



PRESERVING SOLID FUEL FIRING IN A POST-COAL WORLD



A PRESENTATION BEFORE THE:



***Advanced Steam
Traction Trust***

OUTLINE

- About CSR
- Why investigate a coal alternative?
- Torrefied Biomass
- Biofuel Testing
- Future Testing
- Conclusions



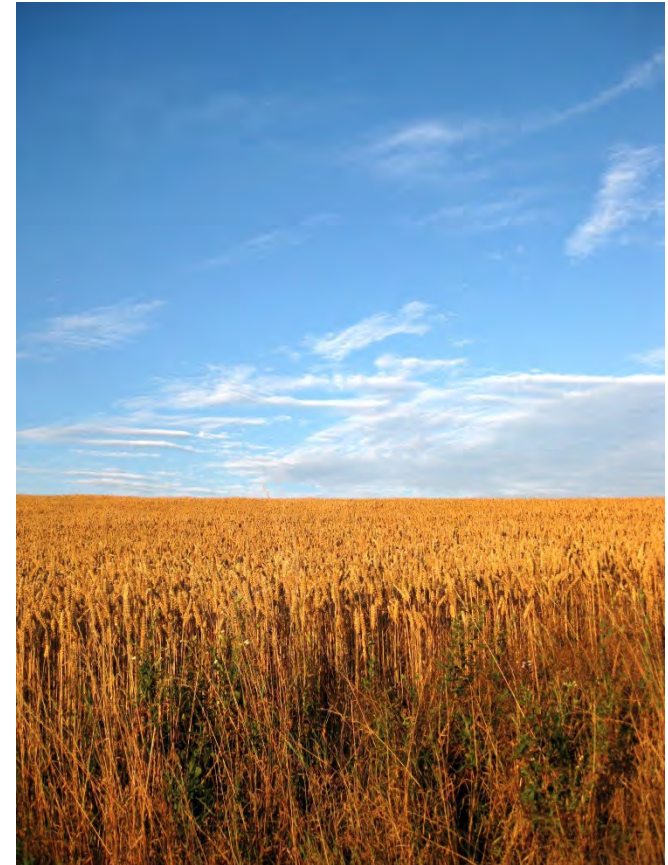
ABOUT CSR



ABOUT CSR



- A multi-disciplinary not-for-profit dedicated to:
 - Innovation
 - Preservation
 - Education
- Founded in 2012



INNOVATION



- Multi-pronged approach towards:
 - Fuel Research
 - Steam Research
 - Locomotion
 - Power Generation
- Key Research Collaborator:



UMD
**Natural Resources
Research Institute**

UNIVERSITY OF MINNESOTA DULUTH
Driven to Discover™

PRESERVATION



- Finding ways to maintain historic rail equipment efficiently and responsibly
- Work with AT&SF 3463
 - On Hold since Nov. 2013
- HSB/KRM



EDUCATION



- White Paper Program
- Presentations
- Zoo Train “Coop-ETition”
 - A new collaboration

Learn**Deep**
MILWAUKEE

Milwaukee
County
Zoo

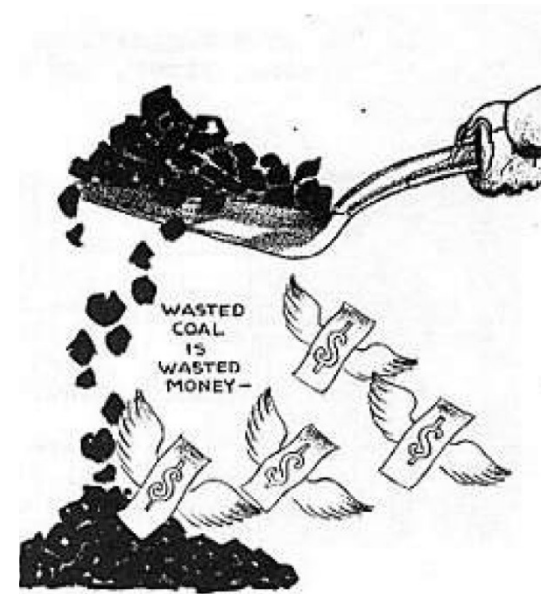


WHY INVESTIGATE A COAL ALTERNATIVE?



WHY INVESTIGATE A COAL ALTERNATIVE?

