Business from technology

GWP-based indicators to describe the climate impacts of wood *use* cycles

IEA Bioenergy Task 38 Expert Working Meeting

How to present the timing of emissions from bioenergy in LCA and GHG accounting

Thursday, April 12th – Friday, April 13th 2012

Argonne National Laboratory, Chicago

Kim Pingoud

VTT Technical Research Centre of Finland

CRF-based metrics

Basic assumption: Cumulative Radiative Forcing (CRF) (or Absolute Global Warming Potential (AGWP)) within some prescribed timeframe appropriate measure for the climate impacts

Generalisation of the GWP_{bio} factors to displaced emissions

- Cherubini et al. (2011): C debt due to biomass harvest, GWP_{bio} factor introduced, analogous to the GWP factors defined for non-CO_2 GHGs, whose atmospheric dynamics different
- Schlamadinger and Marland(1996, 1997): Displacement of fossil C emissions by biomass, cumulative C balance of biomass and fossil C stocks, displacement factor DF as indicator of efficiency
- **Pingoud et al. (2012):** Extension of the GWP_{bio} factors applied to cLCA and scenario analysis. Climate impacts of displacement of fossil fuels and fossil C intensive products by biomass; also consideration of other than instant pulses + bioenergy production scenarios

Cherubini F, Peters GP, Berntsen T, Strømman AH, Hertwich E (2011) CO2 emissions from biomass combustion for bioenergy: atmospheric decay and contribution to global warming. GCB Bioenergy. DOI: 10.1111/j.1757-1707.2011.01102.x.

Marland G, Schlamadinger B (1997) Forests for carbon sequestration or fossil fuel substitution? A sensitivity analysis. Biomass and Bioenergy 13(6): 389-397.

Pingoud, K.; Ekholm, T.; Savolainen, I. (2012) Global warming potential factors and warming payback time as climate indicators of forest biomass use. Mitigation and Adaptation Strategies for Global Change 17: 369–386. Springer. doi-link: 10.1007/s11027-011-9331-9 (online first 3 November 2011)

Schlamadinger, B and, Marland, G (1996) The role of forest and bioenergy strategies in the global carbon cycle. Biomass and Bioenergy 10(5/6):275-300.

GWP_{bio} factor

Relative climate impact of the biomass C **pulse** emission (due to extraction of biomass) causing a temporary C debt in forest, in proportion to an equal fossil C pulse emission (no flow back to tectonic stocks) (Cherubini et al. 2011):

$$GWP_{bio}(T) = \frac{AGWP_{bio}(T)}{AGWP_{fos}(T)} \qquad (1)$$

GWP_{bio} factor a dimensionless index, a function of the mitigation timeframe ***T***.

Analogous to definition of GWP factors of non-CO_2 GHGs describing their CRF in proportion to CO_2; ***T*** = 100 years commonly used.

Impulse response approximation of the Bern2.5CC model used in the calculations

Substitution impacts: GWP_{biouse} factor (1)

When the extracted biomass is used to substitute fossil C emissions and part of the biomass is sequestered into the products, the CRF of climate benefits (with respect to the fossil alternative) can be described by:

$$AGWP_{biouse}(T) = \int_0^T \left(RF\left(S_{displ}(t)\right) + RF\left(S_{seq}(t)\right)\right) dt \qquad (2)$$

where ***RF*** is the instant radiative forcing and $\boldsymbol{S_{displ}}$ and $\boldsymbol{S_{seq}}$ are the atmospheric concentration changes due to displaced fossil C emissions and to biogenic C sequestered into biomass products, respectively.

The concentration dynamics are calculated by the impulse response model by the IPCC, based on the Bern2.5CC model.

