Carbon Balance of Bioenergy Systems Based on Physical Carbon Flows

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Content

- **Carbon Emission Accounting**
- **Carbon Stores and Flows**
- **The Carbon Neutrality Model (CN)**
- **Examples**
- **Conclusions and Consequences**

Carbon Emission Accounting for Bioenergy Systems (1)

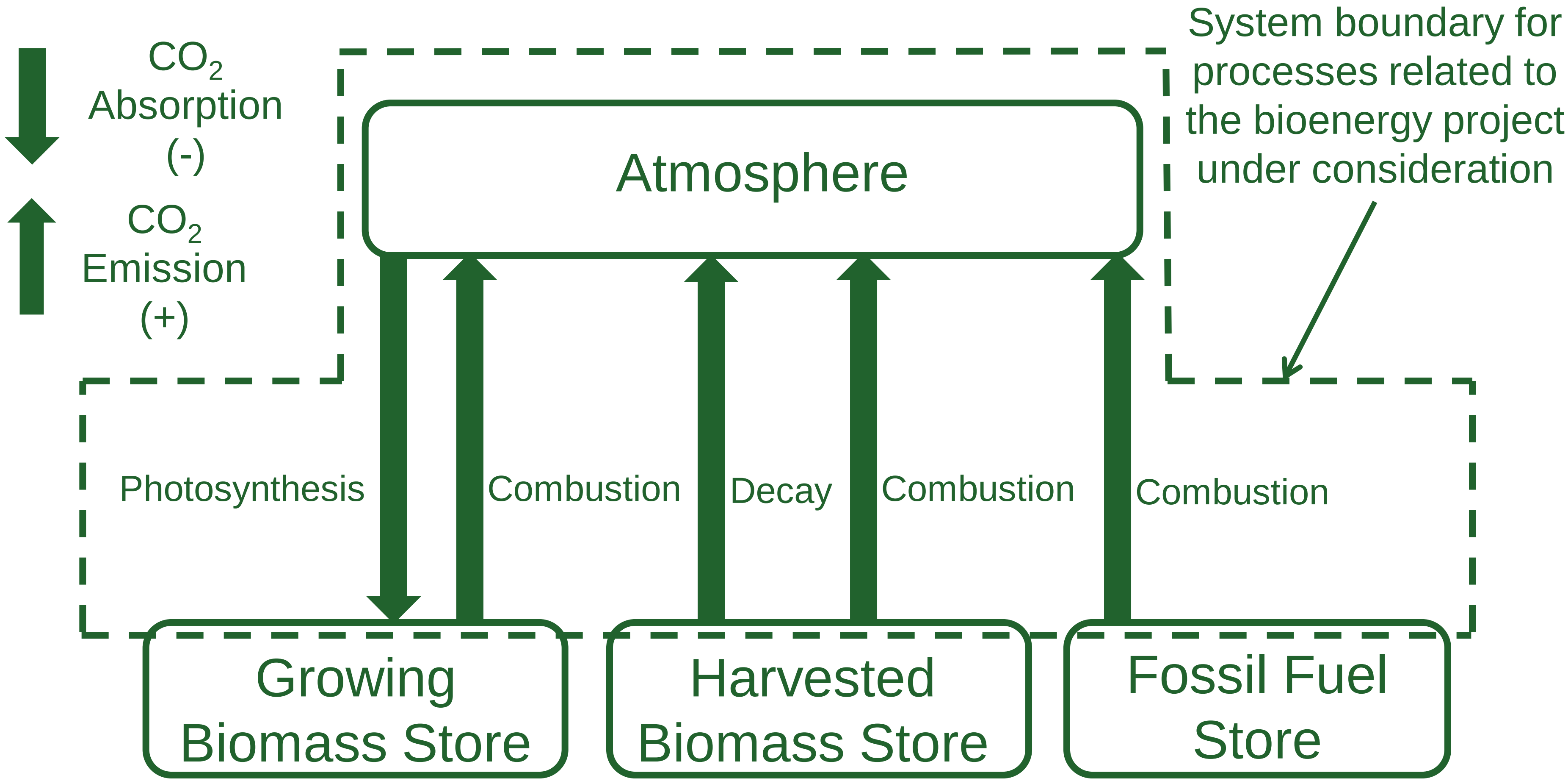
- **Current accounting system ("zero emissions")**: Upstream C losses (including LUC) are included, C combustion emissions set to zero in the energy sector, corresponding C stock losses in the land-use sector are generally not accounted for as would be required by IPCC guidelines.
- **Physical accounting based on C fluxes**: Upstream C losses (including LUC), C combustion emissions, biomass regrowth and avoided decay are included. The result is a time-dependent characteristic of the net C emissions leading to a delay of emission reduction when biomass is substituted for fossil fuels.
- **Current discussion**: Since a number of years physical accounting is under discussion: E.g. the US EPA *Framework for Assessing Biogenic* CO_2 *Emissions from Stationary Sources* proposes counting stack and tailpipe C emissions from bioenergy plants.

