Biochar: Production Fundamentals
Living Web Farms Biochar Crew

- Production Principles:
  - Complete Combustion
  - Carbonization
  - Slow Pyrolysis
  - Feedstocks, Managing Bursts, Post-Production
- Production Systems
- Coproducts:
  - Heat, SynGas, Condensate products
Visible flame is burning wood gas...not the wood itself!

- Requires Oxygen Input
- Higher temperature combustion zone, preheated air, allows cleaner burn
- Biochar production systems use a controlled oxygen environment where gas is separated from the heated biomass, and burned elsewhere
- Creates Heat, Creates Draft (relative pressure)
Pyrolysis and Carbonization

- Decomposition of organic material in the **absence of oxygen**
- Biomass is heated in vessel, only with exit for liberated gases. (retort method)
- Biochar production: Process starts around 300F. Continues until about 850F.
- Volatiles release in the form of gas (**pyrolysis**), Modified carbon structure remains (**carbonization**).
- Carbonization renders carbon impervious to degradation by biological enzymes. A portion of biochar (resident carbon) becomes very difficult for living organisms to consume.
- Slow Pyrolysis: believed to be optimum for biochar as it preserves pore structure
- Other means of pyrolysis and biochar production not discussed here.
Heat Treatment Temperature

- Refers to the temperature that feedstock reaches (after equalization) during pyrolysis.
- Heat treatment temperature is single most important factor in quality of biochar
- Our system: Target HTT up to 900F. Process takes 8-10 hrs.
- **Endothermic** process: Requires Heat Input
- **Becomes Exothermic** process: Heat Output
- In practice, we apply heat at first (<300F), then apply a bit more at end (<850F).
- Residence time at HTT is important factor: feedstock must reach equilibrium with HTT. Rate of heating is important too: affects the amount of ‘secondary carbons’ that may ‘clog pores’ of primary char.
A little bit about feedstocks:

- **Dead or Dying** woody biomass
- Wood Industry: Slabwood, Mill Waste
- Forestry Waste
- Some Farm Residues
- Landscape Waste: chips, trimmings <4” dia.
- Dry! Dry! Dry!
Feedstocks: size and shape

- Determining factors in HTT equilibrium time.
- Our system: <4” cross section
- Tin-Man - 1.5” is OK.
- TLUD - chips, .5-1” cross section
- Gas must be able to Flow through and Out! No Bombs!!!!
- Loads packed too tight: may never reach HTT without excessive heat input
- Loads packed too loose: lower yields, greater bursts, excess air/ignition potential
- Shape can be a factor too.
Traditional Methods

- Pit or Mound method
- 10% efficient
- Very slow: days to weeks
- Requires constant attention
- Average Life Span: 28 Years!!!
- No reclaim of heat, coproducts
- Very polluting
Adam Retort

- Even heating of batch
  - much faster process
  - higher yields
- Reburn of gasses
  - much less pollution
  - Vastly improved health and safety
- Our system is essentially a modified adam retort with tighter control and reclaim of coproducts with condenser and heat exchangers.

source: biochar.bioenergylists.org
tin-man, nested barrel, or 55/30 retort

Two-Barrel Nested Biochar Retort—Prior to Burning

- Fifty-Five Gallon Drum
- Lid with Smokestack
- Thirty Gallon Drum—Inverted and filled with twigs
- Space between drums is filled with twigs to the top of the lid.
- Air holes in outer drum

Two-Barrel Nested Biochar Retort During Burning

- Smoke emergence
- Fire is started at the top and proceeds downwards along space between drums
- Flammable wood gases released from the 30-gallon drum further fuel the fire

source:kerrcenter.com
Managing Bursts

- ‘Bursts’ are a problem specific to batch production systems where the whole mass of feedstock is heated at once.
- Constituents of feedstock break down at different points during the process.
- Sudden releases are expected with single species feedstocks.

