Speciated VOC Emissions from an Outdoor Residential Pellet-burning Hydronic Heater

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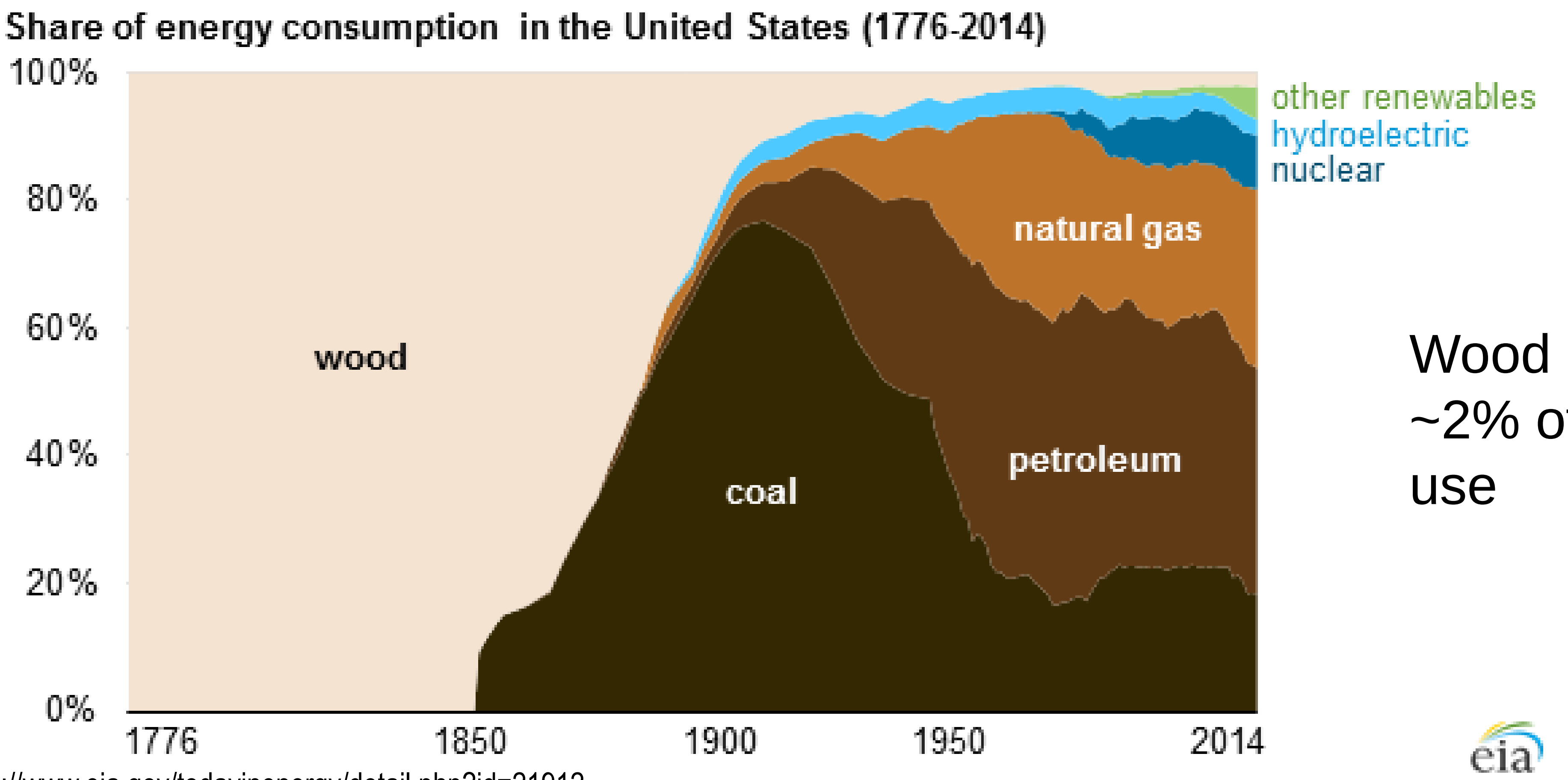
Wood Burning as Energy Source in U.S.