- Over the past decade, we've seen a change in:
 - Availability & Cost and
 - Public Perception of coal
- There is also a growing movement towards environmental sustainability



AVAILABILITY & COST

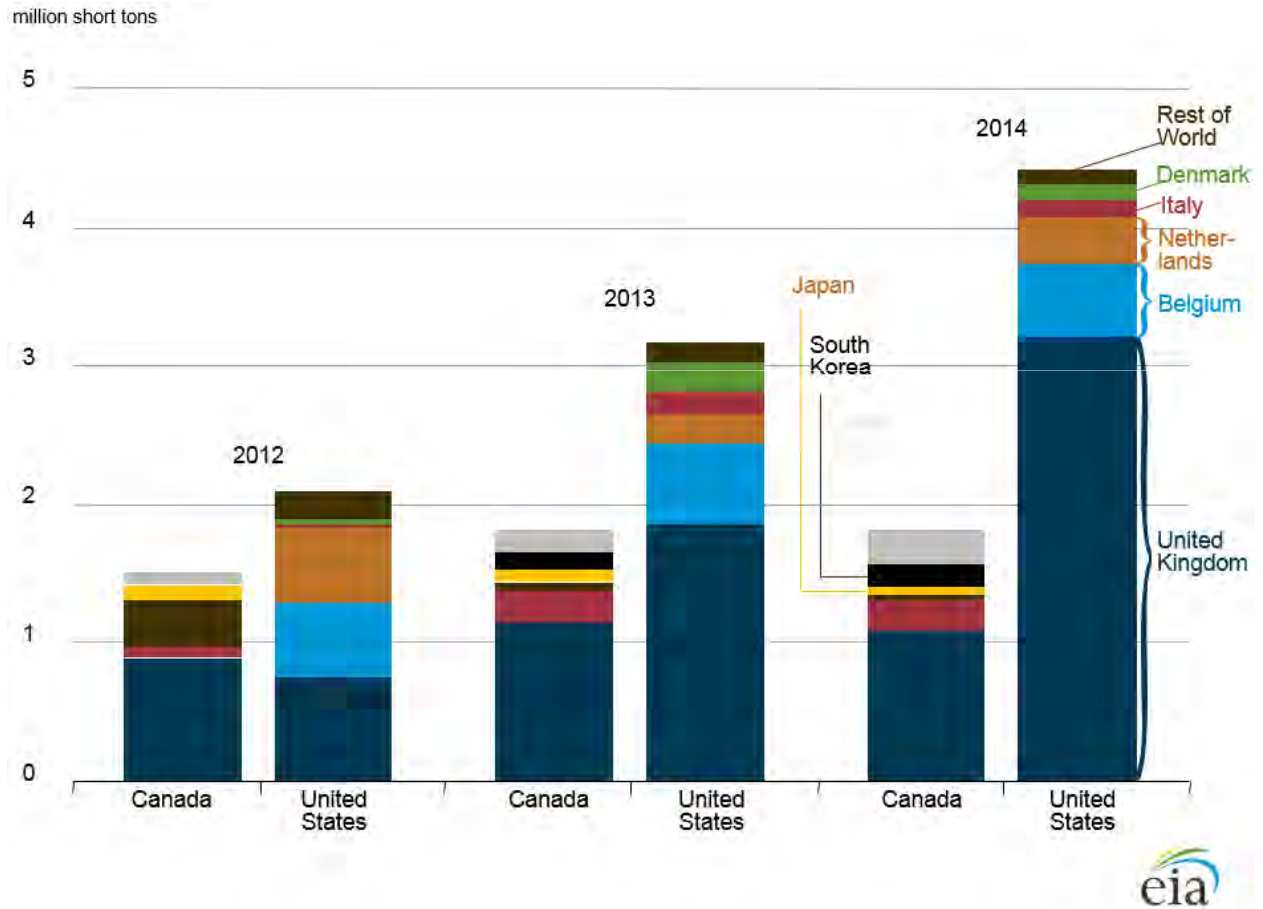
- U.S. and global coal usage dropped significantly
- Steam coal consumption set to decrease 30% by 2050
- Decreased demand = decreased production = increased cost

“These days, though, good coal for steam locomotives isn’t easy to come by. Not only are the appropriate grades of coal expensive, coal’s overall decline is reducing the number of suppliers.”

-Hayley Enoch – Trains Magazine

AVAILABILITY & COST

- Last coal mine in UK now closed
- Chart: US & CAN Biomass Exports
- Growth in UK is from one plant converting from coal to biomass



