elobio
Biofuel policies for dynamic markets

Policy Paper 4 – February 2010

"Land use special"

In this issue:

- Land and biomass use and its influence on biospheric carbon stocks
- Biofuels land use change impacts
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Intelligent Energy Europe

Elobio: a very short introduction

I. The problem:

Increased demand for biofuels could have significant long-term impacts on several commodity markets. Current disputes on this issue (with rising prices in today's markets) require responsible policy.

II. The objective:

Formulation of efficient and low-disturbing policy options that enhance biofuels while minimizing the impacts on e.g. food and feed markets and biomass for power and heat.

III. The activities:

- Review of current experiences with biofuels and other renewable energy policies and their impacts on other markets;
- Iterative stakeholder-supported development of low disturbing biofuels policies;
- Model-supported evaluation of these policies' impacts on food & feed and lignocellulosic markets;
- Assessment of selected optimal policies' impact on biofuels development, potentials and costs.

The Elobio Policy Paper series

In the course of the project (November 2007 – April 2010), the Elobio team will prepare a short series of Policy Papers presenting Elobio results and news in the context of the actual policy debate on biofuels. Key target audience are policy makers at the EU and EU member state level. Contributions will largely be based on (intermediate) results of the project.

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Biofuels and land use change - *challenges for science and policy*

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Land use change (LUC) accounts for about 15 percent of total anthropogenic CO_2 emissions globally. Biofuel production can lead to both gains and losses in biospheric carbon stocks. This can be through changed land management practices, converting land to produce biofuel feedstocks or by displacing activities to other areas and causing land use change somewhere else (iLUC) due to macroeconomic mechanisms and/or regional economic development induced by biofuel initiatives.

Studies show that conversion of natural ecosystems or pastures containing significant carbon stocks into conventional crop cultivations for biofuels (i.e. maize, sugar beet or rapeseed) can cause large up-front C emissions that drastically reduce the mitigation benefit of the biofuels initiative.

Productivity increases in response to increasing demand reduces the LUC effect. The relative contributions of yield growth and cropland expansion to increasing crop output depends on the relative economics of these two principal supply side options, which varies between crops and regions. However, large and rapid increase in inelastic biofuel demand increases the relative contribution of cropland expansion, since this is the major near term response to food price spikes.

Scientists are challenged by quantifying iLUC and linking it to specific biofuel projects. The uncertainties make consideration of iLUC effects a controversial matter when policy instruments are developed. On the other hand, policy makers have to respond to the concerns that iLUC can drastically reduce the climate benefit of ambitious bioenergy initiatives. Current policies driving the biofuel demand may loose public acceptance unless iLUC effects are considered in a satisfactory way.

By the end of 2010 the European Commission will have to report on LUC, which includes a methodology for calculating iLUC effects. In the long-term international agreements on protecting carbon-rich habitats (i.e. REDD mechanisms) could reduce the risks of GHG emissions from iLUC and establishment of a global climate regime involving all countries and including LUC emissions in national GHG emission inventories would make the iLUC concept irrelevant. However, in the short-term other measures are needed and among available options for reducing LUC related risks are: (i) measures giving priority to using residues and wastes; (ii) support for dedicated production systems for 2nd generation feedstocks provided that they do not cause unacceptable LUC related problems; (iii) favouring of feedstock supply systems that have low land demands and/or use areas not attractive for food production and with low risks of high LUC emissions; (iv) promotion of productivity increases in agriculture. The use of so-called iLUC factors that reflect the respective biofuels' iLUC impact risk should encourage producers to present the actual situation and should also stimulate innovative measures to reduce the iLUC risk. Broad acceptance will likely require transparency and accuracy of methodology for calculating iLUC factors.

1. Introduction

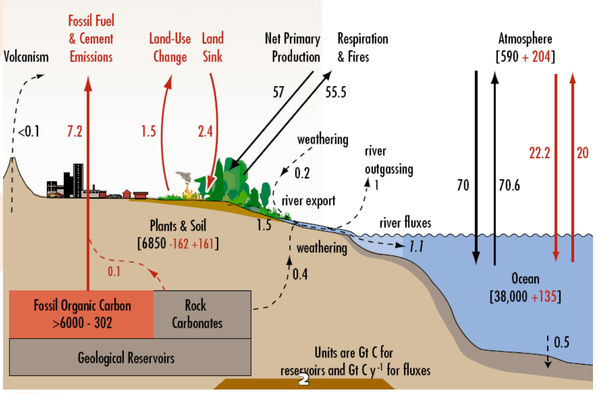
There is presently an intensive public debate as well as substantial scientific activity related to the sustainability of biofuels. The debate concerns both environmental and socioeconomic consequences of the expansion of biofuels production and use. It involves a wide set of issues, many contrasting standpoints, and for many issues anecdotal observations and weakly supported statements are referred to, due to that there is a lack of solid scientific evidence.

