# BIOMASS-BASED CONTROL OF THE CO2 CONCENTRATION IN THE ATMOSPHERE

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## Introduction

Biomass offers two options for controlling the $CO_2$ concentration in the atmosphere: Storage of solar energy to substitute for fossil energy („bioenergy“) and absorption of atmospheric $CO_2$ combined with a permanent storage (“negative emission technologies, NET”). The bioenergy option has been investigated in detail by research and industry over the past 40 years. A number of applications have reached commercial status. The success of this option depends on three inherent properties of the biomass feedstock: time constants of growth and decay processes (time delay), energy yield per unit of carbon (carbon intensity) and secondary effects (upstream processes, land use change). The goal of the NET option is a reduction of the atmospheric $CO_2$ concentration after a zero $CO_2$ emissions status has been reached with a complete replacement of fossil energy systems by renewable energy systems. NET have to fulfil three conditions: existing carbon fluxes and stores in the biosphere are not affected by the operation of NET (additionality); carbon sequestered by NET has to be registered and allocated to NET operators (carbon credit registration); NET carbon registered in the credit system has to be prevented from re-entering the atmosphere (permanent storage). Besides the techno-economic questions, the success of biomass-based control of the $CO_2$ concentration in the atmosphere strongly depends on the time required for the options to be in place and to effectively contribute to reaching the emissions reduction goals, e.g. “2030” and “2050”.

## Bioenergy substituting for fossil energy

A model describing the time dependent carbon flows to and from the atmosphere has been developed allowing the quantification of the carbon emissions reduction achieved by a bioenergy system replacing a fossil reference system. As an indicator the time dependent parameter “carbon neutrality” (CN) is used. CN is defined as the difference between accumulated carbon emissions of the fossil reference system (if it would not have been replaced) and the bioenergy system divided by the carbon emissions of the fossil reference system [1]. CN typically varies between 0 (no reduction) and 1 (full reduction). The model results show a time delay in the emissions reduction, resulting from the time dependency of re-growth (feedstock: purpose-grown biomass) and avoided decay (feedstock: by-product biomass) processes. They also show that the extent of emissions reduction achieved depends on technology related parameters in feedstock preparation (upstream emissions, U) and combustion (carbon efficiency, CE). Example calculations show that bioenergy plants using forest based material have time delays of up to several decades while bioenergy plants using annual or short rotation crops and some biogenic waste fractions have time delays of a few years: **Figure 1** shows CN based on the accumulated avoided fossil carbon (coal) emissions $C_{ref}$ and the net accumulated biomass carbon (logging residues) emissions $C_{bio}$. CN reaches 0.8 after 45 years and is leveling off after 80 years at CN around 0.9. The typical development of CN (negative values at t = 0 and staying below 1.0 beyond t = 100 years) results from the fact that CE of coal generally is higher than that of logging residues and U of logging residues is higher than U of coal. **Figure 2** shows CN for different CE values of fossil fuels being replaced by logging residues. **Figure 3** shows for replacing coal the effect of the re-growth period length (feedstock: purpose-grown biomass): Agricultural crops (1 year), energy crops (15 yrs) and trees (70 yrs). **Figure 4** shows for replacing coal the effect of decay period length (feedstock: by-product biomass): Residues from the agro-food and pulp&paper production (1 year); wood harvesting (7 yrs), sawmill and manufacturing (20 yrs), out-of-use wood products and demolition wood (70 yrs).

Most carbon emissions reduction strategies specify reduction goals (amount, target date; e.g. the “1.5/2°C goal” by 2050). The results of the examples show that some bioenergy plants put in operation during the past decades or planned for the future may not provide the expected contribution to meeting $CO_2$ emissions reduction goals.

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## Biomass-based negative emission technologies (NET)

The three conditions for the success of biomass-based NET (additionality, carbon credit registration, permanent storage) can only be met in biomass plantations managed like forests for wood production (production forests) as illustrated in two examples.

Example 1: An increase of production forests (current carbon store approx. 160 GtC on 2240 Mha, derived from [2]) by 10% would reduce the carbon pool in the atmosphere (approx. 800 GtC) by 2%. This reduction would correspond to a reduction of the $CO_2$ concentration in the atmosphere (currently around 410 ppm) by approx.8 ppm. Establishing such a system depends on the availability of the corresponding land area and an increased demand for log wood. Besides the economic barriers and the time needed for establishing and operating the additional production forest, the requirement of permanently maintaining the additional production forest will make it difficult to implement this example.

Example 2: Forest plantations outside production forests have similar requirements regarding establishing and accounting; the difference lies in the treatment of mature trees. The requirement of permanent storage would be fulfilled by harvesting and burying mature trees [3] which will make it difficult to implement this example as well.

## Conclusions

Both options for a biomass-based control of the $CO_2$ concentration in the atmosphere (bioenergy and negative emission technologies, NET) have limited benefits due to the time dependence of biomass growth and decay. For most of the biomass types it will take several decades from the start of projects to reaching their planned effectiveness. In addition the NET option depends on the implementation of permanent storage capacities. This means that for projects to be started during the next few years, it cannot be expected that the $CO_2$ sequestration goal aimed at will actually be reached at the point in time considered necessary, e.g. around 2050.

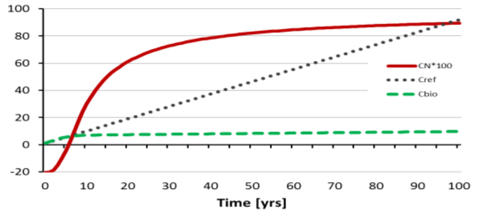

Figure 1: Functions for the definition of CN

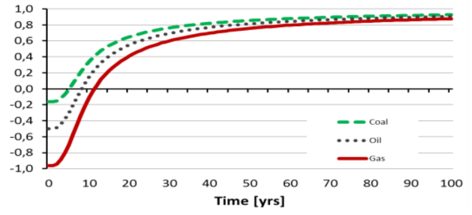

Figure 2: CN for different fossil CE values

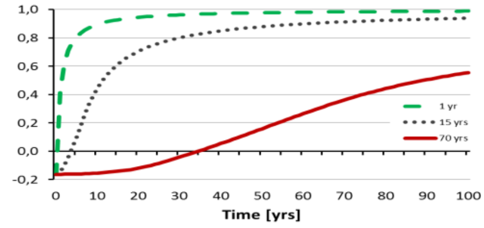

Figure 3: CN for different re-growth periods

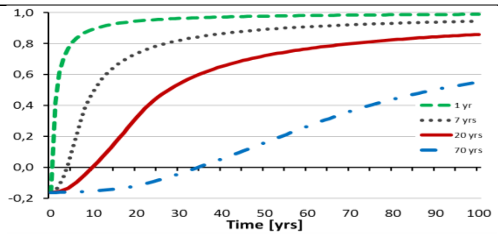

Figure 4: CN for different decay periods

## References

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