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GHG Accounting for Biofuels: Considering CO_2 from Leakage

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1 Background

During the informal consultations of BMU and BMELV on the sustainability requirements of the German Biofuel Quota Law – especially the greenhouse-gas (GHG) accounting methodology for biofuels - Öko-Institut proposed a concept to take into account **potential** CO_2 releases from **indirect** changes in land-use. This paper briefly describes this concept, and adds **indicative** data on the impact of such a concept on the GHG emissions from biofuels in comparison to fossil fuels.

2 GHG from Land-Use and Land-Use Changes

Growing feedstocks for biofuels needs land, which might cause land-use changes **both** regarding

- **direct** effects on the site of farming (or other form of biomass production), and
- **indirectly** through "leakage", i.e. shifts of previous land use to another location where **additional** land-use changes could occur.

Both effects could have significant impacts on the overall GHG balance of biofuels, so that a methodology is needed to include both in GHG accounting.

2.1 Direct Effects

As regards GHG emissions of biocrops stemming from **direct** land-use changes, the carbon balances of the previous (pre-project) land-use and the land-use for biocrops must be established regarding

- **above**-ground carbon content of existing vegetation (if any), as well as the
- **below**-ground (soil) carbon[1].

Each balance might be negative or positive, so that the **total direct** C balance could also be negative or positive.

To derive the respective balances, **IPCC 2006 default data** for direct land-use changes, and soil-carbon changes should be used. To allocate net CO_2 balances to annual bioenergy production, a time horizon of 20 years should be used, i.e. the total net CO_2 emissions from direct land-use changes is distributed over the total energy yield from biocrops for a 20 year time frame.

2.2 Indirect Effects

The GHG emissions related to **indirect** land-use changes (e.g., deforestation) which could result from shifting pre-project land-uses (e.g. food/feed cropping) to other areas **cannot** be determined with respect to a given biocrop project, as this "leakage" could occur in other areas (even outside of a country), with significant time lags, and could be caused by non-project-related actors. Still, the potential magnitude of GHG from leakage could offset any GHG reductions from biofuels, so that the **risk** of leakage should be factored in.

A methodology and some preliminary first data for GHG balances are given in Section 3 of this paper.

[1] It should be noted that direct land-use changes not only affect the C balance, but could also change emissions of CH_4, and N_2O. For reasons of simplicity and data availability, only CO_2 from the net C balance is considered for the direct and indirect GHG emissions from land-use changes.

2.3 Biomass from Residues/Wastes, and from "Unused" Land

Biofuel feedstock production can also come from "unused" (e.g. idle, fallow, marginal or degraded) land, or from collecting unused residues and wastes. In this case, GHG emissions from **direct** land-use change usually are **zero or even negative**[2], and **indirect** effects (leakage) can reasonably **assumed to be zero** as well[3].

For all other cases, avoidance of net GHG emissions from leakage cannot be assured even if a strict certification scheme for each hectare of biofuel feedstock production is assumed.

3 Considering CO_2 from Biofuel-related Leakage

Given this, the GHG accounting for biofuels must

- either **require conditions of zero leakage** (i.e. by "allowing" only residues and wastes as feedstocks, and restricting biocrop production to "unused" land, or considering only yield increases[4]),
- or add a **risk component** for CO_2 from potential leakage to the overall GHG balance.

As currently no realistic means of implementing of the first option is foreseeable, the latter option should be pursued, i.e. the inclusion of a CO_2 risk adder for all biocrops from agricultural land to capture the potential for carbon releases from leakage.

The quantification rule for the risk adder is described below.

3.1 The Risk Adder Approach

To factor in **potential** CO_2 from leakage, **all**[5] land use for biocrop production would be subject to a risk adder based on the potential carbon release of **clearing primary forests**.

