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

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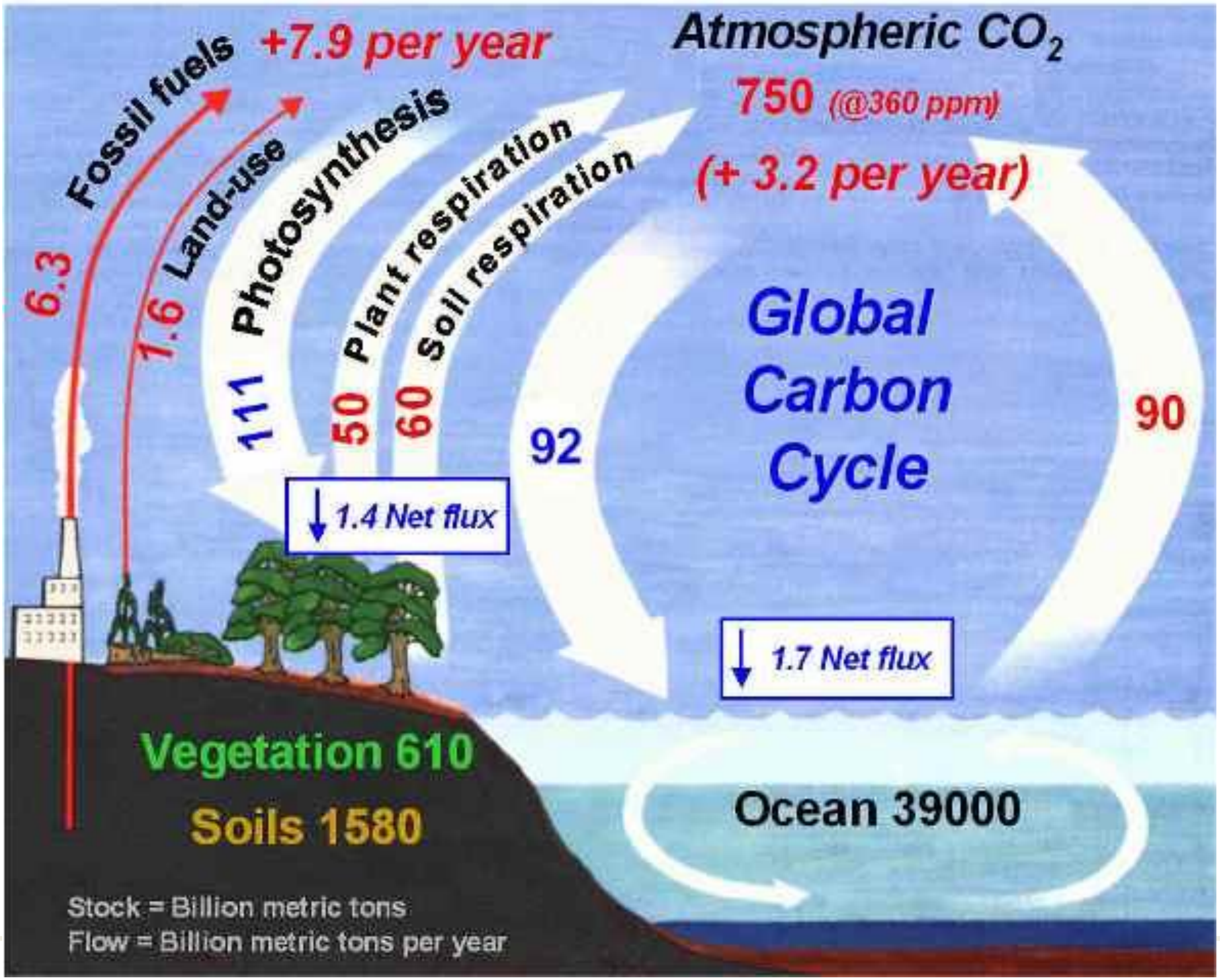
The global carbon cycle



