Los Alamos NATIONAL LABORATORY

Wildland-Urban Interface (WUI) Airborne Toxic Emissions of Formaldehyde and Aerosols from Urban Fuels

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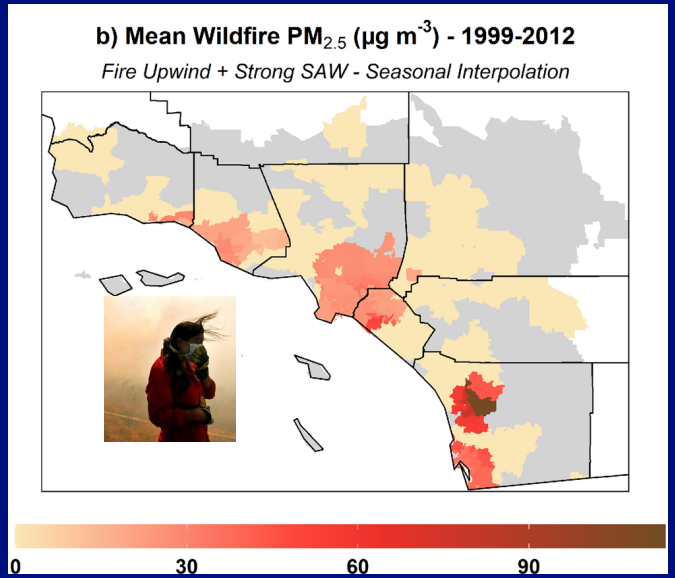
LDRD LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Wildland-Urban Interface (WUI) Emissions

- **Wildfire emissions recently implicated as more toxic than urban sources**
- **More wildfires are crossing over into the WUI**
  - California and Colorado wildfires
  - More neighborhoods threatened due to drought and land use changes
- **What is the airborne toxicity at the WUI?**
  - New types of gas and particulate emissions
  - Emissions include traditional wildland fuels as well as man-made materials
  - We are studying urban fuels, e.g., building materials



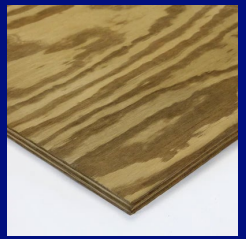
Aguilera et al., Nat Comm. 2021

Urban Fuel Building Materials

- **Home Construction materials: Plywood, flooring, etc.**
  - Oriented Strand board (OSB) with phenol formaldehyde
  - Attic Pine OSB
  - Medium density fiberboard (MDF)
  - Yellow Pine Sheathing
  - Melamine particleboard
  - Untreated dimensional lumber
  - Pressure treated lumber
  - Pressure treated ground contact
- **Sampled in a tube furnace at 600 ^{0}C and 1000 ^{0}C**

OSB

MDF



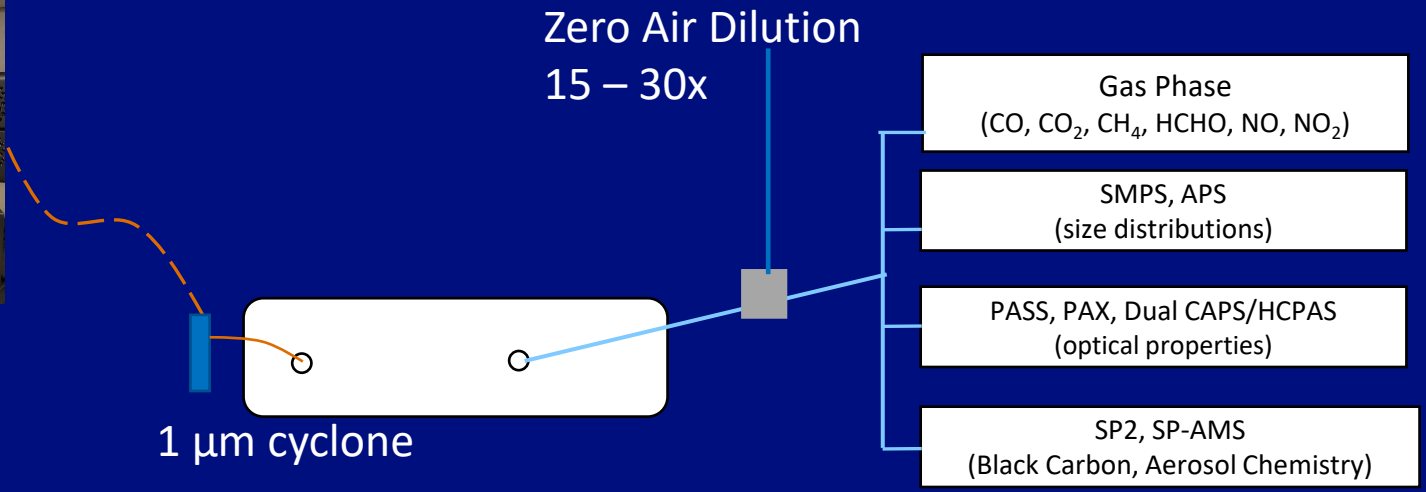
Yellow Pine

Melamine PB

Untreated Lumber

Pressure Treated

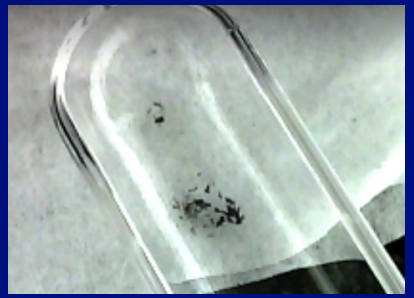
Controlled laboratory burning experiments



Online aerosol and trace gas measurements

- Particulate emission ratios under flaming and smoldering conditions (e.g. Soot/CO)
- Traditionally monitored trace gases: Carbon monoxide, carbon dioxide, methane
- Quantify new particulate (e.g. PAH, metals) and trace gases (e.g. Formaldehyde/CO)

Most of the sample mass is burned in the experiments

	Original Sample	600 ^{0}C	1000 ^{0}C
Redwood tone pressure treated board			
Yellow Pine sheathing			

Main Topics of this presentation:

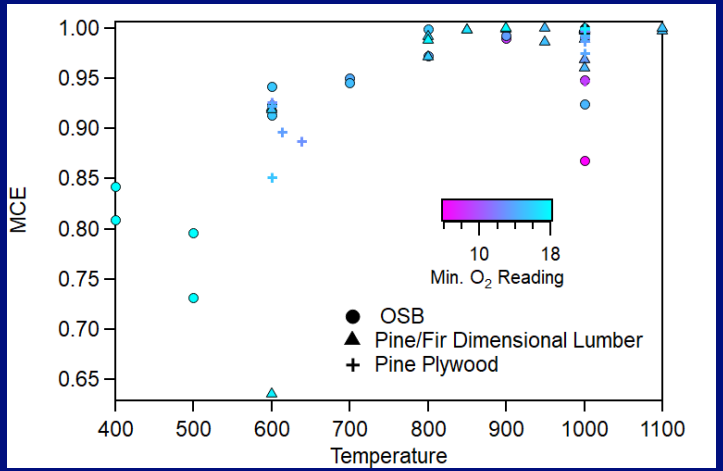
- Characterizing burn conditions
- Optical properties of the aerosol emissions
- Emission Ratios and Emission factors

Burn Conditions

- Set the Temperature
  - 400°C to 1100°C
- Observe amount of available/consumed oxygen (some control with flow rate)
- Calculate Modified Combustion Efficiency

$$\text{MCE} = \frac{\Delta CO + \Delta CO_2}{\Delta CO_2}$$

Close to 1 is flaming, <0.95 smoldering



Burns with a minimum oxygen reading below 10% were repeated at higher flow rates.

