Fuel Effects & Air Toxics in MOVES2010

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Presentation Overview

- Introduction
- Fuel Supply Data
- Gasoline Exhaust Fuel Effects
- Air Toxics
- Diesel Fuel Effects
- Example Fuel Effects
- Future Plans

Definitions

- **Fuel Type**
  - The broadest category, considered a fixed characteristic of a vehicle.
  - Gasoline, diesel, E-85, electric
- **Fuel Subtype**
  - A subcategory of fuel type. Classifies ethanol fuels
- **Fuel Formulation**
  - A specific fuel with specific properties.
  - Each fuel formulation belongs to a fuel subtype.
- **Fuel Adjustment**
  - A multiplicative factor applied to the base emission factors.
- **Fuel Supply**
  - A mapping of fuel formulations to county, month and year.

Fuel Parameters

- **Gasoline**
  - RVP
  - Sulfur level
  - ETOH volume
  - MTBE volume
  - ETBE volume
  - TAME volume
  - Aromatic content
  - Olefin content
  - Benzene content
  - E200 (T50)
  - E300 (T90)

- **Diesel**

- Sulfur Level
- BioDieselEsterVolume
- CetaneIndex *(placeholder)*

Fuel Supply Data Creation

- **MOVES contains a large set of fuel specific data**
  - Thousands of individual fuel formulations and parameters
  - Market share data that relates each fuel formulation to 3,222 US counties, 15 calendar years and 12 months.

Fuel Supply Data Sources

- **Annual EPA RFG samples**
  - Sample fuel properties in RFG programs
  - Limited to a few sites in some states
- **Vehicle manufacturer surveys**
- **Other commercial surveys**
- **Proprietary refinery modeling**
  - Look at individual fuel property volumes and correlate with local VMT
- **Individual state data**
  - Very limited
- **EPA Rulemaking requirements**

Fuel Supply Years

- **Historical and Projected fuel properties and market shares**
  - 1990, 1999, 2002 and 2005 are historical from NEI
  - 2000, 2001, 2003 and 2004 are interpolated
  - 2006 through 2012 are projected
  - 2012 and later fuel data is unchanged

Fuel Supply Analysis

- **CY 2005 and 2012 are the key analysis years**
  - 2005 NEI process
  - 2012 RFS rulemaking fuel projection
  - Intermediate years are interpolated
  - Projection impacted by:
    - Ethanol volumes increases
    - Benzene control
    - MTBE phase-out
    - RVP waivers

Fuel Supply Impact

- **Fuel Corrected Emissions**
  - Computed in MOVES for each fuel formulation
  - Compute for each US county, month and year
  - Most counties have only one fuel formulation
- **Weighted together by each fuel formulations market share**
  - Fuel A * marketshareA + Fuel B * marketshareB + …

MOVES Table Structure: Fuel Formulation, Fuel Supply

FuelFormulation Table	FuelSupply Table
fuelFormulationID	**countyID**
RVP	**fuelYearID**
sulfurLevel	**monthGroupID**
ETOHVolume	**fuelFormulationID**
MTBEVolume	marketShare
ETBEVolume	
TAMEVolume	
aromaticContent	
olefinContent	
benzeneContent	
E200	
E300	
T50	
T90	
bioDieselEsterVolume	
CetaneIndex	
PAHContent	

Gasoline Exhaust Fuel Effects

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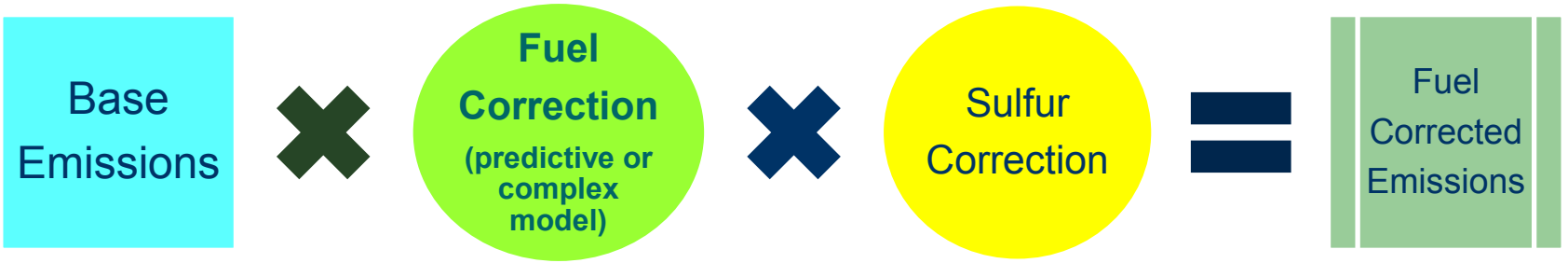
Fuel Effect Models Used in MOVES2010

- **EPA "Predictive" Model**
  - Used only for VOC and NOx
  - Used in RFS rulemaking
- **"Complex" Model**
  - Used only for CO and major air toxic pollutants
  - Published in 1993 and based on 1990 vehicle technology
- **Sulfur Model**
  - Developed for MOBILE6
  - Predicts the effect of sulfur on VOC, CO and NOx

MOVES Table Structure: Fuel Adjustments

GeneralRatioFuelExpression Table	ComplexModelParameters
fuelTypeID	**polProcessID**
polProcessID	**fuelModelID**
minModelYearID	**cmpID**
maxModelYearID	coeff1
minAgeID	coeff2
maxAgeID	coeff3
sourceTypeID	
fuelEffectRatioExpression	

Overall Fuel Adjustment Equation for VOC, CO and NOx



Base Emissions

- **Light-duty HC, CO and NOx emission rates based on I/M program data collected in Phoenix, Arizona**
  - These are defined as “base emissions”
- **“Base fuel” defined from fuel properties in Phoenix during data collection period.**
- **Fuel corrections are calculated as ratio of target fuel emissions : base fuel emissions**

Base Fuels for MOVES Model

Fuel Property Name	Base Fuel 2001+ MY	Base Fuel Pre-2001
Fuel Sub-Type	Conventional Gas	Conventional Gas
RVP	6.9 psi	6.9 psi
Sulfur Level	**30.0 ppm**	**90.0 ppm**
ETOH Volume	0.0 %	0.0 %
MTBE Volume	0.0 %	0.0 %
ETBE Volume	0.0 %	0.0 %
TAME Volume	0.0 %	0.0 %
Aromatic Content	26.1 %	26.1 %
Olefin Content	5.6 %	5.6 %
Benzene Content	1.0 %	1.0 %
E200	41.1 %	41.1 %
E300	83.1 %	83.1 %
Volume to percent Oxygen	0.0 %	0.0 %

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EPA "Predictive" Model

- **Statistical fuel effect models developed by EPA in late 1990's for California oxygen waiver request**
  - Applied by EPA in RFS rules
- **Equations entered in MOVES database**
- **Exhaust VOC and NOx only**
- **Applied to pre-2004 model years**
- **Base fuel varies by model year**