For this, a regional disaggregation based on the carbon content of primary forests which vary between climate zones (e.g. boreal, temperate, tropical etc.) is required. Data for the classification of potential CO_2 from primary forests can be based on IPCC default values. Land used for biocrops in a given country (or regions within "large" countries) would then be subject to a pre-defined CO_2 risk adder.

Depending on the cropping scheme and farming project characteristics, a range of 5 to 30 years can be derived over which the potential for leakage-induced indirect CO_2 would be distributed (i.e. annualized without discounting). As a generic time horizon, it is recommended to apply a value of 20 years.

The risk adder approach follows the global equity logic: **any** land use change - even in the past - has the risk of carbon release, and natural differences in carbon intensity of primary forest systems are taken into account. High-density forest areas also have high yield of biocrops, while forests in temperate and boreal zones have less carbon density, but these zones also have lower crop yields.

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[2] Biocrops which can be grown on marginal and degraded land - such as Jatropha, some perennial grasses, and short-rotation coppice - *increase* the soil carbon through carbon fixation in roots. Biogenic residues and wastes usually have to be disposed. If landfilling is the pre-project alternative, GHG emission savings might occur due to offsets of CH_4 from landfills.

[3] For biocrops grown on „unused" - i.e., idle/fallow, marginal, or degraded - land, potential negative impacts on **biodiversity** have to be considered, as these lands might have high-nature value. On the other hand, growing biofuel feedstocks on degraded land has **positive** effects on (agro)biodiversity. Careful consideration must be given to the reality of residues and wastes being "unused", as these materials might be used as **non-marketed** fertilizers or animal feed by poor neighbors, and reduced availability might result in reduced organic soil carbon with C leakage from soil degradation, or social impacts such as increased food insecurity.

[4] This concept is proposed by Ecofys to hedge the leakage risks. From the author's point of view, there are both severe practical limitations to this concept (e.g. data availability and reliability), and potential negative trade-offs for biodiversity (e.g. intensified agrochemical use, GMO crops).

[5] Exceptions are lands which are "unused" (idle/fallow, marginal, or degraded) as of Jan. 1, 2007

3.2 Indicative Calculation of the Risk Adder

To create an indicative matrix of the quantified risk adders, a first proxy for the forestry classification (with some countries/regions as examples), and the respective carbon intensity data (i.e. t C/ha of forest, assuming mature state) was derived from IPCC data, and is shown in the following table.

	assumptions for C from forest discplacement		
region/country	**t dry biomass/ha**	**C fraction**	**t CO_2/ha**
EU	100	0.47	172
USA	150	0.47	259
Brazil, tropical	300	0.49	539
Brazil, steppe	200	0.47	345
Indonesia, rain forest	300	0.49	539

Source: Öko-Institut calculation based on IPCC data

To express the **theoretical** CO_2 risk adder in terms of CO_2 per unit of biomass energy, the yields of the biocropping system must be known. The following table shows such data for selected crops, and regions.

	assumed yields, GJ/ha		
region/country	**rape/palm**	**cane/maize**	**SRC/SG**
EU	75	230	150
USA		200	175
Brazil, tropical	150	600	400
Brazil, steppe			200
Indonesia, rain forest	175		400

Source: Öko-Institut calculation based on GEMIS 4.4 data

From both tables, the theoretical CO_2 risk adder can be derived, as shown in the next table.

Theoretical "risk adder" for biomass production, kg CO_2/GJ for a time horizon of 20 years			
region/country	**rape/palm**	**cane/maize**	**SRC/SG**
EU	115	37	57
USA		65	74
Brazil, tropical	180	45	67
Brazil, steppe			86
Indonesia, rain forest	154		67

Source: Öko-Institut calculation; SRC = short-rotation coppice; SG = switchgrass

These theoretical figures do not reflect that leakage will concern a mix of land-uses, i.e. not only forests, but also other lands such as savannahs, steppe, bushland or pasture.

The average land-use pattern of each country or region could be established based on FAO data, so that the theoretical CO_2 risk adders per biocrop could be adjusted to reflect the average land-use.

