NESCAUM

Integrated Duty Cycle (IDC) Protocols

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Why focus on test methods?

Test Methods are difficult

Complex

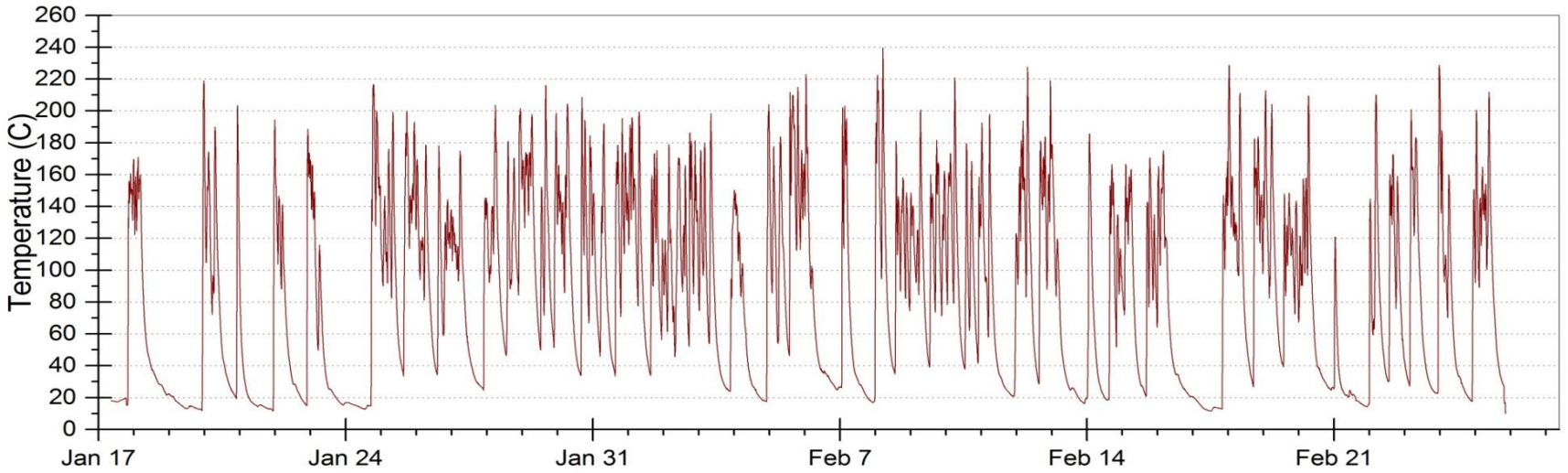
Detail-oriented

Arcane

Understanding what the tests measure and what the values mean is a critical underpinning to identifying top-performing technologies.

If the test is not valid or representative, what value is the data?

