# Lifecycle Greenhouse Gas Emissions due to Increased Biofuel Production

## *Model Linkage*

## Peer Review Report

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## Introduction

The Model Linkages Analysis peer review specifically solicited feedback on the following topics: the use of multiple models and data sources, specifically in regards to land-use impacts; use of models for each component of the analysis, particularly the agricultural, petroleum, and energy sectors; and the use of the results of the models together, particularly in regards to the FASOM and FAPRI models, upstream greenhouse gas (GHG) emission factors, electricity production modeling, and fuel and feedstock transport.

*Energy Independence and Security Act Mandate*

The United States Environmental Protection Agency (EPA) has undertaken a lifecycle assessment of GHG emissions associated with increased renewable fuels production as part of the proposed revisions to the National Renewable Fuel Standard program. The Energy Independence and Security Act (EISA) of 2007 set the first-ever mandatory lifecycle GHG reduction thresholds for renewable fuel categories. EISA 2007 specifies that EPA's lifecycle analysis must to take into account GHG emissions "related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution," including "direct emissions and significant indirect emissions such as significant emissions from land-use changes." In addition, EISA 2007 requires EPA to determine which biofuel production pathways reduce GHG emissions by the required threshold amounts relative to the 2005 petroleum baseline.

*Indirect and Direct Emissions in the Lifecycle Analysis*

The definition of lifecycle analysis set forth in EISA 2007 includes both direct and indirect emissions related to the full fuel lifecycle. EPA defined direct emissions as those that are emitted from each stage of the full fuel lifecycle, and indirect emissions as those emitted from second-order effects that occur as a consequence of the full fuel lifecycle. For example, direct emissions for a renewable fuel would include net emissions from growing of renewable fuel feedstock, distribution of the feedstock to the renewable fuel producer, production of renewable fuel, distribution of the finished fuel to the consumer, and use of the fuel by the consumer. Similarly, direct emissions associated with the baseline fuel would include net emissions from extraction of the crude oil, distribution of the crude oil to the refinery, production of gasoline and diesel from the crude oil, distribution of the finished fuel to the consumer, and use of the fuel by the consumer. Indirect emissions would include other emissions impacts that result from the effects of fuel production or use, such as changes in livestock emissions resulting from changes in feedstock costs and livestock numbers, or shifts in acreage between different crop types. The definition of indirect emissions specifically includes "land-use changes" such as changes between forest, pasture, savannah, and crop land types. Most of the charge questions in this peer reviewer are concerned with relationships between model linkages and indirect effects, both for the petroleum baseline and the renewable fuels emission calculations.

*Description of FASOM, FAPRI and GREET*

To date, no single model adequately accounts for domestic and international, as well as direct and indirect emissions associated with renewable fuels. Therefore, in order to conduct the lifecycle assessment of biofuel production in accordance with the standards set forth by EISA 2007, EPA employed a set of models, each best suited to simulating a particular component of the analysis. On the domestic side, EPA used the Forestry and Agriculture Sector Optimization Model (FASOM) in order to simulate changes in domestic crop prices, agricultural land-use and crop export volumes. FASOM's simulated crop exports link to the integrated Food and Agriculture Policy and Research Institute (FAPRI) models which then simulates agricultural market changes and land-use change internationally. Both models were necessary in the analysis since each provides only a partial view of the agricultural market and land-use changes occurring world wide. FASOM only simulates the United States but does so at a high enough resolution to model land-use conversions according to land-use type. On the other hand, FAPRI simulates global agricultural markets, but at a lower level of resolution. FAPRI generates the amount of the land that will be converted at the national level, but not the land-use types involved in these conversions. EPA relied on the Winrock estimation of land-use conversions using satellite imagery from 2001 and 2004 in order to assign land use-conversion types to the FAPRI-generated changes in land use.

A third model, the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model was used to quantify the emissions factors associated with different steps of the production and use of various fuel types. Fossil fuels are used both in the production of biofuels and could also be displaced by renewable-fuel use in the transportation sector. GREET also estimates the GHG emissions associated with electricity production required for biofuels and petroleum fuel production. For the agricultural sector, EPA also relied upon GREET to provide GHG emissions associated with the production and transport of agricultural inputs such as fertilizer, herbicides, and pesticides.

Domestic agricultural sector GHG emissions are estimated by FASOM. FAPRI results were converted to GHG emissions based on GREET defaults and IPCC emission factors.

*Renewable Fuels Standard Model Linkage Methodology*

To quantify the lifecycle GHG emissions associated with increased domestic biofuels production, EPA compared the impacts of renewable fuels under the EISA mandate to a reference case without EISA. Since it was not practical to conduct an analysis for every year, EPA chose to conduct the analysis using the final year of the Renewable Fuel Standards when they are fully phased in, or 2022. The reference scenario assumed a "business as usual" volume of a particular renewable fuel based on what it would likely be in the fuel pool in 2022 without EISA. EPA then analyzed the incremental impact of increasing the volume of that fuel to the total mix of biofuels needed to meet the EISA requirements while holding volumes of other fuels constant. The total impacts from changes in biofuel production were calculated by taking the difference in total GHG emissions between the two scenarios considered. The direct and indirect GHG emissions associated with the lifecycle of each biofuel were compared to the direct and indirect emissions associated with the lifecycle of petroleum-based fuels. This comparison provides the basis for determining which biofuels will pass the emission reduction threshold required by EISA 2007.

*Secondary Energy Sector Impacts Modeling*

EPA conducted significant modeling of the petroleum and energy sectors in order properly compare GHG emissions resulting from the lifecycle of biofuels with those resulting from the lifecycle of petroleum-based fuels. Certain aspects of the secondary energy sector impacts modeling and the petroleum sector modeling were subject to discussion in this review. These relevant topics are briefly introduced in the following paragraphs.

In the Draft Regulatory Impact Analysis (DRIA), EPA presents preliminary results from an analysis using an EPA version of the Energy Information Agency's National Energy Modeling System (NEMS-EPA)[1] to estimate indirect impacts on energy use associated with increased renewable-fuel consumption. NEMS is a modeling system that simulates the behavior of energy markets and their interactions with the U.S. economy by explicitly representing the economic decision-making involved in the production, conversion, and consumption of energy products. NEMS can represent the secondary impacts that greater renewable fuel use may have on the prices and quantities of other sources of energy, and the GHG emissions associated with these changes in the energy sector. An example of this type of secondary impact is the increase in demand for biofuels from the Renewable Fuels Standard program inducing secondary impacts on oil markets. To illustrate, an increase in the use of biofuels could result in lower U.S. demand for imported oil; lower U.S. imported oil demand could cause the world oil price to modestly decline, and result in an increase in oil consumption outside of the U.S. (referred to here as the "international oil takeback effect"). In addition, with the greater use of biofuels in the United States, EPA estimated that the cost of transportation fuels in the United States would increase. This increase in the costs of U.S. transportation fuels would likely lower the domestic demand for oil beyond the direct substitution of biofuels for gasoline and diesel. The response of U.S. oil demand to price is referred to here as the "rebound effect."

The following sections summarize the responses of the peer reviewers to modeling and model linkages issues related to the analysis of secondary effects in the agricultural, energy and petroleum sectors.

[1] This version is called NEMS-EPA to make it clear that EPA, rather than EIA, conducted this analysis.

## Background of Model Linkages Peer Review and Overview of Results

From May to July 2009, EPA arranged for several peer reviews to be conducted regarding aspects of its revisions to the RFS.  Each of these reviews focused on the projection of emissions from indirect land use changes associated with increased fuel production as specified by EISA 2007. ICF International, an independent third-party contractor, coordinated the peer reviews and adhered to EPA's "Peer Review Handbook "(3rd Edition).

The peer review summarized here focuses in particular on the use and integration of multiple models and data sources in the analysis.

EPA's work assignment requesting the peer review required that peer reviewers be established and published experts with knowledge of the following topics:

- Extensive modeling experience with FASOM, FAPRI, GTAP, and other relevant models
- Lifecycle analysis of transportation fuels (biofuels and petroleum based fuels)
- Agricultural economics and international agricultural markets

Using these criteria, the contractor developed a list of qualified candidates from the public, private, and academic sectors. The contractor compiled candidates from the following sources: (1) contractor experts in this field with knowledge of relevant professional society membership, academia, and other organizations; (2) Internet searches; and (3) suggestions from EPA.

Approximately 20 qualified individuals were initially identified as candidates to participate in the peer review. Each of these individuals was sent an introductory screening email to describe the needs of the peer review and to gauge the candidate's interest and availability. Also, candidates were asked to disclose any real or perceived conflicts of interest (COI) or other matters that would create the appearance of a conflict of impartiality. Candidates also were asked to provide an updated resume or curriculum vitae (CV). The contractor reviewed the responses and COI statements and evaluated the resume/CV of individuals who were interested for relevant experience and demonstrated expertise in the above areas, as demonstrated by educational degrees attained, research and work experience, publications, awards, and participation in relevant professional societies.

A number of candidate reviewers were unable to participate in the peer review due to previous commitments or real or perceived conflicts of interest.  The contractor reviewed the remaining qualified candidates with the following concerns in mind.  As stated in EPA's Peer Review Handbook, the group of selected peer reviewers should be "sufficiently broad and diverse to fairly represent the relevant scientific and technical perspectives and fields of knowledge; they should represent balanced range of technically legitimate points of view."  As such, the contractor selected peer reviewers familiar with the range of model types relevant to EPA's analysis. The peer reviewers collectively possess a thorough knowledge of agricultural and energy market models, partial equilibrium and general equilibrium models, life cycle analyses, and other model types. In addition, the peer reviewers have familiarity with the technical aspects of linking models that contain varying degrees of resolution and rely on distinct data sources. The contractor submitted the proposed peer reviewers to EPA. In accordance with the EPA Peer Review Handbook, EPA reviewed the list of the selected reviewers with regard to conformance to the qualification criteria in the contractor's work assignment, which was established prior to the reviewer selection process. EPA concurred that all of the contractor's peer review selections met the qualification criteria.

The contractor contacted the following five peer reviewers who agreed to participate in the peer review:

1. Dr. Martin Banse, Agricultural Economics Research Institute
2. Mr. Timothy Searchinger, Princeton University
3. Mr. John Sheehan, University of Minnesota
4. Dr. Michael Wang, Argonne National Laboratory

In addition to the initial COI screen mentioned above, the contractor asked the peer reviewers to complete a conflict of interest disclosure form that addressed in more depth topics such as employment, investments/assets, property interests, research funding, and various other ethical issues. The Peer Review Handbook acknowledges that "experts with a stake in the outcome – and therefore a conflict or an appearance issue – may be some of the most knowledgeable and up-to-date experts because they have concrete reasons to maintain their expertise," and that these experts may be used as peer reviewers if COI or the appearance of the lack of impartiality is disclosed. However, upon review of each form, the contractor and EPA determined that there were no direct and substantial COI or appearance of impartiality issues that would have prevented a peer reviewer's comments from being considered by EPA.

EPA provided reviewers with excerpts from the EPA RFS2 Rulemaking Preamble and the Rulemaking Draft Regulatory Impact Analysis (DRIA) concerned with the Lifecycle GHG Analysis, as well as additional materials summarizing EPA's lifecycle approach, and charge questions to guide their evaluation.

The provided questionnaire was divided into three sections. The first set of questions was concerned with EPA's overall approach of linking multiple models and data sources together. The second set focused on the use of the models for each component of the lifecycle assessment. The third set consisted of questions related to issues surrounding data and model integration.

The bulk of the reviewer comments focused on the following issues:

- Comparison of partial equilibrium models with general equilibrium models,
- Identification of problem areas in current modeling approach,
- Identification of issues with the existing integration of FASOM and FAPRI models,
- Disagreement over whether to increase detail of the model, and
- Suggestions for the improvement of models and model linkages.

The following overview provides a synopsis of the reviewer comments in each of these areas with an additional section, *Other Areas of Consensus*.

*Comparison of Partial Equilibrium Models and General Equilibrium Models*

The peer reviewers generally agreed that EPA's approach of linking partial equilibrium models was preferable to using a general equilibrium model such as the GTAP (Global Trade Analysis Project) model, especially given the fact that no existing model comprehensively simulates the direct and indirect effects of biofuel production both domestically and internationally. However, the reviewers each emphasized that partial equilibrium models, such as the FASOM (Forest and Agricultural Sector Optimization Model) and FAPRI (Food and Agricultural Policy Research Institute) models, have both positive and negative qualities. Positive qualities mentioned include the fact that partial equilibrium models include both quantities and prices of crops, whereas general equilibrium models only use price data. Dr. Banse also mentioned that both policy details and commodity details were better covered in partial equilibrium models than in general equilibrium models such as GTAP. The reviewers also mentioned the negative qualities of partial equilibrium models, including a lack of adequate coverage of the linkages between agri-food markets and the general economy, linkages to factor markets, and possible links to other political, cultural, and technological issues that may exert strong influences on indirect emissions from biofuel production.

Despite the fact that all of the reviewers pointed to problematic areas of the current partial equilibrium modeling approach, most of them believed the existing approach to be more reasonable than relying wholly on the GTAP model. Several of the reviewers pointed to the possible advantages of the GTAP model, including its purported "open source" nature, international applicability, and ability to assign land-use conversion types to land-use changes. However, a majority of the four reviewers felt that the disadvantages of an analysis that relied solely on GTAP outweighed the possible advantages of the model. The main disadvantage given was that the level of detail present in GTAP is too coarse, particularly the broad categorization of biomass categories, such as oil seeds. Other disadvantages included the treatment of quantities using price data, lack of transparency, and inability to flexibly model dynamic changes in the global agricultural sector.

*Identification of Problem Areas in Current Modeling Approach*

The reviewers identified a number of problematic areas in the analysis. The section detailing *Peer Reviewer Responses to Charge Questions* will contain more information on the areas of concern raised by each reviewer. The bulleted list below organizes recurring themes in the reviewer comments and details the reviewers who mentioned each theme:

- Proper incorporation of spatial data into the analysis:
    - Use of spatially-explicit models (Banse)
    - Use of satellite data to assign land-use conversion types (Sheehan, Wang)
    - Inclusion of wetlands in land-use conversion analysis (Searchinger)
- Inclusion of all relevant factors into analysis, such as energy market information, and social, political and technological factors (Banse, Wang)

- Inconsistencies surrounding the linkage between FASOM and FAPRI (Searchinger, Banse)
- Integration of emissions factors used in GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation), FASOM, and FAPRI (Searchinger, Wang)
- Concerns with transparency of existing analysis (Wang, Banse)
- Lack of forestry sector in analysis (Wang)
- Concerns with FASOM (Searchinger)

*Identification of Issues with the Existing Integration of FASOM and FAPRI Models*

While the section detailing *Peer Reviewer Responses to Charge Questions* will contain more detail on each of the problem areas identified above, all four peer reviewers detailed specific issues with the integration between the FASOM and FAPRI models. In particular, Mr. Searchinger identified a list of inconsistencies and problems created by linking the models including:

- Differences in predicted changes in crop and livestock production and exports between FASOM and FAPRI
- Problematic results surrounding rice methane emissions
- Indirect land-use change in response to switchgrass
- Estimates in reductions in crop demands
- Calculation of agricultural production emissions, particularly in regards to direct emissions of nitrous oxide
- Integration of emissions factors in the domestic and international analysis

*Disagreement over Whether to Increase Detail of the Model*

The reviewers disagreed over whether incorporating additional, potentially relevant factors into the model would increase the accuracy of the analysis. Dr. Banse and Dr. Wang both stressed that one of the main weakness of the current modeling approach was that it does not take many factors into consideration. Dr. Wang noted in particular that inclusion of the forestry sector might be relevant. He also commented on the influence that social and technological factors may have on the output of the analysis. Dr. Banse recommended including several different models in order to increase coverage of energy market and land-use details not currently included in the modeling approach. In contrast, Mr. Sheehan and Mr. Searchinger both stated that they did not think added detail or resolution would improve the current analysis. Mr. Sheehan commented that it would be more valuable to focus on developing simpler models that are based on a better understanding of the drivers of land-use change. Similarly, Mr. Searchinger warned against incorporating too many ancillary impacts of biofuels into the lifecycle analysis on the basis that these impacts may not be policy relevant.

*Suggestions for the Improvement of Models and Model Linkages*

Each of the reviewers proposed changes to the current modeling approach. Although the reviewers suggested different approaches, several reviewers recommended incorporating additional models into the analysis.

Mr. Searchinger suggested an approach which would rely on multiple models at each stage of the analysis. He commented that although the current approach relies on multiple models, one model is ultimately responsible for each section of the analysis. He felt that this approach failed to adequately address uncertainty, and stated that any one model provides only a limited approach to estimating land-use change and the resulting GHG emissions. Mr. Searchinger suggested examining a range of models in order to develop a meta-analysis of the plausibility of different categories of predictions. He also detailed two additional approaches based on opportunities costs and scenario-based modeling analyses.

Dr. Banse also recommended the inclusion of new models into the existing analysis, but suggested adding new models as sources for additional feedback to the FASOM and FAPRI models. For example, he recommended possibly linking FAPRI to a general equilibrium model such as GTAP in order to better capture the linkages between agricultural and energy markets. He also suggested linking FASOM and FAPRI to models which explicitly include spatial information on land-use changes, such as the IMAGE (Integrated Model to Assess the Global Environment) or CLUE (Conversion of Land-Use Change and its Effects) model.

Mr. Sheehan suggested a third approach, outlining a system dynamics framework of land-use changes using STELLA, although he stipulated that the system dynamics model in its current form would be too simplistic for use in this policy analysis.

Dr. Wang suggested that the forestry sector be included in the analysis, since the lack of a forestry consideration might underestimate the extent of the United State's ability to domestically absorb land demand resulting from U.S. biofuel production.

*Other Areas of Consensus*

Dr. Wang and Mr. Sheehan both considered the 2005 baseline stipulated by EISA 2007 to be inappropriate. Dr. Wang added that the baseline potentially underestimates GHG emissions of petroleum fuels since he predicts that petroleum fuels will come increasingly from unconventional crudes and that global petroleum demand growth over time could generate unanticipated indirect effects in the petroleum sector.

## Peer Reviewer Responses to Charge Questions

The following section includes summaries of the peer reviewer responses to each charge question. Some reviewers answered the questions at their broadest level, while others answered all or many of the sub-questions. Due to the varying format of the responses, responses are grouped as peer reviewers tended to address the issues rather than exactly how they were laid out in the original charge in cases where this seemed more intuitive.

The set of charge questions can be found in Appendix A, and the full text of the peer reviewers' written responses can be found in Appendices B-E.[2] The peer reviewers' curricula vitae can be found in Appendix F. Peer reviewers were instructed to work independently and comments made by peer reviewers are individual opinions and do not represent the views of their affiliated organizations.

### *I. Use of Multiple Models and Data Sources*

### A. Overall Approach

***Charge Question 1: As specified by the Energy Independence and Security Act (EISA) of 2007 Sec 201 (H), EPA's lifecycle analysis has to take into account GHG emissions "related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution", including "direct emissions and significant indirect emissions such as significant emissions from land-use changes". In order to conduct this analysis we consider land-use impacts in response to the effect of renewable fuels on agricultural prices. To capture this effect, our approach has been to use partial equilibrium models to capture market-based impacts, and to convert the land-use changes associated with such impacts into GHG emissions. Are there other approaches to capture indirect impacts?***

All four reviewers agreed that EPA's choice to use partial equilibrium models was reasonable. Dr. Banse commented that linking partial equilibrium models with other quantitative tools is a promising approach to capture market-based impacts from increased biomass demand. He added that partial equilibrium models cover market responses well, due to the fact that both policy details and commodity details are better presented in these models as compared to general equilibrium models. Similarly, Mr. Searchinger commented that partial equilibrium models were preferable to general equilibrium models such as GTAP because general equilibrium models do not have sufficient resolution for this type of analysis. Mr. Sheehan stated that EPA has used the best available tools and approaches for assessing indirect land-use change effects of biofuels. However, he noted further that "the tools that have been applied were never meant to address...the kinds of regulatory questions imposed on EPA by EISA 2007." Dr. Wang commented that the use of partial equilibrium models in place of general equilibrium models should not pose a major problem.

Dr. Banse and Mr. Searchinger further discussed the comparative strengths and weaknesses of general and partial equilibrium models. Both Dr. Banse and Mr. Searchinger stated that GTAP breaks crop types into extremely broad categories which lack the detail present in partial equilibrium models, such as FASOM and FAPRI. As an

[2] Typographical errors in original peer review responses were corrected where noticed.

example, both Dr. Banse and Mr. Searchinger specifically noted that GTAP treats all oil seeds as one crop regardless of source.

Dr. Banse commented that an additional problem in general equilibrium models is that all activities are expressed in dollar values only, and must be translated into commodity volumes. However, while he acknowledged that partial equilibrium models are a better choice for this analysis, Dr. Banse highlighted the inherent partial nature of these models, noting that they do not include the linkages between the agri-food markets and the rest of the economy. He felt that the missing link between the agri-food sector and the energy sector might be important. Dr. Banse also commented that general equilibrium models might provide a powerful tool to capture this link between agricultural and energy markets in the analysis. He suggested linking the FAPRI models with a general equilibrium model in order to provide the data for the endogenous change of biomass demand and energy prices under the reference scenario. Dr. Banse also noted that partial equilibrium models do not cover factor markets (e.g., labor, capital, and land markets). He stated that the assessment of bioenergy options requires a good understanding of the functioning of land markets in different parts of the world. In his opinion, the current approach of modeling domestic land use with the FASOM model seems to cover domestic land-use changes well. He suggested the use of a model such as GTAP or LEITAP/IMAGE in order to provide details of land-use change outside of the United States. Finally, Dr. Banse recommended that the spatial dimension of land-use changes be incorporated into future improvements of the combined modeling approach. In particular, he expressed concern that analyses based on FAPRI or FASOM would not be able to identify “hot spots” in land-use changes.

Mr. Searchinger enumerated several other weaknesses of general equilibrium models which make them unsuitable for EPA’s purpose. He commented that while general equilibrium models rely on production functions, the empirical basis for these production functions is “extremely weak.” As an example, he noted that when Purdue University economists were adjusting the GTAP model to calculate indirect land-use change for the California Air Resources Board, they forced the production functions to reproduce a yield/price elasticity in theory derived from econometric studies. Mr. Searchinger noted that this elasticity may not be valid, and furthermore, that the overall elasticity does not define what variables to adjust to produce that elasticity. He concluded that, “because the relationship of the supply and price of these inputs to outputs is therefore based on limited empirical basis, it is not particularly helpful to vary those input supplies and prices in responses to general equilibrium features.” Mr. Searchinger also commented that the addition of general equilibrium interactions adds considerable uncertainty to the analysis by adding additional interactions and factors that are highly uncertain. He concluded that, “any theoretical gain in comprehensiveness is not worth the cost in uncertainty.”

Continuing his discussion of the weakness of general equilibrium models such as GTAP, Mr. Searchinger discussed the reliance of GTAP on the estimated values of land under crop production versus its alternative value as pasture or managed forest. He explained that in GTAP, the differences in land rents explain the land-use change. However, he pointed out that the standard GTAP model cannot address unmanaged forest because that land type does not have a rent. Mr. Searchinger concluded his comments on the issue of partial versus general equilibrium models by noting that FASOM is an optimization model that is conceptually based on changes in the relative profitability of different land uses. As a result, in Mr. Searchinger’s opinion, FASOM shares many of the same limitations as GTAP.

Mr. Sheehan and Dr. Wang focused on a different set of issues in their responses to Charge Question 1. Both reviewers pointed out that a variety of economic and social factors can influence the extent of indirect land-use change. Dr. Wang stated that it is a major challenge to separate the impacts of economic, political, and social factors on the magnitude of the economic linkage between direct and indirect effects. Mr. Sheehan commented that “political, cultural, technological and infrastructure issues have easily as much impact (if not more) on the land-use equation as the immediate effects of price pressures in the global agricultural market.” Mr. Sheehan also stated that land-use change is fundamentally a system dynamics problem and that this aspect is not adequately captured through the narrow lens of economic equilibrium models. In response to this concern, Mr. Sheehan proposed a new approach for looking at indirect land-use change that is based on system dynamics modeling. The model he proposed uses a STELLA® system dynamics modeling framework and has the capability to flexibly handle dynamic changes in global agriculture and bioenergy technology.

Dr. Wang also expressed several concerns that were not mentioned by the other reviewers. He synthesized the differences between “attributional” and “consequential” lifecycle assessments (LCAs) in his response, and then noted that the consequential LCA approach in place of an attributional LCA approach in emissions regulation development is new. He questioned whether the use of a consequential LCA approach was sound enough for regulation development, and whether the underlying data and assumptions in the consequential approach were reliable and transparent. Although he mentions a few additional questions, Mr. Wang’s main concern was the transparency of the consequential LCA. He voiced that because consequential LCAs are in their early stage of applications for environmental evaluation, there are large numbers of inter-relationships in general equilibrium models, and aggregate emission co-efficients are used inside of these models, stakeholders may not be able to readily identify the effects of individual activities and new technologies on LCA results.

