Farm-scale Char Production:

Affordable 4C Kilns for Quarter-Ton to One-Ton of Biochar Per Workday

Presentation on 1 July 2019 by

Paul S. Anderson, PhD (psanders@ilstu.edu)

US Biochar Initiative Conference, Ft. Collins, Colorado

NOTE: This presentation includes information protected by **Patent Pending** status and law. Anyone utilizing this information should please contact Dr. Anderson to **make arrangements for appropriate involvement.**

Profit Centers from Pyrolytic Char Making

Discussion:

1. Pyrolytic Biomass Reduction (PBR) values may be sufficient.
2. Pyrolytic Carbon Capture and Sequestration (PyCCS) can include all four centers.
3. Use of "wasted" heat can justify action in all the other centers.
4. Not all benefits are monetary.
5. Charcoal is stored energy.
6. **Only ONE needs to have profit.**

Original source: Paul S. Anderson 2019-03
Adaptations by:

Pyrolytic Devices and Technologies

Charcoal Products

*** Standard uses**
- Fuel, filter, substitute material

*** Biochar into soil**
- Multi-purpose amendment

*** Char gasification**
- Engine-quality gases
  - Mechanical & electrical power

Thermal Energy

*** Applications of heat**
- Cooking (TLUD stoves)
- Industrial heat
- Space heating
- Crop drying, etc.

*** Often a "free" by-product**

*** Replace fossil fuels**

Pyrolytic Biomass Reduction & Disposal

*** Tipping fees & avoid landfill**

*** Forest fire protection of homes**

*** Agriculture necessity**

*** Air quality by emission reduction**

Other / Misc.

*** Co-products**
- Chemicals
- Marketable biomass/compost

*** Carbon Offsets**
- When additionality occurs

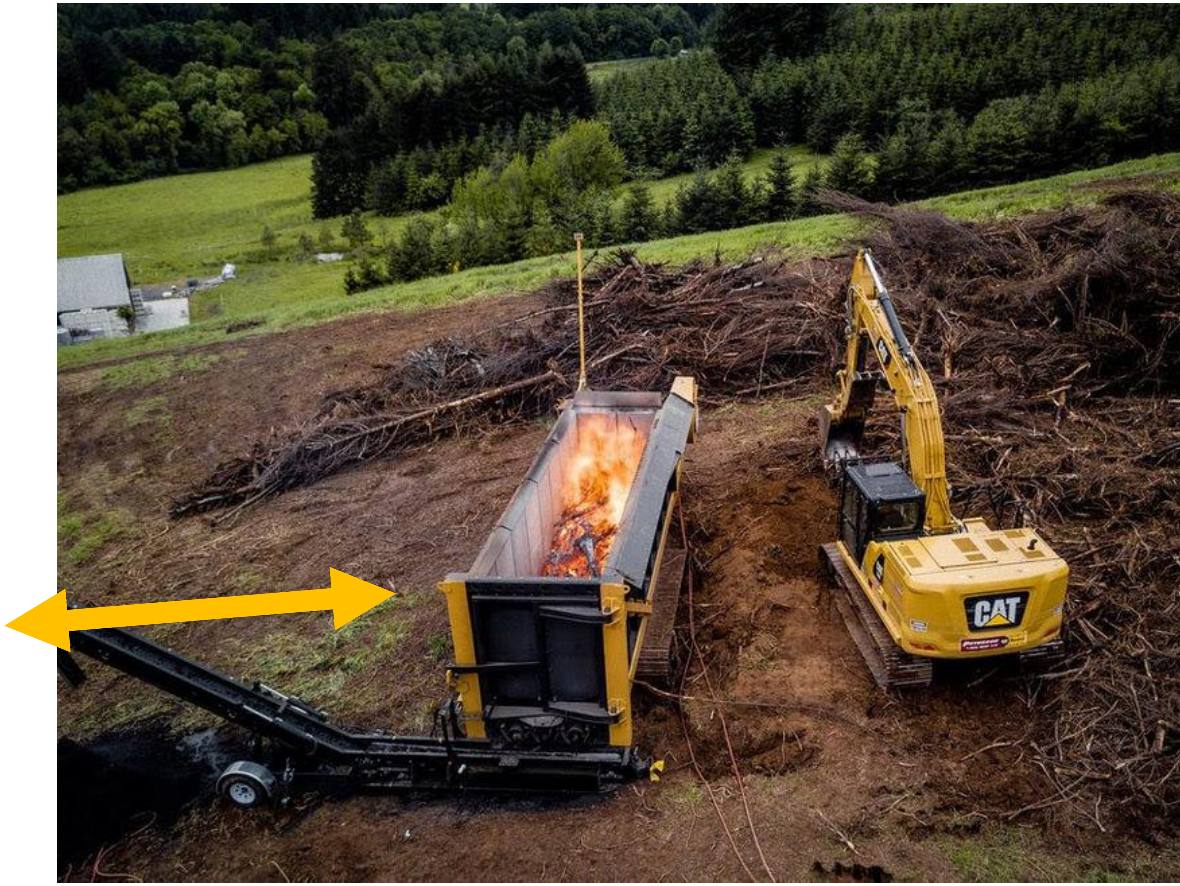
***Climate benefits**

Abstract (original, slightly edited)

- The 4C kiln technology and devices fit into the **massive gap in size and cost options for medium and small biochar operations** such as for farms, woodlots, and places generating “refuse” biomass. The presentation:
- Note: The 4C kiln was conceptualized and first built in 2014 by the author/presenter. The 4C kiln name comes from success as a **“Clean Controlled Covered Cavity Kiln”.** Also known as the **"Anderson 4C kiln."**
- 1. **Review of the options** for sizes, outputs, costs and technologies of biochar production equipment.
- 2. Present the **new 4C kiln technology and designs.**
- 3. **Discuss variables**, including user objectives, diverse feedstocks and locational circumstances, including available funds.
- 4. Explain efforts to **make the 4C kilns available** in appropriate sizes at reasonable prices.

