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The Impact of Biofuels on Air Emissions and Toxins

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Energy Resources Center

The 8th China-U.S. Forum on Frontiers of Cancer Research and
The 5th Zhengzhou International Cancer Forum
Sponsored by the Hormel Cancer Institute and Henan Cancer Hospital

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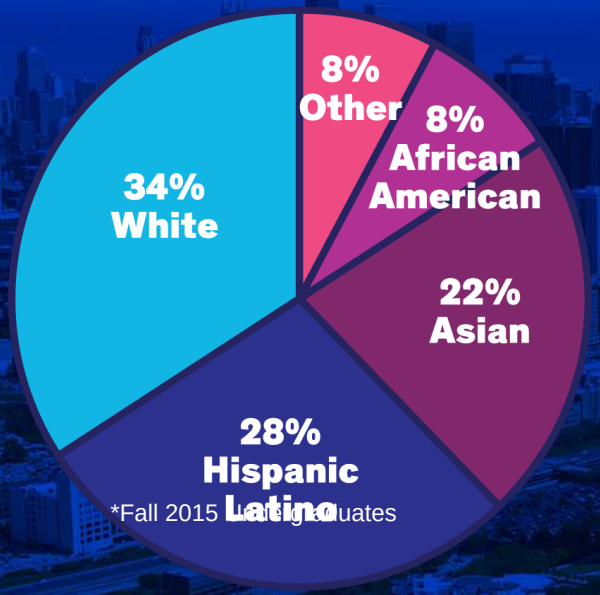
September 15, 2017

University of Illinois at Chicago
Diverse Student Body
29,000 students



- White
- Hispanic/Latino
- Asian
- African-American
- Other

conducting
$368M
total research expenditures

40th
among public universities

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Biofuels Research

- 2 Senior Scientists – 5 Students/Interns – Large Network of Cooperators
- Fuel Ethanol life cycle and combustion emissions modeling
- New biofuels technology evaluation/commercialization
- Land use research using Remote Sensing/Satellite tools
- Pollinator habitat conservation

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Presentation Overview and Terms

Presentation Overview:

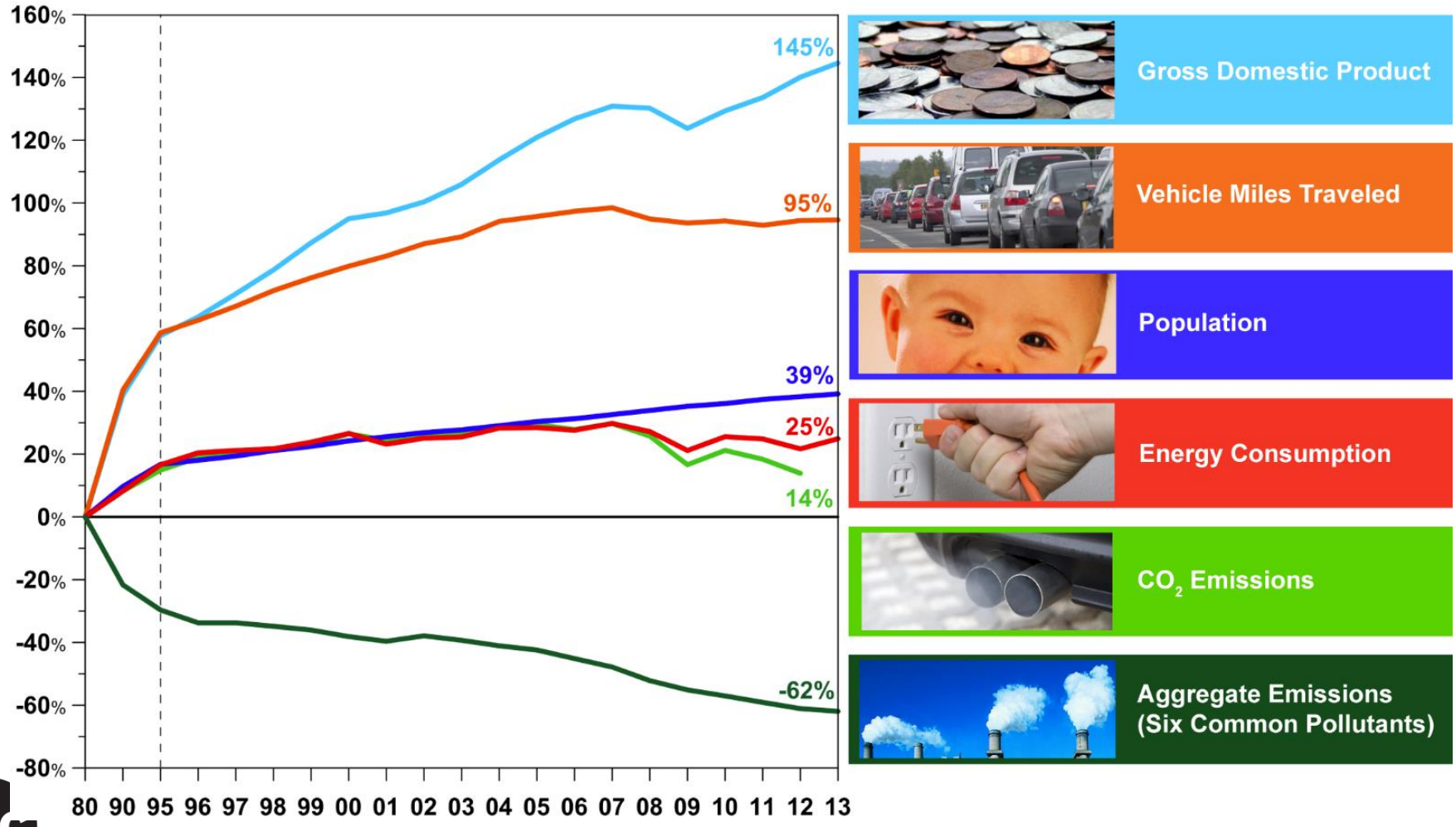
- Emissions Reductions from the US Clean Air Act
- Emissions Reductions of Air Toxins with Ethanol Blended Gasoline
- Can Global Cities Rely on Electric Vehicles to Solve Pollution Problems?
- New Emissions Study for Beijing
- Greenhouse Gas Life Cycle Emissions for Ethanol

