Background Information

The European Commission and governments worldwide have implemented policies to promote bioenergy as a means both of reducing dependency on fossil energy and of reducing greenhouse gas (GHG) emissions. The Scientific Committee of the EEA is issuing this opinion because several policies inaccurately assess the greenhouse gas consequences of different forms of bioenergy, and because the scope of bioenergy suggested by many policy analyses could have serious adverse consequences on a range of environmental concerns.

In this document, bioenergy refers to any energy produced by combusting biomass. Biomass may be in solid form, such as wood chips or pellets burned for electricity; in liquid form, such as ethanol and biodiesel generated from crops or cellulose; or in gaseous form (biogas).

Proper Greenhouse Gas Accounting

In supporting bioenergy, many domestic regulations treat biomass combustion as carbon-neutral vis-à-vis the atmosphere, regardless of the specific source of the biomass. Although greenhouse gas accounting by these laws may count the emissions released by using fossil fuels to produce and refine the biomass[1] they do not count the carbon dioxide (CO_2) actually released by the burning of the biomass itself. They do so either because they explicitly leave this carbon out of the accounting of the emissions from bioenergy or because they endorse bioenergy without explicit greenhouse gas accounting at all on the assumption that bioenergy always reduces greenhouse gas emissions. In this sense, such regulations treat biomass as an inherently ‘carbon neutral’ energy source. For that reason, these laws may treat the shift from fossil fuels to any source of biomass as a 100% reduction in CO_2 emissions. This treatment is incorrect.

Replacement of fossil energy with biomass does not, in itself, reduce GHG emissions from exhaust pipes or chimneys. Burning one metric tonne of bone dry wood, for example, will release roughly 1.8 tonnes of CO_2 into the atmosphere. For this reason, while fossil-fuel related carbon emissions are reduced, the combustion of biomass results in its own CO_2 emissions.

Some justify treating biomass combustion as carbon neutral because they assume that the burning of biomass only returns the carbon to the atmosphere absorbed by growing plants. Plants do absorb carbon, but this thinking makes a ‘baseline’ error because it fails to recognize that if bioenergy were not produced, land would typically grow plants anyway, and those plants would continue to absorb carbon and help to reduce carbon in the air. It is double-counting to credit bioenergy for reducing carbon in the atmosphere through plant growth to the extent plants would grow and absorb that carbon anyway.

A simple example shows why. Imagine a hectare of cropland just abandoned and allowed to reforest. These growing plants would absorb carbon from the atmosphere into plant tissue, i.e. biomass. Some of that biomass would be consumed and the carbon released by animals, fungi or microorganisms and go back into the atmosphere. Other carbon would be stored in vegetation

[1] Some accounting rules, for example those underlying the EU Renewable Energy Directive, also consider the GHG emissions from direct land use change. However, they fail to account for GHGs from indirect land-use change, which does not fix the accounting error addressed here for reasons discussed below.

and soils as the forest grows, and that carbon absorption would have the effect of offsetting some of the emissions of carbon by burning fossil fuels and holding down global warming.[2] However, instead of allowing the forest to grow, if the land were used to grow energy crops and those crops were then burned in an electric power plant, the use of that biomass (the crops) would displace fossil fuel emissions, but the actual CO_2 emitted by the power plant chimneys would not be reduced. Per unit of energy, the CO_2 emissions would typically even be higher than those of a fossil fuel-burning power plant because biomass contains less energy per unit of carbon than petroleum products or natural gas and because biomass is usually burned with a lower efficiency than fossil fuels. Although the growth of the bioenergy crops absorbs carbon, using the land to grow bioenergy crops sacrifices the use of the land to absorb and sequester carbon in the forest. The CO_2 released from the chimney could be legitimately ignored only in cases where, and to the extent that the carbon absorbed by the energy crops and burned in the power plant *exceeded* the carbon that would otherwise be absorbed and sequestered by the growing forest.

Simplifying the various steps in this story, the decision to use the land for bioenergy results in more carbon stored underground in fossil fuels, however this benefit comes at the expense of less carbon stored by plants and soils. Bioenergy reduces CO_2 emissions only to the extent the first effect is larger than the second.

