COMBINED HEAT AND BIOCHAR SYSTEMS

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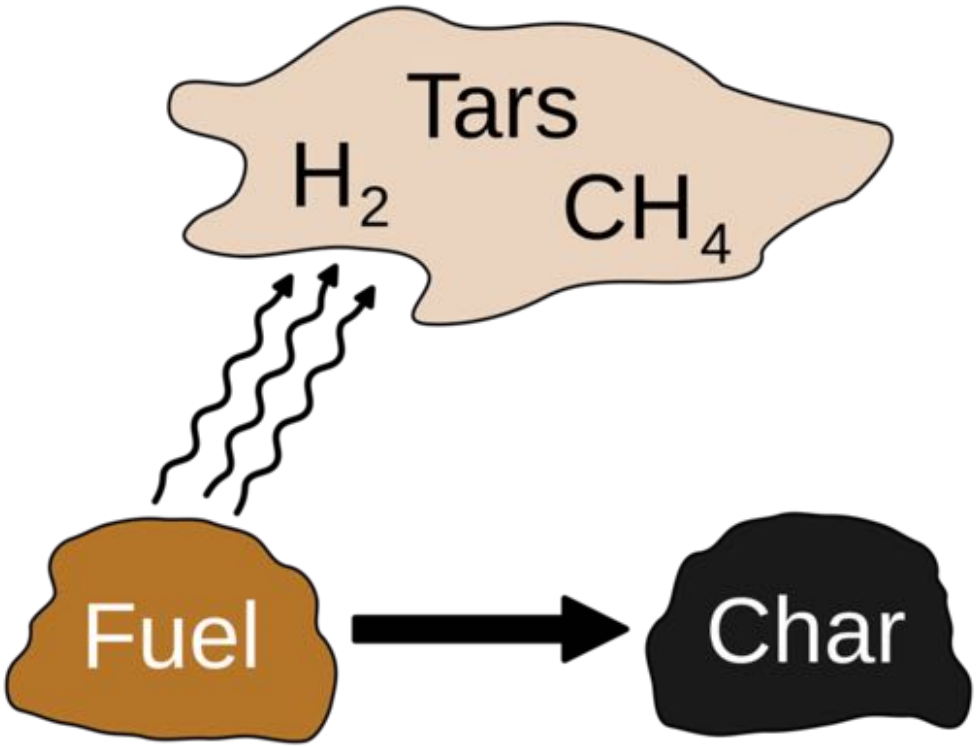
Agenda

1) Technology overview of devices suitable for small to medium scale CHAB
    1) Retort systems
    2) Gasifiers
    3) Biomass furnaces and boilers
2) Applications and Decision Tools
    1) Feedstock considerations
    2) Desired products and product characteristics
    3) Scale and scalability
3) System Integration and Balance of System (BOS)
    1) Feedstock handling
    2) Thermal off-take systems
    3) Biochar quenching and handling
4) Economics
    1) Value of heat for applications
    2) Value of biochar
    3) Site considerations and feedstock supply
    4) Capital and operating costs

Pyrolysis Overview

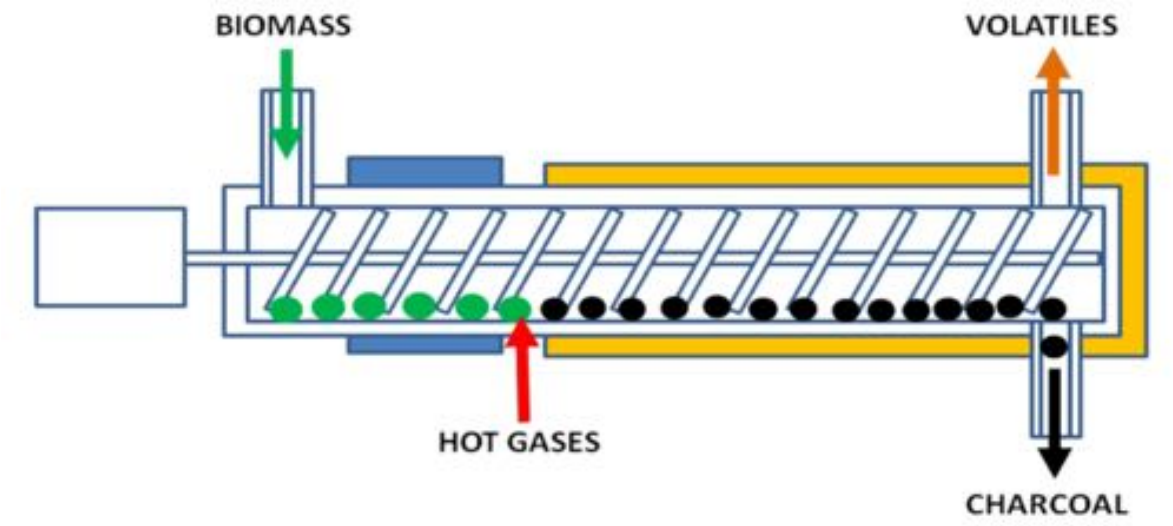
Pyro-lysis: from pyro (fire) and lysis (separation)