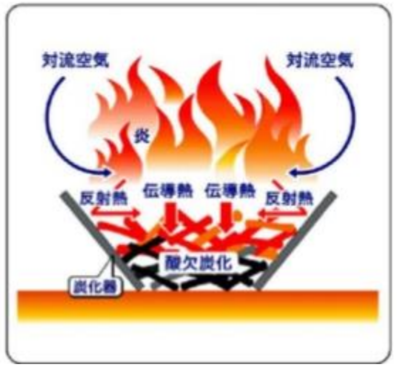
Review of Sizes for Pyrolytic Biomass Reduction & Biochar Production

- Based on input of biomass per day
- Small 1 kg to 1 ton input
  - Retort: Regular and Adam Retort
  - TLUD (Top-Lit UpDraft): Stoves and barrels
  - **Flame cap or cavity kiln:** Cone; pyramid; trough; Kon Tiki
- Medium **Missing size for 1 t to 10 t input**
- Large 10 ton to 200 t/day (20 t/hr x 10 hr)
  - **Air Curtain:** By Air Burner Co. and ROI Carbonator (Approx. $150 K to $600 K)
  - Heated screw: (Installations from $300 K to $1.2 million)
  - Furnaces that have char in the ashes.

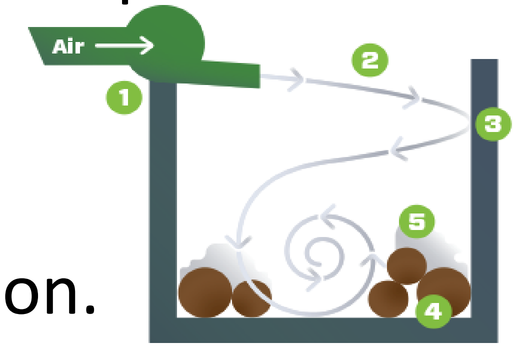


The Challenges: To have Medium-size facilities with clean emissions, safety and biochar

- **A full review** would take all the available time and still be incomplete.



Small = flame cap	||	Large = air curtain
Exposed flames and	||	High volume of air
possible emissions.	||	has much combustion.



BOTH feature a way to "cover" the top to control emissions.

Note the missing middle for medium size char production technology.

- A fundamental issue: **When the volume (pile) of biomass gets to be large, the biomass and char partially insulate and isolate the biomass in the center.**
- Without sufficient air (with O_2), there is not sufficient heat, so pyrolysis slows or even stops.

TWO innovations for the Anderson 4C kilns:

- First part: **Covered Cavity Kiln**
- Second part comes later in this presentation

- **Patent Pending** status on each of them.

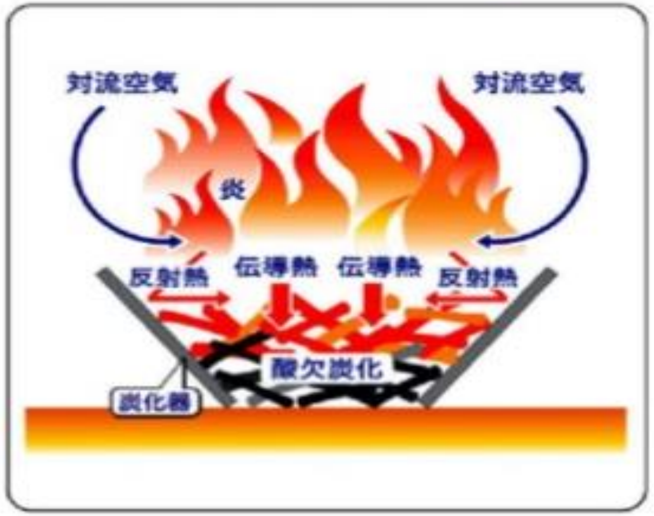
- Participation is **open to everyone on a mutually beneficial basis.**

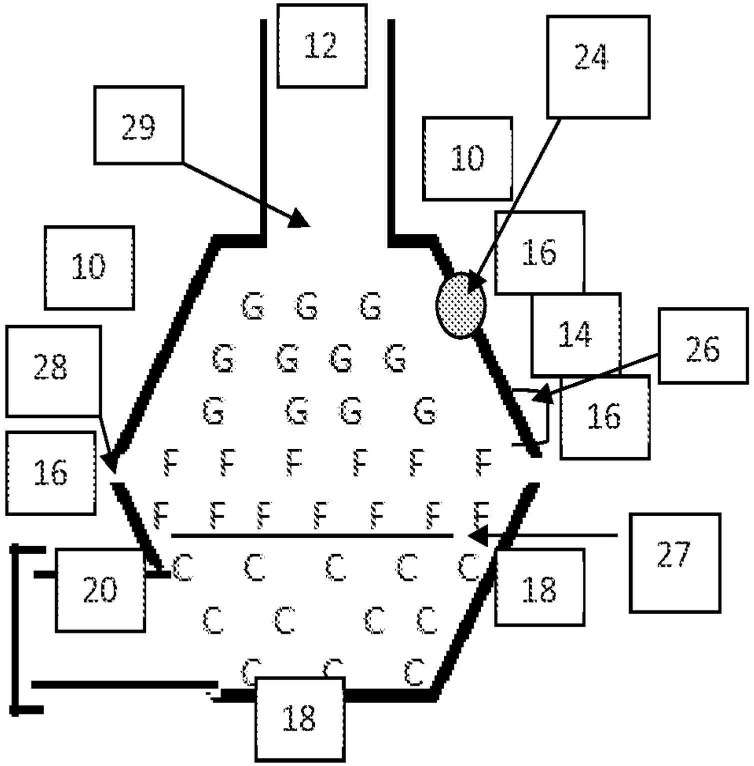
- **Seeking associates, partners,** investors, buyers, researchers, etc.

