Mobile Source Emissions & Biofuels: An Overview of Selected Canadian Federal R&D

Environment Canada Environnement Canada

Canada

Outline

- Emissions Research and Measurement Division Facility
- Biodiesel Targeted Measure
- Light duty ethanol programs
- Biofuels and advanced combustion strategies
- Summary of major findings

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Emissions Research and Measurement Division

- Regulatory
  - Canadian Environmental Protection Act compliance
    - Light duty vehicles, heavy duty engines, off-road engines
- Research
  - Detailed emissions characterization
    - Advanced fuels, aftertreatment, combustion strategies
  - Collaborative R&D
    - Health effects, emissions inventories, source apportionment, real-world emissions measurements
- Support for Technology Development
  - Private sector clients
    - Aftertreatment, fuels, vehicle technologies, engine technologies

Facility

- Four light duty chassis dynamometers
  - One in cold cell
  - One 4WD to be commissioned
- Motorcycle/ATV chassis dynamometer
- HD chassis dynamometer
  - in cold cell
- Two HD engine dynamometers
- Three small engine dynamometers
  - Chainsaws to light duty vehicle engines
- Two SHEDs
- Field sampling

Biodiesel Activities

A Decade of Biodiesel Studies

- *Biodiesels for a Mining Application*

  MSED #95-26745
- *Evaluation of Biodiesel in an Urban Transit Bus Powered by 1998 DDECII6V2 TA and DDC8V71 Engine*

  MSED #95-26743
- *Evaluation of Heavy Duty Engine Exhaust Emissions Using Biodiesel and Oxidation Catalyst DDC 6V71*

  MSED # 96-01
- *Emissions Evaluation of Biodiesel Blends on a Late Model Diesel Truck*

  ERMD # 98-26718

Biodiesel Targeted Measure

- Announced in 2003
  - 500 M litres/year production of biodiesel by 2010
  - Reduction of GHG emissions from on/off-road vehicles by 1.1 Mt by 2012
- Allocated $ 11.9 M (2003-2007)
  - Support programs that encourage wider usage of biodiesel
  - Identify and remove barriers to commercialization of biodiesel production in Canada

Biodiesel Targeted Measure

- Activities:
  - On-road and off-road end user technology demonstrations
  - Emissions analysis, fuel specifications, fuel property analysis
  - Technology R&D and pilot plants (feedstock handling, process conversion)
  - International technology linkages
  - Public awareness, education, outreach

Emissions Studies

- **Urban Transit Buses**
  - BioBus
  - Halifax Transit Authority
  - GVRD Bus Technology Demo
- **Class 8 Highway Trucks**
  - Biodiesel Byway
  - Effect of Biodiesel on Criteria Air Contaminants
- **HDE's & Advanced After-Treatment Technologies**
  - Biodiesel fuel matrix
  - Diesel Particulate Filters
    - Both Passive and Active Regeneration Strategies
  - SCR Technologies (2 manufacturers)
- **Non-Road**
  - BioMer – river tour boats in Montreal
  - BioShip – Cargo Vessel Auxiliary Engine
  - Gen Sets
- **Criteria emissions**
  - CO, NO_X, TPM, HC
  - Fuel consumption
- **Detailed emissions characterization**
  - NMHC, carbonyls
  - organic acids
  - semiquantitative analysis for oxygenated compounds
  - CH_4, N_2O
  - SO_2, NH_3
  - OC-EC
  - PM ions, metals
  - PM/SVOC characterization
    - PAH, NO_2PAH
    - Alkanes, biomarkers, alkylcyclohexanes

Urban Buses

- Test Engines:
  - 98 Cummins 8.3L mechanical fuel injection
  - 02 Cummins 8.3L electronic fuel injection
  - 1999 NOVA LFS Cummins ISC 250
  - 1994 NOVA Classic DDC 6V92
- Test Fuels: B5, B20
- Feedstocks include canola, animal tallow, recycled yellow grease, fish oil

Urban Buses

- *Whether on-road testing, chassis dynamometer testing or engine dynamometer testing*
  - ↓ 2 to 30% PM
  - ↓ 70% EC
  - ↓ 9 to 18% SO_4
  - No change or small ↓ NO_X,
  - ↓ 9 to 31% CO
  - ↓ 11 to 30% HC

Urban Buses

- Common Themes
  - PM
    - Mechanical control engines showed greater decreases than electronic control engines
  - NO_X
    - If observed, electronic control engines showed decrease. No change for mechanical control engines.
  - Fuel Consumption
    - No statistically significant difference compared to ULSD

Class 8 Highway Trucks

- Three Class 8 highway tractors
  - Engines: Cummins, Caterpillar, Mercedes
- Full emissions characterization on chassis dynamometer (HD-UDDS)
- Test Fuels:
  - LSD, Biodiesel Blends; B2, B5, B20, B100
  - One test with ULSD/B20
  - One test with B5 @ -10^{o}C

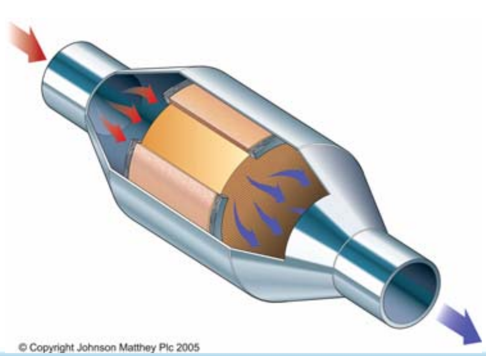
Class 8 Highway Trucks

- All emission changes from LSD to B100 were statistically significant, except CO_2.
  - ↓ 25 to 80% for CO, THC and PM with B100
  - ↑ 4 to 22% for NO_X with B100
- B20 trends were similar to B100 but smaller in magnitude.
  - With B20, the Cummins powered rig showed a modest decrease in NO_X.
- For B2 and B5
  - No difference in NO_X emissions
  - ↓ 9% for PM for B5
  - No difference in PM for B2.

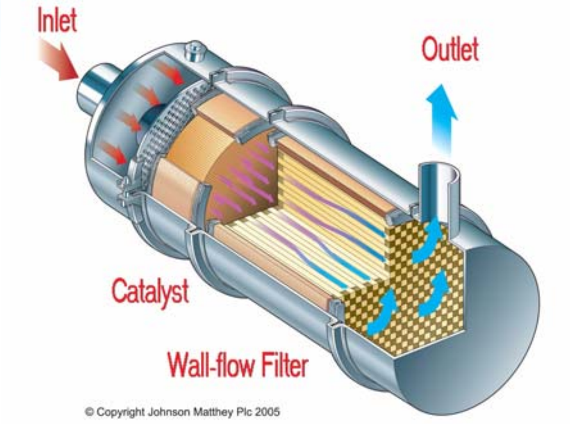
- Two trucks tested on ULSD and B20/ULSD
  - The Cummins powered rig showed no change in NO_X
  - The Mercedes powered rig
    - ↑ 2% for NOX and ↓ 15% for PM.
- Fuel consumption
  - ↑ with B100 fuel
  - No measurable change with B2, B5, and B20

HDE's & Advanced After-Treatment Technologies

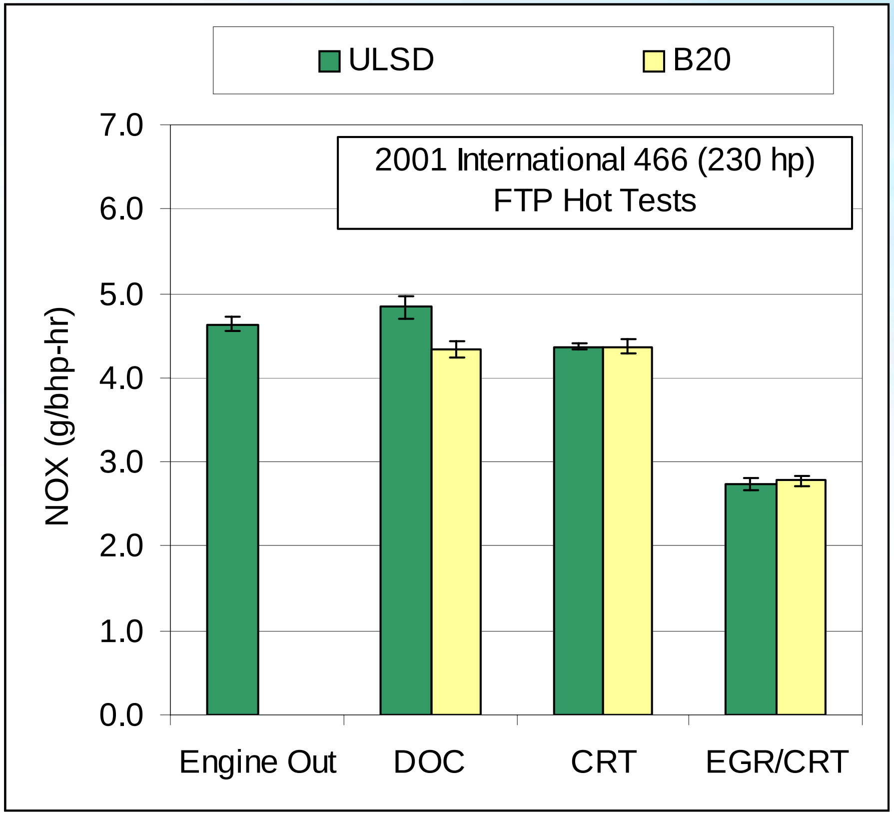
- Fuel Matrix Component of NYC Transit Clean Diesel Demonstration Project
  - 2000 International DT466
    - 10 fuels, 4 after-treatment and engine configurations
    - B20/ULSD tested with DOC, CRDPF, and CRDPF with EGR
  - FTP Transient test
  - Detailed emissions characterization

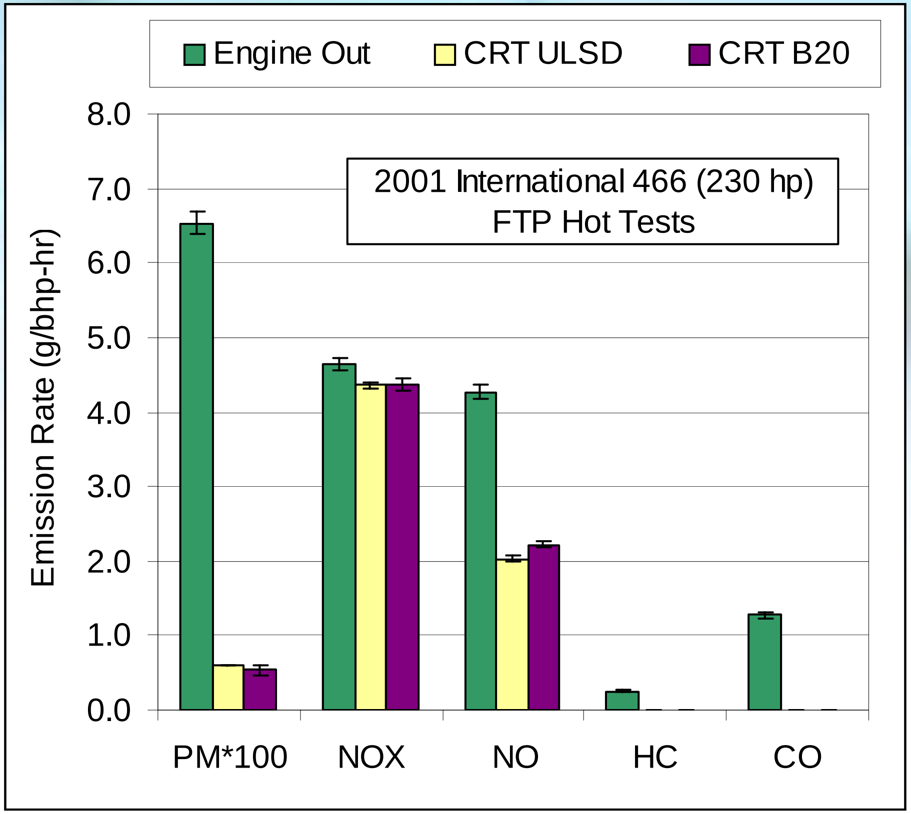


- Biodiesel Fuel Matrix
  - 2004 CAT C11 ACERT
  - 2004 Cummins ISM
    - B5 & B20 blended with ULSD
    - Soy, Canola, and Tallow
  - FTP Transient and Steady State Operation
  - Detailed emissions characterization

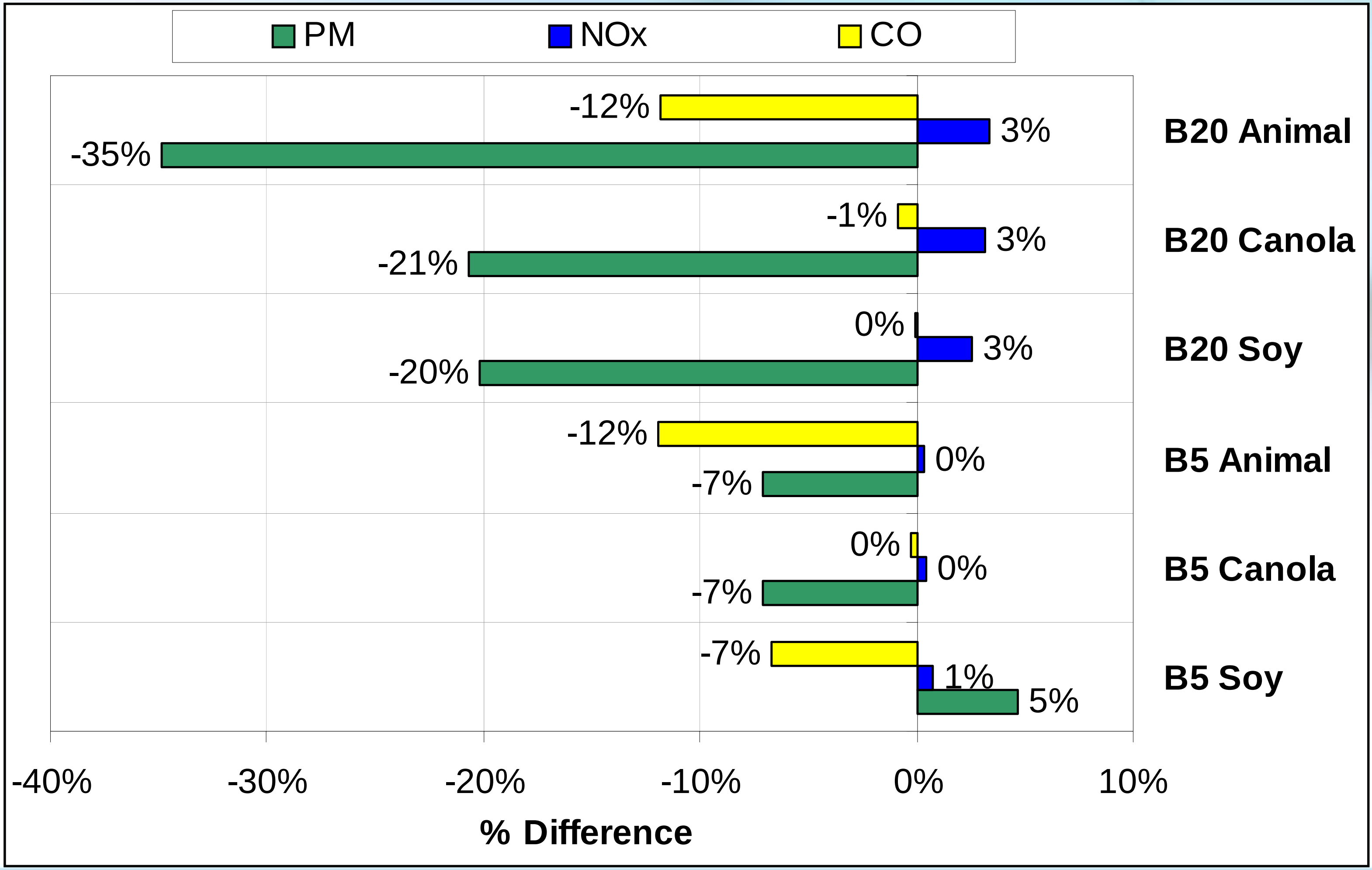


HDE's & Advanced After-Treatment Technologies





HDE's & Advanced After-Treatment Technologies



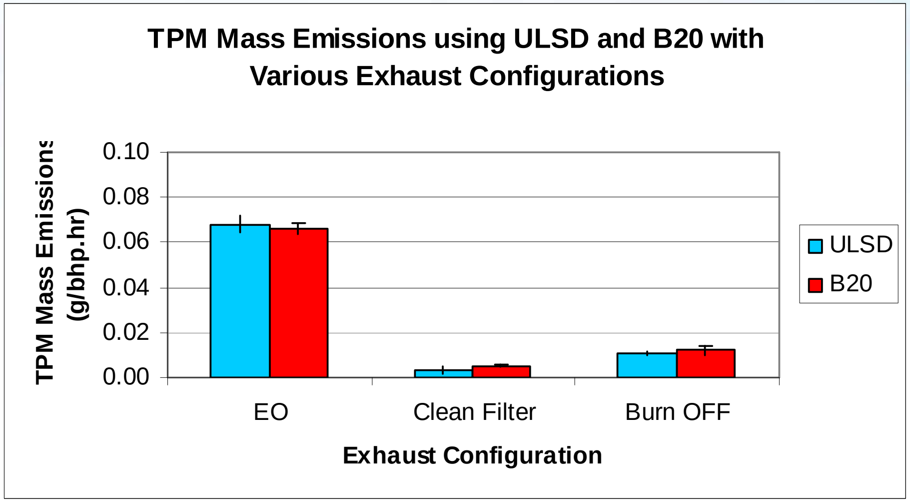
HDE's & Advanced After-Treatment Technologies

