

Oregon Torrefaction

Biomass Test Burns at Coal power Plants and Fuel Production



Oregon Torrefaction





Oregon Torrefaction, LLC

Mission: Advance forest health & rural, forest-rich community vitality

As an Oregon Benefit Company – a purpose of Oregon Torrefaction includes creating a material, positive impact on society and the environment





Consortium for Advanced Wood-to-Energy Solutions

Public-Private Research and Commercialization Entity Focused on Torrefaction of Biomass and Power Plant Use

- \$4.8 million initial investment by USDA and non-profit US Endowment
- Utility Testing of Torrefied Biomass
- Densification
- Manufacturing pathways
- Economics
- Life Cycle Assessment & Carbon Implications
- Full Safety Evaluation
- Address Knowledge Gaps



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Context – Unhealthy Forests

Over 50 years of Fire Suppression = Unchecked Growth

- Ecologically unbalanced Forests
- Excess fuel buildup

Combined with recent severe draught

Now, Forest Fires...

- Burn hotter
- Consuming increasing acreage



Context – Normal and Not



Controlled Burn, Central Oregon USFS

Spokane: *The Spokesman-Review*



Burning Logging Slash →





Context – The Effect





A Solution

Thinning and removal of excess fuel to return **ecological balance**

Need **“Market Pull”** to be efficient

- Biochar
- White Pellet fuel
- Activated Carbon
- Torrefied Biomass as a solid fuel for Power Generation

Torrefied Biomass

- Can substitute for coal
- Deliver Energy and Capacity like Hydro or Geothermal





Basic Tenets

Biomass in Oregon

- Counts as a source of renewable power
- Helps Electric Generating Utilities **fulfill Renewable Portfolio**

Can use biomass in pulverized coal plants BUT...

- The biomass must be made **crispy so that it will pulverize**
- Pulverized torrefied fuel is then fed into the Boiler

Key Things the Torrefied Fuel has to do:

- **Grind well**
- **Burn well**
- **The ash (emissions) have to behave**





Torrefaction

Biomass is roasted in low oxygen environment

- Similar to roasting coffee beans
- About a half step below making charcoal

Thermally efficient process

- > 90% thermally efficient
- Kick start the process with energy → auto-thermal condition
- Carbon-Carbon bond formation ensues that is exothermic

Yields a Product that is...

- Friable (Crispy)
- More energy dense than feedstock
- Moisture content typically < 5%





Torrefaction Effects

Decreases mass (de-water)

Becomes hydrophobic

Resists bacterial & fungal attack

Increases energy density

Decomposes volatile organics

Makes the biomass “crispy”

Yields good grindability

Compatible combustion chemistry

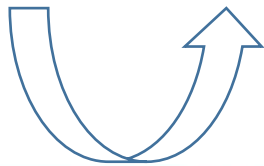
Sulfur & Hg remain low

Kiln Torrefied Biomass Types		
Undensified Material	BTU / lb	MJ/Kg
Canary Reed Grass	9,400	21.84
Wheat Straw	9,700	22.54
Corn Stover	8,200 - 9,700	19.07 - 22.56
Willow	9,400	21.84
Pine	8,500 to 10,000	19.77 - 23.24
Bamboo	8,100 - 9,500	18.84 - 22.10
Giant Cane (<i>Arundo</i>)	10,000	23.24
PRB Coal	8,500	19.75

