

December 14, 2010

Final Report of the CARB Expert Subgroup on "Comparative and Alternative Modeling Approaches"

Disclaimer: While the subgroup benefited from the active participation of its members, not all members had the opportunity to fully participate in the drafting of this final document. Therefore, these recommendations do not necessarily represent full concurrence by all subgroup members and in general should not be considered as necessarily supported by the organizations they represent.

As land use change occurs constantly, and has always done so for a variety of interacting reasons, it is inherently difficult to isolate a single causative factor from many in a complex system involving diverse social, economic and ecosystem processes. Most current estimates of GHG releases caused indirectly by biofuels use economic equilibrium or partial equilibrium models to attribute conversion of uncultivated land to replace biofuel feedstock production on existing farmland. . These models were created primarily to analyze domestic farm policy, international trade and trade policies, with land use change mechanisms constructed to help achieve this analytical end. For CARB, however, the estimation of land use change is the analytical objective. The use of estimates of LUC for regulatory purposes is new and the basis for the estimations rapidly developing. Given the evolving nature of LUC estimation and the lack of a consensus model for LUC assesement, multiple, independent methods should be considered.

Committee Recommendations: CARB should develop protocols for evaluating and comparing different types of methods for estimating ILUC.

1. Continue to improve GTAP's capacity to predict land change response globally in response to a change in domestic biofuel production.

In particular, continuous improvements in data on land use and availability, estimation of important parameters governing land conversion and technology improvement and adoption are necessary.

Committee recommendations: If CARB continues to rely solely on GTAP to estimate ILUC GHG values, then GTAP must be continuously improved for this purpose, within the limits of regulatory stability and predictability. All models need continuous updating and improvement to reflect the latest knowledge and data available. Particularly needed are improved data on global

agricultural and forest land supplies and use, and more regionally specific estimates of land substitution elasticities. The “Elasticities” subgroup has noted the sensitivity of GTAP results to the elasticity values assumed in the model. Their recommendations should be considered in updates to the GTAP model. Similarly, the specific recommendations of the Time Accounting subgroup should be considered when updating its methodology for lifecycle assessment of fuels. Projected changes in agricultural practices (e.g. use of genetically modified seeds, improvements in fertilizer application, and trends toward no till farming) and other technologies affecting land use also should be included as confidence in the robustness of the projections permits. CARB should work with USDA, FAO and other widely recognized sources of data to determine where sufficiently detailed and up-to-date data on land use and agricultural productivity are particularly limiting and provide funding to help these data collection efforts. For California, current national agricultural census data may not reflect California’s unique farming systems and markets. Other important factors that can change over time include changes in demand for crops caused by population growth, wealth, or dietary practices, shifting markets for agricultural products, and changes in land use policies and practices that may influence patterns of land use change. Lastly, the fuels favored by CARB’s LCFS methods will result in increased demand and could alter land use patterns as a result. It is not clear if CARB’s methods and its reliance on a static model such as GTAP can accomodate this dynamic, time sensitive outcome of the use of the model itself. Options for developing a dynamic model version of GTAP are being considered. This should be assessed further by CARB.

These recommendations, resulting changes and the model’s use and assumptions should be reviewed periodically by scientists independent of CARB and the core GTAP user group, with no direct interest in the model’s selection as the primary analytical tool. GTAP’s use and assumptions must be as transparent and accessible to the public as possible. External review will facilitate valuable insight to the GTAP user group and greater confidence to the public.

Committee recommendations: CARB should work with Purdue GTAP model developers and other expert groups to enhance the GTAP model and to establish an independent review capacity.

For the short term, the sugroup was also asked to review the July 2010 update for corn ethanol prepared by Purdue. In that update, three sets of results were presented: one based on 2001 baseline information, a second based on updated informtion through 2006 and a third assuming growth in demand and supply were represented by assumptions of popultion growth and extrapolations of uniform global crop yield. While recognizing the importance of appropriately predicitng increases and supply and demand (and factors such as crop yield), the subgroup recommended the use of the “second” model structure as the best currently available version of GTAP. If CARB is to conduct additional modeling before a further enhanced version of GTAP is

available, this second version which includes some updated information through 2006 should be used.

