Measurement and Characterization of Unregulated Emissions from Advanced Technologies

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This presentation does not contain any proprietary or confidential information

Overview

Timeline

- Project start: October 2006
- Project end: ongoing
- Percent complete: updated in response to needs

Barriers

- Lack of emissions and health impacts data on future fuels and engine technologies
  - Identify regulated and unregulated emissions from pre-commercial fuels

Budget

- FY09: **$475K**
- FY10: **$450 K**

Partners

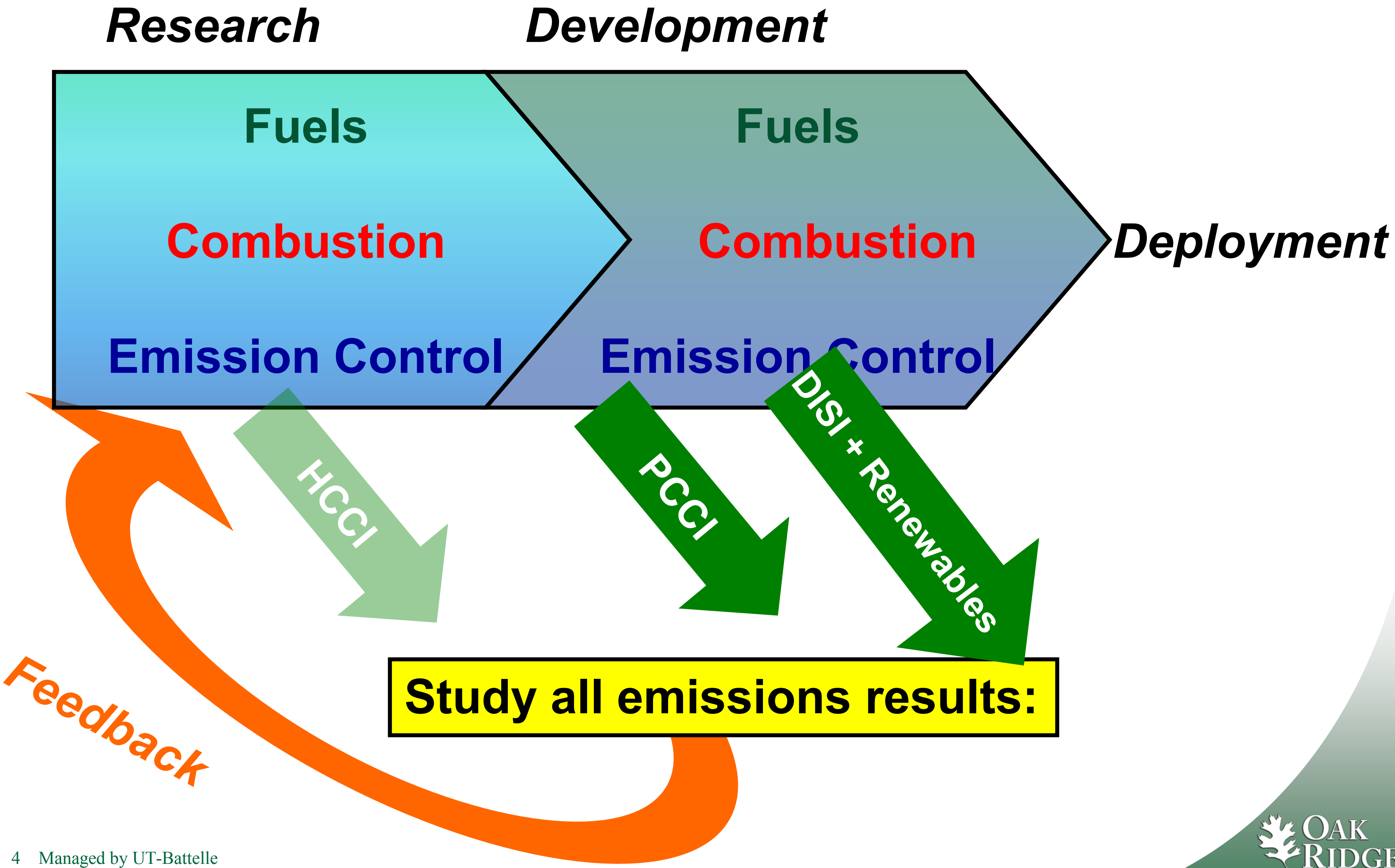
- Working closely with DOE-VT activities on Advanced Combustion Engines and Fuels Technology

Ongoing Need: Measurement and Characterization of Unregulated Emissions from Advanced Technologies

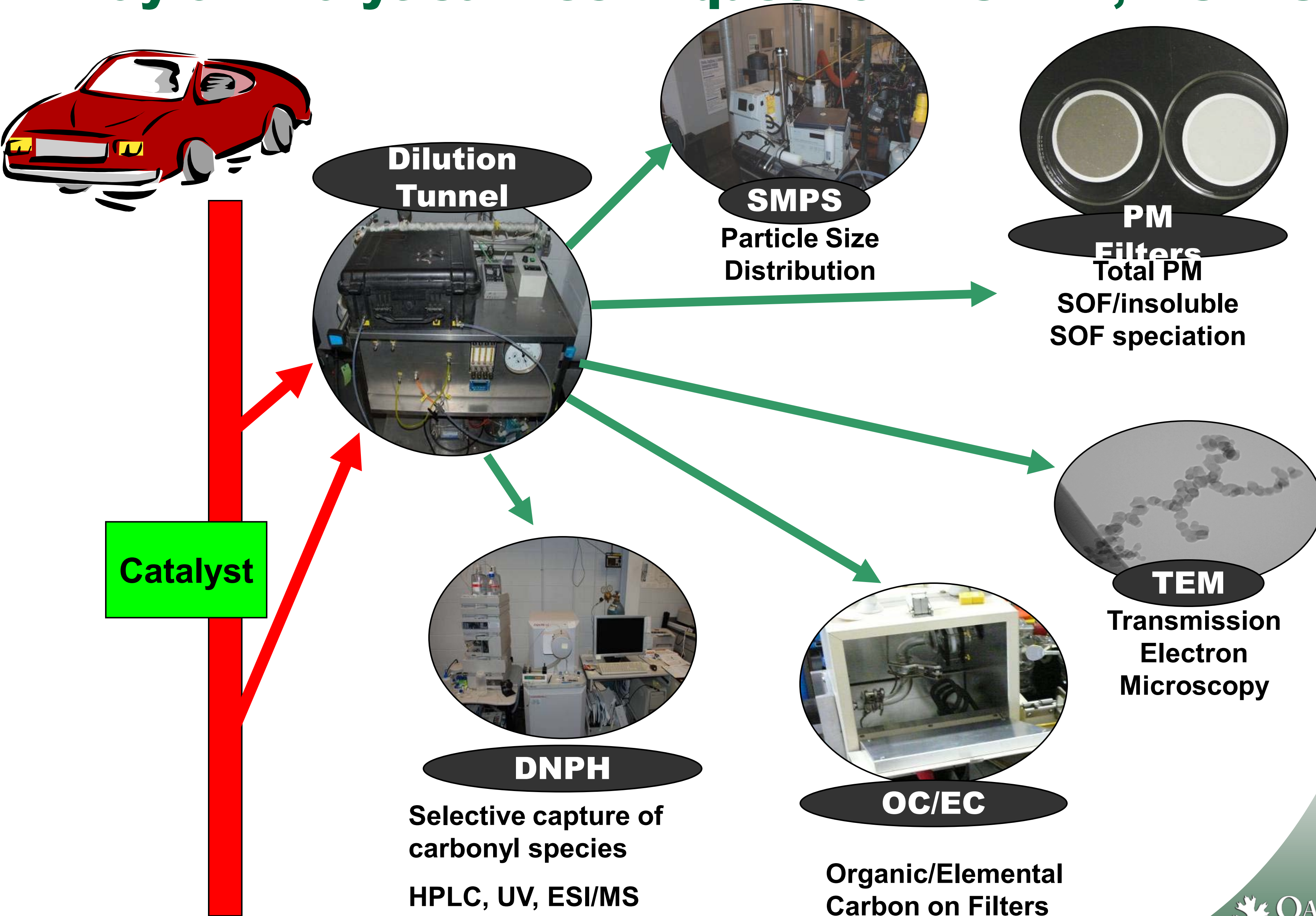
Objective:

- Ensure that advanced petroleum-saving technologies "do no harm"
  - Ethanol and other renewables
  - High-Efficiency Clean Combustion
  - Direct-Injection Spark Ignition

Approach designed to address key barriers



Array of Analytical Techniques for DISI PM, MSATs



Milestones

- **FY09 Milestones (completed):**
  - Characterize mobile source air toxics from vehicles operating on intermediate blends of ethanol and gasoline
  - Identify differences in particle characteristics for PCCI and conventional diesel combustion
- **FY10 Milestone (planned and in progress):**
  - Characterize PM and mobile source air toxics from stoichiometric and lean DISI vehicles operating on blends of ethanol and gasoline (September 30, 2010)

Technical Accomplishments

- Analysis of MSATs from blends of ethanol completed
  - Included E0, E10, E15, E20 for several in-use cars
- Investigated physical characteristics of PM from HECC and conventional combustion
  - Unique centrifugal device used to measure PM density
  - Compared idealized aggregate theory with measured PM
  - Transmission Electron Microscopy (TEM) analysis of particles
- Stoichiometric DISI vehicle on ethanol blends
  - E0, E10, E20 FTP, US06, WOTs, steady-state
  - PM mass, size, number, OC/EC, morphology
- Lean DISI vehicle (Euro-spec) on ethanol blends
  - E0, E10, E20 FTP, US06, WOTs, steady-state
  - PM mass, size, number, OC/EC, morphology
- DPF effects on PM and MSATs from HECC combustion
  - Examine DPF out emissions and DPF regeneration behavior