Definitions for Burns and Aerosol Properties

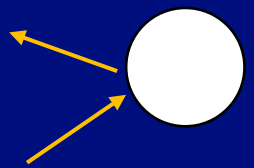
- Black Carbon (BC) = Soot
- Brown Carbon = absorption due to organics that absorb light
- Single Scattering Albedo (SSA)

$$\frac{Scattering}{Absorbing + Scattering} = \frac{Scattering}{Total\ Extinction}$$

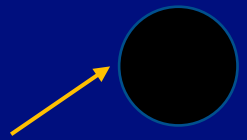
- Absorption Angstrom Exponent

$$AAE = -\frac{log\frac{Abs_x}{Abs_y}}{log\frac{\lambda_x}{\lambda_y}}$$

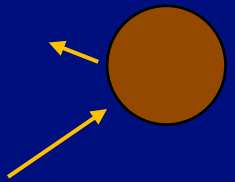
Indicates the spectral dependence of light absorption (brown v black C)



Scattering Aerosol



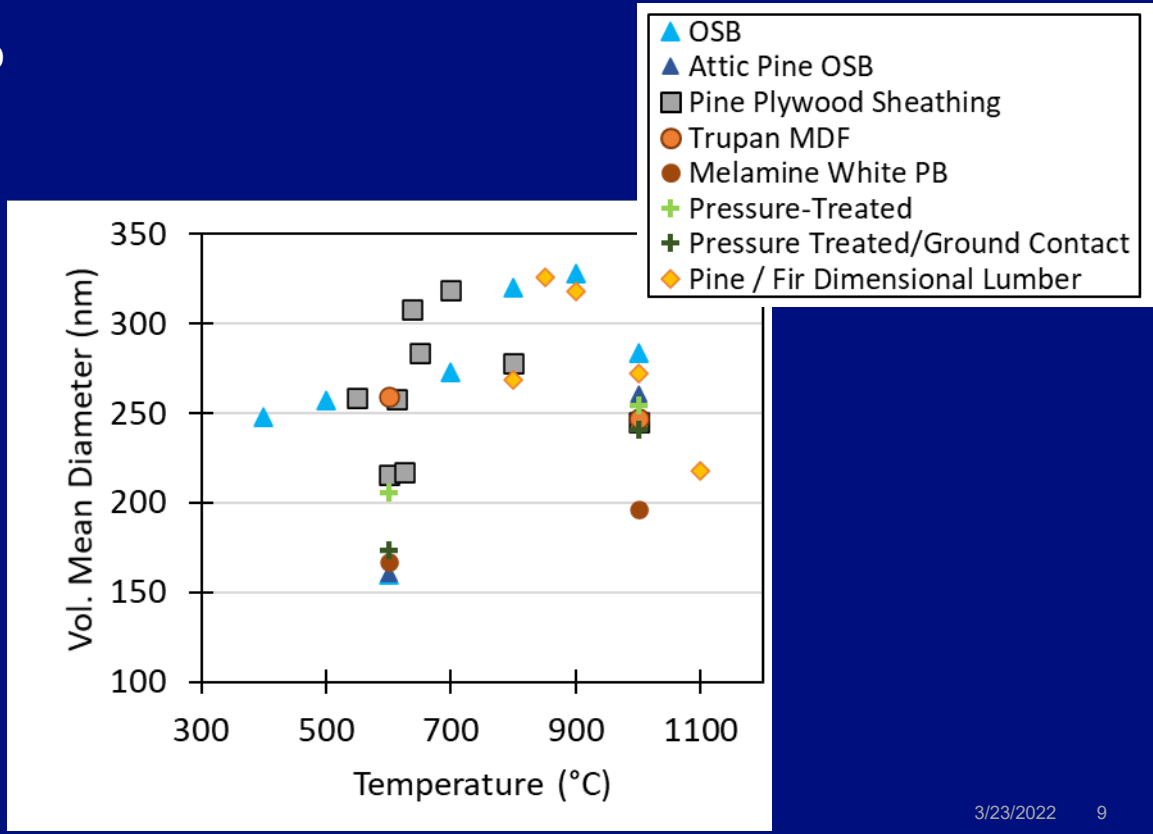
Black Carbon Aerosol
Strongly absorbing



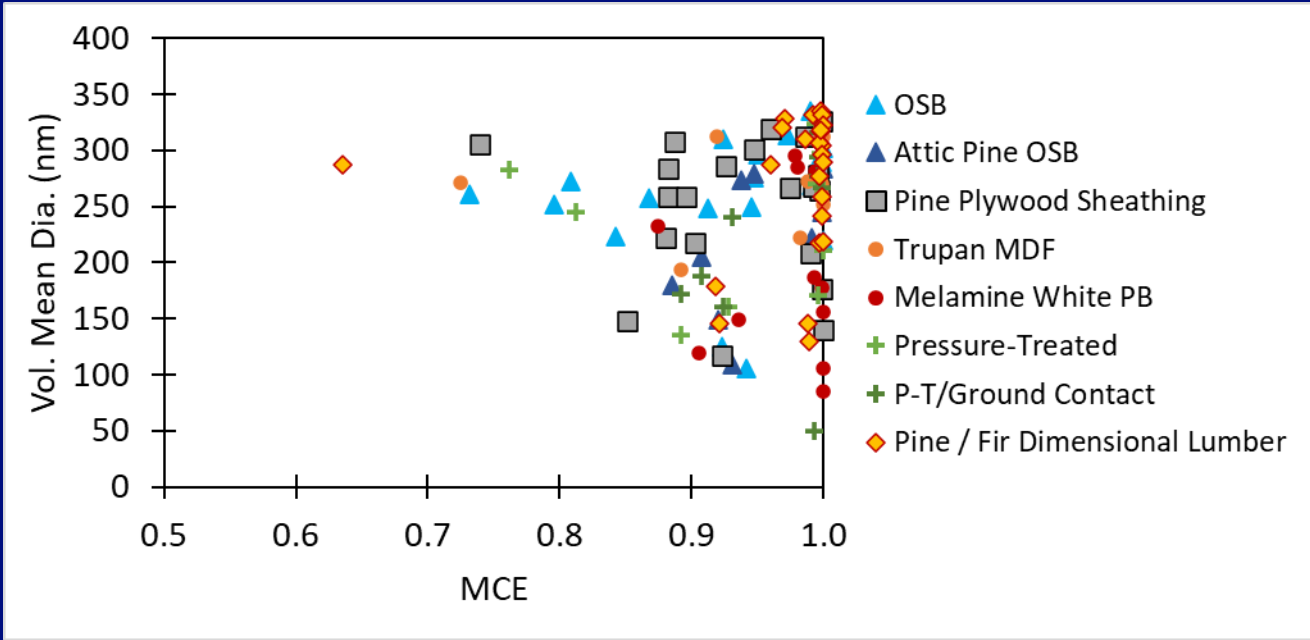
Brown Carbon Aerosol
Absorbs some radiation

Volume Mean Diameter (D_{vm}) varies between 125 – 320 nm

- D_{vm} was variable from 125 to over 300 nm across the different fuels and burning conditions
- We observed variable VMD across fuels for the same temperature.

