LOW-TECH FLAME CARBONIZERS FOR BIOCHAR PRODUCTION: THEORY AND APPLICATIONS

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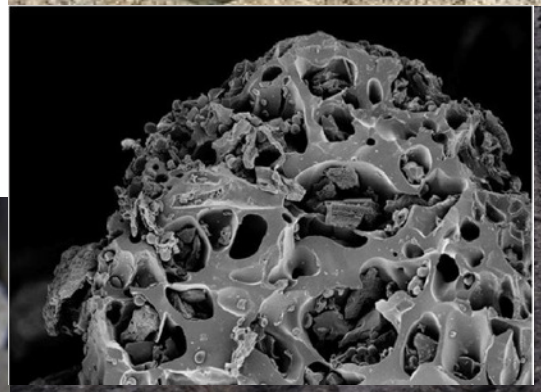
Outline

- What is Flame Carbonization and how does it work?
- Design of a Flame Cap Kiln – NRCS CIG project
- How to Use a Flame Cap Kiln
- Applications of Low-Tech Flame Carbonizers
  - Forestry
  - Agricultural Waste
  - Arborists
  - DIY Backyard Biochar

Biochar is charcoal that you can add to soil*

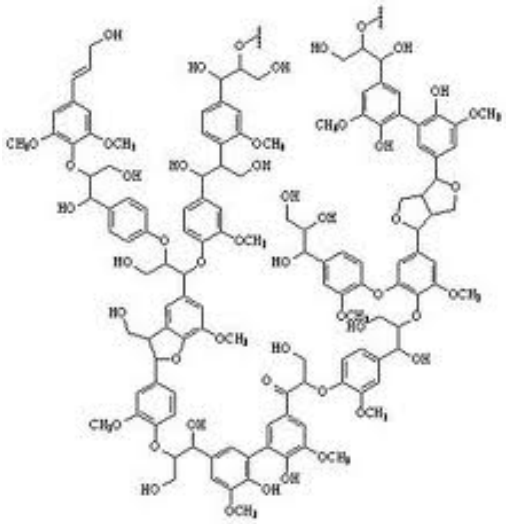


Biochar: A solid material obtained from thermochemical conversion of biomass in an oxygen-limited environment. (IBI, 2012)

How is Biochar Made?

Pyrolysis = separation by fire

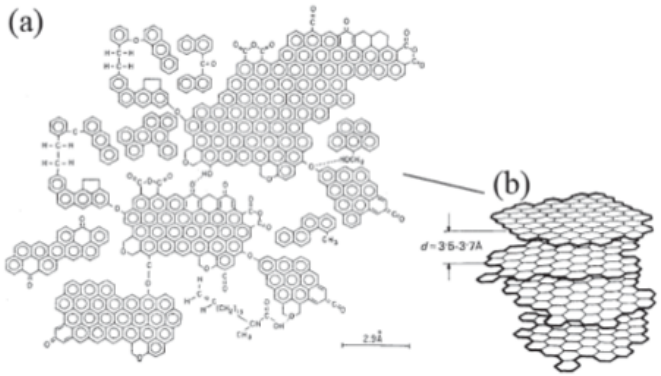
Lightweight volatile gases (mostly hydrogen and oxygen) are separated from solid carbon (char)



