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Developing a spreadsheet model for the calculation of the emissions from indirect land use change (ILUC) as a result of biofuel production-explanatory note

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Rev	Date	Details	Prepared by	Reviewed by	Approved by
02	03/04/2009	Report	**Evridiki Kaliakatsou** Assistant Environmental Economist	**Andrew Luke** Senior Environmental Consultant **Ian Brenkley** Assistant Environmental Consultant	**Jeremy Richardson** Technical Director

Scott Wilson
6 Greencoat Place
London
SW1P 1PL

Tel: 020 7798 5000
Fax: 020 7798 5001

www.scottwilson.com

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1 Explanatory note

1.1.1 This text is an explanatory note to the spreadsheet model for the calculation of the emissions from indirect land use change (ILUC) as a result of biofuel production. The following text explains the scope of the study, the operation of the spreadsheet model and provides an indicative scenario as example in regards with the greenhouse gas (GHG) emissions potential as a result of ILUC from biofuel production.

1.2 Scope of study

1.2.1 This study intends to give an easy to use, early-stage tool for the calculation of the indirect CO_2 emissions associated with biofuel production. The main issue concerning this study is that the emissions associated with biofuel production and use should take into account the indirect release of CO_2 into the atmosphere arising from the conversion of land to biofuel production and the consecutive displacement of the original activity elsewhere. The amount of additional emissions will depend on the vegetation type which covers the land prior to biofuel production and on the type of land where this original land cover (e.g. maize production) will be displaced too. This constitutes a complex scientific matter, which requires years of research to be accurately assessed. However, this study represents an initial approach with the intention to provide a reasonable level of accuracy based on the limited information currently available together with a high level of transparency.

1.2.2 The following sections will describe the key input parameters used in the study, as well as the structure of spreadsheet that has been produced.

1.3 Key input data

1.3.1 These data are primary inputs in the tool which may be provided by the user or alternatively can be extracted from the in-built database. These are listed below:

- Types of biomass (above ground, below ground etc)
- Land use (grassland, cropland, rainforest etc)
- Emission factors for each type of land use (t C or t CO_2 per hectare[1]
- Conversion factor of dry matter to carbon for grassland and cropland
- Carbon stocks of biomass per type of land

1.3.2 Secondary inputs necessary for the calculations involve the proportional factors for the land use change.

[1] Tonnes of carbon and Tonnes of carbon dioxide

1.4 Sources of data

1.4.1 Most of the data as well as the necessary information for building the equations for the calculations have been obtained from the Good Practice Guidance for Land Use, Land-Use Change and Forestry of the IPCC National Greenhouse Inventory Programme and other official publications regarding land use change. Data from non official sources have been avoided for reasons of establishing validity.

1.5 Accuracy of results

1.5.1 This study is an early-stage assessor and calculator for the emissions from the biofuel production involving the indirect land-use change effect. Therefore it is not intended to constitute an exhaustive study of the emissions from indirect land use change - which may take years to accurately assess - but it should serve as a starting point for further research and a stimulus for renewed debate about the impact of biofuels on our climate. The sources of data that have been used though, as well as the methodology (calculations and input selection) that have been followed, are widely recognised as they come from the above mentioned reputable sources and thus we believe, this study can provide an indicative first estimate in regards with CO_2 emissions from indirect land use change as a result of biofuel production.

1.6 Structure of the model

1.6.1 The model is a spreadsheet based tool which expands into four sheets, “Scenarios”, “Emission Calculations”, “Sources-Studies” and “Lists”.

1.6.2 “Scenarios” and “Emission Calculations” sheets are the main interfaces between the user and the tool, where the above mentioned key input data are required to be imported. Colour coding of the cells has been followed so that it is easier for the user to identify which cells need to be altered; these are the working cells which include calculations and thus should **NOT** to be changed; which cells constitute the drop-down menus, and where the results should be found.