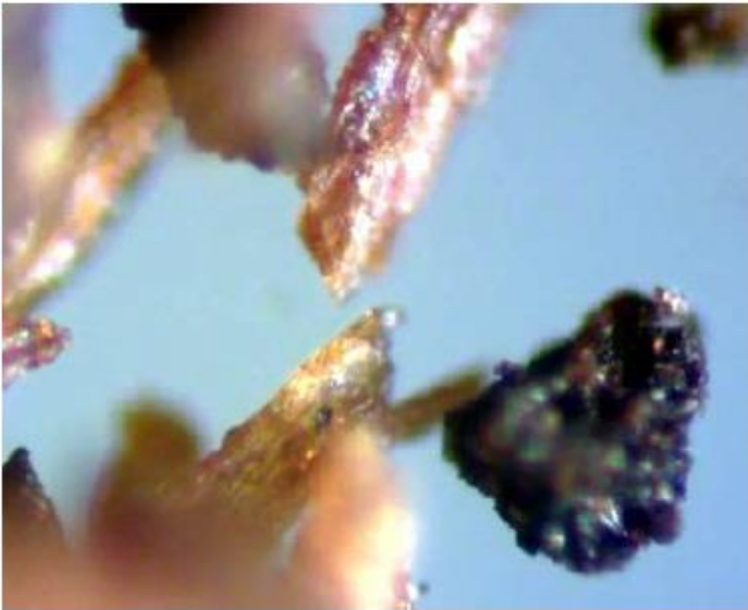


Drying + Torrefaction: White Fiber to Charred Particle

Moisture reduced from 50% to 5%



Hemicellulose → VOC's



Carbon-Carbon Bond Formation





Torrefied Wood Chips from Forest Restoration Treatments





Densified Wood Chips via Warren Baerg Cuber



Torrefied wood and PRB Coal





Boardman Power Plant



Baseload
Power

- 600 MW capacity
- Plant to cease coal operation by Dec. 31 2020
- 100% operation on biomass may be an option
- Need regulatory approval

- Morrow County, North Central Oregon
- 110 Staff; On-line 1980
- 8 pulverizers, ESP for Particulate control
- Powder River Basin (PRB) Coal
- PRB Coal: Low Sulfur, 30% Moisture, 8500 btu/lb
- Full load: operate on 6 pulverizers, 2 Spares



Torrefiers Used for Test burns



ReKlaim



New Biomass Energy



Airex



INL Unit

Boardman Oregon Industrial Park (Homemade):

- ReKlaim (Vertical Wyssmont)
- INL Unit (Horizontal Calciner type)

“Store Bought”:

- New Biomass [Quitman, MS]
- Airex [Quebec]