https://www.eia.gov/todayinenergy/detail.php?id=21912

Wood burning represents ~2% of total U.S. energy use

https://www.eia.gov/todayinenergy/detail.php?id=15431

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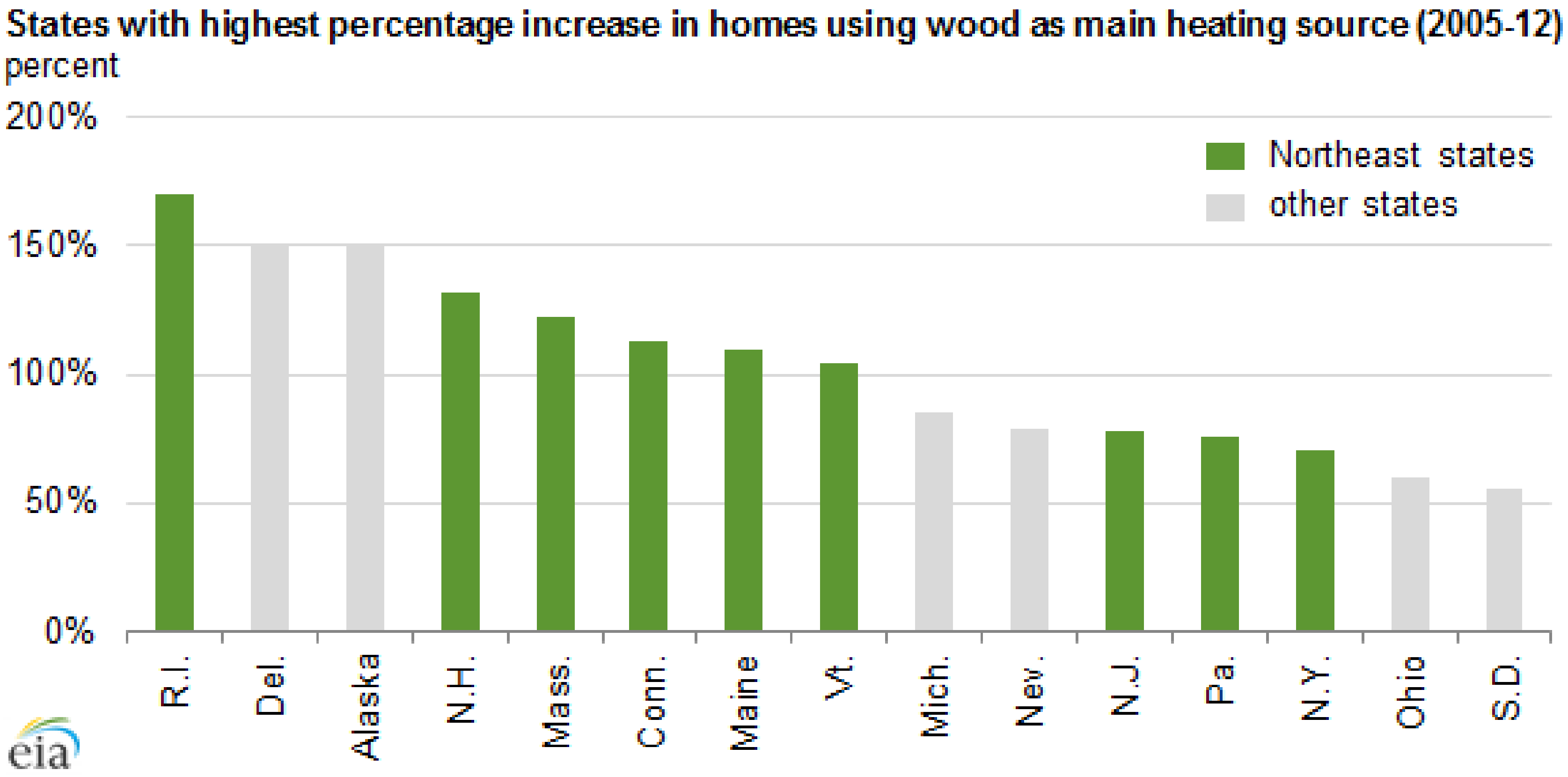


Wood burning as home heating source is becoming more popular in northeastern U.S.

Outdoor Hydronic Heaters

- Outdoor residential wood-fired hydronic heaters (RWHHs) are used as a alternative renewable energy source for home heating predominately in wintertime

- Emissions from RWHHs include air toxics VOCs and PM that can worsen local air quality and contribute to negative health impacts on affected communities

- Few studies have characterized speciated emissions from RWHHs, which can vary by fuel type and appliance design and operation

Study objective: To fully characterize speciated emissions from a pellet burning hydronic heater

United States Environmental Protection Agency

Pellet-burning Hydronic Heater (PBHH)

The European pellet-burning hydronic heater tested in this study is capable of burning various biomass fuel types, e.g. wood chips, straw, wood pellets, etc.