Source: umich.edu

CO_2 emissions from combustion per unit of energy

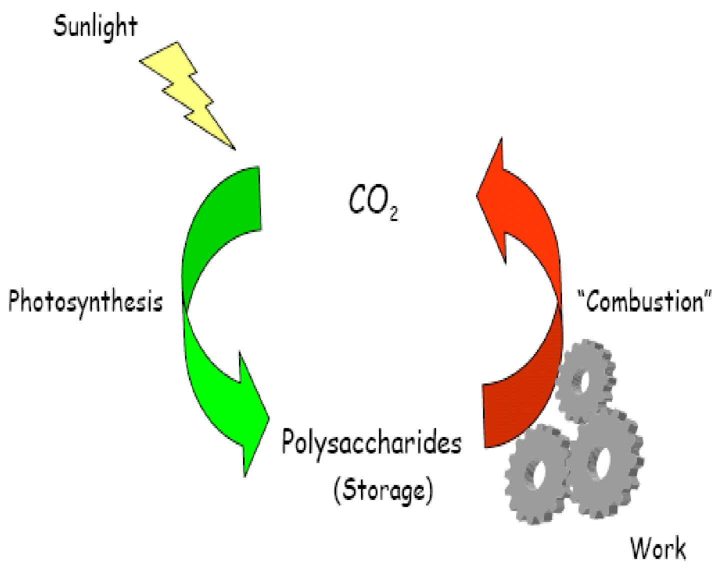
Coal	0.35-0.40 kg CO_2 / kWh
Oil products	0.26-0.30 kg CO_2 / kWh
Natural gas	0.20-0.22 kg CO_2 / kWh
Biomass	≈ 0.40 kg CO_2 / kWh (≈ 0.1 g/J)

If C absorption during plant growth is neglected, CO_2 emissions of biomass combustion are higher than those of fossil fuel combustion.

‚Conventional wisdom‘

CO_2 emissions of biomass combustion need not be counted because plants absorb CO_2 when they regrow