- **Light yellow cells** indicate the input cells, where the user is asked to fill in data for:
    - Total volume of biofuel (litres)
    - Conversion efficiency (litres/tonne)
    - Crop yield (tonnes/hectare)
    - Biofuel yield (litres/hectare)
    - Carbon intensity (gCO_2e/MJ)
    - Baseline scenario GHG saving (no ILUC) (%)
    - Biomass above ground (t C per ha)

    - Forest product after 50 years (t C per ha)
    - Biomass mass for each type of land use (t C/hectare)
    - Conversion factor of dry matter to carbon for grassland and cropland
    - Default biomass carbon stocks present on land converted to Grassland
    - Annual emission factors for managed Grassland and Organic Soils
- **Light green cells** (working cells) indicate the cells that do the calculations and **should not be** altered by the user:
    - Total volume of biofuel (litres)
    - Total mass of biofuel (tonnes)
    - Biofuel land (hectares)
    - % of the land displaced
    - Emissions from each of the different types of land use change (tCO_2e/hectare)
- **Pink cells** indicate the drop-down lists from which the user can select from a limited number of options. These cells interact with certain input cells for the calculations which are placed in the light green cells. That is the reason why certain cells belong in both the light yellow and light green types; the light yellow include the primary input data, and light green calculate the same input data for a given factor which is set by the drop-down lists in the pink cells.
- **Light blue cells** indicate the results cells (total emissions from indirect land use change in tCO_2e and GHG emission savings in %)

1.6.3 The main results table which summarises all the model's outcomes is located in the "Scenarios" sheet.

1.6.4 The "Emission Calculations" sheet includes all the calculations for land conversion. The table at the bottom end of the sheet labelled as "Results" provides the emissions from land use change in tonnes CO_2 per hectare for different land conversions and climatic conditions.

1.6.5 The "Sources-Studies" sheet informs the user of the terminology used, references to existing work on the issue, the source and the quality of data that have been used in the model.

1.6.6 The last sheet is the "Lists" which includes all the selections which supply the drop-down lists of the "Scenarios" and "Emission Calculations" sheets. They can potentially change according to the user's requirements.

1.7 Emission reduction including ILUC

1.7.1 The percentage reduction of GHG emissions from the Life Cycle and the direct land use change reported by the RFA, (RFA Monthly Report 8: 15 April-14 December 2008) does not take into account the ILUC. By incorporating the ILUC in the calculations, it is expected that the emission saving will be lower. The magnitude of that drop depends on the type of land on which the original displaced land use is transferred. For example, converting rainforest instead of grassland will show significantly higher emissions from ILUC and thus the emission savings from the biofuels will be much lower. In summary the calculations of the new percentage savings presented in this report compare the GHG emissions that are emitted from all the operations involved with the cultivation of the feedstock and the production of the biofuel, plus the direct and indirect land use change with the fossil fuel life cycle emissions for the same amount of energy in MJ.

1.7.2 It is important to note that the calculated percentages are really an indication of the potential scale of the effect that ILUC can have on the emission saving percentage of biofuels rather than a precise calculation. Even though the input data are from well respected sources (e.g. IPCC), due to the natural complexities involved in the carbon balance of different ecosystems' the total emission calculations from biofuels must be sensitive to, location, country, climatic conditions, agricultural practice etc). Therefore, if a more precise analysis is sought, then appropriate data for the local conditions should be acquired. This is currently not available.

1.7.3 Therefore in conclusion, the results from the calculation based on the assumptions presented below in 1.8 indicate that the ILUC is a significant factor which should not be ignored and could significantly alter the final analysis of whether biofules reduce GHG emissions overall.

