# US Efforts in Test Method Development for Residential Wood Heating Appliances

Lisa Rector, Northeast States for Coordinated Air Use Management (NESCAUM)
George Allen, NESCAUM
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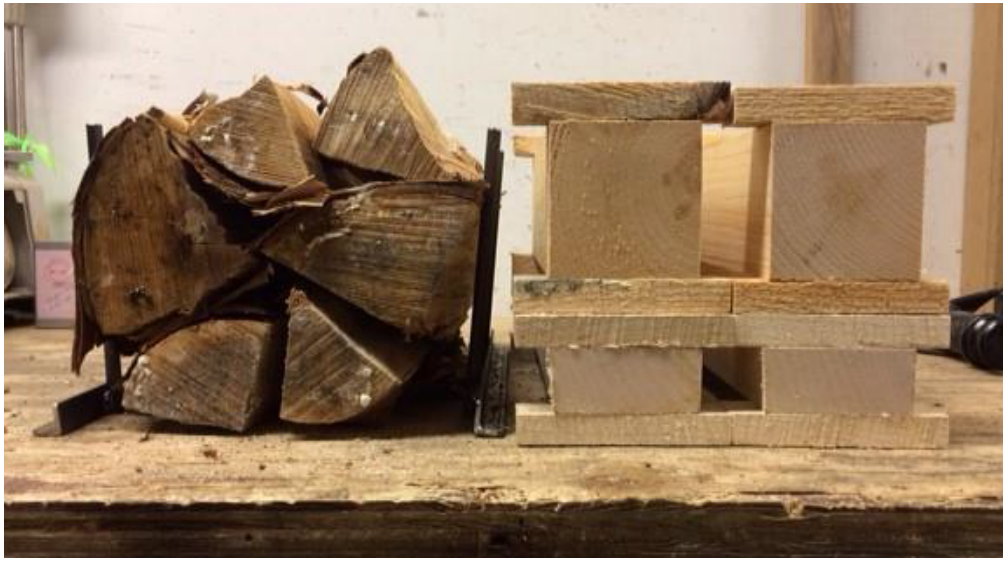
NESCAUM

# Project Context

* US Environmental Protection Agency promulgated new rules (New Source Performance Standards (NSPS) for residential wood heating devices in 2016
* Current test method
  * Operational protocol: 4 burn rates/hot to hot steady state
  * Fueling protocol – douglas fir or red oak cribs
  * Particulate Matter (PM) Measurement - dilution tunnel
* EPA NSPS Step 2 standards effective May 2020 include Alternative Compliance Standards with cordwood test
* States are interested in addressing residential wood heating emissions, especially from incentive programs



# Goals of US Test Method Research

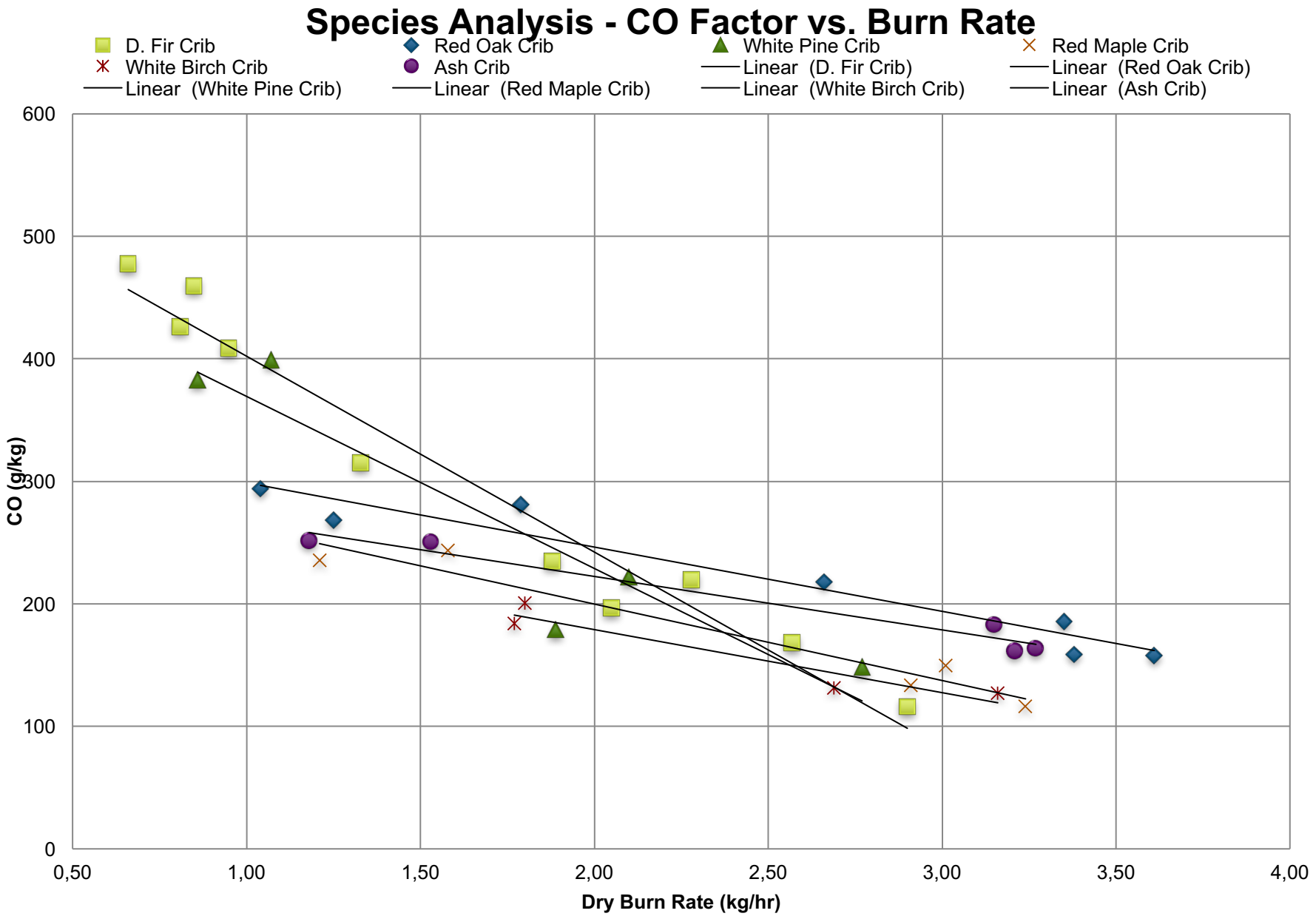
* Develop test methods that:
  * Reflect real world operating conditions
  * Capture typical emission cycles
  * Measure pollutants not currently captured in the existing test method
  * Develop capacity to validate field performance
* Create technical foundation to inform development of the test methods
* Multiple efforts to inform work
  * New York State Energy Research Development Authority (NYSERDA) effort with Brookhaven National Lab (BNL) and NESCAUM to develop methods for pellet, chip and cordwood boilers/furnaces
  * US EPA/NESCAUM effort to develop methods for stoves
  * Washington state/NESCAUM stove protocol testing

