Bioenergy – The Impact of Indirect Land Use Change

Summary and Conclusions from the IEA Bioenergy ExCo63 Workshop

This publication provides the summary and conclusions from the workshop 'Bioenergy – The Impact of Indirect Land Use Change', held in conjunction with the meeting of the Executive Committee of IEA Bioenergy in Rotterdam, the Netherlands on 12 May 2009.

The purpose of the workshop was to inform the Executive Committee on the rapidly evolving international debate on bioenergy and land use – particularly the thorny issue of indirect land use change. The aim was to stimulate discussion between the Executive Committee and invited experts and thereby enhance the new policy-oriented work within IEA Bioenergy.

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INTRODUCTION

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The purpose of the workshop was to inform the Executive Committee about the rapidly evolving international debate on bioenergy and land use (particularly the thorny issue of indirect land use change). Secondly the workshop was designed to identify the challenges and potential ways forward for policy development and cooperation. The aim from IEA Bioenergy's perspective was to stimulate discussion between the Executive Committee and experts working both within and outside the Agreement. This discussion will inform additional policy-oriented work and so influence the further development of the Bioenergy Agreement in both the short and longer terms.

BACKGROUND

While biomass already makes a major contribution to world energy needs, there is scope for expanding this contribution in both developed and developing countries. Major economies are relying on biofuels as part of their strategies to mitigate climate change and to improve their energy security. However increasing use of biofuels will have impacts on the way that land is used. A whole range of sustainability issues must be carefully considered, including the impacts on social development. The environmental impacts associated with land use change must be factored into lifecycle analysis to obtain a realistic view of the greenhouse gas balances associated with the various biofuel production routes.

The significance of the impact of indirect land use change has been highlighted in the last few years. In this important but extremely complex area there is an urgent need for reliable and authoritative information and analysis that can be used by national and international bodies in formulating policy and programmes. This is very much the remit of the IEA Bioenergy Agreement.

Land use and sustainability issues are already being considered in a number of Tasks within the Bioenergy Agreement, in particular:

Task 29 – Socio-economic Drivers in Implementing Bioenergy Projects
Task 30 – Short Rotation Crops for Bioenergy Systems
Task 31 – Biomass Production for Energy from Sustainable Forestry
Task 38 – Greenhouse Balances of Biomass and Bioenergy Systems
Task 39 – Commercialising 1st and 2nd Generation Liquid Biofuels from Biomass
Task 40 – Sustainable International Bioenergy Trade: Securing Supply and Demand

As part of this work, Task 38 organised a workshop in Helsinki in March 2009 which looked at the broad issue of bioenergy and land use. An overall review of 'Bioenergy and Land Use' has also been commissioned by the Agreement, and is being produced by Goran Berndes (Task Leader for Task 30) working closely with Task 38 and other relevant experts in the Tasks. This report will be available by late 2009. The presentations and report from this workshop, and from the Helsinki event, will be important additional inputs into this review. [1]

The four sessions in the ExCo workshop addressed the following issues and questions:
Session 1 – Will the environmental impact of indirect land use change (ILUC) due to bioenergy feedstock production be significant?
Session 2 – What tools and methodologies are available for monitoring ILUC? What are the main technical uncertainties?
Session 3 – How do we assess the impacts of ILUC?
Session 4 – What policy approaches taking account of ILUC are being developed?

Finally there was a session devoted to overall discussion and to developing some conclusions from the workshop.
The main points made by the speakers are summarised below. All the presentations are available on the IEA Bioenergy website. [2]

Transporting wood fuel in Brazil. Courtesy John Tustin, IEA Bioenergy.

Cover picture: *Courtesy Dave de Lang, SenterNovem, the Netherlands.*

SESSION 1 – ENVIRONMENTAL IMPACT OF ILUC

Indirect Land Use Change Due to Bioenergy Production – D. Neil Bird, Joanneum Research, Austria

Neil Bird presented the key concepts behind indirect land use change from bioenergy production by defining it and demonstrating the issue with some examples. He then introduced the conclusions from the Task 38 Helsinki meeting, before going on to present some pointers to minimising the problem of indirect land use change (ILUC).

Task 38 developed the standard methodology for the estimation of greenhouse gases from bioenergy systems some time ago. Direct and indirect land use changes are concerned with the emissions associated with a change of land use to bioenergy feedstock production.

Direct land use change (DLUC) is defined as the land use change that occurs within the system boundary (i.e. on the land that is used to create the feedstock). ILUC occurs outside the system boundary because of the displacement of services (usually food production) provided by the land before the change. It is relatively easy to calculate the emissions from DLUC because the change of use is clear. Emissions from ILUC are not so easy to calculate because it is not clear which land changed use due to the production of feedstock.

It might be possible to expand the system boundary to include lands that change, but this is not simple, as the following example illustrates. Suppose energy crops are planted on land that produced corn; the corn production is lost and this causes ILUC as this is replaced by production elsewhere. If the system boundary is expanded to include the corn production in the bioenergy system, then that land has to come from somewhere else. Perhaps this land was a wheat field. Now the wheat production is lost and this in turn causes ILUC. So now we expand the boundary to include production of wheat in the bioenergy system, but this land must have come from somewhere too. Perhaps this land was grassland for meat production, but now the meat production is lost. So now the system boundary might be expanded again to include meat production. The end result is the loss of one agricultural service cascading through the agricultural system with eventually some unused land being converted to agricultural production. Unused land could be recently abandoned agricultural land or, in the worst case, rain forest. Of course this is a simplified example – there could be increases in yield, product substitution, or decreased demand due to increased prices along the way.

So the key points about ILUC are:

- ILUC must be included in GHG balances;
- ILUC is potentially large. In the worst case it could cause the conversion of tropical peat land or rain forest to agriculture. This means that the bioenergy system may require many years before enough emission reductions are created to compensate for the emissions caused by ILUC (a carbon debt). This has been pointed out by numerous authors [3]. What has not been fully discussed is the timing of the emissions. If the environmental value of the emission reductions decreases with time because reductions are more important now for climate stabilisation than in 50 years, then the carbon debt may never be repaid.
- ILUC is not proximal in either space or service. Goran Berndes has found that crop change in northern Brazil caused the same farmers to relocate production to southern Brazil. Reduction in corn production available for cattle feed in the USA has been shown to cause an increase in soy bean production in Brazil.
- If all land is within the system boundary then ILUC becomes DLUC, but this requires international cooperation.
- ILUC is not limited to bioenergy feedstock production on agricultural lands, but may be caused by any competition for biomass (e.g. paper production being displaced by wood for energy).

Task 38 has begun to look at this problem through a series of workshops and meetings that started in Dubrovnik in 2007 with a discussion on the definition of 'sustainability'. Task 38 observed the discussions on economic modelling of ILUC in Paris in January, and recently (March 2009) hosted a workshop on the issues of direct and indirect land use change in Helsinki (see *http://ieabioenergy-task38.org/workshops/helsink09/*). The key presentations on ILUC from Helsinki are:

- Human Appropriated Net Primary Production (HANPP) – H. Haberl, Klagenfurt University
- DLUC and ILUC and the 10% EU Target – B. Dehue, Ecofys
- US EPA Analysis for Federal Renewable Energy Fuel Standard – V. Camobreco, US EPA
- Biofuels and LUC in a Multiple Policy Setting – P. Havlik, IIASA
- The ILUC Factor Approach – U. Fritsche, Oeko-Institute
- Brazilian Sugarcane Expansion – G. Berndes, Chalmers University

So in conclusion, the solutions to ILUC being proposed are:

- It could be estimated, usually by economic modelling, and the emissions incorporated into lifecycle assessment. This could be done with a simplified approach (e.g. Uwe Fritsche's ILUC factor) or a more complicated methodology involving full economic modelling.
- The system could be designed to decrease the potential for ILUC by increasing biomass utilisation, increasing productivity of land use and having integrated land use strategies.
- A policy structure could be created to include all lands (i.e. converting ILUC to DLUC), but this will require strong international agreements on issues such as Reducing Emissions from Deforestation and Degradation (REDD).

Bioenergy and Indirect Land Use Change – Jeremy Woods, Imperial College, London and Rothamsted Research, United Kingdom

Any form of new demand for biological products has the potential to result in land use change. It may be concluded that the only way to expand the supply of such products is to increase the yield of feedstock crops and/or to expand the area under those crops. However, there are in fact four ways that increased demand could be met through supply responses:

- increases in yield;
- increases in cropped area;
- reduction in wastage/losses; and
- efficiency gains from integrated supply chains

The development of bioenergy as a whole, and biofuels in particular, has been calculated to cause both direct and indirect land use change [3,4]. These assessments have tended to focus on option 2 above, and although they may have included some aspects of the other three options, it currently remains unclear what part each of the options will play in the future provision of bioenergy and biofuels.

A second area of uncertainty and variability is in the impact on both above and below ground carbon stocks, and fluxes that result from either direct or indirect land use change. At the global level, the IPCC calculates that 1.6 GtC is released to the atmosphere as a result of land use change (Table 1). However, they ascribe an uncertainty of ± 0.8 GtC (or 50%) and it is clear that there is a very large spatial and temporal heterogeneity and uncertainty in above and below ground carbon stock estimates.

Table 1: Average annual budget of CO_2 for 1980 to 1989 and for 1989 to 1998, expressed in Gt C yr-1 (error limits correspond to an estimated 90% confidence interval [5]).

	1980 to 1989		1989 to 1998	
	GtC/yr	±	GtC/yr	±
1) Emissions from fossil fuel combustion and cement production	5.5	0.5	6.3	0.6[a]
2) Storage in the atmosphere	3.3	0.2	3.3	0.2
3) Ocean uptake	2.0	0.8	2.3	0.8
4) Net terrestrial uptake = (1)- [(2)+(3)]	0.2	1.0	0.7	1.0
5) Emissions from land use change	1.7	0.8	1.6	0.8[b]
6) Residual terrestrial uptake = (4)+(5)	1.9	1.3	2.3	1.3

a) Note that there is a one-year overlap (1989) between the two decadal time periods.
b) This number is the average annual emissions for 1989–1995, for which data are available.

In part, the variability can be resolved by the categorisation of land into vegetation cover classes and overlaying the underlying soil types and then monitoring the changes over time. This is the mechanism proposed under the Agriculture, Forestry and Other Land Use (AFOLU) mechanism, which is part of the Good Practice Guidance of the National Greenhouse Gas Inventory reporting requirements of the IPCC [6]. In conclusion:

- there is a very large amount of uncertainty in the scale and spatial dispersion of future land use change;
- some aspects may be too difficult and complex to adequately cover in systems models; and
- indirect land use change is not unique to biofuels but covers all activities that affect land including, for example, set-aside/CRP.