Mr. Searchinger divided his response to this charge question into five major areas, the first of which was his discussion of partial equilibrium models (summarized above). In the remaining four topics, Mr. Searchinger strongly recommended that EPA consult a range of models and use additional evidence to establish an indirect land-use change factor. He also suggested that EPA incorporate opportunity cost analysis and scenario-based modeling into its considerations. Finally, he recommended that EPA not focus on 2022 scenarios and that EPA alter its approach to establishing categories. These four discussion points are summarized below.

In his discussion of multiple models, Mr. Searchinger first pointed out that although EPA’s current analysis does rely on multiple models, ultimately each model is only responsible for one component of the analysis. He stated that any one model provides only a limited approach to estimating land-use change and resulting GHG emissions. Mr. Searchinger detailed a few limitations, many of which were concerned with elasticity. For example, he noted that the models compare large numbers of elasticities that are interacting in complicated ways where accuracy is difficult to prove. Mr. Searchinger also commented that since these models rely on prior relationship among economic activities to predict future relationships, they do not account for future changes in those relationships. He noted that these types of uncertainties would compound over time. Mr. Searchinger concluded that “because of these uncertainties, EPA is wrong to place so much emphasis on any one estimate...each model at best provides one plausible scenario of the future.” He offered an alternative solution, which would be to examine a range of models and attempt to develop a meta-analysis. This approach would examine categories of predictions and evaluate their plausibility; it would also rely on opportunity cost analysis. Mr. Searchinger emphasized that EPA should take a cautionary approach to estimates of land-use change from biofuels.

Mr. Searchinger next offered a suggestion to include opportunity cost and scenario-based modeling in the biofuels analysis. He commented that models are only one way of measuring the GHG costs of diverting the carbon-productive capacity of land into fuel production. An alternative would be to directly measure the carbon sequestration equivalent of the carbon-productive capacity of land represented as the carbon sequestration that would occur on this land if left alone. As an example, he commented that most of the cropland in the United States would revert to forest if not used for crops. He suggested dividing this opportunity cost sequestration value by the gallons and megajoules of ethanol produced in order to generate an indirect land use-change factor. Mr. Searchinger also recommended that simplified scenario modeling could provide useful information. He provided an example from Searchinger and Heimlich (2008), a paper that examines land-use change from U.S. biodiesel production from soybeans. He concluded this section by commenting that “this scenario approach is actually the most robust and informative analys[i]s of biodiesel ILUC (indirect land-use change).” Further, he noted that “the rulemaking enterprise by EPA does not require that it generate a single number...a multiple model approach that incorporates opportunity cost and simplified scenario [modeling] would provide the most robust answer to that question.”

In his discussion of the 2022 timeframe, Mr. Searchinger began by noting that “yield improvements expected by 2022 in particular improve the GHG balance [of biofuels]. This approach seems to me flawed.” He continued by stating that, “it is hard to understand how biofuels can be viewed as passing thresholds in, for example, 2012, simply because their continued production is likely to pass thresholds in 2022.” Mr. Searchinger also commented that the reliance on 2022 is predicated on a set of critical assumptions which may or may not be true. He drew particular attention to cellulosic biofuels on this point.

Mr. Searchinger’s last topic of discussion in response to Charge Question 1 was the broad categorization of biofuels. He recommended that EPA utilize more categories for biofuel types and incorporate key assumptions for each of these categories.

***Charge Question 2*: *What are the strengths and weaknesses of different approaches?***

Mr. Sheehan commented that EPA has used a plausible modeling approach. He stated that the only other modeling option that has been documented for measuring indirect land-use change is GTAP. He stated that a strength of the GTAP model is that it accounts for specific trade arrangements for agriculture around the world. He also stated that a perceived strength of the GTAP model is its “open source” nature. However, Mr. Sheehan does not believe that the GTAP model is actually any more transparent than either FASOM or FAPRI. He continued by commenting that GTAP is strictly an equilibrium model that is incapable of properly capturing dynamic changes in the global agricultural sector. He noted that this has forced GTAP modelers to make a number of fixes to their models that are awkward and questionable. He concluded his response by highlighting the strength of the system dynamics modeling approach being developed at the University of Minnesota. However, he noted that this model is still too simplistic to meet the needs of this regulatory process.

Dr. Banse responded to this charge question by listing the strengths and weaknesses of using an extended tool of integrated models with spatial biophysical land-use models and with models covering the linkages between agricultural and energy markets. He mentioned that the strength of this approach would be its coverage of aspects of the analysis that are not currently simulated. He noted that the weakness of such an approach would be that extended tools of more than four models become expensive and inflexible.

**B. Single Model vs. Multiple Sector Specific Tools**

***Charge Question 1*: *Our conclusion in the proposed analysis was that there is no one single model that can capture all of the multi-sector interactions that we need to consider. The thought is that overall CGE models (e.g., GTAP) either do not have GHG emissions included, or do not have adequately refined sectoral specifications (i.e., the agricultural sector including land-use change). Are there other tools and models that we should be considering in this analysis? Are there incongruous assumptions or methodologies we must consider when linking multiple models' results?***

The reviewers all agreed that there is no single model that can capture all of the multi-sector interactions under consideration. Dr. Banse responded that modeling bioenergy requires a combined, integrated modeling tool. He noted that while partial equilibrium models represent a good starting point, they need feedback from other different models. He recommended that a revised analysis approach include links to the overall economy, especially energy markets *via* general equilibrium models, links to the spatial dimension of land-use changes *via* biophysical land-use models at grid-cell level, modeling of GHG emissions at a very detailed level, and modeling of other aspects which might be important at the local level, such as eutrophication.

Mr. Sheehan commented that while it may be worth looking at GTAP as a possible alternative to FASOM and FAPRI, it is not better suited to the task. He added that the biggest weakness in the existing analysis is the use of satellite data to assign specific land use conversion types to land use changes.

Dr. Wang detailed the difficulties of capturing all of the relevant multi-sector interactions involved in the analysis. For example, he commented that "it is obvious that regulatory needs of addressing indirect effects, especially LUCs, are ahead of scientific understanding of interactions among different sectors and among different activities." He emphasized the large amount of uncertainty associated with the LCA emissions results, and commented that the different levels of uncertainty for different effects should be acknowledged in the proposed GHG changes in the rule. Dr. Wang also considered the use of GTAP as an alternative to FASOM and FAPRI. However, he noted that the model is designed for global simulations and may not contain emission co-efficients. He noted that simulated effects from these models need to be combined with emission co-efficients outside of the models to generate emissions of indirect effects. He stated that given the uncertainty associated with these steps, it might be appropriate to generate emissions of indirect effects outside of general equilibrium models so that this step from effects to emissions is transparent. Dr. Wang also drew attention to the fact that GTAP models may not be as detailed as FASOM in addressing the interactions between agriculture and forestry sectors within the United States. However, he noted that the FASOM version used for the EPA analysis did not have the forestry component in use and that consequently the forestry and agriculture interactions were not fully addressed.

In addition, Dr. Wang expressed concern over the transparency of the modeling approach, particularly with regard to the linkage between FASOM and FAPRI. He recommended that the DRIA present domestic land-use change results from both FASOM and FAPRI in order to provide an indication of the similarities and differences between the two models. He also stated that the use of past land-use change patterns between 2001 and 2004 as estimated by Winrock is problematic, noting that this is a major weakness of using FAPRI (relative to GTAP) to produce international land-use changes. Finally, Dr. Wang commented that GREET emission co-efficients were used to supplement available emission co-efficients in FASOM. He recommended that for the activities whose emission co-efficients are available in both FASOM and GREET, it would be helpful if EPA presented a comparison of emission co-efficients from the two models.

Mr. Searchinger's responses to this issue were covered in his response to an early charge question. In summary, he strongly recommended that EPA consider the use of multiple models, as well as opportunity cost analyses and scenario-based modeling in order to provide a more robust analysis of the impacts of increased biofuel production.

## *II. Use of Models for Each Component of Lifecycle*

Mr. Searchinger stated that his answer to this section of charge questions could be found in his responses to earlier charge questions. However, he summarized his position by stating that he does not believe that FASOM should be used because it does not appear to add any reliable additional detail and creates inconsistencies with the FAPRI analysis. He responded more specifically to only a few of the charge questions in this section, as summarized below.

### A. Suite of Models and Tools Used

***Charge Question 1*: *Are appropriate models being used to represent the different aspects of the fuels lifecycle?***

Mr. Sheehan and Dr. Banse agreed that EPA did an adequate job of modeling the lifecycle of fuels. Mr. Sheehan further commented that while additional detail was possible, it would not necessarily be worthwhile given the generic nature of the biofuels/vehicle scenarios being developed for the regulation. He noted an alternative approach in which individual technology/fuel providers are permitted to develop detailed data on the specific impacts of their technology.

Dr. Wang responded to this charge question by briefly discussing some of the key biofuel pathways. He noted that corn ethanol is the most exhaustive pathway simulated and analyzed in the proposed rule with a consequential LCA methodology. He noted that no consequential LCA was conducted to address potential indirect effects for the petroleum gasoline pathway. In the case of the switchgrass ethanol pathway, he commented that international indirect effects may not be valid because FAPRI does not incorporate a switchgrass pathway. Finally, for the soybean biodiesel pathway, he noted that it is not clear how FASOM and FAPRI are designed to simulate biodiesel production from a by-product if soy meal is identified to be the main product.

***Charge Question 2*: *Are all sectors being captured in the same detail? If not, do you have any recommendations for modifying the models to make them more comparable?***

Mr. Sheehan responded that the EPA approach is reasonable given that it is impossible to capture all sectors at the same level of detail. Dr. Banse noted that the spatial dimension is missing from the current analysis. Dr. Wang commented that while the U.S. agricultural sector is simulated at a high level of detail, the forestry sector is not included. Internationally, Dr. Wang pointed out that the agricultural and forestry sectors were simulated with the FAPRI model at a level of detail less than that of the domestic simulations and somewhat less than the level of detail present in the simulation of the international agriculture and forestry sectors in GTAP. He also noticed that the petroleum sector was not simulated for indirect effects. Mr. Searchinger responded to this charge question with a discussion on the analysis of international land-use change. He noted that this component examines sources of new cropland over only a recent four-year period. He suggested that such a short time period seemed inappropriate and was potentially skewed, and recommended a longer analysis including 1980's and 1990's data from the research of Dr. Holly Gibbs.

***Charge Question 3*: *Are all appropriate interactions in the economy and different sector interactions being accurately captured?***

Mr. Sheehan commented that EPA seemed to adequately address interactions occurring across sectors. However, he expressed concern over whether EPA adequately captured future trends in all sectors, specifically how the models project potential future global improvements in agriculture and in future demand for agricultural products.

Mr. Searchinger responded that he did not believe that more interactions with the general economy would be useful to the analysis. He posited that some of the potential interactions that could be modeled are of doubtful policy relevance. For example, he commented that if biofuel production increases transportation fuel costs, it is possible that people would drive less, resulting in fewer GHG emissions. However, Mr. Searchinger noted that, "to the extent that particular biofuels otherwise do not reduce GHG emissions, it would be bizarre to recognize them as passing the threshold on this basis as biofuels that do reduce GHGs independently would accomplish more benefits." Mr. Searchinger noted that some of the impacts of biofuels are essentially ancillary in that the same impacts could be achieved through other simple policy options, and it would be a mistake to incorporate them into a lifecycle analysis.

Dr. Banse highlighted his earlier responses in which he pointed to the missing sectoral interactions between agriculture and other parts of the economy. Dr. Wang also highlighted his earlier responses which drew attention to the lack of indirect effects simulated in the petroleum sector and the lack of inclusion of the domestic forestry sector.

***Charge Question 4*: *What GHG sources are missing or are not captured with sufficient detail in the analysis?***

Mr. Sheehan and Dr. Wang agreed that no major GHG sources were missing from the current analysis. However, Dr. Wang qualified his answer by commenting that the level of detail for individual sources varies greatly. He noted that the Winrock approach was one place where the resolution was weaker and he stated his opinion that the Winrock analysis is not adequate over a longer term.

Dr. Banse and Mr. Searchinger both highlighted GHG sources that were missing from the existing analysis. Dr. Banse noted that a missing source was the eutrophication of both ground and surface water. Mr. Searchinger noted that the most significant omission from the current analysis is the conversion of wetlands, especially peat lands, for biofuel crop production. He also commented that forest-to-pasture conversion spurred directly by meat prices is not included in the current analysis because the FAPRI model operates entirely within the crop sector where diverted crops for feed are replaced entirely by new feed. He pointed out that this is one weakness of the FAPRI model, noting that the model probably underestimates land-use change because proportionally more land must be cleared to replace meat production through pasture than through crops. Mr. Searchinger added that studies have shown direct correlations between the price of beef and the rate of clearing of forest in Latin America, noting that the various GTAP models purport to estimate these effects. However, they depend first on price effects on beef and dairy products and then the costs of land conversion; and GTAP models are probably less reliable sources of predictions of price impacts that the FAPRI model. He concluded that as part of his suggested multi-model, multi-evidentiary analysis, EPA should canvas methods of analyzing these impacts and provide some additional estimates of this direct effect.

***Charge Question 5*: *If you believe the models may not provide sufficient detail or resolution in this analysis, what do you believe the impacts of such shortcomings are on the results of the models? For example, how do potential shortcomings of the models impact overall estimates of lifecycle GHG emission?***

Mr. Sheehan did not feel that added detail or resolution would substantially improve the analyses done by EPA. He instead suggested that there would be more value in developing simpler models that are based on a better understanding of the drivers of land-use change. Dr. Wang commented that the lack of the forestry component in the FASOM version used in the analysis could underestimate the extent of the ability of the United States to domestically absorb land demand from U.S. biofuel production. He added that the lack of land-supply simulation in FAPRI makes the international land-use change results less reliable. Dr. Banse commented that an important aspect in this analysis is the treatment of different degrees of land quality. Land that is additional, meaning that it is currently not used, is often less productive. He concluded that any modeling of an expansion of land use should consider this factor.

## B. Agricultural Sector

***Charge Question 1*: *Are there other models that could be used to better represent agricultural sector impacts domestically and internationally? If so, please specify which model (FASOM or FAPRI) your suggested model would replace or complement.***

Mr. Sheehan and Dr. Wang both responded to this question expressing the opinion that FASOM, FAPRI and GTAP are the only relevant models. However, both pointed out that each of these models is limited in certain respects. Mr. Sheehan stated that new models are needed that can offer better insights on the dynamics of land-use change, but that no such models currently exist in sufficient detail to meet the needs of this regulatory process. Dr. Wang questioned whether the modeling capabilities currently available in the field are sufficient to generate results for use in development of regulation.

Dr. Banse noted that ideal solution would be a FASOM model at global level. However, he suggested that future extension of the modeling framework should try to link the current models with general equilibrium models and spatial biophysical land-use models, such as IMAGE or CLUE.

***Charge Question 2: What are the strengths and weaknesses of the agricultural sector models being used (FASOM and FAPRI)?***

Each of the three reviewers who responded to this charge question (all except Mr. Searchinger) detailed a different set of strengths and weaknesses of FASOM and FAPRI. Mr. Sheehan said a lack of transparency and usability is the largest weakness of the two models. He commented that it is impossible to judge with confidence the workings of the models, what limitations may be biasing the results, or what fundamental data underlying the models may be influencing the outcomes. He stated that the strengths of the models are more a matter of their being, by default, the only available tools. Dr. Wang detailed the general strengths and weaknesses of FASOM, FAPRI, and GTAP in his response. He noted that while FASOM has high resolution for the United States, the lack of international land-use changes in FASOM and the coupling of FASOM and FAPRI create additional uncertainties. On the other hand, he stated that GTAP covers both domestic and international land-use changes, but with a low resolution level. Dr. Banse felt that international land-use changes are not well covered in FAPRI. He recommended a model such as IFPRI’s IMPACT in order to provide further detail.

Mr. Searchinger did not respond directly to this charge question. However, in response to subsequent charge questions he detailed the weaknesses of FASOM and recommended that it be excluded from the analysis.

## C. Petroleum Sector

Mr. Searchinger stated that he addressed the issues raised in the following section in his response to charge question IIA3. His response to charge question IIA3 concluded that some impacts of biofuels are ancillary rather than secondary and that it would be a mistake to incorporate them into lifecycle analysis. More detail on his response can be found in the summary of responses to charge question IIA3.

***Charge Question 1*: *What models or tools are available to capture petroleum sector indirect impacts (e.g., changes in fuels markets and use based on price changes in petroleum due to biofuel use)? What are the appropriate indirect impacts to be considered to ensure a scientifically justifiable comparison with biofuels?***

Two of the three reviewers who responded directly to this question felt that no models currently available could adequately address indirect impacts of the petroleum sector. Dr. Wang did comment that models such as National Energy Modeling System (NEMS) and Market Allocation model (MARKEL) may be capable of modeling these impacts, but that emerging issues such as production from marginal crudes and disturbance of natural habitats make it unlikely that such modeling would be satisfactory. Mr. Sheehan commented that the models available for petroleum and energy sector forecasting are limited, arcane, complex, and difficult to use. He continued by commenting that the social and political implications of petroleum are among the more important issues to be captured, but are probably incompatible with the carbon footprint required of EPA in EISA. In terms of land effects, he noted that any indirect effects of petroleum will be minor.

The third reviewer, Dr. Banse, suggested a few initiatives that link detailed agricultural models to an energy model. For example, Common Agricultural Policy Regionalized Impact analysis (CAPRI) is a regionalized partial equilibrium model that has been successfully linked to the PRIMES energy model. He continued by commenting that other general equilibrium models, such as LEITAP, can capture the linkages between petroleum and agricultural markets. He noted that any model-based approach including endogenous price formation of agricultural and energy markets should be used as a tool to assess the impact of policy options and are not appropriate tools to project future energy prices. Dr. Banse concluded by stating that the link between agricultural and energy prices should be made as transparent as possible, and any analysis should be underpinned by a profound sensitivity analysis of key assumptions and parameter values.

***Charge Question 2*: *We have compared a Btu of biofuel with a Btu of gasoline replaced; is this an accurate and appropriate comparison or would biofuels actually displace differing amounts of petroleum fuels? How would this be modeled?***

The three reviewers who responded to this charge question agreed that this comparison was accurate for the near term. Mr. Sheehan further stated that this was the most appropriate and reasonable approach. Dr. Wang noted that the Btu displacement assumption is a reasonable one for the near future, since ethanol will be used in low and intermediate blending levels with gasoline. He commented further that even if E85 is used in flex fuel vehicles (FFVs), these vehicles may not be optimized for E85 any time soon, considering that gasoline may be the main fuel for FFVs for the foreseeable future. Dr. Banse commented that the current analysis should cover the restriction in blending shares due to the current vehicle fleet (i.e., the problem of the “blending wall”). He continued by commenting that future development of the composition of the vehicle fleet determines which type of petroleum fuel will be displaced. He noted that either sophisticated energy models cover these projections endogenously or a sensitivity analysis (SSA) could help to assess the consequences of future development of the vehicle fleet.

***Charge Question 3*: *Section 2.5.2 of the Draft Regulatory Impact Assessment discusses "Indirect Impacts on Petroleum Consumption for Transportation". This includes the impact of biofuels causing crude and petroleum product prices to decline which could then cause a corresponding increase in consumption. What are your thoughts on the proposed approach to treat these so called rebound or takeback effects?***

Three reviewers responded to this question. Dr. Banse and Mr. Sheehan agreed that these rebound effects are likely to be small. Dr. Banse commented that empirical evidence shows that higher biofuel shares translated to higher consumer costs for blended petrol. He added that the main reason for this trend is the fact that most biofuels are not profitable compared to fossil energy prices. Mr. Sheehan commented that trying to capture rebound effects would be difficult and that the extremely small impact of the EISA targets on overall global petroleum demand makes any analysis "futile." He noted that the level of displacement is within the noise of the analysis and that oscillations in prices also overwhelm any attempt to capture equilibrium price responses to biofuels. In contrast, Dr. Wang hypothesized that a possible biofuels rebound effect may be moderate based on the fact that studies have shown the rebound effect of fuel economy regulations to be moderate. He stated that in an ideal situation, the rebound effect of biofuel supply may be simulated in an economy-wide general equilibrium model. However, he added that accurate simulations require detailed data on short- and long-term price elasticities of transportation fuel demand.

***Charge Question 4*: *EISA mandates comparison of biofuels to a 2005 petroleum baseline. How should this impact our modeling decisions of petroleum fuels*?**

Three reviewers responded to this charge question. Mr. Sheehan and Dr. Wang stated that EISA's use of a 2005 baseline is inappropriate. Dr. Wang added that this decision potentially underestimates GHG emissions of petroleum fuels, since future petroleum fuels will come increasingly from unconventional crudes and since continuing petroleum demand growth over time could generate unanticipated indirect effects in the petroleum sector. Dr. Banse commented that an integrated modeling tool could help to project the endogenous development of bioenergy markets under the reference scenario.

## D. Energy Sector

Mr. Sheehan and Dr. Banse did not respond to the charge questions in this section. Mr. Searchinger remarked that he is still in the process of analyzing the NEMS modeling and made a few additional comments which are incorporated under Charge Question 1 of this section.

***Charge Question 1*: *Changes in biofuel and petroleum fuel production will have impacts on the energy sector due to changes in process energy demand. What are your comments on the preliminary results of NEMS modeling presented in the RIA on this issue?***

Mr. Searchinger noted that if climate change legislation passes, the results of the analysis should change dramatically. He added that one of the effects of any system that limits carbon emissions would be a strong incentive to switch from coal to natural gas. As a result, he stated that it might be expected that natural gas supplies will be stretched. In that event, he said it would be unlikely that a decision to use natural gas rather than coal by biofuel producers would result in a large net increase in the amount of natural gas consumed as opposed to shifts in fuel sources by others.

Dr. Wang commented that while process energy demand for production of biofuels and petroleum fuels can have some impacts on the supply and demand of the electricity sector, the end uses of energy products are the largest energy consuming sources relative to process energy use by the biofuel and petroleum industries. He stated that for this reason, the effects of the proposed rulemaking on the energy sector may be minimal.

***Charge Question 2*: *Are there other tools and models that could be used to capture these impacts?***

None of the four reviews responded specifically to this question.

***Charge Question 3*: *What are the key points to consider?***

None of the four reviewers responded specifically to this question.

***III. Use of Results of Models Together***

**A. Use of FASOM and FAPRI Models**

Mr. Searchinger focused his response to this section of the charge questions on specific parts of the modeling linkage that he found to be problematic. He began by stating that the biggest problem with the EPA analysis stems from commingling FASOM and FAPRI results to produce the same estimate. He continued by commenting that the potential for inconsistent results is large and occurs in a wide variety of components of the analysis. In particular, he drew attention to the difference in predicted changes in crop and livestock production and exports. He noted that the differences shown in the export predictions in Figure 2.6-14 seem to be large and difficult to reconcile.

Mr. Searchinger continued by pointing to several results of the model linkage that “stand out.” First, he noted that Figure 2 in the LCA summary indicates significant differences in relationship between results in the FASOM and FAPRI modeling surrounding rice methane emissions in the corn and switchgrass scenarios. He commented that FASOM predicts large decreases in domestic rice methane emissions from biodiesel, whereas FAPRI predicts very small international increases in rice methane. Expecting the international response to declines in domestic U.S. rice production to be similar, Mr. Searchinger found it hard to believe that there would be overall worldwide declines in rice production from any of the biofuels modeled; and attributed the discrepancy to the discrepancies between models.

The estimated calculation of indirect land-use change in response to switchgrass is the second area that Mr. Searchinger highlighted as needing revision. He noted that EPA predicts only around 20 percent higher ethanol production from switchgrass per acre than corn and that as corn by-products are incorporated, the effective output of ethanol per acre should be lower for corn in 2022. He expressed concern that EPA predicted land-use change emissions that appear to be roughly one-quarter for switchgrass as compared to ethanol. He commented that the magnitude of this difference seemed too high.

Thirdly, Mr. Searchinger commented that another area of discrepancy was the estimates of reductions in demand resulting from increased crop prices. He cited research which states that economists have been surprised at the minor depression of increases in world demand resulting from the increase in crop prices since 2000. Mr. Searchinger recommended that EPA analyze the different results of different models and then evaluate both sets of results against empirical evidence of demand responses in recent years.

Mr. Searchinger also drew attention to the calculation of agricultural production emissions using FASOM. Mr. Searchinger stated that in general FASOM estimates that a switch from soybean and hay production to corn production results in substantial decreases in nitrous oxide emissions, which improves the results for corn but harms the results for biodiesel. He noted that these data are inconsistent with other available evidence and prevailing views.

Mr. Searchinger also commented that FASOM's own emission factors are used to estimate domestic agricultural production emissions, whereas Forest and Agriculture Organization (FAO) data sources and Intergovernmental Panel and Climate Change (IPCC) default factors are used to estimate agricultural production emissions abroad. He expressed concern that this might lead to incompatible results. He also noted that the reliability of the FAO data on these inputs is questionable.