DISI PM Emissions and Alcohol Blend Effects

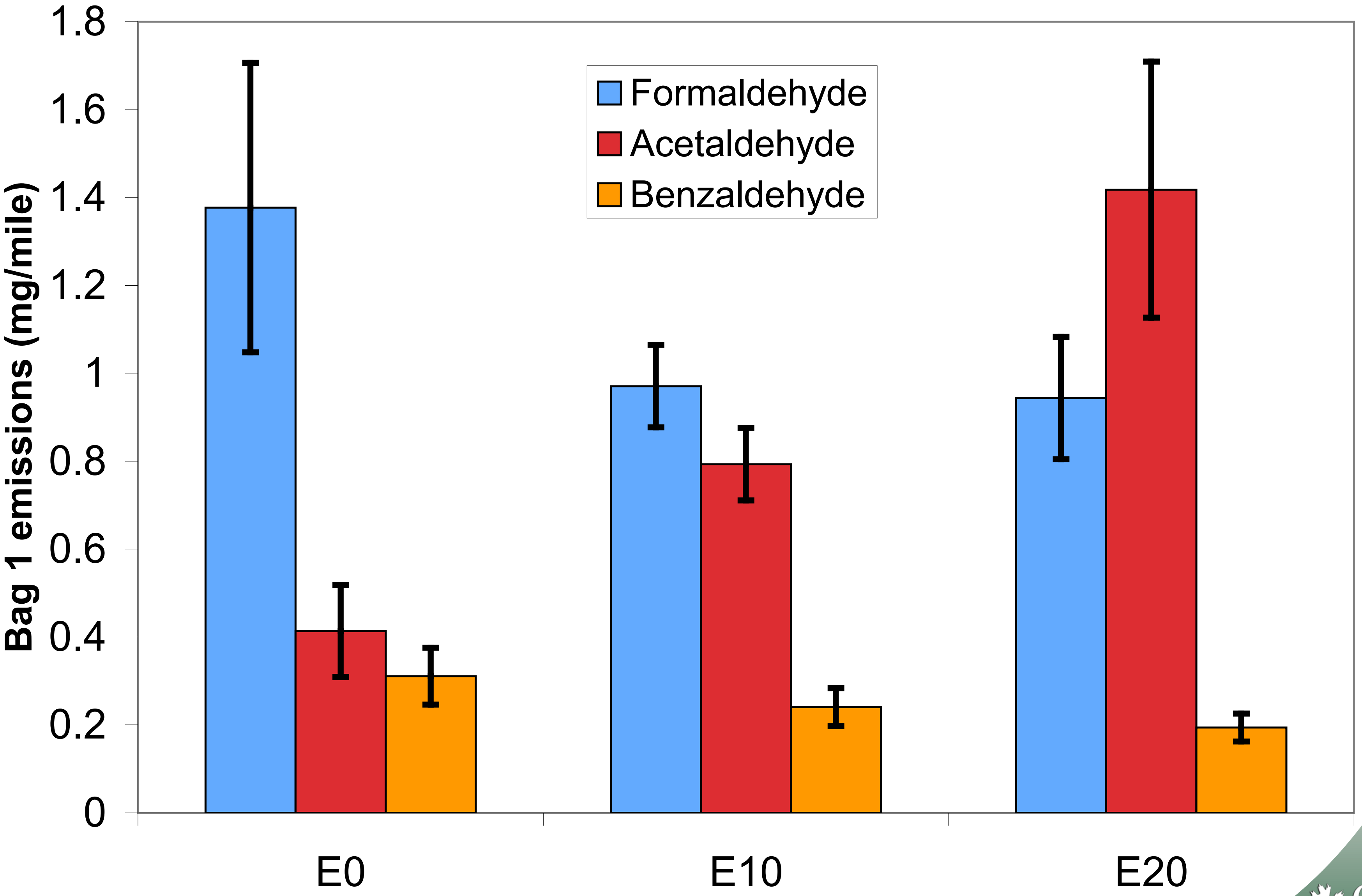
Stoichiometric DISI Vehicle

Lean DISI Vehicle

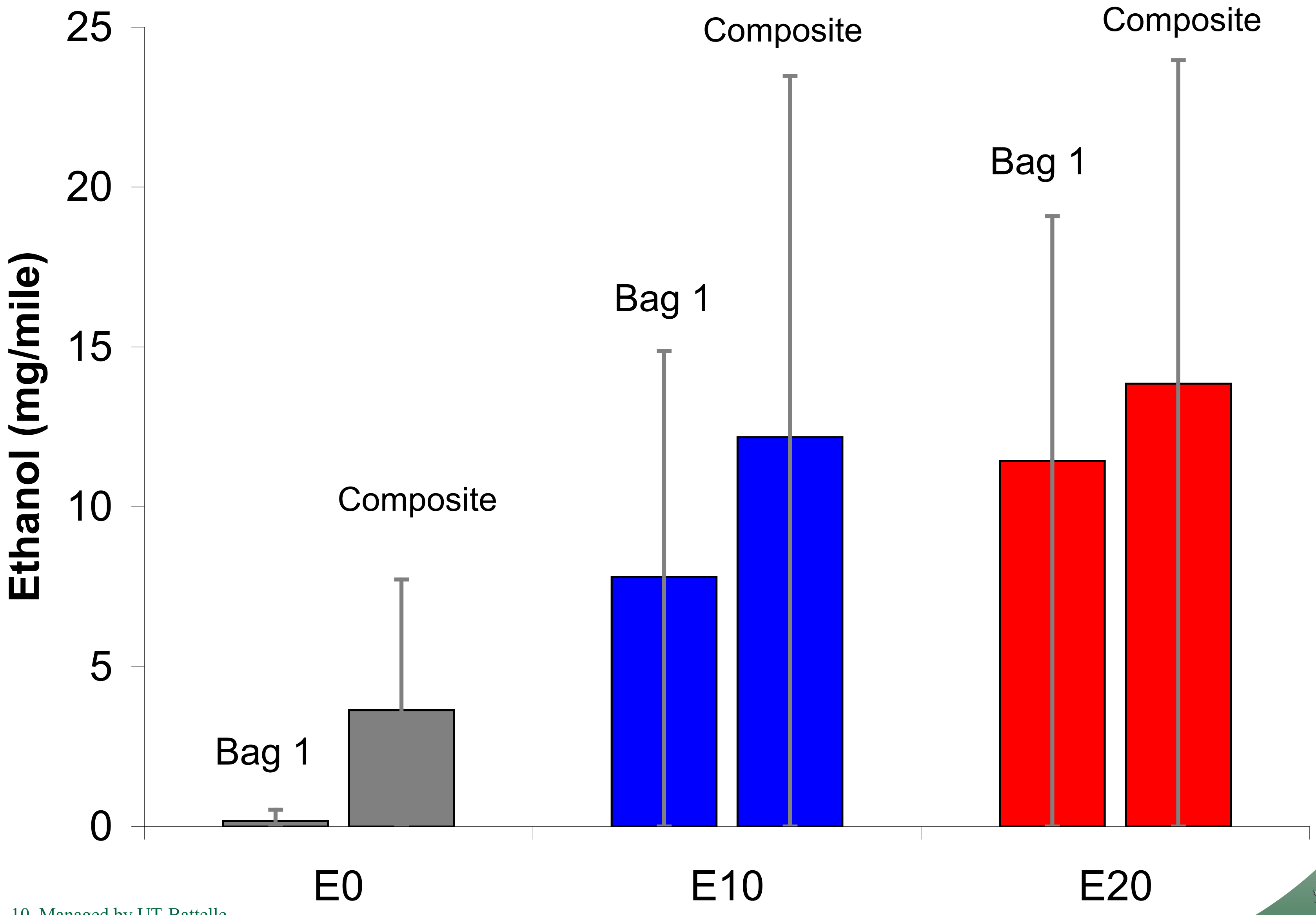
- Examine effects of E10 and E20 on PM characteristics
- Transient cycles and data collection
  - FTP – urban cycle
    - CO, CO_2,HC, NOx, PM mass, PM number
    - Aldehydes and ethanol
  - US06 – harder accelerations
    - CO, CO_2, NOx, HC, PM mass, PM number

- Steady State cycles (30 mph; 80 mph)
  - Pre-catalyst and post-catalyst
  - PM size distribution, Organic Carbon/Elemental Carbon, condensates
  - WOTs and EZ accels: PM number at 10 nm, 50 nm, 100 nm

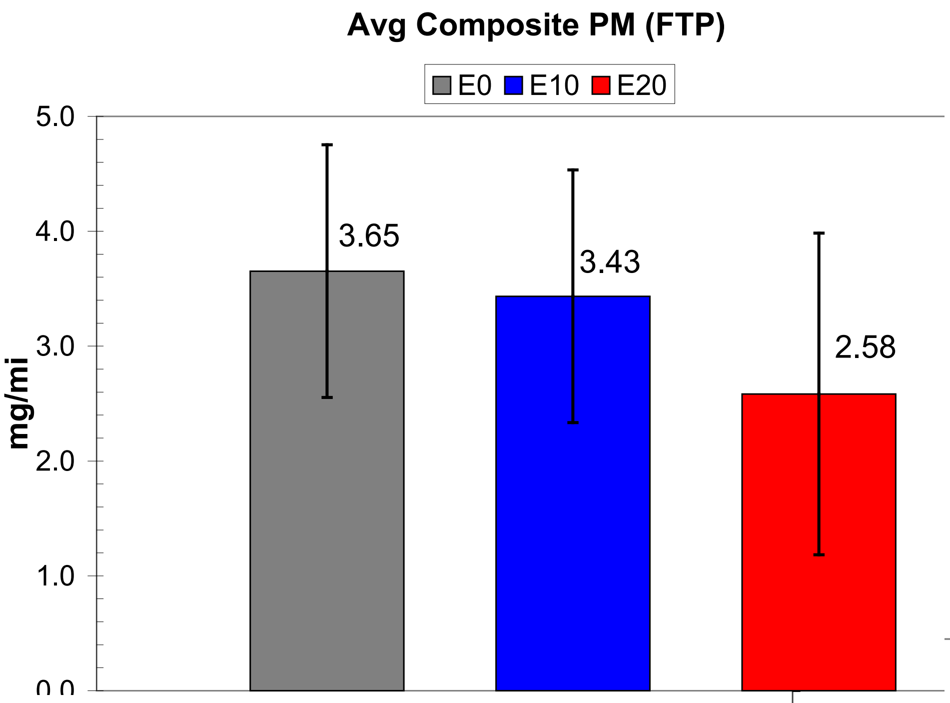
Aldehydes show trend consistent with ethanol blends
Note: Bag 1 emissions only