There are a number of options available to understand and manage the indirect land use change impacts, including:

- developing increasingly complex (scale/resolution and methodology) global land use models coupled to market models and to atmospheric models;
- development and implementation of 'sustainability criteria' implemented through assurance and certification; and
- resolution of boundary conflicts e.g. geographic (winners and losers; links with REDD), and methodological advances covering 'leakage', double accounting, etc.

Positive land use change represents one of the largest opportunities for climate change mitigation and national and regional policies should be targeted to enhance terrestrial carbon stocks. Such policies are unlikely to be successful if exclusively focused on biofuels.

Indirect Effects of Bioenergy: Effects on Landscapes and Livelihoods – Danielle de Nie, IUCN, the Netherlands.

Danielle de Nie presented a paper which she had co-authored with Jeffrey Sayer and Nadine McCormick (all from IUCN). IUCN, the International Union for Conservation of Nature, is the world's oldest and largest global environmental network - a democratic membership union with more than 1,000 government and NGO member organisations, and almost 11,000 volunteer scientists in more than 160 countries.

Ecosystem services are the multiple benefits provided by ecosystems to humans, including:

- provisioning services (food, water and genetic resources);
- regulating services (regulation of climate, flood protection, and water quality);
- cultural services (recreational and spiritual benefits); and
- supporting services (soil formation, pollination, and nutrient cycling).

Human well-being is highly dependent on ecosystems and the services they provide and many of these services are needed for productive bioenergy systems.

In 2005 the Millennium Ecosystem Assessment showed that over the past 50 years ecosystems have been changing more rapidly than ever before. Approximately 60% of the ecosystem services examined in the Assessment are being degraded or used unsustainably. Only four ecosystem services have improved over the past 50 years, three of which involve food production (crop, livestock and aquaculture). For example human activity has caused between 50 and 1000 times more extinctions in the last 100 years than would have happened due to natural processes. The IUCN Red List [7] shows that currently almost 17,000 species are threatened with extinction, whereas only 785 are known to have become extinct in the previous 100 years.

The main reasons for the decline in ecosystems and ecosystem services are: habitat conversion; pollution; over-exploitation of natural resources; climate change; and invasive species.

Many people are *directly* dependent on ecosystems for their subsistence and livelihoods, although the exact number of dependent people is difficult to estimate. Lipton [8] estimated that 75% of the world population who live below the poverty line (i.e. 1.2 billion people living on less than US$1 a day) are directly dependent on ecosystems services for their existence.

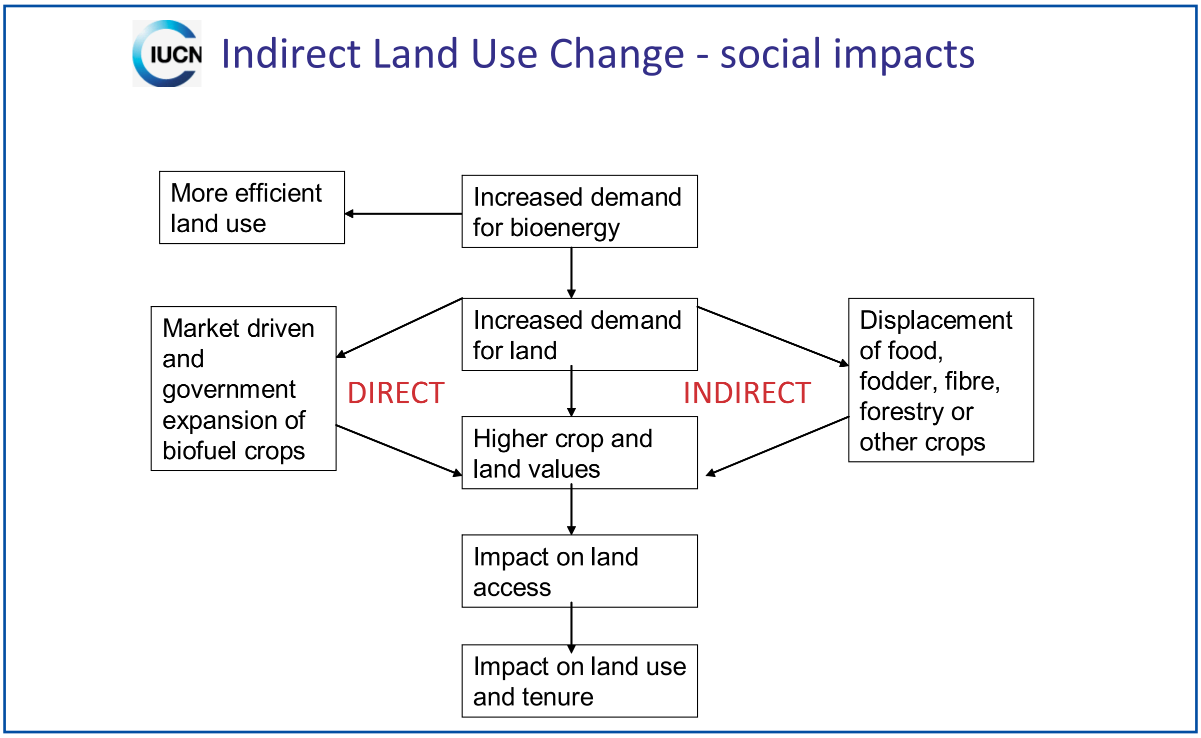

Figure 1. Increased demand for land by biofuel policies impacts on land use and land tenure issues, via both direct and indirect pathways. Courtesy Danielle de Nie, IUCN, the Netherlands. [9]

Furthermore, 2.6 billion people are dependent on traditional forms of biomass (e.g. fuel wood, charcoal) for heating and cooking [10]. This in fact provides a huge opportunity for bioenergy or other sustainable energy solutions. Access to modern energy services could help alleviate poverty and more energy-efficient use of the traditional biomass could provide opportunities to decrease pressure on the resource base of traditional forms of bioenergy, from tropical forest to dry lands.

There is ample evidence that the extra demand for bioenergy cannot be met with intensification of yields alone. The demand for bioenergy, together with the increasing demands for food, feed and fibre will lead to an expansion of arable land. Estimations of how much additional arable land for bioenergy is needed differ a lot. IEA estimates that land requirements under the IEA Alternative Policy scenario will amount to 52.8 million ha in 2030 (compared to 13.8 million ha of arable land in 2004) [11]. Other studies, based on economic model scenarios, estimate land requirements for bioenergy in 2050 as high as 1500 million ha. [12] So the amount of additional land required to meet the demands for bioenergy is unsure, but a significant expansion of the current arable land area should be expected.

To avoid food conflicts and forest conversion, many policies promote the use of 'degraded' or 'idle' land (i.e. the European Directive for the promotion of the use of energy from renewable sources). However, the potential of 'reserve' land, 'marginal', 'degraded', 'underutilised' or 'idle' land may be limited. Land that is 'marginal' in the eyes of an agronomist may not be 'marginal' from a biodiversity or social perspective. The Food and Agriculture Organisation of the United Nations (FAO) and IFPRI (International Food Policy Research Institute) both predict that additional land taken into production for food (even without extra demand for bioenergy feedstock) will take place mainly in South America and Africa [13]. The OECD also mentions South East Asia and the Caribbean as promising regions to deliver large scale biofuel feedstock [14]. So, it is reasonable to expect an increasing demand for land in these regions.

The food price spikes of 2008 demonstrate the impacts that extra demand for biofuel feedstock already has on other markets. While the relative impact that biofuel markets have on commodity and food prices is highly debated, IFPRI found that increased biofuel demand in 2000-07 is estimated to have contributed to 30% of the weighted average increase of cereal prices [15]. One may argue that as food prices go up, poor farmers may benefit from the high prices. This is true if farmers have a surplus to sell to the market and that the higher prices trickle down to this level. However, most subsistence farmers or small holders in developing countries are net food buyers, and suffer from high food prices.

Increasing demands for land coupled with increasing commodity and food prices will lead to higher values of land, which in turn has an effect on land tenure aspects[9] (Figure 1). The value of land is influenced via direct and indirect pathways. As crop production expands there will be additional demand for land to produce biofuel (direct pathway). Indirectly, via displacement, there will be an increased demand for land to produce food, feed, fodder, and fibre. As prices of commodities increase, land values will inevitably increase even further.

Higher land values in turn have an effect on land tenure and land use. Land *use* indicates *what* crop is grown on the land

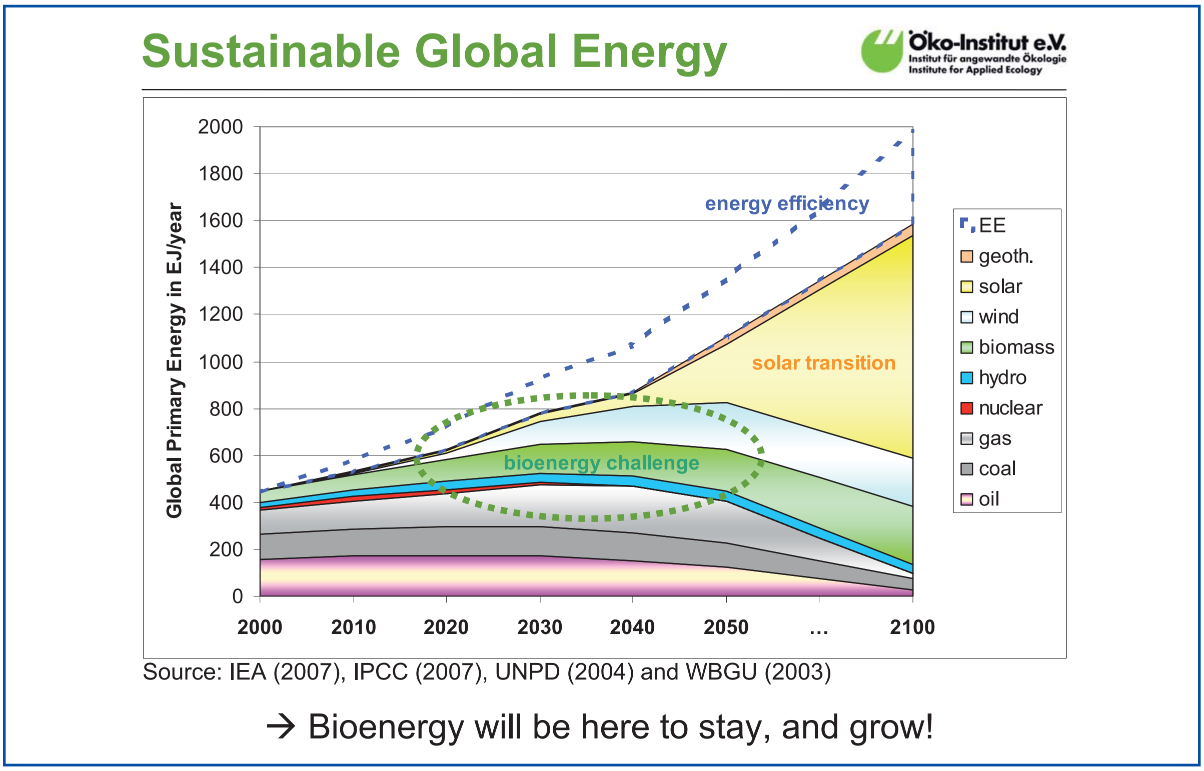

Figure 2. Sustainable Global Energy. Courtesy Uwe R. Fritsche, Oeko-Institute e.V. Germany (see page 12).

and land *tenure* is defined as *who* has access to the land. As land use changes from subsistence farming to cash crop (i.e. for biofuel) the tenure aspects change as well.

