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Indirect Land-Use Change from Biofuels: Recent Developments in Modeling and Policy Landscapes

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This Policy Brief serves as a background paper for the October 2010 seminar, "Carbon Standards in Agricultural Production and Trade," organized by the International Food & Agricultural Trade Policy Council (IPC) with support from Sao Paulo's Federation of Industries (FIESP). The policy brief is adapted from a draft manuscript under development by Julie Witcover and Sonia Yeh. Drs. Yeh and Witcover are research scientists at the Institute of Transportation Studies, University of California, Davis. Dr. Yeh co-led a team of University of California researchers providing technical and policy analyses for the implementation of California's Low Carbon Fuel Standard (LCFS). She co-directs five research teams across the U.S. studying the implementation of a national Low Carbon Fuel Standard. The views expressed by the authors are theirs alone and do not reflect those of IPC or FIESP.

Rising international demand for biofuels to replace fossil fuels used in transport has raised concerns that the induced extra demand for biofuel feedstocks, currently dominated by food-based products, can displace agricultural production. When this occurs, price effects ripple through commodity, land, and related markets. Shifts in land cover in response to those price changes have been termed indirect land-use change (iLUC). Emissions from land-use change have become an important and controversial aspect of biofuel policies, with attention drawn to potentially long periods for biofuel feedstocks to "pay back" carbon lost when the feedstocks themselves or replacement crops move into high-carbon-stock regions. There are additional concerns about other indirect effects, such as biodiversity loss, pressure on local water resources, and disturbance of local land rights (that could accompany the land-use conversion), as well as impacts on food prices and food security or higher emissions elsewhere due to price changes (intensification on existing agricultural land or greater fossil-fuel use outside the biofuels policy area).

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While implementing a carbon price for land-use and all other emissions is, in theory, an effective and efficient way to control greenhouse gas (GHG) emissions to meet climate goals, such a policy is unlikely to be adopted globally within any realistic time frame. In the absence of such a policy, iLUC regulations have emerged as a way to address the urgent issue of land-use change in response to biofuels policies. Thus, estimates of iLUC emissions associated with specific biofuel feedstocks – "iLUC factors" – have entered the regulatory arena. In the United States (U.S.), both the federal Renewable Fuel Standard (RFS2) regulation by the U.S. Environmental Protection Agency (EPA), revised according to the Energy and Independence Security Act of 2007, and California's Low Carbon Fuel Standard (LCFS, implemented by the California Air Resources Board, CARB, as part of California state law Global Warming Solutions Act of 2006, also known as the AB32) require that life-cycle GHG emissions of biofuels must include not only direct but also indirect emissions from significant sources, including land-use change. Whether and how to include iLUC emissions in Europe's Renewable Energy Directive (RED) and the UK's Renewable Transport Fuel Obligation (RTFO) is under review and development. The process has raised questions about whether, and if so, how regulations should account for or influence actions and actors outside policies' immediate jurisdictions, for instance across international borders.

Models are evolving rapidly, getting better at capturing complicated links between agricultural, energy, and animal feed markets forged through new biofuel policies and production. Still, iLUC study results vary considerably: a recent review of iLUC studies covering different feedstocks and policy combinations found iLUC carbon intensities ranging from around 15 gCO2e/MJ to close to 250 gCO2e/MJ.

Separately, the modeling systems used to derive regulatory figures have been subjected to scrutiny over their assumptions and readiness – in terms of accuracy and transparency – for a policy role. Models are evolving rapidly, getting better at capturing complicated links between agricultural, energy, and animal feed markets forged through new biofuel policies and production. Still, iLUC study results vary considerably: a recent review of iLUC studies covering different feedstocks and policy combinations found iLUC carbon intensities ranging from around 15 gCO2e/MJ to close to 250 gCO2e/MJ. Why the wide range? In part because the studies frame questions differently (what policy or feedstock is evaluated, at what time?), and use different methods (model types) or assumptions about behavioral responses to price changes and projections about elements such as agricultural yields; biofuel conversion rates; food, feed and energy demand; available lands; and other factors. Even within particular studies, uncertainty ranges are wide. Some sources of uncertainty will remain even as models continue to be improved. Still, almost all the models agree that the iLUC effect is a real, and potentially large, emissions consequence of biofuels policy on the scales currently being implemented and contemplated.