Terms:

E10	10% Ethanol in Gasoline
E20	20% Ethanol in Gasoline
EV	Electric Vehicle

Emissions Reductions from the US Clean Air Act

Clean Air Act Progress



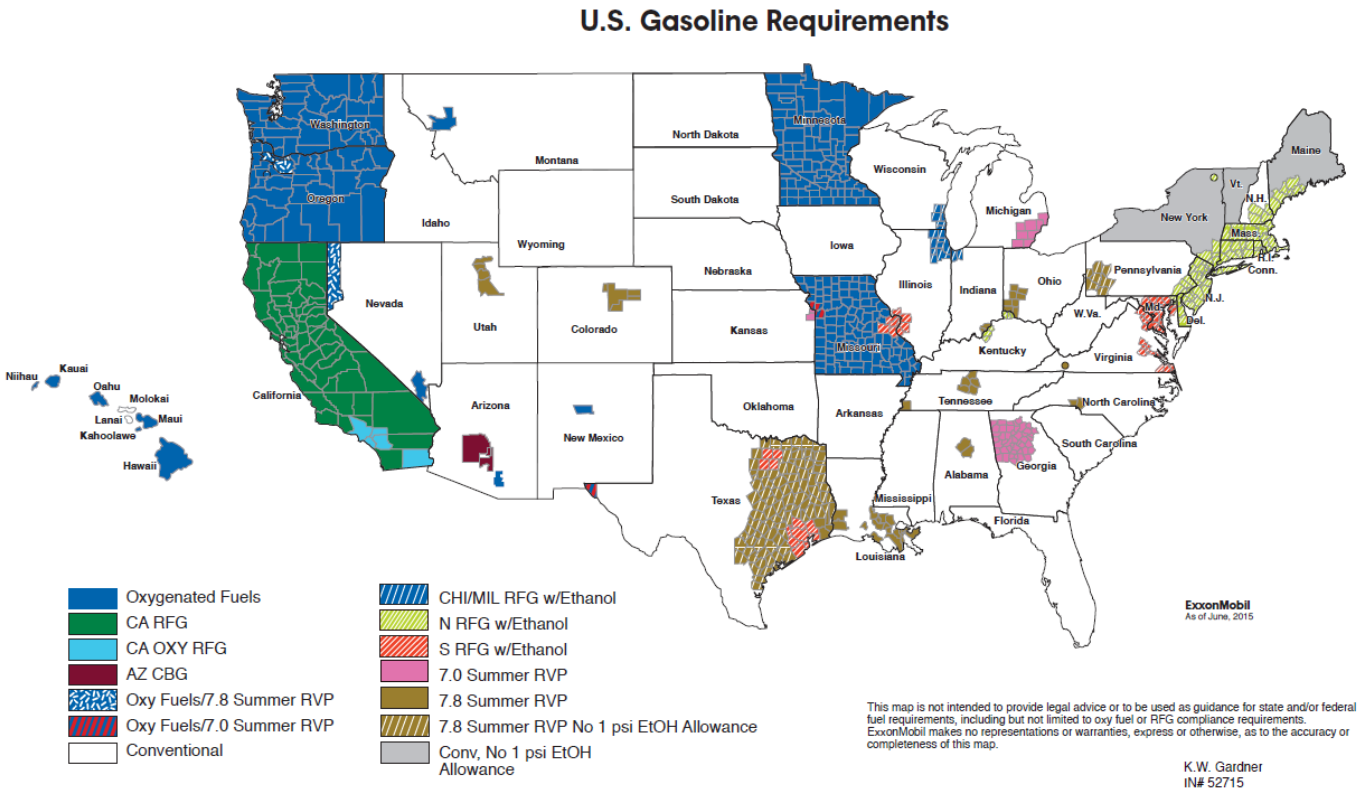
Source: US Environmental Protection Agency

Gasoline-Ethanol Blends

E10 is used in almost all fuel in the US, all regions, across all seasons.
E15 and higher flex fuels are also in use.