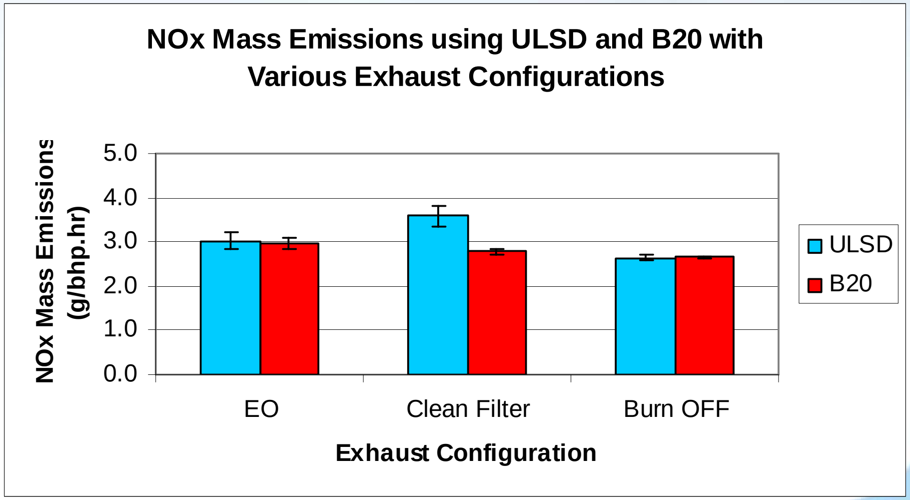
- 1998 Caterpillar 3126E with a prototype exhaust after treatment system
  - Regenerating DPF with SCR
- ULSD and B20 Canola
- FTP Transient

- Use of prototype SCRT with B20 & ULSD:
  - ↓ >95% TPM, CO, THC
  - ↓ 70% NO_X
  - ↑ ratio of NO_2 / NO_X
  - ↑ N_2O
  - Presence of NH_3
  - ↓ PAH, VOC, Carbonyls
  - B20 vs. ULSD without emission control
    - ↓ 16% THC
    - ↓ 7% CO
  - Power and performance changes were not evident during testing

HDE's & Advanced After-Treatment Technologies

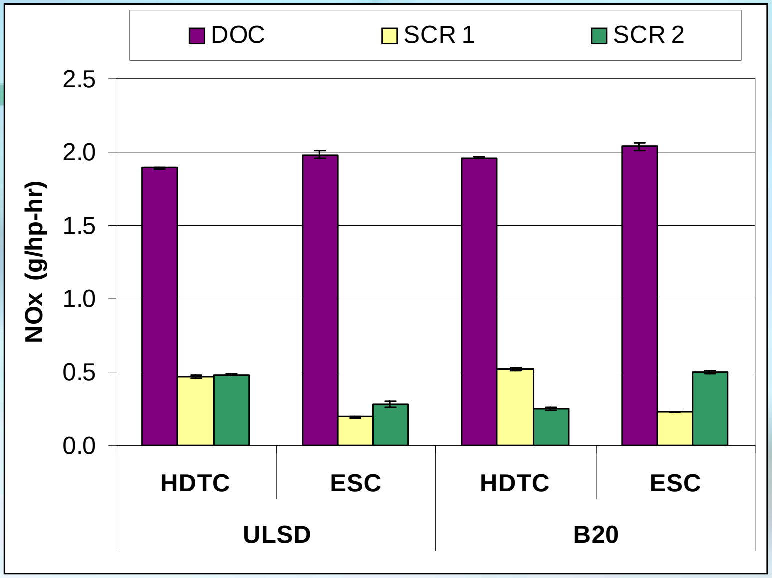
- 2005 Mack 300 HP with internal EGR with active regeneration DPF (fuel injection for trap regeneration)
- >90% PM reduction
- Operation on B20 does not negatively affect emissions



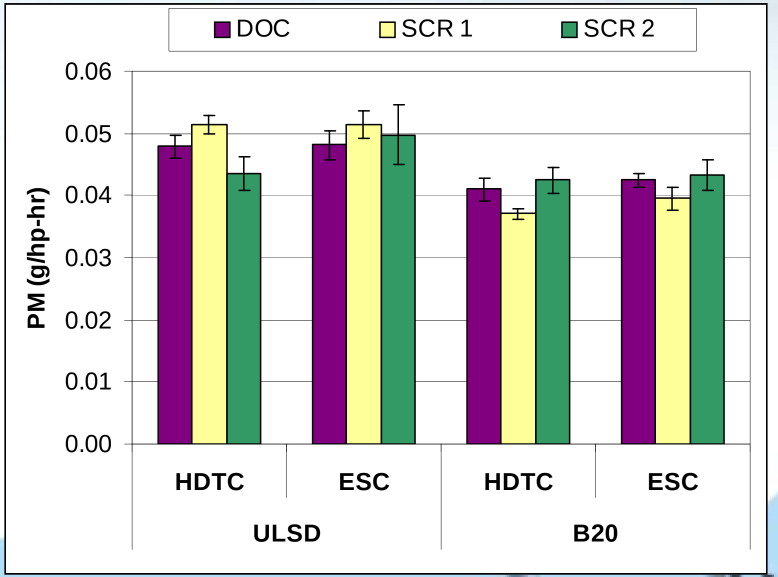


HDE's & Advanced After-Treatment Technologies

- 2004 CAT ACERT
  - 2 selective catalytic reduction systems (DOC+SCR)
  - ULSD and B20 Canola
  - FTP Transient
  - ESC steady state 13 mode



- ↓PM with B20 vs. ULSD with DOC
- ↓PM when SCR#1 is added
- ↓NO_X with both SCR systems
- B20 does not negatively affect PM or NO_X emissions

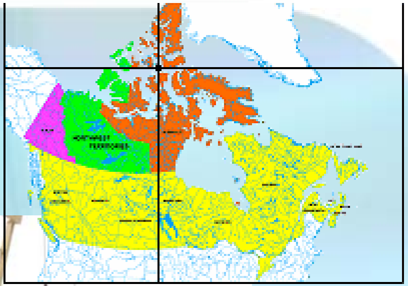


Marine Applications

- *BioMer Demonstration*
- 12 vessels, operating out of 2 ports, used biodiesel from May to Oct 2004
  - B100, B20, B10, B5
- Field Trials
  - 3 boats tested while in service with B100
  - Steady states @ varying speeds
  - Portable emissions sampling system with fuel flow meter
  - CO, NO_X, PM, CO_2
- Engine Dyno Emissions
  - CAT 3176E Marine Engine
  - ISO 8178-4 cycle E5
  - B5, B20, B100 (recycled cooking oil)
  - Complete Emissions Characterization

- Engine Dyno Results
  - ↓ 13-36% CO (B5-B100)
  - ↓ 36% THC (B100, NSD for B5 and B20)
  - ↑5-10% NO_X (B20-B100, NSD for B5)
  - ↓31-82% PM (B5-B100)
  - FC
    - ↓1.8% B5
    - NSD B20
    - ↑3.3% B100

Marine Applications



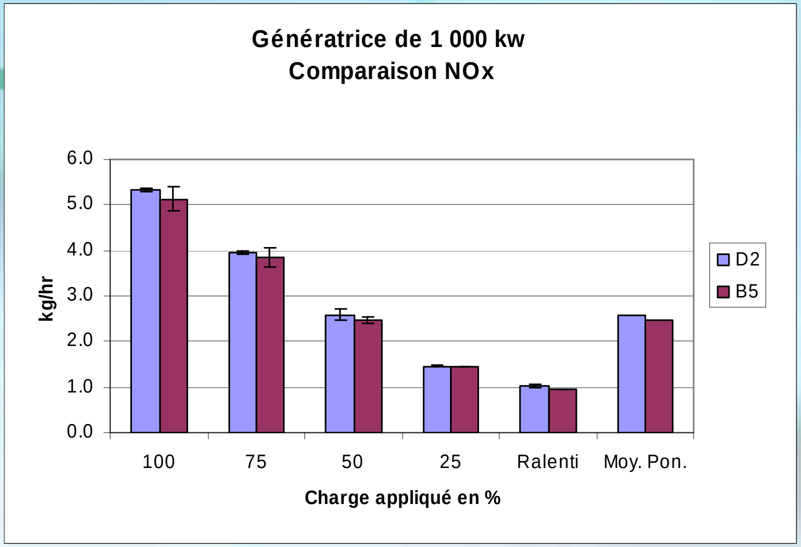
- Merchant vessel Anna Desgagnés
  - 17850 ton ship
  - cargo of heavy machinery, trucks and freights to ports along the Atlantic coast into Resolute Bay (cold temp)
  - one of four generators powered with B20 rendered animal fats and cooking oils

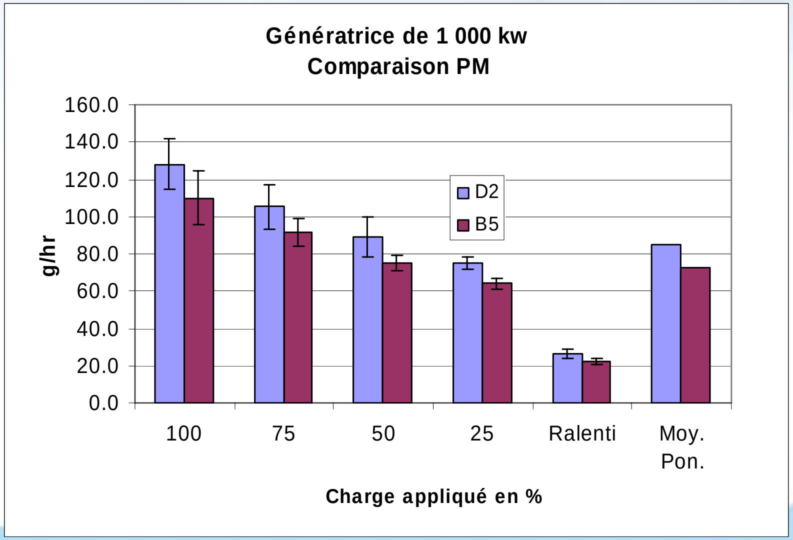
% DIFF B20 *vs* Marine Diesel Oil

CO	-5.6
CO_2	-1.5
NO_X	-4.5
HC	-16
PM	+25
FC	-1.6

Mobile Generators

- 1000 kw and 60 kw generators
  - Caterpillar 51.8L Mechanical
  - Cummins 3.9L Electronic
- LSD #2, B5 and B20
  - Blend of animal fats and cooking oil
- ISO 8178-1:1996 test cycle D2
- Both PM and NO_X reductions observed with B20





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Ethanol Activities

Two Recent Studies

- Tailpipe and Evaporative Emissions from Light Duty Vehicles of 4 Different Technologies Operating on Gasoline and Ethanol-Gasoline Blends (E10 and E20)

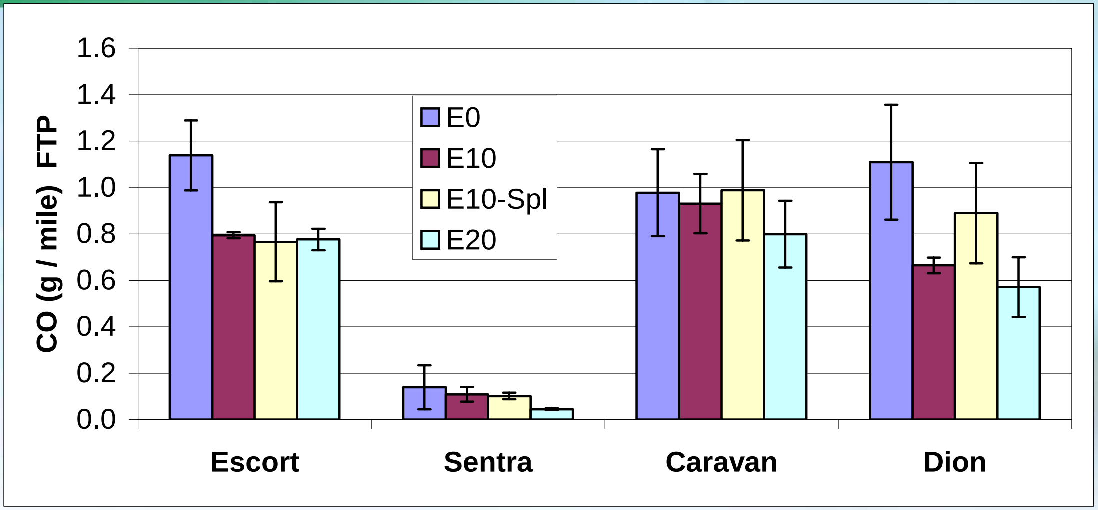
- Tailpipe Emissions from Two Flex-Fuel Vehicles Operating on Gasoline and E85

4 Vehicle Technologies

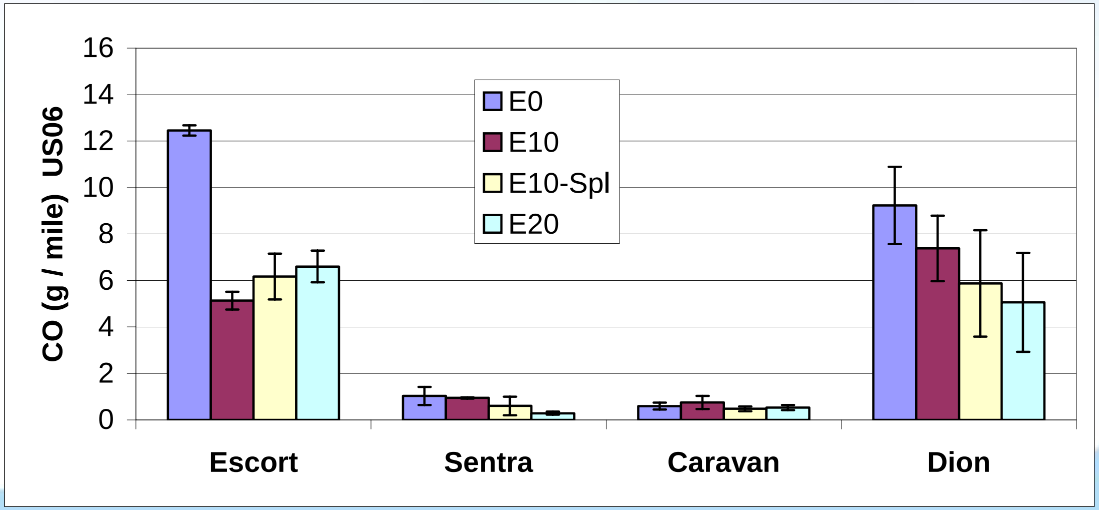
- 4 light duty gasoline vehicles of different technologies
  - Tier 1 (1998 Ford Escort)
  - California SULEV w/zero evap. emissions (2001 Nissan Sentra)
  - LEV LDT Flex-Fuel (2003 Dodge Caravan)
  - Gasoline Direct Injection vehicle (Japanese LEV, 2000 Mitsubishi Dion)
- 4 test fuels
  - Vary fuel ethanol content (E0, E10, E20) while holding sulphur content, RVP, distillation and Octane Number constant.
  - Splash blend at 10% with base fuel
- Standard (20 °C) and cold (-10 °C) temperature testing
- FTP and US06 driving cycles
- Evaporative emissions (heat build and hot soak)

