

Executive Summary

Lifecycle Carbon Footprint of Biofuels

High crude oil prices have fueled interest in alternative, renewable energy sources. At the same time, global climate change issues have drawn the attention of scientists, energy leaders and policy makers.

“Biofuels are at the intersection of two high-profile policy issues: how to achieve greater domestic energy security, and how to respond to the challenges of global climate change,” said Jan Lewandrowski of the USDA Global Change Program Office. In January 2008, university, private sector and government researchers were invited to discuss tools to measure and evaluate lifecycle carbon emissions of biofuels.

This January 2008 workshop was a collaboration of Farm Foundation and USDA’s Office of Energy Policy and New Uses and USDA’s Global Change Program Office. Papers and presentations focused on climate change methodologies, biofuels production technologies, integrating market forces into lifecycle analysis, the carbon impacts of feedstocks and crop production, and the impact of land use changes on carbon emissions. Papers and presentations from the conference are posted on the Farm Foundation Web site, www.farmfoundation.org.

The current research consensus is that under present conditions, ethanol and biodiesel have, on average, positive greenhouse gas (GHG) benefits when used to replace gasoline or petroleum diesel, Lewandrowski said. “What is not clear is whether ethanol and biodiesel will continue to have positive GHG benefits if production and use are ramped up to the levels now being discussed and put into law,” he added.

Lewandrowski identified two specific issues. A variety of feedstock production and refinery processes are currently being used to produce ethanol, biodiesel and feedstocks. Whether ethanol and biodiesel have a positive or negative GHG impact relative to fossil fuels depends on the combination of technologies, practices and inputs used in the feedstock production and refinery processes. The second issue: As the United States increases production and use of ethanol and biodiesel, new lands—including perhaps more marginal land—will be brought into agricultural production to grow feedstock crops or other commodities as production patterns shift. GHG emissions associated with these land use changes must be considered in lifecycle analysis.

In assessing GHG impacts of higher levels of liquefied biofuel production and use, Lewandrowski identified these priority questions:

- What is the appropriate way to deal with biofuel coproducts?
- Is it possible to reduce the uncertainty regarding nitrous oxide (N₂O) emissions related to nitrogen fertilizer use?
- How can emissions associated with domestic and international land use changes be integrated into lifecycle analyses?
- What information gaps exist in data and methodologies, which, if filled would most improve the ability to assess GHG implications of expanded biofuel production and use?
- How can greater consistency and transparency be promoted in applying lifecycle analysis to liquid biofuels?

Lifecycle Analysis

Researchers from universities, the private sector and government briefed workshop participants on their current work in biofuels lifecycle analysis.

David Zilberman of the University of California noted that one shortcoming of lifecycle analyses is their rigidity. They do not reflect behavior adjustment to changes in economic conditions or policies. Current models lack the ability to incorporate such dynamic elements as economic fluctuations. Lacking input on the responsiveness of individuals and companies to incentives and regulations weakens the effectiveness of these analyses as tools for policy development.

Zilberman reviewed his work in developing a lifecycle modeling framework that is sensitive to changes in economic conditions, and can reflect technological changes, risk and uncertainty. This approach will result in better estimates of the GHG effects of such things as corn carbon as the relative prices of fuels change over time. For example, as the price of coal is likely to grow more slowly than the price of natural gas over time, the carbon emissions per unit of corn ethanol is likely to increase. The new approach would make it more feasible to understand proposed policies, such as the impact of a carbon tax on GHG emissions.

Stephen M. Ogle of the Natural Resources Ecology Laboratory at Colorado State University reported on work assessing soil nitrous oxide (N₂O) emissions with crop production for biofuels. Soil N₂O emissions from crop production vary regionally, with the lowest rates occurring in New England, mid-Atlantic and Southeastern states, largely due to lower nitrogen fertilization rates on average compared to application rates in other regions. Further research is needed to determine if lower N₂O emissions would lead to more GHG mitigation through biofuel production in these regions.

Energy costs associated with converting land into crop production could be relatively high if the conversion is from forestland to cropland, Ogle reported. Integrated assessments are needed to consider the economics of corn and soybean production relative to current land uses. Other factors contributing to net emissions may vary regionally, including distance from fields to the refinery, and the ability to exploit coproducts from the biomass to the energy conversion process.