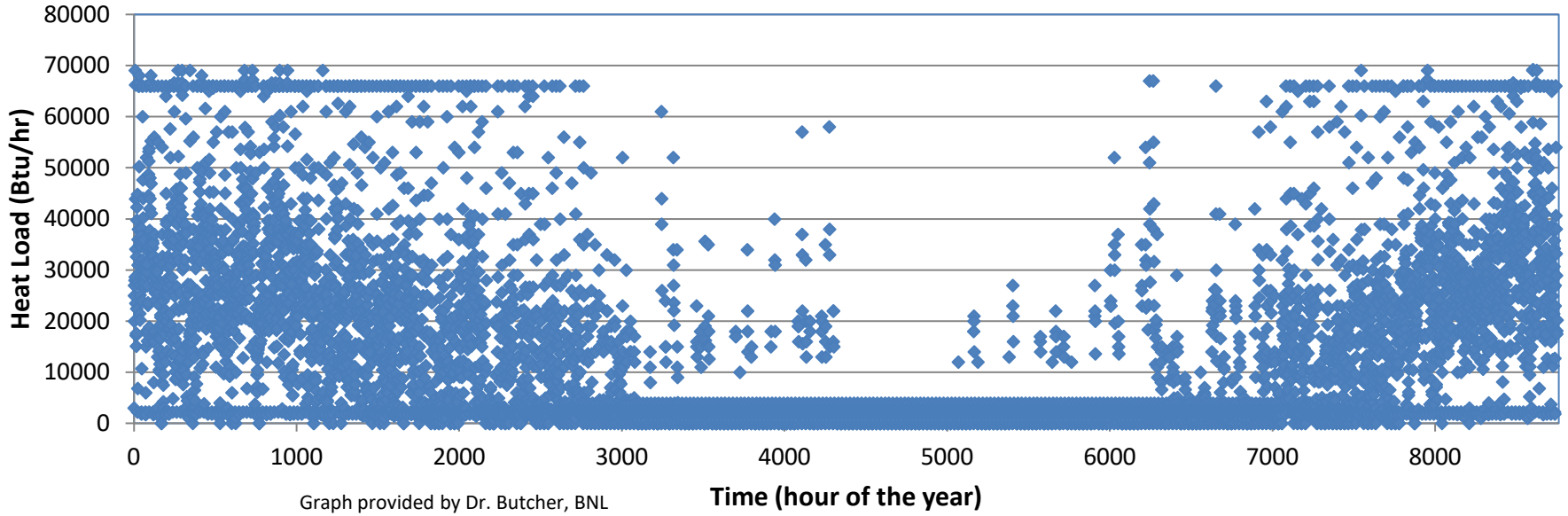
Real-World Operation is Highly Variable



Day-to-day operations highlights:

- Cyclic operations
- Variable loads

In-situ data logging performed, manuscript published in JAWMA

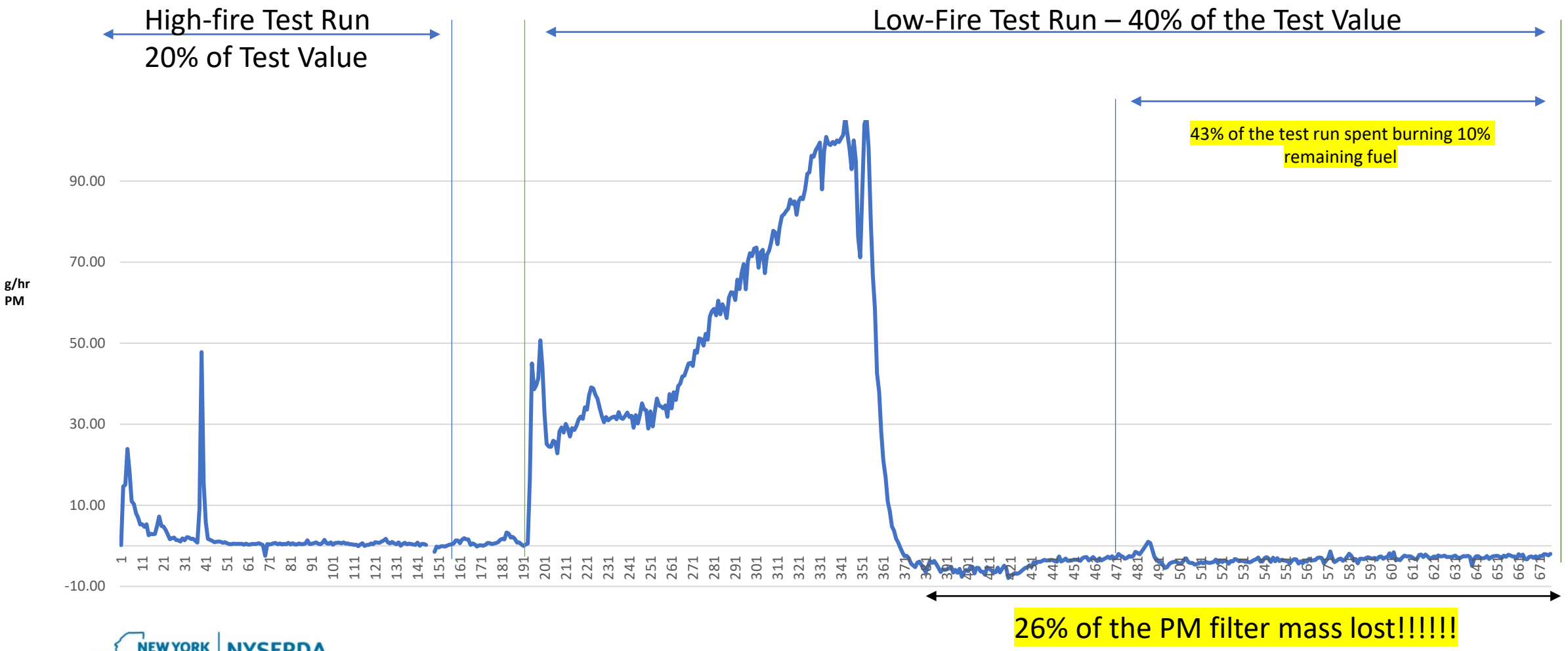


Graph provided by Dr. Butcher, BNL

Annual heat load analysis highlights:

