Biochar

Can it get us back down below 350 ppm atmospheric CO_2?

By CHUCK KUTSCHER

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The opinions expressed here are solely those of the author.

A landmark 2008 paper by NASA's James Hansen et al., the latest measurements of polar ice and new studies of the negative effect of CO_2 on coral lead to the conclusion that atmospheric carbon dioxide must be stabilized below 350 ppm. As the level is now at about 390 ppm and rising rapidly, more attention is being paid not only to reducing carbon emissions but also to removing carbon from the atmosphere and sequestering it in the earth. As I have pointed out previously in this column (*SOLAR TODAY*, Nov./Dec. 2009, p. 20, http://bit.ly/92HNdg), biomass is a renewable energy resource that, if applied properly, can potentially be carbon-negative, as opposed to just carbon-neutral. Reducing deforestation and promoting reforestation are key biological ways to help reduce atmospheric carbon dioxide. Another approach gaining in popularity is the concept of biochar.

Biochar is the charcoal that results from subjecting biomass to temperatures of 350°-600°C (662°-1,112°F) in the absence of oxygen. In the process of "slow pyrolysis," the biomass feedstock is converted over a period of hours to a combination of perhaps 25 percent to 35 percent biochar and the rest biofuel, equivalent to about a 50-50 split on a carbon basis. In fast pyrolysis, up to 80 percent biofuel is created in a matter of seconds. The advantage of the slow approach is that while the carbon-neutral biofuel can be used to displace carbon-emitting fossil fuels (preferably coal), the carbon-negative biochar can be used as a renewable fertilizer, thus sequestering in the soil carbon that was removed from the atmosphere by the plant growth. This all assumes that the overall carbon impacts of land use are properly considered.

Proponents of biochar point to the fertile *"terra preta"* (Portuguese for "black earth") soils found in the Amazon Basin. Researchers believe pre-Colombian farmers produced biochar by smoldering agricultural waste. How long biochar carbon will stay sequestered in different soils (expressed in terms of its half-life, or how long it takes for half of the original biochar to be lost from the soil) can vary over a considerable range. In one interesting exchange of letters in *Science*, Swedish biologist David Wardle stated that, in his experiments, the introduction of biochar increased bacterial growth, which led to more carbon being released. The carbon half-life and crop productivity effects of biochar are dependent on the feedstock used for the biochar, how the biochar is produced, amount of rainfall, soil temperature, specific fungal and microbial colonies present and other soil properties.

For an explanation of the biochar process, see solartoday.org/biochar.

There has been a wide range of opinions regarding the total impact extensive production of biochar might have on world carbon emissions. The most thorough analysis I have seen to date was presented in an August paper in *Nature Communications* by Dominic Woolf et al. (http://bit.ly/bcOK1r). Cognizant of scientific papers that have criticized the negative land-use (and resulting carbon) impacts associated with some biofuels production, the authors placed a number of practical constraints on biochar production, such as excluding the use of rainforests and the conversion of land being used for food crops. They then developed three scenarios for biochar production, the most ambitious being an estimate of the maximum possible amount that could be produced sustainably. Their conclusion was that the production of biochar could theoretically reduce total world greenhouse gas emissions by an amount equal to (at most) about 12 percent of today's emissions. That is substantial, although it is a lot lower than some biochar enthusiasts might claim. One should keep in mind that this was based on the authors' most aggressive scenario and, despite the constraints they placed on land use, some environmental groups have criticized the paper for espousing what they call a huge land grab from indigenous peoples and peasant farmers.

The authors also concluded that if the biomass were instead used to produce the maximum amount of energy, then it would reduce greenhouse gas emissions by about 10 percent of today's value. Considering the number of assumptions made in an analysis of this type and the overall uncertainty, I don't see a big difference between 10 percent and 12 percent. Of course, if the biochar significantly improves crop yields and if the infrastructure needed to distribute it is not too costly or unwieldy, the biochar can provide added societal benefits. On the other hand, if a company is going to the expense of subjecting biomass to pyrolysis, I suspect there would be a great temptation to produce as much high-value fuel or electricity as possible that can immediately be sold on existing energy markets.

The Woolf et al. paper recommended a combination approach in which biomass is used to produce energy in areas that have fertile soils, where that energy could be used to directly displace coal burning. Biochar could be used elsewhere (although enhanced crop production could favor biochar even in the former regions). One thing that bothers me, however, is that while the authors' biochar alternative included sequestration in the soil, their energy production alternative did not include the prospect of geologic sequestration. Yet, as I pointed out in my column on biomass power, instead of burning biomass directly to produce electric power, as assumed by Woolf et al., that biomass could instead be used in an integrated gasification/combined-cycle plant, in which carbon dioxide is captured during the biomass gasification process and geologically sequestered.

Production of biochar could theoretically reduce world greenhouse gas emissions by … about 12 percent.

Such a design could potentially produce highly efficient electricity and reduce overall greenhouse gases considerably more than either of the two approaches discussed by Woolf et al. While geologic sequestration of CO_2 presents challenges to avoid leakage, numerous reputable, peer-reviewed studies and field experiments have concluded that it is feasible and economic, although it will require long-term development to be proven on a large scale. Some who oppose geologic sequestration of carbon dioxide from coal plants argue that even a leakage rate of only a few percent per century would be unacceptable. But Woolf et al. assumed a baseline half-life of 300 years for biochar in the soil. This means that 20 percent of it would enter the atmosphere in 100 years. Half-life would be reduced if the biochar-enhanced soil were subjected to conventional tilling, which would expose the biochar to air.

Slow pyrolysis for the production of a combination of biochar and biofuel is clearly not a panacea and will not by itself solve the greenhouse gas problem. But neither will any other single energy technology. How much of a role biochar can play will depend on its long-term effects on soil productivity and carbon storage and the extent to which direct energy production (especially including carbon capture and storage) proves more practical. We need to better understand the long-term effects of different formulations of biochar in different soils. We also need a comprehensive economic and carbon accounting analysis that considers the transportation and sale of biochar, as well as added profitability resulting from stimulated crop production, and compares the overall cost-effectiveness of biochar to that of bioenergy production. Such an analysis should include sensitivity to future carbon prices.

So biochar is not a magic bullet. But at the very least, it shows promise as a renewable fertilizer with some carbon sequestration potential. It clearly warrants further research to better determine what role it can play as we harness multiple technologies and approaches with the ultimate goal of returning the greenhouse gas concentration in our atmosphere to safe levels. ST