Haiti, Georgia, Burundi, and Zimbabwe—Eritrea has the lowest calorie availability: 1,465 which is below the average of 2,200 calories reported in 2005 by the United Nations Food and Agriculture Organization (FAO). Food security could be threatened and the food gap widened if a price-shock scenario occurs, especially for the 70 lowest-income countries. (The food gap is the amount of food needed to raise global nutritional levels to approximately 2,100 calories per person.)

Economic Research Service writers for the USDA, Stacey Rosen and Shahla Shapouri, warn, “If the rise of food [prices] continues, allocation of food aid must be raised to 35% to help low-income countries over the next decade.” Food aid has not kept up with the global food aid budget. From 2004 – 2006, global food aid donations equaled about 7.5 million tons per year, which was close to a third of the food gap. Increases must be made to offset the “35% rise over the next decade to maintain the 2006 level of food aid that covered 25% of the gap of 8 million tons.” The greatest percent of price-shock on food
will be felt by the countries that use the least amount of imported grains such as Latin America and Caribbean (see table 8).

Table 8

Food Gap, 2016: Baseline vs. Price-Shock Scenario

<table>
<thead>
<tr>
<th></th>
<th>Million tons</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Base</td>
<td>Price Shock</td>
</tr>
<tr>
<td>Asia</td>
<td>3.62</td>
<td>3.94</td>
</tr>
<tr>
<td>Latin America and</td>
<td>1.42</td>
<td>1.76</td>
</tr>
<tr>
<td>Caribbean</td>
<td>20.15</td>
<td>21.36</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>25.23</td>
<td>27.22</td>
</tr>
<tr>
<td>Total 70 Countries</td>
<td>25.23</td>
<td>27.22</td>
</tr>
</tbody>
</table>


For developing countries that import oil, the price tag rose from “$84 billion dollars to $137 billions dollars in 2005” (USDA 6-21). While the rise in energy cost has hurt importing countries, it has encouraged investment in biofuel technology. This is not a new idea: the biofuel industry has created jobs all over the world. In the United States, the ethanol industry is credited for employing close to 200,000 people, in fields ranging from farming to ethanol plant operations (Worldwatch Institute 124). Agricultural research in low-income countries has been limited by national governments, as well as by
international organizations such as the World Bank. Interest in biofuels could change this scenario.

Conclusion

Increased demand for soy and corn in the United States and abroad has taken its toll on food prices. The rising price of oil is wreaking havoc on the American economy as well as global economies. The rising price of oil and the increasing interest in biofuel have created a wide-range of government policies to promote biofuel production. Recently, public debate has intensified over the influence biofuel has on food crop prices. Increased demand, rising fuel prices, and biofuel use are all part of the economic picture. Attributing biofuel production to the rise in food prices is too simplistic; the economics of global supply and demand are driven by several factors interacting. Great care should be taken to ensure poor countries that rely on imported food do not endure severe food shortages because of poor policies. Biofuels provide an opportunity to make adjustments to the market, whether these changes are sustainable farming practices, encouraging poor countries to grow their own fuel or food, or combinations thereof.

Sustainable agriculture can be more widely accepted if social pressure is applied to encourage the production of dual-purpose crops that help reduce, in some measure, the use of fossil fuels and the generation of GHG. Conservation in all areas of energy use is the key to sustainability. In the future, non-food competing crops (i.e., biomass crops such as switchgrass) will have a greater long-term benefit.
Methods

The substance of this project is drawn from over two years of work analyzing the feasibility of biodiesel as an alternative transportation fuel. Most of the information is a review of literature collected from assigned reading during my undergraduate and graduate studies on environment, economics, and social justice. My yearlong subscription to Biodiesel Magazine helped provide current news and information. I received Internet notices on meetings and issues both local and state through the Air Resource Board and Sustainable Biodiesel committees. I attended half a dozen conferences and lectures to get an idea of what the issues were with biofuels for instance—Bioneers, Engineers for a Sustainable World, and the Sustainable Enterprise Conference in Rohnert Park. Scanning bibliographies from books and articles from authors such as: Lester Brown, Jason Hill, and John Sheehan, helped lead me deeper into the knowledge base of biofuels and how they affect our world.

My projects limitations are that I found it difficult to keep up with the industry; it is evolving at a rapid pace. The technologies and studies that pertain to better biofuel feedstock are still in development; next generation biofuel is basically theoretical. Another limitation is that there are no soybean crushing facilities on the West Coast. I was unable to conduct a fieldtrip to visit and learn first hand about biodiesel or corn ethanol production. Fortunately, there are local small biodiesel and ethanol producers, Yokayo Biofuels and Green Energy Network, where I was able to interview and get samples of their biofuels.
Glossary of Terms

**Biodiesel:** a biofuel used in compression-ignition (diesel) engines containing mono-alkyl esters of long-chain fatty acids created by transesterification; using plant or animal oils with an alcohol (typically methanol) and a catalyst such as lye. Another name for biodiesel is methyl esters. Biofuels for diesel engines can also be produced from lignocellulosic biomass using gasification and synthesis such as the Fischer-Tropsch synthesis which converts biomass into liquid fuels.

**Biofuels:** liquid fuels derived from organic matter or biomass.

**Biomass:** organic material from plants or animals including energy crops, agricultural residues, forest product wastes, organic component of municipal (domestic) solid waste and industrial waste, and animal manures.

**Bxx (where xx is a number—for example, B5, B10, etc.):** biodiesel blended with petroleum diesel, with the biodiesel percentage by volume indicated by the number.

**Cellulosic Biomass:** plant fibers composed of linked glucose molecules, in this context are inedible. Examples are grass, wood, and forest waste.

**Cellulosic Ethanol:** ethanol produced from cellulosic biomass, usually using acid-based or enzyme-based reactions to break down the sugars contained in plant fibers. The sugar can then be fermented resulting in ethanol.