Combustion of biomass provides carbon neutral energy



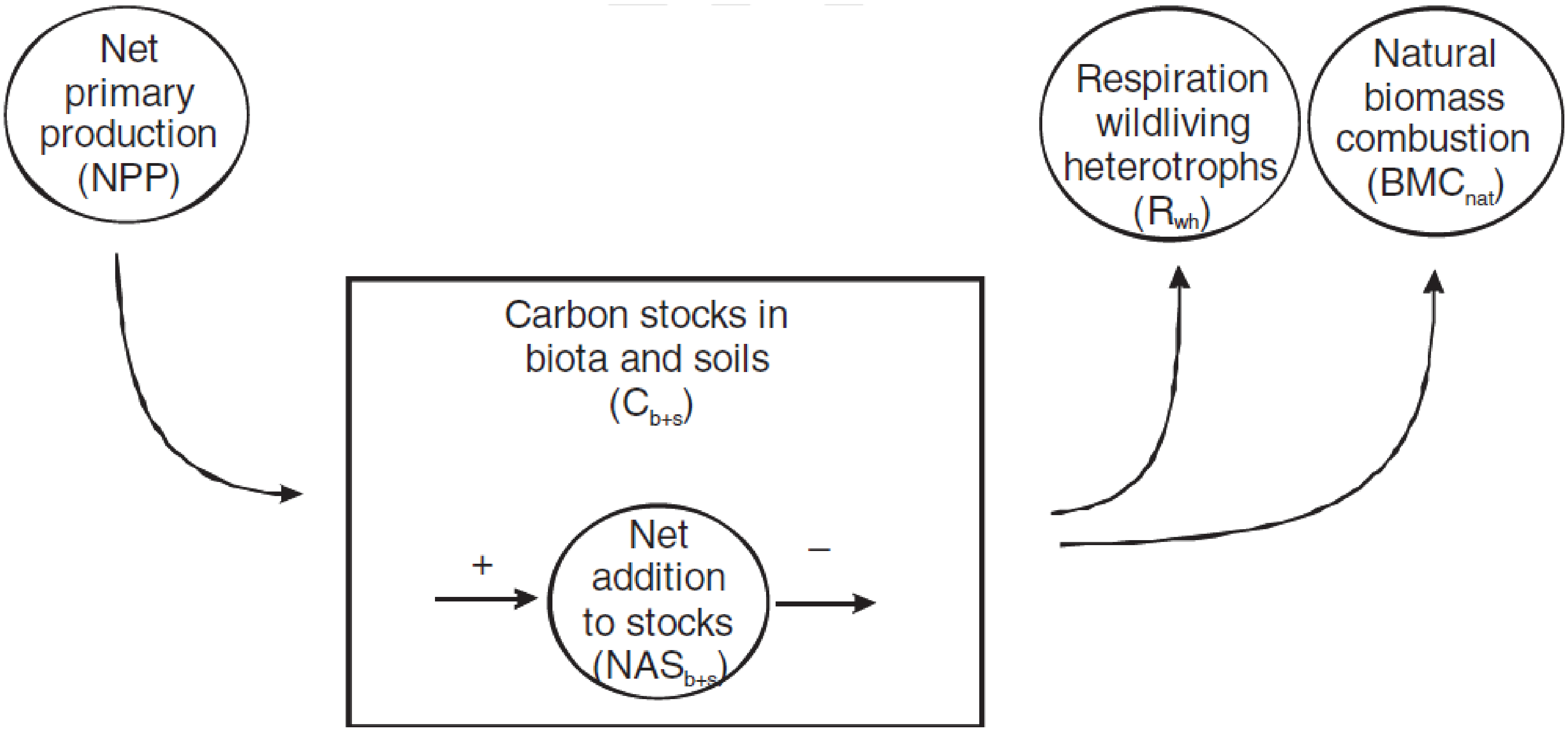
But …

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.

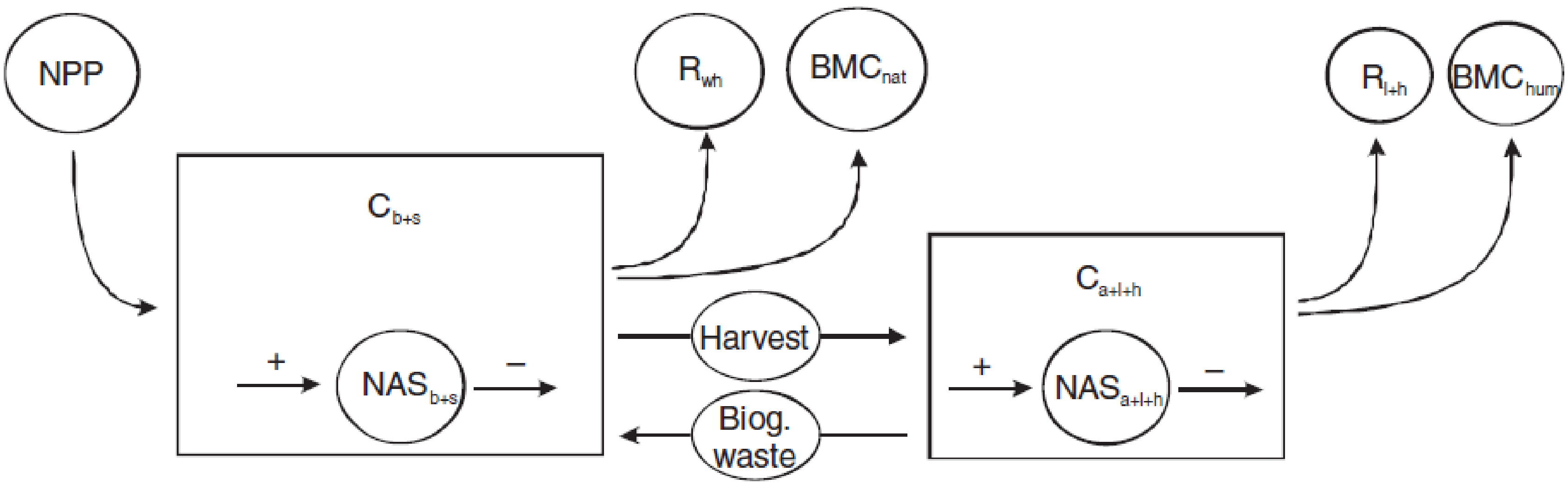
Searchinger 2010, Env. Res. Lett.