CO Emissions

- FTP CO emissions decrease for all vehicle technologies

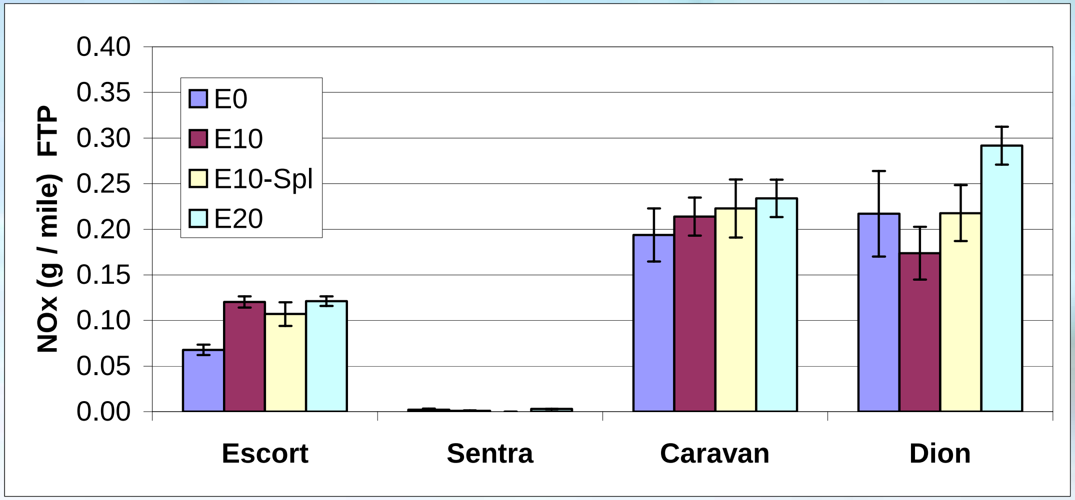


- US06 CO emissions decrease for all vehicle technologies

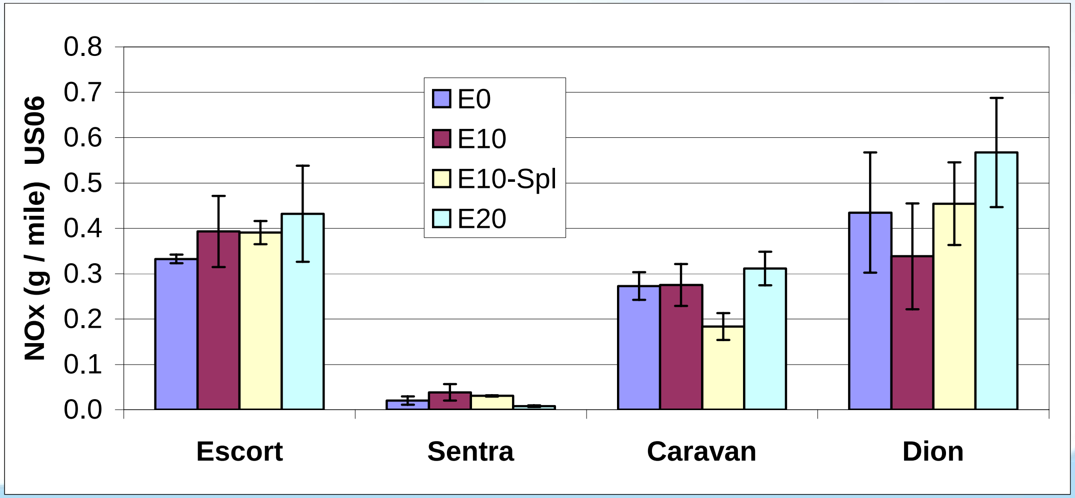


NO_X Emissions

- FTP NO_X emissions increase for all vehicle technologies



- US06 NO_X emissions essentially unchanged for all vehicle technologies



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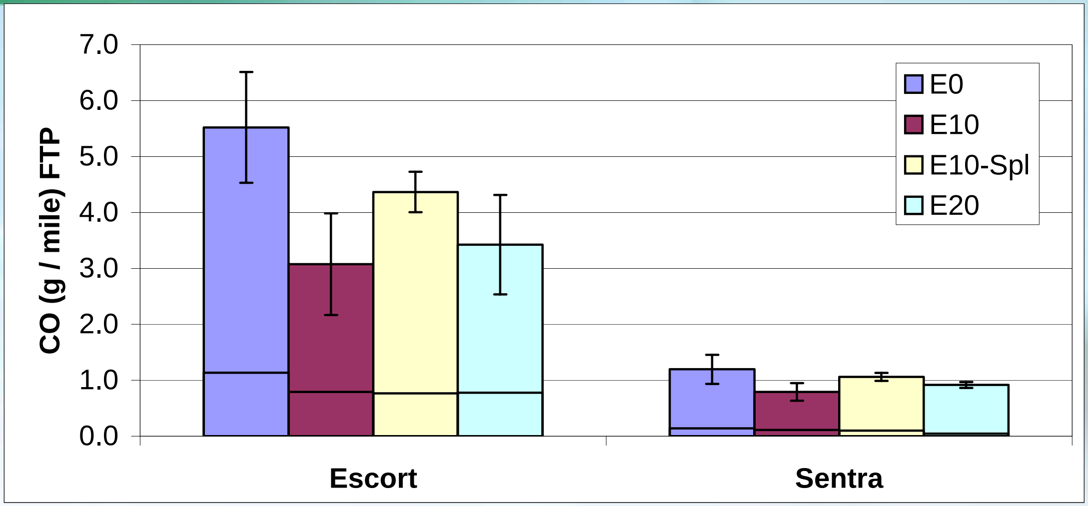
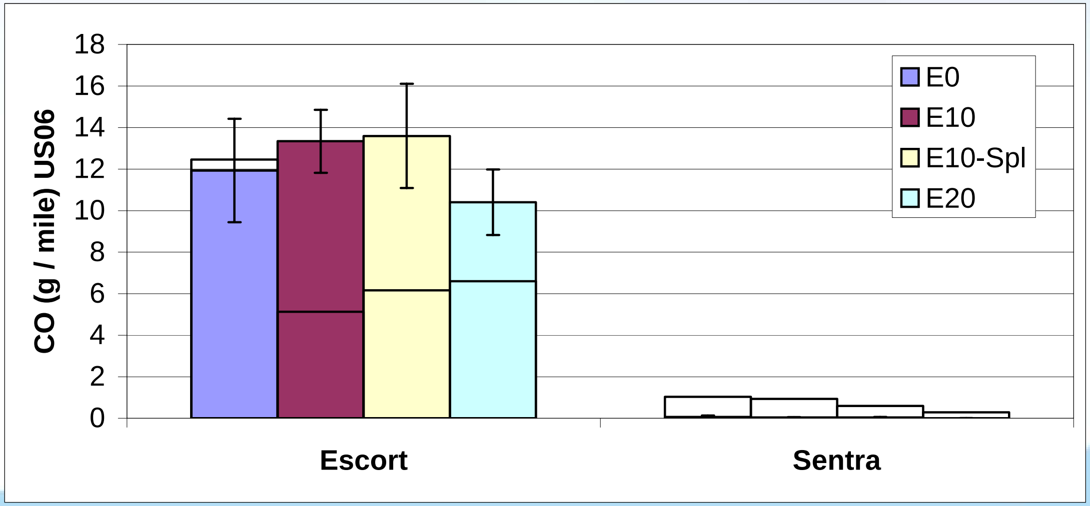
Cold Temperature Effects

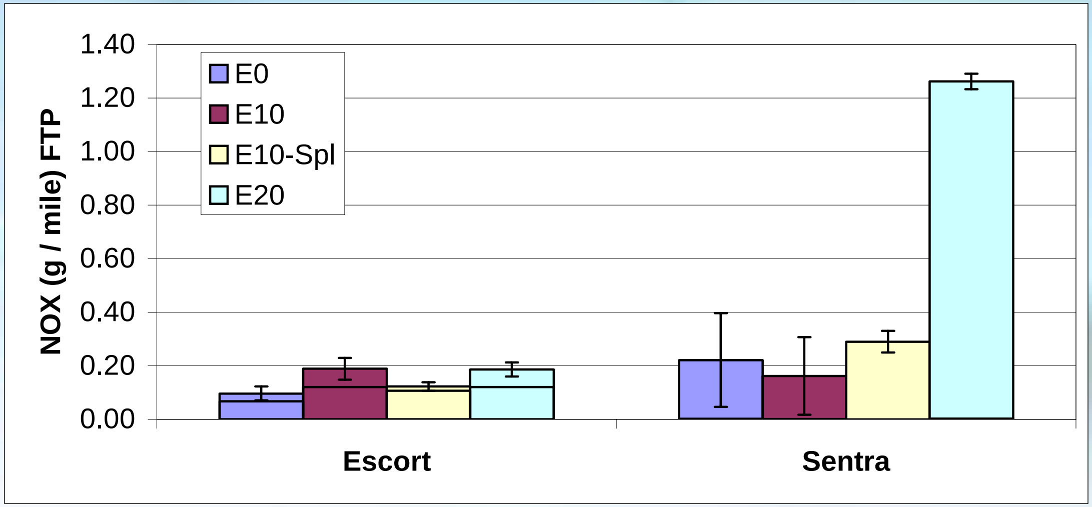
- Cold temperature
  - increases FTP CO emissions
  - increases US06 CO emissions of Escort, not of Sentra.
- FTP CO emissions unchanged to slight decrease with ethanol
- US06 CO emissions unchanged with ethanol

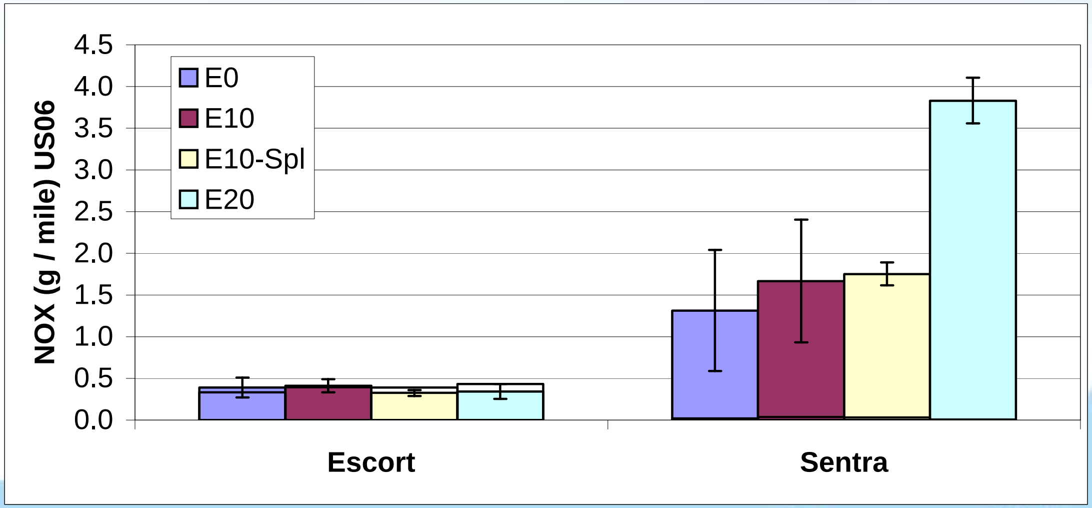




Cold Temperature Effects

- Cold temperature
  - increases FTP NO_X emissions
  - increases US06 NO_X emissions
- FTP NO_X emissions unchanged with ethanol
- US06 NO_X emissions unchanged with ethanol





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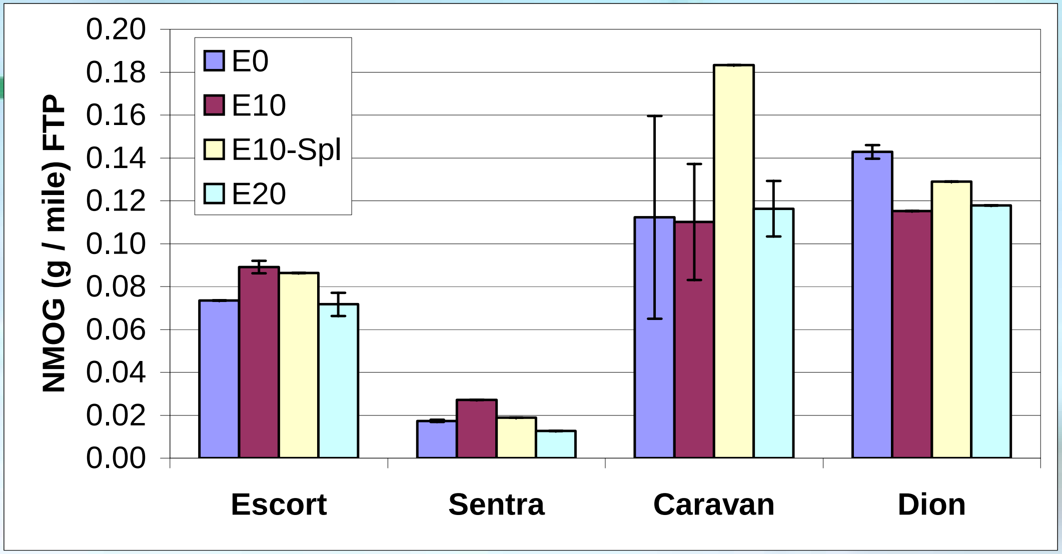
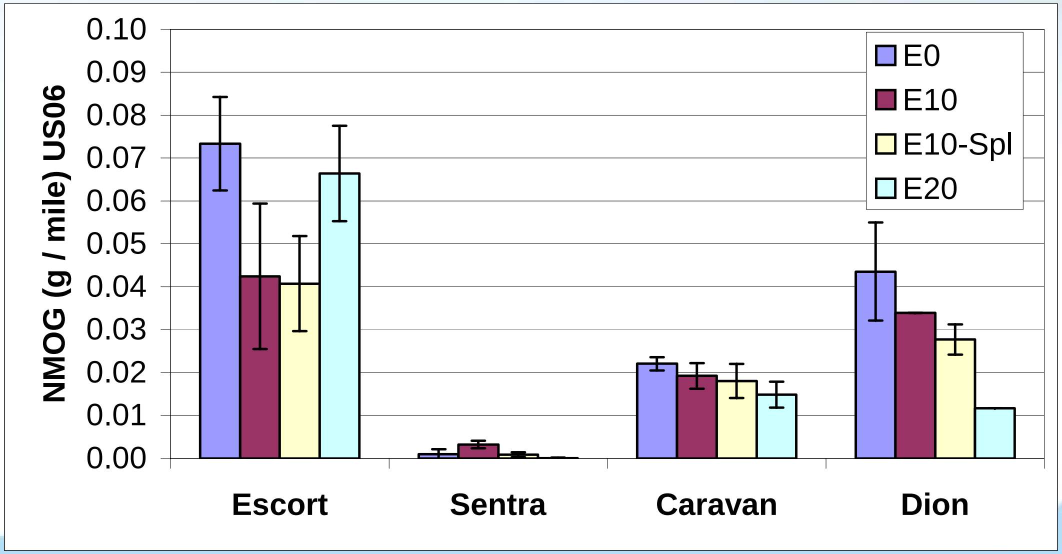
Effect of Ethanol Blend on NMOG

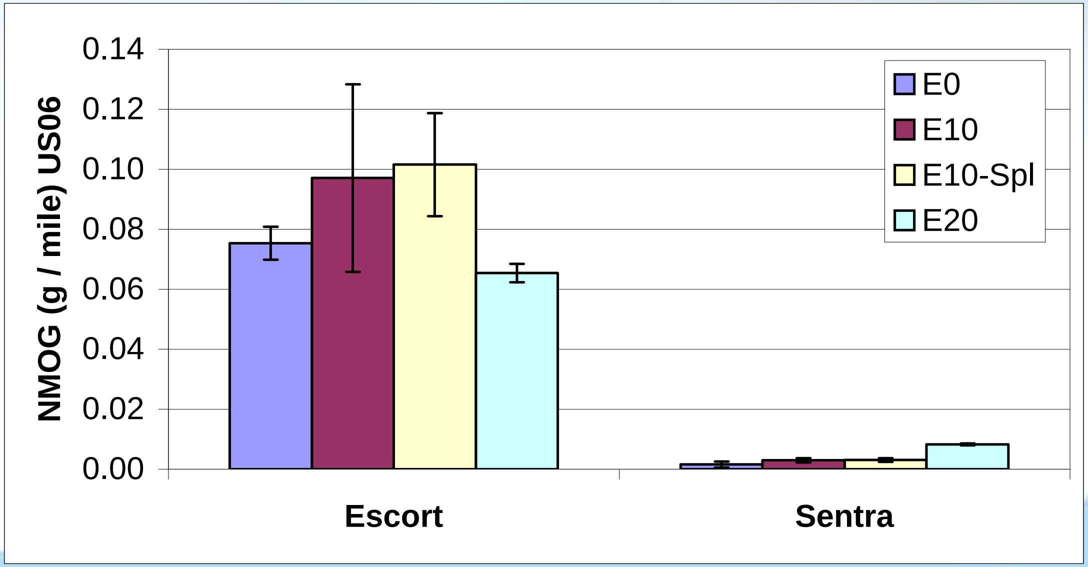
- At 20 °C,
  - FTP NMOG emissions are unchanged with ethanol
  - US06 NMOG emissions appear to decrease with ethanol