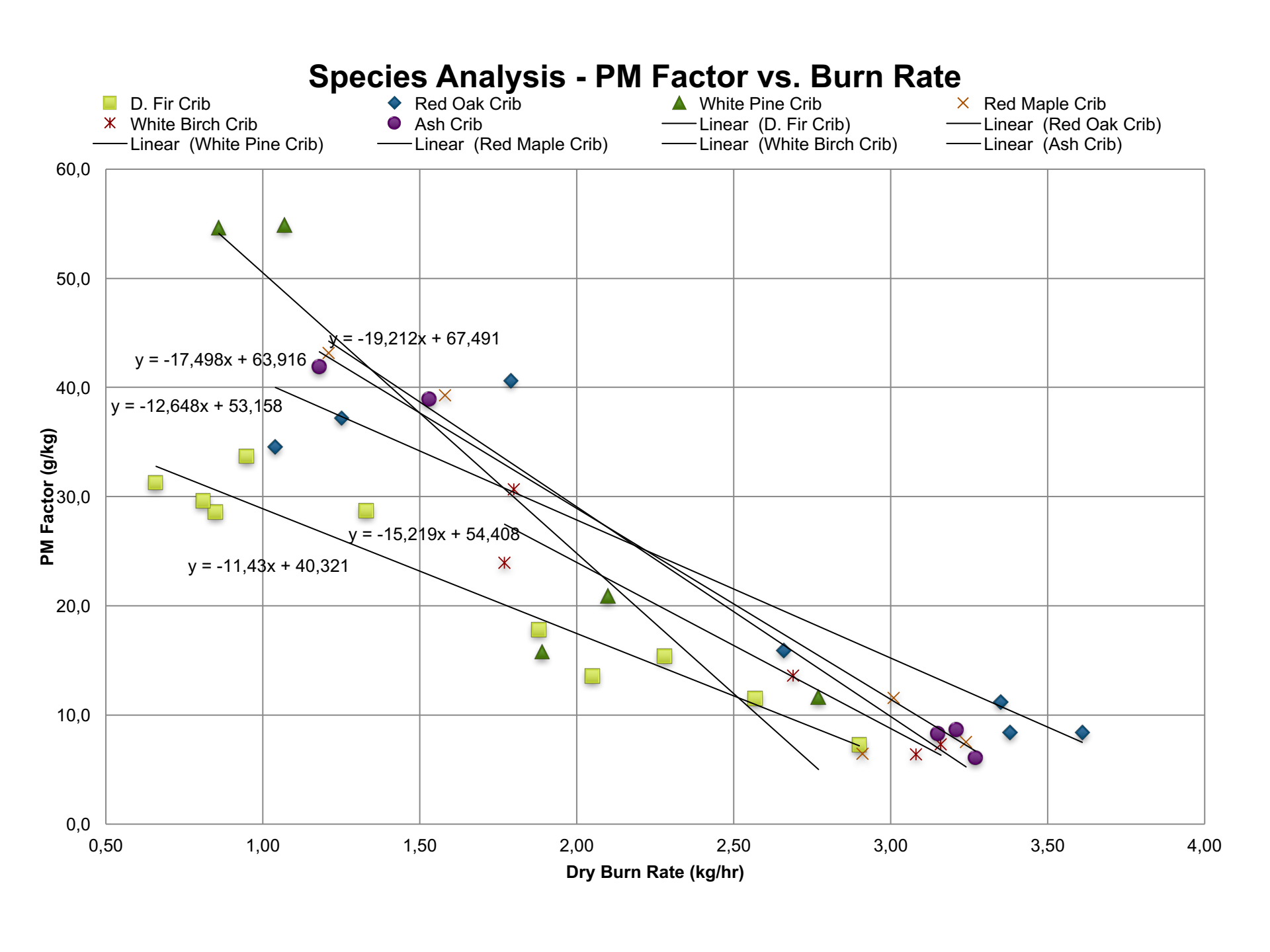
# Project Components

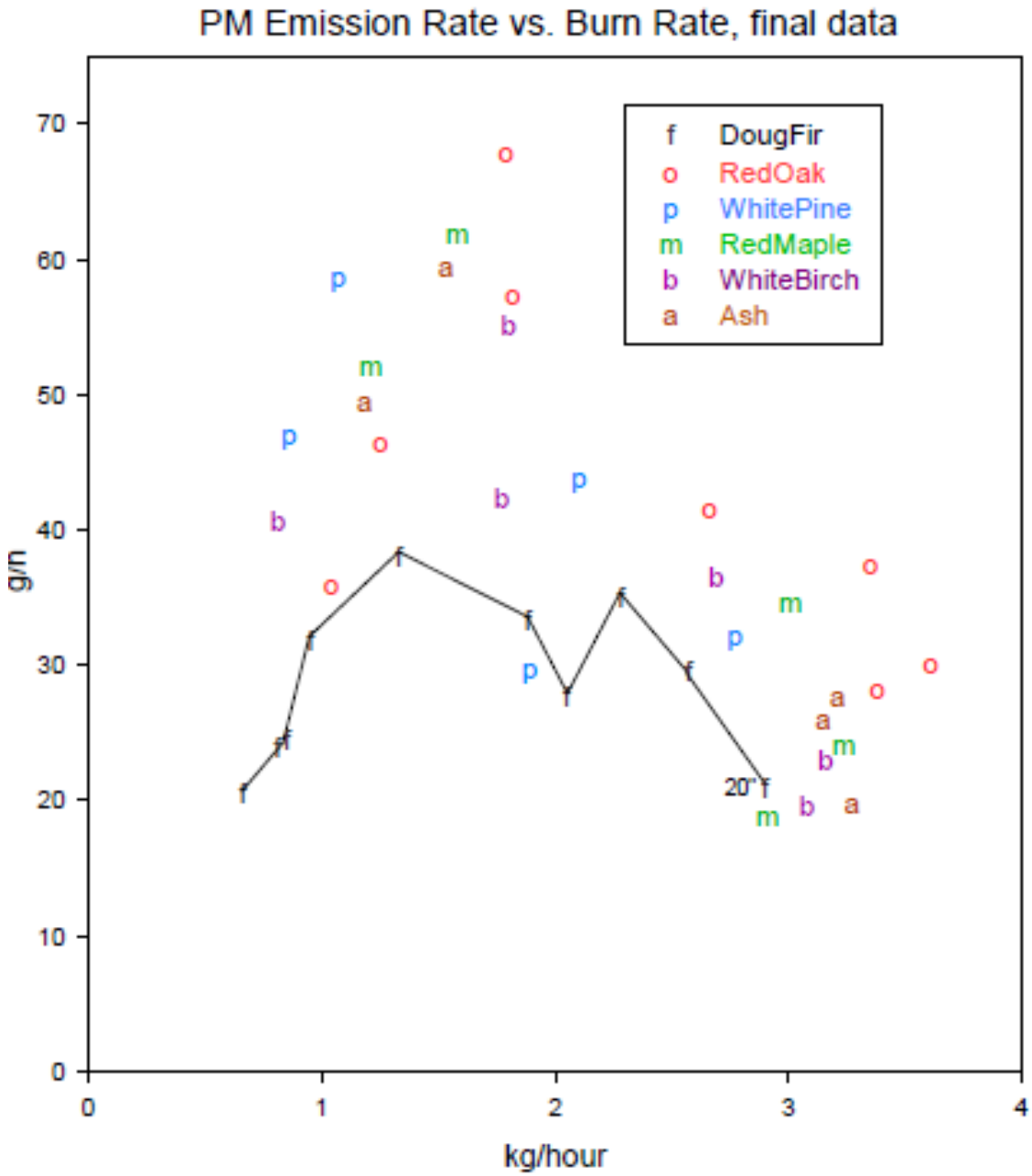
* Analyze real world use via data loggers
* Research fundamental fueling aspects to inform fueling protocol
  * Species impact
  * Crib wood to cord wood fuel
  * Piece size and moisture
* Research and recommend operational protocols
  * Separated performance categories
  * Integrated runs
* Research and recommend improvements to dilution tunnel measurements