This Elobio Policy Report[1] discusses biofuels and land use change (LUC). This is presently one of the most challenging issues for science and policy in the area of bioenergy – challenging since the impacts of LUC can be very substantial and at the same time are difficult to quantify and link to specific biofuel projects. While there are many important aspects to consider, such as biodiversity, hydrology and socio-economy, we concentrate in this report on how land use and especially LUC influences the mitigation effectiveness of biofuels.

2. Land and biomass use and its influence on biospheric carbon stocks

The terrestrial part of the biosphere – comprising the World's land based ecosystems – contains substantially more carbon than the atmosphere. The biospheric carbon is found in both above-ground living and dead biomass and in the soils where it is fixed in the form of humus and charcoal, including plant and animal residues at various stages of decomposition; substances synthesized from the decomposition products; and the living micro-organisms and small animals with their decomposing products.

About 120 Pg (=Gton) of atmospheric carbon is fixed into the biosphere via photosynthesis each year, which is roughly balanced by the plant and soil respiration that transfer back similar amounts of carbon to the atmosphere. This can be compared with the 7-8 Pg/yr of carbon that is transfered from the fossil pool to the atmosphere. Land use change leads to a net transfer of roughly 1.5 Pg/yr of biospheric carbon to the atmosphere, thus relatively small compared to the annual carbon flows between the biosphere and the atmosphere but a substantial contribution to the anthropogenic carbon emissions to the atmosphere.



Biofuel projects can induce changes in biospheric carbon stocks without having caused LUC in the sense that the land type is changed, for instance from being a forest to being cropland. In conventional forestry with long rotations (esp. boreal regions) forest wood extraction obviously causes instant losses of carbon on the stand level, especially in even aged stands subject to clear cutting. Seen over long time scales this type of forest management may be considered as representing a sustainable land use and atmospheric carbon is captured into the forest again as it regrows. Thus, there need not be any systematic change in the forest carbon stocks, although when looking at stand level and using the time scale of a few decades the forest operations imply large net changes in the carbon stocks.

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[1] This report is based on work within Elobio and within the project *Bioenergy and Land Use Change* commissioned by the Swedish Energy Agency and IEA Bioenergy. A longer report will become available at the IEA Bioenergy website later in 2010.

Changes in forest management regimes may lead to systematic changes in forest carbon stocks. Examples include intensified biomass extraction, which can lead to a decrease in soil carbon or in the dead wood carbon pool compared to existing practice, and replacement of natural or semi-natural forest with tree plantations that may still qualify as forests but contain substantially less carbon in soil and aboveground biomass. Again, such shifts in management practices may not represent a step away from long term sustainability, but they can induce large changes in the biospheric carbon stocks over decadal time scales.

Wood extraction practices may also overexploit the forest resource and cause a degradation and forest fragmentation. Such practices are often taking place in the context of a gradual conversion of forests to other land uses such as pastures or croplands. Thus, they are intertwined with other mechanisms that drive LUC and contribute to systematic losses of biospheric carbon. The new land uses can themselves have potential for becoming sustainable on the longer term, but their establishment via conversion of forests have caused a net loss of biospheric carbon.

Similar to forest management, changes in agronomic practice – cultivation techniques and harvesting practices on arable lands – may lead to changes in biospheric carbon stocks. An example is harvest residue management, where residue extraction for bioenergy or other purposes leads to very different outcomes than residues management regimes aiming at soil carbon enhancement. Again, residue extraction can be managed on a sustainable basis but still lead to that soil carbon decreases during some decades until it reaches a new equilibrium (assuming that the same practice prevails several decades).

Some biomass sources, such as aquatic biomass, post-consumer waste and agriculture/forest industry by-flows, have better prospects for use as biofuel feedstock while avoiding LUC and related biospheric C stock changes. However, if these biomass sources were earlier used for other purposes its use for biofuels production can indirectly lead to LUC as the earlier users switch to using new raw materials. For example, black liquor gasification for biofuels production in pulp mills may require that the mills use other fuels to meet their energy needs (although improvements in process efficiency at pulp mills can clearly make black liquor available for other uses than process heat generation). If for instance forest chips are used in the pulp mills instead of black liquor this may induce land use management causing biospheric carbon losses. Also, if left untouched (e.g., in a waste deposit) some of these biomass sources would keep organic carbon away from the atmosphere for a longer time than if used for energy. On the other hand, deposited organic waste may cause methane emissions as they decompose, leading to larger climate impact than if burned directly, although with another time profile.