2. Compare GTAP with other economic modeling approaches to ILUC estimation.

2.1 CARB has chosen the GTAP model as the means to estimate ILUC for the LCFS. US EPA, in contrast, has chosen to use a set of different models and an empirical technique, remote sensing, to estimate ILUC. USEPA uses FAPRI, a partial equilibrium model, and FASOM. FASOM¹ is a national (US) dynamic equilibrium model that accounts for the agricultural and forestry sectors. It can be used to estimate the effects and value of carbon sequestration and related policies on land use in the United States. FAPRI² is a partial equilibrium model of agricultural and select liquid biofuel markets that includes estimates of the effects of agricultural trade, in this case the effects of corn and soybean use for biofuels, and supply decisions on prices and land use both domestically and abroad. Predictions of biofuel-induced land changes from FAPRI are complemented by satellite data analysis carried out by Winrock International in ways that are not entirely transparent.

Further, EPA evaluates new biofuels in the context of the change in the quantity of renewable fuel from a known and explicit base from the implementation of the policy. CARB-LCFS does not, it scores the fuel based on an arbitrary change in a quantity of the fuel produced unrelated to the policy context with perhaps less scrutiny of the base value. The choice between these two approaches influences the model choice and would potentially result in two different answers if one expects non-linearities in market behavior and agricultural and energy policies. These non-linearities or the importance of the baseline are considered in a model comparison piece by the EU-JRC³. The JRCs conclusion is that while such non-linearities exist in the real world, they assert such non-linearities are not well represented within the models analyzed.

The more significant the non-linearities in markets or policies, the greater the difference between the two approaches is likely to be and the more appropriate it would be to score the fuel in the actual context of policy implementation. The fuel ‘score’ solution may only be valid locally, the question is how locally.

This method of scoring the fuel (establishing a GHG emission rate per unit of energy) is not indicative of what the effect of the policy is likely to be in California or the US as a whole. For example, does the California program promote the use of low GHG fuels in transportation or does it, for example, just result in low GHG fuels being shipped to California rather than being used elsewhere under the concurrent obligations of the national RFS2. Because the policy effect

¹http://agecon2.tamu.edu/people/faculty/mccarl-bruce/papers/1212FASOMGHG_doc.pdf

²<http://www.fapri.iastate.edu/about.aspx>

³http://re.jrc.ec.europa.eu/bf-tp/download/ILUC_modelling_comparison.pdf

is not being analyzed, additional calculations such as consumer costs of policy of implementation or actual effects on commodity prices and therefore food costs domestically and internationally cannot be known. CARB should be cautious about asserting policy effects in light of this.

GTAP is probably the right model to score the fuel over an arbitrary change in quantity, but it could be argued it may not be the ideal model, or would be incomplete in analyzing the effect of the policy in the way EPA has, which attempts to obtain a fuel score from the application of policy, and where additional detail in agricultural markets are needed. The impact of the chosen baseline path, the base on which the model imposes an arbitrary or policy-induced change in biofuel production, will influence the fuel score or policy impact if non-linearities exist in the model.

2.2 The European Union JRC model comparison (JRC-IPTC). The Europeans have brought together several modeling groups, most recently the group using the MIRAGE⁴ model to make direct comparisons among the economic models used to infer land use changes associated with agricultural biofuels. This comparison included a significant effort to establish common assumptions, essential for comparison of model behavior and predictions. The authors assert baseline paths are not relevant given the linear nature of models and given their analytical objectives to compare scenarios with arbitrary increases in biofuel production. This study is unique within the field of agriculture modeling for its strenuous effort to undertake a pure comparison of model behavior. Estimates of land use change or emissions remain diverse. The authors list yield response to price, location of response (developed vs developing world) and treatment of the co-products of biofuel production. The regional location and area or scale of response is in part a function of the difference in model structure between Armington⁵ style models which track bilateral trade flows and net trade models which do not track origin and destination of commodities and assume homogeneous goods, but also on the relative area response elasticities around the world. Yield response to price is a key uncertainty which the CARB-LCFS workgroup also has under examination. The diversity of estimates in the models analyzed is reflective of the uncertainty surrounding this response. Differences in co-product treatment appear to be primarily from one outlying model. Co-product treatment from the

