Biochar and Torrefied Biomass Short Course

Penn State Bioenergy Short Course Series

Equipment and Systems for Biochar and Torrefaction

Presentation by: Tom Causer, VP & COO
Advanced Torrefaction Systems, LLC.
9 - 10 am October 25, 2018
The Problems with Biomass

Issues Inhibiting Use:

- Low Bulk Density
- Wet, & highly wet-able
- Expensive to grind
- Problems feeding
- Low Energy Content, per lb.
- Low Energy Density, per vol.
- Bio-reactive
- Extensive variability

Torrefaction is, in theory, the solution for these issues:

- Much Better!
- Higher Bulk Density Weight/Vol.
- Uniformity allows ease of feeding
- Non Bio-reactive
- Big step toward commoditization
- Dry & Hydrophobic
- Easily grind-able
- Higher Energy Density GJ/Weight
Understanding the Torrefaction Transportation Advantage:

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<th>Truck</th>
<th>RR Car</th>
<th>Ship</th>
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<tbody>
<tr>
<td>WWP Energy 'onboard', GJ</td>
<td>438</td>
<td>1,925</td>
<td>787,500</td>
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<tr>
<td>TWP Energy 'onboard', GJ</td>
<td>561</td>
<td>2,468</td>
<td>1,165,154</td>
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<td>%age Improvement</td>
<td>28.2%</td>
<td>28.2%</td>
<td>48.0%</td>
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More Energy per Tonne – More Tonnes per Cubic Meter

Torrefied Biomass Testing at Boardman Power Plant

Test Volume
5,000 tons

2016 & 2017
Supplied By
4 different Torrefaction Units or Companies
Overview

PGE demonstrated stable operation of Boardman Power Plant using 100% renewable Torrefied Biomass fuel

- 4 single pulverizer co-fire tests
- 1 100% torrefied biomass test with 4 Pulverizers

Stable operation on 100% biomass at 257MW gross / 230 MW net

- 1.9 MWhr/ton of torrefied fuel
PGE Test Burns – What was Learned!

Successfully operated the Boardman Power Plant on 100% torrefied wood with no capital modifications to existing systems

All existing coal delivery, storage, conveyance equipment used ‘as is’

Ash – precipitator functioned very well with low opacity despite the first row of collection fields being de-energized

Flame – flame sensors calibrated, combustion air to shape flames

Emissions – Full stack tests completed during the 100% test burns. Real-time results showed drastically lower SOx and Mercury

Overall Observation – Despite significant differences in the torrefied wood supplied by 4 different suppliers, all functioned well together

Pulverizer modifications – “opened up” to accommodate a larger particle size and less dense (and lower moisture) fuel
Technological Approaches to Torrefaction

**Rotary Drum**
- Direct Heating
- Proven Scalability
- Sealing issues
- Potential for fouling

**Microwave**
- Direct Heating
- Unproven Technology
- Potential for High energy usage

**Rotary Kiln**
- Proven Scalability
- Indirect Heating
- Product “stews in its own juices”

**Fluidized Bed**
- Direct Heating
- Proven Scalability
- High Heat Transfer
- Requires uniform particle sizes

**Screw**
- Indirect Heating
- Poor scalability
- Uneven heating/poor product quality

**Multiple Hearth**
- Direct Heating
- Proven Scalability
- High heat transfer
- Good Temperature control

**Moving Bed**
- Direct Heating
- High Heat Transfer
- Channeling/poor product quality possible

**Hybrid**
- More later

**One Example: Heat & Material Balance**

100,000 MT/Yr.; Torr. Temp. about 275 C. and 73% Solids Yield

- **DRYER**
  - 34 MT/h
  - 50% Moisture Content
  - 12 GJ/h

- **Torr. Reactor**
  - 19 MT/h
  - 12% Moisture Content
  - 40 GJ/h Dryer
  - 52 GJ/h Total
  - 18 GJ/h

- **COOLER**
  - 12.5 MT/h
  - 0% Moisture Content
  - 11 GJ/h

- **Supplemental Fuel**
  - 34 GJ/h

- **(-) HHV=32 GJ/h**
  - HHV=324 GJ/h
  - HHV=324 GJ/h
  - HHV=292 GJ/h
A Comparison of the Costs of Delivering White Wood Pellets (WWP) and Torrefied Wood Pellets (TWP) from the East Coast of the US into Europe—Power Plant Burner Tip

FutureMetrics released a White Paper (October 1, 2018) on the costs of delivering WWP from Savannah, GA into Immingham, UK (CIF $192/MT or $10.97/GJ).