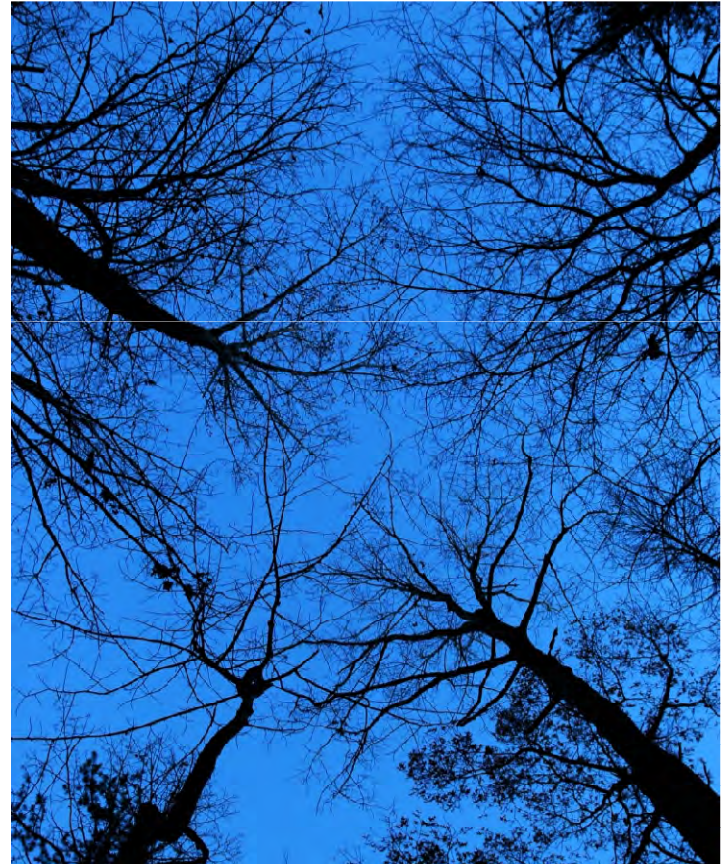
PUBLIC PERCEPTION

- Some operations are receiving pushback from public
- Striking a balance between preservation and public perception
- Being a good neighbor can decrease NIMBYism and is good “business”



SUSTAINABILITY

- Public perception and sustainability are linked
- A sustainable alternative is logical if practical – will it:
 - Decrease Maintenance?
 - Lower Costs?
 - Require Minimal / No Change to Protocol?



TORREFIED BIOMASS



HISTORY OF TORREFIED BIOMASS

- An outgrowth of 1920s coffee roasting technology
- NRRI has been developing for 10+ years
- Scaling up from laboratory to industrial scale
- AKA: “Biocoal”



CHARACTERISTICS OF “BIOCOAL”

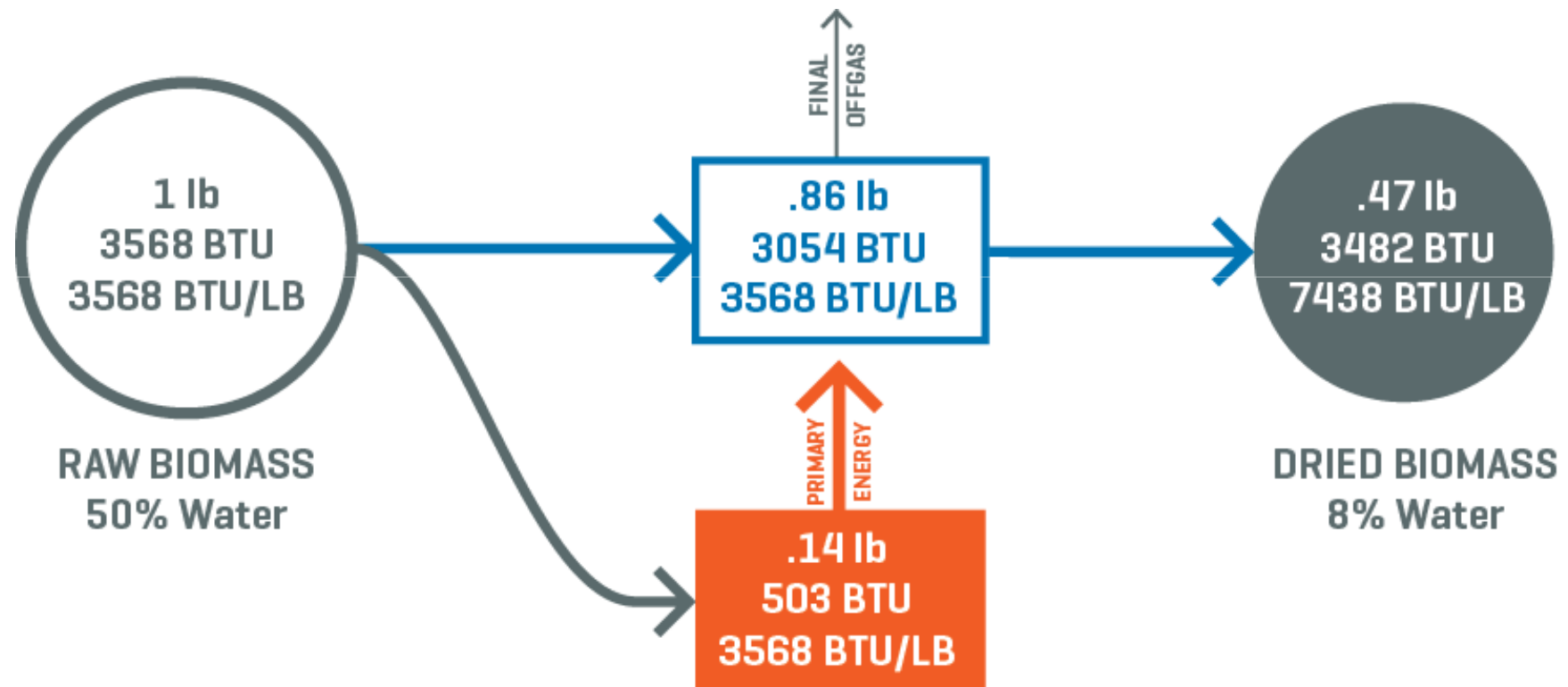
- Hydrophobic
- Same energy density as coal
- Same bulk density as coal
- No heavy metals
- Low in ash and moisture (~1%)
- Minimal / No Net Carbon Impact
- Can be formed into ideal shapes