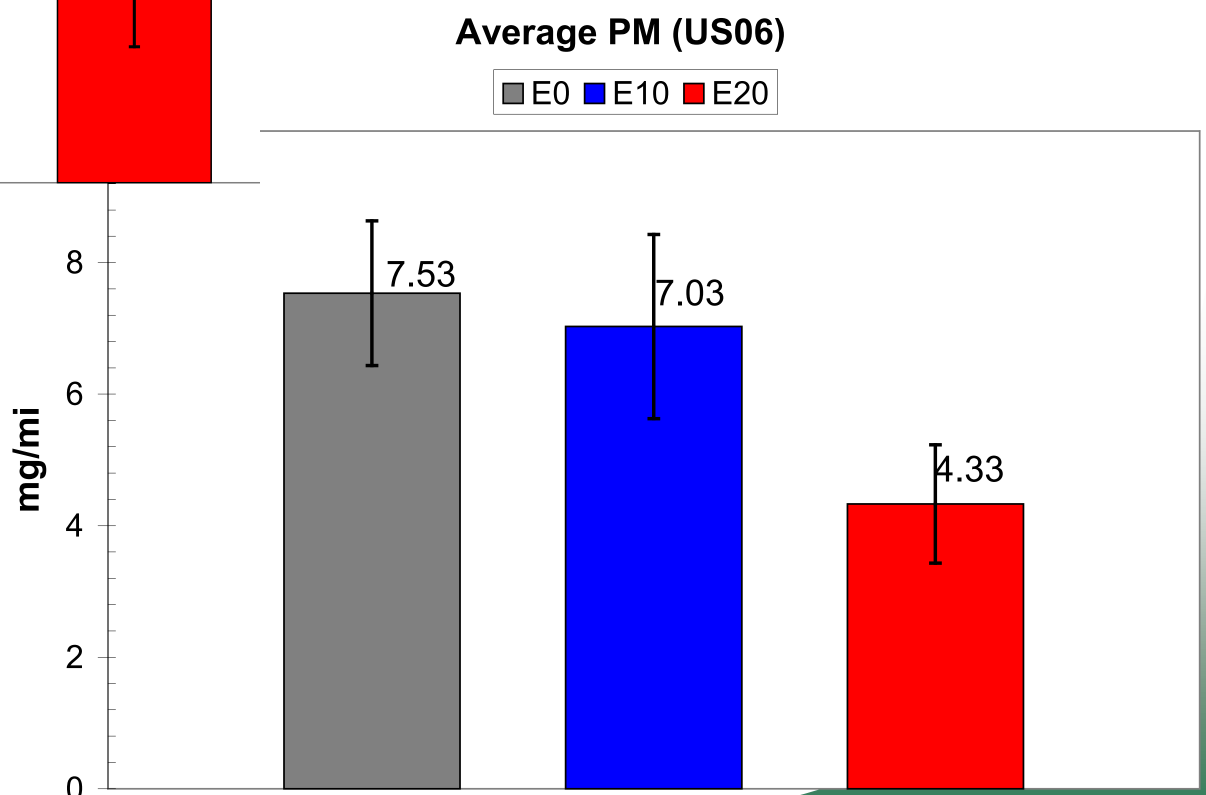


Ethanol emissions trend up with increasing blend level

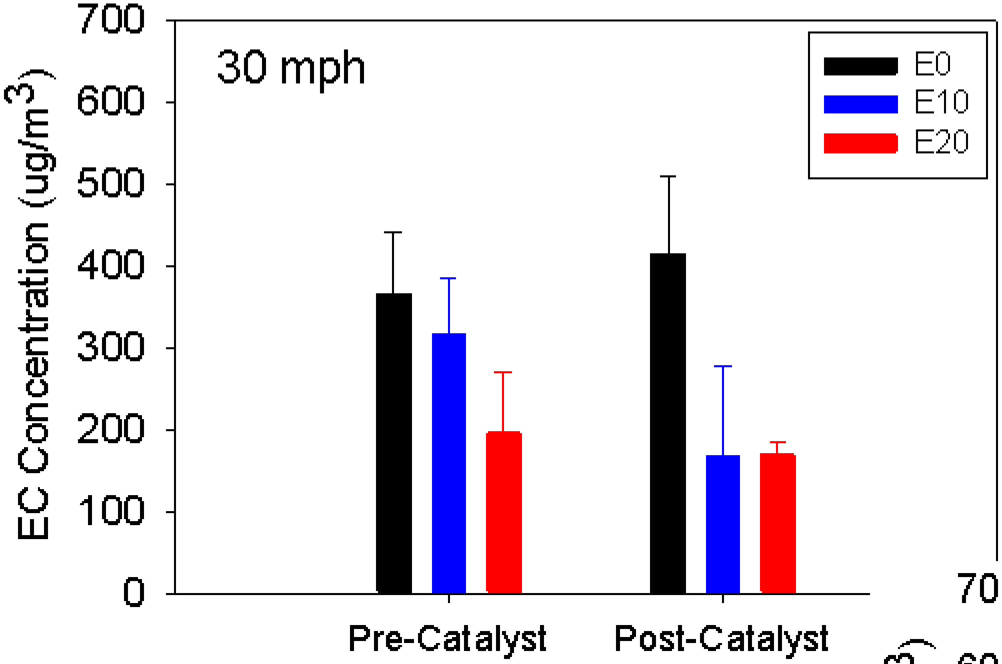


PM mass emissions decrease 30-40% with E20



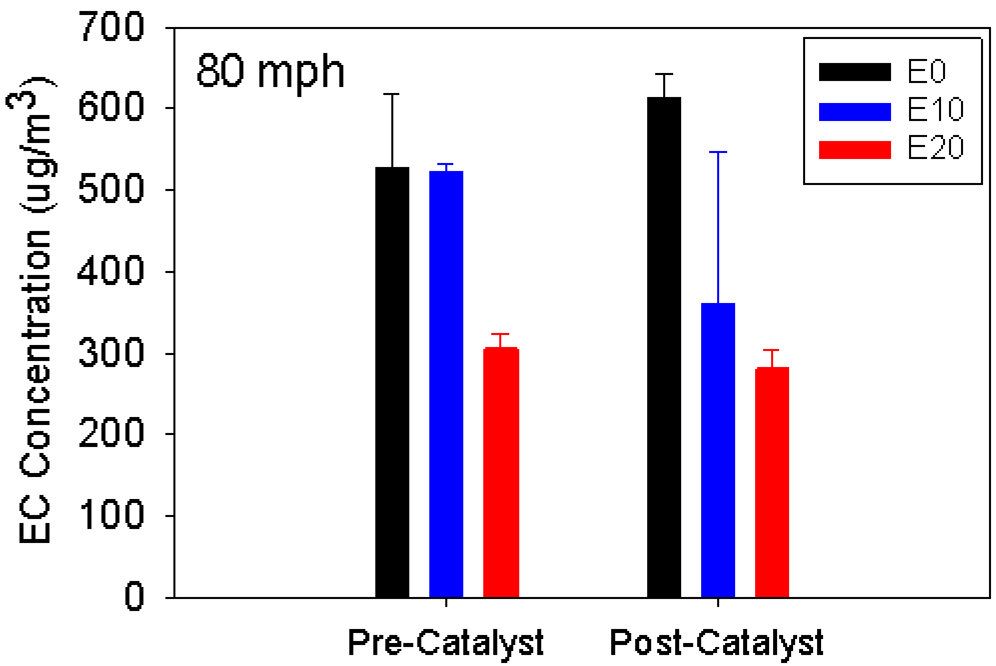


Elemental carbon decreases with increasing ethanol content

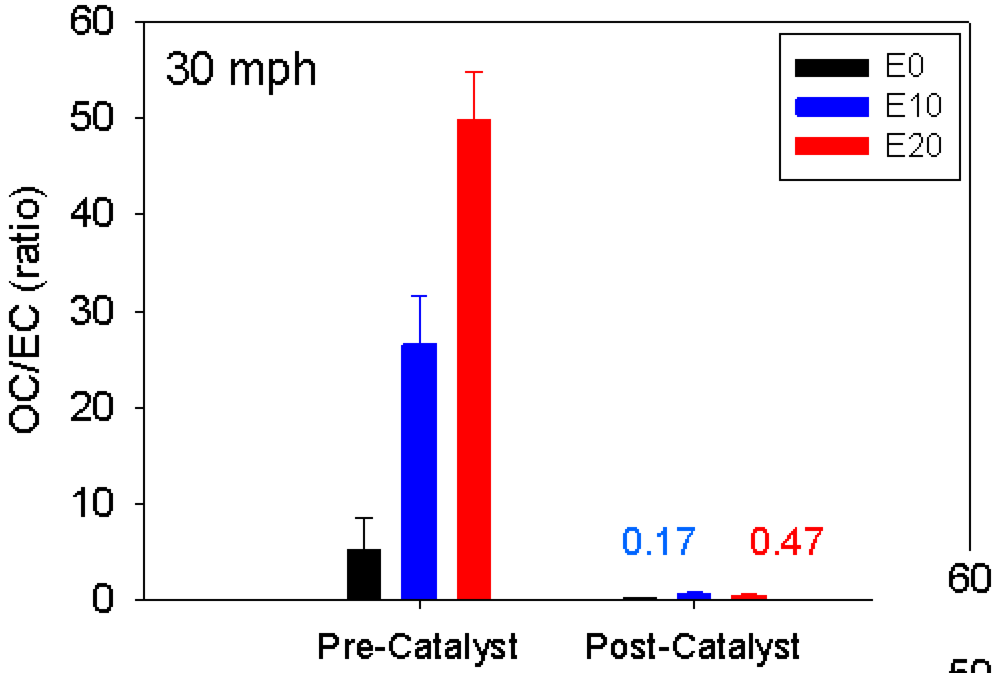


•High speed cruise has higher levels of EC

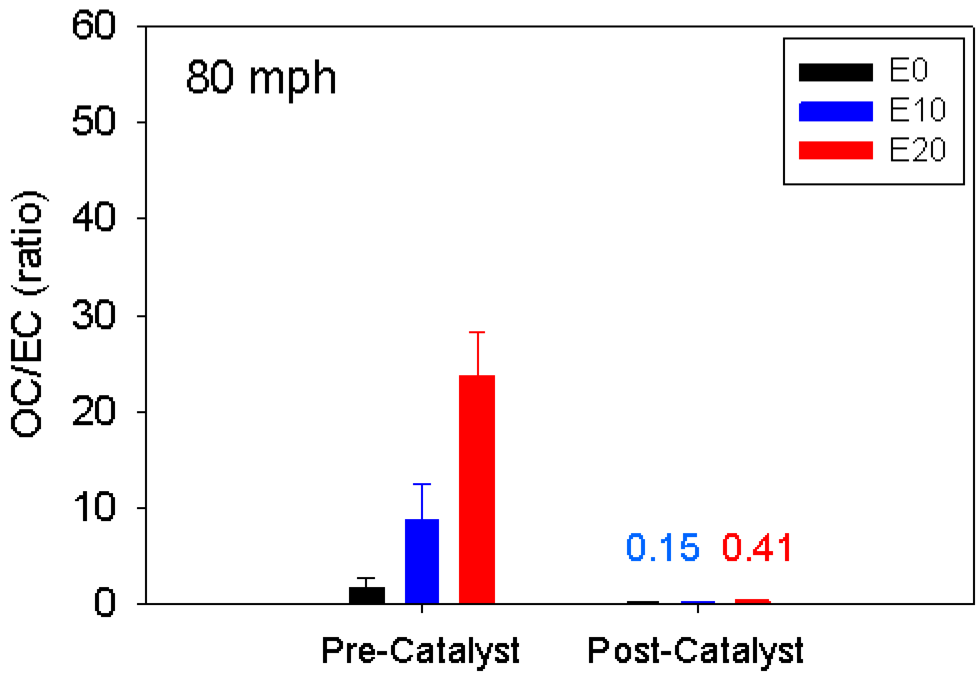