⁴<http://www.cepii.fr/anglaisgraph/workpap/summaries/2002/wp02-17.htm>

⁵ An Armington elasticity is an economic parameter commonly used in models of consumer theory and international trade. It represents the elasticity of substitution between products of different countries, and is based on the assumption made by Paul Armington in 1969 that products traded internationally are differentiated by country of origin and, generally, that bilateral trade flows are “sticky” with quantity changes lagging what would be predicted by price alone. The Armington assumption has become a standard assumption of international computable general equilibrium (CGE models). These models are said to generate smaller and more realistic responses of trade to price changes than implied by models of homogeneous products.⁺

transformation of grains and oilseeds is being addressed by the co-product workgroup. Other large differences among predictions were reported. Even with significant effort, important limitations to the authors's ability to align different predictive models remained unresolved. Nevertheless, this was an important effort and further work should be supported by CARB. An obvious conclusion from the comparison is that different models report different results when asked the same question, so the choice of a model is also in an important way a choice of a result. The elements which are the primary cause of the divergent outcomes are among the factors being considered by the LCFS subgroups, but should receive particular attention given their disparate treatment and resulting model outcomes. This may require financial support and significant effort.

Committee recommendation: Over the next year or so, CARB should set up a permanent technical capacity internally, or preferably, an external advisory group to systematically review and compare ILUC GHG estimates from the diverse models and complementary assessment approaches used elsewhere in the US and Europe.

3. Compare model predictions with data for land use change, especially domestically

The assessment of lifecycle GHG emissions of transportation fuels is relatively new and is in a period of rapid development. No one model or set of models can be expected to do the 'best job' in performing a lifecycle assessment. This is particularly true in the case of indirect impacts of biofuels whose lifecycle GHG assessment are greatly influence by data and assumptions regarding agricultural system response to greater biofuel demand, especially land use changes which result in changes in carbon stocks. While CARB may be limited in its choice of models by considerations of transparency, other databased approaches can be used to directly calculate GHG estimates for fuels. We note that CARB has been able to use proprietary information and modeling results in other regulatory settings and may be unnecessarily restricting itself to the use of GTAP results only in its LCFS analysis. Comparisons with data are complicated because GTAP tries to isolate changes due only to crop demand for biofuels, holding all other factors constant, while markets adjust to a entire range of possible, complex influences on behavior. Additionally, economic modeling such as used here does not lend itself to traditional verification methods such as experimentation (observing what happens with and without a stimulus). Nevertheless, comparisons of predictions from GTAP with actual behavior of domestic markets and land conversion should be possible for some or all of the 2001 to 2009 period, during which biofuel production expanded especially in the United States but also elsewhere. A systematic comparison of GTAP model predictions of domestic land use change and crop exports with the empirical data during this period will identify whether the direction of changes predicted and their magnitude correspond to actual market occurrences. If both the direction and magnitude of changes observed, especially if the role of biofuel production in the data can be isolated correspond with model prediction, then confidence will increase for relying

on existing GTAP results. Where results differ, these differences should be used by CARB to focus on (1) either confirming GTAP results are the most appropriate or (2) developing improvements in GTAP.

An example of a systematic approach for examining the empirical data was recently presented as slides and a short talk at the October CARB working group meeting by Oladosu and Kline (2010). When this study is available for peer review, it may offer or lead to a useful means of reality or interpreting estimates based on economic modeling.

The text in this box was provided by the authors of the study and does not represent the consensus opinion of the sub-group. The subgroup had no opportunity to review or discuss the technical merits of this study and several of its members regard this still unpublished work as premature to include in this report.

