EUROPEAN PARLIAMENT

DIRECTORATE-GENERAL FOR INTERNAL POLICIES

POLICY DEPARTMENT A
ECONOMIC AND SCIENTIFIC POLICY

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Indirect Land Use Change and Biofuels

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Indirect Land Use Change and Biofuels

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DIRECTORATE GENERAL FOR INTERNAL POLICIES
POLICY DEPARTMENT A: ECONOMIC AND SCIENTIFIC POLICY

ENVIRONMENT, PUBLIC HEALTH AND FOOD SAFETY

Indirect Land Use Change and Biofuels

STUDY

Abstract

This study discusses the impact of indirect land use change (ILUC) on greenhouse gas (GHG) emissions from biofuels by evaluating the scale of ILUC linked with the EU biofuels targets. For that, studies carried out for the Commission are critically reviewed and analysed, and a short evaluation of the Commission Report on ILUC is included also.
The study assesses also possible cumulative effects of the biofuels target and use of biomass for energy as projected in National Renewable Action Plans, and draws conclusions on the appropriate level of an ILUC factor.

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AUTHORS

Mr. Uwe R. Fritsche
Ms. Kirsten Wiegmann
Oeko-Institut, Energy & Climate Division
Darmstadt, Germany

RESPONSIBLE ADMINISTRATOR

Mr Lorenzo VICARIO
Policy Department Economic and Scientific Policy
European Parliament
B-1047 Brussels
E-mail: Poldep-Economy-Science@europarl.europa.eu

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ABOUT THE EDITOR

To contact the Policy Department or to subscribe to its newsletter please write to: Poldep-Economy-Science@europarl.europa.eu

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LIST OF ABBREVIATIONS

a annum (year)

BtL biomass-to-liquids (Fischer-Tropsch diesel)

CGE Computable General Equilibrium Model

CO_2eq Carbon Dioxide equivalents

DDGS Distillers Dried Grains and Solubles

DG AGRI European Commission Directorate General for Agriculture and Rural Development

DG CLIMA European Commission Directorate General for Climate Action

DG ENER European Commission Directorate General for Energy

DG ENV Directorate General for Environment

DG TRADE European Commission Directorate General for Trade

DLUC Direct Land Use Changes

EP European Parliament

EPA US Environmental Protection Agency

EtOH Ethanol

ETS European Emission Trading Scheme

FAO Food and Agriculture Organisation of the United Nations

g gram (= 10^{-3} kg)

GBEP Global Bio-Energy Partnership

GHG Greenhouse Gases

GTAP Global Trade Analysis Project

ha hectare (= 10^4 m^2)

IEA	International Energy Ageny
IFPRI	International Food Policy Research Institute
ILUC	Indirect Land Use Change(s)
IPCC	Intergovernmental Panel on Climate Change
JRC-IE	Joint Research Institute of the European Union, Institute for Energy (Ispra)
JRC-IPTS	European Commission Joint Research Centre, Institute for Prospective Technological Studies, Sevilla
k	kilo (1,000)
LCA	Life-Cycle Analysis (or Life-Cycle Assessment)
LUC	Land Use Change(s)
M or mill.	million (1,000,000)
MJ	MegaJoule (= 10^6 J)
MtOE	Million tons of Oil Equivalents
NREAP	National Renewable Energy Action Plans
t	metric ton (= 10^3 kg)
UNEP	United Nations Environment Programme
UN-CBD	United Nations Convention on Biological Diversity
UN-FCCC	United Nations Framework Convention on Climate Change

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EXECUTIVE SUMMARY

Background

At the insistence of the European Parliament (EP) during the co-decision procedure on the Renewable Energy Directive (RED), the Commission was to submit a report to the EP and to the Council reviewing the impact of indirect land use change (ILUC) on greenhouse gas (GHG) emissions and addressing ways to minimise that impact. On December 22, 2010, the Commission released this report, although in a rather brief version[1].

The report was, if appropriate, to be accompanied by a proposal, based in the best available scientific evidence, containing a concrete methodology for emissions from carbon stock changes caused by ILUC, ensuring compliance with the RED, in particular Article 17(2). The report did not deliver on that, though.

Several Commission Services had commissioned studies to evaluate the scale of ILUC linked with the EU biofuels targets, in particular the following:

- Global trade and environmental impact study on the EU biofuels mandate, by IFPRI for DG TRADE (IFPRI 2010)
- Indirect Land Use Change from increased biofuels demand. Comparison of models and results for marginal biofuels production of different feed stock, JRC-IE for DG CLIMA (JRC-IE 2010)
- Impact of the EU biofuels target on agricultural markets and land use - a comparative modelling assessment, JRC-IPTS for DG AGRI (JRC-IPTS 2010).

Aim

The purpose of this study is to:

- evaluate the studies commissioned by the different Directorate Generals regarding, inter alia, the appropriateness of the assumed share of biofuels for 2020 (taking into account National Renewable Action Plans), anticipated biodiesel/ethanol split share of second generation biofuels and electric cars commercially available
- draw conclusions on the level for the ILUC factor, in particular to assess the appropriateness of the ENVI/ITRE adopted specific levels for the ILUC factor at the time of the co-decision procedure, and
- assess possible cumulative effects of the biofuels target and use of biomass for energy as projected in National Renewable Action Plans
- briefly evaluate the Commission Report on ILUC.

Key Results

The study shows that

- the IFPRI study gives a lower-end estimate of ILUC-related GHG emissions from biofuels, and could be improved by using available updates of the GTAP database.
- The JRC-IE study is an important step towards inter-comparability of LUC models, and increases respective insights. Due to the restrictions of the models compared, only very little results on ILUC-related GHG emissions could be derived, though.
- The JRC-IPTS study is another step towards inter-comparability of LUC models. The modelling of global distribution of ILUC is valid, but due to model restrictions, no ILUC-related GHG emissions were calculated.

[1] see EC (2010a). A brief first discussion of this report is given in Section 4 of this study.

With regard to the ILUC factor, the study also reflects other relevant scientific work, and, based on the assessment of the EC studies and this additional work, concludes that the **current scientific knowledge allows deriving a valid quantitative approximation for GHG emissions from ILUC effects which can be differentiated for various biofuels.** It is recommended to define such a robust ILUC factor, and to develop it further in the next years together with the international scientific community, especially activities in the USA, and of the GBEP.

The cumulative effects of the renewable transport fuel target and of the use of biomass for energy in the EU27 are far less certain yet due to uncertainties in projected biomass use in the respective sectors of the EU Member States. The NREAPs do not give enough detail on future imports (nor their origins) of biofuels and bioenergy in general, **but overall LUC from non-biofuel uses (electricity, heat) is expected to be comparably low due to economic restrictions, and the short development period until 2020**.

Based on a study of IEEP (2010) and ongoing work of the EEA[2], it can be estimated that by 2020, the overall majority of LUC – both direct and indirect – will be caused by feedstock production for biofuels. Biodiesel and biogas used for electricity generation will induce a small share of LUC, and even a smaller share can be assumed for biofuels used for heating.

Assuming current bioenergy and land use policy in the EU to remain unchanged until 2020, the order of magnitude of possible ILUC-related GHG emissions could nearly negate GHG savings from fossil fuels substituted by biofuels from dedicated energy crops. On the other hand, a scenario assuming stricter EU (and Member State) policies on land use and bioenergy support could achieve significant net GHG emission reductions, but at higher costs.

The study also gives a **first reflection on the Commission report on ILUC** (released Dec. 22, 2010): This report does not deliver an unambiguous statement on ILUC, pointing out that "a number of deficiencies and uncertainties associated with the modelling, which is required to estimate the impacts remains to be addressed". However, the Commission “acknowledges that indirect land-use change can have an impact on greenhouse gas emissions savings associated with biofuels, which could reduce their contribution to the policy goals, under certain circumstances in the absence of intervention. As such, the Commission considers that, if action is required, indirect land-use change should be addressed under a precautionary approach”.

In the “next steps” section, the Commission report presents policy options which have already been subject to massive critique in the pre- and the formal ILUC consultations of 2009 and 2010 due to their lack of consistency[3]. The Commission is currently assessing the impact of these four options. Due to the resources needed, in terms of time and workload, it is difficult to understand the need to assess the first two options listed by the Commission that are clearly **counterfactual**:

Option (1) "Take no action for the time being, while continuing to monitor" ignores all findings regarding ILUC (even those summarized in the report) which call – also in the report’s wording – for a precautionary ILUC value to be inserted in the GHG balance of biofuels. Furthermore, monitoring ILUC is scientifically impossible due to its nonlocal nature – thus, the “continuing to monitor” could be understood only if its refers to the monitoring of the best available science.

[2] This work is supported by the European Topic Centres for Air and Climate Change (ETC-ACC) and Land Use and Spatial Information (ETC-LUSI). The final report will be published on the EEA website in early 2011.

[3] The outcome of the consultations is available from the DG ENER website, see EC (2009) and EC (2010b).

Option (2) "Increase the minimum greenhouse gas saving threshold for biofuels" cannot be substantiated by current science. This is no definite safe option since this could even mean that GHG emissions from ILUC might increase, as it would increase pressure to cultivate biofuel feedstocks on arable land (which has lowest direct LUC impacts), and thus actually increase displacement and, hence, ILUC.

The other two “options” presented in the Commission report might be, in comparison, potentially more adequate:

Option (3) "Introduce additional sustainability requirements on certain categories of biofuels" is too vague in its formulation – one might only speculate that this would mean to require avoidance of using prime arable or pasture land for biofuel feedstock production.

Option (4) "Attribute a quantity of greenhouse gas emissions to biofuels reflecting the estimated indirect land-use impact" **is the only valid option** which should be explored further, as it represents the quantitative approach towards GHG emissions from ILUC, as recommended in this study. Without any value given by the Commission, even this “option” is of highly speculative nature, though.

In addition to the lack of consistency in the policy option portfolio proposed by the Commission report, another point is noteworthy: Although the report acknowledges that both the **US EPA and the California Air Resources Board already included quantitative ILUC values in their regulations, the Commission does not reflect at all what this means for the European policy towards biofuels. The Commission report does not justify why Europe should have “other science”, or why ILUC should be less important in the EU.**

All in all, the Commission report should be seen as an **interim product only.** The reasons for the lack of appropriate answers to the RED requirements concerning the December 2010 deadline is not properly addressed in the Commission report. The limited size and substance of the report, that could be related to staff restrictions of the responsible DG and time constraints to prepare the report, do not allow a full appreciation of the ILUC challenge, and its regulatory implications for the EU. **It does not contain a concrete methodology for emissions from carbon stock changes caused by ILUC, ensuring compliance with the RED, as requested by the European Parliament.**

Given the preliminary nature of this first review of the Commission report on ILUC, the European Parliament may consider

- to closely monitor the preparation of the Impact Assessment,
- to follow-up on the adequacy of available resources for its preparation,
- to critically reflect the inclusion of key EU resources such as the European Topic Centres, and the EEA, and knowledge available from the US rulemaking on ILUC,
- to call upon the Commission to focus its work especially on option 4 to avoid possible negative responses from the Parliament.

The European Parliament might consider updating its own proposals for an ILUC factor to be included in the RED methodology for GHG emission balances for biofuels based on the evidence compiled in this study.

GENERAL INFORMATION: INDIRECT LAND USE CHANGES

KEY ISSUES

- The production of biofuels feedstocks on arable and pasture land can induce so-called indirect land use changes (ILUC) through **displacing previous production** to other land, both in- and outside of the EU.
- ILUC effects have a **significant impact** on the greenhouse gas (GHG) balance of bioenergy in general, and biofuels in particular. ILUC could also negatively **affect biodiversity**.
- ILUC effects are **not** specific to biofuels or bioenergy, but to **all incremental** land use.
- ILUC effects **cannot be monitored**, only modelled. Current studies in **modelling** ILUC effects of biofuels have significant shortcomings in terms of scope, consistency, and data, but are adequate to determine a **reasonable minimum range** in terms of GHG emissions.
- ILUC effects can be **controlled, reduced, offset and – in the longer-term - even eliminated** through a variety of polices.
- Although ILUC effects on the GHG balance of biofuels can be very high, there are **biofuels with low to zero ILUC impacts**, but these biofuels tend to be **more costly**.
- The overall potential of LUC impacts from biofuels on total global GHG emissions are comparatively small, but LUC-related GHG emissions in general are in the order of 20% of global GHG emissions.

Biofuels and ILUC and its influencing variables

Cultivating biomass feedstocks can have ILUC effects through displacing current agricultural (food, feed) or forest (fibre, timber) production to other areas[4] - e.g. grasslands or forested land – which causes direct land use changes (DLUC) **at the new** location. Thus, LUC effects which are "indirect" to bioenergy are "direct" effects of changes in agriculture (food, feed), and forestry (fibre, wood products).

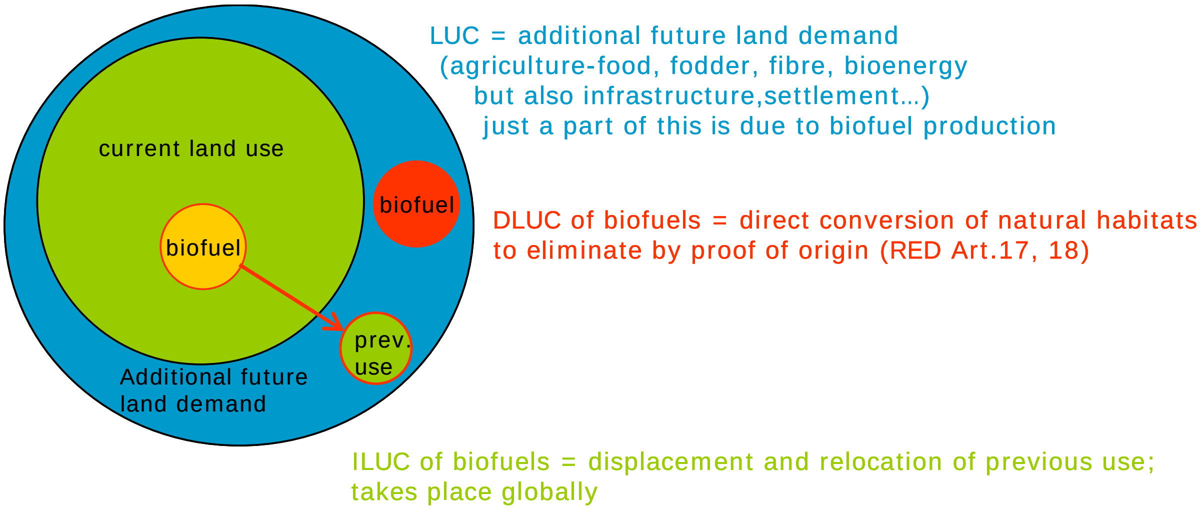
ILUC **cannot** be determined with respect to any **individual** feedstock production activity since the displacement could

- move previous agricultural production to areas outside of a country;
- occur with significant time lags; and
- be distributed through global trading.

[4] A key assumption for this is that demands for displaced production remain the same or even grow. For food and feed, demands are expected to rise in the next decades, depending on population growth, income, and diets (which are interlinked). Still, one needs to consider the price elasticity of demands – if prices for e.g. food and feed rise due to land or price competition with biofuels, the demand for food/feed might be reduced compared to the demand without additional biofuels. Similarly, prices can have an effect on diets (share of dairy and meat), which could reduce the actual displacement.

Consequently, ILUC is "non-local". The non-locality of indirect effect is a result of the non-locality of global commodity markets.
Unless one assumes a **full global "tracing and tracking"** for the origin of **all traded commodities** (irrespective of their respective uses), one cannot know whether a production increase of an agricultural commodity in a given country is induced by rising demands for food or feed, or by a change in trade relations, or by rising demand for, e.g., bioethanol produced from wheat.
For a variety of reasons, such a full global tracing and tracking system is neither feasible in a policy context nor practical in the near future[5]. In consequence, one will have to deal with indirect effects of incremental land use, and find ways to identify and quantify ILUC effects as long as specific policy goals such as net GHG reduction are related to, e.g., biofuels.