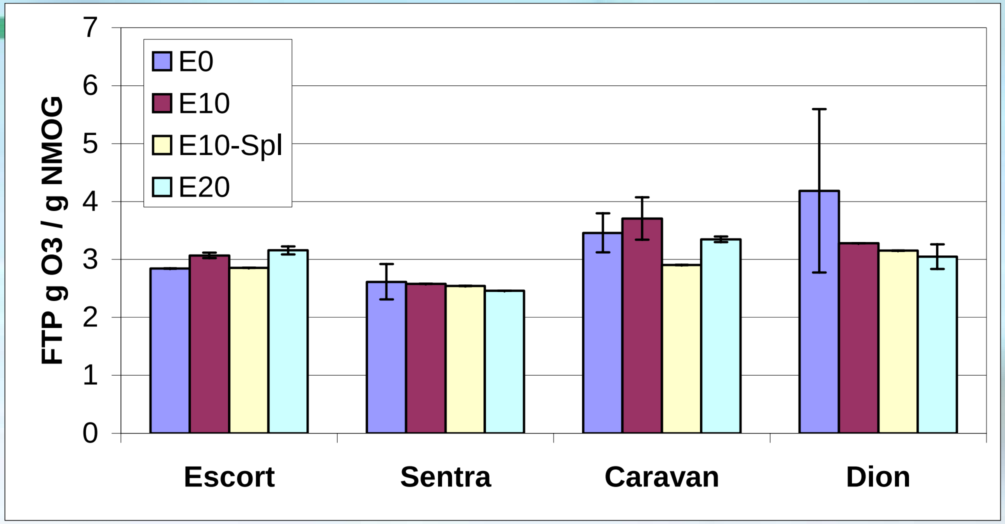
Effect of Ethanol Blend on NMOG

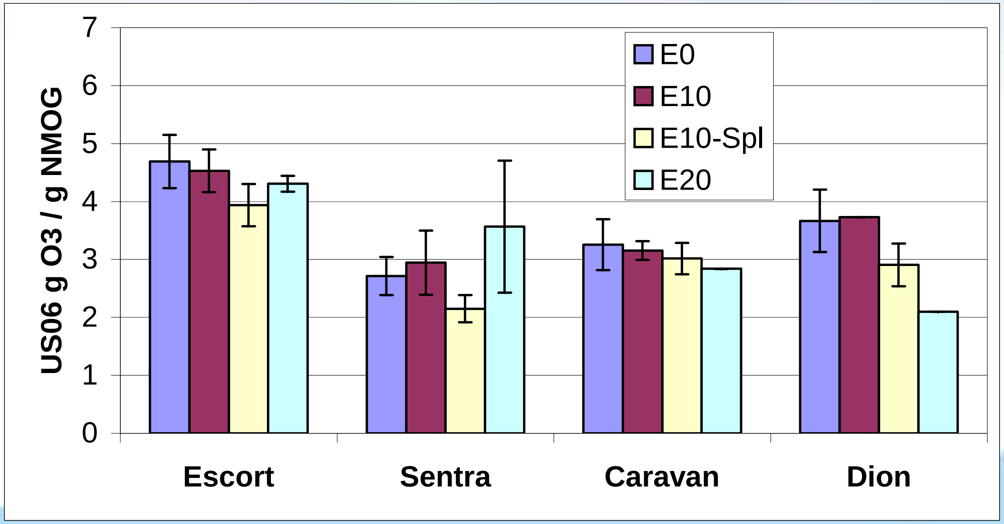
- At -10 ^{o}C, emissions are 2-10x higher than at 20 ^{o}C
  - FTP NMOG emissions are unchanged with ethanol
  - US06 NMOG emissions appear to increase with ethanol



Ozone Specific Reactivity

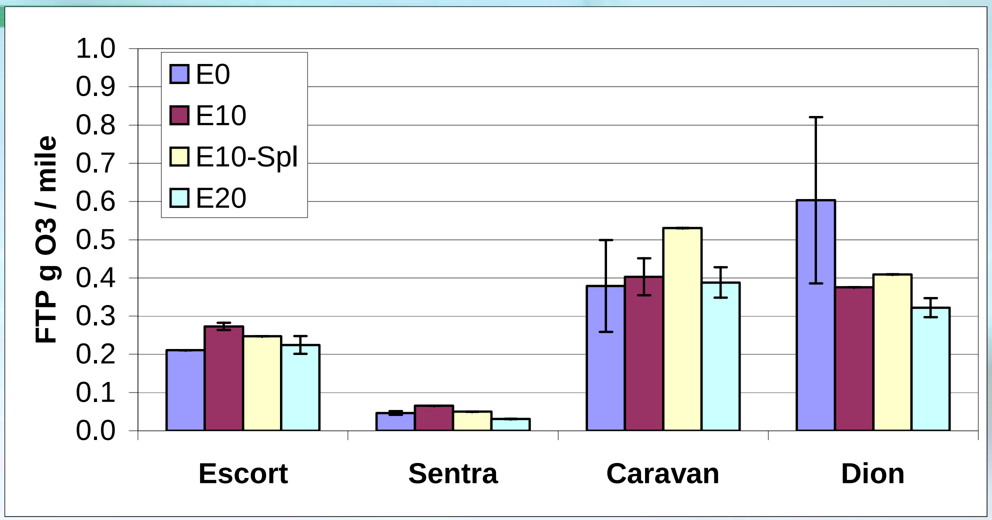
- Small differences among vehicle technologies
- Ethanol has little effect on specific reactivity
- (not shown) Cold temperature increases specific reactivity
  - 25% for Sentra
  - 17% for Escort on FTP
  - Decrease of 17% for Escort on US06

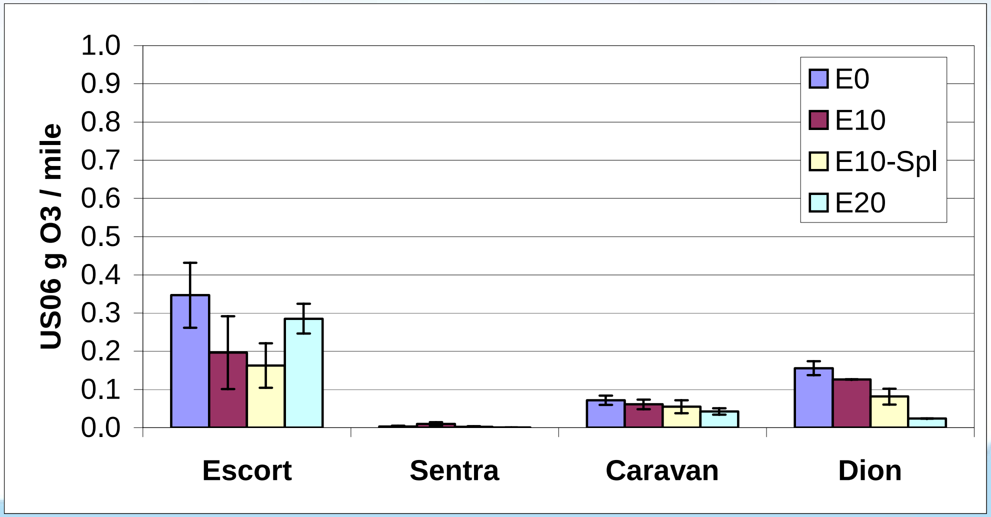




Ozone Forming Potential

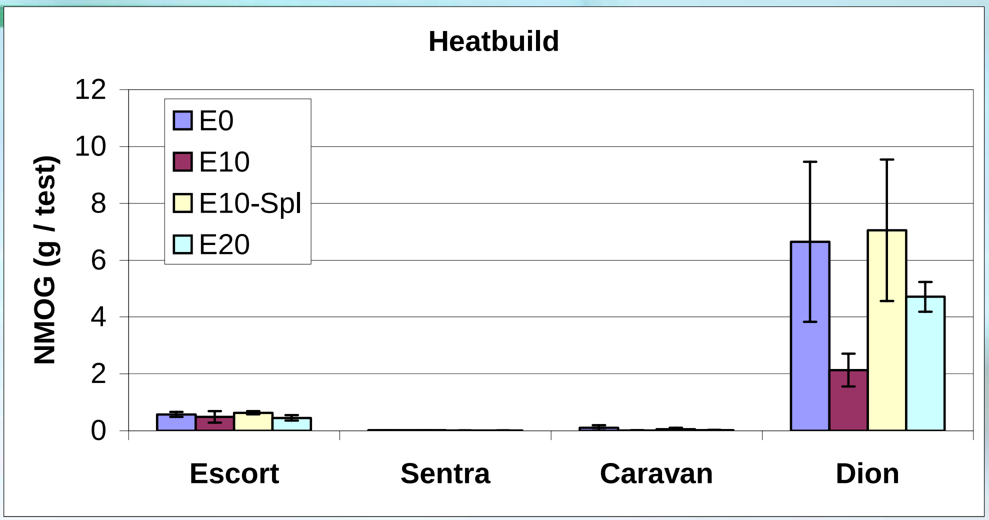
- Greatest factor appears to be vehicle technology followed by driving conditions
- Ethanol has little effect
- Higher NMOG emission rates and higher specific reactivity increases ozone forming potential in cold temperatures

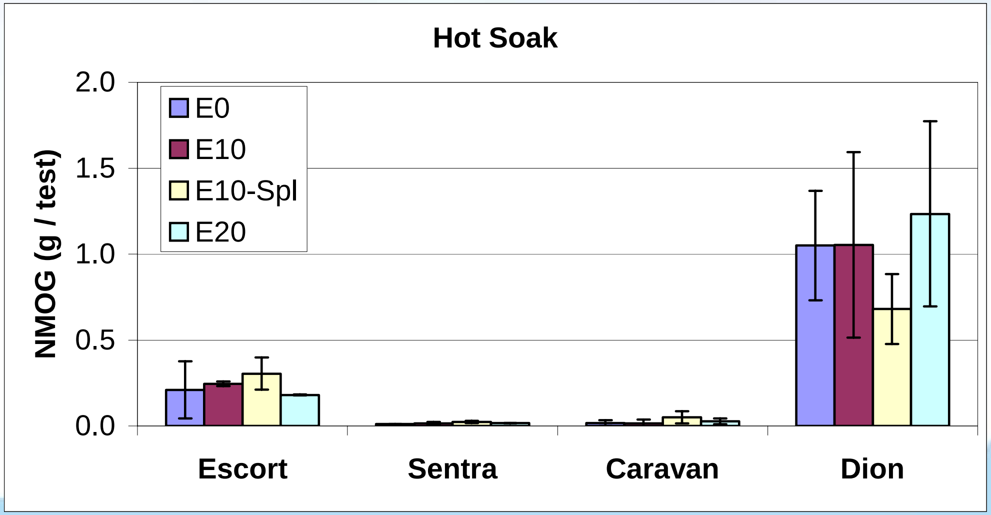




Evaporative Emissions

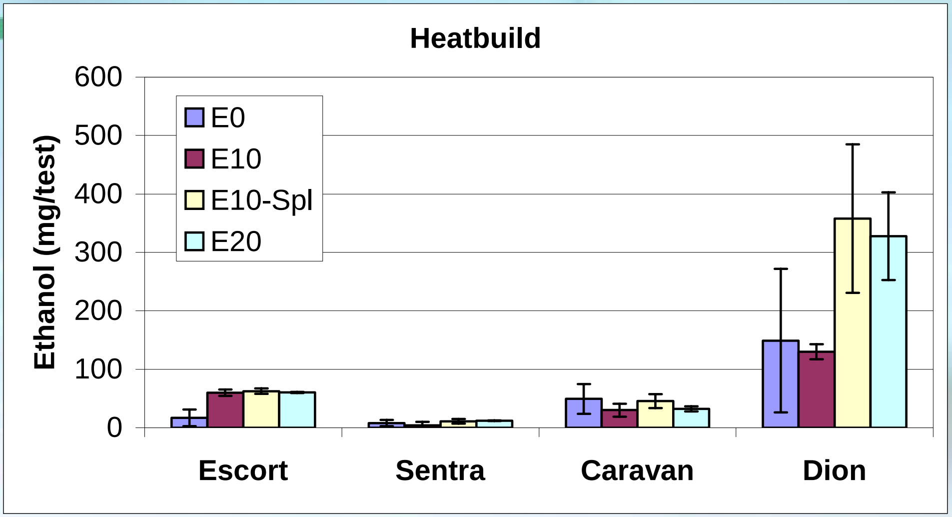
- Evaporative emissions are difficult to quantify with good precision using these procedures
- Effect of emission standards is very apparent
- Total NMOG emissions are higher for heat build than hot soak

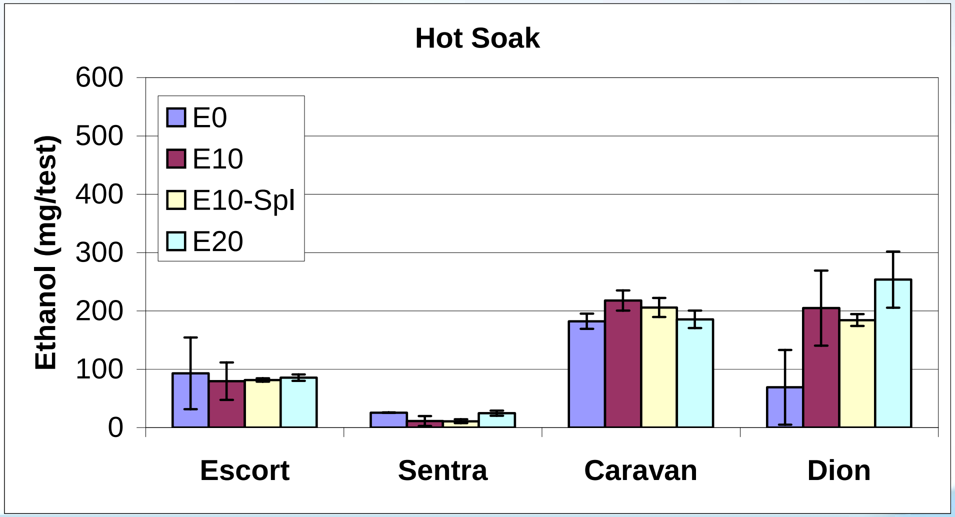




Evaporative Emissions

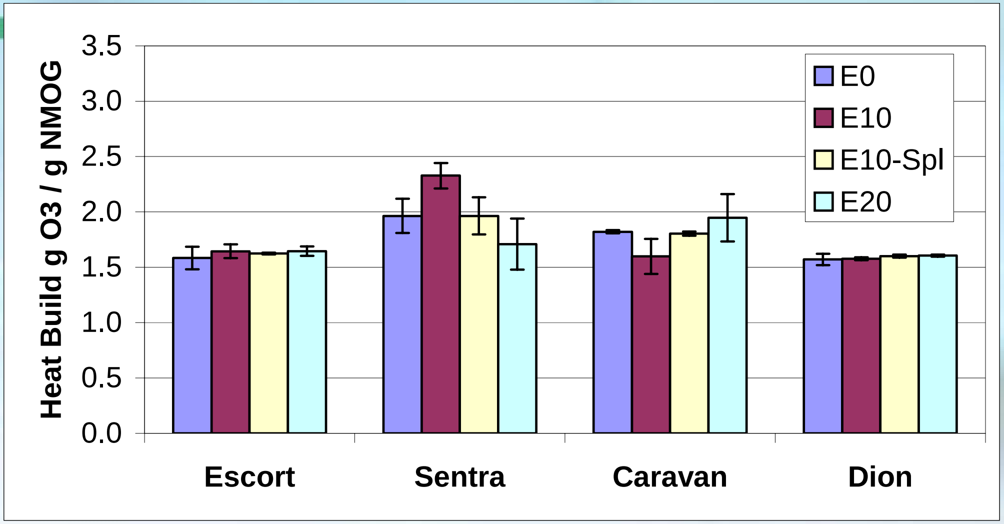
- Even our careful attention to vehicle and canister conditioning resulted in ethanol detected in E0 fuel tests
- Hot soak emissions of ethanol are higher than heat build emissions except for the Dion

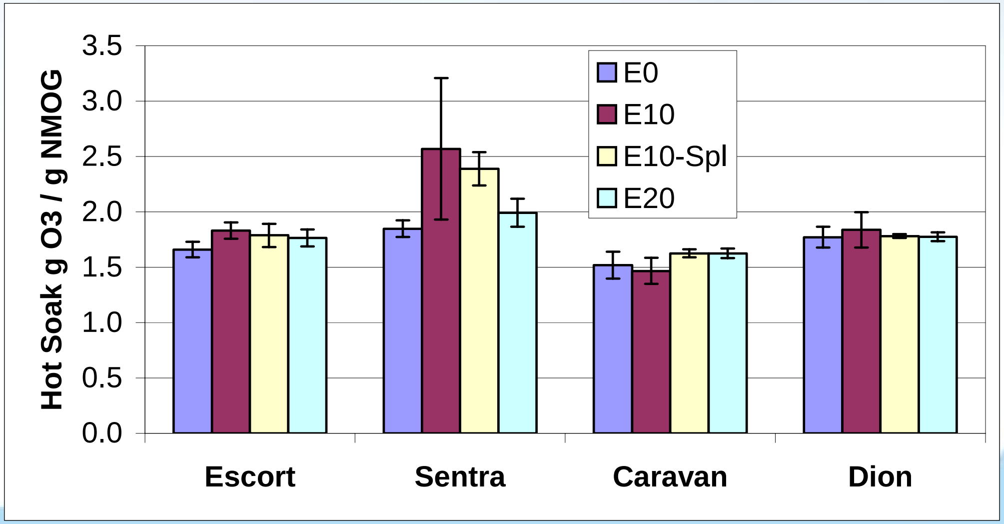




Evaporative Specific Reactivity

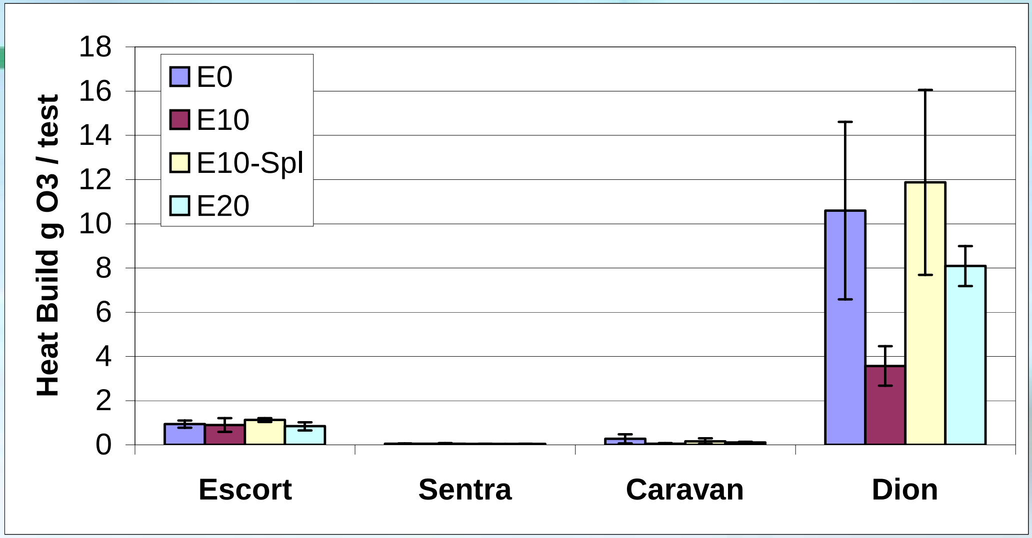
- Specific reactivity
  - Evaporative emissions are less reactive than tailpipe emissions
  - Largest factor is vehicle technology
  - Ethanol has little effect