The study employed an index decomposition analysis (IDA), which is a comparative statics technique for ex-post estimation of the contributions of individual factors or group of factors to the change in a given aggregate variable, if all other factors are held constant (Albrecht et al, 2002). In essence, given a logical relationship between the aggregate variable and its determinants, IDA allocates changes in the former to the individual determinants under *ceteris paribus* assumptions. This methodology is widely applied for decomposing the drivers of energy use and its environmental implications in the literature and by a number of national and international agencies (Ang and Zhang, 2000; Liu and Ang, 2007). It bears some resemblance to the Causal-Descriptive approach reported by Bauen et al., (2010) discussed below. The analysis presented by Oladosu and Kline (2010) defined a chained relationship between corn use for ethanol and corn supply (production, stock and imports), corn use (allocation of the domestic portion of supply among different uses, share of domestic use in supply, and corn land use (yield, inter-crop land transfers and total cropland) factors. The aim of the study was to examine the role the above factors, which include the primary drivers of indirect land use change, rather than to calculate indirect land use change. The IDA was applied to examine the market and land use response to the quintupling of corn use for ethanol between 2001 and 2008 through these factors. The study's findings suggest that the U.S. market response may be more flexible than currently assumed in model estimates of indirect land use change. Most of the increases in corn use for ethanol were found to be due to the reallocation of the domestic portion of supply in favor of corn ethanol, and away from other domestic uses, such as feed. In contrast, increases in the domestic share of supply, which is most important source of indirect land use change, was found to contribute a much smaller net amount over the 2001-2008 period relative to the contributions from domestic use reallocation and increases in production. The study also calculates that the net production contribution during the period was mainly due to yield change, with inter-crop land transfers and new land conversion playing smaller roles. This type of analysis could be extended to other countries to examine the role of demand and supply factors in the change in production/use of various crops. The agglomeration of such global decomposition results could shed light on the role of the different factors often associated with indirect land use change emanating from U.S. ethanol production.

Data sources used in developing the GTAP model assumptions may be incomplete or inadequate. Some original research may be needed to find ways to integrate diverse sources of data concerning economic performance in the crop, livestock and forestry sectors sector during the period of interest for purposes of comparison. Some data may be available to compare GTAP predictions to actual land changes in the US (<http://www.ers.usda.gov/publications/eib14/> ;

<http://www.arb.ca.gov/fuels/lcfs/workgroups/ewg/071510illinois.ppt> ; <http://www.ers.usda.gov/Briefing/LandUse/agchangechapter.htm>). This data may be derived from NASS (<http://www.nass.usda.gov/>), NRI (<http://www.nrcs.usda.gov/technical/NRI/>), and other national sources, and from livestock feeding and other uses (<http://www.ers.usda.gov/data/feedgrains/> ; http://usda.mannlib.cornell.edu/usda/current/FDS-yearbook/FDS-yearbook-03-04-2010_Special_Report.pdf), If little to no conversion of forest to cropland occurred despite expansion of biofuel production, then such data can be used to correct GTAP-based estimates of GHG intensity for Biofuels where such estimates contribute significantly to the value used by CARB (<http://www.fs.fed.us/ne/fia/spatial/index.html> ; http://www.fire.ca.gov/resource_mgt/resource_mgt_forestpractice_gis.php). Alternatively, land cover data analysis could be used with reasonable levels of confidence (<http://landcover.usgs.gov/>). Traditional sources of data might be combined with land cover analysis over time for this purpose. If GTAP predicts changes in forest land to crop land by agricultural management zones, then more focused analysis might be feasible if broader coverage was unworkable.

Committee recommendation: In the near term, CARB should re-examine its conclusion that it must use only models which are publically available such as GTAP since use of other models and their results would likely improve confidence in its lifecycle assessment of biofuels. Over the mid to long term, CARB should fund a study to evaluate existing domestic land use data and relevant market and economic data to determine if alternate means can be established to verify predictions from GTAP and any other partial or general equilibrium models used to infer the land use consequences of crop-based biofuel use. CARB should first compare results for fuels that are produced domestically including biofuels produced largely from domestic feedstock in recognition that (1) the best data and other information likely is available for domestic fuels and (2) significant disparities in analysis of domestic fuels will suggest a serious concern with model result that must be resolved before considering international impacts. CARB should identify data gaps and work with other groups and government agencies to address these gaps.) CARB should adopt a disciplined approach to reviewing the latest relevant analyses in particular for biofuel impacts on land use and carbon change to flag significant differences from then current GTAP results and to determine trends in model approaches that could be considered for GTAP improvements or for use of alternative models that meet CARB requirements for transparency.