The following analysis is based on information from that White Paper and technoeconomic models developed by Advanced Torrefaction Systems, LLC. (ATS)

Assumptions:

- Plant Capacity: 100,000 MT/Yr for both WWP and TWP
- Capital Cost of WWP Plant: $17M
- Capital Cost of TWP Plant: $24.25M (42.6% higher than WWP Plant)
- Depreciation: straight line over 15 year life
- Interest: 15 year loan @ 6% (based on Loan/equity ratio of 60%/40%)
- Wood Fiber Cost: $33/MT @ 50% Moisture
- Finished Moisture content: WWP: 6%
- Finished Moisture Content: TWP: 4%
The Objective

East Coast USA
$33/MT
Transport
Convert
Load
Sea Transport
Unload
CIF
Transport
Unload
Europe

Torrefied Wood Pellets delivered to Boiler Burner Tip, $/MT
CIF $246.20
Burner Tip Cost $269.45

35.74
21.66
15.00
19.07
7.00
15.00
7.00
1.24
84.43

Torrefied Wood Pellets delivered to Boiler Burner Tip, $/GJ
CIF $10.97
Burner Tip Cost $12.00

1.59
0.96
0.31
0.67
0.31
0.85
0.67
0.06
2.82
3.76

Analysis by Advanced Torrefaction Systems, LLC

The Elephant in the Room!

Given all these “advantages”, why hasn’t torrefaction taken off?
Why aren’t new plants built as torrefaction plants? Or, for that matter, why aren’t current white wood pellet plants being converted into torrefaction plants?
There is no “one” single answer!

- Lack of understanding the full potential?
- Early ‘promoters’ were oftentimes not scientists or engineers
- Lots of early stage ‘hype’ – promising more than could be delivered
- Thinking it was easy

There are Technical Challenges!

- Product Quality
- Process Thermal Efficiency
- Process Up-time
- Fire & Explosion Risk
Almost All the Technical Challenges lead back to the Torrefaction Gases – and how these gases are dealt with by the torrefaction process.

Acetic Acid, Formic Acid, Lactic Acid, Methanol, Furfural, Hydroxyacetone, Carbon Dioxide, Carbon Monoxide, and WATER, Lots of Water

What is the ‘Key’ to properly dealing with the Torrefaction Gases?

Answer: To destroy them immediately upon their creation – engineer the system such that the average life expectancy of a torrefaction gas molecule can be measured in fractions of a second.

Never allow these gases to concentrate, escape, cool, or in any way gain access to oxygen causing fire or explosion
Additional Benefits of Catalytic Oxidation

Catalytic oxidation of the torrefaction gases produce large quantities of hot inert gas consisting of **carbon dioxide, nitrogen, and superheated steam**

The entire torrefaction system can be inerted effectively eliminating the potential for fire, explosion, or formation of pyrolysis oils and tars

Higher thermal efficiencies – Lower CAPEX & OPEX

Lower temperature Catalytic Oxidation results in essentially no NOx or CO

Extremely efficient destruction of VOCs

The inert gas stream can be used for steam stripping improving product quality

A torrefaction system requires less supplemental fuel

The supplemental burner is smaller and less expensive

Materials of construction for heat exchangers and duct piping for handling inert gas are much less expensive than for highly volatile torrefaction gases

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**A Tale of Three Torrefaction Demonstration Units**

Michigan Technical University – indirectly heated unit

NRRI, University of Minnesota, Duluth – indirectly heated unit

DOE’s Idaho National Laboratory – indirectly heated unit

**IDAHO NATIONAL LABORATORY TESTING.**

In February, 2016, the Idaho National Laboratory (INL) successfully performed demonstration testing with ATS TorreCat™ Technology. The INL Report can be accessed from a link found on our website at [www.atscat.com](http://www.atscat.com).

**INL Senior Scientist:**

“Torrefaction was never this easy without the catalyst because oxygen levels are much easier to control and there is no black gooey torrefaction oils.”

**Oxygen is the ENEMY of Torrefaction**
Advanced Torrefaction Systems, LLC (ATS) has developed **ATS TorreCat™ Technology**, a patented technology designed to solve the most significant problems hindering the development of commercial-scale torrefaction plants.

*Truly a disruptive innovation and game changer!*

**How would I NOW Approach Torrefaction?**

- **Catalyst System**
- **HOT Inert Gas CO2,N2, & Superheated steam**
- **Excess**
- **Hot Inert Gas**
- **FINAL PRODUCT**
- **HYBRID**
  - Both Direct & Indirect Heating
Market Potential for Torrefaction

“Industrial wood pellets” are white wood pellets used for the production of electricity

In 2016, global consumption of industrial wood pellets was 14M metric tonnes (estimated $2.24 billion)

Global demand for industrial wood pellets is predicted to reach 29M MT by 2020, and to continue to grow at a rapid pace thereafter (FutureMetrics, LLC and Hawkins Wright, Ltd.)