Pyrolysis Methods

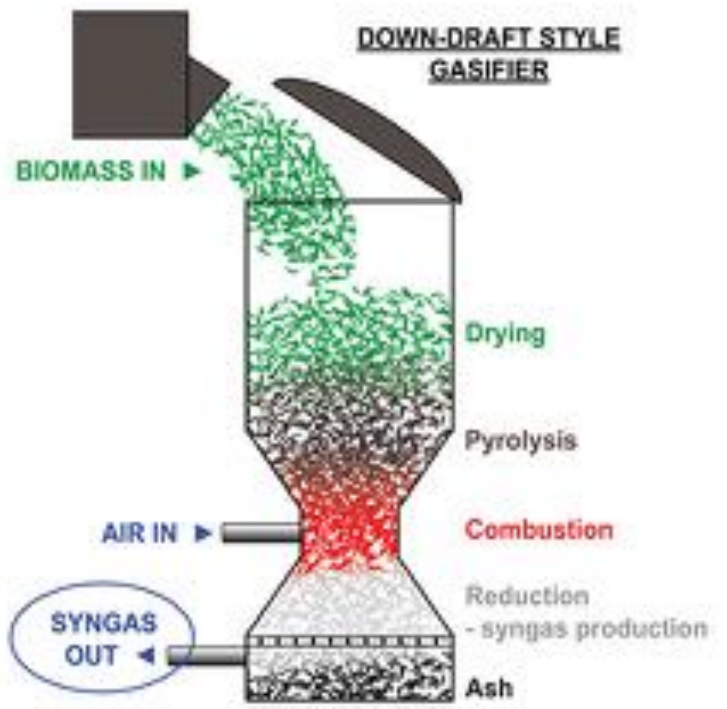
1. Continuous Retort Kilns
2. Gasifiers – updraft, downdraft
3. Multiple Hearth Furnaces
4. Modified Biomass Furnace/Wood Boilers