- Load demand is highly variable
- Need to assess how appliance responds to heat demand rather than specifying load

Anatomy of a Steady-State Test



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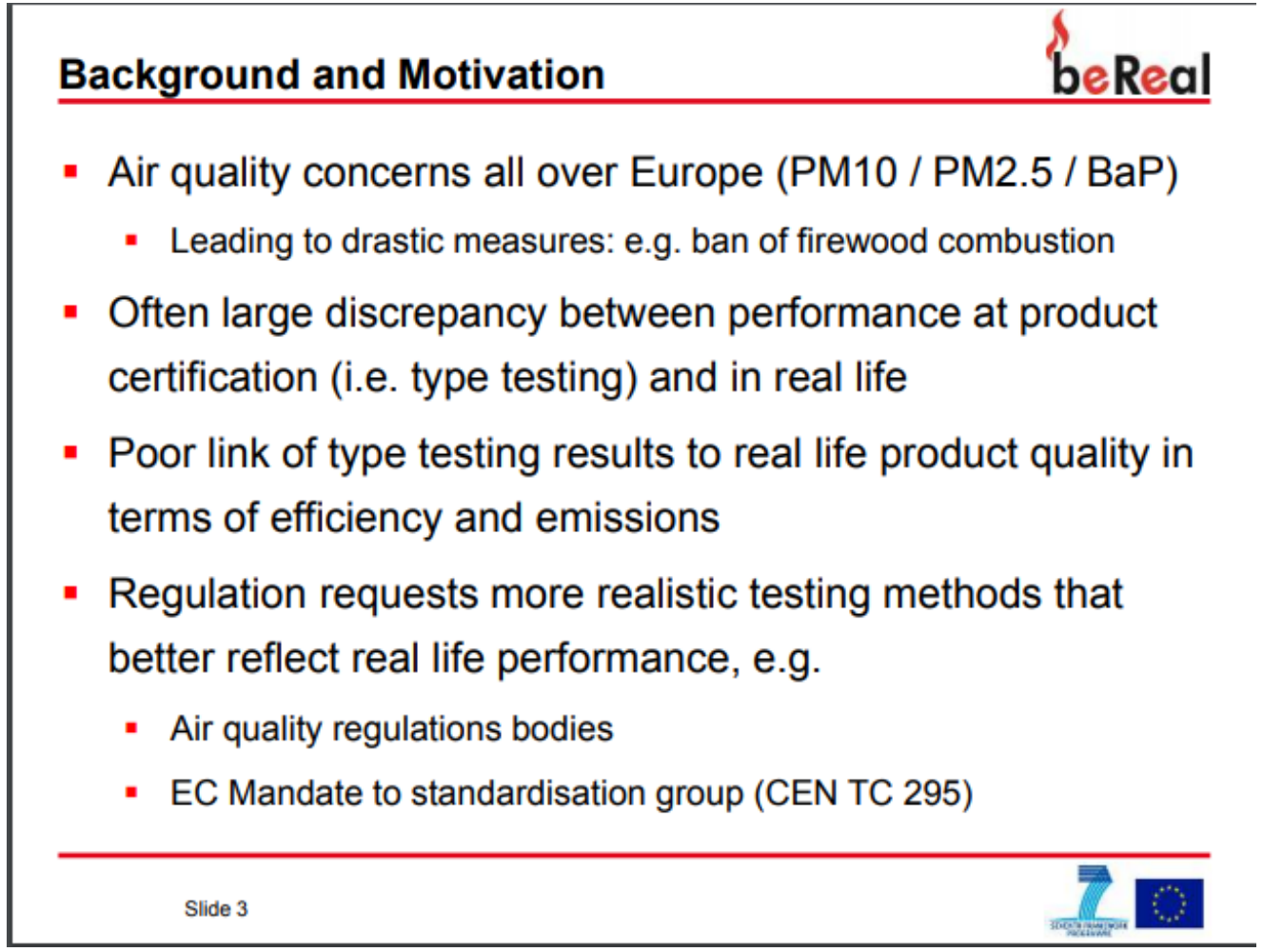
Key issues with existing test methods