**Combustion Engines:** energy released as a result from a chemical process that occurs with fuel and oxygen. Compression-ignition engines also known as diesel engines, compresses air to the point of high heat which ignites the fuel. Gasoline engines also compress the air and fuel but use a spark plug to ignite the fuel.
EEL (energy equivalent per liter/litre): a measure of energy potential from a given fuel relative to producing the same amount of energy of fossil fuel per liter/litre.

Exx (where xx is a number—for example, E85): the number indicates the percentage of ethanol blended with gasoline per volume.

Ethanol: a biofuel typically produced by fermenting plant sugars (usually corn or sugar cane) that can be used in gasoline engines as a fuel.

Feedstock: raw material specifically needed for an industrial process.

First Generation Biofuels: biofuels requiring energy crops for feedstock. Next generation biofuels will use waste products as feedstock.

Fertilizers: a compound given to plants to help them grow, providing three major nutrients, nitrogen, phosphorus, and potassium.

GREET (Greenhouse gases, Regulated Emissions, AND Energy use in Transportation): a model designed by the Argonne National Laboratory to evaluate a fuels' life-cycle impact on the environment.

Greenhouse Gas (GHG): trapped gases in the Earth’s atmosphere (GHG) contribute to the greenhouse gas effect; a naturally occurring phenomenon where gases trap heat, warming the atmosphere, but now is being exasperated by human activity.

Joule (J): the International System of Units (SI), unit of energy to do work.

Land use: modifications by man, to the natural environment, in an effort to accommodate human activity such as farms, settlement, and cities.

Life Cycle Inventory (LCI): the quantification of inputs and outputs of a system to determine its impact on the environment.
Lignocellulosic Feedstock: biomass feedstock used in a variety of ways for production of biofuels. These are cellulose and lignin based materials such as forest residue, grasses, and wood.

Liquefied Natural Gas (LNG): a fossil fuel primarily composed of methane.

Methanol: a chemical compound that is a simple alcohol, also known as methyl alcohol.

Multiple-use Crops: crops that can be used for a variety of purposes those being, food, animal feed, and energy.

Nitrogen Oxides (NOx): the generic term for a group of gases that contains nitrogen and oxygen. Nitrous oxide (N₂O) a greenhouse gas, is produced from combustion.

Particulate Matter (PM): fine particles of solids suspended in gas, such as soot, may carry carcinogens.

Rapeseed: a flowering source of vegetable oil grown in Europe, and especially in Germany. Canola is a rapeseed grown in North American, predominately in Canada.

Renewable Fuels Standard (RFS): a regulation under the United States Energy Policy Act of 2005 that requires an increase in production and sells of renewable fuels. This will require 7.5 billion gallons of renewable fuel to be blended in with gasoline by 2012.

Runoff: surface runoff pollution is caused by water carrying fertilizers and other contaminants to locations where they can cause environmental damage, such as sensitive aquatic areas in gulf streams.

Splash Blending: blending of biodiesel or ethanol with petroleum fuels, without a mixing process.
**Straight Vegetable Oil (SVO):** virgin or waste vegetable oil (WVO) used for an alternative fuel to petroleum diesel fuel. Some diesel engines can run on pure plant oil (PPO) as known in Europe, without modifications, but cold climates may cause gelling, resulting in problems.

**Switchgrass:** a prairie grass found in North America that has potential to be used as a cellulosic feedstock for ethanol production.

**Transesterification:** the process of transforming one ester into a different ester by means of breaking apart the long fatty chains (an ester compound) and combining them with another alcohol. Biodiesel is made from transesterified oils.

**Well-to-Wheels Analysis:** the evaluation of a fuel’s life-cycle contribution to energy use and GHG emissions, starting from the source point (well), and ending at the fuel pump (wheel).
Analysis of the Social, Economic, and Environmental Effects of Replacing Petroleum-based Fuels with Biodiesel Fuels

Once viewed as the silver bullet for our climate in crisis, biofuel is now criticized for compounding the problem. The purpose of this biodiesel feasibility paper is to investigate the current debate regarding biofuel including its impact may be on the environment. Some of the controversial issues are fertilizer use, runoff, land use, loss of habitat and the social aspect of its influence on the price of food. Furthermore, this paper delves into land use policy at home and abroad. I will compare and contrast biodiesel’s role with that of ethanol’s in contributing to the problem, or providing a solution for, climate change. My intent is to provide the public with an examination of the issues surrounding biodiesel as an alternative fuel, and thoroughly address each issue with the goal of making this complex subject understandable. Sustainable biofuel will address the issues of social, economic and environmental equity. The following complex questions must be answered:

- Can biofuels be sustainable given the current issues?
- Can the use of biofuels indeed decrease greenhouse gas (GHG) levels?
- To what extent do biofuels influence the price of soybean and corn in America and what are the implications of this?
History of Greenhouse Gas Policy

Coming together as a global community was not a sudden event; it took 35 years of conferences and persistence. In 1972 the first global conference addressing sustainability, the "United Nations Conference on the Human Environment (UNCHE)," was held in Stockholm, Sweden. The UNCHE conference heightened awareness of the need to secure the earth’s resources for future generations. It wasn’t until twenty years later, that the "United Nations Conference on Environment and Development (UNCED)," dubbed the "Earth Summit," was held in Rio de Janeiro, Brazil. Collective support grew in 1992, resulting in the adoption of the “United Nations Framework Convention on Climate Change (UNFCCC),” in essence, the first step toward combating the danger of global warming. Five years later, in 1997, the UN held another conference in Japan and negotiated what was to be called the “Kyoto Protocol,” which took further action in securing commitments from industrialized nations to reduce GHG emissions to at least 1990 levels. In 2001 the Intergovernmental Panel of Climate Change (IPCC) published its Third Assessment Report, stating that climate change was caused by human activity. After more than two decades of debate, the correlation between GHG emissions and climate was unsubstantiated. It was the IPCC’s Fourth Assessment Report, “Climate Change 2007—A Synthesis Report.” Prepared by scientists from all over the world, that acknowledged humans were responsible for climate change. This afforded policy makers’ solid grounds for mitigating GHG influences.

