ALL POWER LABS

Moving Carbon from Sky to Soil

Agronomic and Carbon Capture Applications of Biochar

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Charcoal concepts

- Fixed Carbon vs. Volatile carbon
- Reverse-Coal Mining

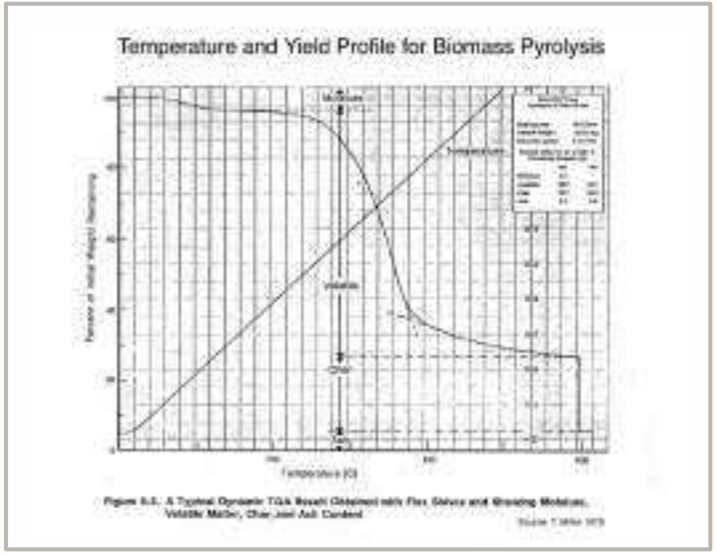
What is Biochar?

- Fixed Carbon vs volatile carbon
- Reverse coal mining

Fixed Carbon vs. Volatile Carbon

Woody biomass breaks down into two major fractions:

- Fixed carbon, which remains as charcoal
- Volatile carbon, which comes off as smoke (tar gases)



~ 80% of the ***mass*** of woody biomass consists of volatiles, 20% of the ***mass*** remains as fixed carbon, between the two, there is roughly 1% ash.

Roughly 50% of the ***carbon*** is in each fraction.

The fixed carbon fraction is taken out of the carbon cycle as biochar, but the volatile fraction is necessarily burned.

Fixed Carbon vs. Volatile Carbon

50% of the carbon embodied as fixed carbon gets taken out of the carbon cycle as biochar, but the volatile fraction is burned to provide heat for pyrolysis.

- Since the volatile carbon came from the atmosphere to begin with, and since biomass would normally decay back into CO_2, the emissions are carbon neutral in the time frame of decay.
- But the fraction that is removed from the carbon cycle makes this process net carbon negative.

What is Biochar?

- Fixed Carbon vs volatile carbon
- Reverse coal mining

Reverse Coal Mining

The trajectory of carbon in biochar amounts to:

- Capturing carbon out of the air with plants
- Making black carbon out of the plant biomass
    - Optionally generating electricity and useful heat
- Burying it in the ground

This is essentially ***reverse coal mining***.
Biochar sequesters *carbon*, not carbon dioxide.

- 1 ton of carbon is equivalent to 3.7 tons of carbon dioxide. Most of the mass of CO_2 comes from the oxygen.
- Sequestered CO_2 takes two oxygen atoms per carbon with it, but C does not.

Advantages of biochar for carbon storage

- It is *permanent*
- It is *precise*
- It is *productive*
- It is *practical*

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Permanence of Biochar

Biochar will never decompose to CO_2 if it is exposed to temperatures high enough to transform its microstructure into a form that is indigestible to microbes. Microbial enzymes can't break down graphitic carbon.