Finally, it needs to be stressed that biofuel projects can lead to both gains and losses in biospheric carbon stocks, and these carbon stock changes can be also reversible. In fact, one major reason to that promising opportunities for biospheric carbon sequestration exist, is that human activities have earlier caused carbon losses from the same locations. Soils have historically lost 40–90 Pg C globally through cultivation and disturbance and cultivated soils normally contains less than half of the original soil organic carbon. Much carbon can be returned to soils and vegetation through changed land management practices and shifts to new types of plants including trees. In this context, commercial availability of technologies for producing biofuels based on lignocellulosic feedstocks may induce changes in land use towards more lignocellulosic crops cultivation. If these new crops are established on croplands that have long been cultivated with conventional food/feed crops both aboveground and soil carbon will likely increase.

3. Direct and indirect LUC

From the perspective of a biofuel project, direct LUC occurs when natural or man-managed land is converted to land for biofuel feedstock production, an example being the clearing of forests to make place for the bioenergy plantation. The emissions from the clearing of vegetation are predominantly CO_2 from the loss of biomass, but may include CH_4 and N_2O emissions if the vegetation is burnt during clearing. Conversely, as noted above, when croplands that historically have been cultivated with conventional food and feed crops are planted with perennial lignocellulosic crops or multi-year woody plantations, carbon in soils and aboveground biomass can increase.

If the converted ecosystem contained large C stores in the soil, there might be substantial emissions for many years after the initial conversion. For example, oil palm expansion has caused significant deforestation in SE Asia and large up-front CO_2 emissions linked to the forest clearing. The CO_2 emissions may be especially large when peat land forests are converted to oil palm plantations due to that the required drainage of the land leads to large soil C emissions that can continue for many decades.

Indirect LUC, or iLUC, refers to the establishment of a land-use activity by means of LUC that is at least partly induced by a bioenergy project elsewhere. It can either be that land users that lose/sell/rent out their land to biofuel feedstock producers re-establish their own land use activities elsewhere, or that LUC occurs outside the biofuel project boundaries due to macroeconomic mechanisms and/or regional economic development induced by biofuel initiatives.

For example, Brazilian sugarcane plantations are to a large extent established on pastures, displacing cattle ranching. Some of the displaced cattle ranchers may re-establish elsewhere, possibly by converting a forest to pasture land. Similarly, establishment of bioenergy plantations on so-called common lands may lead to increased pressure on ecosystems elsewhere when people earlier using the common lands need to use other lands for their subsistence. The role of macroeconomic mechanisms has been illustrated by the notion that a shift from soy to corn cultivation in response to increasing ethanol demand in the US has induced increased expansion of soy cultivation in other countries such as Brazil, partly leading to increased deforestation as soy cultivation expands. Conversely, by-products from biodiesel and ethanol production are used for animal feeding in, e.g., the EU and this use can reduce soybean import from Brazil leading to reduced deforestation pressure in the Amazon region.

4. Understanding and controlling LUC – A challenge for science and policy

Quantifying carbon emissions caused by LUC is difficult due to lacking empirical data and problems of generalizing individual datasets over large diverse areas. The examples given above – and there are many more examples – are illustrative of the additional complexity and consequently of the challenges for science in quantifying iLUC and linking it to specific bioenergy projects. The lack of empirical data and limited knowledge concerning migration and reestablishment patterns among displaced land users presently prevents quantification and establishment of causal chains with high confidence.

Nevertheless, studies clearly show that (i) conversion of natural ecosystems or pastures containing significant carbon stocks into cultivations of conventional crops such as maize, sugar beet and rape seed can cause carbon emissions that can drastically reduce the mitigation benefits of biofuels that use these crops as feedstock; and (ii) if policies induce a large and rapid increase in inelastic biofuel demand in the near term this can lead to cropland extension into natural ecosystems.

