Greenhouse Gas Balances for Biomass: Issues for further discussion

Issue paper for the informal workshop, January 25, 2008 in Brussels

R+D project
Sustainability standards and indicators for the certification of internationally traded biomass

on behalf of the **German Federal Environment Agency**

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1 Background

It is generally agreed that a beneficial greenhouse gas (GHG) balance is a fundamental criterion for the sustainability of biomass for energy use. All schemes in preparation or under discussion refer to this: Belgium, Germany, the EU, the Netherlands, the UK, and also the State of California.

On December 5, 2007, the German Government passed the Biomass Sustainability Ordinance (BSO) which specifies the GHG calculation methodology, reduction targets, and default values for the German legislation on biofuels. Methodology and default values are presented in a separate paper.[1]

As part of an ongoing research project of Öko-Institut and IFEU commissioned by the German Federal Environment Agency (UBA) which – beyond the BSO - concerns sustainability issues of globally traded biomass and the options to implement respective standards, the scope of this issue paper is to open the floor for discussing **further** issues that are not yet sufficiently developed for implementation, and need further consideration, as well as scientific and political discussion.

In that respect, the ongoing research project is working on the following questions:

- How to consider **indirect** land use change effects in GHG balances
- Besides GHG balances, are there other options to consider indirect land use change?
- How to handle significant data uncertainties in the field of
    - carbon stock changes in specific cases;
    - emissions of nitrous oxides;
    - allocation of indirect land use change to specific bioenergy development project;

The following sections briefly introduce these issues, and give a first estimate of the potential GHG emissions resulting from indirect land-use change related to biofuel development.

Some thoughts on the respective implications are given at the end.

1 IFEU: Greenhouse Gas Balances for the German Biofuels Quota Legislation - Methodological Guidance and Default Values; Heidelberg, December 2007

2 How to consider indirect land use change effects in GHG balances

2.1 GHG consequences of indirect land use

In principle, all expansion of (biofuel) crop production is connected with land use change. Since land is mostly dedicated to some purpose (i.e. production of food or other crops, settlement, set aside land, forest, natural protection area), land use competition will be a logical consequence.

A direct land use change is given whenever a new crop scheme is planted in an area where this form of cultivation has not taken place before. The area might have been covered by forest or other natural and near-to-nature ecosystems, but it might also have been idle or set-aside land. The quantification of direct land-use changes is rather well understood and can be based on land cover data and – hence – carbon content data from IPCC default (tier 1) or country-specific (tier 2) values[2].

Indirect land use can be described as the **shift** of the land use prior to biofuel production to another area where a land use change occurs due to maintaining the previous level of (e.g., food) production. This is called “leakage” or “displacement”.

Figure 1 shows two exemplary mechanisms of displacement by increased use of bioenergy in Europe.

The upper part of the figure refers to an increase of biomass imported from the South. In the producing country, good practice and absence of direct land use change may be certified. But the required area for the new crop is no more available for the previous crop for which there is still a demand. The previous cropping will be **displaced** and “move” to other areas which were not in use (natural forests), and will be replaced by the previous cropping.

The lower part in Figure 1 is meant to demonstrate that an increased biomass production **in Europe** may also induce deforestation, though indirectly.