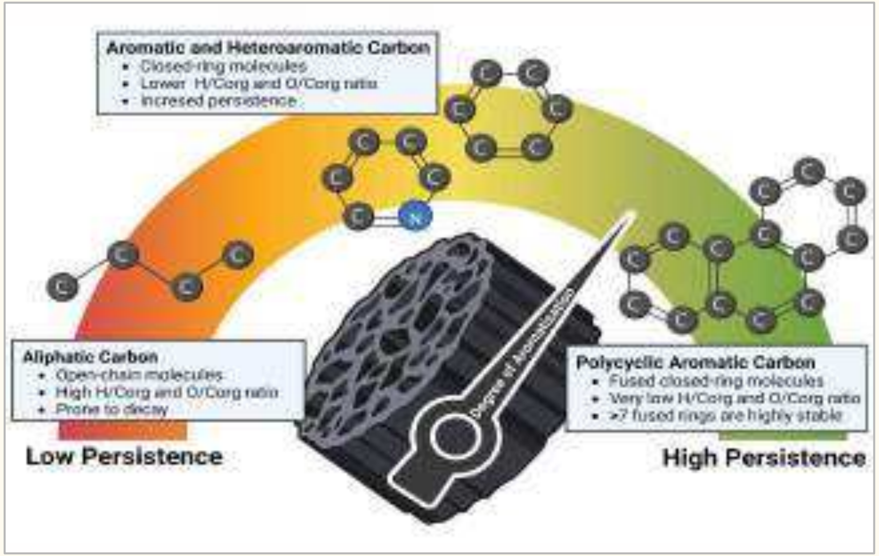

Figure 1: Schematic representation of different molecular forms of carbon in biochar.

Advantages of biochar for carbon storage

- It is *permanent*
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Published works on the permanence of biochar

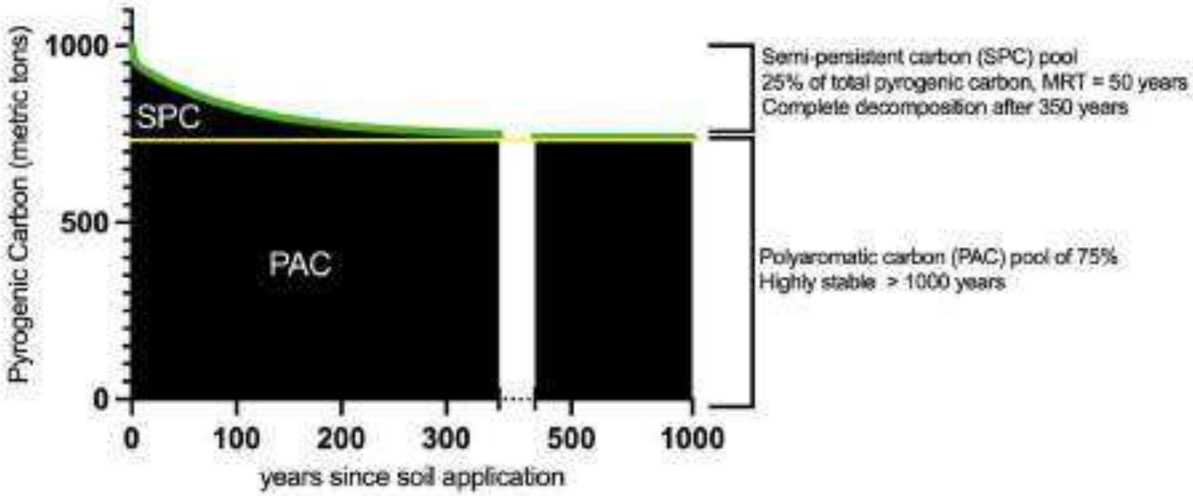

Fig. 2: Sequestration curve of a 1000 tons carbon sink made from soil-applied biochar with an H:C ratio below 0.4. The persistent aromatic carbon (PAC) pool presents 750 t carbon that will remain over more than 1000 years in the terrestrial system. The semi-persistent carbon (SPC) pool has a minimum MRT of 50 years and was modeled on a bi-modal exponential decay function. The complete SPC decay occurs over 350 years. Thus, the total carbon sink decreases to 87.5% after 50 years and reaches the stable PAC plateau of 75.0% of total pyrogenic carbon after 350 years. The decay function is

$$Total\ PyC_{(x)} = a*e^{(-kf*x)} + b*e^{(-ks*x)} + P$$

with a = 45.423, kf = 0.513, b = 212.007, ks = 0.009448, P = 742.5 nd x = year after soil application. The decay curve of the semi-persistent carbon pool is an approximation covering multiple discrete (physical) degradation events rather than a continually harmonious decomposition.

Advantages of biochar for carbon storage

- It is *permanent*
- It is *precise*
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Precision of Biochar Carbon Accounting

Biochar affords a measure of precision and confidence to carbon accounting that is difficult if not impossible for other methods of carbon storage:

- Biochar can be lab tested to determine its precise carbon percentage
- Biochar can be weighed to calculate the precise carbon content
- Biochar can be traded like a commodity

In contrast, accounting for carbon drawdown in living forests, rangelands, and in enhanced weathering schemes is difficult and imprecise.

For the purposes of carbon markets, the precision afforded by biochar is a huge advantage.