1.8 Indicative scenario

1.8.1 Based on a number of assumptions Scott Wilson has developed a scenario to estimate the GHG emissions associated with indirect land use change. These have then been used to adjust the RFAs estimates of the GHG emission savings associated with the production and use of biofuels. The five assumptions used to generate this scenario have been clearly laid out below. The purpose of creating this scenario is (1) to create a reasonable demonstration of the potential scale of GHG emissions from ILUC and its potential implications on the UK's biofuels policy. (2) To stimulate further research on the indirect impacts from biofuel production and in particular to provide additional evidence to support the assumptions that had to be made in this study. The data used regarding the amounts of biofuels imported (in litres) was obtained from the RFA, Monthly Report 8: 15 April-14 December 2008.

- It has been assumed that only land which was previously devoted to agricultural production will need to be displaced elsewhere for example as a result of growing population and increasing food demand. On the other hand, habitats like forests which have been converted to biofuel production are less likely to be displaced elsewhere (for example afforestation projects). Therefore for the purposes of this model we have assumed that only land which was previously devoted to agriculture (cropland and grassland used for agricultural purposes) might need to be displaced elsewhere.

- The percentage of land which will be displaced will depend on various socioeconomic factors. Increasing population will signify higher demand for food production; however it is important to consider that technological progress and increasing productivity will lead to higher yields per unit of land. This means that eventually less land will be required for a certain amount of food production, and therefore less land will probably need to be displaced as a result of biofuel production. Since there are no definitive figures on food demand and technological progress, for the development of this indicative scenario it has been assumed that only 10% of the previous land use will be displaced. It is anticipated that this percentage might reflect a conservative assumption for the near future considering the pressure for more food around the world and the constant technological progress.
- The next key assumption is about where the potential land displacement will occur. It is expected that land displacement will not necessarily occur within the same country. For example land conversion in Brazil from food to biofuel production, might lead to additional land requirement for food production overseas. For that reason it has been assumed that land displacement will occur globally. In addition it has been assumed that the land displacement will occur in six key biomes/habitats[2] in equal proportions. This hypothesis of equal proportions was made due to a lack of credible information on where exactly the global agricultural frontier expansion is occurring. The logic behind this assumption is that in the absence of information of which biomes and habitats would be affected we have assumes an equal distribution amongst all land types analysed. It can be argued that this will lead to a conservative estimate of emissions as it could be reasonable to argue that the majority of the indirect land use change might occur in areas where land rights/ownership are not clear (e.g. tropical forests).
- The displaced land in the above-mentioned 6 habitats/biomes is assumed to be annual cropland in all of the cases. This assumption has been made for the following reason: as the displacement is expected to occur globally there is high uncertainty as for which country and thus climate type will accommodate the displacement of land. Therefore, in the absence of more precise information a land type that results in a more conservative estimation of emissions has been selected.

[2] These six habitats have been selected due to the availability of relevant information from previous studies in regards with emissions from land use change.

- The emissions from the ILUC are assumed to occur in the period which immediately follows the land use change. However, these emissions need to be amortised over a period of years for which it is assumed that a specific piece of land will be used for crop production. Therefore rather than assuming that all the emissions for ILUC occur in the first year of biofuel production, the impact has instead been amortised over a 20 year period. This value has been selected to be in line with the RTFO assumptions about the period over which the land is amortised[3]. Under the indicative scenario the total emissions from the ILUC have been divided by 20 to give the annual emissions.
- In regards to the land use prior to biofuel production, in some cases this has been reported as "unknown". One of the main reasons why land could be reported as unknown is because it is unregistered which implies that this could be forest. Therefore, it is reasonable to assume that this would largely not be displaced (i.e. forest would not be re-grown on another piece of land). However, this would equally imply that the direct emissions associated with the land conversion to biofuels, would be significant. The possibility of including a figure for ILUC from unknown land was considered as a counterbalance for this official omission of direct emissions, but instead it was decided that it was preferable to leave the figures in the model as a more conservative estimation of the emissions from ILUC. We have however, applied similar proportions of grassland, cropland and by-product to the unknown category as some unknown land is likely to have been from these classifications. However, this still means around 70% of unknown land is still unaccounted for in terms of both direct and indirect emissions from land use change.