Mr. Searchinger concluded that these observations raise questions about the use of FASOM. He stated that FASOM includes thousands of coefficients that cannot be independently reviewed. He postulated that inconsistencies of the type mentioned above raise questions about what the FASOM model analysis actually adds to the overall calculations. He concluded that there might be too many factors, including international factors, that will influence the precise details of how U.S. crops respond to biofuels to provide any level of confidence in the regional details estimated by FASOM. Mr. Searchinger commented that FASOM could provide useful information as part of a multi-model approach, but it must be viewed independently and not in conjunction with FAPRI.

***Charge Question 1*: *The agricultural sector results use two economic models: FASOM domestically and FAPRI internationally. What are the possibilities for inaccurately estimating, prices, land-use changes, GHG emissions, and other related impacts under this approach?***

Dr. Wang commented that since FASOM, FAPRI, and GTAP models are all based around the concept of economic equilibrium, they may not be able to simulate transition well. He noted that these models may not be able to predict major technology innovations or other non-incremental changes. Dr. Banse reiterated his position that both FASOM and FAPRI draw on assumptions that are not properly substantiated by linkages to general equilibrium models of the economy. He added that the estimation of GHG emissions based on a non-spatial model seems to be inappropriate. Mr. Sheehan commented that the largest source of error in the analysis is in the estimate of types of land-use changed.

***Charge Question 2*: *Currently the results of the two agricultural sector models are not linked, each is run separately and results used independently of each other. Are there ways to link the two models to present a more consistent representation of domestic and international agricultural sector impacts? If so, how?***

Dr. Wang commented that the linkage of FASOM and FAPRI may be a very challenging, if not impossible task. In addition, he stressed that the outputs and inputs of the two models and the information flows between the two models should be clearly presented in the DRIA. He urged that EPA make detailed presentations of these information flows and comparison of simulation results for the issues covered in both models in order to illuminate the differences and similarities between the two models.

Dr. Banse stated that linking models and ensuring consistency between models is a well-known problem in the modeling literature. He pointed to a few examples where models mutually exchange certain solution variables throughout repeating cycles of calculation without ever aiming at a fully consistent set of solution variables. For example, he detailed an example where the macroeconomic variables from the general equilibrium model might be fed into the partial equilibrium model and the aggregated data fed back into the general equilibrium model until the variables converge. He commented that the question as to how to achieve consistency for variables which are endogenous to both models, such as prices, production, and consumption quantities would remain. He also expressed that a certain level of uncertainty would remain between both models. Dr. Banse cited several different studies that provide particular solutions to this issue in other modeling cases.

***Charge Question 3*: *What components of the model results should we be comparing to ensure consistency?***

Dr. Banse expressed that a certain degree of inconsistency is unavoidable with partial equilibrium models. However, he noted that the most important variables for the analysis are trade volumes; therefore, at a minimum, both partial equilibrium models should generate similar trade figures.

***Charge Question 4*: *What specific aspects of the current approach can be improved in this regard and how?***

Dr. Banse commented that with a re-calibration of behavioral parameters (elasticities) both models should have a similar response to enhanced production of biofuels. He suggested that sensitivity analyses on systematic variation of supply and demand elasticities could help to generate similar response functions between FASOM and FAPRI models.

### B. Upstream GHG Emission Factors

Dr. Banse commented that he had limited expertise to address the remaining charge questions in Sections B to E. The other three reviewers did not all responded to each remaining charge question, as indicated by the summary below.

Mr. Searchinger answered section B with a set of comments generally concerned with electricity co-product issues. He observed that prior lifecycle analyses of biofuels found that cellulosic ethanol, without counting for land-use change, would reduce GHG emissions from 70 percent to 95 percent. However, he noted that EPA found that cellulosic ethanol will reduce GHG emissions by roughly 120 percent even while counting land-use change. Mr. Searchinger offered that the reason for this number is a very large credit for electricity production from the switchgrass by-product. He noted that awarding use of a by-product assumes that in the absence of biofuel production, a comparable amount of biomass would not be used for electricity production. Mr. Searchinger commented that this assumption is questionable since use of biomass for electricity, even when ultimately translated into transportation energy, provides a larger source of potential GHG reductions than use of biomass for biofuels. He commented that use of land to produce switchgrass for biofuels has an ambiguous impact on the amount of biomass made available for electricity production. Therefore, he postulated that switchgrass should not be assigned emissions associated with the production of lignin for electricity nor should it receive GHG credits for that production.

***Charge Question 1*: *We have used emission factors from GREET to represent GHG emissions from fertilizer production and petroleum fuel use in the United States and to represent emissions from fertilizer production internationally. What other data or modeling sources should we use?***

Dr. Wang noted that both GREET and FASOM have emission co-efficients for some agricultural activities, such as fertilizer application rates, $N_2O$ emissions in agricultural fields, and energy use of farming. He suggested that it would be helpful if EPA presented a comparison between the two models where data are available in both models.

***Charge Question 2*: *What better ways exist to link the GHG emission factors with results of different models?***

Mr. Sheehan commented that GREET is a reasonable source for upstream emissions factors.

**C. Electricity Production Modeling**

***Charge Question 1*: *We have used GREET electricity factors that represent the average U.S. grid to represent electricity factors for agriculture, biofuel production use, and biofuel electricity production offset. Is this scientifically justifiable?***

Mr. Sheehan commented that GREET is a reasonable source for upstream emissions factors. Dr. Wang stated that the use of U.S. average electricity GHG co-efficients is a good first step.

***Charge Question 2*: *What other regional or marginal sources of electricity GHG emissions factors should we be using?***

Dr. Wang noted that the effects of electricity use of biofuel LCA production are generally small. However, he suggested that since present and near future U.S. biofuel production will concentrate primarily in the U.S. Midwest, EPA could use Midwest electricity generation mix to generate electricity GHG co-efficients for biofuel evaluation.

**D. Fuel and Feedstock Transport**

Dr. Wang commented on Section D that transportation activities usually have a small contribution to life-cycle GHG emissions of biofuels and petroleum fuels. He noted that while GREET simulation of transportation activities is aggregated and crude, representing the details of transportation logistics for different feedstocks and fuels is time consuming and may not be beneficial.

***Charge Question 1*: *We have used GREET factors to represent transportation emissions for biofuel feedstock, crude oil, and finished product transport and distribution. Is this scientifically justifiable?***

Mr. Sheehan commented that the GREET factors were adequate for the analysis.

***Charge Question 2*: *What other sources of transport GHG emissions factors should we be using?***

None of the four reviews responded specifically to this question.

***Charge Question 3*: *Are there models or sources of data that would capture indirect or market impacts on the transportation sector and transportation sector GHG emissions for the different products considered?***

None of the four reviews responded specifically to this question.

**E. Overall Model Linkage**

***Charge Question 1*: *Are there any other adjustments or calibrations we can make across these models in order to ensure that they are as comparable as possible and lead to consistent results?***

Mr. Sheehan was the only expert reviewer to respond directly to this question. He said it would be good to address the inconsistencies in soybean response found between FASOM and FAPRI. Dr. Wang referenced his above comments on model comparisons.

# Appendix A

## Full Text of Charge Questions

***Use of Multiple Models and Data Sources***

### A. Overall Approach

Charge Question 1: As specified by the Energy Independence and Security Act (EISA) of 2007 Sec 201 (H), EPA's lifecycle analysis has to take into account GHG emissions "related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution", including "direct emissions and significant indirect emissions such as significant emissions from land-use changes". In order to conduct this analysis we consider land-use impacts in response to the effect of renewable fuels on agricultural prices. To capture this effect, our approach has been to use partial equilibrium models to capture market-based impacts, and to convert the land-use changes associated with such impacts into GHG emissions. Are there other approaches to capture indirect impacts?

Charge Question 2: What are the strengths and weaknesses of different approaches?

### B. Single Model vs. Multiple Sector Specific Tools

Charge Question 1: Our conclusion in the proposed analysis was that there is no one single model that can capture all of the multi-sector interactions that we need to consider. The thought is that overall CGE models (e.g., GTAP) either do not have GHG emissions included, or do not have adequately refined sectoral specifications (i.e., the agricultural sector including land-use change). Are there other tools and models that we should be considering in this analysis? Are there incongruous assumptions or methodologies we must consider when linking multiple models' results?

***Use of Models for Each Component of Lifecycle***

### A. Suite of Models and Tools Used

Charge Question 1: Are appropriate models being used to represent the different aspects of the fuels lifecycle?

Charge Question 2: Are all sectors being captured in the same detail? If not, do you have any recommendations for modifying the models to make them more comparable?

Charge Question 3: Are all appropriate interactions in the economy and different sector interactions being accurately captured?

Charge Question 4: What GHG sources are missing or are not captured with sufficient detail in the analysis?

Charge Question 5: If you believe the models may not provide sufficient detail or resolution in this analysis, what do you believe the impacts of such shortcomings are on the results of the models? For example, how do potential shortcomings of the models impact overall estimates of lifecycle GHG emission?

**B. Agricultural Sector**

Charge Question 1: Are there other models that could be used to better represent agricultural sector impacts domestically and internationally? If so, please specify which model (FASOM or FAPRI) your suggested model would replace or complement.

Charge Question 2: What are the strengths and weaknesses of the agricultural sector models being used (FASOM and FAPRI)?

**C. Petroleum Sector**

Charge Question 1: What models or tools are available to capture petroleum sector indirect impacts (e.g., changes in fuels markets and use based on price changes in petroleum due to biofuel use)? What are the appropriate indirect impacts to be considered to ensure a scientifically justifiable comparison with biofuels?

Charge Question 2: We have compared a Btu of biofuel with a Btu of gasoline replaced; is this an accurate and appropriate comparison or would biofuels actually displace differing amounts of petroleum fuels? How would this be modeled?

Charge Question 3: Section 2.5.2 of the Draft Regulatory Impact Assessment discusses "Indirect Impacts on Petroleum Consumption for Transportation". This includes the impact of biofuels causing crude and petroleum product prices to decline which could then cause a corresponding increase in consumption. What are your thoughts on the proposed approach to treat these so called rebound or takeback effects?

Charge Question 4: EISA mandates comparison of biofuels to a 2005 petroleum baseline. How should this impact our modeling decisions of petroleum fuels?

**D. Energy Sector**

Charge Question 1: Changes in biofuel and petroleum fuel production will have impacts on the energy sector due to changes in process energy demand. What are your comments on the preliminary results of NEMS modeling presented in the RIA on this issue?

Charge Question 2: Are there other tools and models that could be used to capture these impacts?

Charge Question 3: What are the key points to consider?

***Use of Results of Models Together***

**A. Use of FASOM and FAPRI Models**

Charge Question 1: The agricultural sector results use two economic models: FASOM domestically and FAPRI internationally. What are the possibilities for inaccurately estimating, prices, land-use changes, GHG emissions, and other related impacts under this approach?

Charge Question 2: Currently the results of the two agricultural sector models are not linked, each is run separately and results used independently of each other. Are there ways to link the two models to present a more consistent representation of domestic and international agricultural sector impacts? If so, how?

Charge Question 3: What components of the model results should we be comparing to ensure consistency?

Charge Question 4: What specific aspects of the current approach can be improved in this regard and how?

**B. Upstream GHG Emission Factors**

Charge Question 1: We have used emission factors from GREET to represent GHG emissions from fertilizer production and petroleum fuel use in the U.S. and to represent emissions from fertilizer production internationally. What other data or modeling sources should we use?

Charge Question 2: What better ways exist to link the GHG emission factors with results of different models?

**C. Electricity Production Modeling**

Charge Question 1: We have used GREET electricity factors that represent the average U.S. grid to represent electricity factors for agriculture, biofuel production use, and biofuel electricity production offset. Is this scientifically justifiable?

Charge Question 2: What other regional or marginal sources of electricity GHG emissions factors should we be using?

**D. Fuel and Feedstock Transport**

Charge Question 1: We have used GREET factors to represent transportation emissions for biofuel feedstock, crude oil, and finished product transport and distribution. Is this scientifically justifiable?

Charge Question 2: What other sources of transport GHG emissions factors should we be using?

Charge Question 3: Are there models or sources of data that would capture indirect or market impacts on the transportation sector and transportation sector GHG emissions for the different products considered?

**E. Overall Model Linkage**

Charge Question 1: Are there any other adjustments or calibrations we can make across these models in order to ensure that they are as comparable as possible and lead to consistent results?

# Appendix B

## Dr. Banse Response to Charge Questions

### Use of Multiple Models and Data Sources

### A. Overall Approach

*Charge Question 1: As specified by the Energy Independence and Security Act (EISA) of 2007 Sec 201 (H), EPA's lifecycle analysis has to take into account GHG emissions "related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution", including "direct emissions and significant indirect emissions such as significant emissions from land-use changes". In order to conduct this analysis we consider land-use impacts in response to the effect of renewable fuels on agricultural prices. To capture this effect, our approach has been to use partial equilibrium models to capture market-based impacts, and to convert the land-use changes associated with such impacts into GHG emissions. Are there other approaches to capture indirect impacts?*

Linking partial equilibrium (PE) models with other quantitative tools to capture market-based impact of an enhanced biomass demand under the EISA regulation is in general a promising approach which has been applied also in other studies to assess bioenergy policy options. Market responses are well covered in PE models due to the fact that both policy details and commodity details are better presented in PE models compared to general equilibrium model which are often build on the GTAP data base. The sectors which proved first generation biomass which are soybeans, rapeseed, sunflower-seed, corn, sugar-beets, and different cereals such as barley or wheat are not presented at commodity level in the GTAP database. Apart from wheat, coarse grains are aggregated in one product category. In the GTAP data base, oilseeds are also aggregated to a single commodity.

Another problem in GE models is the treatment of quantities. All activities are expressed in USD values only. Including mandatory blending shares based on quantities which have to be corrected for different energy contents, needs to be 'translated' into volumes.

Due to the fact that PE models cover quantities and also absolute prices, these models seems to provide an appropriate tool for analyzing the impact of bioenergy policies on agricultural and food markets. This 'pro' contains already a 'cont'. PE models are 'partial', i.e. they cover in detail agricultural and food market but not the linkages between agri-food markets and the rest of the economy! For analyzing bioenergy options the link between the agri-food sector and the energy sector is quite important. Relative prices determine the profitability of biomass use in the energy sectors. And even without a policy-driven demand for bioenergy, biomass, which is currently in most cases not profitable compared with fossil energy, might become attractive under increasing fossil energy prices. This important economic link helps to asses the demand for biomass under a 'non-binding' reference scenario and projects the endogenous growth of bioenergy demand under the 'business as usual' scenario. Here GE models provide a powerful tool to capture this link between agricultural and energy markets. Linking the FAPRI models with a GE model, e.g. a GTAP-type model, could provide the data for the endogenous change of biomass demand and energy prices under the reference scenario.

Apart from the lack of linkages of PE models with non-agricultural sectors, PE models often do not cover factor markets. It might be reasonable to keep labor and capital markets as exogenous in PE models, but land markets are very important. The assessment of bioenergy options requires a good understanding of the functioning of land markets in different parts or the world. Restrictions in land conversion or the limited availability of extra land which could be used for biomass production are the major drivers of direct and indirect land-use changes of bioenergy production. Here the current approach of modeling domestic land use with the FASOM model seems to cover domestic land-use changes in good way. International land-use changes which might play an important role due to the fact that yields at international level might be lower compared to domestic US levels, are modeled differently. Here models such as GTAP or LEITAP/IMAGE with endogenous land supply and demand function could provide details of land-use change outside the US.

Another point which should be considered in future improvements of the combined modeling tool is the spatial dimension of land-use changes. No model applied here has a detailed spatial dimension. Long-term assessments, however, should take into account the distribution of changing land-use patterns within a region or country. Analyses based on models such as FAPRI models or FASOM, are not able to identify 'hotspots' in land-use changes. Spatial land-use models covering different types of soil, are able to identify those areas where the additional or intensified land use due to higher bioenergy production would contribute to already existing environmental problems.

*Charge Question 2: What are the strengths and weaknesses of different approaches*?

Strengths: An extended tool of integrated models with spatial biophysical land-use models and with models covering the linkages between agricultural and energy markets would help to cover the above mentioned features which are missing in the current analysis.

Weaknesses: Extended tools of more than four models become expensive and inflexible! Data collection, scenario design, and maintenance of the models require interaction between different experts (statisticians, modelers, geographers, experts on bioenergy technologies etc.)

### B. Single Model vs. Multiple Sector Specific Tools

*Charge Question 1: Our conclusion in the proposed analysis was that there is no one single model that can capture all of the multi-sector interactions that we need to consider. The thought is that overall CGE models (e.g., GTAP) either do not have GHG emissions included, or do not have adequately refined sectoral specifications (i.e., the agricultural sector including land-use change). Are there other tools and models that we should be considering in this analysis? Are there incongruous assumptions or methodologies we must consider when linking multiple models' results?*

Modeling bioenergy requires a combined, integrated modeling tool. It seems that there is no 'one size fits all' model. PE models are a good starting point but they need feedback from different other models

Links to the overall economy especially energy markets via general equilibrium models; Links to the spatial dimension of land-use changes via biophysical land-use models at grid cell level, e.g. IMAGE, CLUE. In these models land-use changes are modeled endogenously which go beyond the FAPRI/Winrock estimates applied for the current analysis.

GHG emissions should be modeled at the most detailed level, i.e. at grid-cell level. The results, however, can be 'up-scaled' to regional or national level.

Other aspects which might be important at local level, such as eutrophication due to increasing intensity of biofuel production, can only be addressed with explicit spatial modeling tools.

**Use of Models for Each Component of Lifecycle**

**A. Suite of Models and Tools Used**

*Charge Question 1: Are appropriate models being used to represent the different aspects of the fuels lifecycle?*

From my point of view the aspects of the fuels lifecycle are fully covered in the current study.

*Charge Question 2: Are all sectors being captured in the same detail? If not, do you have any recommendations for modifying the models to make them more comparable?*

As mentioned above the modeling of a spatial dimension is lacking in the current analysis. The market interactions are well presented but the associated land use changes are extrapolated on trends and current land use pattern.

*Charge Question 3: Are all appropriate interactions in the economy and different sector interactions being accurately captured?*

Missing sectoral interactions between agriculture and other parts of the economy have been already addressed above.

*Charge Question 4: What GHG sources are missing or are not captured with sufficient detail in the analysis?*

GHG emissions which are related to eutrophication of ground and surface water should be covered in the analysis.

*Charge Question 5: If you believe the models may not provide sufficient detail or resolution in this analysis, what do you believe the impacts of such shortcomings are on the results of the models? For example, how do potential shortcomings of the models impact overall estimates of lifecycle GHG emission?*

An important aspect in the analysis of land-use changes and associated changes in GHG emissions is the treatment of different degrees of land quality. Additional - currently not used - land is in most cases less productive. Any modeling of an expansion of land use should consider this.

**B. Agricultural Sector**

*Charge Question 1: Are there other models that could be used to better represent agricultural sector impacts domestically and internationally? If so, please specify which model (FASOM or FAPRI) your suggested model would replace or complement.*

An ideal solution would be a FASOM model at global level! But future extension of the modeling framework should try to link the current models with GE models and spatial biophysical land-use models, such as IMAGE or CLUE.

*Charge Question 2: What are the strengths and weaknesses of the agricultural sector models being used (FASOM and FAPRI)?*

Domestic agricultural markets and land-use changes are well presented, but international land-use changes are not well covered in FAPRI. Here other PE models such as IFPRI's IMPACT model could provide further details.

**C. Petroleum Sector**

*Charge Question 1: What models or tools are available to capture petroleum sector indirect impacts (e.g., changes in fuels markets and use based on price changes in petroleum due to biofuel use)? What are the appropriate indirect impacts to be considered to ensure a scientifically justifiable comparison with biofuels?*

There are currently some initiatives to link detailed agricultural model, e.g. CAPRI (a regionalized PE model for the EU) with the PRIMES energy model. Other GE models such as the so-called LEITAP model - an extended GTAP model - developed at the Agricultural Economics Research Institute LEI in The Hague (Netherlands) capture the linkages between petroleum and agricultural markets. Any model-based analysis including endogenous price formation of agricultural and energy markets should be used as a tool to assess the impact of policy options. These models are not an appropriate tool to project future energy prices! Therefore the link between agricultural and energy prices should be made as transparent as possible, and any analysis should be underpinned by a profound sensitivity analysis (SSA) of key assumptions and parameter values.

*Charge Question 2: We have compared a Btu of biofuel with a Btu of gasoline replaced; is this an accurate and appropriate comparison or would biofuels actually displace differing amounts of petroleum fuels? How would this be modeled?*

The analysis should cover the restriction in blending shares due to the current vehicle fleet, i.e. the problem of the so-called 'blending wall'. Future development of the composition of vehicle fleet determines which type of petroleum fuel will be displaced. Either sophisticated energy models cover these projections endogenously or SSA could help to assess the consequences of future development of the vehicle fleet.

*Charge Question 3: Section 2.5.2 of the Draft Regulatory Impact Assessment discusses "Indirect Impacts on Petroleum Consumption for Transportation". This includes the* *impact of biofuels causing crude and petroleum product prices to decline which could then cause a corresponding increase in consumption. What are your thoughts on the proposed approach to treat these so called rebound or takeback effects?*

The empirical evidence shows that higher biofuel shares are translated with higher consumer costs of blended petrol. The main reason for this trend is the fact that most biofuels are not profitable compared to fossil energy prices. The projected declines in fossil fuel prices due to enhanced biofuel production are relatively small!

*Charge Question 4: EISA mandates comparison of biofuels to a 2005 petroleum baseline. How should this impact our modeling decisions of petroleum fuels?*

As explained above, an integrated modeling tool could help to project the endogenous development of bioenergy markets under the reference scenario.

**D. Energy Sector**

*Charge Question 1: Changes in biofuel and petroleum fuel production will have impacts on the energy sector due to changes in process energy demand. What are your comments on the preliminary results of NEMS modeling presented in the RIA on this issue?*

No comments.

*Charge Question 2: Are there other tools and models that could be used to capture these impacts?*

Not to my knowledge.

*Charge Question 3: What are the key points to consider?*

**Use of Results of Models Together**

**A. Use of FASOM and FAPRI Models**

*Charge Question 1: The agricultural sector results use two economic models: FASOM domestically and FAPRI internationally. What are the possibilities for inaccurately estimating, prices, land-use changes, GHG emissions, and other related impacts under this approach?*

It has been discussed already above, due to the missing linkages with a GE models capturing also macro-economic developments, e.g. changes factor costs or energy prices, both PE models draw completely on assumptions. Also the estimation of GHG emissions based on a non-spatial model seems to be inappropriate.

*Charge Question 2: Currently the results of the two agricultural sector models are not linked, each is run separately and results used independently of each other. Are there ways to link the two models to present a more consistent representation of domestic and international agricultural sector impacts? If so, how?*

Linking models and ensuring consistency between both models is a well know problem in modeling literature. There are a couple of examples of an iterative use of different models (PE and PE or PE and GE) models with the mutual exchange of certain solution variables after each iteration, without aiming at a fully consistent set of solution variables. PE and GE are combined where macroeconomic variables from the GE model are fed into PE model whereas aggregated information are fed back into the GE models until these variables converge. There remains the question how to achieve consistency for variables which are endogenous to both models, such as prices, production and consumption quantities. Here a certain level of inconsistency will remain between both models.

Other studies go further in aiming at a fully consistent set of solution variables by iteratively running models at different aggregation stages. This, however, is typically limited to the coupling of programming supply models with market models (Helming et al., 2006; Kuhlmann et al., 2006; Britz, 2004; Böhringer and Rutherford, 2006). In these cases, the relative supply response of the market model is effectively replaced by the relative supply response simulated by the programming model. In CAPRI (Britz, 2004), the market model is a PE model, in the work of Helming et al. (2006) and Kuhlmann et al. (2006) the market model is a modified GTAP version. Convergence of model results is reached by running models iteratively and mapping the vector of relative price changes from the market model to the programming model and the vector of relative supply quantity changes from the programming model to the market model. In addition, these model linkages apply mechanisms to ensure that solution variables converge, also in case of implicit supply elasticities being higher than demand elasticities. A full integrated approach of a PE model for dairy products and a GE model is presented in Grant et al. (2006). Jansson et al. (2008) present a full integration of the PE model CAPRI with a GE model.

*Charge Question 3: What components of the model results should we be comparing to ensure consistency?*

As mentioned under point 2, with PE models  a certain degree of inconsistency seems to be unavoidable. However, the most important variables for this analysis are trade volumes. Therefore, if both PE models should have a ‘minimum level’ consistency, they should generate similar trade figures.

*Charge Question 4: What specific aspects of the current approach can be improved in this regard and how?*

Discussed above already. With a re-calibration of behavioral parameters (elasticities) both models should have a similar response to enhanced production of biofuels. Here SSAs on systematic variation of supply and demand elasticities could help to generate similar response functions between FASOM and FAPRI models.

I have limited expertise to address the following points under B. - E.