What is Climate Change?

Climate change is a happening, and it is being caused by human activity. Melting icecaps, horrific storms, deadly heat waves are just a few of the environmental impacts of
global warming. Weather systems such as hurricanes occur in the troposphere, the
innermost layer of the Earth’s atmosphere. Thus, it is the physical properties of the
troposphere that determine the long-term weather patterns of our climate. The greenhouse
effect is a naturally occurring phenomenon on the planet. Atmospheric greenhouse gases
are: water vapor, carbon dioxide, and other gases trapped by Earth’s atmosphere.
Sunlight enters our atmosphere and its energy is absorbed by these gases creating a
blanket of warmth. Carbon burning and similar activities have increased gas levels, and
in turn, disrupted the natural heating and cooling mechanisms on the planet. “The
concentration of CO₂ in the troposphere is higher than it has been in the past 420,000
years and is rising at about 0.5% a year” (Miller 449). The need of urgency is upon this
generation to reduce carbon levels in the atmosphere before it is too late.
What are Biofuels?

Biofuels are a category of alternative fuels, which are, derived from organic
matter, as compared to non-organic alternatives fuels such hydrogen. Three primary
biofuels are biodiesel (a lipid oil-based biofuel), ethanol, and methane (a natural gas).
Biodiesels are known chemically as methyl esters. These methyl esters are made from a
chemical process utilizing a lipid, such as vegetable oil or animal fats, a catalyst such as
lye, and an alcohol such as methanol or ethanol. In a chemical process known as
transesterification, the fatty acid chains are removed from the molecules of straight
vegetable oil (SVO), leaving behind the glycerin backbone and free methyl esters.
Ethanol, also known as ethyl alcohol (grain alcohol), is usually made from corn, but also
can be made from other sugar based feedstocks, such as sugarcane and sugar beets.
Lastly, methane is produced from organic material by anaerobic digestion, a
decomposition process that results in methane and carbon dioxide. All these biofuels are produced from recently living organisms such as plants or animals, whose carbon is part of the carbon cycle. The carbon cycle is the circulation of various forms of carbon between the environment and living organisms. In contrast, fossil fuels take carbon that was long ago sequestered and removed from this active cycle. The burning of fossil fuels results in a net increase of carbon in the carbon cycle and therefore in the atmosphere. Renewable transportation fuels are categorized by the amount of fossil fuel required to produce the renewable fuel. In reviewing biodiesel and its applications the National Renewable Energy Laboratory (NREL) have classified soybean oil as renewable, “because it is solar energy stored in liquid form through biological processes that are much more rapid than the geological time frame associated with fossil energy formation” (Sheehan 10).

Why use Biofuels instead of Fossil Fuel?

Carbon dioxide (CO₂) is targeted as the most important human caused GHG. Fossil fuels contribute 56.6 % of global GHG emissions, more than all other anthropogenic emissions combined (IPCC 36). One major contributor to carbon gases in the atmosphere is the combustion engine. Decreasing fossil fuel use in transportation has the most potential for GHG mitigation. Biofuels have two characteristics that make it globally attractive. First, it helps meet GHG reduction targets, and secondly, it can be substituted for petroleum. Today’s existing automotive engines, both diesel and gasoline, can run on biodiesel and ethanol, respectively. When fuel is injected into an engine cylinder, combustion occurs, either by compressed ignition (diesel) or spark ignition (gasoline). Interestingly, fuel originating from vegetable oil is not a new idea at all.
Inventors Rudolph Diesel and Henry Ford designed their cars to run on vegetable-based fuels in the early part of the twentieth century.

Biodiesel can be mixed with petroleum diesel to make B20 (20% biodiesel, 80% petroleum), which can be used with little or no modification to engines. Pure biodiesel (B100) may necessitate some engine modifications because of the solvent nature of biodiesel, and fuel additives may be needed in cold climates. Ethanol can be mixed with gasoline in various degrees as well, such as, E85 (85% ethanol, 15% gasoline). Some vehicles, Flexible Fuel Vehicles (FFVs), are designed to run on ethanol or gasoline. Splash blending, where these biofuels are mixed with fossil fuels is becoming popular in offsetting petroleum demand, and decreasing GHG emissions. Although biofuels have a great deal to offer in the way being renewable and decreasing GHG, they are creating much debate in their role with influencing the rise of food prices, and land deprivation.

Are Biofuels Part of the Solution or Part of the Problem?

The biofuels debate has revisited old problems and uncovered new ones. Agriculture has been part of our civilization for 10,000 to 20,000 years. With that came some poor environmental management practices. Land clearing methods such as slash-and-burn cultivation were common. Communities that thrived for longer periods of time practiced sustainable farming, those that did not, vanished. Civilizations found out, sometimes the hard way, the importance of sustainability. Because the planet is basically “above its carrying capacity,” today we need to be diligent about sustainability in every aspect of our lives (Meadows 138). Fuel crop biofuels grown by industrialized agricultural methods are adding to an all ready stressed environment. Farming practices that over-till, practice mono-culture (no crop rotation), and fertilizer use, diminish
sustainable biofuels prospects as a viable alternative transportation fuel. Land loss, deforestation, and release of soil carbons are all results from cultivation, whether it is for food, feedstock for cattle, biodiesel, or hand cream; the results are disastrous.

Prudence, care and caution are needed in determining the current course of biofuels production. Biofuels made from food crops are not the optimum source of material for feedstock. It may have been a century ago but those times have passed. With a world population of over 6 billion people we do not have the luxury of diverting land use that is devoted to food crops. Prudence is needed to transition from food crop to non-food crop biofuel feedstocks.

