Bioenergy Life-Cycle Analysis:
Beyond Biofuels

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Biofuels Life Cycle: Feedstock ►Transportation ►Biorefinery ►Processing & Conversion ►Distribution ►End User.
Source: US DOE (http://www1.eere.energy.gov/biomass)

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Bioenergy Life-Cycle Analysis: Beyond Biofuels

Background Paper for the EEA Expert meeting in Copenhagen, June 10, 2008

prepared for EEA

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Content

Foreword

The scope of this background paper for the EEA Expert meeting

"Life-Cycle Assessment Methodologies for Greenhouse-Gas Emissions of bioenergy: Beyond biofuels" to be held in Copenhagen on June 10, 2008

is to present general issues and key questions regarding methodological and data requirements of life-cycle greenhouse-gas balances of bioenergy.

The paper is not meant to give answers, but as background for discussing the issues during the EEA Expert meeting.

The author welcomes comments and critique, and invites readers to provide written feedback[1]. The paper will be revised and finalized after the expert meeting.

This paper is part of Oeko-Institut's work within the European Topic Center on Air and Climate Change, a collaborative activity of organizations working for the EEA.

During the preparation of this paper, the author was fortunate in drawing from ongoing research projects of Öko-Institut and IFEU commissioned by the German Ministry for Environment (BMU) through the Federal Environment Agency (UBA), and related activities carried out for the FAO, and UNEP.

Also, preliminary findings of a brief study for the German WBGU were included.

Darmstadt, June 4, 2008 Uwe R. Fritsche

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1 Introduction

The use of biomass for energy production is rising globally – both in the developing world, and industrialized countries (RES21 2008).

Though the focus of discussions in science, policy, and business of the last years was mainly on **liquid biofuels for transportation**, the current use of biomass is and its future use will be much broader - from electricity (co)generation to direct heating, and from bio-based materials to recovering the energy content of biogenic wastes for bioenergy feedstock provision[2].

However, recent work and studies on life-cycle assessment[3] (LCA) especially for the emissions of greenhouse gases (GHG) were mainly concerned with liquid biofuels[4].

With the upcoming EU Renewable Energy Sources Directive (RES-D), an EU-wide target of 20% renewables in the overall energy system by 2020 will be established, which will increase not only the use of bioenergy for transport fuels, but also for electricity and heat production.

1.1 Bioenergy and Biofuels: Potential and Environmental Issues

Most global energy scenarios imply that in the long-term, bioenergy – and biofuels - can play only a **limited role**, in the order of 15-35 % of total global primary energy (see following figure).

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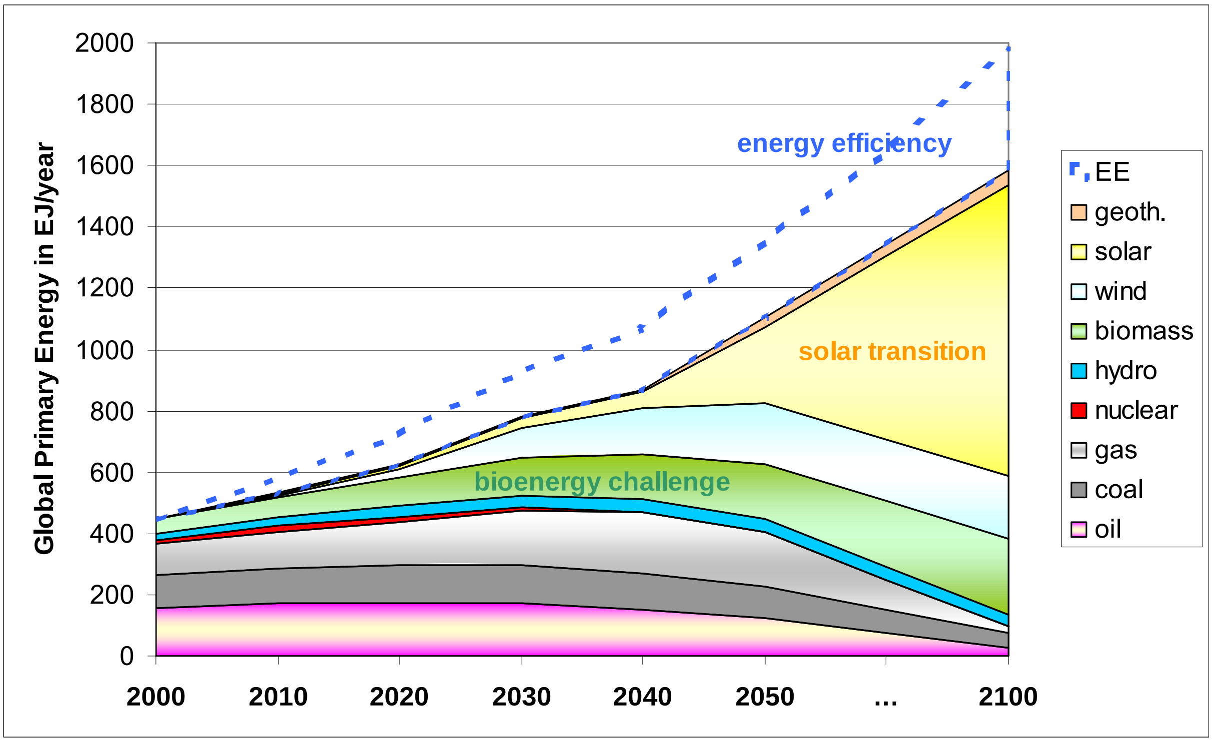
[2] Currently, liquid biofuels for transport have a global share of about 1% in all transport fuels, with approx. 2% in the EU (IEA 2007; EUROSTAT 2008). Total bioenergy currently has a global share of approx. 11% in total primary energy use (Best et al. 2008), thus showing biomass for electricity and heat has a much larger share than for biofuels

[3] Originally, LCA is the acronym for life-cycle assessment, but it is used also for life-cycle analysis, i.e. the “inventory” part of life-cycle assessment. For a more detailed description on the standardized approaches, methodologies, and terms for LCA see ISO 14000ff.

[4] Work of EEA addressed bioenergy more broadly – see EEA 2006 and 2007.

Figure 1 A Sustainable Global Energy Vision



Source: IEA (2007), IPCC (2007), UNPD (2004) and WBGU (2003)

This is due to the **comparatively low** overall conversion efficiency**:** only some 3-4% of the solar energy input is stored in the plant material, i.e. the heating value of the biomass grown. Thus, the land-use efficiency in terms of net energy yield per hectare is low, e.g. at least 2 times lower than current solar-to-electricity technologies, and, with rising solar conversion efficiencies in the longer-term, this factor might well become close to one order of magnitude.

On the other hand, efficiency is only one indicator - the (current) economics clearly favor bioenergy systems against solar-electric and solar-thermal technologies, so that it will take time to develop solar systems which could be cost-competitive.

Furthermore, it must be recognized that the growth of biomass is a "natural" phenolmenon, and that photosynthesis is less a means to store energy[5] but to provide highly organized and structured matter which can be used for a myriad of applications – from food and feed to newspaper and textiles up to building materials.

In that regard, biomass is unique: no other renewable energy source offers similar characteristics, and a long-term perspective requires consideration of the "double nature" of biomass as being a material **and** an energy carrier.

