NEW LIFE CYCLE PROFILE FOR SOY PRODUCTS

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A new, peer-reviewed study funded by the United Soybean Board[1] provides updated data for use in conducting life cycle assessments (LCAs) of industrial products made from domestically produced, renewable soybeans. This study:

- documents the greenhouse gas reduction benefits of soybean agriculture that carry through to industrial and consumer products;
- shows other energy and environmental benefits of soybean-derived feedstocks, especially when compared to their petroleum-based counterparts[2];
- provides life cycle practitioners with new data that eliminates the use of outdated and hypothetical data; and
- provides an important resource for companies to perform LCAs on their specific products made using soy.

Cradle-to-Gate Study Update

As the array of renewable biobased products has increased, so has the interest in evaluating the energy and environmental impacts of these products using LCAs. To conduct a credible LCA, it is critical to use good quality, current data on all raw materials, energy, and processing aids used as well as the environmental outputs associated with producing a product. In the case of soybean agriculture and processing, existing life cycle inventory (LCI) databases contained information that was, in many cases, more than 10 years old and no longer representative of current energy use or raw material production processes.

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[1] The United Soybean Board (USB) is made up of 68 farmer-directors who oversee the investments of the soybean checkoff on behalf of all U.S. soybean farmers. As stipulated in the Soybean Promotion, Research and Consumer Information Act, USDA's Agricultural Marketing Service has oversight responsibilities for USB and the soybean checkoff.

[2] These results are cradle-to-gate, so depending on the use and end-of-life phases of the products results could change.

A key objective of the project was to update the cradle-to-gate[3] LCI databases for U.S. soybean agriculture production and soybean processing. These updated databases are now available to be placed into the U.S. Life Cycle Inventory (U.S. LCI) Database, which is managed by the Department of Energy's National Renewable Energy Laboratory (NREL), and other databases where life cycle practitioners can access them to perform their assessments on products made with a soy-derived feedstock.

Currently, the data included in NREL's U.S. LCI Database represent U.S. soybean agriculture activities from 1998 to 2001. This project collected U.S. agricultural data for the 2001 to 2007 time period. In addition, this project collected data for soybean processing (commonly called crushing) and soy oil refining, which are not currently in the U.S. LCI but can now be added. Existing data on soybean crushing was based on a 1998 NREL biodiesel life cycle report[4]. The National Oilseed Processors Association (NOPA) collected and aggregated data for this project. NOPA was able to obtain actual operating data from 50 U.S. facilities.

Findings Show Environmental Benefits

The updated information for soybean production and processing show:

- average soybean yield for the 2004-2007 time period was 42.3[5] bushels per acre, which represents a 12% increase over the data (1998-2000 average) used in the current U.S. LCI database;
- each bushel of soybeans harvested reduces greenhouse gases (carbon dioxide (CO_2) equivalents) by 32.6 kg (for the 3.36 billion bushels of soybeans produced in 2009 this would translate into the equivalent of taking 21 million cars off the road[6]);
- the calculated release of nitrous oxide (N_2O), a potent greenhouse gas, is 85% less than the data contained in the current U.S. LCI Database due to a corrected emission factor issued by the International Panel on Climate Change (IPCC) in 2006;

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[3] Cradle-to-gate includes all the materials and energy used to create a product beginning with the production of the product's raw material inputs and ending when the product leaves the "factory" gate. For soybean agriculture, this includes the upstream processes that produce the raw materials used in farming through the steps in crop production (i.e., planting, cultivation, and harvesting).

[4] Sheehan, J. et al., **Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus**, NREL/SR-580-24089 (Washington, DC: U.S. Department of Agriculture and U.S. Department of Energy, May 1998)

[5] For the purpose of the LCI database update, a yield of 41.2 bushels per acre is used to take into account a "seed allowance" deduction. This approach was taken to be consistent with the methodology used in the current U.S. LCI database. Using this approach, the new data reflects a 12% increase in yield over what is in the current U.S. LCI database.

[6] The 3.36 billion bushel number represents the most recent soybean production data reported by USDA's National Agricultural Statistics Service (NASS). The equivalency number was calculated using the U.S. Environmental Protection Agency's Greenhouse Gas Equivalencies Calculator (see http://www.epa.gov/RDEE/energy-resources/calculator.html).

- approximately 20% less direct energy is used for soybean production due to reduced diesel and gasoline usage;
- soybean crushing facilities reduced their energy consumption by 45% compared to the 1998 data;
- improved efficiencies at crushing facilities increased both soybean oil and meal yield compared to 1998 data, by 11% and 4% respectively[7]; and
- hexane emissions at crushing facilities decreased over 70% compared to the 1998 data (going from 10.15 kilograms per 1,000 kilograms of oil produced to 2.96 kilograms).

Soybean Yield Up

To put the soybean yield data in perspective, the 2009 yield increased to 44 bushels per acre according to USDA's National Agricultural Statistics Services (NASS). NASS data show that over the last 20 years (from 1990 to 2009) soybean yield per acre increased by 29%. From 2000 to 2009 alone, NASS data show a 15.5% increase in soybean yield per acre. Also during the last 10 years, the number of soybean acres planted in the U.S. has remained relatively constant. The NASS data show that 74.3 million acres were planted in 2000 compared to 77.5 million acres in 2009, with the 10-year average being 73.6 million acres.

