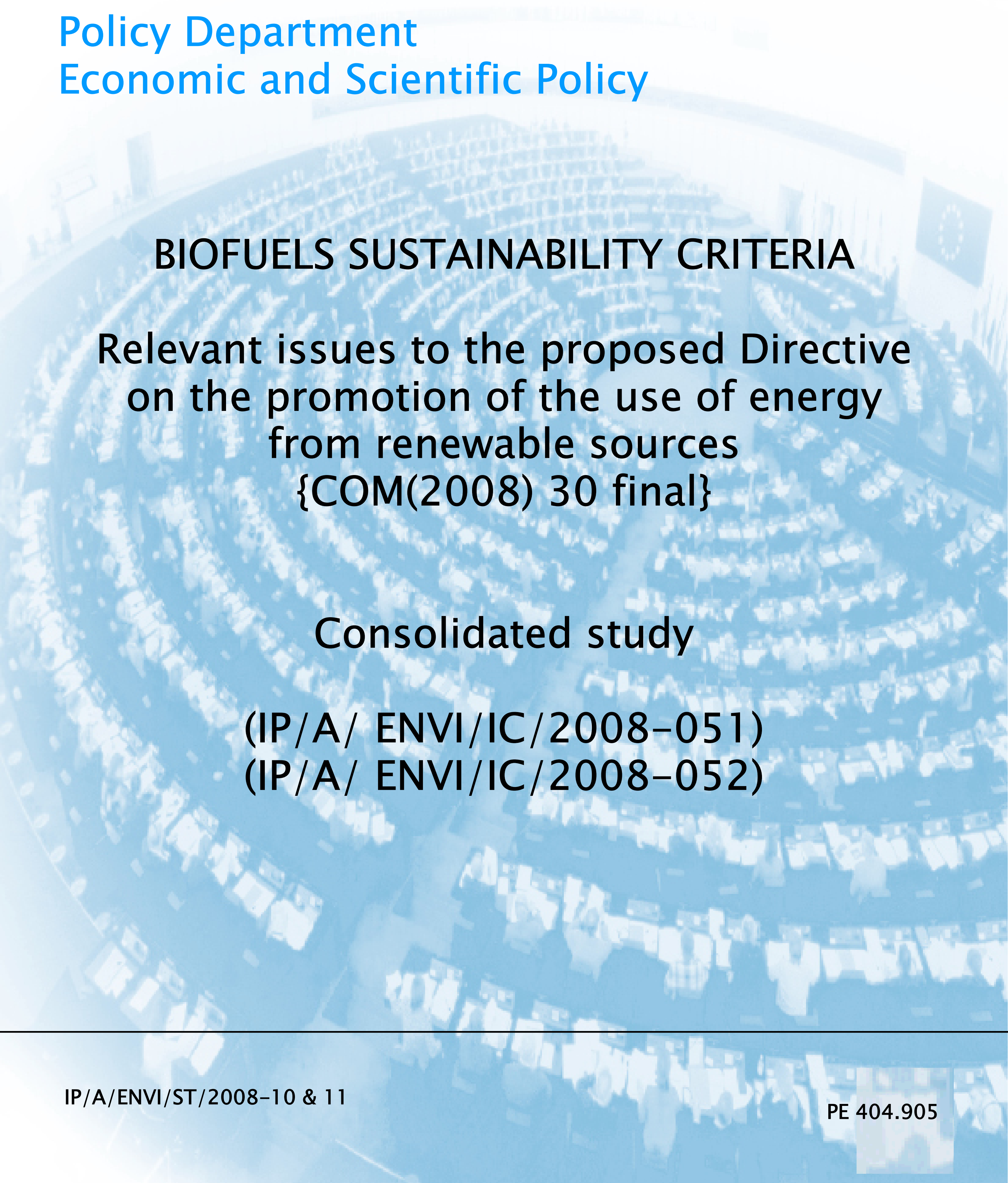
STUDY

Policy Department
Economic and Scientific Policy



BIOFUELS SUSTAINABILITY CRITERIA

Relevant issues to the proposed Directive on the promotion of the use of energy from renewable sources {COM(2008) 30 final}

Consolidated study

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

The role envisioned for liquid biofuels for transport has come under increased scrutiny in the past year or two, due to the potential social and environmental impacts associated with scaling up biofuels production and use from its low level—currently representing about 1% of transport fuels globally. The proposed EU Directive setting a target of 10% biofuels in transport sector by 2020 has therefore raised a number of concerns. The concerns about sustainability are addressed within the proposed Directive through criteria related mainly to GHG emissions, but also to biodiversity and other environmental impacts.

The use of first generation biofuels in temperate climates is land-intensive and inefficient in technical terms, whereas first generation biofuels in tropical climates and second generation biofuels in general—offer a much more effective use of land resources. The use of GHG reduction criteria can provide incentives for producers to rely on the most productive feedstocks when sourcing biofuels for the EU market, which will often mean import of biofuels. A threshold of 50% or more would tend to eliminate many of the first generation biofuels produced in temperate climates.

Member States should be encouraged to link financial incentives to the GHG reduction capabilities. Moreover, such incentives could be better linked to development cooperation in the case of imports, so as to insure that Least Developed Countries (i.e. in Africa) can gain access to larger markets rather than only the major producers such as Brazil.

The calculation of GHG emissions associated with biofuels is complicated by the addition of factors associated with land use change, since the GHG impacts of land use change are beset by uncertainty both in physical terms as well as in the attribution of particular changes to production of particular biofuels. A further complication is introduced when indirect land use changes are incorporated, since these occur through combinations of market forces, illegal land use transformation, and regulatory efforts. Some improvements can be made to existing methodologies in the proposed Directive by being more precise on the system boundaries associated with particular biofuels. More analysis and research is needed in order to improve the incorporation of land use change into estimates of GHG emissions from biofuels.

Use of degraded lands for bioenergy and biofuels production offers an interesting option for combining expanded energy production with decreases in GHG emissions by improving land quality as well as by fuel substitution. The incentives for doing so, however, often need to be high, since biomass feedstock producers will always favour higher quality lands, other things being equal.

Harmonisation with other sustainability schemes is important in order to create more effective markets and provide clearer signals to producers and consumers. Harmonisation efforts need to be undertaken in future revisions of the Directive, both with major producing countries such as the U.S. and Brazil, but also with respect to existing UNFCCC procedures related to CDM, REDD, and other programmes.

1. OVERVIEW OF BIOFUELS AND THEIR POTENTIAL

This introductory section provides a brief overview of biofuels and their potential within the EU and globally. The discussion is focussed almost exclusively on liquid biofuels, since they are the main focus with respect to the sustainability criteria. Where there is a significant connection to or similarity to other energy carriers for biomass (gas, heat, or electricity), specific reference is made so as to identify that type of biomass and/or application. However, it is important to note that the more integrated bioenergy systems and efficient use of resources that accompany maturing markets will not always permit separate consideration of liquid biofuels from other uses. Such a lack of distinction between biomass resources used for liquid vs. solid fuels will be even more appropriate once lignocellulosic conversion (2nd generation biofuels) is commercialised.

1.1 Biomass resources and land availability

Biomass is living matter derived from plants and animals. Energy sources from biomass are often divided into two main categories: wastes or residues, and energy crops. Biomass wastes or residues refer to the remaining biomass after harvesting and/or processing. The two categories differ significantly in the economics of utilisation as well as in biophysical terms.

Biomass residues include forest and agricultural residues (e.g. straw); urban organic wastes; and animal wastes. They normally offer the most widely available and least-cost biomass resource options. The principal challenge is to develop or adapt reliable and cost-effective handling methods and conversion technologies.

Dedicated energy crops refer to plantations of trees, grasses, oilseed crops and other crops that are optimised for energy production; the harvested biomass is used directly or serves as feedstock for further production of specialised fuels. The principal challenges centre on lowering biomass production costs and reducing the risks for biomass growers (e.g. stable prices) and energy producers (e.g. guaranteed biomass supply).

Like other renewable sources, bioenergy can make valuable contributions in climate mitigation and in the overall transition towards sustainable energy, but it also has two decisive advantages over other renewables. First, biomass is stored energy; like fossil fuels, it can be drawn on at any time, in sharp contrast to daily or seasonally intermittent solar, wind, wave and small hydro sources, whose contributions are all constrained by the high costs of energy storage. Second, biomass can produce all forms or carriers of energy for modern economies: electricity, gas, liquid fuels, and heat. Solar, wind, wave and hydro are limited to electricity and in some cases heat. Indeed, biomass energy systems can often produce energy in several different carriers from the same facility or implementation platform, thereby enhancing economic feasibility and reducing environmental impacts (Leach and Johnson, 1999).

Modern bioenergy systems have several other advantages over other energy resources, providing economic development benefits in addition to improving energy services. Bioenergy provides rural jobs and income to people who grow or harvest the bioenergy resources, as bioenergy is more labour-intensive than other energy resources. Bioenergy can increase profitability in the agriculture, food-processing and forestry sectors. Biomass residues and wastes—often with substantial disposal costs—can instead be converted to energy for sale or for internal use to reduce energy bills. Biomass plantations in some cases can help to restore degraded lands. Growing trees, shrubs or grasses can reverse damage to soils, with energy production and sales as a valuable bonus.

Bioenergy is inherently land-intensive (except for wastes, residues and aquatic biomass) and the associated environmental impacts (both positive and negative) are more significant, relative to the energy produced, than those of other energy systems. A comprehensive list of environmental impacts is difficult to summarise, but some key concerns relate to loss of ecosystem habitat, deforestation, loss of biodiversity, depletion of soil nutrients, and excessive use of water. In addition to provision of a renewable energy source, some positive environmental impacts include restoration of degraded land, creation of complementary land use options, and synergies in the provision of fibre and other non-energy products. The modern concept of a biorefinery is an integrated and highly efficient agro-industrial complex that uses multiple feedstocks and creates multiple products—food, feed, fuel, fibre and more—thus maximising the value of land resources and bio-based materials.