Transport, Handling, Outside Storage



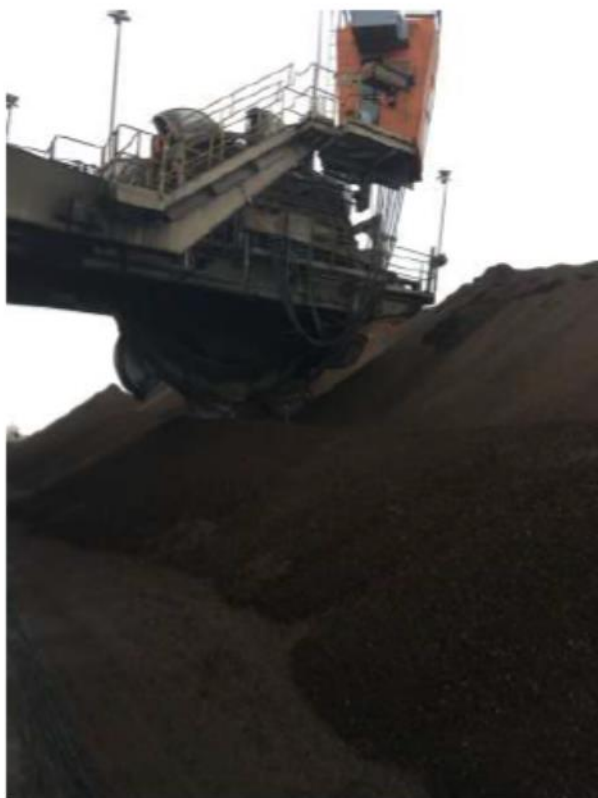
First Delivery Late Sept 2016



Last Delivery – End of Dec 2016
5,000 tons



Moving, Mixing and Pulverizing Fuel



Conveyor to Feed Bldg





Plant Handling – Existing Equipment



Interior Fuel Conveyor



Feed Silo to Pulverizer



Pulverizer Interior





PGE Test Burns – Fuel Learnings

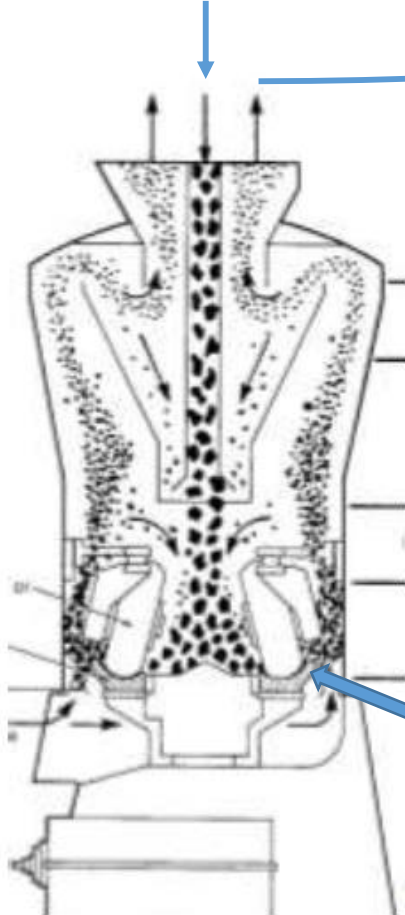
Quality	Kiln Torrefied Biomass	PRB Coal
Energy Density	8,700 Btu/lb (20.24 MJ/kg)	8,500 Btu/lb (19.77 MJ/kg)
Bulk Density	40 lb/ft ³ (640.8 kg/m ³)	60 lb/ft ³ (961.1 kg/m ³)
Hydrophobic?	Yes	Yes
Grindability (HGI)	20-25	55+
Passing <200 mesh (%)	2	70
Moisture (%)	4 to 6	30
Color	Brown to Dark Brown	Black
Form Factor or Shape	Cylinder ≈ 10 mm	Irregular