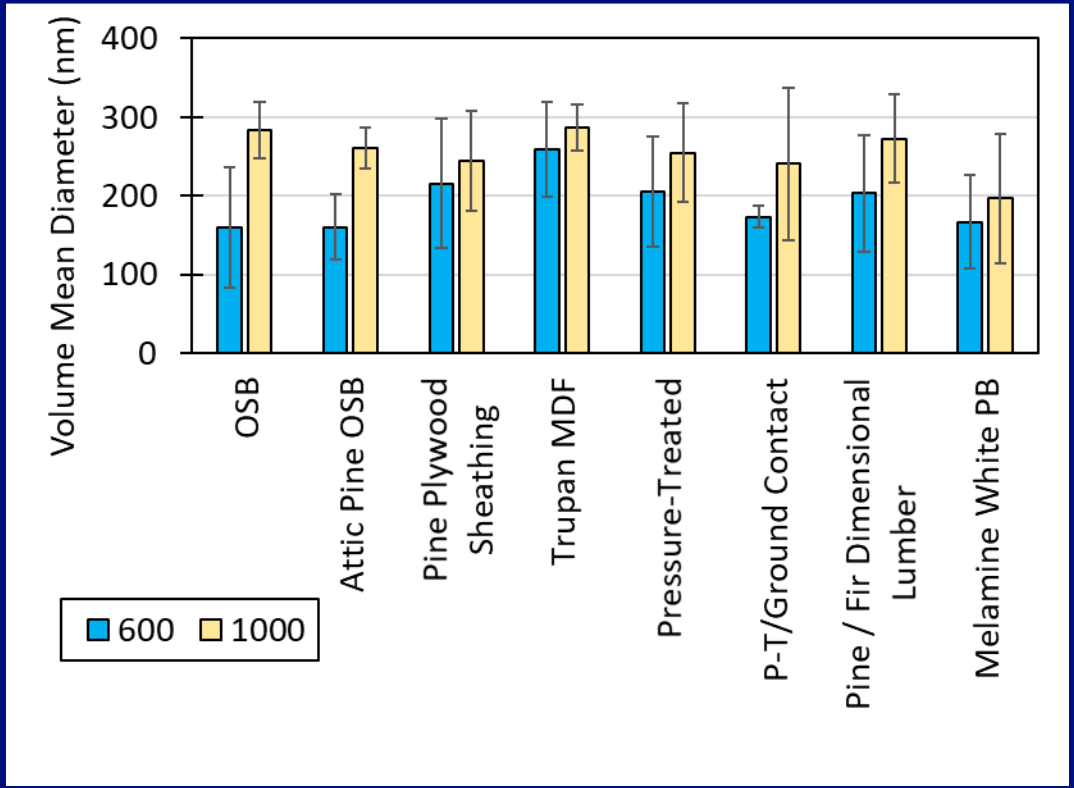


MCE influences volume mean diameter.



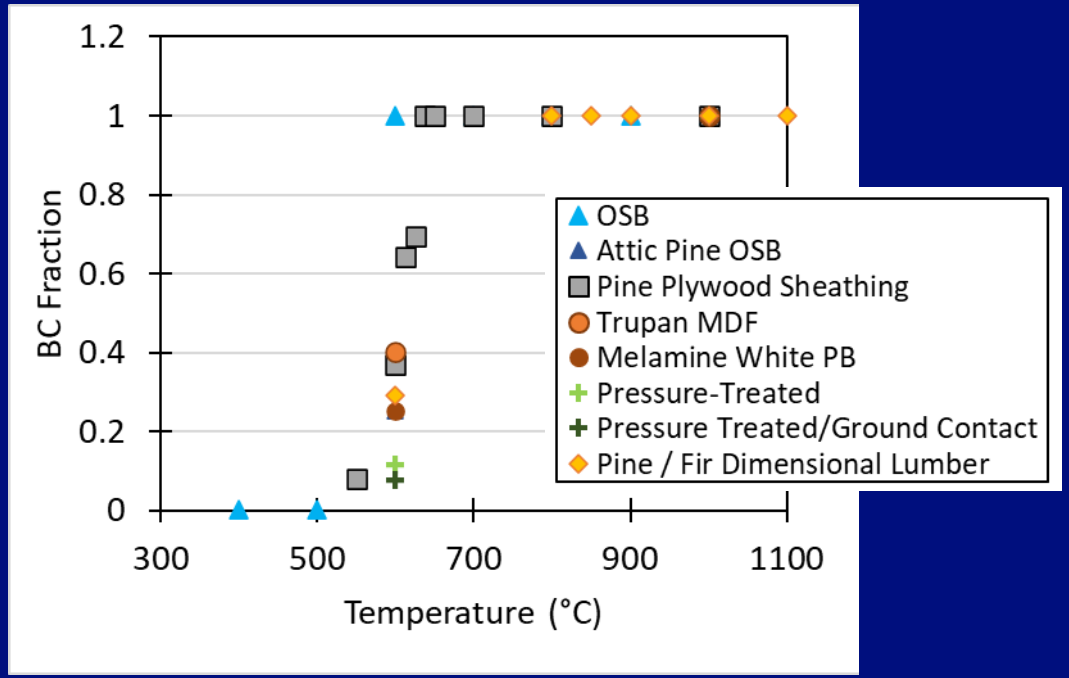
For most fuels, smaller particles are emitted at lower temperature burns.

- Similar particle sizes were observed for pine plywood sheathing, particle board, and MDF.
- Soot formed at 1000°C may be fractal and not sized correctly in the SMPS.



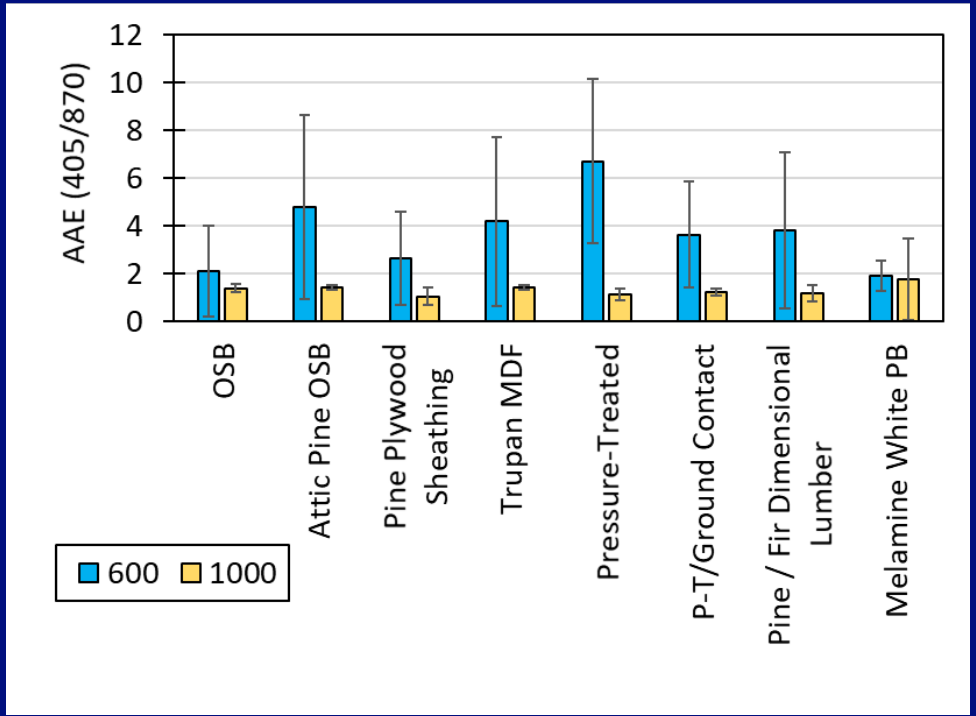
Black carbon (BC) content higher at 1000 ^{0}C than 600 ^{0}C

- Aerosol emitted above ~650°C is almost entirely BC.
- Transition zone in amount of BC between 500 °C and 700 °C
- Similar results to natural fuels.