Models and Policy Scenarios for Estimating "iLUC Effects" and "iLUC Factors" (types, results, and reviews)

Modeling systems analyzing iLUC must characterize three principal pathways of market response to higher feedstock demand: reduced consumption, higher production through higher yields, or higher production through increased cultivated area, even though it is only through this last pathway that iLUC emissions occur. Regulations have thus far been based on economic equilibrium models, with each regulatory agency (for the U.S. and California) relying on a single modeling system to generate results. Strengths of these types of models include history of policy analysis and theoretical underpinning, but there are drawbacks. Among these are uncertainty about certain model parameters, model transparency and ease of use (the complicated representation of multi-market adjustments can make it difficult to glean pathways of causation,

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Table 1. Model types for iLUC emissions evaluation

	Economic equilibrium models (general or partial equilibrium models)	**'Causal-descriptive' modeling**	**'Deterministic' modeling (iLUC 'risk adder')**
Description	Regional supply and demand for biofuel feedstocks and related agricultural commodities; trade; link to energy market	Traces specific market pathways to iLUC change	Uses externally specified average land-use, trade patterns, land cover
Who uses?	California LCFS (GTAP model); U.S. RFS2 (FASOM and FAPRI models); EC (MIRAGE model)	Under development for UK RTFO	Research institute (Öko-Institut)
Pros and cons	Pros: history in policy analysis, captures actual economic behavior and linkages. Cons: many data gaps and uncertainties, false sense of precision, lack of transparency	Pros: transparency, exploration of very new scenarios. Cons: can miss complex market feedbacks; relies on historical trends and expert and stakeholder opinion to identify pathways	Pros: transparency, ease of implementation. Cons: can miss complex market linkages and feedbacks; use of averages may not reflect most likely effects; some seemingly ad hoc assumptions regarding actual v. potential iLUC

and the models themselves must be run by those trained in them). Other proposed methods for analyzing iLUC stress transparency (making them more amenable to stakeholder input), fewer data requirements, and ease of implementation. By simplifying the characterization of market links, however, they risk missing some market feedbacks that drive iLUC.

Models used for iLUC analysis sometimes aim to evaluate an overall "iLUC effect" due to a given policy, namely a measure of additional land-use change emissions estimated to occur as a result of the policy versus what would have happened in the absence of such a policy. For regulatory purposes, however, policy makers try to ascribe an "iLUC factor" to a particular feedstock or pathway, namely an iLUC emissions contribution attributable to that feedstock. There are considerable differences in feedstock-specific results from the iLUC models being used by different regulatory bodies, due to the factors described above (different modeling approaches and assumptions, different time frames for policy evaluation), as well as different methods for allocating effects to specific feedstocks. Results have also changed as the modeling systems themselves have evolved in response to critiques and cross-fertilization.

The piecemeal nature of sensitivity and uncertainty analysis conducted so far by these studies means a plausible range of iLUC results has yet to be established. Other iLUC analysis methods can generate a point estimate "iLUC factor," at perhaps lower thresholds for understanding and acquiring data and greater transparency (with the caveats regarding missing market linkages already discussed). Two examples are causal-descriptive analysis and the deterministic approach of an iLUC 'risk adder.' They, too, could be used to establish ranges via alternative assumptions about pathway responses or average patterns. Table 1 compares these types of models.

Sources of uncertainty in iLUC model analyses range from parameter values on price responsiveness due to lack of data or measurement error, to choice of model type, what to include in the model and at what level of aggregation, and functional forms used within a model, to projections about future developments that provide the without-policy baseline against which the policy effects are measured. Table 2 summarizes areas of key uncertainties across models of indirect land-use change.