Why Torrefaction is Needed

Bulk Coal or Torrefied Biomass

Burner Tip



Spare Grinding Wheel



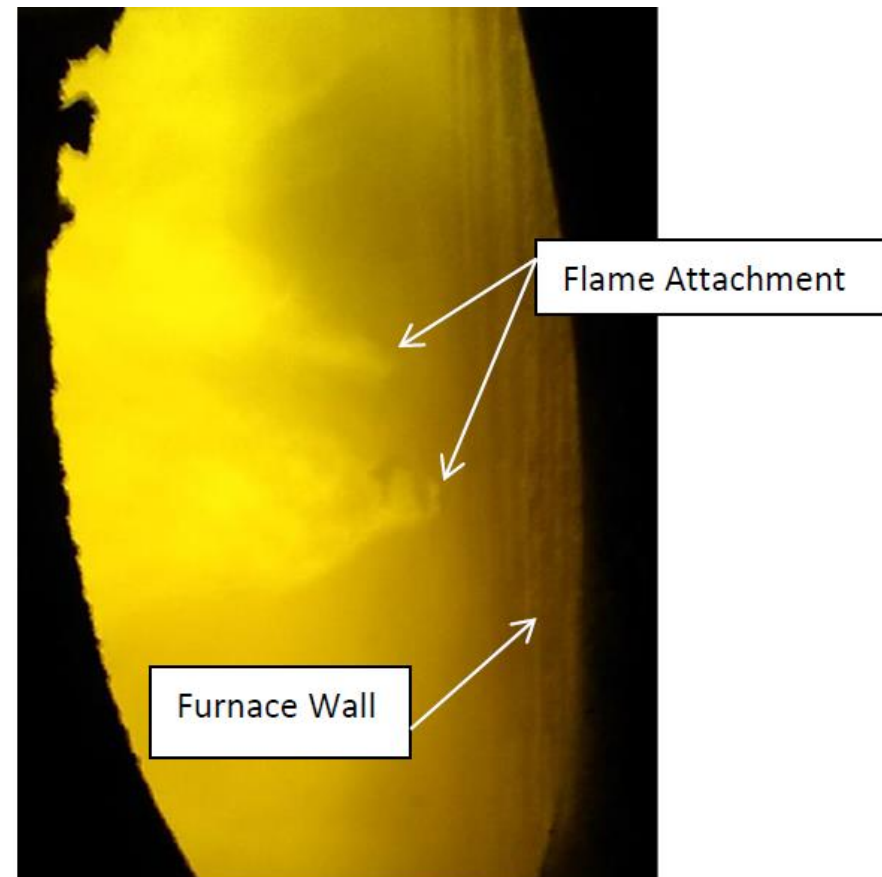
Pulverizer Gallery



Carbon Ignition, Good Flame



Smoke from a low-grade smolder of biomass residuals; the burn was mostly in the upper reaches of the pulverizer





Big Conclusions and Outlook

From Coal Yard to Start of Back Pass = “Perfect”	↑
Good Grind	↑
Good Burn	↑
“No Pluggage Anywhere”	↑
“Bigger” particles getting to the Back Pass	↑
Emissions behaving but need more and longer burn	↔

Key:

- ↑ Good to Go
- ↑ Acceptable but Could be Better
- ↓ Unacceptable
- ↔ Need more Data

Desirable Next Step:
Extended Full Load, 100% Torrefied Biomass for 1 – 2 Weeks



Oregon Torrefaction Status and Outlook

Building a kiln torrefier

- On-line 4th Quarter, 2018
- 12 ton/hr capacity
- 100,000 ton/year
- Malheur Lumber Mill, John Day, OR
- Trans-Shipment to Prineville, OR by truck
- Rail to NW Port(s) or other locations

Purchasing Feedstock Now

Nat'l Forest Treatments to reduce overgrowth in the Woods

Funded by US Endowment for Forestry and Communities

Inquiries from Off-shore and Domestic Companies and Utilities





Thank You



- Idaho National Laboratory
- Boardman Chip Plant
- Ochoco Lumber
- Jim Brewer Consulting
- Black and Veatch
- Coal Combustion Inc.
- Storm Engineering
- Maul Foster
- ReKlaim
- Airex
- New Biomass Energy
- Pacific Ag Services
- Oregon Hay
- Morrow Industrial Park
- Business Oregon
- Oregon Solutions
- Bonneville Environmental Foundation
- US Forest Service
- US Endowment for Forestry & Communities



Contact US

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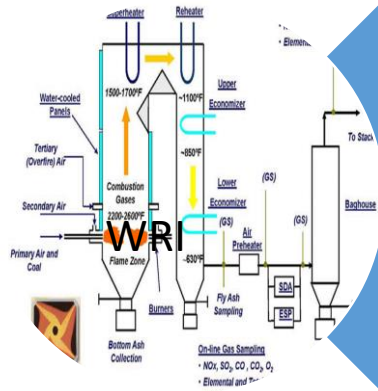
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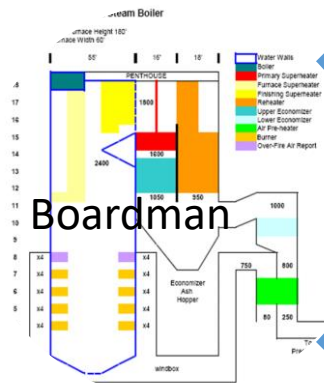


Western Research Institute – Combustion Tests



Upsides

- Can compare PRB Coal with “similar” solid fuels under same combustion conditions
- Has most of the Boardman components but smaller scale
- Offers an initial read on potential for success



Downsides

- Cannot fully predict what will happen in Boardman’s boiler
- Boardman’s burners are more sophisticated
- Introduction of combustion air is different
- Flue gas at WRI is 500 °F cooler





Analytical Comparison: PRB Coal & Five Torrefied Biomass Samples (A-E)