Lignin molecule

Molecular
Nano-scale

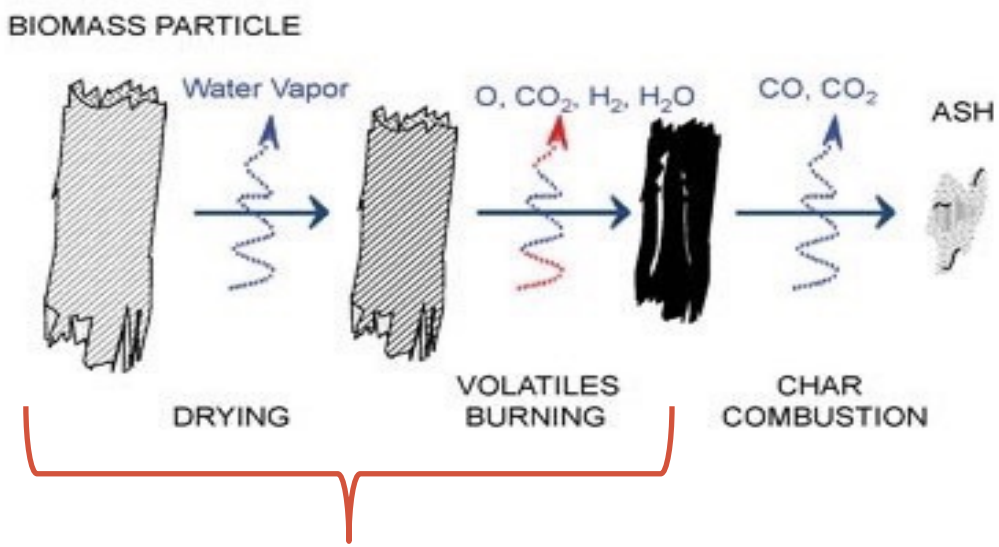
HEAT



Biochar:

- Carbon rings fuse and condense
- Biomass shrinks but retains structure

What is Flame Carbonization?
It is a form of pyrolysis



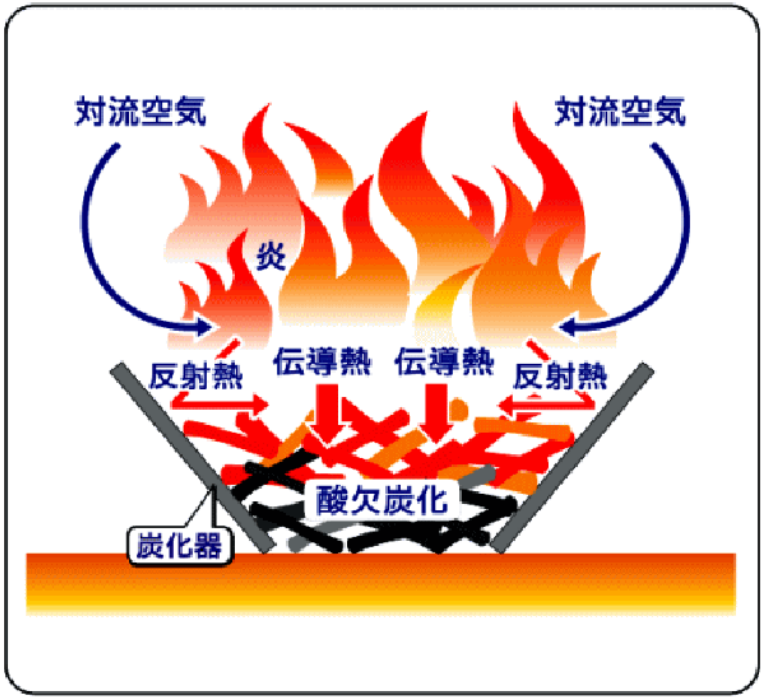
Pyrolysis = thermal decomposition of biomass

- In an open fire, biomass burns in three stages
- **To make char, stop the process before it goes to ash**

Fire Triangle and Pyrolysis

For pyrolysis, remove oxygen, but retain heat and fuel

How a Flame Cap Kiln excludes oxygen



- Pan excludes air from the bottom, preserving char
- Flame excludes air from the top
- Flame heats biomass below, causing gas to volatilize
- This is the essence of Flame Carbonization