4. Alternate approaches to addressing Indirect Land Use Change.

4.1 Bauen et al., 2010, report the results of an alternative approach to modeling the effects of increased biofuel demand on ILUC. They used a causal descriptive methodology based on cause and effect logic to identify and estimate ILUC effects. It makes explicit use of stakeholder input to identify and order cause and effect. They evaluate five different biofuel feedstocks: palm oil, rapeseed (canola) oils, soybean oil, wheat and sugarcane, but not corn. They used statistical analysis of historical market trends, market analysis, and expert opinion and a literature review to

help create logical quantitative relations among cause and effect pathways. They used data from US EPA and Winrock International for terrestrial carbon stocks in different landscape regions and for analysis of historical land use change patterns. Different assumptions (scenarios) are described as an approach to accommodate some of the uncertainty inherent in projecting future land use changes in response to unknown economic events. They reported that their methods predict that some biofuel uses and policies can have foreseeable large effects on land use change, but that these vary significantly depending on the feedstock and scenario anticipated. The largest GHG effects for biofuel use were associated with palm oil and rapeseed oil in their analyses. Wheat use for biofuel under British conditions had a land-sparing effect.

This approach is dissimilar to that used in the GTAP model and chosen by CARB. The GTAP model, a CGE model is an economic optimization model that incorporates a wide array of economic industries and activities to estimate the effects of changes in the conditions of trade on economic behavior around the world. These changes include land use in diverse agro-ecological zones around the world. Land use change is inferred based on model outputs and the *ceteris paribus* assumption that only biofuel crop demand changes.

An advantage of the Causal Descriptive Approach compared to GTAP is that other factors than markets and land values might be incorporated. Bauen et al, however, fail to include some of the most important drivers of land change in their cause and effect chains. These have been described by Kline et al, Turner *et al*, (2007) and others. Through a review of the literature examining deforestation and land use change in tropical regions, Turner et al describe emergence of the field of “land use science,” which examines the role of local practices and phenomena as well as the influence of national policies and international market forces.

A brief review of this extensive literature reveals that GTAP and similar trade models represent a rather one-dimensional view of land use change that is likely to result in potentially significant over- or under-attribution of the role of international market demand for biofuels in local land management and change.

For example, current land use patterns in areas with large terrestrial carbon stocks like tropical forests include frequent use of fire to maintain land tenure or to support shifting agriculture. These practices are encouraged by a lack of social institutions and markets that allow for more durable and productive investments in the productive potential of land. Biofuel demand provides opportunities for the development of markets, which inspire the need for more secure land tenure, create conditions for investment, and increase productivity. The consequence of this cause and effect land use chain is that shifting land use and chronic dependence on fire is reduced. The counter-intuitive effect of biofuel demand can be the conservation of terrestrial carbon stocks, not their depletion. Recent changes in social incentives in Brazil provide an example of these effects at work. Such causal chains are absent from most analyses, including Bauen et al. (2010). For these reasons, we suggest that CARB also consider the use of direct studies of land change in critical areas with large terrestrial carbon stocks and important levels of biodiversity. Such studies are exemplified by the model presented by Dr. Ted Foin during an expert work group meeting and designated collectively as “land change science.” (Turner et al. 2007).

To reduce the risk to terrestrial carbon stocks and large additions of C to the atmosphere from their loss, Bauen et al., recommend measures to directly protect high carbon stock land. While measures to protect lands high carbon stocks should be considered and supported where determined appropriate, CARB does not have authority over these lands and very limited if any ability to influence measures to directly protect high carbon stock land. In general, we do not support CARB adopt specific recommendations which outside of CARB's authority or mandate. The authors also recommend the use of land with low soil organic matter levels or the production of crops and use of management practices which conserve or increase soil carbon, the use of advanced, high yielding agricultural methods that increase yields at a greater rate than inputs used for production, better supply chain efficiency, complete use of co-products and associated integration of crop and livestock systems to optimize resource use and minimize the landscape footprint of these systems. They call these approaches action-based and contrast them with the use of ILUC factors generated by models like GTAP. Their analysis leads to a preference for specific actions over the use of inferential values generated by models. In the LCFS context, however, we note that some of these apply to direct LUC and the others, by increasing yields, will reduce ILUC for a given pathway (and good modeling will show this) but not eliminate it.