C Bestände und Flüsse in einem Ökosystem (ohne Menschen)



Haberl, 2013 GCB Bioenergy, doi: 10.1111/gcbb.12071

C Bestände und Flüsse in einem sozial-ökologischen System



Net sink = NAS_{b+s} + NAS_{a+l+h} = NPP - R_{wh} - BMC_{nat} - R_{l+h} - BMC_{hum}

C_{a+l+h}, NAS_{a+l+h} ... stocks and NAS of artefacts, livestock and humans
R_{l+h} ... respiration of livestock and humans
BMC_{hum} ... human-induced biomass combustion

Eine Vergrößerung von BMC_{hum} ist nur dann C-neutral, wenn sie durch Veränderungen aller anderen Flüsse ausgeglichen wird!

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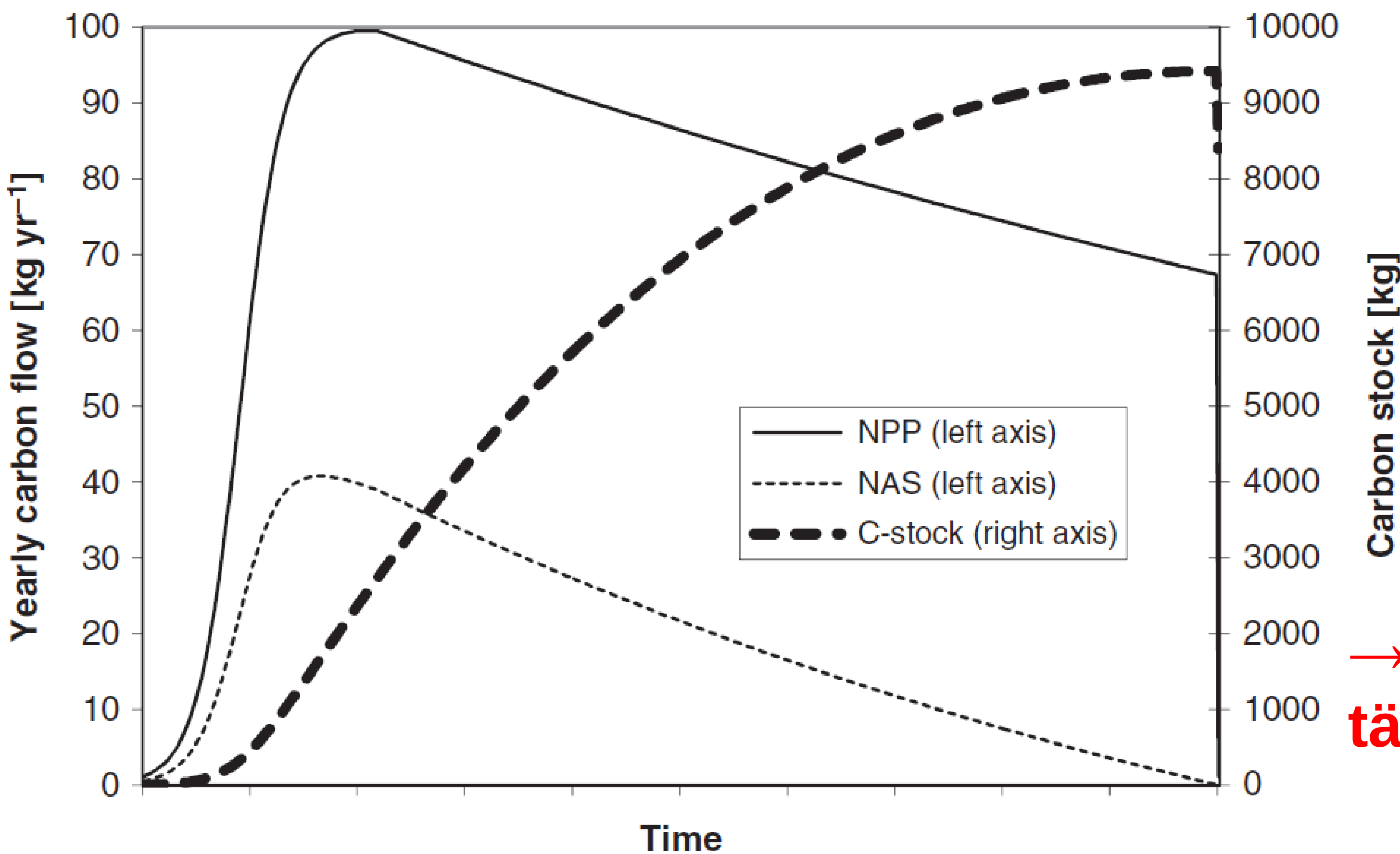
Biomass combustion can only help to reduce CO_2 if

