SCIENCE INSIGHTS *for Biofuel Policy*

Issue 1 (March 2011)

Welcome to the first issue of *SCIENCE INSIGHTS for Biofuel Policy*. This series will explore issues of interest to stakeholders in the European biofuel debate and strive to provide an impartial and concise analysis of the scientific and policy context in which the debate takes place. In doing so, *SCIENCE INSIGHTS for Biofuel Policy* draws on the expertise of LCA[works] and the Porter Institute (part of Imperial College London), as well as pertinent contributions in scientific journals, reports, and issue papers. This inaugural issue focuses on Indirect Land Use Change (ILUC) and provides a comparative analysis of the various modelling efforts undertaken in 2010 to estimate an ILUC emissions factor for multiple biofuel feedstocks against the background of the renewable fuel mandates set forth in the European Commission's Renewable Energy Directive (RED).

Synthesis of European Commission Biofuels Land Use Modelling

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In response to concerns about the impact of expanded biofuels targets (Renewable Energy Directive (RED)/ Fuel Quality Directive (FQD)) on land use, the European Commission initiated three studies to model the land use impacts resulting from the proposed regulation. The studies carried out are as listed below:

- IFPRI modelling using a modified MIRAGE model, with 2 alternative policy scenarios and 5 biofuel incorporation scenarios
- JRC-IPTS modelling using three different models (OECD AGLINK-COSIMO, ESIM and CAPRI)
- JRC-Ispra comparison of 6 models (AGLINK-COSIMO, CARD, IMPACT, G-TAP, LEI-TAP and CAPRI) to model 2 different EU biofuel scenarios.

A fourth study carried out a literature review, drawing on over 150 contributions related to the topic. The literature review concentrated on comparing method and data choices (rather than results) of 22 modelling studies, including the three EU Commission studies.

This paper summarizes the main findings of the three modelling studies and puts key inputs and outputs from the different models into consistent units and frames of reference to facilitate clearer comparison.

Table 1 (on page 4) presents a comparison of the different models used in the three studies. In addition to the major differences between the models summarized in Table 1, further analysis suggests that the models take different approaches to many other critical issues:

- Geographical coverage
- Sectoral coverage
    - Extent to which energy industry is modelled
    - Inclusion of the fertilizer sector
    - Livestock / animal feed
- Crop types modelled, including degree of disaggregation of oilseed crops
- Modelling of co-products, including degree of disaggregation of co-product protein content
- Methods and assumptions for modelling types of land implicated by land use change
- Methods for estimating greenhouse gas impacts of land use change, by historic data trend, agro-ecological zoning etc.
- Sources of historic land use trend data
- Counterfactual scenario definitions
- Future crop yield increases, and whether changes in crop yield are linked to changes in demand
- Changes in crop rotation frequencies and patterns and whether these are linked in the models in demand changes
- Impact of technological advancement

The significant differences between the models are likely to make a significant impact on the modelling results. For example, since increasing biofuels production will impact all sectors of the world economy in some way and all regions, with feedback loops, it is unlikely that partial equilibrium models will give results consistent with the CGE models.

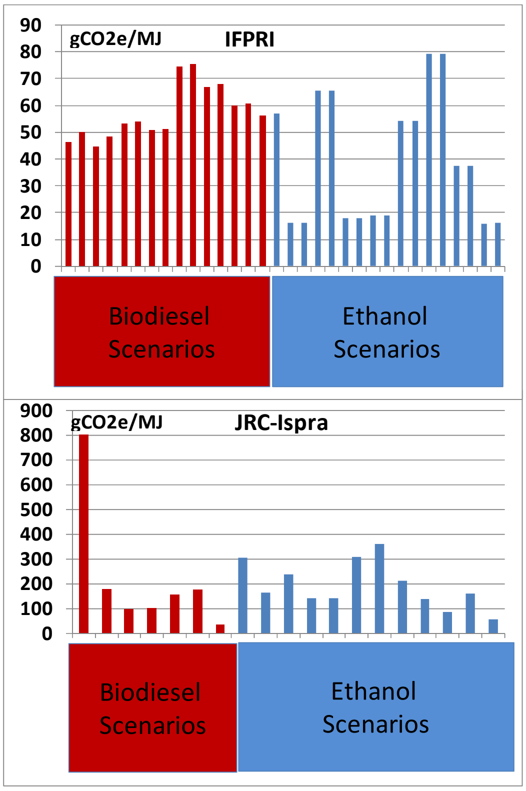

Figure 1. GHG Impacts from IFPRI and JRC-Ispra Studies

All of the models face a number of challenges which have not yet fully been resolved:

- How to include future crop yield increases, when the data and modalities within the models are based on historic data from a world with different market conditions (i.e., before recent dramatic emergence of developing nations, and before biofuels had reached significant market penetrations).
- How to include the impact of technological advancement, which, as with yield increases, will be driven harder in future as a result of global change and growing biofuel markets.
- How to allow for future changes in trade and fiscal policy.

Box 1. Summary of JRC-Ispra Analysis

The JRC-Ispra comparison of 6 models for two EU27 scenarios (marginal ethanol and marginal biodiesel) breaks out the variances in the key factors which impact the overall results:

- Feedstock per toe biofuel (finds good agreement between the models)
- Fraction of feedstock from less food consumption (savings in ILUC as a result of induced lower food consumption varied from 0.5% to 59% for the different models)
- Fraction of feedstock saved by by-product (savings in ILUC as a result of by-products varied from small savings for the LEITAP model to savings around 50% of the potential ILUC for the GTAP model)
- Fraction of increased production attributable to yield change (the CARD-FAPRI model reported a 22% contribution of yield change to EU wheat feedstock production, whilst the AGLINK-COSIMO model reported a 41% change).
- Ratio of average crop yield to frontier crop yield (the GTAP model assumed a ratio of 0.66 whereas the AGLINK-COSIMO and IFPRI-IMPACT models assumed a ratio of 1 -indicating no change).

The results of the modelling are compared in Table 2 and show, to varying degrees, that an increase in land use for agriculture will result from expanded biofuel targets when compared with the counterfactual (i.e., keeping biofuels at current incorporation levels, or allowing market-driven expansion). Figure 1 shows a summary of the GHG implications for biofuels implied by the modelled land use change. For the EU27, the results tend to show that arable land area will still decline, even with the expanded biofuels targets, but by a smaller amount than would otherwise be the case. These results need to be taken in the context of other factors affecting land use. For example, land use for arable crops in the EU27 is expected to decline by around 8.5% by 2020 in the "business as usual" scenario (i.e., without the RED regulation).

Therefore, the land use change resulting from implementation of the RED, for example as modelled by the IFPRI/MIRAGE model (+0.05 to 0.07% land use increase compared with the reference scenario), is small compared with the background rate of change in land use due to other factors over the same timescale. Therefore the significance of the modelling results is very limited. This conclusion is supported by the FAOstat data shown in Figure 2, which demonstrate that year-to-year variation in global arable area since 2000 has been in the order of -2 to +6 Mha, which represents a range of -0.13 to + 0.4% of current global arable area – a far more significant variation than the IFPRI model results of +0.05 to +0.07% spread over 10 years.

As well as the significant level of uncertainty in the results, another concern is the range of results emerging from the different models. Figure 1 shows the range of GHG impacts represented by the modelling results.

The reasons for the wide variation in results between the different modelling studies include a combination of factors:

- Differences between the scenarios modelled (i.e., differences in the forecast transport fuel demand in 2020, differences in the amounts of biofuels assumed will be blended, the amounts of second generation (2G) biofuels in the fuel mix and differences between policy assumptions etc.)
- Differences in the counterfactual scenarios – some models look at the change in biofuels from current levels (about a 3.3% market penetration in Europe), whilst others look at the difference the RED will make compared with biofuel expansion as driven by market forces.
- Differences in the structures of the models (see above), including differences in geographic representation and segmentation, representation of technological advancement and crop yield growth, handling of global trade uncertainties etc.
- Differences in key inputs to the different models (e.g., amounts of land currently used for different crops, current commodity prices, market elasticities, crop yields and biofuel conversion yields etc).
- Differences in treatment of co-products, including degree of disaggregation of co-product protein content.
- Different assumptions for modelling types of land implicated by land use change.
- Differences in assumptions and methods for modelling carbon impacts of land use change.

The analysis described in Box 1 for the JRC-Ispra comparison of 6 models for two EU27 scenarios offers further insight into the reasons for the wide range of results emerging from the different models. The analysis suggests that the values of critical parameters calculated within the different models can vary by one or two orders of magnitude between the models. It is therefore not surprising that the overall modelling results cover such a wide range of outcomes.