Ecofys, the World Wildlife Fund for Nature (WWF) and Conservation International (Ecofys 2010) provide such an action-based approach to addressing iLUC. Rather than assign fuels with a score based on quantitative modeling of international market responses, the Ecofys "Responsible Cultivation Areas" (RCA) methodology establishes qualitative factors which can be used to identify and categorize feedstocks and fuels based on their likely relative risk of inducing iLUC. Under the RCA methodology, feedstocks that do not create new incremental demand for land, including waste-based feedstocks, those that can be grown on land not providing other services, or those that result from increased yields on lands currently under cultivation could all be viable for crediting as eligible for producing low carbon fuels. In stakeholders discussions on iLUC in Europe, researchers at the International Union for the Conservation of Nature (IUCN, 2010) have put forth similar concepts for addressing ILUC through a risk mitigation approach that identifies practical land management and governance conditions under which land use can be considered low risk of increasing GHG emissions. These risk-mitigation approaches would require certification or a similar site-based verification of conditions and practices. They would also require the buy-in of feedstock and fuel producers, no small task given the diversity of players in the marketplace. While such approaches would undeniably add to feedstock and fuel production costs, they have great potential to provide a stronger empirical basis than modeling does to mitigate the risks of iLUC resulting from greater demand for biofuels. We note, however, that under the Ecofys approach and perhaps similar approaches, although lands might currently not be used for crop production, this does not preclude their being used for crop production in the future. Similarly, we again note that while increasing yields may lower the need for expanded crop land, only when yield increases outpace crop demand increases would there be no net impact on land use due to biofuel demand.

Another consideration raised by Bauen et al and others is that ILUC factors are only a static picture of potential effects from biofuels, while the real consequences are dynamic and change over time due to many factors, and take time to occur. The use of quantitative scores as a policy approach to addressing iLUC could affect the factors themselves by changing demand and other conditions upon which they depend.. Thus demand for low ILUC fuels will increase the demand

for those same fuels and in turn increase the ILUC factor. They also note the significant and irreducible uncertainties with static assessments based on models. Since the ILUC factors are in reality dynamic, they should be subject to frequent revision, but this in turns leads to regulatory uncertainty, a conundrum.

4.2 Incorporate Land Use Change science/modeling and calibrated remote sensing into the LCFS regulatory approach.

One alternate method would be to assess land change in targeted regions of special concern based on historical records as well as current monitoring methods, including remote sensing carried out with a high degree of accuracy based on ground truthing and local calibration. The objective of this approach would be to document rates of observable land use change, and compare observed rates with historical ones where possible. This method would not reveal the reasons for land use change, but would provide an empirical basis for estimating its scale and rate, and provide continuously updated and improving estimates of both. A recent NRC (2010) publication sets forth a valuable set of recommendations to enhance and validate remotely sensed data for use in LUC analyses. CARB should aid these efforts, including local ground-truthing for the most significant areas to be protected.

The problem of isolating the effect of biofuel production from the simultaneous influence of other factors remains for a comprehensive modeling exercise to resolve. To assess the causes of land use change in critical or significant locations, however, additional information is required. A complimentary approach could analyze in detail the causes of land change in selected areas of particular interest and importance by using social surveys, analysis of historical patterns of land use change (<http://www.arb.ca.gov/fuels/lcfs/workgroups/ewg/071510time-acct.ppt>) and ecosystem simulation modeling methods. Examples exist of efforts to model the complex land use change systems that occur in less-developed regions (<http://www.arb.ca.gov/fuels/lcfs/workgroups/ewg/071510thailand.pdf>;). The role of prices for corn grain and its substitutes on land management decisions can be estimated where such models exist as part of the complex set of factors motivating land change. Combined with survey methods, these two approaches would provide substantial confidence that if land use changes, its causes and extent can be more accurately identified than when using inferential estimates from a global scale equilibrium model. The use of simulation models and social survey methods, especially if developed for areas identified as critical with respect to terrestrial carbon storage and biodiversity, will provide greater certainty about the causes of land change resulting from crop-based biofuel production and use. Since CARB allows independent estimates of GHG values for biofuels, it would have greater flexibility and confidence about the usefulness and accuracy of its own ILUC estimates if it had empirical evidence for actual behavior in the most critical regions needing protection from development.