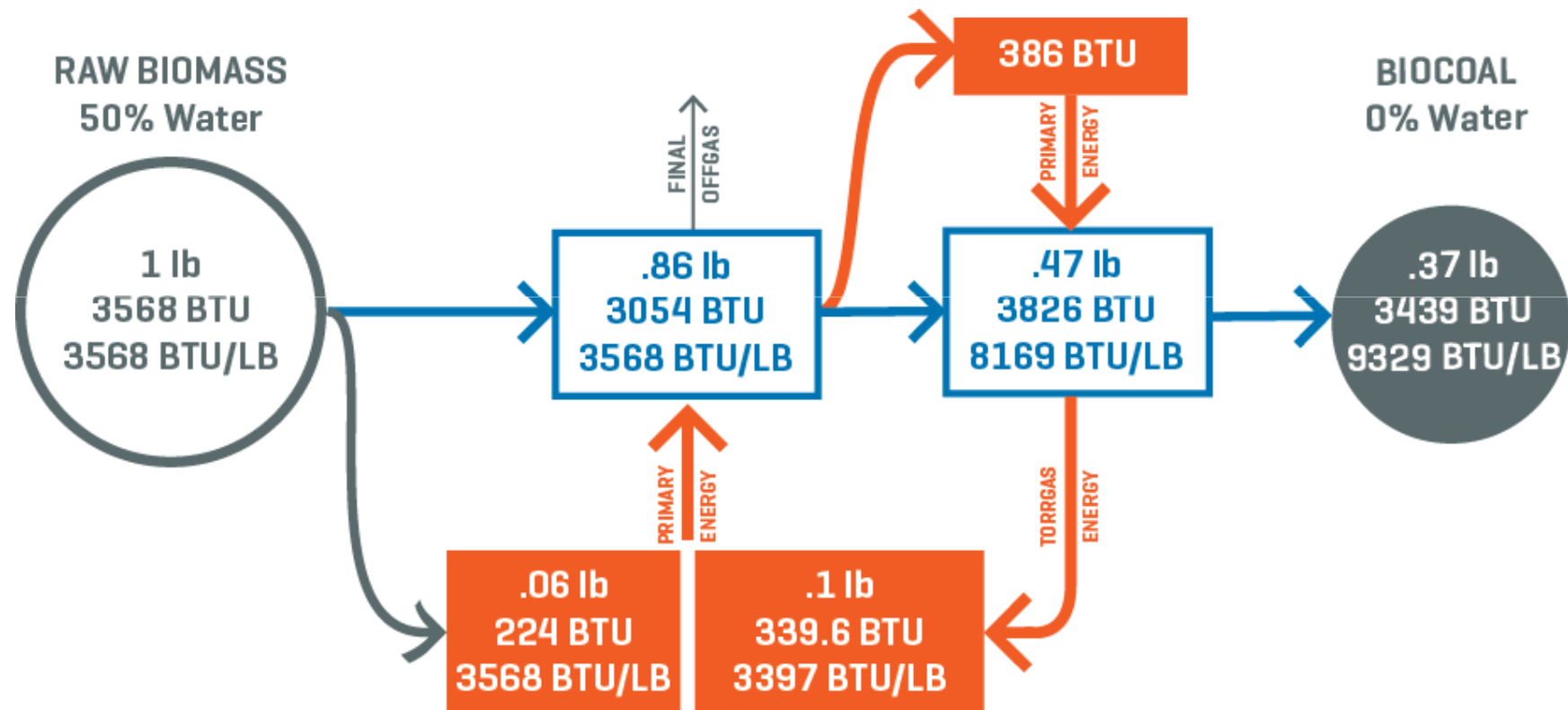
CHARACTERISTICS OF “BIOCOAL”