These observations, together with the analysis in Box 2 are further evidence to suggest that global and partial equilibrium modelling is not yet at a sufficient stage of development to be able to yield consistent predictions of land use change relating to biofuel expansion.
Further work is required to harmonize existing global and partial equilibrium models in terms of the way they handle key elements such as crop yields, use of biofuel co-products, technological development, policy and trade uncertainty and other factors.

In terms of specifically modelling the indirect land use change impacts of biofuel production, standardization is also required of the key input parameters, including future transport fuel demand, biofuel incorporation levels in future, impact of advanced, (second generation/2G) biofuels, amounts and quality of biofuel production co-products and their displacement values for other commodities, such as animal feeds and a range of other factors.

Year	Total arable land (Mha)	Δ fr. previous year (Mha)
2000	1,397.96	--
2001	1,398.03	0.07
2002	1,396.27	-1.76
2003	1,402.60	6.33
2004	1,405.83	3.23
2005	1,412.14	6.31
2006	1,411.72	-0.43
2007	1,411.12	-0.60

Figure 2. FAOstat Data for Global Arable Area.

It is important to recognize that the most important uncertainty facing the modelling is that the environment in which any bio-energy policy will play out will be a dynamic environment. All of the models rely upon modelling the interaction between the new biofuels production value chain and the dynamic global system. The indirect land use change impact is a factor of this interaction and not of the biofuel. To an extent, even a successful harmonization of the different models, taking into account all the factors described above will still not fully address this issue.

Box 2: Analysis of Information in Tables 1 and 2.

Model Type: models are either General Computable Equilibrium Models, covering all sectors of the economy and all world regions, or Partial Equilibrium Models, covering only some sectors and/or some world regions. The different coverage of the models is likely to materially impact the results.

Fuel and Biofuel Demand: the studies use different assumptions for year 2020 transport fuel demand (300 – 389.4 Mtoe), and biofuel incorporation levels (2.3 – 5.3% increase from current levels), and different assumptions about the role of second generation biofuels. Some models include 2G biofuels and others do not. These differences will have a first order impact on the results.

Food Price Impacts: only the IFPRI/MIRAGE model gives results for food price impacts at the global and regional level, predicting very modest increases as a result of the RED of 0.5% by 2020 in Brazil and 0.14% in the EU. The models all give results for price impacts on individual biofuel feedstocks, with very large variations between the models (0 – 1.0% range for most commodities for IFPRI and AGLINK-COSIMO, compared with a range between 10 – 30% for the ESM and CAPRI models). This is a very significant variation.

Land Use Impacts: the different models mainly show small changes in land use resulting from the implementation of the RED, with the exception of the JRC-Ispra model which gives much larger impacts. The IFPRI/MIRAGE model suggest an increase in land use of 0.07 – 0.08% globally and 0.05 – 0.07% in the EU as a result of the RED. The JRC-IPTS models look only at EU land use change, and predicts an overall reduction in land use for arable crops, although a smaller reduction than would have occurred without the RED, by between 0.42 – 2.2%. Comparison of the EU results across the different models suggests more than an order of magnitude difference in the outcomes (and 2 orders of magnitude when comparing the JRC-Ispra results with the others).

Crop Specific Land Use Impacts: each of the models gives results for the expansion of specific, biofuel feedstock crops. Again, the results show a spread of more than an order of magnitude, from the IFPRI/MIRAGE model (+0.33% land expansion for wheat, +2.16% for oilseed rape (OSR)), to the JRC-IPTS CAPRI model (+5.2% for wheat, +23.5% for OSR) and 2 orders of magnitude when comparing with the JRC-Ispra results.

Greenhouse Gas Impacts: only the IFPRI/MIRAGE work explicitly models GHG impacts, using a marginal approach and the land use change coefficients calculated by Winrock International for the USEPA(2010) amortized over 20 years. The JRC-Ispra work approximates GHG impacts of the modelled land use change, using an average LUC emission factor of 95 tonnes CO2 per hectare amortized over 20 years (36). The results of the IFPRI/MIRAGE work show that an indirect land use change impact can be expected, but at a level that would still leave an overall GHG saving of 18 - 21 Mt/yr as a result of the RED.