Ogle and his fellow researchers estimated implied soil N₂O emission of 2% to 2.5% of nitrogen added to soils, which is lower than other studies have identified. This, Ogle said, highlights the need for more research to address the attribution and consequences for indirect N₂O emissions associated with crop production. Regardless of these uncertainties, soil N₂O emissions could be reduced through adoption of improved nitrogen management practices, such as avoiding over application, using precision-farming application practices, and using nitrification inhibitors. Changing nitrogen management practices may be critical for enhancing or even achieving a positive GHG emission reduction with liquid biofuel production compared to fossil fuel usage.

In general, ethanol production from corn has modest potential to decrease GHG emissions relative to fossil fuel combustion, but other bioenergy crops, such as switchgrass or hybrid poplar, may provide significantly larger reductions, Ogle reported. Bioenergy crop production may have other unintended impacts, such as reduction in supplies of food, fiber and forage, loss of biodiversity, more tropical deforestation, and increases in air and water pollution. Climate change policy to reduce GHG emissions is likely to be most effective when developed with consideration of sustainability and avoiding other environmental problems.

Argonne National Laboratory is studying the energy and GHG emission impacts of fuel ethanol as part of its efforts to evaluate the well-to-wheels energy and emission effects of various advanced vehicle technologies and transportation fuels, according to Michael Wang. To date, corn-based ethanol in the United States seems to result in moderate GHG emission reduction. Yet to be determined is if and to what degree GHG reductions will occur as corn ethanol production expands in the next decade. Factors include potential land use changes and the intensity of fertilizer use. However, Wang noted, cellulosic ethanol could substantially reduce GHG emissions. The potential level of GHG reductions by cellulosic ethanol appears to outweigh uncertainties of potential GHG emissions from land use changes by cellulosic biomass growth.

Scott Malcolm of USDA's Economic Research Service, reported that feedstock analysis by that agency indicates expansion of demand for established crops, coupled with demands for unproven commodities such as switchgrass, will challenge the resiliency and adaptability of the agricultural production system. Critical issues include how rapidly technological innovations become commercially viable, how effectively infrastructure is developed, and how farmers respond to market signals.

Changes in land use and production practice will impact soil, water and air quality, he noted. The extent of this impact is expected to vary regionally, and may be influenced by policy and technologies.

Issues of Land Use

To accurately determine the GHG benefits of biofuels, consideration must be given to emissions related to land use changes domestically and globally. In addition, the Energy Independence and

Security Act of 2007 has quantity targets for corn ethanol and “advanced biofuels,” which include sugar ethanol and biodiesel. Potentially, much of the increase in use of advanced biofuels could come from imports, notes Lewandrowski, who is studying deforestation and biofuels with researchers at Ohio State University and the U.S. Department of Energy.

Lewandrowski and his fellow researchers identified two key policy needs: development of methodologies to evaluate GHG emissions associated with land use changes for specific units of imported biofuels, and greater understanding of how increased U.S. demand for biofuels may drive international land use changes, including how U.S. biofuel policies might be designed to minimize GHG emissions from land use changes.

Improved understanding is needed of the impacts of U.S. biofuel policies and international land use changes, according to Tim Searchinger of Princeton University and the German Marshall Fund of the United States. Searchinger reported on two studies he has done calculating GHG emissions as a result of world land use change when the United States uses corn or soybeans from existing cropland to make ethanol or biodiesel. He observed that lifecycle analyses attribute to the biofuel a GHG credit (benefit) for the carbon dioxide taken out of the atmosphere by growing the feedstock. However, these analyses need to recognize that the land would already be storing and possibly continuing to take carbon dioxide out of the atmosphere even if not used for biofuels. As a practical matter, when U.S. cropland is devoted to biofuels, farmers around the world expand their crop acreage to replace it, which triggers the plowing up of forest and grassland.

Searchinger’s studies used models to calculate the amount and location of

such land use change, taking into account biofuel byproducts, ongoing growth in crop yields, and reduction in demand from higher prices. The models also used data to estimate the type of forest and grassland converted in different countries and the resulting carbon loss. The studies estimated that over a 30-year period, each mile driven with corn ethanol and/or soybean biodiesel roughly doubles the emissions otherwise generated by using gasoline. Even ethanol produced from switchgrass grown on average U.S. corn land would increase emissions by 50%. Searchinger discussed a variety of uncertainties in these calculations, but emphasized that emissions could be either lower or higher than the team’s best estimates.

While biofuels may have an important role in GHG mitigation, the rate of mitigation varies with activities, explained Bruce McCarl of Texas A&M University. Global tracking is needed of

leakage, i.e. converting forested acres or land now in the Conservation Reserve Program to corn production, or expansion of crop acres in Brazil or Argentina at the expense of grasslands and rain forests. Grain-based ethanol production is feasible when fuel and carbon prices are high; when those prices drop, bioelectricity or cellulosic ethanol are more economical.