(1) The biomass stems from additional plant growth or

(2) The biomass would have decomposed rapidly if not used for energy

Searchinger 2010, Env. Res. Lett.

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



„Slow in – Fast out“

(Körner 2003, 2007)

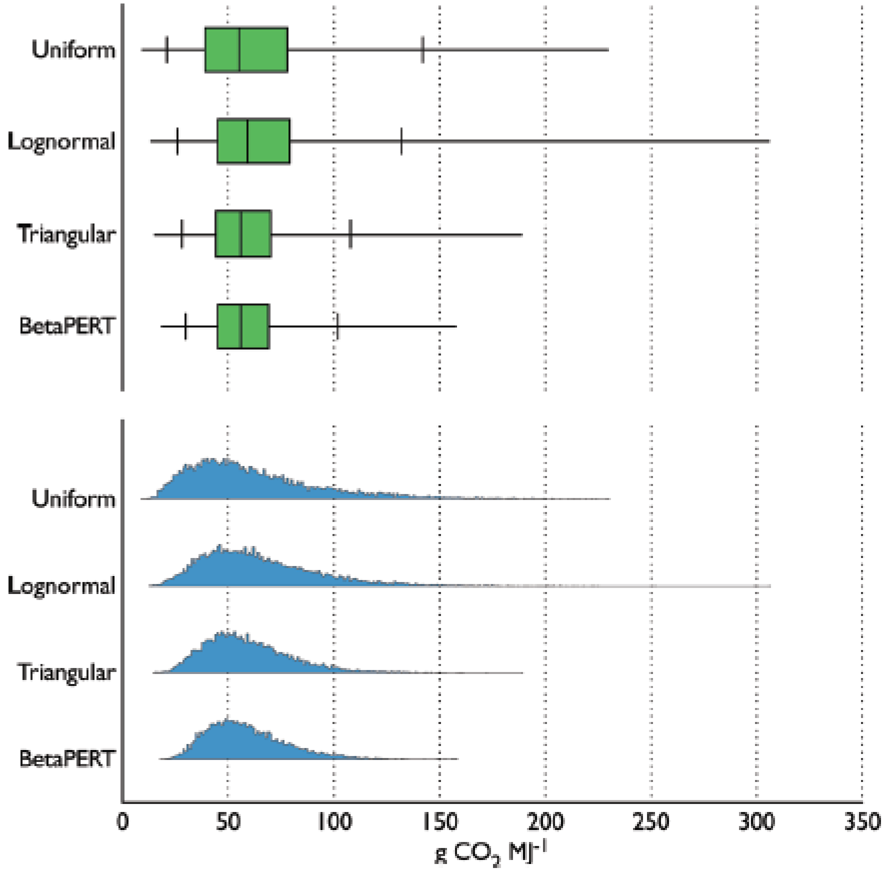
→ „Opportunitätskosten“

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

