# Burning of Wood Products and Reforestation Climate neutral? — An Analysis.

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It is often assumed that the burning of wood or wood products like wood pellets for energy production will be climate neutral. It is argued that the $CO_2$ released from burning of this material "stems from the atmosphere anyway, has been fixed by the photosynthetic activity of plants, and is now returned to the atmosphere again". While arguing like this, it is forgotten that the burning of coal, which also stems "from the atmosphere and has been fixed, initially, by plants" is considered being extremely harmful to the climate. Obviously, originating from the atmosphere and being fixed by plants is not a sufficient argument for climate neutrality.

Why is the burning of coal harmful to the climate, although the carbon came from the atmosphere? The reason is that the coal carbon has been fixed by plants millions of years ago, during a long period, accumulating a huge deposit of carbon below ground, while the carbon dioxide concentration in the atmosphere has been replaced meanwhile by geologic processes. Mining and burning of coal, therefore, create an additional flux of carbon to the atmosphere, raising the atmospheric concentration of carbon dioxide.

## The carbon balance of the Biosphere

Now let us look at the role of carbon in the biosphere. For clarity, we assume the biosphere being undisturbed and in equilibrium with the present atmosphere. The considerations would be the same for the real, already pre-disturbed world: The disturbancies accumulate.

The green plants living on land are binding about 45 billion metric tons of carbon every year, from the atmospheric carbon dioxide. The carbon content of the atmosphere at present amounts to about 800 billion tons of carbon. This process of carbon binding is the net primary production (NPP) of the land-biosphere. By

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this process of NPP, a carbon deposit is formed in the biosphere, in analogy to that of fossil coal: The living vegetation on land contains about 600 billion tons carbon. The dead biomass on and in the soil, the biospheric litter and the soil organic carbon (SOC, humic substances), includes another 2 100 billion tons of carbon. The biospheric "deposit" thus amounts to about 2 700 billion tons of carbon or more than three times the amount of carbon in the atmosphere.

This biospheric carbon deposit is not altered as long as the biosphere is not disturbed. That is because the amount of carbon bound annually by the net primary production (NPP) is lost again, on the other side, by the mortality of living matter to litter and soil organic carbon (SOC). Then, the depletion of the dead biospheric carbon to carbon dioxide in the atmosphere, due to the activity of the organisms in litter and soil, closes the cycle again. If this were not the case, the biospheric carbon deposit would grow indefinitely. The fluxes NPP, litter production and litter and SOC depletion are of equal size. The pools living biomass, litter and SOC do not change, therefore. This is called a "steady state". So the mortality and the depletion fluxes compensate for the carbon bound by the NPP. Either amount to 45 billion tons annually.

We state now: The undisturbed biosphere is neither a source nor a sink for carbon. It would be climate–neutral with respect to $CO_2$. By the way: It also does not produce oxygen, as sometimes assumed, because the amount of $O_2$ produced by the net primary production is completely consumed again by the depletion processes.

Let us summarize: The annual biospheric carbon turnover of 45 billion tons carbon (imported by the net primary production and exported by depletion of dead organic carbon) balances the atmospheric content of about 800 billion tons of carbon, and as well the biospheric deposit of nearly 3 000 billion tons of carbon. This results in an turnover of the atmospheric carbon every 18 years, and of the biospheric carbon every 65 years. Therefore, small biospheric changes may result in large changes in the atmosphere: We have an unstable system.

This global view underlines the importance of the problem, but political decisions need a regionalized view, because the biospheric "deposit" of carbon is considerably varying from one place to another.

Some examples of regional biospheric carbon deposits may demonstrate this fact (all figures given in kilogram of carbon per square meter ground area): A mature central European beech forest 12–18 in the living biomass and additional 9.4–43.4 in dead litter and soil organic carbon. A tropical rain forest about 24 in living plant material and 13.6–50.8 in litter and soil organic carbon. Certain warm temperate coniferous forests, for example in the north–western United States of America, up to 153 in living plant material and to 150 in litter and soil organic carbon. Obviously, enormous amounts of carbon are stored in these regional biospheric deposits.

## Harvesting and burning dead material from the biosphere

Now we will disturb the biosphere by some human activities: What will be the consequences of harvesting recently died off material from a forest, i.e. stems, boughs or branches, in order to burn them directly, or as wood pellets?

