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Time scale dependent negative emission potential of forests and biomass plantations via wood burial, torrefied biomass, biochar and pyrogas condensate sequestration in soil

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The efficiency of Negative Emission Technologies (NET) is dependent on (1) the transformation of the biomass carbon into a form that can be sequestered, (2) the mean residence time of the sequestered carbon, (3) the regrowth and thus carbon re-accumulation of the harvested biomass, and (4) the positive or negative priming of soil carbon. These four parameters define the time scale dependent C-balance of various NET-Systems and permit a global economic and environmental evaluation.

As far as geologic CO_2 storage is considered to be feasible with close to zero losses and if the energy for transport, transformation and disposal is taken from the process bioenergy, conventional BE-CCS has a C sequestration potential of 50 - 70 % depending on the type of biomass and the technology used. Beside unknown risks of deep stored CO_2 and high costs, regrowth of C-accumulating biomass is hampered in the long-term as not only carbon but also essential soil nutrients are mined. Under this scenario, biomass regrowth is expected to slow down and soil carbon content to decrease. These factors enlarge the time horizon until a BE-CCS system becomes carbon neutral and eventual carbon negative (when biomass regrowth exceeds the difference between the harvested biomass carbon and BE-CCS stored carbon).

Thermal treatment of biomass under a low oxygen regime (torrefaction, pyrolysis, gasification) can transform up to 85% of biomass carbon into various solid and liquid forms of recalcitrant carbon that can be sequestered. Depending on the process parameters and temperature, the mean residence time of the torrefied or pyrolysed biomass can last from several decennials to centennials when applied to the soil of the biomass production site. The carbon can thus be stored at comparatively low costs within the ecosystem itself. As the thermal treatment preserves most of the biomass-accumulated nutrients (except N), natural nutrient cycles are maintained within the biomass system. Depending on the quality of the charred biomass (biochar), post thermal treatment and plant nutrient enhancement, regrowth is expected to accelerate and soil carbon content to increase. Overall, the time until such a biochar based CSS systems generates negative carbon emissions (biomass regrowth exceeds the C-loss from CSS transformation) can thus be reduced compared to BE-CCS while increasing the sustainability of the global biomass production system and fostering ecosystem services.

In our presentation we will provide first assessments of various biochar-based CCS systems and compare them to conventional BE-CCS, an evaluation of their global time scale dependent C-sequestration potential and their economic frame. E.g. (1) a biochar system with pyrolysis temperatures of 750°C and without liquefying the pyrolysis gases delivers a very recalcitrant biochar but the C-efficiency is low (40%) and fostering of regrowth is only about 10-15%. A (2) biochar system with trunk burial, pyrolysis of needles, bark, twigs, and branches with organic N-enhancement, and pyrolysis gas condensation and chemical oxidation could achieve a C-efficiency of 85% to 90% and foster regrowth over a time scale of 60% by up to 50%. Future challenges of biochar classification, certification, ecotoxicology, C-leaching, carbon credits and integration into agro-forestry practices will be discussed.