Carbon Emission Accounting for Bioenergy Systems (2)

Types of biomass for energy production

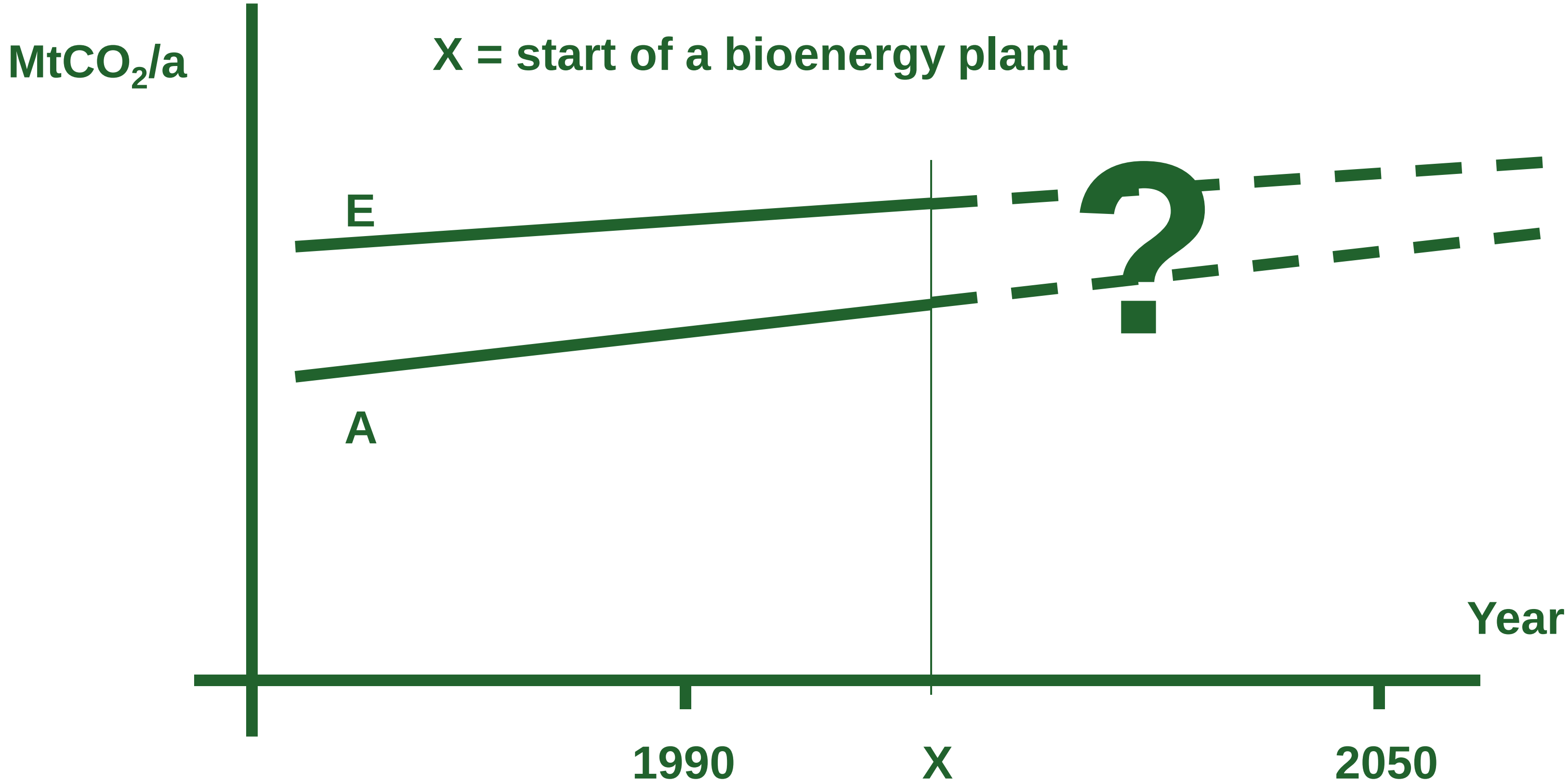
- **“Growing” biomass**: whole trees from additional harvest, thinning, pulpwood, corridor wood and hedges; harvest from energy plantations and agricultural production. These materials will re-grow, harvesting will initially result in reduced absorption.
- **“Harvested” biomass**: harvesting, sawmill and wood manufacturing residues; out-of-use wood products; demolition wood; residues from agro, food and pulp&paper production; biogenic MSW fraction. These materials would decay if they were not burned for energy production.