The carbon input from the atmosphere, the net primary production, will not be altered, since we are harvesting "dead" material only. The flux of carbon back into the atmosphere, which originates from the decomposition of the dead material, will not be altered as well, since the amount of the dead material and the conditions of decomposition remain still the same, at first. Both processes, net primary production and decomposition, are still of equal size, and are therefore compensating each other. Indeed, we introduced a new additional flux, namely the burning of the withdrawn material. This new flux is not compensated. It is a real net flux at the expense of the biospheric carbon deposit in litter and SOC, which increases the biospheric carbon dioxide flux to the atmosphere, and thus raises the atmospheric $CO_2$ concentration. And this net flux will persist, probably over decades or even centuries, until the amount of litter and soil organic carbon has been sufficiently reduced, so that the decomposition flux will be reduced to a value equaling the amount "net primary production minus withdrawn material". This may last tens to hundreds of years, depending on the system state and the climate.

Thus we made the biosphere a source of carbon, just by withdrawing and burning dead material, and contributing to the atmospheric $CO_2$ raise. Considering the burning value of wood and its carbon content, the carbon dioxide emissions by burning of wood are in the same order of magnitude as if we would burn coal, for the similar energy yield. Even worse, in addition we produced high emissions of particulate matter, aerosols, and hazardous gases.

## Harvesting and burning fresh wood from the biosphere

Fresh material for energy production is withdrawn from the biosphere by forest clearing, by direct cutting of fire wood, by burning of waste wood which originates from wood processing companies, or by other similar measures. In each of these cases, the biosphere becomes a source for carbon dioxide, as was explained above already, for the dead material. As explained, the carbon of burned wood is emitted into the atmosphere immediately, and therefore cannot support any more the conservation of litter and soil organic carbon pools, either being long–lasting deposits for carbon.

Withdrawing fresh, living wood has even further consequences. The number of trees and thus the leaf-area-index is reduced. In most cases, this diminishes the net primary production of the forest, which causes an additional imbalance between the fixation and decomposition fluxes for carbon in this ecosystem, to the disadvantage

of the fixation. This forest becomes an even bigger source for carbon than by harvesting of dead material alone.

### Reforestation as "Compensation Measures"?

There are ideas to compensate the excessive emissions of carbon dioxide from industrial sources by planting trees which "bind $CO_2$ und compensate for the emissions". Let us analyze this suggestion.

An immature, growing forest is directing the carbon gained by the net primary production primarily into the living phytomass, mainly the wood, and stores it there. The production of litter is still low, and mainly consists of dying leaves, since dying stems are still lacking. Therefore, there is only a minor input of fast decomposing leaf material into the litter, but nearly no input of slowly decomposing wood material. The decomposition of soil organic carbon dominates. This flux of carbon dioxide by decomposition of litter and soil organic carbon into the atmosphere may partly compensate, or even overcompensate in certain cases, for the $CO_2$ bound by the NPP.

In order to estimate in advance, whether a growing forest, after reforestation of the area, may become a source or a sink for carbon, a thorough analysis of the system state, especially the soil organic carbon state, is indispensable.

By the way: Similar considerations are needed for any land cover change. Up to now, the very important soil organic carbon pool is frequently neglected. Especially in vegetation types with high share of herbaceous material, as steppes, savannas, and even some agriculturally used areas, the soil organic carbon pool is often high. The net primary production of those herbaceous vegetation types is as high or even higher, than that of trees planted instead, and the carbon bound by NPP contributes nearly completely to the litter and soil organic carbon in those vegetation types. Even the low share of slowly decomposed lignin in herbaceous material helps to accumulate high SOC pools over hundreds or thousands of years. After planting of trees in those areas, their NPP may even be lower than the decomposition flux. The system would become a net source for carbon dioxide.

## Short summary

Using wood or wood products, for example wood pellets, to produce energy is in no case climate neutral. The amount of the trace gas $CO_2$ emitted from wood burning is similar to the amount which would be emitted by burning coal for the same amount of energy. Moreover, it is irrelevant weather fresh or dead wood or wood litter may be used.

If the planting of trees or afforestation will be planned, as a measure to compensate for excessively emitted carbon dioxide, it is indispensable to thoroughly investigate

the state of the respective land area, especially the carbon amount in the litter and soil organic carbon, and to analyze the system, using a carbon cycle model. Otherwise it will be unpredictable if eventually a sink or source for $CO_2$ may result, turning the compensation measure into its converse.