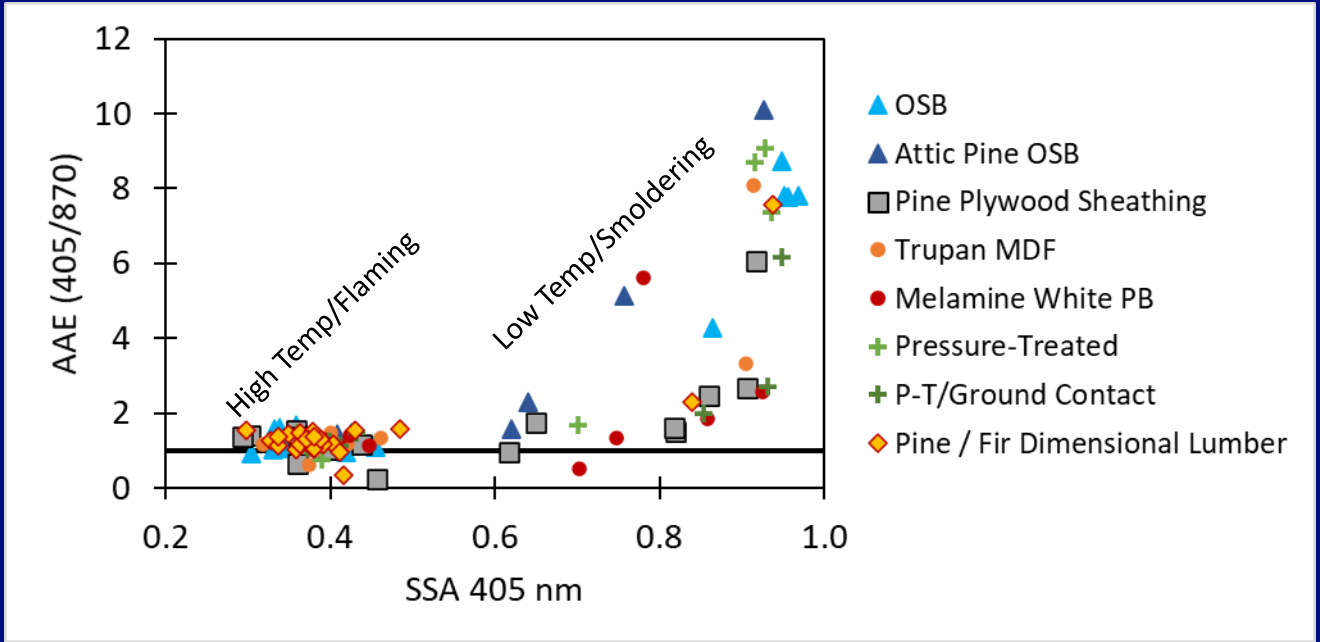


Absorption dominated by BC at 1000 ^{0}C

- Absorption Angstöm Exponent (AAE) used to define absorption from Black versus Brown Carbon
- Most burns at 600 ^{0}C have AAE's > 1 indicating the presence of absorbing organics (Brown carbon)
- For burns at 1000 ^{0}C, the absorption is due to black carbon

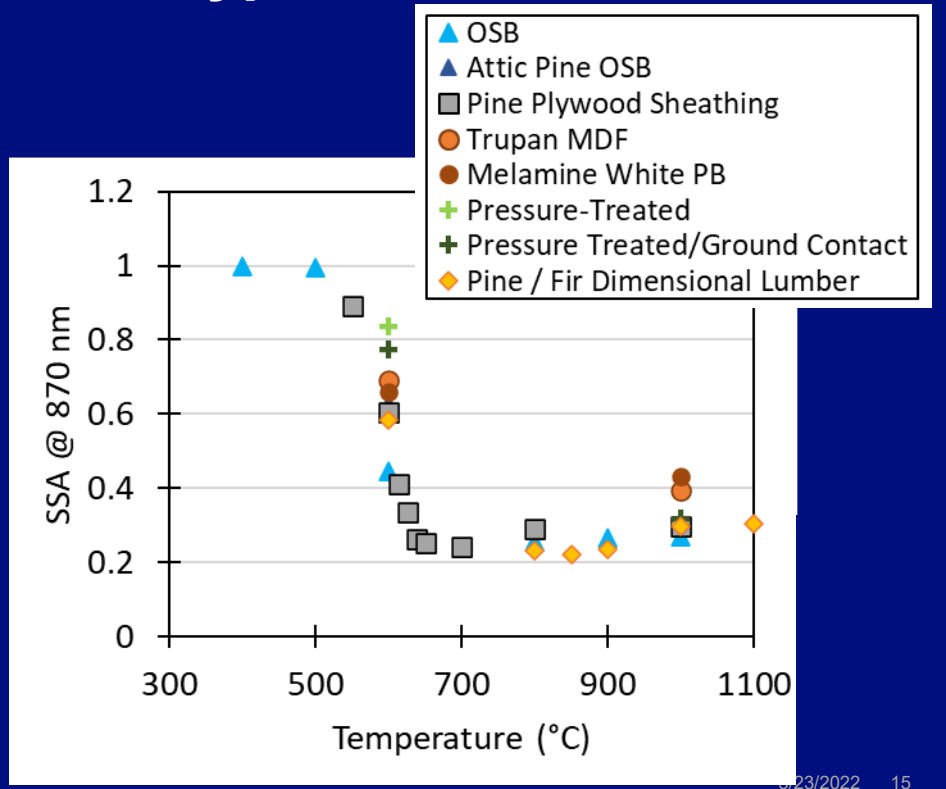


These fresh emissions naturally separate in SSA/AAE space.

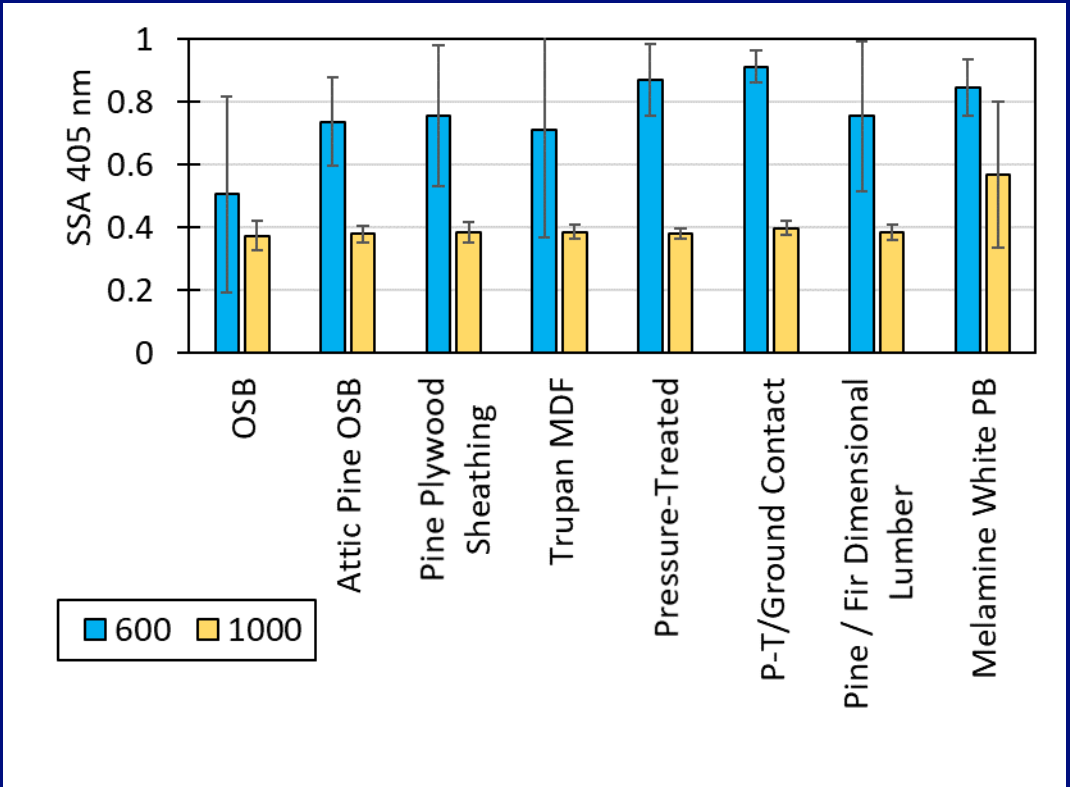


Single Scattering Albedo is more dependent on combustion temperature than fuel type.