[3] Carbon and Sustainability Reporting Within the Renewable Transport Fuel Obligation - Technical Guidance Part 1, Renewable Fuels Agency, Version 2.0, March 2009.

PARAMETERS

COUNTRY	CROP	FUEL	PREVIOUS LAND USE (Land use on 30th November 2005)		TOTAL VOLUME OF BIOFUEL (litres)	CONVERSION EFFICIENCY (l/t)	TOTAL MASS OF CROP (tonnes)	CROP YIELD (t/ha)	BIOFUEL YIELD (l/ha)	BIOFUEL LAND (ha)	CARBON ITENSITY (gCO2e/MJ)	% of the land displaced (10%)	Basecase Scenario-GHG saving (no ILUC)
BRAZIL	SOY	Biodiesel	Cropland		265,971	205	1,297	2.4	491	542	78	54	10%
BRAZIL	SOY	Biodiesel	Unknown land use		5,820,065	205	28,391	2.4	491	11,853	78	1,185	10%
BRAZIL	SOY	Biodiesel	of which Cropland is:	18.5%	1,073,802	205	5,238	2.4	491	2,187	78	219	10%
BRAZIL	SOY	Biodiesel	of which Grassland is:	0.0%	-	205	-	2.4	491	-	78	-	10%
BRAZIL	SUGAR CANE	Bioethanol	Cropland		44,416,916	74.5	596,200	73.5	5476	8,111	25	811	71%
BRAZIL	SUGAR CANE	Bioethanol	Unknown land use		72,091,995	74.5	967,678	73.5	5476	13,165	25	1,317	71%
BRAZIL	SUGAR CANE	Bioethanol	of which Cropland is:	24.4%	17,619,284	74.5	236,500	73.5	5476	3,218	25	322	71%
BRAZIL	SUGAR CANE	Bioethanol	of which Grassland is:	0.0%	-	75.5	-	73.5	5476	-	25	-	71%
MALAYSIA	PALM	Biodiesel	Cropland		26,999,785	230	117,390	20.6	4736	5,701	47	570	45%
MALAYSIA	PALM	Biodiesel	Unknown land use		9,899,082	230	43,039	20.6	4736	2,090	47	209	46%
MALAYSIA	PALM	Biodiesel	of which Cropland is:	18.5%	1,826,381	230	7,941	20.6	5476	334	47	33	46%
MALAYSIA	PALM	Biodiesel	of which Grassland is:	0.0%	-	230	-	20.6	5476	-	47	-	46%
INDONESIA	PALM	Biodiesel	Cropland		16,384,816	230	71,238	17.8	4092	4,004	47	400	46%
INDONESIA	PALM	Biodiesel	Unknown land use		7,233,896	230	31,452	17.8	4092	1,768	47	177	46%
INDONESIA	PALM	Biodiesel	of which Cropland is:	18.5%	1,334,654	230	5,803	17.8	491	2,718	47	272	46%
INDONESIA	PALM	Biodiesel	of which Grassland is:	0.0%	-	230	-	17.8	4092	-	47	-	46%
USA	SOY	Biodiesel	Cropland		158,215,912	205	771,785	2.7	552	286,623	58	28,662	32%
USA	SOY	Biodiesel	Unknown land use		38,560,062	205	188,098	2.7	552	69,855	58	6,986	33%
USA	SOY	Biodiesel	of which Cropland is:	18.5%	7,114,331	205	34,704	2.7	491	14,489	58	1,449	33%
USA	SOY	Biodiesel	of which Grassland is:	0.0%	-	205	-	2.7	552	-	58	-	33%
ARGENTINA	SOY	Biodiesel	Cropland		30,983,140	205	151,137	2.7	552	56,129	48	5,613	44%
ARGENTINA	SOY	Biodiesel	Unknown land use		13,325,474	205	65,002	2.7	552	24,140	48	2,414	44%
ARGENTINA	SOY	Biodiesel	of which Cropland is:	18.5%	2,458,550	205	11,993	2.7	491	5,007	48	501	44%
ARGENTINA	SOY	Biodiesel	of which Grassland is:	0.0%	-	205	-	2.7	552	-	48	-	44%
GERMANY	OILSEED RAPE	Biodiesel	Cropland		58,001,579	205	282,935	2.7	1200	48,335	48	4,833	44%
GERMANY	OILSEED RAPE	Biodiesel	Grassland		813,277	205	3,967	2.7	1200	678	168	68	-94%
GERMANY	OILSEED RAPE	Biodiesel	Unknown land use		54,510,010	205	265,902	2.7	1200	45,425	48	4,543	44%
GERMANY	OILSEED RAPE	Biodiesel	of which Cropland is:	18.5%	10,057,097	205	49,059	2.7	491	20,483	48	2,048	44%
GERMANY	OILSEED RAPE	Biodiesel	of which Grassland is:	0.0%	-	205	-	2.7	552	-	48	-	44%
UK	OILSEED RAPE	Biodiesel	Cropland		2,296,298	205	11,201		1322	1,737	51	174	41%
UK	OILSEED RAPE	Biodiesel	Unknown land use		13,188,416	205	64,334	2.4	1322	9,976	53	998	39%
UK	OILSEED RAPE	Biodiesel	of which Cropland is:	18.5%	2,433,263	205	11,870	2.4	491	4,956	53	496	39%
UK	OILSEED RAPE	Biodiesel	of which Grassland is:	0.0%	-	205	-	2.4	1322	-	53	-	39%
UK	SUGAR BEET	Bioethanol	Cropland		22,577,529	110	205,250	46	5060	4,462	25	446	71%