NOT Flame Carbonization - How a retort excludes oxygen

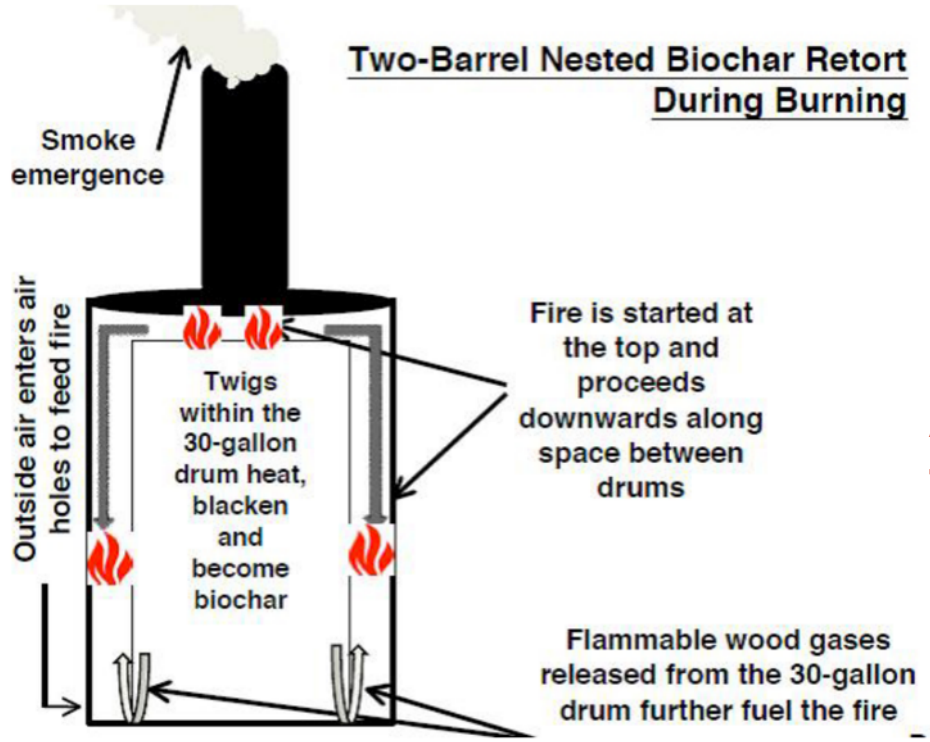


FIGURE 2. Two-barrel nested biochar retort

A steel drum separates the feedstock from the flame

From: Jonathan Pollnow, Biochar Feedstock Research Using a Two-Barrel Nested Retort (2014), Kerr Center for Sustainable Agriculture.

NOT Flame Carbonization -Traditional pits, mounds, kilns

- Smoldering combustion – **no flame**, lots of smoke
- Little to no control over emissions

A family business in India

Massive charcoal production for Brazil's steel industry uses 40% of Amazon timber extraction.

Missouri Kiln: Afterburners burn natural gas to provide a flame that burns the smoke

Missouri Charcoal-Makers Agree to Clean Their Kilns

After years of resisting environmental pressures, industry will install afterburners to reduce thick smoke that hovers in Ozarks.

August 14, 1997|STEPHEN BRAUN | TIMES STAFF WRITER

Flame carbonizers provide their own afterburner – the flame!