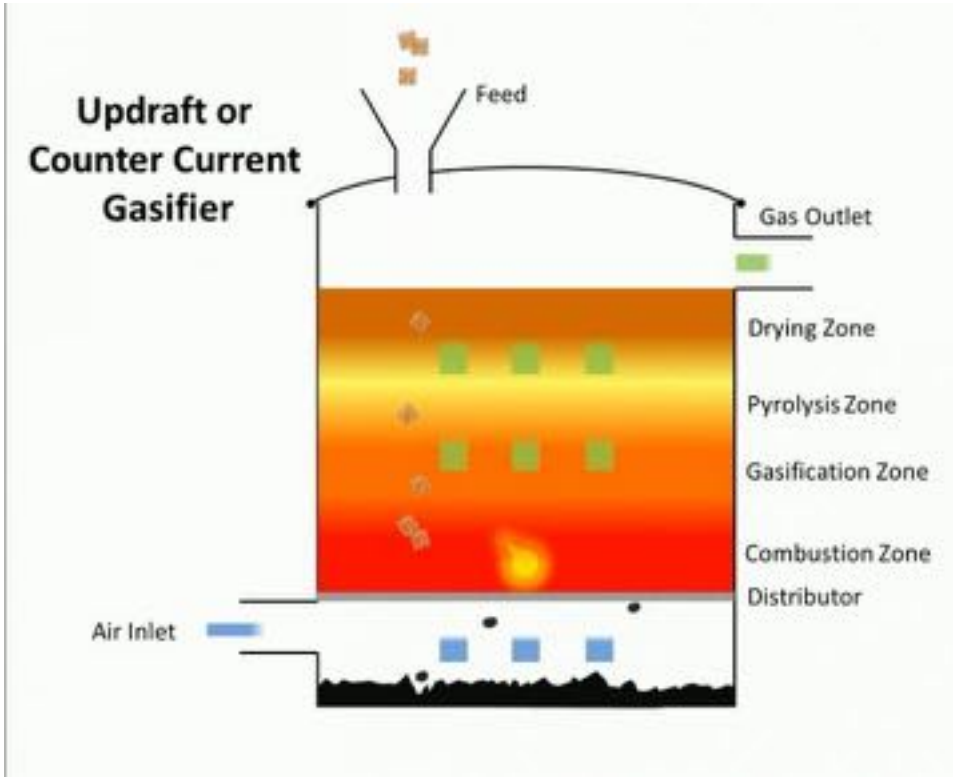
Continuous Retorts



- Indirect heating by burning syngas volatiles
- Most control over biochar characteristics
- Feedstock flexible

