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Goodbye to carbon neutral: Getting biomass footprints right

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ABSTRACT

Most guidance for carbon footprinting, and most published carbon footprints or LCAs, presume that biomass heating fuels are carbon neutral. However, it is recognised increasingly that this is incorrect: biomass fuels are not always carbon neutral. Indeed, they can in some cases be far more carbon positive than fossil fuels. This flaw in carbon footprinting guidance and practice can be remedied. In carbon footprints (not just of biomass or heating fuels, but all carbon footprints), rather than applying sequestration credits and combustion debits, a 'carbon-stock change' line item could be applied instead. Not only would this make carbon footprints more accurate, it would make them consistent with UNFCCC reporting requirements and national reporting practice.

There is a strong precedent for this change. This same flaw has already been recognised and partly remedied in standards for and studies of liquid biofuels (e.g. biodiesel and bioethanol), which now account for land-use change, i.e. deforestation. But it is partially or completely missing from other studies and from standards for footprinting and LCA of solid fuels.

Carbon-stock changes can be estimated from currently available data. Accuracy of estimates will increase as Kyoto compliant countries report more land use, land use change and forestry (LULUCF) data.

1. Carbon footprints of biomass fuels: current guidance and practice

Prominent guidance for carbon footprinting (Table 1) presumes that biomass is inherently carbon neutral. Carbon dioxide emitted in biomass combustion is automatically excluded from carbon footprints.

Guidance from the World Business Council for Sustainable Development and the World Resources Institute (WBCSD, 2004; WRI, 2006; WRI, 2007) recognises that presuming carbon-neutrality is problematic, but it still excludes biomass carbon-combustion emissions from its footprint definitions.

Most published footprint or life-cycle assessment studies take the same approach; they automatically exclude carbon dioxide emitted in the combustion of biomass. This has been reported by Rabl et al. (2007), and it has been confirmed by the author. In an early 2008 survey of over 100 publications by 56 researchers about solid biomass fuels, 25 researchers were identified who had estimated footprints of wood fuel (in log, pellet or chip form). Of those 25 researchers, only Börjesson and Gustavsson (2000) did not presume wood to be carbon neutral.

Published studies presume carbon neutrality of biofuels in either of two approaches: *implicit* sequestration credit or *explicit* sequestration credit. Most studies apply the former approach, simply ignoring the CO_2 flux within a biofuel (Rabl et al., 2007), presuming that 'CO_2 in equals CO_2 out', so using a net flux of zero. Others, such as EcoInvent (2003), use the latter approach, offsetting biomass-combustion CO_2 emissions with a sequestration credit that is nearly equal to the combustion emission. Either way, the biomass combustion footprint is zero or close to it, i.e. carbon neutral.

Disaggregated carbon footprints, using both of these approaches to carbon neutrality, are shown below (Tables 2 and 3), using figures from EcoInvent (2003) for forested logs used as heating fuel. In both cases, for reference to a fossil fuel[1] they are compared to natural gas in residential heating, again using figures from EcoInvent.

2. Problems with current guidance and practice

Current guidance and practice are problematic for three reasons. It defies common sense, contravenes UNFCCC rules and ISO standards and ignores a large body of existing research.

2.1. It defies common sense

If a tree is harvested for fuel, this reduces carbon stocks. However, current approaches to carbon footprinting – by presuming carbon neutrality – do not recognise this.

This is problematic, because first, as Rabl et al. (2003) point out, this can lead to absurd conclusions: for example, if carbon neutrality is presumed, it makes no difference to a carbon footprint if a forest is standing or if it has been chopped down for fuel wood.[2] Second,

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[1] Fossil fuels do not receive sequestration credits, either implicit or explicit, in current guidance and practice.

[2] As long as the land use has not been changed, i.e. the forest is allowed to regrow.

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Table 1
Prominent guidance that presumes bio-based products to be carbon neutral

Guidance	Where biomass carbon-neutrality is presented	Reference
European Union Emissions Trading Scheme	Table 4	European Commission (2007)
European Union Renewable Energy Directive (proposed)	Annex VII	Renewable Energy Directive (proposed) (2008)
PAS 2050 — Specification for GHG emissions of goods and services	Clauses 3.25, 5.3.1 and 5.4	PAS 2050 (2008)
UK Standard Assessment Procedure for Energy Rating of Dwellings, 2005	Table 12	Standard Assessment Procedure (2008)
UK Building Regulations	Table 17	UK Building Regulations (2008)

presumed carbon neutrality generally leads to an understatement of biomass footprints. For instance, if a forest is harvested intensively for fuel, as opposed to being preserved, this makes no difference in today's footprint, even if the carbon stock of the latter clearly exceeds that of the former.