1.2 Land availability

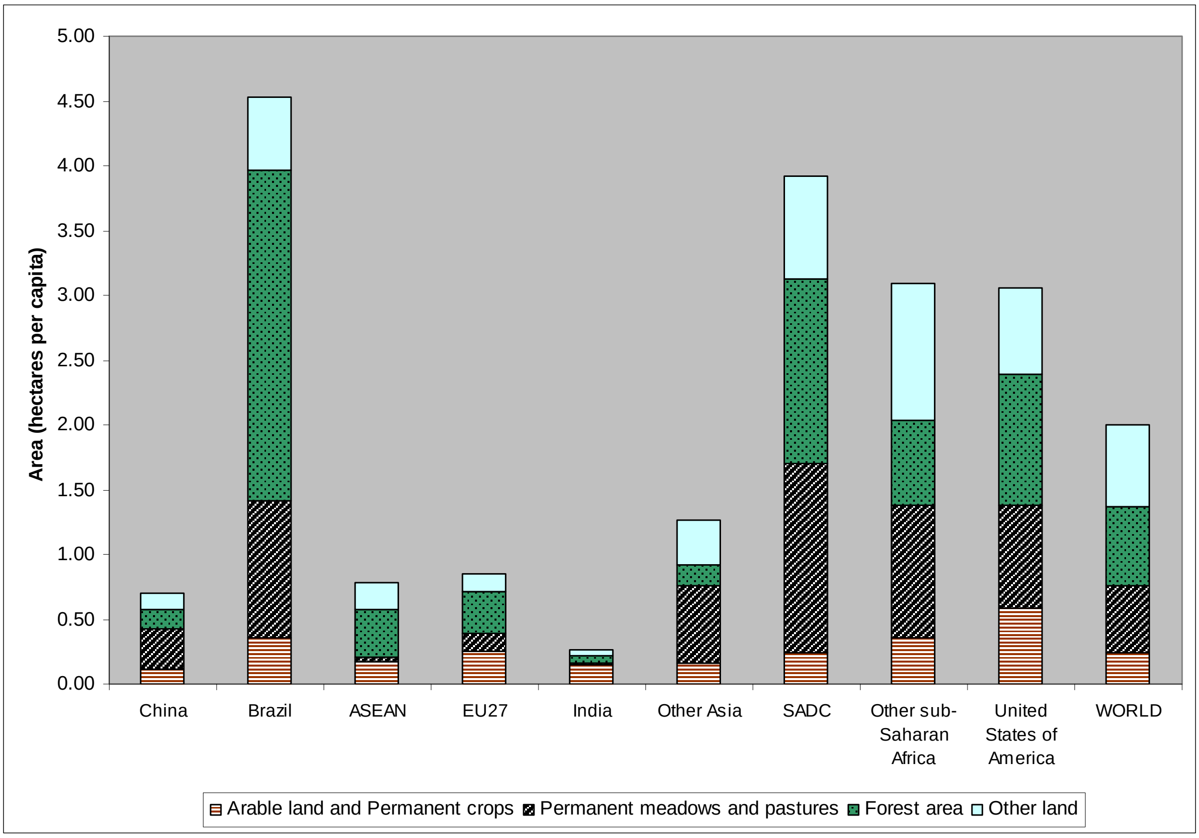
Agricultural reform, climate change and energy security have been central drivers in renewed enthusiasm for biofuels, which have also been seen as providing new opportunities for economic revitalisation in rural areas, in developing and developed countries alike. At the same time, growing demand is raising concerns about food security and environmental impacts. Balancing these concerns has become more difficult in the face of media coverage that tends to polarise the issues. Policy makers need tools to make decisions based on scientific information rather than hasty generalisations.

Currently, the amount of land devoted to growing biofuels is only 25 million hectares, or about 0.5% of 1% of the 5 billion hectares of global agricultural land (Faaij, 2008). Land conflicts have therefore not yet reached significant proportions, although of course it is important to improve scientific analysis before it reaches major proportions so that the potential impacts are better understood. Biofuels have not been a major contributor to increasing food prices or to land degradation, but that does not preclude them causing such problems in the future should biofuels production reach much higher levels and/or move into sensitive regions. Furthermore, as the world faces dwindling and/or more costly supplies of fossil fuels in combination with increasing population, there will inevitably be more land pressures, since renewable resources require more land than the non-renewable fossil fuels they replace.

The distribution of available land is rather uneven with respect to population. Figure 1 shows per capita land by type for various regions and countries. Some developing regions, such as sub-Saharan Africa and Brazil, are well above the world average; by contrast, many regions in Asia are below the world average. On average, one expects that there will be more land pressures and more constrained options for biofuels in many regions of Asia. Even in some parts of Asia, however, there are sparsely populated regions that have significant potential. Yet in terms of regions and bioenergy trade, it seems likely that only Latin America and sub-Saharan Africa could become major exporters.

Biofuel proponents often point to abandoned cropland and other “marginal lands” that can be made available for feedstock production, including uncultivated or low-grade lands that can potentially be used for non-grain cropping and afforestation. Current levels of cultivated land per capita have been dropping in fast-growing economies like China, where it is now 0.12 hectare, which is about half of the world average. A major agricultural exporter like the U.S. has five times this amount, while the EU has about twice this amount. Another issue relates to use economic incentives to promote bioenergy on degraded lands, which could put Least Developed Countries (LDCs) in Africa at a disadvantage since they have not yet reached an economic level where they have many degraded lands that could benefit from such incentives.

Figure 1: Land use per capita by type for selected regions or countries



Source for land use data: FAOSTAT database, www.fao.org
[1]SADC includes the 14 countries of the Southern African Development Community
[2]Arable land and permanent crops indicate current cultivation, but do not determine how much land is potentially cultivable.

A number of developing countries, including many of the LDCs of sub-Saharan Africa have a major comparative advantage in biofuels and in agriculture more generally, but have been impacted negatively by competition from heavily-subsidised agricultural sectors in OECD countries. Agricultural reform could offer some opportunities for them to modernise their agricultural sectors, using biofuels as a driver. Whether or not such increased market access and economic competitiveness brings poverty reduction and sustainable development will nevertheless depend on many other factors, including land tenure, property rights, resource allocation, credit access, and distribution and transport infrastructure. As with many other economic development issues, there are many different strategies for expanding biofuels production, some being much more sustainable and equitable than others. It is up to researchers and analysts to evaluate the alternatives that are feasible and it is up to policy-makers to weigh their advantages and disadvantages.

Use of wastes and residues for bioenergy is important for minimising environmental impacts and land use conflicts, as residues will generally require no additional land. However, use of residues is constrained by collection costs and the fact that they are not optimised for energy purposes. Scenarios for large-scale bioenergy expansion therefore assume that dedicated energy crops of some type will be grown in agricultural areas in order to maximise returns.

In assessing availability of agricultural land for energy crops, it is generally assumed that food and feed requirements should be met first. In some cases energy crops can grow on degraded lands, thereby minimising land use conflicts. In other cases, the same crop may result in multiple products—including food, feed, fuel, fibre and other categories; such multiple-use scenarios will depend on the particular markets that develop.

Provision of economic incentives for bioenergy crops should therefore be concentrated on degraded, abandoned, or marginal lands where possible, and should aim to encourage multiple products.

Woody biomass from residues and improved management in natural forests, even with fairly stringent ecological constraints, can provide a significant amount of bioenergy resources. However, use of woody biomass in some regions, is likely to be considerably constrained by factors such as the demand for industrial roundwood, use of woodfuel for cooking and the important ecological roles of natural forests (Smeets and Faiij, 2007). In the longer-term, aquatic sources of biomass could also become important, particularly algae grown for oil extraction, with the added value of avoiding land use conflicts (Briggs, 2004).

As Figure 1 shows, the EU has modest land availability per capita compared to other world regions. However, it has been estimated that self-sufficiency in food and near self-sufficiency in feed in the EU could be accomplished with a much lower amount of land per inhabitant, perhaps only 0.14-0.18 ha/person, thereby freeing up a considerable amount of land for energy crops (Ragossnig, 2007). Land left fallow for ecological and economic reasons can in some cases be employed for bioenergy production; in the EU, this includes so-called “set-aside” land that has been removed from agricultural production using payment incentives.

More detailed analysis is required in order to assess bioenergy potential, since the land suitable and available for growing biomass for energy depends on many factors, including: climate and soils, availability of sufficient inputs, and various ecological factors. Bioenergy conversion options and estimated bioenergy potentials are reviewed in the next few sections.

1.3 Conversion Options

There are many different routes for converting biomass to bioenergy, involving various biological, chemical, and thermal processes; So-called second generation biofuels include fuels produced at high conversion efficiency through several different biochemical and thermo-chemical pathways, such as the Fischer-Tropsch synthesis1 as well as ligno-cellulosic conversion to ethanol. First-generation biofuels include oil crops esterified into biodiesel and direct fermentation of sugar and starch crops into bio-ethanol.

Due to the variety of conversion options and final products, it is more difficult to make comparisons of efficiency in biomass utilization than it is for other energy options; bioenergy extends to all energy carriers and involves many different pathways and processes. The efficiency of biomass and bioenergy production needs to be assessed across the various parts of the chain—from the land and inputs used for cultivating biomass through intermediate processing to the useful energy that can be harnessed for particular products and applications.

On the agricultural or resource side, efficiency depends on choosing crop species and varieties well-suited to local soils and climate. In Brazil, for example, over 500 varieties of sugar cane are used for bio-ethanol production, some of which are designed and developed for optimal growth in particular micro-climates. The productivity of biomass crops grown in tropical and sub-tropical regions, in terms of energy per unit of land, is 5 times higher on average than typical crops grown in the temperate climates of Europe (Bassam, 1998). But even within Europe, there is considerable variation in the productivity of different energy crops (Table 3).

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[1] Fischer-Tropsch liquid (FTL) can be made from coal, natural gas, or biomass sources; it is a mixture of primarily straight-chain hydrocarbon compounds that resembles a semi-refined crude oil. The mixture can either be shipped to a conventional petroleum refinery for processing or refined on site into “clean diesel,” jet fuel, naphtha, and other fractions (UNCTAD, 2008a).

In terms of minimising overall losses in the industrial conversion side of the production chain, the most efficient use of biomass for energy is for heat, including combined heat and power, where overall system efficiencies can be as high as 80-90%. Matching conversion systems to the scale and structure of demand for heat and power is necessary to minimise costs. Some conversion systems are technologically mature for use of biomass, such as steam turbines and steam engines. Other systems are still under development, such as Stirling engines and the Organic Rankine cycle. Systems differ in scale efficiencies, service requirements, and other characteristics; choice of the optimal system is thus often site-specific (Vamvuka et al, 2007).

Another efficient way to use biomass is for co-firing with coal, since relatively minor modifications can facilitate its integration at a moderate cost. There are several possible technical configurations, and the need for pre-treatment and other operational measures varies with the quality of biomass (JRC, 2006). Depending on the configuration, the type of biomass, and the range of acceptable performance and reliability, the amount of biomass optimally co-fired with coal can range from 2% up to 25% (Rosillo-Calle, 2007). Co-firing with coal is the least expensive "form" of renewable energy other than large hydro, and is among the more cost-effective climate mitigation options; however, the fact that coal is still the main fuel means that it represents more of an energy/climate management device and cannot be regarded as a sustainable option in the long-term.

Liquid and gaseous biofuels are useful in extending the value of biomass to other sectors, including transport sector or in substituting for natural gas. The efficiency in conversion tends to be on the order of 55-65%. Biogas from animal wastes and other types of "wet" biomass is produced through anaerobic digestion, which is the decomposition of biomass using micro-organisms in a low-oxygen environment. Biogas can be used for many different applications: direct use for cooking or heating, electricity generation, compression for use in transport, or it can also be fed into the natural gas grid after clean-up or purification.