	Coal	Coal*	A	B	C	D	E
Proximate Analysis	<i>wt%</i>	<i>wt%</i>	<i>wt%</i>	<i>wt%</i>	<i>wt%</i>	<i>wt%</i>	<i>wt%</i>
Moisture	15.83	30.00	3.66	3.39	5.62	6.22	1.89
Ash	4.57	3.80	1.85	5.37	0.34	0.70	0.94
Volatile Matter	36.70	30.52	71.57	61.71	59.91	68.60	71.48
Fixed Carbon	42.90	35.68	22.92	29.53	34.13	24.48	25.69
Ultimate Analysis	<i>wt%</i>	<i>wt%</i>	<i>wt%</i>	<i>wt%</i>	<i>wt%</i>	<i>wt%</i>	<i>wt%</i>
Moisture	15.83	30.00	3.66	3.39	5.62	6.22	1.89
Ash	4.57	3.80	1.85	5.37	0.34	0.70	0.94
Carbon	59.16	49.20	52.75	52.47	58.33	53.07	55.45
Hydrogen	3.91	3.25	4.68	4.88	4.51	4.99	5.58
Nitrogen	0.68	0.57	0.02	0.43	0.01	0.01	0.02
Sulfur	0.26	0.22	0.24	0.18	0.11	0.21	0.25
Oxygen	15.59	12.97	36.80	33.28	31.09	34.81	35.87
Heating Value	<i>BTU/lb</i>	<i>BTU/lb</i>	<i>BTU/lb</i>	<i>BTU/lb</i>	<i>BTU/lb</i>	<i>BTU/lb</i>	<i>BTU/lb</i>
	10 103	8 402	8 782	9 230	9 677	9 017	9 864

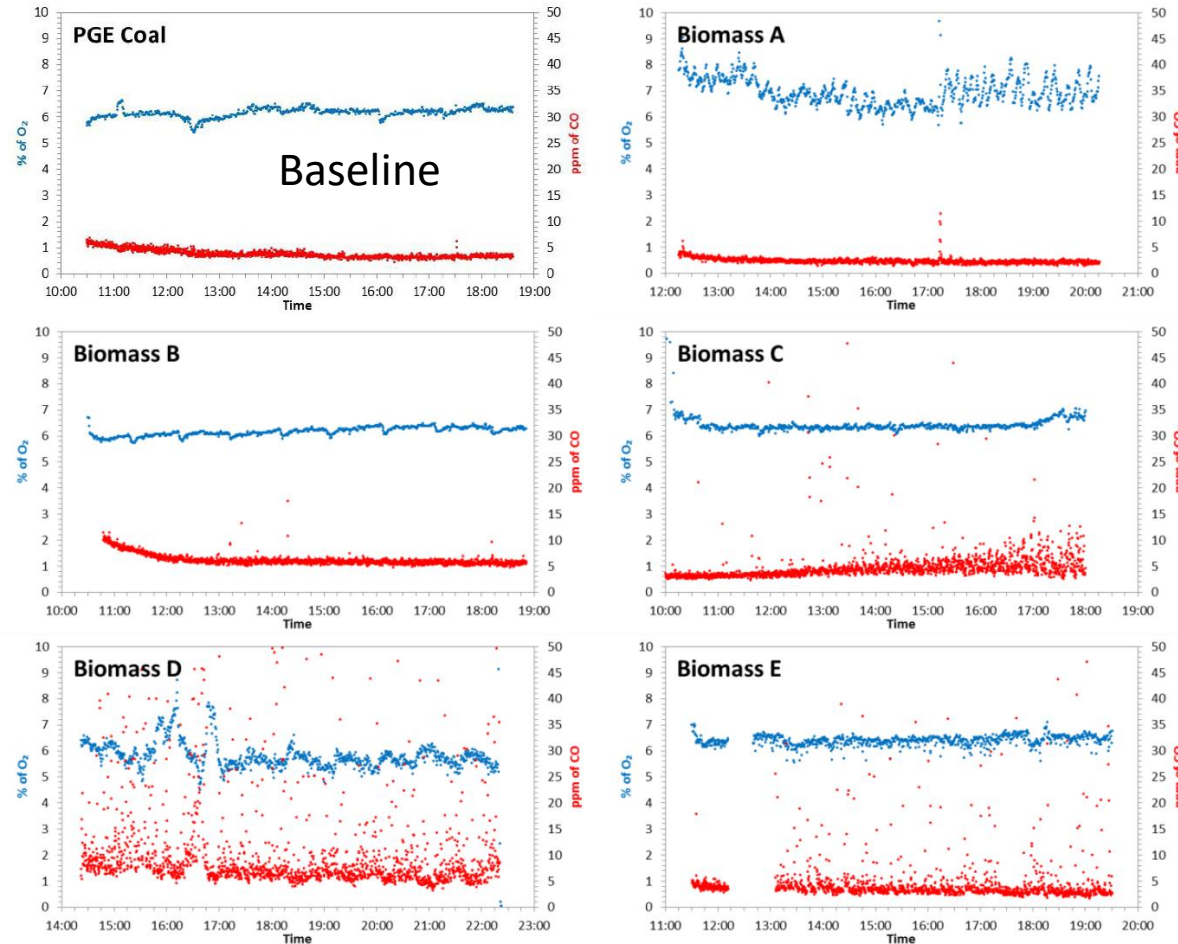
*Normalized coal values to 30% moisture content, typical to moisture as-received at PGE Boardman Plant