Figure 1: Principle of LUC (DLUC and ILUC) Due to Biofuel Production



Source: based on Ecofys (2010), and OEKO (2010)

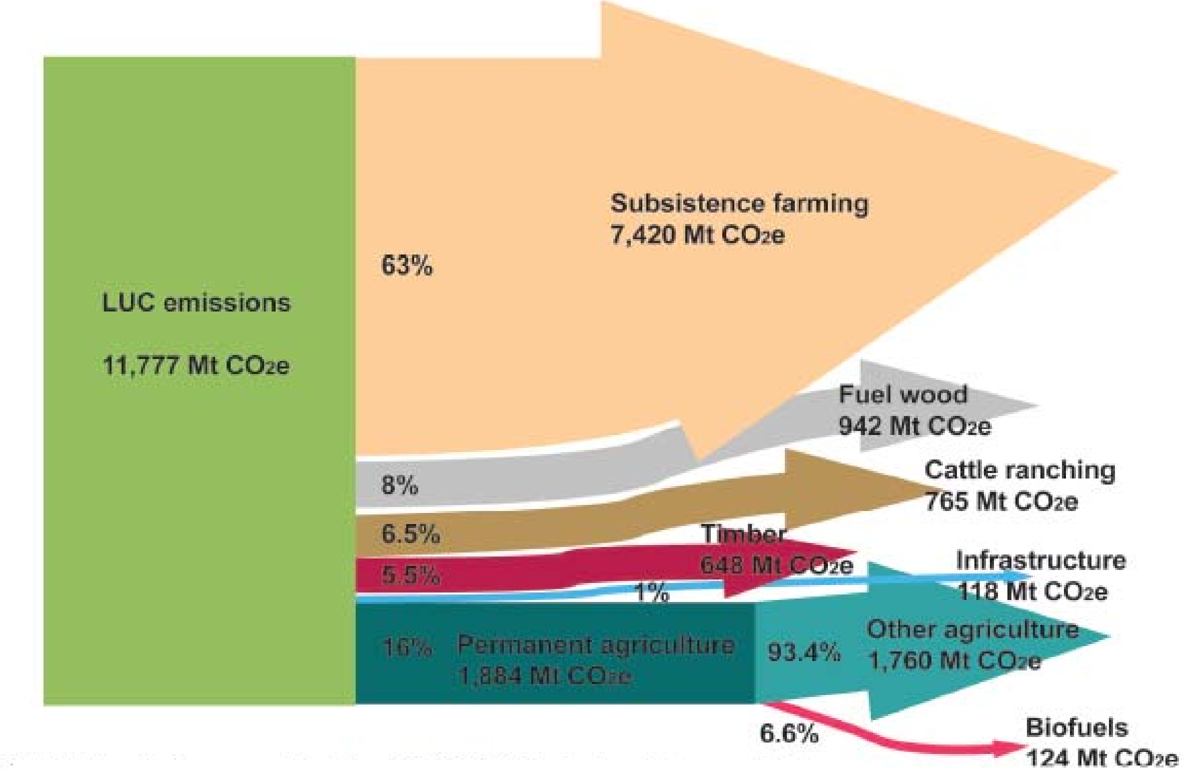
LUC can induce GHG emissions due to oxidation of soil organic carbon and due to burning or decomposition of above-ground biomass[6]. Biofuel production is only one of numerous contributors to LUC.
The magnitude of GHG emissions due to LUC from global biofuel production is small compared to the total emissions from all LUC: agricultural land expansion for food, feed, fibre, cattle ranching, fuel wood and timber (loggings), and expansion of infrastructure generates by far the greater part of LUC emissions.

Figure 2 gives an indication on the dimension of LUC emissions: The current level of biofuel production contributes to LUC emissions from permanent agriculture with less than 6.6%.

The current contribution of biofuels to total global LUC emissions is about 1% (11,777 Mt).

[5] The global governance of land and carbon is still in its infancy (WBGU 2009), and monitoring of **all** land use changes has severe restrictions in spatial and time resolution, and the correlation between LUC and economic activities in a given country or region within a given time is far beyond current data availability.
[6] Art 17 excludes biofuels and bioliquids from raw material obtained from land with high biodiversity value, from land with high carbon stock and from peatland. Art 18 regulates the verification of compliance with the sustainability criteria of Art. 17.

Figure 2: Causes of Global LUC-Related GHG Emissions



Source: Faaij (2010) based on material for the upcoming IPCC 2011 Special Report on Renewable Energies

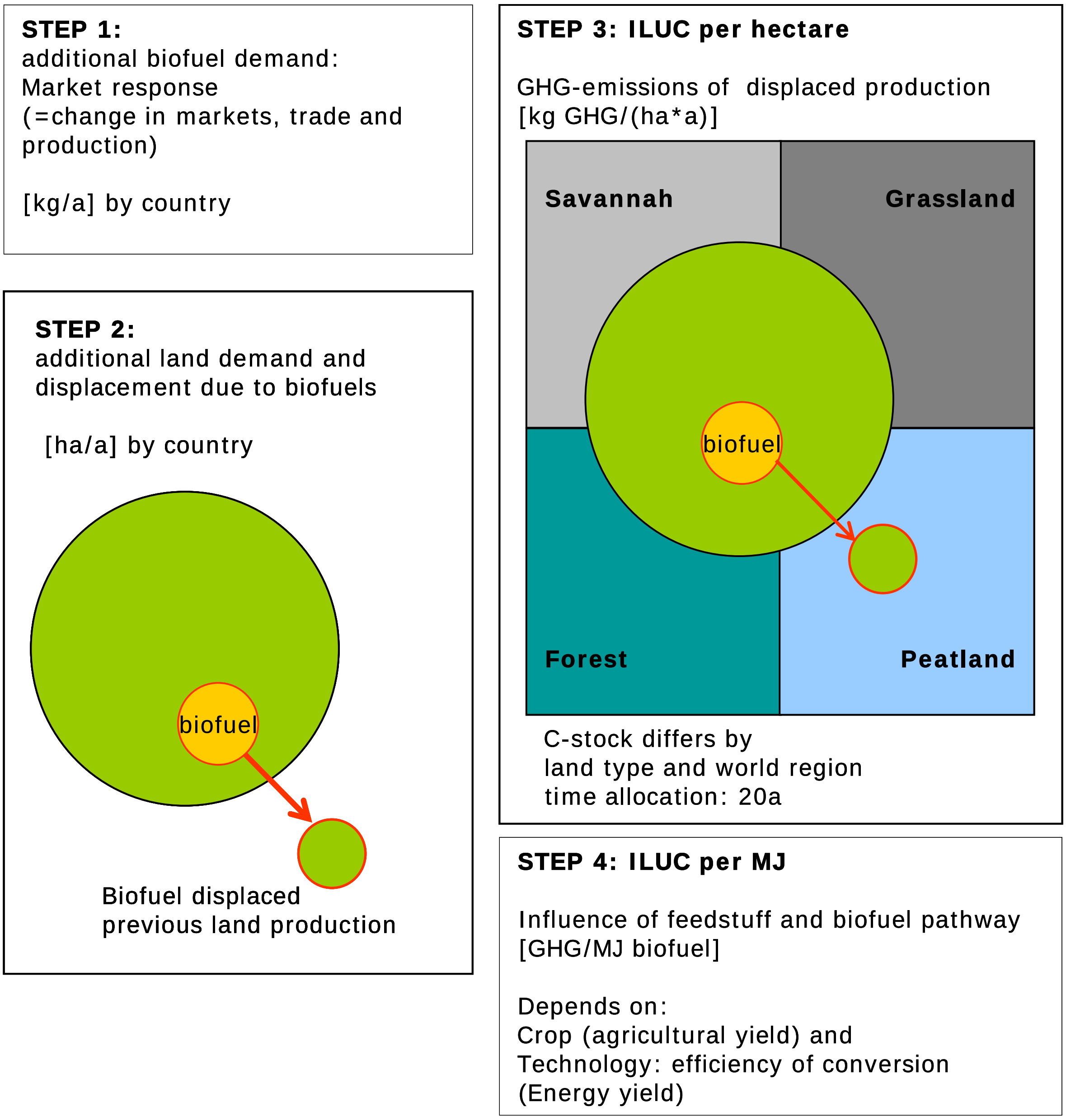
The Science of Quantifying GHG Emissions from ILUC

The market response of additional biofuel demand can be derived from economic models or, alternatively, from causal-descriptive or deterministic approaches – this is explained further below.
For the translation from changed markets to additional land use and resulting GHG emissions by ILUC, biophysical models are needed.

Finally, the biofuel-specific ILUC impact has to be determined, taking into account specific crop yield, and biofuels life-cycles.

The following figure shows the principle four steps needed to calculate GHG emissions from ILUC caused by expanded biofuel production and conversion from energy crops.

Figure 3: Steps to Calculate ILUC-Related GHG Emissions from Biofuels



Source: Authors based on Ecofys (2010), and OEKO (2010)

All four steps have their own specific data needs and modelling challenges, with respective data uncertainties and variations. Furthermore, the **combination** of these models into a coherent flow of data requires special attention to representativeness and robustness of the data used, and to restrictions in the use of data between models with different resolution.

For **steps 1 and 2**, the available scientific approaches for determining ILUC from biofuels are all model-based, but with different complexity, sophistication and transparency.

Complex econometric models (Computable general equilibrium (CGE) models or Partial equilibrium (PE) models) as well as less complex but more transparent causal-descriptive and deterministic models are used.

There is currently no "best" model for ILUC – depending on the scope of questions to be answered, any of the scientific approaches or their combination can be valid[7].

For **steps 3 and 4**, i.e. to calculate the GHG impacts arising from given ILUC, other models have to be used which are not of economic but **biophysical** and technical nature:

To derive the CO_2 emissions resulting from a given ILUC, the carbon (C) content of the affected land **prior** to its conversion must be known, as well as the C content after the conversion. But one also needs to determine what the previous land use was (e.g., cropland, pasture, forest) and if displacement occurred.

Once the GHG emissions from ILUC caused by biofuel feedstock production is determined, the remaining task is to relate these emissions to the final biofuel output. For this, **life-cycle analysis** (LCA) is the appropriate tool which links the various steps of producing the biofuel feedstock. LCA is a data-intense and complex activity, and various models are developed for data management and computational work.

This brief discussion of the modelling approaches to ILUC-related GHG emissions from biofuels clearly indicates that

- the quantification of ILUC emissions requires **coupling** of several models from very different scientific realms (economic, biophysical, technical),
- **each** model has its intrinsic uncertainty,
- data requirements to model global impacts are **very high** unless simplified approaches are used.

These key issues should be kept in mind when reading the following review of ILUC studies prepared for the Commission report on ILUC.

After this review, the issues will be taken up again in Section 2 with an overall conclusion on ILUC methodologies, and respective quantitative data.

[7] The Dutch Environmental Assessment Agency noted on ILUC models: "Models, by definition, provide a simplified version of the world which means that every model has its pros and cons" PBL (2010c). The E4Tech study argued: "Modelling requires projecting impacts in the future, which is inherently uncertain (…) ILUC models cannot be validated or calibrated against historic data because indirect land use change is not an observable parameter, meaning that several potential impact pathways may be possible" (E4Tech 2010). For more detailed and comparative discussion of models, see CARB (2010), CE (2010), Ecofys (2010) and IEA Bioenergy (2009-2010).

1. CRITICAL REVIEW AND EVALUATION OF EC STUDIES AND OTHER RELEVANT WORK ON ILUC

KEY FINDINGS

The study shows

- that the IFPRI study gives a **lower-end** estimate of the ILUC-related GHG emissions from biofuels, and could be improved by using available updates of the GTAP database;
- the JRC-IE study is an important step towards the inter-comparability of LUC models, and increases respective insights. Due to the restrictions of the models compared, only **very little results on ILUC-related GHG emissions** could be derived, though;
- the JRC-IPTS study is another important step towards the inter-comparability of LUC models, and adds to the insights gained from the JRC-IE study. The spatially explicit modelling of the global distribution of ILUC is valid, but due to the restrictions of the models, no ILUC-related GHG emissions were calculated.

Overall, the EC models give clear evidence that ILUC is a **significant contributor to GHG emissions from biofuels**, and underline that there are several options to reduce ILUC effects.

With regard to the ILUC factor, the study also reflects other relevant scientific work, and, based on the assessment of the EC studies and this additional work, concludes that the current scientific knowledge **allows deriving a valid quantitative approximation for GHG emissions from ILUC** effects which can be differentiated for various biofuels.

1.1. IFPRI Study

1.1.1. Aim and Scope of the IFPRI Study

The object of the IFPRI study was to examine the impact of changes in EU biofuels policies on both the global agricultural production and the environmental performance of EU biofuel policy. The study paid particular attention to the ILUC effects of the main biofuel feedstocks.

1.1.2. Key Assumptions of the IFPRI Study

The IFPRI study used a global computable general equilibrium model (CGE)[8] to estimate the impact of EU biofuels policies.

The model simulations covered the period from 2009 to 2020 and started from a baseline scenario that excluded the EU biofuels mandate. Therefore, the consumption of biofuels in the baseline scenario was assumed to remain stable at the 2008 level of 3.3%. In the next step, three alternative trade policies were calculated against the baseline scenario, as shown in the following table.

Table 1: Scenario Assumptions in the IFPRI Study

Scenario Name	Short Name	Short Description of Scenario
Baseline	Baseline	EU biofuels mandate is not implemented 2008 level of biofuel use of 3.3% is kept stable until 2020
3 trade policy scenarios: EU biofuels mandate of 5.6% biofuels is implemented in all three scenarios (linear increase from 3.3% to 5.6% in 2020)		
EU mandate scenario = central scenario	BAU	No change in trade policies are considered
Full Trade Liberalization	FT	Full multilateral liberalization of biofuel sector
EU-Mercosur	MCS	Liberalization of biofuels trade between EU and MERCOSUR

Source: IFPRI (2010)

The following paragraph gives an overview of aspects factored in by the model calculation:

The baseline scenario incorporated the latest IEA forecasts of energy prices, and OECD data on economic growth. It also maintained the EU anti-dumping levy on biodiesel imports from the US, detailed rendering of the biofuel policies of US and Brazil (incentives and targets) as well as conservative biofuels mandates of 5% in China, Canada, Japan, Australia, New Zealand, Switzerland, Indonesia and Indonesia. These assumptions resulted in an increase in EU demand of biofuels by 70% and in an 8% increase of world production/consumption of biofuels by 2020. The model calculation also took into account the use of by-products from the biofuels production.

The results of the IFPRI study do not assume major changes in the diet of the world population. In the agricultural sector, the end of set-aside policy and the sugar reform in the EU were assumed. Yield increase was differentiated by crops and world regions, and price-induced intensification of crop production was incorporated.

[8] The IFPRI model is an extensively modified version of the MIRAGE model with a database from GTAP, extended to give more detail on biofuels, fertilizer effects, and GHG emissions from LUC.

The time horizon for land-use accounting was 20 years, i.e. IFPRI assumed that the land will be used over 20 years for biofuel production. Thus, total GHG emissions due to LUC were divided by 20 to get annual contributions of ILUC. GHG emissions were calculated on base of C stocks from the IPCC database (IPCC 2006) which differentiates into the categories forest, peatland, grassland and savannah.

Sensitivity analyses were conducted to assess the robustness of the model results with regard to alternative assumptions on the size of the EU biofuels policy target, and on several parameter settings:

- Mandate policy targets

EU 27 biofuel share by 2020	4.6%	5.6%	6.6%	7.6%	8.6%
EU 27 biofuel amount [MtOE]	14.5	17.8	20.7	23.9	27

- Variation of elasticity of land-fertilizer
- Variation of elasticity of crop-energy crop
- Variation of elasticity of crop-pasture (cattle)
- Variation of elasticity of land use extension
- Technology pathway

1.1.3. Key Results of the IFPRI Study

The key results of the IFPRI study can be summarised as follows:

- ILUC has an important effect on the environmental sustainability of biofuels
- The 5.6% mandate (under current assumptions of the central and free trade scenarios) seems not to threaten the environmental viability of biofuels
- ILUC emissions increase rapidly for biofuel targets above this threshold, and diminish the emission benefits of biofuels (non-linear relation of ILUC and biofuel demand). In the study, the non-linearity of the model was highlighted and the respective ILUC emissions were determined by a sensitivity analysis for different mandate levels.
- Under trade restrictions (central scenario), biodiesel production is mostly domestic. But further increase, regardless of duties (as in the central scenario and free trade scenario), will lead to an increase of bioethanol imports, mainly from Brazil.
- Imports of Brazilian sugarcane ethanol will reduce GHG emissions of EU biofuels policy since this is the most efficient option in terms of GHG among 1st generation biofuels. Consequently, eliminating trade barriers will improve the environmental performance of the EU's biofuels policy.
- For biodiesel, no option will reach the RED threshold of 35% and 50% GHG emission savings if ILUC effects are included. Only palm oil will generate emission savings at all (12%) but only in case of a more ambitious technology path.
- Hence, the split between bioethanol and biodiesel is of high importance for the general ILUC of EU biofuels policy.
- In both biofuel scenarios, the largest cropland expansion will be in Brazil, followed by the EU-27 as the second-largest impact. The assumed EU biofuel mandate would results in a global cropland expansion of 0.8 to almost 1 million hectares, this is a share of 0.07% to 0.08% of total global cropland in 2020 (for detailed figures see Table 2).
- Globally, grassland/savannah and pasture appear as the main source for cropland expansion.