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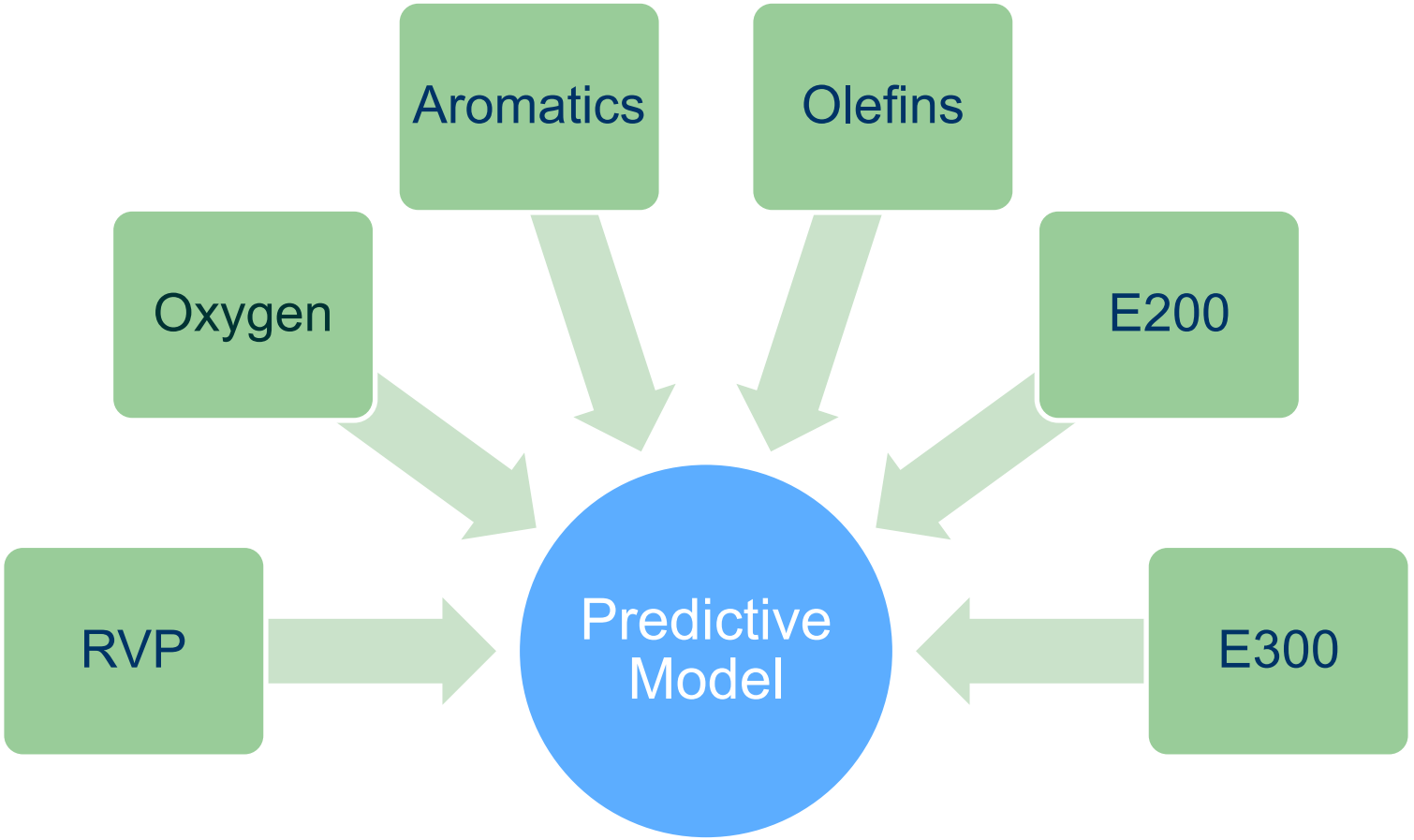
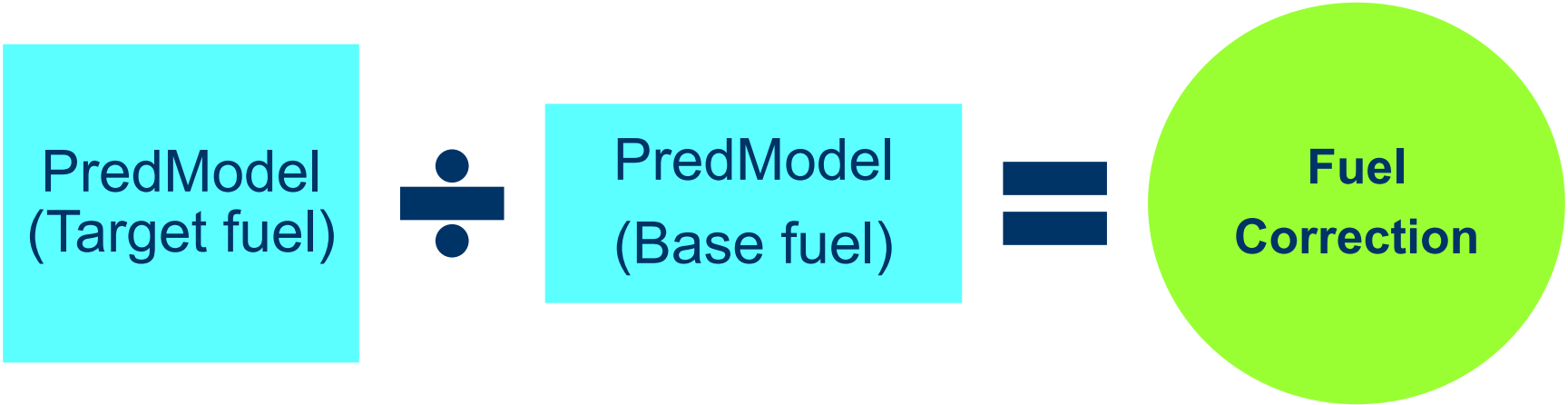
Predictive Model
Fuel Correction for VOC and NOx