Advantages of biochar for carbon storage

- It is *permanent*
- It is *precise*
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- It is *practical*

Productivity of Biochar Carbon

Other modes of carbon storage are not productive; they passively store carbon. In contrast, the carbon in biochar is *productive*:

- Biochar can radically enhance plant productivity.
- Biochar can trigger forces of nature that store additional carbon without requiring additional human input.
- Biochar can be co-produced with electricity and heat

Biochar used in agriculture is carbon sequestration that can yield a return on investment. Biochar can carry out long term carbon storage right now, without any contingencies on yet undiscovered scientific breakthroughs.

Capturing carbon out of the atmosphere is tough due to the concentration of CO_2 being about 0.039%, but plants already do it for free. We just have to keep the CO_2 from coming back out.

Chapter 2: Negative Priming

What is Negative Priming?

And why do we want it?

- What is Negative Priming (NP)?
- The 'Five Spheres'
- NP and the Keeling Curve
- Historic Negative Priming
- Negative Priming with BC, Compost
- Negative Priming with Co-composted biochar

What is negative priming?

Negative priming is a phenomenon where the addition of carbon to soil triggers the soil to store more and more carbon without additional intervention. Think of it as a deposit of carbon that earns interest.

- The *negative* in *negative priming* comes from ‘carbon negative’—taking carbon out of the atmosphere.
- The *priming* in *negative priming* means a stimulus or an initial action, like priming a pump with the liquid to be pumped.

The priming effect in soil describes the loss of stable carbon from soil after fresh organic matter is added. Negative priming describes the opposite.

Negative Priming

- What is negative priming (NP)?
- The 'five spheres'
- NP and the Keeling curve
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- NP with biochar, compost
- NP with co-composted biochar

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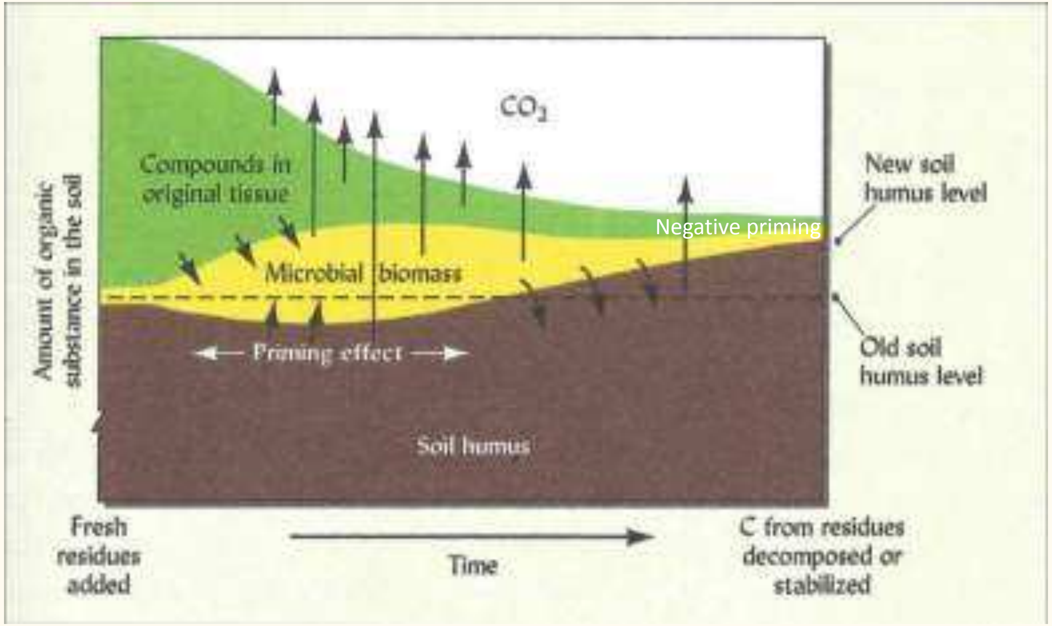
What is negative priming?

Negative priming is largely due to stabilized microbial organic matter.



A schematic illustration of the changes in soil carbon fractions when new forest residues are added, taken from Figure 12.5 from the Soil Organic Matter chapter of *The Nature and Properties of Soils*, 15th ed. The priming effect is called out in this figure, but negative priming is not labeled in the original graphic. Negative priming is the subsequent increase in soil humus levels following the reduction in microbial biomass.