Carbon Stores and Flows in Bioenergy Systems (1)



Carbon Stores and Flows in Bioenergy Systems (2)

Emissions (E) and Absorptions (A) of CO_2 within the System Boundary



Carbon Stores and Flows in Bioenergy Systems (3)

Development of A and E after the Start of a Bioenergy Plant

- ”Growing” biomass: Absorption decreases by the amount absorbed by the plants prior to burning and increases through re-growth of the plants. Combustion emissions are of the same magnitude as the fossil emission avoided (typically somewhat higher). It takes time until re-growth accumulates to full compensation of the combustion emissions.
- “Harvested” biomass: Absorption remains zero, combustion emissions are of the same magnitude as the fossil emission avoided (typically somewhat higher), decay emissions become zero. The “avoided” decay emissions usually are small initially and it takes time until they accumulate to a full compensation of the combustion emissions.
- The decay and re-growth processes extend over time periods of between 1 and more than 100 years. They are independent of forest and agriculture management practices outside the system boundary prior to and after the start of the bioenergy plant.

The Carbon Neutrality (CN) Model (1/2)

- **CN is a time dependent quantity describing the net carbon emission reduction of a bioenergy project substituting biomass fuels (bio) for fossil fuels (ref)*)**
- **The model for calculating CN includes the processes**
  - *Combustion*
  - *Upstream processes (fuel production including LUC)*
  - *Avoided decay (harvested biomass)*
  - *Regrowth (growing biomass)*
  - *Enhanced secondary growth (if stored permanently)*
  - *Reduced absorption (growing biomass)*
- **The parameters describing these processes are project related time dependent input data for the model**

***) Definition by B. Schlamadinger et al., Biomass and Bioenergy, Vol. 8, no. 4, 1995)**

The Carbon Neutrality (CN) Model (2/2)