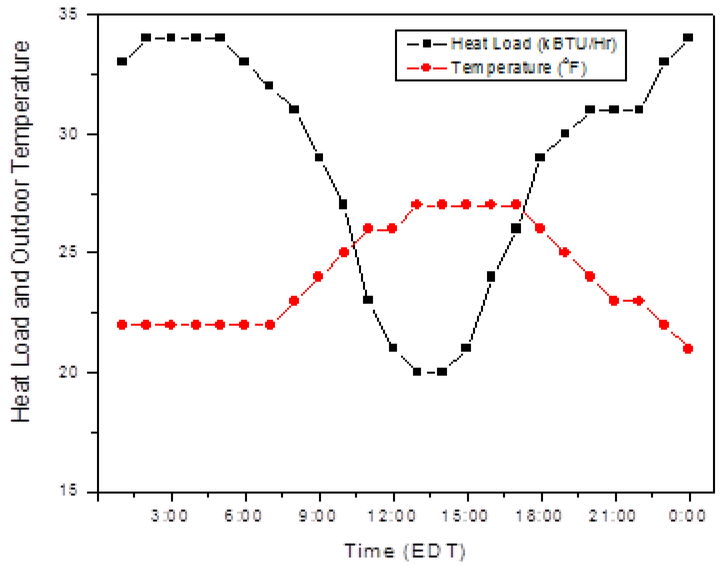
- 20 kW rated thermal output
- Single combustion chamber with two-pass upflow heat exchanger, integral ash bin, and ash screw
- Flat-bottom fuel bin and auger dropping pellets onto a reciprocating grate with both underfire and overfire air supply
- Induced draft fan in stack added to replace normal natural draft operation

Experimental Conditions

PBHH Operating Conditions:

- Syracuse cycle: representing wintertime conditions for a 232 m^2 (~2500 sq ft) home in Syracuse, NY
- Steady state conditions: min. load, full load
- Each test lasted 6 hours

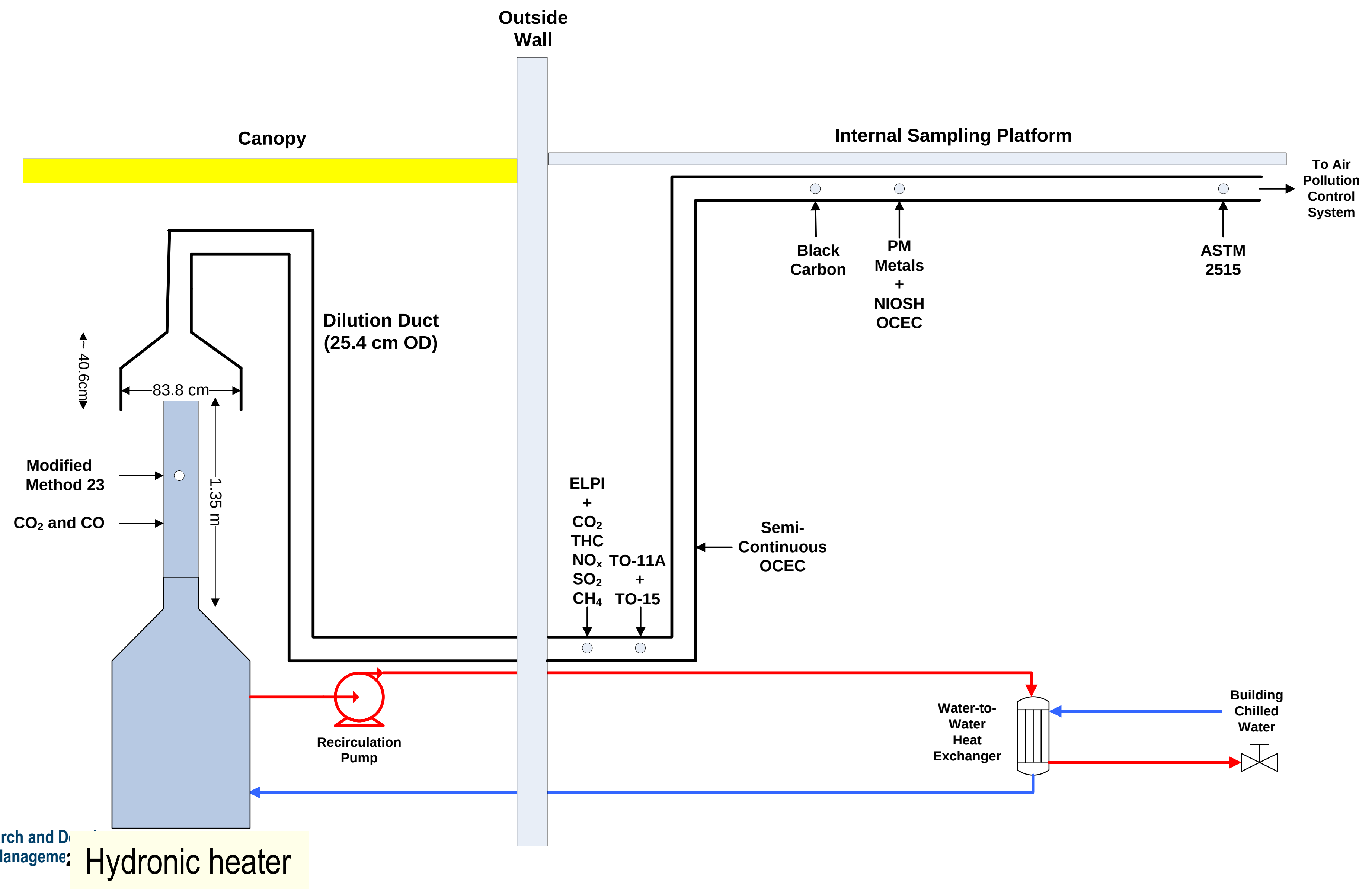
Syracuse heat load profile



Fuels:

- Hardwood pellets
- Switchgrass pellets

PBHH Emissions Sampling



~15:1 dilution

Online Measurement Methods

Continuous Measurements:

- CEMS – CO_2, CO, O_2, NOx, THC
- FTIR – SO_2, CH_4, VOCs
- ELPI – particle size distribution
- Magee AE-22 Aethelometer, DMT PAX – BC
- Sunset OC/EC Anaylzer – Semicontinuous OC/EC

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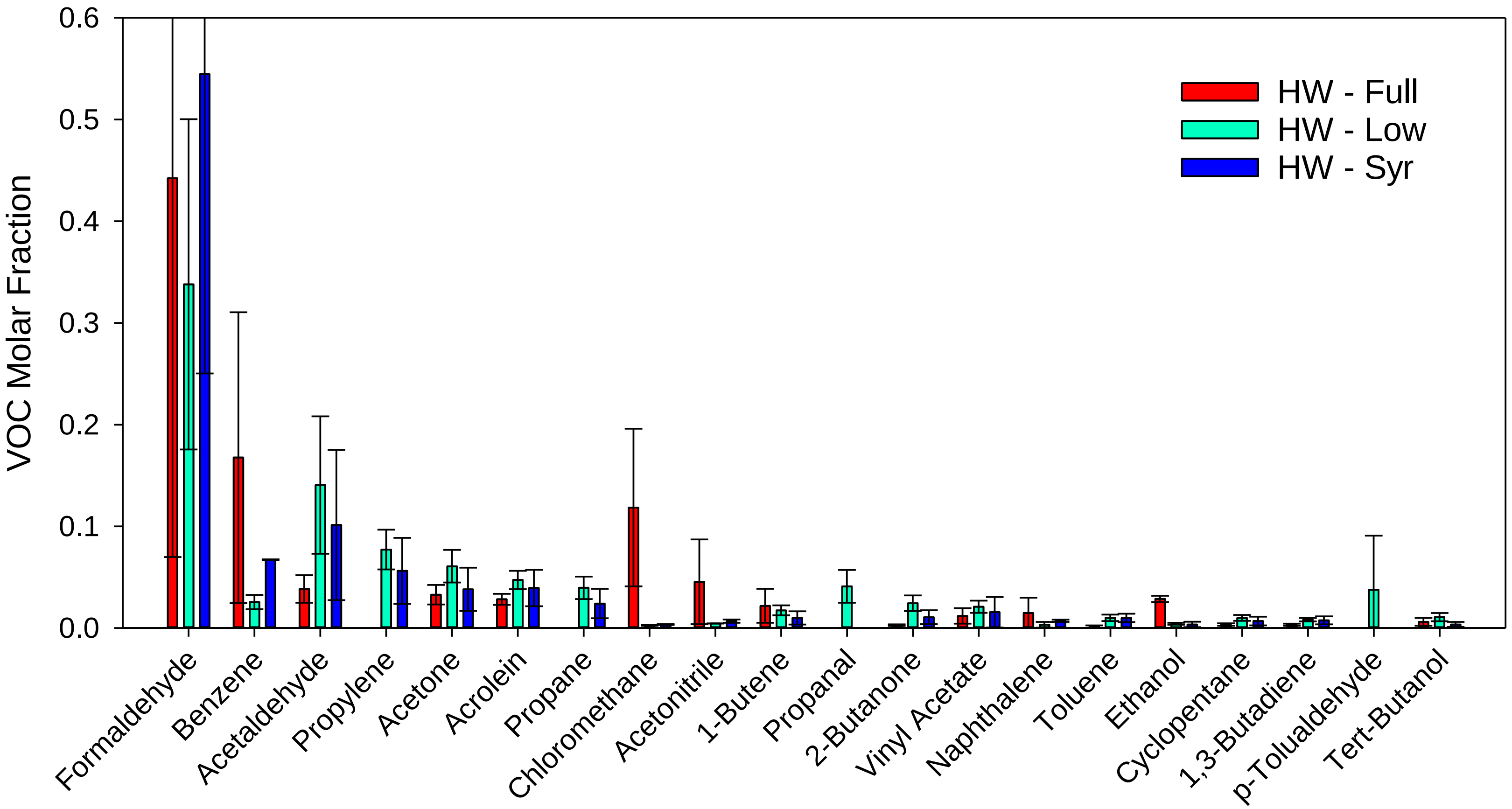
Offline Measurement Methods