U.S. grown soybeans provide an abundant supply of food for humans and feed for livestock as well as ingredients for biobased products. Soybeans contain both protein and oil. The oil makes up approximately 20% of the soybean by weight. During the processing step, soybeans are crushed to produce soybean meal (protein) and soybean oil. Soybeans are grown primarily for meal, with the oil being a co-product. During the period from 1999 to 2008, according to USDA data, surplus end-of-year stocks of soybean oil ranged from 1.1 to 3.1 billion pounds, with the 10-year average being 2.3 billion pounds. These surpluses of soybean oil, combined with its chemical and physical properties, make it an attractive feedstock for industrial products.

Trends Point to Continued Progress

Data collected for LCI databases represent snapshots in time and therefore are in need of regular updating. Trends indicate that there will be continued efficiency increases in soybean production. For example, companies that provide soybean seeds to farmers have technology under development that is projected to increase soybean yields by 40 percent in the next decade.

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[7] In 1998 it took 5,891 kilograms of soybeans to produce 1,000 kilograms of oil, but the new data show only 5,236 kilograms of soybeans needed to produce 1,000 kilograms of oil, representing an 11% increase in efficiency. In 1998, 1,316 kilograms of soybeans produced 1,000 kilograms of meal but the new data show only 1,267 kilograms of soybeans needed to produce 1,000 kilograms of meal, representing a 4% increase in efficiency.

Another important trend deals with tillage practices used for soybean agriculture. Updated data on the number of acres in conservation tillage[8] were not readily available at the time this study was conducted so the LCI data was left unchanged from the current U.S. LCI Database. The current conservation tillage information in the U.S. LCI Database is based on data contained in a 2002 report. However, newly available information[9] shows that more acreage is being placed into conservation tillage. Updated information gathered for the new report shows 63% of U.S. soybean acreage in conservation tillage, up from 56% cited in the 2002 report. Of the land in conservation tillage, the new data show 41% was in no-till conservation up from the 33% cited in the 2002 report.

Conservation tillage practices disturb less soil and reduce the tractor usage. For example, no-till conservation can result in fuel savings ranging from 3.5 to 5.7 gallons per acres. Mulch tillage can save approximately 2 gallons per acre. Conservation tillage practices also leave more crop residue on the soil surface than conventional tillage. More residue on the soil surface enhances moisture retention and reduces irrigation demand by up to several inches of water per year. No-till leaves less exposed soil and results in less soil erosion (up to 90%), and less nitrogen and phosphorus fertilizer runoff (up to 70%). No-till also promotes the building of soil organic matter, which consumes CO_2 in addition to the CO_2 sequestered by the growing soybean plant.

Soy Delivers Environmental and Energy Benefits to Products

Also, as part of this project, life cycle inventories for soybean-derived feedstocks were either updated or created if no previous inventory existed. Four feedstocks, methyl soyate, soy resin, soy polyol and soy lube base stock, were selected as they are used in a wide assortment of biobased products. These updated and/or new inventories will serve as a ready-to-use platform for LCA practitioners who wish to conduct life cycle studies on downstream products made with these materials.

In the case of biodiesel production, the National Biodiesel Board (NBB) provided new data that was used to update the inventory data for methyl soyate. Previous estimates of the energy used during biodiesel production relied on process modeling and data from a very small number of plants using older technology. NBB conducted a broad survey of its member companies and collected data on measured energy consumption and materials used at operating biodiesel facilities in 2008. The 2008 data show that biodiesel production facilities reduced their energy consumption by 27% compared to the 1998 data.

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[8] Conservation tillage is defined as any tillage and planting system that covers more than 30% of the soil surface with crop residue after planting, to reduce soil erosion by water. No-till, ridge-till, and mulch-till are types of conservation tillage.
[9] Based on a report being prepared by the Conservation Technology Information Center, West Lafayette, Indiana.

The raw data collected on the four feedstocks was modeled in the SimaPro LCA software[10], and the BEES[11] impact assessment methodology was used to calculate the life cycle impact assessment (LCIA) results. The BEES methodology was selected because it covers a broad range of environmental, health, and energy categories that meet the International Standards Organization (ISO) requirements and it is used by USDA for assessing biobased products for the Federal BioPreferred℠ Program. LCA modeling was also done on the petroleum-based counterparts to these soy feedstocks so that a comparison of environmental impacts could be made.

For most of the BEES impact categories, the soy-based feedstocks were better than or equivalent to the petroleum-based alternative. In particular, soy-based feedstocks each showed significantly reduced greenhouse gas emissions compared to their petroleum-based counterparts. (See the full report for all results and a discussion of how to interpret the results.)

Authors and Reviewers

Omni Tech International, Ltd. conducted the study for USB and Four Elements Consulting, LLC, performed the LCA modeling. The study has been peer reviewed by a group of international reviewers to verify that the project was performed in accordance with ISO 14040 and 14044 Life Cycle requirements to ensure credibility and objectivity of the data and results. Reviewers included Dr. Martin Patel of Utrecht University (chairperson) and Michael Levy of the American Chemistry Council.

A copy of the report can be found at www.soybiobased.org.

[10] SimaPro 7, a commercially available LCA software product that contains U.S. and European databases on a wide variety of materials and processes as well as an assortment of European- and U.S.-developed impact assessment methodologies. For more information, go to www.pre.nl.

[11] BEES is a life cycle impact assessment methodology developed by the National Institute of Standards and Technology.