# Fueling Protocol Species/Fuel Configuration

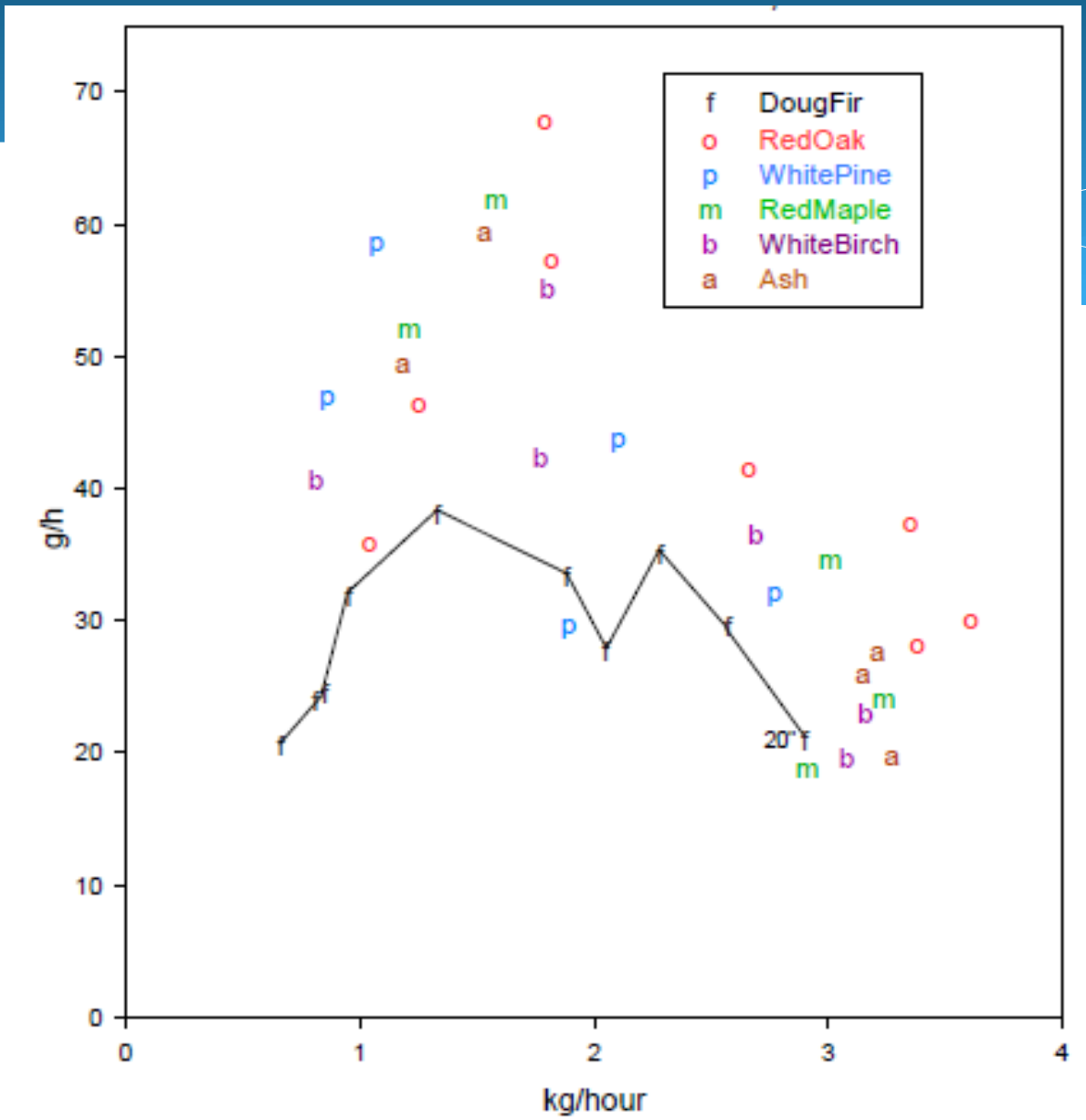
* Testing on a pre-NSPS stove
* Crib species variability
* Crib to cordwood variability


Species Analysis - CO Factor vs. Burn Rate
D. Fir Crib
Red Oak Crib
White Pine Crib
Red Maple Crib
White Birch Crib
Ash Crib
Linear (D. Fir Crib)
Linear (Red Oak Crib)
Linear (White Pine Crib)
Linear (Red Maple Crib)
Linear (White Birch Crib)
Linear (Ash Crib)
CO (g/kg)
600
500
400
300
200
100
0
0,50
1,00
1,50
2,00
2,50
3,00
3,50
4,00
Dry Burn Rate (kg/hr)


Species Analysis - PM Factor vs. Burn Rate
D. Fir Crib
Red Oak Crib
White Pine Crib
Red Maple Crib
White Birch Crib
Ash Crib
Linear (D. Fir Crib)
Linear (Red Oak Crib)
Linear (White Pine Crib)
Linear (Red Maple Crib)
Linear (White Birch Crib)
Linear (Ash Crib)
y = -19,212x + 67,491
y = -17,498x + 63,916
y = -12,648x + 53,158
y = -15,219x + 54,408
y = -11,43x + 40,321
PM Factor (g/kg)
Dry Burn Rate (kg/hr)
60,0
50,0
40,0
30,0
20,0
10,0
0,0
0,50
1,00
1,50
2,00
2,50
3,00
3,50
4,00


PM Emission Rate vs. Burn Rate, final data
f DougFir
o RedOak
p WhitePine
m RedMaple
b WhiteBirch
a Ash
g/h
kg/hour
0
10
20
30
40
50
60
70
0
1
2
3
4
20"