Class of Pollutant	Method	Analysis
Particulates	ASTM Method E2515-11	Gravimetric
Elemental analysis	EPA Method IO-3.3	XRF
OC/EC	NIOSH Method 5040	TOT
SVOCs/PAHs	EPA Method 0010	HRGC/LRMS
PCDD/Fs	EPA Method 23	HRGC/HRMS
HCl	EPA Method 26A	Ion chromatography
Carbonyls	EPA Method TO-11A	HPLC
VOCs	EPA Method TO-15	GC/MS
Bottom ash	Grab sampling	AA & mass loss on heating
Particulate morphology	Not applicable	SEM/TEM

VOC Profiles – Hardwood (HW)

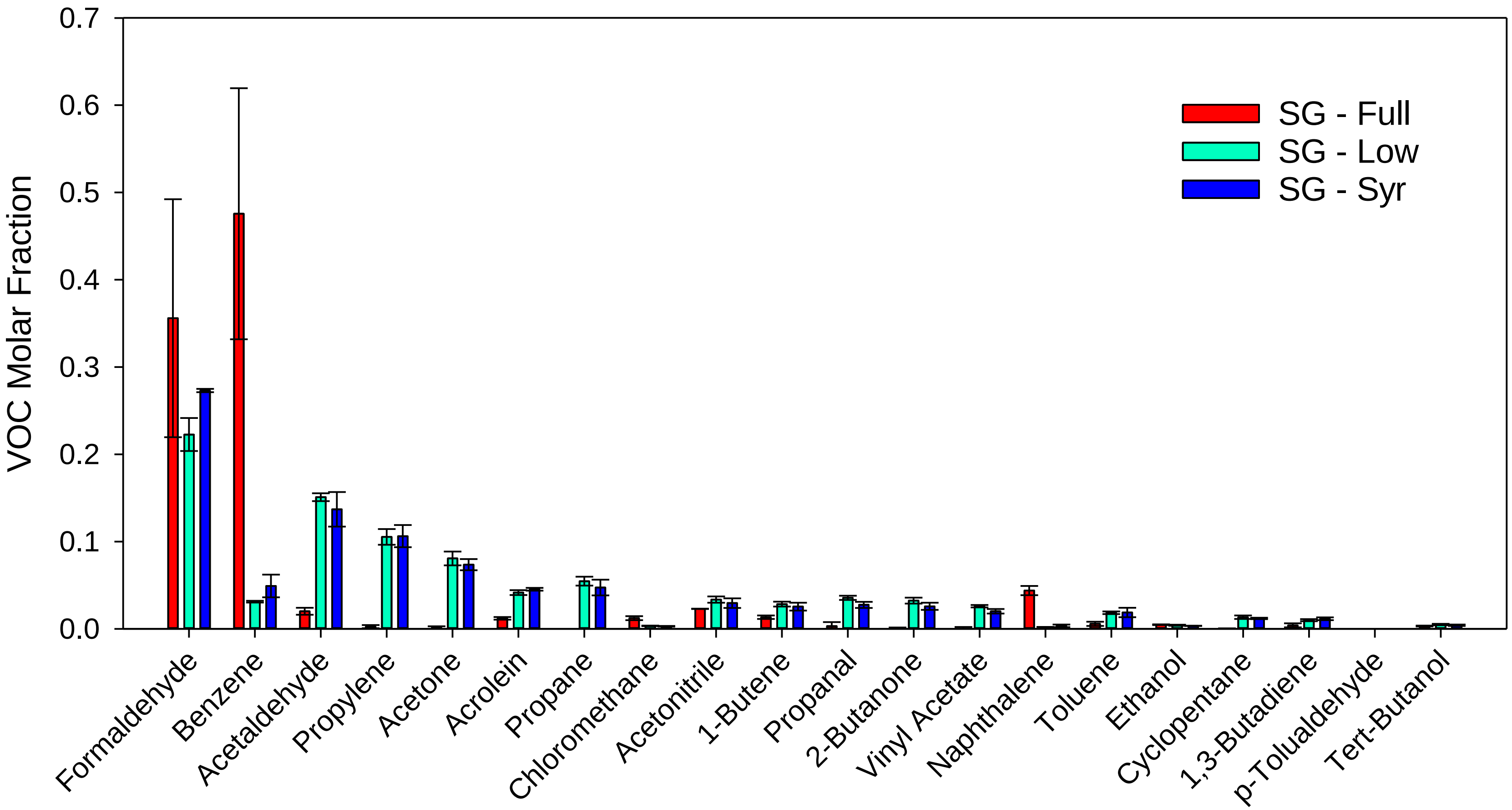


Most abundant VOCs include carbonyls, aromatics and other partial combustion products