Committee recommendations: As a longer term effort, CARB should develop the research capacity to carry out empirical verification of land use change for critical areas around the world with high terrestrial carbon stocks, and for selected areas of the US landscape that are predicted by GTAP to be affected. Should these effects be shown not to occur or to occur at a scale less or greater than predicted, CARB's ILUC GHG methodology can be adjusted accordingly.

CARB should fund research that directly studies land change processes in selected critical areas with large terrestrial C stocks using dynamic simulation modeling and social survey methods. Results from these analyses should be used to improve estimates of ILUC GHG emissions based on GTAP. This might be carried out in cooperation with other affected parties with similar interests like US EPA or other multi-state agencies or groups.

CARB should evaluate adopting the Causal Descriptive Approach to modeling ILUC reported by Bauen et al. If the evaluation finds that this methodology can produce reasonable results commensurate with other approaches, it could be considered an alternative source of ILUC emissions factors. Additional Causal Descriptive pathways that reflect the potential for positive effects on forest and other natural land conservation should be added to those proposed by Bauen et al. These can be parameterized by local land change science studies in areas with critical conservation needs previously discussed.

In the near-term, CARB should consider participating in other efforts and forums to establish verifiable, site-based methods to directly reduce the likely occurrence of LUC, such as the joint Ecofys/WWF/CI effort to define Responsible Cultivation Areas, and the Roundtable on Sustainable Biofuels. The Ecofys modeling approach represents a simpler approach which merits consideration. Persistent uncertainties over the magnitude of iLUC magnitude as well as the ever-changing nature of international markets, land use, and terrestrial carbon dynamics create some doubt as to whether investments by CARB (and others) in further improvements to GTAP and underlying databases will increase the confidence in results and their acceptance by key stakeholders. So, in addition to evaluating other models of iLUC, over the longer-term CARB should also formally weigh action-based and site-based approaches to mitigating risk of iLUC, such as biofuel certification, as an enhancement to or even an alternative to quantitative iLUC modeling.

5. Model integration: CARB should establish a process to review new approaches to estimating ILUC as these are developed and published in the peer reviewed literature. For the sake of consistency and fairness, it is desirable that all fuels are evaluated using a consistent set of tools. For this reason it is unlikely to be practicable to allow different obligated parties to be regulated according to different methods of analysis. However, if new methods of calculating the land use emissions of some or all regulated fuels are developed, CARB should periodically

review the new methods and determine what changes may be appropriate to their methodology. Keeping the analysis current must be balanced against the need for regulatory stability. Given the time and expense required to revise the land use change emissions analysis, a revision frequency of three to five years seems appropriate. These revisions should include external expert review of proposed estimates and the methods used. Coordination of this ongoing analysis with other regulatory agencies in the US, the EU or elsewhere may facilitate an ongoing open process of revision, as well as allowing development of standard tools and databases.

In many cases new analysis of indirect land use emissions or related phenomena may not be developed using identical terms, definitions, datasets or assumptions, which can hamper direct comparison between approaches and hinder the adoption of parts of alternative approaches. Jumping from one model to another will undermine the stability of the regulations, and so it is preferable to adapt existing models to incorporate new information than to replace the underlying models. It may be possible to develop meta-models that attempt to compare different approaches in a consistent way. It may also be possible to use the new approaches to inform a qualitative sensitivity analysis of the primary model or models. Understanding what factors -- whether structural parts of the models, or underlying data or assumptions -- significantly alter the results can inform refinements in the model or in the way the model is applied.