This would reduce the risk adder figures, depending on the share of primary forests in a given country/region.

To indicate the overall effects, three cases were assumed:

name of case	share of leakage affecting forested land
"maximum"	75%
"medium"	50%
"minimum"	25%

To indicate the effect of the risk adder on the overall GHG emission balance of biofuels, the following "default" data were used[6]:

"Default" GHG emissions from biomass production & processing		
kg CO_{2eq}/GJ	farming only	farm-to-wheels, incl. conversion, by-product allocation*, transport
Rapeseed to RME	33	**31**
palmoil to PME	15	**65**
sugarcane to EtOH	5	**26**
maize to EtOH	19	**41**
SRC/SG to BtL	3	**9**

* = by-product allocation included based on lower heating values (NCV); RME = rapeseedoil methyl ester; PME = palmoil methyl ester; EtOH = ethanol; BtL = biomass-to-liquid (Fischer-Tropsch diesel)

With these figures, the following tables show the quantitative effects of the proposed regionalized CO_2 risk adder for various biofuel routes.

	GHG emissions in kg CO_{2eq}/GJ with risk adder excluding conversion/by-products/transport		
biofuel route, farming only	maximum	medium	minimum
Rapeseed to RME, EU	119	90	62
palmoil to PME, Indonesia, rain forest	131	92	54
palmoil to PME, Brazil, tropical	150	105	60
sugarcane to EtOH, Brazil, tropical	39	27	16
maize to EtOH, USA	67	51	35
maize to EtOH, EU	47	38	28
SRC/SG to BtL, EU	46	32	17
SRC/SG to BtL, Brazil, tropical	54	37	20
SRC/SG to BtL, Brazil, steppe	68	46	25

Source: Öko-Institut calculation; data refer to GHG emissions from farming only, i.e. no conversion included and no allocation of by-products assumed

To compare these farm-to-wheel GHG balance for biofuels with the respective well-to-wheel GHG emissions from fossil fuels, the following data were used:

6 All data from GEMIS 4.4 database, no direct land-use C releases included.

GHG emissions from reference systems, well-to-wheel in kg CO_{2eq}/GJ	upstream well-to-tank	direct tank-to-wheel	total well-to-wheel
fossil diesel	11	74	85
fossil gasoline	15	74	89

Source: Öko-Institut calculation based on GEMIS 4.4 data for Germany in year 2005

With the calculated GHG emissions for biofuels including the risk adder, the **relative** GHG emissions of the biofuels in comparison with fossil fuels were derived (biodiesel and FT diesel compared to fossil diesel, ethanol compared to fossil gasoline).

	GHG emissions relative to fossil diesel/gasoline, excluding conversion/by-products/transport		
biofuel route, farming only	**maximum**	**medium**	**minimum**
Rapeseed to RME, EU	**40%**	**6%**	-27%
palmoil to PME, Indonesia, rain forest	**54%**	**8%**	-37%
palmoil to PME, Brazil, tropical	**76%**	**23%**	-30%
sugarcane to EtOH, Brazil, tropical	-54%	-68%	-82%
maize to EtOH, USA	-21%	-40%	-60%
maize to EtOH, EU	-45%	-56%	-68%
SRC/SG to BtL, EU	-46%	-63%	-80%
SRC/SG to BtL, Brazil, tropical	-37%	-57%	-78%
SRC/SG to BtL, Brazil, steppe	-20%	-46%	-72%

Source: Öko-Institut calculation; RME = rapeseedoil methyl ester; PME = palmoil methyl ester; EtOH = ethanol; BtL = biomass-to-liquid (Fischer-Tropsch diesel)

As can be seen from the table above, the maximum and medium cases of the CO_2 risk adder would result in **no GHG savings** for all 1st generation biodiesel options, while the minimum case would mean that approx. 30% of GHG savings compared to fossil diesel would be possible.