• Similar EC concentration pre- and post-catalyst implies small PM losses



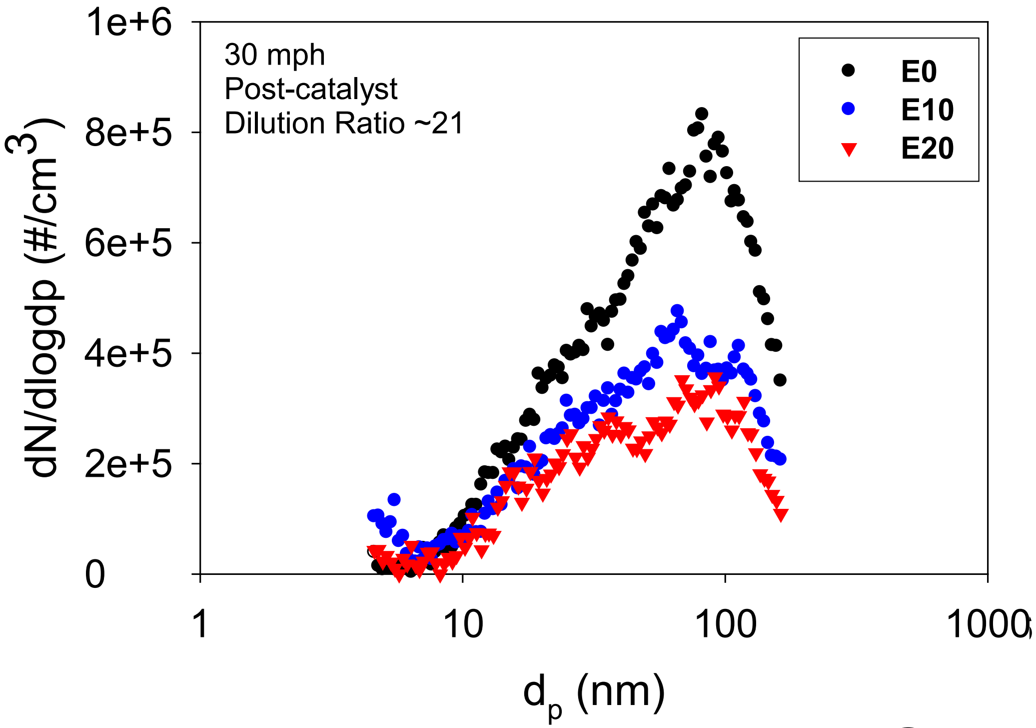
OC/EC increases 10-fold with increasing ethanol



- OC effectively removed by the catalyst
- Catalyst = 100-fold decrease in OC/EC!



Size distributions consistent at both steady-state points

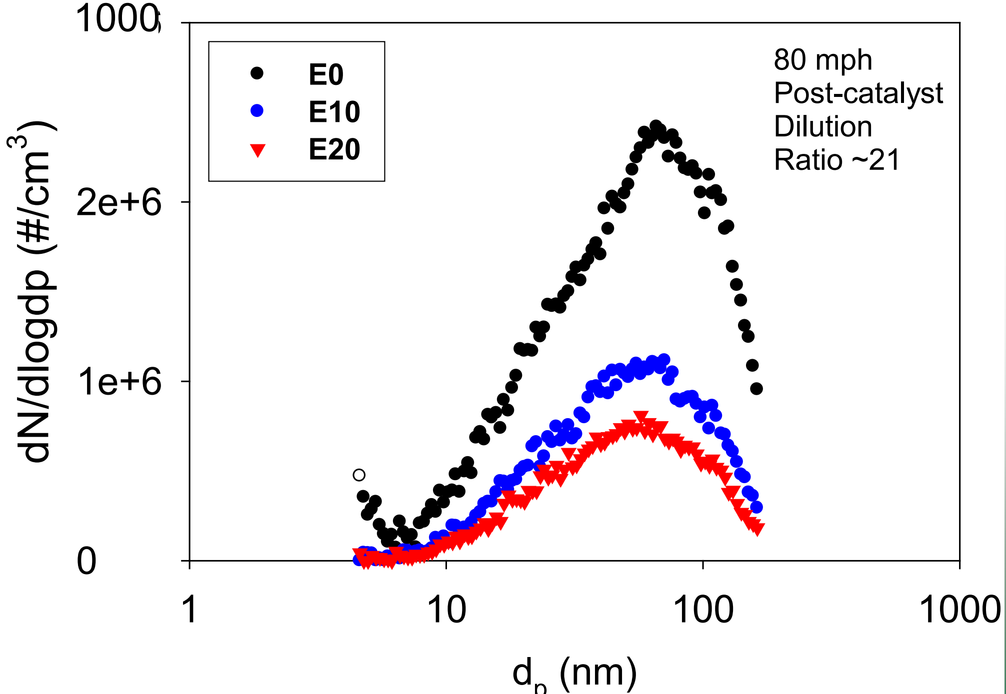


Ethanol content does not change general shape of size distribution but reduces peak.