CHARACTERISTIC	WOOD	WOOD PELLETS	CHARCOAL	BIOCOAL	COAL
Moisture Content (% wt)	30 - 45	7 - 10	1 - 5	1 - 5	10 - 15
Calorific Value (BTU/lb.)	3,850 – 5,100	6,450 – 6,850	8,000 – 9,500	8,600 – 11,000	8,600 – 13,500
Volatiles (% db)	70 - 75	70 - 75	10 - 12	55 - 65	15 - 30
Bulk Density (lb/cu. ft.)	12.5 - 15.6	34.3 - 46.8	12.5	46.8 - 53.1	49.9 - 53.1
Vol. Density (BTU / cu. ft.)	53.7 - 80.5	201.3 - 279.1	161.0 - 171.8	402.6 - 501.9	493.8 - 638.8
Dust	Average	Limited	High	Limited	Limited
Hydroscopic Properties	Hydrophilic	Hydrophilic	Hydrophobic	Hydrophobic	Hydrophobic
Biological Degradation	Yes	Yes	No	No	No
Milling Requirements	Special	Special	Classic	Classic	Classic
Handling Properties	Special	Easy	Easy	Easy	Easy
Product Consistency	Limited	High	High	High	High
Transportation Cost	High	Average	Average	Low	Low

PROPERTIES OF WOOD DRYING



PROPERTIES OF TORREFACTION



COLERAINE ENERGY LAB - STATS

- Manufactures two types of torrefied biomass
- Able to make 14 tons-per-day
- Research scale and pre-industrial scale
- One-of-a-kind facility



Former Oliver Iron Mining Company RR
Backshop complex in Coleraine, MN

COLERAINE ENERGY LAB - 2014



COLERAINE ENERGY LAB - TODAY



BIOFUEL TESTING



WHY THE MILWAUKEE COUNTY ZOO?



- Size of the engine
 - Allows testing with 500 pounds of fuel, not tons
 - Large enough locomotive to generate significant draft
- Low risk operation
- Friendly management
- Relatively convenient location

BIOFUEL TESTING – ROUND ONE

- Goals:
 - Compare coal with biocoal, noting:
 - Temperature
 - Smoke / emissions characteristics
 - Other factors
 - Determine whether a non-modified engine can successfully burn the fuel
- Tests done in June 2016



BIOFUEL TESTING – ROUND ONE

- A lesson in compromise:



THE SETUP

MANUFACTURER: SANDLEY, 1977
TRACTIVE FORCE (lbs.): 2,070
LOCOMOTIVE WEIGHT (lbs): 14,000 (Approx.)
FIREBOX GRATE AREA (ft²): 4.375
BOILER PRESSURE (psi): 200
DRIVER DIAMETER (in.): 21.75
PISTON B x S (in.): 5.5 x 8
TRACK GAUGE (in.): 15



**TORREFIED BIOMASS
(PRE-WEIGHED)**

DIGITAL PRESSURE SENSOR FITTING

ENGINEER / FIREMAN (K. RISTOW)

EXTRA SPARK ARRESTING HARDWARE

**SMOKEBOX INSTRUMENTED
WITH THERMOCOUPLE**

DATA ACQUISITION WIRING

DATA ACQUISITION HARDWARE

DATA ACQUISITION LAPTOP

CSR RESEARCHER (W. FENGLER)