For 1st generation EtOH and 2nd generation biodiesel, all cases result in GHG savings compared to fossil fuels.

As this calculation considers only the GHG emissions from biofuel cropping (i.e. farming and harvesting), it is just a first proxy. To identify the total effect of the CO_2 risk adder, the "downstream" conversion and transports must be considered also, and the allocation of by-products as well.

The following table shows the results of such an indicative calculation which factors in the full farm-to-wheel life-cycles, and also allocated by-products based on their (lower) heating values[7].

[7] The **lower** heating value of a fuel is its **net** calorific value (NCV).

	GHG emissions in kg CO_{2eq}/GJ with risk adder including conversion, by-product allocation, transport		
biofuel route, farm-to-wheel	**maximum**	**medium**	**minimum**
Rapeseed to RME, EU	117	89	60
palmoil to PME, Indonesia, rain forest	180	142	103
palmoil to PME, Brazil, tropical	199	154	110
sugarcane to EtOH, Brazil, tropical	60	48	37
maize to EtOH, USA	89	73	57
maize to EtOH, EU	69	60	50
SRC/SG to BtL, EU	52	37	23
SRC/SG to BtL, Brazil, tropical	59	42	25
SRC/SG to BtL, Brazil, steppe	73	52	30

Source: Öko-Institut calculation; RME = rapeseedoil methyl ester; PME = palmoil methyl ester; EtOH = ethanol; BtL = biomass-to-liquid (Fischer-Tropsch diesel); data include conversion and allocation of by-products based on NCV

In comparison to the „farming only" results, farm-to-wheels results usually are higher[8]. Accordingly, the GHG balances of biofuels give smaller (if any) GHG reductions when compared to fossil fuels:

	GHG emissions relative to fossil diesel/gasoline, including conversion, by-product allocation, transport		
biofuel route, farm-to-wheel	**maximum**	**medium**	**minimum**
Rapeseed to RME, EU	**38%**	**4%**	-30%
palmoil to PME, Indonesia, rain forest	**112%**	**67%**	**21%**
palmoil to PME, Brazil, tropical	**135%**	**82%**	**29%**
sugarcane to EtOH, Brazil, tropical	-30%	-43%	-56%
maize to EtOH, USA	**5%**	-14%	-33%
maize to EtOH, EU	-19%	-30%	-41%
SRC/SG to BtL, EU	-39%	-56%	-73%
SRC/SG to BtL, Brazil, tropical	-30%	-50%	-70%
SRC/SG to BtL, Brazil, steppe	-14%	-39%	-64%

Source: Öko-Institut calculation; RME = rapeseedoil methyl ester; PME = palmoil methyl ester; EtOH = ethanol; BtL = biomass-to-liquid (Fischer-Tropsch diesel); data include conversion and allocation of by-products based on NCV

As can be seen from the table above, all cases of the CO_2 risk adder would result in **no GHG savings** for 1st generation biodiesel options (except RME in the minimum case), while 1st generation EtOH (except EtOH in the US for the maximum case) and 2nd generation biodiesel result in GHG savings compared to fossil fuels for **all** cases.

Proposed approach: The **average** of the medium and minimum cases of the risk adder (i.e. leakage assumed for land with 33% forests) would result in **all** 1st generation biofuels **except PME** showing GHG savings, with a range from 20% for RME (EU), 30% to 40% and 50% for EtOH (from US, EU, and Brazil, respectively). The 2nd generation biofuels would give 60 to 70% reductions.

Perspectives: GHG savings will **be higher** for biocrop systems with net carbon **increases,** i.e. **direct** land-use changes from annual crops (e.g. soy, wheat) to **perennial** biocrops (e.g. short-rotation coppice, switchgrass, palm, sugarcane), and for biocrops on "unused" land. Furthermore, biofuels from residues/wastes have high GHG reduction potentials, as they cause **nearly zero risks** for leakage.

[8] For RME, by-product allocation **reduces** the GHG balance compared to the farming-only case.