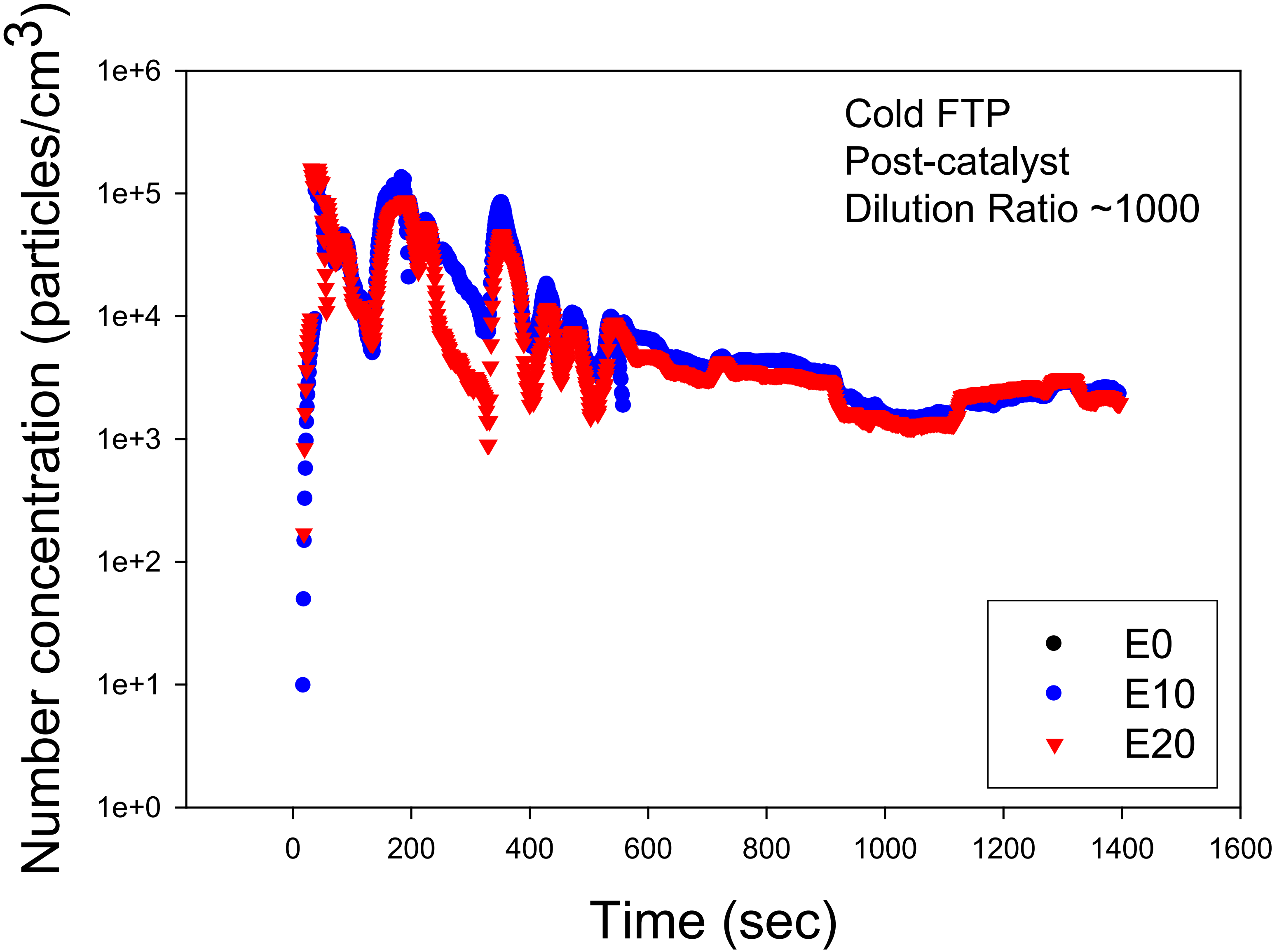
E20 reduces total number concentration by about 50% at 30 mph and 70% at 80 mph

Geometric mean diameter for all distributions ~ 50 nm

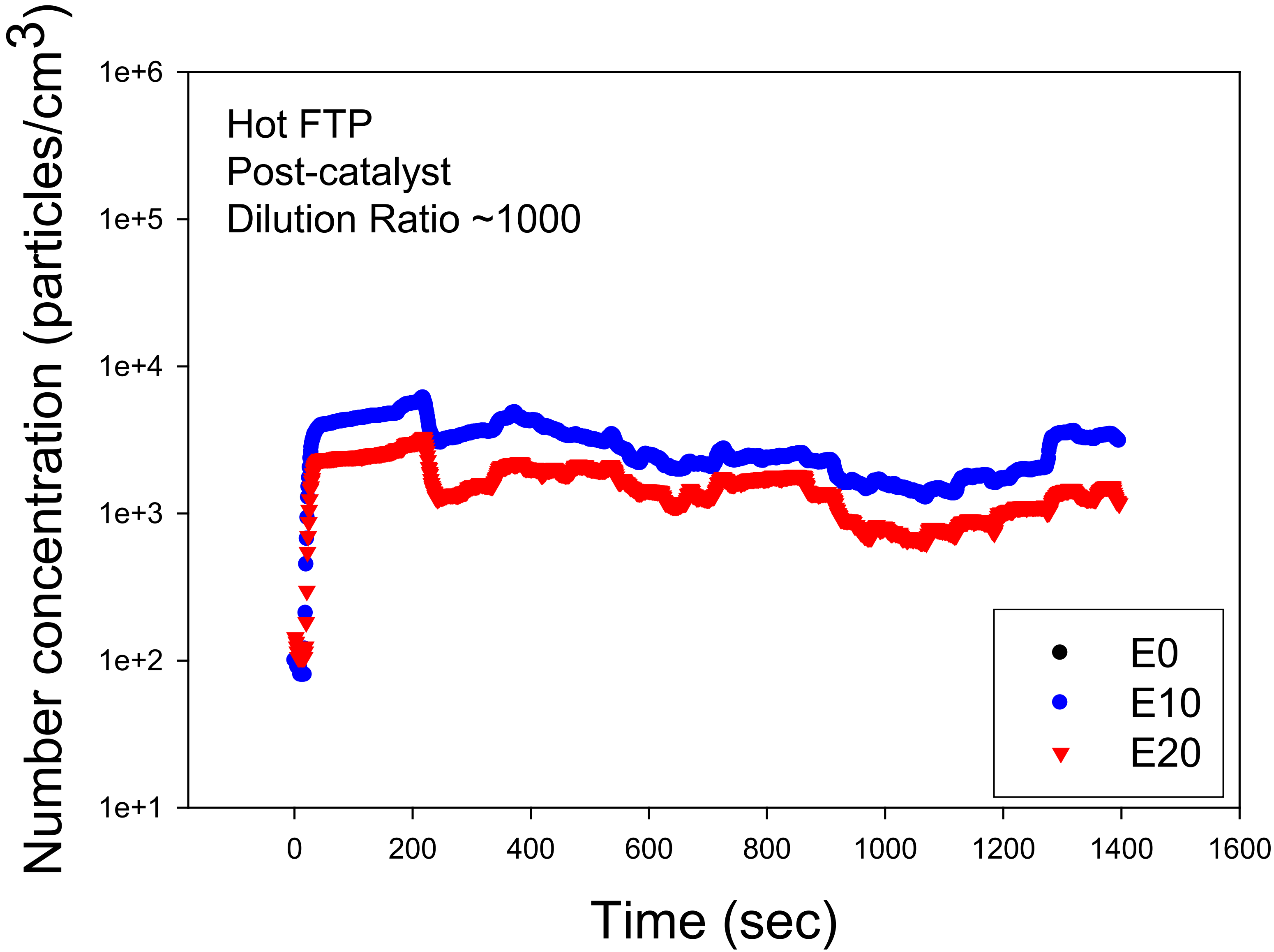
Particle size similar to diesel exhaust particles

