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Carbon Neutrality - What Are We Talking About?

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The global climate is changing at a very fast rate, with extreme heat waves, heavy precipitations, but also abnormally long or repeated periods of drought. The consequences are a real disaster for human society. The cause is well identified: it is the intensification of the greenhouse effect due to the injection into the atmosphere of gases that absorb thermal infrared radiation. The gas most responsible for this greenhouse effect increase is carbon dioxide (CO_2). In order to contain global warming within limits where we can hope not to be excessively penalized by its impacts, the scientific community agrees that within a few decades, we will have to become carbon neutral. The recent IPCC reports clearly state this. A good number of states, regions, municipalities and companies have declared that they will achieve carbon neutrality in the near future.

What exactly is carbon neutrality?

Also called net zero emission, carbon neutrality is clearly defined by the IPCC: it is the state where the CO_2 emitted by humanity is fully compensated by the CO_2 **absorbed by humanity**. Is this really what people who talk about achieving carbon neutrality have in mind? They frequently explain that carbon neutrality is obtained when the amount of CO_2 emitted is entirely compensated by the amount of CO_2 **absorbed by nature**. They are totally at odds with the IPCC definition: to determine whether carbon neutrality is achieved, what has to be counted is not what nature removes from the atmosphere, but what is removed from the atmosphere thanks to human action. Neutrality implies that our emissions do not impact the action of nature itself, everything must take place as though humanity did not emit any CO_2 at all.

But there is another incompatibility between what people have in mind and what the IPCC is advocating. CO_2 is a gas that mixes quickly with the atmosphere as a whole. Regardless of where it is emitted, within less than a year, the CO_2 emitted in one hemisphere is distributed over both hemispheres. Can we then speak of local carbon neutrality (local, i.e. on a smaller scale than the entire planet)? The CO_2 emitted in one place can be absorbed in another place. A country that locally absorbs all the CO_2 it emits would still receive in its atmosphere a contribution from the emissions of all the other countries. The definition given by the IPCC implies, in talking about carbon neutrality, that we consider the emissions and absorptions over the entire planet. The carbon neutrality of a country, a region, a city, a company... does not make sense. What can make sense for an agent is his or her own contribution to carbon neutrality. An agent who removes from the atmosphere, at home or elsewhere on the globe, as much CO_2 as he or she emits can obviously claim to have achieved carbon neutrality. But at the local level, this would have only a tiny impact. And it will be very difficult to demonstrate equality between emissions and voluntary removals.

Clearly, if every country were to reach carbon neutrality, the global neutrality called for by the IPCC would be achieved. But it is unrealistic to believe that all countries will be able to achieve neutrality in the sufficiently short-term to keep global warming within the desirable limits. Global neutrality obviously implies that there will be countries that cause the absorption of more CO_2 than they emit.

What lies behind "carbon neutrality" as understood by the various entities mentioned above?

In truth, this pseudo carbon neutrality consists in a local contribution to the stabilization of the atmospheric concentration of CO_2. When all of what is emitted is absorbed, the balance is zero. If all the CO_2 emitted on Earth were absorbed by nature, the atmospheric concentration of CO_2 would be stabilized. But climatologists know that, given the inertia of the climate system, this would not prevent climate warming to continue to increase for a few decades, with the consequences that we can envision. Note that, just as with carbon neutrality, we cannot talk about a local stabilization of the concentration. The stabilization can only be global.

While the pseudo "carbon neutrality" can at best achieve stabilization of the CO_2 concentration in the atmosphere, we will see that true carbon neutrality results in a progressive reduction of this concentration.

Disregarding human interference, nature emits 300 billion metric tons of CO_2 per year and absorbs the same amount. Given the current excess CO_2 added by man, and today's temperature and atmospheric CO_2 concentration, exchanges between the vegetation and the atmosphere lead to an additional net average annual absorption of 2.4 billion metric tons of carbon, stored in plants, litter and soil. Ocean-atmosphere exchanges lead to an additional net uptake of 3.2 billion metric tons of carbon by the ocean. That is 5.6 billion metric tons of carbon or 20.5 billion metric tons of CO_2 contributed by humanity that nature removes from the atmosphere annually. With a zero man-made contribution to the atmospheric CO_2 concentration (emissions – absorption is zero, i.e. true carbon neutrality), nature would decrease the amount of CO_2 in the atmosphere by ≈20 billion metric tons annually. But these figures are directly connected to the current situation: a temperature increase leads to less natural absorption. Absorption also decreases when the CO_2 concentration in the atmosphere decreases.

What procedures can we use to reach true carbon neutrality?

Here and there, we see announcements of fabulous procedures to directly capture the CO_2 present in the atmosphere, procedures whose capacities are touted. So far, the actual realizations are far removed from the promised scale. Solutions based on increasing the absorption capacities of the natural processes that already absorb half of the man-made CO_2 emissions every year are more realistic.