Table 2: Scenario Data in the IFPRI Study

scenario		without	with EU mandate	land expansion			
(mio ha)	2008	2020 baseline	2020 BAU	due to EU mandate	% of biofuels	total (incl. mandate) (2008-2020)	% total
Brazil	68	89	89	0.48	0.54%	26.57	29.7%
China	138	142	142	0.01	0.01%	4.46	3.1%
EU27	87	100	100	0.08	0.08%	13.69	13.6%
IndoMalay	33	34	34	0.01	0.04%	1.35	3.9%
LAC	34	40	40	0.04	0.10%	5.70	14.3%
World	**1121**	**1243**	**1243**	**0.82**	**0.07%**	**122.85**	**9.9%**
scenario		**without**	**with EU mandate**	**land expansion**			
(mio ha)	**2008**	**2020 baseline**	**2020 FT**	**due to EU mandate**	**% of biofuels**	**total (incl. mandate) (2008-2020)**	**% total**
Brazil	63	89	90	0.69	0.77%	26.78	29.9%
China	138	142	142	0.01	0.01%	4.46	3.1%
EU27	867	100	100	0.05	0.05%	13.66	13.6%
IndoMalay	33	34	34	0.01	0.04%	1.35	3.9%
LAC	34	40	40	0.04	0.10%	5.70	14.3%
World	**1121**	**1243**	**1243**	**0.98**	**0.08%**	**123.00**	**9.9%**

Source: IFPRI (2010); absolute figures were rounded by the authors

The table above shows a detailed listing of cropland expansion by region for the baseline scenario and both biofuels scenarios (BAU and free trade).
The additional land demand can be calculated by the difference of the baseline and the BAU resp. the FT scenario. World crop land expansion due to EU biofuel mandate is 0.8 Mha for the BAU scenario and almost 1 Mha for the FT scenario. This is a share of 0.07% to 0.08% of total global crop land in the year 2020.
The largest cropland expansion is located by far in Brazil (ethanol exports), EU-27 creates the second intense impact (domestic use of biofuels). Other Latin America and Indonesia and Malaysia are affected in each scenario with 0.04 and 0.01 Mha.
In the free trade scenario, the amount of domestic biofuel production and use in the EU is shrinking in favour of Brazilian sugar cane ethanol.

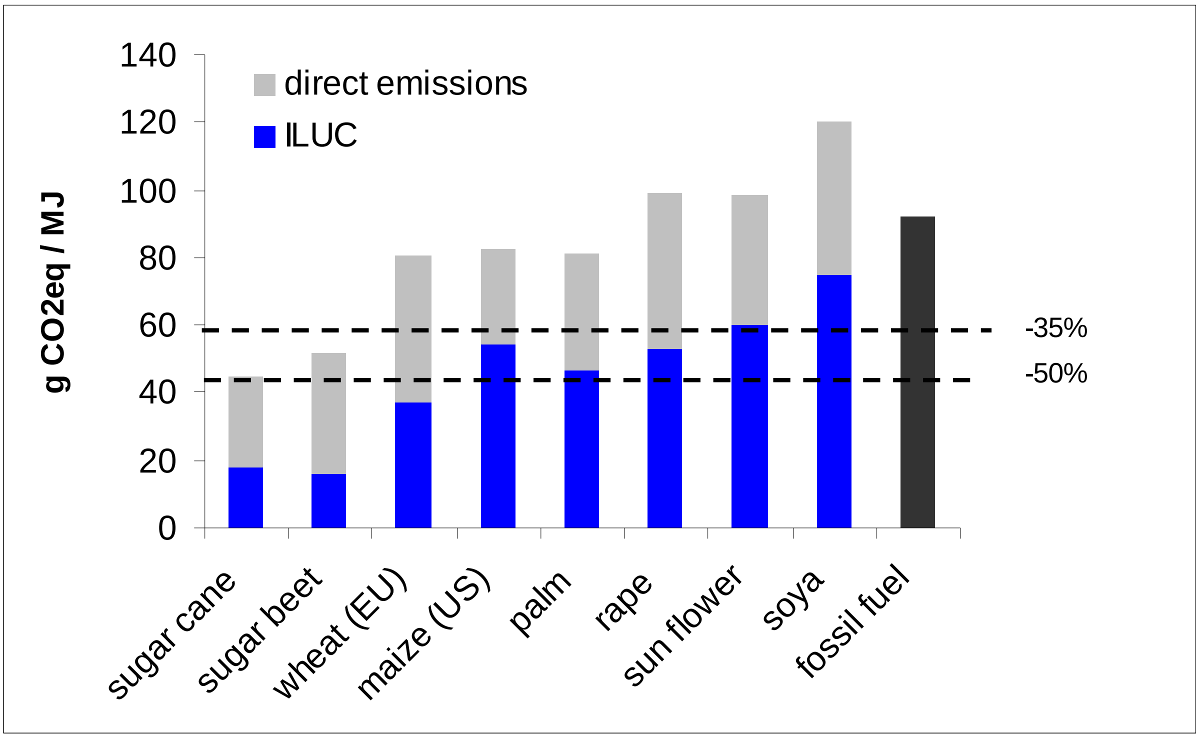
Table 3: Average ILUC in the IFPRI Study

	ratio ethanol:biodiesel		
Scenario	**45:55**	**35:65**	**25:75**
BAU	18.0	31.0	45.0
Free Trade	19.5	32.5	45.5

Source: IFPRI (2010); data given in g CO_2eq/MJ

The table above indicates that the average ILUC factors determined by IFPRI are quite sensitive to the ethanol/biodiesel ratio due to the comparatively low ILUC for ethanol which is a result of the assumed high share of sugarcane-based EtOH from Brazil.
This is shown in the following figure which breaks down the direct and ILUC emissions of GHG for the different biofuels.

Figure 4: Marginal ILUC and Direct Emissions of Biofuels



Source: Author's illustration based on data from IFPRI (2010)

1.1.4. Key Shortcomings and Omissions of the IFPRI Study

In the following, the key shortcomings of the IFPRI study are summarised:

- The fuel split of between biodiesel (55%) and bioethanol (45%) in the policy scenarios (BAU; FT, MCS) is inconsistent with the split given in the NREAPs (75% biodiesel) and the current fuel split (about 80% diesel). The IFPRI analysis clearly indicates – similar to other studies - that there are more cost-efficient and low GHG options for bioethanol than for biodiesel.
- In the sensitivity analysis, single parameters were varied step by step. It would have been interesting to derive a "corridor of ILUC results" by combining all ILUC-diminishing assumption in a minimum scenario on the one hand, and on the other, summarize all ILUC-strengthening factors as a maximum scenario.
- The use of lignocellulosic biomass and 2nd generation biofuel technologies (based on ILUC-neutral residues and wastes) was **not implemented** in the model. However, these feedstocks and technologies will most probably get market relevance only after 2015, so that their share in 2020 will remain low.
- The GHG emissions per hectare of oil palm are significantly underestimated since both the proportion of new oil palm plantations on peatland is too low, and the GHG emissions from peat oxidation per hectare do not cover deep drainage which is needed for oil palm plantations (JRC-IE 2010).

1.1.5. Overall Assessment of the IFPRI Study

The IFPRI study is quite detailed and comparatively well documented. It uses a CGE model which is comprehensive in scope, and has extended resolution for different biofuels. The scenarios give a good representation of the ILUC-relevant questions, but the focus on 1st generation biofuels only is unfortunate, even if the contribution of 2nd generation biofuels to the EU market by 2020 is most probably small[9].

The spatial resolution is also good, with covering the most relevant countries, and the modelling of land use expansion due to feedstock production uses Agro-Environmental Zoning which improves the representation of yields, and respective carbon releases.

The IFPRI model has severe restrictions, though, which are caused by its relying on the GTAP database: The economic structure of the modelling if based on 2004 data, and the GTAP database has a very restricted representation of the EU (agricultural and energy) market. Currently, the GTAP team at the US Purdue University is updating and extending its database so that it would be very helpful to recalculate the scenarios with the new version[10].

Furthermore, the scenarios developed in the IFPRI study suffer from **inadequate definitions** of the biofuel dynamics:

As can be seen from the NREAPs, the diesel-to-gasoline ratio of the EU road transport is most likely to stay much in favour of diesel, instead of the close to parity assumption of IFPRI[11]. As the GHG impacts modelled by IFPRI are far higher for biodiesel than for (mainly Brazilian sugarcane-based) ethanol, this results in a significant underestimation of potential GHG impacts of the EU biofuel demand by 2020.

Last but not least, the biofuel targets in the IFPRI policy scenarios are all set to 5.6% by 2020, which is far too low compared to the NREAPs projections which translate into some 8% (see Section 3.1 for details). Given that IFPRI found an **increase** of ILUC impacts with rising biofuel mandates, this core assumption also leads to a massive underestimation of potential GHG impacts of the EU biofuel demand by 2020.

Even in the sensitivity analysis where IFPRI analyzed the impact of an 8.6% biofuel mandate by 2020, only 35% of the biofuels were assumed to be biodiesel. If the more realistic share of 75% would have been used, the ILUC impacts would have been far higher.

All in all, the IFPRI study gives a "lower-end" estimate of the ILUC-related GHG emissions from biofuels, and could be improved by using available updates of the GTAP database.

[9] This is substantiated by the JRC-IPTS study (see Section 1.3): "The energy share of biofuels is assumed to reach 8.5% in 2020, of which 7% consists of first generation and 1.5% second generation biofuels (JRC-IPTS 2010, p. 30).

[10] The IFPRI study acknowledges this: "However, the quality of the original EU social accounting matrix in the GTAP7 database is poor. Moving to the latest GTAP7.1 database (released in mid-February 2010) that includes updated EU SAMs could improve the analysis". (IFPRI 2010, p. 13)

[11] The JRC-IPTS study (see Section 1.3) assumed a diesel:gasoline ratio of 70:30 by 2020 (JRC-IPTS 2010, p. 30), which is close to the 75:25 ratio projected by the NREAPs for 2020.

1.2. JRC-IE Study

1.2.1. Aim and Scope of the JRC-IE Study

The aim of the JRC-IE study is an assessment of the effects of ILUC in order to support the Commission's debate on how to address ILUC emissions in legislation. Therefore, the marginal changes in demand for particular biofuels in specific regions were calculated with different models.

Results of previous studies were almost impossible to compare since they are based on different assumptions. Thus, the JRC-IE study based all models on the same general scenario formulation. In order to include results of the IFPRI study (see Section 1.1), the scenario assumptions of JRC-IE were much based on those of IFPRI.

1.2.2. Key Assumptions of the JRC-IE Study

Six agro-economic general and partial equilibrium models were compared in this study:

1. AGLINK-COSIMO from OECD
2. CARD from FAPRI from Iowa State University
3. IMPACT from IFPRI
4. GTAP from Purdue University
5. LEITAP from LEI, Wageningen University
6. CAPRI from Bonn University/EuroCARE[12]

Most of these models are linear in practice[13] what means that changes in total crop area are roughly in proportion to extra land demand for a particular biofuel. Therefore, the models calculate scenarios of a marginal demand increase for biofuels against the baseline.

The key scenarios are summarised in the following table.

[12] Since CAPRI is an EU-focused models which does not calculate global land use expansion, this model is not represented here.

[13] This is despite the assumption that "quality of the new land to decline as more is taken, and that yield increase will show diminishing returns to increasing spending" (JRC-IE 2010, p. 7).

Table 4: Scenario Formulation in the JRC-IE Study

Scenario Name	Short Description of Scenario
Baseline	EU biofuels mandate is not implemented 2008 level of biofuel use of 3.3% is kept stable until 2020
Policy scenarios: marginal request of biofuel by region (1 MtOE)	
Marginal extra ethanol demand in the EU	EU uses of ethanol from sugar cane and biodiesel, as well as EU imports of biodiesel are fixed at the baseline levels → incremental demand met by ethanol from EU wheat
Marginal extra biodiesel demand in the EU	EU uses of ethanol from wheat and ethanol from sugar cane and biodiesel, as well as EU imports of biodiesel are fixed at the baseline levels → incremental demand met by biodiesel from EU oilseeds
Marginal extra ethanol demand in the US	Total biofuel use in EU is fixed at the baseline level → incremental demand met by ethanol from maize in US
Marginal extra palm oil demand in the EU	Domestic biodiesel production in EU is fixed at baseline level, increased biodiesel demand being supplied with imports from Malaysia/Indonesia (only GTAP and LEITAP)
Marginal extra ethanol from Brazilian sugar cane	(only AGLINK-COSIMO)
Marginal extra biodiesel in US	(only AGLINK-COSIMO)

Source: Author's compilation based on JRC-IE (2010)

The model simulations cover the period of 2009 - 2020. There is very little information on general scenario assumptions such as energy prices, economic growth or agricultural and trade policies[14], and nothing is mentioned about changes in the diet of the world population so it should be expected that there are no changes assumed.

Since the models are treated to react linear, no assumptions concerning biofuel mandates of non-EU countries were incorporated.

Most of the models rely on FAO data for the average yield per country, with exception of FAPRI-CARD which uses PSD/USDA data. Price-induced yield increase was incorporated.

The model calculations took into account the use of by-products from the biofuels production.

[14] But the fact that two ethanol scenarios were run (EU and US) indicates for biofuel policies that do not base on free trade.

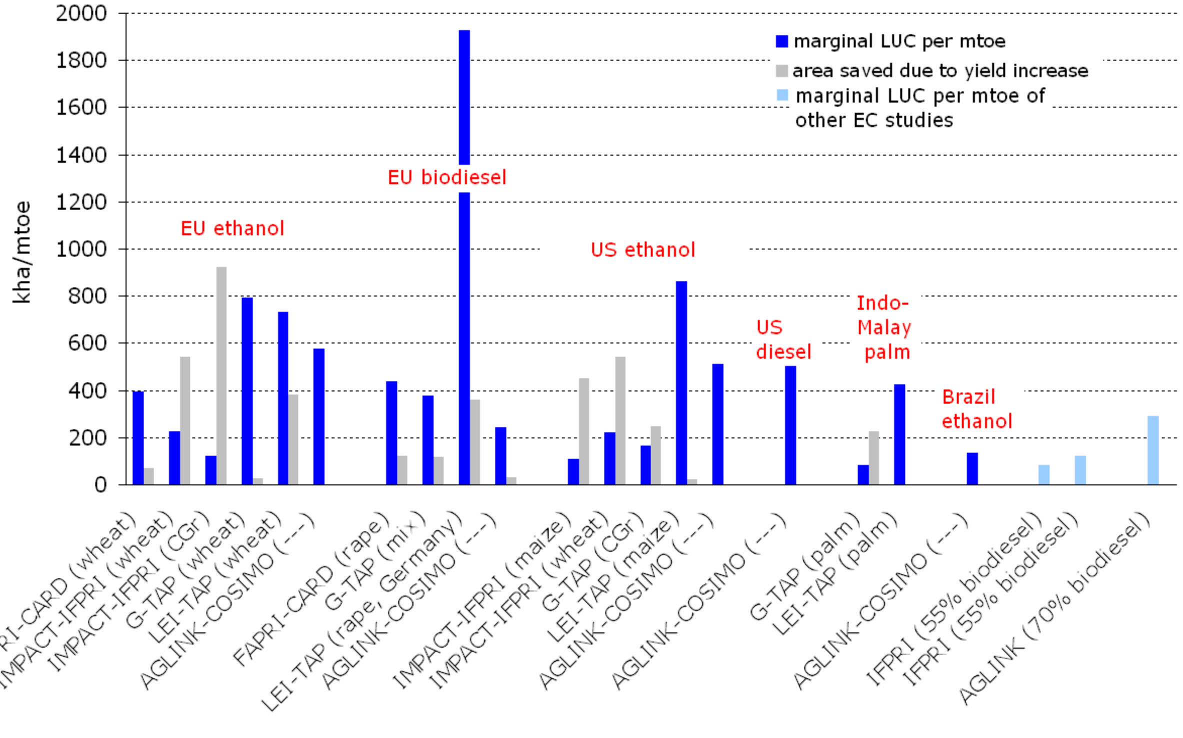
1.2.3. Key Results of the JRC-IE Study

Results of the models are given in terms of hectares, only FAPRI-CARD reported GHG emissions using GTAP emission factors for regional land use change.

The study results can be summarised as follows:

- All models show **significant extra land demand and resulting LUC in all biofuel scenarios**
- The differences induced by the models are grater than those of the scenarios. There is no clear indication that bioethanol or biodiesel are preferably in terms of LUC.
- The high land demand in the LEITAP EU scenarios result from crop-mix shifting with resulting yield **decrease**. Furthermore, LEITAP accounts for shifts from pasture to cropland. In both EU scenarios, the EU turns to a meat importer with meat produced from cattle grazing (in Argentina and Brazil).
- All models except GTAP do only insufficient take into account the difference between yields on existing and new crop-area. This leads to a general underestimation of indirect land use change.