**B. Upstream GHG Emission Factors**

*Charge Question 1: We have used emission factors from GREET to represent GHG emissions from fertilizer production and petroleum fuel use in the U.S. and to represent emissions from fertilizer production internationally. What other data or modeling sources should we use?*

*Charge Question 2: What better ways exist to link the GHG emission factors with results of different models?*

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*Charge Question 2: What other sources of transport GHG emissions factors should we be using?*

*Charge Question 3: Are there models or sources of data that would capture indirect or market impacts on the transportation sector and transportation sector GHG emissions for the different products considered?*
*E. Overall Model Linkage*

*Charge Question 1: Are there any other adjustments or calibrations we can make across these models in order to ensure that they are as comparable as possible and lead to consistent results?*

**Reference:**

Böhringer, C. and T.F. Rutherford (2006), Combining Top-Down and Bottom-Up in Energy Policy Analysis: A Decomposition Approach. ZEW Discussion Paper 06-007.

Britz, W. (2004), CAPRI Modelling System Documentation. Common Agricultural Policy Regional Impact Analysis. Bonn.

Grant, J.H., Hertel, T.W. and T.F. Rutherford (2006), Extending General Equilibrium to the Tariff Line: U.S. Diary in the Doha Development Agenda. Paper presented on the 9th Conference on Global Economic Analysis, June, 15-17 2006, Addis Abeba.

Helming, J., Tabeau, A., Kuhlmann, T. and F. van Tongeren (2006), Linkage of GTAP and DRAM for Scenario Assessment: Methodology, Application and some Selected

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Kuhlmann, T., Tongeren, F. van, Helming, A., Tabeau, A., Gaaff, A., Groeneveld, R., Koole, B. and D. Verhoog (2006), Future Land-Use Change in the Netherlands: An Analysis based on a Chain of Models. Agrarwirtschaft, Vol. 55, No. 5/6: 238-247.

**Appendix C**

## Mr. Searchinger Response to Charge Questions

### Use of Multiple Models and Data Sources

Although the discussion below provides a significant number of comments, my schedule has not permitted me to engage in the full quantitative review of the analysis. I therefore plan to supplement these comments with additional comments as part of the general public comment.

### A. Overall Approach

*Charge Question 1: As specified by the Energy Independence and Security Act (EISA) of 2007 Sec 201 (H), EPA's lifecycle analysis has to take into account GHG emissions "related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution", including "direct emissions and significant indirect emissions such as significant emissions from land-use changes". In order to conduct this analysis we consider land-use impacts in response to the effect of renewable fuels on agricultural prices. To capture this effect, our approach has been to use partial equilibrium models to capture market-based impacts, and to convert the land-use changes associated with such impacts into GHG emissions. Are there other approaches to capture indirect impacts?*

Question one asks about the general approach EPA is using to estimate indirect land-use change. I believe

1. The sound use of partial equilibrium models, combined with the use of historical data on land-use change, represents a plausible and preferable approach to the use of general equilibrium models.
2. Even so, EPA should not rely on any single economic model, which is capable even when sound of providing only one plausible prediction. EPA should consult a range of models and use additional evidence to establish an indirect land-use change factor that represents a cautionary approach to provide reasonable assurance that biofuels meet the thresholds established by Congress.
3. Among the additional evidence EPA should use are opportunity cost analysis and scenario-based modeling.
4. EPA should not focus on 2022 scenarios; and
5. EPA should alter its approach to establishing categories so that they are not based on so high level of speculation about the evolution of technology and economic developments about the future.

### 1. Use of Partial Equilbrium versus General Equilibrium Models

The preamble states that EPA preferred partial equilibrium to general equilibrium models such as GTAP because of their greater resolution. That is a valid reason, particularly with regard to GTAP. The underlying GTAP model has treats all oil seeds as one crop regardless of source, notwithstanding such enormous variations as those between oil palm and soybeans. In that category, it also fails to separately represent the vegetable oil market, which is critical to modeling biodiesel. This broad treatment of crop categories is only one example of the enormous differences in the detailed treatment of the agricultural sector between the available general equilibrium models and models such as the FAPRI model.

More broadly, the general equilibrium models as a whole have other limitations that make them inferior for the purpose EPA is seeking to the extent EPA chooses to rely on any single model. Production functions play a critical role in models such as GTAP, which allows them to adjust production levels in responses to changes in supply and price of various inputs. The changes in price and supply of inputs in turn is much of what responds to the "general" feature of these models, i.e., the non-agricultural sectors, as changes in the agricultural sector alter other parts of the model, which alter demand and inputs back to the agricultural sector. However, the empirical basis for these production functions is extremely weak, making them the subject of enormous criticism within the economics literature. The form of the production functions is also typically chosen, as in GTAP, for its ease of mathematical manipulation. The limitations are sufficiently strong that when Purdue University economists were adjusting the GTAP model to calculate indirect land-use change for the California Air Resources Board, they forced the production functions to reproduce a yield/price elasticity in theory derived from econometric studies. Even if that overall elasticitiy were valid (and its empirical basis was also weak), the overall elasticity would not tell you what variables to adjust to produce that elasticity. Because the relationship of the supply and price of these inputs to outputs is therefore based on limited empirical basis, it is not particularly helpful to vary those input supplies and prices in responses to general equilibrium features.

For other reasons as well, the addition of general equilibrium interactions raises more questions than answers. The impact on the overall economy of ethanol depends heavily on its costs of production, as well as its impact on oil prices. Those factors are highly uncertain and disputed. As a result, the additional interactions between those economic changes and biofuel production are also uncertain. Any theoretical gain in comprehensiveness is not worth the cost in uncertainty.

The other theoretical advantage of the general equilibrium models is that they provide a basis for estimating which lands will be converted to crop production. In the GTAP model, for example, that depends on the value of land under crop production versus its alternative value as pasture or managed forest. Differences in rents explain the land-use change. However, the standard GTAP model cannot address unmanaged forest because it does not have a rent. The standard model also accordingly lacked conversion cost estimates. And of course the models also lack a way of representing non-economic factors in estimating conversion. Other modelers, including John Reilly at MIT, have attempted to develop supply curves for unmanaged land using conversion cost estimates, with assumptions about the relative productivity of new lands. However, overall, the data sources for these estimates are sufficiently weak that it seems more reliable to follow the EPA approach of examining sources of new cropland by country and allocating cropland expansion based on this historical experience.

Significantly, however, although the FASOM model is also a partial equilibrium model, to my understanding it is an optimization model that also is conceptually based on changes in the relative profitability of different land uses. As a result, some of the same limitations of the GTAP model are shared by the FASOM model. For that reason, while the FASOM model has more resolution for the U.S. than the GTAP model, this is among the reasons to question the co-use of FASOM and FAPRI.

For these reasons, I believe the approach taken by EPA, particularly in its use of the FAPRI mode, combined with use of historical data on land conversion, is preferable to the use of alternative models to the extent EPA chooses to rely on any one model.

**2. Use of one model versus multi-model approach**

EPA has used different models for different features of its analysis, but ultimately it uses one model for each feature and then combines them into a whole. In effect, therefore, EPA relies on a single model for each part of the overall calculation. This approach is seriously flawed because it fails to properly address both model uncertainty and what I will call reality uncertainty

Although I share EPA's preference for partial equilibrium, econometric models such as the FAPRI model, any one model provides only a limited approach to estimating land-use change and resulting GHG emissions. Some of the limitations are methodological. For example, teasing out elasticities from underlying data is never straightforward because changes between supply and demand of different products each affect the other. And models compared large numbers of elasticities interacting in ways that are hard to prove are accurate because there are always other factors that also explain variations in year to year production levels. In addition, long-term elasticities differ from short-term elasticities and are even harder to measure because of intervening causal events. Beyond these fundamental limitations in economic methods, models inherently use prior relationships among economic activities to predict future relationships, but other events intervene to change the relationships. Country agricultural sectors as a whole can improve or degrade. New crop varieties, crop diseases or weather patterns can shift the economics of production in different locations. Government infrastructure investments can change the cost structure. Currency fluctuations can play a major role. These uncertainties compound over time.

Because of these uncertainties, EPA is wrong to place so much emphasis on any one estimate. The models of land-use change are akin to models of climate change. The underlying causal mechanisms are well known and established, and the basic thrust of the different models is similar, but the magnitudes differ based on model differences and different assumptions about future emissions scenario and feedback loops. It would be wrong for EPA to base climate policy on any single model, and it is similarly wrong for EPA to base ILUC on any single model. Each model at best provides one plausible scenario of the future.

The sensitivity analyses presented, although also useful, do not substitute for the use of multiple models and approaches. These sensitivity analyses still use the same models, varying only one assumption (or at most a couple) at a time. The workings of these models contain enormous quantities of equations and elasticities, and inputs include hundreds of assumptions. These sensitivity analyses alter select assumptions but the results are still linked to the specific models chosen.

An alternative approach would examine a range of models and attempt to develop a meta-analysis. This approach would examine categories of predictions and evaluate their plausibility: percentage of diverted crops that are "recouped" through by-products;

percentage of diverted crops that are not replaced; percentage of replacement that occurs in certain ecosystem types. This approach would also use the opportunity cost analysis described below. Necessarily, in light of uncertainty, EPA must also choose a level of confidence. There clearly are sources of biofuels that do not cause significant land-use change, such as the use of corn stover. Given that fact, and the harsh consequences of pursuing biofuels that might increase greenhouse gas emissions, EPA should take a cautionary approach to estimates of land-use change from other biofuels and establish ILUC factors that provide a reasonable level of assurance that biofuels reflecting these factors do in fact reduce greenhouse gases at the levels established by Congress.

**3. Opportunity Cost and Scenario-Based Modeling**

Producing biofuels diverts the carbon-productive capacity of land from other uses into energy production. When biofuels are produced directly on forests, the greenhouse gas implications of this diversion are measured by the losses in storage and ongoing sequestration. When biofuels divert crops or cropland, carbon storage is not sacrificed directly because the carbon produced is consumed by people and livestock and put back into the atmosphere through their metabolism. The greenhouse gas implications are therefore measured by the losses in storage and sequestration that occur when the productive capacity of additional lands are altered to replace the food. ILUC is therefore a measurement of the greenhouse gas costs of diverting the carbon-productive capacity of land into fuel production.

The models are one way of measuring these effects, but only one way and they present a broad range of uncertainties. An alternative way is simply to measure directly the carbon sequestration equivalent of the carbon-productive capacity of land represented as the carbon sequestration that would occur on this land if left alone. In general, for example, most of the cropland in the United States would today revert to forest if not used for crops. (Although much of this cropland was originally prairie, fire maintained this prairie landscape and with fire interrupted, the land typically comes back in trees. These grasslands were probably equally productive of carbon but in different ways.) If the productive capacity of these lands were not disturbed, they would probably sequester carbon at a rate of 7.5 to 12 tons (Searchinger 2009, p. 8). Dividing these figures by the gallons and mega joules of ethanol produced generates an ILUC factor. This figure is not adjusted by the reductions in demand, but it could be (and the size of these demand reductions is likely to be limited). On the other hand, this figure also does not calculate the up-front losses of long-sequestered carbon when mature ecosystems are disrupted.

Some might argue that this analysis is counterfactual as the land would otherwise stay in crop production. But the point is that crop production represents one use of the productive capacity of land that is not focused on sequestration. This foregone sequestration is one measure of what that productive capacity would be in the form of sequestration. In addition, abandoned agricultural land typically reverts to alternative uses. And if the world commits to carbon reduction strategies, land will be valued for its carbon sequestration potential, and using land for biofuels in a very real sense will forego these alternative uses. A future world that values terrestrial carbon is not merely a possible but likely future that the present form of analysis largely ignores.

Simplified scenario modeling also provides useful information. Searchinger & Heimlich 2008 provide an example of such an approach. That paper examined land-use change from U.S. biodiesel production from soybeans by assuming first that diverted biodiesel replaced exports. Countries that purchased U.S. vegetable oil then replaced that vegetable oil on the world market, including increasing their purchases in the U.S., based on a range of scenarios. For example, the main scenario assumed that countries would replace vegetable oil according to their current mix of vegetable oils in proportion to their countries' present external suppliers. Under any plausible scenario of where and how vegetable oil would be replaced, and assuming decreases in demand and price-induced yields, indirect land-use change emissions were high enough to result in increases in emissions overall for soybean biodiesel over 30 years. Although modeling analyses are more complex, that does not mean they are more accurate. After extensive review of different world land-use models and discussions with leading modelers, I have come to believe that this scenario approach is actually the most robust and informative analyses of biodiesel ILUC.

The rulemaking enterprise by EPA does not require that it generate a single number. It requires that EPA generate a yes/no answer for each category of biofuels analyzed. A multiple model approach that incorporates opportunity cost and simplified scenario scenario would provide the most robust answer to that question.

**4. 2022 Analysis**

The lifecycle analysis focuses exclusively on a 2022 analysis. Yield improvements expected by 2022 in particular improve the greenhouse gas balance. This approach seems to me flawed.

First and most simply, biofuels generated between now and 2022 might still fail greenhouse gas accounting based on all of the assumptions otherwise used by EPA. For example, lower yields translate directly into more land-use change per unit, and the model appears also to assume a variety of improvements in productive efficiency over this time. It is hard to understand how biofuels can be viewed as passing thresholds in, for example, 2012, simply because their continued production is likely to pass thresholds in 2022.

Second, this reliance on 2022 makes the whole analysis predicated on a series of critical assumptions that may or may not come true. That is particularly true of cellulosic biofuels, which do not yet exist. Yields of switchgrass, where it is grown, conversion efficiency and by-product generation can at this point be only conjectured. EPA relies on NREL analysis, and even a cursory review of its predictions over the years on the commercial development of cellulosic ethanol would reveal that they have been consistently wrong. Under the terms of the EISA, biofuels from facilities constructed in this time that pass greenhouse gas thresholds based on 2022 assumptions will forever be deemed to do so regardless of the reality in 2022. The one thing that can be confidently predicted of 2022 is that the assumptions and analysis generated by EPA today will turn out to be materially wrong in at least some significant features, and the longer the out-year used for the analysis, the more wrong it is likely to be.

**5. Categorization**

The use of 2022 timeframe is only one example of the most significant problem with the analysis, which is its broad categorization of biofuels, for example, into switchgrass ethanol or soy-based biodiesel. Having categorized biofuels broadly, EPA must then make assumptions about where these biofuels will be grown, with what yields, and with what efficiency and production techniques. The corn analysis actually hints at an alternative approach by varying the lifecycle analysis based on different production techniques.

EPA should utilize more categories for all biofuels and should incorporate into these categories key assumptions. For example, switchgrass ethanol might pass future greenhouse gas tests if switchgrass produced in the U.S. meets certain yields or more on lands of certain productivity or less, if the switchgrass is converted into ethanol with certain production efficiencies, and if it produces certain electricity co-products that displace a grid of a certain carbon-intensity (more discussion on electricity co-products below). This approach would greatly increase the reliability of the estimates by turning pure assumptions into criteria.

*Charge Question 2: What are the strengths and weaknesses of different approaches?*

My answers to question one and question three largely provide my answers to question two. Put shortly, I do not believe that FASOM should be used, as it does not appear to add any reliable additional detail and does create inconsistencies with the FAPRI analysis for reasons described in more detail in my answer to question 3. I believe, in general, that the EPA is using a plausible modeling approach, subject to some specific criticisms in my answer to question three.

**B. Single Model vs. Multiple Sector Specific Tools**

*Charge Question 1: Our conclusion in the proposed analysis was that there is no one single model that can capture all of the multi-sector interactions that we need to consider. The thought is that overall CGE models (e.g., GTAP) either do not have GHG emissions included, or do not have adequately refined sectoral specifications (i.e., the agricultural sector including land-use change). Are there other tools and models that we should be considering in this analysis? Are there incongruous assumptions or methodologies we must consider when linking multiple models' results?*

**Use of Models for Each Component of Lifecycle**

**A. Suite of Models and Tools Used**

*Charge Question 1: Are appropriate models being used to represent the different aspects of the fuels lifecycle?*

*Charge Question 2: Are all sectors being captured in the same detail? If not, do you have any recommendations for modifying the models to make them more comparable?*

*Charge Question 3: Are all appropriate interactions in the economy and different sector interactions being accurately captured?*

*Charge Question 4: What GHG sources are missing or are not captured with sufficient detail in the analysis?*

A few potentially large sources of greenhouse gas emissions are missing from the analysis.

Wetlands: The most significant omission is wetlands. As one illustration of the significance, the European Commission Joint Research Center has calculated that if only 2.5% of the rapeseed diverted to biodiesel in Europe is replaced by palm oil produced by expanding into peatlands in Southeast Asia, the emissions from the peat alone indefinitely cancel out otherwise existing greenhouse gas benefits from biodiesel (de Santi 2008). That analysis assumes no emissions from any other land-use change or from lost forest.

On a worldwide basis, wetlands have provided a significant percentage of cropland. In the U.S., agriculture is the estimated source of conversion for roughly 70% of wetland loss, or roughly 70 million acres. That is roughly one fifth of the cropland actually planted and probably a significantly higher percentage of the total crop production. In the U.S., wetlands have provided the home for two of the three main sugarcane producing regions – south Florida and Louisiana, and outside of Brazil, wetlands could provide a main area of sugarcane expansion. Many of the best agricultural lands in Europe are also former wetlands. Wetlands are common in tropical forests.

It is difficult to estimate what percentage of future land conversion around the world is likely to come from wetland conversion. However, the evidence is reasonable that one quarter of future palm oil expansion in Southeast Asia will go through peatlands, and in other regions, a scenario-based approach would be reasonable. Wetlands store large quantities of carbon. Their exclusion almost certainly leads to a substantial underestimate of emissions from land-use change, particularly for biodiesel. To provide an ultimately reasonable estimate of ILUC, the EPA analysis should be modified to include their conversion.

Pasture Conversion Spurred Directly by Meat Prices – The FAPRI model works entirely within the crop sector, and diverted crops for feed are replaced entirely by new feed. In reality, feed diversion and higher feed prices also increases the incentive to clear forest for pasture to produce beef in alternative ways. This is one of the weaknesses of the FAPRI model and probably underestimates land-use change because proportionately more land must be cleared to replace meat production through pasture and than through crops. Studies have shown direct correlations between the price of beef and the rate of clearing of forest in Latin America (Chomitz 2007).

There will undoubtedly be those who criticize the assumption in the model that cropland displacement of grazed Brazilian pasture will result in equal proportions of forest clearing. That is one of the toughest factors to estimate, and intensification is very probably one of the additional responses. However, the price of beef pushes pasture expansion independently of cropland expansion, and that is not accounted for.

The various GTAP models purport to attempt to estimate these effects. They depend first on price effects on beef and dairy products, and then the costs of land conversion. On the other hand, the GTAP models are probably less reliable sources of predictions of price impacts than the FAPRI model. As part of the multi-model, multi-evidentiary analysis, EPA should canvas methods of analyzing these impacts, and provide some additional estimates of this direct effect.

*Charge Question 5: If you believe the models may not provide sufficient detail or resolution in this analysis, what do you believe the impacts of such shortcomings are on the results of the models? For example, how do potential shortcomings of the models impact overall estimates of lifecycle GHG emission?*

**B. Agricultural Sector**

For international land-use change, the modeling approach examines sources of new cropland over only a recent four year period. Although the information provided is useful, such a short period seems inappropriate and potentially skewed, particularly for modeling long-term effects that will take place as biofuel production expands over at least thirteen years. A longer analysis would seem appropriate. Dr. Holly Gibbs, now of Stanford University, has reported recent analysis of cropland sources for the 1980's and 1990's, and this data should also be included.

*Charge Question 1: Are there other models that could be used to better represent agricultural sector impacts domestically and internationally? If so, please specify which model (FASOM or FAPRI) your suggested model would replace or complement.*

*Charge Question 2: What are the strengths and weaknesses of the agricultural sector models being used (FASOM and FAPRI)?*

**C. Petroleum Sector**

For reasons mostly described above, I do not believe that more interactions with the general economy would be useful. But an additional reason is that some of the potential interactions are also of doubtful policy relevance. For example, if biofuel production increases transportation fuel costs, reduced driving could result that provides greenhouse gas reductions. But to the extent particular biofuels otherwise do not reduce greenhouse gas emissions, it would be bizarre to recognize them as passing the threshold on this basis as biofuels that do reduce greenhouse gases independently would accomplish for more benefit. Congress could also accomplish the same reductions through energy taxes without the additional financial or carbon costs of these biofuels that otherwise would not meet GHG standards. Correlatively, it is hard to imagine that Congress would wish to deny biofuels if reductions in production costs result in cheaper transportation that increases driving so as to offset some or all of the greenhouse gas reductions from biofuels that do pass thresholds. In other words, some impacts of biofuels are essentially ancillary in that the same impacts could be achieved through other simple policy options, and it would be a mistake to incorporate them into lifecycle analysis.

I have no other comments at this time on the other parts of the petroleum sector analysis.

*Charge Question 1: What models or tools are available to capture petroleum sector indirect impacts (e.g., changes in fuels markets and use based on price changes in petroleum due to biofuel use)? What are the appropriate indirect impacts to be considered to ensure a scientifically justifiable comparison with biofuels?*

*Charge Question 2: We have compared a Btu of biofuel with a Btu of gasoline replaced; is this an accurate and appropriate comparison or would biofuels actually displace differing amounts of petroleum fuels? How would this be modeled?*

*Charge Question 3: Section 2.5.2 of the Draft Regulatory Impact Assessment discusses "Indirect Impacts on Petroleum Consumption for Transportation". This includes the impact of biofuels causing crude and petroleum product prices to decline which could then cause a corresponding increase in consumption. What are your thoughts on the proposed approach to treat these so called rebound or takeback effects?*

*Charge Question 4: EISA mandates comparison of biofuels to a 2005 petroleum baseline. How should this impact our modeling decisions of petroleum fuels?*

**D. Energy Sector**

I am still analyzing the NEMS modeling. However, if climate change legislation passes, the results should change dramatically. One of the effects of any system that limits carbon emissions should be a strong incentive to push from coal to natural gas. As a result, we can expect that natural gas supplies will be stretched. In that event, it seems unlikely that a decision to use natural gas rather than coal by biofuel producers would result in a large net increase in the amount of natural gas consumed as opposed to shift fuel sources by others.

*Charge Question 1: Changes in biofuel and petroleum fuel production will have impacts on the energy sector due to changes in process energy demand. What are your comments on the preliminary results of NEMS modeling presented in the RIA on this issue?*

*Charge Question 2: Are there other tools and models that could be used to capture these impacts?*

*Charge Question 3: What are the key points to consider?*

**Use of Results of Models Together**

In addition to relying on a single set of model estimates, the biggest problem with the EPA analysis comes from the commingling of FASOM and FAPRI results to produce the same estimate. The potential for inconsistent results is large and occurs in a wide variety of components of the analysis. I am still analyzing the numbers and therefore cannot provide a complete analysis at this time, but a couple of points stand out. One is the difference in predicted changes in crop and livestock production and exports. The differences shown in the export predictions in Figure 2.6-14 seems to me very large and very hard to reconcile, and it is not clear to me at this time precisely how EPA has attempted to reconcile these differences. Quite obviously, the FAPRI predictions of international land-use change cannot simply be used in conjunction with the FASOM predictions of domestic changes in agricultural land use and production. And some odd results stand out. For example, Figure 2 in the LCA summary indicates that while domestic rice methane emission reductions (presumably as calculated by FASOM) remain similar in corn and switchgrass scenarios, in the corn scenario international rice emissions (presumably as calculated by FAPRI) increase by roughly the same amount, but in the switchgrass scenario, they increase by what appears to be only half as much. Relatedly, FASOM predicts large decreases in domestic rice methane emissions from biodiesel, but FAPRI predicts very small international increases in rice methane. In general, the international response to declines in domestic U.S. rice production should be similar and it is hard to believe that there would be meaningful, worldwide overall declines in rice production from any of the biofuels modeled. This discrepancy would appear to be one of the modeling discrepancies.

Another area that requires serious focus is the estimated calculation of indirect land-use change in response to switchgrass. EPA predicts only around 20% higher ethanol production from switchgrass per acre than corn and once corn by-products are taken into account, the effective output of ethanol per effectively dedicated acre should be lower for corn in 2022. Yet, EPA predicts international and use change emissions that appear to be roughly one quarter for switchgrass ethanol compared to corn ethanol. That only possible explanation is that far less productive acres are used to produce this ethanol, but the magnitude seems high. EPA also predicts that switchgrass in the U.S. will result in significant declines in emissions from international livestock while corn ethanol will result in small increases in international livestock. The production of DDG by-products could help explain this result, but again it seems excessive, particularly if only marginal land would be used to produce switchgrass in the U.S. I have not had an opportunity to investigate these results in detail, but plan to do so and encourage EPA to investigate them further as well.

Another area of discrepancy appears to be the estimates of reductions in demand although I am still analyzing the numbers. Economists have so far marveled at the minor depression of increases in world demand resulting from the run-up in crop prices since 2000 (Westhoff 2008). EPA should not only analyze the different results of the different models but should evaluate both against other empirical evidence of demand responses in recent years.