The use of food crops for transportation biofuels provides another example. Food crops absorb carbon. If food crops that would grow anyway on existing cropland are diverted to bioenergy use, this alternative use of the crops alone does not necessarily result in additional plant growth and additional absorption of carbon to offset the emissions from energy use. For this reason, these crops do not justify failing to account for the carbon dioxide emitted from exhaust pipes, as is typical. However, this use of crops can set in motion a series of indirect responses by way of market forces:

- Food crops do not typically keep carbon away from the atmosphere for long periods of time because the crops are consumed by people and livestock. In the process of fuelling themselves with these crops, people and livestock return almost all carbon to the atmosphere as respiration and wastes. If food crops are used for bioenergy and not replaced, so fewer crops are consumed, there is a reduction in GHGs which occurs physically because people and livestock release less CO_2 to the atmosphere. However, reducing consumption of food by increasing prices is not a desirable way of reducing GHGs.

- If the crops are replaced elsewhere, then the greenhouse gas consequences of the bioenergy depend on how they are replaced. If more crops are grown on the same land, additional carbon is absorbed from the atmosphere. If more land is converted to crops, then the calculation must include the lost carbon storage or sequestration due to changing land-use.

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[2] Baldocchi *et al.* (2008) *Aust J Botany* 56: 1-26 / Le Quéré *et al.* (2009) *Nature Geosci* 2: 831-836 / Richter and Houghton (2011) *Carbon Management* 2(1), in press.

Overall, the net indirect effects determine the CO_2 consequences of diverting crops to bioenergy. Only if and to the extent those indirect effects are *beneficial* can they justify ignoring some of the carbon dioxide emitted by vehicle tailpipes from the use of these biofuels.

The net effects of using land to produce biomass for energy use vary over time, and any comprehensive accounting system needs to consider many different aspects of land and energy use. Ultimately, however, it is useful to focus precisely on where and how physical changes occur in the absorption or emission of carbon through the use of bioenergy. Because bioenergy does not physically reduce emissions from exhaust pipes and chimneys, it must be true mathematically that bioenergy can reduce greenhouse gas emissions (except by reducing other human consumption of biomass, such as food) only if, and to the extent that:

(1) land and plants are managed to take up additional CO_2 beyond what they would absorb without conversion into bioenergy, or
(2) bioenergy production uses feedstocks, such as crop residues or wastes, that would otherwise decompose and release CO_2 to the atmosphere anyway.

Biomass that meets these criteria results in 'additional carbon' and has potential to reduce greenhouse gas emissions when used for energy.

The basic error in the assumption of general carbon neutrality of biomass is the failure to count the production and uses of biomass that land would generate *if not used for bioenergy (the counterfactual).* To assess the consequences on global warming alone, accounting must assess the rates of plant growth with and without bioenergy production, and the changes induced by bioenergy production in the total amount of carbon stored in terrestrial plants and soils. A few advantageous and detrimental examples help to illustrate the effects:

Advantageous examples:

- Some lands once covered with tropical forests are overrun by invasive grasses that frequently burn. These grasses generate few human benefits and only offer limited carbon storage. Planting bioenergy crops on these lands potentially increases the carbon absorbed by plant growth and reduces the carbon lost to fire, generating additional biomass for energy use without displacing carbon storage, food or fibre used by people.

- When bioenergy uses wastes that would otherwise be disposed of and allowed to decompose, it has the effect of reducing the carbon emitted by that waste. Although the burning of this biomass instead of fossil fuels still emits carbon, that carbon is offset by the reduced decomposition of this waste material.

- When bioenergy uses crop residues that would otherwise be burned, the same advantages occur. When bioenergy uses crop residues that would otherwise be ploughed back into the soil, there may also be a short-term net gain in carbon because much of those residues would otherwise decompose. However, care must be taken to ensure that this loss of residues does not lead to reduced productivity and therefore reduced plant growth or reduced carbon sequestration in soils.[3] Furthermore, the accounting must reflect any increases in GHG emission from fertiliser production required to replace the nutrients from the residues.