Figure 5: Marginal Land Use Changes for All Models and Scenarios



Source: Author's computations based on data from IFPRI (2010), JRC-IE (2010) and JRC-IPTS (2010)

- The JRC-IE study also analyzed the origin of LUC. For this, the LUC impact of each scenario and model was disaggregated into specific regions and the "rest of the world" (see following table). Most of the EU models and related scenarios project that the largest share of LUC will occur **outside** the EU.
- The models show a large variation regarding where LUC occurs (1% - 124% within in scenario regions).

- For the biodiesel scenarios "LUC outside the EU" occurs in "other Asia", India, Indo-Malaysia, Argentina, US and in Sub-Saharan Africa.
- For the ethanol scenarios, "LUC outside EU" occurs mainly in "other Asia", USA, Brazil and Sub-Saharan Africa.

Table 5: Share of Total LUC Change by Region

Scenario	within Scenario Region	within Rest of World
Biodiesel Scenarios		
LEITAP EU D	26%	74%
FAPRI EU	8%	92%
AGLKINK EU	25%	75%
GTAP mix EU	41%	59%
AGLINK US	1%	99%
LEITAP Indonesia	124%	-24%
GTAP Indo-Malaysia	42%	58%
Ethanol Scenarios		
LEITAP Wheat EU-FR	55%	45%
FAPRI Wheat EU	103%	-3%
AGLINK Wheat EU	35%	65%
GTAP Wheat EU	44%	56%
LEIPTAP Maize US	90%	10%
AGLINK Coarse Grain US	9%	91%
GTAP Coarse Grain US	41%	59%
AGLINK sugar cane Brazil	123%	-23%

Source: JRC-IE (2010)

In the JRC-IE study, a decomposition of the influence of the different model parameters was presented for all models and scenarios:

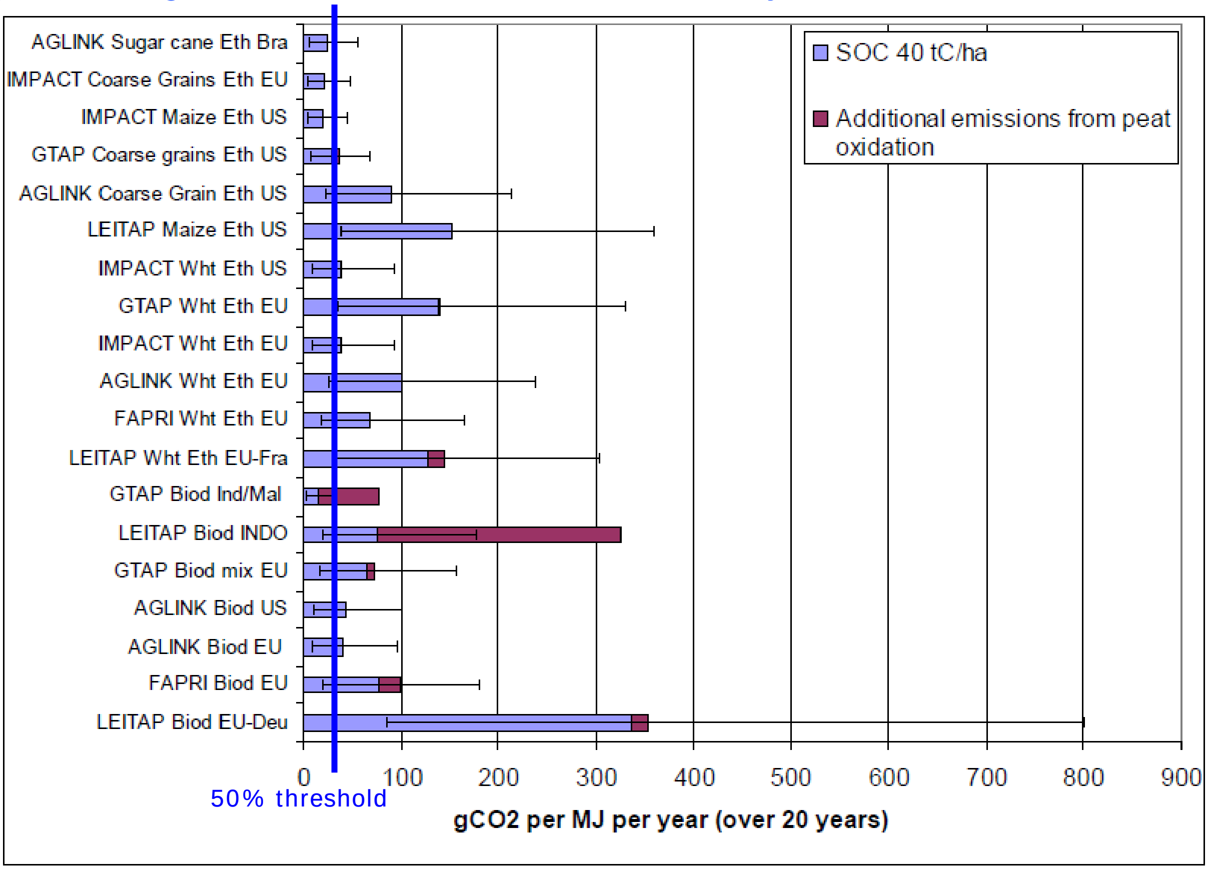
1. Allocation of land use of biofuel and of by-product
2. Fraction of crops saved by by-products (replaced fodder)
3. Yield changes
4. Crop displacements

The main influence shows the incorporation of by-products in the model. Yield changes[15] contribute only a small amount of area saved, crop displacements contribute to a higher amount.

[15] Average yield changes include price induced intensification, a shift in the crop mix and changes in the regional distribution of crops.

In the framework of this study it was not possible to give detailed results of GHG-emissions due to indirect land use change that would account for the large variations of soil properties and climate around the world. But the study presents a rough estimation based on 40 t of soil carbon per hectare[16] (see following figure).

Figure 6: Rough Indication of ILUC in the JRC-IE Study



Source: JRC-IE (2010); carbon release from soil is 40 t/ha/year over a 20 year time horizon

The rough estimates show that ILUC induced GHG emissions have an important effect on the environmental sustainability of biofuels. However, in many scenarios the ILUC emissions alone are so high that the 2017 reduction requirement of 50% given by the RED cannot be met.

Since all models in the JRC-IE study did not include GHG emissions from peat oxidation, a conservative estimation was added afterwards for those scenarios that assume an increase of palm oil from Indonesia/Malaysia.

Not a result but highlighted in the JRC-IE study is the fact that ILUC emissions are just one of the indirect emissions caused by biofuels.

GHG emissions due to intensification and emissions from cultivation activities (fertilizer use, energy use etc.) new cropland have to be added.

[16] IPCC default values for land conversion in the EU and North America are in a range of 38-95 t C/ha. The maximum is 95 t/ha is shown by error bars in the illustrated results.

1.2.4. Key Shortcomings and Omissions of the JRC-IE Study

In the following, the most relevant shortcomings and points of critique are summarised:

- The JRC-IE study says “It is always the yield at the frontier of cropland which matters” (JRC-IE 2010, p. 102). This implies that a procedure has to be implemented into the modelling that compiles a marginal yield different from average yields. Preferably, an approach should be included which differentiates between marginal cropland as well as by region and previous land use. But all models except GTAP only insufficient take into account the difference between yields on existing and new cropland. This leads to a general **underestimation** of ILUC.
- All models of the study were able to deliver results in terms of land expansion but only the GTAP model calculated GHG emissions from ILUC.
- Nevertheless, in order to answer the initial question of ILUC emissions of biofuels, JRC-IE did a rough estimate of GHG emissions based on the land expansion in each scenario. This procedure was not able to consider the released carbon of the land in spatial resolution which may have lead to different results.
- Furthermore, ILUC-related emissions are basically influenced by the feedstock (agricultural yield) and its downstream conversion to biofuels (energy yield). This has not been addressed in the study.

1.2.5. Overall Assessment of the JRC-IE Study

The JRC-IE study is an important step towards the inter-comparability of LUC models, and increases respective insights. Due to the restrictions of the models compared, only very little results on ILUC-related GHG emissions could be derived, though.

The study clearly underlines the importance of key model assumptions such as yields and co-product treatment.

1.3. JRC-IPTS Study

1.3.1. Aim and Scope of the JRC-IPTS Study

The aim of the JRC-IPTS study is to analyse the impacts of EU biofuel policies on agricultural production, trade and land use within and outside the EU, up to the year 2020.

Particular attention is given, to the extent possible with the three models used, to the land use implications of these policies.

1.3.2. Key Assumptions of the JRC-IPTS Study

The JRC-IPTS study used the three partial-equilibrium, agro-economic models AGLINK-COSIMO, ESIM and CAPRI to estimate the impact of EU biofuels policies and compared the results to each other.

The model simulations cover the period of 2009 until 2020 and start from a baseline scenario including the EU biofuels mandate.

Against the baseline, the "counterfactual" scenario is calculated assuming **no** mandatory target for the biofuel share of total transport fuel, and no incentives for biofuels.

Table 6: Scenario Assumptions in the JRC-IPTS Study

Scenario Name	Short Name	Short Description of Scenario
Baseline	Baseline	EU biofuels mandate is implemented Each biodiesel and ethanol reaches a share of 8.5% in 2020 with a ratio of 70:30 for biodiesel:ethanol.
Counterfactual scenario	CF	EU biofuel mandate is not implemented, no incentives for biofuels

Source: JRC-IPTS (2010)

The following paragraph gives an overview of aspects factored in by the model calculation:

Both scenarios adopt the same projections of exogenous trends (population, incomes, total transport fuel demand, crop yields), whilst also assuming that EU trade measures for biofuels remain unchanged and that all countries outside the EU continue with their biofuel policies as already either implemented or announced at the start of 2009. Detailed characterizations of these aspects are not given in the report.

The model calculations consider the use of by-products of biofuel production as well as a small amount of 2nd generation biofuels in the baseline scenario from 2016 on (1.5% by 2020). For the 1st generation biofuels and by-products, technical progress is considered, based on past trends.

In the agricultural sector, the end of set-aside policy and the sugar reform in the EU is assumed for AGLINK/COSIMO and ESIM but not for CAPRI. Yield increase is differentiated for crops and world regions and based on past trends. Price-induced intensification of crop production is incorporated. Unfortunately, palm oil is not covered in the models and therefore not reflected in the reported land use changes.

There is no information about underlying assumptions on global food consumption (rising population, changes in diets etc.), though.

Sensitivity analyses were conducted to assess the robustness of model results with regard to alternative assumptions on

- the share of ethanol and biodiesel (least cost combination of both fuels)
- future yield increase (faster yield growth due to price-induced intensification
- feed displacement from dried distillers grains from bioethanol production (protein-rich wheat DDG replaces a higher proportion of protein rich fodderplants – e.g. soy, fodder legumes).

1.3.3. Key Results of the JRC-IPTS Study

Despite the objective to analyse the land use change **impact** of the EU renewable transport fuels mandate, none of the three models used by IPTS met this challenge – the modelling stopped at step 2, indicating changes in land use, but not in GHG emissions.

CAPRI and ESIM are EU-focussed models which do not cover LUC in a global perspective. Accordingly, these two models are not able to deliver the necessary information in order to calculate GHG emissions of ILUC from biofuels. Therefore, no results of ESIM and CAPRI are presented in this study.

The AGLINK-COSIMO model identifies world-wide LUC, though. The model output gives changes in area cropped with cereals, oilseeds and sugar. In the model calculations, land expansion of these crops is based on reductions in other agricultural land uses (permanent crops and pasture). In reality, cropland expansion sources from both pasture and land not previously used for agriculture.

The key results of the AGLINK-COSIMO calculations can be summarised as follows:

- Biofuels induce ILUC of about 5 million ha. The EU renewable transport fuel mandate results in a world-wide land expansion of 0.7% of land used for cereals, oilseed and sugar crops by 2020.
- The by far largest cropland expansion is located in Brazil, with EU-27 as the second largest impact area. Nevertheless, in the EU-27 a decrease of agricultural area occurs, and biofuel production dampens this.
- Since oil palm is a permanent crop, the land demand of biodiesel from palm oil is **not** covered by AGLINK-COSIMO, but the model considers EU biofuel impacts on palm oil trade. The authors of this study estimated an additional land demand of about 1 million ha[17] in Indonesia and Malaysia for palm oil by 2020.
- Under trade restrictions (BAU scenario), the amount of biodiesel is 65% of all biofuels while ethanol is 35%. In this case, the EU is then a main producer and net exporter of biodiesel.

[17] This estimation is based on the data and assumptions for future yield growth given in the JRC-IPTS study, indicating a slowed-down annual yield increase of 3%.

- Against this, free trade will lead to a completely different market situation: The EU would become a net importer and the proportion of biodiesel and bioethanol will change from to 53% biodiesel and 47% ethanol.
- This shift towards ethanol leads to higher imports of ethanol from Brazil. Brazilian sugarcane ethanol reduces the LUC impact of the EU biofuels policy since it has the highest biofuel yield per hectare among 1st generation biofuels. As a consequence, only 1 million ha additional land is used to biofuel production (instead of 5 million ha in the BAU scenario). This is an amount of 0.1% of land used for cereal, oilseed and sugar crops by 2020.

  Just as in the IFPRI-study, AGLINK/COSIMO shows that eliminating trade barriers will improve the environmental performance of the EU's biofuels policy. And it becomes visible again that the split in bioethanol and biodiesel and the origin of biofuels is of great importance for the land use impact of EU biofuels policy.
- The faster yield growth scenario was run as a sensitivity analysis. An additional yield increase of annually 0.3% was assumed (e.g., due to prince-induced intensification). The results of this scenario show the significant influence of future yield changes on the model calculation: Saved land demand due to yield increase almost compensates the full amount of land expansion of the baseline scenario. The net result is only 0.2 million ha land expansion due to EU biofuel mandate.

Table 7: Scenario Data in the JRC-IPTS Study

		Scenarios 2020					
		without	with EU mandate	land expansion 2008-2020			
million ha	**2008**	**CF**	**baseline**	**due to EU mandate**	**% of biofuels**	**total (incl. mandate)**	**% total**
World	721	746	751	5.2	0.7%	29.4	3.9%
Brazil	47	62	63	1.0	1.6%	15.7	25.1%
Argentina + other Latin Am.	41	41	42	0.7	1.7%	0.3	0.7%
China	72	73	73	0	0.0%	1.1	1.4%
India	78	82	82	0.2	0.2%	3.6	4.4%
IndoMalay	not given; own calculation:			>=1,0			
other Asia	71	72	72	0.6	0.8%	1.5	2.1%
EU-27	72	67	68	1.5	2.2%	-3.2	-4.7%
USA	92	91	91	0.3	0.3%	-0.8	-0.9%
Canada	24	25	26	0.1	0.5%	1.4	5.6%
Russian Fed.	52	53	53	0.2	0.3%	0.7	1.3%
Ukraine	22	25	26	0.2	0.8%	3.4	13.2%
Australia	22	22	23	0.3	1.2%	0.8	3.7%
Africa	97	100	100	0.2	0.2%	3.3	3.3%
Rest of World	31	30	30	0.0	0.0%	-0.5	-1.8%

Source: JRC-IPTS (2010)

1.3.4. Key Shortcomings and Omissions of the JRC-IPTS Study

In the following, the most relevant shortcomings and points of critique are summarised:

- The results of AGLINK-COSIMO include neither data on carbon stock (per hectare and land type) nor the source of land extension (by land type). Hence, ILUC-induced GHG emissions of biofuels were not calculated[18].
- Similar to the IFPRI study, the sensitivity analysis varied single parameters step by step. It would have been interesting to derive a "corridor of results" by combining assumptions leading to low land use in a minimum scenario on the one hand, while on the other, combine all factors increasing land use in a maximum scenario.

1.3.5. Overall Assessment of the JRC-IPTS Study

The JRC-IPTS study is another important step towards the inter-comparability of LUC models, and adds to the insights gained from the JRC-IE study.

The spatially explicit modelling of the global distribution of ILUC is valid, but due to the restrictions of the models, **no** ILUC-related GHG emissions were calculated, though.

1.4. Cross-Comparison of the EC Studies

In this sub-section, the most relevant aspects concerning results and model parameters of the three studies carried out for the EC are compared against to each other.

1.4.1. Land Use Change

All EC studies show a significant influence of biofuel-induced LUC, but the level of results differs significantly. Both scenario of the IFPRI study represent the **lower end** of land expansion with a marginal ILUC of 84 kha/MtOE in the BAU scenario.

The maximum is given by LEITAP EU biodiesel scenario with almost 2,000 kha/MtOE (see Figure 5).

The differences between the models are larger than those between the scenarios within the models. Thus, it cannot be concluded that biodiesel or bioethanol have to be preferred in terms of LUC.

In the IFPRI study and the JRC-IPTS study, LUC from biofuels occurs mainly in Brazil and EU. In the JRC-IE study, it is spread wider: besides Brazil, also other Latin America, the USA, the Russian Federation, Indonesia, Malaysia and Sub Saharan Africa are affected.