The good news is biofuels do not have to be produced from crops devoted to food; the lessons learned from these “first-generation” fuels aide in understanding the requirements for the “next-generation” fuels (WorldWatch Institute 24). We can’t discredit the biofuels direction as a wrong one, it was the only direction we had at our disposal. The biofuels debate has brought attention an even larger problem around the world, the use of limited natural resources.

Analyzing the feasibility of biodiesel as an alternative to petroleum fuels cannot be done in a vacuum. The world economy is made up of checks and balances. Gathering the experiences of countries such as Germany and Brazil, which have been in the biofuels industry longer than the United States, helps perceive the challenges. Germany grows much of its biodiesel feedstock from rapeseed crops. Brazil, which has a long history of ethanol production, grows its feedstock from sugar cane. Palm oil from Indonesia has primarily been exported for food and cosmetics, but biofuels add to the competition for palm oil. The price of feedstock for biodiesel is rising, exacerbating economic challenges.
for the United States and other countries. All countries have the same challenges but in different ways, to produce biofuels in a sustainable manner.

Most countries raise crops best suited to their climates. Sugar cane and palm oil do well in the tropics, whereas corn does well in the hot/dry climate of the midwestern United States. Soya bean, generally known as soybean, has been modified to grow in both hemispheres. Cultivation practices directly affect the degree to which land use is sustainable. Some growers have monocultures, where one kind of crop is grown; others have rotation crops, where many crops are grown on the same land throughout the year. Ideally, monocultures are avoided because they require more fertilizer and tilling. Producing corn takes less water and fertilizer when rotated with soybean because the latter returns nutrients to the soil. Tilling releases some carbon; however, this can be avoided with crop rotation, or better yet, no-till cultivation (Worldwatch Institute 50).

The primary crop in the oilseed market is the soybean. Soybeans are big business because of their many uses. They can be easily exported as whole beans or crushed domestically. The protein-rich soybean is a source for livestock feed and provides an oil source for the food industry. Such multipurpose crops are therefore gaining priority in the use of agricultural land. Growing demand for food and the added demand for biofuels are causing the price of oilseed commodities to rise. In 2006 soybean accounted for more than half of the world’s total oilseed production (224.6 million tons or 203.8 million tonnes). The United States is the leader in soybean production, followed by Brazil, Argentina, and China, respectively (Becker-Weidel). Yet, a small percentage of soybeans are dedicated to biodiesel feedstock. Brazil does not have the infrastructure to crush
soybean so it ships then off as the whole oilseed. However, until recently Brazil was the
top ethanol producer in the world. (see Table 9)

Table 9
World Biofuels Production, 2006

<table>
<thead>
<tr>
<th>Total ethanol:</th>
<th>38,200 million litres (liters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>18,300 million litres 47.9%</td>
</tr>
<tr>
<td>Brazil</td>
<td>15,700 million litres 41.1%</td>
</tr>
<tr>
<td>Others</td>
<td>4,200 million litres 11%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total biodiesel:</th>
<th>6153 million litres (liters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>2499 million litres 40.6%</td>
</tr>
<tr>
<td>United States</td>
<td>852 million litres 13.8%</td>
</tr>
<tr>
<td>France</td>
<td>625 million litres 10.2%</td>
</tr>
<tr>
<td>Italy</td>
<td>568 million litres 9.2%</td>
</tr>
<tr>
<td>Others</td>
<td>1,609 million litres 26.2%</td>
</tr>
</tbody>
</table>


History of the Soybean in Brazil

Soybeans did not originate in Brazil, they originated in China. Researchers eventually developed a strain that thrived in lower latitudes, enabling the cultivation in
Brazil. In 2005 Brazil’s soybean exports netted close to $10 billion, making agriculture very attractive to investors.

The story of Brazil’s great natural resource, the Cerrado, a huge tropical savanna, is a long journey from discovery to exploitation, from empowering the local farmer, to cutting and burning the rainforest to accommodate large-scale production. Brazil has produced biofuels for more than two decades. In their article “The Brazilian Soybean Complex,” Goldsmith and Hirsch note that Latin America faces transportation, socioeconomic, and environmental problems. Even though Brazil is the top ethanol producer, it does not have the crushing capacity to produce biodiesel at large scale from soybeans. Increased soybean cultivation in the Cerrado is pushing the cattle industry toward the forest. Cattle grazing, according to Robert Schneider, an economist for the World Bank, are considered “one of the main causes of tropical deforestation in the Brazilian Amazon” (qtd. in Worldwatch Institute 198). Brazil, as reported by Maria Pia Palermo, has the world’s largest tropical forest (20% of its area), is home to 30% of the world’s plants and animals, and is being diminished by large-scale agriculture.

Land use is an important issue in Brazil because it is thought that it will be difficult to enforce environmental laws if small producers get involved. Going from public to private ownership creates some difficulty with enforcing conservation law. Brazil has a land preservation law, but companies do not generally obey the Forestry Code, which requires nature preservation of 20% of rural properties. There may be some hope with some kind of certification system for sustainable farming. In an interview with the Brazilian newspaper Tierramérica, Délcio Rodrigues, energy expert with Vitae Civilis, a Brazilian nongovernmental organization active in fighting climate change,
states, “pressure from European importers to respect environmental standards could prevent some harm” (qtd. in Osava).

Growth of biofuels in Latin America appears inevitable. In 2001 Colombian law stipulated 10% biofuel mixture by 2009; which could result in using some of the 600,000 tonnes (661,000 tons) of African palm oil being used for food. In Argentina, the Biofuels Act approved in April 2006 requires 5% biofuel mixture by January 2010.