Overview: The large spread of results for price impacts, land use impacts and GHG emissions suggests that further work is required to explore the differences and standardize the modelling, including modelling approaches/methodology as well as inputs/ assumptions.

Table 1. Comparison of General Model Characteristics

	IFPRI MIRAGE	JRC-IPTS AGLINK-COSIMO	JRC-IPTS ESIM	JRC-IPTS CAPRI	FAPRI-CARD (as used in JRC-IE)	IMPACT (as used in JRC-IE)	GTAP (as used in JRC-IE)	LEITAP (as used in JRC-IE)
Model Type (1)	GE	PE, dynamic recursive	PE, comparative static	PE, comparative static	PE	PE	GE	GE
Regionsl	All	52 countries	EU27, Turkey, USA	EU27 + 33 non EU	All	All	All, in 87 regions	All
Sectorsl	All	Ag	Ag	Ag	Ag	Ag	All	All
Crops (2)	VO, PO, SC, SB, WT, SO, PO	WT, VO, MA, SC, SB	OS, VO, WT, MA, SC	WT, MA, OC, OS, VO, SB	Arable crops, SO, PO	SC, SB, MA, WT, other cereals	WT, MA, SC	VO, WT, MA, SC, SB
Disaggregation of oilseed crops	Yes (rape, soy, palm, sunflower) – see p. 89	No (P23)	Yes, 3 individual oilseeds (P. 101)	Yes, 2 individual oilseeds (P. 101)	Yes	No (P. 59)	Yes, in GTAP-E modified to GTAP-BIO	No (P.37 of CE Literature Review)
2G Biofuels Included(3)	Yes, exogenous	Yes	Yes	No	Yes - exogenous	No	No	Yes
Co-products included?	Yes (but not glycerol from biodiesel) – see p. 89	Yes	Yes	Yes	Yes	No	Yes	No (Tyner et al 2009)
Co-product protein content modelled?	Yes for oilseed cake (p. 89). No for DDGS (modelled by energy content – p.90)	Yes, but for DDGS assumed exogenously (P25). Ruminants & non-ruminants treated separately (P26)	No	Yes (P. 81)	Yes (P.29)	No, co-products not modeled.	Yes for oilseeds cakle. Yes, to some extent for DDGS (P20)	No. Animal feed substitution fixed at 20% of maize value (DDGS), 15% of wheat value (DDGS) and 30% of oilseeds value
Yield growth modelled as a function of demand growth?	Yes (see P. 33)	Yes (P. 58)	Yes (P.61)	Yes for some major crops only (see www.capri-model.org/faq_e.htm)	No (Lywod 2009), with some modification of yield for price (ADAS UK 2008)	Yes)P.58)	Yes, using yield-on-price elasticity of 0.25 in all regions	Yes
Idle land modelled separately or as part of forest/grassland?	Idle land not modelled – extensification assumed to be in forest or pasture (p58)	Idle land not modelled. Extensification of cropland into pasture not modelled in EU15 (P.100)	Idle land not modelled	Idle land not modelled (see www.capri-model.org/faq_e.htm)	Not specified. In EC reports	Idle land modelled separately (P. 58)	Not specified. In EC reports	Not specified – but model distinguishes between marginal and average land productivity
Method for estimating type of LUC	Historical with Agro-ecological Zoning (AEZ) (p58, P94)	Not specified. Model appears to model only existing arable land.	Not specified. In EC reports.	Not specified. In EC reports.	Bio-physical suitability (P.20)	Sub-national disaggregation of crop area	Economic Suitability with Agro-ecological Zoning (AEZ) (P.20)	Bio-physical suitability (P.20)
Source of historic trend data	GTAP-7 which is based on FAO for crops (P28)	FAO for crops (P22)	Not specified. In EC reports	FAOstat (see www.capri-model.org/faq_e.htm)	FAPRI	Not specified. In EC reports	GTAP-E	Not specified. In EC reports
Impact of extensification modeled endogenously?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Emissions from fertilizer use modeled?	Yes	No	No	No	Yes	No	Yes	Via IMAGE
GHG emissions from land conversion modeled?	Yes, partly	No	No	No	Yes	No	Yes	Via IMAGE

[1] GE: Computational general equilibrium models explain the relationship between supply, demand, and prices across all sectors of the economy and assess the impacts of changes within sectors on the rest of the economy over time. PE: Partial equilibrium models consider only a subset of sectors of the economy (e.g. energy, agriculture, forestry) and model the impacts of changes within these sectors over time.