Likely disadvantageous or mixed examples:

- Clearing or cutting forests for bioenergy crops releases large stores of carbon into the atmosphere and may reduce ongoing carbon sequestration if the forest would otherwise continue to grow. Regrowing forests or planting bioenergy crops will absorb carbon that offsets the emissions from their combustion over time, but it may take decades for this carbon absorption to reach the level of the lost carbon storage and foregone carbon sequestration of the forest.[4]

- Using a food crop for bioenergy replaces fossil emissions with emissions from biomass combustion and does not absorb any additional carbon because the crop would be grown anyway. However, there may be indirect impacts, as discussed above. The loss of the crop could spur price increases and additional market reactions that may include reduced overall crop consumption, higher yields and therefore increased carbon absorption on existing farmland; or conversely cause the conversion of new lands to crops, which may release more carbon. The final greenhouse gas balance depends on the magnitude of each effect, but reduced food consumption may be an additional effect that must be guarded against.[5]

Proper accounting needs to reflect not merely the loss of existing carbon stocks in the pursuit of biomass production for energy, but also any decline of carbon sequestration that would occur in the absence of bioenergy use. For example, forests worldwide, but particularly in the northern hemisphere, are accumulating biomass and carbon for a variety of reasons,[6] and this growth absorbs carbon from the atmosphere. Some estimates of bioenergy potential suggest that biomass reduces greenhouse gas emissions so long as it only harvests this net forest growth and leaves the carbon stocks of the forests stable. But merely keeping carbon stores stable ignores the additional carbon sequestration that would occur in the absence of wood harvest for bioenergy (the counterfactual) and therefore does not make bioenergy carbon neutral.[7] For this reason, sustainable forestry in the traditional sense does not necessarily mean that bioenergy produced from a forest is carbon neutral.

Eventually, if harvested forests are allowed to re-grow, they will achieve close to the same carbon storage levels as unharvested forests, as growth greatly slows as forests reach maturity. At that point, the use of the biomass would become carbon neutral. But achieving this parity

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[3] Blanco-Canqui and Lal (2009) *Crit Rev Plant Sci*, 28, 139-163
[4] Searchinger et al. (2008) *Science* 319, 1238-1240 / Searchinger (2009) *Science*, *326,* 527-528 / Searchinger (2010) *Environm. Res. Lett.*, *5,* doi:10.1088/1748-9326/5/2/024007
[5] Fargione et al. (2008). *Science* 319, 1235-1238
[6] Pan et al. (2011) *Science* 333: 988-993 / Richter and Houghton (2011) *Carbon Management* 2(1), in press / Erb et al. (2008) *J Industr. Ecol.*, 12, 686-703.
[7] Haberl et al. (2003) *Land Use Policy*, 20, 21-39.

may take decades or even centuries, which means there could be increases in greenhouse gases in the atmosphere for a long time, which goes against policy goals of carbon neutrality.[8]

Origins of the Accounting Error

The assumption that all biomass is carbon neutral results from a misapplication of the original guidance provided for national level counting under the United Nations Framework Convention on Climate Change (UNFCC). Under UNFCCC accounting, countries separately report their emissions from energy use and from land-use change. For example, if a hectare of forest is cleared and the wood used for bioenergy, the carbon lost from the forest is counted as a land-use emission. To avoid double-counting, the rules therefore allow countries to ignore the same carbon when it is released from a chimney. This accounting principle does not assume that biomass is carbon neutral, but rather that emissions can be reported in the land-use sector. This accounting system is complete and accurate because emissions are reported from both land and energy sectors worldwide.

These conditions do not apply to any treaties and regulations, such as the Kyoto Protocol, that seek to limit emissions from energy use but do not limit emissions from land-use, or do so only weakly and that do not apply worldwide. If the removal of trees from a forest does not count toward emissions limits on land-use under a legal rule that also exempts CO_2 emitted by bioenergy, then carbon needs to be counted when it goes up a chimney or out an exhaust pipe because it would otherwise be legally ignored completely.

A law that applies greenhouse limits only to the energy sector must therefore count CO_2 emissions from bioenergy combustion except emissions from burning 'additional biomass' in the manner discussed above, i.e. biomass whose production and harvest absorbs more carbon from the air than land and its plant growth would otherwise absorb or reduces non-energy emissions.[9] The Kyoto Protocol imposed only limited restrictions on emissions from land-use which do not apply worldwide, so new accounting rules are required to count CO_2 from bioenergy use. But the accounting regime adopted for the Kyoto Protocol improperly maintained the exemption of carbon from burning biomass. This error was followed by the following European directives or provisions:

- The European Union's Emissions Trading System[10] (which caps emissions from major factories and power plants) ignores CO_2 emissions from biomass combustion;

- The Renewable Energy Directive[11] (which requires that Member States increase their use of renewable energy to 20% by 2020) explicitly sets CO_2 emissions from biomass combustion to zero (see Annex to this opinion).