McCarl posed these questions, the answers to which may influence future research and public policies:

- Will society choose to reward biofuel carbon recycling?
- Will energy prices remain high in the short run?
- Will ethanol and biodiesel subsidies persist?
- When will cellulosic ethanol be producible at scale?
- Can biofuel feedstock yields be increased?

Figure 1: U.S. Trade in Ethanol and Biodiesel (in 1,000 Gal)

	2004	2005	2006	2007
U.S. Ethanol Imports				
Brazil	86,184	28,896	429,114	175,560
Caribbean Basin Initiative	56,364	79,044	212,856	180,138
Total U.S. Imports	148,764	110,334	680,904	364,056
U.S. Biodiesel Imports				
Malaysia	11,570	6,692	16,591	30,222
Indonesia	0	0	7,669	37,066
Total U.S. Imports	16,538	14,831	52,570	105,338
U.S. Biodiesel Exports				
European Union	764	3,914	17,156	152,670
Total U.S. Exports	5,357	8,817	36,123	183,142

Source: ITC Statistics

- Can energy recovery efficiency from biofeedstocks be increased?
- Will there be a switch from farm subsidies to energy or carbon subsidies?
- Will food technical progress remain high?
- Will the science community expand the definition of biofuels away from corn ethanol?

Bruce Babcock of Iowa State University, reported on work he is doing with colleagues Hongli Feng and Ofrir D. Rubin on the GHG impacts of ethanol from Iowa corn. Lifecycle analysis considers how corn is produced and how it is processed into ethanol, but fails to address a third factor—what emissions would be without corn ethanol, Babcock explained. He and his colleagues are researching a system-wide accounting (SWA) method that considers all potential changes in GHG emissions resulting from biofuel expansion.

They found that growing corn in rotation with soybeans generated 35% less GHG emissions than growing corn after corn. “Based on average corn production, ethanol’s GHG benefits were lower in 2007 than in 2006 due to an increase in continuous corn in 2007. When only additional corn was considered, ethanol emitted about 21.5% less GHGs than gasoline,” the researchers reported.

The SWA method involves comparing total baseline emissions with corn ethanol emissions, which makes it important to specify the baseline and the scenario. If baseline ethanol production is zero and all baseline Iowa corn is grown in a corn-soybean rotation, a shift to continuous corn to provide corn for

ethanol production would reduce net GHG emissions by 32.6% per liter of gasoline displaced. If 2006 planted acreage and ethanol production is taken to be the baseline and the 2007 changes in Iowa acreage represent the scenario to be analyzed, emissions are reduced by 19.6% per liter of gasoline displaced, Babcock reported. The difference reflects 140,000 hectares of idle land brought into production in 2007.

The Knowledge Base

In discussions led by Roger Conway of USDA’s Office of Energy Policy and New Uses, the researchers summarized the knowledge base.

The knowns:

- Lifecycle analysis is a valid tool, but additional work is needed to fully account for the impacts of land use changes domestically and globally.
- With the exception of N₂O, GHG emissions of biofuels can be calculated relative to petroleum fuels, though researchers agree additional data may be needed.
- Impacts of land use changes in the United States can be predicted with economic models.

The unknowns:

- Biofuels production is expected to increase significantly both in the United States and globally. What effect large-scale biofuel production will have on GHG emissions is yet to be determined.
- How will U.S. biofuel production impact domestic and global land use changes?

- What is the projected growth path of feedstock supplies?
- What is the role of technology? How will it impact agriculture relative to climate issues?

Research gaps and needs:

- Methodology is needed to integrate land use change into lifecycle analysis and increase the quality of data. The food and meat sectors should also be considered.
- A standard method for lifecycle analysis is needed that addresses the best method to estimate coproduct credits, define system boundaries and determine consistent time frames.
- Research is needed on how to design policies that encourage production of biofuels that maximize GHG reductions and minimize other environmental effects. How can U.S. biofuels policies be developed that discourage other countries from adopting land use practices that increase GHG?
- International standards are needed for critical measures in lifecycle analysis.
- How rapidly can producers in the crop and livestock sectors respond to market signals?
- Long-term, one or two energy sources will not be sufficient. Research is needed to identify all energy sources and production options.
- Research is needed on how to achieve sustainable energy production, assessing such factors as nitrogen loss, carbon emissions and air, water and soil quality.