Negative Priming

- What is negative priming (NP)?
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The ‘five spheres’

Carbon can reside in one of five ‘spheres’

1. the **atmosphere** — air
2. the **hydrosphere** — rivers, lakes, and oceans
3. the **biosphere** — living organisms
4. the **lithosphere** — rocks and minerals
5. the **pedosphere** —soils

Soil is a mixture of air, water, living organisms, minerals, and the necromass of organism—soil organic matter.

To fight climate change, we want to get carbon out of the atmosphere into the other ‘spheres’. ***The pedosphere is the only sphere where negative priming occurs.***

Negative Priming

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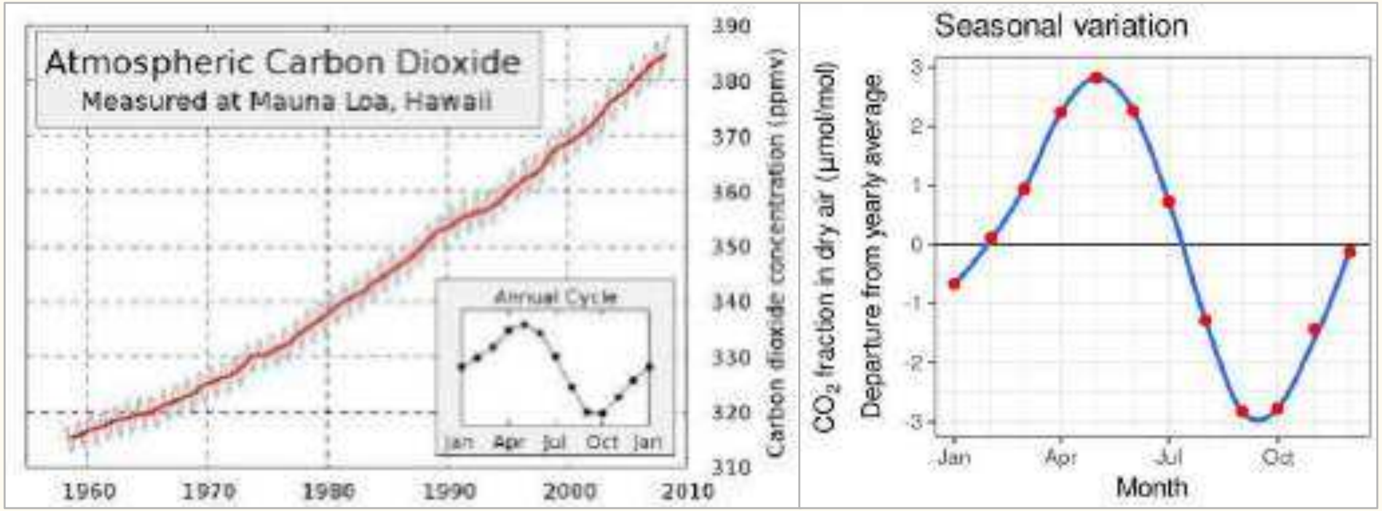
Negative priming and the Keeling curve

The Keeling Curve is the name of the graph that first showed the alarming rise of CO_2 in the atmosphere. This curve has a saw-tooth shape that is due to seasonal plant growth and decay. Plant growth can sharply draw down atmospheric CO_2; decay can sharply increase it.



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Historic negative priming

The most compelling historic example of negative priming is the phenomenon of Terra Preta reproducing itself.

Terra Preta is amazonian dark earth, an ancient biochar soil famous for being permanently fertile, with yields double to triple the yields of the weathered tropical soils around it.

Negative Priming

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Historic negative priming

Terra preta reproduces itself (minus the charcoal content) from forest litter landing on it, like sourdough starter to which fresh flour is added. It so reliably reproduces itself that locals actually mine it and sell it as compost, leaving it time to grow back..

Terra preta being mined. From the 2011 BBC Documentary on terra preta titled "The Secret Of Eldorado"

Negative Priming

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bit.ly/4dcFDcK

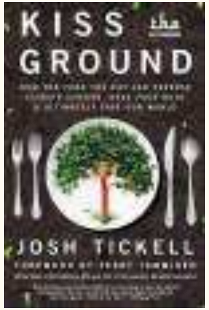
Negative priming with biochar and compost

Biochar has been confirmed to trigger negative priming, enough to compensate for the carbon released from burning the volatile carbon in biomass during its production.


Global Change Biology Bioenergy

ORIGINAL RESEARCH Open Access

Soil carbon increased by twice the amount of biochar carbon applied after 6 years: Field evidence of negative priming



John Wick of the Marin Carbon Project has confirmed that scattering compost on range land can trigger negative priming. After a single application of compost to range land, he has observed soil carbon increasing for 15 years. This was reproduced in a second study in a different climate with a different soil type. Featured in the book *Kiss the Ground*.

