

## **Significant Climate Mitigation Is Available from Bio-char**

### ***Produces Carbon Negative Process When Coupled with Bio-fuels Production***

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Turning biomass into “bio-char” (also known as “agri-char”) can store massive amounts of carbon in soils on a time scale of hundreds to thousands of years.<sup>1</sup> This high-carbon, fine-grained residue can be produced either by smoldering biomass utilizing centuries-old techniques (i.e., covering burning biomass with soil and letting it smolder) or through modern pyrolysis processes.

By the end of this century, bio-char sequestration “schemes, in combination with bio-fuel programs, could store up to 9.5 [GtC or 34.83 GtCO<sub>2</sub>-eq.] per year—more than emitted by all of today’s fossil-fuel use,” which is 8.4 GtC or 30.8 GtCO<sub>2</sub>-eq.<sup>2</sup> Such soil sequestration schemes have the potential to be implemented quickly and at scale in developing countries.<sup>3</sup>

Bio-char application to soil also reduces nitrous oxide and methane emissions from soils, providing further GHG reductions.<sup>4</sup> In addition, bio-char restores degraded soils, improves crop yields,<sup>5</sup> and supports higher value crops in regions with poor soils.<sup>6</sup>

Bio-char was practiced as a soil enhancement technique by ancient Amazonian peoples in lieu of slash-and-burn agriculture, and is expanding today with more sophisticated but still relatively low-tech strategies that can be implemented at scale in the developing world and that are energy positive and carbon negative.<sup>7</sup>

Simply by switching to slash-and-char from slash-and-burn, which turns biomass into ash using open fires that release significant GHGs,<sup>8</sup> 12% of anthropogenic carbon emissions caused by land use change could be reduced annually,<sup>9</sup> which is approximately 0.66 Gt CO<sub>2</sub>-eq. per year or 2% of all annual global CO<sub>2</sub>-eq. emissions.<sup>10</sup>

Modern techniques produce bio-char through a chemical process known as pyrolysis, which has a significantly greater potential to mitigate climate change than traditional slash-and-char methods. Through pyrolysis, biomass can be turned into a liquid or gas bio-fuel, as well as bio-char; under some circumstances, the costs are already favorable.<sup>11</sup> Indeed, the pyrolysis process itself is an energy positive process, yielding 3-9 times more energy than invested.<sup>12</sup>

While pyrolysis gas-capture without carbon sequestration is a carbon-neutral energy source, researchers calculate “emissions reductions can be 12-84% greater if bio-char is put back into the soil instead of being burned to offset fossil-fuel use,” making the process carbon negative,<sup>13</sup> (i.e. taking more carbon out of the atmosphere than it puts in) and reversing climate change by allowing an ever-increasing soil carbon sink to build up.

Lehmann has “calculated emissions reductions for three separate bio-char approaches that can each sequester about 10% of the annual U.S. fossil-fuel emissions” (1.6 GtC per year or 5.86 Gt CO<sub>2</sub>-eq. in 2005) and claims “even greater emissions reductions are possible if pyrolysis gases are captured for bio-energy production.”<sup>14</sup>

## Endnotes

\* Institute for Governance & Sustainable Development, <http://www.igsd.org>.

<sup>1</sup> See Lehmann, Johannes, *Terra Preta de Indio*, Soil Biogeochemistry, Cornell University

<[http://www.css.cornell.edu/faculty/lehmann/terra\\_preta/TerraPretahome.htm](http://www.css.cornell.edu/faculty/lehmann/terra_preta/TerraPretahome.htm)> (internal citations omitted); see also Winsley, Peter, *Biochar and Bioenergy Production for Climate Change Mitigation*, 64(1) *New Zealand Science Review* 5-10, at 5 (2007) <[http://www.biochar-international.org/images/NZSR64\\_1\\_Winsley.pdf](http://www.biochar-international.org/images/NZSR64_1_Winsley.pdf)>; Kern, Dirse C., *New Dark Earth Experiment in the Tailandia City – Para-Brazil: The Dream of Wim Sombroek*, 18th World Congress of Soil Science (9-15 July 2006). Not only do bio-char enriched soils contain more carbon, 150gC/kg compared to 20-30gC/kg in surrounding soils, but bio-char enriched soils are, on average, more than twice as deep as surrounding soils.