- **Core company, territorial associates, licensees, specialty users.**

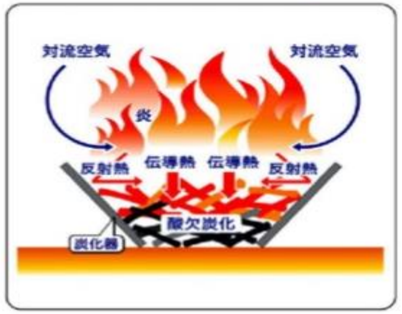
Covered Cavity Kiln (First part of the Anderson 4C kiln)

- **Flame cap is a cavity kiln with an open top =>>>>**
  - Cone, pyramid, trench, trough, etc.
- **Clean Controlled Covered Cavity (4C) kiln (2014):**

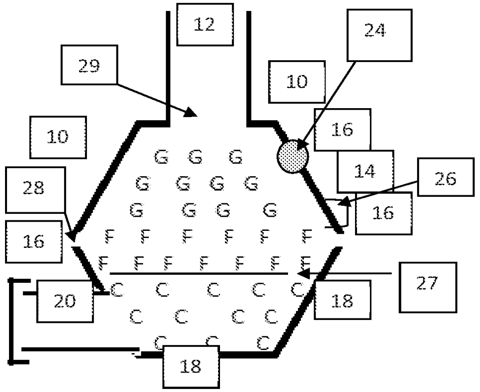




Advantages of Covered Cavity Kiln



- **Lower emissions:**
  - Less influence of winds.
  - More time for concentrated combustion of gases
  - Door facilitates control of direction and volume of entering air
  - Controlled exit of emissions
    - Allows for monitoring with instruments to control operations
- **Controlled** (channeled) exit of heat
  - Facilitates finding uses of the heat
  - Facilitates using the heat to pre-dry incoming fuel
- **Char extraction** options instead of tipping or shoveling
- Can be **scaled larger** more easily (to be discussed).
- Good quality char (see next).



Char quality: Test results of char from Anderson 4C kiln

ANALYTICAL CHEMISTS
and
BACTERIOLOGISTS
Approved by State of California

SOIL CONTROL LAB

42 HANGAR WAY
WATSONVILLE
CALIFORNIA
95076

Tel: 831 724-5422
FAX: 831 724-3188

Account No.:
Lab Number No. Acct.#
Batch
0 1
CODE:
Code
www.controllabs.com

Paul Anderson

Date Received:
Sample Id.:
Sample id. Number

Proximate Analysis

	as-Received	Dry Weight
Moisture	50.51	0.00 percent
Bulk Density	0.340	0.168 g/cc
	21.21	10.50 lb/cu ft
Carbon (C)	41.8	84.5 percent
Hydrogen (H)	1.83	3.70 percent
Nitrogen (N)	0.4	0.9 percent
Oxygen (O -calc.)	0.1	0.2 percent
Ash	5.3	10.7 percent
	100.0	100.0 Sum
Butane Activity	2.9	6.0 g/100 grams

Interpretation

H/Corg.	0.53	0.53
Stabilized Carbon	33.5	67.6 percent

The H/C ratio must be below 0.7 for the carbon to be considered stable. And because some may still not be stable we calculate at 80% of the total carbon stable.

Interpretation

Range (based on typical samples received)	Rating relative to biochars
Moisture	High
Stabalized Carbon (est.on H/C Ratio and total dry wt.)	High
Bulk Density	Low to Mid.
Ash	Med. To High
Activity	Low to Mid.

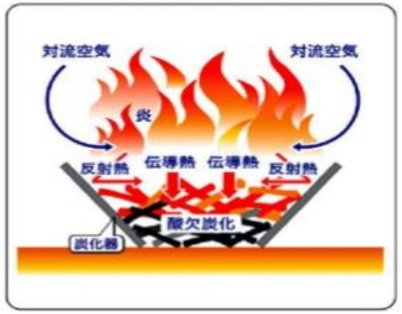
Analyst: Frank Shields

A Division of Control Laboratories Inc.