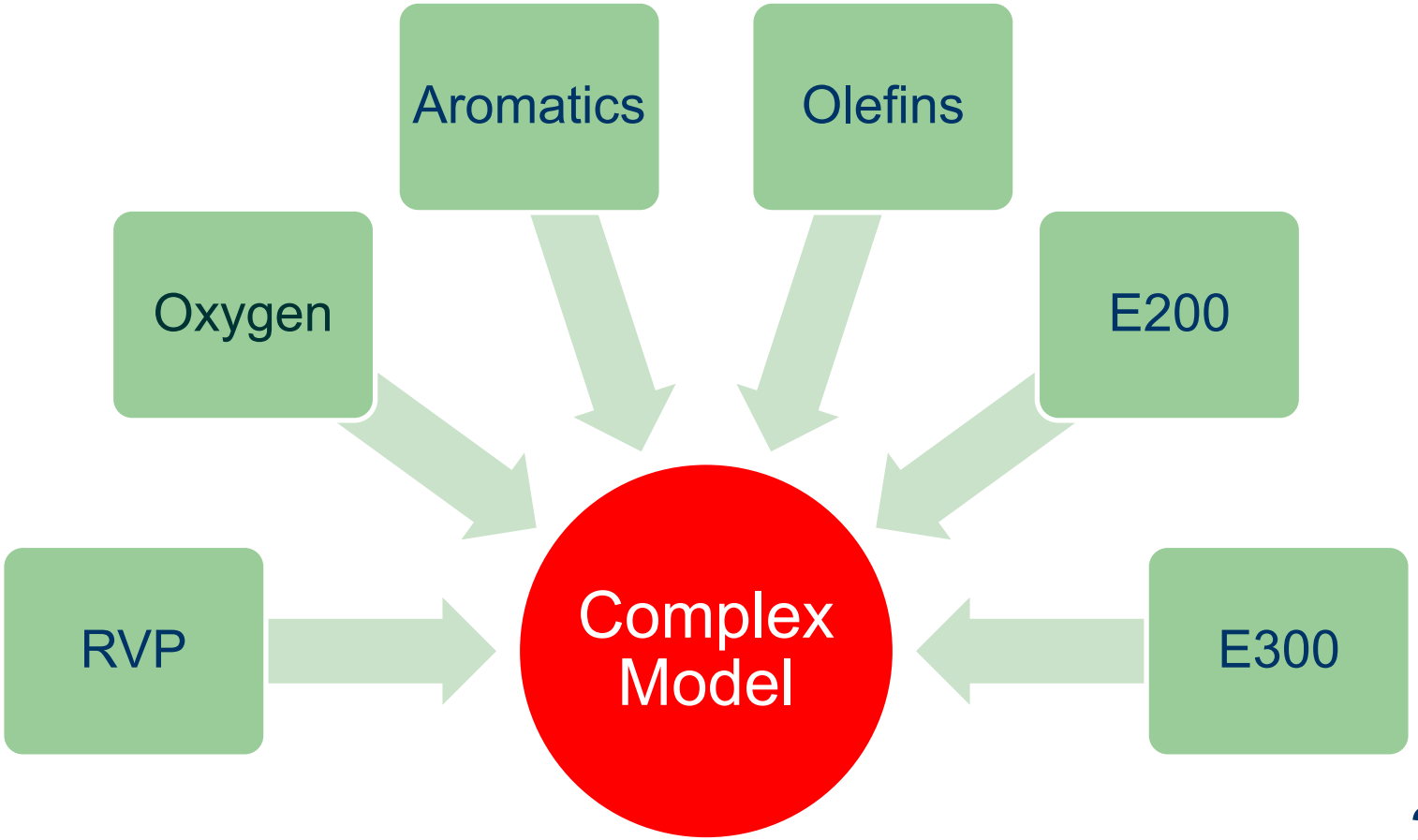
Predictive Model
Fuel Correction Equation



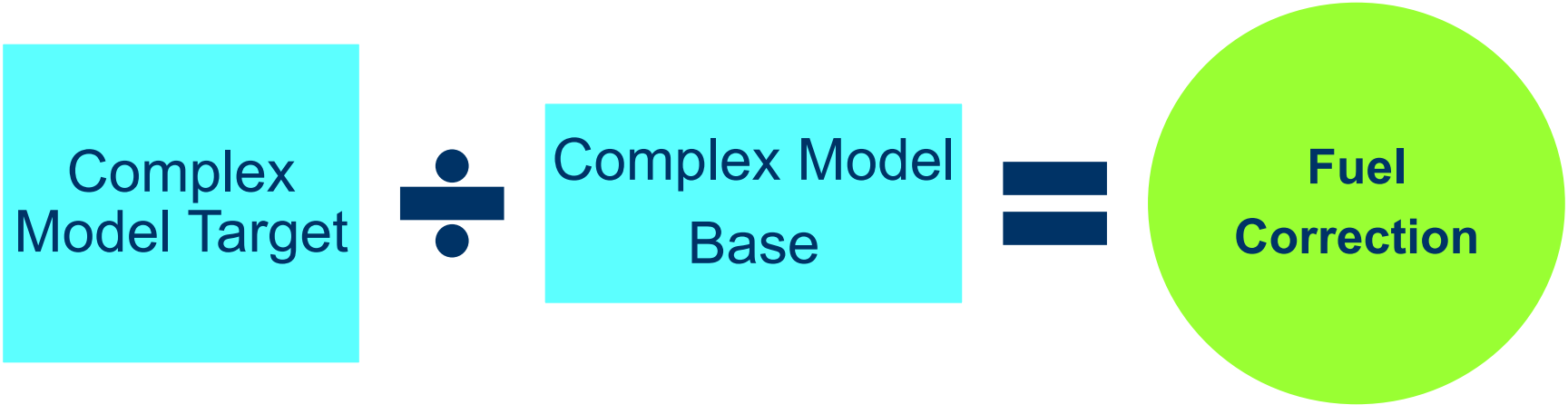
"Complex" Model

- **Statistical fuel effect models developed by EPA in early 1990's to support RFG program**
- **Used for CO on pre-2004 model year vehicles**
- **Equations entered in MOVES database**
  - Ten separate statistical "exponential" models weighted together based on technology groups
- **Base fuel varies by model year**