Likewise, with higher land and crop values, changes in land access from smallholder farming to large scale biofuel plantations might take place. Local communities who have not formalised their land tenure and land rights aspects are particularly vulnerable to these changes. Indigenous people, whose land rights are not acknowledged by local authorities, belong to this vulnerable group.[9]

Women are often responsible for food production in subsistence livelihoods. In fact women produce 50% of the world's food supply; however, they only own 2% of all the land.[11] When the land use changes from subsistence farming to cash crops, usually men take control over the land [16]. In Africa, 90% of the land remains outside the formal legal system [11], meaning that prior informed consent for large-scale biofuel developments is much harder to attain.

This is not just a theoretical model. In the real world changes are already taking place. Private sector companies have been speculating with high land values and acquiring land overseas. Land values in Brazil have increased 20% on average, but there are some parts of the state of Paraná where land values quadrupled compared to the 2007 prices. European investors have acquired land in West and East Africa for biofuel plantations, and not always with adequate consultation.

Other indirect socio economic effects of biofuels are related to labour and competition for labour. The competition of available labour for producing food and biofuel feedstock may cause subsistence farmers to divert labour from food production to the production of biofuel feedstock. Subsistence farmers, who previously produced crops for their family and community, now produce for external markets. While efficiencies and income may improve, risks are higher when linked to global market mechanisms, to food prices for example. Furthermore, bioenergy projects may cause migration of workers and their families to an area which then increases pressure on available resources (food, water, energy). This can be the case when labour intensive crops are used as a biofuel feedstock, such as *Jatropha curcas*. Other resources, such as water, are impacted by biofuel production as well, which may lead to undesirable situations in which, for example, food and biofuel production compete for the same water resource.

In conclusion, not all bioenergy systems pose equal risks to landscapes and livelihoods. In fact, modern bioenergy systems may provide an opportunity for people currently dependent on traditional forms of bioenergy, by improving the emissions from fuel use and by reducing the time needed to collect fuel. However, with biofuel policies influencing changing patterns of land tenure, social inequality could increase. The world's poorest may become even poorer if they lose their (informal) access to land resources. Much depends on the security of land tenure and social equity prior to the development of bioenergy projects. Clear definitions are urgently needed to define 'marginal' and 'degraded' land. However, to gain insight in social aspects and land tenure aspects, there must be an overall approach. Mitigation of negative indirect effects of bioenergy is going to be a huge challenge, particularly where land tenure is not formalised. Governments, NGOs, the private sector and academia should join forces in facing these challenges.

SESSION 2 – TOOLS AND METHODOLOGIES FOR MONITORING ILUC

Bioenergy and Land Use: Background Drivers, Marginal Effects and Analytical Options – Jan-Erik Petersen, European Environment Agency, Denmark

Jan Erik Petersen emphasised the trade-offs and synergies between food and fuel production. Agriculture is a major source of environmental pressure worldwide, and climate change is a very important environmental and economic threat. There is a great need to develop renewable sources of energy, but this must be seen in the context of global land use trends, especially deforestation and the growing need to provide increasing supplies of food and enable sustainable development. Bringing these factors together leads to a wide range of trade-offs as illustrated in Figure 3.

OECD models estimate that by 2030 there will be a 46-48% increase in global food demand [17]. This will require a 10% increase in world farmland, even allowing for current levels of annual yield improvements. On the other hand, many countries are setting targets for substituting fossil fuels by renewable sources, as shown for biofuels and selected countries in Table 2 (for a more complete overview see Petersen [18]). With an increasingly connected world these national targets interact to create new demand and trade levels for bioenergy products. Minimising negative land use impacts from global biofuel demand will encourage substantial resource investment to develop and suitable sustainability standards and other policy approaches to be implemented, supported by a global governance structure that recognises the interactions between national policies.

Table 2: Biofuel targets for selected major economies (status in April 2008)

Country (group)	Blending target or mandate	Quantity or Share	Target year
Brazil	M	25% ethanol 5% biodiesel	2007 2013
Canada	M	5% ethanol 2% biodiesel	2010 2012
China	T	15% of fuel for transportation	2020
EU-27	T	10% of transport fuel	2020
India	M	10% ethanol 5% biodiesel	2008 2012
Japan	T	6 billion litres	2020
USA	M	134 billion litres	2022

One important aspect of analysing the land use effects of biofuel targets links to identifying so called 'marginal effects' and the consideration of questions like 'Which land use or biomass use is the marginal factor?'. How can we best estimate the marginal effects of additional increments in food consumption or biofuel demand? Modelling marginal effects requires us to hold everything else constant, whereas in reality many factors are changing (for example global food demand). It is therefore very difficult to cope with these single and combined marginal effects. Nevertheless, it becomes clear that analysing the marginal effects of single country targets provides only a partial picture of global effects.

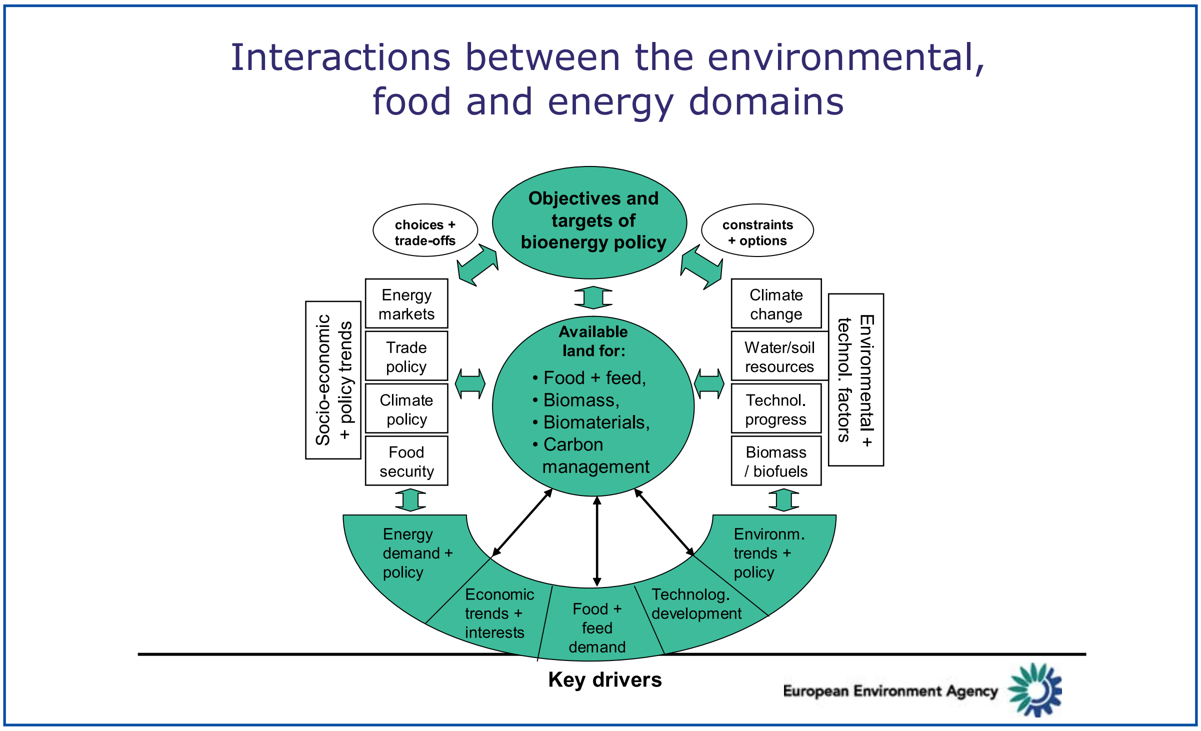

Figure 3. Drivers, constraints and trade-offs associated with bioenergy production. Courtesy Jan-Erik Petersen, European Environment Agency, Denmark.

Agricultural land use change and land use intensity is a key environmental issue, and marginal effects are important here too. For example increasing productivity by increasing inputs raises the risk of nutrient leaching or increased N_2O emissions. Choices between different energy crops and management approaches have a critical influence on the overall environmental impact of energy cropping and can provide opportunities for improving environmental management. As in other areas however, the preservation of critical natural capital requires a precautionary approach.

A number of tools are available to analyse the impacts of increasing levels of bioenergy production. These include life cycle analysis, agro-economic modelling, satellite and field observations, and scenario analysis. But each of these has some weaknesses as Table 3 below shows.

Table 3: Comparing methodological approaches

Tool	Weakness
Life cycle analysis	Copes poorly with indirect land–use change effects
Agro-economic modelling	Environmental impacts are generally not covered
Satellite and field observations	Hard to link back to economic drivers
Scenario analysis	Results very much depend on assumptions and choice of system boundaries

Developing the appropriate tools for analysing the multiple impacts of bioenergy production therefore poses some significant and critical science issues. These include:

- Development of integrated assessment frameworks.
- Increased awareness of the impact of system boundaries (spatial and time scales, alternative land uses, policy areas affected).
- Linking agro-economic and land use models with energy and general equilibrium models to analyse the interactions between different economic and policy domains.
- Analysis of policy options for steering bioenergy production (including sustainability criteria, carbon trading and taxes, support for research and technology development, rural, regional, and international development tools).
- Transfer from a global to a local governance structure with the associated knowledge transfer.