SCENARIOS

COUNTRY	CROP	PREVIOUS LAND USE	Land use type that will be displaced	Type (select one):	Where to be displaced (emissions from land displaced tCO2e loss): Lowland tropical forest SE Asia	Peatland Tropical Rainforest SE Asia	Amazonian Rainforest	Woody Cerrado and Cerradão	Grassy Cerrado	Abandoned Cropland to Corn	Total emissions from ILUC (tCO2e)	GHG savings with ILUC: GHG emissions including LCA, LUC (tCO2 e)	Diesel LCA GHG emissions (tCO2 e) for the same MJ amount	Total GHG emissions including ILUC (tCO2 e)	GHG emission savings (%)
					16.67%	16.67%	16.67%	16.67%	16.67%	16.67%					
BRAZIL	SOY	Cropland	Cropland	Annual Cropland	12,145	13,966	9,088	2,768	1,573	371	1,996	687	763	2,682	-252%
BRAZIL	SOY	Unknown land use													
BRAZIL	SOY	of which Cropland is:	Cropland	Annual Cropland	49,033	56,384	36,692	11,174	6,350	1,497	8,056	2,772	3,080	10,829	-252%
BRAZIL	SOY	of which Grassland is:	Grassland	Warm Temperate Wet	-	-	-	-	-	-	-	-	-	-	
BRAZIL	SUGAR CANE	Cropland	Cropland	Annual Cropland	181,858	209,121	136,084	41,441	23,551	5,552	29,880	23,652	80,862	53,532	34%
BRAZIL	SUGAR CANE	Unknown land use													
BRAZIL	SUGAR CANE	of which Cropland is:	Cropland	Annual Cropland	72,139	82,954	53,982	16,439	9,342	2,202	11,853	9,382	32,076	21,235	34%
BRAZIL	SUGAR CANE	of which Grassland is:	Grassland	Warm Temperate Wet	-	-	-	-	-	-	-	-	-	-	
MALAYSIA	PALM	Cropland	Cropland	Annual Cropland	127,819	146,981	95,647	29,127	16,553	3,902	21,001	42,004	76,687	63,005	18%
MALAYSIA	PALM	Unknown land use													
MALAYSIA	PALM	of which Cropland is:	Cropland	Annual Cropland	7,478	8,599	5,596	1,704	968	228	1,229	2,841	5,220	4,070	22%
MALAYSIA	PALM	of which Grassland is:	Grassland	Warm Temperate Wet	-	-	-	-	-	-	-	-	-	-	
INDONESIA	PALM	Cropland	Cropland	Annual Cropland	89,775	103,233	67,178	20,458	11,626	2,741	14,750	25,490	46,858	40,240	14%
INDONESIA	PALM	Unknown land use													
INDONESIA	PALM	of which Cropland is:	Cropland	Annual Cropland	60,945	70,081	45,605	13,888	7,892	1860.4814	10,014	2076.320935	3,817	12,090	-217%