1.4 Potential in various world regions

Biomass potential can be assessed across various end-use sectors, technology options, and product markets. Since a major scaling up of biomass-to-energy is most likely to be based on energy crops, the availability of agricultural land provides a first indication of the overall potential. A recent study evaluated the potential in Europe, focusing on the EU-27 and Ukraine (Fischer et al, 2007). The land that could potentially be made available is quite significant, amounting to about 37% of total agricultural lands in the EU and 75% of total agricultural lands in Ukraine. The choice of what end-use markets (heat, power, transport, gas supply) to which the biomass supply should be directed depends on a combination of economic and political considerations.

The lack of progress on renewable energy in the transport sector and the lack of cost-effective alternatives to petroleum fuels have led in recent years to greater emphasis on liquid biofuels at the EU policy level. Estimates of production potential for first and second generation biofuels are given in Table 1. The projected transport demand for the EU-27 in 2030 is 17.6 EJ; the potentials thus amount to about 20% to 50% of projected transport energy demand in 2030 or 40% to 70% if Ukraine is included.

The use of large quantities of land for transport fuels raises the questions of whether it would be better to prioritise biomass resources for solid fuels in stationary applications or perhaps for biogas where larger-scale use of gas is envisioned, i.e. to substitute for imported natural gas. The choice between different end-use sectors for biomass resources is to some extent a political decision in terms of supporting emerging industries and technologies. In practice, particular investments will depend on the cost and performance in particular applications and scales of demand, which are reviewed in the next section.

Table 1: Estimated potential production of biofuels in Europe in 2030 for different scenarios (Exajoules)

		1st generation only				*2nd generation*			
		EU15+	**EU12**	**Ukraine**	**Total**	**EU15+**	**EU12**	**Ukraine**	**Total**
ARABLE land	Baseline	1.5	2.1	2.3	5.9	2.3	3.2	3.4	8.9
	Low	1.3	2.1	2.3	5.7	2.0	3.2	3.4	8.6
	High	1.8	2.5	2.6	6.9	2.8	3.8	3.8	10.4
PASTURE	Baseline	Not used				Not used			
	High	Not used				1.3	1.0	0.8	3.1
TOTAL	High	1.8	2.5	2.6	6.9	4.1	4.8	4.6	13.5

Source: Fischer et al, 2007

NOTE: baseline assumes current yield trends; low assumes more organic farming; high assumes higher yields

Biomass accounts for about 10% of the roughly 470 exajoules (EJ) primary energy that is now consumed globally; biomass accounts for more than all other renewables and nuclear power together (IEA, 2007). However, the majority of biomass use is still for traditional purposes in cooking and heating in developing countries. There exists considerable uncertainty in estimates for traditional biomass use in developing countries, since these fuels are often not purchased commercially and therefore must often be estimated indirectly.

A variety of modern and efficient bioenergy systems have reached maturity in recent decades and are now deployed widely, although mainly in OECD countries. As a result, there are a range of technology platforms for efficient conversion of biomass, especially in the case of heat and power. Although liquid biofuels have increased rapidly in recent years, the amount is still relatively small, representing less than 6% of biomass used for energy globally.

A recent study assessed global bioenergy potential in major world regions in the long-term (2050) after accounting for food and feed production, using four scenarios under which the intensity of cultivation, level of technology, and amount of irrigation (starting from zero or rain-fed) were successively increased (Smeets et al, 2004). A summary of the estimated potentials for the four scenarios is given in Table 2.

Overall, the global potentials range from 30% to over 200% of projected global energy consumption in 2050. Other sources of bioenergy that are not included in these potentials include animal wastes, organic wastes, and bioenergy from natural growth forests. Inclusion of such sources would increase the potentials by an additional 10 to 50%, depending on the assumptions (Smeets et al, 2007). Nor is aquatic bioenergy production included, the potential for which could be quite large, such as in the case of algae-oils for bio-diesel (Briggs, 2004).

Table 2: Estimated biomass potential for four scenarios and various world regions in 2050

	Potential (Exajoules)				*Share of world total*			
Region/Scenario:	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
North America	27	63	156	186	10%	12%	13%	14%
Oceania	40	55	92	106	15%	11%	8%	8%
East and West Europe	12	26	43	62	4%	5%	4%	5%
C.I.S. and Baltic States	48	76	188	203	18%	15%	16%	15%
sub-Saharan Africa (SSA)	46	114	280	335	17%	22%	24%	25%
Latin America & Caribbean (LAC)	58	130	202	232	21%	25%	17%	17%
Near East & North Africa	2	2	31	33	1%	0%	3%	2%
East and South Asia	37	46	181	188	14%	9%	15%	14%
World	***270***	***512***	***1173***	***1345***				
SSA+LAC	*104*	*244*	*482*	*567*	*39%*	*48%*	*41%*	*42%*

Source: Smeets et al, 2004

The bioenergy potential of Latin America and sub-Saharan Africa together accounted for 39% to 48% of global potential. The high potential results from the large areas of suitable cropland, large areas of pasture land and the low productivity of existing agricultural production systems. Since these regions together account for less than 20% of global population, they seem to be the most likely regions to become major exporters of biomass and bioenergy. Highly productive crops such as sugar cane could contribute significantly to global bioenergy supply as well as supporting sustainable development in Africa (Johnson and Matsika, 2006).

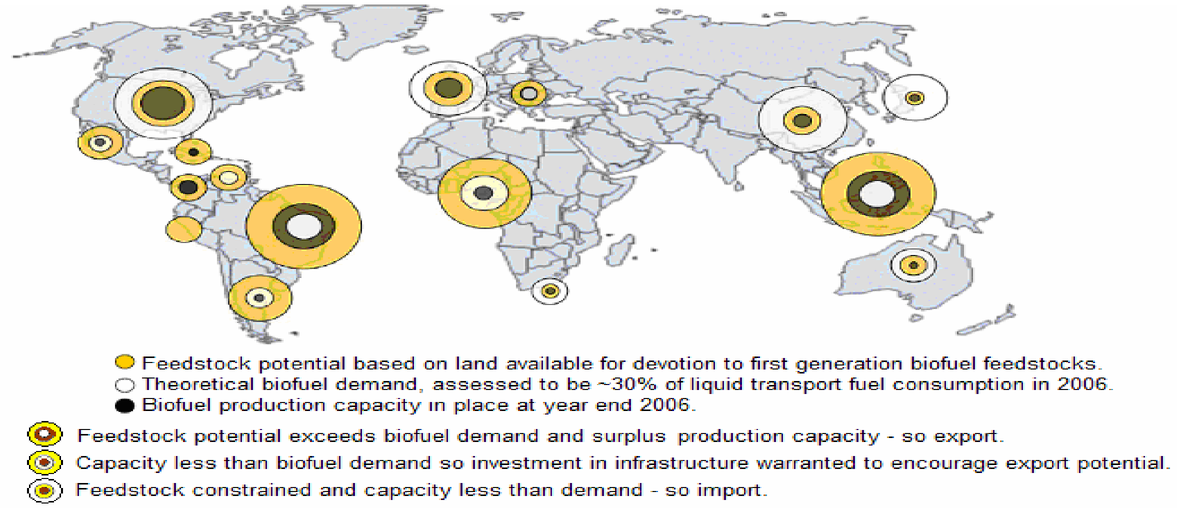
It is important to note that these are technical potentials; the economic potential would be lower, as would the potential in the case when strict ecological criteria are applied. The application of strict ecological criteria and economic criteria for forest-based biomass resulted in reductions of availability by more than half in many world regions (Smeets and Faaij, 2007). Such restrictions would tend to have less effect on availability of agricultural lands for bioenergy, since there is more flexibility and more options available than for forests.

1.5 International Trade

The underlying economic and environmental logic for North-South bioenergy trade arises mainly from this large difference in productivity. The economic and environmental costs for international transport generally amount to only 1-2% of the total product cost in the case of liquid biofuels and slightly more in the case of solid biomass trade (Hamelinck et al, 2003; Johnson and Matsika, 2006). An estimate of potential global trade in biofuels in relation to supply capacity and demand is shown in Figure 2.

The figure confirms the discussion in some of the preceding sections as to the productivity of biomass in different world regions, and combines with it analysis on the demand side in the case of liquid fuels. The high potential in the region of sub-Saharan Africa is coupled with very low demand there (except for South Africa) and consequently there is an excellent opportunity to become a major next exporter; indeed, without exports, biofuels will be less competitive due to the low liquid fuels demand and subsequent lower economies of scale that would result from focusing on domestic demand (Johnson and Matsika, 2006). Consequently, the notion that countries should meet domestic demand first comes in conflict in many cases with the market/trade principles of comparative advantage. Low demand and high potential is also found in Southeast Asia and parts of Latin America, which would also therefore suggest increased investment in capacity in those regions. High-consuming regions in temperate climates such as North America and Europe will need to import under nearly any cost-competitive scenario with relatively free trade in biofuels.

Figure 2: estimated biofuel supply and demand in relation to capacity for various world regions



Source: New Energy Finance, 2007

2. ENERGY YIELDS AND GHG EMISSION IMPACTS

2.1 Energy Yields

It is difficult to summarise environmental impacts across all the different crops, applications, and conversion processes for biomass-energy systems. In general, most of the impacts come from the land-use side rather than the industrial side of bioenergy production, due to the land-intensive nature of biomass compared to other energy sources. Environmental impacts and emissions are closely linked to the energy and other input requirements for growing biomass; the most productive options are those that have lower input requirements and require less land and/or lower quality soils. Feedstock growing costs are also strongly related to land use, and feedstock costs are generally the major cost component for bioenergy systems.

Table 3: estimated yields, inputs, and costs for energy crops in Europe

crop	energy inputs required (GJ_{prim}/ha/yr)	typical net energy yield (GJ/ha/yr)	production cost (EUR/GJ)	status and comments
rape	11	110-180	12-20	widely grown in Germany and France, requires better quality land
sugar beet	12	250-370	8-12	annual crop, requires good quality land, surpluses used for ethanol production
SRC-willow	5	180-280	2-6	perennial crop with typical rotation of 3-4 years, suited for colder and wetter climates
poplar	4	150-250	2-4	perennial crop planted for pulpwood production, rotation of 8-10 years
miscanthus	14	180-350	2-6	perennial crop harvested each year, little commercial experience, suited to warmer climates

Source: adapted from Faiij, 2006.

A summary of the energy inputs, energy yields, and production costs for some key energy crops grown in Europe is given in Table 3. Crops used for biofuels such as rape and sugar beet require better quality land and tend to have higher inputs and higher costs. SRC-Willow and poplar are low cost and low input perennial crops that are versatile and competitive biomass resources in many regions. Miscanthus is a promising crop; it is a perennial grass in the highly productive C4 class, to which sugar cane belongs. However, there is only limited experience with miscanthus; yields and input requirements are still rather uncertain. Furthermore, its growth will generally be limited to warmer climates within Europe.