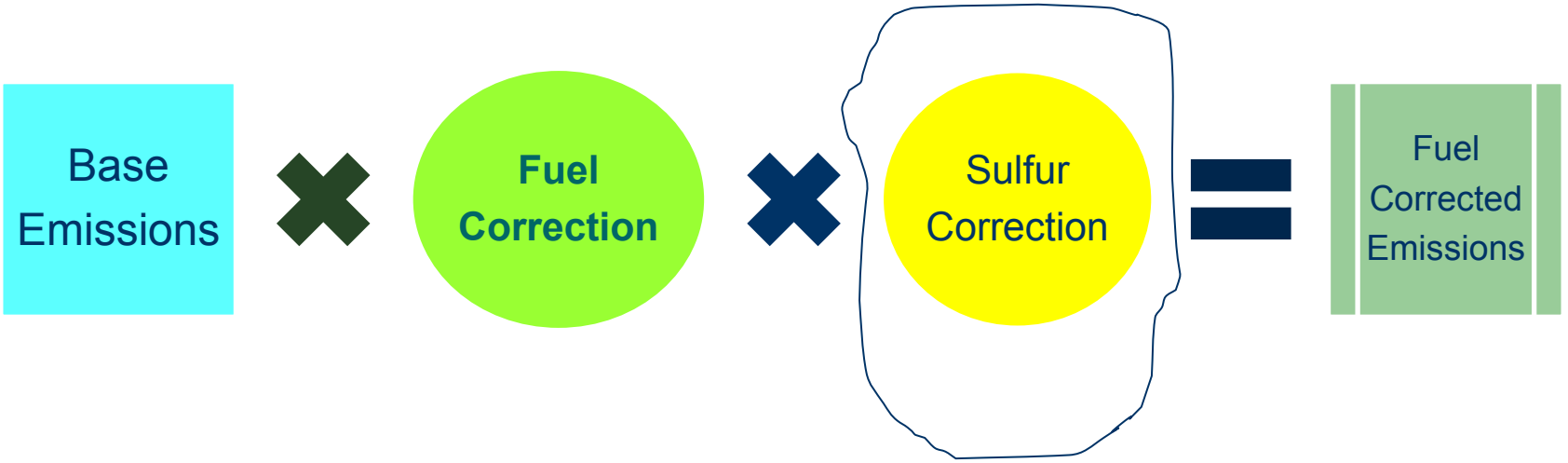
Complex Model Fuel Correction for CO



Complex Model
Fuel Correction Equation for CO



Sulfur Correction Model



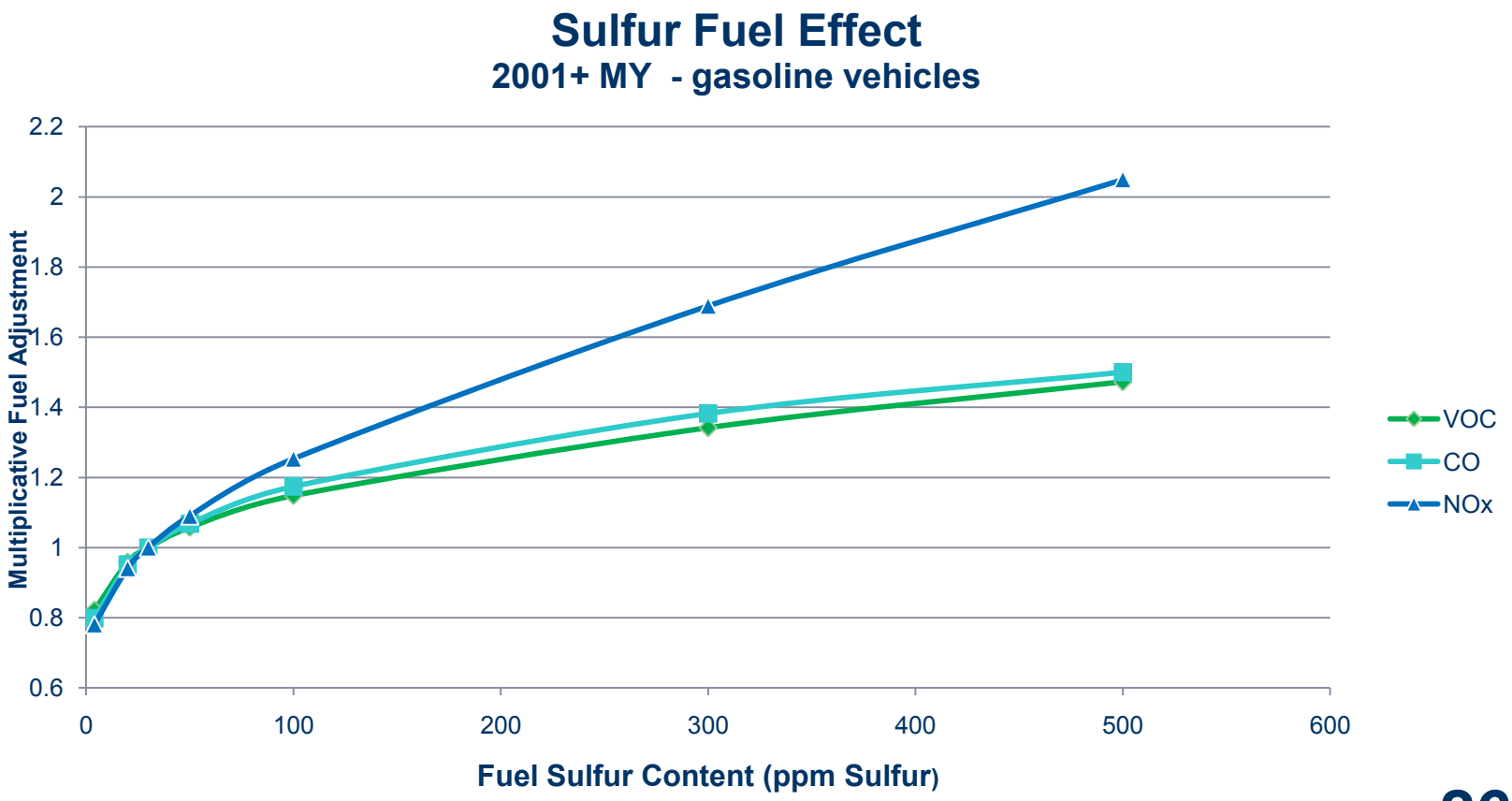
Sulfur Correction Model (MOBILE6)

- **VOC, NOx and CO use the sulfur correction model**
- **Sulfur effects are applied**
  - to ALL model years
  - Sulfur effects are the ONLY effects applied to 2004+ MY
- **Model Structure – emissions to fuel sulfur**
  - Log-Linear
  - Log-Log
- **Models the following sulfur processes**
  - Short term effects
  - Long term effects
  - Irreversibility

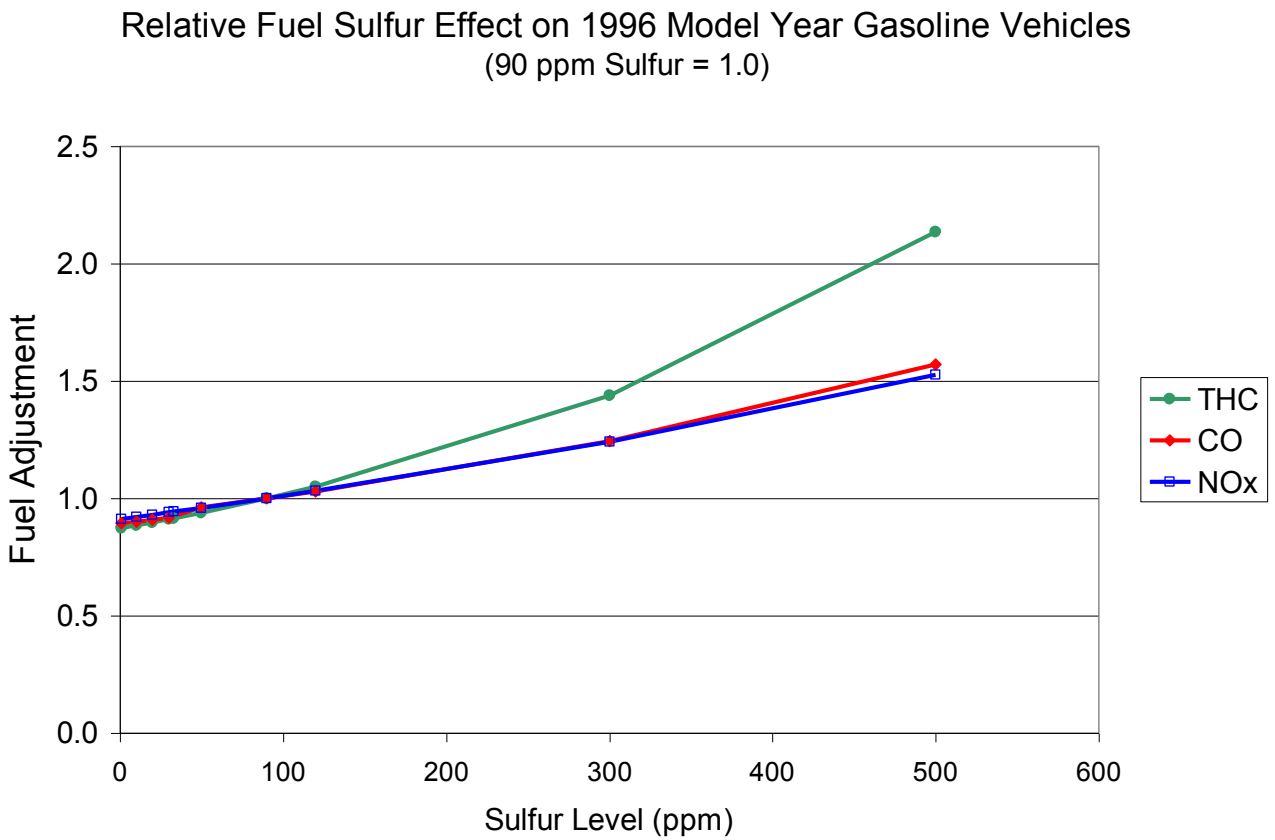
Sulfur Correction Model (con't)