The Elobio project employs an ecological-economic world food system modelling framework (see Elobio Policy Paper No.3) for the analysis of accelerated biofuel production. For the quantification of direct and indirect LUC a general equilibrium approach is applied by modelling responses of consumers and producers to price changes induced by the competition of biofuel feedstock production with conventional uses (food, feed and fiber) of available resources. The advantage of this approach is that it not only permits modelling LUC but also considers production intensification on existing agricultural land, use of biofuel by-products such as animal feed as an additional input into feed markets, as well as consumer responses to changing availability and prices of food commodities.

Land conversion is explicitly modelled to maintain full consistency between the spatial agro-ecological zones approach used for appraising land resources and land productivity and the expansion of cultivated land as determined in the world food system model. Carbon losses from vegetation and soils due to LUC occur mainly at the time of land conversion, but greenhouse gas savings resulting from use of biofuels rather than fossil fuels accumulate only gradually over time. The modelling framework projects spatially explicit agricultural land uses and applies a carbon accounting method, based on IPCC Tier 1[2] approaches to quantify vegetation and soil carbon pools for each scenario. The net balance of accumulated greenhouse gas savings due to fossil fuel substitution and the cumulated carbon losses resulting from land conversion for several periods are calculated and compared. This provides quantification of the cumulative GHG savings of expanded biofuel use for transport (Scenario quantification given in the Caption to Figure 1). Since all agricultural land uses are modelled this quantification includes the impact of LUC and iLUC.

Figure 1 is illustrative of that LUC GHG emissions can impact net GHG savings especially on the near term while the relative importance of LUC GHG emissions for cumulative net GHG savings decreases over time. In the cases presented in Figure 1, biofuels produced from lignocellulosic feedstocks contribute an increasing share of biofuel supply, which leads to improved cumulative GHG savings over time due to higher GHG savings from gasoline/diesel substitution and reduced LUC-GHG emissions. Future fossil fuels in the transport sector may yield higher GHG emissions, and improve the case for biofuels: transport fuels from less conventional oil resources and coal based Fischer-Tropsch diesel both have higher lifecycle GHG emissions than the gasoline and diesel used today. Thus, depending on how the GHG emissions connected to gasoline/diesel production and use develop over time, emissions savings from biofuel use can be larger or smaller than shown in Figure 1.

New cultivated land is usually converted from existing pastures or natural grass- and forest land, habitats that contain higher carbon stocks compared to cultivated land and thus result in cumulative GHG losses as shown in Figure 1. These LUC GHG emissions are associated with land use conversions due to *additional* use of cultivated land in 2020, 2030 and 2050 compared to a scenario without any crop-based fuels. Additional use of cultivated land falls in the range of 18 million hectare (scenario WEO-V1 in 2020) to over 40 million hectares (TAR-V1 in 2050).

To put into perspective global cultivated land currently amounts to 1567 million hectares (data for year 2000) with approximately 60 percent being used to produce crops for direct food consumption and a third for animal feed crops. In a baseline projection without any use of agricultural feedstocks for biofuel production the expansion of arable land to meet growing food and feed requirements during 2000 to 2020 amounts to about 90 million hectares of additional land put into cultivation (by 2050 an additional 184 million hectares). Africa and Latin America account for more than 80 percent of total net arable land expansion.

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[2] The IPCC Good Practice Guidance (Penman et al 2003) and Greenhouse Gas Inventory Guidelines (IPCC 2006) provide recommendations on methods and default values for assessing carbon stocks and emissions at three tiers of detail, ranging from Tier 1 (simplest to use; globally-available data) up to Tier 3 (high resolution methods; specific for each country and repeated through time). Penman et.al: Available at: http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_contents.
Intergovernmental Panel on Climate Change (IPCC). 2006. IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4: Agriculture, Forestry and Other Land Use.