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[5] In the long-run, "artificial" photosynthesis might be possible with a conversion efficiency of approx. 10 to 15%. This could drastically narrow the gap to solar electricity systems.

In addition, the production of energy from biomass has a significant potential effect on a range of ecosystem services (see below).

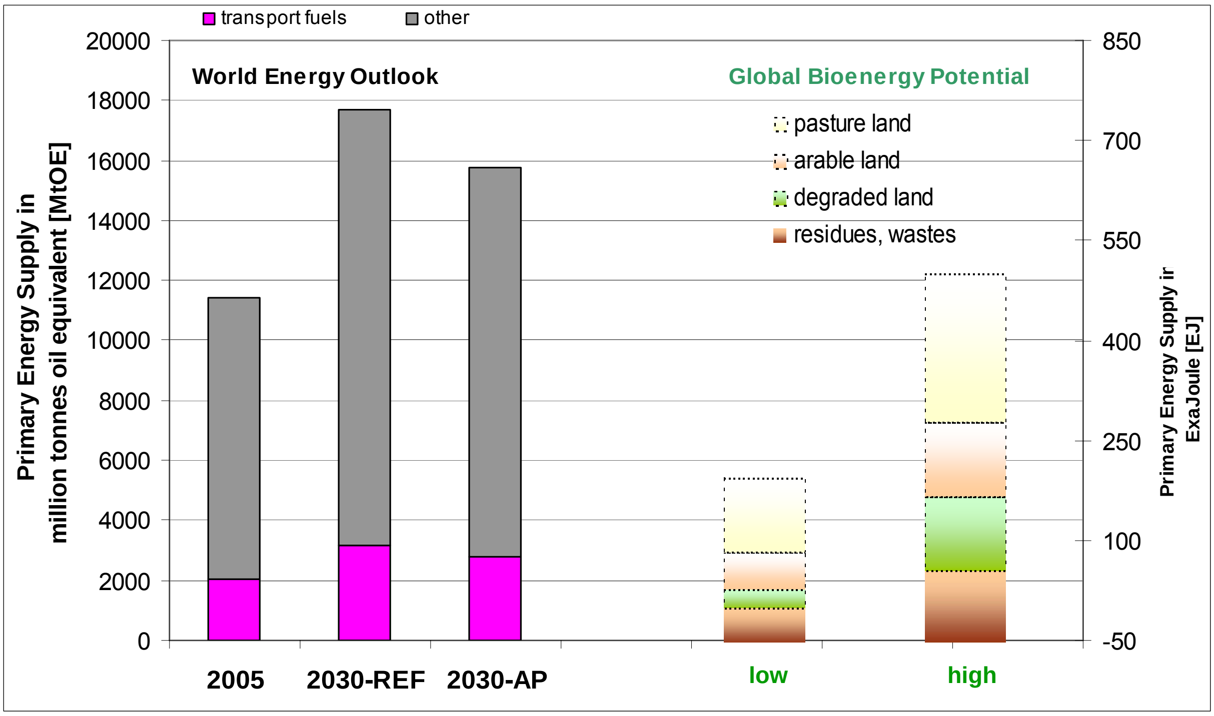
Though bioenergy is seen by some to be a panacea for a range of energy, environment and poverty problems, the sustainability performance of bioenergy - and biofuels - depends on where and how it is produced, processed, and used.

The sustainable potential of bioenergy is a function of developments in agriculture and forestry, as well as the overall dynamics of the food, feed and fiber markets. Its potential is further depending on the impact of global climate change, and the regionally differentiated adaptation measures to adjust to that change. One has to face a complex interaction of various driving forces, and massive feedback loops which make projections a matter of large uncertainty.

Still, current science allows to depict the **order of magnitude** to which bioenergy **could sustainably** contribute to the world's energy needs without compromising food, feed, and fiber requirements.

A **low** figure can be derived from pessimistic assumptions on agricultural productivity, moderate energy and high agricultural commodity prices, and severe climate change impacts on soils, and precipitation patterns. The **high** figure assumes optimistic values for productivity increases as well as high energy and agricultural commodity prices.

Figure 2 Global Energy Supply and Sustainable Bioenergy Potential



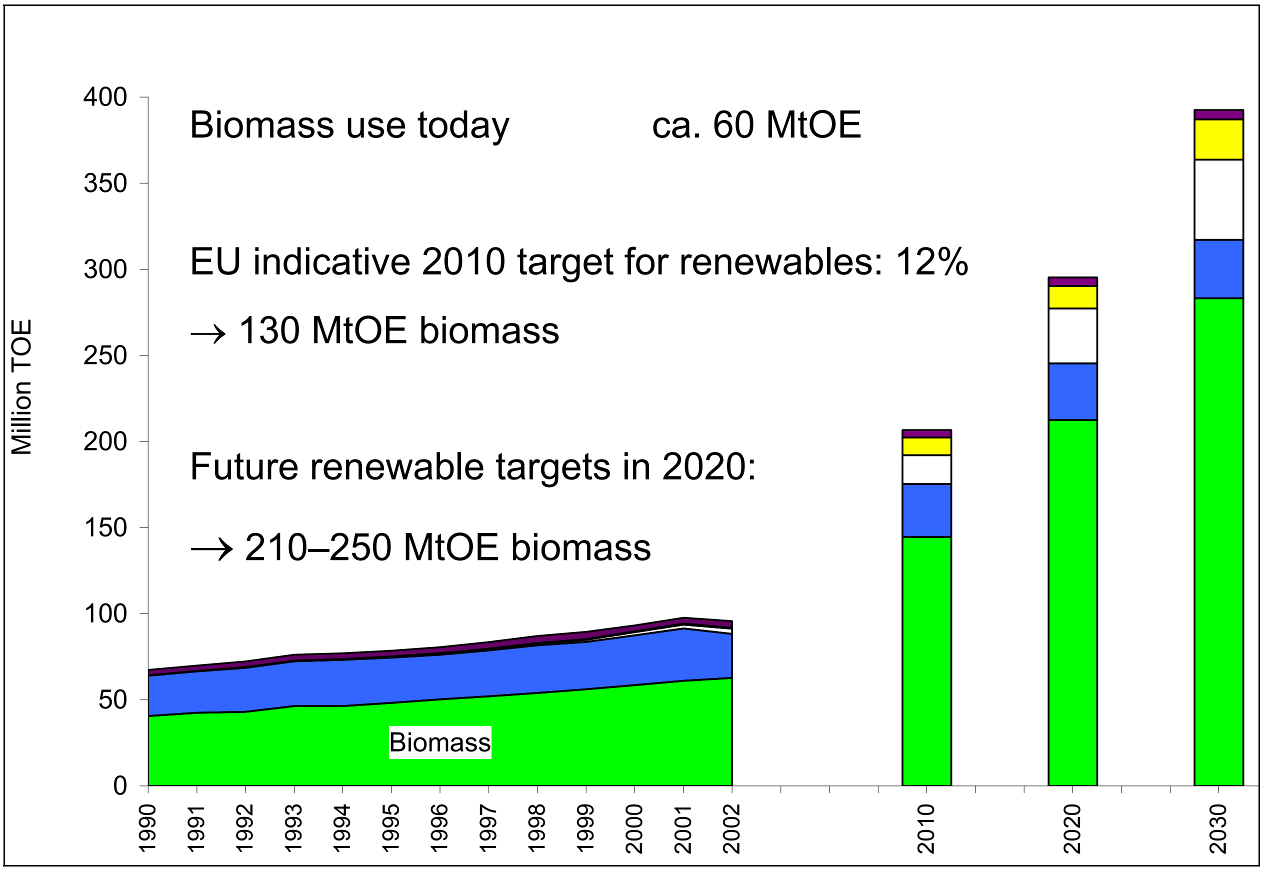
Source: own calculation based on IEA (2007) and Best et al. (2008)

Comparing the low and the high estimate of the longer-term global sustainable bioenergy potential, with current and projected total global energy supply needs as projected in IEA's World Energy Outlook underlines **the opportunities which sustainable bioenergy offers.**[6].