- **Sulfur effect is a function of sulfur level**
  - Emission effect calculated relative to 30 ppm (90 ppm on pre-2001 MY)
- **Effects "capped" below 30 ppm to avoid undue extrapolation of data at lower sulfur levels**
- **< 30 ppm cap based on ARB analysis**
  - 20% reduction in NOx and VOC from 30 → 5 ppm

Sulfur Model Results



Sulfur Model Results (con't)



Air Toxics

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Air Toxic Pollutants in MOVES2010

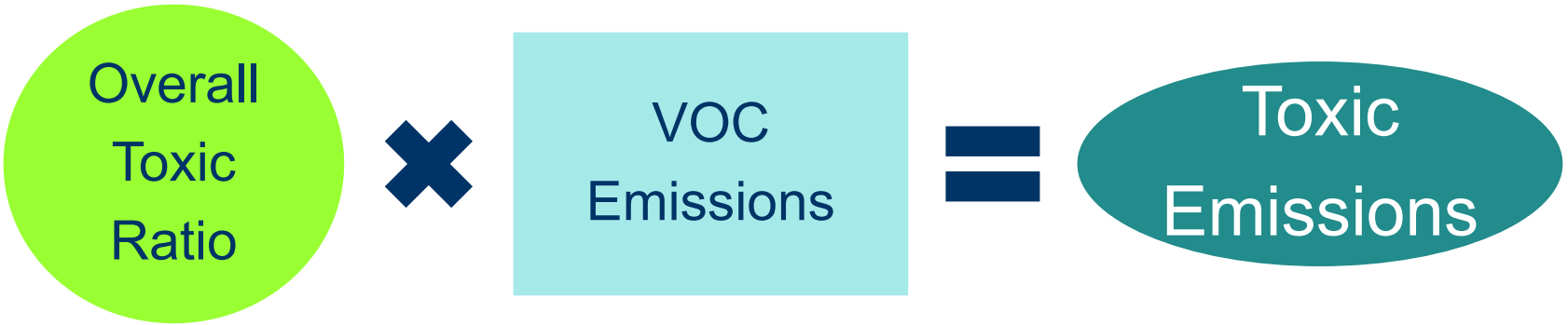
• Benzene	exh & evap
• MTBE	exh & evap
• 1,3 Butadiene	exh
• Formaldehyde	exh
• Acetaldehyde	exh
• Acrolein	exh
• Naphthalene	exh & evap, ratioed to PM2.5
• Ethanol	new for MOVES (exh&evap)

Future Additional Air Toxics

- 2,2,4 Trimethylpentane, Ethyl Benzene, Hexane
- Propionaldehyde, Styrene, Toluene, Xylene
- Mercury, Arsenic, Chromium, Manganese, Nickel
- 30 gaseous and particular PAH compounds
- 16 dioxin and furan compounds

- Will be added in a future MOVES version

Air Toxic Equation



Air Toxic Ratios

- **Complex Model is used to compute Toxic Ratio**
  - Benzene
  - 1,3 Butadiene
  - Formaldehyde
  - Acetaldehyde
- **MTBE emissions are a function of fuel MTBE volume. Taken from MOBILE6 model.**
- **Acrolein and Naphthalene are simple ratios**

Ethanol

- Ethanol is a new air toxic pollutant in MOVES
- Ethanol emissions are a function of fuel ethanol volume
- MOVES contains new factors for E5, E8, E10 (E15, E20 and E85 will be added in the future)
- Effects are the same as those used in the MSAT Rulemaking
  - Testing done at SwRI
  - Environment Canada
  - EPA ORD testing.

Complex Model: Air Toxic Ratio

Toxics / VOC Target Fuel ÷ Toxics / VOC Base Fuel = **Overall Toxic Ratio**

Air Toxic to VOC Ratio

- **Complex model is run for each air toxic compound**
  - Base Fuel
  - Target Fuel (fuel to be evaluated)
- **Complex model is run for VOC**
  - Base Fuel
  - Target Fuel (fuel to be evaluated)
- **Toxics / VOC Base Fuel is computed**
- **Toxics / VOC Target Fuel is computed**