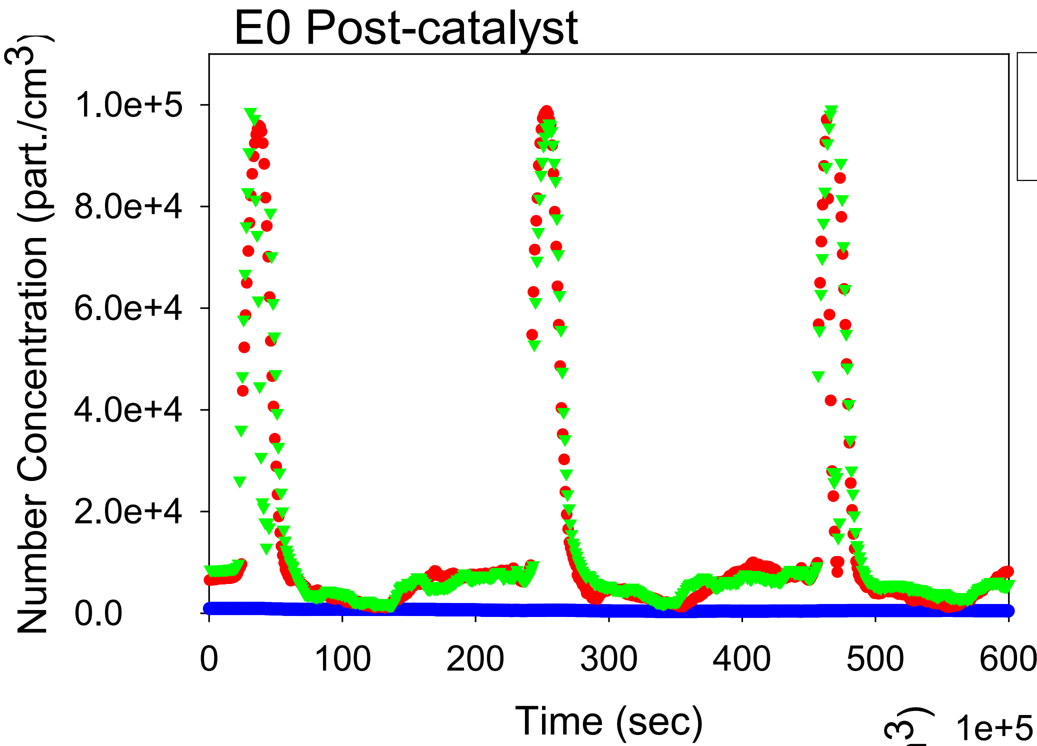


E-blend has little effect on cold-start number concentrations



E-blend lowers number concentrations during hot start cycles

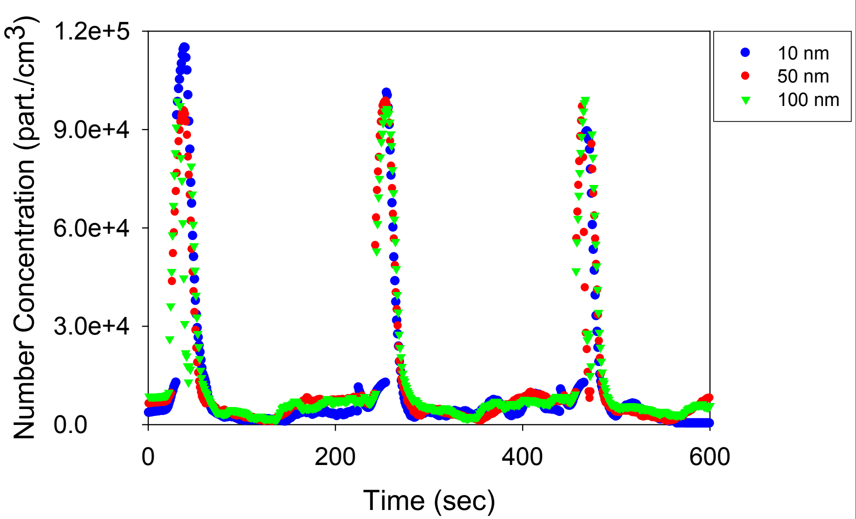


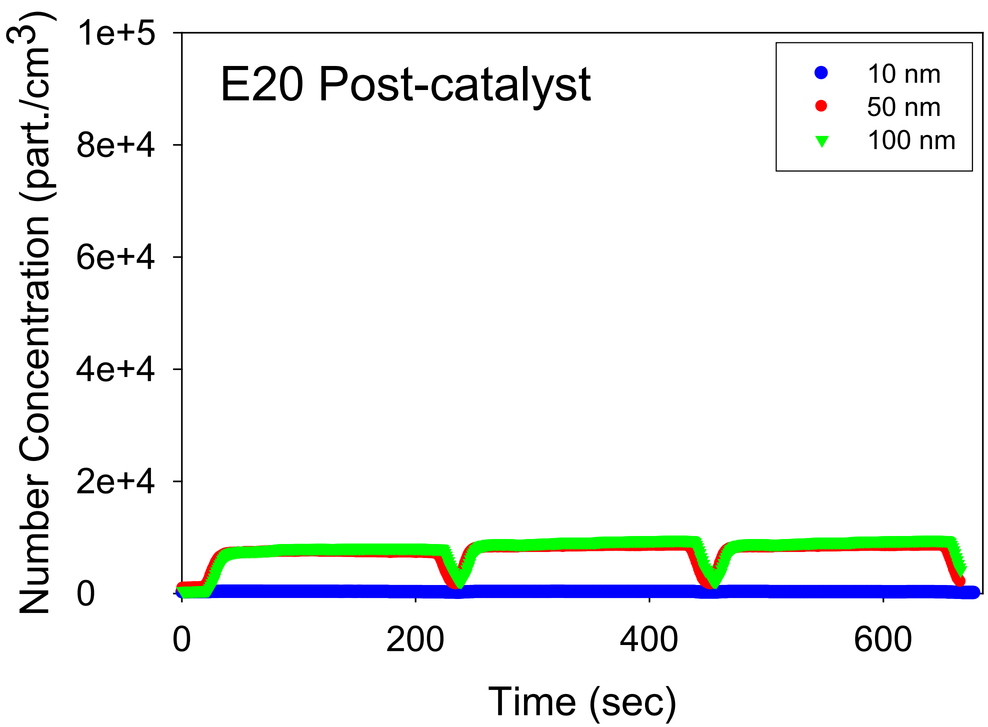


Wide Open Throttle 0 – 80 mph

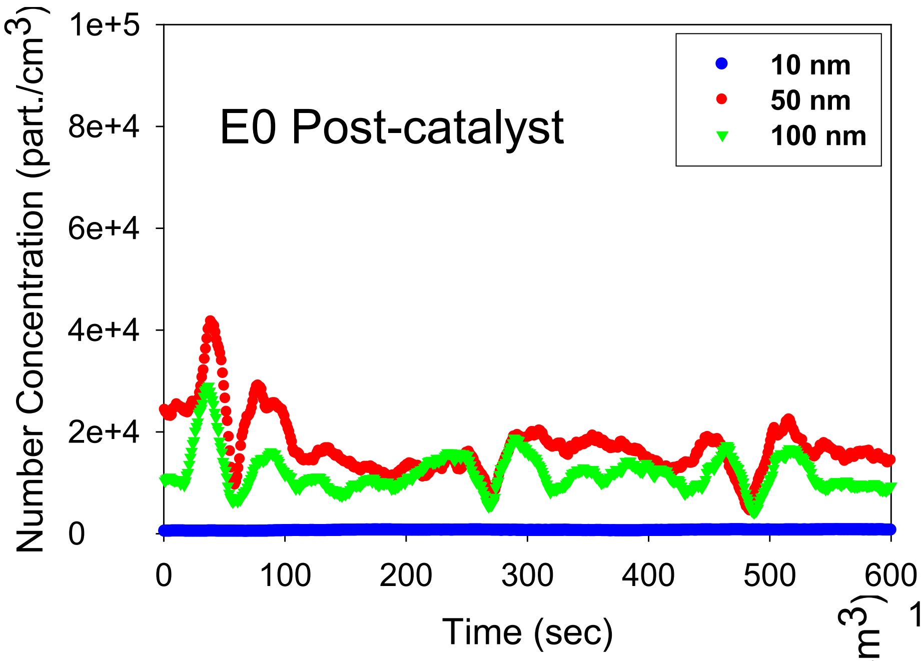
- E20 truncates spikes in 50 and 100 nm particle emissions during hard accelerations