VOC profiles are influenced by heating load

Note: not corrected for dilution or mass fuel burned

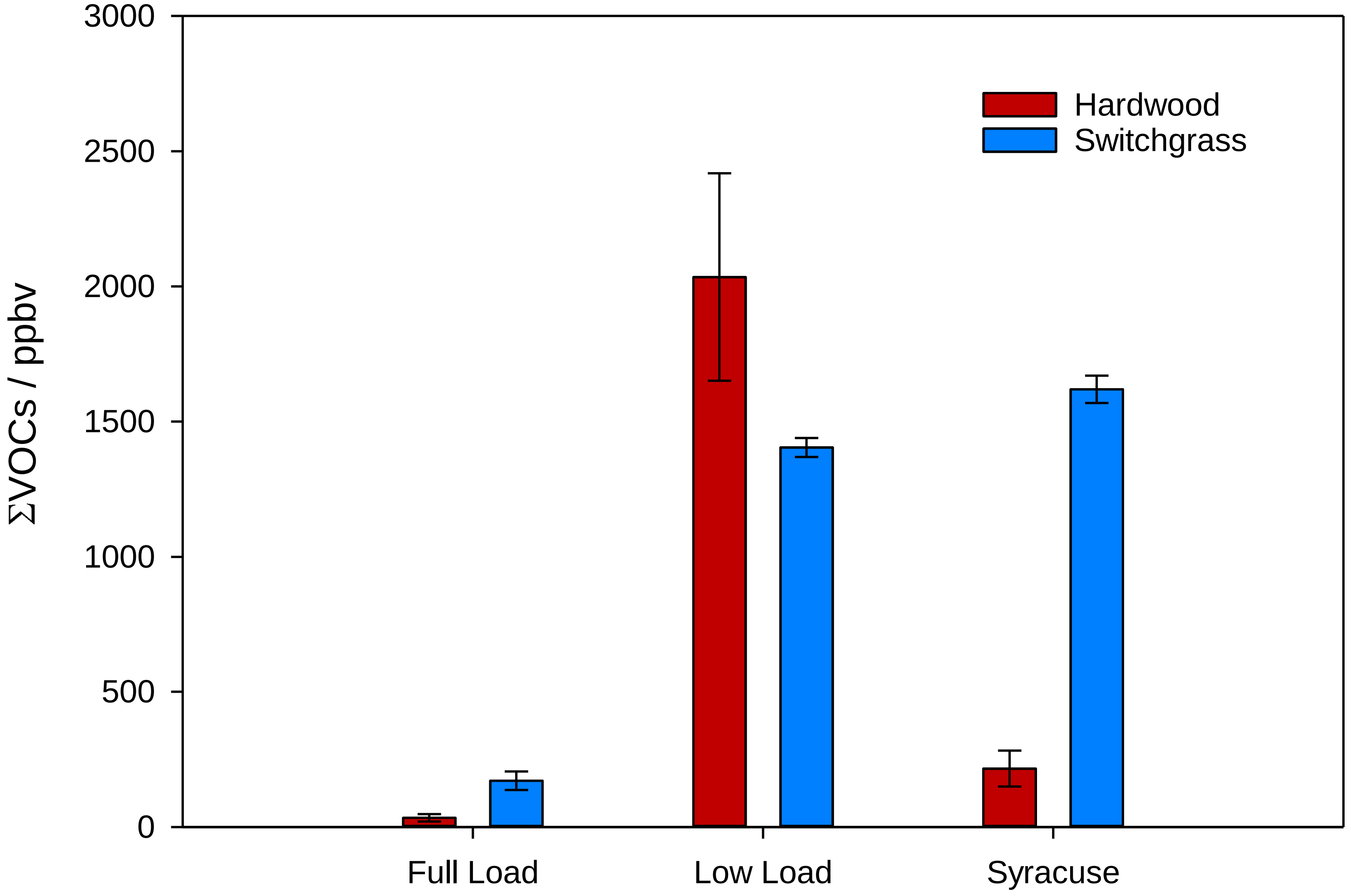
VOC Profiles – Switchgrass (SG)



VOC profile for full load has higher benzene fraction, lower contributions from most other VOCs