Avoid excess gas (dirty burn) problems by:
- Mixing feedstock species
- Providing adequate combustion air
- Providing secondary burn option, oversize heat capture capability, alternative uses for gas - electrical generation? gas containment? Wide open possibilities
- Important factor in DIY systems: bursts are where the most heat is generated, takes the most management, and is hardest on your equipment.
Post-production:

- Must be adequately cooled prior to oxygen exposure
- Accelerated cooling with addition of water:
  - Burst of steam may help fracture char even more
  - May help to accelerate ‘wetting’ - refers to period where biochar will temporarily repel water, and float
- Biochar is **hygroscopic**
  - Will pull water in from the air - more on humid days
  - **No joke:** action of pulling in water causes friction - can cause spontaneous combustion.
- Store raw unwetted char in airtight container if storing large enough quantities
  - We use **coated** poly woven bags: Shed rain and *discourage* air movement
Processing:

- Crushing and screening:
  - Investment in equipment is dependent on scale of operation
    - for TLUD or Tin-Man: think tamping tools and hardware cloth frames

- Effects of particle size:
  - Migration through soil
    - larger pieces likely stay suspended in sandy soils
    - smaller pieces will likely exchange nutrients easier, eventual more even distribution in soil; even ingested and moved by earthworms,
  - water and air exchange, safe harbor (large fungal strands),
  - ¼” and less mix seems optimum - best of both worlds
  - Larger pieces can be re-crushed, or used in non-soil applications
  - Still subject to breakdown due to weathering (freeze-thaw)
Safety

- Obvious fire and burn risks: high flow water source, fire extinguishers
- Sudden ignition
  - Properly built vessels: adequate gas escape,
  - Gas flowing in right direction: Know your relative pressures in system
  - Safety valves on system
- Gas exposure: not your regular campfire smoke
- Condensates:
  - Organic Vapor mask
  - Avoid prolonged skin contact
- Dust Hazard
  - Processing and Application in field
Co-Products: Syngas

- AKA Producer gas, wood gas
- **Not your regular campfire smoke!**
- Combination of combustible and noncombustible gases:
  - Carbon Monoxide, Hydrogen, Methane
  - Nitrogen, Carbon Dioxide
- Includes many complex condensable vapors (condensates)
- Usually less than half the potency of natural gas
- Can be fed directly into generators, engines with little modification
- See: APL generators, FEMA gasifiers, Anything by Wayne Keith (driveonwood.com)
Co-Products: Condensates

- Wood Vinegar, ‘Bio-Oil’, Tar/Pitch at Varying Fractions
- Our normal ratio: <1% light oil, 80% Vinegar, 18% heavy oil, 2% pitch
- Wood Vinegar (pyroligneous acid)
  - Proven as herbicide, fungicide, fungal food, bio-stimulant at different dilutions
  - Very interesting agricultural applications, including animal feed supplement
- Heavy Oils, Tar and Pitch
  - Oils can burned in modified equipment
  - Asphalt and Roofing applications
  - Fenceposts
- Wood tar is NOT coal tar/petroleum tar. It is less toxic, therefore not as likely to beat back biological degradation when used in ground-contact applications
Co-Products: Heat

- Produced through the combustion of excess syngas - that which is not used to sustain the process
- Direct
  - Pre-drying incoming feedstock
  - ‘pumped’ into greenhouses
- Via Heat Exchange
  - Many ways to do this.
  - We use large flue gas/water exchangers
- Stirling
- Best method can efficiently handle bursts
  - Large capacity exchangers, variable speed pumps, large mass heating, adequate storage
TLUD
Thomas Reed, Paul Anderson: Champion Cookstove. Open source, “Refugee” Design
References and Resources

- Biochar Workshop with Bob Wells - Production with the 55/30 ‘Tin-Man’ retort: https://www.youtube.com/watch?v=svNg5w7WY0k
- Clever automated TLUD: https://www.youtube.com/watch?v=7BF8fkEE_4I
- More on simple TLUDs: www.biochar-international.org/sites/default/files/1G_Toucan_TLUD_for_Biochar.pdf