[2] MA: maize PO: palm oil OC: oil crops OS: oilseeds SB: sugar beet SC: sugarcane SO: soy VO: vegetable oil WT: wheat

[3] 2nd generation biofuels

[4] From feedstock production only

Page references refer to sources 1, 2 and 3 corresponding to the models described in the applicable column of the table

Source: adapted from Netherland Environment Agency, 2010 with Imperial College LCA works analysis, September 2010

References

[1] IFPRI, Global Trade and Environmental Impact Study of the EU Biofuels Mandate

[2] JRC, Indirect Land Use Change from increased biofuels demand - Comparison of models and results for marginal biofuels production from different feedstocks

[3] JRC -IPTS, Impacts of the EU biofuel target on agricultural markets and land use: a comparative modelling assessment

Table 2: Summary of EU Commission Biofuel Land Use Modelling

	Study	IFPRI EU Mandate Scenario	IFPRI EU Trade Liberalization Scenario	JRC-IPTS AGLINK-COSIMO	JRC-IPTS ESIM	JRC-IPTS CAPRI	JRC Ispra - Marginal EU Ethanol	JRC Ispra - Marginal EU Biodiesel
Model Type & Description	Model	MIRAGE modified	MIRAGE modified	AGLINK-COSIMO	ESIM	CAPRI	AGLINK-COSIMO, CARD, IMPACT, G-TAP, LEITAP, CAPRI	AGLINK-COSIMO, CARD, IMPACT, G-TAP, LEITAP, CAPRI
	Model Type	CGE	CGE	PEM	PEM	PEM	CGE and PEM	CGE and PEM
Fuel & Biofuel Demand Assumptions	2020 forecast EU27 transport fuel demand	316 Mtoe (1)	316 Mtoe (1)	300 Mtoe (2)	389.4 Mtoe (3)	351.4 Mtoe (4)	300 Mtoe (5)	300 Mtoe (6)
	Modelled increase in biofuels 2010 - 2020	7.3 Mtoe (7) =2.3% of fuels (5.6%-3.3%)	7.3 Mtoe(7) =2.3% of fuels (5.6%-3.3%)	3.7% 1G, 1.5% 2G (8)	5.2%(9)	3.7% (10)	Marginal increase of 1Mtoe (ref 2, p14)	Marginal increase of 1Mtoe (ref 2, p14)
	Contribution of 2G Biofuels by 2020	7.0 Mtoe (11) 2.2% of fuels assuming 2G count double	7.0 Mtoe (11) 2.2% of fuels assuming 2G count double	1.5% energy by 2020 = 4Mtoe (12)	3.95 Mtoe1.4% of fuels (13)	1.5% energy by 2020 = 4Mtoe (12)	2G biofuels not modeled	2G biofuels not modeled
	2G Biofuels included in model	no	no	yes	yes	No	Exogenous invariable	Exogenous invariable
Food Price Impacts	Global food price impacts (basket)	+0.5% (Brazil) (14)	+0.5(Brazil) (14)	N/A (15)	N/A (15)	N/A (15)	N/A (31)	N/A (31)
	EU27 food price impacts (basket)	+0.14 (14)	+0.14% (14)	N/A (15)	N/A (15)	N/A (15)	N/A (31)	N/A (31)
	Price Impact on feedstock commodity	World impacts: Wheat +0.28% Maize +0.33% Oilseeds +0.06% Rapeseed +1.03% Sugar +0.17% (15a)	World impacts: Wheat +0.30% Maize +0.02% Oilseeds +0.06% Rapeseed +1.06% Sugar +0.19% (15a)	~1 – 2% higher with RED for all commodities: Wheat: -0.068% - 0.832% Sugar: - 0.173%-2.457% (16)	Soft wheat +8% Maize +22% Sugar +21% Rapeseed +10% Sunflower +6 – 7% (17)	Cereals +10.2% Maize +8.0 Oilseeds +19.5% Rape +29% Sunflower +12% (18)	N/A (31)	N/A (31)