# Species Analysis – Emission Factor/Emission Rate



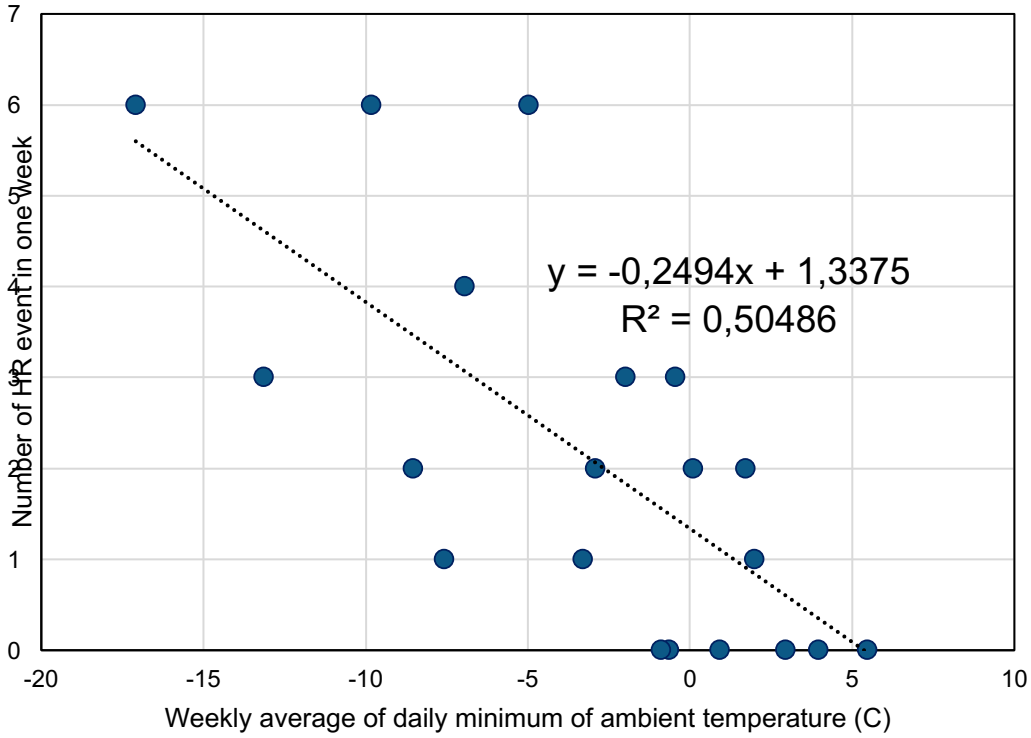
# Operational Protocol
# Data Logger Analysis

* Logging stack temperature profiles to obtain in-use data
* Devices monitored
  * 4 EPA NSPS Step 1 certified Outdoor Wood Boilers
  * 4 indoor furnaces
  * 25+ wood stoves
* Three climate zones
  * Northern New York
  * Long Island, New York
  * Washington state

# Data Logger Results – OWB (House 16)

| Normalized Temperature Range | Percentage of time |
|---|---|
| 0 < T < 20% | 95.34% |
| 20% < T < 40% | 4.37% |
| 40% < T < 60% | 0.19% |
| 60% < T < 80% | 0.06% |
| 80% < T < 100% | 0.04% |

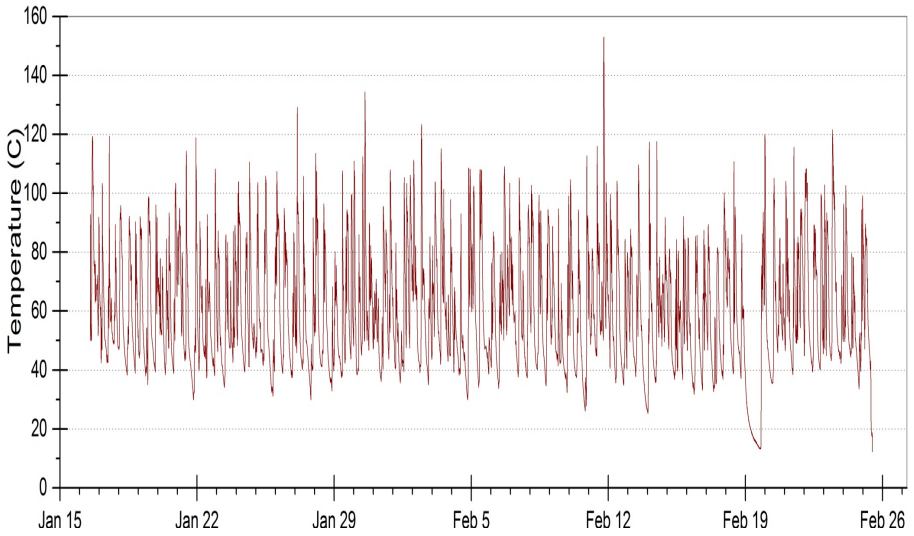
HR event vs. Weekly Average of Min Temperature

