

Received: 23 January, 2025  
Accepted: 10 February, 2025  
Published: 11 February, 2025

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## Commentary

# Criticism of the Prevailing Belief that Wood Combustion is CO<sub>2</sub> - Neutral

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Any fuel of plant origin that has grown by absorbing CO<sub>2</sub> from the atmosphere via photosynthesis burns in a CO<sub>2</sub>-neutral way since virtually its entire carbon content is recycled into the atmosphere during combustion. This or very similar formulations are often used to explain the supposed CO<sub>2</sub> neutrality of burning plant biomass. This statement would be true if the CO<sub>2</sub> produced was released into the atmosphere at the same rate as it disappears from it. But as is well known, this is not the case nowadays. At present, CO<sub>2</sub> in the atmosphere is mainly produced by burning fossil fuels such as coal, oil, and natural gas. It is mainly removed from the atmosphere through photosynthesis and distribution in seawater. However, these processes are far from sufficient to remove CO<sub>2</sub> from the atmosphere at a sufficient rate to achieve CO<sub>2</sub> neutrality.

Obviously, the above idea of CO<sub>2</sub> neutrality is based on the completely arbitrary assumption that only the CO<sub>2</sub> produced by burning wood (as an example of plant biomass) is recycled in a sustainably managed forest via tree growth, while the CO<sub>2</sub> from other combustion sources is not available for photosynthesis. In the atmosphere, however, more or less all of the CO<sub>2</sub> emissions from all sources are mixed so it must be assumed that the amounts used to regrow the forest also correspond to this atmospheric mix from different sources. This means that due to its low percentage in the mix, the CO<sub>2</sub> from wood burning only contributes a small degree to regrowth, while CO<sub>2</sub> from fossil sources, due to their much greater relative frequency in the mix, are also the main contributors to photosynthesis and therefore to plant growth.

To emphasize this one more time, CO<sub>2</sub> neutrality in the atmosphere would be present if in a given time interval the

rate of carbon entry (in Gt C)/year or Pmol/year) into the atmosphere were equal to the rate of carbon exit (in Gt C/year or Pmol/year) from the atmosphere into a sink such as photosynthesis. It is impossible, to yield such a result, which can be mathematically formulated as  $\Delta CO_2^{atm} / \Delta t = 0$  (for CO<sub>2</sub> neutrality), simply from the carbon cycling associated with wood combustion alone. In the presence of other CO<sub>2</sub> sources, it is imperative that these are also included in the neutrality analysis.

Of course, all CO<sub>2</sub> molecules are identical and therefore indistinguishable, regardless of which carbon-containing fuel source they originate from. This applies to their uptake in photosynthesis as well as their distribution in (sea) water.

The following example should serve to further explain the relationships for the CO<sub>2</sub> changes in the atmosphere, using data from Friedlingstein, et al. [1].

For the atmospheric amount of CO<sub>2</sub> a value of NO<sub>atm</sub> = 74.827 Pmol or 898.75 Gt C has been found using a ppm value of 423. The quantity of carbon bound in the vegetation is then NO<sub>wood</sub> = 0.514 74.827 = 38.483 Pmol or 462.22 Gt C [1]. To a first approximation, the atmosphere can be regarded as an ideal gas of reference volume V<sub>atm</sub><sup>ref</sup> (288.15 K).

According to L. Boltzmann, all particle types of gas are arranged in such a way that the energy distribution with the maximum probability is adopted spontaneously [2,3]. For an ideal gas in a given volume, this means that the maximum multiplicity is achieved when the entire volume is homogeneously filled with the respective particles. This applies

to all particle types in the atmosphere, including  $\text{CO}_2$  molecules from different sources. Consequently, all  $\text{CO}_2$  molecules must be present as a complete mixture. This in turn means that  $\text{CO}_2$  molecules enter the efflux reactions of the atmosphere in the same proportions, as they are present in the atmospheric mixture. These proportions are given by the known influxes from different sources.

All emissions (in Gt C/yr) are constant, and the total  $\text{CO}_2$ -efflux (absolute values for effluxes) with  $E_{\text{Lsink}} = 2.9$  (land sink) and  $E_{\text{ocsink}} = 3.0$  Gt C/yr (ocean sink) is given by  $J_{\text{out}} = E_{\text{Lsink}} + E_{\text{ocsink}}$  Gt C/yr.  $E_{\text{Lsink}}$  contains mainly the efflux  $J_{\text{ps}}$  via photosynthesis. The two influxes are  $E_{\text{fos}} = 9.3$  (fossil emission) and  $J_{\text{woodb}} = 0.8 E_{\text{LUC}}$  Gt C/yr (wood burning of  $0.8 E_{\text{LUC}}$  is an arbitrary assumption).  $E_{\text{LUC}} = 0.9$  (land use change) contains  $J_{\text{woodb}}$  plus  $J_{\text{def}}$  (deforestation). The total influx then is given by  $J_{\text{in}} = E_{\text{fos}} + J_{\text{woodb}}$  Gt C/yr. The respective masses of  $\text{CO}_2$  in the atmosphere after a given time  $t$  are, for example,  $N_{\text{fosb}} = E_{\text{fos}} \times t$  and  $N_{\text{woodb}} = J_{\text{woodb}} \times t$  Gt C. The total amount that has entered the atmosphere during time  $t$  is given by  $N_{\text{in}} = N_{\text{fosb}} + N_{\text{woodb}}$  Gt C.

