PROJECT facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Carbon Sequestration

04/2008

Enhancing Carbon Sequestration and Reclamation of Degraded Lands with Coal-Combustion and Biomass-Pyrolysis Products

Background

Terrestrial sequestration of carbon can occur by three mechanisms, all of which first require "capture" or fixation of atmospheric carbon by photosynthesis into plant tissues. If captured by herbaceous plants, much of the carbon is quickly returned to the atmosphere by microbial activity when the plant dies, but a small percentage of it is incorporated by the humification process into soil humic material that may have a mean residence time of 25–50 years. If captured as woody tissue by trees, carbon sequestration on the order of tens to a hundred years can be achieved. The third terrestrial mechanism that can store carbon—which has only recently been recognized—is photosynthetic carbon in herbaceous or woody plants (i.e., biomass) and occurs when the biomass is heated under oxygen-limited conditions (i.e., pyrolysis) to produce bio-liquids and bio-gases that can be used to generate energy. In contrast to combustion, the pyrolysis process does not consume all the biomass carbon, and thus a solid residue or "char" is produced. The amount of char produced can be as much 50–60 percent of the initial carbon present in the biomass. Significantly, the char is highly resistant to decomposition and thus may have a residence time in soil of hundreds to thousands of years. While some biomass pyrolysis does occur naturally in wildfires, pyrolysis under controlled conditions can yield a significant amount of energy and also optimize the properties of the char that is produced. In addition to its high resistance to microbial and chemical degradation, some of the desirable properties in char include high ion-exchange capacities and substantial microporosity, which allow it to retain nutrients and water and thereby make it a useful additive to increase the fertility of soil. Also, because energy is produced at the same time that recently fixed atmospheric carbon (as opposed to fossil carbon) is being sequestered, the biomass pyrolysis process can be considered "carbon negative" and is the only form of energy production that inherently has this distinction (biomass combustion, for example, can at best be "carbon neutral" unless additional steps are taken to capture and sequester the recently fixed atmospheric carbon that is re-released as CO_2 during combustion). Technical estimates of the potential for biomass pyrolysis coupled with soil storage to sequester carbon suggest that several hundred gigatons of carbon emissions could be sequestered or offset by 2100, which is a large fraction of the total needed to mitigate global climate disruption.

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Description

The FY 08 research focus is on the characterization of unburned carbon present in fly ash from coal-fired power plants and in the residue from the pyrolysis of biomass to determine their suitability as soil additive, both alone and in various combinations with other coal combustion products. The following will be determined: 1) the physical and chemical properties of several types of char derived from each of the principal sources (coal char and biomass char); 2) the stability of selected chars towards oxidation when used as a soil additive; 3) the impact of the char-based additives (CBAs) on the production of greenhouse gases (N_2O and CH_4) by soil; 4) the impact of CBAs on the composition of the soil microbial community; and 5) the potential toxicity (if any) of CBAs towards plants and microbes, as well as the potential beneficial effects of CBAs on plant growth. Based on the results of these laboratory tests, in FY 09 one or more additive protocols will be recommended and an experimental plan for a subsequent field trial will be developed where the protocol(s) can be tested under realistic conditions.

Primary Project Goal

The overall goal of this project is to study the use of coal-combustion and biomass-pyrolysis products to foster carbon sequestration in degraded lands. This has the triple benefits of carbon storage, byproduct utilization, and land reclamation.

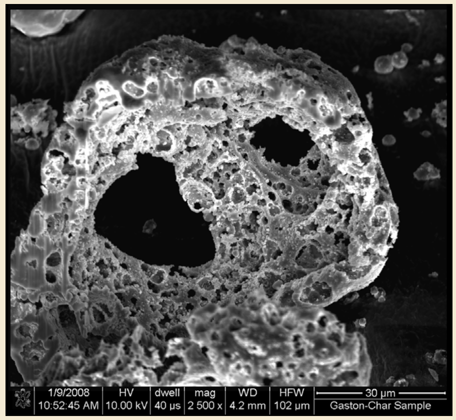
Objectives

The current objectives are—

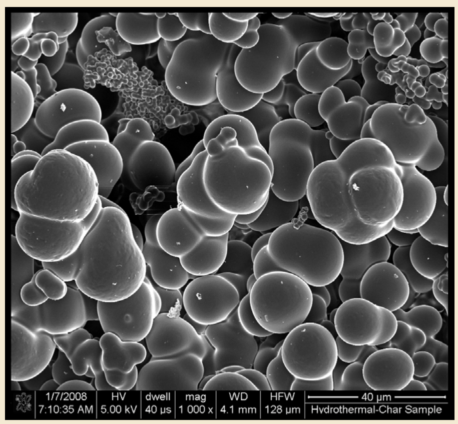
- To contrast the characteristics of coal-char and bio-char.
- To explore the potential usefulness of soil additives containing various combinations of fly ash and char (either from coal or biomass) to promote soil carbon sequestration and the restoration of degraded lands.

Benefits

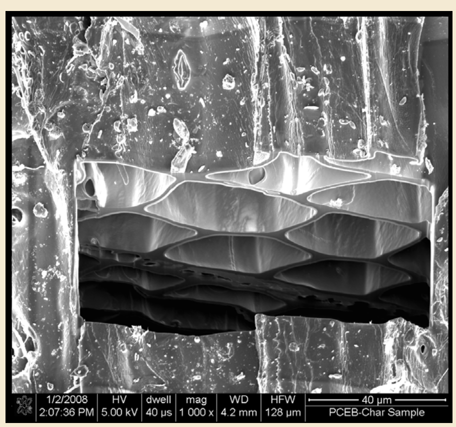
The successful use of coal ash to enhance poor soil will benefit carbon sequestration efforts, utilize a coal waste product, and increase soil fertility.



Focused ion beam (FIB) section of coal char from Alabama.



Hydrothermal char from cellulose (sample courtesy of Max Planck Institute, Potsdam, Germany).



FIB section of char from pine wood (sample courtesy of Eprida Corporation, Athens, GA).

Electron micrographs of three chars.

PARTNERS

Oak Ridge National Laboratory (ORNL)

Pacific Northwest National Laboratory (PNNL)

Virginia Polytechnic and State University

PERIOD OF PERFORMANCE

01/01/2000 to 09/30/2009

COST

Total Project Value
$1,815,000

DOE/Non-DOE Share
$1,815,000 / $0

Accomplishments

To date, the project has accomplished the following:

- Laboratory experiments have shown that fly ash's alkalinity, porosity, and organic sorbent properties significantly promote the humification reaction.
- Observations have shown that increasing soil pH alone may lead to less carbon near the surface but may also lead to a beneficial mobilization of carbon to deeper soil levels.
- Laboratory testing of metal releases stemming from fly ash additives to soils have shown very low potential for leaching of metals and no toxicity of the leachates when measured using the Microtox technique.
- Sampling of field sites where fly-ash additives have been used have shown that after 15–30 years lands treated with fly ash have higher levels of carbon in the soil.
- Laboratory studies of additives involving fly ash and biosolids have shown that biosolids do not necessarily increase carbon sequestration and often increase the risk of leaching of toxic metals.
- Laser-induced breakdown spectroscopy has been found to be adaptable into a rapid-analysis field instrument.
- Extensive characterization of a variety of chars derived from coal or biomass has been initiated. Significant chemical and morphological differences have been observed.
- Eleven journal articles, abstracts, reports, and conference papers have been published.

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