VOC profiles from low and Syracuse tests are similar

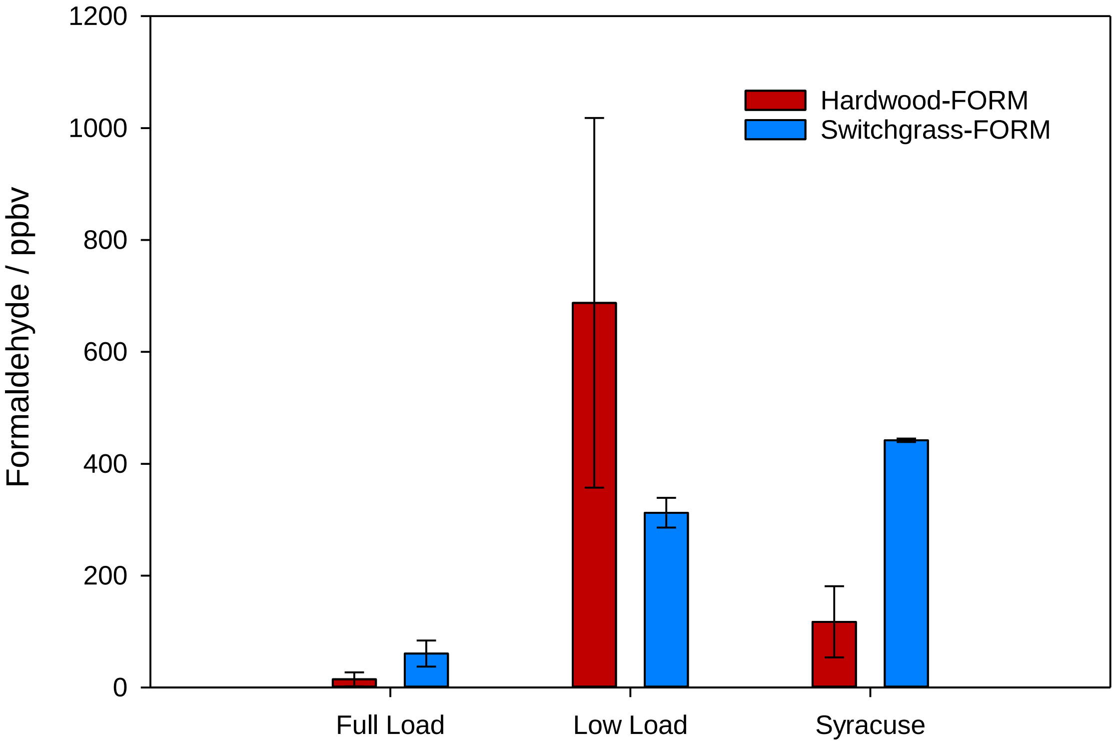
Total speciated VOCs by condition



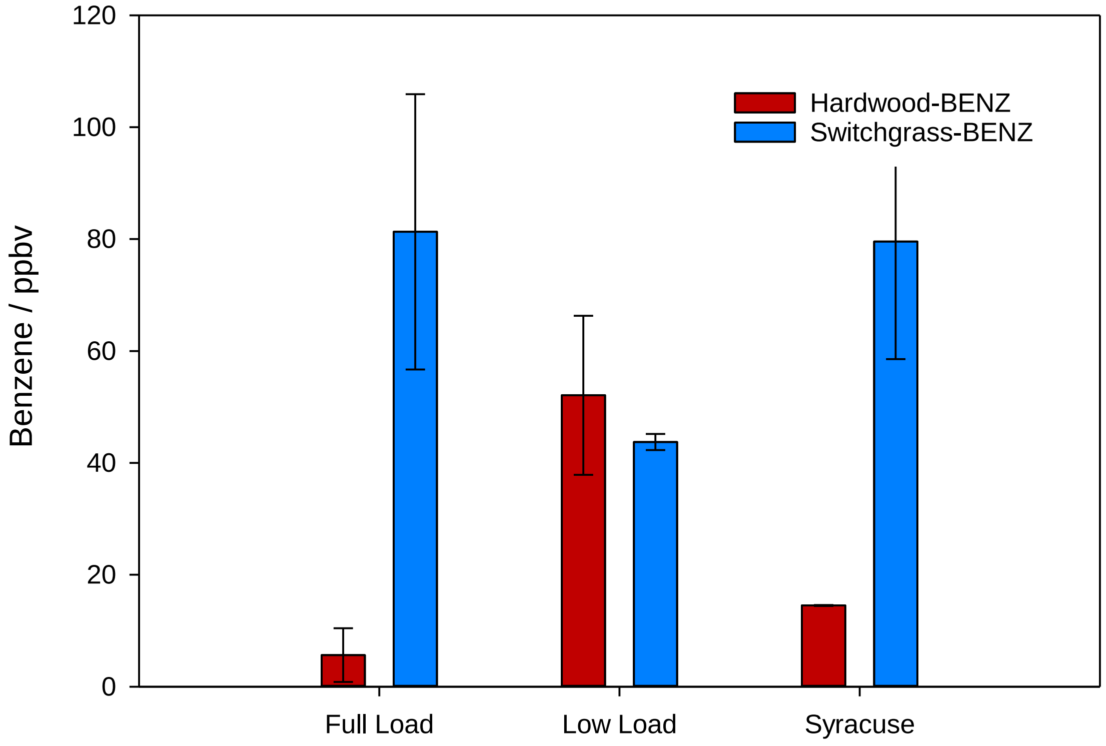
Highest total speciated VOC concentrations were observed for low load and switchgrass/Syracuse cycle