It would be of interest to fully understand these different regional impacts.

[18] As mentioned earlier, the calculation of ILUC-related GHG emissions is a four-step approach of which only the first is based on economic modelling. The last three steps just would have to be carried out outside of AGLINK-COSIMO.

1.4.2. ILUC Emissions

All studies were meant to support the scientific and political debate on how to address ILUC emissions in legislation. But only in the context of two models (GTAP and IFPRI), GHG emissions from LUC (including ILUC) were analysed.

The IFPRI approach for ILUC-related GHG emissions seems to be the most sophisticated so far: Global average land expansion is translated to marginal emissions per feedstock and region. The results represent well the differences of yield and conversions rates between biofuels, and regions.

Minimum ILUC emissions are associated with ethanol from sugar cane (<20 g CO_2eq/MJ), and highest are from soy-based biodiesel (~80 g CO_2eq/MJ).

Since the broad model comparison did not lead to results in terms of GHG, JRC-IE prepared a rough indication of ILUC emissions based on IPPC default values.

The resulting GHG emissions show a wide variation, from 30 g CO_2eq/MJ for AGLINK sugarcane to ~ 350 g CO_2eq/MJ for LEITAP EU biodiesel. The JRC-IPTS study did not deliver results in terms of GHG.

Regardless the method, all studies indicate the importance of ILUC effects in the environmental assessment of biofuels.

All studies stress the importance of incorporating model parameters on which carbon release due to LUC depends: marginal yields of new cropland, previous land use and carbon stocks.

1.4.3. Important Parameters

All studies present sensitivity analysis in order to assess model reaction, robustness and the influence of important model parameters, especially the use of by-products and future yields.

All studies showed the importance of assumptions concerning yield increase – both exogenous yield increase (specified outside of the model, e.g. from trends) and endogenous yield increase from price-induced intensification and factor intensification.

IFPRI assumed by far the highest yield increase of all studies (by factor 10 for price-induced intensification – see Table 13 in the Annex) and represents the lowest land expansion of all studies.
JRC-IE gives a very transparent decomposition of model parameters which allows a deep insight the influence of allocation of land use change to biofuel and by-products and land set free due to yield increase.

1.5. Other Relevant Studies

The scientific and policy discussion of ILUC effects of biofuels and their GHG implications is by no means restricted to Europe – quite contrary, its origin should be seen in US studies by Searchinger (2008) and Fargione (2008) which received much attention. Since then, many more studies were carried out both in Europe and the USA, but also in, e.g., Brazil.

In the following, three recent studies from Europe are presented briefly, and ILUC-related work in the USA and from IEA Bioenergy is considered also[19].

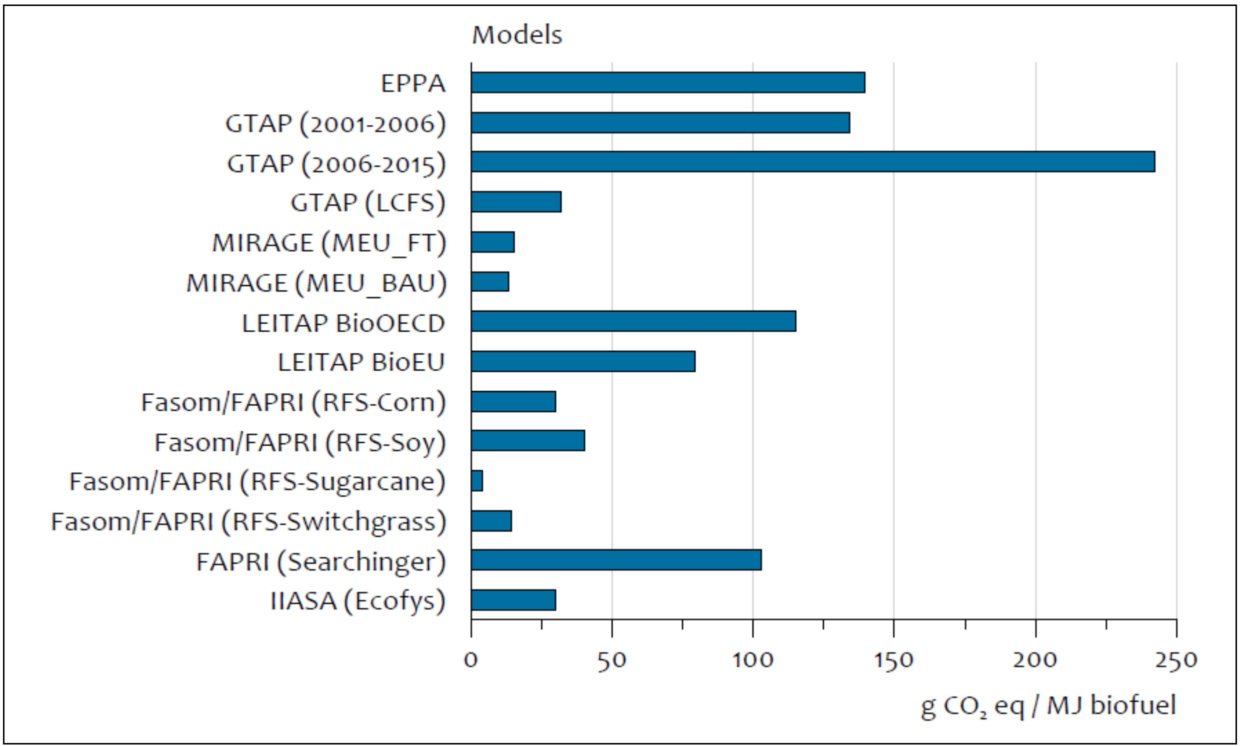
1.5.1. PBL Studies

The Dutch Environmental Assessment Agency (PBL) recently published a series of research papers dealing with ILUC (PBL 2010a-e). The studies evaluated

- overall approaches to identify ILUC (PBL 2010a).
- impacts of ILUC on biodiversity (PBL 2010b),
- the question of using models to determine ILUC (PBL 2010c),
- effects of intensifying agricultural production to reduce ILUC (PBL 2010d), and
- effects of by-products on ILUC (PBL 2010e).

This comprehensive set of studies gives an excellent scientific discussion of the key issues around ILUC, and underlines that the current state of science allows deriving a "reasonable" range of quantitative values for ILUC-related GHG emissions from biofuels (including two of the models of the EC studies – MIRAGE and LEITAP).

Figure 7: ILUC-related Emissions of Selected Biofuels/Feedstock Mixes in Various Studies



Source: PBL (2010c)

1.5.2. E4Tech Study

A recent study of E4Tech for the UK Department of Transport developed fuel-chain-specific ILUC values using the descriptive-causal approach for several EU-relevant biofuel life-cycles (E4Tech 2010).

[19] For an overall summary of recent LUC-related literature, see Fritsche/Sims/Monti (2010). It should be noted also that several activities tried to bring together the EU and US researchers (OECD 2009), and to summarise global knowledge on ILUC (e.g. GBEP 2009).

The study objective was to demonstrate the validity of the approach, and to capture views and insights of a range of stakeholders who have an understanding of the systems involved in ILUC to ensure that calculated ILUC factors are based on best available scientific and economic evidence.

This study estimates the ILUC impacts of key biofuel feedstocks: palm oil, rapeseed oil, soybean oil (for biodiesel), wheat and sugarcane (for ethanol). For each feedstock, several different ILUC factors are calculated using scenarios to represent different assumptions regarding the context and cause and effect relationships. To quantify the land used in each of the future scenarios, E4Tech used a combination of four different approaches:

- Statistical analysis of historical trends to quantify the market responses to the additional feedstock demand and estimate business as usual trends.
- Market analysis to gain insights into likely evolution of markets and to identify product substitutions.
- Expert input and literature review provided qualitative validation of the statistical and economic analyses.
- Variations in parameters from the statistical analysis to reflect likely ILUC scenarios.

The study concludes that the size of ILUC-related impacts of biofuels can indeed be large but varies significantly depending on the feedstock used and the future context considered.

Table 8: Range of ILUC emissions in the E4Tech-Study

Feed stuff	ILUC emissions [g CO_2eq / MJ]
Palm biodiesel	6-82
Rapeseed biodiesel	15-35
Soybean biodiesel	9-66
Wheat ethanol	-53 to -5
Sugar cane ethanol from Brazil	8-27

For example, if palm oil plantations continue to expand onto high carbon stock land (forest land or peat land), the risks of ILUC are large: Depending on scenario assumptions, the calculated ILUC factor ranges from 6 to 82 g CO_2eq/MJ palm biodiesel. Only if effective policy to protect high carbon stock land and prevent expansion of palm onto peat land is assumed, the low end of the range will be achievable.

The modelled ILUC impacts of wheat ethanol are much lower than the other biofuels, mainly due to a large "credit" given to the by-product DDGS which is used as animal feed[20]. Against this sugarcane ethanol from Brazil ILUC impacts are ranging significantly at a higher level since there are no co-products for sugarcane ethanol), but a result of the assumed land use and the high productivity of sugarcane in Brazil.

The E4Tech study concludes:

"ILUC factors provide a quantification of the impact but remain imprecise as a result of possible changes in the context and uncertainties in underlying assumptions and carbon stock figures. (...) Also, as it is not possible to "observe" ILUC, it is not possible to scientifically test and validate the different approaches for modelling ILUC and developing ILUC factors.

[20] The ILUC study of E4Tech applied the substitution method to allocate for by- and co-products. If the EU RED methodology would have been used, the results would be quite different. For an interpretation of this, see footnotes 6 and 7.

This makes it difficult to reach a consensus on the "right" assumptions for the different biofuel chains, especially when trying to estimate future impacts. However, ILUC factors can be helpful in understanding the potential magnitude of impacts under certain situations, and therefore the risks posed by ILUC, and how they may change under different situations. Their derivation also helps understand the factors that affect them and hence how they can possibly be influenced" (E4Tech 2010, p. 146).

1.5.3. Oeko-Institut's iLUC Factor Approach

Oeko-Institut developed from 2007-2010 the iLUC Factor, a simplified approach to estimate ILUC-related GHG emissions of biofuels (OEKO 2010). This simple and transparent methodology based on statistical data. Its key to avoid complex modelling of agricultural markets is assuming that

1. current global patterns of land use for agricultural export are an adequate approximation to derive global averages of potential GHG emissions from indirect LUC
2. for the near future, the pattern of global trade in agricultural commodities can be derived from observed trade trends.

The single steps of calculation the ILUC factor and the incorporation into life-cycle GHG-emissions are:

1. Theoretical ILUC factor:
   Amount of land displaced by biofuel production by country (based on key agricultural commodities influenced by bioenergy feedstock production, i.e. rapeseed, corn (maize), palmoil, soy, and wheat and its yields
2. Theoretical C-release per ha (and year)
   Annualised changes in carbon stock of new land differentiated by arable land, grass land, savannah and tropical rain forests annulated
3. C-release per MJ
   Divide (2.) by energy net yield of a biofuel per ha (average or crop specific – see below)
4. ILUC risk level
   The ILUC risk level then describes how likely it is that one hectare of displaced crops will lead to land use change, as accompanying effects[21] - e.g. 25% or 50%
5. Addition of iLUC factor to the LCA based and direct LUC emissions

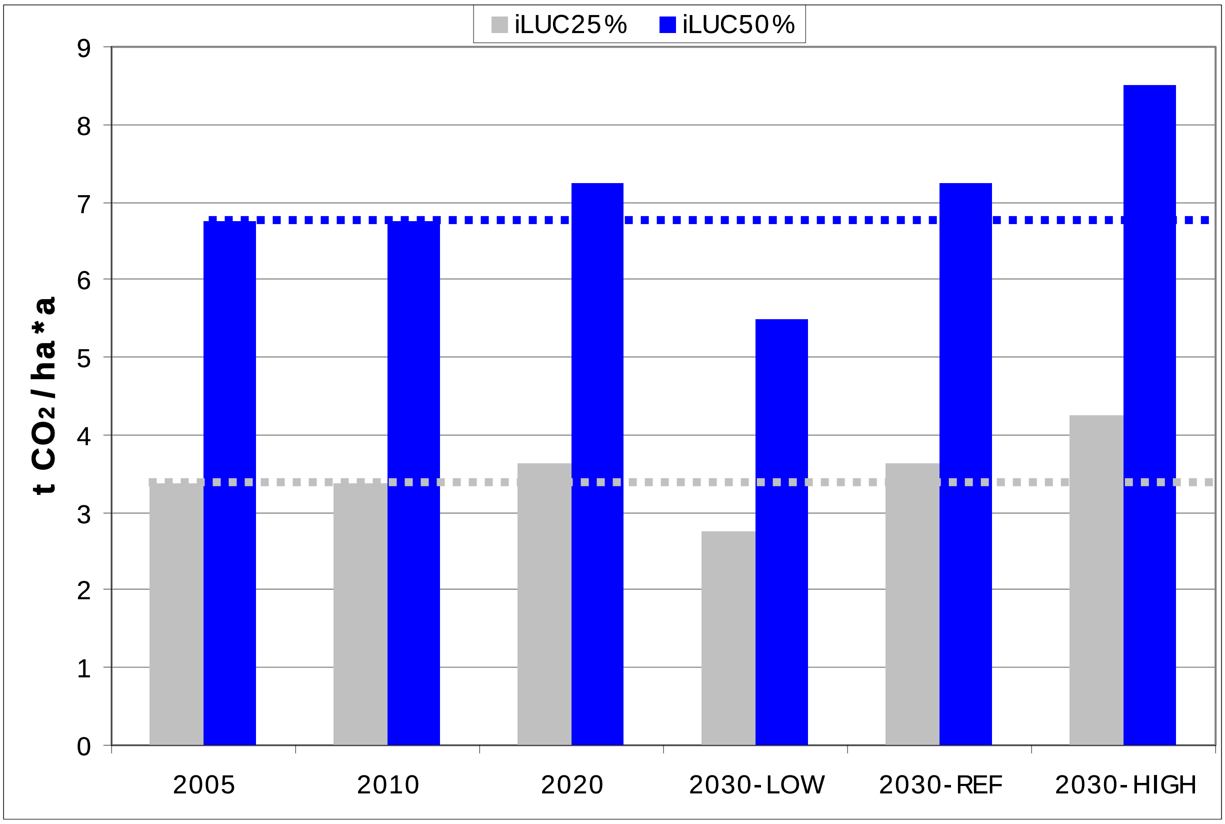
Furthermore, the method of the iLUC factor allows deriving scenarios, e.g., concerning land use policy such as no conversion of high carbon stock land.

Oeko-Institut assumes that for the near future (i.e. until 2020), a 25% risk level is valid, as the existing production base for biofuels has, by definition, no LUC impacts. After 2020, the risk level may rise to 50%, depending on the development of the overall biofuels demand. With a risk level of 25%, the land-based ILUC factor for the year 2010 would be 3.4 t CO_2/ha for a 20 year period to annualise the LUC emissions.

[21] such as demand-induced yield increases or substitution of fodder from biofuel-byproducts

Oeko-Institut also projected future levels for the land-based ILUC factor, especially for three scenarios for 2030 in which a "low" case assumes that policies to avoid conversion of high carbon stock land especially in Argentina, Brazil and Indonesia would be successfully implemented, a "high" case assumes that land conversion patterns remain similar to those in 2010, and a "reference" case which presents the average of the low and high cases.

Figure 8: Per-Hectare ILUC Factors for 2005 - 2030



Source: OEKO (2010); dashed lines indicate the 2005 iLUC factor for 25% and 50% risk levels

To translate the land-based iLUC factor to a given biofuel, the values given above (t CO_2/ha/year) need to be divided by the fuel-specific yield ($GJ_{biofuel}$/ha/year), resulting in energy-specific emission factors (g $CO_2/MJ_{biofuel}$):

- With an exemplary net energy yield of a biofuel life-cycle of 100 $GJ_{biofuel}$/ha, the 25% iLUC factor for 2010 translated into 34 g $CO_2/MJ_{biofuel}$, while the 50% iLUC factor would result in 68 g $CO_2/MJ_{biofuel}$.
- For a more detailed result, the LCA approach must be applied to take into account not only ILUC (and its allocation to by- and co-products), but also other life-cycle GHG emissions. In the following table, the GHG emissions of selected biofuels are shown, differentiating between emissions from life-cycle analysis (LCA), LCA plus direct LUC (+dLUC), and this sum plus the 25% and 50% risk level iLUC factors, respectively (both for 2010).