Germany as the Pioneer

The pioneer in growing feedstock for biodiesel is Germany. This country is far ahead of the United States with experience in producing biodiesel. In the early 1990s, researchers were investigating the prospect of using local crops for biofuel. Researchers contacted local farmers to get their input about the feasibility of using biodiesel feedstock from processed rapeseed. This turned out to be a good fit. Germany’s cold climate is well suited for rapeseed cultivation. Rapeseed, an oilseed related to the mustard seed, produces canola oil, a good source of protein for animal feed. The USDA’s 2004 Foreign Agriculture Service’s GAIN (Global Agriculture Information) Report indicates that Germany has a potential 11.8 million hectares (27 million acres) of land available for crops, of which 1.5 – 2 million hectares (2.4 – 4.9 million acres) can be used to produce rapeseed¹. Having an abundant supply, Germany is creating policies to earn revenue from biofuel sales and to create demand. However, it has added a tax to biodiesel, which has slowed the market. To stimulate more growth, Germany intends to introduce a compulsory blending policy that will ask for a 4.8% biodiesel blend, creating a demand of 1.5 million tonnes (1.65 million tons). This is not an impossible figure to meet: the

¹ See downloaded version of report “Germany Oilseeds and Products Biofuels in Germany – Prospects and Limitations 2004.”
country is using only 10% of its biodiesel industry’s capacity, 5 million tonnes (5.5 million tons)\(^2\). In 2006 the yearly production capacity for biodiesel was 2 million tonnes (2.2 million tons)\(^3\). In the biodiesel industry, Germany is the global leader in domestic supply and demand.

Malaysia and Indonesia

Malaysia is the top producer of crude palm oil. (see Table 10) The first palm oil plantations established in Malaysia date back to the early twentieth century. Globally, 90% of palm oil is used for food, margarine, and vegetable oil. The remaining 10% is for industrial uses. The African palm that produces the oil will be in greater demand because of its healthier traits as consumers move away from trans fats in food.

Table 10

Palm Oil-Producing Countries Top 10 List

<table>
<thead>
<tr>
<th>(% of world production)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Malaysia</td>
</tr>
<tr>
<td>2. Indonesia</td>
</tr>
<tr>
<td>3. Nigeria</td>
</tr>
<tr>
<td>4. Thailand</td>
</tr>
<tr>
<td>5. Colombia</td>
</tr>
<tr>
<td>6. Cote d'Ivoire</td>
</tr>
<tr>
<td>7. Ecuador</td>
</tr>
<tr>
<td>8. Cameroon</td>
</tr>
<tr>
<td>9. Congo</td>
</tr>
<tr>
<td>10. Ghana</td>
</tr>
</tbody>
</table>

Source: Stats provided by <http://www.uga.edu/fruit/oilpalm.html>.

\(^2\) See Planet Ark interview by Michael Hogan.
\(^3\) See web article “Biodiesel Capacity in Germany 2006.”
Palm oil cultivation has the gravest consequence on tropical forests. Slash-and-burn methods used in the past created pollution; since then have been banned by the Malaysian government. Indonesia has paid a steep environmental and socioeconomic price for misusing land in the production of food crops. Those include, damage to the cultures of indigenous peoples displaced by large producers, and to animals such as orangutans and Samarian tigers, which have been driven close to extinction.

The United States of America

Corn and soybeans grown on American soil are in high demand for both food and biofuels. The United States is a major player in the exporting business, with close to 20% of total feed grain exports. Yet the percentage set aside for biofuels is not astronomic. In 2005, 14.3% of the corn harvest was allocated for ethanol, and 1.5% of soybeans harvested were set aside for biodiesel (Hill). But even a slight rise in the already great demand may strain the whole grain and oilseed economy.

Demand for ethanol in the United States was mostly driven by policies put forth by environmentalists and agricultural lobbyists. In 1990 the Clean Air Act required oxygenation in fuel to reduce pollution. The Reformulation Gasoline Program (RFG) required mixtures of ethanol or MTBE (methyl tertiary butyl ether) to improve combustion for cleaner emissions. Ethanol has grown as the fuel additive since MTBE was found in groundwater and many states banned the use.

Feedstock, the raw material needed to make ethanol, is primarily corn. This creates competition with other grain crops. The top-produced feed grain in the United States is corn; wheat is second. Corn has a multitude of uses as shown in Table 11.
Table 11

Feed Grain Database: Yearbook Table

<table>
<thead>
<tr>
<th>Year</th>
<th>Corn Syrup (HFCs)</th>
<th>Glucose and Dextrose</th>
<th>Starch</th>
<th>Alcohol</th>
<th>Alcohol Products</th>
<th>Seed</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>540.57</td>
<td>217.09</td>
<td>245.70</td>
<td>705.95</td>
<td>131.00</td>
<td>186.00</td>
<td>20.10</td>
</tr>
<tr>
<td>2002</td>
<td>531.84</td>
<td>219.28</td>
<td>255.73</td>
<td>995.50</td>
<td>131.00</td>
<td>186.90</td>
<td>20.01</td>
</tr>
<tr>
<td>2003</td>
<td>530.19</td>
<td>227.93</td>
<td>271.49</td>
<td>1167.55</td>
<td>132.00</td>
<td>187.40</td>
<td>20.56</td>
</tr>
<tr>
<td>2004</td>
<td>520.67</td>
<td>221.89</td>
<td>278.64</td>
<td>1323.07</td>
<td>132.80</td>
<td>189.00</td>
<td>20.79</td>
</tr>
<tr>
<td>2005</td>
<td>528.61</td>
<td>229.31</td>
<td>275.38</td>
<td>1602.78</td>
<td>135.00</td>
<td>190.20</td>
<td>19.90</td>
</tr>
<tr>
<td>2006</td>
<td>510.11</td>
<td>238.97</td>
<td>271.68</td>
<td>2117.09</td>
<td>136.00</td>
<td>190.42</td>
<td>23.58</td>
</tr>
<tr>
<td>2007</td>
<td>500.00</td>
<td>235.00</td>
<td>270.00</td>
<td>3200.00</td>
<td>134.50</td>
<td>192.80</td>
<td>22.70</td>
</tr>
</tbody>
</table>