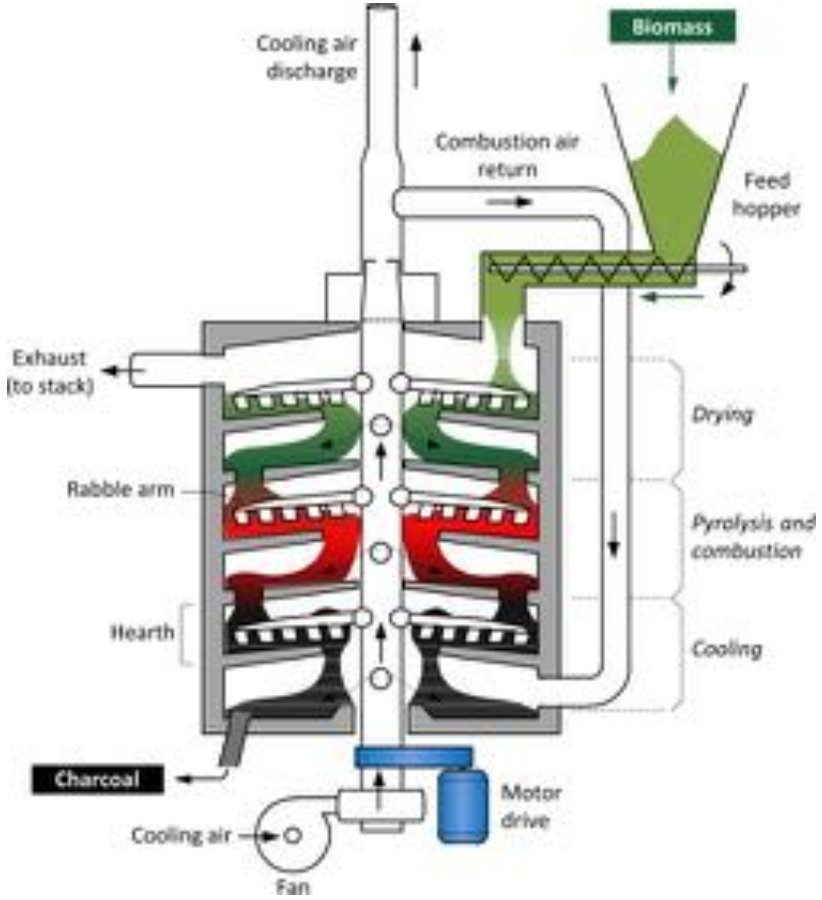
Gasifiers





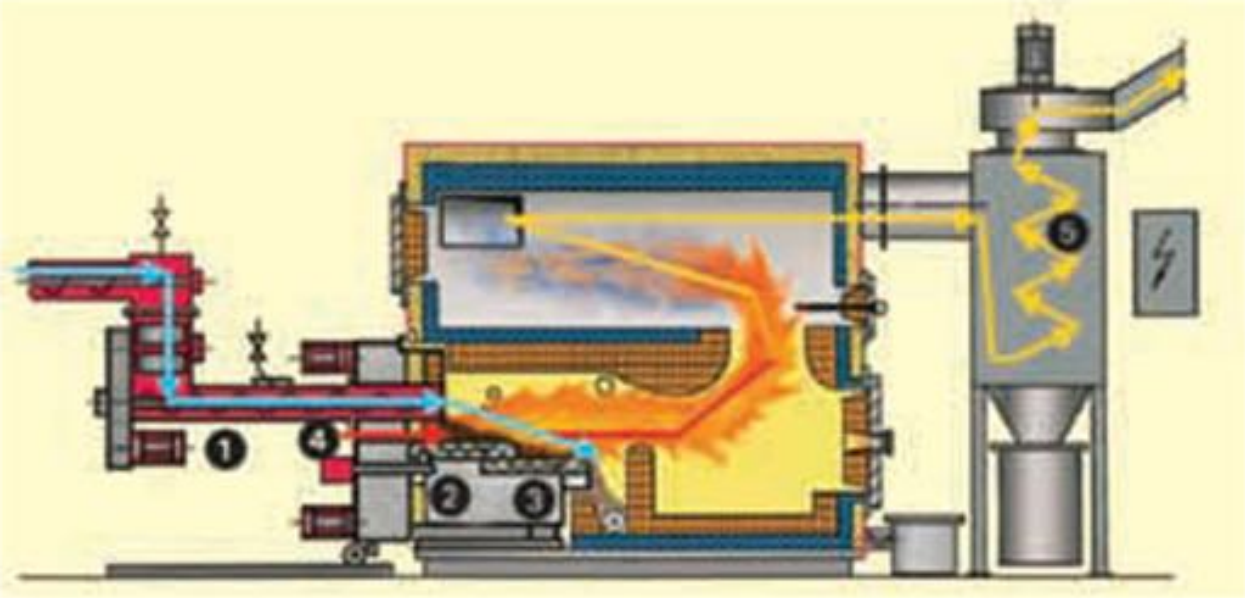
- Zoned combustion and limited air
- Downdraft most suitable for clean, engine quality gas
- Updraft can produce more char, but lower gas quality
- Gas quality not important for close-coupled heat applications

Multiple Hearth Furnace



- Combustion process with zoned combustion
- Feedstock flexible, can use fibrous, non-uniform feedstocks like crop waste

Biomass Energy Furnaces



- Combustion process with excess air
- Needs uniform feedstock particle size
- Char recovery depends on ash removal system

CHAB potential: Fraga Farm, Tualatin, OR

- 100 head goat dairy
- Overgrown Xmas trees – 20 acres
- Heat needed for cheese processing
- Biochar used in goat barn

CHAB potential: grain dryer, ND

Potential to save $60,000 a year on propane

CHAB potential: Big Red Worms, Lincoln, NE

Current processing volumes:

- Food waste – 50,000 pounds per month (500 cy)
- Wood chips for compost – 1000 cy per month
- Wood chips for fuel – 500 cy per month
- Heat output to heat and chill warehouse – 1MMbtu/h
- Desired biochar for 10% addition to compost – 150 cy per month

Future processing volumes:

- Food waste – 500,000 pounds per month (5000 cy)
- Wood chips for compost – 10,000 cy per month
- Wood chips for fuel – 5000 cy per month
- Heat output – 10 MMbtu/h
- Desired biochar for 10% addition to compost – 1500 cy per month

Combined Heat And Biochar (CHAB) study for Nebraska Forest Service

Manufacturer	Model	Tech type	biomass in (dry pounds/h)	biochar out (dry pounds/h)	biochar efficiency	Thermal output, MMbtu/h
ARTi Char	ARTi 2.0	Pyrolysis Retort with Heated Auger	667 per train Up to 5 trains in one container	167-250 per train	25% - 35%	5 MMbtu/h per train
Energy Americas Solutions (EAS)	BET 49-S	Biomass Furnace	372	60	16%	3.5
ICM, Inc.	ICM BC-30	Up Draft Gasifier	1833	403	22%	8.4
Organilock	BB1000	Biomass Furnace with integrated dryer	150	24	16%	1
Pyrocal	Pyrocal CCT 12	Biomass Furnace - Multiple Hearth	550	138	25%	2.8
	Pyrocal CCT 18		1400	350	25%	6.8