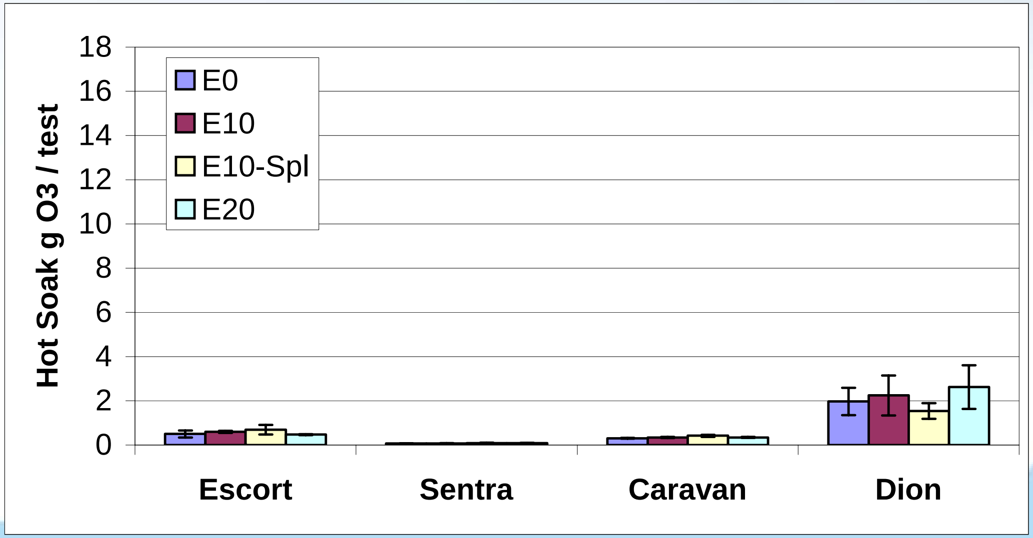




Evaporative Ozone Forming Potential

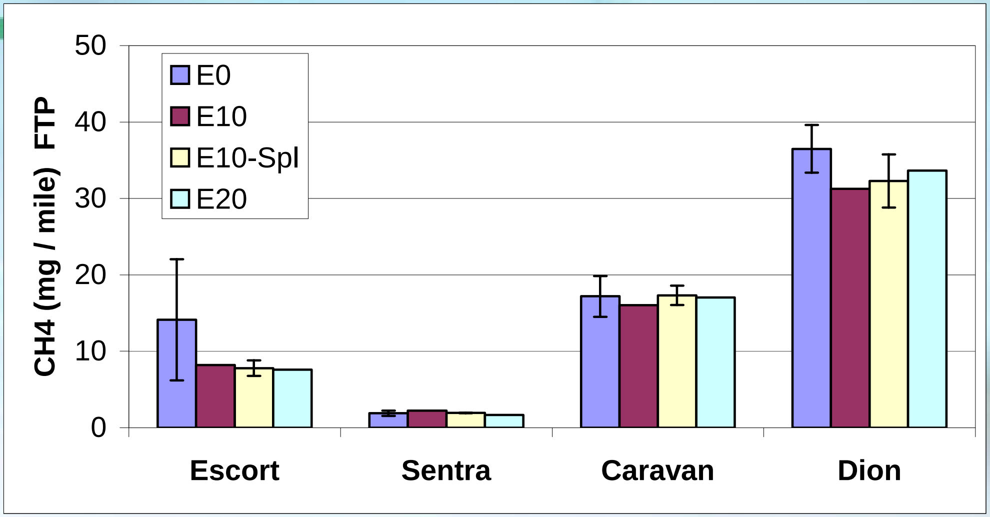
- Largest factor is vehicle technology
- Ethanol has little effect

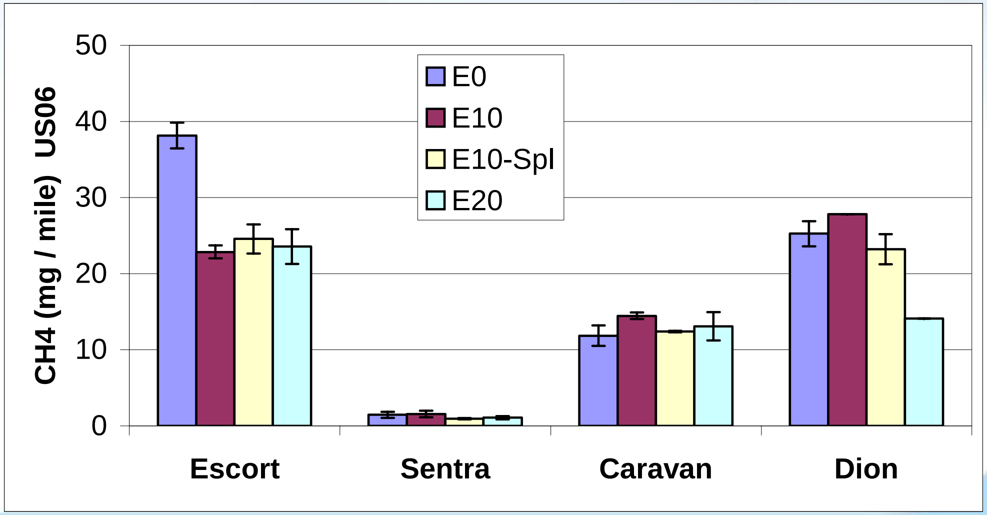




GHG Emissions

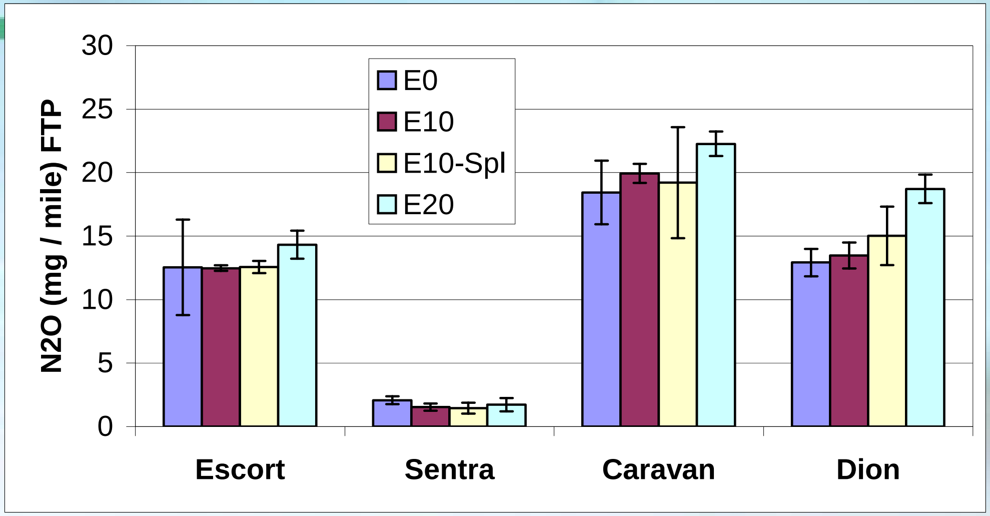
- Methane
  - both FTP and US06 emissions unchanged with ethanol
  - except for the Tier 1 vehicle

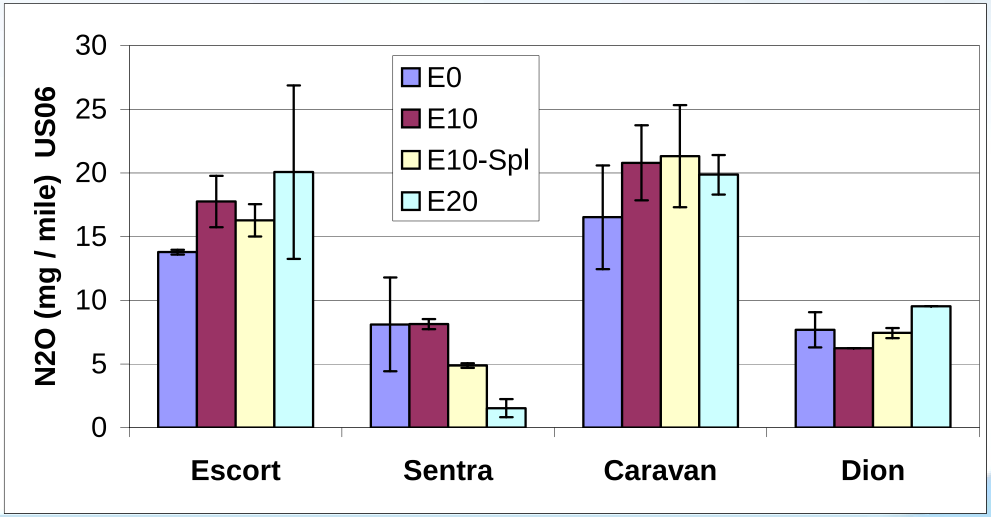




GHG Emissions

- Nitrous oxide emissions show no consistent pattern.
- Effects depend on both driving cycle and on vehicle technology





Vehicle Emissions

- 2 Studies
  - Tailpipe and Evaporative Emissions from Light Duty Vehicles of 4 Different Technologies Operating on Gasoline and Ethanol-Gasoline Blends (E10 and E20)
  - Tailpipe Emissions from Two Flex-Fuel Vehicles Operating on Gasoline and E85

Flex-Fuel Vehicles

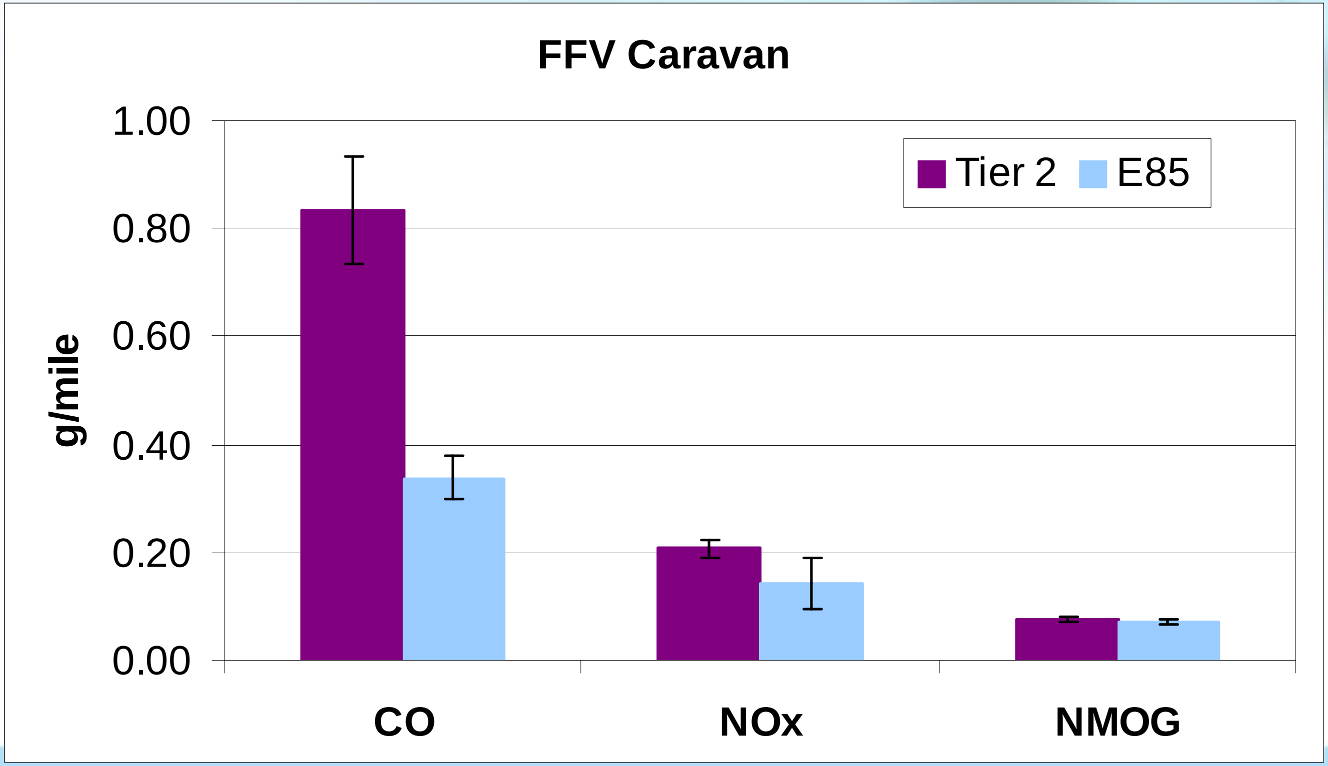
- Two flex-fuel vehicles tested over Federal Test Procedure
  - 2002 Chrysler Caravan
    - US EPA NLEV LEV LDT and California LEV 1 LDT
  - 2004 Chrysler Sebring
    - US EPA Interim Non-Tier 2 Bin 8 and California ULEV 1

- Test Fuels
  - Tier 2 certification gasoline
  - E85 from local distributor

- Emissions measured
  - Regulated emissions (CO, NO_X, NMOG)
  - GHGs (CO_2, CH_4 and N_2O)
  - Detailed NMOG analysis

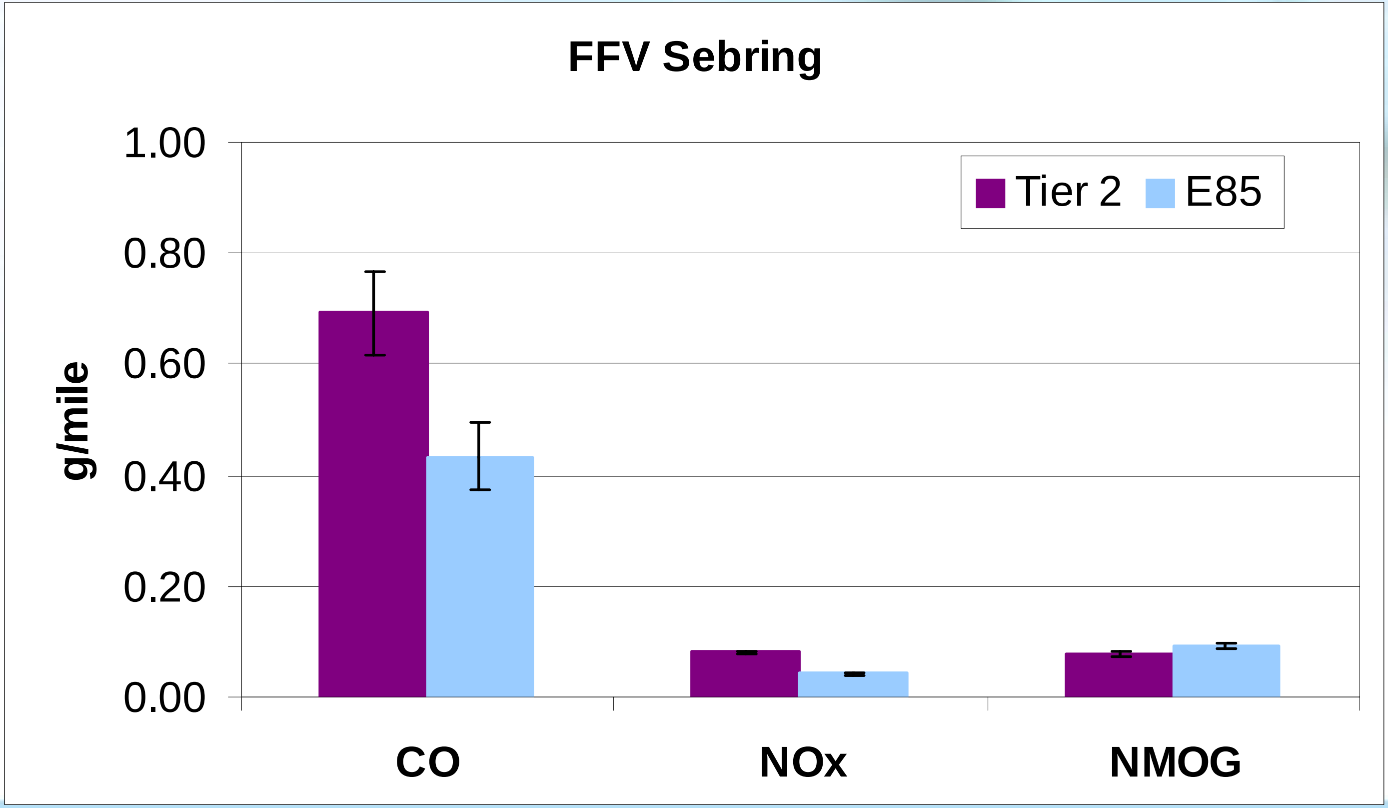
2002 FFV Caravan: Regulated Emissions

- CO and NO_X emissions decrease with E85
- NMOG emissions unchanged
- *Fuel sensor reached only <u>64%</u> on E85*