For the derivation of the following results, it was assumed that due to the indistinguishability of the  $\text{CO}_2$  molecules originating from different sources, their probability of entering the photosynthesis reaction, for example, depends on their relative frequency in the atmospheric mix. If, for instance, there is about 13 times more  $\text{CO}_2$  of fossil origin in the mix than from wood combustion (with  $N_{\text{woodb}}/N_{\text{in}} = J_{\text{woodb}} \times t / (E_{\text{fos}} + J_{\text{woodb}}) \times t$ ,  $N_{\text{fosb}}/N_{\text{in}} = E_{\text{fos}} \times t / (E_{\text{fos}} + J_{\text{woodb}}) \times t$  yielding  $N_{\text{fosb}}/N_{\text{woodb}} = E_{\text{fos}}/J_{\text{woodb}} = 12.917$ ), then in a given time interval 13 times more fossil  $\text{CO}_2$  than  $\text{CO}_2$  from wood burning will be removed from the atmosphere via this pathway.

The time-related change of the total mass of  $\text{CO}_2$  in the atmosphere ( $G_{\text{ATM}}$  in Friedlingstein's publication [1]) is given by

$$\frac{\Delta \text{CO}_2}{\Delta t} = E_{\text{fos}} + 0.8 E_{\text{LUC}} - E_{\text{Lsink}} - E_{\text{ocean}} \quad (\text{in GtC / yr}), \quad (1)$$

the effluxes e.g. via photosynthesis (with  $J_{\text{woodb}} = 0.8 E_{\text{LUC}}$ ) are

$$J_{\text{woodps}} = \frac{N_{\text{woodb}}}{N_{\text{in}}} \times J_{\text{ps}} = \frac{J_{\text{woodb}} \times t}{(E_{\text{fos}} + J_{\text{woodb}}) \times t} \times J_{\text{ps}} = 0.284, \text{ and} \quad (1a)$$

$$J_{\text{fosps}} = \frac{N_{\text{fos}}}{N_{\text{in}}} \times J_{\text{ps}} = \frac{E_{\text{fos}} \times t}{(E_{\text{fos}} + J_{\text{woodb}}) \times t} \times J_{\text{ps}} = 2.6916 \text{ GtC / yr}, \quad (1b)$$

(the photosynthesis flux  $J_{\text{ps}}$  equals  $E_{\text{Lsink}} + J_{\text{woodps}} + J_{\text{fosps}}$  must add up to  $J_{\text{ps}} = 2.9$  Gt C/yr).

These equations result from the fact that each efflux pathway takes up  $\text{CO}_2$  molecules from different sources in the same proportions as they occur in the atmospheric mixture. These are identical to those of the constant influxes, so that, for instance for the photosynthetic efflux pathway, the following proportionality equation is obtained,  $J_{\text{woodps}}/J_{\text{ps}} = J_{\text{woodb}}/J_{\text{in}}$ .

In order to assess  $\text{CO}_2$  yield, these effluxes are now compared with the respective influxes from the corresponding sources. This is done by calculating quotients (taking absolute values for effluxes) according to

$$\frac{J_{\text{woodps}}}{J_{\text{woodb}}} = \frac{J_{\text{ps}}}{E_{\text{fos}} + J_{\text{woodb}}} = 2.9 / (9.3 + 0.72) = 0.2894, \text{ and} \quad (1c)$$

$$\frac{J_{\text{fosps}}}{E_{\text{fos}}} = \frac{J_{\text{ps}}}{E_{\text{fos}} + J_{\text{woodb}}} = 2.9 / (9.3 + 0.72) = 0.2894. \quad (1d)$$

Although both influxes are very different, their yield quotients (via photosynthesis) are identical.