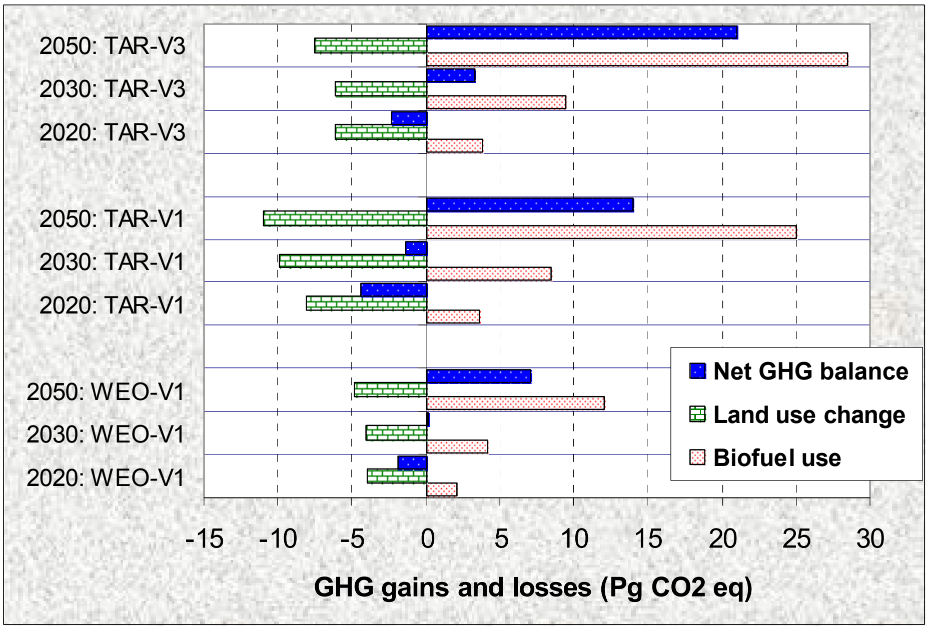

Figure 1. **Cumulated net GHG savings of biofuel scenarios (Pg CO_2^{eq}).** The bars "Biofuel use" show GHG savings from biofuel replacement of gasoline and diesel, "Land use change" bars show GHG emissions caused by LUC and iLUC, "Net GHG balance" bars shows the result of subtracting "Land use change" emissions from "Biofuel use" savings. The share of biofuel use in total transport fuels is in WEO 3.5% in 2020 and rising to 6% in 2050, and about twice these levels in TAR. Percentage second-generation of total biofuels are (2020/2050): TAR-V3: 22/55; TAR-V1: 2/26; WEO-V1: 3/30 (*Source: Fischer et.al, 2009*[3]).

In general higher agricultural productivity growth will decrease projected land conversions for food, feed and fuel. Conversion of degraded or marginal land for biofuel feedstock production can increase carbon stocks in soils especially when grasses and trees required for the second generation biofuel production chain are established.

5. Policy challenge

Policymakers have to respond to the concerns that LUC can drastically reduce the climate benefits of ambitious bioenergy initiatives. Presently developing implementation of energy and climate policy and regulation in EU and USA faces the challenge of quantification and assignment of iLUC emissions to specific bioenergy chains, which meets objections referring to that this cannot (yet) be done with very high level of confidence due to lack of data and methodology verified as sufficiently correctly reflecting reality.

There have been a number of proposed policy approaches to address LUC and to minimize the impacts both in Europe and in the US. The EU Renewable Energy Directive (RED) sets a 10% renewable energy target in transport by 2020. The RED also includes binding sustainability criteria which biofuels must meet before they can be counted towards the target. In brief, sustainability criteria for biofuels and bioliquids included in the Directive are:

- Minimum requirement for GHG saving, relative to fossil fuel, of at least 35% from the outset, 50% in 2017 (60% for new installations)
- Areas that contain high carbon stock should not be converted for biofuels to avoid risk of causing big GHG losses through the release of carbon stored in the soil and in plants

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[3] For a detailed description of the scenarios see Fischer et.al (2009), 'Biofuels and Food Security': Report available at: http://www.iiasa.ac.at/Research/LUC/Homepage-News-Highlights/Biofuels%20Report%20Final.pdf

- Areas with high biodiversity should not be used for biofuels production in order to avoid disturbing biodiversity and disrupting natural habitats

The Commission is required to report on how to address indirect land use change in the RED by December 2010. As a first step in addressing ways to minimize the impact of indirect land use change, the Commission services have drafted a preparatory list of possible elements of a policy approach[4].

The policy elements included were:

A. Extend to other commodities/countries the restrictions on land use change that will be imposed on biofuels consumed in the European Union
B. International agreements on protecting carbon-rich habitats
C. Do nothing
D. Increase the minimum required level of greenhouse gas savings
E. Extend the use of bonuses
F. Additional sustainability requirements for biofuels from crops/areas whose production is liable to lead to a high level of damaging land use change
G. Include an indirect land use change factor in greenhouse gas calculations for biofuels
H. Other policy elements that respondents may wish to raise

Experts and stakeholders were invited to submit comments to the above list. Most of the reflections to this consultation suggested policy option A and particularly policy option B. However they also indicated that this is an ultimate solution and needs to be tackled in different platforms. One of the mechanisms considered within the UNFCCC is REDD (Reducing Emissions from Deforestation and Degradation) that aims at providing positive incentives for non-Annex-I countries to reduce GHG emissions from deforestation and forest degradation. REDD will include the avoidance of deforestation, forest carbon management, and the enhancement of forest carbon stocks.