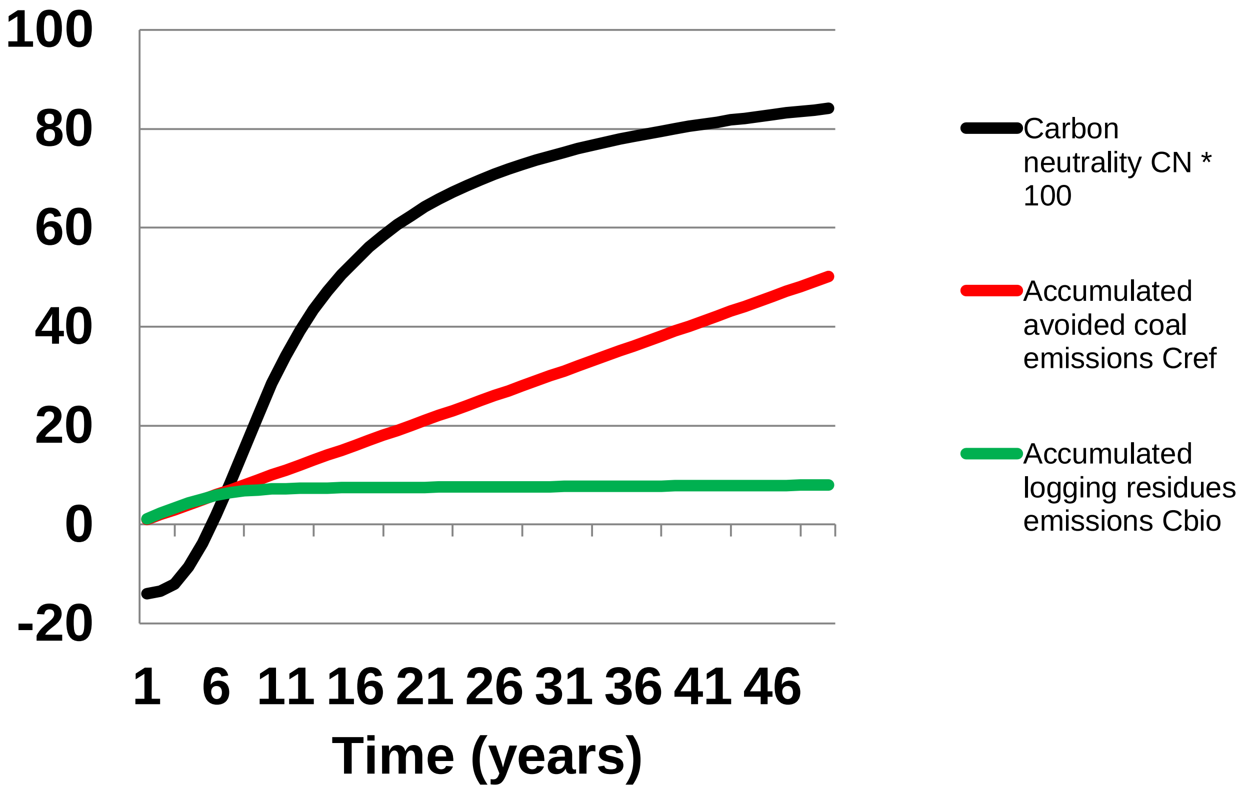
- $CN(t) = [C_{ref}(t) - C_{bio}(t)]/C_{ref}(t)$
  Carbon neutrality after operation time [-]
- $C_{ref}(t) = \int c_{ref}(t)dt$
  Accumulated carbon emissions of the fossil fuel reference system after operation time t [toC per MJ useful energy]
- $C_{bio}(t) = \int c_{bio}(t)dt$
  Accumulated carbon emissions of the bioenergy system after operation time t [toC per MJ useful energy]

First approximations: $C_{bio}(0)$ is roughly equal to $C_{ref}(0)$ and $CN(0) = 0$. With the re-growth or decay processes approaching completion at time t, $c_{bio}(t)$ approaches 0 and $CN(t)$ approaches 1.

Example 1: Carbon Neutrality

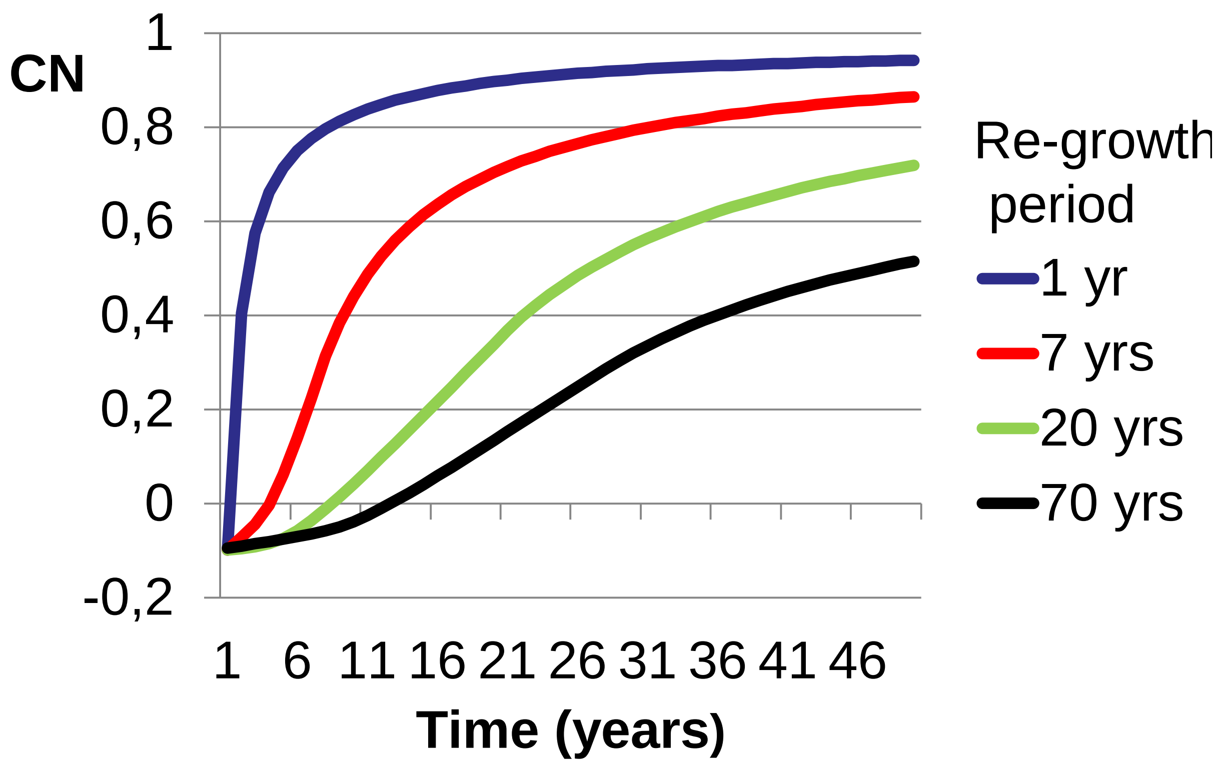
CN(t) = [Cref(t) – Cbio(t)]/Cref(t)