2.2 GHG emissions overview

Since biomass sequesters carbon, GHG emissions of bioenergy systems are neutral. However, since there are fossil energy and other input requirements for biomass feedstocks, there are some energy losses and hence some net GHG emissions result. In some cases, there can also be N_2O and methane emissions associated with biomass for energy systems, both of which are also GHGs. The GHG savings for liquid biofuels tend to be less than that of solid biofuels mainly because of the fossil fuel being replaced, i.e. since coal is the most carbon-laden fossil fuel, any substitution for it has proportionally higher carbon savings. For most liquid biofuels, GHG reduction is directly related to the yield and energy balance of the feedstocks. A rough indication of GHG reductions and yields for various liquid biofuels is given in Table 4.

Table 4: Estimated ranges of GHG reductions and yields for various biofuels

fuel	**Process**	**feedstock**	**location**	**GHG reduction** *(relative to petrol or diesel)*	**Yield** *(litres per hectare)*
ethanol	fermentation	corn	U.S.	15-35%	3000-4000
ethanol	fermentation	sugar beet	Europe	45-65%	4000-5000
ethanol	fermentation	sugar cane	Brazil	80-90%	6000-7000
ethanol	enzymatic hydrolysis & fermentation	cellulosic	U.S.	70-90%	4500-5500
biodiesel	extraction & esterification	soya	Brazil	30-50%	500-600
biodiesel	extraction & esterification	rape	Germany	40-60%	1000-1400
biodiesel	extraction & esterification	Oil palm	Indonesia	75-85%	4000-6000
biodiesel	Fischer-Tropsch method *(biomass as raw material)*	various	various	50-100%	varies

Source: adapted from IEA (2004) and Sakar and Kartha (2007)

There are other potential GHG impacts associated with growing biomass, which depend on the previous use of lands. Land that stores a significant amount of carbon and is cleared to grow biomass incurs a “carbon debt” that has to be “paid off” before the system becomes a net carbon sink again (Fargione et al, 2008). On the other hand, degraded lands that are used for biofuels will tend to incur a low carbon debt or none at all, depending on the properties of soil, the root systems of the new crops, the impact on nutrients, and other factors.

The wide range in GHG reductions and yields for biomass and biofuels, even when substituting for the same fossil fuel, are due in part to the fact that biomass that is produced in tropical and sub-tropical climates has an average productivity that is on average 5 times higher than that of biomass grown in the temperate regions of Europe and North America (Bassam 1998). Since developing countries are located predominantly in the warmer climates and lower latitudes, they have a tremendous comparative advantage. However, the large amount of financial capital available in Europe and North America facilitates the technology and strong infrastructure that can compensate somewhat for the natural disadvantage.

2.3 GHG Reduction Goal and Default Values

The 35% GHG savings targeted in Article 15.2 (Renewable Energy Directive ((2008)19) is modest but appropriate given the current state of knowledge. The heated debate induced by the recent publications of Fargione *et al* (2008) and Searchinger *et al* (2008) demonstrates the degree to which lifecycle GHG emissions from biofuel crops are still poorly understood. The best approach the Directive can take is not to exhaustively research the most realistic, likely achievable target; but rather to ensure that administrators have sufficient flexibility to alter the target in response to the growing body of scientific knowledge. This could be achieved by adding a section to Article 15 prescribing the conditions under which the target of Article 15.2 could be altered.

Parliament could encourage the development of new knowledge on lifecycle GHG emissions, by favouring use of the Annex VII Part C methodology over use of the default values (i.e. following Article 17.1(b) or (c) rather than (a)), for example by eliminating the exception list described in Article 17.2.

2.4 Improvements to the Methodology Equation Terms

The methodology equation given in Annex VII Part C provides a useful quantitative structure for estimating lifecycle GHG emissions. However, there are many uncertainties and difficulties encountered when analysts attempt to estimate the values for the various terms in the equations. An evaluation and critique of the various terms in the equation is provided in the Annex to this report. In general, differences in how one calculates GHG emissions related to the choice of a "system boundary," i.e. separating the emissions associated with the biofuel from other related emissions. Such difficulties have been encountered in the UNFCCC methodology panel or the Clean Development Mechanism (CDM) for a number of cases (UNFCCC, 2006, 2007a, 2007b). The discussion in the Annex to this report therefore focused on some practical solutions for improving the estimates and avoiding double-counting.

2.5 Co-product Allocation

The co-product allocation methodology outlined in Sections 15 and 16 is thorough but elementary. It chooses to allocate emissions among co-products according to energy content; crop residues are excluded from the accounted co-products.

ISO 14041 recommends the more sophisticated approach of avoiding allocation either by dividing the process into multiple sub-processes, or by expanding the system boundary to include the functions of all co-products (ISO, 1998). Division into sub-processes is usually impossible for biofuel refining, but expansion of the system boundary is possible and has been demonstrated in the literature (Kim and Dale, 2002; Rosentrater, 2005; Cederberg and Stadig, 2003). In the system expansion approach the GHG emissions associated with the unit system, as well as the GHG emissions associated with other unit systems affected by the various co-products, are accounted together. A set of simultaneous equations is solved to show the degree to which each product contributes to the GHG total. The method accounts for the degree to which various products substitute for each other in markets. Though this method of accounting is relatively new and requires sophisticated analysis, it is recommended by the ISO and deserves encouragement. The Directive should explicitly favour it.

When system expansion is not possible, the ISO standard recommends that inputs and outputs to the system be partitioned in a way that "reflects the underlying physical relationships between them." One way to do this is to measure the energy consumption associated with a unit-process-based substitute for each co-product, and use these energies as the allocation factors (Shapouri et al, 2002).

Only as a last resort does the ISO standard recommend to use an allocation method based on economic or physical values, such as energy content as proposed in the draft Directive.

3. LAND USE CHANGES

Land use change has been a significant source of global GHG emissions through time, between 1989 and 1998 land use change accounted for 1.6 ±0.8 Gt C yr^{-1} (IPCC LULUCF, 2000). GHG emissions from land use change can significantly change carbon stored as a result of the harvest or removal of vegetation, as well as accelerated decomposition rates of soil carbon (IPCC, 2000a). Conversion of forest and grasslands to cropland for biofuels production can result in significant GHG emissions and reduce the relative carbon savings of biofuels over fossil fuel sources. Growing recognition of the contribution emissions from land use change can have on the GHG impact of biofuels has increased attention and caution regarding accuracy of LCA calculations (Fargione et al. 2008).

Biofuel feedstock production can contribute GHG emissions from direct land use change, emissions from conversion of land from a prior use (e.g. forest) to biofuel feedstock production, as well as indirect land use change, emissions from conversion of other lands as a result of biofuels production due to increased agricultural pressure or demand for biomass material. Direct land use change GHG emissions are incorporated into the Methodology Equation and recommendations regarding the terms addressing this source are discussed in the Annex. Indirect land use change GHG emissions are not currently incorporated into the Methodology Equation and an evaluation of options to include this term is included below in section 3.2.

3.1 Restrictions on types of land

The suggested restrictions on types of land to be used for the production of biofuels, pose a set of problems, of which the suggested definition of ‘degraded grasslands’ is particularly troublesome, since it has potentially severe implications for ‘global equity’.

The problem resides in a disregard of causality combined with an unfortunate temporal delimitation of what constitutes ‘degraded grassland’. While stating that “[b]iofuels and other bioliquids /…/ shall not be made from /…/ grassland that is species-rich, not fertilised and not degraded”, Article 15 defines the local conditions for a future production of biofuels – without taking into account under what circumstances these areas originally came about, or not. Moreover, it points out that only “land that had one of the following statuses in or after January 2008, whether or not the land still has this status” can be used for this purpose.

These criteria may in practice have far-reaching consequences for some African countries, which, due to their previous development trajectories and present socio-economic conditions, have comparatively little degraded grassland. On a global scale, their situation is, though, very different from that of other more developed countries, like Brazil, which, as a result of active development policies, has quite a substantial amount of already degraded grassland – which, according to the suggested criteria, then could be used to expand the country’s bioenergy production. Ironically, this implies that Article 15 actually could benefit the more developed Brazil in its competition with less developed African countries on a future global biofuels market. Hence, by setting a date for what is defined as degraded or not degraded grassland, without recognizing bioenergy’s potential for stimulating economic growth in some areas, the suggested article could thereby potentially hamper some developing countries’ opportunity to achieve socio-economic development through the production of bioenergy. Whether or not the restrictions would have such impacts requires more detailed analysis based on both physical and economic parameters.

3.2 Carbon stocks

Section 7 of Annex VII states that emissions from land use change shall be calculated based on the difference in carbon stocks between reference and actual land use in terms of bioenergy per unit area per year. Default reference and actual land use carbon stock values are provided in Section 8 that can be used for calculations if actual data are not available. Carbon stock and productivity values provided in the proposed Directive for calculations of the annualised emissions from carbon stock changes caused by land use change (e_l) are not harmonized with the IPCC Guidelines of National GHG Inventories. Carbon stock and productivity values can vary significantly by ecological zone based on climate, soil, terrain, and management conditions (IPCC Guidelines, 2006). Clearly defined land use classifications and incorporating climate region specific carbon stock values based on the IPCC Guidelines and productivity values based on FAO agro-ecological zones (AEZ) will reduce uncertainty and improve transparency of calculations.

The IPCC Guidelines for National GHG Inventories provides guidance on classification of land-use categories so they are applied as appropriately and consistently as possible in inventory calculations. The proposed Directive would be well advised to harmonize GHG emissions calculations with the IPCC Guidelines to the greatest degree possible. In doing so, opportunities to coordinate with National GHG Inventory efforts and data resources increase, as well as improving consistent and transparent GHG accounting.

Article 15 in the proposed Directive excludes biofuels production, from ‘continuously forested areas’ defined as land with a canopy cover >30% and height >5m and provides carbon stock values for ‘lightly forested areas’ defined simply as not continuously forest areas. Forest cover classifications from the IPCC Guidelines, included in the proposed revised Table 5 below provide increased stratification of forest types and could reduce the uncertainty of estimates of GHG emissions and removals (IPCC, 2006). Based on these IPCC forest cover classifications global forest and land cover maps, including data for GIS, are readily available online (IPCC, 2006).

As highlighted in IPCC Guidelines, carbon stock varies by climate zone, soil type, ecological zone, and management practice (IPCC Guidelines Ch3). Carbon stock values in Annex VII 8 C of the proposed Directive are not stratified to account for these differences. Climate zones and carbon stock changes in perennial croplands after one year of conversion have been included in the proposed revised Table 5. The differences in annual change in carbon stock by climate zone in perennial croplands shown in Table 5 demonstrate the potential to improve the accuracy of GHG emissions calculations when carbon stock values are further stratified. Further stratification by soil type, ecological zone, and management practice may be too cumbersome for a table; however, a web-based tool could be developed to allow users to input land cover classifications and calculate emissions from land use change.