"CARIO" ROLLER BEARING BOXES

**FIREBOX INSTRUMENTED WITH
THERMOCOUPLES**

ROLLER BEARING TRUCKS

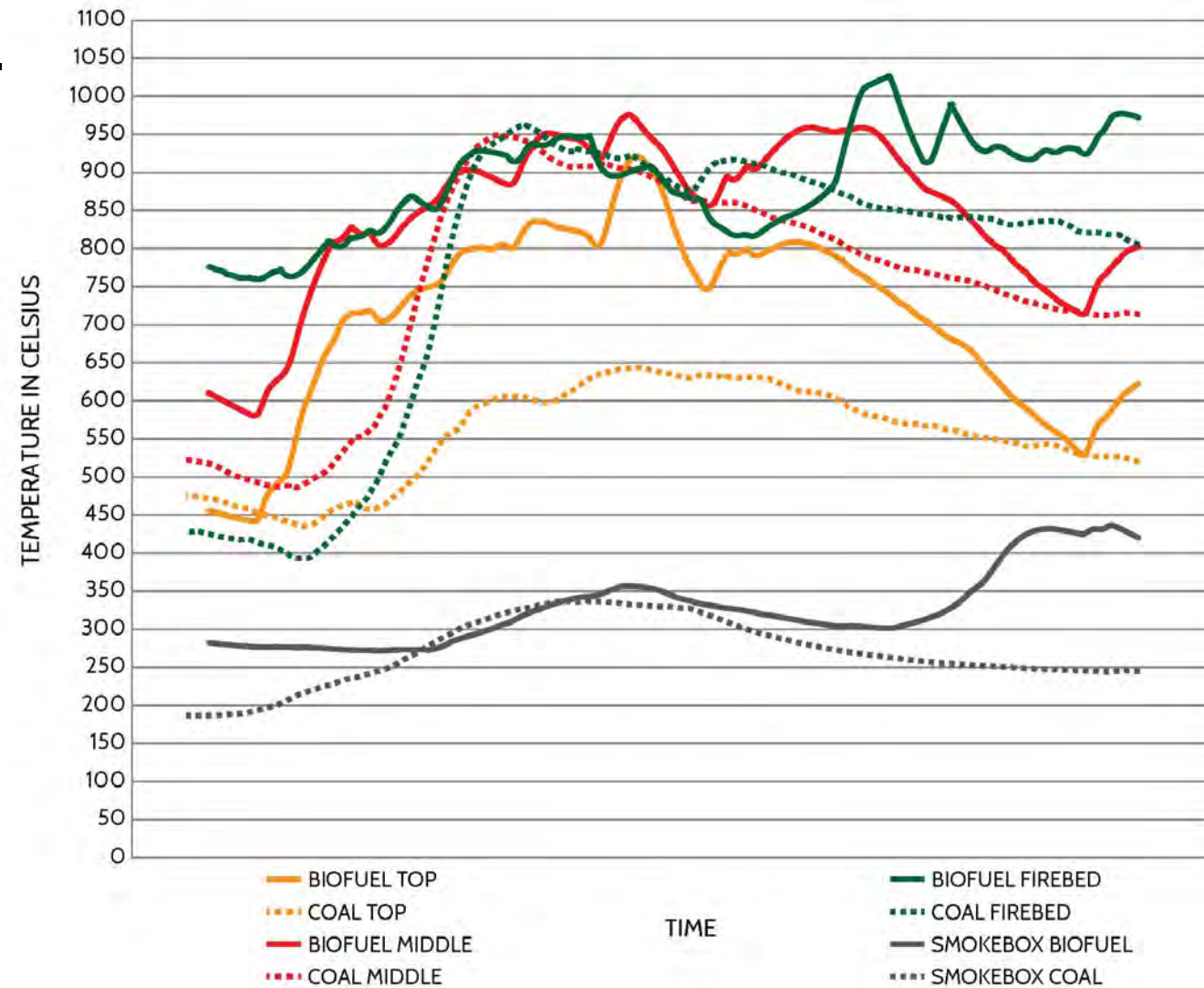
WATER FLOW METER



COALITION for
SUSTAINABLE RAIL

FOOTAGE OF THE
FIRST TORREFIED BIOMASS-POWERED
STEAM TRAIN RUN

RESULTS



FINDINGS

- Near-equal steaming ability as coal
- Low smoke
- Issues to be addressed:
 - Fuel sizing too small
 - Small sizing and densification method led to spark entrainment