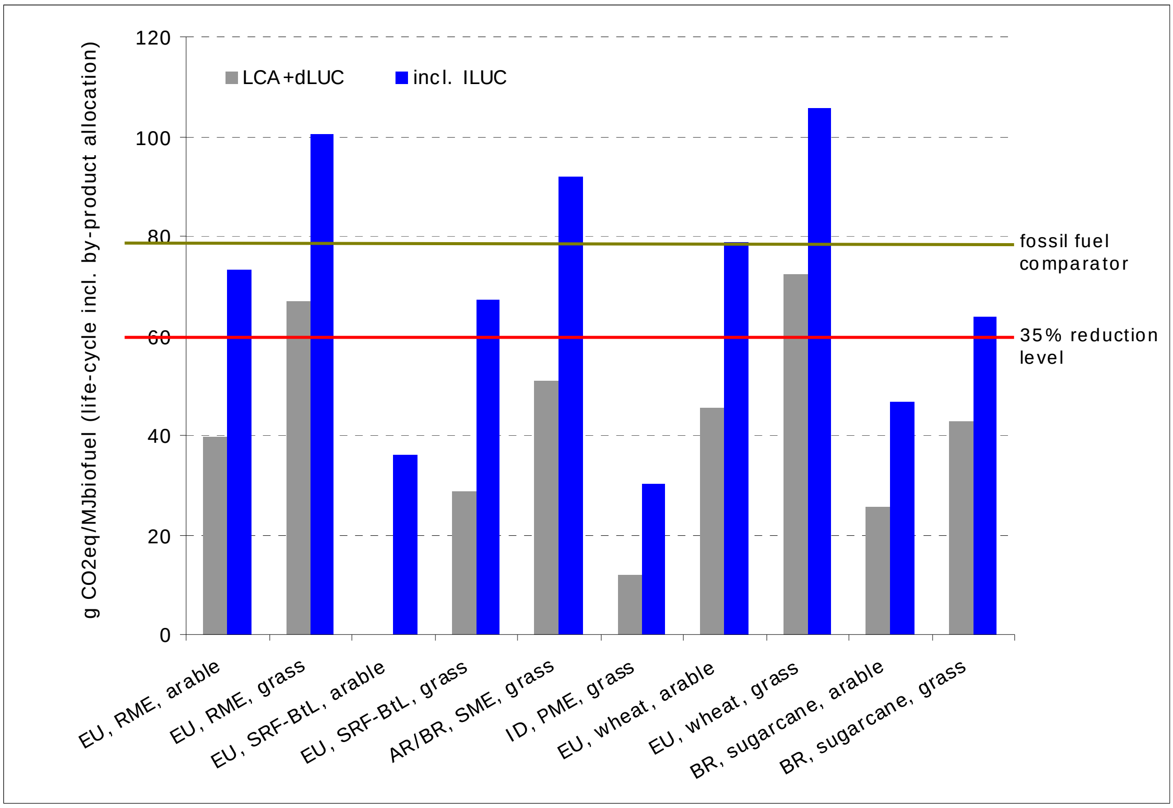
Table 9: Life-Cycle GHG Emissions from Biofuels including ILUC in 2010

	GHG emission g $CO_2eq/MJ_{biofuel}$				reduction vs. fossil fuel			
Region, feedstock, previous land use	LCA	+dLUC	+iLUC 25%	+iLUC 50%	LCA	+dLUC	+iLUC 25%	+iLUC 50%
Biodiesel options								
EU, rapeseed, arable	40	40	73	107	-54%	-54%	-15%	**24%**
EU, rapeseed, grass	40	67	100	134	-54%	-23%	**16%**	**55%**
EU, SRF*, arable	14	-2	36	75	-84%	-103%	-58%	-14%
EU, SRF*, grass	14	29	67	106	-84%	-67%	-22%	**22%**
AR/BR, soy, grass	20	51	92	118	-76%	-41%	**7%**	**37%**
AR/BR, soy, sav.	20	188	188	188	-76%	**118%**	**118%**	**118%**
ID, oil palm, grass	43	12	30	48	-50%	-86%	-65%	-44%
ID, oil palm, degr.	43	-55	-55	-55	-50%	-163%	-163%	-163%
ID, oil palm, forest	43	213	213	213	-50%	**147%**	**147%**	**147%**
Ethanol options								
EU, wheat, arable	45	45	79	112	-46%	-46%	-7%	**32%**
EU, wheat, grass	45	72	106	139	-46%	-15%	**24%**	**63%**
BR, sugarcane, arable	26	26	47	68	-69%	-70%	-45%	-20%
BR, sugarcane, grass	26	43	64	85	-69%	-50%	-25%	**0%**
BR, sugarcane, degr.	26	-1	-1	-1	-69%	-101%	-101%	-101%
BR, sugarcane, sav.	26	120	120	120	-69%	**41%**	**41%**	**41%**

Source: OEKO (2010); fossil comparators from EU RED; positive (bold **in red**) figures indicate that no emission reduction is achieved but **an increase**; *= short-rotation forestry as feedstock for BtL (Fischer-Tropsch diesel); AR= Argentina, BR= Brazil; sav.= savannah; degr.= degraded land; grass= grassland (pasture)

The results are shown in the following figure in which the fossil fuel comparator and the 35% RED reduction level are also indicated.

Figure 9: Life-Cycle GHG Emissions of Biofuels and Impacts from ILUC in2010



Source: OEKO (2010); RME= rapeseed oil methyl ester; SRF= short-rotation forestry; BtL= biomass-to-liquid (Fischer-Tropsch) diesel; SME= soybean oil methyl ester; PME= palmoil methyl ester

Given that until 2020, the 25% risk level for ILUC is adequate, the results of Oeko-Institut's iLUC factor show that for EU feedstocks, only 2nd generation biodiesel from short-rotation forestry (on arable land) would achieve the GHG reduction required by the RED, while the imported 1st generation palmoil-based biodiesel and ethanol from sugarcane would also be acceptable.

All in all, the iLUC factor approach as developed by Oeko-Institut is fully compatible with the EU RED methodology for GHG emissions from biofuels. Its database should be improved to cover e.g. impacts of displacement in more detail, especially for pasture, for which data available from the E4Tech study or work of the JRC and PBL could be used.

1.5.4. US EPA Studies

The US Environmental Protection Agency (EPA) worked from 2008-2010 on GHG emissions from biofuels as a part of revisions to the National Renewable Fuel Standard program (RFS). The RFS is mandated in the Energy Independence and Security Act of 2007 (EISA) which established eligibility requirements for renewable fuels, including mandatory life-cycle GHG reduction thresholds which determine compliance with four renewable fuel categories. These GHG emission thresholds require a 20 % improvement compared to the 2005 life-cycle GHG emissions of fossil (gasoline or diesel) fuels for any renewable fuel produced at new facilities, a 50% reduction in order to be classified as biomass-based diesel or advanced biofuel, and a 60% reduction in order to be classified as cellulosic biofuel.

For this, EPA published a final methodology and assessment in 2010 (see EPA 2010) which includes ILUC quantitatively (see RFS data in Figure 7), and is performing further analysis and review with input from the US National Academy of Science.

1.5.5. CARB Expert Group on Indirect Effects

On 1 January 2010, the California Low Carbon Fuels Standard (LCFS) regulation became effective after several years of intense discussion which especially focused on the quantification of GHG emissions from ILUC caused by increased use of biofuels. The LCFS aims to reduce California's GHG emissions from transport fuels by reducing the carbon intensity of the overall fuels in the state. The reduction, starting in 2011, aims to achieve a 10% reduction by 2020.

The California Air Resources Board (CARB) determines the carbon intensity of all fuels, including biofuels, by calculating life-cycle GHG emission factors which include direct and indirect impacts, especially ILUC.

CARB created, similar to the default values of the EU RED, so-called "lookup tables" for the most relevant fuels in California – but in stark contrast to the EU, the CARB data include **fuel-specific ILUC factors** determined by modelling (CARB 2010).

A summary of selected GHG emission factors including ILUC from the CARB work are given in the following table.

Table 10: CARB Values for ILUC in the Californian LCFS

		g CO_2eq / MJ_{fuel}		
Fuel	**Pathway Description**	**Direct Emissions**	**Land Use or Other Indirect Effect**	**Total**
Gasoline	average crude oil delivered to CA refineries, average efficiencies	95.9	-	95.9
Ethanol from Corn	Midwest average 80% Dry Mill, 20% Wet Mill, Dry DGS	69.4	30	99.4
Ethanol, CA average	80% Midwest average 20% CA Dry Mill, Wet DGS, NG	65.7	30	95.7
Ethanol from BR sugarcane	average production processes	27.4	46	73.4
Diesel	average crude oil delivered to CA refineries, average efficiency	94.7	-	94.7
Biodiesel	from Midwest soybeans	21.3	62	83.3

Source: CARB (2010); CA= California; DGS= Distillers Grains and Solubles; NG= natural gas; BR= Brazil

Compared to the EU "fossil comparators", the Californian data on gasoline and diesel are approx. 10% higher, but the life-cycle GHG emissions of biofuels are rather similar to the data given here (see Table 9), with ILUC factors similar to the 25% iLUC factor determined by Oeko-Institut (see Section 1.4.3).

While the LCFS became operational in 2010, the data for the GHG balances are subject to further review and adjustment to reflect growing knowledge. For that, CARB operates an expert group and works with US EPA, universities, and other experts to improve its figures, and extend the work to other biofuel pathways.

CARB's Expert Group on Indirect Effects will prepare a report by early 2011 on which CARB will consider changes or adaptations of its ILUC values.

1.5.6. IEA Bioenergy Work on Indirect Effects

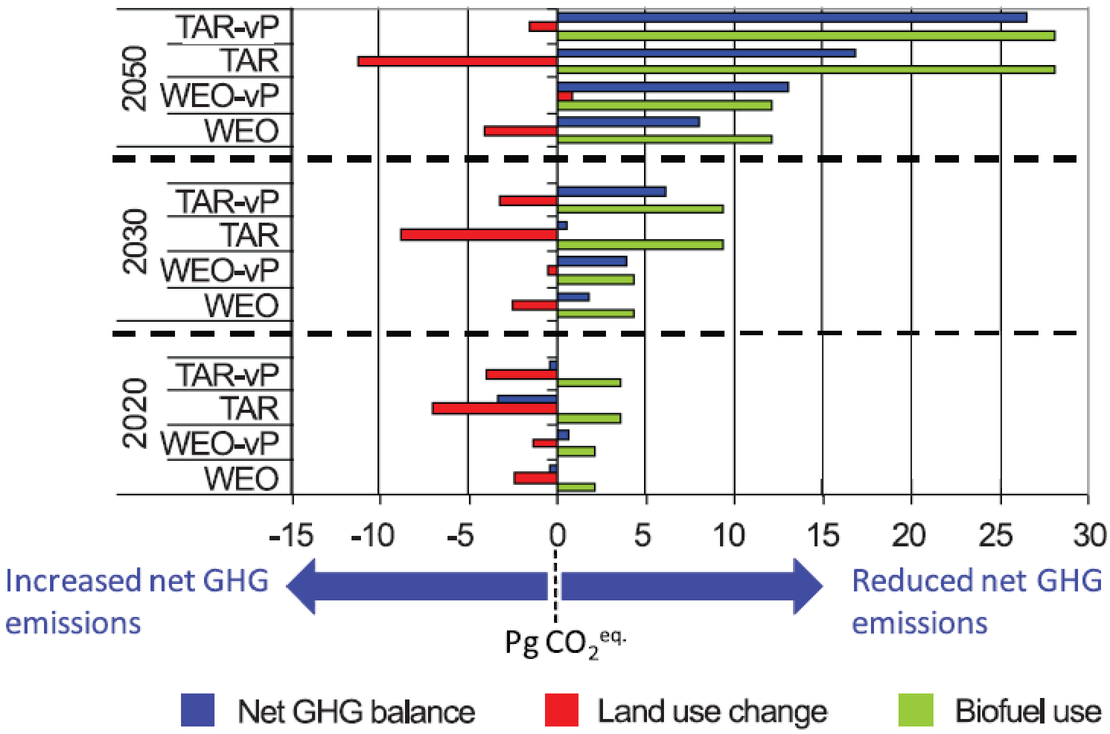
The International Energy Agency (IEA) implementing agreement for bioenergy (IEA Bioenergy in short) has several activities towards ILUC – most prominently, Bioenergy Tasks 38 (on GHG emissions) and 40 (on international trade) as well as the IEA Bioenergy Executive Board published reports and conference proceedings on this from 2008 onwards.

The most recent report "Bioenergy, Land Use Change and Climate Change Mitigation" (IEA Bioenergy 2010), refers to scenarios in which the longer-term LUC effects of selected biofuel strategies were modelled (ELOBIO 2010):

1. The **World Energy Outlook Scenario** (WEO) has regional biofuel use up to 2030 as projected by the IEA World Energy Outlook 2008 reference scenario (4.2% of total in 2020 and 5.4% in 2030) 2nd generation biofuels are gradually deployed after 2015 (4% of all biofuels in 2020 and 19% in 2030).
2. The **Target Scenario (TAR)** has been constructed on the basis of announced biofuel targets before 2010[22]. It has roughly twice as high biofuel use and faster deployment of 2nd generation biofuels (33% of all biofuels in 2020 and 51% in 2030).

The following figure shows the accumulated GHG gains and losses for the two biofuel scenarios (WEO and TAR) and their variants with crop higher productivity growth (WEO-vP and TAR-vP). Cumulative net GHG savings are closely linked to the effects of arable land expansion and subsequent land use conversions.

Figure 10: Accumulated Net GHG Savings of Biofuel Scenarios



Source: IEA Bioenergy (2010), based on ELOBIO (2010); The green 'Biofuel use' bars show GHG savings (positive) from biofuel replacement of gasoline and diesel; the red 'Land use change' bars show GHG emissions (negative) caused by LUC and iLUC; and the blue 'Net GHG balance' bars show the result of subtracting 'Land use change' emissions from 'Biofuel use' savings.

[22] "Historically targets and mandates have been by far the most important driver for increased biofuel demand. Political and socio-economic circumstances as well as technological developments have often been reasons for changing envisaged targets" ELOBIO (2010) p. 14

In 2020, the net emission balance is only slightly positive for the WEO-vP scenario while the other scenarios show higher GHG emissions compared to REF with no accelerated biofuel consumption. However, by 2030 all biofuel scenarios show a positive GHG emission balance, which increases further until 2050 mainly due to the use of 2nd generation fuels on the basis of lignocellulose. For the scenarios WEO-vP and TAR-vP, which assume additional crop yield improvements the GHG emission balances are even better.

These results clearly indicate the **need to consider ILUC effects in a dynamic view**: In the short-term (i.e. up to 2020), negative LUC effects of global biofuels development might compensate any GHG emission savings from substituted fossil fuels, but in the medium- to long-term, the overall GHG emission balance of biofuels might well become very positive if more productive feedstock and conversion systems are developed.

In that regard, IEA Bioenergy concluded as a key message:

"The effects of indirect land use change are especially difficult to quantify and achieving a consensus on the extent of the impact is unlikely in the near future. Even so, it can be concluded that land use change can affect greenhouse gas balances in several ways, with both beneficial and undesirable consequences from bioenergy's contribution to climate change mitigation. However, bioenergy does not always entail land use change. The use of post-consumer organic residues and by-products from the agricultural and forest industries does not cause land use change if these materials are wastes, i.e. not utilised for alternative purposes" (IEA Bioenergy 2010, p. 2).

Furthermore, the report argues:

"Food, fibre and bioenergy crops can be grown in integrated production systems, mitigating displacement effects and improving the productive use of land. Lignocellulosic feedstocks for bioenergy can decrease the pressure on prime cropping land. The targeting of marginal and degraded lands can mitigate land use change associated with bioenergy expansion and also enhance carbon sequestration in soils and biomass. Stimulation of increased productivity in all forms of land use reduces the land use change pressure". (ibid)

These findings are consistent with outcomes of IEA Bioenergy Task 38 workshops (IEA Bioenergy Task 38, 2009 and 2010), and the results of the IEA Bioenergy/IEA RETD project on "Better Use of Biomass for Energy" (BUBE) which also underlined the longer-term options to significantly reduce LUC impacts from bioenergy if more advanced production and conversion systems are successfully introduced (IEA Bioenergy/IEA RETD 2010; CE/OEKO 2010).

2. CONCLUSIONS ON AN ILUC FACTOR

The broad variety of studies and respective models on ILUC-related GHG emission impacts from biofuels discussed in the previous section cannot be summarized easily, but some conclusions can be drawn.
Without going into details[23], agro-economic models depend extensively on critical input parameters such as land and commodity prices, and internal model structure (e.g., handling of by-products). The models simulate future worlds, and the quality of the simulation depends on appropriate data inputs, their (recursive) handling to derive future trends, and the overall completeness of interactions between commodities and markets handled within the model[24].

By necessity, the outcome of such modelling varies between models, studies, and scenario assumptions for the modelling. Furthermore, it is currently impossible to run one model with the database of another one, or several models with on identical database to identify model-specific deviations (or shortcomings)[25].