The IPCC Guidelines provide detailed guidance on calculating annual emissions from carbon stock changes as a result of land use change. Using a three tiered approach, the IPCC Guidelines allow for improved accuracy of calculations at higher tiers if data and resources are available. The proposed Directive would be well advised to harmonize emissions calculations of changes in carbon stock as a result of land use change with the IPCC Guidelines. This could be achieved by either requiring users to use the IPCC Guidelines when calculating emissions from carbon stock changes caused by land use change. Otherwise a table or web based tool using carbon stock values for land use types eligible for biofuels production under the proposed Directive could be developed to facilitate users.

Using the FAO agro-ecological zones methodology for calculating the productivity values of biofuels crop production could improve the accuracy of emissions calculations. The FAO agro-ecological zones methodology calculates potential crop yields by matching crop environmental requirements and land resources (IIASA, 2000). To facilitate users a simplified table of biofuel crop production by climate zone or web-based tool with further stratified crop production values could be generated based on the FAO agro-ecological zones methodology.

3.3 Direct land use changes

There has been increasing concern that carbon losses from intensification of agriculture and clearing of natural lands leads to large emissions that are not fully accounted for in analysis of the lifecycle assessment of biofuels production (Fargione et al. 2008, Searchinger et al. 2008). GHG emissions from direct land use change are addressed in two of the methodology equation terms (refer to Annex), namely e_l, annualised emissions from carbon stock changes caused by land use change and e_{cc}, emissions from the extraction or cultivation of raw materials. Specific recommendations regarding estimates of e_{cc} have been addressed in section 2.4 above. Recommendations regarding the term e_l are addressed below and more specifically in the Annex to this report.

Carbon stock values

The IPCC Guidelines for National GHG Inventories provide detailed guidance on calculating annual emissions from carbon stock changes as a result of direct land use change. Using a Tier 1, 2, or 3 approach, the IPCC Guidelines allow for improved accuracy of calculations with each successive Tier if data and resources are available. If land-use and management data are limited, as may be the case for biofuel feedstock producing regions, Tier 1 estimation methods provide guidelines on using currently available resources including aggregate data, maps, and default values. Tier 2 and 3 estimation methods provide guidelines for incorporating more detailed country-specific data and using additional modelling resources to refine estimates. As recommended in the amended proposal v1.0 to the Directive, it would be well advised to harmonize the GHG emissions calculations for emissions due to land use changes with the IPCC Guidelines to the greatest degree possible. Following the IPCC Guidelines provides the opportunity to coordinate with National GHG Inventory efforts and use existing data resources, as well as improving consistent and transparent GHG accounting.

The Directive could, as proposed in the amended proposal, require users to use the IPCC Guidelines when calculating emissions from carbon stock changes caused by land use change. Since estimates based on the IPCC Guidelines are calculated in terms of annual carbon stock changes, in order to annualise emissions from land use change over 20 years based on bioenergy production the equation in Section 7 would need to be revised. To facilitate use, a revised version of the table in Annex VII Section 8 or a web based tool with estimates carbon stock values generated for eligible land use types based on the IPCC Guidelines could be developed to facilitate users. A revised table or database of carbon stock values should be stratified by land cover classifications consistent and climate zone with the IPCC Guidelines. A proposed revised table follows in Table 5.

Article 15 in the proposed Directive excludes biofuels production, from ‘continuously forested areas’ defined as land with a canopy cover >30% and height >5m and provides carbon stock values for ‘lightly forested areas’ defined simply as not continuously forest areas. Forest cover classifications from the IPCC Guidelines, included in the proposed revised Table 5 below, provide increased stratification of forest types and could reduce the uncertainty of estimates of GHG emissions and removals (IPCC, 2006).

Based on these IPCC forest cover classifications global forest and land cover maps, including data for GIS, have been developed and are readily available online (IPCC, 2006). Use of these materials could aid in transparent and accurate land cover classification.

Carbon stock values in the existing table in Annex VII 8 C are not stratified to account for differences in climate zones. The value in stratifying by climate zone is illustrated in Table 5 by the differences in changes in carbon stock one year after conversion in perennial croplands by climate zone. Further stratification by soil type, ecological zone, and management practice may be too cumbersome for a table; however, these characteristics can be incorporated into the estimation of carbon stock values based on the IPCC guidelines and presented through a web-based tool to allow users to input land cover classifications and calculate emissions from land use change.

Productivity values

Section 7 of Annex VII provides default values for a limited number of biofuel crops and the amended proposal of Directive indicates that actual productivity values shall be used for calculating e_{l},. If available suing actual values is appropriate. Where actual values may be either unavailable or unreliable, the Directive should indicate an approved alternative source for productivity values. Agricultural data in the FAOSTAT database includes yield per hectare by country and year (FAOSTAT, 2007). Use of this database would provide a transparent and accurate source of productivity data. If resources and data allow, using the FAO agro-ecological zones methodology for calculating the productivity values of biofuels crop production could further improve the accuracy of emissions calculations. The FAO agro-ecological zones methodology calculates potential crop yields based on a model which incorporates crop environmental requirements and land resources (IIASA, 2000).

3.4 Indirect land use changes

Indirect land use change occurs when pressure on agriculture due to the displacement of previous activity or use of the biomass induces land-use changes on other lands (Gnansounou et al. 2008). The GHG emissions that result from indirect land use change are known as leakage, defined by the IPCC as changes in emissions and removals of GHG outside the accounting system that result from activities that cause changes within the boundary of the accounting system (IPCC, 2000). Article 15 of the proposed Directive prohibits conversion of natural ecosystems for biofuels production. However no similar restrictions limit conversion of natural ecosystems to agricultural production that result from indirect land use change from increased biofuels production.

Several recent studies have highlighted that GHG emissions in biofuels production from indirect land use change are more significant than emissions from direct land use change. Recent estimates from Searchinger et al. (2008) based on scenarios to estimate the effect of increasing corn ethanol production in the US, conclude that indirect land use emissions double the emissions of corn ethanol relative to gasoline. Farrell and O’Hare (2008) concluded that shifting corn-soybean production to only corn for ethanol may induce soybean expansion into forest, which would result in GHG emissions 6 times higher than gasoline. The magnitude of indirect land use changes is not expected to be linear, but several factors have been identified which determine the change in cropland including: production of co-products, crop prices, and crop yield (Searchinger et al. 2008).

Several challenges exist to accurately quantifying emissions resulting from indirect land use at a global scale. No current global models of indirect land use change exist. A global trade and economic model with country by country and crop by crop data would be needed.

Searchinger et al. (2008) use the FAPRI international model for their analysis, however since this is a partial equilibrium model interaction with other economic sectors is not accounted for. Analysis by the US EPA using the FASOMGHG model provides assessments of leakage as a result of agriculture and forestry sector activities in the US, though the applicability globally may be limited (US EPA, 2005). Revisions to the GTAP and CLUE models have been proposed and may better account for displacements resulting from indirect land use change (Gnansounou et al. 2008).

Methodologies for accounting for indirect land use change are also being developed. CDM methodologies for bioethanol production from sugar cane include consideration of GHG from indirect deforestation by requiring a fixed area radius around a project site to be annually monitored in order to assess the land use change impact of the plantation on the forested area (UNFCCC, 2007). The Dutch government has proposed a general methodology to estimate indirect land use based on determining the relevant markets/areas delivering biofuels to the country, the expansion of each of these markets due to biofuels due to food/feed and in total, how the additional demand is being met, the GHG emissions of expansion of these markets, the impacts of market expansion over biofuels and food/feed, and dividing these effects by the amount of biofuels per market (Cramer Commission, 2007).

Table 5: Carbon stock by climate zone and land use classification

IPCC Climate Zone	Tropical			Temperate		Boreal	Polar
Land Use Classification	Dry	Moist	Wet	Dry	Moist		
Reference Land Use							
Open and fragmented forest							
Other wooded land							
Other land cover: Grassland							
Other land cover: Desert							
Actual Land Use							
Annual cropland							
Perennial cropland[2]	1.8 ±75%	2.6 ±75%	10.0 ±75%	2.1 ±75%		N/A	N/A

Open and fragmented forest: Land covered by trees with a 10%-40% canopy cover and height >5m (open forest) or mosaics of forest and non-forest land (fragmented forest), including natural forests and forest plantations.

Other wooded land: Land with a 5-10% canopy cover of trees of height >5m or with a shrub cover >10% and height <5m.

Other land cover: All other non-forest land, including grassland, agricultural land, barren land, and urban areas.

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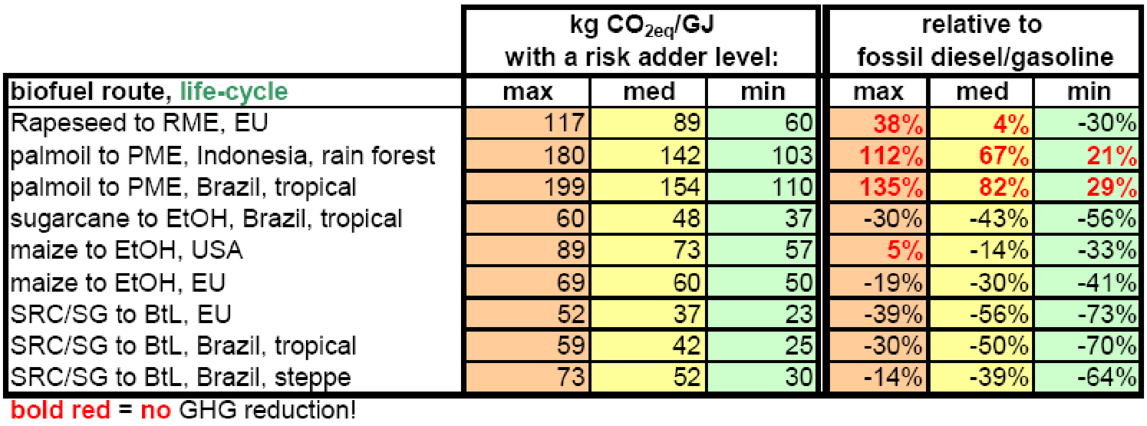
[2] Perennial cropland carbon stock in biomass after one year of land conversions to cropland (Δ C tonnes ha $^{-1}$) (IPCC Guidelines, 2006). Error range represents a nominal estimate of error, equivalent to two times standard deviation as a percentage of the mean (IPCC Guidelines, 2006).