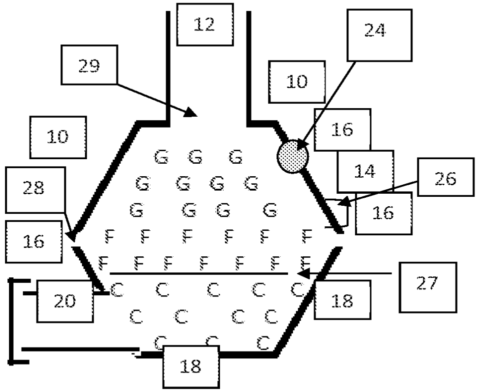
	as-Received	Dry Weight
Moisture	50.51	0.00 percent
Bulk Density	0.340	0.168 g/cc
	21.21	10.50 lb/cu ft
Carbon (C)	41.8	84.5 percent
Hydrogen (H)	1.83	3.70 percent
Nitrogen (N)	0.4	0.9 percent
Oxygen (O -calc.)	0.1	0.2 percent
Ash	5.3	10.7 percent
	100.0	100.0 Sum
Butane Activity	2.9	6.0 g/100 grams

Based on our testing it looks like excellent char. The ash is 10% so reporting on an ash-free basis it brings the carbon much higher in this natural fraction. The butane activity is a mid-ranged based on typical findings on dry wt basis. -- Frank Shields Oct. 2014

Disadvantages of Cavity Kilns, both open-top and covered



- **Fuel input is gradual** and requires presence and attention of the user.



- **Possible incomplete charring** if the biomass fuel becomes buried between incoming biomass and the bed of produced char that is cooling.
- **Lack of control** of internal temperatures, resulting from

**** **Lack of control of air flows.** ****

- **[Note: We will deal with these problems.]**

Anderson 4C Kiln – Barrel (55 gallon = 0.2 m^3) :

For Farm and Forest Pyrolytic Biomass Reduction and Biochar Production





YIMBY = Yes In My Back Yard

I have never had a complaint about smoke release. I am quite careful to keep the flame cap going.

http://www.drtlud.com/wp-content/uploads/2019/01/4C-Kiln-for-CHAB-2019-01-23.pdf

Anderson 4C Kiln – Special Tank (210 gallon = 0.8 m^3)

http://www.drtlud.com/wp-content/uploads/2019/01/4C-Kiln-for-CHAB-2019-01-23.pdf

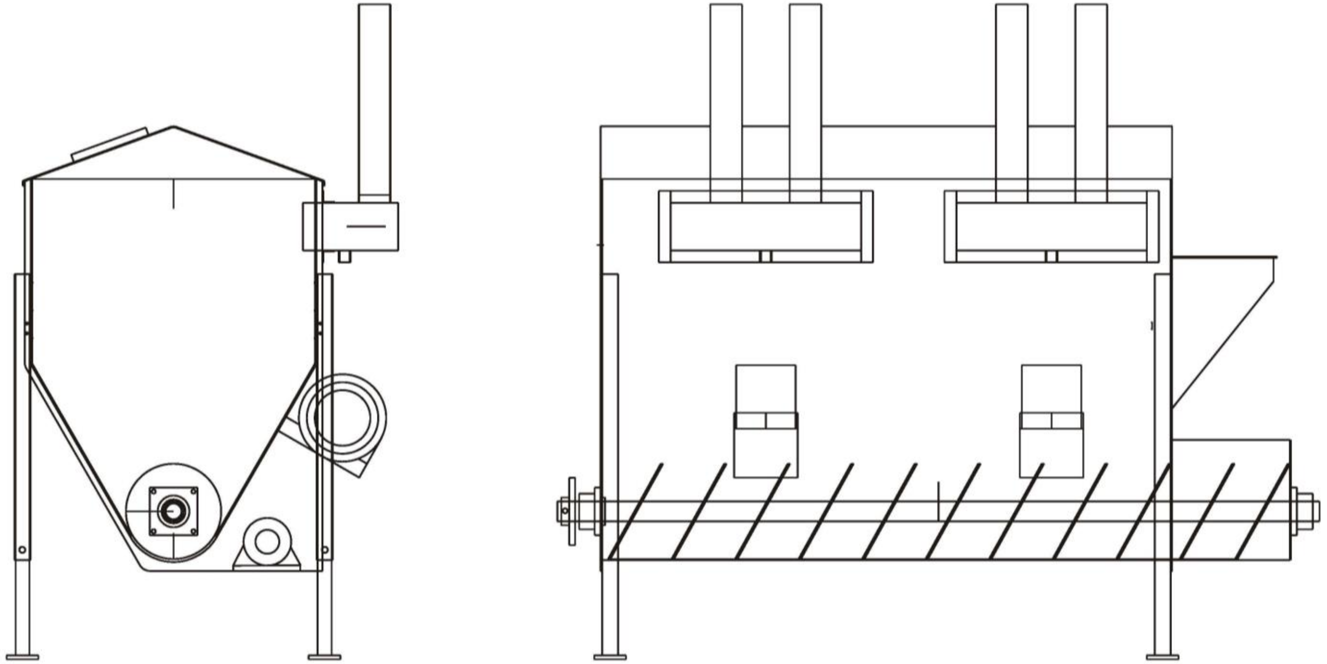
Anderson 4C Kiln – Fuel Tank (275 gallon = 1 m^3):

For Farm and Forest Pyrolytic Biomass Reduction and Biochar Production

http://www.drtlud.com/wp-content/uploads/2019/01/4C-Kiln-for-CHAB-2019-01-23.pdf

Anderson 4C Kiln – Large Tank

(4x6x8 ft) (1200 gallon or 4.5 m^3 or 6 yd^3)



First public **demonstration will be on Friday 19 July** in Goodfield, Illinois at a meeting of the **Illinois Biochar Group** (IBG).