Offline Measurement Methods

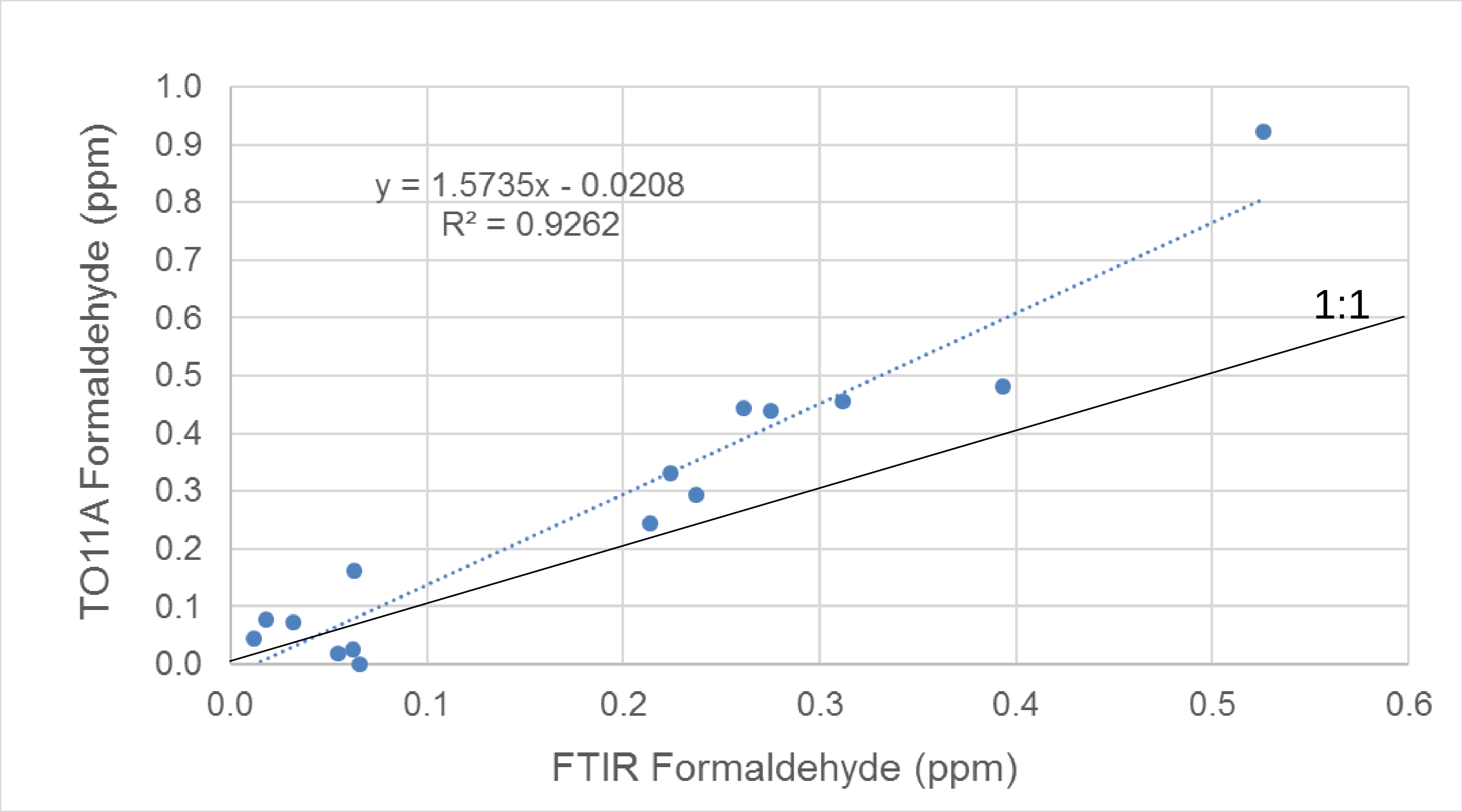
Formaldehyde Emissions



Benzene Emissions



Formaldehyde Method Comparison



Each point represents average over single test

TO11A measures higher formaldehyde by ~60% compared to FTIR

More intercomparison tests are needed

Future Work

Next steps…

- Finalize emission factors for speciated emissions data on a heat and mass basis
- Compare results with literature values on hydronic heater VOC emissions (i.e. Aurell et al., 2012, Johansson et al., 2004)
- Further investigate TO11A vs FTIR comparison
- Unknowns analysis of VOC data to identify unspeciated VOCs and improve speciation profiles

Ackwnowledgements

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Questions?