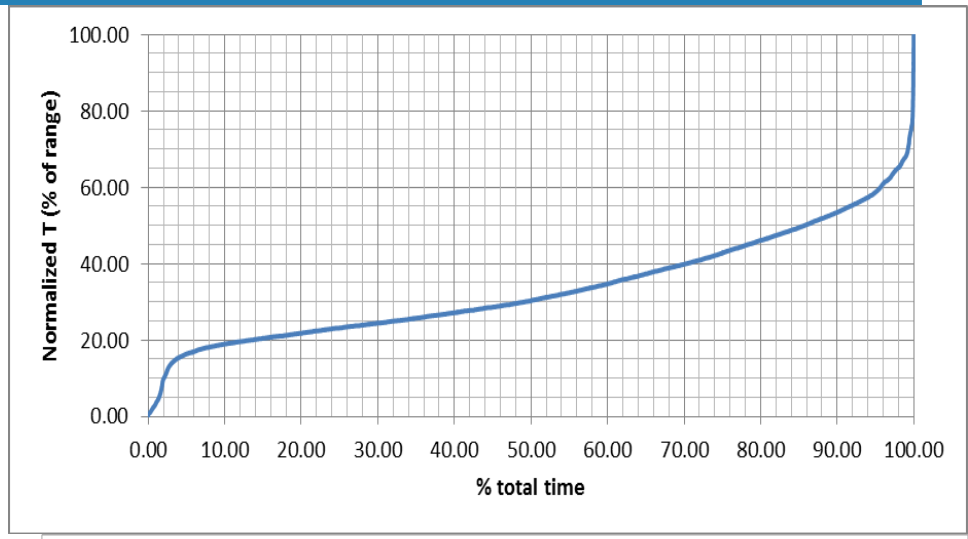


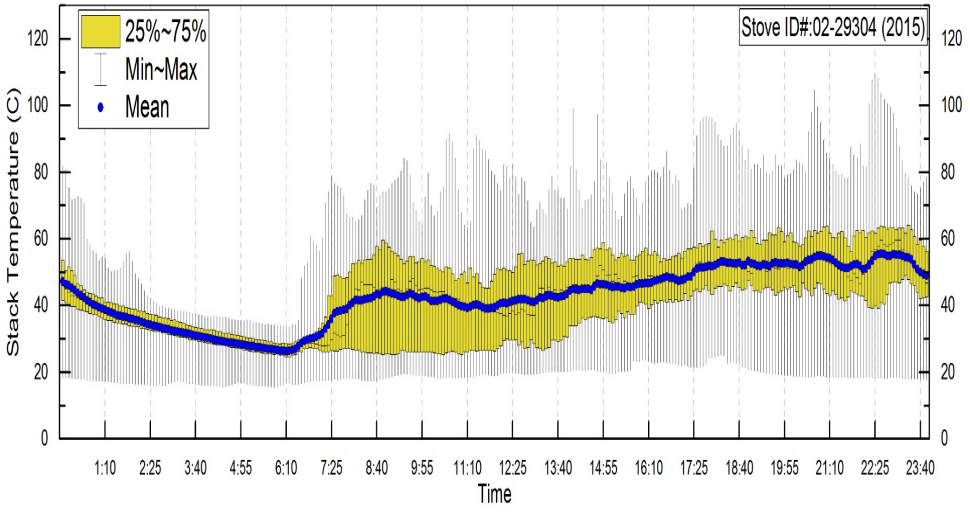

- 6 Cold starts during 103 days
- 37 Total hot reloads
- 1 hot reload every 45.5 hrs of operation

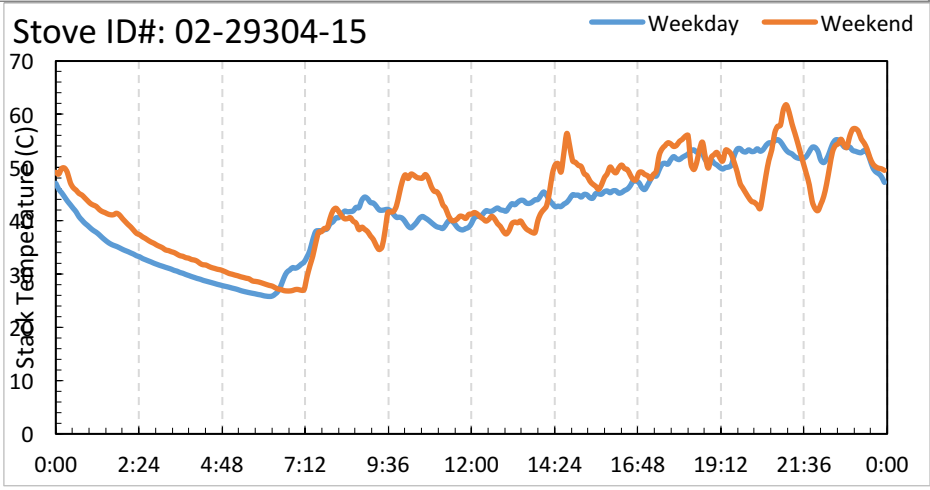
| OWB - House 16 | |
|---|---|
| Time OWB not in use | 32.0 % |
| Time OWB in-use | 68.0 % |