Case: Logging residues substituting for coal



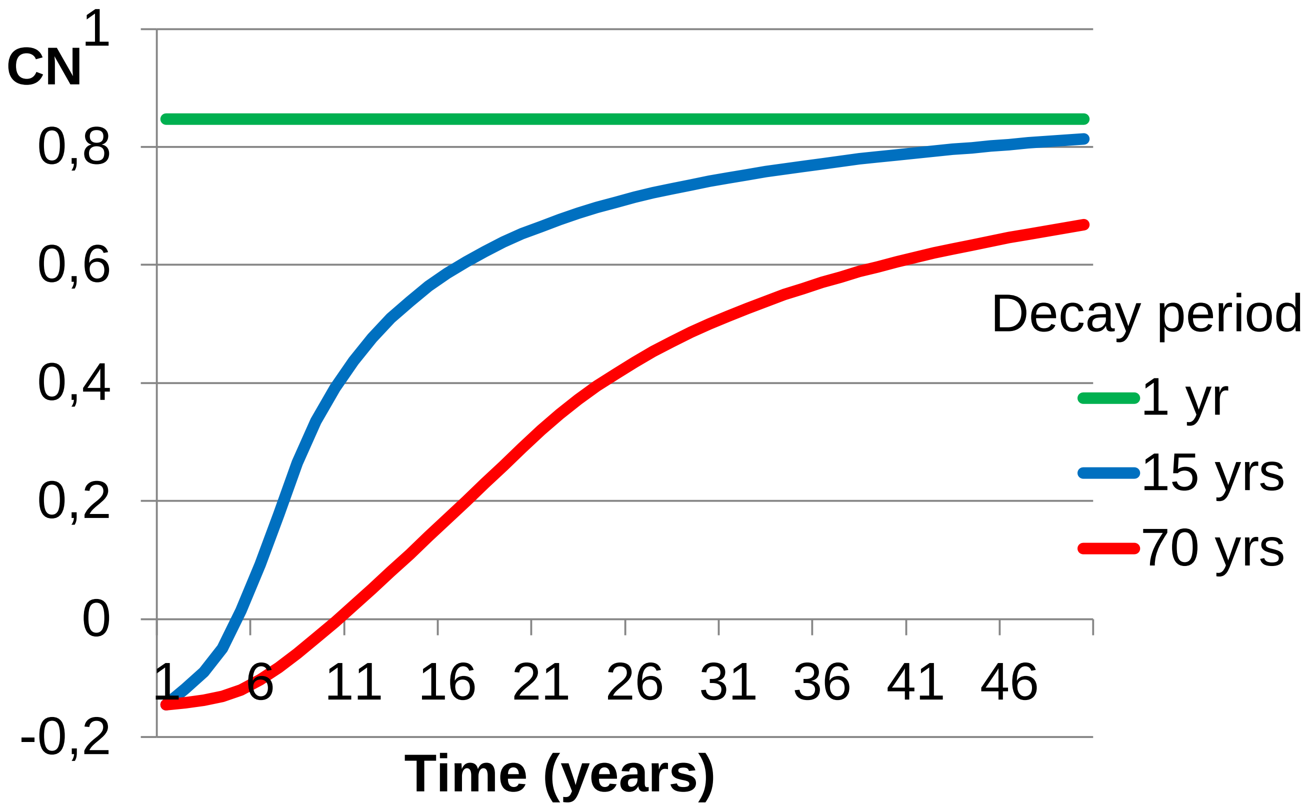
Example 2: Carbon Neutrality with different re-growth periods