See https://marincarbonproject.org/ for more information

Negative priming with co-composted biochar

In terrestrial ecosystems, plants are the only organisms that fix carbon. Bacteria and fungi cannot do this; they only transform plant-derived carbon into more stable forms.

Over the lifetime of a plant, approximately 70-75% of the carbohydrates produced by the plant are put into the soil as root exudates. A portion of these exudates are metabolized, but a portion contributes to microbial biomass which then results in microbial necromass, which makes up much of the stable soil carbon.

Co-composted biochar can radically increase both the plant drawdown and reduce the decomposition of carbon to CO_2.

Chapter 3: Co-composting: the force multiplier

Co-composting: the force multiplier

Why co-composting is a universal best practice

- What biochar does to compost
- What compost does to biochar (BC)
- BC abates N2O and methane emissions
- Co-composted BC and plant fertility
- Co-composed BC and negative priming

Co-Composting

- What BC does to compost
- What compost does to BC
- Biochar abates N_2O & CH_4
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What biochar does to compost

Biochar’s primary effects on compost accelerated decomposition and much higher composting temperatures.

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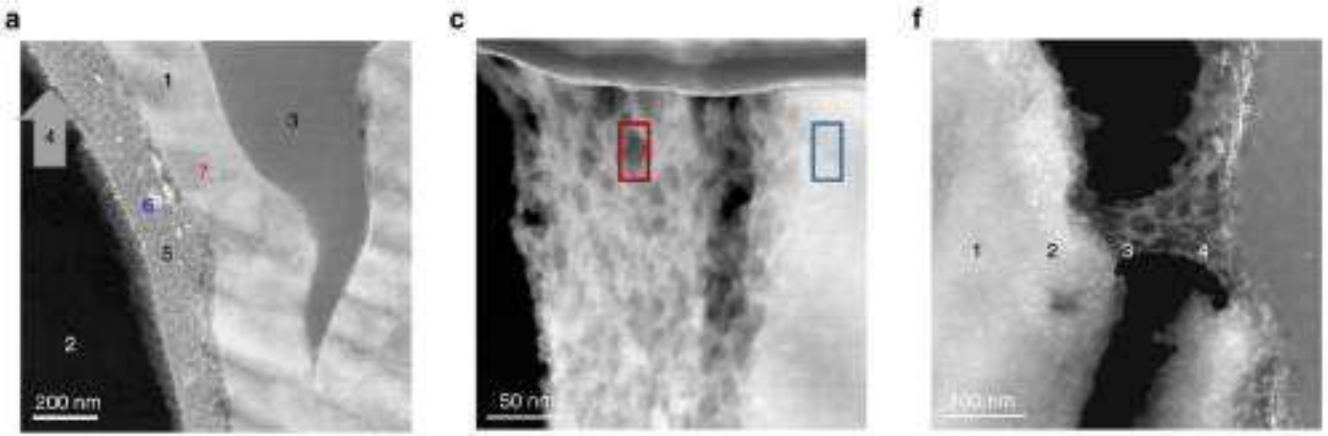
What compost does to biochar

Composting coats biochar with a spongy coating that is responsible for retaining moisture and for all of the nutrient retention and exchange.

Fig. 5

From: Organic coating on biochar explains its nutrient retention and stimulation of soil fertility



This coating appears to play a role in the negative priming observed in co-composted biochar.

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Biochar abates N_2O and methane emissions

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Article | Open access | Published: 25 April 2013

Biochar and denitrification in soils: when, how much and why does biochar reduce N_2O emissions?

María Luz Cayuela, Miguel Angel Sánchez-Monedero, Asunción Roig, Kelly Hanley, Akio Enders & Johannes Lehmann

Scientific Reports 3, Article number: 1732 (2013) | Cite this article

Abstract

Agricultural soils represent the main source of anthropogenic N_2O emissions. Recently, interactions of black carbon with the nitrogen cycle have been recognized and the use of biochar is being investigated as a means to reduce N_2O emissions. However, the mechanisms of reduction remain unclear. Here we demonstrate the significant impact of biochar on denitrification, with a consistent decrease in N_2O emissions by 10–90% in 14 different agricultural soils. Using the ^{15}N gas-flux method we observed a consistent reduction of the

Electrically conductive biochar *radically* abates N_2O and methane emissions from compost, and continues to abate N_2O in soil. Emissions abatements of both N_2O and methane have been observed to be over 90%.