It is essentially through photosynthesis that nature absorbs carbon. The vegetation develops by absorbing CO_2 which it transforms into sugar for its metabolism and its above surface and underground growth. The sugar is also food for the fungi and micro-organisms in the soil that live in symbiosis with the plant. Part of the carbon thus absorbed is rejected to the atmosphere by the plant's respiration. The remaining carbon is stored within the plant (trunk, stems, leaves), in the soil (roots, fungi, micro-organisms), and in the litter formed by the decay of dead plant parts that fall to the ground. In the oceans, but also in continental water bodies, the carbon dissolves in the surface water. Some of it sinks to the bottom where it can remain dissolved. Here also, the storage is achieved via photosynthesis: phytoplankton and cyanobacteria consume the carbon. The carbonated skeletons of the plankton and of the organisms that have grazed on it then form a sediment on the ocean floor, thus storing the carbon.

Photosynthesis therefore plays an essential role in the removal of atmospheric CO_2. Hence, it is logical, in order to remove more CO_2 from the atmosphere, to try to enhance photosynthetic absorption. Reforestation of areas where the forest has been destroyed, promoting the extension of existing forests, planting new forests, are all actions that can increase the amount of CO_2 removed from the atmosphere by photosynthesis. However, we must be aware of two issues: land occupation by the restored or new forests must not compete with the necessary production of food crops; the efficiency of newly planted trees should not be overestimated. It takes several decades for a young tree to grow sufficiently to contribute significantly to CO_2 removal; the trees we intend to rely on in 30 to 50 years have to be planted now. And the plantations must be perennial, otherwise a significant part of the carbon absorbed would be re-emitted into the atmosphere. Currently, land use changes, particularly deforestation, are responsible for 10% of the global CO_2 emissions.

Attempts to increase carbon uptake by the ocean involve geoengineering: the idea is to enhance the growth of phytoplankton by providing it with larger amounts of the minerals that it needs to grow and multiply, iron in particular. The problem is that, while we know how to bring these minerals to sea water, we have no assurance that the phytoplankton will effectively benefit from them before they dissolve in the water, or sink to the bottom. Moreover, we do not have control over the interactions between these minerals and the rest of the ocean fauna and flora. The results obtained from test dispersals are not very conclusive. Another way to use the oceans in the fight against global warming is the restoration of mangroves, which also play an important protective role for biodiversity and coastal areas (an essential issue with the inexorable rise of the sea level).

Removing carbon from the atmosphere is only the first step. Once extracted, the carbon has to be stored in such a way that it does not return to the atmosphere. With trees, the wood stores the carbon as long as the tree is alive. When the wood dies and decays, or when the wood is burned, the carbon is re-emitted to the atmosphere. Storage in wood can be extended, possibly for centuries after the tree's death, if the tree is used as lumber. But wood is not the only storage done by forests. Carbon is stored in the soil and in the litter on the ground. Forests are the vegetation cover that stores the most carbon in the soil. Since the litter decays quite rapidly, its carbon is re-emitted as CO_2 and methane (which will be oxidized to CO_2 within about ten years). The perenniality of the forest is important not only in terms of wood storage, but also in terms of carbon storage in the litter and soil. A deforested area will lose its litter rapidly; the carbon in the soil will also disappear within a few years. In both instances, the carbon is re-emitted to the atmosphere as CO_2 and methane.

Forests are not alone in storing carbon in the soil. Grasslands, and particularly grazed grasslands, store almost as much carbon in the soil as forests. However, this advantage must be weighed against the fact that ruminants emit significant amounts of methane, a greenhouse gas that is much more potent than CO_2, and which will be oxidized to CO_2 within about ten years. Fields tilled after harvest and used for a single annual vegetation cycle see their soil lose most of its carbon. Hence the value of multicropping which, by reducing this natural loss, increases the carbon content of the soil and increases its fertility.

Despite all the efforts that can be undertaken, fossil fuel use will continue, as well as CO_2 emissions from other processes[1]. Carbon neutrality is a requirement if global warming and its impacts are to be limited. The means available to absorb the CO_2 emitted to the atmosphere require a significant extension of the surfaces currently covered with forests[2] along with a change in agricultural practices, all of which will not be easily achieved at a sufficient level on a global scale. Obviously, carbon neutrality will not be achieved without a drastic reduction of CO_2 emissions: the carbon that humanity has not emitted will not have to be removed. Evidently, the first action we should undertake is to reduce our emissions.

Phasing out fossil fuels, the main source of energy worldwide, without endangering the fragile social balance is a real challenge that will require difficult technological and societal shifts in the coming decades.

1 The combustion of biomass emits CO_2, as does the combustion of any carbon compound. This emission is often treated as zero emissions because it is balanced by the growth of the vegetation that produced the fuel. However, we should make sure we are not counting the same thing twice: the amount of CO_2 emitted during biomass combustion must not have been previously counted as CO_2 absorption during the plant's growth. But, more important, the CO_2 that will have to be removed is not the one that has potentially been removed during the plant's growth but the one that is emitted during the combustion. CO_2 cannot be eliminated before it is produced.

2 If we wanted to absorb the 45 billion metric tons of carbon emitted annually by humans thanks to forests, we would need an area of 1000 billion hectares of forest with the average characteristics of the current world-grade forests, i.e. cover 20% of the global land area with mature forests.