Land Use Implications	Global Land use impact (change vs. 2010)	0.07% increase in cropland (19)	0.08% increase in cropland (19)	+0.7% increase in cereals, oilseed and sugar area(20	N/A (21)	N/A (21)	0.32 – 1.02 increase in cropland (32)	0.34 – 2.70 increase in cropland (32)
	EU27 Land use impact (change vs. 2010)	0.07 (22) increase in cropland vs. reference case (without RED)	0.05% (22) increase in cropland vs. reference case (without RED)	-6.5% , vs. counterfactual of - 8.6% (23) Cereals +1.5% Oilseeds +5.6%	-0.72% (1.1 Mha out of total 152 Mha), vs. -1.15% in counterfactual (24)	+0.05% increase in land for cereals, +10.5% increase in land for oilseeds (25)	0.1 – 1.4 Mha/toe = 0.7 – 9.8 Mha for 7 Mtoe biofuel = 0.007 – 0.1% of global arable (33)	0.2 – 2.0 Mha/toe = 1.4 –14.0 Mha for 7 Mtoe biofuel = 0.014 – 0.14% of global arable (33)
	EU Land use impact (by commodity)	Wheat +0.33 Maize +0.61 Oilseeds +0.13 Rapeseed +2.16 Sugar +0.09 (26)	Wheat +0.13 Maize +0.08 Oilseeds +0.10 Rapeseed +2.23 Sugar +0.03 (26)	Wheat +3.0% Maize +-0.3% Total Cereals +1.5% Oilseeds +5.6% Beet+10.6% (27)	Wheat +2% (28) Maize +3.9% Sugar +0.3% Rape +5.2% Soy -3.4% Sunflower +4.4%(28)	Wheat +5.2% Maize +4.9% Sugarbeet -1% Rape +23.52% Sunflower +6.5% Oilseeds +10.5% Fallow -5.6%	0.98 – 3.16% increase in wheat planted area (34)	7.6 – 61.0% increase in Oilseed Rape (OSR) planted area (34)
GHG Implications	GHG Reference System	92 gCO2e/MJ (29)	92 gCO2e/MJ (29)	N/A	N/A	N/A	None used (29)	None used (29)
	Amortization period	20 years	20 years				20 years	20 years
	Land Use Change Carbon Coefficient	Based on Winroc International for the USEPA(2010)	Based on Winroc International for the USEPA(2010)				Average of 95 tonnes CO2e/ha	Average of 95 tonnes CO2e/ha
	Direct GHG Emission Savings Implied by RED	18.17 Mt/yr (30)	21.11 Mt/yr (30)	N/A	N/A	N/A	N/A	N/A
	Modeled ILUC GHG Emissions due to RED	5.3 Mt/y (30)	5.9 Mt/y (30)	N/A	N/A	N/A	N/A	N/A
	Net GHG Savings due to RED	12.8 Mt/yr (30)	14.22 Mt/yr (30)	N/A	N/A	N/A	N/A	N/A
	Implied ILUC "Factor"	37.3.0g/MJ wheat 17.8 g/MJ sugcane 53.0 g/MJ RME 46-50 g/MJ Palm biodiesel(30a)	16.1 g/MJ wheat 18.9 g.MJ sugcane 51.0 g/MJ RME 45-48 g/MJ Palm biodiesel(30a)	N/A	N/A	N/A	56 – 359 g/MJ (35)	34 – 801 g/MJ (35)
	Implied Crop-specific GHG Saving including ILUC (positive numbers indicate overall GHG saving)	-7.0g/MJ wheat 54.0 g/MJ sugcane 8.8 g/MJ RME -18/-22 g/MJ Palm biodiesel(30b)	-5.0g/MJ wheat 55.5 g/MJ sugcane 7.4 g/MJ RME -18/-22 g/MJ Palm biodiesel(30b)	N/A	N/A	N/A	N/A	N/A

Source: Imperial College LCA works analysis, September 2010

This document has been produced by LCA works, as part of series exploring scientific and policy developments in the field of bioenergy and land use. Authors are Mark Akhurst (Honorary Research Fellow, Imperial College London), Nicole Kalas (LCA works) and Dr Jeremy Woods (Lecturer in Bioenergy at Imperial College London). For more information or to be added to our mailing list, please contact Mark Akhurst at m.akhurst@imperial.ac.uk.