Beyond Current "iLUC Factors"?

In current regulations, an "iLUC factor" from land-use change resulting from increased biofuel demand is included within life-cycle GHG emissions that must meet a regulatory threshold of a certain percentage reduction from gasoline and diesel emissions. In the U.S. EPA's RFS2 rulemaking, the "iLUC factor" is analyzed as a measure of a feedstock's contribution to the overall policy's effect in evaluating whether biofuel from that feedstock's life-cycle GHG emissions (including iLUC emissions) meet a 20%, 50%, or 60% reduction for renewable fuel, biomass-based diesel or advanced biofuel, and cellulosic biofuel, respectively. Under the California LCFS, an "iLUC factor" is added to a biofuel's life-cycle GHG-intensity rating (the CI value) that rates the GHG performance of biofuels. Low carbon fuels such as biofuels can be mixed with fossil fuels (gasoline or diesel) or provided as dedicated fuels to meet the policy target of reducing the state-average GHG intensity of California's transportation fuels by 10 percent by 2020. The lower GHG-intensity rating a feedstock and production pathway gets, the more carbon credits (and thus economic

Table 2. Key elements and uncertainties in estimating iLUC-related GHG emissions.

Key component	**Key uncertainties**
Feedstock demand	Fuel yield; co-product markets; price elasticity of demand
Trade balance	Tariffs and other trade barriers (e.g., subsidies); trade impacts of increased biofuel demand (altered trading patterns)
Area and location of lands converted	Increases in crop yields; productivity of new land; bioenergy-induced additional productivity increase; land-use elasticities; supply of land across different uses; availability of idle, marginal, degraded, abandoned, and underutilised land and unmanaged forest; methodology of allocating converted land (e.g., grassland vs. forests)
GHG emissions from land use and land use change	Biofuel cultivation period; soil and biomass carbon stock data (especially peatlands); soil nitrogen emissions; time accounting of carbon emissions
Other non-iLUC emissions and climate effects	GHG emissions from agriculture production changes such as cattle, methane emissions from rice cultivation and fertilizer inputs; albedo changes (e.g., snow on former boreal or temperate forest land)