The problem here is not academic; it is real. Global forest stocks are declining, and a significant reason for this is harvesting for use as fuel (FAO, 2005).

2.2. It contravenes UNFCCC rules and ISO standards

The basis of UNFCCC reporting rules, the Kyoto Protocol, states in Article 3.3 that "net changes in greenhouse gas emissions by sources and removals by sinks resulting from direct human-induced land-use change and forestry activities… measured as verifiable changes in carbon stocks in each commitment period, shall be used…" to measure compliance with Kyoto targets. At least two leading Kyoto-compliant countries, Switzerland (BAFU, 2008) and the UK (UK DEFRA, 2006), report on this basis, showing that Article 3.3 is put into practice.

Measuring net changes in carbon stocks (as opposed to presumptive carbon neutral) is also the principle behind International Standard 14064-2 for greenhouse-gas reporting. This ISO standard, in sections A.2.1 and A.3.3–A.3.5, includes requirements to report GHG sources, sinks and reservoirs (ISO14064-2, 2006). Although this standard applies to project footprinting and is presented rather generically, clearly it can be applied to footprinting of organisations or products.

2.3. It ignores a large body of existing research

Although much guidance and practice presumes biomass to be carbon neutral, there exists a robust, credible and well-known body of research suggesting that this is not automatically justified. The principle, as Marland and Marland (1992) put it, is that:

> "Trees are equally effective in preventing the accumulation of CO_2 in the atmosphere if they remove a unit of C from the atmosphere or if they supply a sustainable source of energy that substitutes for a unit of C discharged by burning fossil fuels….The most effective strategy for using forest land to minimize increases in atmospheric CO_2 will depend on the current status of the land, the productivity that can be expected, the efficiency with which the forest harvest is used to substitute for fossil fuels, and the time perspective of the analysis. For forests with large standing biomass and low productivity the most effective strategy is to protect the existing forest. For land with little standing biomass and low productivity, the most effective strategy is to reforest or otherwise manage the land for forest growth and C storage. Where high productivity can be expected, the most effective strategy is to manage the forest for a harvestable crop and to use the harvest with maximum efficiency either for long-lived products or to substitute for fossil fuels. The longer the time perspective, the more likely that harvesting and replanting will result in net C benefits."

In other words, the *Marland Approach* presumes that:

- Sequestration and biofuel usage are equally valid means of lowering net carbon emissions.
- For a given tract of existing or potential forest, the choice between preserving it and harvesting it for biofuel depends on: 1) energy conversion efficiency, and 2) productivity (or yield).

Since being proposed in 1992, the Marland Approach has been developed in numerous other studies (Schlamadinger et al., 1994; Schlamadinger and Marland, 1996a; Schlamadinger and Marland, 1996b; Schlamadinger et al., 1997; Marland and Schlamadinger, 1997; and Schwaiger and Schlamadinger, 1998) and by an International Energy Agency Task Force (IEA Bioenergy Task 38). It is presented in the Encyclopedia of Energy (2004), and it has been applied by the

Table 2
Current footprint method, excluding biomass combustion emissions

Approach	Implicit sequestration credit	No sequestration credit
Fuel	Harvested logs	Natural gas
Footprint g CO_2eq/MJ		
Cultivation-to-harvest or production	2.5	3.6
Processing	0	3.5
Transport	0.25	7.8
Combustion	2.15[a]	55.1[b]
Total	4.9	70.0

[a] Non-CO_2 GHG emissions only, i.e. combustion of biomass (in this case, logs) is presumed to be carbon neutral.
[b] All GHGs, including CO_2.

Table 3
Current footprint method, including explicit sequestration credit and combustion debit

Approach	Explicit sequestration credit	No sequestration credit
Fuel	Harvested logs	Natural gas
Footprint g CO_2eq/MJ		
Sequestration credit	−164.25	0
Cultivation-to-harvest or production	2.5	3.6
Processing	0	3.5
Transport	0.25	7.8
Combustion[a]	166.4	55.1
Total	4.9	70.0

[a] All GHGs, including CO_2.

Table 4
Proposed footprint method, with biomass carbon-stock depletion

Scenario	Biomass carbon-stock depletion	
Fuel	Harvested logs	Natural gas
Footprint g CO_2eq/MJ		
Cultivation-to-harvest or production	2.5	3.6
Processing	0	3.5
Transport	0.25	7.8
Combustion[a]	2.15	0.1
Carbon-stock decrease[b]	164.25	55.0
Total	169.15	70.0

[a] Non-CO_2 GHG emissions only.
[b] A decrease in carbon stock is shown as a positive number, because carbon footprints are measured as emissions. An increase in carbon stock would be shown as a negative number.