ARTI Char

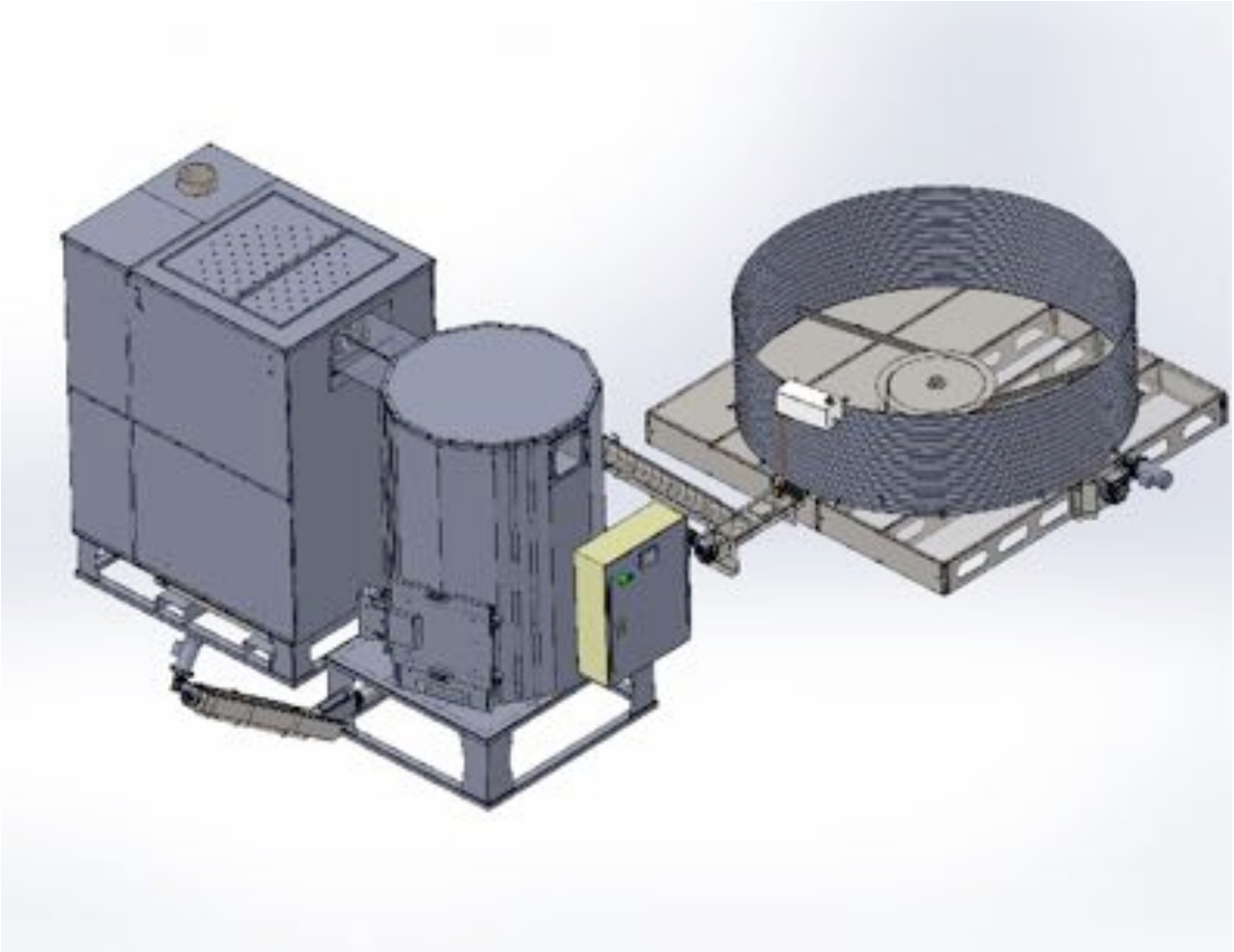
Continuous Retort

https://artichar.com/

ARTI Char

Char cooling tower

Organilock BB-1000



Biomass Furnace https://organilock.com/

Organilock Furnace at High Plains Biochar, Wyoming

Furnace from Organilock makes biochar from wood chips, manure, other biomass

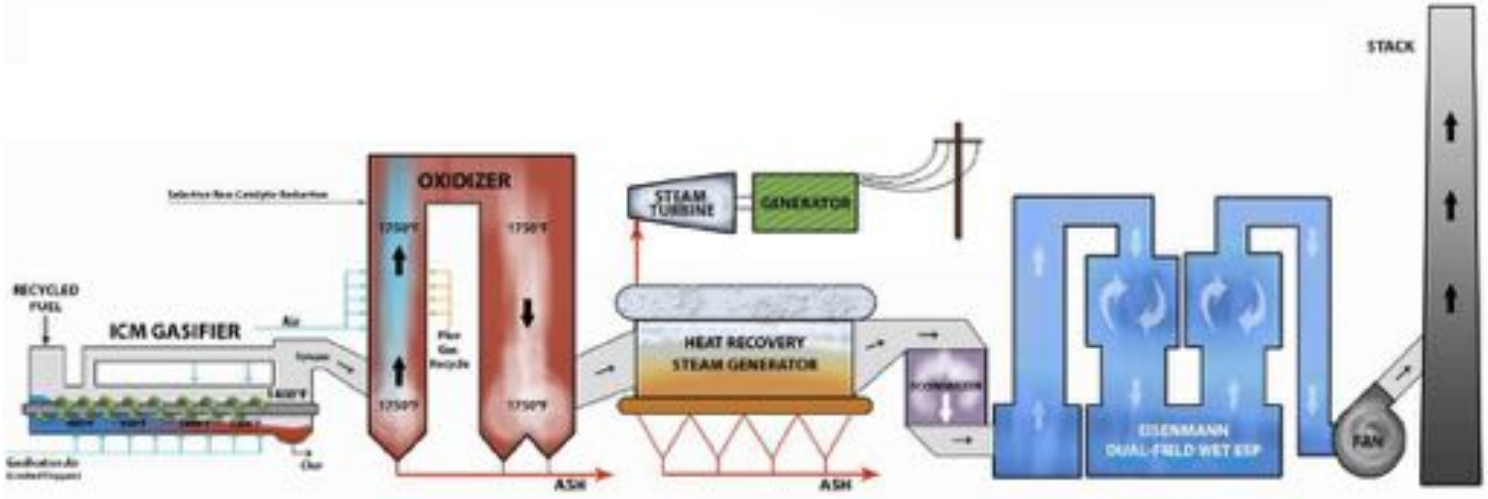
Energy Americas Solutions,LLC /BET

Biomass Furnace

https://terra-char.com/

Energy Americas Solutions,LLC /BET

ICM Gasifier



http://icminc.com/

ICM Gasifier

