BIOdiesel TechNOTES

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Biodiesel Education Program, University of Idaho
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BIODIESEL ENERGY BALANCE

A life cycle analysis of soybean biodiesel by University of Idaho researchers shows that biodiesel produces 5.54 times more energy than it consumes in fossil fuels. This study, "Energy Life-Cycle Assessment of Soybean Biodiesel Revisited," is available at: BiodieselEducation.org. This paper is an updated version of a study done in 2009.

In 1998, the first comprehensive life-cycle inventory (LCI) for biodiesel produced in the United States from soybean oil was completed by the National Renewable Energy Laboratory (NREL). The 1998 study found that biodiesel yielded 3.2 units of energy for every unit of fossil energy consumed over its life cycle. According to the 2009 study, the biodiesel energy balance had improved to 4.56.

Why the difference? Soybean agriculture and biodiesel production have become more energy efficient in the 13 years since the NREL study.

At the time of the NREL study, the most recent detailed data available on soybean production was from the U.S. Department of Agriculture's (USDA) 1990 Farm Costs and Return Survey (FCRS). The 2009 study, in contrast, uses data from 2002, and the 2011 study uses data from 2006. Even though more recent data were available in some categories, year 2006 data were chosen because 2006 had the most recent, most complete set of agricultural data. Mixing data from different years may bias the result.

The life-cycle inventory used for the 2011 study was constructed to resemble the 2009 study and the 1998 NREL study in order to make comparisons between the three time periods.

Trends in soybean agriculture

To stay competitive, U.S. farmers are continually minimizing their input costs and increasing productivity. One major change that occurred between 1990 and 2002 is the increased adoption of no-till practices by soybean farmers. No-till use increased in soybean production from about 10 percent of acreage in 1990 to about a third in 2000. Thus, significantly fewer soybean acres required fuel for tilling over this time period.

The most significant change in U.S. soybean production since 1990 is the use of genetically engineered (GE) soybeans, which have had a major effect on pesticide use. The 1990 soybean production data used in the NREL report did not include any GE soybeans because they had not been introduced into U.S. agriculture yet. However, by 2002, seventy-five percent of the soybeans planted were genetically engineered, and today almost all soybeans in the United States are GE varieties. Genetically engineered soybeans with herbicide-tolerant and pest management traits increase yields

What is Life Cycle Analysis?

"Life Cycle Analysis" is a tool used to estimate the environmental, energy, and economic performance of a product or a system. In essence, it is a budgeting process that accounts for all inputs (raw materials and energy) and outputs (products, waste materials, and components that impact the environment, such as CO_2).

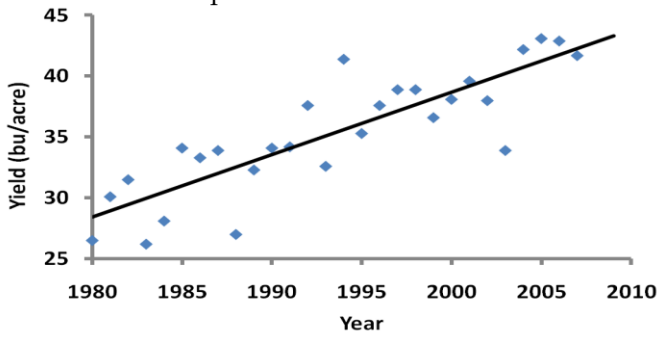
A life cycle analysis can help determine whether biodiesel is a renewable fuel. Developing renewable fuels is desirable because they are derived from sustainable sources of energy. However, the production of renewable fuels involves fossil energy (for example, petroleum-based fertilizers and diesel fuel are used in the production and transportation of biodiesel).

The amount of fossil energy used for biodiesel must be measured over the entire life cycle of biodiesel production (from planting the feedstock to transporting the biodiesel to its final destination) to determine the extent to which biodiesel production depends on petroleum fuels. The degree to which biodiesel is renewable is largely a factor of the amount of fossil energy used in its production.

through improved weed and pest control. Using GE soybeans also reduces pesticide use and costs. Based on data published in the National Agricultural Statistics Service's (NASS) Agricultural Chemical Usage survey, over the 5-year periods from 1990 to 1994; 1995 to1999; and 2000 to 2004, the average herbicide use was 1.18, 1.11 and 1.09 lb/acre/year respectively.