[8] Cherubini et al. (2011) *GBC Bioenergy*, doi: 10.111/j.1757-1707.2011.01102.x, Cherubini et al. (2011) *Ecol. Modell.*, doi:10.1016/j.ecolmodel.2011.06.021 (in press).
[9] Searchinger (2009) *Science*, *326,* 527-528.
[10] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a system for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC, as subsequently amended. For full documentary history, see http://ec.europa.eu/clima/documentation/ets/index_en.htm, for an overview see http://ec.europa.eu/clima/policies/ets/index_en.htm.
[11] DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/E.

The European Union has also adopted two directives to spur transportation biofuels that at present also fail to include proper GHG accounting, specifically:

- The renewable fuels portion of the Renewable Energy Directive,[12] which requires that member countries use qualifying renewable energy for 10% of their transportation fuel, for which Member States have indicated that biofuels are to provide the great majority.

- The Fuel Quality Directive,[13] which requires reductions in the carbon intensity of transportation fuels.

Both these directives use the same lifecycle accounting systems to evaluate the greenhouse gas consequences of biofuels. Under these lifecycle systems, emissions involved in growing crops and refining biofuels are counted, as are those from direct land-use change. For example, if a bioenergy crop is planted in a previously forested area, the carbon released by the loss of the forest is counted as an emission of the bioenergy crop. But the accounting in these systems still ignores the *actual* emissions of CO_2 emitted from the exhaust pipes of vehicles that use biofuels, without any assurance that the biomass is additional. If the bioenergy is supplied by crops grown on existing cropland, the analysis in effect incorrectly assumes one of the following scenarios to be true: (i) this land would otherwise grow no plants, (ii) the crops it would generate are not otherwise replaced, or (iii) the crops are replaced entirely by intensifying planting and harvesting of existing cropland. If the crops are grown on grassland, the analysis counts the emissions from the conversion to cropland (in carbon lost from soils and grass), but fails to assess the consequences of replacing the forage that this land would otherwise generate for livestock. Only a fully comprehensive accounting of indirect effects could fix this error.[14]

Even with proper accounting, care should be taken that biofuels are not credited with GHG reductions based on estimates that they will indirectly lead to reductions in food consumption.

Some people have suggested that as an alternative to accounting for indirect land use change, policymakers could use the same flawed accounting system but require that biofuels reduce greenhouse gas emissions by a higher percentage compared to fossil fuels, for example by 75% instead of the 50% that will be required in the EU Renewable Energy Directive. Doing so would not solve the problem. As long as the accounting ignores the CO_2 emissions from exhaust pipes

[12] DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:en:PDF)

[13] Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32009L0030:EN:NOT)

[14] To be theoretically accurate, the accounting system should count the emissions emitted by exhaust pipes and then provide a credit for biomass to the extent it results in additional carbon reductions in the sense discussed in this opinion and its background document. The same result can be achieved backwards by assuming the biomass is carbon neutral, which means ignoring the emissions from exhaust pipes, and then adding the emissions from indirect land-use change. Incorporating indirect land-use change emissions into a typical lifecycle analysis therefore arrives at the correct GHG emission result. However, this approach will also credit biofuels for the GHG reductions due to reduced crop consumption, even if these result in hunger, and policy-makers need to exclude the reductions due to that effect unless they wish to pursue policies of reducing GHG emissions in that way.

without counting the indirect effects on land-use, the accounting assumes that plant growth cancels out exhaust pipe emissions regardless of whether there is additional plant growth.

Indeed, rather than a partial or compromise way of fixing this wrong accounting, higher greenhouse gas thresholds alone could exacerbate the problems. The incorrect accounting in effect only counts greenhouse gas emissions from the use of energy and other inputs in the making of biofuels while ignoring the effect of using land. Tighter thresholds will encourage making biofuels using more land, and more productive land, even to generate fewer litres of biofuels, if doing so reduces GHG emissions from inputs (such as energy or fertiliser), even when the true net GHG consequences would be worse.