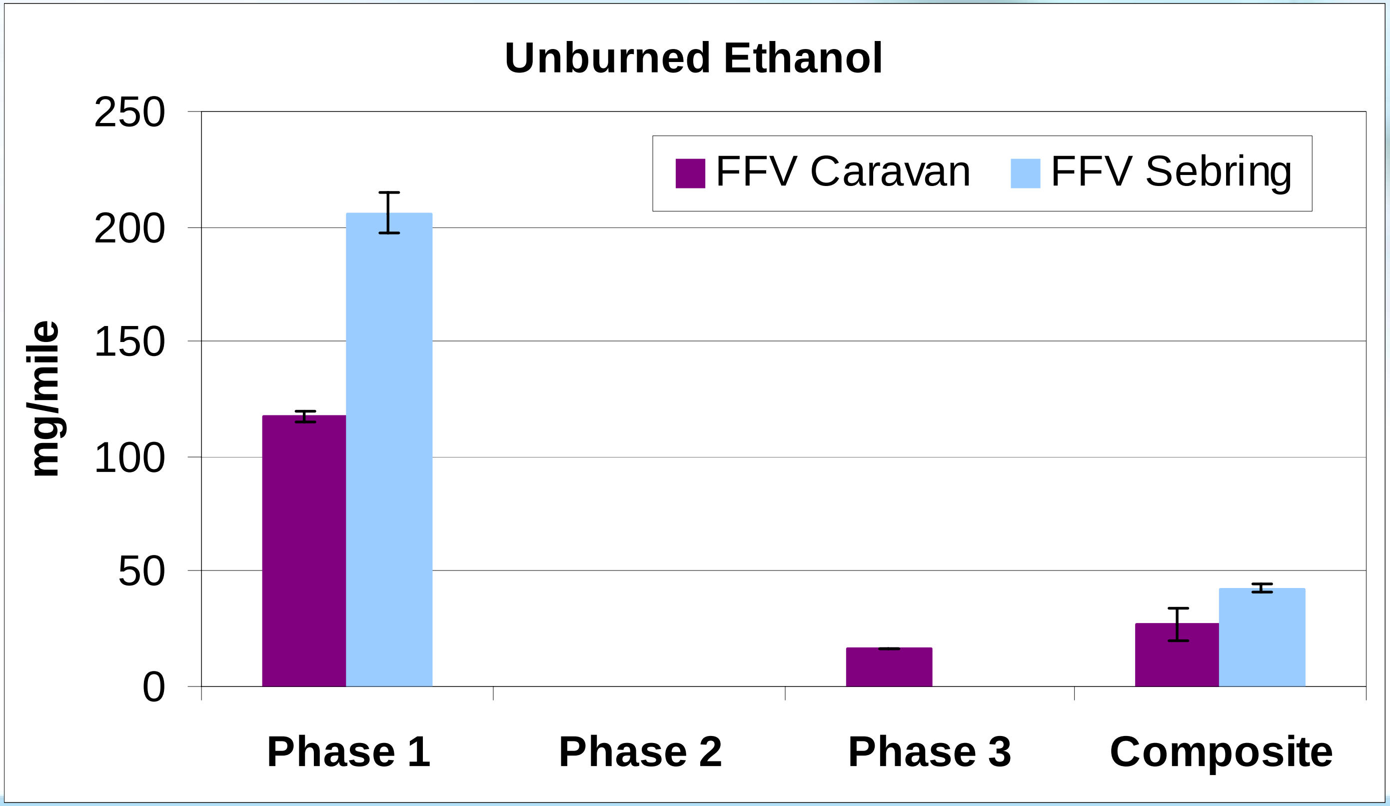
2004 FFV Sebring: Regulated Emissions

- CO and NO_X emissions decrease with E85
- NMOG higher with E85 (cold start)



Unburned Ethanol

- Unburned ethanol is included in NMOG
- Found predominantly on cold engine start



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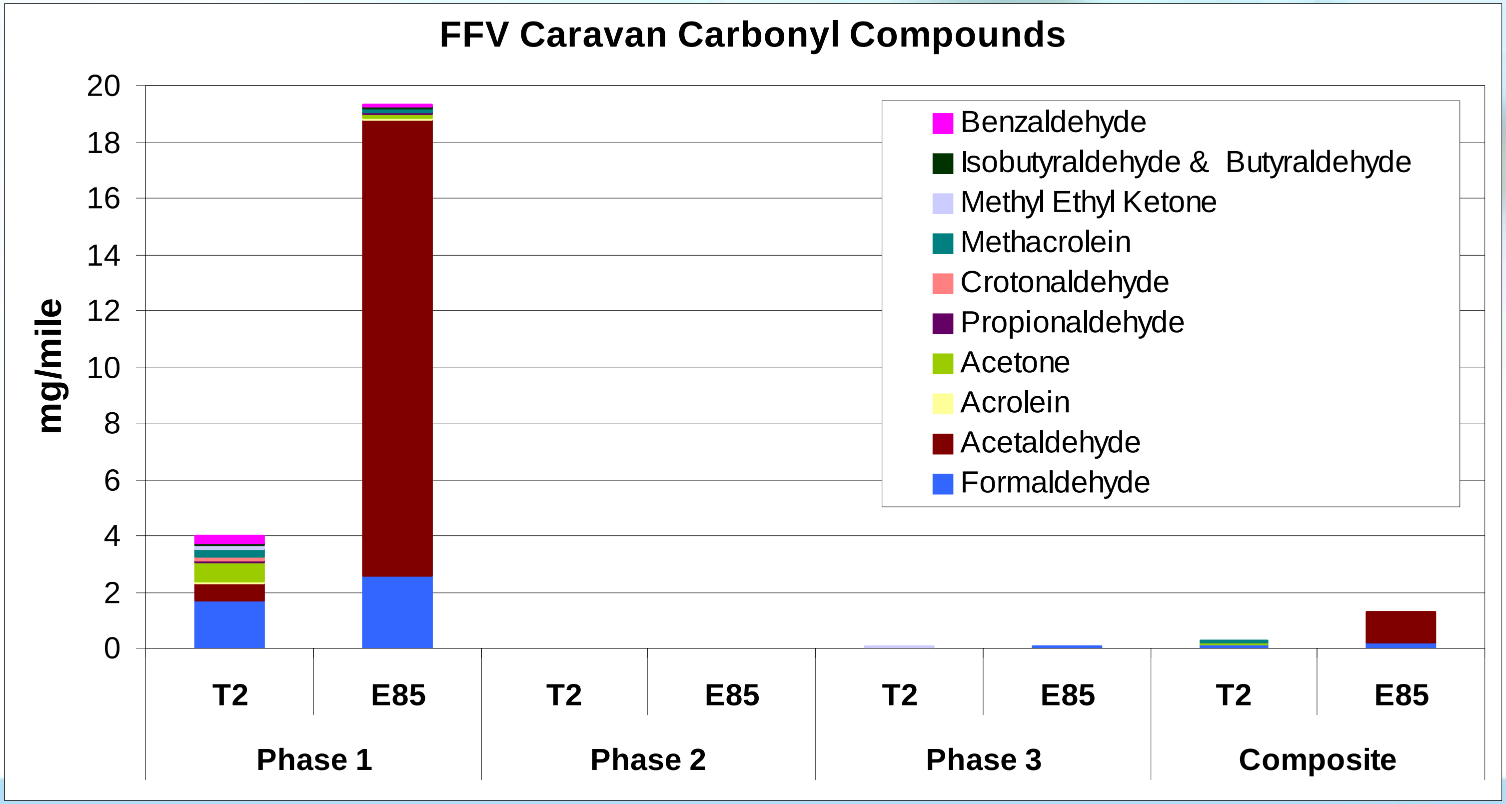
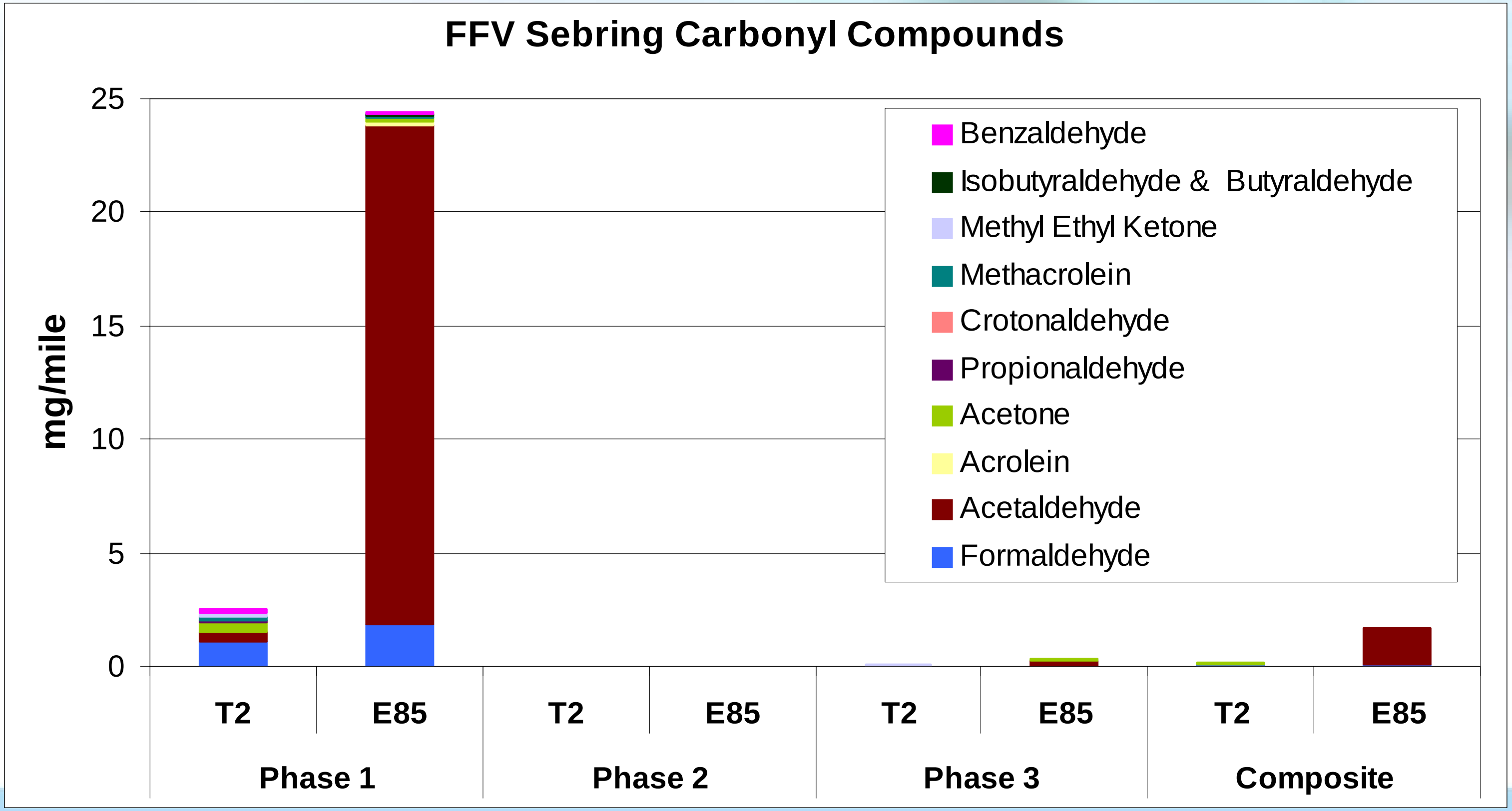
2002 FFV Caravan: Carbonyl Compounds

- Carbonyl compounds emitted predominantly on cold start
- E85 results in increases in formaldehyde, acetaldehyde and acrolein emissions



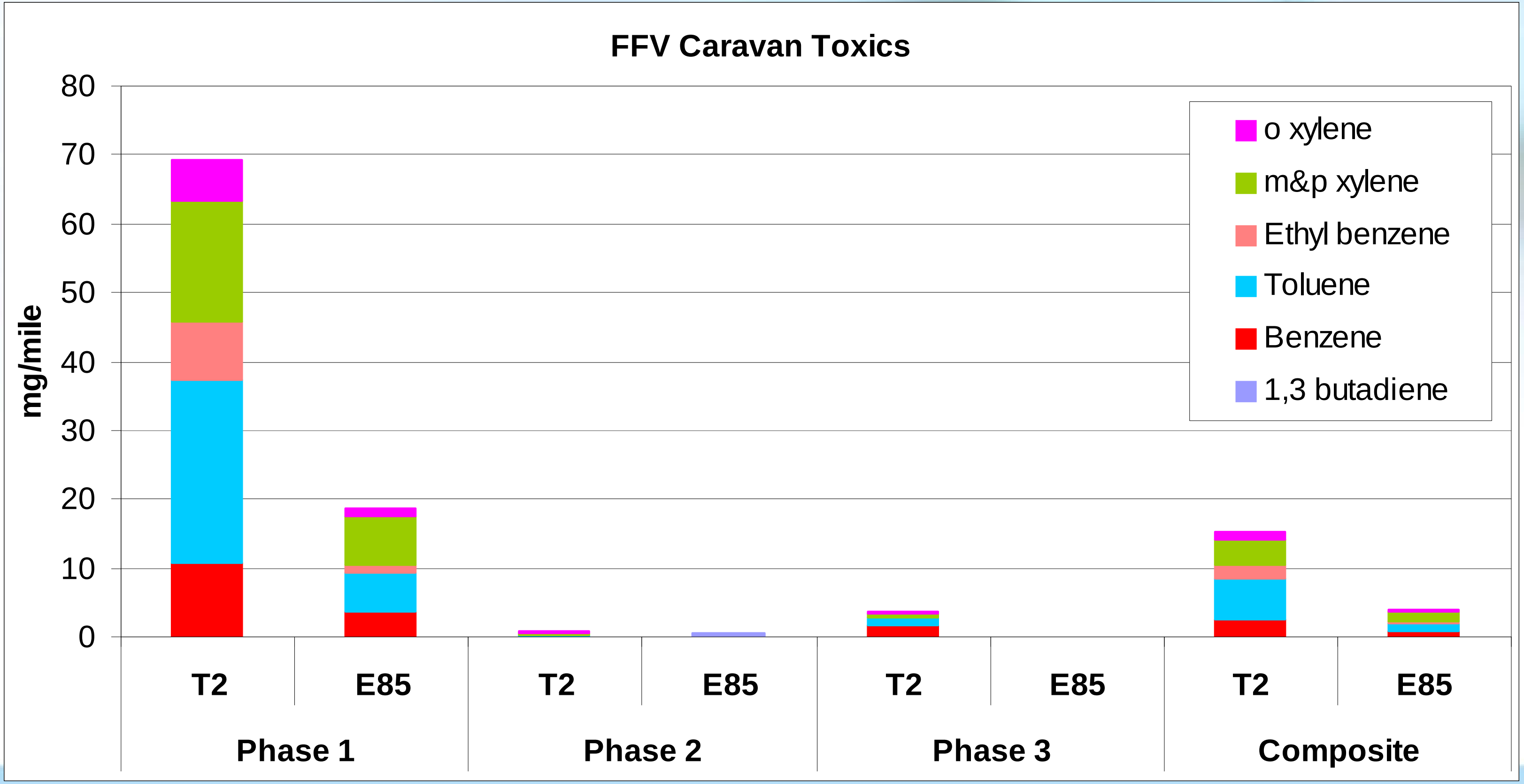
2004 FFV Sebring: Carbonyl Compounds

- Acetaldehyde emissions increase with E85
  - 25x for Caravan
  - 50x for Sebring