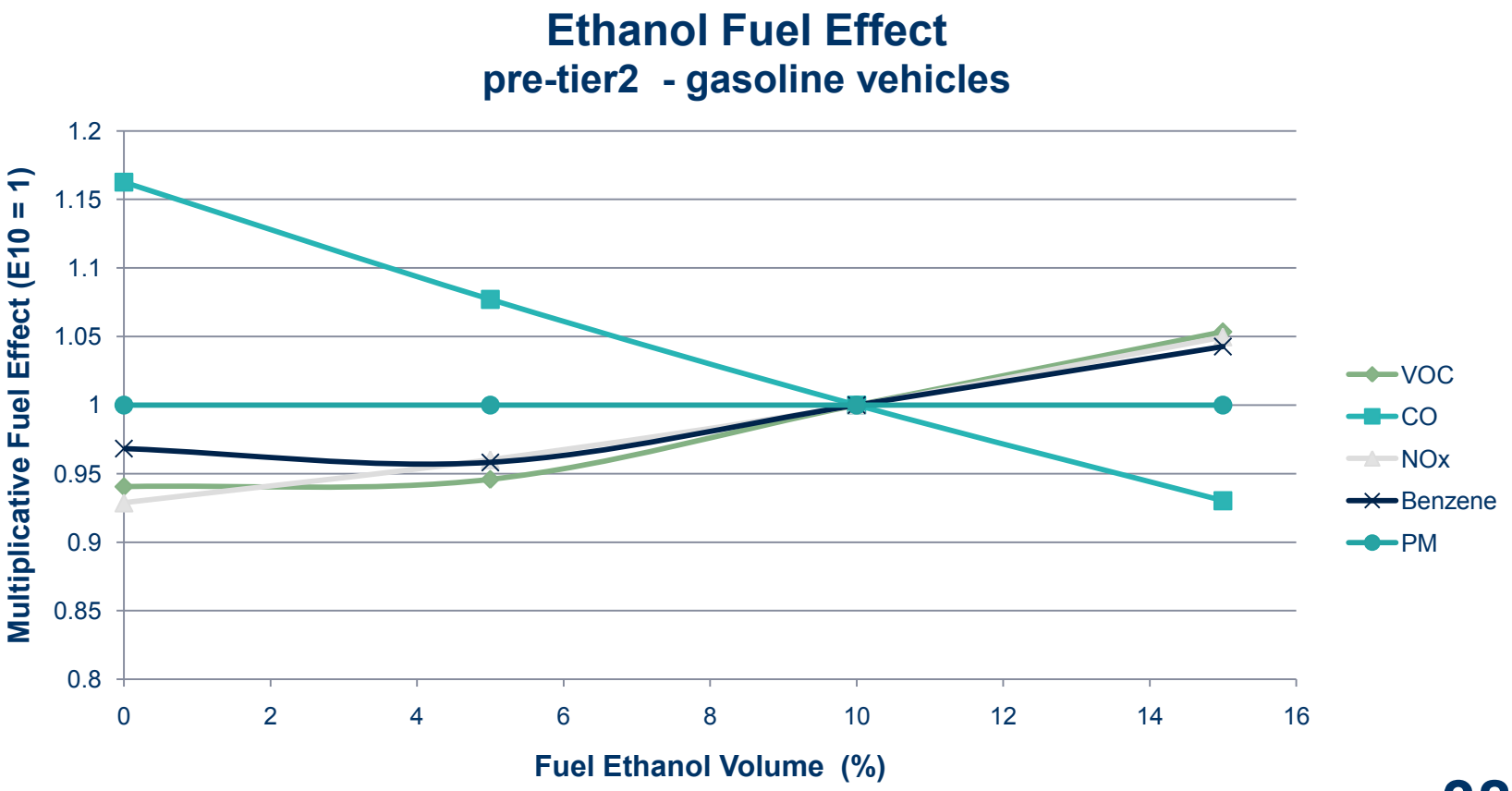
Air Toxic Correction Factors

- **All correction factors accounted for in MOVES VOC emission computation**
  - Speed / operating mode
  - I/M
  - Temperature
- **Separate factors for start / running and for evaporative emissions (where required)**

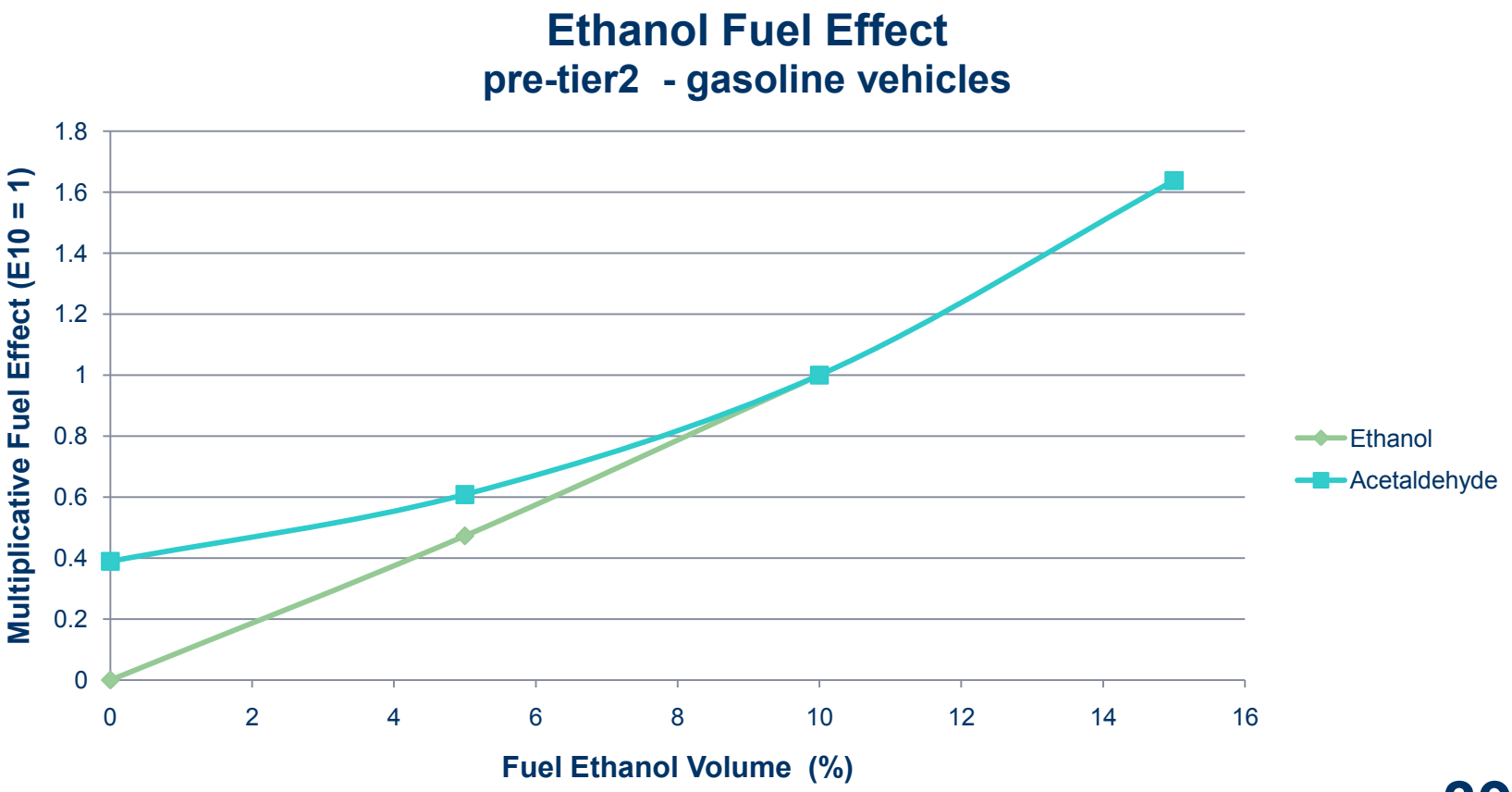
Example Results: Gasoline Exhaust Fuel Effects

Results will vary depending on fuel interactions; these results vary 1 fuel property while keeping others constant

