#### 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

### Combustion

- 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

- Recomposition 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.</li>
- 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: 28Years!!!
- No reclaim of heat, coproducts
- Very polluting



### Adam Retort

- Even heating of batch
  - $\circ$  much faster process
  - $\circ$  higher yields
- Reburn of gasses
  - $\circ$  much less pollution
  - $\circ$  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



source:kerrcenter.com

#### Managing Bursts



CelluloseHemicelluloseLigninOther

• '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** 
  - $\circ$  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),
  - $\circ$   $^{1}\!/_{4}$  " 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

Fig. 14

#### References and Resources

- Construction plans for 'Champion' TLUD: www.bioenergylists.org/files/Construction%20Plans%202009-03-11.pdf
- Biochar Workshop with Bob Wells Production with the 55/30 'Tin-Man' retort: <u>https://www.youtube.com/watch?v=svNg5w7WY0k</u>
- Clever automated TLUD: <u>https://www.youtube.com/watch?v=7BF8fkEE\_4I</u>
- More on simple TLUDs: <u>www.biochar-international.org/sites/default/files/1G</u> Toucan TLUD for Bioc <u>har.pdf</u>