Nettoflüsse von organischem Kohlenstoff zwischen Biosphäre und Atmosphäre bei der Biomasseverbrennung – die Bedeutung von systemischen *feedbacks*

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Präsentation am 14. Klimatag
Organisiert vom CCCA
BOKU, 4.-5.4.2013
The global carbon cycle

Source: umich.edu
### CO₂ emissions from combustion per unit of energy

<table>
<thead>
<tr>
<th>Fuel</th>
<th>CO₂ emissions (kg CO₂ / kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>0.35-0.40</td>
</tr>
<tr>
<td>Oil products</td>
<td>0.26-0.30</td>
</tr>
<tr>
<td>Natural gas</td>
<td>0.20-0.22</td>
</tr>
<tr>
<td>Biomass</td>
<td>≈ 0.40 (≈ 0.1 g/J)</td>
</tr>
</tbody>
</table>

If C absorption during plant growth is neglected, CO₂ emissions of biomass combustion are higher than those of fossil fuel combustion.
‘Conventional wisdom‘

CO\textsubscript{2} emissions of biomass combustion need not be counted because plants absorb CO\textsubscript{2} when they regrow

Combustion of biomass provides carbon neutral energy
But …

Land grows plants, whether it is used for bioenergy or not

Assuming that CO$_2$ emitted during biomass combustion is offset through plant growth results in many cases in double-counting of carbon.

C Bestände und Flüsse in einem Ökosystem (ohne Menschen)

Net primary production (NPP)

Respiration wildliving heterotrophs ($R_{wh}$)

Natural biomass combustion ($BMC_{nat}$)

Carbon stocks in biota and soils ($C_{b+s}$)

Net addition to stocks ($NAS_{b+s}$)

Eine Vergrößerung von \( \text{BMC}_{\text{hum}} \) ist nur dann C-neutral, wenn sie durch Veränderungen aller anderen Flüsse ausgeglichen wird!

Net sink = \( \text{NAS}_{b+s} + \text{NAS}_{a+i+h} = \text{NPP} - R_{\text{wh}} - \text{BMC}_{\text{nat}} - R_{l+h} - \text{BMC}_{\text{hum}} \)

\( \text{C}_{a+i+h} \), \( \text{NAS}_{a+i+h} \) ... stocks and NAS of artefacts, livestock and humans

\( R_{l+h} \) ... respiration of livestock and humans

\( \text{BMC}_{\text{hum}} \) ... human-induced biomass combustion

Biomass combustion can only help to reduce CO₂ if
(1) The biomass stems from additional plant growth or
(2) The biomass would have decomposed rapidly if not used for energy

Entwicklung von Flüssen und Beständen über die Zeit (*plot scale*)

„Slow in – Fast out“

(Körner 2003, 2007)

→ „Opportunitätskosten“

Nach Odum 1969
Critical issues determining the C balance of biomass combustion

• Purpose-grown biomass
  – What would have happened on the land if not used to grow bioenergy crops? C sequestration, food or energy crops, etc.?
  – If food or feed crops are replaced: are they replaced? If so, how: intensification (increased yields = more plant growth) and/or land-use change (e.g. deforestation elsewhere -> iLUC)?

• Residues
  – What would have happened with the residue if not used for bioenergy? (burning, use as fertilizer)
  – Reduced use of residues as fertilizer may deteriorate soils and result in C loss from cropland soils
Probabilistic analysis of iLUC emissions of US corn ethanol

- Emissions of petroleum-based gasoline are ≈ 100 gCO₂-eq MJ⁻¹
- Life-cycle emissions of corn-based ethanol excluding iLUC are 30-70 gCO₂-eq MJ⁻¹
- Neglecting iLUC is equivalent to assuming that iLUC emissions were zero

Figure: Plevin et al., 2010, Env Sci Tech 44, p. 8019
Other emission data: Chum et al., 2011, in: IPCC-SREEN
Annual wood harvest versus carbon stocks in Norwegian forests
Payback time of the C debt resulting from increased wood harvest, Norway

- **Red line**: Drop in the forest carbon stock due to increased logging.
- **Green dashed line**: Accumulated reduction in carbon emissions from coal combustion due to increased supply of pellets.
- **Blue line**: Accumulated reduction in carbon emissions from fossil fuels due to increased supply of liquid biofuels.
Gesucht: THG-Kostenkurve für globale Bioenergie

A, B, C, D .... Bioenergy production sequesters C
E, F .... Bioenergy production produces GHG but less than fossil fuels
G, H .... Bioenergy produces more GHG than fossil reference
We don‘t know which percentage of the global bioenergy potential is climate-friendly

• Beneficial examples
  – Biomass grown on degraded lands in dryland areas (e.g., salinized croplands in Australia) or on degraded, erosion-prone tropical lands
  – Biomass residues and biogenic wastes that would otherwise decompose (if not needed to sustain soil fertility)

• Questionable to detrimental examples
  – Most current ‘first generation‘ biofuels from cropland (rape/soy oil, ethanol from maize)
  – Increasing harvests in existing forestry systems to produce more fuelwood

• Disastrous examples
  – Palm oil produced on cleared tropical forests, especially if peatlands are lost
  – Almost any energy bioenergy pathway that results in deforestation (directly or indirectly)