Footnotes to Tables1 and 2:
(1) Page 45, reference 1
(2) Page 36, reference 2
(3) From Page 83, Table 5.4 of reference 3, biofuels are assumed to contribute 8.5% (assumed on an energy basis) of the transport fuel pool in 2020. Biofuel volumes given are 21,239 million litres of ethanol and 28,196 million litres of biodiesel, equivalent to 10.8 Mtoe of ethanol and 22.3 Mtoe of biodiesel (using conversion factors from JEC of 508 toe per million litres of ethanol and 791 toe per million litres of biodiesel). Total is therefore = 10.8+22.3 = 33.1 Mtoe/year, which will represent 8.5% of the fuel pool. Total transport fuel demand therefore = 33.1/0.085 = 389 Mtoe/year
(4) From section 4.6, page 69 of reference 3, baseline transport fuel demand is taken from PRIMES 2007, and results state that "biofuel demand in the baseline is simulated to increase to about 24.6 million tonnes oil, equivalent by 2020, which corresponds to 7% of total transport fuel consumption". Therefore total transport fuel demand in 2020 would be 24.6/0.07 = 351.4 Mtoe.
(5) From AGLINK-COSIMO (JRC-IPTS) study, page 36 of reference 3.
(6) From AGLINK-COSIMO (JRC-IPTS) study, page 36 of reference 3.
(7) From page 11 of reference 1, model assumes that currently 3.3% of transport fuel pool is biofuels, which will increase to 5.6% by 2020, an increase of 2.3%. Reference 1 states that 5.6% of the year 2020 transport fuel demand will correspond to 17.8 Mtoe. Therefore, 2.3% will be given by 17.7*(2.3/5.6) = 7.3 Mtoe
(8) From page 30, table 3.4 of reference 3, biofuel consumption by 2020 will be 8.5% (assumed by energy), of which, 7% will be 1G biofuels, 1.5% 2G. Assuming that current biofuels blending is 3.3% (taken from reference 1 data), then the increase is 8.5 – 3.3 = 5.2, of which 1.5% is 2G, leaving an increase in 1G biofuels of 3.7% of the transport fuel mix
(9) From page 82, section 5.4 of reference 3, year 2020 biofuel demand is forecast to be 8.5% of the fuel mix, representing an increase of 8.5-3.3 = 5.2% of the fuel pool, assuming that current levels of biofuel incorporation are 3.3%, as given in reference 1.
(10) From section 4.6, page 69 of reference 3, "biofuel demand in the baseline is simulated to increase to about 24.6 million tonnes oil, equivalent by 2020, which corresponds to 7% of total transport fuel consumption". Therefore, assuming that current biofuel incorporation is 3.3% (ref 1), this will represent an increase of 3.7% of the fuel pool.
(11) From page 11 of reference 1, model assumes that by 2020 5.6% of transport fuels will be 1G biofuels and that total biofue4ls will be 10% with 2G counting double. Therefore 0.5*(10-5.6) = 2.2% of the fuel pool will be physical 2G biofuels by 2020. If (note 7), 2.3% of the fuel pool represents 7.3 Mtoe, then 2.2% represents 7.3*(2.2/2.3) = 7.0 Mtoe.
(12) Table 3.4 of Reference 2. 2G biofuels are assumed to have no land use imlications.
(13) From page 83 of reference 3, table 5.4, if 21.2 + 28.2 = 49.4 billion litres of biofuel is equivalent to 8.5% of the transport fuel pool, then the 2G biofuels (3.3 + 5.0 = 8.3 billion litres represents 8.5*(8.3/49.4) = 16% of all biofuels (by volume) and therefore 0.16*8.5 = 1.4% of the total fuel pool. This is equivalent to 3,300*508 + 5,000*791 = 3.95 Mtoe (using the conversion factors from note 3).
(14) From page 12 of reference 1.
(15) Reference 3 does not model global or regional average price impacts, and just models the price impacts on individual commodities concerned.
(15a) From excel spreadsheet Annex 1 to reference 1, table S5.
(16) By eye from figures 3.2 and 3.3 in reference 1, the increase in prices for the commodities modeled, compared with the case without RED regulation is very modest. From page 33 "Differences in EU commodity balances of the main ethanol feedstocks, cereals and sugar should impact on their world market prices. However, these impacts are very small, due to the low total share of ethanol feedstock demand in these commodity markets (see Figure 3.2). The effects of EU policies on world market prices for biodiesel feedstocks vary (Figure 3.3). The price differences for oilseeds are marginal. Data from pages 23 and 29 of reference 3.