Substitution impacts: GWP_{biouse} factor (2)

The GWP index can be generalised to describe the **net** climate benefits of the whole biomass lifecycle:

$$GWP_{netbio}(T) = \frac{AGWP_{bio}(T) + AGWP_{biouse}(T)}{AGWP_{fos}(T)} \qquad (3)$$

$$= GWP_{bio}(T) + GWP_{biouse}(T) \qquad (4)$$

Where $\boldsymbol{GWP_{netbio}}$ is the GWP of the net climate impact of the biomass extraction and use, and $\boldsymbol{GWP_{biouse}}$ that of the plain use cycle.

The timeframe $\boldsymbol{T}$ after which $\boldsymbol{GWP_{netbio}} \leq 0$ is the **Cumulative Warming Payback Time**.

Substitution impacts: GWP_{biouse} factor (3)

Note that in case biomass is used just to bioenergy displacing fossil fuels immediately (no temporary product C stock):

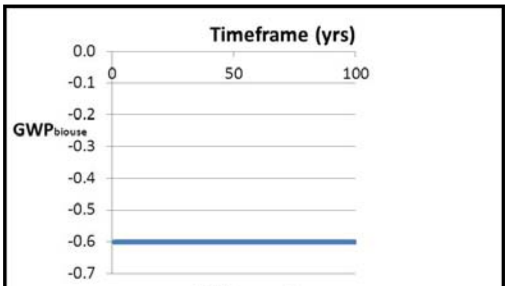
$$GWP_{biouse}(T) = -DF \qquad (5)$$

where DF is the displacement factor (Schlamadinger and Marland, 1996 and 1997).

Note that DF could also basically be estimated by energy system models taking into account the market-mediated effects.

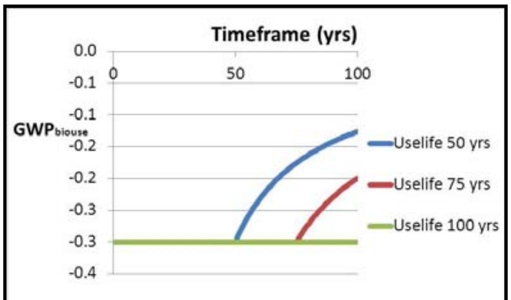
Substitution impacts: GWP_{biouse} factor (4)

- Pure fossil C displacement in the year of bm extraction:



GWP_{biouse} when the displacement factor DF = 0.6

- Pure C sequestration into bm products (temporary C stock):



GWP_{biouse} when 30% of biomass sequestered to long-lived products

Further generalisations (1)

- The method could also be applied in aLCA to generate C footprint estimates of all the emissions taking place during the lifecycle of the product (in this case **no** substitution impacts would be considered, but the sequestered biomass C would be included, described as a negative eq. emission).
- The emissions with different timing could be represented as an eq. fossil C emission occurring at initial time if the timeframe is fixed (e.g. 100 yrs). Example: life cycle of a house and its emissions during contruction phase and use phase, e.g. from heating and renovation.

Further generalisations (2)

- The method can also be generalised from single 'product' LCA to scenario analysis, to arbitrary biomass extraction scenarios, for example, continuous biomass extraction (step pulse).
- The use of CRF metrics could also be applied instead of the C neutrality factor (Schlamadinger and Spitzer 1995; Zanchi et al. 2011) when comparing bioenergy and fossil fuel systems by defining a Cumulative Warming Neutrality factor:

$$CWN(T) = 1 - \frac{AGWP_{bio}(T)}{AGWP_{fos}(T)} \quad (6)$$

Schlamadinger B, Spitzer J (1995) CO_2 mitigation through bioenergy from forestry substituting fossil energy. In: Biomass for Energy, Environment, Agriculture and Industry. Proceedings of the 8th European Biomass Conference, Vienna, Austria, 3–5 October 1994, Vol 1 (eds Chartier P, Beenackers AACM, Grassi G), pp. 310–321. Oxford, Pergamon.

Zanchi G, Pena N, Bird N (2011) Is woody bioenergy carbon neutral? A comparative assessment of emissions from consumption of woody bioenergy and fossil fuel. GCB Bioenergy. DOI: 10.1111/j.1757-1707.2011.01149.x