The development of the bioenergy potential could increase income of exporting countries, and revenues for farmers and the forestry sector, favor rural job creation, and reduction of import bills for fossil fuels (UN Energy 2007).

Similar considerations on the potential of sustainable bioenergy in the European Union result in similar findings (EEA 2006; 2007; 2008), as shown in the following figure.

Figure 3 Sustainable Bioenergy Potential in the EU



Source: EEA (2006 + 2007)

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[6] Further global potential analysis is currently carried out by Copernicus Institute (University of Utrecht), and the Potsdam Institute for Climate Research on behalf of the WGBGU.

1.2 Impacts of Bioenergy Production and Use

The dominant factors determining cost, environmental, biodiversity and social impacts of bioenergy (including biofuels) are

- the characteristics of the land used for producing biofuel feedstock (forestland, cropland, marginal or degraded)[7] and
- the feedstock conversion process employed, including the feedstock characteristics (crop, grass, woody, residues/wastes).

Depending on the feedstock used, where and how it is grown and the manner in which it is processed, the greenhouse gas balance, energy yields and environmental impacts of bioenergy differs significantly.

Life-cycle analysis (LCA) is needed to determine the positive and negative impacts of bioenergy, especially regarding greenhouse-gas emissions, especially in order to take into account direct and indirect land use change effects in Europe and across the world, see Section 2).

The specific impacts of bioenergy (including biofuel) vary, as each fuel type and system of production has different potential impacts (EEA 2007; FAO 2008; Fargione et al. 2008; Searchinger et al. 2008; UNEP/IEA 2008).

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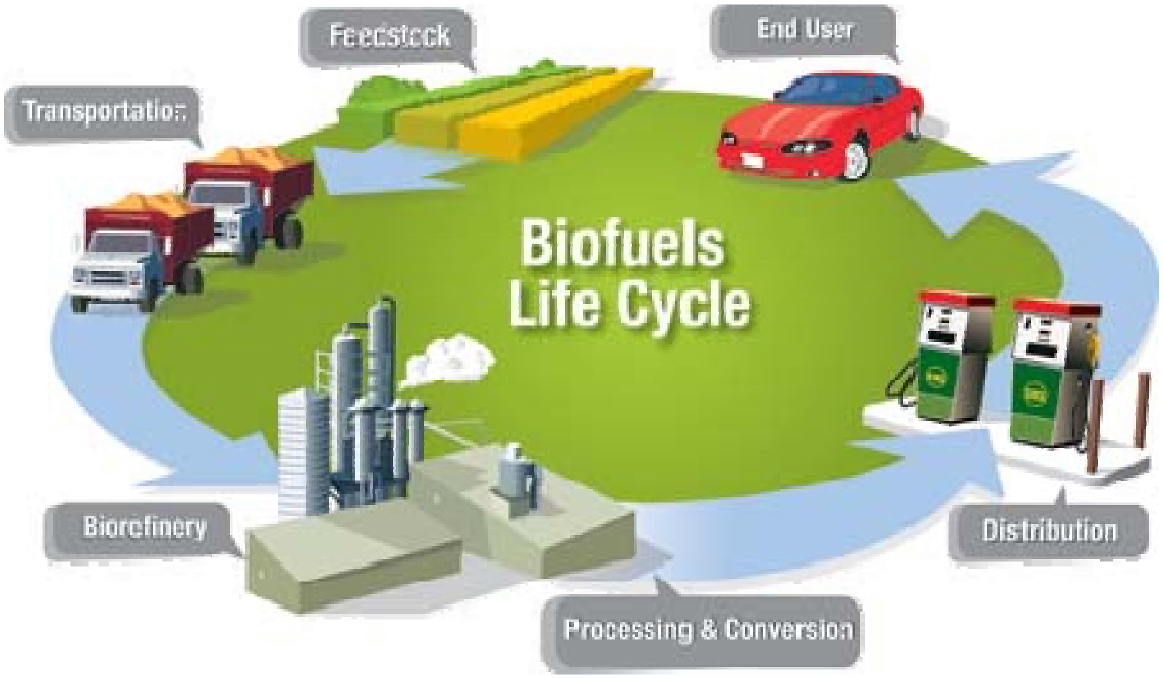
[7] Note that biogenic residues and wastes do not impose land-use or land-use changes. (AJO: this needs to be explained more in the text: quite a large share is not from forestry and agriculture but from waste)

2 Life-Cycle Analysis

To capture the full environmental impacts from bioenergy (including biofuel) production, distribution and use, a comprehensive analysis of all activities from feedstock cultivation and harvest, fuel production and its use in vehicles (in the case of biofuels) is needed which takes into account all inputs (e.g. fertilizer, auxiliary energies), and outputs (e.g. by-products, residues and waste treatment).

The analytical framework for that is called "life-cycle analysis" (LCA), and has been developed in the 1980-1990ies in the context of sustainable product development. The LCA approach uses standardized methodologies and terms as defined by ISO in its 14000 series of standards, and was applied in a variety of cases in a multitude of countries. The following figure shows the simplified flows in a biofuel life-cycle (see Section 2.1). Its application to other bioenergy pathways is discussed in Section 2.2.

Figure 4 Principle Scheme of A Biofuel Life-Cycle



Source: US DOE (http://www1.eere.energy.gov/biomass)

2.1 GHG Emissions from Biofuels

Besides energy security concerns and rising oil prices, a major global driver of biofuel development is concern about climate change, caused primarily by the burning of fossil fuels, but also by land-use change (deforestation, conversion of wetlands, reduction of organic carbon in soils). LCA calculations allow determining the net GHG emissions from biofuels "from cradle to grave". Due to their complex nature, they are sensitive to assumptions on system boundaries, crop variety, by-product use, and land use changes. It has also proven difficult to integrate indirect land use effects into the

LCA approach. Other methodological tools, such as agro-economic modelling, may therefore have to be combined with LCA analysis for this purpose (Kløverpris et al. 2008; Petersen 2008), though the discussion on that is open still (Fritsche et al. 2008).

Several recent review studies found that the largest differences in results come from allocation methods chosen for by-products, assumptions on N_2O emissions, and land-use-related carbon changes (Larson 2006; Macedo/Seabrab/Silva 2008; UNEP 2008; Zah et al. 2007). Clearly, GHG emissions vary with location, feedstock type, and biofuel conversion routes.

The majority of existing LCA concerns **liquid biofuels** from grains and oilseeds in the EU, the USA, and sugarcane ethanol in Brazil (MNP 2007-2008; von Blottnitz/Curran 2007). A limited number of LCA studies considered vegetable oil, biodiesel from palm oil, cassava, jatropha, and biomethane from biogas (UNEP 2008). For so-called 2nd generation biofuels such as lignocellulosic ethanol, and biodiesel from gasification and subsequent Fischer-Tropsch synthesis (called biomass-to-liquid = BTL or FT diesel), only scenario-based (prospective) LCA studies are available due to the early stage of these technologies.