Therefore, the total carbon stored in these soils can be one order of magnitude higher than adjacent soils. See *id.*

<sup>2</sup> Marris, Emma, *Putting the Carbon Back: Black is the New Green*, 442 *Nature* 624-626 (10 August 2006)

<<http://www.nature.com/nature/journal/v442/n7103/full/442624a.html>>; Lehmann, Johannes, et al., *Bio-Char Sequestration in Terrestrial Ecosystems – A Review*, 11 *Mitigation and Adaptation Strategies for Global Change* 403-27, at 414-15 (Springer 2006) (citing Berndes, G., et al., *The contribution of biomass in the future global energy supply: A review of 17 studies*, 25 *Biomass and Bioenergy* 1-28 (2003))

<<http://www.css.cornell.edu/faculty/lehmann/publ/MitAdaptStratGlobChange%2011,%20403-427,%20Lehmann,%202006.pdf>>.

In 2006, global fossil fuel emissions were 8.4 GtC or 30.8 Gt CO<sub>2</sub> eq. See Global Carbon Budget Team, *Recent Carbon Trends and the Global Carbon Budget*, The Global Carbon Project, Nov. 15, 2007 <[http://www.globalcarbonproject.org/global/pdf/GCP\\_CarbonCycleUpdate.pdf](http://www.globalcarbonproject.org/global/pdf/GCP_CarbonCycleUpdate.pdf)>.

<sup>3</sup> Cornell University, *Simpler Way to Counter Global Warming Explained: Lock up Carbon In Soil and Use Bioenergy Exhaust Gases for Energy*, *ScienceDaily* (12 May 2007)

<<http://www.sciencedaily.com/releases/2007/05/070511211255.htm>> (“Biochar sequestration, combined with bioenergy production, does not require a fundamental scientific advance, and the underlying production technology is robust, clean and simple, making it appropriate for many regions of the world,” said Lehmann. “It not only reduces emissions but also sequesters carbon, making it an attractive target for energy subsidies and for inclusion in the global carbon market.”). Fast local implementation can take advantage of “[m]obile pyrolysis plants ... that not only convert biomass into bio-oil, bio-char, and gas, but also use the energy from the gas to power the process, with no other energy needed.” Winsley, Peter, *Bio-char and Bioenergy Production for Climate Change Mitigation*, 64(1) *New Zealand Science Review* 5-10, at 7 (2007) <[http://www.bio-char-international.org/images/NZSR64\\_1\\_Winsley.pdf](http://www.bio-char-international.org/images/NZSR64_1_Winsley.pdf)>.

Winsley explains that an “advantage of biochar is that it is one of the few technologies to address climate change that creates net economic as well as environmental benefits. ... Baum & Weitner (2006) contend that ‘production and application costs of biochar may be fully recovered, even in the absence of a carbon market, based solely on crop production benefits and fertiliser cost savings.’ ... Lehman *et al.* (2006) contend that ‘the most promising strategy for cropping of biomass as feedstock for biochar production is the concurrent production of bio-fuels by pyrolysis.’ They conclude that biofuel production using pyrolysis ‘has great potential to generate electricity at a profit in the long term, and at a lower cost than any other biomass-to-electricity system.’” See also Wilson, Kelpie, *Birth of a new wedge: agrichar (terra preta)*, *Energy Bulletin* (5 May 2007) <[http://www.truthout.org/docs\\_2006/050307R.shtml](http://www.truthout.org/docs_2006/050307R.shtml)> (If recognized as an emissions offset under the Kyoto Protocol, experts at a UK biomass company claim “the impact of [bio-char] on nitrous oxide emissions alone would be enough incentive to fund needed projects.”)