- Catalyst removes 10 nm particles



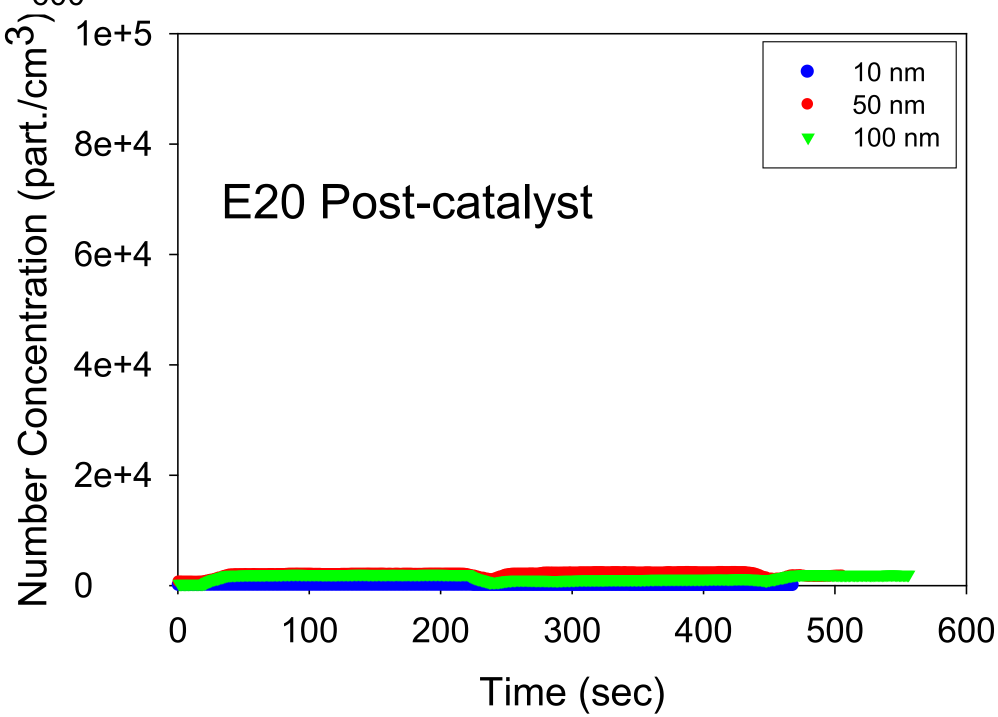


Moderate Acceleration - 0 to 50 mph



- Particles may be generated in in-cylinder fuel rich zones
- Ethanol reduces amount of carbon available for soot formation through CO formation pathway (Wu et. al, 2006)

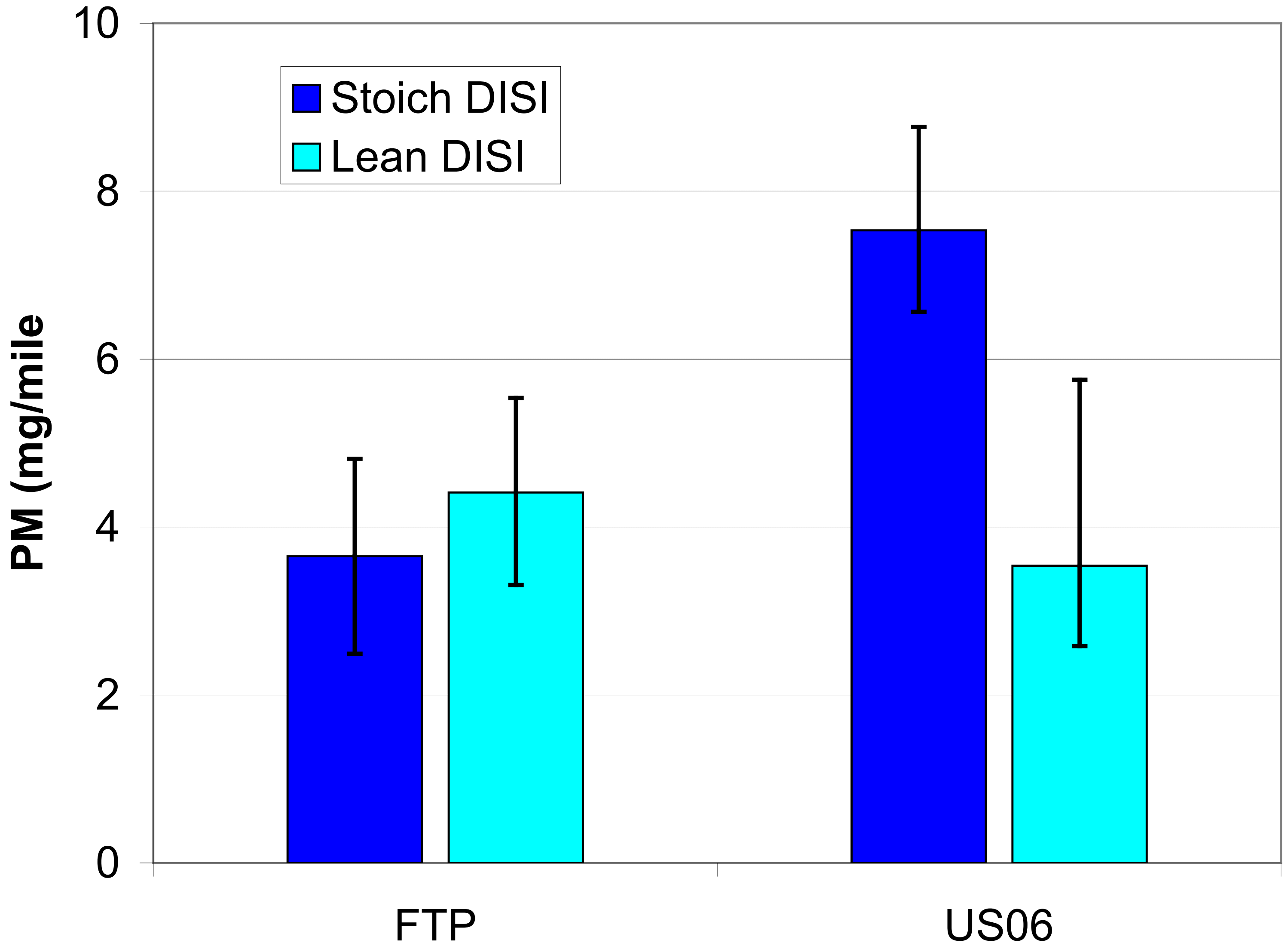
- As for the WOT accelerations, 50 and 100 nm particle emissions reduced by E20



Future Work

- **Rest of FY10**
  - Data analysis from lean burn DISI vehicle
  - Investigate DPF effects on PM and MSATs from HECC operation
  - Volatile/non-volatile PM measurement
- **FY11 and beyond**
  - Start-stop emissions for hybrids/plug-in hybrids
  - Urea SCR filter analysis for ACES project
  - Continue to look at DISI MSATs/PM from “other” alcohol blends
    - Butanol and multi-alcohol blends

PM mass emissions of lean DISI in comparison with stoichiometric (E0 only)



Collaboration and Coordination

- **DISI studies:**
  - FEERC vehicle team: Brian West, Shean Huff, John Thomas, Kevin Norman, Larry Moore
  - GM for providing the lean DISI vehicle
  - Vehicle Technologies - EERE
    - Advanced Combustion and Efficiency program
    - Vehicle Systems
    - Fuel Technologies
- **PM studies**
  - ORNL-HTML for microscopy
  - National Institute of Occupational Safety and Health
    - Co-developed protocol for exposure metric for engine exhaust particles in mines based on particle surface area
  - University of Maryland
    - Co-wrote paper on PM density
  - CRC for PM Measurement Workshops
  - Caterpillar
    - Assisted with particle morphology effects on optical light-scattering measurements

Conclusions

Implications of E-blend use in DISI vehicle:

- Up to 1.5 mpg loss in tank fuel economy
- Decrease in formaldehyde and benzaldehyde, but increase in acetaldehyde with higher ethanol
- 30 to 40% reduction in PM mass and elemental carbon emissions
- Several-fold increase in PM organic carbon - effectively removed by catalyst
- At least 50% reduction in total particle number concentration for 30 and 80 mph.
- Reduction of 50 and 100 nm particle emissions during acceleration.

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