Another major discrepancy appears likely in the calculation of agricultural production emissions, and it is difficult to distinguish the problem of incompatibility with other problems with FASOM's calculations, many of which appear incongruous. In general, FASOM estimates that a switch from soybean and hay production to corn prediction results in substantial decreases in nitrous oxide emissions, which improves the results for corn but harms the results for biodiesel. These results appear inconsistent with the evidence and prevailing views. To my understanding, model estimates and data on actual field emissions predict higher direct emissions of nitrous oxide from corn than soybeans and hay (Parkins & Kaspar 2006; Wagner-Riddle & Thurtell 2004), and also higher runoff rates of nitrogen, which should lead to higher off-site emissions (Simpson 2009; Donner 2008). For example, Simpson 2009 predicts runoff rates of nitrogen from hay at one sixth of those from corn. Part of the error appears to be excessively high assumption of nitrogen fertilization for hay. The FASOM model, according to the EPA, assumes that hay receives 150 pounds of nitrogen per acre, almost 50% higher than corn, and also fixes large quantities of nitrogen. In general, leguminous hays such as alfalfa receive little or no fertilization, and while other hays receive fertilizer, they do not fix nitrogen. As a perennial, hay also tends to take up nitrogen throughout the growing season, which appears to reduce the available nitrate to runoff and also nitrous oxide formation. I have not had a chance to review NASS data independently, but one review of NASS data by the University of New Hampshire estimated that corn received average

U.S. fertilizer of 125 pounds per acre, while alfalfa received none and non-leguminous hay received only 25 pounds per acre.

Although FASOM is used to estimate agricultural production emissions, FAO data sources and IPCC default factors are used to estimate agricultural production emissions abroad. The result is almost certainly incompatible. In addition to this incompatibility, the reliability of the FAO data on these inputs is questionable.

Although EPA states that it plans to replace the FASOM nitrous oxide calculations with Daycent calculations, these errors raise grave questions about the use of FASOM. Any model, such as FASOM, includes thousands of coefficients that cannot be independently reviewed. When a model makes major predictions that are inconsistent with scientific data, it raises serious questions about the model as a whole, and just fixing those errors that are easily caught by reviewers does not imply that the remainder of the model is sound. More broadly, the problems with these calculations raise questions about what the FASOM model analysis actually adds to the overall calculations. To the extent I could tell, much of the presumed merit of using FASOM for domestic calculations is that FASOM calculates greenhouse gas emissions directly. But if these emissions factors and calculations are questionable and incompatible with international calculations of agricultural production to replace diverted crops in the U.S., then that is not an advantage. FASOM can also calculate forestry interactions, but since FAPRI cannot, the potential inclusion of forestry interactions creates source of potential inconsistencies between domestic and international reactions. Finally, FASOM provides a host of spatial detail within the U.S., which can be used among other things to vary production emissions by soil type. But again, if the production emissions are suspect anyway, this detail is of little advantage. And this level of detail is likely a false precision. There are simply too many factors, including international factors that will influence the precise details of how U.S. crops respond to biofuels to provide any level of confidence in the regional details estimated by FASOM.

I believe that FASOM could provide useful information as part of a multi-model approach, but it must be viewed independently and not in conjunction with FAPRI, and the questions raised above about particular applications of FASOM counsel for caution in its overall use. However, the potential added value from FASOM in domestic detail is simply not worth the cost in inconsistency with the international analysis.

### A. Use of FASOM and FAPRI Models

*Charge Question 1: The agricultural sector results use two economic models: FASOM domestically and FAPRI internationally. What are the possibilities for inaccurately estimating, prices, land-use changes, GHG emissions, and other related impacts under this approach?*

*Charge Question 2: Currently the results of the two agricultural sector models are not linked, each is run separately and results used independently of each other. Are there ways to link the two models to present a more consistent representation of domestic and international agricultural sector impacts? If so, how?*

*Charge Question 3: What components of the model results should we be comparing to ensure consistency?*

*Charge Question 4: What specific aspects of the current approach can be improved in this regard and how?*

**B. Upstream GHG Emission Factors**

Prior lifecycle analyses of biofuels generally found that cellulosic ethanol, without counting land-use change, would reduce greenhouse gas emissions from 70% to 95%. EPA finds that it will reduce greenhouse gas emissions by roughly 120% even while counting land-use change. One of the reasons appears to be a very large credit for electricity production by a switchgrass by-product.

The basic question is whether any emission by-product is warranted. At a minimum, the awarding of a by-product assumes that in the absence of biofuel production, a comparable amount of biomass would not be used for electricity production. That seems questionable. Use of biomass for electricity, even when ultimately translates into transportation energy, provides a larger potential source of greenhouse gas reductions than use of biomass for biofuels. Many states have enacted renewable energy standards for electricity. Any land that could produce biomass for biofuels could also produce biomass exclusively for electricity and thereby reduce greenhouse gas emissions more. As a result, use of land to produce switchgrass for biofuels has an ambiguous impact on the amount of biomass made available for electricity production. While switchgrass ethanol should therefore not be assigned emissions associated with the production of lignin for electricity, it should also not receive the greenhouse gas credits for that production. See the discussion of this co-product issue in Supporting Online Information for Farrell et al. 2008.

*Charge Question 1: We have used emission factors from GREET to represent GHG emissions from fertilizer production and petroleum fuel use in the U.S. and to represent emissions from fertilizer production internationally. What other data or modeling sources should we use?*

*Charge Question 2: What better ways exist to link the GHG emission factors with results of different models?*

**C. Electricity Production Modeling**

*Charge Question 1: We have used GREET electricity factors that represent the average U.S. grid to represent electricity factors for agriculture, biofuel production use, and biofuel electricity production offset. Is this scientifically justifiable?*

*Charge Question 2: What other regional or marginal sources of electricity GHG emissions factors should we be using?*

**D. Fuel and Feedstock Transport**

*Charge Question 1: We have used GREET factors to represent transportation emissions for biofuel feedstock, crude oil, and finished product transport and distribution. Is this scientifically justifiable?*

*Charge Question 2: What other sources of transport GHG emissions factors should we be using?*

*Charge Question 3: Are there models or sources of data that would capture indirect or market impacts on the transportation sector and transportation sector GHG emissions for the different products considered?*

**E. Overall Model Linkage**

*Charge Question 1: Are there any other adjustments or calibrations we can make across these models in order to ensure that they are as comparable as possible and lead to consistent results?*

# Appendix D

## Mr. Sheehan Response to Charge Questions

### Use of Multiple Models and Data Sources

### A. Overall Approach

Charge Question 1: As specified by the Energy Independence and Security Act (EISA) of 2007 Sec 201 (H), EPA's lifecycle analysis has to take into account GHG emissions "related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution", including "direct emissions and significant indirect emissions such as significant emissions from land-use changes". In order to conduct this analysis we consider land-use impacts in response to the effect of renewable fuels on agricultural prices. To capture this effect, our approach has been to use partial equilibrium models to capture market-based impacts, and to convert the land-use changes associated with such impacts into GHG emissions. Are there other approaches to capture indirect impacts?

EPA has, at this time, used the best available tools and approaches for assessing indirect land-use change effects of biofuels. That said, it is important to point out that the tools that have been applied were never meant to address in a systematic or comprehensive way the kinds of regulatory questions imposed on EPA by EISA 2007. The analyses done by EPA's researchers must be viewed at best as a preliminary and limited look at the question of indirect land-use change.

As Geist[3] has pointed out, land-use change is fundamentally a system dynamics problem. Thus, perhaps the greatest limitation of the models used by EPA is the fact that they are only partial equilibrium economic models and are not equipped to deal with the complex dynamics of land use around the globe. In addition, understanding land-use change and the influence that bioenergy may have on it calls for a more comprehensive way of looking at the problem. Geist et al identify many other factors in land-use change that will not be adequately captured through the narrow lens of economic equilibrium models. Political, cultural, technological and infrastructure issues have easily as much impact (if not more) on the land-use equation as the immediate effects of price pressures in the global agriculture market.

Consistent with Geist's comments on land-use change, I have proposed a new approach to looking at indirect land-use change that is based on system dynamics modeling. The approach is outlined in the schematic in Figure 1. It uses a system dynamics modeling approach that is more appropriate for understanding the dynamics of global land use in a holistic manner.

[3] Geist, H. and Lambin, E. (2002). "Proximate Causes and Underlying Driving Forces of Tropical Deforestation." *BioScience*, **52/2**, pp 143-150.

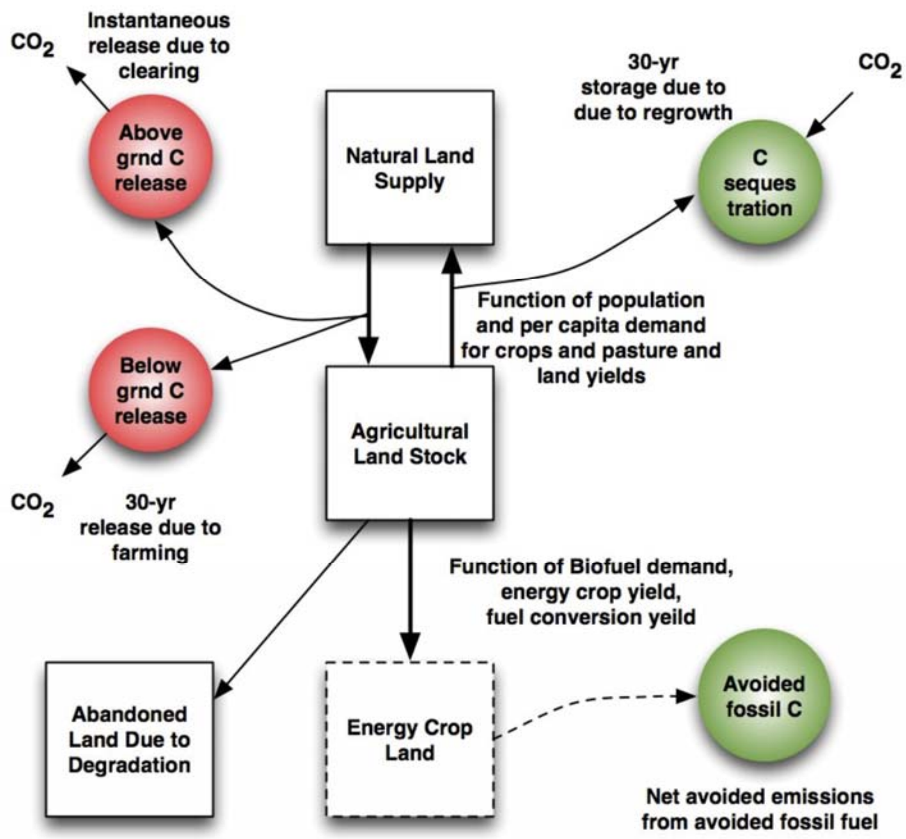


Figure 1. A system dynamics approach to land-use change

This model, quite crude and simplistic in comparison to the models now in use by EPA, offers some advantages over the economic modeling that is central to the analysis done by EPA. It is, first of all, truly dynamic. Built using the STELLA® system dynamics modeling framework,4the model has the capability to flexibly handle dynamic changes in global agriculture and in bioenergy technology. Rather than focusing on the details of economic trade and competition in the global agriculture market, the model considers the simple question of demand for land required to meet both the requirements of EISA 2007 and future global demand for food, feed and fiber. The basic premise of the model is simple—we must meet the future demands for food.

*Charge Question 2: What are the strengths and weaknesses of different approaches?*

As indicated above, the basic approach that EPA has taken truly represents the best available modeling today. The only other modeling approach that has been documented for measuring indirect land-use change involves the use of GTAP to predict price response and regional agriculture production response to biofuels. It has been used by the California Air Resources Board to document its estimates of indirect land-use change in support of its Low Carbon Fuel Standard (LCFS). Among its strengths is that this model accounts for specific trade arrangements for agriculture around the world. A perceived advantage of GTAP over the FASOM and FAPRI models used by EPA is its "open source" nature. This makes the model more accessible to others who want to test

[4] ISEE Systems (2009). Stella® 9.2. Lebanon, NH.

out and work with future scenarios for biofuels. I actually question the “openness” of the model. It’s long history, complexity and the arcane nature of its development actually obscure its apparent transparency. Even more problematic for GTAP (compared to FAPRI/FASOM or our own STELLA® model is the fact that it is a strictly an equilibrium model that is incapable of properly capturing dynamic changes in the global ag sector. This has forced the GTAP modelers to use awkward and questionable “fixes” to force their analysis to reflect future changes in agriculture that cannot be explicitly captured in a static model. Indeed most of these fixes must be done externally to the model.

The biggest strengths of the system dynamics modeling approach being developed here at the University of Minnesota are its simplicity, transparency and completely dynamic nature. The biggest weakness is that the model is still too simplistic to the meet the needs of a regulatory process.

**B. Single Model vs. Multiple Sector Specific Tools**

Charge Question 1: Our conclusion in the proposed analysis was that there is no one single model that can capture all of the multi-sector interactions that we need to consider. The thought is that overall CGE models (e.g., GTAP) either do not have GHG emissions included, or do not have adequately refined sectoral specifications (i.e., the agricultural sector including land-use change). Are there other tools and models that we should be considering in this analysis? Are there incongruous assumptions or methodologies we must consider when linking multiple models’ results?

I agree with EPA’s conclusion that there is currently no single model that can capture all of the multi-sector interactions that need to be considered. GTAP has many limitations. While it is worth looking at GTAP as a model that can provide a different perspective on the agriculture sector, it is not any better suited to EPA’s task than FASOM and FAPRI. In the suite of models being used by EPA, the biggest weakness is in the satellite data based analysis used to translate regional land-use changes to specific types of land substitution. By working with a fixed time frame, EPA has no ability to understand current dynamics of land-use change or the specific economics and other drivers that might influence the type of land that would shift into agriculture or energy production based as a result of biofuels growth.

**Use of Models for Each Component of Lifecycle**

**A. Suite of Models and Tools Used**

*Charge Question 1: Are appropriate models being used to represent the different aspects of the fuels lifecycle?*

Yes. I believe that the EPA has done an adequate job in modeling the life cycle of the fuels. More detail is always possible, but the added insights might not be worthwhile given the generic nature of the biofuels/feedstock/vehicle scenarios being developed for the regulation. The only alternative to approach that might be considered by EPA would be one in which individual technology/fuel providers are permitted to develop detailed data on the specific impacts of their technology.

*Charge Question 2: Are all sectors being captured in the same detail? If not, do you have any recommendations for modifying the models to make them more comparable?*

It is impossible to capture all of the sectors in the same level of detail. I believe that EPA's analysis of each sector is reasonable given the timing and nature of the work.

*Charge Question 3: Are all appropriate interactions in the economy and different sector interactions being accurately captured?*

While I cannot speak with sufficient confidence on the details underlying the FASOM and FAPRI models, I believe that EPA has adequately addressed interactions that occur across sectors. That does not mean that I think EPA has necessarily captured future trends in all sectors adequately. Here, my biggest concern is with how the models project potential future global improvements in agriculture and in future demand for ag products.

*Charge Question 4: What GHG sources are missing or are not captured with sufficient detail in the analysis?*

No major sources of GHG emissions are missing or not captured in the analysis.

*Charge Question 5: If you believe the models may not provide sufficient detail or resolution in this analysis, what do you believe the impacts of such shortcomings are on the results of the models? For example, how do potential shortcomings of the models impact overall estimates of lifecycle GHG emission?*

I don't feel that added detail or resolution will substantially improve the analyses done by EPA. Rather, I think there would be more value in developing simpler models that are based on a better understanding of the causes of land-use change. As pointed out earlier, the data on the types of land-use change that will occur is based on an entirely empirical analysis that has no theoretical basis for predicting future land-use changes.

**B. Agricultural Sector**

*Charge Question 1: Are there other models that could be used to better represent agricultural sector impacts domestically and internationally? If so, please specify which model (FASOM or FAPRI) your suggested model would replace or complement.*

I know of no other alternatives to FASOM and FAPRI other than GTAP. Indeed, what is needed are new models that can offer better insights on the dynamics of land-use change. Currently, no such models are available in sufficient detail to meet the needs of a regulatory process.

*Charge Question 2: What are the strengths and weaknesses of the agricultural sector models being used (FASOM and FAPRI)?*

Lack of transparency and lack of useability beyond a limit set of experts represents the biggest weakness of the FASOM and FAPRI models. Even with the detail that EPA has provided on its analysis using these models, it is impossible to judge with confidence what is going on in these models, what limitations in the models may be biasing the results, or what fundamental data underlying the models may influencing the outcomes. The strengths of the models are more a matter of their being, by default, the only available tools for the job.

**C. Petroleum Sector**

*Charge Question 1: What models or tools are available to capture petroleum sector indirect impacts (e.g., changes in fuels markets and use based on price changes in petroleum due to biofuel use)? What are the appropriate indirect impacts to be considered to ensure a scientifically justifiable comparison with biofuels?*

Capturing petroleum sector indirect impacts is a big problem. No satisfactory tools are available to address these issues. As with agriculture, the models available for petroleum and energy sector forecasting are limited, arcane, complex and difficult to use. Social and political implications of petroleum (among the more important issues to be captured) are probably incompatible with the carbon footprint analysis required of EPA in EISA. In terms of land-use effects, there is no denying that any indirect effects of petroleum will be minor in comparison to land effects of biofuels.

*Charge Question 2: We have compared a Btu of biofuel with a Btu of gasoline replaced; is this an accurate and appropriate comparison or would biofuels actually displace differing amounts of petroleum fuels? How would this be modeled?*

Comparing biofuels and petroleum on Btu basis is the most reasonable and appropriate approach to take.

*Charge Question 3: Section 2.5.2 of the Draft Regulatory Impact Assessment discusses "Indirect Impacts on Petroleum Consumption for Transportation". This includes the impact of biofuels causing crude and petroleum product prices to decline which could then cause a corresponding increase in consumption. What are your thoughts on the proposed approach to treat these so called rebound or takeback effects?*

Trying to capture these rebound effects is, in my view, futile. The economic models available are simply not up to the task. This second order effect is probably not worth capturing. Furthermore, the extremely small impact of the EISA targets on overall global petroleum demand makes any analysis an exercise in counting the number of angels on the head of a pin. The level of displacement is simply within the noise of any analysis. The wild swings in prices that occur also overwhelm any attempt to capture equilibrium price responses to biofuels.

*Charge Question 4: EISA mandates comparison of biofuels to a 2005 petroleum baseline. How should this impact our modeling decisions of petroleum fuels?*

EISA'a mandate of comparison against a 2005 petroleum baseline is inappropriate. That said, I do not see that EPA has any choice in its modeling approach other than the one taken in the analysis reported to date. EPA has at least acknowledged this problem in its impact analysis by considering future changes in petroleum's carbon foot print, even if it cannot take such changes into account in its threshold analyses.

**D. Energy Sector**

No comments on this section.

*Charge Question 1: Changes in biofuel and petroleum fuel production will have impacts on the energy sector due to changes in process energy demand. What are your comments on the preliminary results of NEMS modeling presented in the RIA on this issue?*

*Charge Question 2: Are there other tools and models that could be used to capture these impacts?*

*Charge Question 3: What are the key points to consider?*

**Use of Results of Models Together**

**A. Use of FASOM and FAPRI Models**

*Charge Question 1: The agricultural sector results use two economic models: FASOM domestically and FAPRI internationally. What are the possibilities for inaccurately estimating, prices, land-use changes, GHG emissions, and other related impacts under this approach?*

The largest source of error is in the estimate of types of land-use changed. This is a significant weakness in the analysis

*Charge Question 2: Currently the results of the two agricultural sector models are not linked, each is run separately and results used independently of each other. Are there ways to link the two models to present a more consistent representation of domestic and international agricultural sector impacts? If so, how?*

I have no information to offer.

*Charge Question 3: What components of the model results should we be comparing to ensure consistency?*

*Charge Question 4: What specific aspects of the current approach can be improved in this regard and how?*

**B. Upstream GHG Emission Factors**

*Charge Question 1: We have used emission factors from GREET to represent GHG emissions from fertilizer production and petroleum fuel use in the U.S. and to represent emissions from fertilizer production internationally. What other data or modeling sources should we use?*

*Charge Question 2: What better ways exist to link the GHG emission factors with results of different models?*

**C. Electricity Production Modeling**

*Charge Question 1: We have used GREET electricity factors that represent the average U.S. grid to represent electricity factors for agriculture, biofuel production use, and biofuel electricity production offset. Is this scientifically justifiable?*

*Charge Question 2: What other regional or marginal sources of electricity GHG emissions factors should we be using?*

**D. Fuel and Feedstock Transport**

*Charge Question 1: We have used GREET factors to represent transportation emissions for biofuel feedstock, crude oil, and finished product transport and distribution. Is this scientifically justifiable?*

*Charge Question 2: What other sources of transport GHG emissions factors should we be using?*

*Charge Question 3: Are there models or sources of data that would capture indirect or market impacts on the transportation sector and transportation sector GHG emissions for the different products considered?*

**E. Overall Model Linkage**

*Charge Question 1: Are there any other adjustments or calibrations we can make across these models in order to ensure that they are as comparable as possible and lead to consistent results?*

It would be good to address the inconsistencies in soybean response found between FASOM and FAPRI

# Appendix E

## Dr. Wang Response to Charge Questions

### Use of Multiple Models and Data Sources

### A. Overall Approach

*Charge Question 1: As specified by the Energy Independence and Security Act (EISA) of 2007 Sec 201 (H), EPA's lifecycle analysis has to take into account GHG emissions "related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution", including "direct emissions and significant indirect emissions such as significant emissions from land-use changes". In order to conduct this analysis we consider land-use impacts in response to the effect of renewable fuels on agricultural prices. To capture this effect, our approach has been to use partial equilibrium models to capture market-based impacts, and to convert the land-use changes associated with such impacts into GHG emissions. Are there other approaches to capture indirect impacts?*

*Charge Question 2: What are the strengths and weaknesses of different approaches?*

I will define indirect effects here to include secondary and tertiary effects caused by direct actions. Inclusion of direct and indirect effects of life cycles of biofuels and petroleum fuels requires use of traditional life-cycle analysis (LCA) models (which usually address emissions of direct effects) and computational general equilibrium (CGE) models and/or partial equilibrium models (which can, in theory, address indirect effects). In EPA's NPRM analysis, partial equilibrium models (i.e., FAPRI and FASOM), instead of CGE models (e.g., GTAP), were used. In the context of analyzing indirect effects of biofuel production, use of partial equilibrium models in place of general equilibrium models should not pose a major problem.

The linkage between direct actions and indirect effects is understandable in theory. The difficulty is how to accurately quantify the magnitude of indirect effects. By definition, indirect effects are derivatives of direct actions. While indirect effects can be caused by economic factors, political and social factors can play an important role in the magnitude of the economic linkage between direct actions and indirect effects. In fact, these three sets of factors are often intertwined to cause aggregate indirect effects. It is a major challenge to estimate and separate the impacts of each of three sets of factors on aggregate indirect effects. Efforts have been made so far to examine land-use changes (LUCs) of biofuel production solely from economic factors. One could argue that the other two sets of factors, such as those through government intervention, can weaken (or strengthen) the economic linkage between direct actions and indirect effects, which has not been addressed in the current efforts of examining LUCs of biofuel production.

For the economic linkage between direct actions and indirect effects, while it is generally agreed that CGE models may be used to address indirect effects of biofuel production, there are two distinctly different LCA approaches that can be used to assess emissions of direct and indirect effects during the life cycle of transportation fuels – the attributional and consequential LCAs.

Traditionally, LCAs for transportation fuels have been conducted with the attributional LCA approach, through which individual processes/activities (direct effects) of a fuel cycle are identified (especially with detailed technology characterization), and the energy use and emission burdens of individual processes/activities are assessed. The approach was developed from conventional engineering/technical analysis of system designs and performance. To address emissions of indirect effects, CGE models are being used to determine indirect effects. Emissions of the determined indirect effects are then estimated with emission coefficients, which are then combined into traditional LCAs. In fact, California Air Resources Board in its recently adopted low-carbon fuel standards relied on attributional LCA, supplemented with a CGE model (the GTAP model) to address LUCs of biofuel production.

On the other hand, the consequential LCA approach takes into account the direct effects and the indirect effects together by using economic models. Historically, consequential LCAs were conducted with economic input-output models within an economy (usually within a country), but have recently been expanded to the global economy. Emission coefficients may be built in these economic models to generate aggregate emission results of all direct and indirect effects. EPA applied the consequential LCA approach in its RFS2 NPRM by using the FASOM model (for emissions of domestic direct and indirect effects of biofuel production) and the FAPRI model (for international indirect effects, which were then combined with emission coefficients to generate emissions). Some of the needed emission co-efficients in EPA's consequential LCA were derived from the GREET model, while others (such as emission factors of land conversions) were developed for EPA through the NPRM effort.

Use of consequential LCAs in place of attributional LCAs in emissions regulation development is a new endeavor. I have several questions regarding use of consequential LCAs in RFS2 regulation development. Is consequential LCA methodology sound enough for regulation development? Are data and assumptions in consequential LCA models reliable and transparent? How are responsibilities for meeting regulatory requirements attributed to different parties? Are there risks of double-regulating certain parties as different sectoral environmental policies are developed? Will certain parties be regulated for the actions of other parties remotely related to the regulations? Are consequential LCAs transparent so that others can track down key assumptions and their impacts on results?