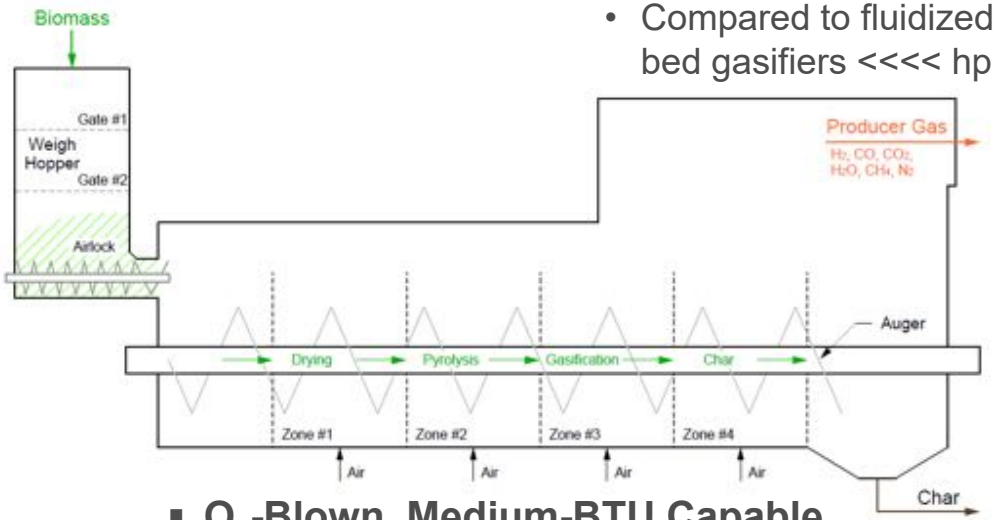
- ICM TECHNOLOGY -
Air-Blown Atmospheric Gasification

- **Better Control**
  - Mass input
  - Low rpm auger
  - Retention time
  - Zoned air input
- **For BioChar**
  - Lower maximum bed temperatures
  - Flexible controls

- **Robust Design**

- **Small Footprint**
  - 9’ x 36’ = 300 TPD
  - 6’ x 20’ = 30 TPD

- **Low Energy**
  - Minimal size reduction
  - 300 ton/day gasifier
    - < 10 hp auger
    - < 75 hp fan
  - Compared to fluidized bed gasifiers <<<< hp



