ifeu -
Institut für Energie-
und Umweltforschung
Heidelberg GmbH

Synopsis
Current Models and Methods Applicable to Indirect Land-Use Change (ILUC)

Executive Summary

Commissioned by
Bundesverband der deutschen
Bioethanolwirtschaft e.V. (BDB^e)

Heidelberg, September 2009

Executive Summary

Background and Objectives of the Study

The discussion on sustainability criteria for bioenergy, which has been led with great vehemence internationally during the last two years, gradually approaches a canon of basic principles. This was also documented at the end of April 2009 in the European Directive on the Promotion of the Use of Energy from Renewable Sources (2009/28/EC). The aspect where both the data records and applicability still leave the most important questions unanswered concerns the indirect land-use change. The European Commission is therefore supposed to submit a report according to Article 19 (6) of the Directive until the end of 2010 (presumably already before March 2010), in which this topic is investigated..If possible, a proposal shall be made that includes a concrete methodology based on the best scientific knowledge available to account for greenhouse gas emissions due to indirect land-use change (ILUC).

In March 2009, such an approach was included for the first time in the legal regulations of California (LCFS 2009). The U.S. EPA (2009) also submitted a proposal in May. Its realization, however, was obstructed by a five-year moratorium including a scientific reassessment in the meantime due to an agreement in the House of Representatives on June 24, 2009.

Due to the great number of these processes, the debate on the “best possible” method to evaluate ILUC will be intensified in both the European and international context. Against this background, the BDB^{e} commissioned the IFEU to provide an inventory and assessment of current models and methods suited to account for the effects of indirect land-use changes. In the scope of this activity, the strengths and weaknesses of each model were to be analyzed, possibilities of development with regard to further policy goals presented, and fields of action identified.

Results

In summary, three basic approaches to ILUC calculation became discernible which might be of relevance to the further discussion of this topic:

- Complex **macro-economic and/or econometrical models**;
  models such as GTAP, FASOM, FAPRI, for example, which are predominately applied to the legislation in the U.S. as well as California; the scientific foundation relative to ILUC is provided, among others, by Searchinger et al. (2008), Kim et al. (2009), Plevin (2008);
- Simplified **deterministic approaches**;
  approaches such as the ILUC factor (Fritsche 2007, 2009) or the bonus according to the European Directive on Renewable Energy Sources (2009/28/EC);
- Other approaches which strike a **balance** between these two approaches (Lywood 2009, FoE 2008) or focus on ILUC risk minimization (Dehue 2009, Eickhout 2008).

Macro-economic models were originally developed to quantify the effects of interventions into agricultural markets. Recently, they are also drawn upon to calculate ILUC effects and/or indirect and direct land-use changes altogether.

The main problem of the econometrical models lays in their complex nature – due to their complexity, the calculatory procedures and results are hardly comprehensible to experts not involved in their making. This necessarily entails a “faith” into these models. On the other hand, the strongly varying results among the prominent examples of the Renewable Fuel Standard in the USA with the FASOM / FAPRI model mix, the Low Carbon Fuel Standard of California with the GTAP model and Searchinger et al. (2008), demonstrate that an increase of complexity does not necessarily result in a greater accuracy, since the differences of the results are virtually “pre-programmed” on account of the multitude of parameters applied. The distinctly higher results of Searchinger, for example, primarily ensue from the fact that his calculations neglect future yield increases. Whether and to which extent yields will increase in the future strongly depends on the particular crop and the respective agro-ecological zone (AEZ).

However, the use of such models is extremely valuable to gain knowledge on market reactions, interactions, sensitivities, and the dimensions of effects. But it may be questionable to implement such a model in the scope of a legislative enactment as long as the scientific community has not agreed upon the “right” model. Results ranging from 30 to 104 g CO_{2eq}/MJ for corn ethanol, for example, don’t satisfy the requirement of scientific precision.

As much as the results derived from econometrical models may scatter, they at least give an orientation as to the potential order of magnitude. First, it is observable that the cases of calculated ILUC greenhouse gas emissions from the U.S. and California consistently reveal values above zero. However, the effects from using co-products , for example, as animal feed, considered in the EPA and Californian models and the resulting calculated reductions of land use can hardly be understood by experts who were not involved in the development of the models. Despite comprehensive documentation, the models prove to be too complex in order to realize whether, for example, distinctly different LUC values are calculated for feedstocks from co-products produced on the US market than for products produced on the EU market.