In order to facilitate these developments, there will need to be significant public investment in a number of measures which include:

- Development of suitable global data sets on land use and farming systems.
- Consideration of the interactive impact of national policies on global resources.
- The creation of global mechanisms for review and management of resources.
- The creation and maintenance of sufficient capacity for integrated analysis, in terms of both inter-disciplinary knowledge and manpower.
- Knowledge transfer and extension to producers.

Investment in this work will be essential to the development of a better basis for policy decisions and for successfully implementing policy measures for ensuring the environmental sustainability of biofuel production.

Evaluating the Impacts of Indirect Land Use Change – Bas Eickhout, Netherlands Environmental Assessment Agency, the Netherlands

Bas Eickhout drew attention to the fact that any increase in demand for biofuels must be seen in the context of likely increases in demand for food, feed and forestry. The implications of these increases in demand for land use can be complex. Direct impacts of land use change can be addressed by sustainability criteria (as being developed as part of the EU directive on renewables). However the possible displacement of existing or future agriculture is not addressed by the current criteria. Competition for natural resources is likely to have an impact on prices.

The sustainability criteria, recognised for example by the Cramer Commission include: GHG balance; biodiversity; competition with food; environment (soil, water, air); welfare; and wellbeing (social effects). Most of these aspects are included in the developing European policies, but only apply to the feedstock production aspects of biofuels, not to the complete cycle.

So far, the science of land use change is not sufficiently developed to fully assess the potential size of indirect effects, and so many existing studies assume no indirect impacts. Many agro-economic studies do not consider sustainability criteria, and handle land use issues poorly. However the IMAGE model has been used to calculate the long term potentials for bioenergy in a range of energy scenarios.

Monitoring of macro impacts of changes in land use is a very important topic, and is given high priority by the Dutch Ministry of Environment. Biophysical monitoring is of great importance. Satellite monitoring can provide good evidence of changes in land cover, but this is not the same thing as changes in land use. When reliable, national statistics are the most important source of information – FAO statistics being the primary source of such information. Very few statistics on water use are available.

As far as the carbon emissions aspects are concerned the analysis is difficult because there are large uncertainties in land use emissions. Using UNFCCC initiatives is a logical approach, although data for non-Annex I countries are scarce. Biodiversity is another very important factor, but the definition is unclear and there is very little data, and what exists is not very up-to-date (for example the Red List of endangered species).

So overall the situation is that while a lot of data is available at the national level, the reliability and quality is often questionable. A balanced overall picture is only possible by using a combination of information from national statistics and local knowledge, which can usefully be supplemented by local radar images. At present the impacts on water use and biodiversity remain uncertain.

As far as socio-economic monitoring is concerned, national statistics are available via FAO and the IEA, who provide data on volumes, prices, the level of trade and productivity of biofuel production. However for specific data on bioenergy additional sources are still needed. Examples include the Global Bioenergy Partnership (GBEP), commercial sources like F.O. Licht and country-specific data (e.g. for USA). In the socio-economic area too, analyses at the country level are necessary to assess the impact of bioenergy. Examples are available for instance from the Copernicus Institute. Information on societal consequences is not available on a global basis, and analysis is therefore heavily dependent on case study material. Most of these case studies are from Brazil, with few other examples.

While these data need to be improved, their improvement will not in itself be sufficient for a thorough analysis. Appropriate models are also necessary since causality and valuation questions both require the development of a model-based, scenario-oriented approach, in cooperation with producer countries, including multi-stakeholder dialogues.

Ideal bioenergy models would be able to answer the following questions associated with an increase in bioenergy production:

- What are the impacts of blending obligations?
- What is the effect on availability and prices of other commodities?
- What are the land use consequences?
- What happens to the GHG balance?

Currently ideal models are not available since most economic models have been ignoring land use issues. Biophysical models, on the other hand are poor at capturing economic mechanisms, although they can capture impacts on land use, GHG balance and biodiversity. See Figure 4 below.

In order to run the model, an assumption about a land supply curve must be made; with production costs rising as land quality falls. However such an analysis does not take into account sustainability criteria. The land supply curve can be adjusted to reflect the social and environmental costs of using land which is sensitive. To do this properly a detailed analysis at a regional level is required but the information to facilitate this is not yet available.

Ideally a combination of three approaches is needed:

- Global CGE model to assess global impacts, by addressing trade issues and impacts on economy.
- Global integrated assessment model to assess impacts on GHG balance and biodiversity.
- A regional partial equilibrium model to assess agricultural opportunities and impacts.

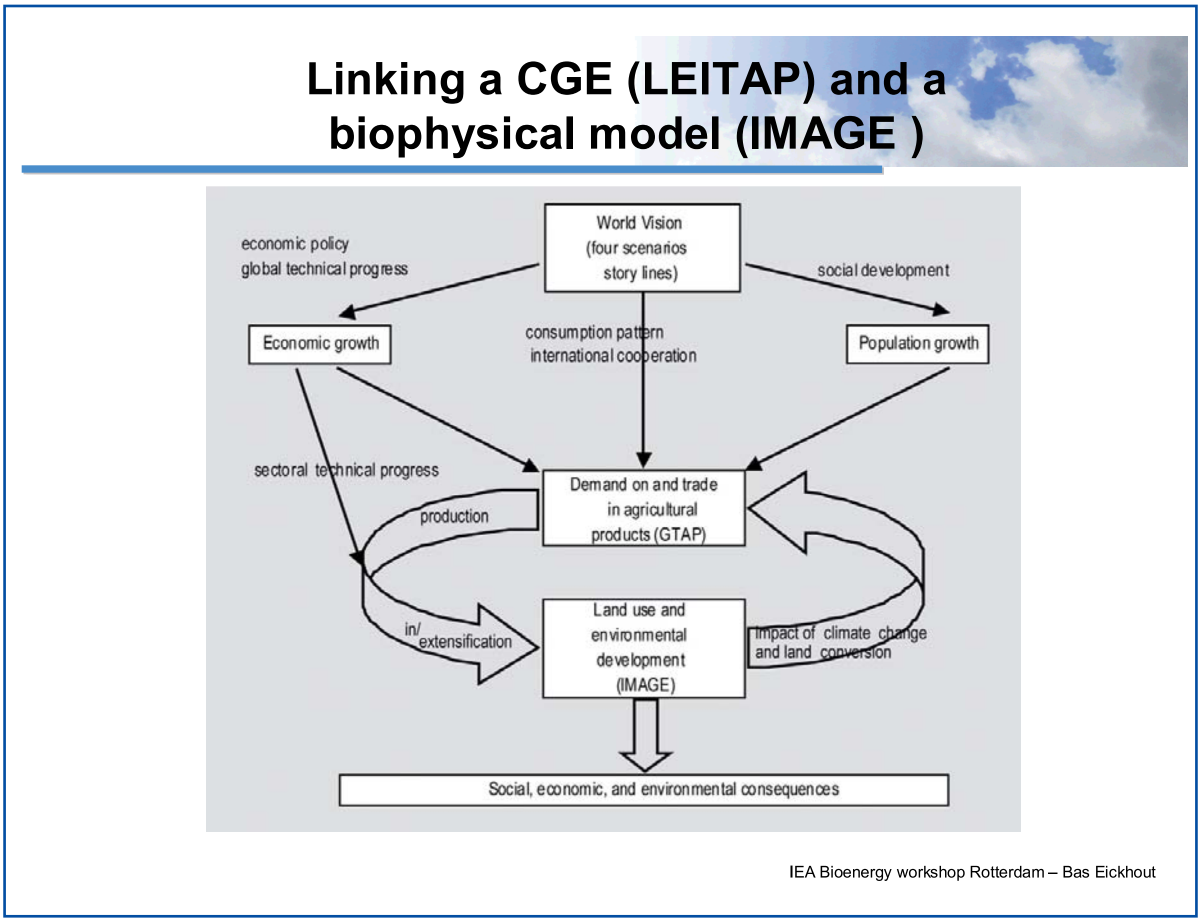

Figure 4. An example of how biophysical and economic models can be linked. Courtesy Bas Eickhout, Netherlands Environmental Agency, the Netherlands.

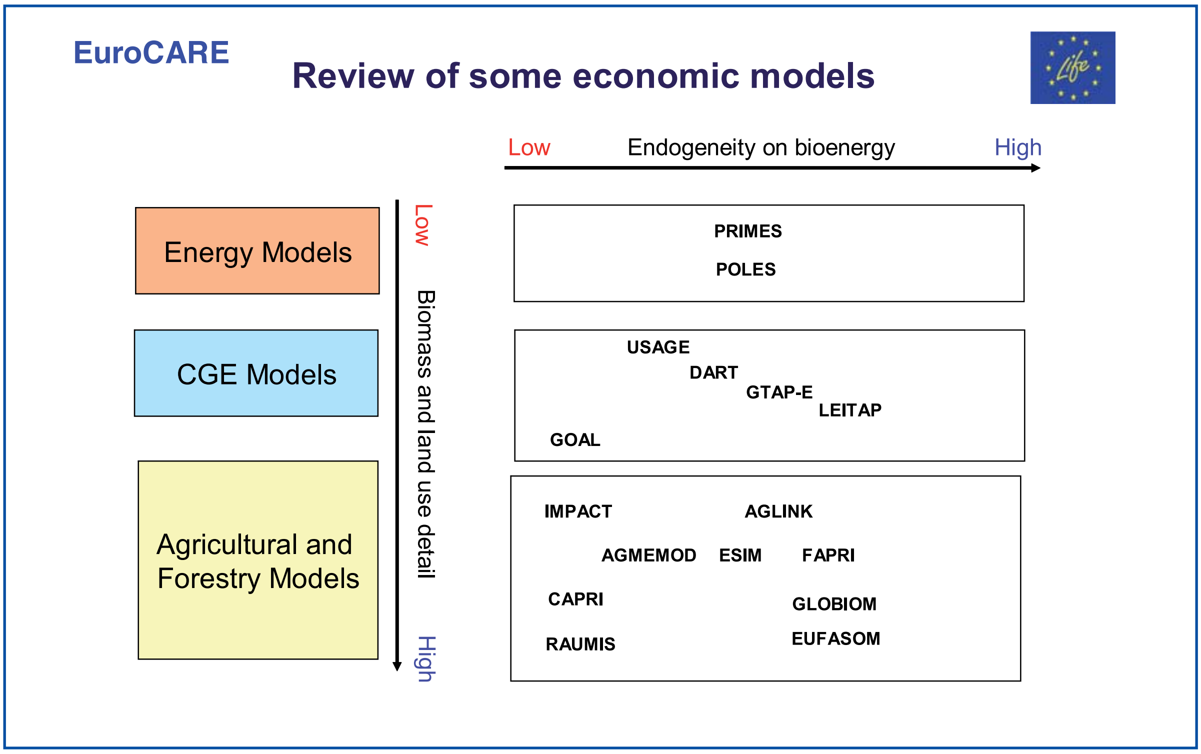

Figure 5. Review of some economic models. Courtesy Peter Witzke, EuroCare, Germany.