Consequential LCAs may not be as transparent as attributional LCAs are. With attributional LCAs, stakeholders can track down step by step where the major emission sources are and what impacts technology advancements might have on LCA results. Since consequential LCAs are in their early stage of applications for environmental evaluation and since there are large numbers of inter-relationships in CGE models and aggregate, crude emission co-efficients are often used inside of CGE models, Stakeholders may not be able to readily identify effects of individual activities and new technologies on LCA results with the consequential LCA approach. To compound these problems, FASOM and FAPRI models that EPA has used for RFS2 were not available to stakeholders.

## B. Single Model vs. Multiple Sector Specific Tools

*Charge Question 1: Our conclusion in the proposed analysis was that there is no one single model that can capture all of the multi-sector interactions that we need to consider. The thought is that overall CGE models (e.g., GTAP) either do not have GHG emissions included, or do not have adequately refined sectoral specifications (i.e., the agricultural sector including land-use change). Are there other tools and models that we should be considering in this analysis? Are there incongruous assumptions or methodologies we must consider when linking multiple models' results?*

In developing the RFS2 NPRM, EPA certainly faced a difficult reality. That is, there is no single model available to address both direct and indirect effects of biofuels and petroleum fuels that occur in the U.S. and outside of the U.S. Since indirect effects, especially indirect LUCs, were identified only very recently, there are no enough technical analyses to address many important factors in addressing indirect LUCs with CGE models. Such factors include baseline understanding of global food supply and demand in the future, agricultural technological advancements over time in major countries and their implications on future crop yield growth globally, carbon stocks in different land cover types, among many other factors. It is obvious that regulatory needs of addressing indirect effects, especially LUCs, are ahead of scientific understanding of interactions among different sectors and among different activities. In my opinion, while LCA emission results of direct effects such as farming and biofuel production technologies are with some degree of certainty, results from CGE models and partial equilibrium models are subject to great uncertainty. The fact of different levels of certainty or uncertainty for different effects should have been acknowledged and reflected in the proposed GHG changes in the NPRM.

Some CGE models such as the GTAP model may be designed for global scale simulations, but they may not contain emission co-efficients. Simulated effects from these models need to be combined with emission co-efficients outside of the models to generate emissions of indirect effects, as CARB did in its LCFS. Considering the uncertainty involved in simulation of indirect effects (e.g., LUCs) and in developing emission co-efficients (such as carbon emissions of land conversions), it may be indeed more appropriate to generate emissions of indirect effects outside of CGE models so that this step from effects to emissions is transparent.

CGE models such as GTAP may not be as detailed as FASOM to address the interactions between agricultural and forestry sectors within the U.S. In order to adequately address the dynamics of these two critical sectors for U.S. biofuel production, FASOM is a preferred model to use. Unfortunately, the FASOM version that was used for the EPA NPRM analysis did not have the forestry component. That is, while FASOM is capable of addressing the interactions between the two sectors, the completed FASOM simulations for EPA did not address the interactions. Nonetheless, FASOM has addressed interrelationships among different sub-sectors within the agricultural sector.

In developing GHG changes by biofuels relative to petroleum fuels, EPA combined results from FASOM, FAPRI, Winrock, and GREET. The combination of FASOM and FAPRI was intended to address domestic and international LUCs and other indirect effects. However, the NPRM and the DRIA did not present how exactly the two models were combined for the purpose of generating consistent domestic and international

LUCs. I suspect that the underlined linkage between FASOM and FAPRI lies primarily in changes in U.S. grain exports that are caused by U.S. biofuel production. I realize that FAPRI is capable of generating U.S. domestic LUCs as well as international LUCs, while FASOM generates only domestic LUCs. It would have been helpful if the DRIA presented domestic LUC results from both FASOM and FAPRI. This would have provided some indication how similar or different results from the two models are.

The combination of FAPRI and Winrock results was needed to compensate FAPRI's lack of predicting the types of land conversion to meet the land requirements for food production predicted by FAPRI. That is, while FAPRI predicts land requirements, it does not predict how the requirements are to be met. On the other hand, FASOM does predict land demand and land supply for reaching a new equilibrium. This difference in FAPRI and FASOM poses a major methodology inconsistency of estimated domestic and international LUCs. Furthermore, use of the past LUC patterns between 2001 and 2004 as estimated by Winrock for future land supply to meet FAPRI-predicted land demand is problematic. This is a major weakness of using FAPRI (relative to using GTAP) to produce international LUCs. The GTAP model is designed to predict land demand and supply for key individual countries, though the level of details of the GTAP model may need significant improvements.

The linkage between FASOM and FAPRI on the one hand and GREET on the other hand was somewhat causal in the NPRM. Wherever needed, GREET emission co-efficients were used to supplement available emission co-efficients in FASOM. While GREET emission co-efficients were developed from EPA emission databases such the AP-42 documents and various engineering analyses, it is not clear how emission co-efficients in FASOM were developed. The two models may have relied on very different data sources and approaches to develop emission co-efficients. For the activities whose emission co-efficients are available in both FASOM and GREET, it would have been helpful if EPA had presented a comparison of emission co-efficients from the two models.

**Use of Models for Each Component of Lifecycle**

**A. Suite of Models and Tools Used**

*Charge Question 1: Are appropriate models being used to represent the different aspects of the fuels lifecycle?*

Besides comments made in the above section, below are specific comments on some of the key biofuel pathways.

Corn Ethanol. It is the most exhausted pathway simulated and analyzed in the NPRM with the consequential LCA methodology.

Petroleum Gasoline. No consequential LCA was conducted to address potential indirect effects for this pathway.

Switchgrass Ethanol. International indirect effects that were simulated with FAPRI may not be valid, because FAPRI does not have switchgrass and a simple assumption of increased CRP enrollment was made as a crude proxy of switchgrass growth in the U.S.

Soybean Biodiesel. One could argue that biodiesel is a by-product of soybean production (soy meals may be the main product), it is not clear how FASOM and FAPRI are designed to simulate biodiesel as a by-product as soy meal as a main product. This problem is especially compounded by the fact that there are many edible oil substitutes for soy oil.

*Charge Question 2: Are all sectors being captured in the same detail? If not, do you have any recommendations for modifying the models to make them more comparable?*

Below are my comments on simulations of key sectors for the NPRM.

The U.S. Agriculture Sector. It was simulated with great details with the FASOM model.

The U.S. Forestry Sector. It was not included in the completed simulations.

The International Agricultural and Forestry Sectors. These sectors were simulated with the FAPRI model with the level of details less than simulations of the U.S. agricultural sector done with the FASOM model. They were simulated at the level of details somewhat less than or equal to simulations of international agricultural and forestry sectors with GTAP.

The Petroleum Sector. It was not simulated for indirect effects.

*Charge Question 3: Are all appropriate interactions in the economy and different sector interactions being accurately captured?*

Not completely. See above comments.

*Charge Question 4: What GHG sources are missing or are not captured with sufficient detail in the analysis?*

It appears to me that all major GHG emission sources were captured in the analysis. But the level of details involved in individual sources varies greatly. One of the emission sources that was not addressed in detail is GHG emissions from land conversions. While the Winrock approach may be OK to use at this time to estimate GHG emissions of different land conversions, the approach is certainly not adequate since the approach did not have or generate enough data and understanding regarding carbon stocks in above-ground biomass for different vegetations, carbon in different soil types, and the maturity level of vegetation for different land types in different parts of the world. Also, methane emissions from animal husbandry and certain practices such as rice farming in FASOM may be subject to great uncertainty.

*Charge Question 5: If you believe the models may not provide sufficient detail or resolution in this analysis, what do you believe the impacts of such shortcomings are on the results of the models? For example, how do potential shortcomings of the models impact overall estimates of lifecycle GHG emission?*

The lack of the forestry component in the FASOM version for this analysis could underestimate the extent of U.S. ability to domestically absorb land demand of U.S. biofuel production.

The lack of land supply simulation in FAPRI makes the international LUC results in the NPRM less reliable.

**B. Agricultural Sector**

*Charge Question 1: Are there other models that could be used to better represent agricultural sector impacts domestically and internationally? If so, please specify which model (FASOM or FAPRI) your suggested model would replace or complement.*

*Charge Question 2: What are the strengths and weaknesses of the agricultural sector models being used (FASOM and FAPRI)?*

Three models (FASOM, FAPRI, and GTAP) are available to address domestic and international LUCs. There are some on-going efforts to create new models and/or to improve these existing models for LUC simulations. While FASOM is very detailed for U.S. domestic LUC modeling, the lack of international LUCs in FASOM and the necessary, but somewhat mechanical, coupling of FASOM and FAPRI creates some additional uncertainties with the EPA approach.

On the other hand, GTAP covers both domestic and international LUCs, but with a low resolution level.

Ultimately, it is a question whether the modeling capabilities currently available in this field are adequate enough to generate results for regulation development purpose.

**C. Petroleum Sector**

*Charge Question 1: What models or tools are available to capture petroleum sector indirect impacts (e.g., changes in fuels markets and use based on price changes in petroleum due to biofuel use)? What are the appropriate indirect impacts to be considered to ensure a scientifically justifiable comparison with biofuels?*

*Charge Question 2: We have compared a Btu of biofuel with a Btu of gasoline replaced; is this an accurate and appropriate comparison or would biofuels actually displace differing amounts of petroleum fuels? How would this be modeled?*

*Charge Question 3: Section 2.5.2 of the Draft Regulatory Impact Assessment discusses "Indirect Impacts on Petroleum Consumption for Transportation". This includes the impact of biofuels causing crude and petroleum product prices to decline which could then cause a corresponding increase in consumption. What are your thoughts on the proposed approach to treat these so called rebound or takeback effects?*

*Charge Question 4: EISA mandates comparison of biofuels to a 2005 petroleum baseline. How should this impact our modeling decisions of petroleum fuels?*

Models such as NEMS and MARKEL that focus mainly on the energy sector may be capable of addressing indirect effects of the petroleum sector. However, with emerging issues such as production of marginal crudes (e.g., oil sands) and disturbance of nature habitats in oil field operations, I do not expect that these models can now address indirect effects of the petroleum sector at a satisfactory level. In addition, introduction of additional models in NPRM analysis will cause additional inconsistencies among models used.

As for the analysis done on the Btu to Btu displacement between ethanol and gasoline, this is a reasonable assumption for the near future, since ethanol will be used in low and intermediate blending levels with gasoline. Even if E85 is used in FFVs, FFVs may not be optimized for E85 any time soon, considering that gasoline may be the main fuel for FFVs for the foreseeable future.

The so-called rebound effect of biofuel supply to the transportation energy pool is an interesting academic issue. The same issue was raised in the past for U.S. passenger vehicle fuel economy regulations. Studies have shown that the rebound effect of fuel economy regulations was moderate. This could indicate that the rebound effect of biofuel supply will be probably moderate. In the ideal situation, the rebound effect of biofuel supply may be simulated in an economy-wide CGE model. But accurate simulations require detailed data on short- and long-term price elasticities of transportation fuel demand.

The EISA specified 2005 as the baseline year for petroleum fuels. This was certainly an oversight during EISA development. This decision potentially underestimates GHG emissions of petroleum fuels, since future petroleum fuels will come increasingly from unconventional crudes and since continuing global petroleum demand growth over time could generate unanticipated indirect effects in the petroleum sector.

**D. Energy Sector**

*Charge Question 1: Changes in biofuel and petroleum fuel production will have impacts on the energy sector due to changes in process energy demand. What are your comments on the preliminary results of NEMS modeling presented in the RIA on this issue?*

*Charge Question 2: Are there other tools and models that could be used to capture these impacts?*

*Charge Question 3: What are the key points to consider?*

It is certainly true that process energy demand for production of biofuels and petroleum fuels can have some impacts on the supply and demand of the energy sector. However, end uses of energy products (such as transportation energy use, electricity use by industry, commercial, and residential sectors) are the largest energy consuming sources, relative to process energy use by the biofuel industry and the petroleum industry. For this reason, the effects of the RFS2 (especially the corn ethanol volume simulated) on the energy sector may be minimal.

**Use of Results of Models Together**

**A. Use of FASOM and FAPRI Models**

*Charge Question 1: The agricultural sector results use two economic models: FASOM domestically and FAPRI internationally. What are the possibilities for inaccurately estimating, prices, land-use changes, GHG emissions, and other related impacts under this approach?*

*Charge Question 2: Currently the results of the two agricultural sector models are not linked, each is run separately and results used independently of each other. Are there ways to link the two models to present a more consistent representation of domestic and international agricultural sector impacts? If so, how?*

*Charge Question 3: What components of the model results should we be comparing to ensure consistency?*

*Charge Question 4: What specific aspects of the current approach can be improved in this regard and how?*

Both FASOM and FAPRI are developed on the theory that economy operates at equilibrium. One may question if economy in particular and society in general operate at equilibrium instead of transition. Even if one believes that equilibrium could eventually be reached, the transition from one equilibrium to another could be important to simulate. Unfortunately, neither FASOM nor FAPRI is capable of simulating transition. Similarly, GTAP cannot simulate transition either. This poses a fundamental question: does lack of simulations of transition generate an unrealistic new equilibrium? This may be a reason why there is a key dis-connection between economic modeling and technical modeling. Economic modeling on the equilibrium basis naturally predicts incremental changes, while technical modeling could predict dramatic changes. Economic modeling, especially with CGE models such as FASOM, FAPRI, and GTAP, might not predict major technology innovations as society has experienced over time. Thus, one may question the rationale of using economic modeling for developing regulation that is intended to promote technology innovations such as advanced biofuels.

Programming linkage of FASOM and FAPRI may be a very challenging, if not impossible, task. However, the outputs and inputs of the two models and the information flows between the two models should be clearly presented in DRIA. Eventually, a model with both domestic and international coverage may be the way to go. But data availability for such model will be a major issue to ensure necessary modeling resolution level. Existing global scale models (such as GTAP) were created for different purposes. Their adaptation for accurate biofuel LUC simulations will continue to be a time- and resource-consuming process.

For now, detailed presentation of information flows between FASOM and FAPRI and comparison of the simulation results for the issues covered in both models (such as U.S. domestic LUCs) could be made for shedding light on differences and similarities between the two models.

**B. Upstream GHG Emission Factors**

*Charge Question 1: We have used emission factors from GREET to represent GHG emissions from fertilizer production and petroleum fuel use in the U.S. and to represent emissions from fertilizer production internationally. What other data or modeling sources should we use?*

*Charge Question 2: What better ways exist to link the GHG emission factors with results of different models?*

Both GREET and FASOM have emission co-efficients for some agricultural activities (such as fertilizer application rates, N2O emissions in agricultural fields, energy use of farming, etc.). It would be helpful if EPA presents a comparison between the two models for where data are available in both models. This comparison will shed light on differences and similarities between the two models. Where differences exist between the two models, EPA may decide to reconcile the differences.

**C. Electricity Production Modeling**

*Charge Question 1: We have used GREET electricity factors that represent the average U.S. grid to represent electricity factors for agriculture, biofuel production use, and biofuel electricity production offset. Is this scientifically justifiable?*

*Charge Question 2: What other regional or marginal sources of electricity GHG emissions factors should we be using?*

Use of U.S. average electricity GHG co-efficients is a good first step. The effects of electricity use on biofuel LCA results are generally small. However, since present and near future U.S. biofuel production will concentrate primarily in the U.S. Midwest, EPA could have used Midwest electricity generation mix to generate electricity GHG co-efficients for biofuel evaluation.

**D. Fuel and Feedstock Transport**

*Charge Question 1: We have used GREET factors to represent transportation emissions for biofuel feedstock, crude oil, and finished product transport and distribution. Is this scientifically justifiable?*

*Charge Question 2: What other sources of transport GHG emissions factors should we be using?*

*Charge Question 3: Are there models or sources of data that would capture indirect or market impacts on the transportation sector and transportation sector GHG emissions for the different products considered?*

Transportation activities usually have a small contribution to life-cycle GHG emissions of biofuels and petroleum fuels. While GREET simulation of transportation activities is aggregate and crude, getting into details of transportation logistics for different feedstocks and fuels is time consuming and the benefit of doing so may be minimal.

## E. Overall Model Linkage

*Charge Question 1: Are there any other adjustments or calibrations we can make across these models in order to ensure that they are as comparable as possible and lead to consistent results?*

See my comments above on model comparisons where appropriate.

# Appendix F

## Curricula Vitae of Selected Reviewers

| CURRICULUM VITAE |  |
| ---: | --- |
| **PERSONAL INFORMATION** | |
| Name | Banse, Martin |
| E-mail | martin.banse@wur.nl |
| Nationality | German |
| Date of birth | 10.03.1961 |
| | |
| **WORK EXPERIENCE** | |
| Dates (from – to) | Since March 2006 |
| Name of employer | LEI-WUR, The Hague (Netherlands) |
| Type of business or sector | Research |
| Occupation or position held | Senior Researcher |
| | |
| Dates (from – to) | 2001 – February 2006 |
| Name of employer | Georg-August Universität Göttingen (Germany) |
| Type of business or sector | University |
| Occupation or position held | Assistant Professor |
| Dates (from – to) | 1996 - 2001 |
| Name of employer | Georg-August Universität Göttingen (Germany) |
| Type of business or sector | University |
| Occupation or position held | PostDoc reseeacher |
| Main activities and responsibilities | Research and lectures |
| | |
| **EDUCATION AND TRAINING** | |
| Dates (from – to) | 1990 - 1996 |
| Name and type of organisation providing education and training | Georg-August Universität Göttingen (Germany) |
| Principal subjects/occupational skills covered | Agricultural economics, (Ph.D. Thesis: Transition of Hungarian Agri-food Industries) |
| Title of qualification awarded | Ph D. |
| Level in national classification | Level A |
| | |
| Dates (from – to) | 1984 -1990 |
| Name and type of organisation providing education and training | Georg-August Universität Göttingen (Germany) |
| Principal subjects/occupational skills covered | Agricultural economics (Diploma Thesis: Economy-wide impact of agricultural policies in Germany) |
| Title of qualification awarded | Diploma |
| Level in national classification | Level A |

**COMPETENCES**

- Applied policy analysis, especially the analysis of international agricultural trade policy as well as bioenergy.
- Quantitative analysis of policy measures and structural changes based on partial and general equilibrium approaches.
- Data processing, econometric estimation of required parameters for

quantitative models.

- Development of computable models (partial and general equilibrium) and required data base.
- Analysis of the institutional setting of international agricultural trade policy, especially the further development of the WTO framework.
- Analysis of trade and agricultural policy analysis in transition economies.
- Economics of EU integration: Analysis of agricultural market, financial and distributional, effects of EU enlargement to Central European countries

SELECTED PUBLICATIONS

- Banse, M., A. Tabeau, G. Woltjer, G. and H. van Meijl (2008). Will EU Biofuel Policies Affect Global Agricultural Markets? European Review of Agricultural Economics 35(2):117-141.
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- Peter Witzke, Martin Banse, Horst Gömann, Thomas Heckelei, Thomas Breuer, Stefan Mann, Markus Kempen, Marcel Adenäuer and Andrea Zintl (Ignacio Pérez Domínguez and Marc Müller, eds.) (2008). Modelling of Energy-Crops in Agricultural Sector Models - A Review of Existing Methodologies. Published by European Commission, JRC/IPTS, Seville. http://ftp.jrc.es/EURdoc/JRC42597.pdf
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- Banse, M. (2003). Russia at the Gate to WTO. Impact of Russian WTO Membership on Mongolia. Study No. 6. International Trade Policy/WTO. Ministry of Industry and Trade. Ulaanbaatar, Mongolia. http://www.trade-policy.mn/pdf/study-06.pdf (06.09.05)

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**POSITIONS**

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| 2007 - Present | PRINCETON UNIVERSITY (Woodrow Wilson School of Public Policy and Princeton Environmental Initiative)<br>*Research Scholar and Lecturer in Public and International Affairs*<br><br>THE GERMAN MARSHALL FUND OF THE UNITED STATES<br>*Transatlantic Fellow* |

**PREVIOUS EMPLOYMENT**

| | |
|---|---|
| 2007-08 | GEORGETOWN ENVIRONMENTAL LAW AND POLICY INSTITUTE, GEORGETOWN UNIVERSITY LAW CENTER, *Senior Fellow* |
| 2007 | MARYLAND DEPARTMENT OF NATURAL RESOURCES<br>*Special Assistant to the Secretary for the Chesapeake Bay* |
| 1989-2007 | ENVIRONMENTAL DEFENSE FUND<br>*Senior Attorney, Co-Founder and Co-Director, Center for Conservation Incentives*<br>Led work on wetlands, flood policy reform, federal agricultural policies and many ecosystem restoration efforts |
| 1987-1989 | GOVERNOR ROBERT P. CASEY, Pennsylvania<br>*Deputy General Counsel*<br>Oversaw education and environment legal departments, litigated at all federal and state levels, General Counsel to Pennsylvania Board of Education |
| 1986-1987 | HON. EDWARD R. BECKER, U.S. Court of Appeals (3d Circuit), law clerk |
| Summers 1984-1986 | HELLER, EHRMAN, WHITE & McAULIFFE, San Francisco<br>PAUL, WEISS, RIFKIND, WHARTON & GARRISON, Washington, D.C.<br>WEIL, GOTSHAL & MANGES, New York |
| 1980 | New York City cab driver |

**EDUCATION**

| | |
|---|---|
| 1983-1986 | YALE LAW SCHOOL, J.D.<br>*Senior Editor, Yale Law Journal,* Coker Fellow (taught first year writing) |

| | |
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| 1978-<br>1982 | AMHERST COLLEGE, B.A.<br>*Summa Cum Laude, Phi Beta Kappa* |
| 1981 | UNIVERSITY OF ZIMBABWE, Semester abroad |

**AWARDS**

National Wetlands Protection Award (1993) – Awarded by United States Environmental Protection Agency & Environmental Law Institute

THOMAS J. WATSON FOUNDATION – Fellowship award in 1982-83 to study worker participation in management in Europe.

## SELECTED PUBLICATIONS

Biofuels

Searchinger T., "Biofuels:  Effects on Land and Fire: Exchange, "*Science* 321:200 (2008)

Searchinger, T. & R.A. Houghton, "Biofuels Clarifying Assumptions: Exchange," *Science* 322:372-374 (2008)

Searchinger T., et al., "Use of U.S. Croplands for Biofuels Increases Greenhouse Gas Emissions Through Land Use Change," *Science* 319:1238-1240 (2008)

Searchinger, T., et al., Online Supporting Materials for Searchinger T., et al., "Use of U.S. Croplands for Biofuels Increase Greenhouse Gas Emissions Through Land Use Change," *Science* 313:1238-1240 (2008)

Searchinger, T., *Greenhouse Gas Emissions from Biofuels:  How Land Use Change Alters the Equation* (German Marshall Fund, Washington, DC 2008)

Searchinger, T. & Ralph Heimlich, *Greenhouse Gas Emissions from Soy-Based Biodiesel Incorporating Land Use Change*, paper presented at Farm Foundation workshop on lifecycle emissions from biofuels, Miami Beach, FL, January, 2008 (to be incorporated into published proceedings in press)

Searchinger, T., *Response to New Fuels Alliance & Wang & Haq Criticisms of New Science Papers* (2008) (monograph)

Searchinger, T., "Government Policies and Drivers of World Biofuels, Sustainability Criteria, Certification and Their Limitations" in SCOPE Biofuels Book to be published by Cornell University Press (in press)

Searchinger, T., *Summaries of Analyses in 2008 of Biofuels Policies by International and European Technical Agencies* (German Marshall Fund, Washington, DC 2008)

*Water and Agriculture*

Searchinger, T. "Cleaning Up the Chesapeake Bay: How to Make an Incentive Approach Work for Agriculture," *Southern Environmental Law Journal* (2008)

Searchinger, T. "The Procedural Due Process Approach to Administrative Discretion: The Courts' Inverted Analysis," 93 *Yale L.J.* 1017 (1986).

Searchinger, T. & D. Rader, "Bush's Cynical Attack on Wetlands," *New York Times* (August 19, 1991)

Searchinger, T., "The Murky Water of Wetlands Regulation," *Christian Science Monitor* (August 26, 1991)

Searchinger, T. (principal author*), How Wet Is a Wetland? The Impacts of the Proposed Revisions to the Federal Wetlands Delineation Manual*. (Environmental Defense Fund and World Wildlife Fund, Washington, D.C. 1992) (book) (Principal author)

Searchinger, T. "Wetland Issues 1993: Challenges and a New Approach," 4 *Mar. J. Cont. Legal. Issues* 13 (1993)

Searchinger, T. "Pollution Trading to Protect the Environment: Lessons from Acid Rain," *Revista de la Economia Social y de la Empresa* No. 16, (1993) (title translated from Spanish)

Searchinger, T., "Preliminary Thoughts from a Member of the Environmental Community Regarding the Proposed East River Tidal Barrage," in *Final Conference Proceedings on the East River Tidal Barrage* (American Society of Civil Engineers, Columbia University and New York Academy of Sciences) (April 29, 1993)

Searchinger, T. "Money Down the Drain," *New York Times* (May 21, 1993) (op-ed)

Searchinger, T., *Food For Thought: The Case for Reforming Farm Programs to Preserve the Environment and Help Family Farmers, Ranchers and Foresters* (2001) (principal author)

Searchinger, T (principal author)., *Katrina's Costly Wake, How America's Most Destructive Hurricane Exposed a Dysfunctional, Politicized Flood-Control Process* (2006)

Searchinger, T & S. Friedman, *Getting More Bank for the Buck: An Evaluation of EQIP Ranking Criteria* (EDF 2003)

Faber, S. & T. Searchinger, *Fresh Ideas for a Farm Safety Net* (EDF 2006)

Searchinger, T., *A Brief Summary of Agricultural Conservation Program* (ABA Enviornment Conference, Keystone, Colorado, 2005)

<u>Legal</u>

Searchinger, T. "The Procedural Due Process Approach to Administrative Discretion: The Courts' Inverted Analysis," 93 *Yale L.J.* 1017 (1986).