One analyst predicts global demand for industrial wood pellets to reach 42M MT by 2025 (FutureMetrics, LLC)

Currently Europe consumes the lion’s share but other markets, especially Japan, are predicted to become significant (FutureMetrics, LLC)

Given the tremendous economic advantages offered by Torrefaction, it should capture a big portion of the Growth

Biochar
Charcoal is produced from pyrolysis of carbonaceous matter

Biochar is charcoal prepared specifically for application to soil for Agronomic or Environmental Management purposes

Charcoal / Biochar can be produced in either anoxic or oxic processes

Anoxic – limited air or oxygen – no flame
Oxic – air or oxygen present – w/flame
Missouri Type Charcoal Kiln

Continuous Rotary Hearth Kiln
VOC Emissions
Drying Zone
Combustion Zone
Cooling Zone
Charcoal Product

Combustion Air

Floating Damper
Feed Material
Rabble Arms at each hearth
Combustion Air Return

Rabble Arms Drive

Clay Pipe Stacks
Roof Ventilation Ports

Concrete Walls and Roof
Steel Doors
Air Pipes

Anoxic Charcoal Technologies Missouri Type Charcoal Kiln Clay Pipe Stacks Roof Ventilation Ports Concrete Walls and Roof Steel Doors Air Pipes
There are many ways to produce Charcoal/Biochar – some more environmentally friendly than others!

Retort For Charcoal Manufacture
Industrial Scale Pyrolysis

An Example of Innovation in Biochar Production
A SUCCESS STORY: Pyrocal Pty Ltd (Australia)

Dr. James Joyce  I  Director / Principal Engineer

Continuous Carbonisation Technology (CCT)

Char & Energy from conventional biomass and biomass that cannot be handled by conventional technologies

Development commenced as BiGChar in 2009 in Mackay, Queensland

Moved from R&D to commercial operation in 2014.

Based in Toowoomba, Queensland

PYROCAL =  Design + Build + Deliver

How does Pyrocal CCT work?

Multiple Hearth Gasifier

Biomass enters and is transported downwards through multiple hearths

Burning volatiles rise upwards to heat the entering biomass in seconds, by direct contact.

After 3 stages & ~100 seconds gasification is halted and char is discharged & cooled

Results in the production of a stable & highly porous carbon rich product (char)

Temperature at Discharge – 580 C.- 680 C.
Key features of CCT?

Accept Many Biomass Residues
- green waste, cotton gin trash, rice hull,
- almond hull, grape marc, food wastes,
- sugarcane trash, rice straw, biosolids

Low Installed Cost
- Minimal site works required
- Readily relocatable

Produces Low Cost char

Generates Low Cost Heat

Runs for long periods unattended

Emissions compliance

(c) PYROCAL 2018
A Word of Advice from James:

“One thing is clear, a business based entirely on char as the revenue source is unlikely to be sustainable. The main product of the process is energy, char should be considered as a valuable by-product, but not the primary reason you carbonise biomass.”

Black Pearl Charcoal
Pyrocal uses its own facility in Toowoomba to produce premium barbeque charcoal.

Made from 100 percent Australian grown nutshells including one or more of walnut, pecan, macadamia, hazelnut and pistachio shells.
Toowoomba, QLD  (Tanuki Pty Ltd)
Installed 2017  4 t/d nut shell (Pecan/maca)  1 t/d char  600 kW steam boiler

Whitton, NSW  (Voyager Craft Malt)
- Installed 2016
- 4 t/day walnut shell
- 1 t char/day
- 300-500 kW hot water
- 150 days/year
Adelaide, SA (Jeffries Compost)

- To be commissioned early 2019
- 30 t/day compost overs
- 8.5 t char/day
- 3 MW steam boiler
- 400 kWe ORC generator
- >250 days/year

Grassdale via Dalby, Qld (Grassdale Fertilisers)

- 60,000 Cattle Feedlot Operation
- 2% char in feed ration
- Reduces the effects of Aflatoxins on the cattle
- Biochar increases feed-use efficiency
- Increasing feed efficiency means lower methane emissions
- Carbon carries through into the manure
- The manure is processed through a manure granulation facility
- Results in an organic fertilizer with a marketable value greater than its competition
Grassdale via Dalby, Qld (Grassdale Fertilisers)

115 t/day saw mill residues
13.6 MW heat to fertiliser dryers

15 t char/day (10 t/day to cattle feed)
>300 days/year

Dual CCT18 hearths
4 sets

To be commissioned early 2019

Grassdale via Dalby, Qld (Grassdale Fertilisers)

Rotary dryers for fertiliser granules
Thank You!

Thomas P. Causer

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