- Using the same loading configuration for every test
- Burning fuel loads to 100%
- Mal-Adaptations - vaguely written methods allow broad interpretation
- UNLIKE any other test method
  - NO replicate runs so no assessment of performance variability
  - Test until you pass

Integrated Duty Cycle (IDC) Testing

- Builds on European framework - 4.9 million Euro project – BeReal - http://www.bereal-project.eu/
- Overlays typical US installation over BeReal approach: (1) building stock, (2) user operational patterns, and (3) annual demand profiles.
- Revised protocol to reflect differing US use profiles, emission measurement methods, and regulatory framework.



Development of IDC Protocols

- Built on philosophy of European Test Method Effort (BeReal), BUT applied to reflect US market conditions.
- Added replicate testing
- Adopts new measurement approaches
  - TEOM
  - pDR
  - CO and CO_2 measurements in the dilution tunnel
  - Moves away from ASTM methods and returns to use of EPA Methods
- Developed in partnership with many stakeholders
  - Industry consultants
  - Manufacturers
  - National experts on PM measurement
  - National Lab (Brookhaven National Lab)
  - Regulators (local, state, federal)
  - State energy organization
  - Testing labs

IDC Protocols

Assesses appliance performance under variable operation and fueling configurations

Requires three repeat runs to determine performance variability

Requires appliance to be tested with production settings

Does not allow variation in setpoints during testing other than those specified in protocol

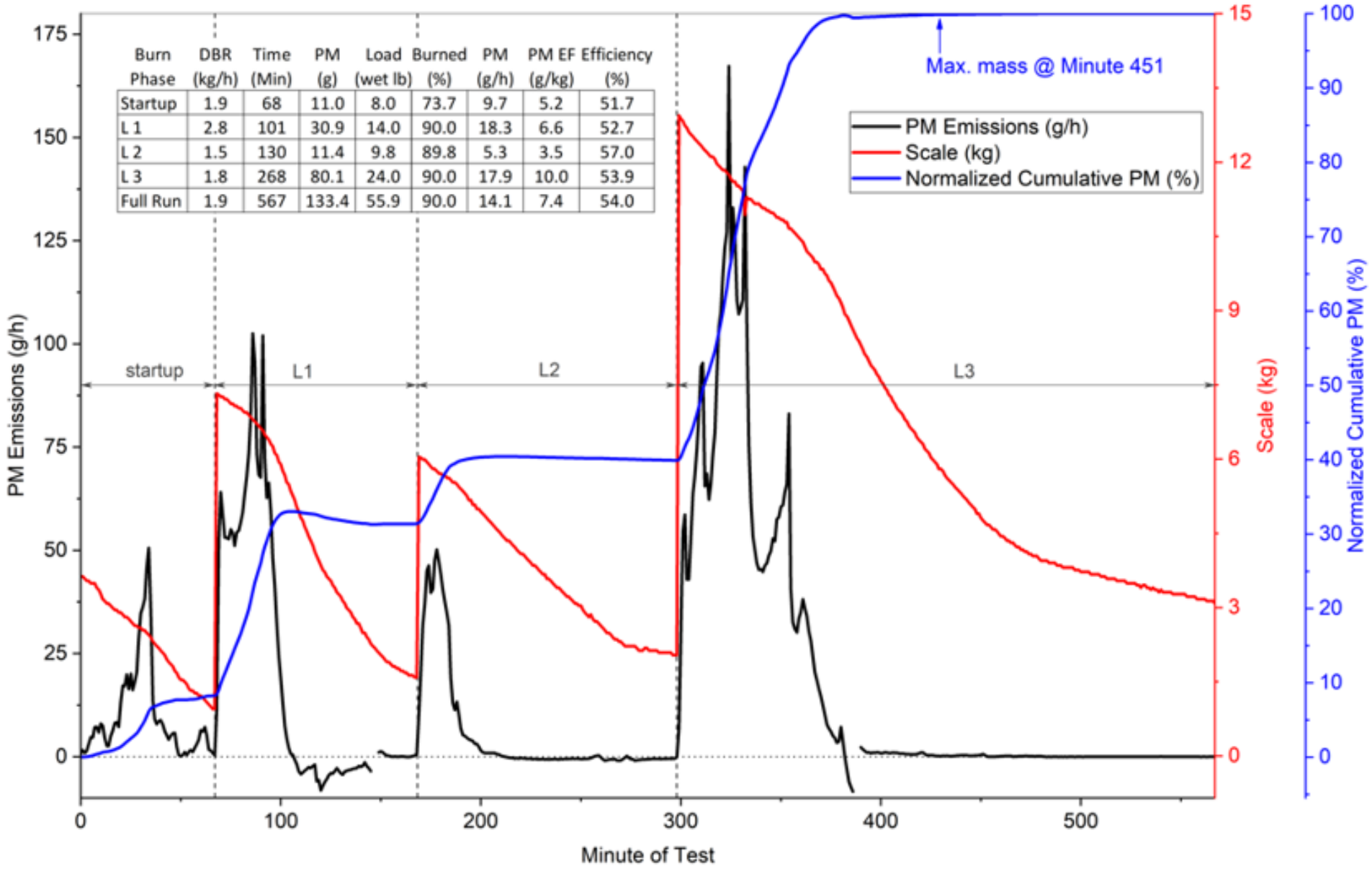
Fueling calculator creates common approach for fueling across all certification tests that scales to appliance firebox volume