Co-Composting

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Co-composted biochar and plant fertility

Co-composted biochar enables high levels of plant productivity with minimal fertilizer due to radically enhanced ionic nutrient retention and exchange (CEC and AEC).

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Co-composted biochar and negative priming

Co-composed biochar enhances negative priming at several levels:

- Adding biochar (black carbon) appears to bias compost to make stable solids rather than CO_2
- Boosting plant productivity boosts root exudates (green carbon), which feeds the soil biome
- Co-composted biochar stimulates soil (and therefore carbon stabilization) by fungi (white carbon).

Chapter 4: What gasification does for biochar

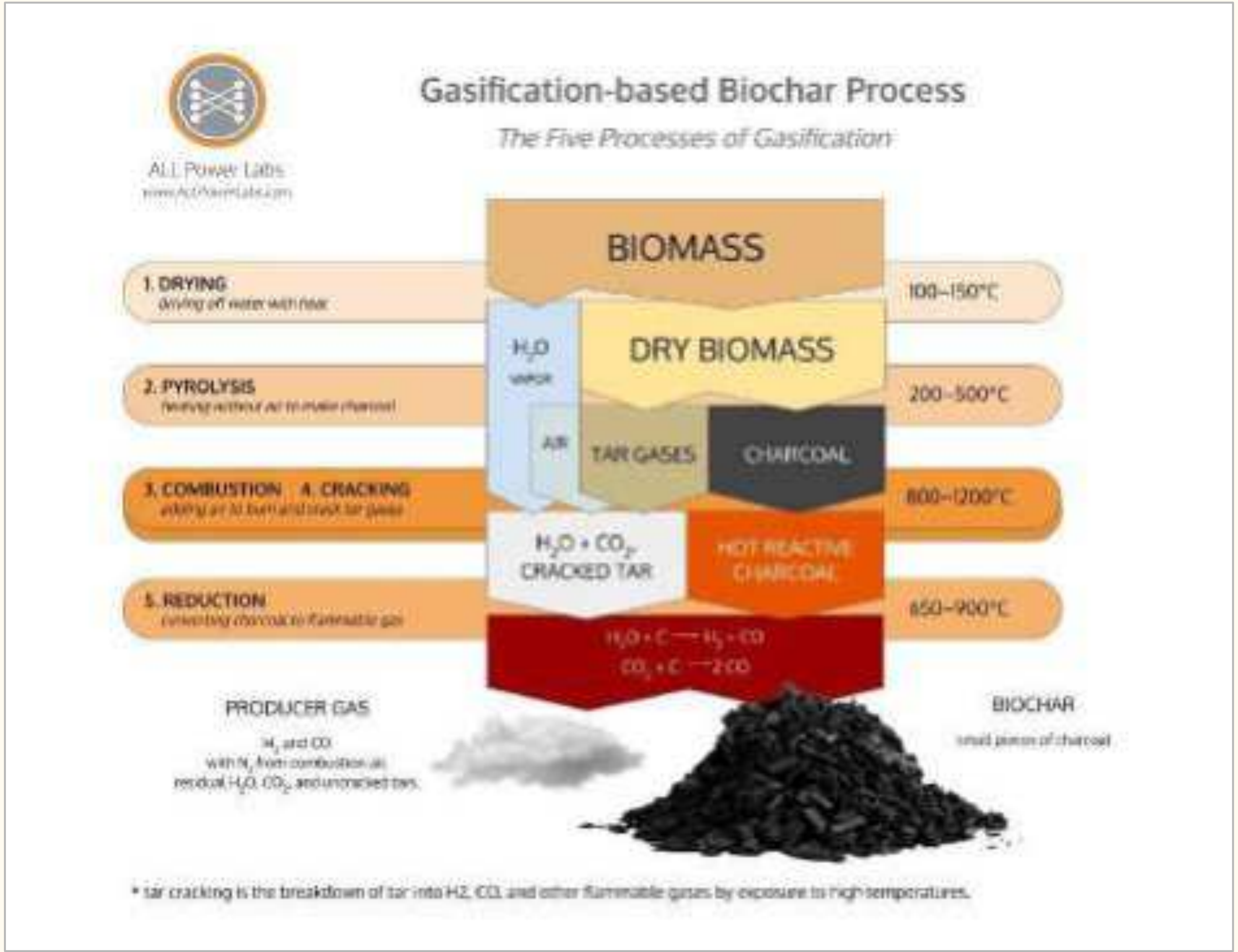
What gasification does for biochar

Unexpected and unforeseen benefits

- The five processes of gasification
- Reduction reactions
- Four consequences
- The gasification trifecta