The majority of LCA studies found that producing 1st generation biofuels from current feedstocks results in 20-40 % reductions of GHG emissions (relative to fossil fuels) if the most efficient systems are used, and direct and indirect land-use change-related carbon releases are excluded. The 2nd generation biofuels typically promise a higher GHG reduction in the order of 70-90 percent, as compared to fossil diesel and gasoline, however these figures also exclude land-use change related carbon emissions.

2.2 Other bioenergy systems: electricity from biomass, and biomethane

A few studies cover bioenergy more broadly, taking into account electricity generation, cogeneration[8], and heating (e.g., OEKO 2008).

The GHG balances of converting biomass into electricity or into biomethane which is a substitute for (compressed) natural gas depend heavily on the source of the biomass feedstocks, and the conversion efficiencies.

When perennial biomass crops (short rotation coppice, grasses) or solid wastes (straw, forest residues) are used for electricity generation, net GHG reductions in the order of 80 to 90 percent can be achieved compared to coal- or diesel-based generation.

Biomethane from processed biogas derived from biogenic residues and wastes (e.g. organic household wastes, manure) achieves even higher GHG reductions. If biogas comes from the fermentation of e.g., maize or wheat silage, and the residues from the

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[8] i.e., combined heat & power production (CHP), but also combined heating, cooling and electricity provision.

biogas plant are returned to the field as fertilizer, a net GHG reduction of 50 to 65 percent, compared to fossil oil, can be realized (Wenzel 2008).

Note that all these results do **not** factor-in carbon emissions from land-use changes.

2.3 GHG Emissions from Direct Land Use Changes

The total life-cycle GHG emissions of bioenergy crops depend not only on the “cradle-to-grave” balance, but also on the **net** carbon flows associated with land-use **changes** that occur when biocrop cultivation systems are established.

GHG emissions from **land-use change** associated with feedstock production can occur whenever a 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 (arable) land. The quantification of direct land-use changes can be based on data and CO_2 emission calculcation methodologies from IPCC default (tier 1) or country-specific (tier 2) values[9].

If bioenergy feedstock production using **annual** crops such as maize, wheat or rape replaces natural grasslands or forests, the GHG emissions will increase, as the previous land-use stored carbon both above- and below-ground. Once the land is cleared from the previous vegetation, and ploughing took place, this amount of carbon will be released more or less quickly.

Perennial feedstocks such as sugarcane, oil palm, or jatropha also store carbon in soils, and establish significant above-ground carbon stocks. If perennial crops are established on e.g. previous grassland, the net carbon balance might be zero. But if tropical forests, wetlands or carbon-rich grasslands are converted into biofuel feedstock production areas, the GHG emissions incurred by the land-use change will drastically increase the biofuel GHG emissions, and could **more than offset** GHG reductions compared to fossil fuels.

On the other hand, replacing agricultural crops such as soy with biofuel feedstocks such as sugarcane could increase net soil carbon. Similarly, switching from pasture to cultivating perennial feedstocks, e.g., short-rotation coppice or perennial grasses, the soil carbon stock might increase as well (Fehrenbach/Fritsche/Giegrich 2008)[10].

As can be seen from recent scientific work, GHG emissions increase drastically if **conservative** assumptions are made for direct land-use change, especially if bioenergy feedstock cultivation requires clearing of tropical rainforests (i.e., deforestation), or takes place on carbon-rich peatland.

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[9] 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.

[10] Note that the biological fixation of C in root systems and soil occurs during the lifetime of the plantation. If at the end of the use phase the roots are removed, only the soil-based carbon with be sustainably sequestered.

On the other hand, if **perennial** plants such as short-rotation coppice, jatropha, or varieties of palm are grown on **low-carbon** soils (e.g., marginal or degraded lands), the impact can be positive: as the plants store carbon in their root system, a biological sequestration takes place and GHG emissions **are reduced (**Tilman/Hill/Lehman 2006)[11].

2.4 GHG Emissions from Indirect Land-Use Change

In addition to the GHG implications of direct land-use change, one has to consider also potential **indirect** effects (leakage): If land used currently for feed or food crops is changed into bioenergy feedstock production, and the demand for the previous land-use (i.e. feed, food) remains, the displaced agricultural production will move to other places where unfavourable land-use changes could occur – e.g., tropical forests, wetlands, or carbon-rich grassland might be converted to farming.

Indirect land use can be described as a consequence of **shifting** land uses prior to bioenergy feedstock production to **other** areas where land use change occur due to maintaining the previous level of (e.g., food) production[12].

If the associated carbon releases – both from above and below-ground – are allocated to the bioenergy feedstock production which initially caused the displacement, the GHG balance will be affected severely. Still, not all bioenergy production will cause indirect GHG emissions:

First, displaced feed or food production could be compensated by higher agricultural yields which may be a consequence of higher food/feed prices[13]. The intensification of traditional agriculture could “free” land for bioenergy feedstock production without displacement, although the “freed” land has an opportunity value for e.g. sequestering carbon which should be included in the GHG balance.

Second and most prominently, if bioenergy crops are cultivated on fallow, marginal or degraded land where previously **no** conventional crops were grown, **no** displacement takes place and – hence – no indirect GHG emissions can occur. If perennial biofuel crops are cultivated on such land, they will **sequester** carbon and thus have the potential to **reduce** associated emissions. Quantitatively, growing perennial crops on degraded lands has the highest potential for both avoiding displacement, and for biologically storing additional carbon in soils. . However, the agro-economic and socio-economic challenges of using such land productively should not be underestimated. In

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[11] see previous footnote.

[12] see e.g., Fehrenbach/Fritsche/Giegrich 2008; Fritsche 2007; Fritsche et al. 2008; Searchinger at al. 2008

[13] Note that this may be accompanied by increases in other environmental impacts related to the intensified cultivation, e.g., agrochemical releases and run-off, soil erosion, etc. (see Appendix).

addition, there is very little land in the world that is not under informal land use by local inhabitants or has no biodiversity value[14].

Work in the UK is underway to shed more light into the discussion on indirect land-use effects (RFA 2008).

While this ongoing activity has not yet provided results, the so-called “iLUC” factor (for indirect land-use change) has been proposed for European bioenergy to quantify the indirect GHG emissions from potential displacement (see Fritsche et al. 2008a).

Even if **no direct** land-use change is assumed, the iLUC factor will worsen the GHG balance, depending on its level of its application.

In a recent study for the German WGBU (OEKO 2008), a “medium” level of 50% risk to induce indirect land-use change was assumed, with respecting GHG emissions consequences[15]. The results are shown in the following two figures for electricity cogenerated from biomethane stemming from various bioenergy feedstocks (Figure 5) and for electricity cogenerated from bio-oils and solid biomass (Figure 6)[16], which demonstrates the profound impact of taking into account GHG emissions from direct and indirect LUC.