Does not allow the use of manufacturer instructions, only owners manual information.

Cordwood Stove IDC

- Operation Protocols – 5 phases
  - incorporates operational patterns reflective of daily and annual operations: start-up, building heat, maintaining heat, overnight burns
  - Measurements from matchlight to test end
  - Phases end when 90% of fuel charge is burned
- Fueling Protocols – 4 fuel loads
  - Each load has different loading volume, fuel configuration, and coal bed weights
  - Fuel piece configuration scales in size and number of pieces by firebox volume
  - Requires fuel analysis of test load
- Measurement Protocols
  - Real-time PM Measurements
  - CO measured in the dilution tunnel and stack
  - CO_2 measured in the dilution tunnel
- Efficiency Measurements
  - Minute by minute calculations

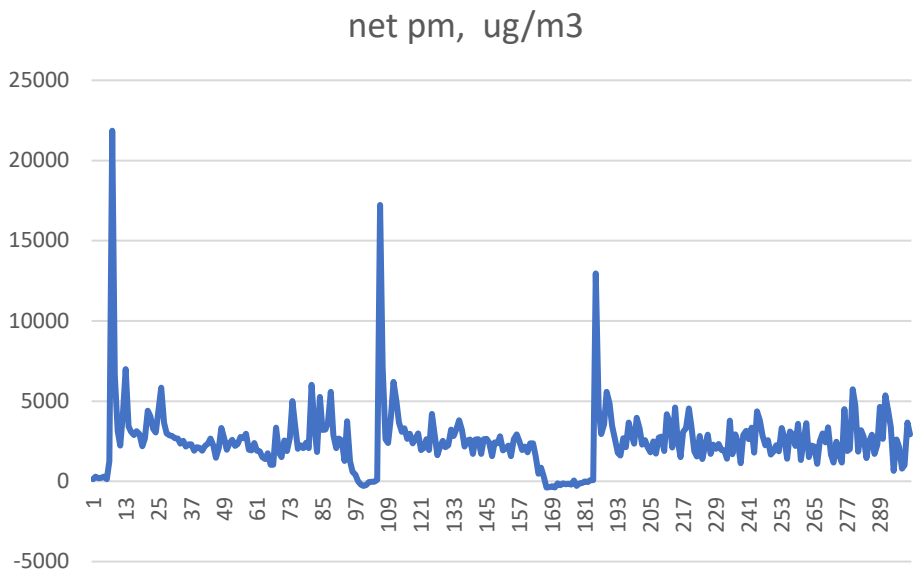
Phase	Mode	Air Setting	Fuel load/coal bed
L1	Start-up	High	• 4 lb/ft^3 • Kindling & starter fuel • No coal bed
L2A	High	High	• 7 lb/ft^3 • Small pieces • Coal bed ~1.2 lb/ft^3
L2B	Med	Low	None
L3	Maint.	Low	• 5 lb/ft^3 • 2-3 large pieces • Coal bed ~1.9 lb/ft^3
L4	Overnight	Low	• 12 lb/ft^3 • Mix of small & large pieces • Coal bed ~2.5 lb/ft^3