Since there is an additional efflux possibility via  $E_{\text{ocsink}}$ , this must also be taken into account. The yield quotients via this pathway are given by

$$\frac{J_{\text{woodoc}}}{J_{\text{woodb}}} = \frac{E_{\text{ocsink}}}{E_{\text{fos}} + J_{\text{woodb}}} = 3.0 / (9.3 + 0.72) = 0.2994, \text{ and} \quad (2a)$$

$$\frac{J_{\text{fosoc}}}{E_{\text{fos}}} = \frac{E_{\text{ocsink}}}{E_{\text{fos}} + J_{\text{woodb}}} = 3.0 / (9.3 + 0.72) = 0.2994. \quad (2b)$$

Both pathways ("ps" and "oc") differ only slightly because their respective effluxes (2.9 and 3.0 Gt C/yr) have similar values. For the entire process, the result is

$$\frac{J_{\text{woodps}} + J_{\text{woodoc}}}{J_{\text{woodb}}} = \frac{J_{\text{ps}} + E_{\text{ocsink}}}{E_{\text{fos}} + J_{\text{woodb}}} = \frac{J_{\text{out}}}{J_{\text{in}}} \quad (3a)$$

$$= 0.2894 + 0.2994 = 0.5888, \text{ and}$$

$$\frac{J_{\text{fosps}} + J_{\text{fosoc}}}{E_{\text{fos}}} = \frac{J_{\text{ps}} + E_{\text{ocsink}}}{E_{\text{fos}} + J_{\text{woodb}}} = \frac{J_{\text{out}}}{J_{\text{in}}} = 0.5888. \quad (3b)$$

A quotient value of 1.0 would mean that the total  $\text{CO}_2$  efflux is equal to the total  $\text{CO}_2$  influx ( $J_{\text{out}} = J_{\text{in}}$ ). Then  $\text{CO}_2$  neutrality would be present and the  $\text{CO}_2$  yield of the atmosphere would be zero Gt C. The sum of all effluxes is then equal to the sum of all influxes, that is,  $J_{\text{out}} = J_{\text{in}}$ , or  $J_{\text{out}}/J_{\text{in}} = 1.0$ . If  $J_{\text{out}}/J_{\text{in}} < 1.0$ , no  $\text{CO}_2$  neutrality can occur and  $\text{CO}_2$  would accumulate in the atmosphere. If, on the other hand,  $J_{\text{out}}/J_{\text{in}} > 1.0$ , the atmosphere would lose  $\text{CO}_2$ .

Under current conditions, only about 29% of the  $\text{CO}_2$  produced by wood burning (first influx pathway) is removed from the atmosphere via photosynthesis (first efflux pathway). The same applies to the  $\text{CO}_2$  produced from fossil fuels (second influx pathway). Again, only 29% of this source is removed via photosynthesis. About 30% of the total  $\text{CO}_2$  is taken up by seawater (second efflux pathway). This is followed by a drop in pH, which may be lethal for many marine organisms. The remainder of about 41% remains in the atmosphere and adds up to the  $\text{CO}_2$  accumulated over previous years.

The results show that the flux ratios of efflux and influx for a given efflux pathway, such as photosynthesis, are the same for all CO<sub>2</sub> sources. This can be verified by adding further CO<sub>2</sub> sources and/or sinks. For example, an additional combustion of synthetic gasoline (e-fuel) produced from atmospheric CO<sub>2</sub> and burned instead of fossil gasoline (a third efflux pathway "sy" is thus created in concert with the additional efflux  $J_{syn}$  and influx  $J_{synb}$ ,  $J_{synb} J_{syn} = J_{synb} = 0.1 J_{ps} = 0.29$  Gt C/yr yields,

$$\frac{J_{woodps}}{J_{woodb}} = \frac{J_{fosps}}{J_{fosb}} = \frac{J_{synps}}{J_{synb}} = \frac{J_{ps}}{J_{in}} = 0.2894, \quad (4a)$$

$$\frac{J_{woodoc}}{J_{woodb}} = \frac{J_{fosoc}}{J_{fosb}} = \frac{J_{synoc}}{J_{synb}} = \frac{J_{oc}}{J_{in}} = 0.2994, \text{ and } (4b)$$

$$\frac{J_{woodsy}}{J_{woodb}} = \frac{J_{fosy}}{J_{fosb}} = \frac{J_{synsy}}{J_{synb}} = \frac{J_{sy}}{J_{in}} = 0.0289. \quad (4c)$$

This results in a slightly increased flux quotient formed from all effluxes and influxes,

$$\frac{J_{out}}{J_{in}} = \frac{J_{ps} + J_{oc} + J_{sy}}{J_{in}} = 0.2894 + 0.2994 + 0.0289 = 0.618. \quad (4d)$$

The same result would be produced if no synthesized fuel was burned and no fossil fuel was replaced.