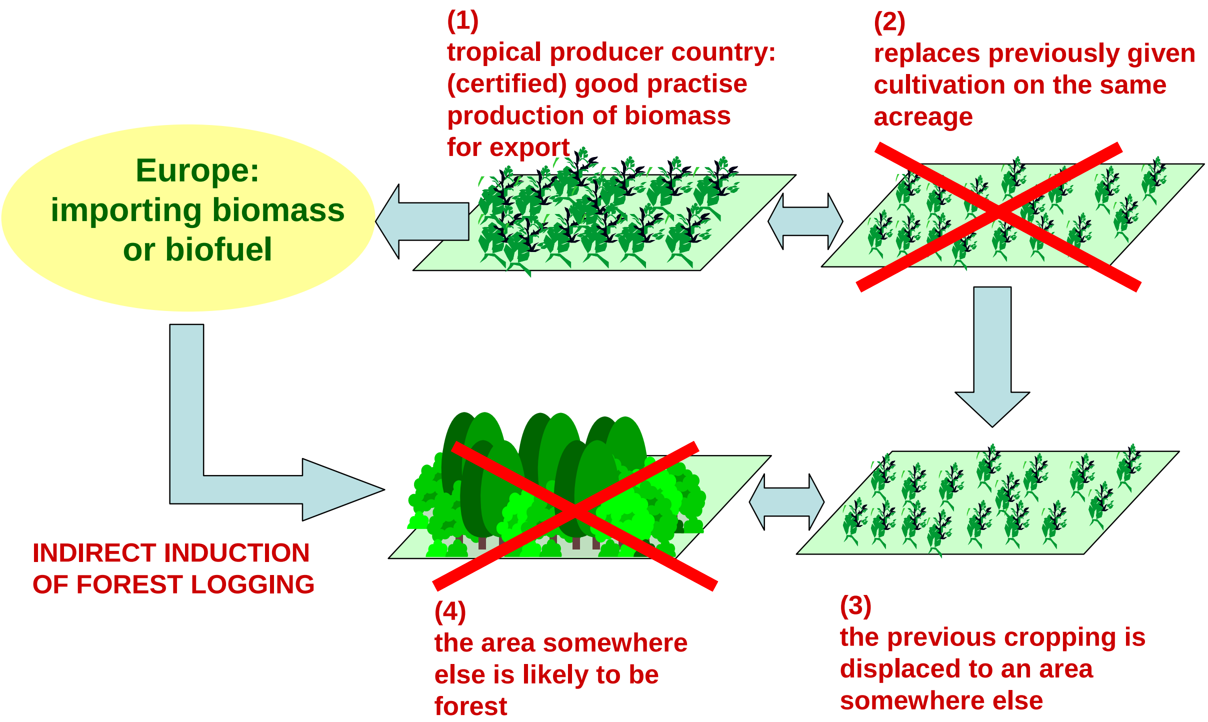
In fact it is irrelevant where - at what location – biocropping replacing previous land-uses occurs. Agro-markets are global, and globally, land for cropping is limited. As long as the demand level for agro-products is not reduced, previous cropping will **al-**

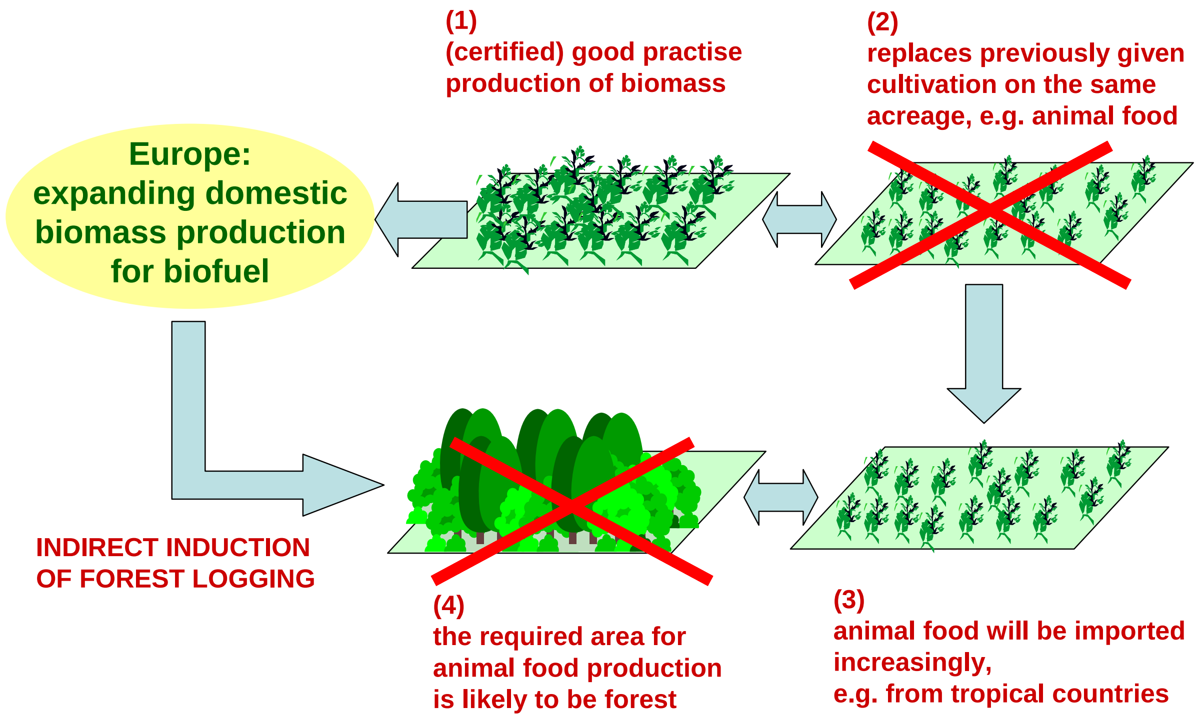
[2] This is valid for above-ground carbon. Less is known for the below-ground carbon balances of land-use changes, and very few data exist on the changes in N_2O emissions.

ways shift to other areas – most probably to where the cheapest and easiest conversion of land for agricultural use is possible.