- SSA ranged from 0.3 – 0.9 at 600 ^{0}C
- SSA was much lower at 1000 ^{0}C ranging from 0.3-0.4 indicating more absorbing particles.
- Next slide is the direct comparison at 600 ^{0}C and 1000 ^{0}C



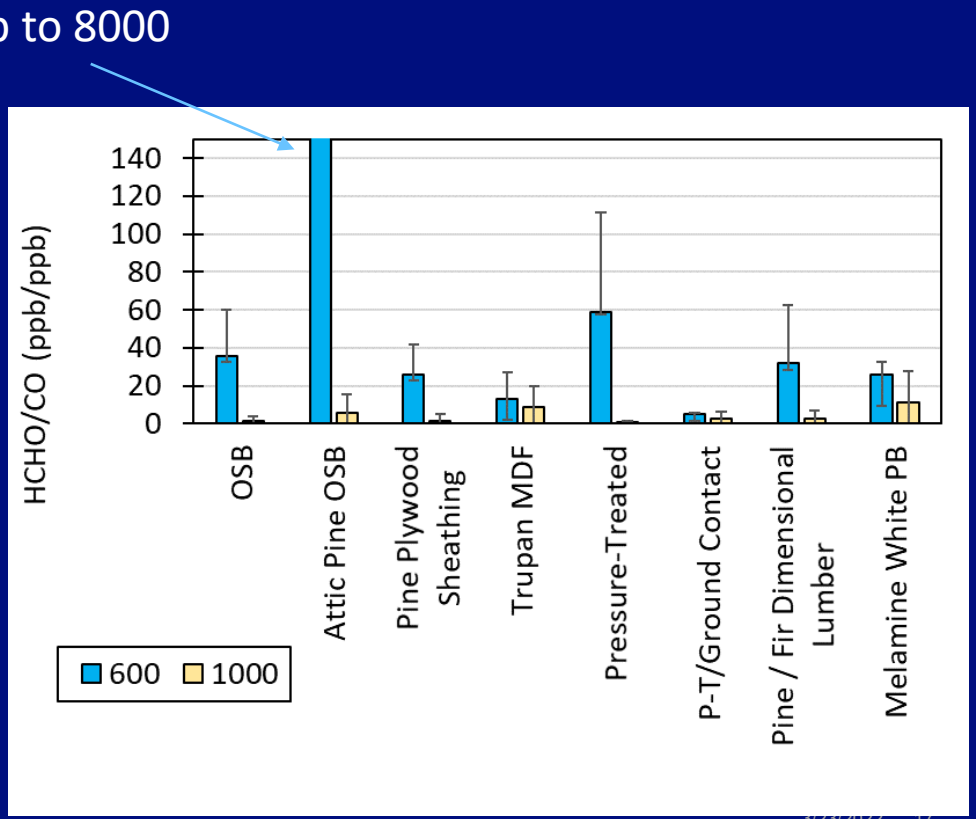
Experiments at 1000 ^{0}C were had consistent SSAs across fuel types.



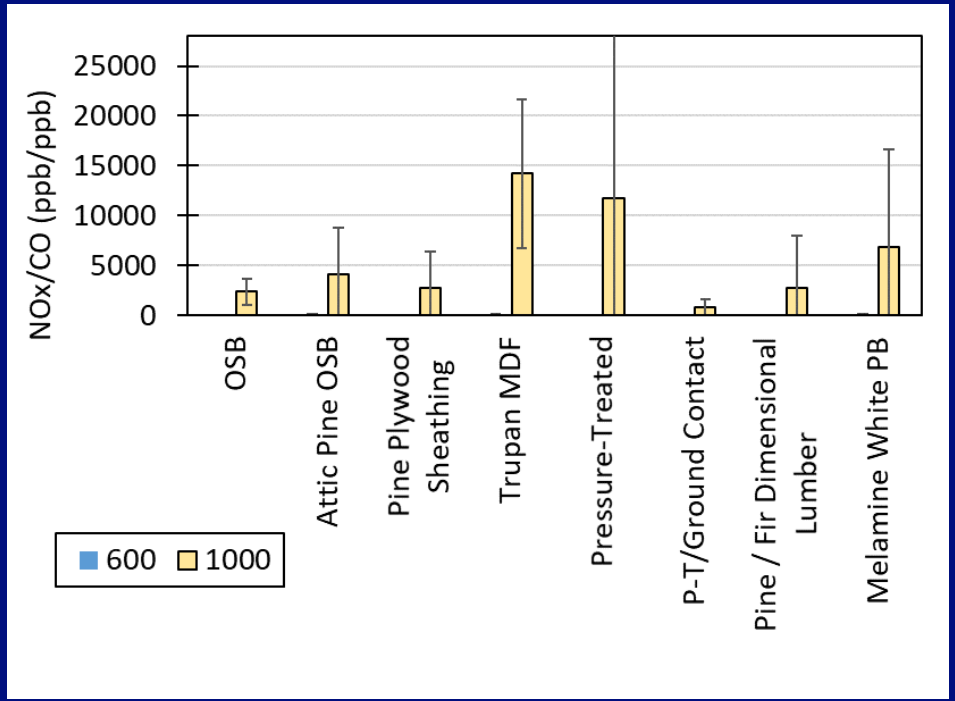
- More variability is observed at 600 ^{0}C likely reflecting the variable combustion conditions at this temperature.

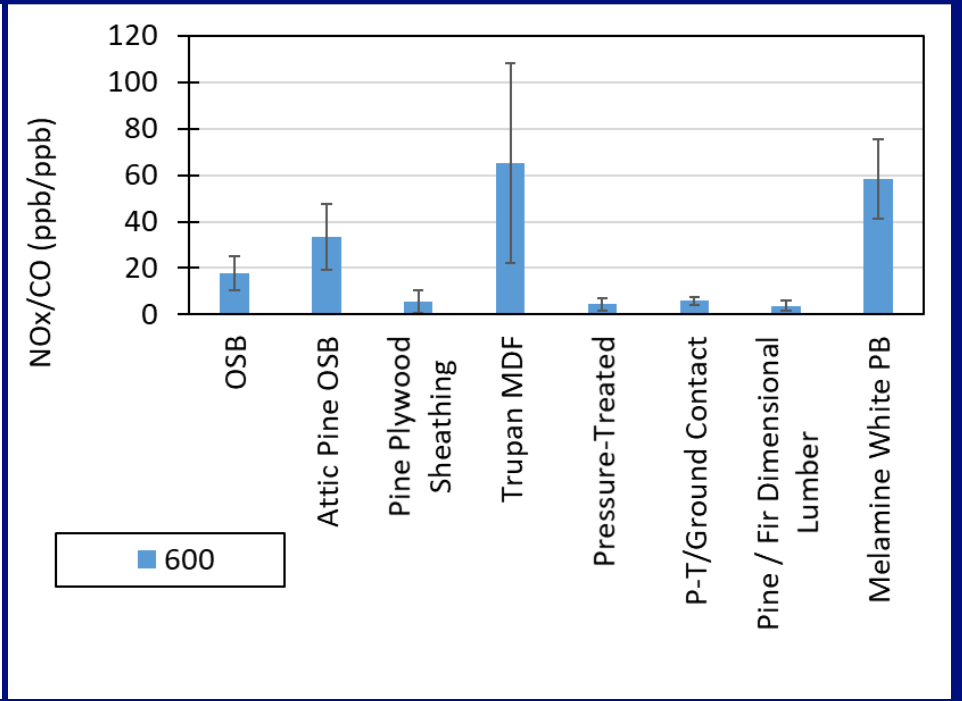
Formaldehyde Emission Ratios are higher for the lower temperature burns.

- We tried to capture only primary HCHO emissions.
  - residence time
  - time trace (needed to go up initially)
- ERs from wildland fuels are a similar range (up to ~50) but they are likely a combination of primary emissions and secondary formation.