UNFCCC (2003) in its guidance for national reporting of wood harvesting.

3. Liquid biofuels set a precedent

Challenging the presumed carbon neutrality of biofuels is not entirely new. Only a few years ago, transport biofuels – mainly bioethanol and biodiesel – were considered inherently carbon neutral. This was challenged by a number of studies (for example, EMPA, 2007; or RTFO, 2008) showing that land use change can make footprints highly carbon positive.

Today, researchers and governments generally accept that land-use change must be accounted in liquid biofuel footprints. This change of perception – accepting that biofuels are not automatically carbon neutral – was painful. It hurt biofuel producers, who had invested in new capacity with strong government encouragement, and governmental flip-flopping on biofuels' benefits damaged credibility with the public (Politics, 2008). Early action on the issue posed in this paper – which is similar but not the same as the land use issue – can minimise this sort of pain.

4. The fix: add a footprint line-item of carbon-stock change

To avoid absurd or inaccurate results and to comply with UNFCCC rules, this paper suggests that rather than applying sequestration credits and emission debits, carbon footprints should instead apply a 'carbon-stock change' line item. This method generates accounts more consistent with common sense, UNFCCC aims and the 'Marland branch' of existing literature.

To show how this proposed method would work, two scenarios for changes in carbon stocks are presented. In the first scenario (Table 4), standing trees are being cut and used for fuel. Net carbon stocks in the forest are being depleted, either via deforestation or conventional harvesting. The footprint is equal to that calculated by the current method, but without the sequestration credit (which in the case of carbon-stock depletion, is not justified).

In the second scenario (Table 5), the wood being combusted is not reducing carbon stock, i.e. carbon stocks in the forest are not affected. (It is presumed to be some sort of waste wood that would have decomposed or somehow returned its carbon to the atmosphere anyway.) The footprint is equal to that calculated by the current method, with the sequestration credit.

These are only two out of many possible scenarios for the biomass footprint. Clearly, a number of intermediate scenarios can be envisioned, depending on the extent of carbon stock depletion. Scenarios can also be envisioned where carbon-stock is accruing, which could lead to a net negative footprint for the biomass fuel. The effect over time should be considered (and time periods under consideration should become explicit, which they are not under current guidance and practice); carbon stock should somehow be integrated over time and multiple harvest cycles.

Table 5
Proposed footprint method, without biomass carbon-stock depletion

Scenario	No biomass carbon-stock depletion	
Fuel	Waste logs	Natural gas
Footprint g CO_2eq/MJ		
Cultivation-to-harvest or production	2.5	3.6
Processing	0	3.5
Transport	0.25	7.8
Combustion[a]	2.15	0.1
Carbon-stock decrease	0	55.0
Total	4.9	70.0

[a] Non-CO_2 GHG emissions only.

To show more precisely what is going on, carbon-stock change might be presented as a selection of subcategories (that are suggested by under UNFCCC rules and monitored by Switzerland, the UK and probably some others): afforestation, reforestation, deforestation and forest management. Perhaps over time it could be disaggregated even further into carbon in soil, carbon in technosphere reservoirs and other such categories.

Carbon-stock changes can be estimated from data currently made available by the Intergovernmental Panel on Climate Change (2008). Accuracy of estimates will increase as Kyoto-compliant countries report more land use, land use change and forestry (LULUCF) data.

5. What is carbon stock?

IPCC's guidance (2008, Annex A) defines carbon stock as "the quantity of carbon in a pool." Further, it defines carbon stock changes as: "The carbon stock in a pool can change due to the difference between additions of carbon and losses of carbon. When the losses are larger than the additions, the carbon stock becomes smaller, and thus the pool acts as a source to the atmosphere; when the losses are smaller than the additions, the pools acts as a sink to the atmosphere."

These appear to be useful definitions. Over time, it will likely be necessary to detail and disaggregate them further.

6. Areas for further research

To work well in practice, the argument of this paper will need to be detailed much further: how should carbon stock be defined, i.e. what constitutes a forest or other carbon stock; what is waste, i.e. what can be combusted with a presumed zero depletion of carbon stock[3]; how to integrate carbon stock over time; how to subcategorise its additions and depletions; and how to deal with various types and sources of biomass.

Much of this need not be original research. A large body of knowledge, based on the Marland Approach, can be adapted to this purpose.

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[3] A reviewer of an earlier version of this paper has pointed out that, for instance, some people might define used furniture as waste-wood, with a presumed carbon-stock decrease of zero upon combustion. Others might say that combusting the used furniture constitutes carbon-stock decrease. This paper does not resolve that difference of opinion, but recognizes its importance and suggests that it be studied further.

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