Comparison of Available Modelling Approaches for Indirect Land Use Change Assessments Related to Biofuels – Peter Witzke, EuroCARE, Germany

Peter Witzke briefly reviewed some potential ways in which a higher demand for biodiesel in the EU could trigger indirect land use change. He emphasised the importance of looking at the situation with a global perspective; these needs should be included in the development of modelling tools if they are to be useful.

Another important challenge for modelling efforts related to biofuels is the multitude of policies potentially impacting on the sector. In the EU this originates from:

- the Common Agricultural Policy which influences the competitiveness of feedstock crops;
- regional and structural policies offering investment aid of various forms;
- energy policy steering the competitiveness of biofuels against conventional fuels; and
- trade policies interfering with trade in feedstocks and biofuels.

Only a subset of modelling tools is capable of explicitly depicting the impact of these separate policies on incentives for the use or production of biofuels. These are systems that permit an endogenous representation of supply and demand side behaviour. Many modelling systems use a shortcut for the policy representation which assumes that all policies can be aggregated into one technical instrument such as a mandatory quantity target or a carbon price applied to agriculture.

Existing models can be classified in two dimensions: the degree of endogeneity or explicitness in the representation of behaviour, as mentioned above, and the focus on biomass production and hence land use issues.

A first cluster of models are energy models such as the European models PRIMES or POLES. These offer great detail and care in the treatment of the energy economy but typically represent biomass production in only a simplified form (using independent supply functions), such that their contribution to ILUC modelling is very limited (if they offer global scope at all).

The second cluster of models (CGE models) often relies on the GTAP database in order to provide the global coverage which is essential. Models which have a strong focus on agriculture (like LEITAP and some other variants of GTAP-E) are the most promising for an analysis of ILUC problems. The incorporation of Agro-Ecological Zones (AEZ) and detailed treatment of by-products has significantly enhanced the capabilities of GTAP versions used on this area. Models without an agricultural focus (like DART (Klepper, Petersen) or USAGE (Dixon, Rimmer) and those without global coverage (like GOAL, Gohin) will give only limited insight on ILUC.

The third cluster of models combines various partial equilibrium models, which typically offer greater detail for biomass production and land use than CGEs. However, most partial equilibrium models only have an implicit policy representation. This still allows the global implications of global biofuel policies on agriculture and land use change to be worked out, such as in the well-publicised work by IFPRI with the IMPACT model. Notable exceptions with an explicit treatment of biofuel policies have been developed at the OECD (AGLINK) and FAPRI with some others following like ESIM.

The partial equilibrium cluster combines the subset based on behavioural equations for agriculture and the subset of programming models with an explicit objective function. Examples include large LPs like FASOM, EUFSOM or

GLOBIOM which provide for strong disaggregation of technologies and regions to cope with the specialisation tendencies of LPs, along with models from the NLP class, like the German models RAUMIS (VTI, Braunschweig) and CAPRI (U Bonn). So far only GLOBIOM seems to meet the criterion of global land use coverage.

There are a number of critical issues. The first is the definition of 'available area' which may crucially determine the outcome and so deserves detailed scrutiny. The second is the calibration problem, when statistical time series are short or non-existing (for example for second generation technologies). The third issue, which is well known to experts, is the difficulty of estimating yield elasticity when observed yield changes are the combined result of changes in technology, industry structure, incentives, and regional aggregation effects, when feedstock production is expanding to less suitable land. The fourth issue is both a solution and a problem. Linkage of models can be a solution if specific advantages of models can be exploited, such as in the interactions of LEITAP, IMAGE and CLUES, or GTAP and CAPRI. However this also creates some difficulties if consistency in model applications is to be ensured.

In concluding, Peter Witzke pointed out the importance of reliable statistical data required to produce worthwhile modelling results, and the increasing complexity of models, as more and more aspects and details need to be integrated.

SESSION 3 – ASSESSING THE IMPACTS OF ILUC

Assessing Land Uses and Possible Sustainable Transition Paths to Biofuels Development – Richard Nelson, Kansas State University, USA

Bioenergy/biofuel feedstocks such as grains, cellulose, and oils are gaining increased attention as a means of providing clean energy that can potentially help offset future energy demands. Bioenergy/biofuel resource production almost always requires a land base. That land will provide services relating to energy, food, feed and fibre production, agronomic and environmental quality, and agricultural and economic markets. Which services are displaced will have a definite impact on how the 'sustainability' of bioenergy production and trade is perceived and estimated or determined.

The US Energy Independence and Security Act (EISA) of 2007 established goals for consumption of biofuels and calls for a total of 36 billion gallons per year of biofuels in the marketplace by 2022. In addition, advanced biofuels, such as those derived from cellulose and oilseed crops, must establish their ability to reduce greenhouse gas (GHG) emissions, including allowances for indirect land use relative to their petroleum alternatives, by at least 50%. Other countries also have similar energy and environmental goals for renewable energy and biofuels production.

The US EISA requirement of 21 billion gallons per year of renewable fuel from cellulosic and other advanced biofuels means:

- the sustainable use of resources generated on conventional cropland (e.g. residues) needs to be addressed; and
- expansion onto at least some portions/percentages of agricultural land bases other than conventional cropland will probably be needed for bioenergy feedstock production.

The agricultural sector definitely has a large role to play in helping meet the world's energy and economic security goals and maintaining or enhancing environmental quality. Cropland already contributes to world biofuel production and other non-bioenergy feedstocks. Rangeland, pastureland, grassland, and scrubland (some of which are defined as 'marginal' or degraded acreages) may possibly be able to support some bioenergy feedstock production systems.

However, use of lands not previously utilised for bioenergy production has not been rigorously evaluated from an agronomic, energy, and environmental perspective in order to assess their ability to provide a sustainable base for bioenergy feedstock production. Quantitative and qualitative assessments involving resource type and geoclimatic parameters, net energy returns, water and soil impacts and supply (quantities at specific costs) associated with each individual biomass resource at the local level, are critical to optimising global production and more importantly 'sustainability' with respect to bioenergy production.

The following issues must specifically be evaluated when considering expansion of all biofuels on a global scale.

- *Agronomic:* The type of land base utilised for production of dedicated energy crops or for collection of residues is extremely important in establishing correct resource assessments and supplies. The amount of soil erosion and change in soil tilth, including carbon content, that an agricultural land base experiences is a function of many factors: type of crop, rotation where applicable, field management practices (tillage), timing of field management operations, physical characteristics of the soil type (soil erodibility, % slope), and localised climate (rainfall, wind, temperature, solar radiation, etc.). Previous research has emphasised both the importance of these parameters and the sustainable biomass development for both agricultural crop residue removal as well as herbaceous energy crop development[19,20]. The variation in biomass crop yields due to local geo-climatic variability is also extremely important and will drive localised biofuel production economics.

- *Energy:* Each potential cellulosic bioenergy generation or production scenario has different direct and indirect (embodied) energy requirements. Direct energies such as diesel fuel consumption relate to in-field planting and establishment, maintenance (herbicides, pesticides and fertiliser application) and harvesting and collection. Indirect energies involve the energy required to manufacture all herbicides, pesticides and fertilisers needed for optimal crop growth as well as seed production. Energy analyses, which go directly to the 'renewability' of the biofuel, must accurately estimate and quantify direct and embodied energies and their associated carbon dioxide discharges created by in-field biofuel production or collection.

- *Environmental:* Land bases appropriate to both residue removal and collection and dedicated energy crop production should be at least partially defined by parameters/values obtained from the earlier agronomic section. In addition, water consumption, efficiency of use, nitrogen, phosphorus, potassium, and lime use and their associated water quality impacts will vary across all geoclimatic areas and by crop type. These are as important from an economic perspective as well. Bioenergy crops such as photoperiod sorghums and sweet sorghum, which require less water and fertiliser than other conventional commodity crops, may hold environmental and energy use promise, especially on marginal acreages with minimal rainfall and degraded soils.

The following are some areas that would benefit from further research with respect to land use optimisation and biofuel production.

- Agronomic/environmental parameters should be strongly considered, evaluated, and used to assess/evaluate bioenergy systems and sustainable production considering:
  - soil erosion and tilth;
  - carbon sequestration and release potential;
  - water use and retention; and
  - nutrient requirements and replenishment, and land classification(s).

- Definitions of what constitutes marginal lands using accepted and applicable national prominent geoclimatic parameters (agronomic and environmental) should be determined and researched. A working definition of 'marginal lands' should be provided in consultation with other prominent national and international agencies, and the area of marginal lands should be determined by individual region.

- The water use and supply parameters and requirements for possible candidate bioenergy feedstocks that can be produced on a large-scale should be estimated.

Expanding biofuel production is a must to help meet global demands for clean and alternate energy sources. Use of under-utilised land bases could be key to expanding the supply of bioenergy feedstocks. However, quantitative and qualitative bioenergy feedstock assessments must involve correct evaluation of all resource types and geoclimatic parameters, net energy returns, water and soil impacts, and supply (quantities at specific costs). This must be done in a logical and sustainable manner which promotes long-term soil and water sustainability. In addition, yield improvements in all crops are extremely important as they may be able to offset expansion onto lands currently used for food, feed, and/or fibre production.

The Indirect Land Use Change Factor: A Simplified Approach to Assess GHG Implications of Indirect Land Use Change from Bioenergy – Uwe R. Fritsche, Oeko-Institut e.V., Germany

The term 'indirect land use change' (ILUC) refers to the potential effects which may be caused by cultivating biomass (for bioenergy, biofuels, or biomaterials) on land which previously was used for the production of, e.g. feed, food or fibre. The previous use is displaced by the new biomass cultivation. It can be reasonably assumed that the demand for feed, food or fibre formerly produced remains unchanged, the displaced production would 'move' to somewhere else where land areas may have high carbon stocks (e.g. forests) which are reduced if used for cultivating the displaced production, thus causing CO_2 emissions. These potential CO_2 emissions are indirectly caused by the biomass cultivation which displaced the former use[a] . The CO_2 balance of ILUC corresponds to that of DLUC, but the question is which areas are concerned. Since displacement may not only take place within a country, but also outside the original country due to global trade, ILUC effects can only be allocated to biomass cultivation through models.