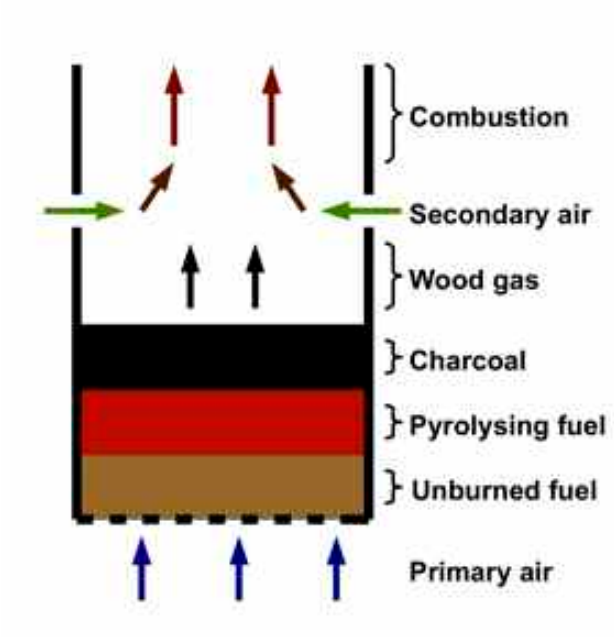
Flame Carbonizer Types by Airflow

- Concurrent, Axial Flow
  - TLUDs (Top Lit Up Draft gasifiers)
  - Biochar Burn Piles and Ricks (Conservation Burns)
- Countercurrent Flow
  - Flame Cap Kilns using passive countercurrent flow
  - Air Burners using active countercurrent flow

Concurrent Axial Flow Combustion

- Air flow and fuel flow (gas) move in the same direction
- In this example:
  - No external limits on air entrainment
  - High flame velocity
  - Flame cools at the top, producing soot

TLUD uses concurrent, axial flow



Entrained air is limited, reducing flame length

Jack Daniels Rick Burn

- Concurrent, axial flow is slowed by the hood/exhaust system
- Smoke burns in the hot zone, reducing emissions

Counter-current flow combustion

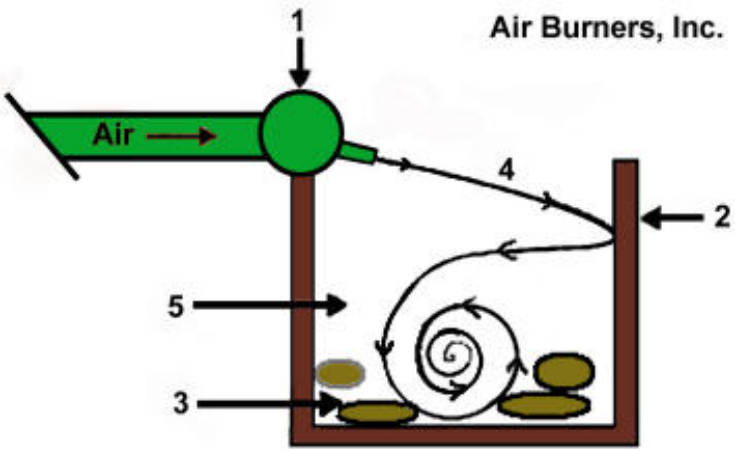
- Gas flows upward while air flows downward
- Counter-current flow is established as burning fuel draws air downward
- Flames stay low and close to fuel
- Smoke burns in the hot zone

Japanese Cone Kiln uses counterflow air

Photo: http://aoiuminokai.junglekouen.com/d2011-01.html

In Japan these simple cone-shaped kilns are sold by the Moki Company in several sizes ranging from 50 cm to 150 cm in diameter.

Air Curtain Burner – active counterflow



Active counter-current flow using a blower.
Designed for complete incineration.

Air Burner turned green wood into char

Biochar made in the Airburner was worked into soil at the site and trees planted in the biochar-amended soil

Variations on the Flame Cap Kiln

Pits, Trenches, Cones and Tubes

They all work just fine! See: BackyardBiochar.net for links

Going BIG

Brandon Baron, The Tree Service, Burns, Oregon
https://www.facebook.com/The-Tree-Service-Burns-Oregon-1380772675486319/

Kiln Design: NRCS BIOCHAR FARMS

- Natural Resources Conservation Service (USDA) Conservation Innovation Grant to South Umpqua Rural Community Partnership
- Farmers in Oregon often have forest land and forestry residue that they burn for disposal
- Farmers with livestock have manure that can be a problem to handle
- Combine two waste steams to create valuable biochar compost

More info at: http://ubetbiochar.blogspot.com/

Umpqua Community College welding students made our first prototype kilns

The Oregon Kiln

- Sized for forestry slash
- Comes with its own afterburner!