Encouraging researchers to use, as much as possible, the framework and datasets of the models adopted by CARB as the basis for future work will facilitate the ongoing refinement of these models. Establishing a process for different regulatory bodies to share as much as possible a common set of models and datasets will make the work of future researchers more valuable and the regulatory efforts more tractable.

Committee recommendation: Starting immediately and continuing for the long term, CARB should work with other regulators in the US and abroad to establish a framework for new analysis of land use change that would facilitate incorporation of new data and analytical methods into existing regulations. Development of this framework could be assisted by the external advisory group described in Section 2 above.

References:

- Albrecht J. D. Francois and K. Schoors (2002) A Shapley decomposition of carbon emissions without residuals, *Energy Policy* 30:727-736
- Ang B.W. and F.Q. Zhang (2000) A survey of index decomposition analysis in energy and environmental studies, *Energy* 25:1149-1176

Bauen, A., Chudziak, C., Vad, K., and Watson, P. (2010). A Causal Descriptive Approach to Modeling the GHG Emissions Associated With the Indirect Land Use Impacts of Biofuels. Final Report. E4tech. 83 Victoria St., London, UK.

Dumortier, J., et al. 2009. Sensitivity of carbon emission estimates from Indirect land-use change. Working paper 09-WP 493. Center for Agricultural and Rural Development. Iowa State University, Ames Iowa.

Ecofys, 2010. Responsible Cultivation Areas: Identification and certification of feedstock production with a low risk of indirect effects. A report prepared by Ecofys with support from World Wildlife Fund and Conservation International. Available at:
http://www.ecofys.com/com/publications/Responsible_Cultivation_Areas.htm

IUCN. 2010. “Reducing the risk of Indirect Land Use Change: credible landscape planning as one meaningful approach,” discussion draft.
http://cmsdata.iucn.org/downloads/iucn_on_iluc_4_february_2010_rev.pdf

JRC-IPTS (Joint Research Centre - Institute for Prospective Technological Studies). Impacts of the EU biofuel target on agricultural markets and land use: a comparative modelling assessment; report JRC 58484/EUR 24449 EN; Seville
http://ec.europa.eu/energy/renewables/studies/doc/land_use_change/study_jrc_biofuel_target_iluc.pdf)

Kline, K., Dale, V.H., Lee, R., Leiby, P., 2009. In defense of biofuels, done right. Issues Sci. Technol. 25, 75-84.

Liu N. and B.W. Ang (2007) Factors shaping aggregate energy intensity trend for industry: Energy intensity versus product mix, Energy Economics 29 (2007) 609–635

Morgan G. et al. 2009. Best Practice Approaches for Characterizing, Communicating, and Incorporating Scientific Uncertainty in Climate Decision Making. Report from the U.S. Climate Change Science Program Synthesis and Assessment Product 5.2.

Oladosu G.A. and K. Kline (2010) Empirical Data and Decomposition Analysis of U.S. Corn Use for Ethanol Production, Presentation to the California Air Resources Board (CARB) Low Carbon Fuel Standard Expert Workgroup Meeting, Sacramento, CA October 14-15, 2010
<http://www.arb.ca.gov/fuels/lcfs/workgroups/ewg/101410decomposition.pdf>

NRC. Verifying Greenhouse Gas Emissions. Methods to Support International Climate Agreements. National Research Council. Washington, DC , 124 pg.(2010)

Searchinger T, Heimlich R, Houghton RA, Dong F, Elobeid A, Fabiosa J, Tokgoz S, Hayes D and Yu T-H,. Use of US croplands for biofuels increases greenhouse gases through emissions from land-use change *Science* **319**:1238–1240 plus supporting materials (2008).

Tyner at al., 2010. Land use changes and consequent CO2 emissions due to US corn ethanol production: a comprehensive analysis. Final Report, Argonne national Laboratory. July 2010. Dept. of Agricultural Economics, Purdue University.

Turner, B.L. II, Lambin, E.F., and Reenberg, A. (2007). The emergence of land change science for global environmental change and sustainability. PNAS 104(52)20666-20671.
(<http://www.pnas.org/content/104/52/20672.full.pdf+html?sid=c68a1e79-fada-45ea-b4fe-cf84f406d0a8>)