Searchinger, T., "Lucas v. South Carolina Coastal Commission: An Enigmatic Approach to the Environmental Regulation of Land," <u>in</u> John Echeverria (ed.), *Let the People Judge: Wise Use and the Private Property Rights Movement* (Island Press, Washington, DC 1995)

Searchinger, T. & F. Runge, "Who's Really Getting Taken?" *The New Democrat* (1995)

Searchinger, T., *Economic Implications of Takings Law*, Georgetown University Law Center CLE Conference (2002)

PRESENT FOCUS AND PRIOR WORK DESCRIPTION

PRESENT RESEARCH FOCUS

Present research focuses on policy challenges in reducing greenhouse gas emissions from agriculture and the environmental effects of biofuels.

ENVIRONMENTAL DEFENSE FUND

Led work on wetlands protection, the Clean Water Act, federal agricultural policies, flood policy, takings and major ecosystem restoration work in the Everglades, Missouri and Mississippi River ecosystems.

<u>Agriculture and Private Land Incentive Work</u>

Co-founder of Center for Conservation Incentives, a center with annual budget of $2.5 million and 20 staff dedicated to expanding use of incentives on private land

Proposed Conservation Reserve Enhancement Program to USDA. Helped draft and win approval for state plans restoring hundreds of thousands of acres of wetlands and riparian buffers along the Minnesota and Illinois Rivers, and the Chesapeake Bay.

Created and coordinated the "Carrot Coalition" that successfully advocated large increase in conservation funding in 2002 farm bill.

Helped design ongoing innovative advanced nutrient management programs in Iowa and Pennsylvania and author of many detailed analyses of agricultural programs.

<u>Wetland Protection and Takings</u>

Won National Wetland Protection award from ELI/EPA for work as principal author of *How Wet is a Wetland?*, a book that helped persuade Bush Administration to abandon proposed changes in wetland definition in 1991-1992

Author of amicus briefs in virtually all wetland and takings cases before the U.S. Supreme Court over the last fifteen years, as well as many Court of Appeals cases.

Many articles and speeches on economic and legal issues related to takings

Substantial work in resisting amendments to Clean Water Act and Takings legislation in 1995

Significantly influenced Clinton Administration wetland agenda in 1993

<u>Major Ecosystem Work</u>

Attorney in major water quality litigation regarding the Everglades (1989-present), and complex multi-party Missouri River litigation for 2003-2006.

In depth analysis and advocacy work related to Coastal Louisiana restoration, Everglades restoration, and restoration of the Upper Mississippi River and author of several reports

<u>Flood and Water Project Policy</u>

Made special presentation to Vice-President Gore and cabinet members regarding non-structural responses to great Upper Mississippi River flood of 1993, which helped lead to largest floodplain buy-out effort in U.S. history

Introduced idea of institutionalized independent peer review of water projects in Congressional testimony in 1999, which Senate enacted in 2006.

Represented Army Corps of Engineers economist in disclosing wrongdoing on study of

Upper Mississippi River lock expansions and served as major source for extensive press coverage of flaws in Corps of Engineers planning process in 2000 and 2001

Testified frequently to Congress and National Academy of Sciences on potential reforms to flood policies and navigation policies

Other

Work on Acid Rain trading scheme incorporated into 1990 Clean Air Act, and extensive site-specific and regulatory work related to sewage treatment plants, combined sewer overflows, and drinking water protection and conservation

GOVERNOR ROBERT P. CASEY

Deputy General Counsel. Provided general oversight of legal staff of environment and education departments.

Reviewed and approved all regulations, all federal litigation and attorney hiring.

Authored several briefs to the U.S. Supreme Court and handled significant state litigation including $600 million tax case, and two cases involving state separation of powers.

Led year-long negotiations on safety improvements at nuclear power plant.

# John J. Sheehan

*Home: 7044 Fox Paw Trail, Littleton, CO 80125*
*Tel: 303.932.2628 Mobile: 303.921.8514 email: jsheehan303@me.com*

**PROFESSIONAL EXPERIENCE**

**University of Minnesota Institute on the Environment, St. Paul, Minnesota**
**February 2009 to present**

**Program Coordinator, Biofuels Sustainability**

**SHEEHANBOYCE, LLC, LITTLETON, COLORADO**
**August 2008 to present**

**Principal**

Consultant on biofuels and sustainability. Clients include DuPont, Biotechnology Industry Organization, AgProcessing, Inc., the University of Minnesota, the National Biodiesel Board, and the Natural Resources Defense Council.

**LIVEFUELS, INC., MENLO PARK, CA**
**August 2007 to August 2008**

**Vice President, Strategy and Sustainable Development**

- Established critical business partnerships
- Developed detailed echno-economic model of algae oil production options
- Planned and led first algae harvest campaign at southern California site
- Organized and wrote comprehensive two-volume proposal to Department of Defense for development and commercialization of algae-based jet fuel
- Conducted various strategic and technical analyses
- Represented the company

**NATIONAL RENEWABLE ENERGY LABORATORY, GOLDEN, COLORADO**
**July 2001 to July 2007**

**Senior Engineer II, 2004 to 2007**
**Senior Engineer I, 1995 to 2003**
**Senior Project Coordinator, 1991 to 1994**

2005 to 2007

**Strategic Energy Analyst, Strategic Energy Analysis Center**
Key responsibilities included leading cross-cutting strategic analyses of DOE's energy efficiency and renewable energy technology portfolio. Major products included:

- 50-year projected benefits of energy efficiency and renewable energy technology based on integrated energy market models
- 30-year projected market penetration for biofuels technology in support of Presidential advanced energy initiative using system dynamics model

# *John J. Sheehan*

*Home: 7044 Fox Paw Trail, Littleton, CO 80125*
*Tel: 303.932.2628 Mobile: 303.921.8514 email: jsheehan303@me.com*

**PROFESSIONAL EXPERIENCE (CONT'D)**

**NATIONAL RENEWABLE ENERGY LABORATORY, GOLDEN, COLORADO**
**July 2001 to present (continued)**

1998 to 2005

**General Support to DOE Client and NREL Biomass Program Technology Manager**
Rapid response for DOE "fire drills" as well as ongoing support for development of high level analysis and reports on an as-needed basis for DOE and for the NREL technology manager. Frequent spokesperson for DOE and NREL.

2001 to 2003

**Lead, Life Cycle Assessment (LCA) of Corn Stover-to-Ethanol Technology**
Landmark study of energy, air quality, greenhouse gas and soil impacts of stover-to-ethanol.

- Unprecedented multi-disciplinary, multi-institutional team of scientists and engineers
- First time rigorous modeling of soil carbon and soil erosion impacts incorporated in an LCA
- Published in Yale University's *Journal of Industrial Ecology*

1998 to 2002

**Biofuels Strategic Analyst**
Responsible for a wide variety of projects. These include:

- Lead author 1999, 2000 and 2001 editions of bioethanol/biofuels annual outlook reports
- Lead author 1998, 2000, 2001, 2002 editions of bioethanol/biofuels multi-year technical plans
- Contributor to 2000 and 2002 process design reports for bioethanol and first edition of DOE's *Biomass Multi-Year Program Plan*

1995 to 1998

**Biodiesel Project Manager**
Responsible for coordinating, monitoring and reporting on internal and external biodiesel R&D

- Led a multi-institutional team in the first life cycle assessment of biodiesel made from soybeans
- Co-led a close-out report on DOE's 20-year research program on microalgae

1993 to 1998

**Biofuels Program Strategic Planner**
Responsible for development of multi-year technical and strategic plans

- Contributed to 1994 *Biofuels at the Crossroads* plan and 1995 *NREL Biofuels Strategic Plan*
- Lead author 1996 and 1997 editions of *Multi-Year Technical Plan for Ethanol*

1991 to 1993

**Biofuels Program Coordinator.**
Responsible for monitoring and reporting of subcontracted and in-house research activities

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1990 to 1991

**MERCK PHARMACEUTICAL COMPANY, WEST POINT, PENNSYLVANIA**
**July 1990 to July 1991**

**Senior Process Engineer**
Process development and support of commercial recombinant vaccine production line; including improvements to downstream recovery of the Recombivax™ hepatitis B vaccine from yeast

# John J. Sheehan

*Home: 7044 Fox Paw Trail, Littleton, CO 80125*
*Tel: 303.932.2628 Mobile: 303.921.8514 email: jsheehan303@me.com*

**PROFESSIONAL EXPERIENCE (CONT'D)**

**W.R. GRACE & CO CORPORATE RESEARCH DIVISION, COLUMBIA, MARYLAND**
**February 1985 to July 1990**

1989 to 1990 — **Senior Research Engineer**
Responsible for the development and testing of new membrane filtration devices for use in bioprocessing in conjunction with W.R. Grace's Amicon Division.

1987 to 1989 — **Research Engineer**
Responsible for development and scale up enzyme recovery step in process for l-aspartame synthesis

1985 to 1987 — **Senior Engineer**
Responsible for bioprocess development activities, including the scale up of phenylpyruvic acid production as a precursor for l-phenylalanine production

**RADIAN CORPORATION, MCLEAN, VIRGINIA**
**June 1979 to June 1982**

**Chemical Engineer**
Responsible for environmental analysis of energy technologies for EPA and DOE

**OTHER EXPERIENCE**

**DOUGLAS COUNTY SCHOOL DISTRICT RE-1**
**BOARD OF EDUCATION, CASTLE ROCK, COLORADO**
**November 1993 to November 2005**

**EDUCATION**

1985 — **Master of Science in Chemical Engineering**
Lehigh University, Bethlehem, Pennsylvania
September 1982 to February 1985

- Masters Thesis: *Evaluation of the Operating Characteristics of a Hollow Fiber Microporous Filter for Concentration of Cell Suspensions*

1979 — **Bachelor of Science and Engineering in Chemical and Biochemical Engineering**
University of Pennsylvania, Philadelphia, Pennsylvania
September 1975 to May 1979

- Spring Semester 1978 at Université de Technologie de Compiègne, Compiègne, FRANCE

**SKILLS**

- Ability to work effectively with DOE clients and other stakeholders
- Excellent written and oral communication skills
- Ability to lead multidisciplinary and multi-institutional teams
- Ability to collect and incorporate broad based stakeholder concerns
- Advanced computer skills in life cycle assessment, project management. word processing, spreadsheet, graphics and presentation software
- Skilled life cycle practitioner

# John J. Sheehan

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*Tel: 303.932.2628 sheehan303@comcast.net*

## Selected Publications

Sheehan, J. "Biofuels and the conundrum of sustainability. *Current Opinions in Biotechnology. In Press.*

Lynd, L.; Larson, E.; Greene, E.; Laser, M.; Sheehan, J.; Dale, B.; McLaughlin, S.; Wang, M. "The role of biomass in America's energy future: Framing the analysis". *Biofuels, Bioproducts and Biorefining. 3:113-123 (2009).*

Lynd, L. Laser, M., Bransby, D., Dale, B., Davison, B., Hamilton, R., Himmel, M., Keller, M., McMillan, J., Sheehan, J., Wyman, C.. "How biotech can transform biofuels." *Nature Biotechnology 26*, 169 - 172 (2008).

Pena, N. and J. Sheehan, "Biofuels and Transportation." *CDM Investment Newsletter: A joint initiative of BEA International and the Climate Business Network. No 3,* pp 3-10 *(2007).*

*Office of Energy Efficiency and Renewable Energy, Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs: FY 2008. Budget Request*. Prepared by National Renewable Energy Laboratory, Golden, CO (2007). http://www1.eere.energy.gov/ba/pba/gpra_estimates_fy08.html

Sheehan, J. "Putting 'Sustainable' before 'Energy': Biofuels in a Sustainable Energy Future." *Viewpoints Americas*. Americas Society and the Council of the Americas, New York, NY (2007). http://www.americas-society.org/article.php?id=522

Sheehan, J. "Potential Carbon Emissions Reductions from Biofuels by 2030." In *Tackling Climate Change in the U.S.: Potential Carbon Emissions Reductions from Energy Efficiency and Renewable Energy* (Kutscher, C., ed.). American Solar Energy Society (2007). www.ases.org/climatechange

Graham, R.; Nelson, R.; Sheehan, J.; Perlack, R.; Wright, L. "Current and Potential U.S. Corn Stover Supplies." *Agronomy Journal,* Vol 99, pp. 1-11 (2007).

*Office of Energy Efficiency and Renewable Energy, Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs: FY 2007. Budget Request*. Prepared by National Renewable Energy Laboratory, Golden, CO (2006). http://www1.eere.energy.gov/ba/pba/gpra_estimates_fy07.html

Paustian, K.; Antle, J.; Sheehan, J.; Paul, E. *Agriculture's Role in Greenhouse Gas Mitigation.* Pew Center on Global Climate Change. Arlington, Virginia (2006).

Sheehan, J.; Paustian, K.; Walsh, M.; Nelson, R. "Energy and Environmental Aspects of Using Corn Stover for Fuel Ethanol?" *Journal of Industrial Ecology*, Vol. 7, Nos. 3-4, p 117-146 (2003).

Nelson, R.G., Marie E. Walsh, John J. Sheehan, and Robin L. Graham. 2003. "Methodology to Estimate Removable Quantities of Agricultural Residues for Bioenergy and Bioproduct Use." *Applied Biochemistry and Biotechnology*, Vol. 113 pp. 13-26.

Sheehan, J.; Himmel, M. "Outlook for Bioethanol Production from Lignocellulosic Feedstocks: Technology Hurdles." *Agro-Industry*, Vol 12, No. 5. pp. 54-57 (2001).

Sheehan, J. "The Road to Bioethanol: A Strategic Perspective of the U.S. Department of Energy's National Ethanol Program." *ACS Symposium Series 769: Glycosyl Hydrolases for Bioconversion*. American Chemical Society, Washington, D.C., pp. 2-25 (2001).

Wooley, R.; Ruth, M.; Glassner, D.; Sheehan, J. "Process Design and Costing of Bioethanol Technology: A tool for Determining the Status and Direction of Research and Development." *Biotechnology Progress*, Vol 15, pp. 794-803 (1999)

Sheehan, J.; Himmel, M. "Enzymes, Energy and the Environment: A Strategic Perspective on the U.S. Department of Energy's Research and Development Activities for Bioethanol." *Biotechnology Progress*, Vol 15, pp. 817-827 (1999)

John Sheehan; Camobreco, V.; Duffield, J.; Graboski. M.; Shapouri, H. *Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus: Final Report*. National Renewable Energy Laboratory, Golden, CO (1998).

Sheehan, J.; Tyson, K. S.; Duffield, J.; Shapouri, H.; Camobreci, V.; Graboski, M. "Life Cycle Inventories of Biodiesel and Petroleum Diesel. *BioEnergy '98: Expanding Bioenergy Partnerships—Proceedings, Vol 2*, pp. 1230-1239 (1998). Report No. NREL/SR-580-24089.

Sheehan, J.; Dunahay, T.; Benemann, J; Roessler, P. *A Look Back at the U.S. Department of Energy's Aquatic Species Program—Biodiesel from Algae*. Prepared for the U.S. Department of Energy Office of Fuels Development. National Renewable Energy Laboratory, Golden, CO (1998). Report No NREL/TP-580-24190.

Himmel, M.E.; Adney, W.S.; Baker, J.O.; Elander, R.; McMillan, J.D.;Nieves, R.A., Sheehan, J.J.; Thomas, S.R.; Vinzant, T.B.; Zhang, M. "Chapter 1: Advanced Bioethanol Production Technologies: A Perspective." In *ACS Symposium Series: Fuels and Chemicals from Biomass*, pp 2-45 (1997). American Chemical Society, Washington, DC.

Sheehan, J. "Bioconversion for Production of Renewable Transportation Fuels in the United States: A Strategic Perspective." *ACS Symposium Series No. 566: Enzymatic Conversion of Biomass for Fuels Production* (Himmel, M et al, ed.) American Chemical Society, Washington, D.C., pp. 1-52 (1994).

Sheehan, J.; Levy, P. "Performance Characteristics of Polysulfone and Cellulose Membranes for the Ultrafiltration of Biological Streams." *BioPharm*, Vol 4, No. 4, (1991).

Sheehan, J.; Hamilton, B.; Levy, P. "Pilot Scale Membrane Filtration of an Extracellular Bacterial Protease." *ACS Symposium Series No. 419: Downstream Processing and Bioseperations* (Hamel, J.-P. et al, ed). American Chemical Society, Washington, D.C., pp. 130-155 (1990).

Kargi, F.; Curme, J.; Sheehan, J. "Solid Substrate Fermentation of Sweet Sorghum to Ethanol." *Biotechnology and Bioengineering*; Vol 27. pp. 34-40 (1985).

# Recent Presentations

*Algae for biofuels production*. Presented at CTSI Clean Technology Conference, Boston, MA. June 6, 2008

*The life cycle of biofuels—the nitrogen problem*. Presented to the US Environmental Protection Agency Science Advisory Board's Integrated Nitrogen Committee, Washington, DC. April 11, 2008.

*Defining sustainable biofuels—or, "It isn't easy being green"*. Presented at Ecological Society of America Workshop on the Ecological Dimensions of Biofuels. Washington, DC, March 10, 2008.

*A US perspective on the economic sustainability of biofuels.* Presented at US-EC Task Force on Biotechnology Research Workshop on Biotechnology for the Development of Sustainable Bioenergy, San Francisco, CA. February 22, 2008.

*Algae—an "end-run" around the food-vs-fuel debate?* Presented at the Sixth Legislative Agriculture Chairs Summit, St. Louid, MO. January 20, 2008.

*Impacts of policy mechanisms on biofuels and agriculture.* Presented at NREL Energy Policy Forum, Golden, CO. November 27, 2007.

*Algae for biofuels*. Presented at Platt's Renewable Diesel Conference, Houston, TX, November 2007.

Algae as a source of jet fuel. Presented at Consortium for Alternative Aviation Fuels Initiative, Washington, DC. November 7, 2007.

*The renaissance of algae as a vital element of long term biofuels production*. Presented at National Biodiesel Board Biodiesel Technical Workshop (Invitation Only), Chicago, IL, October 18, 2007. (First prize winner for best talk).

*Agriculture and climate change*. Presented at the National Association of State Departments of Agriculture National Meeting, Seattle, Washington, September 25, 2007.

*Algae: biofuel of the future?*. Inside CleanTech Webinar September 18, 2007.
www.media.cleantech.com

**MICHAEL Q. WANG, Ph.D.**

Senior Scientist
Manager of the Systems Assessment Section
Center for Transportation Research
Energy Systems Division

Argonne National Laboratory

**SUMMARY**

Dr. Wang is the current manager of the Systems Assessment Section of the Center for Transportation Research (CTR) at Argonne National Laboratory. He manages 14 members and an annual budget of $4 million. Dr. Wang's research areas include the evaluation of energy and environmental impacts of advanced vehicle technologies and new transportation fuels, the assessment of market potentials of new vehicle and fuel technologies, and the projection of transportation development in emerging economies such as China. In addition to his work in the United States, Dr. Wang has collaborated with governmental agencies, automotive companies, energy companies, universities, and research institutions in China, Japan, Brazil, Canada, South Africa, Europe, and Southeast Asia.

Dr. Wang's accomplishments include the development of Argonne's GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) software model for life-cycle analysis of advanced vehicle technologies and new fuels. At present, GREET has more than 10,000 registered users worldwide. Dr. Wang's research and the GREET model have been used by governmental agencies in North America, Asia, and Europe to develop transportation fuel policies such as low-carbon fuel standards and vehicle greenhouse gas emission regulations.

As an active participant in professional organizations — including the Society of Automotive Engineers and the Transportation Research Board — Dr. Wang chairs the committees of professional associations and organizes technical sessions at major conferences and workshops. He also has participated in several annexes of the International Energy Agency. Dr. Wang is an active board member of the not-for-profit Energy Foundation and the International Council for Clean Transportation, and he is the former chair of the Subcommittee on the International Aspects of Transportation Energy and Alternative Fuels of the U.S. Transportation Research Board. Additionally, Dr. Wang serves as a technical advisor to the China Automotive Technology and Research Center and is a member of the External Advisor Board of the Institute for Environmental Science and Policy at University of Illinois at Chicago.

Dr. Wang has published extensively. He has authored 173 publications (77 journal articles and book chapters, 24 conference papers, 35 peer-reviewed formal reports, and 37 informal reports and technical memorandums). Further, as a sought-after speaker, Dr. Wang has made 120 invited presentations at professional conferences and to various organizations.

## EDUCATIONAL BACKGROUND

| | |
|---|---|
| Ph.D., 1992 | Environmental Science, University of California at Davis (Thesis: The Use of a Marketable Permit System for Light-Duty Vehicle Emission Control) |
| M.S., 1989 | Environmental Science, University of California at Davis |
| B.S., 1982 | Agricultural Meteorology, China Agricultural University, Beijing |

## PROFESSIONAL EXPERIENCE

| | |
|---|---|
| 1993 to present | Section Manager and Vehicle and Fuel Systems Analyst, Center for Transportation Research, Energy Systems Division, Argonne National Laboratory |
| 1992–1993 | Assistant Research Engineer, Institute of Transportation Studies, University of California at Davis |
| 1991–1993 | Special-term Scientist Appointee, Center for Transportation Research, Energy Systems Division, Argonne National Laboratory |
| 1991–1992 | Post-doctoral Researcher, Center for Transportation Analysis, Oak Ridge National Laboratory |
| 1989–1991 | Post-graduate Researcher, Department of Civil Engineering and Division of Environmental Studies, University of California at Davis |
| 1982–1985 | Lecturer, Agro-Meteorology Department, China Agricultural University, Beijing |

## PROFESSIONAL ASSOCIATION MEMBERSHIPS

| | |
|---|---|
| 04/2008 to present | Member, Alternative Transportation Fuels Committee, Transportation Research Board, National Research Council, USA |
| 01/1998 to present | Member, North American Chinese Overseas Transportation Association |
| 09/1993 to present | Member, Society of Automotive Engineers |
| 02/2002–10/2008 | Chair, Subcommittee on International Aspects of Transportation Energy and Alternative Fuels, Transportation Research Board, National Research Council, USA |
| 07/1990–06/2008 | Member, Mobile Source Committee, Air and Waste Management Association |
| 03/1997–08/2007 | Member, Energy Conservation Committee, Transportation Research Board, National Research Council, USA |

## MAJOR PROFESSIONAL AWARDS

| | |
|---|---|
| 06/2008 | Received the 2008 DOE Hydrogen Program R&D Award in Recognition of Outstanding Hydrogen Well-to-Wheels Analysis and Contributions to Systems Analysis |
| 04/2008 | Awarded a Certificate of Appreciation in recognition of outstanding contribution and commitment at Argonne National Laboratory to pollution prevention and environmental stewardship through development of the GREET life-cycle model, Office of Science, U.S. Department of Energy |
| 12/2007 | Received the Pollution Prevention/Waste Minimization Spirit Award, Argonne National Laboratory |
| 06/2007 | Received the Distinguished Performance Award, Board of Governors for Argonne National Laboratory |
| 05/2006 | Received an Honorable Mention for Awards for Excellence in Technology Transfer: GREET Model for Evaluating Energy/Emission Impacts of Advanced Vehicle/Fuels, Federal Laboratory Consortium for Technology Transfer |
| 05/2006 | Named Runner-Up for the Category of New Methods and Tools, 2005 SAE Environmental Excellence in Transportation Award: GREET Model for Transportation Life-Cycle Analysis |
| 05/2005 | Received the 2005 DOE Hydrogen Program R&D Award in Recognition of Outstanding Achievement in Developing a Hydrogen Production Cost Model Known as H2A |

## MAJOR PROFESSIONAL ACTIVITIES AND ADVISORSHIPS

| | |
|---|---|
| 11/2008 to present | Member of the Editorial Board of *Frontiers of Energy and Power Engineering in China,* High Education Press of China and Springer of the U.K. |
| 10/2008 to present | Member of the Advisory Board of the China Automotive Energy Research Center, Tsinghua University, China |
| 09/2008 to present | Member of the Sustainability Task Force Advisory Committee, National Biodiesel Board, USA |
| 08/2008 to present | Member of the Advisory Committee, The Fulbright Commission on Brazil–U.S. Biofuel Network, Brazil |
| 06/2007 to present | Expert, Working Group on Greenhouse Gases, Roundtable on Sustainable Biofuels, Switzerland |
| 06/2007 to present | Member of the board of the International Council for Clean Transportation |
| 10/2004 to present | Technical advisor to the China Automotive Technology and Research Center |
| 09/2003 to present | Member of the External Advisory Board, Institute for Environmental |

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|---|---|
| | Science and Policy, University of Illinois at Chicago |
| 12/2001 to present | Advisor and reviewer of the China Sustainable Energy Program of the Energy Foundation, San Francisco, CA |
| 04/2001 to present | Board Director, the Energy Foundation, San Francisco, CA |
| 12/2000 to present | Overseas Chinese Expert Advisor, Science and Technology Commission of Beijing Municipal Government |
| 11/2004–12/2006 | Member of the Technical Advisory Group for the Total Fuel-Cycle Analysis of Marine Transportation Project, Rochester Institute of Technology, New York |
| 06/2002–09/2006 | Member of a Ph.D. student dissertation committee, University of Illinois at Chicago |
| 08/2004–12/2005 | Invited reviewer for life-cycle analysis of gas-to-liquids, SasolChevron, London, U.K. |
| 02/2004–10/2005 | Member of the International Team, Sustainable Transportation Task Force, China Council for International Cooperation on Environment and Development |
| 01/2005 | Organized and chaired a technical session at the 2005 Annual Meeting of the Transportation Research Board, Washington, DC, Jan. 12 |
| 06/2001–06/2004 | Key participant of the IEA Annex XV on fuel-cell systems analysis |
| 05/2000–05/2003 | Member of the Technical Review Committee for a project on life-cycle assessment of corn stover to ethanol production, National Renewable Energy Laboratory, Golden, CO |
| 02/2002–04/2003 | Invited reviewer of a gas-to-liquid study, ConocoPhillips, Houston, TX |
| 1998–2003 | Organized technical sessions for the 1998, 1999, 2001, and 2003 Transportation Research Board annual meetings |
| 01/2000–01/2003 | Board director, North American Chinese Overseas Transportation Association |
| 07/2002–12/2002 | Invited reviewer of a life-cycle study of Fischer-Tropsch diesel, Sasol Technology Company, South Africa |
| 01/2002–10/2002 | Invited reviewer of a European well-to-wheels study on vehicle/fuel systems, Fuel-Cell Activities Group of the General Motors Corporation, Detroit, MI |
| 05/2000–10/2001 | Invited reviewer of a study on energy and emission benefits of fuel ethanol in China, Environmental Resources Management, Hong Kong |
| 07/1999–07/2001 | Member of the Technical Advisory Committee for a project on fuel-cycle analyses of vehicle/fuel systems, California Air Resources Board, Sacramento, CA |
| 01/2002 | Coordinated a workshop on life-cycle analysis of advanced vehicle |

| | |
|---|---|
| | technologies and transportation fuels for the 2002 Annual TRB Meeting, Washington, DC, Jan. 13 |
| 02/2001 | Invited reviewer of a gas-to-liquid study, Shell Gas and Power, U.K. |
| 1998–1999 | Organized technical sessions for the 1998 and 1999 annual meetings of the Air and Waste Management Association |
| 01/1998–10/1998 | Member of the Peer Review Committee for a project on life-cycle analysis of biomass to fuel oxygenates, California Air Resources Board, California Energy Commission, California Department of Forestry and Fire Protection, and California Department of Food and Agriculture, Sacramento, CA |
| 01/1996–10/1996 | Member of the Technical Advisory Committee for a study on economics and environmental impacts of alternative-fueled vehicles, Canadian Energy Research Institute, Calgary, Alberta, Canada |

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**INVITED PROFESSIONAL PRESENTATIONS (120)**

"Life-Cycle Analysis of Transportation Fuels and Plug-In Hybrids," Monthly Meeting of SAE Rockford-Beloit Section, Rockford, IL, November 3, 2008.