<sup>4</sup> See Lehmann, Johannes, et al., *Bio-Char Sequestration in Terrestrial Ecosystems – A Review*, 11 *Mitigation and Adaptation Strategies for Global Change* 403-27, at 418 (Springer 2006)

<<http://www.css.cornell.edu/faculty/lehmann/publ/MitAdaptStratGlobChange%2011,%20403-427,%20Lehmann,%202006.pdf>>.

Nitrous oxide represents 9% of global anthropogenic GHG emissions while methane represents 16%. Of these emissions, agriculture is responsible for 84% and 52% respectively. Thus nitrous oxide from agriculture represents 7.56% of global GHG emissions while methane emissions from agriculture represent 8.52% of global GHG emissions. See Netherlands Environmental Assessment Agency, *Global greenhouse gas emissions increased 75% since 1970*, Nov. 13, 2006 (stating nitrous oxide and methane emissions as a percentage of global GHG emissions in 2004); <<http://www.mnp.nl/en/dossiers/Climatechange/TrendGHGEmissions1990-2004.html>>; U.S. Environmental Protection Agency, *Global Mitigation of non-CO<sub>2</sub> Greenhouse Gases (EPA Report 43-R06-005)*, at V-1 (June 2006) (estimating that 15% of global climate emissions are from nitrous oxide and methane emissions attributable to agriculture). <[http://www.epa.gov/climatechange/economics/downloads/GM\\_SectionV\\_Agriculture.pdf](http://www.epa.gov/climatechange/economics/downloads/GM_SectionV_Agriculture.pdf)>.

<sup>5</sup> See Marris, Emma, *Putting the Carbon Back: Black is the New Green*, 442 *Nature* 624-626 (10 August 2006)

<<http://www.nature.com/nature/journal/v442/n7103/full/442624a.html>>; Lehmann, Johannes, et al., *Bio-Char Sequestration in Terrestrial Ecosystems – A Review*, 11 *Mitigation and Adaptation Strategies for Global Change* 403-27, at 414-15 (Springer 2006) (citing Berndes, G., et al., *The contribution of biomass in the future global energy supply: A review of 17 studies*, 25 *Biomass and Bioenergy* 1-28 (2003)).

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<<http://www.css.cornell.edu/faculty/lehmann/publ/MitAdaptStratGlobChange%2011,%20403-427,%20Lehmann,%202006.pdf>>; see also e.g. Lehmann, Johannes and Rondon, Marco, *Biological nitrogen fixation by common beans (*Phaseolus vulgaris* L.) increases with bio-char additions*, 43 *Bio Fertil Soils* 699-708 (Springer-Verlag 2007) <<http://www.css.cornell.edu/faculty/lehmann/publ/BioFertSoils%202006,%20online%20first,%20Rondon.pdf>>.

<sup>6</sup> See Lehmann, Johannes, et al., *Bio-Char Sequestration in Terrestrial Ecosystems – A Review*, 11 *Mitigation and Adaptation Strategies for Global Change* 403-27, at 410 and 416 (Springer 2006)

<<http://www.css.cornell.edu/faculty/lehmann/publ/MitAdaptStratGlobChange%2011,%20403-427,%20Lehmann,%202006.pdf>>; Lehmann, Johannes and Rondon, Marco, *Bio-Char Soil Management on Highly Weathered Soils in the Humid Tropics*, in *BIOLOGICAL APPROACHES TO SUSTAINABLE SOIL SYSTEMS*, at 517-30, at 519 (CRC Press 2006); Winsley, Peter, *Biochar and Bioenergy Production for Climate Change Mitigation*, 64(1) *New Zealand Science Review* 5-10, at 5-7 (2007) <[http://www.biochar-international.org/images/NZSR64\\_1\\_Winsley.pdf](http://www.biochar-international.org/images/NZSR64_1_Winsley.pdf)>; see also generally, Lehmann, Johannes, et al., *AMAZONIAN DARK EARTHS: ORIGIN, PROPERTIES, MANAGEMENT* (Kluwer Academic Publishers 2003).