WRI Results

O₂ and CO Combustion Concentrations



O₂: Consistency of burn over time

CO: Quality of burn over time





WRI Conclusions

Re-Cap: Five Torrefied Biomass Samples Compared to PRB Coal

There were sample differences in grinding, combustion, ash behavior

Some modifications to fuel feed and particulate controls may be needed

Scale differences at WRI can account for some operational effects

“Overall the biomass materials can be used as a substitute fuel for pulverized coal.”





Torrefied Biomass Power Plant Tests

Facility	Location	Owner	Capacity (MW)	Coal Type	Max Mills @ Full Load	Test Year
Plant Scholz	Florida	Southern Company	49	Bituminous	3	2013
Taconite Harbor	Minnesota	Minnesota Power	150	Sub-Bituminous	4	2016
Boardman	Oregon	Portland General Electric	600	Sub-Bituminous	6	2016-17



Test Conditions

Facility	Engaged Mills at Test	Torr Biomass (tons)	Original Torrefied Fuel	Supplier	Load Test Type
Plant Scholz	1,3	500	Wood Pellets	EarthCare	Partial & Full
Taconite Harbor	1,4	120	Wood Chips to Pellet	New Biomass Energy	Partial
Boardman	1,4	5,000	Wood Chips to Pellet & Pellets + <i>Arundo</i>	Oregon Torrefaction	Partial & Full

Notes:

1. Tested Fuels were all derived from “traditional” Kiln-Torrefied sources

2. Steam Flashed Fuel has been tested at:

- Thunder Bay, Ontario Power Group
- Boardman, Portland General Electric



Taconite Harbor Results

11 hours of total testing, 120 tons

Tested 25% Torrefied Biomass to 75% PRB Coal

Learnings:

- Dusty fuel
- Due to relative dryness of the torrefied biomass....
 - ❖ Low pressure (30 psi) steam was injected into the fuel bunker prior to entry into the Plant
 - ❖ Moist environment reduces static electricity and potential for explosions
- Coal Feeders sensitive to Woody Fuel
- Initial Operator Intervention needed on Mills
- Then – operated like coal
- Flame pattern, backpass sparklers not unusual
- Different Mill Emptying pattern
- Although a limited test, CEM data showed....
 - ❖ No increase in emissions
 - ❖ No emissions limits exceeded

“Steep Learning Curve”





Plant Scholz Results

Successfully fired up to 100% Torrefied Wood; 500 tons

For Safety, Treat Torrefied Wood like PRB Coal

Torrefied Wood Pellets yields:

- Brittle Fuel
- Lots of Fines
- High Fuel Moisture

Boiler efficiency reduced by high moisture

Emissions greatly reduced when firing torrefied wood



Torrefaction After Densification





Truck Delivery: Super Sacks + Bottom Dump



Dumping Directly to Receiving Grate



Outdoor Storage: Nov/Dec '16 thru Sept '17



Bottom Dump



Wind Row



Stack - Reclaim



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Durability



North-Central Oregon

- 8 - 10 inches of Rain
- 2 – 6 inches of Snow
- Dust Storms



Torrefied Wood Pellets
“Homemade”



Torrefied then Pelletized
“Store Bought”



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2016–17 Initial (3) Test Results – Single Pulverizer

All tests completed safely, successfully per plan; 484 tons – Dec/2016

Moderate physical & operational modifications

- Reduced tortuous path by eliminating pulverizer obstructions
- Tempering air only – no heated air flow in pulverizers

Needed higher primary air flow; alters the burner flame shape

Flame scanners will need modification

A dusty fuel and will need dust suppression and control

Not enough run time to assess fouling and slagging





100% Torrefied Biomass (4th) test

Four Pulverizers – Late February 2017

1,429 tons of torrefied biomass (fuel sat outside for 3 to 4 months)

255 MW (43% of Full Load); 278 MW Peak

- 5 hour duration
- 1,275 MW-Hr

Generated very little Ash - Recall: 2x to 5x less ash feeding in (Encouraging but Not Definitive)

Plant Interior Fuel Gallery Conveyor

- Dust production exceeded dust control system
- Imperative to have electrical grounding systems checked and validated

CEMs + Onsite stack testing

- CO, Hg and SO₂ below detection method
- NO_x consistent with normal Plant Operation on coal
- Particulates were < current limits
- Opacity similar to that observed for coal





One Pulverizer, 6-Day Run – 5th Test

≈ 600 tons per day; 3,100 tons; September 2017

Fuel sat outside for 9 months

Sprayed water on pile prior to Plant Entry for Dust Control

Pulverizer worked better with wet torrefied biomass

Lower Bulk Density means moving fuel 3x faster





Observations and Lessons from 3 Power Plants & WRI

It's a Dusty Fuel – spraying water on it is Okay; Ensure electrical grounding systems are checked / validated

Torrefied Biomass can take some Weathering

Handle, Transport and Store like PRB Coal

Lower Bulk Density will mean moving fuel faster

Will always start Testing with One Mill in Play followed by Multiple Mill Testing

- Fuel will Hold Up and Clean Out Differently in the Mill
- Operator Intervention Until Comfortable (get the grind right, ensure no pluggages, pyrite rejects acceptable, over use ignitors)
- Primary Air will need to increase; no need to use heated air
- Flame Shape will be altered
- A Saving Grace: **Power Plants are “Operationally and Physically Robust”**; Unlike WRI – they have a lot more “Dial”

Extended Time Test Burns Should follow





Kiln Torrefied Fuel Manufacturing Learnings

Irregular-sized Chips work but Uniform sized Particle is preferable

Can dry then torrefy in the same tube but better to do separately

VOCs must be handled correctly to avoid “problem cascades”

- Thermal Oxidizer
- Condensation

Torrefied Product requires cooling

- Water spray
- Cooling Screws

“Off the Shelf” horizontal or vertical calciners/thermal Heaters can be used as Kiln Torrefiers + BOP

- Just One Less Thing
- Warranty Wrap
- Technical Support





Post Torrefaction Learnings

Advisable to hold torrefied fuel for short period to **ensure cool-down**

White wood pellets can be torrefied and maintain form

Torrefied biomass can be densified without binder

- Cubed
- Pelletized
- Extruded

Densification is enhanced with a binder and is likely more durable

- HTC
- Combine light and dark roasts

Handle and Store Similar to Powder River Basin (PRB) Coal