It may be made clear at this point that this overview study cannot contain any comprehensive analysis of the models – a substantiated assessment may be derived from the recently published ICF (2009) peer review report on the FASOM/FAPRI combination. In it, selected experts[1] conclude that despite the basically good suitability of the model combination

- no model alone could give the “right” answer, since each model (incl. GTAP and other models) possesses specific strengths and weaknesses which inevitably leads to deviating results
- the complexity of the models is already too high in order to enable transparency (Sheehan, Searchinger)
- the complexity is not yet sufficient in order to adequately include all relevant factors (Banse, Wang).

At a LUC-Workshop attended by high-ranking participants in Vonore, Tennessee, in May 2009 it was subsumed in a similar fashion that one single model invariably processes one single partial aspect of the overall problem only, whereas the necessary combination of models produces additional uncertainties due to the creation of interfaces (Dale et al. 2009). The step towards understanding which models lead to which results under which assumptions and data applications still has to be made.

---

[1] Dr. Martin Banse (Uni Wageningen), Tim Searchinger (Princeton), John Sheeham (Univ. of Minnesota), Dr. Michael Wang (Argonne)

Deterministic approaches somehow represent the opposite of macro-economic models, or model combinations, as far as complexity is concerned. In particular, the “risk adder” elaborated by Fritsche (2007) which has been further developed into the **ILUC factor** (Fritsche 2009) has to be mentioned in this regard. In this approach, at first the global GHG emissions which might stem from land-use change of agricultural products considered as relevant to the bioenergy sector (irrespective of the real use) are calculated on account of existing data. In a second step, the quantitative influence of land-use changes due to an increased future biofuel demand is determined. Attenuating effects, such as future yield increases, use of fallow land, transition to the utilization of residuals, and other LUC-reducing factors are included. However, some of the determinations are the result of overall assumptions and estimations that are not based on scientific empirical facts.

The LUC “ sectoral average” thus obtained is allocated to the various biofuel types on the basis of the respective biomass yield per hectare and the respective conversion rates. The allocation methodology accounts for co-products according to their heating value (according to the Renewable Energy Directive). A further development of the ILUC factor based on empirical values from Gibbs (2009) is in a state of planning (Fritsche 2009).

One weakness of this top-down approach is the undifferentiated derivation of LUC emissions of biofuel production by only one uniform LUC value applicable to the overall sector which is translated to the single biofuel types as a “sectoral average”, irrespective of regional effects, the actual effects of the respective biomass, and co-product effects. This results in the effect that the lowest ILUC GHG emissions are allocated to biofuels from high-risk LUC and ILUC areas. In concrete terms this means: rape crops in Germany possessing a low yield per hectar lead to a higher ILUC risk than palm-oil crops in Southeast Asia that are seen in a closer geographical context with high-risk areas such as the tropical rainforest. This may be consistent if we were to assume a worldwide communicating system within the limited area of cultivable land available. However, effectively, all systems with a high area-dependent yield are preferentially treated, even if these systems stand in a direct connection with the most problematic LUC effects (e.g. palm oil in the AEZ of the tropical rainforests).

Fritsche (2009) therefore perceives the necessity of adjusting the current ILUC factor by a kind of regional “risk mapping.” The authors of this study also see the need of improving the method of the ILUC factor approach by accounting for regional and path-specific effects.

Opposed to the macroeconomic models which do not differentiate between direct and indirect effects as far as LUC is concerned, when using the ILUC factor, it must be ascertained that there is a clear delineation to the direct effects in order to prevent double counting.

A combination of macroeconomic model information and its integration into a more simple deterministic approach could be the “silver bullet.” Various authors have already worked in this direction with **spread-sheet models**. Especially the model developed by Lywood (2008, 2009) may be mentioned in this regard. It examines first (on the basis of historical data) which proportion of a certain increased demand of biomass is met by an increased land use and which is met by an increased productivity. After the inclusion of co-products, a net-land-use effect ensues. As far as the co-products are concerned, an assessment is made of the quality of ensuing intraregional and interregional substitution effects and kinds of land areas re-assigned to agricultural land areas in the respective regions (also on the basis of historical data). This, in turn, yields in the CO_2 release from the new land surfaces which is converted into an annual ILUC factor. This approach is hence both biomass-specific and regionally specific.