<sup>7</sup> Interest in Amazonian black soils and bio-char's ability to store carbon were pioneered and promoted by Dutch scientist Wim Sombroek who wrote the seminal work on the subject in 1966—*Amazonian Soils*—the first detailed scientific study of bio-char. See Marris, Emma, *Putting the Carbon Back: Black is the New Green*, 442 *Nature* 624-626 (10 August 2006) <<http://www.nature.com/nature/journal/v442/n7103/full/442624a.html>>. Dutch companies and researchers continue to be heavily involved in the pioneering research into pyrolysis bio-char and bio-fuels production. See e.g. Bramer, E.A., et al., *A novel technology for fast pyrolysis of biomass: PyRos reactor*, available at:

<<http://www.brdisolutions.com/pdfs/bcota/abstracts/3/z244.pdf>> (discussing development of a pyrolysis reactor at Twente University). Researchers at Wageningen University have also been active bio-char researchers. See e.g. Kuyper, T., et al., *Mycorrhizal responses to bio-char in soils – concepts and mechanisms*, 300 *Plant Soil* 9-20 (Springer 2007) <<http://www.css.cornell.edu/faculty/lehmann/publ/PlantSoil%20300,%209-20,%202007,%20Warnock.pdf>>. Clean Fuels, a Dutch company, has several ongoing bio-fuel and bio-char production projects throughout the developed and developing world. See <http://www.cleanfuels.nl/>.

<sup>8</sup> See Lehmann, et al., *Bio-Char Sequestration in Terrestrial Ecosystems – A Review*, 11 *Mitigation and Adaptation Strategies for Global Change* 403-27, at 403-07 and 418 (Springer 2006) <<http://www.css.cornell.edu/faculty/lehmann/publ/MitAdaptStratGlobChange%2011,%20403-427,%20Lehmann,%202006.pdf>>. Researchers estimate that between 38-84% of the biomass carbon in vegetation is released during the burn, whereas converting the biomass into bio-char by means of simple kiln techniques sequesters more than 50% of this carbon in bio-char. See *id.* at 407.

<sup>9</sup> *Id.* at 407-08.

<sup>10</sup> See Raupach, Michael, et al., *Global and Regional Drivers of Accelerating CO<sub>2</sub> Emissions*, 104 *Proceedings of the National Academy of Sciences* 24, (underlying data available at: <http://www.pnas.org/cgi/content/full/0700609104/DC1>) (indicating that between 2000-2005 land use emissions annually represented on average 1.5 GtC of the total 8.7 GtC global emissions or 5.5 Gt CO<sub>2</sub> eq. of 31.9 Gt CO<sub>2</sub> eq. of global emissions—17.25% of total). A reduction of 12% of land use emissions equals 0.66 Gt CO<sub>2</sub> eq., approximately 2% of annual global CO<sub>2</sub> eq. emissions. Lehmann's original estimates were based on a 0.2 GtC offset of the 1.7 GtC emissions from land use change estimated in 2001 by the IPCC. See Lehmann, et al., *Bio-Char Sequestration in Terrestrial Ecosystems – A Review*, 11 *Mitigation and Adaptation Strategies for Global Change* 403-27, at 407-08 (Springer 2006) <<http://www.css.cornell.edu/faculty/lehmann/publ/MitAdaptStratGlobChange%2011,%20403-427,%20Lehmann,%202006.pdf>>. Given the increase in fossil fuel emissions to 8.4 GtC, total anthropogenic emissions in 2006, including the estimated 1.5 GtC from land use change, were 9.9 GtC. Thus, despite an increase in overall CO<sub>2</sub> eq. emissions, using Lehmann's original 0.2 GtC reduction still results in an approximate 2% reduction in global CO<sub>2</sub> eq. emissions. See Global Carbon Budget Team, *Recent Carbon Trends and the Global Carbon Budget*, the Global Carbon Project, Nov. 15, 2007 <[http://www.globalcarbonproject.org/global/pdf/GCP\\_CarbonCycleUpdate.pdf](http://www.globalcarbonproject.org/global/pdf/GCP_CarbonCycleUpdate.pdf)> (giving 2006 global carbon emissions estimates).