www.illinoisbiochargroup.org

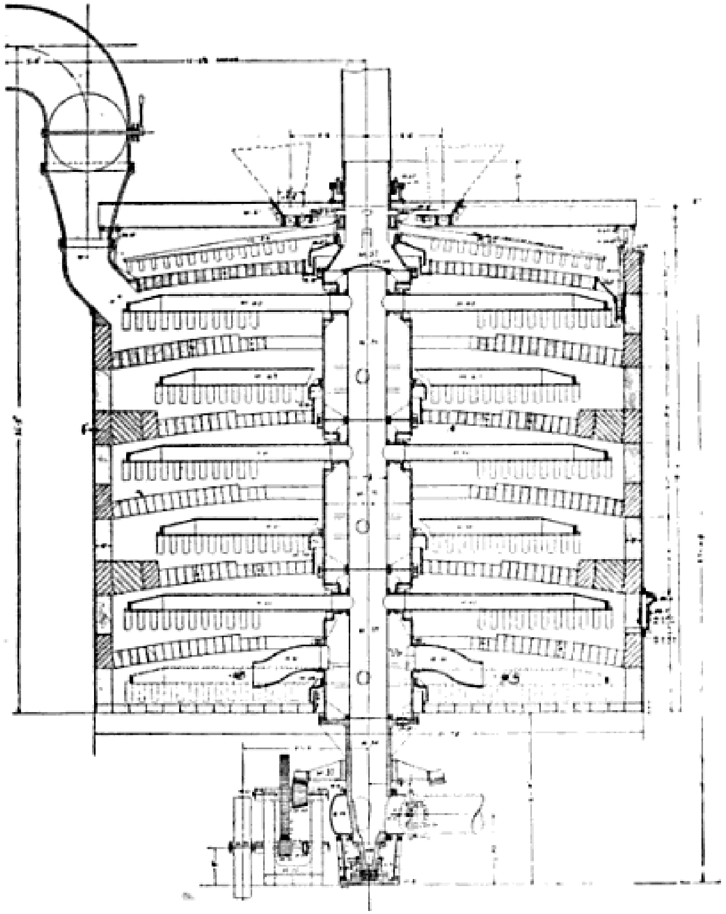
Above: Fabrication underway of a 4x6x4 ft test unit with ~2.4 m^3 capacity.

TWO innovations for the Anderson kilns:

- **Why two? Because the first one is deficient by itself.**
- Covered Cavity Kiln (1st innovation, 2014) has **three deficiencies found in all flame cap cavity kilns.**
  - **Fuel input is still gradual** and requires attention of the user).
  - **Possible incomplete charring** if the biomass fuel becomes buried.
  - **Lack of control of air flows**

- **The second innovation is how to solve these problems**
  - Facilitate and be able to **automate** the fuel delivery
  - Assure **complete charring** of the biomass
  - Much **better control** over the air flows, emissions, availability of heat
  - **Continuous** operations possible, as well as **batch** operations
  - Sufficiently **low cost**, low maintenance and low labor requirements

Prior art for internal spacing for pyrolysis



Example 7-A.
Herreshoff Roaster or
Rotary Hearth Furnace

Example 7-B.
BIGchar (Australia) Rotary Hearth Process
Pyrocal Pty Ltd (Australia)

Moving internal physical structures can be complicated and costly.

Second innovation for the Anderson kilns:

- **Supported spaces for pyrolysis.** **Use Support arms** that
  - 1. **Create pockets (gaps)** in the interior of stacks of biomass **while supporting the pile.**
  - 2. Provide **flow of air** (with O2) with spark if needed for combustion of pyrolysis gases, 1thereby raising the heat.
  - 3. Include **thermal sensor** for regulation of the heat
  - 4. **Ability to extinguish fire** and lower temperature when desired

- **Remove support arms to allow the biomass to collapse downward so that further biomass can be added at the top.**

