Next level carbon cycling, quantifying the carbon recycling potential

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Carbon dioxide emissions from industrial activities have accumulated in the atmosphere in excess of 880 gigatons (Gt) since preindustrial times (Ciais et al., 2013). The conventional approaches to climate change, market based mechanisms, energy efficiency or technology have proved less efficient than recent economic downturns at curbing the emission rate. We propose to account for the atmospheric stock as source of carbon. This stock, being the largest manmade with approximately 240 Gt of carbon (C), has much more potential than just a sink. In other words we consider the stock of carbon in the anthroposphere as a carbon "mine", from concentrated, heterogeneous and high grade fossil fuels to dilute, low grade but homogeneous atmospheric carbon and its consequences on the climate.

The current trend shows an average of 7.8 Gt of C emitted per year from fossil fuel combustion and cement production, excluding land use changes (Ciais et al., 2013). As opposed to cutting off the flow of fossil carbon from the lithosphere to the atmosphere, with carbon capture and storage (CCS) for example, this article argues in favor of closing the anthropogenic carbon cycle, consistent with the industrial ecology principles. The primary option consists of extracting carbon from the atmosphere by physico-chemicals methods, and then storing it in another reservoir. Currently, not all the carbon emitted accumulates in the atmosphere (about half, or 4 Gt of C per year), the rest is split more or less equally between oceanic and terrestrial sinks. This tells us that increased concentration in the atmosphere stimulates photosynthesis (CO_2 fertilization) so that soils and biomass capture part of the emissions. Thus the indirect route through photosynthesis is also a valuable option. A wide variety of materials and energy are already derived from biomass. Out of this anthropogenic carbon, a new cycle appears, using the atmosphere as a source.

A few studies have quantified carbon metabolism at the national scale (Orthofer et al., 2000; Pacala et al., 2007; Uihlein, Poganietz, & Schebek, 2006). Global carbon metabolism involves flows and stocks or reservoir consisting of accumulated emissions in the atmosphere as well as carbon stored in products such as plastics, construction materials, wastes and agricultural lands. The main anthropogenic carbon flows are from the agricultural and energy sectors to the atmosphere. Thus, to shift from an anthropogenic sink to a source, carbon would have to accumulate in biomass, soils and manmade products, both energy and non energy related. Natural carbon reservoirs on Earth have been quantified and the purpose of this article is to quantify anthropogenic stocks (Budzianowski, 2012). With reliable data for the stocks of wood and plastic products in the EU, the estimated carbon stocks in wood and plastic are respectively two and four orders of magnitude less than the smallest natural carbon reservoir, the biosphere, with 560 Gt of C. In comparison, wastes contained in EU landfills alone store approximately one tenth of the carbon available in the biosphere, making them the second largest manmade stock.

The next step is to quantify the magnitude of carbon flows, in particular the extent to which the anthroposphere can absorb or recycle carbon. The difference between anthropogenic emissions and the amount of carbon recycled indicates the necessary reductions to reach a steady state and mitigate climate change. While measures to restrict carbon dioxide emissions and upstream fossil fuel combustion are a necessity, we emphasize carbon re-cycling potential (Lawrence et al., 2014). The number of ways carbon can be recycled – some more developed than others – might lead to delayed action on climate change. However we argue in favor of raw figures, to show the distance separating us from a steady state and low level, anthropogenic carbon cycle. In order to quantify the recycling rate or equivalently the potential to displace fossil resources, both direct valorization of CO_2 and indirect routes through biomass are considered. Since recycling requires energy, biomass provides both a renewable source of energy and material. The bioenergy potential of agricultural lands, non-competing with food supplies, has been estimated recently (Haberl et al., 2011). We then attempt to link the energy and material potential to process efficiencies for conversion of CO_2 to both energy vectors and materials.

Should the human induced carbon cycle balance itself in the future, we might even reduce atmospheric CO_2 concentration and eventually face atmospheric instead of fossil or lithospheric carbon depletion. Many questions remain to be answered on carbon management but this approach has the advantage of bringing anthropogenic carbon into a full circle analogous and parallel to the natural carbon cycle.

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