In some of the scientific and most of the political discussions around ILUC, the range of results from ILUC modelling has often been translated into "uncertainty" – which is quite misleading, as the future – by definition – cannot be known with any "certainty" today.

Global commodity markets have an intrinsic uncertainty, because important drivers are unknown in their future values, or subject to a range of possible expressions. Thus, any future projection for markets will necessarily show error ranges which will increase with projected time horizons.

Still, the outcome of basically all model exercises show that GHG emissions from ILUC caused by increased biofuel demands are significant, and the range of respective results on GHG emissions from ILUC is comparatively small[26].

The following table shows this range, as given in the Commission's ILUC report.

Table 11: ILUC Values in Various Studies

GHG Emissions from ILUC in g CO_2eq / $MJ_{biofuel}$	Maize ethanol	Soya biodiesel
Searchinger et al. (2008)	156	165-270
CARB (2009)	45	63
EPA (2010)	47	54
Hertel et al. (2010)	40	-
Tyner et al. (2010)	21	-
IFPRI MIRAGE (2010)	54	75

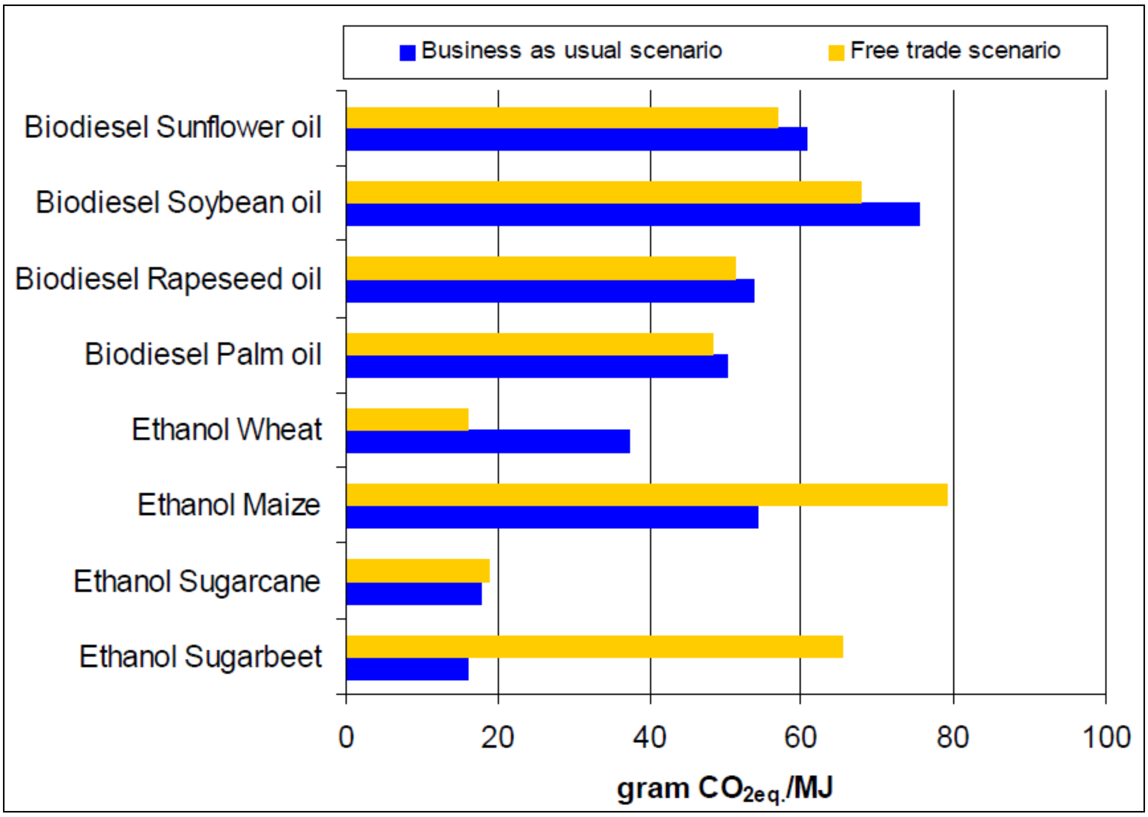
Source: EC (2010)

[23] For a recent review of models for ILUC, and the respective implications for policy, see Fritsche/Sims/Monti (2010) and PBL (2010c)
[24] For example, the role of by-products from biofuel feedstock conversion is a key issue – until recently, only few agricultural models considered this, although the treatment of by-products will have a dominant role regarding ILUC results (PBL 2010e).
[25] There is some progress made in the last year on this, though: The JRC-IE prepared a modelling framework which can use inputs from several other models, and databases (JRC-IE 2010). This work should be continued and extended to cover also data from e.g. the GTAP model run for CARB.
[26] The only study with radically different results is the E4Tech work on wheat-based ethanol in Europe (E4Tech 2010), but this result can be explained easily by the methodology used (by-product substitution).

The table indicates that for maize-based ethanol, recent studies show a range of 40-50 g $CO_2eq/MJ_{biofuel}$, and soybean-based biodiesel is in the range of 50-75 g $CO_2eq/MJ_{biofuel}$[27].

The following figure illustrates the results from the IFPRI study (IFPRI 2010) which has been discussed in Section 1.1.

Figure 11: ILUC Emissions of Selected Biofuels in the IFPRI Study

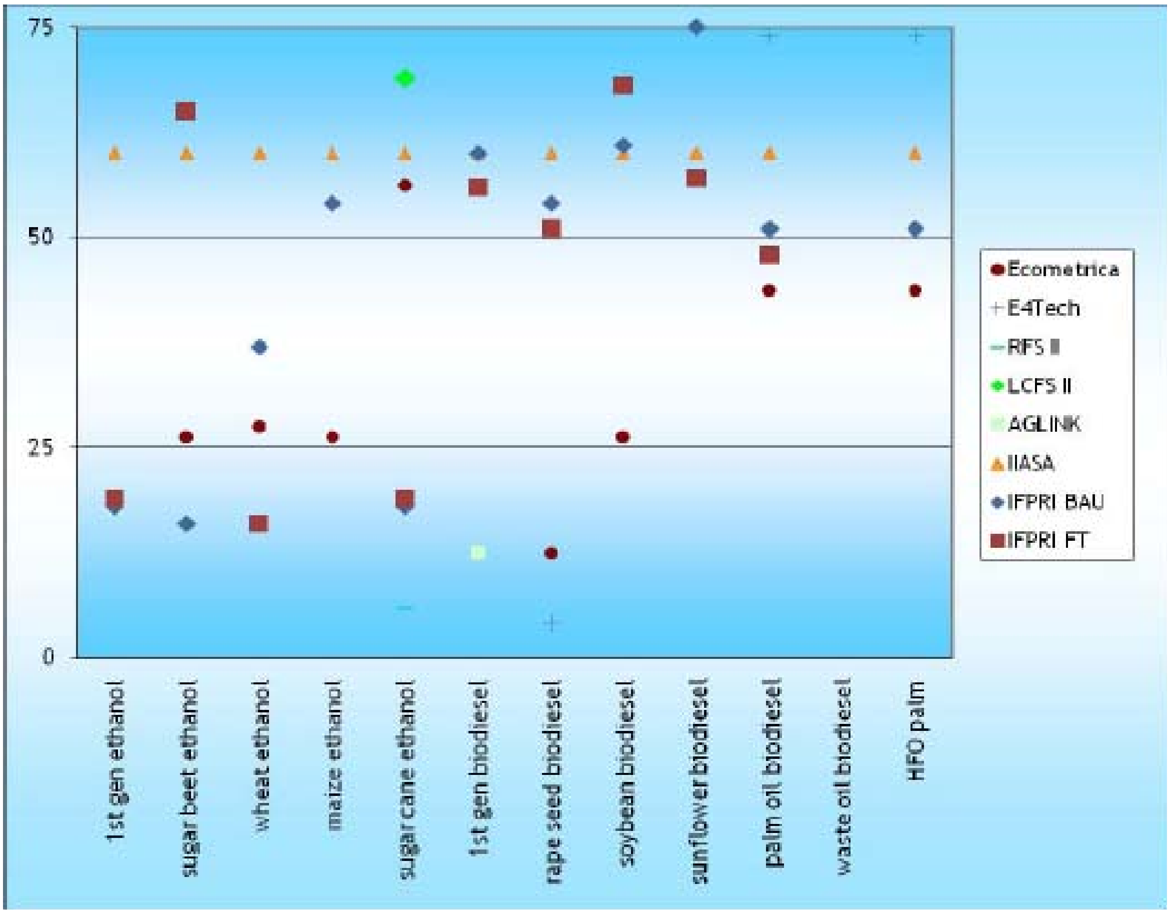


Source: EC (2010)

As already mentioned, these results give a lower-end estimate of ILUC emissions in comparison to the other two EC studies. But they are in good agreement with the other studies. Earlier work of CE Delft for a consortium of European NGOs also compiled ILUC results from various studies (CE 2010), as shown in the following figure.

[27] The higher figures from Searchinger (2008) can be explained by outdated LUC assumptions

Figure 12: ILUC Emissions of Selected Biofuels in Various Studies



Source: CE (2010); AGLINK data on LUC were converted by CE into GHG emissions

The range of results of all these studies is, as said, comparatively narrow, given the differences in modelling, scenarios, and allocation methods.

The discussion of current studies and models on ILUC resulted in comparatively moderate figures for ILUC which could, in principle, be implemented into EU policies for biofuels.

Still, the various approaches to quantify GHG emissions from ILUC could be refined further and substantiated with better data on direct LUC trends from global monitoring, and be improved by adding more adequate estimates of future trade patterns.

A more fundamental solution of ILUC could come from a revised LUC accounting under the international climate regime, **but would require also a "cap" on LUC emissions which will be hard to negotiate within the near future.**

3. POSSIBLE CUMULATIVE EFFECTS OF BIOENERGY USE IN THE EU27 BY 2020

In addition to the question of ILUC effects resulting from biofuels, it is important to evaluate the cumulative impacts of all bioenergy use in the EU-27 by 2020, as the RED sets an overall renewable energy target of 20% by 2020 which will be met only if bioenergy use is – in parallel to biofuels for transport - increased substantially also for electricity generation, and heating.

The mandatory renewables target for 2020 in the RED establishes only an EU-wide average without differentiating the target into specific forms of renewable energies. Thus, EU Member States have freedom in how to reach the 20% target, and are also subject to burden-sharing and virtual trade. Given that, the only adequate information source to evaluate the 2020 total bioenergy use in the EU is currently the NREAPs prepared by (most of) the Member States.

3.1. Relevant Studies

There are two recent studies which try to estimate the respective cumulative impacts of biofuels and bioenergy use for electricity and heat:

- IEEP conducted a study which explicitly analysed the GHG emissions from “total” ILUC resulting from the overall biofuels (and partially bioenergy) use in the EU-27 by 2020, and
- EEA carried out similar work, but also established several scenarios on future bioenergy use in the EU-27.

Both studies are briefly discussed below.

3.1.1. IEEP Study

The Institute for European Environmental Policy (IEEP) recently released a study on ILUC-related GHG emissions associated with EU-wide use of liquid biofuels according to the NREAPs by 2020 (IEEP 2010). The study is a first analysis and estimate of the effects of ILUC associated with the increased use of conventional biofuels that EU Member States have planned for within their NREAPs[28].

ILUC effects have been calculated using recently released studies by the European Commission, especially the JRC-IE work (JRC-IE 2010) discussed in Section 1.2.

IEEP took the 2008 biofuel use as a baseline, then calculated the projected 2020 biofuel use, and assumed the difference to be the increase in biofuel consumption due to the RED target. As IEEP did not include 2nd generation biofuels in the study, the calculated total EU 2020 biofuel consumption (see following table) excludes contributions from advanced biofuels[29].

[28] There were 23 NREAPs available at the time of drafting the IEEE study, and its analysis is based upon these.

[29] The overall amount of 2nd generation biofuels by 2020 is most probably rather small, though: the NREAPs project only 8% of the total biofuels to be “advanced” (e.g. from lignocellulosic feedstocks) which is well within the overall uncertainty of the IEEP study.

Table 12: Increase in EU 1st Generation Biofuels Use from 2008 to 2020

Country	Bioethanol	Biodiesel	Biofuels Total
UK	1640	1764	3403
Spain	255	2380	2635
Germany	396	1963	2360
Italy	442	972	1414
France	160	916	1076
Greece	414	136	550
Czech Republic	66	396	462
Ireland	121	304	425
Netherlands	143	252	394
Sweden	250	123	373
Romania	140	228	366
Portugal	27	313	340
Finland	26	280	306
Bulgaria	42	150	192
Luxembourg	22	150	172
Slovenia	17	154	171
Denmark*	-5	130	125
Lithuania	20	85	106
Austria	25	79	104
Slovakia	43	22	65
Latvia	0	11	11
Malta	6	3	9
Cyprus*	0	-14	-14
Total	**4250**	**10797**	**15047**

Source: IEEP (2010); data given in ktOE (1000 tonnes of oil equivalent); * = Cyprus and Denmark show negative figures as they anticipate making use of a high proportion of advanced biofuels by 2020 which could not be included in the study. Thus, the negative figures were excluded from further analysis by IEEP

The ILUC conversion factors used by IEEP were taken from the JRC-IE study (JRC-IE 2010) and determined by IEEP with lower and upper bounds:

biofuel	ILUC conversion factor [ha/ktOE]
biodiesel (low)	0.39
biodiesel (high)	0.52
bioethanol (low)	0.23
bioethanol (high)	0.44

Source: IEEP (2010)

These ILUC conversion factors were then multiplied by the anticipated additional usage of conventional bioethanol and biodiesel in 2020 (see Table above) to estimate the hectares of potential ILUC, resulting in a total additional land demand of 4 to 7 million ha.

To estimate the emissions associated with ILUC, the IEEP study used a conversion factor of 57 t C/ha (equivalent to 209 t CO_2/ha or 10 t CO_2/ha/year), based on an average of the IPCC default data (IPCC 2006), and then annualised the LUC-related emissions over a 20 year time horizon. With that, IEEP calculated the total EU-27 GHG emissions related to ILUC from biofuels for transport as between 44 and 73 million t of CO_2eq per year.

This translates into an ILUC factor of 70 – 116 g $CO_2/MJ_{biofuel}$ which is a rather high range (see Section 2), compared to the GHG emissions from fossil diesel and gasoline of ~ 84 g CO_2eq/MJ_{fuel}.

Taking into account the GHG emission reduction of 50% compared to fossil fuels needed for biofuels to be eligible after 2017 for the RED target, the net GHG emissions from biofuels for transport are reduced to 27 to 56 million t of CO_2eq per year. This represents an overall GHG emission factor of 43 – 89 g $CO_2eq/MJ_{biofuel}$ which would, given the lower value, still allow for a significant GHG reduction compared to fossil fuels, but would not achieve any GHG reduction for the higher value.

The IEEP study also considered liquid biofuels used for electricity and heat, as given in eight of the NREAPs. Using the same methodology for ILUC, the IEEP study estimated that an additional amount of 1 – 2 million ha of land would be needed, resulting in an additional net GHG emission of 10 – 20 million t of CO_2eq per year. Thus, IEEP estimates a total net GHG emission of 54 to 93 million t of CO_2eq per year for all additional biofuel use in the EU by 2020 due to ILUC. It should be noted that this values doe not include GHG emission savings due to avoided fossil fuel use, though.

All in all, the IEEP study is a reasonably well documented approach to estimate the ILUC impacts from a “business-as-usual” projection of future biofuel use in the EU by 2020. It uses a comparatively high range of ILUC factors for its analysis, but **the overall findings are deemed well substantiated, and underline the need to see ILUC as a serious issue affecting massively future EU emissions of GHG from biofuels.**

It must be noted, though, that the IEEP study did not consider the bioenergy use as such, as it only accounted for liquid biofuels for transport, and for electricity/heat production. Furthermore, the GHG emission figures presented in the IEEP study do not represent the net GHG balance of biofuels, as there was no overall accounting for avoided GHG emissions from fossil fuel use substitution due to biofuels.

3.1.2. EEA Study

The European Environment Agency (EEA), supported by the European Topic Centres on Air and Climate Change (ETC-ACC) and on Land Use and Spatial Information (ETC-LUSI), carried out **an update** of its earlier studies on environmentally-compatible bioenergy potentials (EEA 2006+2007) and the cost-effective use of bioenergy (EEA 2008) which will be published in early 2011. In this report, a baseline scenario and several “environmentally compatible” scenarios are developed and take into account cumulative ILUC from all bioenergy use. Details cannot yet be reported here.