Design Parameters for Oregon Kiln

- Economical
  - Pyramid shape cheaper to fabricate than cone – approx. $650
- Sized for feedstock
  - Five foot top base
  - Four foot bottom base
  - Logs 4 to 5 feet long and up to 6” diameter
- Ergonomic and safe for hand loading
  - Only 2 feet high
  - Heat generation is proportional to surface area (25 square feet)
- Portable but Durable
  - 14 gauge steel
  - Less than 200 lbs
  - Easy to unload

How to Use the Oregon Kiln

- #1 Use dry feedstock – ideally less than 25% moisture

Start With a Top-Lit Biochar Burn Pile in the Kiln

- Pile loosely
- Light on top

Once the first pile burns down, add more

- Add new material, one layer at a time
- Make sure each layer has the same size material

Quenching Time

When the kiln is full and flame is gone, it is time to quench

Utah State Workshop Video

- https://www.youtube.com/watch?v=c-tzu0P9hzI&feature=youtu.be

Utah - Kilns in use

The crew is making eight kilns per day of biochar. They are working great! The main fuel is dead aspen, up to 8 inch logs are being consumed quickly, anything wet or larger slows production.

Application:
The Fuel Problem in Oregon

Conventional Burn vs. Biochar Burn

- Conventional Burn: Flame under cold biomass makes smoke
- Biochar Burn: Flame on top burns smoke
- Quench with water to save the char

Biochar Burn Saves Soil

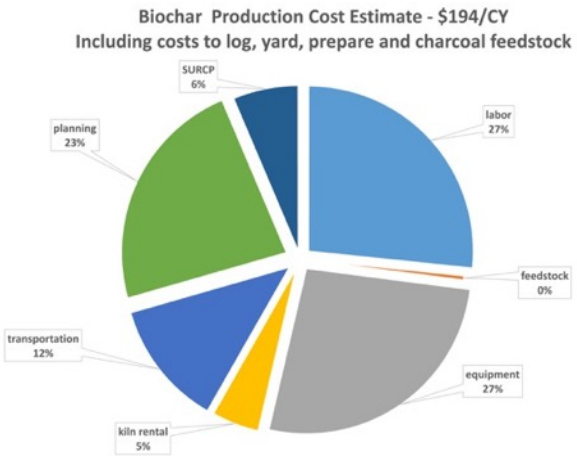
Conventional Burn is hot, sterilizing soil. Nothing will grow for a long time.

Biochar Burn is cooler and char protects the soil. New life sprouts in the spring.

Spring 2017: Biochar Burn Piles from Fall 2015

Drew Veg Biochar Stewardship Contract - Umpqua NF

Oregon Kiln Production Model	
Oregon Kiln Specs	
conversion efficiency (dry basis)*	0.13
biochar produced per kiln, m3	1
char density (Mg/m3)	0.095
biomass processed per kiln (bdMt)	0.731
average feedstock moisture	20%
% ash in biochar, dry basis	10.2
Crew and Site Parameters**	
Crew size	6
Kilns per person	2
Total kilns	12
batches per day	2
Shift length, hrs	10
Total daily biochar output, Mg	2.28
total biomass processed, bMdt	17.54