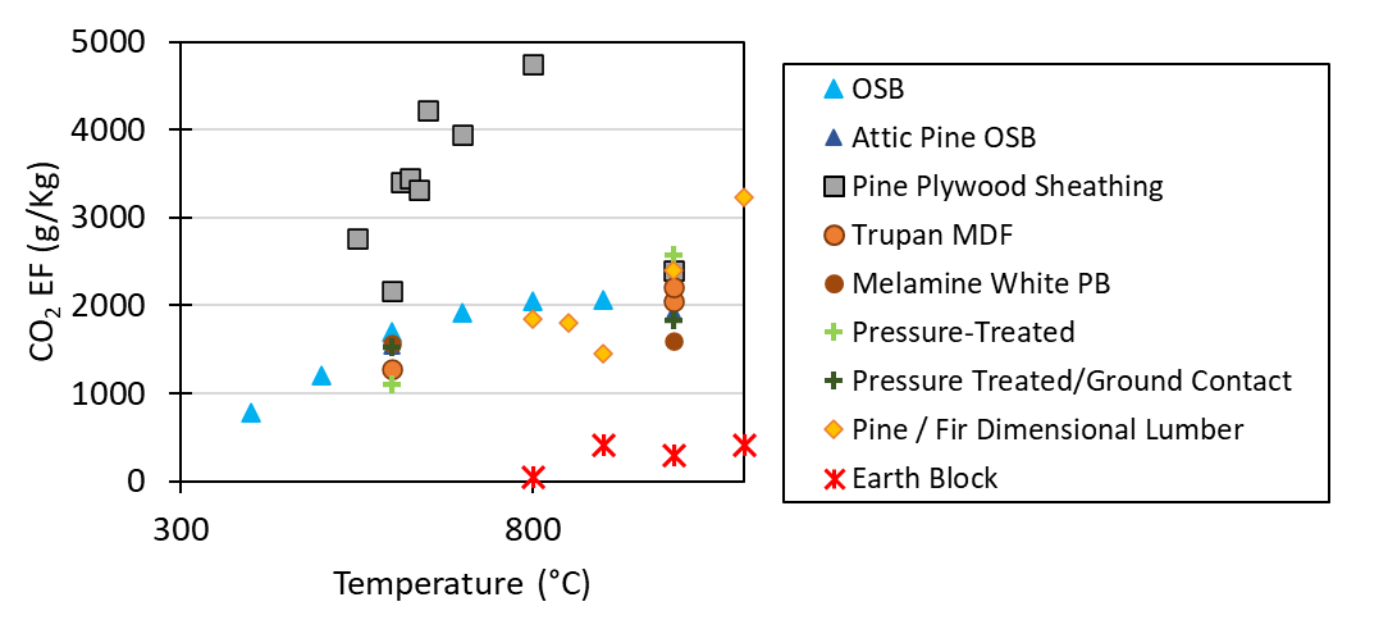


Emissions of NO_x, relative to CO, were much higher at the 1000°C burns.





Emission Factors for CO_2 break out more by fuel type than we observed for the emission ratios.

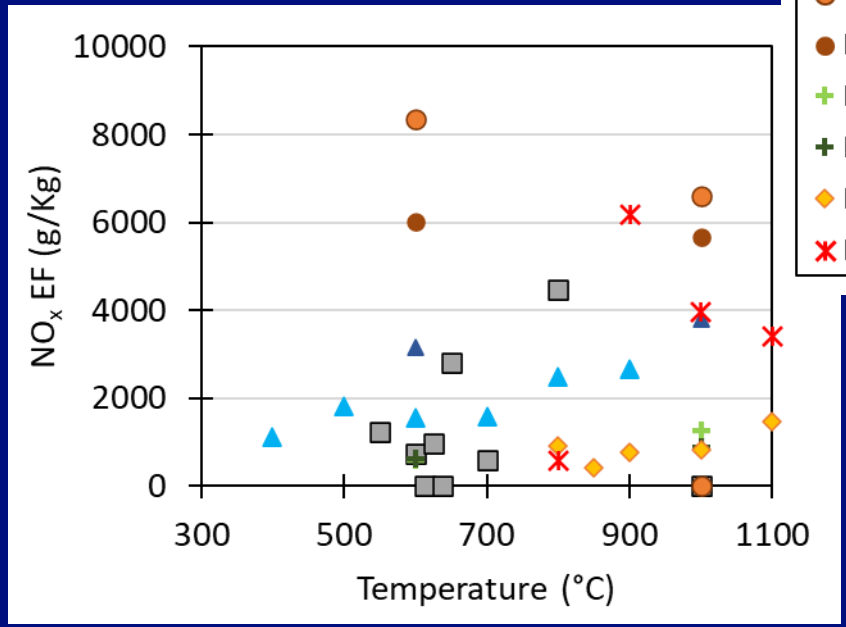


-Earth Block samples provided by Michele's lab as a potential new type of fire-resistant building material.

NOx EFs for the Earth Block samples are fall on the high end of the other urban fuel samples.

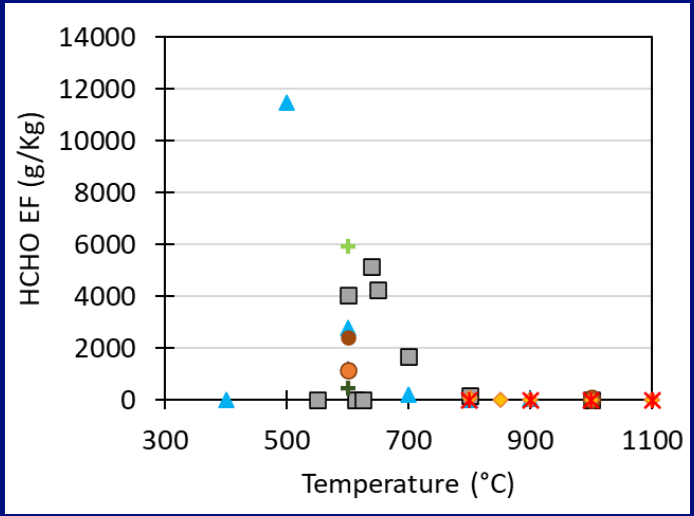
In general, we observe higher EFs at higher temperature.

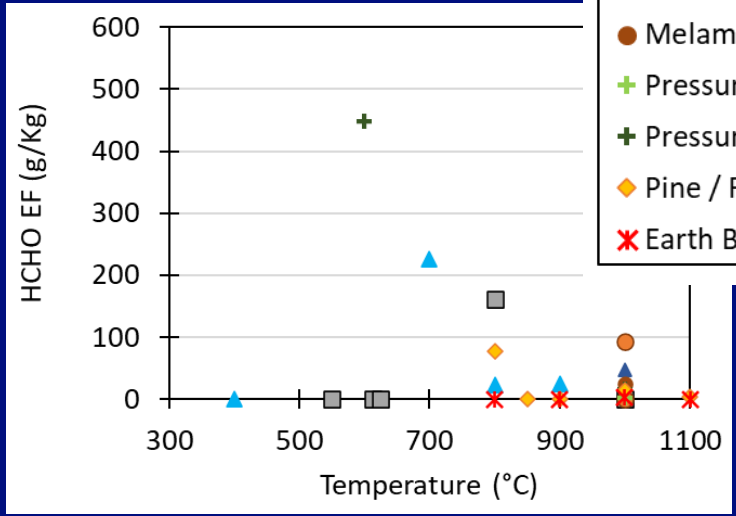
MDF has the highest EFs at all temperatures with a slightly lower EF at the highest temperature.

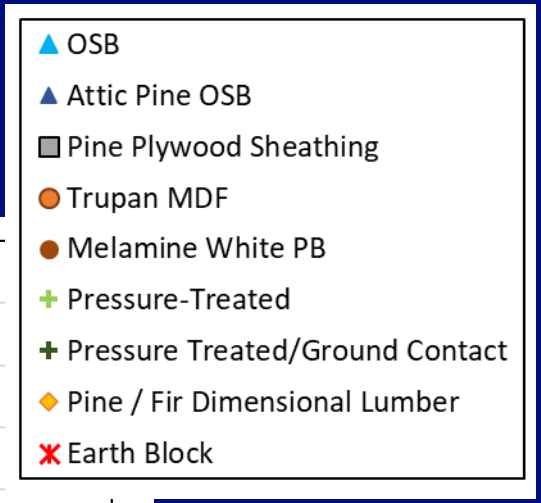


Formaldehyde emission factors are consistently low (among fuel types) at higher temperature.