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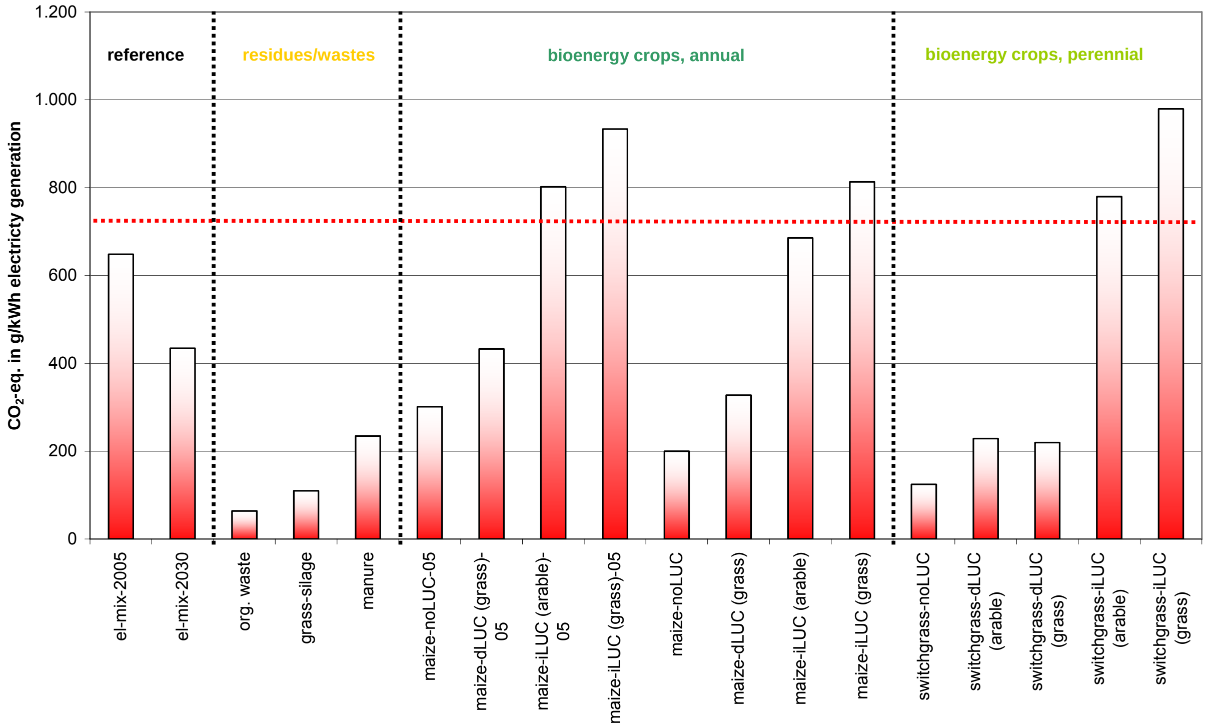
[14] see Fritsche et al. (2008b) for ongoing work in that regard.

[15] The iLUC factor represents the global average GHG emissions per ha per year of **theoretical** displacement – in reality, **not all** bioenergy will cause indirect land-use change, as some of the feedstocks will come from land which is currently used for bioenergy feedstock production, and from land “set free” through the intensification of existing land-uses (e.g. grazing, what/maize cropping). To reflect this, the iLUC factor was calculated for a simplified three-level range from “minimum” (25%) to medium (50%) and maximum (75%). The minimum is the near-term level (2010 timeframe), and the maximum the post-2030 level, with the medium level representing the in-between. Note that the “maximum” level is below 100% even in the long-run, as future land-use intensification, and longer-term global GHG caps must be considered (Fritsche et al. 2008).

[16] The results are calculated for Germany, but do reflect the principle outcome for other EU countries as well, with the exception of GHG emissions from auxiliary electricity needs (see Section 3.2.1).

Figure 5 GHG emissions from electricity mix in Germany 2005 and 2030, and cogenerated electricity using biomethane from various feedstocks

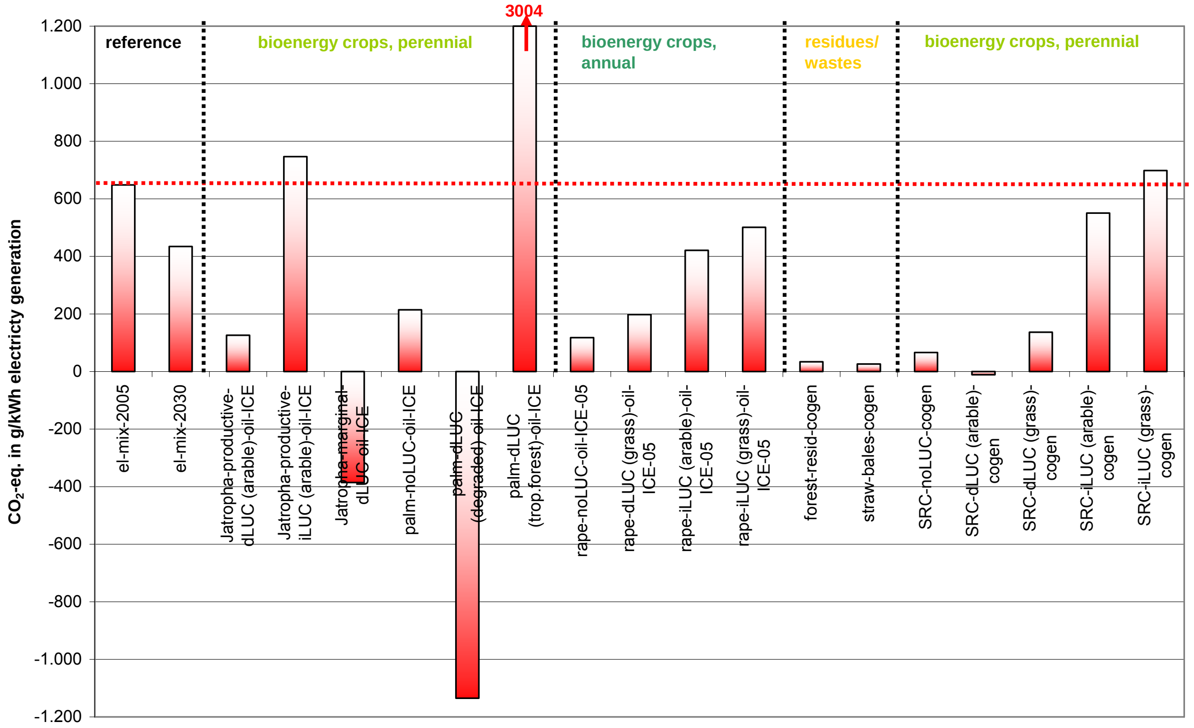


Source: OEKO (2008); data for electricity cogenerated in internal combustion engines (ICE), by-product allocation using energy contents: noLUC = without C emissions from direct/indirect land-use change (LUC); dLUC = including C emissions from direct LUC, without indirect LUC; iLUC = including C emissions from direct and indirect LUC (iLUC factor 50%)

Even for electricity from biomass such as Jatropha (grown on productive land), or lignocellulose (SRC, switchgrass), GHG from **direct** LUC effects reduce the GHG reduction potential when compared to the 2030 electricity generation mix expected for Germany. If indirect effects are added, there will be no GHG reduction at all in most cases.

Still, bioenergy systems could, as said before, also reduce the overall GHG emissions through biological C fixation in soils to an extend that the total GHG balance becomes negative – this would, according to OEKO (2008), be the case for bio oil from Jatropha grown on marginal land, and for palm oil from plantations established on degraded lands.