# Data Logger Results
# Wood stove

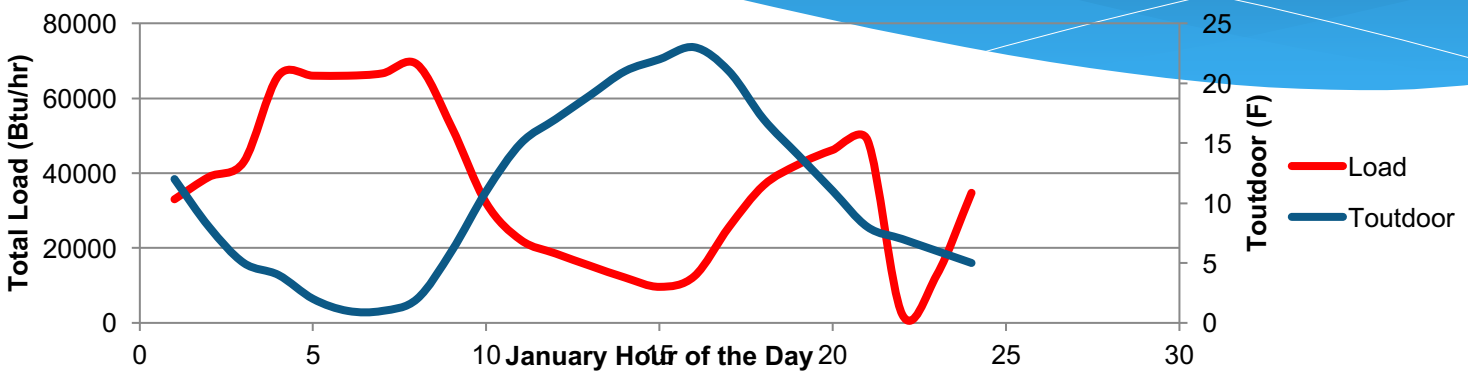


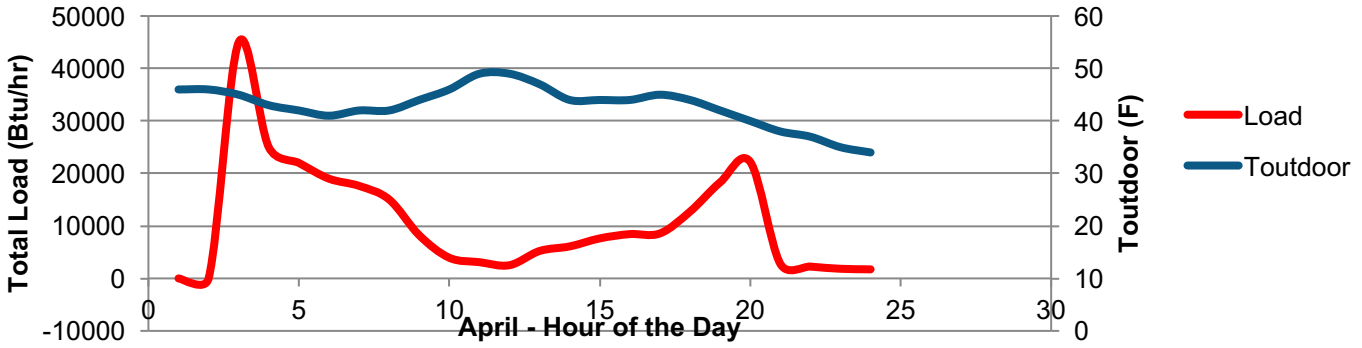



# Operational Protocols
# Modeling Analysis of Load Patterns



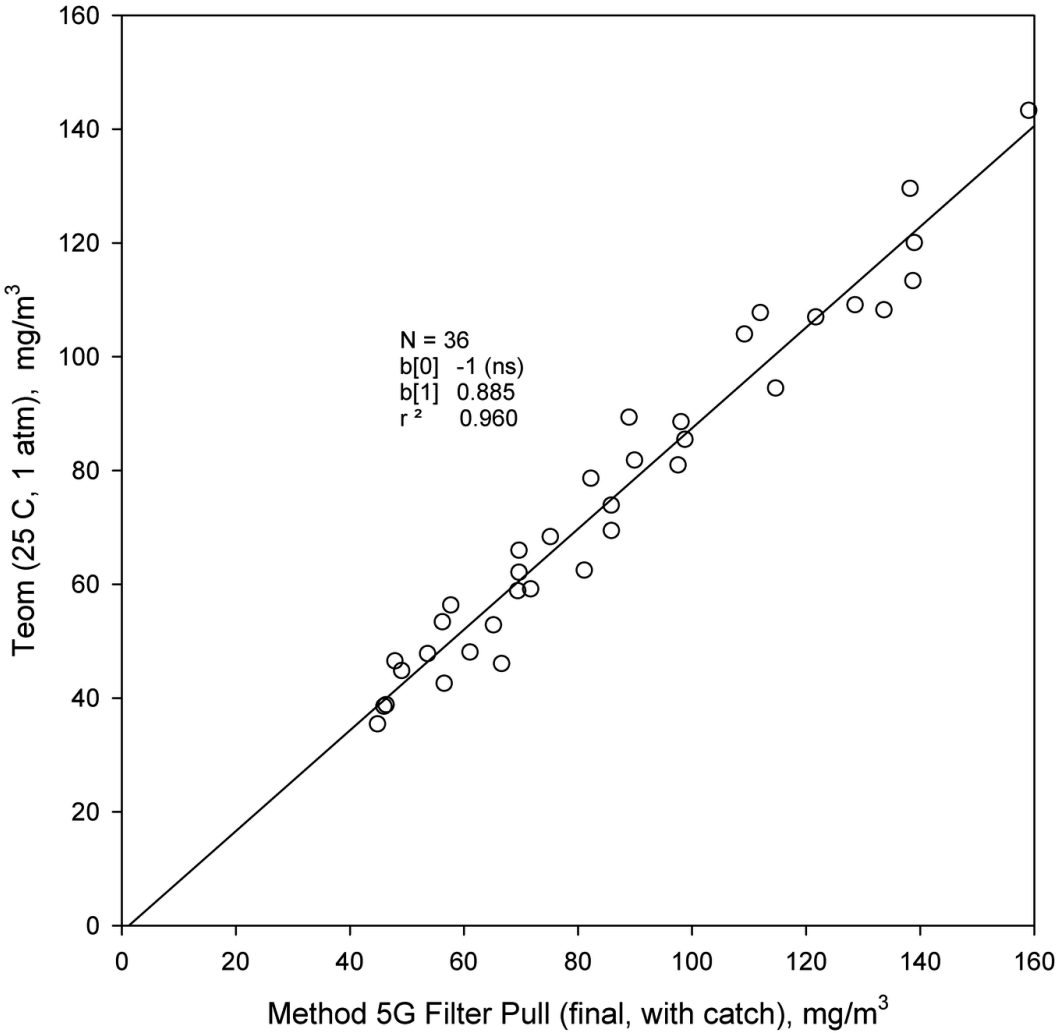




**Typical heating system load profile**
**Albany, 2500 ft$^2$, with DHW and night setback**

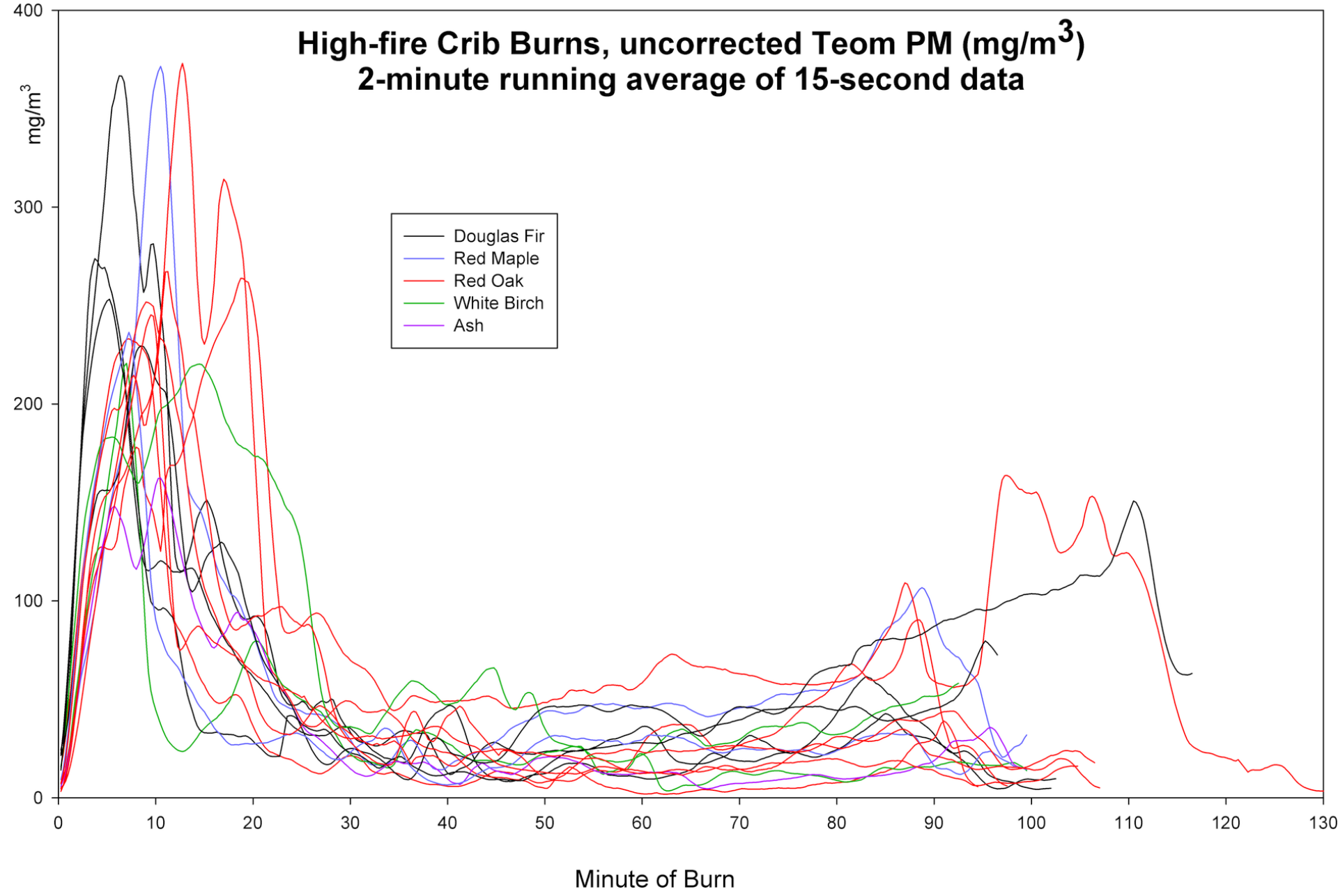
*Graphs courtesy of BNL*

# Operational Protocol – TEOM* data

## 25C Teom vs. Filter PM in dilution tunnel
## August 2016 - January 2017 Crib Tests




**tapered element oscillating microbalance*


High-fire Crib Burns, uncorrected Teom PM (mg/m3)
2-minute running average of 15-second data
mg/m3
Douglas Fir
Red Maple
Red Oak
White Birch
Ash
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
Minute of Burn

# PM Measurement

* Project Components
  * Filter type – glass fiber vs Pall Emfab (Teflon coated)
* Other considerations
  * Avoid liquid water anywhere in sample system
  * Limit filter temperature during sampling
  * Limit dilution tunnel temperature
  * Sample duration (# of filters/run)
  * Filter equilibration conditions (T/RH, Time)
  * Balance resolution (0.01 mg or better)

# Thank You

# Questions?

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BROOKHAVEN NATIONAL LABORATORY

NEW YORK STATE OF OPPORTUNITY.

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