"Life-Cycle Analysis of Biofuels: Issues and Results," Biofuels and Sustainability Conference, University of Illinois at Urbana-Champaign, IL, October 21, 2008.

"Life-Cycle Analysis of Biofuels: Issues and Results," Special Committee on Domestic Biofuels, State of Wisconsin Joint Legislative Council, Madison, WI, October 14, 2008.

"Life-Cycle Analysis of Biofuels: Issues and Results," American Chemical Society Congressional Briefing, Washington, DC, August 1, 2008.

"GREET Life-Cycle Analysis Model Development," Workshop on Measuring and Modeling the Lifecycle GHG Impacts of Transportation Fuels, Berkeley, CA, July 1-2, 2008.

"U.S. Biofuel Development and Life-Cycle Energy and Greenhouse Gas Results," CICY, Merida, Mexico, June 25, 2008.

"Life-Cycle Analysis of Biofuels and Key Issues," Pan-American Congress on Plants and Bioenergy, Merida, Mexico, June 23, 2008.

"Issues and Results of Life-Cycle Analysis of Vehicle/Fuel Systems," USCAR Fuels Working Team, Southfield, MI, June 13, 2008.

"New Transportation Fuels and Advanced Vehicle Technologies: Issues and Life-Cycle Results," Workshop on Chinese Auto Industry Near-Term Energy Conservation and New Energy Potentials, Beijing, China, May 29-30, 2008.

"Life-Cycle Energy and Greenhouse Gas Results of Fischer-Tropsch Diesel Produced from Natural Gas, Coal, and Biomass," the 8th World GTL Summit, London, the U.K., May 13-14, 2008.

"Energy, Greenhouse Gas Emissions and Water Use of Fuel Ethanol," University of Minnesota, May 6, 2008.

"Energy, Greenhouse Gas Emissions and Water Use of Fuel Ethanol," Governors' Ethanol Coalition Meeting, Chicago, IL, April 28, 2008.

"Well-to-Wheels Energy and Greenhouse Gas Emission Results and Issues of Fuel Ethanol," Biomass 2008 Conference, Alexandria, VA, April 17-18, 2008.

"Well-to-Wheels Energy and Greenhouse Gas Emissions of Vehicle/Fuel Systems with the GREET Model," SAE Congress, Detroit, MI, April 15, 2008.

"Life-Cycle Energy and Greenhouse Gas Results of Fischer-Tropsch Diesel Produced from Natural Gas, Coal, and Biomass," the 7th GTLtec, Doha, Qatar, February 18-19, 2008.

"Well-to-Wheels Energy and Greenhouse Gas Emission Results and Issues of Biofuels," University of Illinois at Chicago, February 7, 2008.

"Biofuel Life-Cycle Results and Issues," Transportation Research Board Annual Meeting, Washington, DC, January 15, 2008.

"Challenges of Chinese Motor Vehicle Growth and Fuel Supply," Transportation Research Board Climate Change Workshop, Washington, DC, January 13, 2008.

"Well-to-Wheels Greenhouse Gas Emissions of Alternative Fuels," Governors' Summit on Alternative Transportation Fuels and Vehicle Technologies, Tampa, Florida, December 13-14, 2007.

"GREET Life-Cycle Analysis of Vehicle/Fuel Systems," Roundtable on Environmental Health Sciences, Research, and Medicine, Washington DC, November 29, 2007.

"Energy and Greenhouse Gas Impacts of Fuel Ethanol," Clean Vehicles and Fuels Symposium and Exhibition, Stockholm, Sweden, November 7-9, 2007.

"Energy and Greenhouse Gas Impacts of Fuel Ethanol," 2007 Biobased Product Outlook Conference, Iowa State University, Ames, IA, November 5, 2007.

“Life-Cycle Analysis of Biofuels with the GREET Model,” GBEP Meeting, Washington, DC, October 9, 2007.

“Well-to-Wheels Analysis of Transportation Fuels with the GREET Model,” Stationary Engine Combustion Conference, Downey, CA, September 19, 2007.

“Energy and Greenhouse Gas Impacts of Fuel Ethanol,” General Motors Corporation’s Fuel Ethanol Workshop, Beijing, China, September 20, 2007.

“Life-Cycle Analysis of Transportation Fuels with the GREET Model,” Harvard University, August 10, 2007.

“Well-to-Wheels Results of Transportation Fuels from the GREET Model,” Symposium on Climate Change, Endicott House, August 8-9, 2007.

“Life-Cycle Analysis of Transportation Fuels with the GREET Model,” Institute of Transportation Studies, University of California at Davis, July 24, 2007.

“Life-Cycle Analysis of Transportation Fuels with the GREET Model,” USCAR Fuels Working Group Meeting, Southfield, MI, July 19, 2007.

“Life-Cycle Energy and Greenhouse Gas Results of Fischer-Tropsch Diesel Produced from Natural Gas, Coal, and Biomass,” 2007 SAE Government/Industry Meeting, Washington, DC, May 14-16, 2007.

“Alternative Transportation Fuel Potentials for Energy and Environmental Benefits,” Shanghai Forum, Shanghai, China, May 24-27, 2007.

“Life-Cycle Analysis of Vehicle/Fuel Systems with the GREET Model,” NAS Review Committee Meeting, Washington, DC, April 25, 2007.

“Projection of Chinese Motor Vehicle Growth, Oil Demand, and CO2 Emissions through 2050,” 2007 SAE Congress, Detroit, MI, April 19, 2007.

“Life-Cycle Analysis of Bioethanol with the GREET Model,” First IFP/Ademe Workshop on Methodology of GHG Calculations for Production of Biofuels for Transportation, Paris, France, March 2, 2007.

“Life-Cycle Analysis of Bioethanol with the GREET Model,” Applied Physics Laboratory, Johns Hopkins University, February 8, 2007.

“Life-Cycle Energy and Greenhouse Gas Emission Impacts of Different Corn Ethanol Plant Types,” XVI International Symposium on Alcohol Fuels, Rio de Janeiro, Brazil, November 29, 2006.

“Alternative Transportation Fuels and Life-Cycle Effects,” GE Global Research Center, Niskayuna, NY, October 23, 2006.

“Status of Methanol Fuel and Methanol Vehicle Development in China,” the 4th Methanol Forum, Houston, TX, October 18, 2006.

“Energy and Greenhouse Gas Emission Impacts of Fuel Ethanol,” LERDWG Meeting, Washington, DC, September 13, 2006.

"Transportation Energy Use and Alternative Transportation Fuel Implications," Oriental Rostrum Shanghai, Shanghai, China, September 15, 2006.

"Energy and Greenhouse Gas Emission Impacts of Fuel Ethanol," World Biofuel Symposium, Beijing, China, September 14, 2006.

"Energy and Greenhouse Gas Emission Impacts of Fuel Ethanol," Ethanol School 2006, Montreal, Canada, September 29, 2006.

"Life-Cycle Analysis Results of Vehicle/Fuel Systems with the GREET Model," Energy Modeling Forum on Climate Change Impacts and Integrated Assessment, Snowmass, CO, August 3, 2006.

"Well-to-Wheels Analysis of Vehicle/Fuel Systems with the GREET Model," JASON Team, La Jolla, CA, July 17, 2006.

"Alternative Transportation Fuels Development and Issues in the U.S.," Alternative Fuel Study Team of the National Development and Reform Commission, Beijing, China, July 8, 2006.

"Chinese Transportation Energy Use and Sustainability Implications," SAE Government/Industry Meeting, Washington, DC, May 8, 2006.

"Well-to-Wheels Analysis of Vehicle/Fuel Systems with the GREET Model," IEA Annex VII Meeting, Palo Alto, CA, April 26, 2006.

"Well-to-Wheels Analysis of Vehicle/Fuel Systems with the GREET Model," California Energy Commission, Sacramento, CA, April 25, 2006.

"Well-to-Wheels Analysis of Vehicle/Fuel Systems," Workshop on Modeling the Oil Transition, Washington, DC, April 20-21, 2006.

"Energy and Greenhouse Gas Emission Impacts of Fuel Ethanol," Sustainable Bioenergy Workshop, Urbana, IL, April 14, 2006.

"Energy and Greenhouse Gas Emission Impacts of Fuel Ethanol," Ford Motor Company, Dearborn, MI, April 7, 2006.

"Vehicle Cycle Analysis of Advanced Vehicle Technologies and Energy and Emission Effects of Fuel Ethanol," GM R&D Center, Warren, MI, April 6, 2006.

"Well-to-Wheels Analysis of Advanced Vehicle Systems with New Transportation Fuels," Workshop on WTW Efficiency Analysis, Tokyo, Japan, March 7-8, 2006.

"Life-Cycle Analysis of Advanced Vehicle Technologies and New Fuels," Sustainable Systems Symposium, Ohio State University, Columbus, OH, March 2-3, 2006.

"Energy and Greenhouse Gas Emission Results of Fuel Ethanol," Governors' Ethanol Coalition Meeting on Ethanol Plant Permitting, Kansas City, MO, February 10, 2006.

"Chinese Energy Use and Sustainability Implications," School of Forestry and Environmental Studies, Yale University, New Haven, CT, February 9, 2006.

"Life-Cycle Analysis of Vehicle/Fuel Systems — Applications of the GREET Model," Northwestern University, Evanston, IL, January 18, 2006.

“Energy and Greenhouse Gas Emission Benefits of Cellulosic Liquid Fuels,” BIO Pacific Summit on Industrial Biotechnologies and Biofuels, Honolulu, Hawaii, January 13, 2006.

“Well-to-Wheels Results of Advanced Vehicle Technologies Fueled with Different Transportation Fuels,” Advanced Transportation Workshop, Global Climate Change Project of Stanford University, Palo Alto, CA, October 10-11, 2005.

“Energy and Greenhouse Gas Emissions Results of Fuel Ethanol,” IFQC Biofuels Policy and Technical Briefing, Washington, DC, October 5, 2005.

“Well-to-Wheels Analysis of Vehicle/Fuel Systems with the GREET Model,” EPA Mobile Source Technical Review Subcommittee Meeting, Washington, DC, September 13, 2005.

“Energy and Greenhouse Gas Emission Impacts of Fuel Ethanol,” National Corn Growers Association’s Renewable Fuels Forum at the National Press Club, Washington, DC, August 23, 2005.

“An Update of Energy and Greenhouse Gas Emission Impacts of Fuel Ethanol,” DOE/EU Biorefinery Workshop, Washington, DC, July 21, 2005.

“A Next Generation Modeling Framework for Well-to-Wheels Analysis of Hydrogen Fuel-Cell Vehicle Scenarios,” J. Koupal and M. Wang, SAE Government/Industry Meeting, Washington, DC, May 10, 2005.

“Well-to-Wheels Energy Use and Emissions of Advanced Vehicle/Fuel Systems,” M. Wang and N. Brinkman, SAE Congress, Detroit, MI, April 13, 2005.

“An Update of Energy and Emission Effects of Fuel Ethanol,” General Motors Corporation Energy and Environment Strategy Board, Pontiac, MI, April 6, 2005.

“Updated WTW Energy and Emission Effects of Fuel-Cell Vehicles with Hydrogen Produced from Different Pathways,” National Hydrogen Association Annual Meeting, Washington, DC, March 30, 2005.

“Integration of GREET into EPA’s MOVES Model,” MOVES Workshop, Ann Arbor, MI, March 16, 2005.

“Well-to-Wheels Energy and Greenhouse Gas Emissions of Fitscher-Tropsch Diesel,” California Energy Commission, March 14, 2005.

“Energy and Emission Effects of Vehicle/Fuel Systems,” University of Illinois at Chicago, March 8, 2005.

“An Update of Energy and Emission Effects of Fuel Ethanol,” presentation to three General Motors Corporation Vice Presidents, Detroit, MI, February 11, 2005.

“An Update of Energy and Emission Effects of Fuel Ethanol,” the 10th Annual National Ethanol Conference, Scottsdale, AZ, February 8, 2005.

“Well-to-Wheels Energy and Emission Effects of Hybrid Electric Vehicles and Fuel-Cell Vehicles,” Agricultural Equipment Technology Conference, Louisville, KY, February 13-15, 2005.

"Alternative Fuels and Powertrains: WTW Analysis of Energy Use, Greenhouse Gas Emissions, and Regulated Emissions," R. Larsen and M. Wang, Energy Panel Meeting, Naperville, IL, November 8, 2004.

"Well-to-Wheels Energy and Emission Effects of Hybrid Electric Vehicles and Fuel-Cell Vehicles in the U.S.," MIT/Industry Consortium on Advanced Automotive Electric/Electronic Components and Systems Workshop, Barcelona, Spain, October 5-6, 2004.

"Energy and Emission Effects of Advanced Vehicle Technologies and New Transportation Fuels," 2004 Beijing Environmental Forum, September 14-16, 2004.

"Transportation Sustainability: Life-Cycle Effects of Vehicle/Fuel Technologies," Transportation Research Board's Conference on Integrating Sustainability in Transportation Planning, Baltimore, MD, July 11-13, 2004.

"Fuel-Cycle Energy and Greenhouse Gas Emission Impacts of Fuel Ethanol," Workshop on Economic and Environmental Impacts of Bio-Based Production, Chicago, IL, June 8-9, 2004.

"MOVES/GREET: An Integrated Framework for Life-Cycle Analysis," J. Koupal and M. Wang, California Fuel-Cell Partnership Workshop, Sacramento, CA, April 21, 2004.

"Well-to-Wheels Energy Use and Emissions of Greenhouse Gases and Criteria Pollutants of Vehicle/Fuel Systems," USCAR ACEC Meeting, Southfield, MI, March 18, 2004.

"Well-to-Wheels Energy Use and Greenhouse Gas Emissions of Hybrid Electric and Fuel-Cell Vehicles," SAE Chicago Section Monthly Meeting, Argonne National Laboratory, February 19, 2004.

"Fuel-Cycle Energy and Greenhouse Emission Impacts of Fuel Ethanol," the 40th Annual Meeting Missouri Valley Economic Association, Kansas City, MO, February 27, 2004.

"Well-to-Wheels Energy Use and Greenhouse Gas Emissions of Hybrid Electric and Fuel-Cell Vehicles," *ASM* International Calumet Chapter Purdue University Calumet, February 12, 2004.

"Well-to-Wheels Energy Use, Greenhouse Gas Emissions, and Criteria Pollutant Emissions, Hybrid Electric and Fuel-Cell Vehicles," University of Illinois at Chicago, Institute for Environmental Science and Policy, December 5, 2003.

"Fuel-Cycle Energy and Greenhouse Gas Emission Impacts of Fuel Ethanol," D. Santini and M. Wang, World Summit on Ethanol for Transportation, Quebec City, Canada, November 2-4, 2003.

"Well-to-Wheels Energy Use, Greenhouse Gas Emissions, and Criteria Pollutant Emissions — Hybrid Electric and Fuel-Cell Vehicles," M. Wang and D. Santini, SAE Powertrain & Fluid Systems Conference, Pittsburgh, PA, October 27-30, 2003.

"Well-to-Wheels Energy Use and Greenhouse Gas Emissions of Fischer-Tropsch Diesel," EFI Member Conference "Gas to Market," Mark Hopkins Hotel, San Francisco, CA, October 15-17, 2003.

"Assessment of Well-to-Wheels Energy Use and Greenhouse Gas Emissions of Fischer-Tropsch Diesel," M. Wang and D. Santini, Alternative Diesel Fuels Symposium, Sacramento, CA, August 19-20, 2003.

"Well-to-Wheels Analysis of Vehicle Technologies and Transportation Fuels, Development and

Application of the GREET Model," Analysis Roundtable, the National Bioenergy Center, National Renewable Energy Laboratory, Golden, CO, June 28-30, 2003.

"Well-to-Wheels Energy Use, Greenhouse Gas Emissions, and Criteria Pollutant Emissions of Hybrid Electric Vehicles and Fuel-Cell Vehicles," 2003 SAE Future Transportation Technologies Conference, Costa Mesa, CA, June 23, 2003.

"Well-to-Wheels Energy and Emission Impacts of Hybrid Electric Vehicles and Fuel-Cell Vehicles," the 3rd International Advanced Automotive Battery Conference, Nice, France, June 10-13, 2003

"Fuel-Cycle Energy and Greenhouse Gas Emission Impacts of Fuel Ethanol," U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH, May 8, 2003.

"Well-to-Wheels Energy and Emission Impacts of Vehicle/Fuel Systems, Development and Application of the GREET Model," technical briefing to Congressional Staff, Washington, DC, April 23, 2003.

"Fuel-Cycle Energy and Emission Impacts of Fuel Ethanol," U.S. Department of Energy — California Ethanol Workshop, Sacramento, California, April 14-15, 2003.

"Well-to-Wheels Energy and Emission Impacts of vehicle/Fuel Systems — Development and Application of the GREET Model," California Air Resources Board, Sacramento, CA, April 14, 2003.

"Benefits and Costs of Hydrogen Fuels," 2003 Annual Meeting of the Transportation Research Board, Washington, DC, January 11-14., 2003.

"Fuel Choices for Fuel-Cell Vehicles: Well-to-Wheels Energy and Emission Impacts," 2002 Fuel-Cell Seminar, Palm Springs, CA, November 17-21, 2002.

"Energy and Greenhouse Gas Emission Effects of Fuel Ethanol," Congressional Briefing organized by the Environmental and Energy Study Institute, Washington, DC, July 31, 2002.

"Energy and Greenhouse Gas Emission Impacts of Ethanol and Biodiesel," Transportation Research Board's Summer Energy and Air Quality Meeting, Port Huron, MI, July 8-9, 2002.

"Fuel Choices for Fuel-Cell Vehicles: Well-to-Wheels Energy and Emission Impacts," 2002 SAE Future Car Congress, Washington, DC, June 3-5, 2002.

"Energy and Greenhouse Gas Emission Effects of Fuel Ethanol," World Biofuel 2002, Seville, Spain, April 23-24, 2002.

"Fuels for Fuel-Cell Vehicles: Energy and Emission Implications," Electric Vehicle Association of America's Electric Transportation Industry Conference, Sacramento, CA, December 13, 2001.

"Well-to-Wheel Analysis of Vehicle/Fuel Systems — Five Completed Studies," International Energy Agency's Annex XV Workshop, Sacramento, CA, December 10-11, 2001.

"Energy and Greenhouse Gas Emission Effects of Fuel Ethanol," World Fuel Ethanol Congress, Beijing, China, October 28-31, 2001.

“Fuel Ethanol from Corn and Cellulosic Biomass: Energy and Greenhouse Gas Emission Effects,” Conference on Sustainability of Biobased Products, Dartmouth College, September 6, 2001.

“Energy and Emission Impacts of Fuel-Cell Fuels, Use of the GREET Model,” International Energy Agency’s Annex XV Workshop, Lucerne, Switzerland, July 1-2, 2001.

“Well-to-Wheel Analysis of Fuel-Cell Vehicle Fuels,” U.S. Environmental Protection Agency’s Workshop on Fuel-Cell Technologies, Cincinnati, Ohio, June 26-27, 2001.

“Transportation Fuels Infrastructure: Energy, Emissions, and Cost Implications,” Future and Economics of Transportation Fuels, Cologne, Germany, March 11-13, 2001.

“Fuel-Cycle Greenhouse Gas Emissions of Fuel-Cell Fuels: Implications for Vehicle Fuel Choices and Fuel Economy,” SAE Congress, Detroit, MI, March 5-8, 2001.

“Transportation Fuel-Cycle Analysis: What Can the GREET Model Do?” U.S. Environmental Protection Agency’s Fuel-Cycle Modeling Workshop, Louisville, KY, May 26, 1999.

“Fuel-Cycle Energy and Emissions Impacts of Fuel Ethanol,” meeting of the National Research Council’s Review Committee of the DOE Bio-Fuels Program, Washington, DC, December 17, 1998.

“Natural Gas-Based Hydrogen for Fuel-Cell Vehicles: Fuel-Cycle Energy Use and Emissions,” Fuel-Cell Vehicle Workshop, Institute of Transportation Studies, University of California at Davis, CA, November 11, 1998.

“Fuel-Cycle Fossil Energy Use and Greenhouse Gas Emissions of Corn and Cellulosic Ethanol,” annual meeting of the Canadian Renewable Fuels Association, Chatham, Ontario, Canada, June 11, 1998.

“Fuel-Cycle Fossil Energy Use and Greenhouse Gas Emissions of Fuel Ethanol Produced from U.S. Midwest Corn,” Governors’ Ethanol Coalition meeting, Des Moines, IA, October 30, 1997.

“Estimating Environmental Benefits of Alternative-Fueled Vehicles: What Can Be Done Now?” The North Central Texas Council of Governments, Arlington, TX, April 23, 1997.

“Full Fuel-Cycle Energy and Greenhouse Gas Emission Impacts of Various Vehicle Technologies and Their Potential Use in Emerging Markets,” the 2$^{nd}$ North American Energy Policy Roundtable, Wheaton, IL, April 8, 1997.

“Hybrid Electric Vehicle Total Energy Cycle Analysis,” meeting of the Alternative Fuels Committee, Transportation Research Board, Washington, DC, January 15, 1997.

“An Update on the Life-Cycle of AFV Emissions,” 1996 International Alternative Fuels Conference, Milwaukee, WI, June 27.

“Economics and Emissions of Alternative-Fueled Vehicles,” Monthly Meeting of the Society of Automotive Engineers, Rockford-Beloit Section, Rockford, IL, April 3, 1995.