Figure 6 GHG emissions from electricity mix in Germany 2005 and 2030, and cogenerated electricity using solid biomass and bio-oils from various feedstocks



Source: OEKO (2008); data on bio-oils for electricity cogeneration in diesel engines for, and for solid biomass in steam-turbine CHP systems: by-product allocation using energy contents: noLUC = without C emissions from direct/indirect land-use change (LUC); dLUC = including C emissions from direct LUC, without indirect LUC effects; iLUC = including C emissions from direct and indirect LUC (iLUC factor 50%);

These examples should underline the need to consider **both direct and indirect** land-use change issues in calculating GHG emission balances for bioenergy life-cycles.

2.5 International and national perspectives on Bioenergy Life-Cycle GHG emissions

To capture all relevant effects of biofuels on GHG emission balances, the already complex life-cycle analyses have to be extended to take into account carbon flows from direct and indirect land-use changes associated with the biofuel feedstock production. These flows can, depending on location, cropping scheme, and previous land-use, be either positive or negative, but are large enough to be taken into consideration in any analysis that aims to be “complete”.

To date, uncertainties of LCA exist not only with respect to GHG impacts from direct and indirect land-use change, but also arise from different approaches to factor-in co-and by-products, such as milling cake and glycerine in the biodiesel life-cycles, or protein and excess electricity from ethanol production.

Some countries are in the process to establish or have already started to implement legally binding sustainability standards for biofuel production which explicitly require net GHG emission benefits of biofuels. Germany's Biofuel Sustainability Ordinance (Fehrenbach/Fritsche/Giegrich 2008), and the EU Commission Proposals for a Renewable Energy Sources Directive[17], as well as proposals made in the Netherlands (Bergsma/Dornburg 2007), and the United Kingdom (RTFO 2007), all include not only GHG reduction targets or reporting obligations for biofuel providers, but also methodological standards and default data for GHG emission calculations of biofuel production.

Outside of Europe, further research is carried out, in particular supported by US Department of Energy (DOE)[18] and the United Nations Environment Programme (UNEP). The G8 Global Bioenergy Partnership (GBEP) established a GHG Task Force to help sharing and harmonizing LCA data and methods for biofuels and recently decided to include solid biomass as well (GBEP 2008). The GBEP Task Force is expected to deliver a report in early 2009.

With FAO's BIAS project, a methodological framework for GHG emission accounting is being prepared with a special focus on developing countries (FAO 2008), and UNEP is working for a more adequate representation of LCA GHG data from developing countries[19].

From all that, more reliable and comprehensive life-cycle GHG emission balances will become available in the near term, but fundamental uncertainties regarding e.g., indirect LUC effects and nitrous oxide emission factors will remain for the next years (see Sections 3.1 and 3.2.3).

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[17] The EU RES-D proposal is based on data and methodologies from EUCAR/JRC/CONCAWE (2007). Its allocation method for by-products, and the direct LUC-related GHG emission data are explained in an Annex to the draft.

[18] see US presentations at the 2nd GBEP Task Force on GHG Methodologies (GBEP 2008).

[19] For that, UNEP has, in cooperation with FAO, IEA, and UNIDO, applied for funding a targeted research project through the Global Environment Facility. Approval of that project is expected in Summer 2008.

3 Key Questions and Issues and Intended Outcome for the expert meeting

The expert meeting will address issues of methodology and of data in parallel groups (see agenda).

3.1 Methodological Issues in Bioenergy Life-Cycle GHG Emissions

3.1.1 System boundaries, wastes, and by-product allocation

One of the basic problems of LCA is to choose adequate system boundaries for the analysis. In most cases, current (or in some cases "future") biomass production and conversion systems are defined within the scope of the LCA, with other processes (e.g. electricity and materials, transport) as "background systems" which are not explicitly modeled[20].

This might need to be re-considered for high penetration scenarios where bioenergy becomes part of the "background".

The definition of "wastes" is another core issue which needs careful attention, as wastes are an important part of the overall bioenergy potentials. Thus, how to define and differentiate wastes (which do not receive any "burden") from residues and by-/co-products (see below) is another key issue.

The methods to address processes and systems with **multiple** outputs (e.g. refineries, cogeneration systems) so that one of them is seen as "main", and all others as "by-" or "co-" products has been discussed widely, and is another basic problem of LCA.

The RES-D proposal of the EU requires allocation for all biofuel systems based on heating values of by- and co-products, mainly based on considerations of data availability, and consistency.

Key questions for the expert meeting

- Are there cases for which bioenergy should be part of the "background" system?
- How to consistently define residues, wastes, and by-/co-products?
- Can the EU RES-D approach for energy-based allocation and the system boundary assumptions for residues/wastes be used also for the wider area of bioenergy?

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[20] This restriction is mainly due to model complexity and data requirements. The consequence of restricting the scope is that issues such as "indirect effects" occur, i.e. effects which are outside of the modelling scope (see Section 2.4).

3.1.2 Direct Land-Use Change

As presented previously, GHG emissions from direct LUC could be of high importance. Currently, IPCC default data are most widely used for biofuel feedstock provision, but the LCA of bioenergy requires to consider a broader range of feedstocks, including residues and wastes.

With IPCC data being valid mainly for annual crops and forests, feedstocks such as perennial grasses and short-rotation coppice need to be added to the default data list with consistent definitions of above- and below-ground as well as soil carbon.

Key questions for the expert meeting

- How to develop emission factors and calculation methods for feedstocks (such as perennials) that are not covered by IPCC?
- How to deal with soil carbon releases from direct LUC with respect to time (distribution over which time span)? Is the IPCC default of 20 years an appropriate choice?
- Should GHG emissions from removal of pre-project above-ground biomass be discounted over the same time horizon, or treated differently (e.g. direct emissions from slash burning)?

3.1.3 Indirect LUC

As presented briefly in Section 2.4, the treatment of GHG emissions from so-called indirect LUC is a yet unresolved issue which needs to be dealt with for bioenergy in general.

In that context it is important to note that **if the full** scope of all biomass provision would define the system boundaries, **no indirect** effects would occur.

Key questions for the expert meeting

- Which approach is adequate to address indirect LUC, and ho to express and allocate GHG emissions from indirect LUC quantitatively?
- If the “iLUC factor” concept is used, which level of risk is appropriate for which time horizon?
- How to deal with methodological issues linked to system boundaries and projected changes in background factors such as increasing global food demand?
- If future climate change negotiations lead to caps on GHG emissions from a majority of countries (including e.g., Brazil, Indonesia) and sectors (including agriculture and LUC), will this take care of GHG emissions from indirect LUC also?