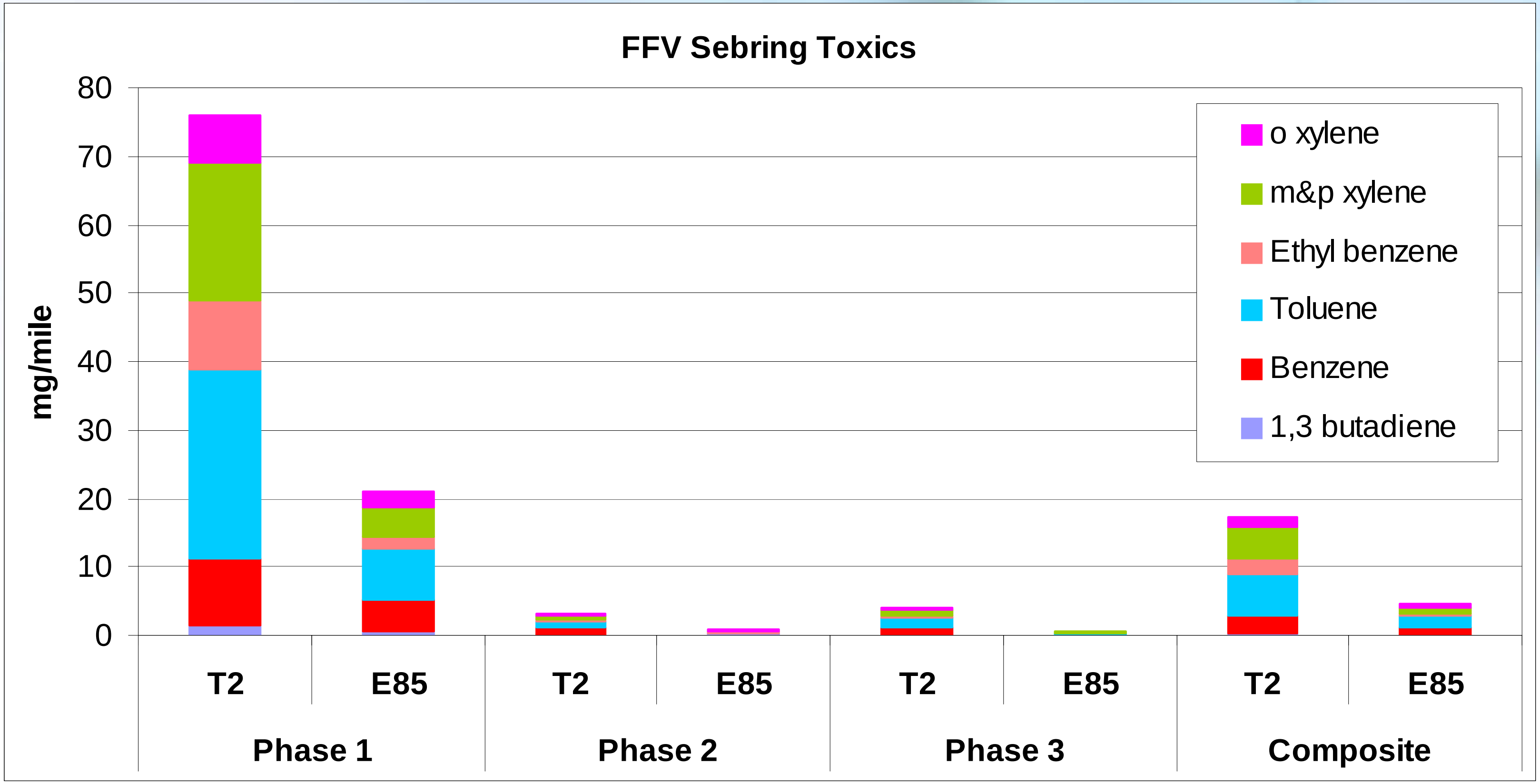


2002 FFV Caravan: Toxic Emissions

- Toxic hydrocarbon emissions are reduced with E85
- With both fuels, found predominantly on cold engine start



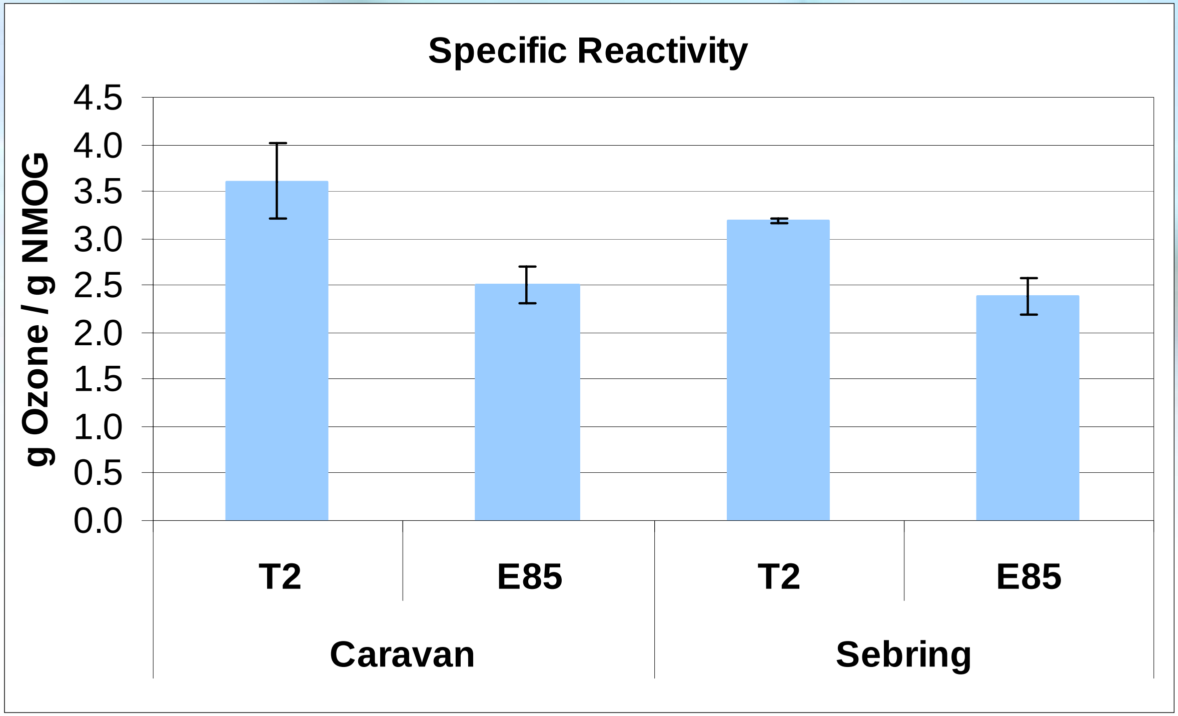
2004 FFV Sebring: Toxic Emissions



Specific Reactivity

- The specific reactivity of E85 is lower than the Tier 2 fuel

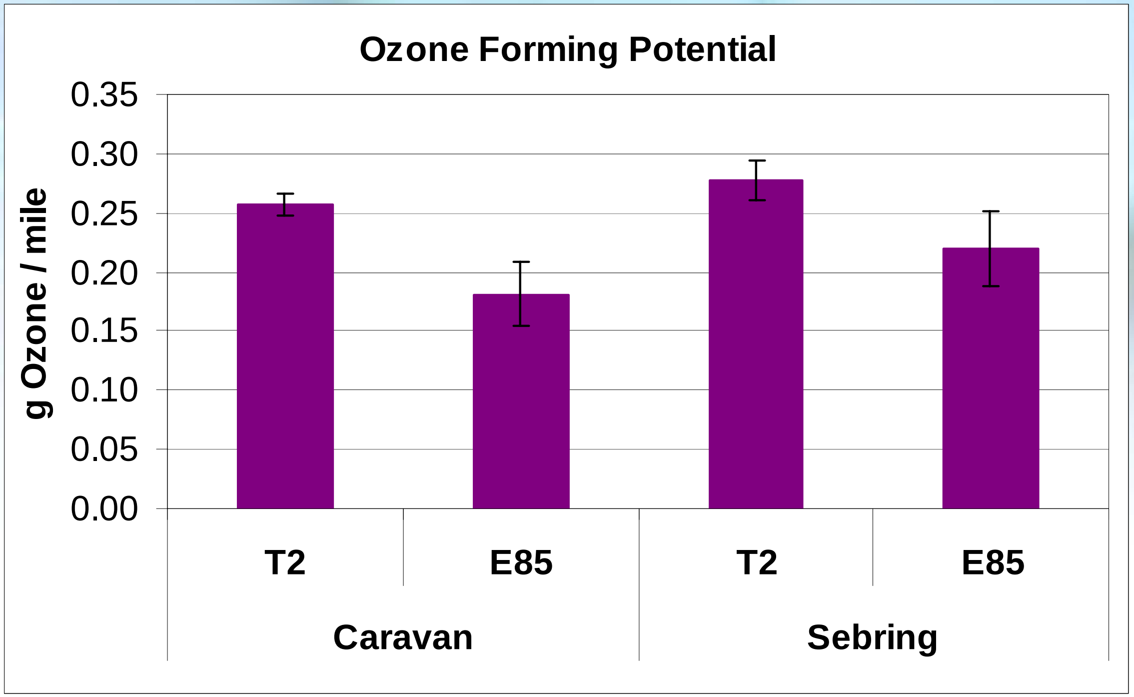
- The specific reactivity of the emissions from the newer vehicle technology are lower than the old technology



Ozone Forming Potential

- The ozone forming potential of E85 is lower than the Tier 2 fuel

- The ozone forming potential of the emissions from the newer vehicle technology are slightly higher than the old technology



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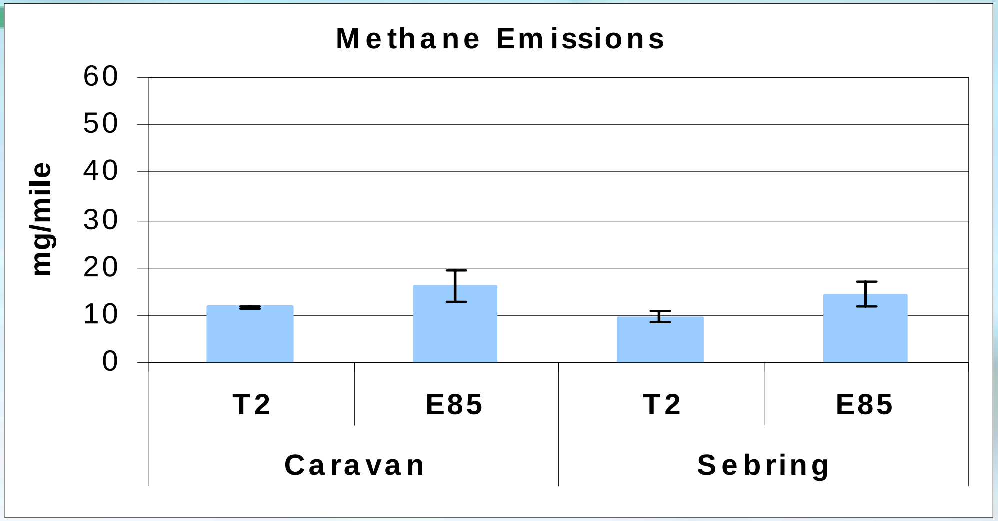
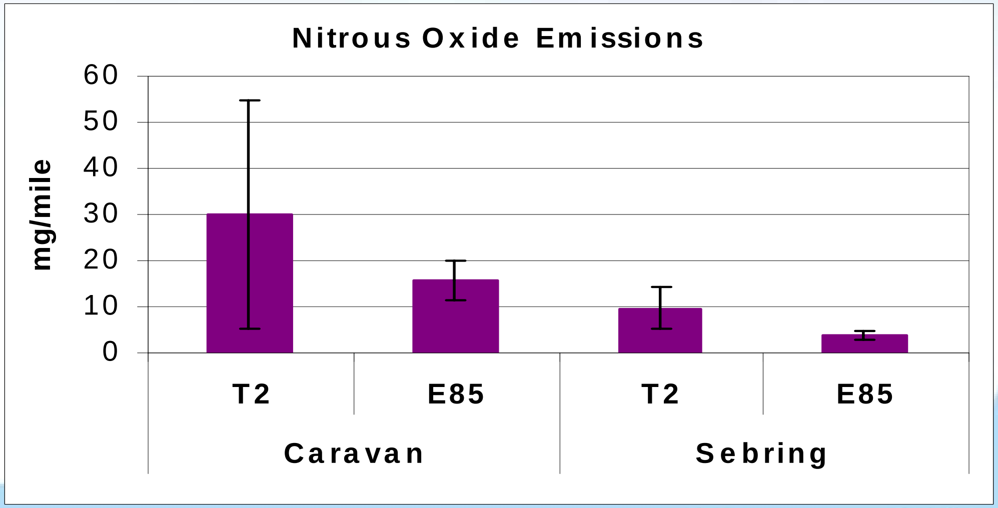
GHG Emissions

- Methane emissions
  - Increase with E85
  - Very similar for two vehicles

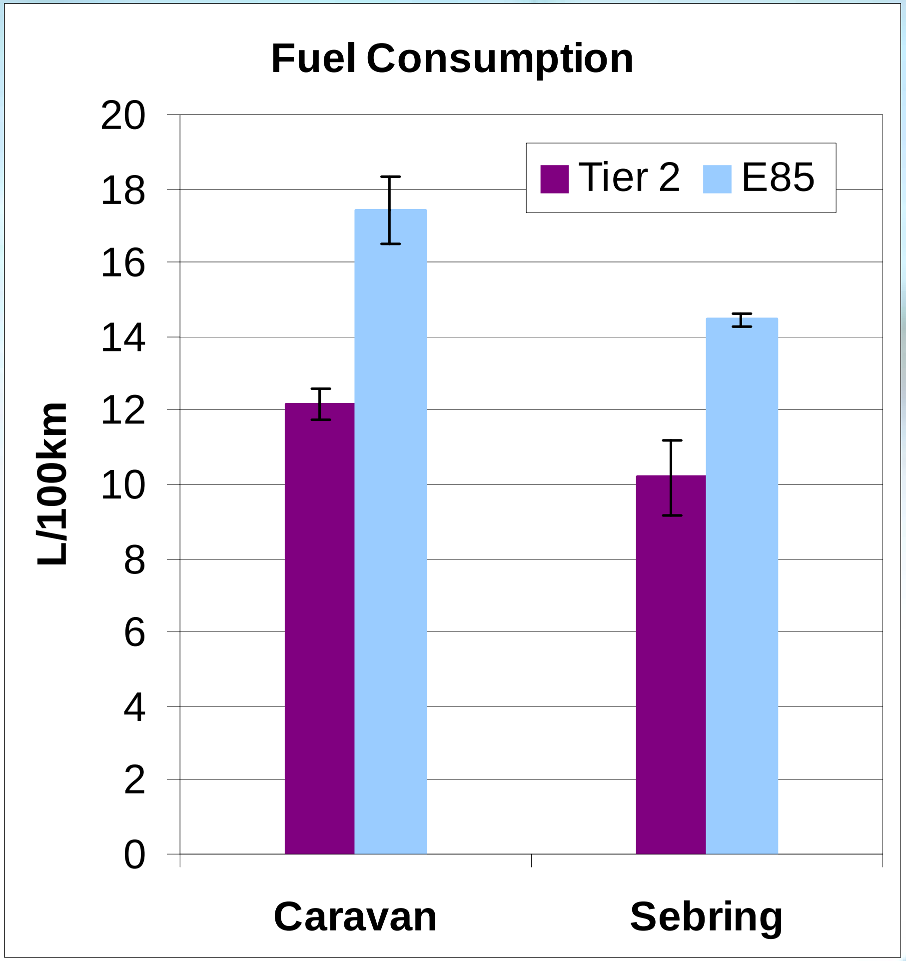


- Nitrous oxide emissions
  - Decrease with E85
  - Decrease with more stringent emission standard



Fuel Consumption

- E85 has lower energy density, therefore a larger volume is consumed for the same amount of driving
- Actual CO_2 emission rates were within 2% of expected based on complete conversion of fuel C to CO_2
- CO_2 emission rates were within 3% between the fuels
- **Lower carbon content of fuel offset by lower energy density.**
- **CO_2 benefits are not achieved at the tailpipe.**



Summary

- For the vehicles tested, low ethanol gasoline blends (E10, E20)
  - Reduce FTP and US06 CO emissions
  - Increase FTP NO_X emissions; US06 emissions unchanged
  - Had little effect on FTP and US06 NMOG emissions
  - Had little effect on Specific Reactivity of NMOG emissions
  - Had little effect on CH_4 and N_2O emissions
  - Had little effect on the evaporative NMOG emissions nor their specific reactivity.