JOIN US IN OCTOBER 2017: visit www.UBETbiochar.blogspot.com

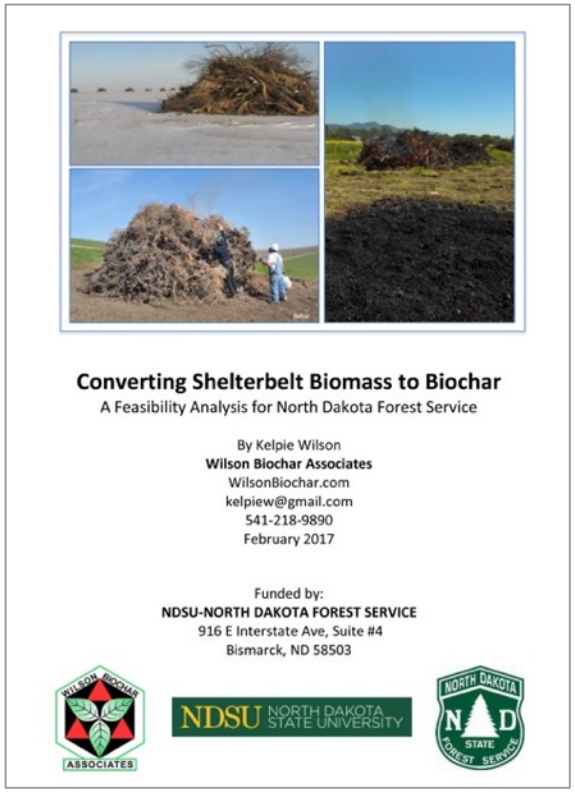
Application: Ag Waste

Peter Hirst and Sonoma Biochar Initiative pioneered the Conservation Burn technique *(Top Lit Open Burn Pile or Biochar Burn)* turning vineyard prunings into biochar

More info at:
http://sonomabiocharinitiative.org/

Shelterbelt Renewal

Biochar feasibility analysis for North Dakota State University



Converting Shelterbelt Biomass to Biochar

A Feasibility Analysis for North Dakota Forest Service

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February 2017

Funded by:
NDSU-NORTH DAKOTA FOREST SERVICE
916 E Interstate Ave, Suite #4
Bismarck, ND 58503

Biochar technology	$/cubic yard biochar produced	$/ton biomass processed
1. Top-Lit Open Burn Pile	62.48	25.12
2. Flame Cap Kiln	37.70	20.58
3. Burn Pit	22.68	28.35

https://www.ag.ndsu.edu/ndfs/documents/wba-converting-shelterbelt-to-biochar.pdf

New Biochar Enhancement: NRCS Conservation Stewardship Program

CONSERVATION ENHANCEMENT ACTIVITY E384135Z:
Biochar production from woody residue

Offers additional payment for converting woody residue to biochar

Contact your local NRCS office for more information

Application:
Brush disposal option for Arborists

- Price for chipping - $200/hr
- Price for biochar burning - $200/hr?
- No expensive chipper to maintain
- Separate firewood from small branches & brush
- Arborist gets the firewood to sell
- Customer gets biochar made from small brush, valued at $250/cy
- Burn permit required, but…
- No smoke to bother the neighbors

Application: DIY Backyard Biochar

Smoke into Biochar

Safe Burn Practices for Recovering Biochar for Use in Soil and Compost

Biochar
Have you heard about the benefits of Biochar? Biochar is charcoal that you can add to soil or compost. It helps retain moisture and nutrients and it promotes beneficial microbes in soil. Biochar can be expensive to buy, but if you have burn piles, you can make your own biochar and have a cleaner, safer fire as well.

There are five requirements you need to follow if you want to make biochar in your burn pile. These principles will also ensure that your fire is as smoke-free as possible:

1. Use only dry wood
2. Burn small brush separately from thicker logs (greater than 4" in diameter)
3. Make small piles that are loose with good airflow and no dirt. A good pile size is four to five feet in diameter and four to six feet tall
4. Light the piles on the top
5. Have a water hose nearby so you can quench the fire and save the charcoal

YOU CAN KEEP SMOKE OUT OF THE ATMOSPHERE
THE CARBON THAT WOULD HAVE GONE UP IN SMOKE STAYS IN THE BIOCHAR!

Small brush burns quickly when dry. You need to consolidate it as it burns down and put it out with water before it burns to ash. Three brush piles this size made one cubic yard of biochar. Biochar sells for between $200 - $400 a cubic yard.

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How to carbonize old lumber

THANK YOU!

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