Burn Phase | DBR (kg/h) | Time (Min) | PM (g) | Load (wet lb) | Burned (%) | PM (g/h) | PM EF (g/kg) | Efficiency (%)
Startup | 1.9 | 68 | 11.0 | 8.0 | 73.7 | 9.7 | 5.2 | 51.7
L 1 | 2.8 | 101 | 30.9 | 14.0 | 90.0 | 18.3 | 6.6 | 52.7
L 2 | 1.5 | 130 | 11.4 | 9.8 | 89.8 | 5.3 | 3.5 | 57.0
L 3 | 1.8 | 268 | 80.1 | 24.0 | 90.0 | 17.9 | 10.0 | 53.9
Full Run | 1.9 | 567 | 133.4 | 55.9 | 90.0 | 14.1 | 7.4 | 54.0
Max. mass @ Minute 451
PM Emissions (g/h)
Scale (kg)
Normalized Cumulative PM (%)
startup
L1
L2
L3
PM Emissions (g/h)
Scale (kg)
Normalized Cumulative PM (%)
Minute of Test

Auto-Feed (Pellet & Chip) Stove IDC

Phase	Mode	Time
1	High	60
2	Low	30
3	Off	10
4	Low	30
5	High	30
6	Off	20
7	Med	90
8	Low	30

- Operation Protocols – 8 phases
  - incorporates operational patterns reflective of daily and annual operations: different operational modes, and restart periods.
  - 3 starts – one cold, two warm – time differential
- Fueling Protocols
  - Each fuel allowed must be assessed.
  - Requires fuel analysis of test fuel
- Measurement Protocols
  - Real-time PM Measurements
  - CO measured in the dilution tunnel and stack
  - CO_2 measured in the dilution tunnel
- Efficiency Measurements
  - Minute by minute calculations



Cordwood/Auto-Fed Hydronic Heater IDC

IDC Test Procedure Summary	
Start-up Phase	• Startup • Pull off heat as needed when approaching operating temperature limit and ramp up to 100%
Phase 1	100% heat demand 60 minutes

Phase 2	• 13% heat demand (+/-2%) for 120 minutes or after one cycle, whichever comes first.
	• If unit:
	  • cycle 0-30 minutes = 6 cycles in Phase 4.
	  • cycle 31-60 minutes = 4 cycles in Phase 4.
	  • cycle 61-90 minutes = 3 cycles in Phase 4.
	  • cycle 91-120 minutes = 2 cycles in Phase 4.
	  • No cycle = 1 cycle Phase 4.

Phase 3	No heat demand for 45 minutes
Phase 4	Forced cycling - Must complete 1-6 cycles, as determined by cycling time in Phase 2.
Phase 5	• 100% heat demand for 60 minutes

- Single Protocol for units with and without thermal storage
- Operation Protocols – 5 phases
  - incorporates operational patterns reflective of daily and annual operations: start-up, building heat, maintaining heat, overnight burns
  - Measurements from matchlight to test end
- Fueling Protocols
  - Each fuel allowed in test method must be assessed.
  - Three fuel loads for cordwood boilers – different size and fuel configurations
    - Fuel piece configuration scales in size and number of pieces by firebox volume
  - Requires fuel analysis of test fuel
- Measurement Protocols
  - Real-time PM Measurements
  - CO measured in the dilution tunnel and stack
  - CO_2 measured in the dilution tunnel
- Efficiency Measurements
  - Minute by minute calculations