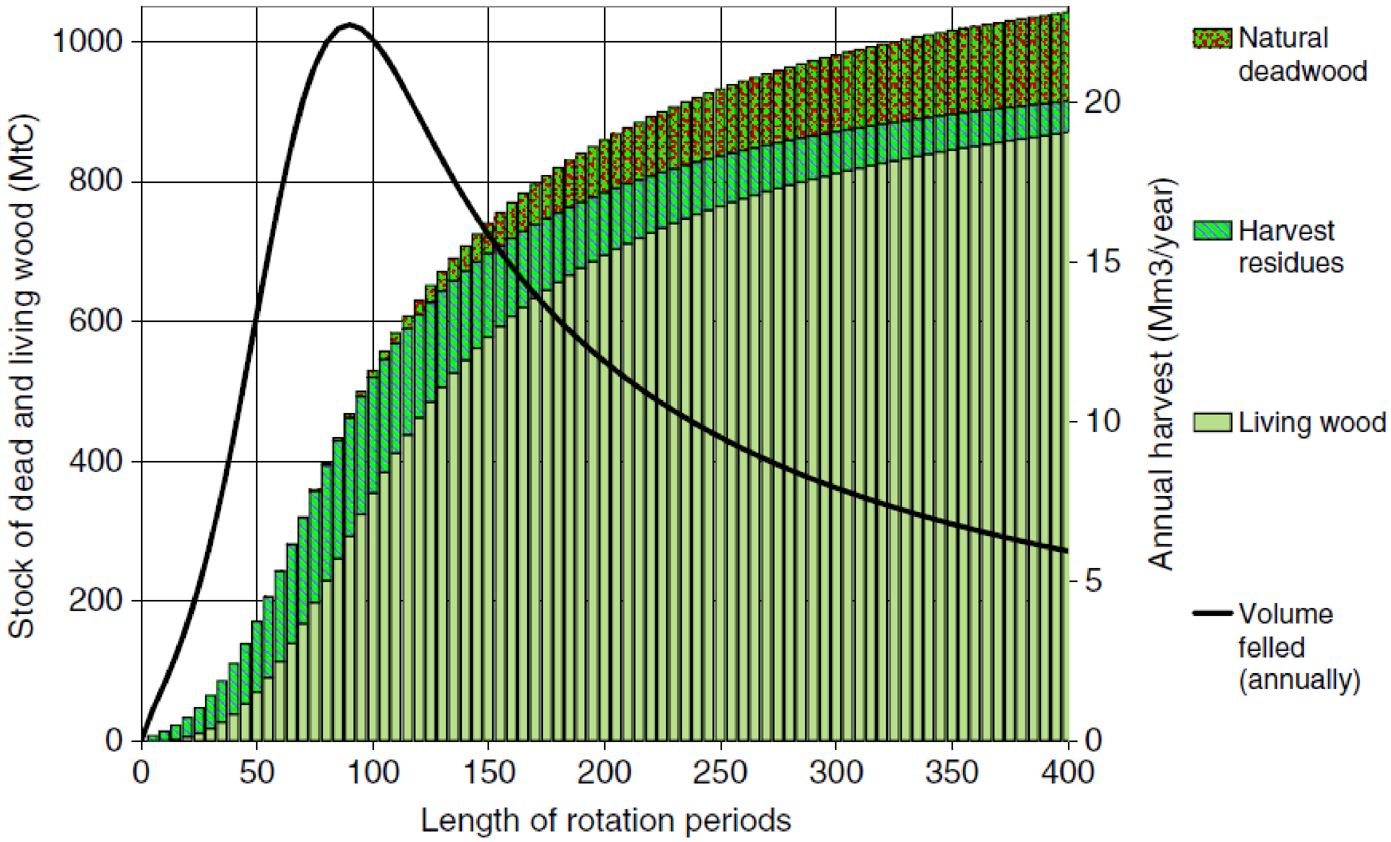
Probabilistic analysis of iLUC emissions of US corn ethanol



- Emissions of petroleum-based gasoline are ≈ 100 gCO_2-eq MJ^{-1}
- Life-cycle emissions of corn-based ethanol excluding iLUC are 30-70 gCO_2-eq MJ^{-1}
- Neglecting iLUC is equivalent to assuming that iLUC emissions were zero