Recent analysis by the Oeko-Institut proposed accounting for GHG emissions from indirect land use change by using an “iLUC factor” for calculating the GHG balance of biofuels (Oeko Institute, 2008). The impact of applying an iLUC factor, a bonus or penalty from the GHG emissions resulting from indirect land use change, on the GHG impact of biofuels production are shown in Figure 3. GHG emissions estimates presented in Figure 3 are stratified by biofuel type, an important consideration since indirect land use change will not be the same for all crops, and based on a range of iLUC factor levels.

Figure 3: GHG emissions from indirect land use change based on iLUC factor approach (formerly known as “risk adder”) approach.



	kg CO_{2eq}/GJ with a risk adder level:			relative to fossil diesel/gasoline		
biofuel route, life-cycle	**max**	**med**	**min**	**max**	**med**	**min**
Rapeseed to RME, EU	117	89	60	**38%**	**4%**	-30%
palmoil to PME, Indonesia, rain forest	180	142	103	**112%**	**67%**	**21%**
palmoil to PME, Brazil, tropical	199	154	110	**135%**	**82%**	**29%**
sugarcane to EtOH, Brazil, tropical	60	48	37	-30%	-43%	-56%
maize to EtOH, USA	89	73	57	**5%**	-14%	-33%
maize to EtOH, EU	69	60	50	-19%	-30%	-41%
SRC/SG to BtL, EU	52	37	23	-39%	-56%	-73%
SRC/SG to BtL, Brazil, tropical	59	42	25	-30%	-50%	-70%
SRC/SG to BtL, Brazil, steppe	73	52	30	-14%	-39%	-64%

bold red = **no** GHG reduction!

Source: Fritsche, 2008a

Market changes through time can be expected to change the indirect land use change resulting from biofuels production. If an approach such as the “iLUC factor” were applied a mechanism to revise estimates through time would be needed. Germany advocates to introduce a bonus for biofuels from residues/wastes and unused/degraded lands based on the iLUC factor (25% level) (Fritsche, 2008). Alternatively it has been suggested that a dynamic iLUC factor bonus be introduced – 25% level through 2012, 50% until 2015, and 75% until 2020 (Fritsche, 2008). Alternatively, biofuels prone to induce indirect land use change risks could receive an iLUC factor penalty (Fritsche, 2008).

It is important to note that this is **only one** approach and other methodologies have not yet emerged since the issues addressed are not yet well-researched. Therefore, it would be logical for the Directive to call for more research on this topic, and to recommend to the EC Research programme to support such research.

4. USE OF DEGRADED AND DEFORESTED LAND

Increases in demand for biofuel will necessary require large areas of land to be converted for the cultivation of bioenergy crops. Concerns have therefore been expressed about the possible conflict with land used for food production and environmental conservation.

However, research and experience have shown that certain energy crops like trees and grasses can sometimes be grown on very degraded land too marginal for food crops and can even promote land restoration before food production is able to take place.

These energy crops have the potential to extend the land base available for agricultural activities and also create new markets for farmers. The widely discussed Jatropha plant, for example, can store moisture, stabilize soil, and slow down, if not reverse, desertification while it grows (Dufey, 2006).

The question that will be addressed in this section is what the potential is of growing bioenergy crops on degraded lands in developing countries. To answer this question three sub-questions will be considered:

- What is the area of degraded land in developing countries?
- What is the potential of growing bioenergy crops on degraded land in developing countries?
- What are possible incentives for the use of degraded lands for bioenergy crop cultivation?

The discussion will start, however, with an overview of the most common definitions of degraded lands.

4.1 Definitions of degraded lands

Land degradation generally signifies the temporary or permanent decline in the productive capacity of the land (UNEP, 1992a). Another definition describes it as, “a long-term loss of ecosystem function and services, caused by disturbances from which the system cannot recover unaided" (Gretchen, 1995). More recently, the Millennium Ecosystem Assessment has defined land degradation in drylands as an “expression of a persistent decline in the ability of a dryland ecosystem to provide goods and services associated with primary production” (Millennium Ecosystem Assessment, 2005).

This link between degradation and its effect on the productivity of the land (both in terms of primary production or the provision of goods and services) is central to nearly all published definitions of land degradation. The emphasis on land, rather than soil, broadens the focus to include natural resources, such as water and vegetation. In this sense, deforestation can also be considered as a form of land degradation.

Land degradation affects a significant proportion of the land surface and large areas of degraded lands occur on lands previously used for agriculture and lands abandoned after excessive erosion, over-grazing, desertification, or salinization. According to some estimates as much as one-third of the world’s population – poor people and poor countries suffer disproportionately from its effects (UNEP, 2007).

4.2 Estimates of degraded lands

Despite the global importance of land degradation, the available data on the extent of land degradation are limited. To date, there are only two studies with global coverage and both have considerable weakness. But in the absence of anything better they have been widely used as a basis for national, regional, and global environmental assessments. (Millennium Ecosystem Assessment, 2005)

The best known study is the Global Assessment of Soil Degradation (Oldeman et al. 1991). GLASOD was compiled from expert judgments and, while invaluable as a first global assessment, it has since proven to be not reproducible and inconsistent. The second study with global coverage is that of Dregne and Chou (1992), which covers both soil and vegetation degradation. It was based on secondary sources, which they qualified as follows: ‘‘The information base upon which the estimates in this report were made is poor. Anecdotal accounts, research reports, travellers’ descriptions personal opinions, and local experience provided most of the evidence for the various estimates.’’ (Dregne and Chou in Millennium Ecosystem Assessment, 2005)

Apart from these global assessment there have been some regional studies, such as “the Assessment of the Status of Human-induced Soil Degradation in South and South East Asia” (ASSOD) (van Lynden and Oldeman 1997), “Degradation of the drylands of Asia” (Kharin *et al*., 1999) and the World Atlas of Desertification (Middleton and Thomas 1997). An ongoing project is the Land Degradation Assessment in Drylands project (LADA) and it is expected that this project will provide more detailed land degradation data in the future. For an overview of the different assessment studies, see Kniivila (2004).

Table 6 and Table 7 show some of the results from the GLASOD project. As can be soon from these tables, estimates of both areas affected by soil degradation and the severity of land degradation are lowest in North America and highest in Europe. Africa, Asia and Latin America are somewhat in between.

Table 6: Degree of soil degradation by sub continental regions (% of total area). Adopted from World Atlas of Desertification (UNEP, 1992b)

	None	**Light**	**Moderate**	**Strong**	**Extreme**
Africa	83	6	6	4	0.2
Asia	82	7	5	3	<0.1
Australasia	88	11	0.5	0.2	<0.1
Europe	77	6	15	1	0.3
North America	93	1	5	1	0
South America	86	6	6	1	0
World					
Percentage	85	6	7	2	<0.1
Area (‘000km^2)	110483	7490	9106	2956	92

Table 7: Land Degradation severity by region (% of area by severity class). Adopted from World Atlas of Desertification (UNEP, 1992b)

	None	Light	Moderate	Severe	Very Severe	Total degradation: Light-Very Severe	Degradation: Moderate – Very Severe
Sub-Saharan Africa	33	24	18	15	10	65	42
North Africa and Near East	30	17	19	28	7	70	52
Asia and Pacific	28	12	32	22	7	72	61
North Asia east of Urals	53	14	12	17	4	47	33
South and Central America	23	27	23	22	5	77	50
Europe	9	21	22	36	12	90	70
North America	51	16	16	16	0	44	29
World	35	18	21	20	6	65	47

Based on the results from the Global Assessment of Soil Degradation project, the Fourth Global Environmental Outlook published by the United Nations Environment Programme estimated that y 1990, land degradation had affected an estimated 5 million km2 of the Africa and in 1993, 65% of agricultural land was degraded. In Latin America, estimates show that 3.1 million km2, or 15.7 per cent, of the land is degraded. Furthermore, it has been assessed that the problem is more severe in Meso-America, where it affects 26 per cent of the territory, while 14 per cent of South America is affected (UNEP, 2007)

Even though the GLOSAD project indicated Europe to be most affected by soil degradation, a more recent result from the Land Degradation Assessment in Drylands LADA project shows that between 1981 and 2003 trends in soil degradation are more pronounced in Africa and South East Asia, whereas the degradation trend in Europe shows little change (see figure 1).

It should be borne in mind, however, that the numbers need to be handled with care and to determine the true extent of degradation and identify precisely where the problems occur will require more in-depth follow-up studies, combining analysis of satellite data with extensive ground-truthing.

4.3 Deforestation

According to the Fourth Global Environmental Outlook (UNEP, 2007) and based on FAO data and studies, the global forest area shrank at an annual rate of about 0.2 per cent between 1990 and 2005. Losses were greatest in Africa, and Latin America and the Caribbean. However, forest area expanded in Europe and North America. In Asia and the Pacific, forest area expanded after 2000, mainly thanks to large-scale reforestation efforts in China.

In addition to the changes in global forest area, significant changes also occurred in forest composition, particularly in the conversion of primary forest to other types of forests (especially in Asia and the Pacific). It is estimated that over the past 15 years there has been an annual loss of 50,000 km2 of primary forest, while there has been an average annual increase of 30000 km2 of planted and semi-natural forests (UNEP, 2007). Primary forests now comprise about one-third of global forest area.

4.4 Discussion

Even though some of the figures and estimates in the previous section need to be handled with care, it can be concluded that theoretically there is a considerable area of degraded land available for cultivating bioenergy crops. However, the potential of using these degraded lands for bioenergy cropping will depend on a number of factors.

First, the potential for using degraded lands for bioenergy crops will depend on the suitability and availability of the degraded land area. A study by Hoogwijk *et al*. (2003) has explored the range of future world potential of biomass for energy according to different biomass categories. Even though, the study does not specifically focus on energy crops for biofuels, the results do give some indication about the potential contribution from using degraded lands, both in terms of land area that can be used and productivity of bioenergy crops on degraded lands.

According to the study, the potential bioenergy supply from biomass production on degraded lands will be in the range of 8-110 EJ per year, based on an available area of 430-580 Mha and an annual yield between 1-10 Mg per hectare depending on the environmental and management conditions. As can be seen from table 3 this is significantly smaller than the contribution from biomass production on surplus agricultural land, but still considerably larger than the contribution from other biomass categories. Biomass production on degraded also has a much lower productivity as compared to biomass production on surplus agricultural land.