What gasification does for biochar

- The five processes
- Reduction reactions
- Four consequences
- The gasification trifecta



What gasification does for biochar

- The five processes
- The reduction reactions
- Four consequences
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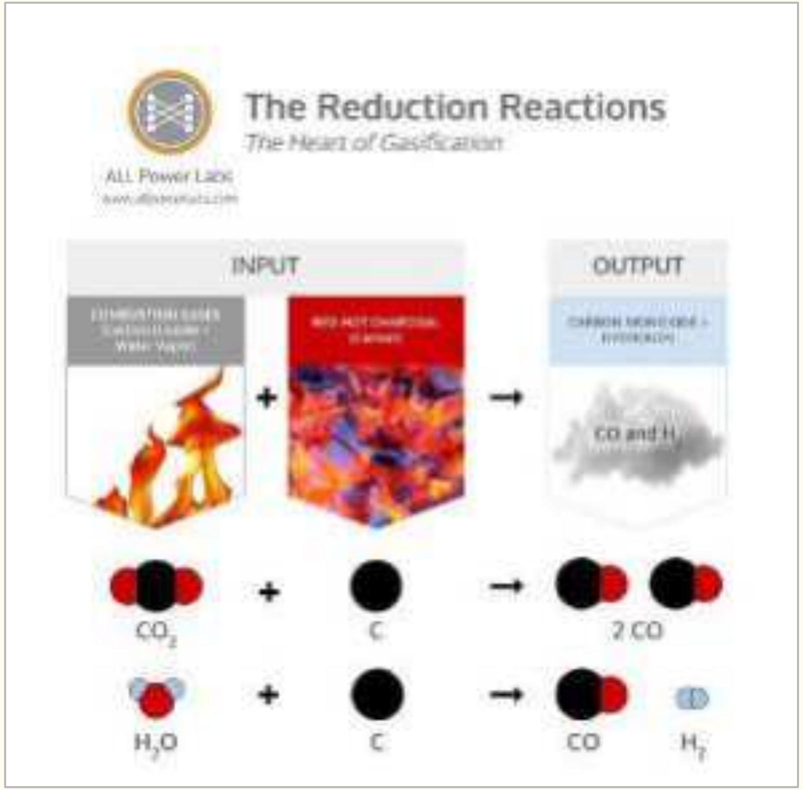
The reduction reactions

(We mean reduction as in the opposite of oxidation.)



What gasification does for biochar

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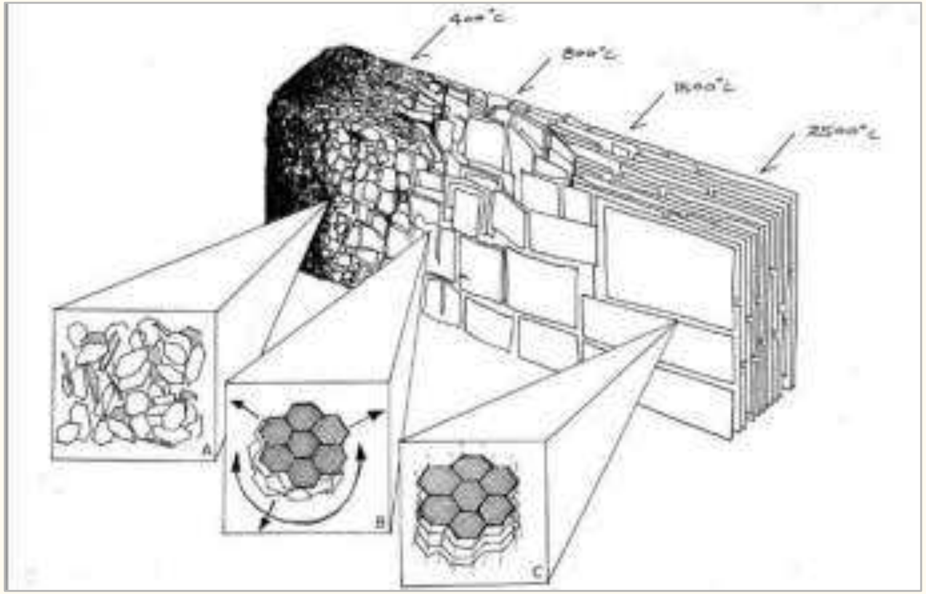
The four consequences of gasification on BC