BIOFUEL TESTING – ROUND TWO



BIOFUEL TESTING – ROUND TWO

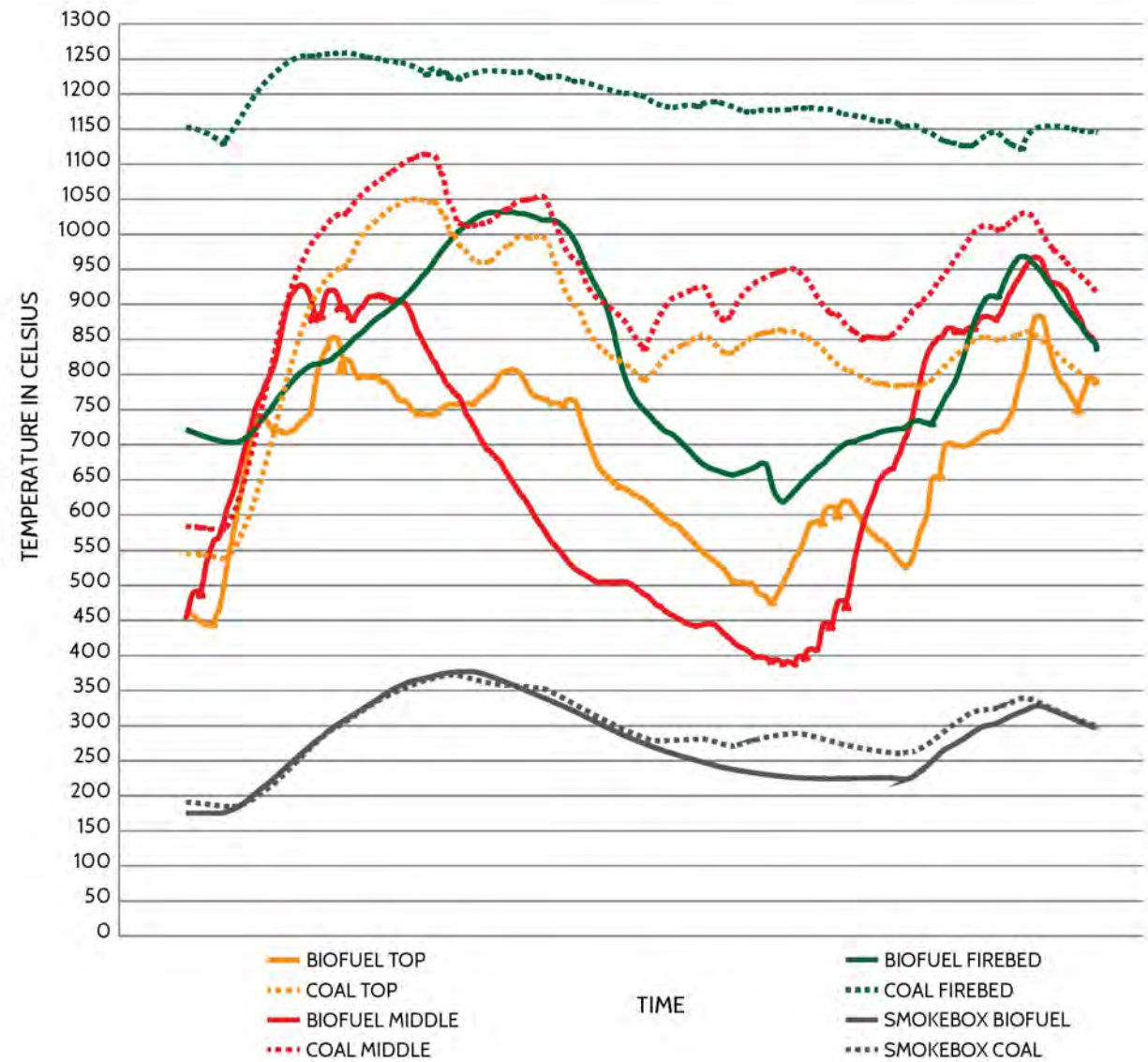
- First delivery of fuel from Coleraine Labs
 - 500 lbs
 - Densified in ram briquetter with minimal binder
- Same instrumentation
- Same comparative test
- October 2016