Therefore, it is impossible to 'monitor' indirect effects. LUC can be detected in a given area or even globally, but, as this LUC can have many causes, it is not possible to relate this occurrence to one specific driver or location.

An Issue of Perspective: Displacement is a problem of truncated system boundaries, i.e. an issue of scope. Today's accounting of GHG balances of biofuels is done with partial analysis (involving only biofuels, with no explicit modelling of the agro- and forestry sectors, or other land uses). This results in all LUC occurring outside of the scope – being 'indirect'. Hence, ILUC is a construct, and <u>all</u> incremental land uses imply indirect effects unless the scope is widened to all drivers, and all land uses.

The ILUC factor approach: As a deterministic and simplified approach to quantify potential release of CO_2 from LUC caused by displacement, the ILUC factor was developed by Oeko-Institut in 2007. As displacement 'works' along trade flows, shares of displaced land were derived from land used for key agro-exports using 2005 yields from FAO data.

To derive average impacts, explicit assumptions were made about which DLUC is likely and whereabouts (e.g. grassland to maize in EU and US). IPPC-based DLUC emission factors coupled with regional land use shares for each agro commodity were used. From that, the average CO_2 emissions per hectare of displaced land is derived and discounted over 20 years, which gives 20 t CO_2/ha/yr as the theoretical global average ILUC factor if all land used for biofuels would induce displacement risk. The real risk is lower, though, bearing in mind that set-aside or abandoned land may be used, and intensification of production (higher yields) reduces ILUC.

Current work on the ILUC factor concerns an update of the 2005 data to a 2010 estimate, and refining the LUC characteristics of displacement using historic data for agricultural land expansion (1980-2000) derived by Holly Gibbs (Standford University). Furthermore, the concept of 'ILUC risk mapping' will be further worked out to identify the countries and regions under most threat from ILUC. For this, CGE model results (e.g. GTAP) will be coupled with spatially explicit suitability and carbon maps, and infrastructure data. This will be based on country studies carried out in Brazil, China, India, and South Africa[b] . In parallel, research will be carried out with UNEP and FAO in the context of GBEP. This will include developing countries views[c] to derive policy

[a] Note that besides CO_2, indirect land use change might negatively affect biodiversity if displaced production moves into biodiversity-rich areas.

[b] First results will be presented at the 2nd Joint International Workshop on Bioenergy, Biodiversity Mapping and Degraded Lands to be held July 7-8, 2009 at UNEP in Paris

[c] See for details: Summary of the GBEP Workshop on Indirect Land Use Change: Status of and Perspectives on Science-Based Policies; held May 15, 2009 in New York http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/2009_events/Workshop_ILUC_NY_15May_2009/GBEP_ILUC_workshop_-_Summary.pdf

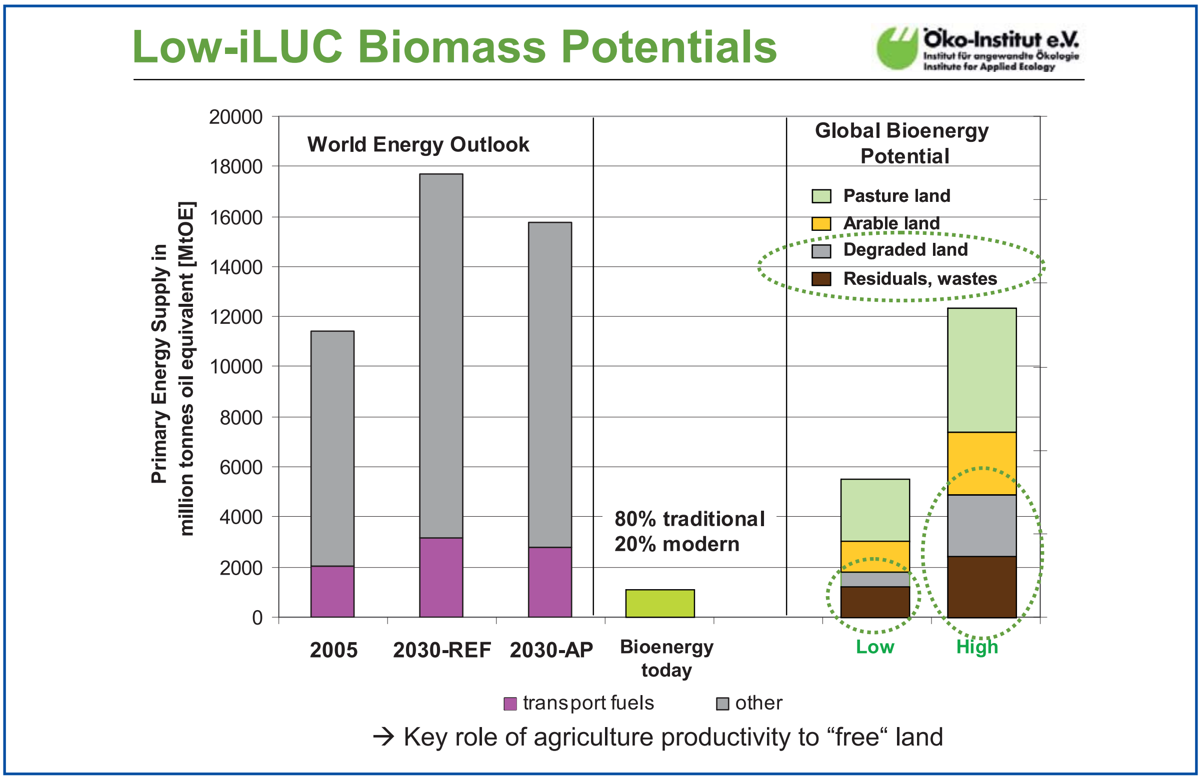

Figure 6. Low-ILUC biomass potentials. Courtesy Uwe R. Fritsche, Oeko-Institute e.V. Germany.

options for reducing ILUC risks through sourcing priorities favouring low-ILUC biomass feedstocks, and developing project-based offsets. In addition, the formation of an 'investor alliance' for sustainable supply; bundling investment in degraded land and respective infrastructure 'overhead' will be supported based on country study results.

The principal conclusions are:

- Indirect LUC is an artefact of restricted systems boundaries, and may be created by any incremental land use – if the biomass cultivation is used for electricity, heat, transport, biomaterials, food, feed, or fibre, or if other land used displaces previous production.
- Modelling ILUC is possible to some degree, and simplified approaches such as the ILUC factor allow identifying the order of magnitude of potential effects.
- Mapping of degraded land could provide a basis for incentivising its use to produce low-ILUC risk biomass, but this would be at higher cost. Incentives are therefore needed, along with biodiversity and social safeguards for developing degraded land.

In the long-term, ILUC could be reduced to zero if the global conventions could fully cover all land use and biomass markets. In principle, the UN Conventions on Climate Change and on Biodiversity, as well as their protocols, could be developed further. Potentially negative consequences of indirect land use changes on climate protection and biodiversity would be generally avoided if the scope of CO_2 emission caps also included carbon from any land use change, and all biodiversity-relevant areas were protected.

Indirect Land Use Change in the Bioenergy Sector: A View from Brazil – Emmanuel Desplechin, Brazilian Sugarcane Industry Association (UNICA), Brazil

In Brazil, sugarcane is the basic input not only for producing sugar but also for an incredibly diverse range of value-added products, particularly ethanol to power cars, breaking the stranglehold of fossil fuels on society and reducing GHG emissions.

Currently, ethanol consumption in Brazil exceeds the use of gasoline. Ethanol is consumed in two ways: blended into gasoline (25% mandatory blend) and directly in Flex-Fuel Vehicles, which can run on pure ethanol or petrol, or any mix of the two. This gives consumers the possibility to choose the fuel they want. These Flex-Fuel Vehicles today account for almost 90% of the sales of new cars. More than 50% of the gasoline consumption has been replaced with ethanol, using only 1% of Brazilian arable land. 88% of all the sugarcane grown is harvested in the South-Central region while the remaining 12% comes from the northeast coast. Both areas are 2,500 km away from the Amazon rainforest (a distance equivalent to Paris/Moscow).

Looking at the net growth in agricultural land use in the Centre-South of Brazil (the main agricultural production area), between 2002 and 2006 [21], the land used for sugarcane increased by 949,000 ha, while the land for other crops increased by 3,226,000 ha. The expansion of these agricultural crops mainly took place on pasture lands (which decreased by almost 6 million ha, because of the intensification of livestock production), with almost 2 million ha of land released left over.

On the projected expansion of land allocation for sugarcane cane, grains and pastures between 2008 and 2018 [21], foresee a net increase of 380,000 ha in occupied land which is not sugarcane, nor grains nor pastures. This land, which would account for 0.1% of the whole country, can be planted with forests, for citrus, tobacco, native vegetation, etc. but not necessarily sensitive biomes such as the Amazon rainforest, the Atlantic forest or the Pantanal. If expansion takes place onto the cerrado, it should be noted that there are eight types of cerrado, from '*denso*' to '*campo sujo*', the latter being a type of pasture with a very low level of biodiversity. Finally, the 380,000 ha increase in occupied land in 10 years should be compared with the 1,500,000 ha of deforested land per year.

Comparing the increased area dedicated to sugarcane with the annual deforestation rate in the Legal Amazon clearly shows that the two activities are unrelated. The main drivers for deforestation lie in a combination of poorly structured policies, lack of resources, poverty and lack of environmental education, etc.

ILUC is now in the public debate and is being introduced in major regulatory initiatives, amongst which are the CARB Low Carbon Fuel Standard, and the EPA rules for the implementation of the Renewable Fuel Standard. The European Union Renewable Energy Sources Directives asks for the European Commission to analyse '*ILUC in relation to all production pathways* and submit by the end of 2010 *a report reviewing its impact and address ways to minimise this impact'*. However, in the absence of a sound and globally accepted methodology to assess potential emissions caused by ILUC, what are the best regulatory responses to tackle a phenomenon whose magnitude and importance is yet unknown?