Summary

- For the vehicles tested, a higher ethanol gasoline blend (E85)
  - Reduced FTP CO and NO_X
  - Had little effect on FTP NMOG
  - Significantly increased carbonyl emissions
    - Acetaldehyde 25-50x greater
  - Decreased toxic hydrocarbons
    - Fuel dilution effect
  - Reduced the specific reactivity of FTP emissions thereby reduced ozone forming potential
  - Increased CH_4 emissions
  - Decreased N_2O emissions

Biofuels and Advanced Combustion Strategies

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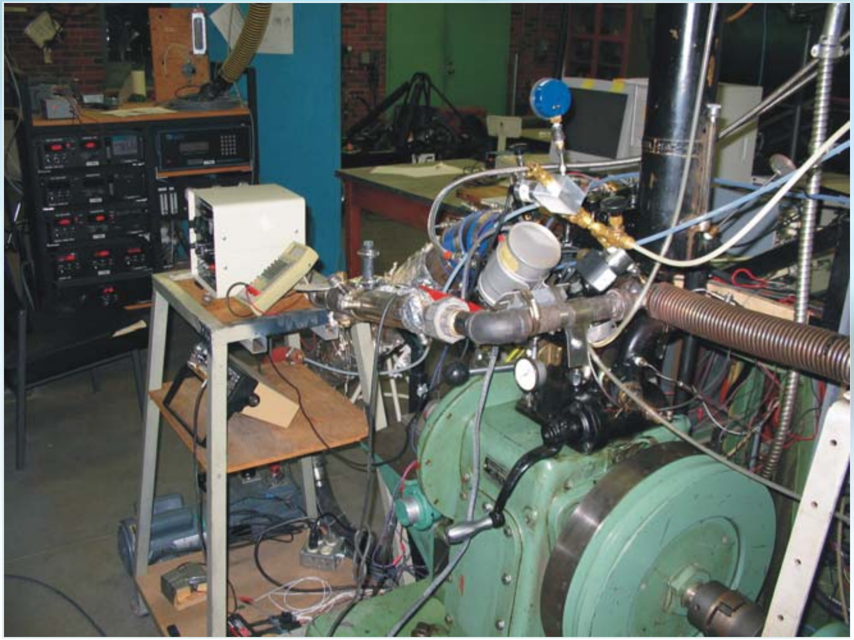
HCCI

- Homogeneous Charge Compression Ignition is a low temperature combustion strategy that can result in very low NO_X and PM emissions with high thermal efficiency.
- HCCI is an auto-ignition process
  - start of combustion is controlled by temperature and pressure not spark (SI) or fuel injection (CI)
- Because it is a low temperature process, engine out CO and unburned HC emissions are high in a relatively cool exhaust gas
  - Very challenging for conventional TWC or OC technologies



UofA HCCI facility
Waukesha CFR engine and dynamometer

HCCI

- Two collaborative projects looking at gasoline-like and diesel-like fuels in HCCI combustion in a research engine
  - University of Alberta – ideal fuels with different octane numbers prepared from iso-octane and heptane or ethanol and heptane
  - National Research Council of Canada – ideal fuel of n-heptane studying effect of engine parameters and EGR on combustion efficiency.
- Dilute exhaust samples were collected in canisters and analyzed by GC-FID and GC-MS for NMHC, oxygenated organics, CH_4 and N_2O
  - NRC study also included carbonyl sampling with DNPH cartridges
- Ideal fuels allow chemical reaction mechanisms to be studied
  - Provides information useful in computer modeling of HCCI combustion

Effect of Ethanol on HCCI Combustion

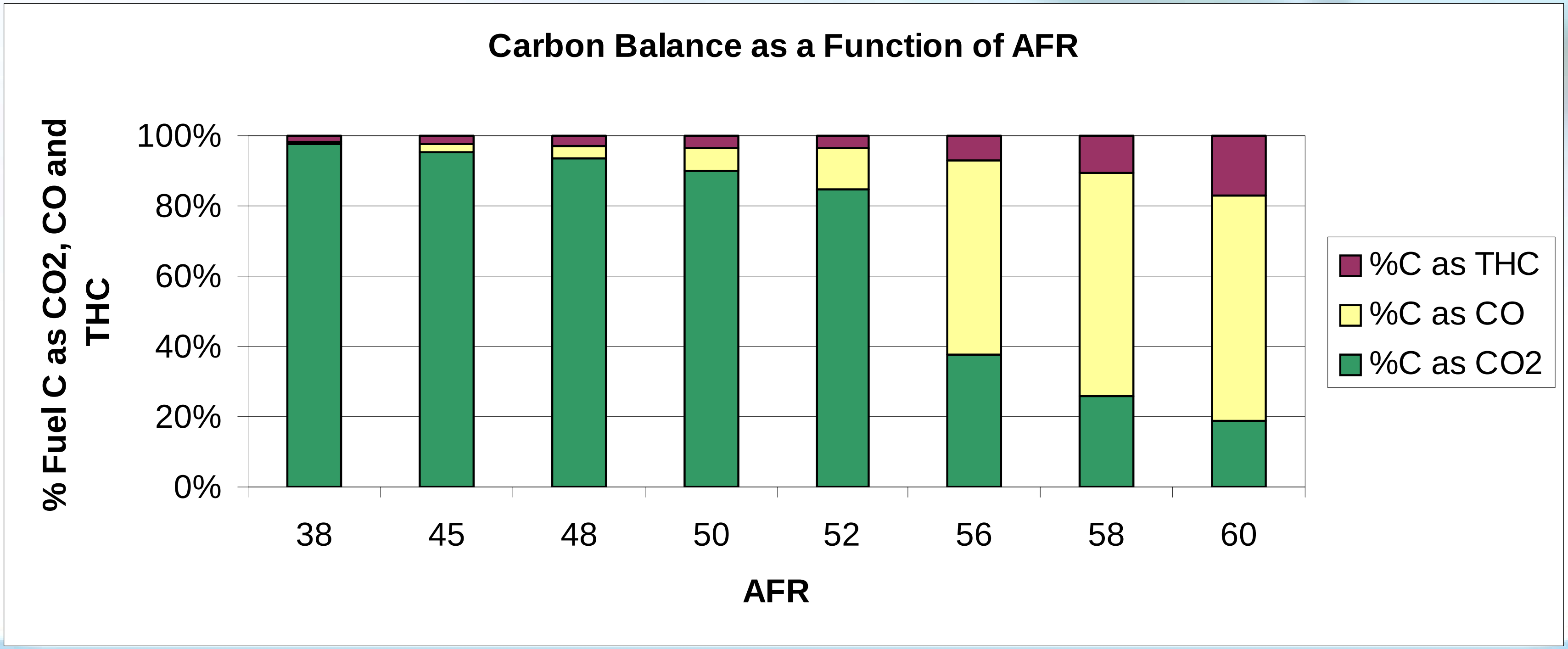
- Ethanol has an octane number similar to iso-octane when measured in the standard manner.
- Ethanol's latent heat of vaporization is about twice that of iso-octane, providing a strong cooling effect on the intake charge, particularly as the mixture is made more fuel-rich.
  - This led to experimental problems of transferring the engine from its initial CNG-fueled, spark-ignition operation to HCCI as well as problems in maintaining a constant intake mixture temperature and thus controlling combustion.
- *HCCI combustion is much more sensitive to fuel properties than conventional SI combustion.*

NMOG Emissions from HCCI

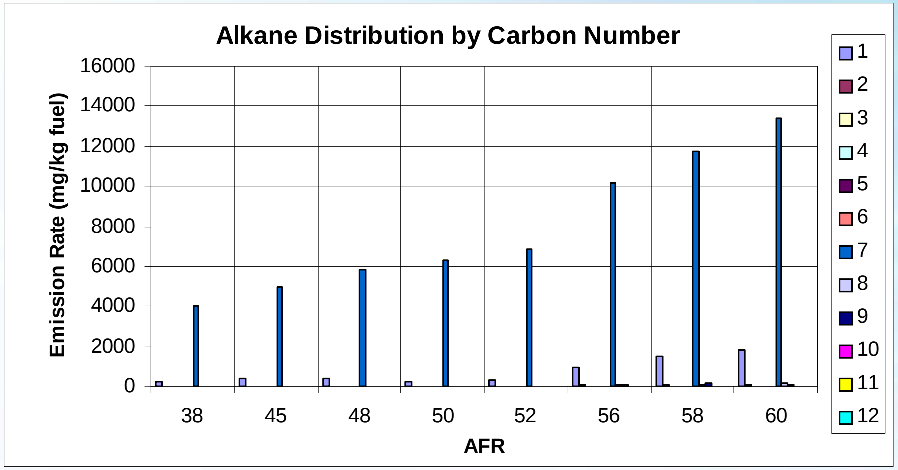
- Unburned fuel compounds account for 58-75% of the NMOG emissions, depending on conditions.
- Partial combustion products, alkenes and carbonyls are the next most prominent components of NMOG
  - Low molecular weight alkenes (ethylene, propylene, isobutene and 1-butene) account for 7-25% of NMOG
  - Carbonyl compounds account for 12-33% of NMOG.
  - Formaldehyde dominates carbonyl emissions (41-50%).
  - Methane emissions are also significant (1-5% of NMOG)
- HCCI combustion appears to form unsaturated cyclic compounds (cycloalkenes and aromatics).
  - Whether these compounds come from the lubrication oil or the combustion process is still not clear.

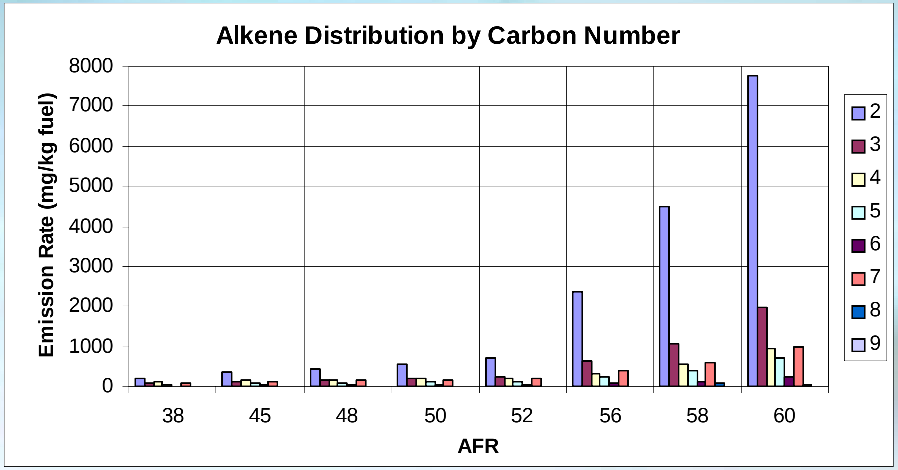
Carbon Balance of HCCI Emissions

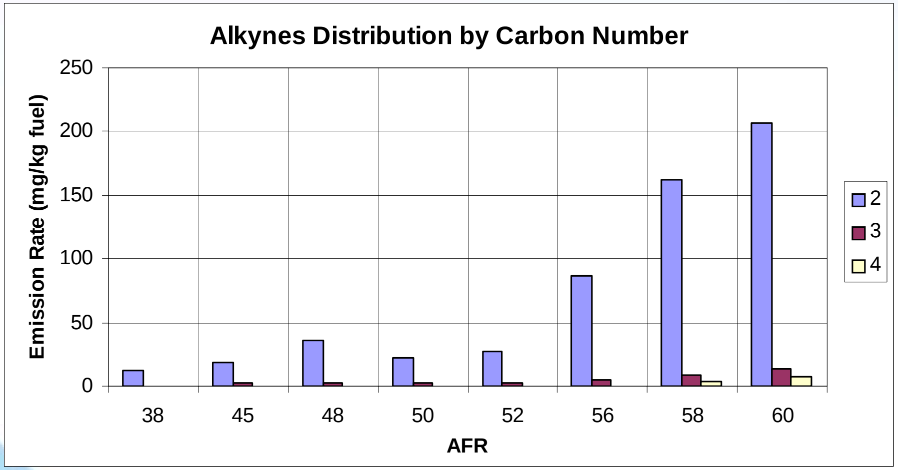
- Fraction of carbon emitted as CO and HC increases with decreasing combustion temperature
- The HC fraction becomes more "reactive" and contains more unburned fuel components

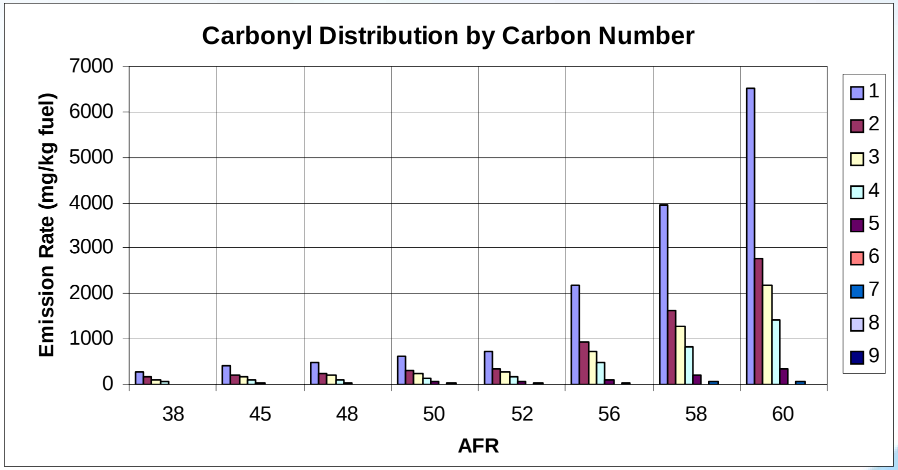


NMOG Emissions from HCCI









Advanced Emissions Characterization

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What else is in there?

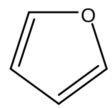
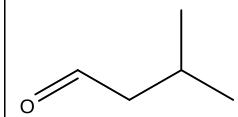
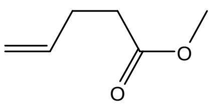
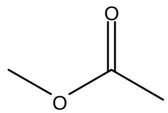
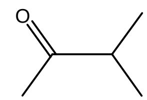
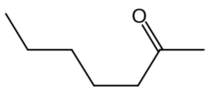
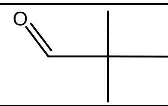
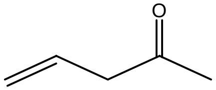
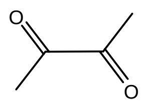
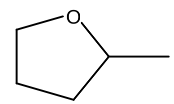
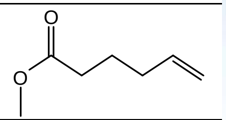
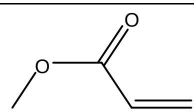
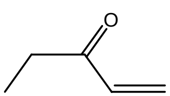
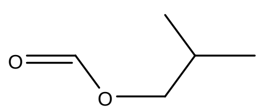
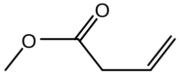
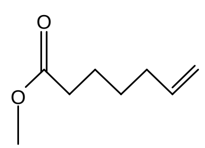
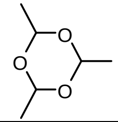
- Semiquantitative GC-MS / GC-FID analysis strategy developed to identify organic “unknowns” in gas phase emissions
  - Carbonyls not in TO-11 method
  - FAME fragments
  - Other oxygenated species (e.g. furans)
- Cryogenic preconcentration GC-MS operated with same parameters as GC-FID method for NMHC analysis
- Qualitative identification by GC-MS by library search and peak purity tools
  - No co-eluting compounds
  - Library search criteria better than 900 for identification
- Semiquantitative analysis by GC-FID by relative retention time identification and average response factor of NMHC.
- For carbonyl compounds found in TO-11 method
  - semiquantitative analysis agreed between within ±20%
  - linearity better than 0.94 over order of magnitude concentration.

- Information from this method will be used to determine what compounds to include in an oxygenated compound method.

Biodiesel Emissions

- Low Molecular Weight FAMEs
  - Produced by cracking of higher MW fuel FAMEs
  - Other than Acetic Acid Methyl Ester, FAMEs are unsaturated
- Furans
  - Concentration appears not to change from Diesel to B100
- Nitro-compounds
  - Nitromethane
  - Nitrophenol in diesel, B20 and B100 emissions
- Carbonyl compounds not in TO-11 method
  - At least 10 carbonyl compounds were identified, many unsaturated.
- Unusual Finds
  - MTBE appears to be produced by the combustion process. Levels are above dilution air concentrations
  - Isobutyl formate was identified but its occurrence is not consistent

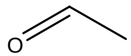
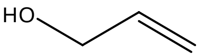
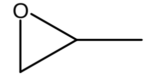
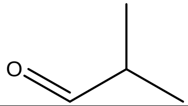
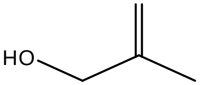
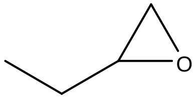
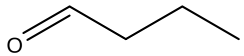
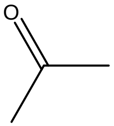
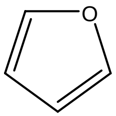
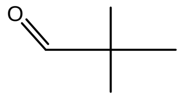
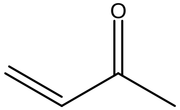
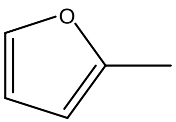
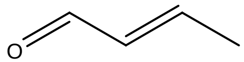
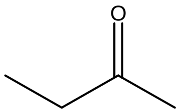
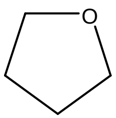
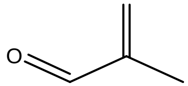
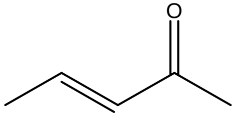
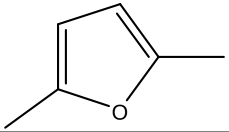
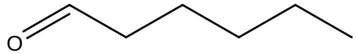
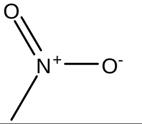
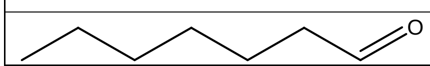
Biodiesel Emissions

Compound	**Structure**	**Compound**	**Structure**	**Compound**	**Structure**
Furan		Isovaleraldehyde *(3-Methylbutanal)*		4-Pentenoic Acid Methyl Ester	
Methyl Acetate *(acetic acid methyl ester)*		Methyl isopropyl ketone *(3-Methyl-2-Butanone)*		2-Heptanone	
Trimethylacetaldehyde *(2-Methyl-2-propanal)*		4-Penten-2-one		Heptanal	
2,3-Butanedione		2-Methyl tetrahydrofuran		5-Hexenoic Acid Methyl Ester	
Methyl Acrylate *(2-Propenoic Acid Methyl Ester)*		Ethyl Vinyl Ketone		Octanal	
Isobutyl Formate		3-Butenoic Acid Methyl Ester		6-Heptenoic Acid Methyl Ester	
		Paraldehyde			

HCCI Emissions

- The GC-MS qualitative analysis found that partial oxidation of hydrocarbons had taken place, resulting in a variety of alcohols, aldehydes, ketones, oxiranes and furans in the dilute exhaust.
- A number of hydrocarbons were identified that were not present in the quantitative analysis. These compounds were mostly branched pentadienes. A number of of these pentadiene isomers were found but correctly identifying them was difficult as the mass spectra are nearly identical.

HCCI Emissions

Structure	Name	Structure	Name	Structure	Name
	acetaldehyde		allyl alcohol		propylene oxide
	isobutryaldehyde		methyl allyl alcohol		1,2-Epoxybutane
	butyraldehyde		acetone		furan
	trimethylacetaldehyde		methyl vinyl ketone		2-methyl furan
	crotonaldehyde		methyl ethyl ketone		Tetrahydrofuran
	methacrolein		t-3-penten-2-one		2,5-dimethylfuran
	hexanaldehyde				nitromethane
	heptanaldehyde				
	octanaldehyde				

Thank you!