There is a high risk that crop production displaced through biofuel development will lead to deforestation or the conversion of other natural areas with rather high carbon stocks, e.g. wetlands, bogs, or savannah land.

Figure 1 Two exemplary mechanisms for indirect land use change





Source: IFEU/FSC 2008: Criteria for a Sustainable Use of Bioenergy on a Global Scale; R+D-project on behalf of UBA; draft version, Heidelberg

2.1.1 GHG accounting for indirect land use

No GHG balancing scheme has – yet - taken indirect land use changes into account, though some considerations exist[3].

A pertinent approach was proposed in Fritsche (2007)[4], calling for a "risk adder" which could be defined from the global average share of area in utilization for producing agro products for export purpose and the land use change given in the corresponding regions.

The estimation of the potential of indirectly caused GHG emissions takes into account that not only rain forests might be affected, but **all** countries trading agro-products across borders. These countries are potentially incited to increase biomass production for the global market of biofuels and thus, in these countries displacements effects are likely to occur. The share of area utilized for producing biomass for export reflects the origin and country specific yields. The data can be acquired from the FAO.

3 In the context of the discussions about the Dutch Sustainability Standards for biofuels, Ecofys introduced some considerations on indirect land-use effects in 2007 which were informally discussed with Oeko-Institut.
Quite recently, Alex Farell and his team from the UCB submitted a parallel estimation of GHG impacts from indirect land-use change as part of the Californian considerations on the Low-Carbon Fuel Standard (see for details: http://www.arb.ca.gov/fuels/lcfs/lcfs.htm). Their findings are included in the Annex to this paper.

4 Fritsche, Uwe 2007: GHG Accounting for Biofuels: Considering CO_2 from Leakage; Extended and updated version, Darmstadt (Germany), May 21, 2007; working paper prepared for BMU by Oeko-Institut, Darmstadt

The average share factor has to be adapted because not every increase of biomass production will lead automatically to indirect land use change.

Until 2005, biomass for biofuels was predominantly produced on former set-aside land, or the increase of production has been provided by intensification of formerly marginal areas. In both cases, no displacement is likely to occur (risk adder = 0).

As at least a doubling of biofuel use in Germany is expected up to the year 2020, half of this production can be estimated to be covered by areas currently in utilization.

Concerning the other half, Fritsche (2007) anticipates about 50 % to be produced on areas inducing displacement, and the other 50 % by production of 2nd generation biofuels from lignocellulosic residues (up from 2015) which again won't cause displacement.

Based on these assumptions from a German point of view, displacement effects have to be taken into account for 25 % of biofuel up to 2020.

As of now, the "risk adder" is not introduced to the default value system of the Biomass Sustainability Ordinance due to the need of further substantiation. However, the resulting values by this approach are shown in the corresponding sectors and tables below for information.

2.2 Default values for indirect land use change effects

In the following section, this approach is applied to the selected biofuel systems and "risk adder"-values are calculated. According to Fritsche (2007) and in line with the settings for direct land use change a conservative carbon release due to conversion of high carbon content natural systems to arable land is determined to 300 t CO_2 per ha.

A share of 25 % takes 75 t CO_2 per ha. Divided by 20 years it results in 4 t CO_2 per ha and year (roughly rounded).

The results for the selected biofuel systems are given in Table 1.

In Table 2 and Table 3, the risk adder calculations are integrated into the default value list of the German BSO, annex 2.

As can be seen, the **order of magnitude** of GHG emissions from biofuels including those from potential indirect land-use change is very substantial, and fits to the findings of the UCB team (see Annex to this paper).

Therefore, it is recommended to examine the GHG balances of indirect land-use change more closely, and to explore further research cooperation in that regard, e.g., as part of the GBEP Greenhouse-Gas Working Group.