However, the REDD mechanism only refers to forest ecosystems, and the accession to this mechanism is voluntary. As indicated in the UNEP-WCMC (2008) study[5] forests are not the only ecosystems that need to be considered; a considerable amount of carbon is also stored in other ecosystems like wetlands (unforested) and peatlands. Also, the REDD mechanism has as its aim to influence activities on the locations where the deforestation and forest degradation takes place. Consequently, the mechanisms may not allow to include off-site REDD activities (for instance development of bioenergy projects with low risk of causing iLUC) even if those could significantly impact deforestation rates. The same limitation applies to LULUCF, where Annex I (developed) countries are obliged to report on carbon stock changes from only afforestation, reforestation and deforestation.

On the longer term, a possible worldwide commitment to binding targets and inclusion of biospheric C flows in the national accounting would make the concept of iLUC irrelevant. However, such a situation may not become reality in the near term. In fact, the specifications of the REDD mechanism were to be discussed in December 2009, during the COP 15. At the end of the two-week conference, a draft accord was reached which is not legally binding. Even though the recent Copenhagen Accord pays attention to REDD, development of the REDD mechanisms is postponed to the COP in 2010 in Mexico. Thus, addressing iLUC arising from biofuel demand through international climate policy is not likely to happen very soon. Therefore, a significant number of participants to the EC pre-consultation opted for the policy element G; introducing crop and region specific iLUC factor(s) in GHG calculations as a short-to-medium term solution. However, due to the lack of empirical data and established and verified methodology, studies aiming at quantifying iLUC report diverging results and this makes the process of introducing iLUC factors difficult. Recently, the Low Carbon Fuel Standard (LCFS) of California postponed inclusion of iLUC into the regulations until 2011 based on that the

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[4] iLUC consultation document and te conribuitions can be reached from http://ec.europa.eu/energy/renewables/consultations/2009_07_31_iluc_pre_consultation_en.htm

[5] http://www.unep-wcmc.org/climate/pdf/Carbon%20storage%20in%20protected%20areas%20technical%20report.pdf

knowledge, methodologies and empirical data presently available was regarded an insufficient basis for sound policy regulation in regards to the indirect impacts of biofuels production.

It is indeed a challenge to define iLUC factor(s) for the European Commission. However, if the Commission sets high priority to ensuring that the near term biofuel expansion does not lead to large GHG emissions connected to LUC, it may still be necessary to proceed in this direction. When providing default values to be used it is vital that the defined values can encourage reporting of actual data rather than using the default values – and actors should become encouraged to find ways to reduce iLUC risks. An alternative response to LUC concerns (presently being established in Germany) is to discourage biofuels from dedicated feedstock and instead promote biofuels based on crop and forest residues. Such a response could be complemented with instruments promoting dedicated production systems for 2nd generation feedstocks, given that it can be shown with sufficient confidence that these can be established in ways that avoid the LUC related problems facing 1st generation feedstocks.

Obviously, there are biofuel options that are unlikely to give a positive contribution to climate change mitigation due to large GHG emissions arising from the conversion of carbon-rich ecosystems to bioenergy plantations. However, it is also evident that unfavorable climate performance due to LUC emissions in the short term does not disqualify all biofuels from being part of a long term solution to the climate problem. Given the urgency of finding solutions for the transport sector - accounting for around 20% of global greenhouse gas emissions, its' sole dependence on oil, and solid growth rate - well performing biofuels are likely to have an important role to play.

Promotion of productivity increases in agriculture may allow substantially increased supply and limit cropland expansion. Increased productivity in livestock production can make pasture land available for biofuel production. The direct emissions of biofuels production can also become lower in the future as soil C stabilize at a new equilibrium level, conversion technologies improve and use renewable process fuels, and feedstock production systems develop into less GHG intensive systems – possibly even reverting some of the biospheric C losses that occurred during the early biofuel expansion period.

When implementing controls and conditions policymakers should not only pay attention to risks related to LUC. There are also many opportunities: bioenergy production can in many different ways be integrated with agriculture so as to improve the overall productivity in land use and to provide different environmental services, including protection against erosion and leakage of nutrients to water bodies, increased biodiversity in agricultural landscape – and also accumulation of carbon in soils and standing biomass enhancing the climate benefit. In addition to hedging against risks policymakers should enable and stimulate a development where actors can see benefits in realizing such opportunities.

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