INDONESIA	PALM	of which Grassland is:	Grassland	Warm Temperate Wet	-	-	-	-	-	-	-	-	-	-	
USA	SOY	Cropland	Cropland	Annual Cropland	6,426,265	7,389,637	4,808,770	1,464,395	832,220	196,178	1,055,873	303,743	449,379	1,359,616	-203%
USA	SOY	Unknown land use													
USA	SOY	of which Cropland is:	Cropland	Annual Cropland	324,863	373,564	243,095	74,029	42,071	9,917	53,377	13,658	20,308	67,035	-230%
USA	SOY	of which Grassland is:	Grassland	Warm Temperate Wet	-	-	-	-	-	-	-	-	-	-	
ARGENTINA	SOY	Cropland	Cropland	Annual Cropland	1,258,444	1,447,099	941,693	286,770	162,972	38,417	206,770	49,226	88,607	255,996	-189%
ARGENTINA	SOY	Unknown land use													
ARGENTINA	SOY	of which Cropland is:	Cropland	Annual Cropland	112,265	129,095	84,008	25,583	14,539	3,427	18,446	3,906	7,031	22,352	-218%
ARGENTINA	SOY	of which Grassland is:	Grassland	Warm Temperate Wet	-	-	-	-	-	-	-	-	-	-	
GERMANY	OILSEED RAPE	Cropland	Cropland	Annual Cropland	1,083,693	1,246,151	810,927	246,948	140,341	33,082	178,057	92,243	164,720	270,300	-64%
GERMANY	OILSEED RAPE	Grassland	Grassland	Warm Temperate Wet	14,895	17,173	11,070	3,163	1,668	164	2,407	4,522	2,331	6,929	-197%
GERMANY	OILSEED RAPE	Unknown land use													
GERMANY	OILSEED RAPE	of which Cropland is:	Cropland	Annual Cropland	459,239	528,084	343,648	104,650	59,473	14,019	75,456	15,954	28,489	91,409	-221%
GERMANY	OILSEED RAPE	of which Grassland is:	Grassland	Warm Temperate Wet	-	-	-	-	-	-	-	-	-	-	
UK	OILSEED RAPE	Cropland	Cropland	Annual Cropland	38,944	44,783	29,142	8,875	5,043	1,189	6,399	3,852	6,567	10,251	-56%
UK	OILSEED RAPE	Unknown land use													
UK	OILSEED RAPE	of which Cropland is:	Cropland	Annual Cropland	111,110	127,767	83,144	25,319	14,389	3,392	18,256	4,265	6,959	22,521	-224%
UK	OILSEED RAPE	of which Grassland is:	Grassland	Warm Temperate Wet	-	-	-	-	-	-	-	-	-	-	
UK	SUGAR BEET	Cropland	Cropland	Annual Cropland	100,040	115,037	74,860	22,797	12,955	3,054	16,437	11,831	40,798	28,269	31%
										Total Figure	1,730,257	612,105	1,064,552	2,342,362	-120%

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