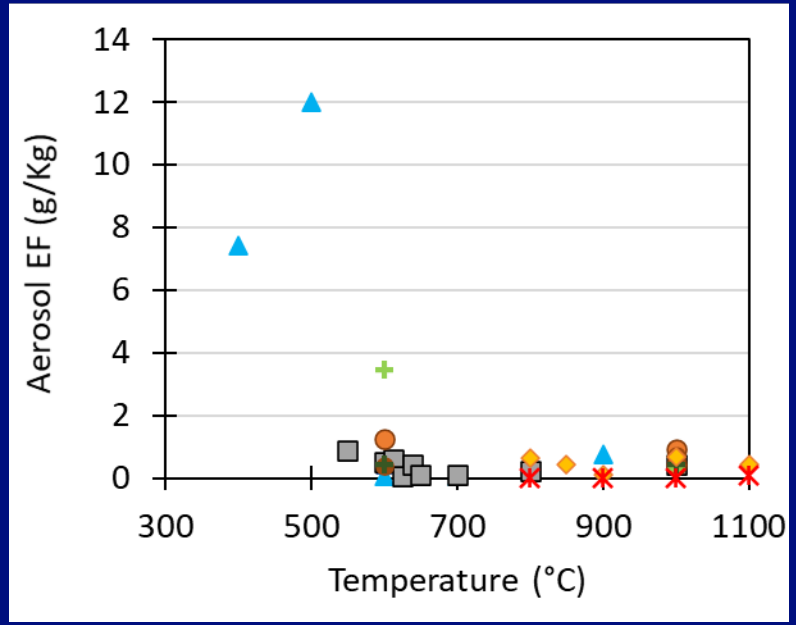
Emissions are most variable at 600°C, similar to the variability observed in aerosol optical properties.

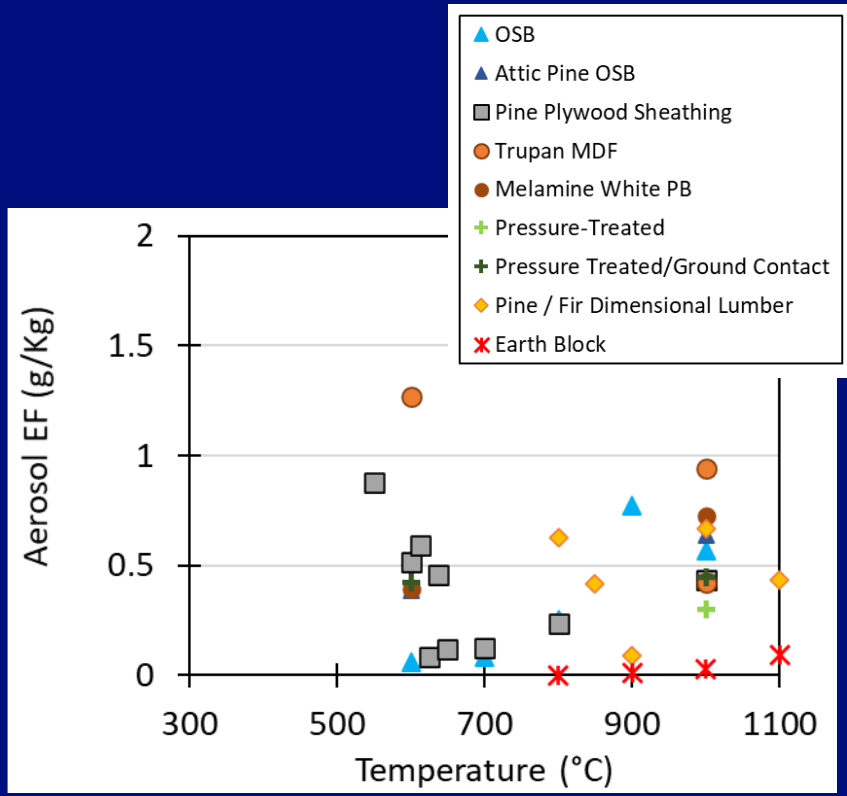






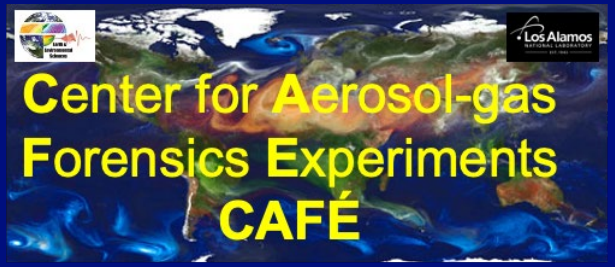
Aerosol emission factors from the Earth Block samples are lowest.



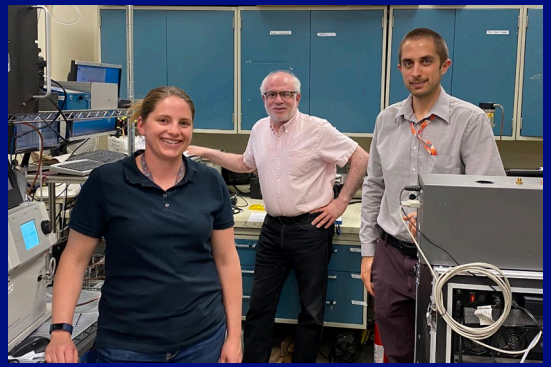


The highest aerosol emission factors were observed for OSB at low temperature.

Summary



- 8 building materials studied
- More BC emitted (~1 mass fraction) at 1000 ^{0}C
- More Formaldehyde emitted by building materials examined here
- Future work, mass spectral analysis for signatures and PAH's



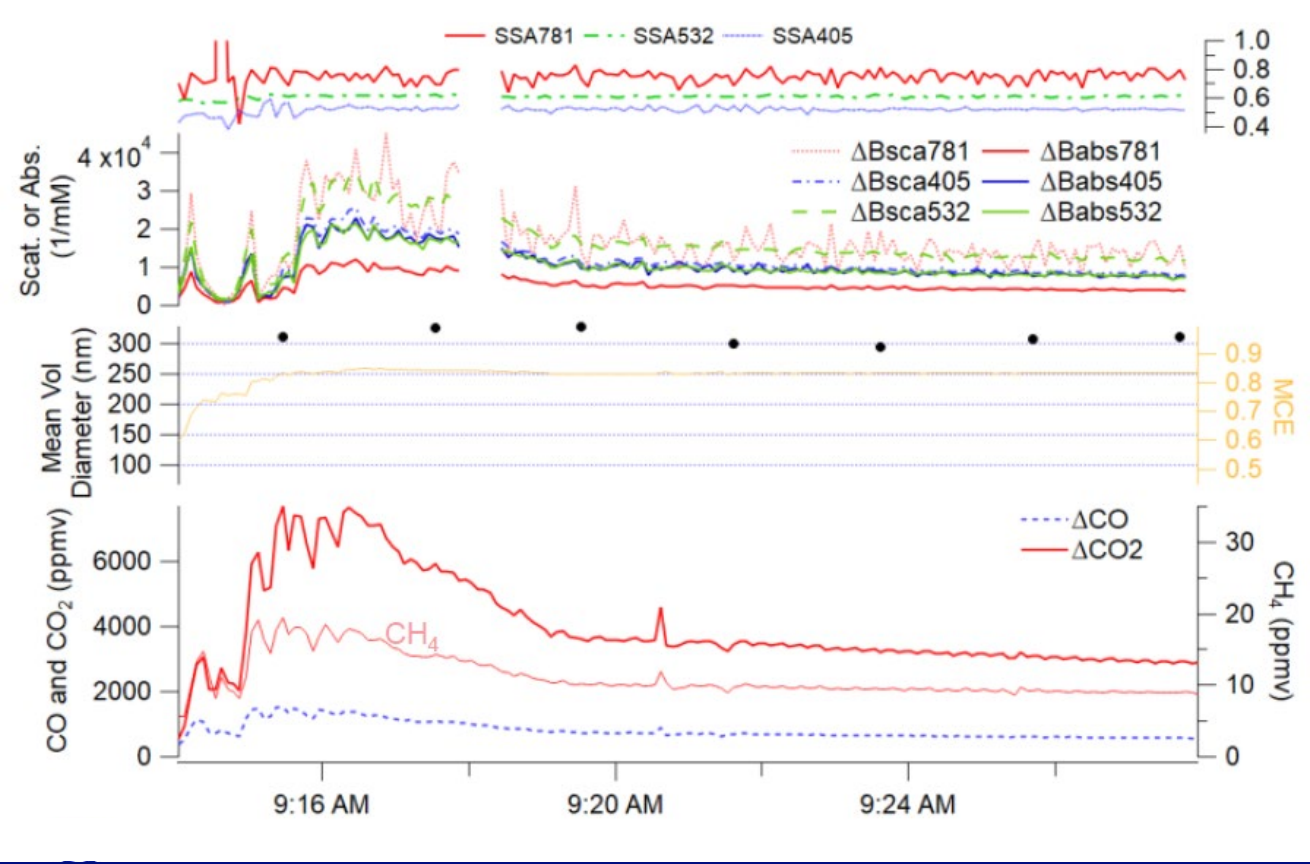
Thank you for your attention!