Note: Latest data may be preliminary or projected
*Note: Numbers may be rounded up S.Johnson

Source: USDA

In 2001 the allocation for ethanol production was 706 million bushels; in 2006, it had reached 2117 million bushels, an increase of almost 300% comprising more than half the year’s total of 3,487 million bushels. Corn is a valuable commodity for livestock feed; it is processed into many food and industrial products, such as starch, sweeteners, corn oil, beverages, and fuel alcohol- ethanol. Livestock feed and biofuel demand will heighten the demand for corn. During 2002 – 2006, corn prices rose by 50%; soybean oil, 60%; and wheat, 45% (Rosen and Shapouri 25). In a recent study, the Center for Agricultural
and Rural Development (CARD) concluded that ethanol expansion would increase 7%, to 1.8% more than expected simply because of more corn being used for ethanol production (Informa page 52). It may seem like a large increase, but in comparison to demand for food, it is minuscule; the amount of food needed to feed the current population is estimated to double in the next 50 years (Hill).

Two forms of feedstock, corn and soybean oil, follow different paths and make different contributions to the food crop competition. Both corn and soybean producers are clamoring for more land, and both are competing with each other against wheat growers. The acreage used for corn production has reduced that used for soybeans, and soybeans have reduced that used for wheat. However, as noted by the Soybean Backgrounder, these crops are all basically trading spaces on limited acreage. Cropland allocation between the three major U.S. crops was relatively stable from 1990 – 2005. The number of shared acres has hovered around 5% of 212 million acres (USDA). Marginal farmland could be converted, but that would require modification of the Conservation Reserve Program authorized by the Food Security Act of 1985.

Demand from China

Even though China grows its own soybeans, it cannot meet internal demand for the crop. China is becoming the largest market for soybeans and soybean meal, growing by more than 20 million tonnes (22 million tons) since the mid-1990s. Growth is expected to continue since China’s livestock, dairy, poultry, and aquaculture sectors demand protein meal. In 2007 the total amount of imported edible oil rose to more than 23 million tons (20.8 million tonnes). Of this, oil from soybeans comprised 8.38 million tons (7.6 million tonnes). This phenomenal growth in imports did not happen overnight,
but it did start to accelerate after the agreement for World Trade Organization (WTO) accession in the later part of 2001. China's economy is experiencing growth, and the people are becoming wealthy, which results in urbanized diets. A growing livestock sector fuels increased demand for bulk feed grains. The publication WTO Accession Will Increase China's Agricultural Imports predicts that as incomes in China continue to increase, more people will eat meat, fish, fruits, vegetables, and processed foods, and will eat out more often (USDA). These urbanized diets are much the way Western nations have been eating for decades.

Land Use: Food versus Fuel

The world’s strained ecosystems reflect the difficulty of sustainably feeding the growing global population, currently estimated at 6.7 billion people. Aquifer depletion, soil erosion, and habitat loss are just a few indicators of the stress on natural resources caused by our growing need for food crop production. The appetite for “dual-purpose crops”—soybeans, corn, sugar cane, and palm oil—is increasing, though their consumption as food constitutes the greatest portion of the demand. Yet any added stress to the environment because of land use is questioned. Do we really need to use these crops for fuel? A key point: Biofuels are readily available now and can help reduce GHG emissions today, potentially giving us a means to immediately improve the environment instead of waiting for a better solution(s). Our society will have to adjust and accommodate for the time being.

On the demand side, growth of the biofuel industry and burgeoning incomes in populous countries, such as China and India, has expanded the market for grains.
A capitalist society has strengths and weaknesses. One weakness is the lack of ability to capture the full value of a natural resource. Free trade, as seen in commodity markets, does not consider the potential consequence of high food prices (starvation) and the downside to demand (shifting land use). Agricultural products are traded as commodities, as with any item (e.g., metals) traded among industrialized countries. Food commodities are grouped in several categories, for example, the grain and oilseed food group. Food crops, whether exported or imported, are susceptible to price variation due to supply and demand. In the free market, food has no more intrinsic value than lumber and other natural resources. No matter the environmental costs, if it pays more to cut lumber than to grow it another year, then the harvest begins or is “cashed in,” as phrased in Tietenberg’s book *Environmental and Natural Resource Economics* (259). If more land is needed for cultivation and the price is right, the natural environment must yield to progress.

Increasing food prices favor some (producers) but are unfair to others (consumers). While producers earn more, people who can no longer afford food regard higher prices as at best an inconvenience and at worst a calamity.

The economics of global supply and demand make it difficult to identify the cause(s) of recent increases in the price of food. A report prepared for the Renewable Fuels Foundation, “Analysis of Potential Causes of Consumer Food Price Inflation,” summarizes its findings as follows—No single factor is the driver of consumer food prices over time— or the moderately higher-than-average inflation during the first three quarters of 2007— but rather there is a complex and interrelated set of factors that contribute to food price inflation (7). Grain prices are the result of the complex interplay
of several factors, including crop rotation and substitution versus demand for, and related costs of, fuel, food, and petroleum.

Conclusion

Being part of the solution is helping mold policy that will offset the harms of using cropland for biofuels, that is to insure that land preservation stays in tact, two motivate policymakers to move on to next generation biofuels. As consumers we can decide where and how our biofuels are produced. This biodiesel feasibility analysis will make policy recommendations intended to alleviate social, economic, and environmental concerns. One alternative is a certification system or “Fair Trade,” system for biofuels, similar to the trading system used in the coffee industry to encourage appropriate farming practices. Taking action involves promoting sustainable fuel, “voting” with one’s dollars, participating at a community level, and drafting public policy. Other opportunities are for greenhouse gas mitigation is energy conservation, carbon sequestration, walking communities, smart growth. Opportunities in the future are, next generation biofuels made from high oil yield crops that don’t compete with food, and fuel hybrid plug-in diesel automobiles. It will take all of these and more to combat global warming, biofuels are not the one solution. Such is the saying.... “There is no silver bullet, only silver buckshot” (Weinberg 4).