The simplest way to achieve a quotient of 1.0 (CO<sub>2</sub> neutrality) may be realized by reducing drastically  $J_{fosb}$ . Reducing this CO<sub>2</sub> influx by a factor of 0.557 yields,

$$\frac{J_{woodps}}{J_{woodb}} = \frac{J_{fosps}}{J_{fosb}} = \frac{J_{ps}}{J_{in}} = 0.4915, \quad (5a)$$

$$\frac{J_{woodoc}}{J_{woodb}} = \frac{J_{fosoc}}{J_{fosb}} = \frac{J_{oc}}{J_{in}} = 0.5085, \text{ and } (5b)$$

$$\frac{J_{out}}{J_{in}} = \frac{J_{ps} + J_{oc}}{J_{in}} = 1.0. \quad (5c)$$

The same result can be also produced by adding an CO<sub>2</sub> efflux pathway ("sy"). Increasing the CO<sub>2</sub> efflux by the addition of a CO<sub>2</sub> utilizing reaction ( $J_{syn} = 1.421 J_{ps}$ ,  $J_{synb} = 0$ ) yields

$$\frac{J_{woodps}}{J_{woodb}} = \frac{J_{fosps}}{J_{fosb}} = \frac{J_{ps}}{J_{in}} = 0.2894, \quad (6a)$$

$$\frac{J_{woodoc}}{J_{woodb}} = \frac{J_{fosoc}}{J_{fosb}} = \frac{J_{oc}}{J_{in}} = 0.2994, \quad (6b)$$

$$\frac{J_{woodsy}}{J_{woodb}} = \frac{J_{fosy}}{J_{fosb}} = \frac{J_{sy}}{J_{in}} = 0.4113, \text{ and } (6c)$$

$$\frac{J_{out}}{J_{in}} = \frac{J_{ps} + J_{oc} + J_{sy}}{J_{in}} = 1.0. \quad (6d)$$

As has been shown [4,5], such a reaction could be realized by electrochemical reduction of atmospheric CO<sub>2</sub> to graphene-like carbon. Such a CO<sub>2</sub>-consuming reaction seems particularly suitable for reducing the CO<sub>2</sub> content of the atmosphere on a large scale for two reasons: the reduction only to C requires significantly less energy than the reduction to e-fuel (hydrocarbon), for example, and the resulting carbon is non-hazardous and hence storable.

With regard to wood burning for energy supply, it seems particularly worth mentioning that this process emits about twice the amount of CO<sub>2</sub> compared to natural gas combustion with the same energy output. In addition, wood combustion is known to be extremely harmful to humans and possibly also to many animals and plants.

In summary, it can be stated that fossil fuels and fuels of plant origin, such as wood, do not differ in terms of their atmospheric CO<sub>2</sub> yield. Consequently, their respective ability to influence CO<sub>2</sub> neutrality given the same CO<sub>2</sub> production rate must be also identical. This is not surprising, as it is always the same molecule that is released into and removed from the atmosphere, even if the involved processes take place via several different CO<sub>2</sub> input sources and output pathways. Only the influxes and effluxes of this molecule over the same time interval are decisive for the temporal change in the atmosphere

( $\Delta CO_2^{atm} / \Delta t$ ) and consequently also for CO<sub>2</sub> neutrality.

The statement that wood burning can only release that amount of CO<sub>2</sub> that it has already absorbed from the atmosphere through photosynthesis over the years as it grows, as catchy as such a statement may be for many scientists, bears absolutely no relationship to the amount of CO<sub>2</sub> in the atmosphere. It is simply inappropriate and leads to the erroneous conclusion that wood burning is CO<sub>2</sub> neutral.

## References

1. Friedlingstein P, Jones MW, O'Sullivan M, Andrew RM, Bakker DCE, Hauck J, et al. Global Carbon Budget 2021. Earth Syst Sci Data. 2022;14:1917-2005. Available from: <https://essd.copernicus.org/articles/14/1917/2022/>
2. Alonso M, Finn EJ. University Physics Volume III Quantum and Statistical Physics. Amsterdam, London, Manila, Singapore, Sidney, Tokyo: Addison-Wesley; 1968;434-456. Available from: <https://scirp.org/%28S%28351jmbntvnsjt1aadkposzje%29%29/reference/referencespapers?referenceid=3655128>
3. Dill K, Bromberg S. Molecular Driving Forces: Statistical Thermodynamics in Biology, Chemistry, Physics, and Nanoscience. New York: Garland Science; 2010;81-90. Available from: <https://doi.org/10.4324/9780203809075>
4. Esrafilzadeh D, Zavabeti A, Jalili R, Atkin P, Choi J, Carey BJ, Brkljača R, et al. Room temperature reduction to solid carbon species on liquid metals featuring atomically thin ceria interfaces. Nat Commun. 2019;10:865. Available from: <https://www.nature.com/articles/s41467-019-08824-8>
5. Daeneke T, Khoshmanesh K, Mahmood N, de Castro IA, Esrafilzadeh D, Barrow SJ, et al. Liquid metals: fundamentals and applications in chemistry. Chem Soc Rev. 2018;47(11):4073-4111. Available from: <https://pubs.rsc.org/en/content/articlelanding/2018/cs/c7cs00043j>