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Market penetration of biodiesel

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ABSTRACT

This research examines in detail the technology and economics of substituting biodiesel for diesel #2. This endeavor examines three areas. First, the benefits of biodiesel are examined, and the technical problems of large-scale implementation. Second, the biodiesel production possibilities are examined for soybean oil, corn oil, tallow, and yellow grease, which are the largest sources of feedstocks for the United States. Examining in detail the production possibilities allows to identity the extent of technological change, production costs, byproducts, and greenhouse gas (GHG) emissions. Finally, a U.S. agricultural model, FASOMGHG was used to predict market penetration of biodiesel, given technological progress, variety of technologies and feedstocks, market interactions, energy prices, and carbon dioxide equivalent prices.

FASOMGHG has several interesting results. First, diesel fuel prices have an expansionary impact on the biodiesel industry. The higher the diesel fuel prices, the more biodiesel is produced. However, given the most favorable circumstances, the maximum biodiesel market penetration is 9% in 2030 with a wholesale diesel price of $4 per gallon. Second, the two dominant sources of biodiesel are from corn and soybeans. Sources like tallow and yellow grease are more limited, because they are byproducts of other industries. Third, GHG prices have an expansionary impact on the biodiesel prices, because biodiesel is quite GHG efficient. Finally, U.S. government subsidies on biofuels have an expansionary impact on biodiesel production, and increase market penetration at least an additional 3%.

Contents

1. Introduction

Gasoline and diesel fossil fuels are significant sources of greenhouse gas (GHG) emissions particularly carbon dioxide, amounting to approximately 31% of U.S. emissions [52]. Such

Abbreviations: FASOMGHG, Forest and Agricultural Sector Optimization Model Greenhouse Gas; EPA, Environmental Protection Agency; GHG, greenhouse gas; GWP, Global Warming Potential; IPCC, International Panel on Climate Change.

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emissions contribute to the greenhouse effect, causing the earth to become warmer and precipitating climate change as extensively discussed in Intergovernmental Panel on Climate Change [1]. On the other hand if society were to widely use biodiesel in place of fossil fuels this would potentially reduce emissions since biofeedstocks absorb CO_2 from the atmosphere during growth and release it upon combustion of the feedstock or the energy products derived from them. Thus biofuels in part recycle carbon dioxide mitigating greenhouse gas emissions and in turn slow down climate change. In addition biofuels have at least five other potentially beneficial characteristics:

- Biofuels are renewable.
- Biofuels could reduce the amount of petroleum imports required in many countries in turn, improving the balance of payments, increasing national energy security, and reducing reliance on imports from potentially political unstable areas of the world.
- Biofuels produced on a large scale can reduce demand for fossil fuels and could potentially constrain the growth in fossil fuel prices.
- Biofuels often have cleaner tail pipe emissions and also contain oxygen that when blended with fossil fuels reduces emissions of hydrocarbons (HC), carbon monoxide (CO), particulate matter (PM), mercury, and sulfur dioxide (SO_2), although they tend to increase NOX emissions [2–12,42,43].
- Biofuels use of agricultural and forestry feedstocks provides another market for commodities boosting agricultural prices and producers' incomes.

2. Analysis of biodiesel market penetration

Biodiesel production rapidly expanded from about 5 million gallons in 2001 to 250 million gallons in 2006 [13]. Even though high oil prices have lately tended to reduce biodiesel production, several forces may contribute to long-term expansion in the biodiesel industry.

- High petroleum prices are raising diesel prices and the likely increasing costs of future oil production. Depletable resources follow Hotelling's [44] prices in the long run and tend to increase over time, as petroleum is depleted.
- Government mandates, such as the provisions of the Energy Independence and Security Act of 2007 [54] that includes mandates of up to 36 million gallons of biofuels.
- The public and government's concern over global warming may provide a value for biodiesels CO_2 recycling characteristics. The U.S. government has discussed the use of GHG emission price in a cap and trade system, such as in the Lieberman-Warner Climate Security Act of 2008 [14].

There are also negative forces that hinder the expansion of the biodiesel industry:

- Cost of feedstocks have risen rapidly threatening industry viability.
- U.S. biofuel subsidies are set to expire at the end of 2009.
- Large energy requirements for ethanol may push soybean oil prices above breakeven points.

The purpose of this research is to predict biodiesel market penetration given a wide variety of issues. The issues examined in this research are:

- The imperfect nature of biodiesel substitution for conventional diesel. Several technical problems will arise from large-scale production of biodiesel and is discussed extensively in the next section.
- An agricultural simulation model, FASOMGHG, is updated to include a biodiesel industry. The simulation model can help predict biodiesel market penetration and capture market interactions. The biodiesel industry competes with other industries for feedstocks and supplies a variety of byproducts.
- The agricultural model allows simulation as if the United States had a cap and trade system on greenhouse gas emissions. Thus, an equivalent carbon price can predict market penetration of biodiesel.
- The simulation model can help predict biodiesel market penetration given a variety of fossil fuel prices. For instance, higher fossil fuel prices raise an agricultural producer's cultivation, harvesting, and processing costs, but also boost prices for biodiesel.
- The agricultural model can simulate the biodiesel market penetration, if the United States government continues or removes the subsidies on biofuels.

Clearly the long-term effects of these forces cannot be fully observed in today's world as we have never simultaneous high petroleum prices, high domestic U.S. GHG emission prices, elapsed subsidies, and high competition from ethanol. Consequently, we employ an agricultural model that incorporates:

- Lifecycle and more generalized procedures that calculate the GHG offsets of biofuels.
- Competition from ethanol production.
- Competition from electricity production from biomass and manure.
- Renewable fuel standard requirements.

In doing this we follow a number of previous studies and use an agricultural sector simulation model. Namely, we follow studies on:

- Lifecycle accounting as in Wang et al. [56] or Mann and Spath [15] doing our own analysis of GHG consequences.
- Ways agriculture might modify production patterns in the face of GHG mitigation alternatives as in Adams et al. [16], Callaway and McCarl [17], McCarl and Schneider [18], Antle et al. [19], Lewandrowski et al. [20], Lee et al. [45], and US EPA [53].
- Ways agriculture might alter production patterns in the face of higher energy prices as analyzed in Francl [21], McCarl et al. [46], USDA Office of the Chief Economist [51], Antle et al. [22], Konyar and Howitt [23], and Schneider and McCarl [24,27].
- Ways agriculture might react to biofuel activities: Tyner et al. [25], McCarl et al. [26], Schneider and McCarl [27], Lee, McCarl, and Gillig [45], and US EPA [53].

3. Biodiesel fuel properties

Biodiesel is not a perfect substitute for diesel fuel and hence this section examines the compatibility between these fuels using #2 diesel as the basis. This discussion of fuel properties is based on using methanol as an input, because methanol is the cheapest alcohol and the most widely researched. The fuel properties change if other alcohols are used [28,5,10,12].

The most important property of diesel fuel is the cetane number. Diesel engines do not have spark plugs. The engine's piston compresses the fuel and air mixture until heat and pressure ignite the mixture. This ignition point is identified by the cetane number. Cetane numbers for several fuels are listed in Table 1. Conventional diesel fuel generally has cetane numbers ranging