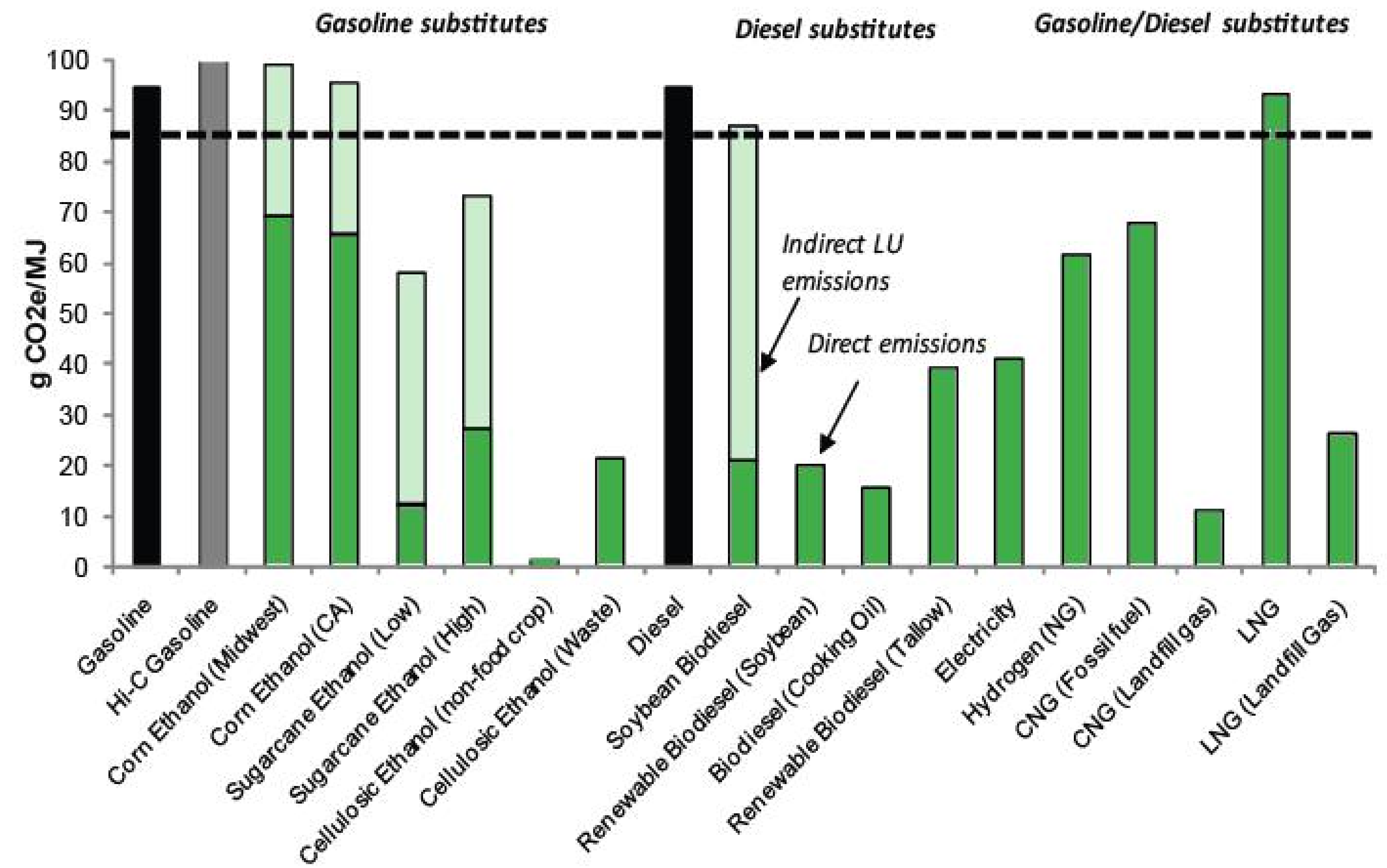

Figure 1. *California LCFS greenhouse gas (GHG)-intensity ratings (gCO2e/MJ) for transportation fuels, adjusted for vehicle efficiency. Although uncertainties are not indicated in this graph, the uncertainties of indirect emissions are much larger than the uncertainties of direct emissions. Source: CARB (2009, 2010). The cellulosic ethanol pathways do not yet have an iLUC value.*

value) it can generate to meet a performance-based regulation. For example, at a carbon price of \$100/metric ton CO2e, the additional "carbon credit values" biofuel can generate are \$0.31 and \$0.67 per gasoline gallon equivalent (equivalent to \$0.21 and \$0.45 per gallon or \$0.05 and \$0.12 per liter of ethanol) for CI values of 70 and 40 gCO2e/MJ, respectively (the baseline CI value in California is 96 gCO2e/MJ). Alternatively, at lower CI values, an oil provider can provide or purchase a smaller volume of low carbon fuels to meet the annual average emission intensity target. Figure 2 shows an example of GHG intensity values of fuels rated in California, indicating the relative magnitude of direct versus indirect LUC emissions in the regulation.

Recent work reviewing iLUC modeling has highlighted the data uncertainties, modeling choices, and scenario dependencies inherent in iLUC modeling; these make it more difficult to argue that a single model or scenario of the future has sufficient scientific grounding to generate a single iLUC factor to serve as the basis for a policy decision with large social, economic and technology implications. Some have suggested dealing with uncertainty by choosing an "iLUC factor" from a probability distribution. However, considerable work would remain to get reliable probability distributions (using one or more models and scenarios). A second

Scientists and policymakers have argued that incorporating iLUC in biofuel life-cycle GHG emissions accounting is the only way to reflect the true life-cycle GHG emissions associated with the production and use of biofuels. Some stakeholders, including a wide range of interests from biofuel producers, oil companies, and NGOs promoting the view that biofuels represent a unique opportunity to promote development in developing countries and reducing GHG emissions, on the other hand, take exception to regulating biofuel production based on land-use conversion decisions elsewhere in the world, outside their sphere of influence.