Case: Growing biomass substituting for coal



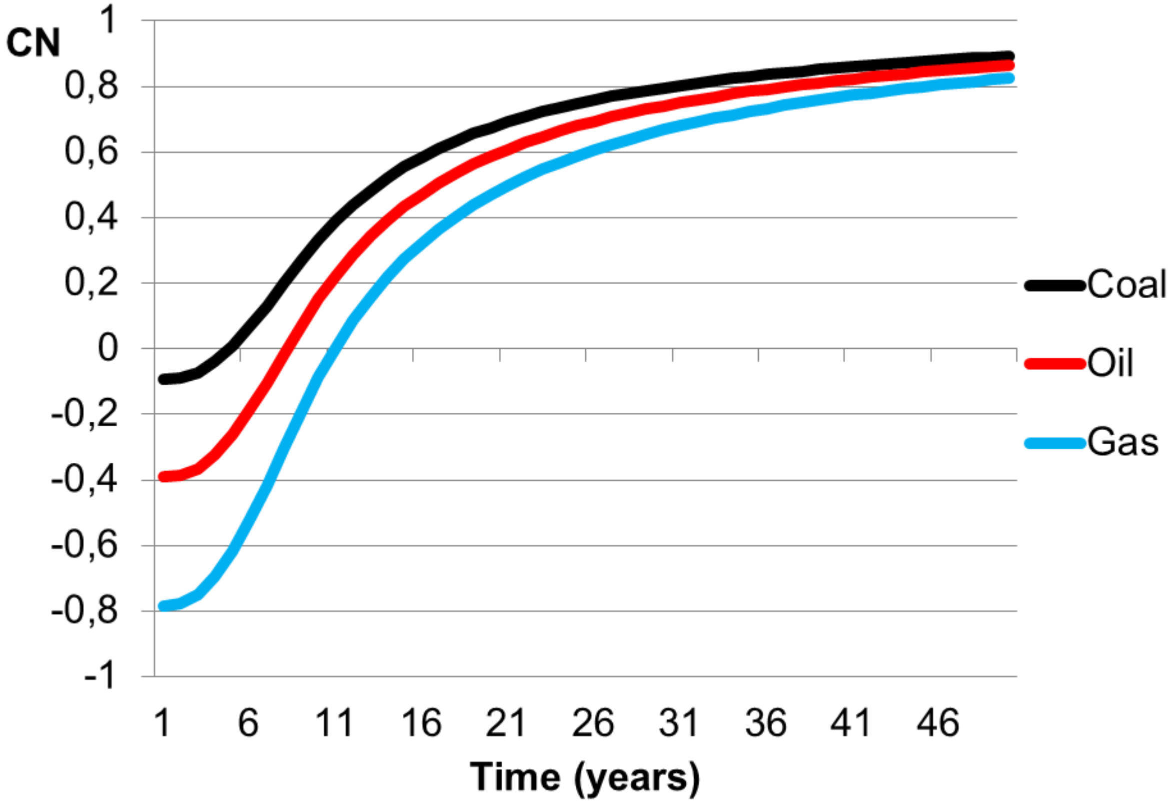
Example 3: Carbon Neutrality with different decay periods