Making biochar via gasification has four major consequences:

1. Conductivity
2. Recalcitrance
3. Cleanliness
4. Activation



What gasification does for biochar

- The five processes
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Conductivity is critical

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Article | Open access | Published: 31 March 2017

Rapid electron transfer by the carbon matrix in natural pyrogenic carbon

Tianran Sun, Barnaby D. A. Levin, Juan J. L. Guzman, Akio Enders, David A. Muller, Largus T. Angenent & Johannes Lehmann

Nature Communications 8, Article number: 14873 (2017) | Cite this article

15k Accesses | 385 Citations | 51 Altmetric | Metrics

Abstract

Surface functional groups constitute major electroactive components in pyrogenic carbon. However, the electrochemical properties of pyrogenic carbon matrices and the kinetic preference of functional groups or carbon matrices for electron transfer remain unknown. Here we show that environmentally relevant pyrogenic carbon with average H/C and O/C ratios of less than 0.35 and 0.09 can directly transfer electrons more than three times faster than the charging and discharging cycles of surface functional groups and have a 1.5 V

What gasification does for biochar

- The five processes
- Reduction reactions
- The four consequences
- The gasification trifecta

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Cracking and char cleanliness

Environment International

Volume 121, Part 1, December 2018, Pages 169-179

Application of biochar to soils may result in plant contamination and human cancer risk due to exposure of polycyclic aromatic hydrocarbons

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Highlights

- The PAH concentrations in biochars were 638–12,347 μg/kg depending on production parameters.
- Root exudates of vegetables enhanced the PAH release from biochars.

What gasification does for biochar

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- Reduction reactions
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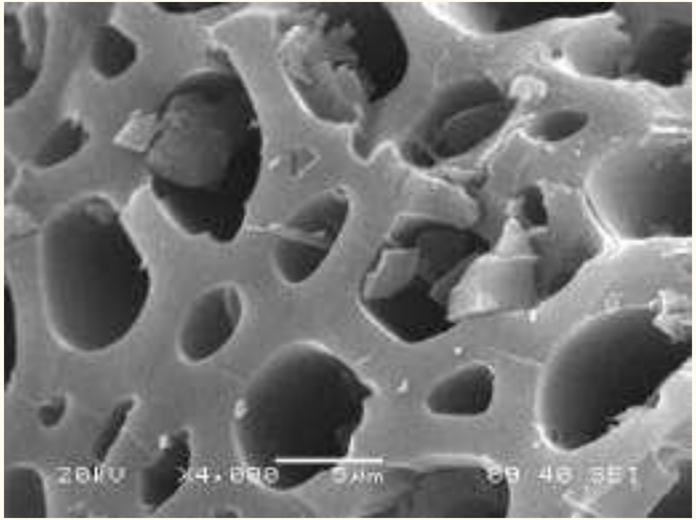
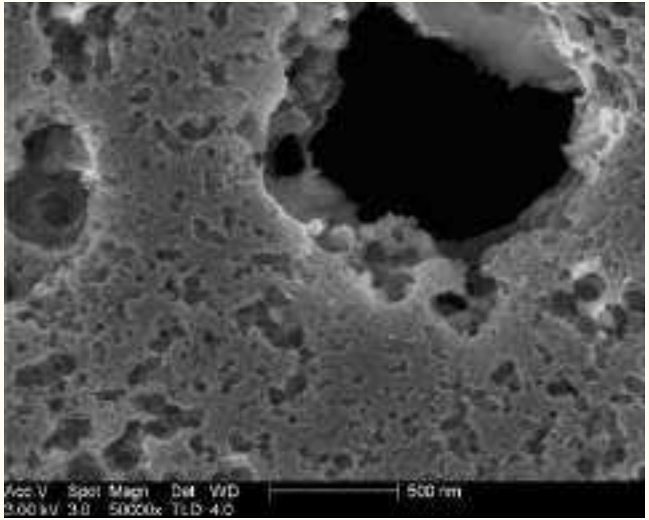
Reduction and activation

Reduction reactions perforate the char; reduction reactions are what ‘activate’ activated carbon.



Without reduction



With reduction

The gasification trifecta

Biochar made through gasification is what enables "reverse coal mining". The gasification-based biochar trifecta is as follows:

- On-demand renewable energy
- Regenerative agriculture
- Carbon sequestration with benefits

Introducing the machine that does all this...