idea is to establish a "tiered" approach, whereby a more easily obtained 'default value' based on currently available data gives way to figures generated by more sophisticated modeling as that becomes available. It has also been suggested that, if iLUC analysis were based on a shorter time frame with frequent programmed updates, some of the uncertainty associated with projections could be reduced if not eliminated. Other suggestions for dealing with uncertainties include supplementing, or replacing, the "iLUC factor" altogether; we discuss some preliminary strategies next.

Avoiding or Mitigating iLUC through Policy Design?

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Table 3 summarizes some proposed mitigation strategies to reduce or avoid iLUC, the intended actor or level of actions, and some associated issues. Note that the strategies have not been rigorously vetted by models or formally proposed by governments as viable policy solutions.

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Table 3. Mitigation strategies being proposed or discussed to avoid, reduce or mitigate iLUC.

Strategy	Level(s) and actor(s)	Issues
Control direct emissions, work toward int'l policies covering all land activities	National and international level; governments, industry, NGOs	Allows iLUC emissions until protections in place; more upward pressure on food price when all land-use conversions are covered
Encourage non-land-using feedstocks (such as imposing an iLUC factor to a particular feedstock pathway)	National level; governments	Concerns about regulating on the basis of actions by others outside the jurisdiction, choosing a single number given uncertainties; no incentive for improvement given feedstock choice
Macro measures targeting efficiency of agricultural supply (e.g., producer set-aside funds)	Firms and industry level; governments, NGOs, and international bodies	Do not address iLUC effect directly, hard to measure additionality, thin on details of how a credit system would work
Avoid displacement (UK Ecofys and Winrock case study work) [avoids price response]	Project level; supply-chain actors, certification industry	Shares issues with other certification schemes (including the Clean Development Mechanism, or CDM), difficult to scale up, hard to measure additionality, thin on details of how a credit system would work
"Contain" iLUC via direct LUC areas [doesn't avoid price response]	Regional level; supply-chain actors	Designing, assessing containment (requires theory of incomplete price transmission), thin on details of how a credit system would work
"Contain" iLUC via avoiding iLUC-prone areas	Regional level; supply-chain actors, targeting production systems	Assessing successful containment (given uncertainty regarding location of iLUC response), hard to measure additionality, thin on details of how a credit system would work

In the short term, governments should work with academic communities and stakeholders to improve models uncovering the drivers (if not always the magnitude) of iLUC to gain a better handle on the challenging task of improving the scientific understanding of iLUC. Government policies seeking to improve the design of strategies to mitigate iLUC impacts must be vetted through a robust set of models, stakeholder engagements, certification bodies, and local communities.

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To mitigate iLUC emissions, policy makers should aim to directly incentivize the development and use of low-GHG biofuels from less land-using sources, including organic waste, crop residues, and forest waste. Biofuels produced from cellulosic energy crops grown on degraded lands can have lower iLUC effects due to less direct competition for land for food and other agricultural production. This pathway also tends to have a better sustainability performance than food crops due to lower intensity of agricultural inputs (fertilizer, irrigation, and pesticides). While commercial development of low-iLUC biofuels lies largely in the future, there are indications the U.S. could produce large quantities at a reasonable cost given sustained and aggressive efforts to accelerate the development and penetration of low carbon alternative fuels and technologies. To prevent iLUC and other unintended consequences, governments should also adopt enforceable, effective sustainability policies to prevent conversion of ecologically sensitive and high-carbon areas for biofuels or any other purpose; encourage appropriate use of fertilizers and other inputs for biofuels and other crops to reduce harmful environmental impacts from excess runoff; and work to improve access for the poor to food, especially if prices rise. These policies, not specifically aimed at biofuels, target the sweeping economy-wide changes needed to reduce the unwanted "leakage" effects from biofuel (or other) policies that affect land use.

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