- **Patent pending**

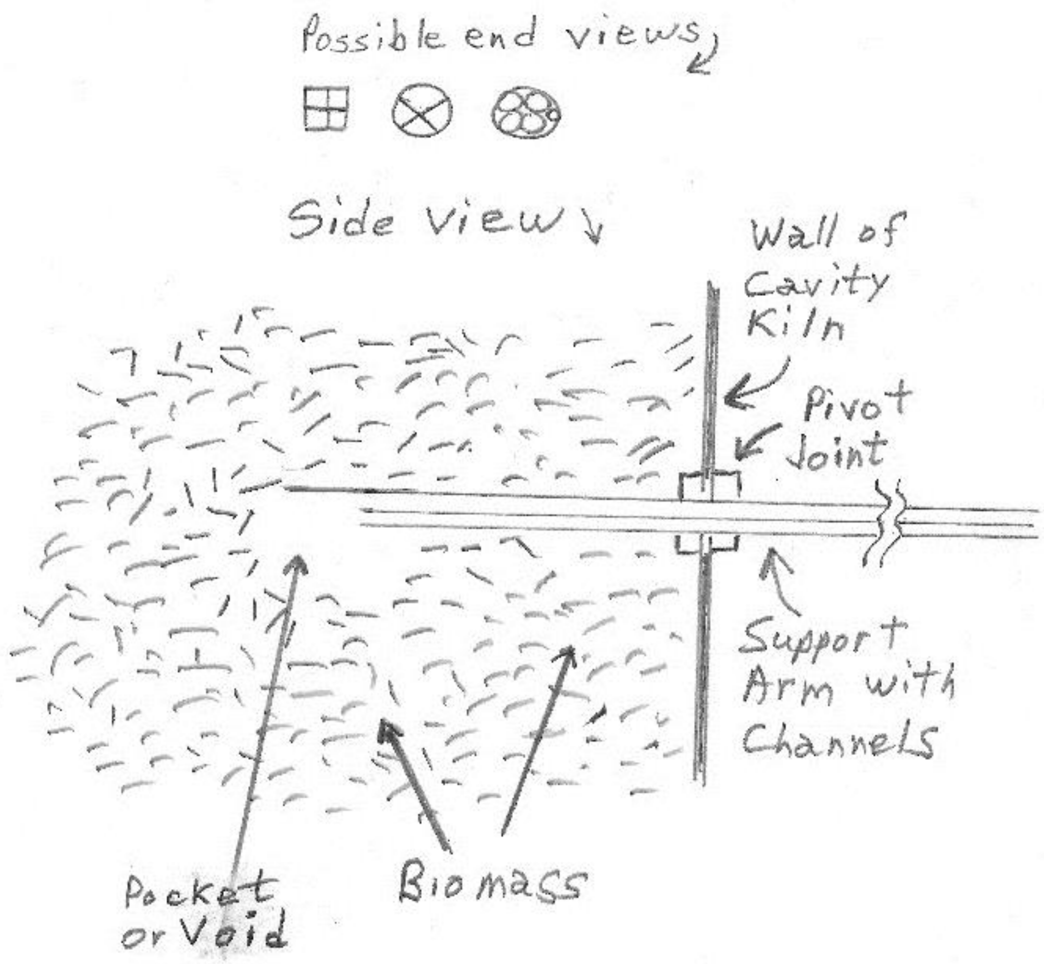
Supported spaces for pyrolysis (Second part of Anderson kiln)

- **A. Support arms are inserted to:**
  - **Create pockets** (gaps) in the interior of stacks of biomass while supporting the pile.
  - **Provide flow of air** (with O2) with spark if needed for combustion of pyrolysis gases, thereby raising the heat.
  - **Place thermal sensors** for regulation of heat
  - **Deliver fire-extinguishing water** or inert gases when desired
  - **Deliver recirculating hot gases** to change or maintain desired temperatures.

- **B. Remove support arms to allow the biomass to collapse downward** so that further biomass can be added at the top.

- **Repeat A and B** to obtain desired results.

- **Patent Pending: Cooperation is encouraged.**



Operational Notes:

- The supported spaces and support arms methods work for **both batch and continuous operations** of char making.
- The correct usage is for progressive pyrolysis **without aggressive combustion** inside the volume of biomass.
- Temperatures should **not exceed 900 deg C,** protecting the metal of the 4C kiln, eliminating the need for refractory lining, and not consuming much of the created char.
- The created heat will be consistent and appropriate for heat capture as for **space heating and water heating.**
- **Aggressive operation is possible** by forcing extra air, but requires appropriate modifications that can add to costs.

Examples of biomass types, sizes and shapes
(E = Easy, R = Reasonable, P = Problematic, D = Difficult)

- Sawdust (P)
- Mulch (R)
- Chips and Pellets(R)
- Reeds and stems (E)
- Brush and small branches (E)
- Arm-size branches (R)
- Cordwood (P)
- Whole trunks (specify several diameters) (P)
- Full size root balls of trees (D).

The ability to handle so many different forms of biomass can mean **substantial savings on current pre-processing** for biomass disposal.
Example: Eliminate grinding and chipping whenever possible.

Visualizing a ton of biomass (1 ton => 200 kg biochar)

- Many variables can cause high variations in estimates:
  - Moisture Content (MC), branches vs. trunks, hard/soft woods, compaction
- **Wood chips**, dry 380 kg/m^3. Therefore, 1 t = ~2.6 m^3
- An average **seasoned cord of hardwood** weighs more than 2 tons!!
  Unstacked = 200 cubic feet (5.66 m^3).
  Therefore, 1 t = 2.7 m^3 1 t = ~ a half cord
- **Both chips and cord wood: 1 ton = fits in the bed of a full-size pickup truck.**
- Could double these volumes if low density biomass, but pyrolysis could be much faster.

Energy content of 1 ton of dry biomass

- Dry biomass has about 16 mJ per kg.
- Allow 6 mJ/kg to be remaining in the produced char plus some loss.
- 10 mJ/kg x 1 ton = 10 k mJ (10 gJ = gigaJoules) released per 200 kg of biochar produced.
- 10 gJ = 0.9 million BTU = 95 therm = 2800 kWh

- Average house uses 40 therm per month in winter. Allowing for only 50% thermal efficiency, approx. 1 ton of biomass could heat a home for one month in a cold climate (Estimate because of many variables.)
- Further discussion about heating with biomass instead of fossil fuels.

Visualizing 5 tons of biomass (5 ton => 1 t biochar)

- Many variables can cause high variations in estimates:
  - Moisture Content (MC), branches vs. trunks, hard/soft woods, compaction
- **Wood chips**, dry 380 kg/m^3. Therefore, 5 t = 13 m^3
- An average **seasoned cord of hardwood** weighs more than 2 tons!! Unstacked = 200 cubic feet (5.66 m^3). Therefore, 5 t = 14 m^3
- **Both chips and cord wood: 5 tons = ~ 2/3rd full 20 ft. shipping container.**

Visualizing 20 tons

- 20 t = 10 cords = tri-axle load of wood.

  or a loaded 40 ft. shipping container.
- Could double these volumes if low density biomass.