3.2 Data Issues in Bioenergy Life-Cycle GHG Emissions

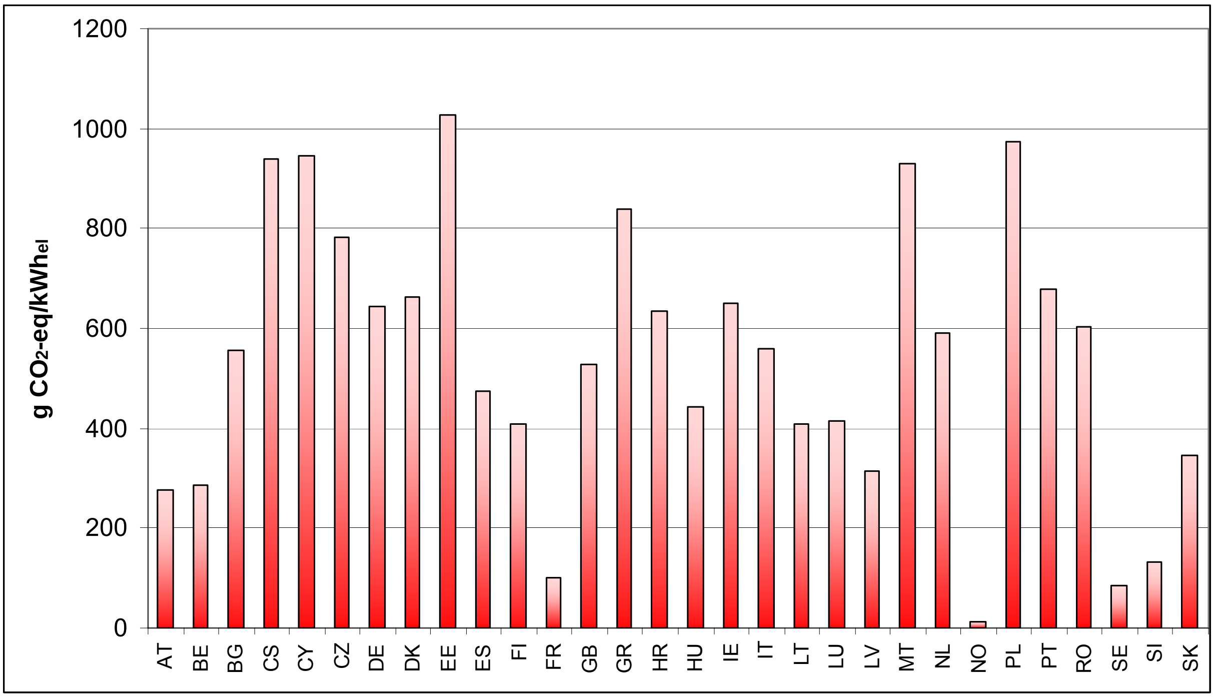
Besides methodological also data issues arise for life-cycle GHG emissions from bioenergy.

3.2.1 Reference Systems for Electricity

First, the considerations on reference systems for electricity need to reflect that in contrast to fossil transport fuels (diesel, gasoline), “the” reference electricity systems des not exist.

Within the EU, the GHG emissions from the national electricity generation mixes (taking into account upstream life-cycles) differ widely, as shown in the following figure.

Figure 7 GHG Emissions from Electricity Generation in EU Countries in 2005



Source: own calculation with GEMIS 4.5

The emissions vary by one order of magnitude between Member States – thus, reference and background systems need to be treated consistently with respect to electricity trade, “embedded” emissions in electricity-intense products (e.g. aluminum), and electricity-intense processing (e.g. pelletizing).

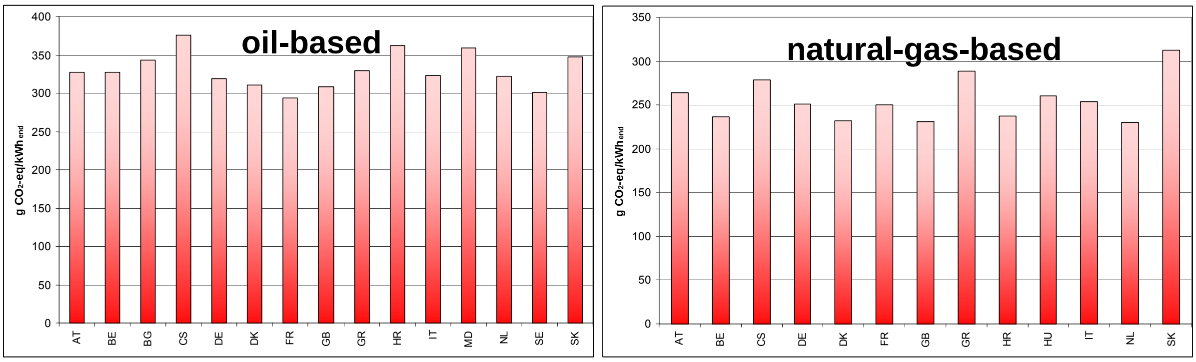
Key questions for the expert meeting

- Which factors need to be considered when developing the reference system for electricity?
- Should the reference system for electricity be the EU average or country specific, and should it be average or marginal?
- Should seasonal influence on the energy mix (e.g., hydroelectricity and wind fluctuations) be taken into account?

3.2.2 Reference Systems for Heating

As regards reference and background systems for fossil-based heat provision, the following figures indicate that the regional differences are comparatively small for oil- and natural-gas based heating.

Figure 8 GHG Emissions from Oil- and Natural Gas-based Heat Production in the EU Countries in 2005



Source: own calculation with GEMIS 4.5

In that regard, an “averaged” heating system might be suitable to define, similar to the “reference” diesel and gasoline data developed by JRC for the EU RES-D proposal.

Key questions for the expert meeting

- Should the reference system for heating be the EU average, or country-specific?
- Should average figures be used or marginal systems?
- Should specific future developments (e.g. ultra-low sulfur oil; PM_{10} restricitons for small-scale systems) be considered?

3.2.3 Data Uncertainties: CH_4 and N_2O

In addition to reference and background systems and their regional differences, key data uncertainties are associated with the emissions of CH_4 (for manure and biogas/biomethane processing), and N_2O from fertilizer, and LUC.

Key questions for the expert meeting

- What are the key factors to be considered when dealing with reference background systems for CH_4 and N_2O emissions in a spatial manner?
- How can relevant reference data sets / systems be most efficiently developed?
- Which data for N_2O emissions should be used (IPCC default, tier1/2,…)?
- Which data for CH_4 emissions from biogas systems (e.g. leakage from manure storage), and biogas processing (upgrade to biomethane, compression to CNG) are to be used?
- Should credits for **avoided** CH_4 and N_2O emissions be included, and, if yes, based on which data sources?

3.3 Data for Land-Use Changes

As said under methodologies, data on potential LUC effects of general bioenergy feedstock provision is required, and regional differentiation (soils, climate) is – due to the relatively high impacts on results – a necessity in the future.

Key questions for the expert meeting

- To what extend is the disaggregation of GHG emission from LUC needed for “adequate” results?
- What are the most suitable approaches and data sets for dealing with this issue?

4 Intended outcome of the expert meeting

The expert meeting aims to bring together the experts in the area of LCA GHG emissions from bioenergy (including biofuels) to collect evidence and give guidance on coherent LCA methodologies for all bioenergy as well as adequate default data for implementation.

The participants of the expert meeting will brainstorm and discuss adequate GHG methodologies and data gaps for bioenergy use for the heating and electricity sectors.

The intended outcome of the expert meeting is a technical paper with an overview of existing methodologies and data sources as well as **recommendations on**

- possible ways forward towards more **harmonized approaches,** and
- areas which require further analysis and research.

The outcome of the meeting and the technical paper is to be made available to users through the EEA, ETC ACC website and/or CIRCA web sites.