Soybean yields also have been improving over time because of new seed varieties, improved fertilizer and pesticide applications, and new management practices. The data showed a significant increase in soybean yield since the 1990 data used in the NREL study (Figure 1). Soybean yield was 34.1 bushels per acre in 1990, which increased to 38 bushels per acre in 2002. In crop year 2007, the USDA estimated the soybean yield as 41.7 bushels per acre. On average the yield had increased at about 0.5 bushels/acre per year.

Figure 1. U.S. national average soybean yield 1980-2007 and expected trend to 2010



Source: Ash and Dohlman, Office of the Chief Economist

Trends in oilseed crushing

A soybean processing facility uses energy in the form of electricity and natural gas: electricity to power motors and provide lighting, and natural gas for heat and drying. USDA ERS reported a U.S. average oil yield of 11.39 pounds of oil per bushel of soybean in 2002/2003. The oil extraction rate has increased since the NREL study, when it was only 10.16 pounds of oil per bushel. Also, the use of hexane (the petroleum-based solvent used to extract the oil) has gone down by half compared to that reported by NREL.

In the 2009 and 2011 studies, energy was allocated based on the mass fraction of the final product. Soybean crushing and biodiesel production produce not just oil and biodiesel, but also oilseed meal and glycerin. The energy input was allocated among these products on the basis of the weight of the various products.

Trends in biodiesel production

Biodiesel producers have adopted energy-saving processing equipment to minimize production costs. For example, heat integration technologies have resulted in the capture and reuse of heat that was previously discharged.

After adjusting the inputs for energy efficiencies and after allocating a portion of the energy to the co-product (the oilseed meal), the total energy required to produce a gallon of biodiesel was 25,700 BTU in the 2009 University of Idaho study, compared to 36,400 BTU in the NREL report (Figure 2).

Energy requirements of biodiesel production

Transesterification (the chemical process of converting oil into biodiesel) accounts for about 60 percent of the total energy required in the biodiesel life-cycle inventory. Soybean agriculture accounts for 18 percent of the total energy requirements, followed by soybean crushing, which requires almost 15 percent of the total energy.

Biodiesel is renewable

Because biodiesel produces 5.54 times the fossil energy it takes to produce the fuel, biodiesel is a renewable fuel.

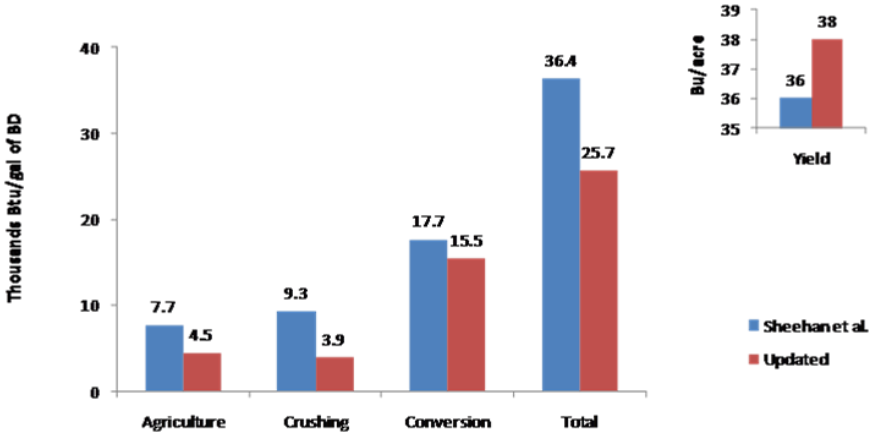


Figure 2. Comparing energy requirements for selected biodiesel subsystems and total life-cycle energy requirements between the 2006 study and the Sheehan et al (1998 NREL) study