---

4 See Policy Recommendations
Policy Recommendations

Support Small-Scale Biofuels Ventures

Governments can provide support through tax incentives to encourage small-scale biodiesel or ethanol production. Currently in California, cooperatives and small-scale biofuels producers have no direct payments for ethanol or biodiesel production (Schumacher).

Appropriate Technologies

Increase investment in new technology or education in low-income countries that are consistent with their agricultural use. Domestically produced biofuels can help offset the rising costs for oil-importing developing countries.

Purchasing Power

Branding is a powerful market tool that can influence the purchasing power of local and global communities. Certification programs such as Fair Trade have been successful in promoting social and environmentally responsible practices with agriculture producers (Conroy 102).

Support Next-Generation Biofuel

The 2005 Energy Policy Act set a target of 250,000 gallons (946,000 liters) of ethanol produced from cellulosic feedstock by 2012. At this time the most cost biofuels are ethanol produced from sugar cane, and biodiesel produced from recycled animal fats or vegetable oil (Worldwatch 67). Cellulosic feedstocks do not compete with food crops however, it is important to research the hazards and implications of genetically modifying enzymes that are needed to break down cellulosic biomass.

Education

Create an open unbiased information system that creates a forum to support sustainable biofuels. This sort of a forum can serve various purposes such as information sharing with stakeholders, and educating the public. A smaller version of the international network—Renewable Energy Policy Network (REN21)—would offer techniques and overcoming obstacle to waste oil feedstock procurement. Further discussion would bring new ideas and community action geared towards overcoming barriers to waste oil procurement biodiesel production (Render). Forming an
educational community-based network is ideal for inspiring and promoting sustainable biofuels.

Support Sustainable Land Use

Support the U.S Congress Conservation Reserve Program (CRP) by ensuring we continue to subsidize farmers for converting their eroding land to grassland or trees by perennial land cover. Another opportunity is to promote best farming practices by limiting water and fertilizer use. This implies no-till cultivation, and crop rotation with nitrogen rich vegetation, as recommendations.

Promote Plug-in Hybrid Electric Vehicles (PHEV)

The technology is out there for these highly fuel efficient cars but the incentive for car manufactures is not. Feebates could level the playing field for PHEVs and allow them to compete with the less fuel-efficient automobiles. Feebate, a revenue neutral strategy, is the major alternative system within a market-based mechanism to provide an incentive for consumers to purchase green and efficient vehicles. The feebate will charge a certain amount of fees on the buyers of vehicles that exceed a determined rate of fuel consumption. There are PHEV vehicles on the road now as conversions gasoline hybrids however; biodiesel users are looking forward to as diesel hybrid. Plug-in enthusiasts are designing and promoting the use and sale of PHEVs in California (CaICars).

End ‘Splash and Dash’

In 2004, Congress passed a provision meant to encourage the production of biodiesel by providing a tax credit for biodiesel blended with regular diesel fuel. This tax credit matched pennies for percentage for example, B2 would get a 2-cent credit, and B99 would receive a 99-cent credit. This credit applied to exported biodiesel as well causing problems with The European Union (EU) competition. The tax credit was giving unfair advantage with tankers from Malaysia, who would stop at a U.S port, add a bit of petroleum diesel, and get the tax credit where it would undersell Europe’s domestic biodiesel. The provision coined “splash and dash” was to expire in 2006 but was extended to 2008 as part of the Energy Policy Act of 2005 (Kram). The tax credit was unfair to producers of 100% biodiesel, neat biodiesel, because they would not qualify unless they splashed petroleum diesel into their batch.
Social Justice

The challenging part of this project was striving to grapple with the pros and cons of biofuels produced from food crops. Biofuels in themselves are a good idea—provided they decrease reliance on foreign oil, reduce GHG emissions, and create jobs. Yet biofuels reliant on food crops as feedstock incur—food price increases, land use problems, and loss of habitat. The foods price perspective changes when viewed from, the delivering end, the farmers in America. Still there is the bigger question about farming, why is it commodity driven? This does not make sense, although the economics do, nonetheless there are people that are starving. One reason is they are poor and cannot afford food, the other is their infrastructure to farm has been disrupted by the free market. Haiti is an example of the free market disrupting local farmers. Rice was grown domestically until imported rice was less expensive than locally grown therefore rice farming was abandoned. Haitians are starving. American farmers have also seen market failures. In the mid-eighties family farms where being forced into foreclosure because of large agricultural competition. The challenge of large-scale agriculture is a duality that can be positive or negative, it easier to mange policy wise fair trade, certification etc. but it tends to create disruption in the much-needed small farms. Cities have experienced social upheaval because farmers having to flee the rural areas and relocate to the city. This influx of people causes a surge in the need for jobs and affordable housing. Food crops alone have mixed social implications and biofuels may provoke more problems; unless, crops grown for biofuels provide a local energy source that does not disrupt the food supply.
Ecological Issues

Growing food crops for biofuel feedstock taxes the environment by increasing water use, run-off, and fertilizer use. On the plus side biofuels play a key role in the reduction of GHG emissions; on account of, transportation fuels are the largest contributor to emissions. Large-scale agriculture and cattle grazing has created destruction of forests and loss of habitat on Brazil's Cerrado region. Palm oil production in Malaysia threatens the indigenous peoples and has almost driven the Samarian tiger and Orangutan into extinction. Over fertilization and soil degradation have caused huge dead zones on America's gulf stream. Adding biofuel crop demand to this type of ecological squander is not desirable for sustainability. Biofuels must transition away from food crops as a source of feedstock. These threats will now go away with the shift to next generation biofuels, but at least they will not add to the destruction of sensitive ecological areas.