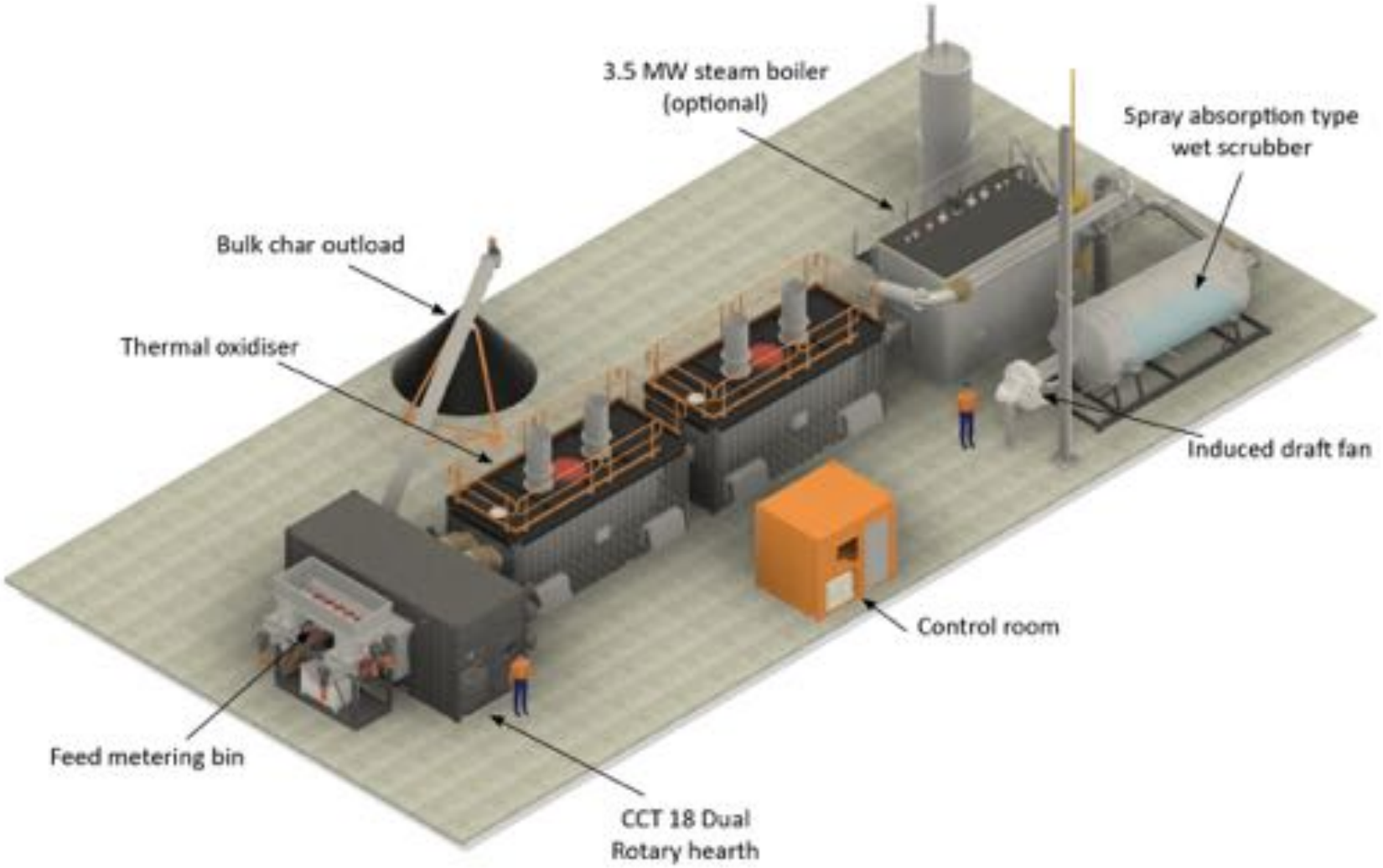
- **O_2-Blown, Medium-BTU Capable**

Pyrocal CCT

Multiple hearth furnace

https://www.pyrocal.com.au/

Pyrocal Dual CCT18



Company Contacts

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Feedstocks and Moisture

Model	Wood chip feedstock format	Max moisture content (wet basis)	Other Feedstock Capabilities
ARTi 2.0, one train	Up to 3" minus. 1" for best performance	50%, with integrated dryer. For direct feed to the reactor ideal moisture 10-25%	Manure, grain hulls, corn stover, nut shells
EAS/BET 49-S	3" minus with no fines or dust or sawdust	60% (25% min)	Chopped hemp stalks
ICM BC-30	One plane 3/4" or less, or strips 6 inches long. Best performance requires 3/8" to 2".	15% - can handle up to 35% - 40%	Straw, corn stover, chicken and dairy manure mixed with wood chips
Organilock BB1000	Wood fiber through a 3/4" hammer mill screen for best performance. No bark.	35%	Manure, wood pellets, sawdust
Pyrocal CCT 12	Chipped or shredded up to 3/4" thick x 2" long/wide for best performance. Can accept up to 1.5" thick and 4" long .	35% - Less than 20% recommended	Manure, nut shells, MSW, hog fuel
Pyrocal CCT 18			

Thermal Outputs

Model	Thermal output, MMbtu/h	Thermal offtake types	Integrated thermal options provided by vendor
ARTi 2.0	5 MMbtu/h per train	Direct flue gas for dryers or greenhouses, flue gas-to-air heat exchangers, hot water boiler, steam boiler	integrated dryer using flue gas
EAS/BET 49-S	3.5	Direct flue gas for dryers or greenhouses, flue gas-to-air heat exchangers, hot water boiler, steam boiler	flue gas-to-air heat exchanger or hot water boiler
ICM BC-30	8.4	Direct flue gas for dryers or greenhouses, flue gas-to-air heat exchangers, hot water boiler, steam boiler. Can have one duct that can feed a boiler and another duct that goes to a dryer.	none