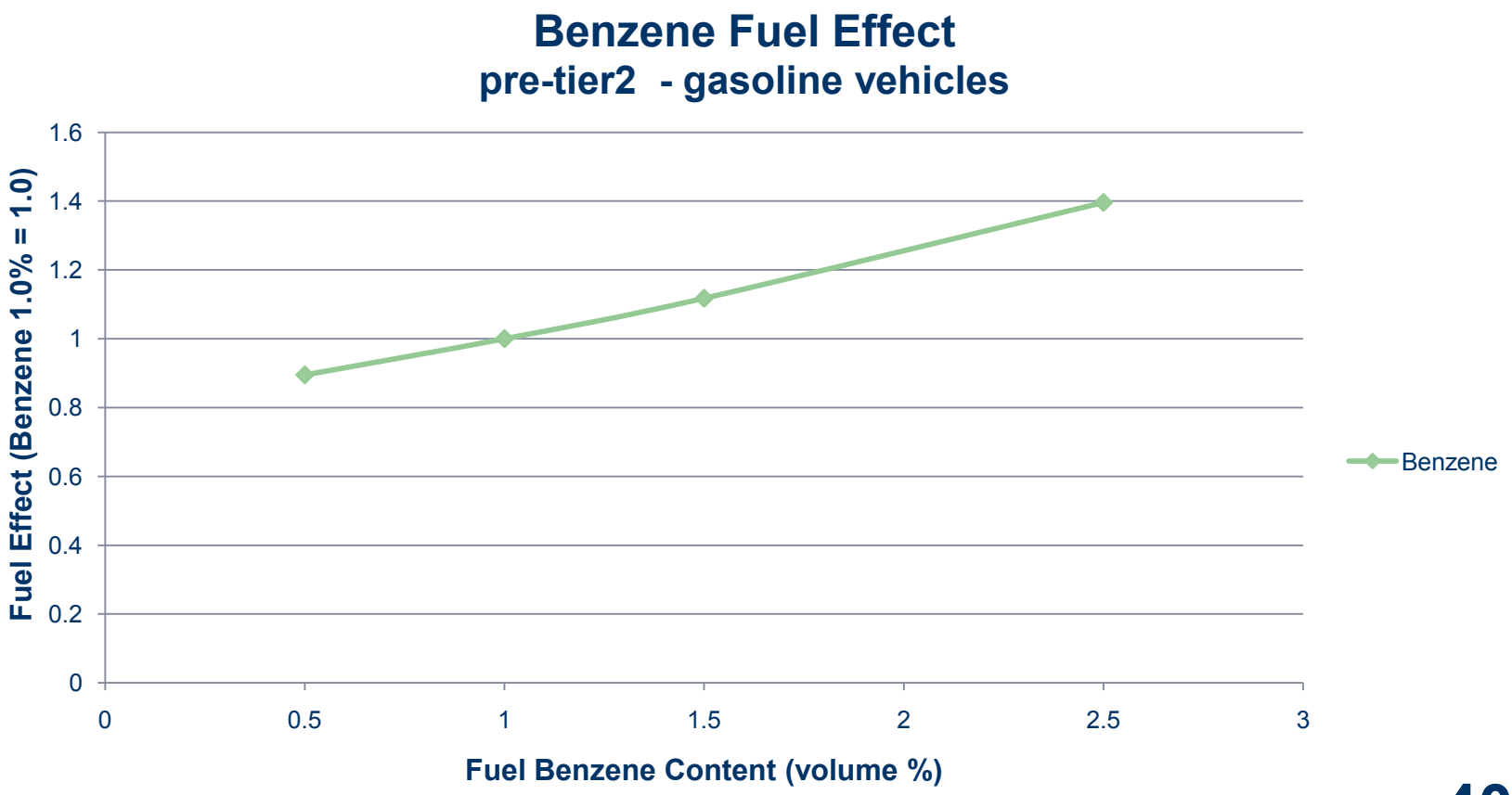
Fuel Ethanol Effects



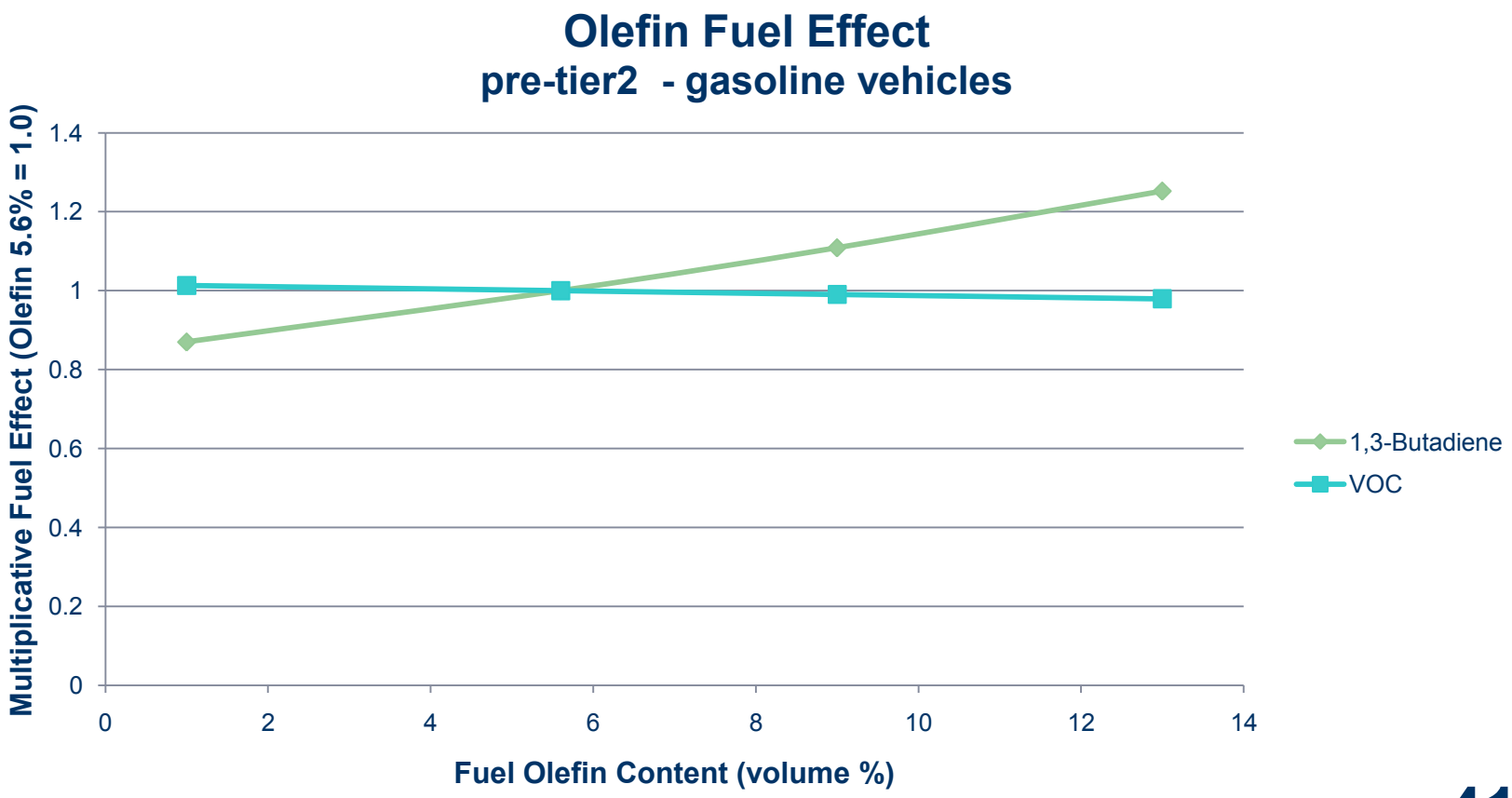
Fuel Ethanol Effects (con't)