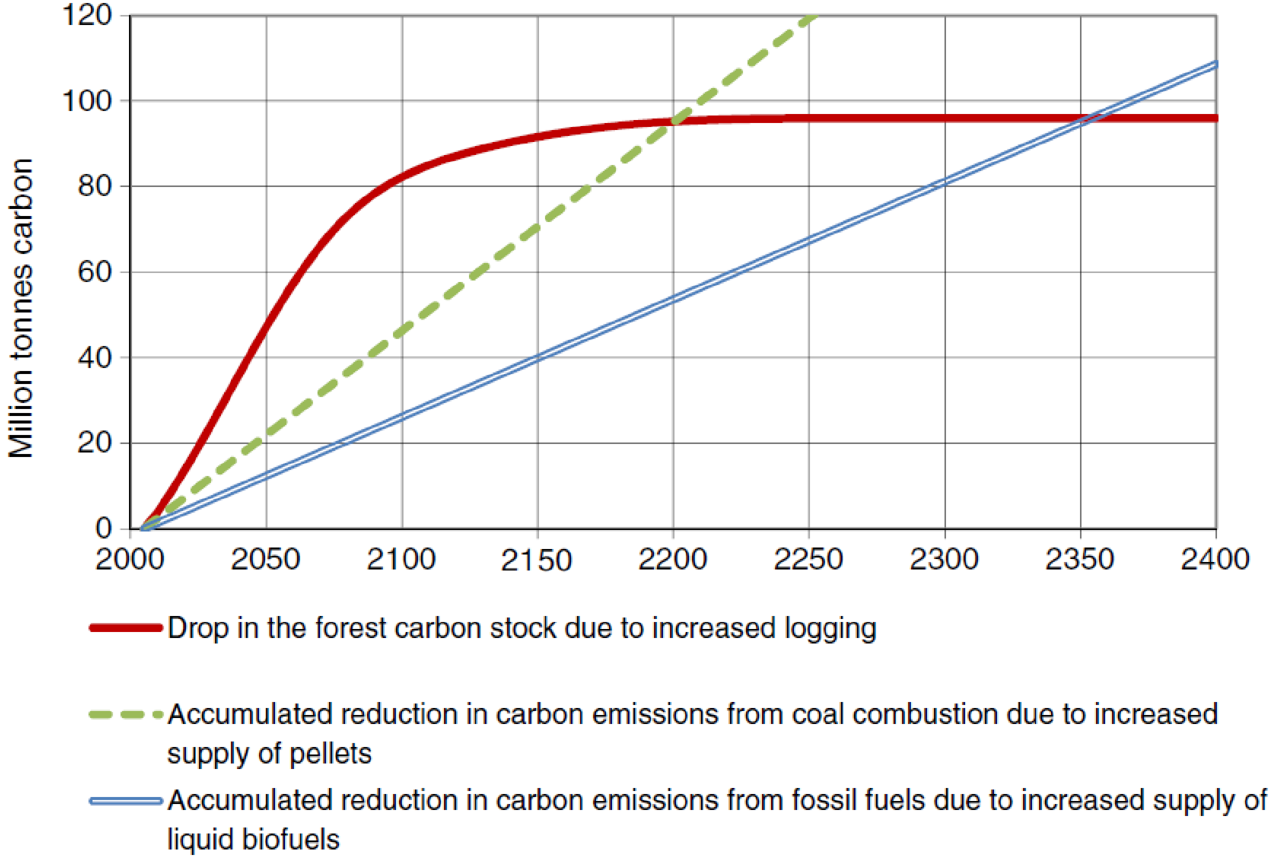
Figure: Plevin et al., 2010, Env Sci Tech 44, p. 8019
Other emission data: Chum et al., 2011, in: IPCC-SREEN