Acknowledgements

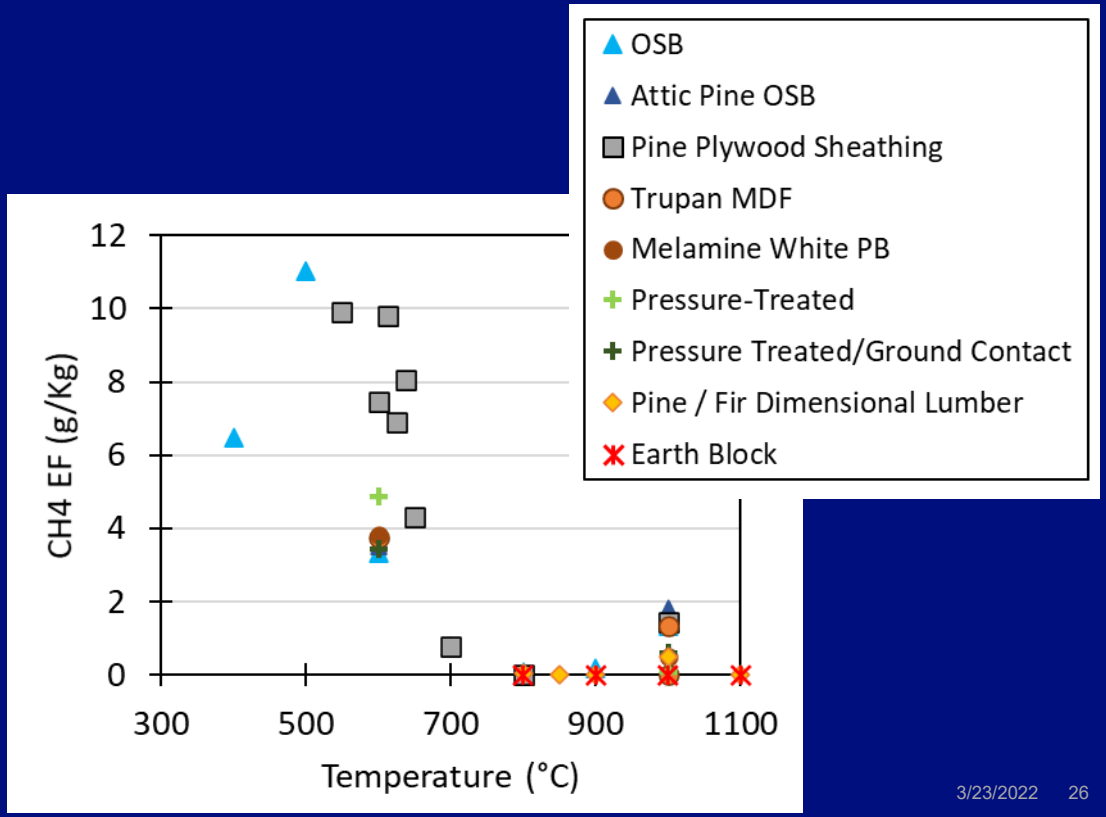
- Michele Barbato, Nitin Kumar – Univ. of California, Davis

Extra Slides

Burning experiment example of online measurements

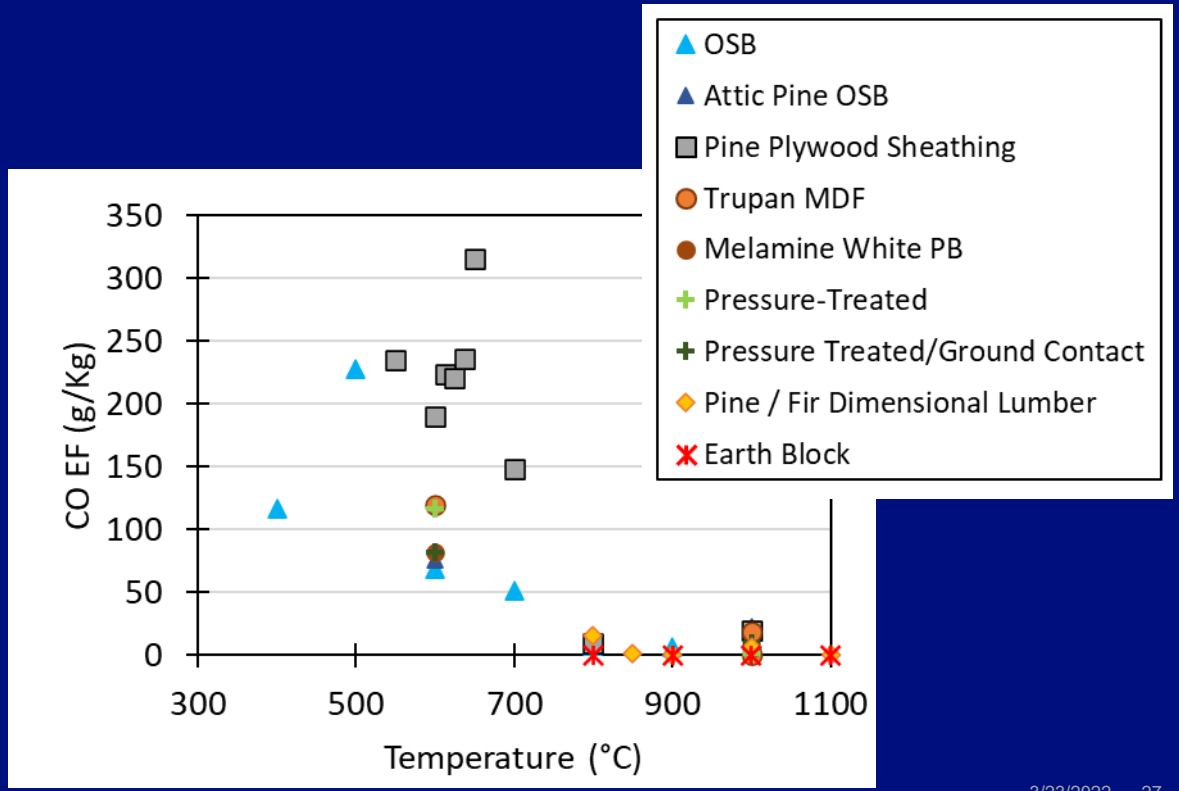


CH4 EFs


OSB
Attic Pine OSB
Pine Plywood Sheathing
Trupan MDF
Melamine White PB
Pressure-Treated
Pressure Treated/Ground Contact
Pine / Fir Dimensional Lumber
Earth Block
CH4 EF (g/Kg)
0
2
4
6
8
10
12
300
500
700
900
1100
Temperature (°C)

Emission Factors – emission per kg of fuel burned

Earth Block samples provided by Michele's lab as a potential new type of building material.



The CH_4/CO emission ratio was higher at 600°C but not significantly.