Table 8: Contribution of each biomass category to the global site potential (adopted from Hoogwijk *et al.*, 2003)

Category	Remarks	Potential bioenergy supply in EJ per year
I: Biomass production on surplus agricultural land	Available area 0 –2.6 Gha, yield energy crops 10 –20 Mg h−1 y−1	0 –988
II: Biomass production on degraded lands	Available area 430 –580 Mha, yield 1–10 Mg ha−1 y−1	8–110
III: Agricultural residues	Estimate from various studies	10 –32
IV: Forest residues	The (sustainable) energy potential of the world's forest is unclear. Part is natural forest (reserve). Range is based on estimate from various studies	10 –16 (+32 from bio-materials waste)
V: Animal manure (dung)	Estimates from various studies	9 –25
VI: Tertiary residue (organic waste)	Estimates from various studies	1–3
VII: Bio-materials	This depends highly on demand for biomaterials. Area 416 –678 Mha. This demand should come from category I and II	Minus (0) 83–116
Total		33–1130

The second issue that needs to be considered when assessing the potential of using degraded lands for bioenergy crops in developing countries is closely related to the observation which was made by Hoogwijk *et al*. in relation to the relative low productivity of growing bioenergy crops on degraded land. In fact the same factors that have held back agricultural growth in developing countries will also plague bioenergy development and growing crops on degraded land will continue to be challenging. In addition, the lack and poor quality of infrastructure especially in marginal areas, limited human capital and weak institutions will equally constrain the growth of biomass production in developing countries. Hence, even though, in theory, a large area of degraded land is available for bioenergy crop production, investments will be needed in order to overcome the existing barriers.

Finally, assessments and estimates of the potential for growing bioenergy crops on degrade lands typically don’t take into direct consideration socio-economic issues related to land rights and traditional land-use systems. Areas that are defined as being degraded in a biophysical sense might well be part of traditional land use systems. Furthermore, based on several case studies in developing countries, Webb (2001) has argued that where degradation is current and severe it cannot be assumed that affected households see this as a major concern. According to Webb land degradation is often a high priority as a "public good" (required to sustain food consumption for future generations as well as the integrity of global biotic systems), it can be a low priority at the household level. Food insecure households decide to arrest degradation or allow it to continue according to constantly shifting concerns and capacities that are only partially determined by the condition of the soil. There is therefore a real threat that the likely expansion of agricultural land for production of bioenergy crops could exacerbate conflicts over land rights and ‘landlessness’ issues in several developing countries, forcing rural dwellers to migrate, losing their access to key forest resources and ecosystem services.

4.5 Conclusions

This section has assessed the potential of using degraded lands for cultivating bioenergy crops with a focus on developing countries. From the assessment, it appears that large amounts of degraded land are available in developing countries which could potentially be used for bioenergy crop production. However, some caution is needed and local land use rights and habits need to be properly taken into account. Furthermore, one should also be careful not to overestimate the potential of growing bioenergy crops on degraded lands and be realistic about the barriers that still exist in degraded areas in terms of poor infrastructure, limited human capital and weak institutions.

5. HARMONISATION WITH OTHER PROPOSALS AND MECHANISMS

Parallel with the EU process there are also other similar efforts initiated elsewhere. An awareness of similarities and differences with these other processes would naturally be beneficial for the Directive in the interest of creating and efficient and effective market. Of special interest are the processes underway in Brazil and in California. Also of special note, and therefore discussed below, is the expected relation between certain elements of the Directive and the rules for CDM and other Kyoto mechanisms.

5.1 Brazil

In Brazil, there are several activities underway. One is the Economic-Ecological Zoning (EEZ) effort currently developed by the Ministry of Agriculture and Food, intended to map the Brazilian territory and identify the adequate areas for various biofuel crops (sugar cane and different oil-based crops). Another activity is the establishment of a Program for the Certification of Biofuels, which is currently being development at the National Institute of Meteorology, Standardization and Industrial Quality (Inmetro), along with contributions from the ministries that act in the sector (MAPA, Ministry of Environment, Ministry of Labour etc). This regulatory framework is intended to serve as the basis for an evaluation of the entire production process of biofuels (in its first phase the effort will focus on ethanol), from the crop field to the factory, and it is set up to be carried out be third-party verifiers. The framework establishes physical-chemical requirements for ethanol, as well as principles, criteria and indicators to be met by the producers during the production process, all with the socio-environmental aspects in view. Inmetro has already presented a draft on Regulations for the evaluation of ethanol production, which is almost ready, and only awaits some contributions from the different ministries. In short, there will be a second Sectoral Panel at Inmetro (the first Panel took place in June 2007) in the presence of various ministries, the President’s Office, and the production sector, which will finalize the Regulation. After this phase, the Regulation will be published in the “Diário Oficial da União” and certifiers can apply to become accredited at Inmetro.

5.2 California Low Carbon Fuel Standard

The California Low Carbon Fuel Standard (LCFS) is one of two significant proposals in the U.S., both legislated but still in the rulemaking process. The LCFS requires the average carbon intensity of transportation fuels to be reduced 10% relative to 2006 levels, by 2020 (State of California, 2007).

Carbon intensity is defined on an energy basis. The 10% reduction is measured against either the 2006 level for gasoline or the 2006 level for diesel fuel, depending on the alternative fuel(s) being blended to achieve the 10% reduction, and on the type of vehicle in which the fuel is intended to be consumed (California Air Resources Board, 2008).

Though ethanol and biodiesel are likely to be the most important low-carbon fuels used to satisfy the LCFS, compressed natural gas, liquid petroleum gas, electricity and hydrogen may also contribute to the carbon intensity calculated for each fuel. Hence the LCFS does not constitute a biofuels quota, and in theory could be satisfied with no contribution from biofuels at all. However, a subsidiary quota for “ultra low carbon fuel” is being negotiated that could make biofuels a more imperative contributor to the fuel supply.

The LCFS distinguishes between transportation fuel and the "blendstock" fuels that are blended to create the transportation fuel. The carbon intensity of any blendstock biofuel does not need to meet threshold requirements similar to those required in the Directive, since it may be mixed with other blendstock fuels of various carbon intensities that will sum to meet the LCFS.

The carbon intensity associated with each blendstock biofuel is always permitted to be a default value provided by the California government. For each type of fuel, multiple default values will be available, with more conservative values for fuels with poorly documented origins or processing pathways, and less conservative values for fuels with well-defined origins and processing pathways.

Obligated parties to the LCFS will be allowed to provide actual fuel carbon intensities, if the underlying data meet a minimum level of quality.

Biofuels used in meeting the LCFS must meet certain quality criteria. These are under development, but preliminary negotiations indicate the following, likely outcomes:

- Chain-of-custody tracking will be required using the federal Renewable Identification Number (see Renewable Fuel Standard, below);
- Obligated parties will be certified and audited;
- GHG emissions from both direct and indirect land-use change will be accounted for, with regular updates based on the rapidly evolving knowledge on this topic;
- Further sustainability criteria are unlikely to be required under the LCFS; however, it is likely that some sustainability reporting may be required, most likely a statement of (non) compliance with the standards being developed by the Roundtable on Sustainable Biofuels.

Obligated parties to the LCFS may generate tradable credits from transportation fuels having carbon intensities below the regulated threshold. The credits are bankable but borrowing is disallowed.

Renewable Fuel Standard

The U.S. Congress passed a Renewable Fuel Standard (RFS) as part of the Energy Security Act of 2005, and expanded the RFS in the Energy Independence and Security Act of 2007. The expanded RFS requires 36 billion gallons of "renewable fuel" by 2022, of which at least 21 billion gallons must be "advanced biofuel," which in turn must include at least 16 billion gallons of "cellulosic biofuel." These three types of fuel are defined as follows (U.S., 2007a).

- *renewable fuel* is biofuel derived from "renewable" feedstocks, including crops on existing agricultural or silvicultural land, forest slash and thinnings, algae, animal waste, and yard and food waste;
- *advanced biofuel* is any renewable fuel other than corn ethanol; and
- *cellulosic biofuel* is any renewable fuel derived from cellulose, hemicellulose or lignin.

The volume requirements of the RFS ramp up to the 2022 values beginning in 2008. The RFS also requires 1 billion gallons of "biomass-based diesel" (biodiesel) by 2012. Biomass-based diesel simultaneously counts toward the renewable fuel target.

Each biofuel must meet minimum GHG reduction requirements, measured with respect to the GHG emissions associated with an equal quantity of the fossil fuel it substitutes.

These minimum reductions are: renewable fuel: 20%; advanced biofuel and biomass-based diesel: 50%; cellulosic biofuel: 60%. The Administration is permitted to lower each of these reduction targets, individually, by up to 10 percentage points if the original target proves technologically infeasible.

Obligated parties to the RFS receive a "Renewable Identification Number" (RIN) for each batch of biofuel imported or produced; electronic tracking of the RINs is the government's basis for monitoring compliance with the RFS. RINs may be generated beyond the minimum quantities established by the RFS, and may be traded among the obligated parties (U.S., 2007b).

The RFS includes no other specific sustainability criteria, but an assessment of environmental and resource conservation impacts of the RFS, as well as recommendations for mitigating these, are required every three years.

5.3 Clean Development Mechanism

The Clean Development Mechanism of the Kyoto Protocol (CDM) permits non-Annex I parties to generate Certified Emission Reductions (CERs) that can be purchased and used by Annex I parties to meet their Kyoto obligations. All CDM projects must follow a baseline and monitoring methodology that has been approved by the CDM Executive Board. To date the Executive Board has approved no methodology for projects centred around cultivation of biofuel crops,[3] so the CDM provides no GHG balance methodology with which the Directive needs to harmonize. Several proposed CDM methodologies deal with biofuels; however proposed methodologies may be revised significantly prior to approval by the Executive Board and therefore do not constitute a significant reference point for the proposed Directive.

Some approved methodologies address related issues, however. Methodology ACM0006, Consolidated Methodology for Electricity Generation from Biomass Residues, considers the GHG value of displacing fossil electricity with biomass electricity, but the GHG balance of crop growth is not accounted. Methodology AM0047 (UNFCCC, 2007) also considers the GHG value of displacing fossil energy, but again excluding life-cycle GHG emissions relating to the biofuel's source.

In the context of the CDM, biofuels have received special attention on the issue of double-counting. Specifically, concern has been expressed that biofuel producers and consumers could potentially generate CDM credits from the same biofuels. One implication for future, biofuels-based CDM projects is that the produced biofuels will be required to displace fossil fuels (be consumed) in the same non-Annex I country. Though this concern is very relevant to the CDM, it should be of little concern to the proposed Directive, since the Directive is not accounting the GHG benefits of the biofuels for the purpose of meeting Framework Convention goals.

Of more interest may be the uncertain effects of the Directive on the CERs market. On the one hand, the large international market for biofuels supported by the Directive may mature the biofuels industry to the point that many biofuels-based CDM projects will be implemented and biofuels CERs flood the market. On the other hand, European demand for biofuels could divert biofuels away from domestic consumers in the non-Annex I countries, taking biofuels technologies out of the suite of potential CER sources.

5.4 Incentives for using marginal lands and feedstocks

A number of initiatives are underway internationally to evaluate the conditions and incentives related to land conversion and the use of marginal lands. One new effort within the UNFCCC is the programme on Reducing Emissions from Deforested and Degraded (REDD) land. The creation of incentives for using marginal lands and feedstocks from the production of bioenergy could prevent an expansion into hitherto untouched areas and serve the double purpose of protecting biodiversity as well as adapting to climate change through a restoration of abandoned land areas. Perhaps more importantly, it is also regarded as a way to avoid a competition between food and bioenergy production. The underlying assumption here is that bioenergy production will find its way to already abandoned areas, particularly when technological advancements in the form of second generation ethanol, generated from lignocellulosic crops, are introduced. While these production technologies have a radically improved energy balance, bioenergy production should be economically competitive also in these areas.