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Abbreviations

BioKraftQuG	German Biofuel Quota Law
BSO	Biofuels Sustainability Ordinance (Verordnung über Anforderungen an eine nachhaltige Erzeugung von Biomasse zur Verwendung als Biokraftstoff, BioNachV)
CAP	Common Agricultural Policy
CDM	Clean Development Mechanism
EEA	European Environment Agency
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FQ-D	EU Fuel Quality Directive
FSC	Forest Stewardship Council
HNVC	Area of High Nature Conservation Value
IUCN	International Union for the Conservation of Nature and Natural Resources
NGO	Non-governmental organization
OEKO	Öko-Institut (Institute for applied Ecology)
RES-D	EU Renewable Energy Sources Directive
UBA	German Federal Environment Agency (Umweltbundesamt)
UNEP	United Nations Environment Programme

Appendix: Beyond GHG - other Environmental Impacts of Bioenergy

Besides GHG emissions, other environmental impacts of bioenergy production can arise from feedstock production, processing, and distribution. Most dominantly are impacts on land used for feedstock production, and the respective effects on water, soil quality, and biodiversity. These impacts depend on various factors such as feedstock, cultivation practise and land management, location, and downstream processing routes. For 1st generation biofuels, the environmental impacts of feedstock production are similar to those of traditional agriculture, as the same crops and cultivation systems are applied.

Still, bioenergy production in general and 2nd generation feedstocks and biogas in particular offer more choices for environmentally sound feedstock provision than conventional agriculture, as the interest is in overall biomass yield, and less in oil or starch content. Furthermore, they can make use of a broader variety of crops, cultivation schemes, and nutrient recycling options, and could be grown with less agrochemical inputs.

Water Quantity and Quality

Globally, agriculture uses more than ⅔ of the available freshwater, with even higher shares in some (developing) countries. Biofuel feedstock production has two key impacts of water supplies: the amount of water required for feedstock production could deplete fresh water resources, and the runoff of agrochemicals can affect the quality of water bodies.

As only a fraction of nitrogen fertilizer is typically taken up by plants, excess N can leach into surface waters, or being emitted into the atmosphere. Nitrogen runoff can cause eutrophication of surface waters, and pesticides may cause long-term pollution of groundwater bodies..

Even perennial plants such as jatropha and pongamia which can be grown in semi-arid areas on marginal or degraded lands require some irrigation during hot and dry summers which could put pressure on scarce water resources.

Furthermore, the processing of feedstocks into biofuels can use large quantities of water, mainly for washing plants and seeds, and for evaporative cooling. Biodiesel and ethanol production result in organically contaminated waste water that, if released untreated, could increase eutrophication of surface water bodies.

Existing wastewater treatment technologies, though, allow dealing effectively with organic pollutants and wastes. Fermentation systems can reduce the biological oxygen demand of wastewater by more than 90 percent, so that water can be reused for processing, and methane can be captured and used for power generation.

In Brazil, the majority of milling waste water (vinasse) is used for irrigation and fertilization of the sugarcane plantations, thus reducing both water demands, and eutrophication risks.

As regard impacts in downstream distribution and storage, ethanol and biodiesel are biodegradable, reducing potential impacts on soil and water from leakage, and spills.

Soils

As a general rule, organic carbon in soils decreases over time when land is converted from natural cover to agricultural production. Intensive farming can cause soil erosion by removing permanent soil cover, ploughing and tilling, and by using machinery for harvesting. Erosion further reduces organic carbon in soils.

Intensive harvesting methods can further compact the soil, thus reducing its capacity to hold moisture. Depending on the biophysical composition of soils, the removal of whole plants (or respective residues) can reduce nutrient recycling and – hence - soil quality, and lead to increased GHG emissions through losses in soil carbon.

In contrast, growing perennials such as palm, short-rotation coppice, sugarcane or switchgrass instead of annual crops can **improve** soil quality by increasing soil cover and organic carbon levels. In combination with no-tillage and reduced fertilizer and pesticide inputs, also positive impacts on biodiversity can arise.

Cultivating perennials (including jatropha and pongamia) in semi-arid climates and on degraded lands can reduce erosion, and restore organic matter in the soil due to their extended root system which is not subject to harvesting.

Biodiversity Concerns

The impacts of biofuel feedstock production on biodiversity are closely linked to the land-use practices, and to the location of the production. The potentially most severe threat comes from expanding the cultivated land into biodiversity-rich ecosystems such as rain forests, savannahs, and wetlands. The conversion of “virgin” land through deforestation, for example, causes the destruction of habitats for many species, and the loss of ecosystem functions.

In that regard, the biofuels’ displacement effects of shifting agriculture to previously “unused” lands, and the potential intensification of existing agricultural land-use will both reduce valuable biodiversity resources in natural forests, grasslands, and wetlands, which are habitats for a large number of mammals, birds, and wild plants.

On the other hand, biofuel feedstock production using perennial crops could increase biodiversity when compared to annual agricultural crops: there is evidence of more biodiversity in palm oil plantations than in fields of annual grains. Still, the equation is evident only if palm oil replaces these crops, not tropical forests or wetlands, and even than indirect effects (“displacement”) must be considered.

Biofuel feedstock production on fallow and degraded lands could also increase biodiversity by offering shelter, nutrients, and moisture in previously harsh environments. Here, perennial crops could provide all-year ground cover, improving the soil and water retention. Nevertheless, even marginal and degraded lands can have significant biodiversity value on their own in offering habitats for species adapted to local conditions.

As regard agrobiodiversity, key concerns of biofuel feedstock production is that high-intense monoculture systems will dominate, and potentially, genetically modified organisms might be used in parallel. On the other hand, 2nd generation feedstocks consist of many cellulosic crops (perennial grasses, woody biomass) which offer greater diversity and variability than traditional agricultural crops, and require fewer agrochemical inputs. Still, crop selection must consider effects on native species, and should avoid invasive species which might dominate also natural areas outside of the plantation.

Another opportunity for biodiversity is intercropping with grasses and trees, or bushes. "Stepping stones" of vegetation left undisturbed from harvesting or mowing foster diversity and habitats for small mammals and birds.

Still, there is concern that biofuel monoculture crops could replace existing small-scale farming of varied crops which may have a high nature conservation value.

Furthermore, expansion of bioenergy crops into previously "set aside" land (e.g. in Europe) or "conservation reserve land" (e.g. in the USA) will increasing erosion and reduce wildlife habitats. Similarly, sugarcane expansion into lands previously used for cattle grazing might displace cattle to find pasture in rainforests, or the *cerrado*, a savannah covering more than 25 percent of Brazil, and home to 50% of Brazil's endemic species and 25% of its threatened species. Leaching from sugarcane plantations, and spills from processing plants could also endanger the Pantanal in Brazil's southwest, one of the world's largest wetland areas. In South-East Asia, palm plantations are extended into natural forests, instead of being operated on degraded land. Here, the interest is to combine timber sales from forest cutting with investments in the new plantations, but the consequences are endangered species such as tigers, Asian elephants, and the Sumatran rhinoceros.

To contain these risks, key biodiversity areas – those of high-nature conservation value – must be identified and protected against both direct biofuel developments, and indirect pressure from displacement. Land-use mapping, satellite-based monitoring and verification and sustainable resource management are needed to reduce the threads of uncontrolled biofuel feedstock expansion, and revenues from biofuels sales (and potentially for carbon fixation in soils) could be used to finance such schemes.

However, the successful protection of existing forests and grasslands as important carbon sinks and harbours of biodiversity is likely to require additional economic incentives, e.g. via carbon payments, and the development of effective management regimes for the sustainable use of such ecosystems.