FIRING UP – COAL VS. BIOCOAL



RESULTS



FINDINGS

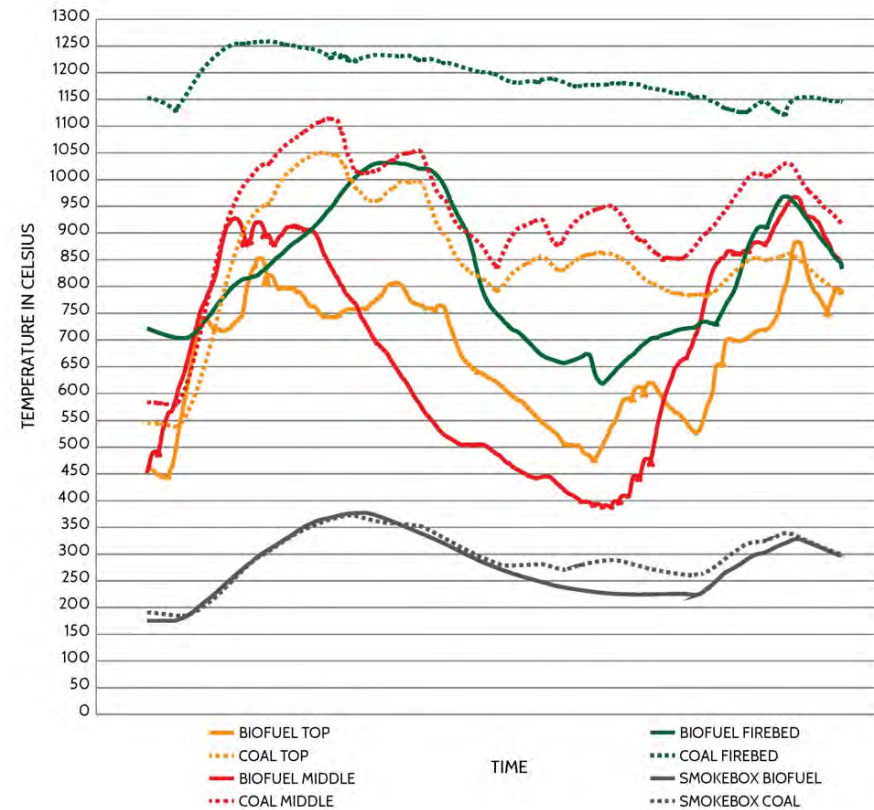
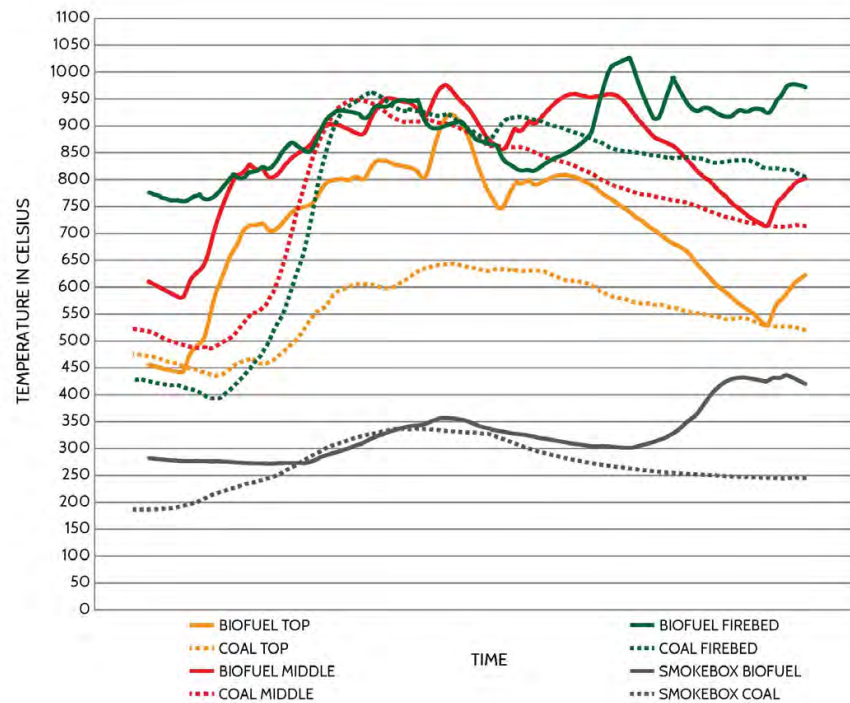
- Nearly zero smoke
- Lower temps compared with coal (densification)
- Large pellets enabled deeper firebed
- Issues to be addressed:
 - Lack of solid densification binder resulted in spark entrainment
 - Additional densification research undertaken thereafter



EMPIRICAL COMPARISON: TEST 1 V. 2



DATA COMPARISON: TEST 1 V. 2



FUTURE RESEARCH



FUEL-SIDE RESEARCH

- Hydrothermal carbonization (HTC)
 - Aqueous conversion of biomass
 - Results in more lignin in wood = natural binder
- Densification improvements
- Fuel blending
 - 50% biomass / 50% bituminous
 - 90% biocoal / 10% HTC
 - Others?



DENSIFICATION RESULTS

THEN



NOW



FUTURE TESTS: PART ONE - ZOO

- NRRI has developed the following blends of fuels for CSR to test at Zoo:
 - 98% biocoal, 2% binder
 - 49% biocoal, 49% coal, 2% binder
 - 90% biocoal, 10% HTC
- All blends to be densified with new briquetter
- Scheduled for early November 2017



FUTURE TESTS: PART TWO - EVRR

- The Everett Railroad (Pennsylvania) has graciously offered use of its 2-6-0 for standard gauge trials
- Following Zoo tests, CSR plans to scale up to make 7-10 tons of fuel for EVRR tests
- Fuel type / blend to reflect Zoo test results



CONCLUSIONS

- The potential of torrefied biomass to serve as a fuel for heritage rail is quite high
- Having experienced research collaborators is key in achieving improvements and successes
- Research is iterative, and taking a scalable approach keeps results repeatable and enables realistic scaling

MANY THANKS TO:

- The MILWAUKEE COUNTY ZOO
- The NATURAL RESOURCES RESEARCH INSTITUTE
- NEW BIOMASS ENERGY
- The EVERETT RAILROAD
- Photographers Oren B. Helbok, Dick Gruber, and the CENTER FOR RAILROAD PHOTOGRAPHY & ART
- And last, but not least, CSR's Supporters, without whom this research would not be possible!

THANK YOU!

WOLFGANG A. FENGLER
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COALITION for SUSTAINABLE RAIL



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