Annual wood harvest versus carbon stocks in Norwegian forests



Holtsmark, 2011 Climatic Change
DOI 10.1007/s10584-011-0222-6

Payback time of the C debt resulting from increased wood harvest, Norway



Holtsmark, 2011 Climatic Change
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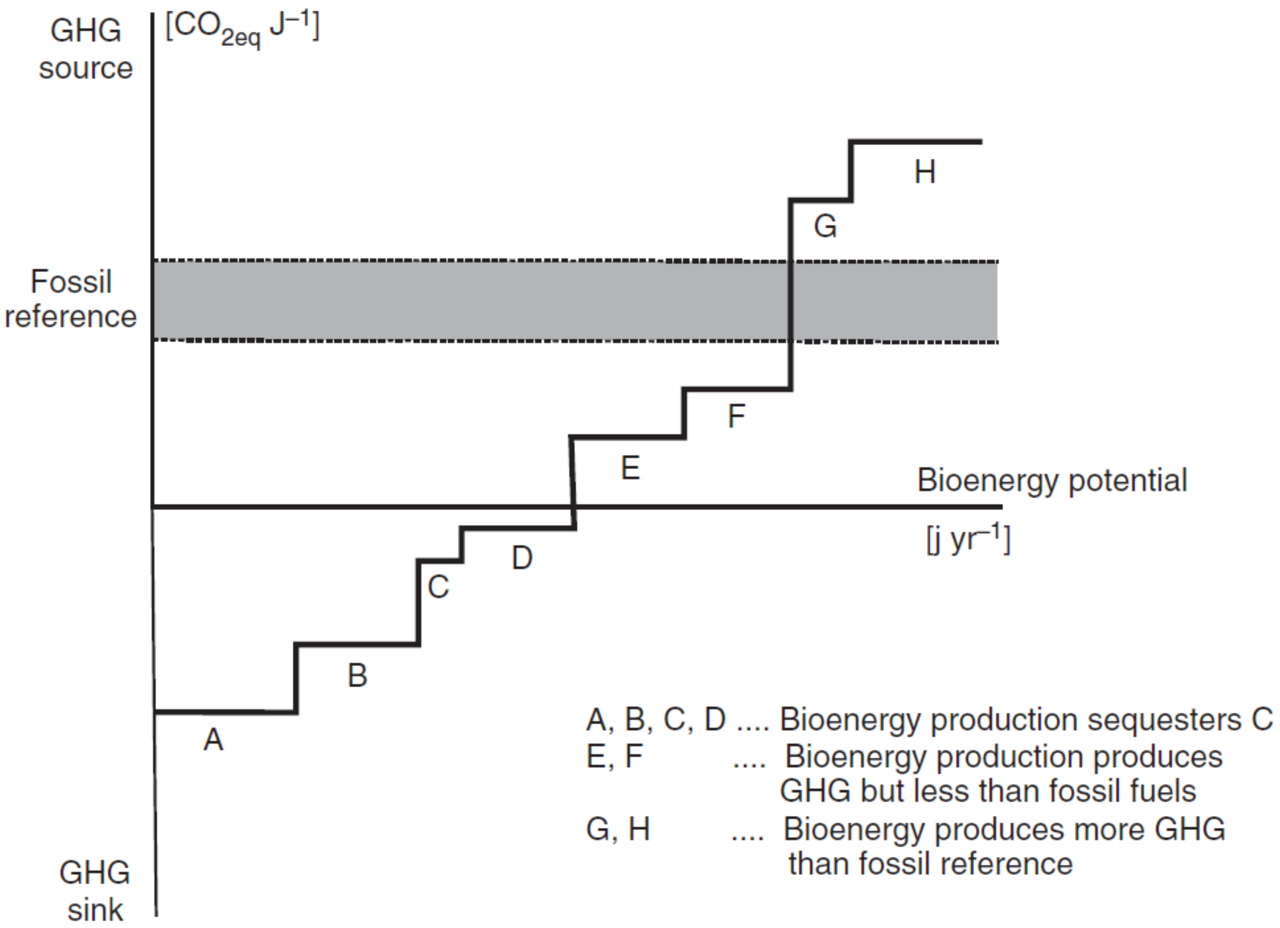
Gesucht: THG-Kostenkurve für globale Bioenergie



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)