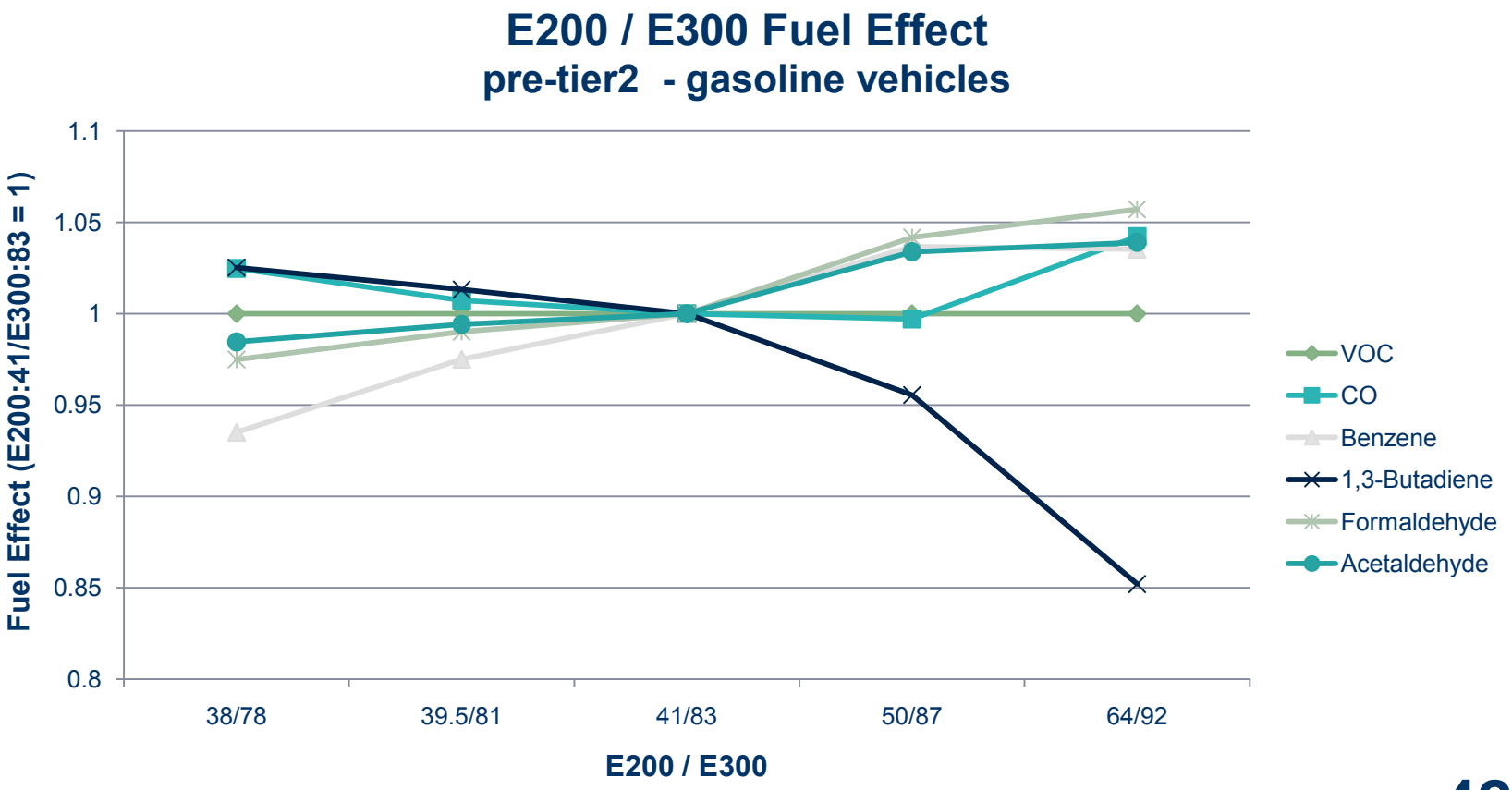
Benzene Fuel Effects



Olefin Fuel Effects



E200 / E300 Fuel Effects



Diesel Fuel Effects

Diesel Fuel Effects

- **Fuel Sulfur only affects sulfate and gaseous SO2 emissions**
  - Fuel sulfur balance is used.
  - sulfate = 1.37142E-07 g SO4 / gfuel- ppmS
  - SO2 = 1.96003E-06 g SO2 / gfuel- ppmS
- **Air toxic / VOC ratios for diesels**
  - Simple constants
  - Function of air toxic pollutant
  - Model year group (i.e., trap equipped) – ***future update***
- **Biodiesel factors based on EPA analysis for RFS2**

Air toxic / VOC ratios for diesels

Pollutant	Toxic / VOC
Benzene	0.0109
1,3 Butadiene	0.0063
Formaldehyde	0.0808
Acetaldehyde	0.0298
Acrolein	0.0036
Naphthalene	0.0013
Ethanol	0.0000
MTBE	0.0000

Biodiesel Effects

Pollutant Name	% Change on BD20 relative to BD0
HC	-14.1
CO	-13.8
NOx	2.2
PM2.5 and PM10.0	-15.6
Benzene	-14.1
1,3 Butadiene	-14.1
Acetaldehyde	-14.1
Formaldehyde	-14.1
Naphthalene	-15.6
Acrolein	-14.1

Future Work

- **Update fuel effects and toxic emissions for Tier 2 vehicles**
  - Ethanol, RVP, T50, T90 and Aromatics effects from EPA/DOE/CRC “EPAct” test program
  - Sulfur effects from current research
- **E85 capability**
- **Expand air toxics**
  - Seven additional gaseous pollutants
  - 15 new PAHs
  - Metals
  - Dioxin - Furans

References

- **Complex Model**
  - U. S. EPA. 1993. Final Regulatory Impact Analysis for Reformulated Gasoline. December 13, 1993. http://www.epa.gov/otaq/regs/fuels/rfg/ (ria.zip)
- **Predictive Model**
  - (EPA 420 R-07-004, *"Regulatory Impact Analysis: Renewable Fuel Standard Program",* USEPA, OTAQ, Assessment and Standards Division, April 2007)
- **MOBILE6.2 Sulfur Model**
  - (EPA420-R-01-039, "*Fuel Sulfur Effects on Exhaust Emissions, Recommendations for MOBILE6*", Venkatesh Rao, July 2001).

References - Recent Air Toxic

- Southwest Research Institute, 2007. Flex Fuel Vehicles (FFVs) VOC/PM Cold Temperature Characterization When Operating on Ethanol (E10, E70, E85). Prepared for U. S. Environmental Protection Agency.
- Environment Canada, 2007. Comparison of Emissions from Conventional and Flexible Fuel Vehicles Operating on Gasoline and E85 Fuels. ERM Report No. 05-039, Emissions Research Division.
- Durbin T. D., Miller J. W., Younglove T., Huai T., Cocker K., 2007. Effects of fuel ethanol content and volatility on regulated and unregulated exhaust emissions for the latest technology gasoline vehicles. Environmental Science and Technology 41, 4059-4064.
- Southwest Research Institute. 2007. Flex Fuel Vehicles (FFVs) VOC/PM Cold Temperature Characterization When Operating on Ethanol (E10, E70, E85). Prepared for U. S. Environmental Protection Agency. Available in Docket EPA-HQ-OAR-2005-0161.