(17) Page 74 of reference 3 Data shown are compared with the counterfactual scenario with no RED regulation.
(18) Page 83 of reference 3
(19) From page 58 of reference 1
(20) From page 45 of reference 3.
(21) The ESIM and CAPRI models do not address land use change outside the EU27 – see table 5.2 on page 77.
(22) Page 60 table 7 of reference 1
(23) Page 37 – 38 of reference 3.
(24) Page 70 of reference 3 "The effect of EU biofuel policies on total EU area used for agricultural production is very small. In the baseline, the area used for agricultural production decreases between 2009 and 2020 by 0.72% (1.1 million hectares out of a total of 152 million hectares). Under the counterfactual scenario, agricultural land use would decrease by 1.15% (1.8 million hectares). Thus, the decrease in agricultural land is only slightly greater under the counterfactual than in the baseline."
(25) Page 83 of reference 3 "Cereals area is hardly affected, being only 0.05% higher, whereas oilseeds area is 10.5% higher with the biofuel polices. These higher rates of land use for energy crops are at the expense of land devoted to fodder activities and to fallow, which is lower by 0.2% and 5.6%, respectively. Yields for the main energy crops are also somewhat higher in the baseline compared with the counterfactual, reflecting a shift from lower- to higher-yielding crop varieties and a greater degree of intensification of production systems."
(26) The IFPRI study does not mention land use change by commodity in the main report, but the Microsoft excel annex to the report, table S5 gives the results of this modeling.
(27) Page 38, table 3.11 of reference 3
(28) Page 71, table 4.1 of reference 3.
(29) For IFPRI/MIRAGE: Page 62 of reference 1, note 20 to Table 10. For JRC-Ispra: no calculation was made of GHG "savings for biofuels, only of GHG "emissions" from LUC, so no comparator was used
(30) Pages 12 and 63 of reference 1.
(30a) Page 65 Table 12 of Reference 1.
(30b) Page 66 Table 13 of Reference 1.
(31) This report does not consider impacts on commodity prices.
(32) From reference 2, table 42 on page 71, the ranges of LUC impact are as follows: wheat ethanol 0.22 to 0.79 ha/toe biofuel, EU RME biodiesel 0.23 to 1.93 ha/toe biofuel. Assuming biofuels will increase from current 3.3% to 10% by 2020, assuming all 1G biofuels, and assuming year 2020 transport fuel is 300 Mtoe (all authors assumptions), then for wheat low range, the area of iLUC will be 0.22*(0.1-0.033)*300M = 4.4 Mha globally, if all increased biofuel blended was wheat ethanol. The wheat upper bound would therefore be = 14.0 Mha. For biodiesel, the range would be 4.6 to 37.0 Mha for the biofuel increase. If global arable land is 1.4 billion ha, then these ranges represent 0.32 to 1.02% of global cropland for ethanol and 0.34 to 2.70% of global cropland for the biodiesel.
(33) Reference 2, page 69, figure 13. Calculations based on 7 Mtoe biofuel, based on Reference 1, and 1,500 Mha of global arable land, based on FAOstat.
(34) Assuming global planted areas (2008 FAOstat data) are 223.5 Mha (wheat) and 30.3 Mha (Oilseed Rape (OSR)), then the increases for wheat of 4.4 to 14 Mha would represent a 1.96 to 6.26% increase in area of that commodity to provide all EU biofuels. For rapeseed biodiesel the increase would be 15.2 to 122% increase. Assuming that wheat ethanol and rapeseed biodiesel contributed 50% each to the increase in biofuels needed to meet the RED, then the increases would be: wheat 0.98% to 3.16% and rapeseed 7.6% to 61%.
(35) Reference 2, page 76, table 43, Based on 95 tonnes per ha land use change emissions over a 20 year amortization period. Excludes peat-land impacts.
(36) Figure (1) used by others (e.g. Elke Stehfest (PBL) in presentation at JRC-IE Ispra workshop on "The Effects of increased demand for Biofuels feedstocks on the world agricultural markets and areas" – EU report in publication). This figure is derived from [Searchinger et al 2008] and was used by others to compare models with and without emissions estimates) and spread over 20 years, in line with the EU-Renewable Energy directive.