In order to further support this technological and logistically development Article 18:4 of the suggested Directive establishes that “for the purposes of demonstrating compliance /…/ the contribution made by biofuels produced from wastes, residues, non-food cellulosic material, and ligno-cellulosic material shall be considered to be twice that made by other biofuels”. The idea is, again, to create and further incentivize a market for these fuels.

Unfortunately, the regulatory incentives are in this case based on an incomplete analysis of the actual market conditions. As bioenergy use increases and farmers adopt the lignocellulosic crops, they will consider the development in both food and bioenergy sectors when planning their operations. In practice, economic realities at the farm level may then still lead to a competition between lignocellulosic crops and food crops, since good soils also have the higher yields for the lignocellulosic crops. in effect, the farmer will therefore use the best soil to plant the crop that provides the best, all depending on price levels in the different markets. Accordingly, an increase in food crop prices will thus produce a movement for these bioenergy crops in the direction of poorer soils. On the other hand, if the prices for the bioenergy crops increase more than food crop prices, this will cause a movement of lignocellulosic crops to better soils. From this follows that the lignocellulosic crops may be possible to produce on more marginal soils, but this does not mean that they will find their way there automatically. They will rather be pushed away from the better to the poorer soils by rising land (and food/feed crop) prices.

On a similar account, Article 18:4 may even be counter-productive to the ambition of reducing GHG emissions. Once the new lignocellulosic crops become more readily available, and market conditions favour the production of bioenergy crops on fertile soils to get maximum yield, they will effectively substitute for more traditional bioenergy crops. It is at this point that the intention to give lignocellulosic crops twice the demonstration value of traditional bioenergy crops could become a problem. From the buyers’ side, increasing access to the new crops could easily become a way to show compliance, while in fact it would generate an effective slow-down in the de facto reductions of emissions.

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ANNEX – DISCUSSION OF GHG ACCOUNTING METHODOLOGY EQUATION

The methodology described in Part C of Annex VII is in principle sound and sufficiently flexible to allow adjustment through rulemaking after the Directive is issued. The equation in Section 1 of Annex VII Part C represents the methodology with a linear equation of five additive and three subtractive terms, though Sections 3, 15 and 16 allow non-linear adjustments to the equation. This annex will refer to the linear equation as the "Methodology Equation," and suggest several improvements to the terms comprising it. The equation is listed here for reference purposes:

"Greenhouse gas emissions from the production and use of transport fuels, biofuels and other bioliquids shall be calculated as:"

$E = e_{ec} + e_l + e_p + e_{td} + e_u – e_{ccs} - e_{ccr} – e_{ee}$,

where:

E = total emissions from the use of the fuel;

e_{ec} = emissions from the extraction or cultivation of raw materials;

e_l = annualised emissions from carbon stock changes caused by land use change;

e_p = emissions from processing;

e_{td} = emissions from transport and distribution;

e_u = emissions from the fuel in use;

e_{ccs} = emission savings from carbon capture and sequestration;

e_{ccr} = emission savings from carbon capture and replacement; and

e_{ee} = emission savings from excess electricity from cogeneration.

(COM, 2008, p. 53)

e_{cc}, emissions from the extraction or cultivation of raw materials

Section 6 states that "[c]apture of CO_2 in the cultivation of raw materials shall be excluded" from e_{cc}. Though this is appropriate for the *harvested* biomass, it ignores significant, valuable potentials for soil carbon accumulation and fails to encourage the favourable agricultural practices that encourage it (Lal, 2004; Tilman et al, 2006). Giving explicit credit to such practices may be the single most powerful statement about non-climate environmental and social impacts the Directive could make. Language in Section 6 of Annex VII, Part C should be modified to allow accounting of soil carbon accumulation, or a separate, subtractive term should be added to the Methodology Equation to represent soil carbon sequestration.

Biofuels production can lead to significant CO_2 emissions from soil carbon losses, as well as N_2O emissions from fertilizer use. Further clarification and specification of how these emissions should be calculated could reduce uncertainty in emissions calculations performed under the Directive. Management practices affect soil organic carbon storage in cropland depending on the type of residue, tillage, fertilizer, and irrigation practices used (IPCC, 2006). The IPCC Guidelines include guidance on how to calculate annual emissions from cropland remaining cropland and the Directive could require that emissions calculations be based on these guidelines. For countries with limited data resources, the Guidelines allow estimates based on aggregate data such as those available from the FAO.

Intensification of agriculture to meet growing demand for energy crops, while providing adequate global food supply, is expected to lead to greater inputs of fertilizer to provide increased crop yields (Tilman et al, 2006).

A recent publication of Crutzen et al. (2008) demonstrated that N_2O emissions from the production of common biofuel crops including corn and rapeseed can contribute as much or more GHG emissions as fossil fuel use. Calculating N_2O emissions from fertilizer use is complicated by terrestrial N_2O production and requires very detailed information regarding soil conditions (CCAP, 2008). IPCC Guidelines provide an approach for estimating both direct and indirect N_2O emissions from agricultural soils that could potentially be incorporated in the Directive (IPCC, 2000b). Nevertheless, there remains considerable uncertainty, since N2O is very hard to measure, and more research should be supported in order to improve such approaches.

Section 6 also states that "[c]ertified reductions of greenhouse gas emissions from flaring at oil production sites anywhere in the world shall be deducted." This statement should be removed. First, it is not clear whether such emissions would be included in the calculation of ecc in the first place. Second, if such reductions are certified, as in the form of CERs or other tradable reductions, deducting them from ecc would amount to double counting. These emission reductions would be counted once as tradable credit (CER, ERU, or freed up EUA, depending on location) and second as reduced ecc. Finally, flaring is one of many possible upstream emission reduction activities that might comprise a certified reduction. Other activities could include leakage reduction at natural gas transmission and distribution facilities, coal mine methane capture and destruction, reduced venting and losses from oil and gas field operations, PFC reduction at aluminium smelters, etc. The following language could be substituted:

"[c]ertified reductions of greenhouse gas emissions from extraction, processing, or transportation of raw materials that can be used towards GHG emission reduction obligations (e.g. CERs, ERUs, EUAs) should be accounted for as if such reductions did not occur."

el, annualised emissions from carbon stock changes caused by land use change

Section 7 of Annex VII states that emissions from land use change shall be calculated based on the difference in carbon stocks between reference and actual land use in terms of bioenergy per unit area per year. Default reference and actual land use carbon stock values are provided in Section 8 that can be used for calculations if actual data are not available. Carbon stock and productivity values can vary significantly by ecological zone based on climate, soil, terrain, and management conditions (IPCC Guidelines, 2006). Clearly defined land use classifications that incorporate climate region specific carbon stock values estimated based on the IPCC Guidelines and productivity values based on FAO datasets could reduce uncertainty and improve transparency of calculations.

ep, emissions from processing

Language should be added to Section 9 stating that emissions due to the combustion of crop residue are not counted, similarly to the exception made in Section 11.

eccs, emission savings from carbon capture and sequestration

Realistic, commercial-scale implementations of carbon capture and sequestration (CCS) will place the industrial process at the sequestration site, or near the sequestration site with a pipeline connection. Hence, a CCS operator accounting GHGs under the Directive will intuitively omit the sequestered CO_2 from e_p so that a separate e_{ccs} term is unnecessary. Providing it encourages inadvertent double-counting of the sequestration benefit. However, if the sequestered CO_2 originates from a biomass resource, then sequestration does in fact provide a separate benefit that would be correctly captured by the e_{ccs} term. Either e_{ccs} should be eliminated from the Methodology Equation, or the language of Section 12 should be modified to allow only contributions from biomass-based CO_2.

e_{ccr}, emission savings from carbon capture and replacement

The existence of this term in the Methodology Equation seems inappropriate, since e_{ccr} does not represent emission savings associated with an alternative fuel, but rather a fossil fuel savings associated with a bio-based co-product of the alternative fuel. This is inconsistent with the careful effort in Sections 15 and 16 to segregate GHG emissions associated with fuels, from GHG emissions associated with their co-products.

Furthermore, it is essentially impossible to track, with existing administrative systems, the destiny of such bio-based products and services and to know whether or not they are in fact replacing fossil-derived CO_2.

Future Directives, voluntary GHG reduction measures, and future agreements under the Framework Convention may credit GHG reductions from commercial products and services. Including commercial products and services in this Directive aimed at energy consumption may add administrative burden to future efforts to reduce emissions from commercial products and services, and encourages confusion among entities affected by the multiple regulations on these.

It is suggested to eliminate the term e_{ccr} from the Methodology Equation.

e_{ee}, emission savings from excess electricity from cogeneration

Section 14 allows a credit for excess electricity generation, "...except where the fuel used for the cogeneration is a co-product other than agricultural crop residue." The distinction between "co-product" and "residue" will differ greatly depending on the interpreting party. Either this restriction should be eliminated, or "agricultural crop residue" should be defined explicitly as it is, for instance, in Section 16.

The final sentence in Section 14 reads, "The greenhouse gas emission savings associated with this excess electricity shall be taken to be equal to the amount of greenhouse gas that would be emitted when an equal amount of electricity was generated in a power plant using the same fuel as the cogeneration unit." This requirement fails to properly account the emission savings associated with excess electricity. The emission saving is best estimated as the emissions associated with the grid electricity displaced. Hence, this sentence should be replaced with a sentence referencing the language in Section 9, e.g., "The greenhouse gas emission savings associated with this excess electricity shall be taken to be equal to the amount of greenhouse gas that would be emitted when an equal amount of electricity is generated with the average, regional emission intensity defined in Section C.9 of this Annex."

The original approach appears to be related to the counterfactual of what would happen to the biomass residue (if that were the fuel) were it not used in the cogeneration facility. The author of the Directive appears to imply that were it not used for cogeneration, then this "excess biomass residue" would be used for electricity generation elsewhere. But the formulation in the proposed Directive assumes a very specific counterfactual – boilers and a simple power plant with its overall lower energy efficiency, which is not necessarily correct. Furthermore, the fundamental questions relates to the nature of the biomass residue in question. Is it a residue of the crop produced for the biofuel in question? If this residue were not otherwise generated (an added assumption), then perhaps a credit is due—and perhaps a credit is also due to the use of residue for the heat as well—if not, is the residue typically wasted or otherwise used? (UNFCCC, 2006). The overriding point is that there is no simple answer and there will continue to be different interpretations. However, in the interest of having a straightforward approach, it is better to use the average regional emission intensity rather than choosing a specific case as in the proposed formulation in the Directive.