Anderson 4C Kiln – in a 20 ft Shipping Container

(up to 8,000 gallons or 30 m^3 or 40 yd^3)

- **Note: Many details and options for the interiors and processes of large Anderson 4C kilns are not yet publicly disclosed.** **Patent pending.**
- **Business partners and initial users are also being sought. Contact Paul Anderson at** psanders@ilstu.edu
- **Pure speculation** (This will take some work but will be worth the effort):
  - E-Z off-on transport to locations Moveable on site
  - Multiple units by one operator Higher throughput with some loss of biochar
  - Rented or leased Low cost Biomass-specific designs to maximize throughput
  - Permanent installation where appropriate, especially if heat has a market
  - Self-contained Lowest emissions Durable

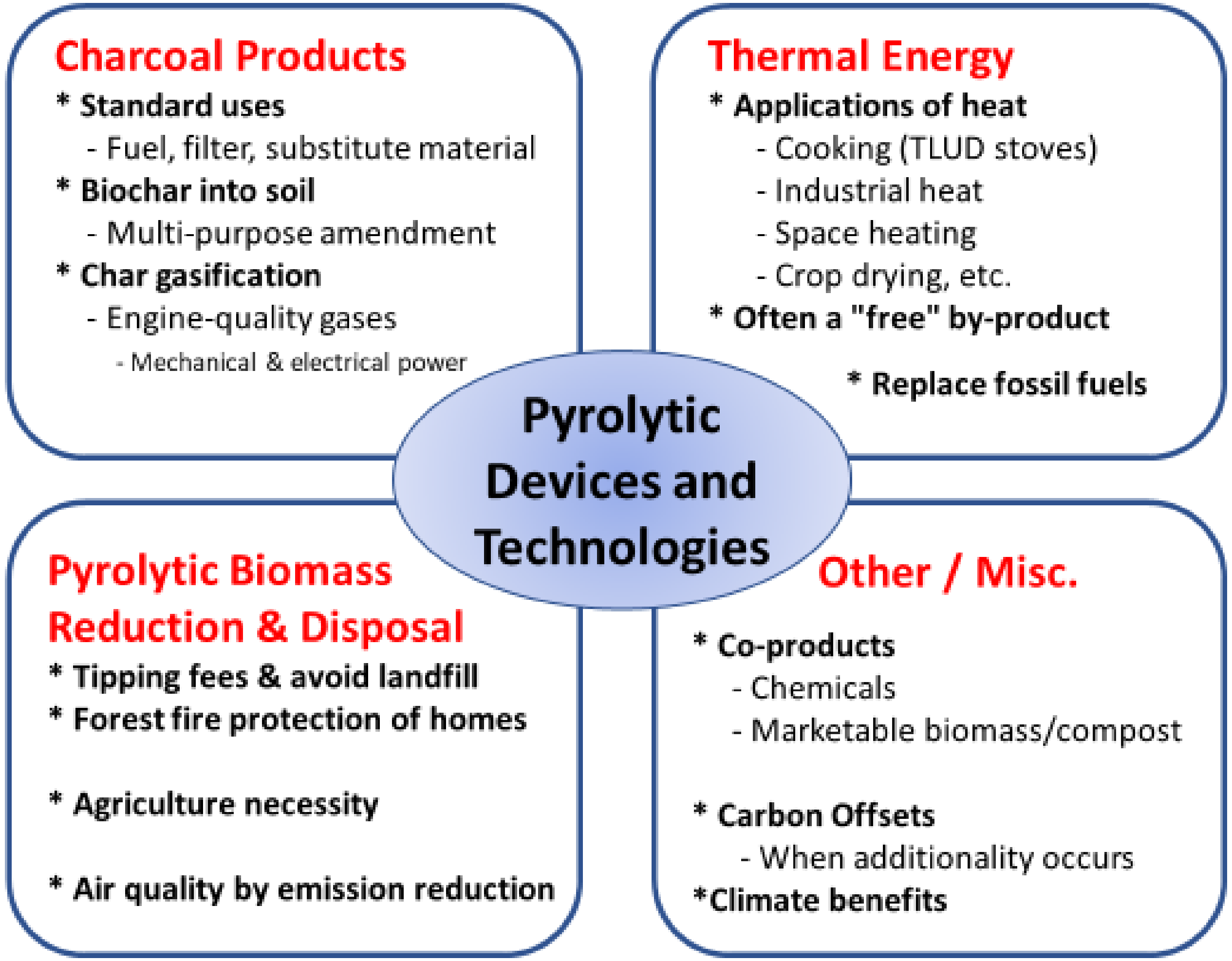
Energy content of 5 tons of dry biomass

- Dry biomass has about 16 mJ per kg.
- Allow 6 mJ/kg to be remaining in the produced char plus some loss.
- 10 mJ/kg x 5 ton = 50 k mJ (50 gJ = gigaJoules) released per 1 t biochar.
- 50 gJ = 4.7 million BTU = 473 therm = 14,000 kWh

- **To be considered: Heating of schools by use of Anderson 4C kiln technology and local biomass, with biochar output.**

Economics of 4C Pyrolysis

- Manually operated by one person.
- Mechanical loading/unloading is possible at extra cost.
- **Financial feasibility is impacted by costs of biomass feedstock, labor, equipment, value of the char produced, and value of heat and by products.**
- **There are MANY business models.**



SUMMARY:

- The 4C kiln technology and devices help fill the massive gap in size and cost options for medium and small biochar operations such as for farms, woodlots, and places generating “refuse” biomass.