3.2. Conclusions on Cumulative Effects

With the given data from the NREAPs, and the assumption that until 2020, no major shift in biomass use for electricity and heat generation occurs, the IEEP estimate on the cumulative ILUC effects of all biofuel use in the EU could be realistic if no change in current policies is assumed. On the other hand, the EEA study shows that assuming a full implementation of EU-wide sustainable biomass potentials for the electricity, heat and transport sector could be managed **without** major ILUC effects **if drastic** (and not market-based) **shifts** towards far higher productive biofuel feedstock provision, higher efficiencies in conversion and far more active use of residues and wastes are assumed.

Thus, the studies create a corridor of political **opportunity**: if EU policies successfully address the ILUC challenge and consistently regulate the sustainability of **all** bioenergy use, **then** the cumulative GHG effects of bioenergy development until 2020 could be positive, i.e. net GHG savings could be realised.

4. FIRST REFLECTIONS ON THE EC ILUC REPORT

The Commission released its report on indirect land-use change related to biofuels and bioliquids on Dec. 22, 2010 in which the following issues were covered (EC 2010):

- a brief summary on ILUC and respective analytical work carried out for the EC;
- a comparison of ILUC figures found on that analytical work, and from other studies;
- a summary of the literature review on ILUC carried out by the JRC;
- a compilation of international developments regarding ILUC;
- a summary of the ILUC consultation responses, and
- a final 1-page section on preliminary conclusions and next steps.

The short report – it has a total of 14 pages – makes, in substance, two key points:

1. The Commission acknowledges that ILUC can have a significant impact on GHG emissions associated with biofuels, and ILUC should be addressed under a precautionary approach.
2. The Commission will present the Impact Assessment, if appropriate together with a legislative proposal for amending the Renewable Energy Directive and the Fuel Quality Directive as necessary no later than by July 2011.

The report clearly states that further analytical work is under way by the JRC and by IFPRI to refine the ILUC modelling, and to derive feedstock-specific ILUC values also for higher biofuel shares than assumed in the earlier IFPRI study.

But the Commission report does not deliver an unambiguous statement on ILUC, pointing out that "a number of deficiencies and uncertainties associated with the modelling, which is required to estimate the impacts remains to be addressed". However, the Commission “acknowledges that indirect land-use change can have an impact on greenhouse gas emissions savings associated with biofuels, which could reduce their contribution to the policy goals, under certain circumstances in the absence of intervention. As such, the Commission considers that, if action is required, indirect land-use change should be addressed under a precautionary approach”.

The “next steps” present policy options which have already been subject to massive critique in the pre- and the formal ILUC consultations of 2009 and 2010 since there is a lack of consistency (EC 2009a; 2010b).

The Commission is currently assessing the impact of these four options. Due to the resources needed, in terms of time and workload, it is difficult to understand the need to assess the first two option listed by the Commission that are clearly **counterfactual**:

Option (1) "Take no action for the time being, while continuing to monitor" ignores all findings regarding ILUC (even those summarized in the report) which call – also in the report’s wording – for a precautionary ILUC value to be inserted in the GHG balance of biofuels. Furthermore, monitoring ILUC is scientifically impossible due to its nonlocal nature – thus, the “continuing to monitor” could be understood only if its refers to the monitoring of the best available science.

Option (2) "Increase the minimum greenhouse gas saving threshold for biofuels" cannot be substantiated by current science. This is no definite safe option since this could even mean that GHG emissions from ILUC might increase, as it would increase pressure to cultivate biofuel feedstocks on arable land (which has lowest direct LUC impacts), and thus actually increase displacement and, hence, ILUC.

The other two "options" presented in the Commission report might be, in comparison, potentially more adequate:

Option (3) "Introduce additional sustainability requirements on certain categories of biofuels" is too vague in its formulation – one might only speculate that this would mean to require avoidance of using prime arable or pasture land for biofuel feedstock production.

Option (4) "Attribute a quantity of greenhouse gas emissions to biofuels reflecting the estimated indirect land-use impact" **is the only valid option** which should be explored further, as it represents the quantitative approach towards GHG emissions from ILUC, as recommended in this study. Without any value given by the Commission, even this "option" is of highly speculative nature, though.

In addition to the lack of consistency in the policy option portfolio proposed by the Commission report, another point is noteworthy: Although the report acknowledges that both the US EPA and the California Air Resources Board included quantitative ILUC values in their regulations, the Commission does **not reflect** what this means for the European policy towards biofuels. After more than two years of discussion on the Federal and State level in the US, several major studies and modelling work carried out by US institutions, ILUC has been taken into account already in the US regulation – still, with more work to be done on refinement and data improvements, but clearly the science-based political decision in favour of a quantitative ILUC approach was made in the US. The Commission report does not justify why Europe should have "other science", or why ILUC should be less important in the EU.

All in all, the report should be seen as an **interim product only.** The reasons for the lack of appropriate answer to the RED requirements concerning the December 2010 deadline is not properly addressed in the Commission report. The limited size and substance of the report, that could be related to staff restrictions of the responsible DG and time constraints to prepare the report, do not allow a full appreciation of the ILUC challenge, and its regulatory implications for the EU. **It does not contain a concrete methodology for emissions from carbon stock changes caused by ILUC, ensuring compliance with the RED, as requested by the European Parliament.**

Given the preliminary nature of this first review of the Commission report on ILUC, the European Parliament may consider

- to closely monitor the preparation of the Impact Assessment,
- to follow-up on the adequacy of available resources for its preparation,
- to critically reflect the inclusion of key EU resources such as the European Topic Centres, and the EEA, and to reflect more properly the US rulemaking on ILUC,
- to call upon the Commission to focus its work especially on option 4 to avoid negative responses from the Parliament.

The European Parliament might consider updating its own proposals for an ILUC factor to be included in the RED methodology for GHG emission balances for biofuels based on the evidence compiled in this study.

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ANNEX

The Annex gives details on the issues discussed in the study. It is structured according to the chapters.

Details on LUC and ILUC from Bioenergy, and Biofuels

In Section 1, the four key steps to calculate ILUC-related GHG emissions from increased biofuel production based on energy crops were presented (see Figure 3).
Each step has its own specific data needs and modelling challenges, with respective data uncertainties and variations.
Furthermore, the **combination** of these models into a coherent flow of data requires special attention to representativeness and robustness of the data used, and to restrictions in the use of data between models with different resolution.

For steps 1 and 2, the available scientific approaches for determining ILUC from biofuels are all model-based, but with different complexity, sophistication and transparency:

- **Computable general equilibrium** (CGE) models: These models simulate the future market response to additional biofuel demand by calculating equilibrium states for the global market using equations for international trade, agricultural economics and energy markets. The equations are derived from a variety of assumptions, especially prices elasticities and yield developments as well as prices for key commodities (e.g., land, oil). By comparing a baseline scenario **without** additional biofuel demand with a scenario which includes more biofuels, CGE models determine **changes** in land use which are "caused" by the additional biofuel demand, compared to the baseline scenario. An advantage of CGE models is their comprehensiveness, i.e. they cover all relevant markets and their interactions. Disadvantages of CGE models are that they treat the global economy on a rather aggregated level, and are quite complex so that their assumptions, internal mathematical structures and respective model results are very intransparent.
- **Partial equilibrium** (PE) models: These models are similar to CGE, but "zoom in" to a specific region (e.g. Europe) and "freeze" the global interactions by using economic relations derived from broader CGE models. The PE model increase the resolution of market interaction **within** their specific region, e.g. modelling more detailed agro commodities and energy carriers as well as technologies. Therefore, PE models are less comprehensive in modelling, but also less complex. Their represent a compromise between regional detail and global impacts.
- **Causal-descriptive and deterministic** models: They represent an alternative to economic optimization models (CGE, PE) by using a bottom-up approach to establish **causal chains** between additional production of biofuels and its LUC impacts. The construction of such chains can be based on historic (statistical) data, or, for future projections, on expert opinions. In consequence, these approaches are less data-intense and far more transparent than CGE or PE models, but limited through the simplifications needed to describe causal chains. Therefore, they lack the comprehensive scope of agro-economic equilibrium models.

There is currently no "best" model for ILUC – depending on the scope of questions to be answered, any of the scientific approaches or their combination can be valid[30].

For **steps 3 and 4**, i.e. to calculate the GHG impacts arising from given ILUC, other models have to be used which are not of economic but **biophysical** and technical nature:

- To derive the CO_2 emissions resulting from a given ILUC, the carbon (C) content of the affected land **prior** to its conversion must be known, as well as the C content after the conversion to biofuel feedstock production. For both, the IPCC default data on DLUC can be used (IPCC 2006), but one also needs to determine what the respective land use was, i.e. was cropland or pasture land or forests or savannah affected by the ILUC-driven land conversion. For this, high-resolution data **maps** on land cover are needed which are created from remote sensing, i.e. aerial surveys and satellite monitoring[31].

- Once the GHG emissions from ILUC caused by the biofuel feedstock production is determined, the remaining task is to relate these emissions to the final biofuel output. For this, **life-cycle analysis** (LCA) is the appropriate tool which links the various steps of producing the biofuel feedstock, its transport and conversion into the final liquid product with auxiliary inputs such as fertilizer, diesel fuel, process heat and electricity, and also factors in possible co- and by-products (e.g. animal feed). LCA is a data-intense and complex activity, and various models are developed for data management and computational work. Of importance for ILUC is the way LCA models deal with multiple outputs of a product life-cycle[32]: For example, the production of biodiesel from rapeseed oil also provides extraction cake which can be used for animal feed, and glycerine (a base chemical). The ethanol production from maize yields a high-protein co-product called DDGS which is an important feedstock for cattle. Depending on the allocation of the ILUC-related GHG emissions (and other emissions from production, e.g. N_2O from fertilizer application and production, diesel for harvesting etc.) to the biodiesel or ethanol and their co-products, the GHG emissions can vary by a factor of 2 or more. This is not an uncertainty, but an effect of different methodologies to account for by- and co-products in LCA[33].

This brief discussion of the modelling approaches to ILUC-related GHG emissions from biofuels clearly indicates that

- the quantification of ILUC emissions requires **coupling** of several models from very different scientific realms (economic, biophysical, technical),
- **each** model has its intrinsic uncertainty,
- data requirements to model global impacts are **very high** unless simplified approaches are used.

[30] The Dutch Environmental Assessment Agency noted in its report on ILUC models: "Models, by definition, provide a simplified version of the world which means that every model has its pros and cons" PBL (2010c). The E4Tech study argued: "Modelling requires projecting impacts in the future, which is inherently uncertain (...) ILUC models cannot be validated or calibrated against historic data because indirect land use change is not an observable parameter, meaning that several potential impact pathways may be possible." (E4Tech 2010). For a more detailed and comparative discussion of models see CARB (2010), CE (2010), Ecofys (2010) and IEA Bioenergy (2009-2010).

[31] The processing of aerial and satellite photographic data into land cover change information is a data-intense procedure subject to uncertainty. Gibbs et al. (2010) give a good example of such ILUC-related data processing.

[32] For a discussion of allocating by-products with regard to ILUC see IER (2009), PBL (2010e), Taheripour (2010).

[33] To reduce the variation of LCA results due to the allocation method, the GHG accounting rule of the RED for biofuels **requires energy-based** allocation in which the lower heating values of the main product (i.e. the biofuel) and the by-products are used to distribute the total GHG emission burdens to all products.

The following table is a compilation of the relevant factors (parameters) influencing ILUC and related GHG emissions of biofuels.

Table 13: Detailed Listing of Parameters Influencing ILUC-Related GHG Emissions

	Parameter	Influence of Parameter
1	Previous crop (What is displaced?)	Crop its use (food, fodder, fibre) → important for relocation (see no. 3)
2	world region (From where was it displaced?)	Yields of previous crops differ by land type and world region → important for relocation (see no. 3)
3	Land demand due to substitution (How many hectares are necessary to replace previous use?)	Land demand depends on • yield of new land (how to determine?) • different ways to substitute : o 1:1 o by another biomass (e.g. soy instead of rape oil; differ in hectare yield) o changes in demand why only a part has to be substituted (e.g. due to high prices change in diet result)
4	Relocation of crop cultivation to satisfy remained demand (Where does relocation takes place?)	Calculation of LUC induced GHG emissions depend on: • different land types (peatland, forest, grassland etc.) and world regions • data quality: variability in estimates of c-stock in different land types • methodology: determination of future converted land type
5	Land captured by land use change	• by now no consensus if abandoned and unused degraded land have to be included or excluded in the ILUC definition • how to account for land that was deforested for other reasons and is later converted to crop land for energy cropping?
6	Energy crop: feed stock and use of feedstock (how displaced?)	• biofuel policy (biodiesel/bioetOH, 1st/2nd generation) •
7	Future demand of food, feed	Depends on size of population, future diets (varies with commodity prices)
8	Future demand of fibres and technical plants	
9	Use of by-products of biofuel production	allocation of land demand to biofuel and by-product substitution of other biomass uses of byproducts (e.g. energy rich fodder from cereals replaced by oil extraction cake…equivalent?)
10	Biofuel demand	EU and global biofuel policies influence: • absolut biofuel supply • amount of biodiesel and EtOH • origin of biofuels (domestic, imports)

	Parameter	Influence of Parameter
11	Biofuel pathway (yield of energy)	• Availability of technology (e.g. 2nd generation) • Feedstuff energy crops, wood, waste/residues
12	Other bioenergy demand	EU and global bioenergy policies influence the demand of solid and gaseous fuels for heating and electricity. Except waste and by-products different biomass competes for land.
13	Yield projection	changes in yield are influenced exogenous: • Variation of estimation concerning exogenous yield increase • climate change • new technologies and endogenous (increasing biofuels): • price induced intensification • biofuels→ less rotational land→ shrinking yields
14	Time	• Choice of reference year (2005, 2008, …) as baseline • Time allocation period: usually 20 a (=duration of assumed biofuel production on this land)

Source: Author's compilation

Details on Studies Evaluated

Table 14: Comparison of Study and Model Assumptions for Yield Increase

	2008-2020			
	IFPRI		IPTS	
	Baseline	BAU (FT is similar)	Baseline and Counterfactual	Faster Yield Growth
EU-27				
wheat	5.0%	5.11%	10.7%	13.9%
maize	5.0%	5.07%	19.4%	23.3%
rape	5.0%	5.90%	21.8%	25.7%
sugar beet	21.0%	22.20%	9.3%	12.9%
Brazil				
all crops	37.0%			
sugar cane	37.0%			
2017-2023				
	EU Ethanol Scenario			
	FAPRI	GTAP	LEITAP	AGLINK
EU-27				
wheat	0.09%	-0.07%		
maize	-0.07%			
rape	0.00%	-0.22%		
sugar beet	0.00%	-0.18%		
Brazil				
all crops	0.00%	-0.01%		
sugar cane	0.01%	-0.02%		
World				
average			-0.02%	0.03%
wheat	0.16%			
maize	0.01%			
sugar cane	0.00%			
2017-2023				
	EU Biodiesel Scenario			
	FAPRI	GTAP	LEITAP	AGLINK
EU-27				
average			0.004%	
wheat	0.04%	0.04%		
maize	0.06%			
rape	0.00%	0.14%		
sugar beet	0.00%	0.03%		
Brazil				
sugar cane	0.01%	0.00%		
World				
average			-0.01%	0.00%
wheat	-0.02%			
maize	0.02%			
sugar cane	0.00%			

Source: Author's calculations based on IFPRI (2010), JRC-IE (2010) and JRC-IPTS (2010)

The table below gives the data underlying Figure 5

Table 15: Shares of Marginal LUC and Land Saved by Yield Increase

Scenario	Model	Feedstock	Land Expansion [ha/ktOE]	Area Saved by Yield Increase [kha]
EU ethanol	FAPRI-CARD	Wheat	394	70
	IMPACT-IFPRI	Wheat	223	540
	IMPACT-IFPRI	coarse grains	120	920
	G-TAP	Wheat	794	27
	LEI-TAP	Wheat	731	380
	AGLINK-COSIMO		574	---
eu biodiesel	FAPRI-CARD	rapeseed	437	120
	G-TAP	Mix	377	115
	LEI-TAP	Biodiesel Germany	1928	360
	AGLINK-COSIMO		242	29
US ethanol	IMPACT-IFPRI	Maize	110	450
	IMPACT-IFPRI	Wheat	220	540
	G-TAP	coarse grains	165	246
	LEI-TAP	Maize	863	20
	AGLINK-COSIMO		511	---
US biodiesel	AGLINK-COSIMO		510	---
extra palm oil	G-TAP	mainly palmoil	82	227
	LEI-TAP	mainly palmoil	425	0,4
extra EtOH-Brazil	AGLINK-COSIMO		134	---
Results from other EC studies (own recalculation to MtOE)				
BAU	IFPRI	(55% biodiesel 45% ethanol)	84	---
FT	IFPRI	(55% biodiesel 45% ethanol)	122	---
Baseline	AGLINK (70% biodiesel)	70% biodiesel 30% ethanol	288	---

Source: Author's calculations based on IFPRI (2010), JRC-IE (2010) and JRC-IPTS (2010)

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