Table 1 Determination of default values for indirect land use change for seven cases of generating biofuels according to the risk-adder approach (Fritsche 2007)

		Ethanol from				FAME from			
Required area		**wheat Europe**	**Maize / corn N. America**	**Sugar cane tropics (L.America)**	**Sugar beet Europe**	**Rapeseed Europe**	**soybean tropics (L. America)**	**soybean America**	**Palm oil South East Asia**
not allocated	**ha/GJ**	0.0174	0.0131	0.0121	0.0089	0.0200	0.0607	0.0632	0.0079
allocated	**ha/GJ**	0.0095	0.0072	0.0107	0.0057	0.0107	0.0168	0.019	0.0038
Risk adder (R.A.)	t CO_2/(ha*a)	4	4	4	4	4	4	4	4
R.A. not allocated	kg CO_2/GJ	*69.5*	*52.6*	*48.5*	*35.7*	*79.8*	*242.7*	252.8	*31.5*
R.A. allocated		32.9	25.0	42.7	22.7	47.7	76.1	79.2	15.0
		straight vegetable oil				**Hydrogenated vegetable oil**			
Required area		**Rapeseed Europe**	**soybean tropics (L. America)**	**soybean America**	**Palm oil South East Asia**	**Rapeseed Europe**	**soybean tropics (L. America)**	**soybean America**	**Palm oil South East Asia**
not allocated	**ha/GJ**	0.0200	0.0600	0.0625	0.0079	0.0210	0.0630	0.0657	0.0082
allocated	**ha/GJ**	0.0119	0.0188	0.0196	0.0037	0.0125	0.0198	0.0206	0.0039
Risk adder (R.A.)	t CO_2/(ha*a)	4	4	4	4	4	4	4	4
R.A. not allocated	kg CO_2/GJ	79.8	240.1	250.1	31.4	83.8	252.1	262.6	33.0
R.A. allocated		49.7	75.3	78.4	15.6	50.0	79.0	82.3	15.7

Table 2 GHG balance results per system without allocation of co-products for ethanol and FAME

Biofuel / Biomass origin / step of production chain	Ethanol				Biodiesel (FAME)			
	Wheat Europe	**Maize** (corn) North America	**Sugarcane** Latin America	**Sugar beet** Europe	**Rapeseed** Europe	**Soybean** Latin America	**Soybean** North America	**Palm oil** Southeast Asia
direct land use change	*47.8* [a)]	*36.1* [a)]	*180.1* [a)]	*24.5* [a)]	*54.9* [a)]	*923.9* [a)]	*173.8* [a)]	*236.7* [a)]
indirect land use change	*69.5* [b)]	*52.6* [b)]	*48.5* [b)]	*35.7* [b)]	*79.8* [b)]	*242.7* [b)]	*252.8* [b)]	*31.5* [b)]
production of biomass	40.7	32.4	22.1	17.8	48.8	41.0	48.2	13.9
transport of biomass	1.3	1.2	1.8	2.6	0.7	1.6	1.6	0.2
conversion step I	-	-	3.3	8.6	12.1	19.8	25.1	15.0
transport between conversion steps	-	-	-	-	0.2	3.9	3.6	4.5
conversion step II	62.6	45.6	1.1	35.2	8.2	8.3	8.3	8.4
transport to fuel storage for admixture	0.4	4.8	5.5	0.4	0.3	0.3	0.3	0.3
Total without LUC	**105.0**	**84.0**	**33.8**	**64.6**	**70.4**	**74.9**	**87.0**	**42.1**
Total with direct LUC	***152.7*** [a)]	***120.2*** [a)]	***213.9*** [a)]	***89.1*** [a)]	***125.3*** [a)]	***998.8*** [a)]	***260.8*** [a)]	***278.8*** [a)]
Total with indirect LUC	*174.5* [b)]	*136.6* [b)]	*82.3* [b)]	*122.3* [b)]	*150.3* [b)]	*317.6* [b)]	*339.9* [b)]	*73.6* [b)]

a) Worst case situation, contradicts generally criteria for sustainability (conversion of areas with high C storage) only to apply as long direct land use cannot be verifiably excluded; when excluded, indirect land use change has to be considered.

b) Indirect land use change implemented as a „risk adder“ according to a proposal by U. Fritsche: lump-sum 4 t CO_2-eq. pro ha

all figures given in kg CO_2-equivalents per GJ

Table 3 GHG balance results per system without allocation of co-products for straight and hydrogenated vegetable oil