Computable General Equilibrium (CGE) models have severe limitations. CGE models can provide indications of changes from simulated scenarios, identify the best and worst cases and rank results. They can also give an idea about the magnitude or relative scale of the impacts and track or explain the economic reasons leading to the results. However, because they take given world economic conditions, they cannot respond to the changing environment, shifts in policies, increased productivities, use of degraded, marginal or idle lands, etc. In addition, for these models to be run properly, accurate data must be put into the model. The best data available are not necessarily used because they are not easily available or for simplification purposes they are replaced in the model by macro data, which adds to the uncertainty of the outcome. Small changes in input parameters can lead to large errors, and the more complex the model, the less accurate the results[d]. This explains why modellers usually avoid putting too much weight or credence on precise numbers.

CGE models are therefore inadequate for policy recommendations. Current predictive models do not define responsibilities, and are of little use to the industry which cannot use them to inform best management practice. They are uncertain and difficult to use for policymakers, since they are very sensitive to assumptions. The temptation for policymakers to use CGE models to define a penalty to be included in the calculation of emissions from crops for biofuels is at best speculative and at worst legally questionable. For example, applying the same penalty for all biofuels made from crops grown on arable land, independent of feedstock and production pathways, as it had been considered by the European Parliament in 2008, would disqualify all existing biofuels as they would not meet the GHG efficiency thresholds set in the legislation.

In UNICA's view:

- All assessments of carbon emissions caused by ILUC should be based on sound and empirical science. International co-operation, involving researchers and scientists from countries where crops for biofuels are produced, is absolutely critical and indispensable in order to get the best available data, and also to capture the local drivers of land use change. So the need is to develop globally harmonised methodologies to assess ILUC.
- The introduction of any penalty, based on current available methodology, would not reduce ILUC but simply disqualify all existing biofuels production realised on arable land. In addition a penalty would not allow producers to minimise ILUC by implementing best management practices.
- Because ILUC can only be tackled by public policies, regulators should collaborate at the global level in order to:
  - Implement consistent policies to fight deforestation.
  - Encourage land use planning - such as the agro-ecological zoning to be released in Brazil and the use of land which is both available and suitable for crops for biofuels without displacing other crops.
  - Promote biofuels with high environmental (GHG) performances and high productivity.

SESSION 4 – POLICY APPROACHES WHICH TAKE ACCOUNT OF ILUC

Ensuring that Biofuels Deliver on their Promise of Sustainability – Charlotte Opal, Roundtable for Sustainable Biofuels, EPFL, Switzerland

The Roundtable on Sustainable Biofuels (RSB) is an international multi-stakeholder initiative drafting standards for sustainable biofuels through an open and consultative process. In August 2008, the RSB released 'Version Zero' of a global sustainability standard for biofuels, the result of 12 months of stakeholder consultation. Since that time, nearly 900 organisations and individuals from forty countries have given feedback on Version Zero through in-person regional stakeholder meetings, the Bioenergy Wiki, and directly to the RSB Secretariat at the Energy Center at the Swiss Federal Institute of Technology in Lausanne, Switzerland (EPFL).

Version Zero encompasses the major environmental, social, and economic risks and opportunities of biofuels production and processing. The major potential *direct* effects outlined in Version Zero include impacts on soil, water, and air quality; biodiversity; and workers and communities. The major potential negative *indirect* effects identified include

[d] UNICA's letter to CARB showed how unrealistic assumptions give greatly different outcomes. ***http://www.arb.ca.gov/lists/lcfs09/129-unica_comments_to_carb_on_sugarcane_ethanol.pdf***

loss of stored carbon and biodiversity through displacing feed, food, and fibre production into areas not already used for agriculture, and macroeconomic impacts on food prices leading to decreased food security for the world's poor.

Using lands that do not compete with feed, food, and fibre production, however, would have no indirect impacts on land use change or food prices. And certain projects might even affect these variables in positive ways, if new biomass is gained from lands already in production (e.g. through harvesting winter cover crops, by using crop residues without compromising soil quality, or by increasing yields) and/or
by restoring lands that have been degraded to a more productive state.

The RSB's new governance structure has discussed introducing an incentive policy to encourage those types of land use and productive activities that have fewer potential negative indirect impacts. Many problems exist with the definitions of waste (even something with little economic value might have an alternative use – diverting it from this use would still be an 'indirect effect') and 'degraded' or 'idle' land, as well as with identifying true yield improvements. There are also potentially broader definitions of 'low-risk for indirect impact' biofuels, based on optimal use of co-products. The RSB stakeholders feel that it is too soon to introduce an incentive policy in the short-term, but hope to continue to drive scientific consensus on this issue so as to be able to introduce such a policy in the near future[e].

Legislation on Indirect Land Use Change: An EU Perspective – Paul Hodson, European Commission, Belgium

In his presentation Paul Hodson outlined the EU legislative framework, reviewed the impact of indirect land use change on greenhouse gas emissions, and addressed ways to minimise that impact.

The Renewable Energy Directive (directive 2009/28) sets a binding target for a 20% overall share of energy from renewable sources by 2020, along with a 10% binding target for renewable energy in transport. It establishes a sustainability scheme for qualifying biofuels and bio-liquids which includes a minimum rate of GHG saving of 35%, rising to 50% in 2017, and to 60% for new installations in 2018, along with rules for calculating GHG impact and restrictions on land from which biomass may come.

In addition the Fuel Quality Directive (directive 2009/33) sets a 6% binding target for reduction in unit GHG emissions from road transport by 2020. It also includes sustainability requirements for biofuels (identical to those in the Renewable Energy Directive).

The legislation also requires some further work, including a report and possible legislative proposal on extending the sustainability requirements to all bioenergy (by December 2009), and a report and possible legislative proposal on ILUC by December 2010 – the Commission Services aim is to deliver this report in March 2010. Specifically the EU legislative requirement on indirect land use change:

'The Commission shall, by 31 December 2010, submit a report to the European Parliament and to the Council reviewing the impact of indirect land use change on greenhouse gas emissions and addressing ways to minimise that impact. The report shall, if appropriate, be accompanied, by a proposal, based on the best available scientific evidence, containing a concrete methodology for emissions from carbon stock changes caused by indirect land use changes, ensuring compliance with this Directive, in particular Article 17(2). Such a proposal shall include the necessary safeguards to provide certainty for investment undertaken before that methodology is applied... The European Parliament and the Council shall endeavour to decide, by 31 December 2012, on any such proposal submitted by the Commission.' (Renewable Energy Directive, Article 19(6); equivalent provisions in Fuel Quality Directive)

A programme of analytical work is under way in the Commission which includes: CGE modelling (CEPII/IFPRI, using GTAP); PE modelling; and retrospective analysis.

Some of the important issues to address in this analytical work include:

- The need for proper modelling of co-products, which can be very significant, particularly in the European context.

- The need to model the full range of land types including:
  - recently abandoned agricultural land;
  - recently deforested land; and
  - peat land.

- The need for a convincing story about land conversion. For example according to the EPA, 27% of the land converted to arable in the EU between 2001- 2004 came from forest. What land is this?

- The EU scheme includes restrictions on the land from which biofuel can come (by excluding forest, wetland, peat land etc.). There are comparable restrictions within the US EISA. Will these restrictions make any difference (e.g. through a premium price), and if so how can this be modelled. If such provisions are ineffective, what is their point?

Policy options under examination include an indirect land use change 'factor' in the greenhouse gas calculation methodology. This does, however, raise some issues:

- Imagine we attribute a GHG impact to all the goods a supermarket sells (not only the fuel). If we use the 'factor' approach, the total amount of land use change attributed to all goods will far exceed the real amount. Can this be justified?

- If we respond by attributing the factor only to 'new' demands, how do we deal with biofuels that are 'in the baseline'? Can such biofuels be identified? Should they be exempted?

[e] For more information about the RSB, please visit http://EnergyCenter.epfl.ch/Biofuels .

- Where crops replace forest, the quantity of crops (aggregated over 20 years) is generally less than the quantity of timber (at least, by energy value). Can we justify attributing all the carbon stock loss to the crops?

- The introduction of a GHG factor will probably lead to more biofuel (to fulfil the Fuel Quality Directive target) and could lead to more indirect land use change. Is this desired?

- Part of the solution to the problem of indirect land use change is to encourage yield improvements. Under an indirect land use change factor, how can we avoid penalising farmers who improve yields?

Alternatives to the 'factor' approach are also being considered. These include:
- One product's 'indirect land use change' is another product's 'direct land use change'. Can this gap be addressed for other products?

- Would a higher 'cushion' (minimum GHG saving) for biofuels and bio liquids be effective?

- Could 'bonuses' be included in the GHG calculation for biofuels and bio liquids that avoid damaging land use change?

- Could additional sustainability requirements be applied to biofuels from crops/locations systematically associated with damaging land use change (e.g. requirement to show avoidance of this damage)?

The next steps in developing the approach will involve consultation on policy options and analytical approaches.

The Californian Low Carbon Fuel Standard and Indirect Land Use Change – John Courtis, Air Resources Board, California, USA

In California, greenhouse gas emissions of some 169 million tonnes are required to meet the 2020 target of stabilising GHG emissions at 1990 levels, and then to meet the stringent 2050 target of reducing emissions by 80%. Emissions from transport are increasing rapidly, and are affected by the amount and type of fuels used, motor vehicle efficiencies and the number of vehicle miles travelled. To address this issue California announced the introduction of the Low Carbon Fuel Standard (LCFS) in 2007, and after preparation work was completed, the LCFS was approved for implementation in April 2009.

Under the LCFS, petroleum and biofuels suppliers must achieve a 10% reduction in the carbon intensity of their fuels by 2020 (based on a 2010 baseline). The Air Resources Board (ARB) has established carbon intensity values for some fuels and will establish values for others. A profile for compliance has been adopted, which provides for a gradual reduction in the early years, accelerating as 2020 approaches, and providing the basis for continuing improvement post 2020. ARB will provide software tools for fuel carbon reporting, and for tracking credits. Regulated parties (i.e. the fuel suppliers) must report on performance quarterly and annually, and will be audited. They must supply a mix of fuels with a carbon intensity over the year which meets the standard, and can purchase or bank credits to meet the standard. Companies can generate their own carbon intensity values, or argue for adjustment of the default values to match their own specific circumstances.