As for this proposal, two details must be primarily examined more closely:
1) the historical context is in fact reasonable, but the increases in crop yields are only regarded globally.

2) A differentiation of the various world regions will be effected upon inclusion of the co-products. However, the interactions between the land uses in the various regions of the world are not treated despite the globalized market, i.e. the international entanglement of ILUC remains unaccounted for.

Lywood introduces the substitution method to calculate ILUC effects. At present, this is not foreseen in general by the Renewable Energy Directive, but is mentioned in the scope of monitoring and reporting GHG savings by the Member States, to be used by the European Commission as a reference model (Article 23), as well as in Annex V, Part C, Numbers 15 to 16 and in Article 19 Paragraph 7. The European Commission makes the allocation method, instead of the substitution method, compulsory for the individual calculation of co-products due to the various options of an optimized assessment on the business-management level. On the higher-ranking (economic) level, the Commission must apply the substitution concept as referential standard when performing the risk assessment of GHG emission savings.

Lywood, for example, credits DDGS produced in Europe with soy meal produced in South America with considerably lower crop yields per hectar, i.e. correspondingly considerable LUC effects. If the co-products were to produce such decisive (decisively positive in the case of wheat) ILUC effects, such an approach would be justifiable. This effect was also displayed in an IFEU study (Rettenmaier et al. 2008) with the scope of co-product scenarios.

As a matter of principle, the specification of a certain co-product as substituted product may represent a justified scenario. For a general model, however, the question will be asked how the substitution of this very product (e.g. soy meal, produced in freshly uprooted forests in South America) can be proven to be applicable to the entirety of co-products. An elaboration would therefore consist of determining the influence which possible (imaginable) substitution consequences other than soy substitution might have on the results in the Lywood model.

Verifications as to which assumptions sufficiently represent reality are always needed. To this end, comparative calculations could be done with various macroeconomic models, since they claim to depict the “marginal” (limit) substitution effects. An extensive reciprocal reproducibility of the LUC values should be feasible if the relevant parameters are identically set. According to the state of analysis, this is not the case at present considering the results from the U.S. and California, even though this cannot be negatively attributed to any one of the approaches alone, because none of them is at present sufficiently transparent in the opinion of the authors.

Conclusions

With the tight time schedule of the European Commission and the discussion in the U.S., ILUC effects will constitute a core subject of sustainability requirements and greenhouse-gas balances for bioenergy sources in the near future.

Each of the approaches presented does not allow by itself for a final assessment of this complex subject. The great variations of the results indicate that a considerable deficit exists in limiting the quantitative dimension of the effect. If one were to present the scope of published results derived from the various approaches, macroeconomic models would exclusively lead to additional LUC emissions, whereas the Lywood approach also calculates net savings in individual cases. The deterministic ILUC factor determines, depending on the respective basic approach, either a malus (additional crops on “normal land”) or a bonus (degraded land).

In any case, the results lead to significant effects in the overall life cycle assessment of bioenergy, regardless of the approach applied. This is of considerable importance with regard to the possibility of fulfilling the necessary emission saving rates.

The discussion on the “right” approach or the “right” model will therefore have to continue. The authors perceive the necessity of including ILUC adequately as a consequence of additional land use for biomass crops intended for energy purposes, food production, and fiber utilization. Whether one of the abovementioned approaches will prove successful as an acceptable standard, must at present be evaluated as undecided. Most certainly, complex models are urgently needed in order to explore the indirect effects of the additional biomass production which depend on market reactions and to make interactions evident. However, a high rate of transparency and comprehensibility of the results for the non-experts as well will be inevitable for their implementation in legal acts. At the moment, science catches up relative to politics and its imposed objectives. The goal should be similar results pertaining to ILUC reproduced with the various models and approaches, once the factors responsible for deviations have been realized.