For example, higher thresholds could encourage ethanol or biodiesel with extremely low yields on highly productive land over biofuels that attain far higher yields on less productive lands with the use of reasonable levels of fertilizer, and over biofuels from wastes and residues that need somewhat more energy in processing or transportation. Because of that effect, such a system would also incentivize biofuels with worse consequences for hunger, biodiversity and other ecosystem values.

Although estimating the indirect consequences of biofuels presents inherent uncertainties, the proper alternative cannot be to assume that biomass is carbon free and emits no CO_2, which is the assumption in existing biofuels directives. That approach is an error as the CO_2 is real and there may be no direct source of additional biomass. We strongly recommend that any accounting system quantify the greenhouse gas emissions attributable to the use of land, both direct and indirect, when evaluating the use of biofuels.

Different Sources of Biomass

The following table of different forms of biomass highlights the degree of likely potential error in the existing directives:

Source of biomass	**Degree of likely accounting error**
Converting forests currently sequestering carbon to bioenergy crops	Very high
Harvesting live trees for bioenergy and allowing forest to regrow	High
Diverting crops or growing bioenergy crops on otherwise high-yielding agricultural land	High
Using crop residues	Variable
Planting high-yielding energy crops on unused invasive grasslands	Low
Using post-harvest timber slash	Little or none
Using organic wastes otherwise deposited in landfill	Little or none

Scope of the Consequences

The directives mentioned above are influenced by studies projecting bioenergy as a potentially large and carbon-free replacement for fossil fuels. For example, the International Energy Agency has projected bioenergy as potentially the source of more than 20% of world primary energy supply by 2050,[15] while a report by the Secretariat of the UNFCCC has claimed bioenergy can supply 800 exajoules per year (EJ/yr),[16] which is far in excess of total world energy use today. Policies that consider bioenergy as carbon neutral therefore may have significant ramifications.

Producing several hundred EJ/yr of bioenergy would require a multifold increase in the human harvest of the world's plant production. Today, the total global biomass harvest for food, feed, fibre, wood products, and traditional wood use for cooking and heat amounts to approximately 12 billion tonnes of dry matter of plant material per year. This biomass has a chemical energy value of 230 EJ/yr, which is the maximum energy available if all harvested food, timber and residues were diverted to energy use. The agricultural and forestry practices implemented to generate these products have not, on balance, increased the total quantity of biomass production, but have in reality diverted production from natural ecosystems, which indicates the challenge of producing large volumes of additional biomass.[17]

Management of the world's land and ecosystems for human needs can occur more or less sustainably, but virtually all human uses of land and consumption of plants have some environmental costs.[18] Generating food and fiber requires human use of perhaps 75% of the world's highly productive, ice and desert-free land.[19] That includes direct use of roughly half of this land for agriculture, clearing of lands for crops and livestock grazing of grasslands and savannahs, and management of a substantial fraction of the world's forests for wood production. In addition, more than 70% of the water withdrawn from rivers and aquifers is used for current agriculture.[20] This agricultural intensification has doubled the amount of reactive nitrogen in the world, leading to the large-scale pollution of marine ecosystems, including extensive algal blooms and waters with low levels of oxygen.[21]

As human uses of land have already reached troubling levels, an important policy goal should be to minimise the environmental consequences of additional human demands on land-use.[22] It is very unlikely that a doubling of global human biomass harvest or more could come without serious environmental consequences.

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[15] International Energy Agency (2008), *Energy technology perspectives: Scenarios and strategies to 2050*. IEA, Paris.

[16] UNFCC Secretariat (2008), Challenges and opportunities for mitigation in the agricultural sector, Technical Paper (FCCC/TP/2008/8, Geneva) http://unfccc.int/resource/docs/2008/tp/08.pdf, p. 23.

[17] Haberl et al. (2007), *Proc. Natl. Acad. Sci.*, 104, 12942-12947. The figures in exajoules are computed from the quantities of biomass harvested for different human purposes set forth in this paper as well as in Krausmann et al. (2008). *Ecol Econ* 65: 471-487.