The benefits of the scheme are expected to be:
- a reduction of 16 million tonnes of GHG emissions from the transportation sector by 2020;
- creation of a durable framework for near and long-term transition to low carbon fuels;
- encouragement for technology innovation;

Table 4: Land use change results – corn ethanol

	A	B	C	D	E	F	G	Mean
Economic Inputs								
EtOH production increase (bill. Gal.)	13.25	13.25	13.25	13.25	13.25	13.25	13.25	
Elasticity of crop yields wrt area expansion	0.5	0.75	0.5	0.5	0.5	0.66	0.75	
Corn yield elasticity	0.4	0.4	0.2	0.4	0.4	0.25	0.2	
Elasticity of land transformation	0.2	0.2	0.2	0.3	0.1	0.2	0.2	
Model Results								
Total land converted (million ha)	4.03	2.68	5.48	4.56	3.01	3.83	3.66	3.89
• Forest land (million ha)	1.04	0.37	1.46	0.89	1.00	0.73	0.55	0.86
• Pasture land (million ha)	3.00	2.32	4.02	3.65	2.01	3.10	3.10	3.03
US land converted (million ha)	1.74	1.16	2.01	2.12	1.14	1.46	1.32	1.56
• US forest land (million ha)	0.70	0.36	0.82	0.81	0.48	0.46	0.40	0.58
• US pasture land (million ha)	1.04	0.79	1.19	1.31	0.66	1.00	0.92	0.99
ILUC carbon intensity (gCO_{2e}/MJ)	33.6	18.3	44.3	35.3	27.1	27.4	24.1	30.0

Table 5: Land use change results – sugarcane ethanol

	A	B	C	D	E	Mean
Economic Inputs						
EtOH production increase (bill. Gal.)	2.00	2.00	2.00	2.00	2.00	
Elasticity of crop yields wrt area expansion	0.50	0.75	0.50	0.50	*	
Sugarcane yield elasticity	0.25	0.25	0.25	0.25	0.25	
Elasticity of land transformation	0.20	0.20	0.30	0.10	0.20	
Model Results						
Total land converted (million ha)	1.28	0.85	1.46	0.94	0.94	1.09
• Forest land (million ha)	0.43	0.22	0.36	0.40	0.26	0.33
• Pasture land (million ha)	0.85	0.63	1.10	0.54	0.68	0.76
Brazil land converted (million ha)	0.89	0.59	1.06	0.60	0.55	0.74
• Brazil forest land (million ha)	0.30	0.15	0.25	0.26	0.13	0.22
• Brazil pasture land (million ha)	0.59	0.44	0.81	0.34	0.42	0.52
ILUC carbon intensity (gCO_{2e}/MJ)	56.7	32.3	54.5	48.3	38.3	46

* Brazil = 0.80, all other = 0.50

- establishment of a model for regional and national standards; and
- setting the stage for future reductions.

The LCFS will stimulate investment rising to an estimated US$250 million by 2020, and will increase fuel diversity by increasing the use of low carbon corn or sugarcane ethanol; cellulosic ethanol; renewable diesel and biodiesel; and electricity, hydrogen, natural gas; and by decreasing the use of petroleum, and high carbon biofuels.

Lifecycle analysis is essential in defining the carbon intensities of the various fuels. Lifecycle analysis considers the GHG emissions from all facets of fuel production, distribution, and use. The approach used in the LCFS includes direct land use effects using the CA GREET model, as well as indirect land use change effects (or ILUC) using GTAP to model land use change along with external analysis to estimate GHG impacts. GTAP was selected as best available model because it is:

- Well-established, publicly available
- Based in academia (Purdue University)
- Backed up by experience of thousands of GTAP applications and 7,500 worldwide individual contributors
- Supported by 26 core institutions, including USDA and US EPA

ARB worked with experts at the University of California and Purdue to run the model. In order to estimate carbon intensity associated with land use change, GTAP was used to calculate the additional area of land devoted to biofuels production, and relevant emission factors used to calculate the additional greenhouse gas emissions. A time factor was then applied to give a related carbon intensity figure.

The calculations indicated that for each billion gallons of corn ethanol produced in the US, which would use some 2.5 million acres of land, there would be some 0.7M acres of land conversion worldwide, taking account of the potential for by-product substitution, increased yields etc. Different approaches to the time accounting issue were modelled, since biofuel production typically leads to a spike in emissions due to land use change, followed by a reduction in emissions compared with fossil fuel usage. Using the best available data inputs, multiple sensitivity models were made and the results peer reviewed via workshops. The results depended on many factors including the elasticity of crop yields to area expansion, yield elasticity, and elasticity of land transformation as shown in Tables 4 and 5. This leads to a range of values between 18.3 and 56.7 g/of CO_2/MJ , and led to ARB adopting a proposed value of 30g CO_2/MJ for corn ethanol and 46g CO_2/MJ for sugar cane ethanol

While this analysis is based on the best available science, and is generally supported by peer reviewers, it is recognised that there is a need to refine the analysis by additional expert work and peer review.

Economic analysis has indicated that the cost of compliance with these measures could be negative during the 2010-2020 period, but this depends on a number of variables, notably crude oil prices and the production costs of alternative fuels. However these measures should lead to a reduction of GHG emissions of 16 million tonnes of CO_2 equivalent/year by 2020, achieving 10% of the overall GHG reduction target, with no other adverse effects and the potential for reductions in some other pollutants when used in conjunction with the introduction of advanced vehicles.

The next steps in developing the LCFS include:

- a review of the land use change aspects by 2011, with a formal review by 2012 and in 2015;
- continuing work on carbon intensity values, the development of a guidance document on the evaluation process for carbon intensity figures; and
- the establishment of an experts group to evaluate issues associated with land use change, reporting to the Air Resources Board by 2011.

DISCUSSION AND CONCLUSIONS

The environmental and social effects of both direct and indirect land use change associated with expansion of bioenergy can be significant and should be fully factored into assessments of the relative benefits and dis-benefits of expanded production and use of biomass. Such assessments must include both economic and social factors.

In the long-term, an integrated approach to land use has to be developed, covering the supply of biomass for food, feed, forestry and energy, and coupled with a global and comprehensive greenhouse gas management regime.
Such an approach needs to look across a number of policy areas and include measures aimed at crucial issues such as deforestation. With this comprehensive approach, separate consideration of indirect land use change becomes unnecessary since all land uses come within the system boundary. Such a policy structure which includes all lands requires a strong international agreement on issues along the lines of proposals for 'Reducing Emissions from Deforestation and Degradation' (REDD). There is an urgent need to adjust the REDD to favour biomass for energy production but in the meantime there is also a need for pragmatic approaches which can be applied in the short-term.

Indirect Land Use Change (ILUC) is a relatively new and complex area of research, involving the need to integrate a number of policy considerations (agriculture, environment, energy, society, biodiversity ...), different stakeholders, and different regions. So far the field is still rather immature, with many unanswered questions and few firm conclusions, so it must be viewed as '*work in progress*'. Nonetheless current thinking and modelling can provide useful insights to reduce risks from ILUC.

A wide range of models exist or are being adapted to look at this issue but with different areas of focus. There is an opportunity for a more harmonised approach to this modelling which could be facilitated by coordinated inter-model comparison and development. Further development of the modelling approach requires close attention to the usability of the models and their outputs, the intended audience and purpose of the modelling; all of which requires intensive engagement and dialogue with the various stakeholder groups.

Improved availability and reliability of the data required for the modelling is urgently needed, particularly on land use. This would be well facilitated by the development of national bioenergy observatories which could feed in this information on the ground.

Developing an appropriate approach to minimising adverse effects from indirect land use change will require more than a simple consideration of energy and greenhouse gas mitigation, given the complexity of the issue, illustrated by the discussions of case studies on the ground. The social implications and consideration of the multiple environmental services provided by land; including issues relating to biodiversity, soil and water also need to be included. The impacts of land use change need to be equitably shared amongst agriculture, bioenergy, energy, forestry and other sectors. A comprehensive approach will require clear and consistent land use definitions, particularly for 'idle' and 'degraded' lands which fully represent and satisfy the local requirements.

The research to understand direct and indirect land use change is still ongoing, and it may be a number of years before a comprehensive appreciation emerges which policy makers can use with confidence. However policy decisions have to be made now based on available approaches and information. Current models are proving helpful in framing these decisions despite their present shortcomings. A number of approaches are being developed and were illustrated by the workshop speakers.

- The ILUC Factor approach estimates the potential indirect effects by considering the types of land and crops used to produce agro-exports and estimating a theoretical global average value (estimated at 20t CO_2/ha/year) then applying a high, medium or low risk factor for the supply of biofuels from a particular area to produce emission estimates associate with ILUC.

- The RSB Approach is based on voluntary global principles, which through codes of conduct could reward producers for activities with low risk of indirect impacts, such as using residues and wastes, improving yields, and using land which does not conflict with conservation needs or short-term production of other crops.

- Within the EU, the Renewable Energy Directive and Fuel Quality Directive will provide a report on ILUC by 2010 with steps to minimise impacts. Regulations may be based on modelling and may possibly factor in ILUC in GHG calculations and other measures.

- In California, the introduction of the Low Carbon Fuel Standard will lead to a 10% reduction in fuel carbon intensity by 2020. Compliance will be assessed using lifecycle analysis, with effects of ILUC calculated using the GTAP model. For example the proposed carbon intensity value for corn ethanol has been calculated at 27 gCO_{2e}/MJ.

These measures recognise that there is further scope for improved methodologies and data that will provide a firmer basis for policies aimed at reducing risks due to adverse land use change impacts, and allow for better review as information becomes available.

It was also recognised that much new agricultural activity will require additional land, and that ILUC is an issue for all crops, not just bioenergy. There is therefore a need to integrate this ILUC discussion into agriculture in general and to improve agricultural practices. Improved agriculture productivity will allow increased output using less land and so reducing the LUC and ILUC risks. Improved agricultural growth will also lead to more carbon storage in the soil and so contribute to carbon sequestration. So there is a win-win possibility to reduce CO_2 in the atmosphere, create more biomass and more agricultural outputs on the same area, without risks of ILUC.

IMPLICATIONS FOR IEA BIOENERGY

IEA Bioenergy is already playing a key role in the development of a sustainable global biofuels industry. Many of the existing Tasks are already contributing expertise and knowledge to the field, with the Agreement able to act as a focus for international coordination of the technical work on issues such as land use change.

As part of a comprehensive communications effort currently under development IEA Bioenergy will seek to work jointly with other international and national bodies working in this area and actively seek collaboration to develop better information and modelling approaches, as well as playing a role in developing and monitoring the impact of regulatory and legislative approaches.

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IEA Bioenergy

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