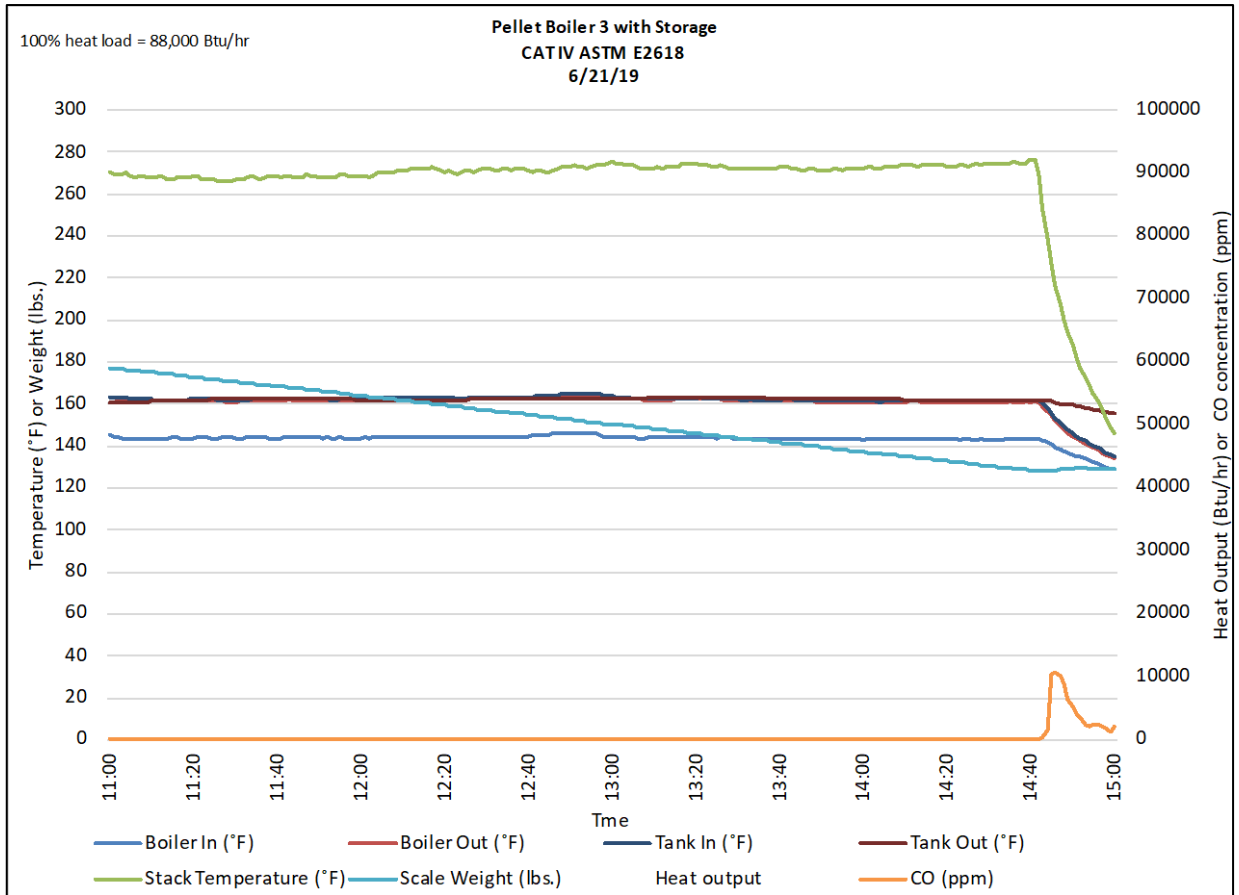
What's the Difference

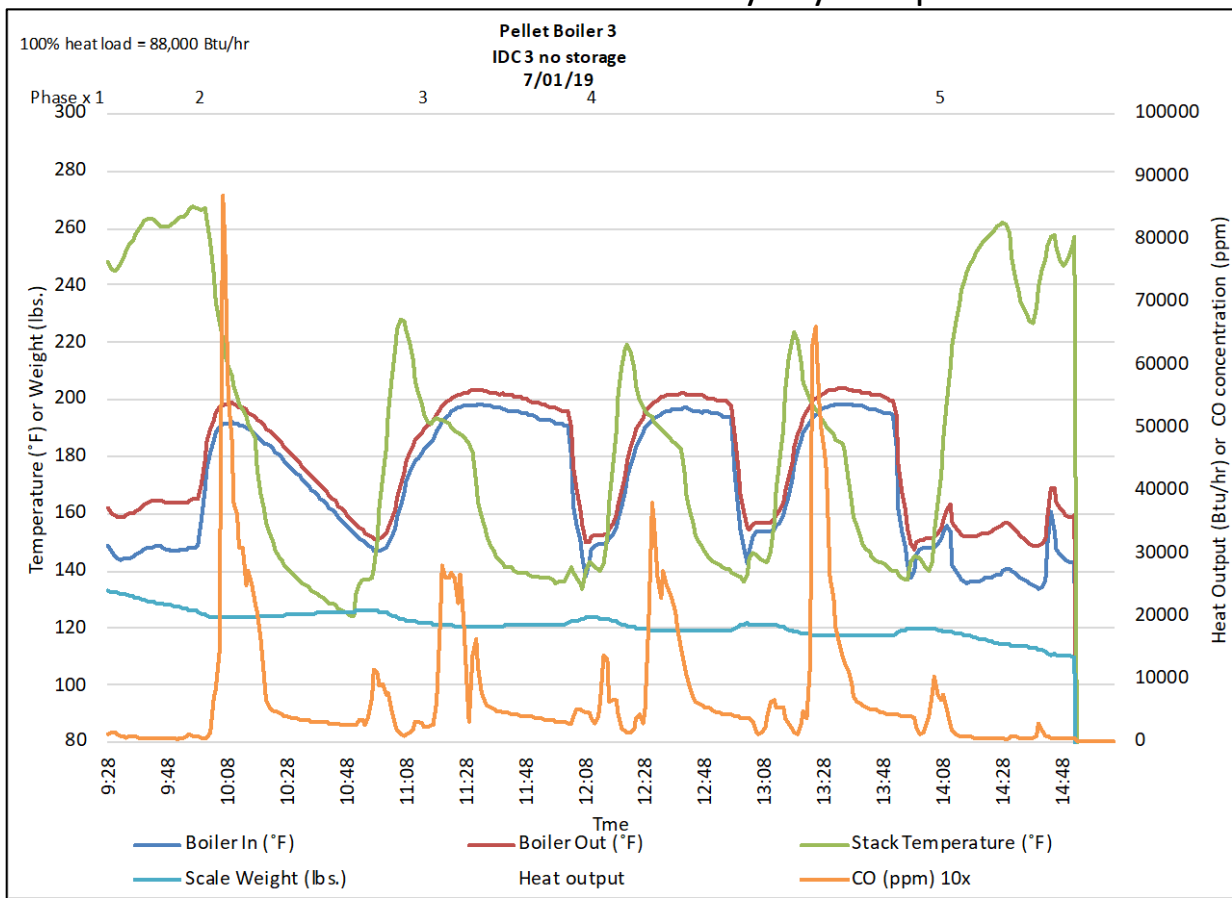
Current FRMs

- Steady state test- fixed load over specified duration of time
- Hot-to-hot test
- No replicate testing
- Manufacturers instructions can modify key test parameters

IDC

- Variable heat loads and loading – for central heating responds to calls for heat.
- Cold to hot test, includes start-up and restarts in central heater
- Three (3) replicates
- Manufacturers instructions cannot modify key test parameters





Overview of Research – Residential Appliances

Operation and Fueling Protocols

Stoves – cordwood & pellet

- Protocol completed
- Fuel calculator completed
- More than 250 runs completed informing protocol
- Developing data for EPA consideration

Hydronic Heaters – pellet & cordwood thermostatically controlled devices with or without thermal storage

- Protocol completed
- Fuel calculator completed
- Almost 200 runs informing protocol
- Developing data for EPA consideration

Furnaces

- Protocol completed
- Developing data for EPA consideration

Measurement Methods

- Development of real-time PM Measurement for use in lab and field measurements.
- Research to inform method precision and SVOC loss.

Fuel Specifications

- Developing data to assess impacts of fuel species and moisture content to inform fueling protocols.

Coming Soon

- JAWMA Dedicated Issue – 11 publications on Residential Wood Heating work
- Work supported by NYSERDA
- Manuscripts from
  - Brookhaven National Lab
  - Clarkson University
  - Clearstak
  - Cornell
  - NESCAUM
  - NYS DEC and NYS DOH
  - Stony Brook University

Thank you for your time!

Any questions?