Organilock BB1000	1	Direct flue gas for dryers or greenhouses, flue gas-to-air heat exchangers, hot water boiler. Company is working on an integrated chiller option.	Integrated boiler consists of a 350 gallon tube heat exch. 1700 F flue gas going in, 300 F exhaust T. Integrated dryers can use both flue gas and hot water
Pyrocal CCT 12	2.8	Hot combustion flue gas at temperatures of 700 to 850 deg C, suitable for all conventional boiler types as well as dryers. .	none
Pyrocal CCT 18	6.8		

Decision Matrix: Biochar Production and Co-Products

Model	Conversion efficiency (dry mass basis)	Max biochar production per month (cy)	Precision control of biochar characteristics	Other co-products
ARTi 2.0	25-35%	840	yes	Condensates and wood vinegar
EAS/BET 49-S	16%	214	no	none
ICM BC-30	22%	1,452	yes	none
Organilock BB1000	16%	86	no	none
Pyrocal CCT 12	25%	495	yes	none
Pyrocal CCT 18	25%	1,260		

Decision Matrix: Feedstock Flexibility

Model	Technology	Handles non-uniform particle size	fibrous or fluffy feedstocks	high moisture feedstocks (>35%)
ARTi 2.0	Pyrolysis Retort with Heated Auger			
EAS/BET 49-S	Biomass Furnace			X
ICM BC-30	Up Draft Gasifier	X		X
Organilock BB1000	Biomass Furnace with integrated dryer			
Pyrocal CCT 12 and CCT 18	Biomass Furnace - Multiple Hearth	X	X	

Decision Matrix: Scale and Scalability

Model	Thermal output, MMbtu/h	Max biochar production per month (cy)	Matched to current BRW production	Matched to 10x expanded BRW production	Scalable by adding units in parallel
ARTi 2.0	5 MMbtu/h per train	840	no	yes	yes
EAS/ BET 49-S	3.5	214	yes	no	yes
ICM BC-30	8.4	1,452	no	yes	yes
Organilock BB1000	1	86	yes	no	no
Pyrocal CCT 12	2.8	495	no	no	no
Pyrocal CCT 18	6.8	1,260	no	yes	yes

Decision Matrix: Vendor Provided System Integration

Model	Feedstock handling integration	Thermal offtake integration	Advanced automation
ARTi 2.0	X		X
EAS/BET 49-S	X	X	
ICM BC-30			X
Organilock BB1000	X	X	X
Pyrocal CCT 12 and CCT 18			X

Tom – BOS

Tom - Economics

Conclusions