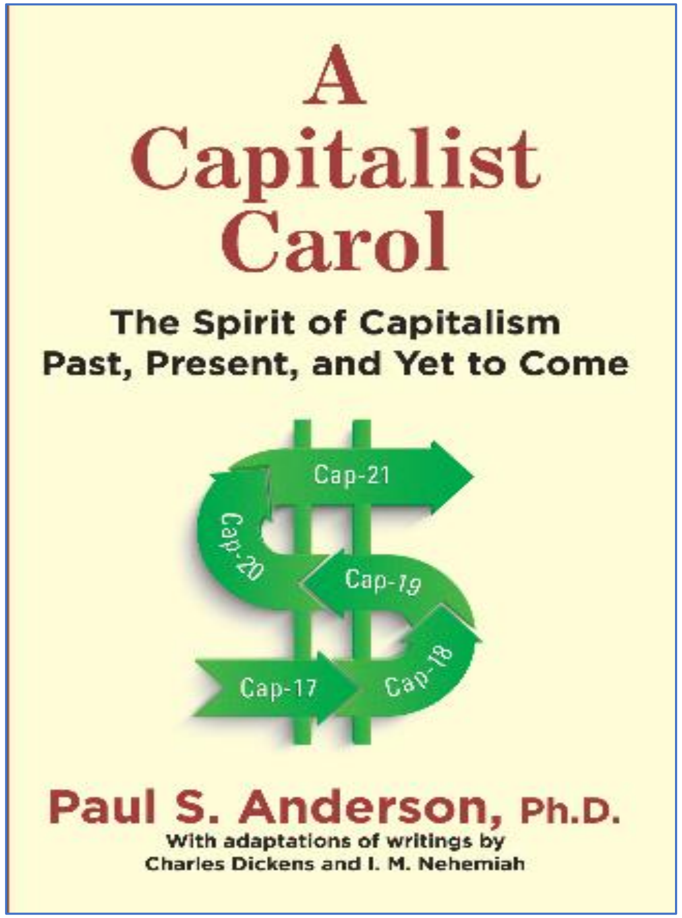
Table of sizes of Char makers:

	A	B	C	D	E	F
	Size >>>> Issue (below)	55 gallon (Barrel)	~140 < 180 gallon	275 gallon (5 barrels) (1 m3)	750 gallon (14 barrels)	1500 gallon (~ 20 barrels)
a	Dimensions W x H x L or D = Diameter x L)	(D) 2 x 3 ft		2 x 4 x 5 ft (40 ft3)	4 x 6 x 4 ft ~100 ft3 (2.8 m3)	4 x 6 x 8ft= 200 ft3 (~5.66 m3)
b	Fuel input (estimates per h)	25 kg ~50 lbs			250 kg 500 lbs (Quarter ton)	500 kg 1000 lbs (Half ton)
c	Char output (w/ 20% yield)	5 kg 10 lbs 1 wheelbarrow (WB)			50 kg 100 lbs 10 WB	100 kg 200 lbs 20 WB
d	Thermal energy output as 70% of total (30% in char) 12 MJ/kg 8 K BTU/lb	300 MJ 83 kW-h 284 K BTU	Almost 1 M BTU (Under EPA interest)	1500 MJ 415 kW-h 1.4 M BTU	3000 MJ 830 kW-h 2.8 M BTU	6000 MJ 1660 kW-h 5.6 M BTU
e						
f						

	A (repeated)	F (with new units)	G	I	J	K
	Size >>>> Issue (below)	1500 gallon (~ 20 x 55 gal)	2000 gallon (2 x 1000 gal)	4000 gallon (4 x 1000 gal)	Inside a 20 ft shipping container	Inside a 40 ft shipping container
a	Diameter / Length	4 x 6 x 8ft= 200 ft3 (~5.66 m3)			7 x 7 x 20 ft ~ 1K ft3 (~28 m3)	(~60 m3)
b	Fuel input (est. per hr)	500 kg 1000 lbs (Half ton)	1000 kg 2000 lbs (One ton per hour)			10 – 20 tons
c	Char output (w/ 20% yield)	100 kg 200 lbs (New volume ???)				2 – 4 tons/hour
d	Thermal energy output as 70% of total (30% in char) 12 MJ/kg 8 K BTU/lb	6 GJ Gigajoules 1.66 MW-h 5.6 M BTU	12 GJ Gigajoules 3 MW-h 10 M BTU	GJ MW-h M BTU	GJ MW-h M BTU	GJ MW-h M BTU
e						
f						

What makes Paul Anderson tick?

- I am working to solve Ultra serious problems that face us.
  - Environment and Climate
  - Poverty overseas and TLUD stoves
  - American socio-political structure
  - Population growth
- My positions and attitudes are revealed in a recent book.
  - ***A Capitalist Carol***
  - **Free as digital book**
  - www.capitalism21.org
  - ***A Capitalist Carol*** **is a novella that looks at the past, present and future of capitalism, and touches on climate issues, and advocates for the consideration and implementation of "Capitalism 21."**



- The need for middle-scale and affordable large-scale pyrolysis is great.
- **So Let's do it!!!!!** I do not work alone. All are invited to participate.

Questions and Comments:

- Be sure to see the posters.
- Contact information:
- psanders@ilstu.edu   +1-309-531-4434 (c)