In life-cycle analyses in general respectively balancing the life cycles of bioenergy sources in particular, two modules which must be joined for an overall assessment are to be distinguished:

- direct effects which ensue from process balancing (classical LCA)
- indirect effects which have to be registered and evaluated in their entirety by a separate method.

Regardless with which method a calculated ILUC value is determined, the scientific community is aware that it invariably can only represent an auxiliary, albeit acceptable, construct. In reality, the so-called “indirect effects” of biomass production are direct effects caused by other sectors (e.g. food and fiber production). However, the ideal solution of a uniform model to encompass all sectors in an integrative regulation of land-use changes and resulting greenhouse-gas emissions sought for by theory in practice appears to be realistic at best in the mid or long term, whereas this expansion of dimension is at present more a theoretical thought.

References

Dale, V., Efroymson, R., Kine, K., Goss Eng, A., Haq, Z.: Land-Use Change and Bioenergy: Report from the 2009 Workshop by ORNL and DOE; Vonore, Tennessee; Mai 2009

Dehue, B., Meyer, S.: Responsible Cultivation Areas; Practical definition and methodology to identify areas for responsible energy crop cultivation; im Auftrag von Shell Global Solutions und Neste Oil; Utrecht 2009

Eickhout, B.: Monitoring macro-impacts of bioenergy; PBL publication number 500143002/2008

Fritsche, U.: GHG Accounting for Biofuels: Considering CO_2 from Leakage; Extended and updated version, Darmstadt (Germany), May 21, 2007

Fritsche, U. et al: The ILUC factor as a means to hedge risks of GHG emissions from ILUC associated with bioenergy feedstock provision, Oeko Institute, 2008

Fritsche, U.: Accounting for GHG Emissions from Indirect Land Use Change: The iLUC Factor Approach; IEA Bioenergy Task 38 Workshop “Land Use Changes due to Bioenergy - Quantifying and Managing Climate Change and Other Environmental Impacts”, Helsinki, 30.-31. März 2009

Gibbs, H.: Mapping Land Sources for New Biofuel Croplands; AAAS Annual Meeting, 2009

ICF International: Life Cycle Greenouse Gas Emissions due to Increased Biofuel Production, Model Linkage; Peer Review Report, 2009

Kim, H., Kim, S., Dale, B. E.: Biofuels, Land Use Change, and Greenhouse Gas Emissions: Some Unexplored Variables; Environ. Sci. Technol., 2009, 43 (3), 961-967• DOI: 10.1021/es802681k • Publication Date (Web): 06 January 2009

LCFS - Low Carbon Fuel Standard: Proposed regulation to implement the low carbon fuel standard, California Air Resources Board (CARB) 5 Mar 2009

Lywood, W.: Evidence provided by Ensus Ltd to the RFA study on the indirect effects of biofuels, Ensus Ltd, Apr 2008, UK RFA, www.renewablefuelsagency.org, Methodology for evaluation of indirect land use change from biofuel crops and estimate of GHG emissions

Lywood, W.: Indirect LUC modelling; JRC/EEA/OECD Workshop, Paris 2009; http://re.jrc.ec.europa.eu/biof/pdf/iluc_bioenergy_policies_paris/ensus_iluc_modelling.pdf

Plevin, R.: Analysis of GHG Emissions from Indirect Land Use Change; Life Cycle Assessment VIII Seattle, WA September 30, 2008

Rettenmeier, N., Reinhardt, G., Gärtner, S., Münch, J.: Bioenergy from grain and sugar beet: Energy and greenhouse gas balances; IFEU study commissioned by the Verband Landwirtschaftliche Biokraftstoffe LAB (heute: BDB^e); 2008

Searchinger, T. et al.: Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change, : Science, 2008, Vol. 319. 5867, pp.1238-1240, 10.1126/science.1151861.

Tipper, R. et al.: A practical approach for policies to address GHG emissions from ILUC associated with biofuels, Arbeit für Ecometrica für Greenergy, Technical Paper - TP-080212-A; Jan 2009

UNICA: Comments on California's Low Carbon Fuel Standard; Brief an CARB vom 16.April 2009

U.S.EPA: Draft Regulatory Impact Analysis: Changes to Renewable Fuel Standard Program; EPA-420-D-09-001; May 2009 http://www.epa.gov/OMS/renewablefuels/420d09001.pdf