Psychological and Moral Dimensions of Change

The issue of food versus fuel is a preview of things to come. Our planet is at max capacity. We can no longer afford to do things the same way as we have done in the past. New thinking, new ideas are the only salvation we have as tools. We do not have the luxury of taking our natural resources for granted. We no longer can assume the free market will take care of itself. People are starving, farmers are losing money, and something appears to be broken in the economic system with food commodities. Change is needed, not only in how we get fuel in our gas tanks, but how we get fuel in our stomachs.
APPENDICES
### GHG Savings with B20

#### Gasoline
- Forecast for 2006: 16 billion gallons
- Carbon dioxide per gallon: 19.4 lbs/gallon
- Total GHG: 3.10E+11 metric ton
- Metric ton: 2204.6

#### Diesel
- Forecast for 2006: 3 billion gallons
- Carbon dioxide per gallon: 22.2 lbs/gallon
- Total GHG: 6.66E+10 metric ton
- Metric ton: 3.02E+07

**B20 reduces CO2 by 20%**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel fuel consumption</td>
<td>3.00E+09</td>
</tr>
<tr>
<td>Total diesel vehicles</td>
<td>845000</td>
</tr>
<tr>
<td>Biodiesel GHG</td>
<td>6.66E+10</td>
</tr>
<tr>
<td>GHG/vehicle</td>
<td>78816.56805</td>
</tr>
<tr>
<td>GHG saved</td>
<td>6.04E+06</td>
</tr>
<tr>
<td>Equivalent vehicles</td>
<td>76.63363363</td>
</tr>
<tr>
<td>Taken off the road</td>
<td></td>
</tr>
</tbody>
</table>
Biodiesel: typical annual yields by feedstock

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>US Gallons/acre</th>
<th>Litres/hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean</td>
<td>44</td>
<td>100</td>
</tr>
<tr>
<td>Sunflower</td>
<td>88</td>
<td>800</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>110</td>
<td>1,000</td>
</tr>
<tr>
<td>Castor</td>
<td>140</td>
<td>1,300</td>
</tr>
<tr>
<td>Jatropha</td>
<td>170</td>
<td>1,500</td>
</tr>
<tr>
<td>Palm Oil</td>
<td>650</td>
<td>5,800</td>
</tr>
<tr>
<td>biomass (FT)</td>
<td>&gt;500</td>
<td>&gt;5,000</td>
</tr>
<tr>
<td>Algae</td>
<td>&gt;5,000</td>
<td>&gt;50,000</td>
</tr>
</tbody>
</table>

Source: Geneva UNCTAD Conference 30 November 2006, Biodiesel: technology perspectives Presented by Lew Fulton
“The Clean Energy Scam,” TIME Magazine Fact Sheet

This article was heavily biased against biofuels. It drew foregone conclusions and failed to acknowledge or interview a representative sample of scientists or groups opposing the study on which this article was based – by Tim Searchinger on land use for biofuels.

Biodiesel has proven sustainability attributes. For every unit of energy it takes to make domestic biodiesel, 3.5 units are gained, or biodiesel has the highest energy balance of any liquid fuel.

Biodiesel has a 78% life cycle carbon dioxide reduction, which even takes into account growing soybeans - these studies were done on soy-biodiesel, as the historical majority of biodiesel in the U.S. has been made from soybean oil.

Grunwald incorrectly attributes rainforest destruction to biofuels. The article fails to mention that numerous factors contribute to deforestation, and many of these factors predate the emergence of commercial scale biofuel production. A UK Department of International Development study cited illegal logging as a major source of the problem, noting, “One of the biggest factors driving illegal logging has been the emergence of China as a major power. Between 1997 and 2005, China’s forest product imports more than tripled. The country now buys half of all international-traded tropical logs. One out of every two is illegally harvested... China is also having a big influence on the timber trade in Africa and Latin America.”

Biodiesel reduces EPA regulated emissions on average by 50 percent compared to petroleum diesel fuel.

In 2007 alone, biodiesel's contribution to reducing greenhouse gas emissions was the equivalent of removing 700,000 passenger vehicles from America's roadways.

There is in fact a surplus of soybean oil. According to U.S. Census data, we have more than 400 million gallons of soybean oil sitting in inventory. Plus, biodiesel is made from byproduct oils from growing soybeans or other crops, not the protein meal part of the oilseed crop. In soybeans, the protein is 80 percent of the bean. Further, no new acres have been introduced for cropland in the U.S. since 1959, according to the USDA. The U.S. is the largest exporter of soybeans.

Recently, a Merrill Lynch commodity strategist, Francisco Blanch, said that oil and gasoline prices would be about 15 percent higher if biofuel producers were not increasing their output. In addition, Fatih Birol of the Paris-based International Energy Agency, said that biofuels are playing a “critical role” in satisfying world demand, and without them, “it would be much more difficult to balance global oil markets.”
The tax incentive for biodiesel in the U.S. more than pays for itself with a net gain to the U.S. economy of $13.6 billion that would otherwise be spent on foreign oil. The biodiesel industry within the next several years will add more than 39,000 jobs.

As the demand for biodiesel continues to grow, the biodiesel industry is working to develop new feedstocks for biodiesel production. Algae, arid variety crops, waste greases, and other feedstocks have great potential to expand and diversify available material for biodiesel in a sustainable manner.

Formerly, a UN employee had called biofuels a “crime against humanity.” The UN’s Food and Agriculture Organization (FAO) quickly came out and said, "We regret that the report of the Special Rapporteur has taken a very complex issue, with many positive dimensions as well as negative ones, and characterized it as a 'crime against humanity,'” said its spokesman. “FAO strongly feels that food security and environmental considerations must be fully addressed before making investments or policy decisions, and we are actively working to ensure this happens.”

FAO has calculated that today 41.88 million km² land are available for agriculture, although just 15.06 mill km² are in use, and only 0.11 million km² are used for biofuels production today, which is no more than 1% of that area.
Works Cited