[18] Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-Being*. Washington, D.C.: Island Press

[19] Precise figures are limited by problems of definition, yet these general figures are reflected in Erb et al. (2010) *J Land Use Sci*, 2, 191-224 / UNEP (2007) *GEO-4 Environment for Development*. Nairobi: UNEP.

[20] Comprehensive Assessment of Water Management in Agriculture. 2007. Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture. London: Earthscan, and Colombo: International Water Management Institute.

[21] Gruber and Galloway (2008) *Nature* 451, 293-296 / Erisman et al. (2008) *Nature Geosci* 1, 636-639.

[22] IAASTD (2009) *Agriculture at a Crossroads*. Washington, D.C.: Island Press.

Because of their inherently high demands for land and water, large bioenergy production targets will also compete with uses of land and water to meet other human needs or to reduce the consequences of our existing land-use. These needs and challenges include reducing malnutrition, increasing food production for a growing population, improving the well-being of animals used for livestock, and reducing the environmental pressures resulting from agriculture. Although there are potential biomass sources that can reduce greenhouse gas emissions and be generated sustainably, more realistic expectations for bioenergy potential are necessary to avoid causing harm. These estimates should focus on the potential to generate 'additional' biomass,' which means biomass that does not merely displace biomass now used to meet other human needs, or biomass used to maintain or build carbon stocks in plants and soils.

Appendix: GHG accounting in the Renewable Energy Directive

The Renewable Energy Directive (RED) uses the following methods to account for the GHG emissions from bioenergy (see Annex V to Directive 2009/28/EC):

Total GHG emissions from the use of a fuel = Emissions from extraction or cultivation of raw materials + annualised emissions from carbon stock changes resulting from direct land-use change + emissions from processing + emissions from transport and distributions + emissions from the fuel in use – emission savings from carbon accumulation via improved agricultural management – emission savings from carbon capture and geological storage – emission savings from carbon capture and replacement – emission savings from excess electricity from cogeneration.

However, emissions from the fuel in use are set to zero for biofuels and bioliquids, which implies that these fuels are assumed to be carbon neutral.[23]

The annualised emissions from carbon stock changes resulting from land-use change are calculated as follows:

Annualised emissions = $(CS_R – CS_A)$ x 3.664 x 1/20 x 1/P – e_B

In this formula, CS_R is the carbon stock of biota and soils under reference land-use, CS_A the carbon stock of biota and soils under land-use with bioenergy production. 3.664 is a factor to convert carbon to CO_2. 1/20 means that the change in C stocks $(CS_R – CS_A)$ is evenly distributed over 20 years. P is the energy yield of the energy crop, and e_B is a bonus that is credited if the biofuel is obtained from restored degraded land.

This formula accounts for carbon emissions resulting from land-use change for energy crops as annualised stock change (20 years) resulting from the conversion of land to energy crops. It gives a credit to bioenergy produced on degraded land. However, while it provides a credit for all the carbon included in the crops diverted to biofuels, it neglects some essential components:

- Indirect land-use change: By ignoring the carbon emitted from the exhaust pipe when the fuel is used, when the crop would be grown anyway, the formula assumes carbon neutrality even when the plants used to produce the fuel did not absorb additional carbon. In effect, this formula does not account for the food, feed or fibre production of the 'reference land-use'. For example, if grassland is converted to bioenergy, the forage used as feed is not taken into account.[24] If food supply is to be held constant, the forage must be produced elsewhere, which potentially results in GHG emissions from land conversion elsewhere. If the forage is not replaced, there are greenhouse gas benefits but at potentially important costs to food production which vary with the productivity of the grassland.
- The land's ongoing carbon sequestration: If the land directly converted to energy crops is a growing forest, it would continue to sequester carbon. The loss of this sequestration is not accounted for.

[23] See http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:en:PDF (Annex V).
[24] Alberici et al. (2010) *Annotated example of a land carbon stock calculation using standard values*. Ecofys, London.

- The opportunity cost: If the land would not be required for food, feed or fibre production, it could also be converted to another use to increase its carbon sequestration. For example, if grassland products are not required, the grassland could be converted to forests and would sequester large amounts of carbon over several decades if not centuries. This foregone carbon sequestration is another real cost that should also be considered when policymakers consider biofuels.