Biofuel / Biomass / origin — step of production chain	straight vegetable oil				Hydrogenated vegetable oil			
	rapeseed oil	**soybean oil**		**palm oil**	**rapeseed oil**	**soybean oil**		**palm oil**
	Europe	Latin America	North America	Southeast Asia	Europe	Latin America	North America	Southeast Asia
direct land use change	54.9 a)	913.9 a)	171.9 a)	236.1 a)	57.6 a)	970.1 a)	182.5 a)	248.6 a)
indirect land use change	*79.8 b)*	*240.1 b)*	*250.1 b)*	*31.4 b)*	*83.8 b)*	*254.9 b)*	*265.5 b)*	*33.1 b)*
production of biomass	48.8	40.1	47.2	13.8	51.3	43.1	50.6	14.5
transport of biomass	0.7	1.6	1.6	0.2	0.8	1.7	1.7	0.2
conversion step I	12.1	19.5	25.3	14.9	12.7	20.8	26.3	15.7
transport between conversion steps	-	-	-	-	0.2	4.1	3.7	4.7
conversion step II	-	-	-	-	10.5	10.5	10.5	10.5
transport to fuel storage for admixture	0.2	3.9	3.5	4.4	0.7	0.7	0.7	0.7
Total without LUC	**61.9**	**65.2**	**77.6**	**33.3**	**76.2**	**80.8**	**93.6**	**46.3**
Total with direct LUC	***116.8 a)***	***979.1 a)***	***249.6 a)***	***269.4 a)***	***133.9 a)***	***1.051 a)***	***276.1 a)***	***294.9 a)***
Total with indirect LUC	*141.8 b)*	*305.7 b)*	*327.7 b)*	*64.7 b)*	*160.1 b)*	*335.7 b)*	*359.0 b)*	*79.4 b)*

a) Worst case situation, contradicts generally criteria for sustainability (conversion of areas with high carbon storage) only to apply as long direct land use cannot be verifiably excluded; when excluded, indirect land use change has to be considered.
b) Indirect land use change implemented as a „risk adder" according to a proposal by U. Fritsche: lump-sum 4 t CO_2-eq. pro ha

all figures given in kg CO_2-eq. per GJ

3 Open issues of C stocks in natural vegetation and agricultural systems

The most accepted data basis for the calculation of carbon stock changes due to land use change is the Intergovernmental Panel on Climate Change (IPCC)[5].

All exemplary calculation and even the default values given by the German BSO (Annex 2) show the significant influence on the total result by the land use change figures.

IPCC data, though, are not valid to deliver adequate answers to all questions in terms of the high variability of C content in biomass and soil, neither in natural systems nor in agricultural systems.

It remains an open issue how a case-by-case calculation of C stocks and cumulative stock changes can be made operational.

4 Open issues of emissions of nitrous oxide (N_2O)

In addition to C stock uncertainty, there is a broad range of N_2O emissions from agricultural systems. High variation is also stated for natural systems – however, the absolute numbers are smaller.

The IPCC assumes that 1% of applied fertilizer N is emitted as N_2O-N. This is adopted for instance in the defaults values in annex 2 of the German BSO. This parameter is highly relevant, and IPCC refers to a range rather than a single data point.

Apart from this, a recent publication by Crutzen[6] proposed significantly higher emission rates, resulting in factors of about 3 or 5 with regard on the 1% emission based on IPCC.

So, N_2O is obviously another open issue for discussion during the next years.

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5 IPCC Guidelines for National Greenhouse Gas Inventories, 2006, Tables 4.3, 4.4, 4.7, 6.4:
http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.htm
IPCC's calculation tool for carbon storage in soil:
http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/annex4a1.htm

6 Crutzen, P.J., Mosier, A.R., Smith, K. A. Winiwater, W. : N_2O release from agro-biofuel production negates climate effect of fossil fuel derived "CO_2 savings"; in: Atmos. Chem. Phys. Discuss., 7 (2007) 11191–11205 www.atmos-chem-phys-discuss.net/7/11191/2007/

Annex:

Estimates for GHG emissions from indirect LUC in the USA

Direct Emissions*	Gasoline	Midwest Corn Ethanol	CA Ultra Low Sulfur Diesel**	Canola Biodiesel**	Renewable Diesel** (Palm)
g/MJ	94	88	93	32	21
Indirect emissions by fuel and type of LUC* **	Corn ethanol - CRP	Corn ethanol – tropical forest	Sugarcane ethanol – tropical forest	Canola biodiesel – tropical forest	Palm diesel– tropical forest
g/MJ	140	**540**	289	1031	197
Uncertainty: corn ethanol – tropical forest	20-yr, low emission factor	20-yr, mid emission factor	20-yr, high emission factor	100-yr, low emission factor	100-yr, high emission factor
g/MJ	420	540	826	84	165

*(California Alternative Fuels Plan, CEC-600-2007-004-REV)

** No adjustment for drivetrain efficiency

*** See posted spreadsheet. Assumes 20 year amortization period, among other things.

Source: *Presentation of Prof. Michael O'Hare. University of California, Berkely at the CARB LCFS Working Group 3 meeting, Sacramento, CA, January 17, 2008 based on data from Alex Farell (see http://www.arb.ca.gov/fuels/lcfs/lcfs.htm).*