<sup>11</sup> Winsley, Peter, *Bio-char and Bioenergy Production for Climate Change Mitigation*, 64(1) *New Zealand Science Review* 5-10, at 7 (2007) <[http://www.bio-char-international.org/images/NZSR64\\_1\\_Winsley.pdf](http://www.bio-char-international.org/images/NZSR64_1_Winsley.pdf)> (“[B]iochar ... creates net economic as well as environmental benefits. ... Baum & Weitner (2006) contend that ‘production and application costs of biochar may be fully recovered, even in the absence of a carbon market, based solely on crop production benefits and fertiliser cost savings.’ ... Lehman et al. (2006) contend that ‘the most promising strategy for cropping of biomass as feedstock for biochar production is the concurrent production of bio-fuels by pyrolysis.’ They conclude that biofuel production using pyrolysis ‘has great potential to generate electricity at a profit in the long term, and at a lower cost than any other biomass-to-electricity system.’”); Kram, Jerry W., *Pyrolysis Char Rejuvenates Tired Soils*, *Biomass Magazine*, Oct. 2007 <[http://www.biomassmagazine.com/article.jsp?article\\_id=1298](http://www.biomassmagazine.com/article.jsp?article_id=1298)> (“Compared with

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ethanol production, pyrolysis that produces biochar and bioenergy from its exhaust gases is much less expensive, Lehmann said, when the feedstock is animal waste, clean municipal waste or forest residues collected for fire prevention.”) See also Wilson, Kelpie, *Birth of a new wedge: agrichar (terra preta)*, Energy Bulletin (5 May 2007) <[http://www.truthout.org/docs\\_2006/050307R.shtml](http://www.truthout.org/docs_2006/050307R.shtml)> (If recognized as an emissions offset under the Kyoto Protocol, experts at a UK biomass company claim “the impact of [bio-char] on nitrous oxide emissions alone would be enough incentive to fund needed projects.”); Cornell University, *Simpler Way to Counter Global Warming Explained: Lock up Carbon In Soil and Use Bioenergy Exhaust Gases for Energy*, ScienceDaily (12 May 2007) <<http://www.sciencedaily.com/releases/2007/05/070511211255.htm>> (noting that public and private companies are already producing gas and liquid bio-fuels through pyrolysis, and consider bio-char the secondary product).

<sup>12</sup> Lehmann, Johannes, *Bio-Energy in the Black*, 5(7) Front Ecol. Environ. 381-387, at 384-85 (The Ecological Society of America 2007) <<http://www.css.cornell.edu/faculty/lehmann/publ/FrontiersEcolEnv%205.%20381-387.%202007%20Lehmann.pdf>>.

<sup>13</sup> Lehmann, Johannes, *A Handful of Carbon*, 447 Nature 143-44 (10 May 2007) (citing Gaunt, A., and Lehmann, J., *From Plant to Power Plant*, Presentation at Power-Gen Renewable Energy and Fuels (Las Vegas, 7 March 2007) <<http://209.85.165.104/search?q=cache:DoItwcGeuXkJ:www.css.cornell.edu/faculty/lehmann/publ/Nature%2520447.%2520143-144.%25202007%2520Lehmann.pdf+a+handful+of+carbon+lehmann&hl=en&ct=clnk&cd=1&gl=us>>.

<sup>14</sup> *Id.* (citing Lehmann, Johannes, et al., *Bio-Char Sequestration in Terrestrial Ecosystems – A Review*, 11 *Mitigation and Adaptation Strategies for Global Change* 403-27, at 414-15 (Springer 2006)).