Case: Harvested biomass substituting for coal



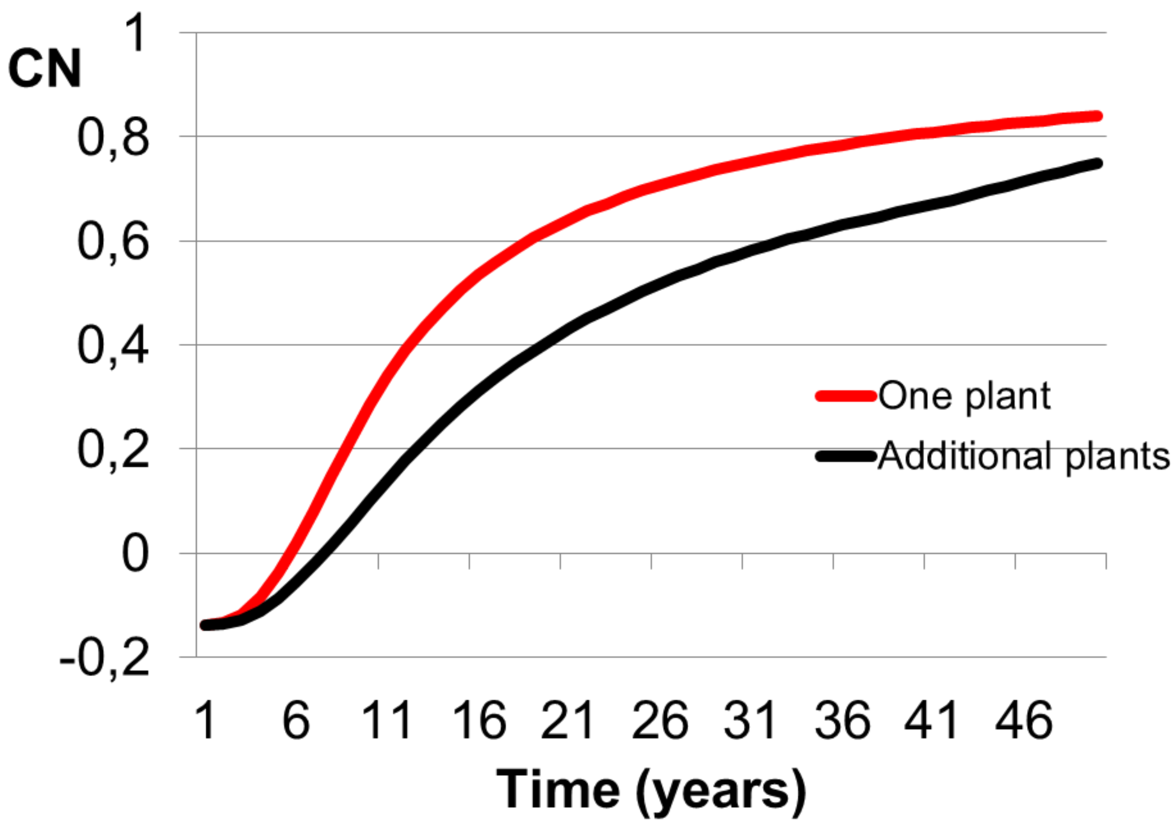
Example 4: Carbon Neutrality with different fossil fuels substituted

Case: Logging residues substituting for coal, oil or gas



Example 5: Carbon Neutrality – one additional plant each year for 40 years

Case: Logging residues substituting for coal



Conclusions and Consequences

- Assuming zero carbon emission from biomass combustion in an energy plant does not reflect the physical carbon flows to and from the atmosphere. The growth and decay processes associated with the operation of a biomass plant result in a time delay of the carbon emission reduction when substituting biomass for fossil fuels.
- The time delay is independent of forest management practices outside the system boundary prior to and after the start of the biomass plant. Thus, many of the biomass plants put in operation during the past decades and are planned for the future will not provide the expected contribution to meeting the CO_2 reduction goals (amount, target date) set by the EU or national governments.
- The carbon balance model presented calculates the physical time dependent net reduction of CO_2 emission to the atmosphere through biomass fuels substituting for fossil fuels in an energy plant.

Selected Statements

European Commission Joint Research Centre, JRC70633, EUR 25354 EN (2013), "Carbon accounting of forest bioenergy", p. 18:

"From the studies analyzed it emerges that in order to assess the climate change mitigation potential of forest bioenergy pathways, **the assumption of biogenic carbon neutrality is not valid under policy relevant time horizons** (in particular for dedicated harvest of stem wood for bioenergy only) if carbon stock changes in the forest are not accounted for."

Selected Statements

US EPA (40 CFR Part 60, EPA-HQ-OAR-2013-0602; 3 August 2015, “Carbon Pollution Emission Guidelines …”, p. 1160:

”There are circumstances in which biomass is grown, harvested and combusted in a carbon neutral fashion **but carbon neutrality is not an appropriate a priori assumption**; it is a conclusion that should be reached only after considering a particular feedstock’s production and consumption cycle. There is considerable heterogeneity in feedstock types, sources and production methods and **thus net biogenic carbon emissions will vary considerably.”**