Specially reformulated gasolines are used in high polluted urban areas.

Reformulated gasolines contain ethanol



Emissions Reductions of Air Toxins with Ethanol Blended Gasoline

Gasoline

- Finished gasoline typically contains more than 150 separate compounds
  - some blends may have many more compounds
- Cancer risk of several compounds

Benefits of Ethanol Blended into Gasoline

- Increased ethanol results in lower burned gas and exhaust temperatures.
- High Octane Rating (wanted by car manufacturers for higher knock resistance in engines)
  - In fuel formulations ethanol substitutes for and dilutes other octane enhancers such as benzene, toluene, and xylene.
- Oxygenate in Fuel (reduces certain emissions)
- Reduction in Key Toxins from Combustion Process

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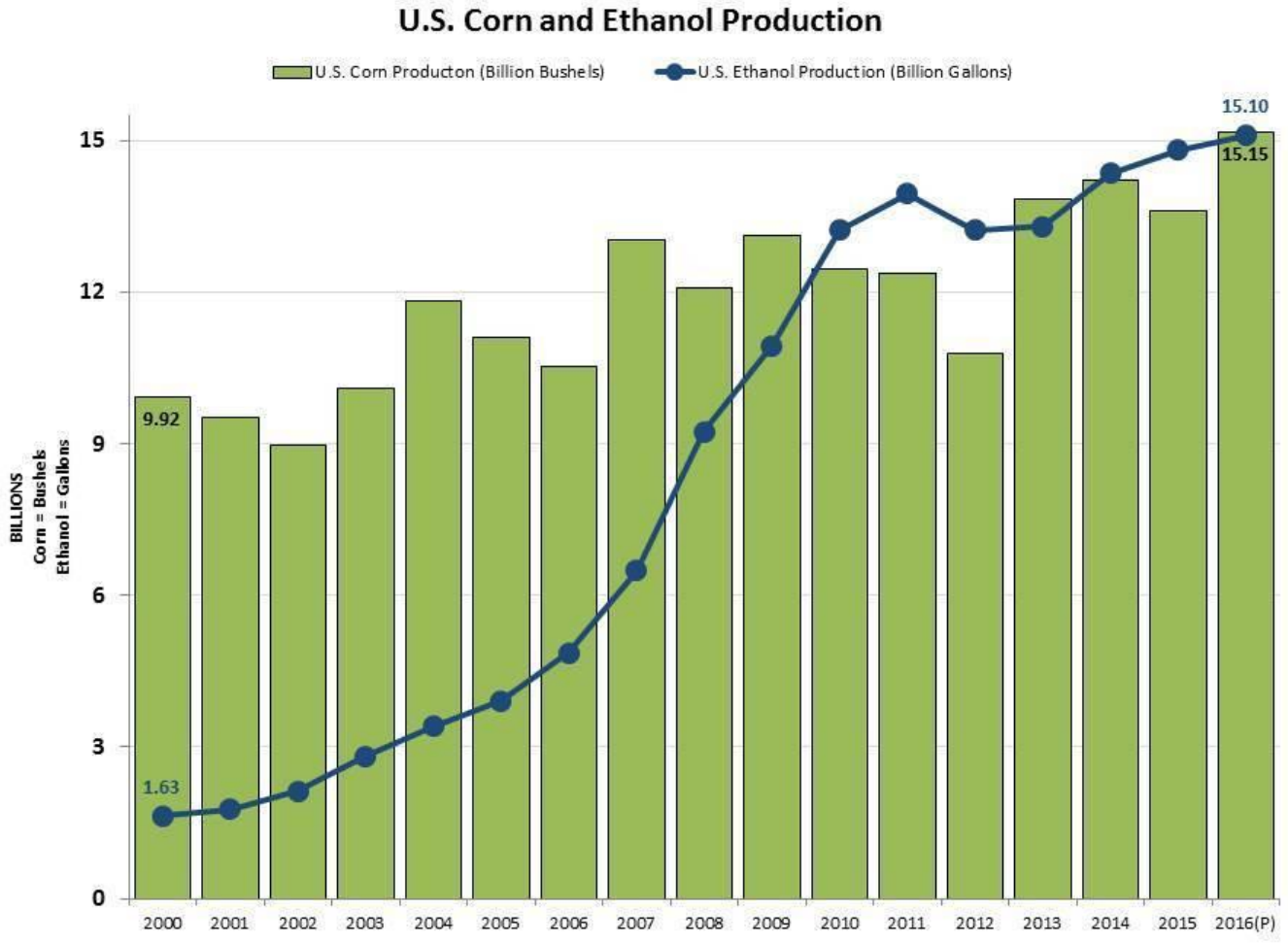
Increase in Corn Ethanol Use



Decrease in Air Toxins

Ambient and Emission Trends of Toxic Air Contaminants in California

Environmental Science & Technology Article

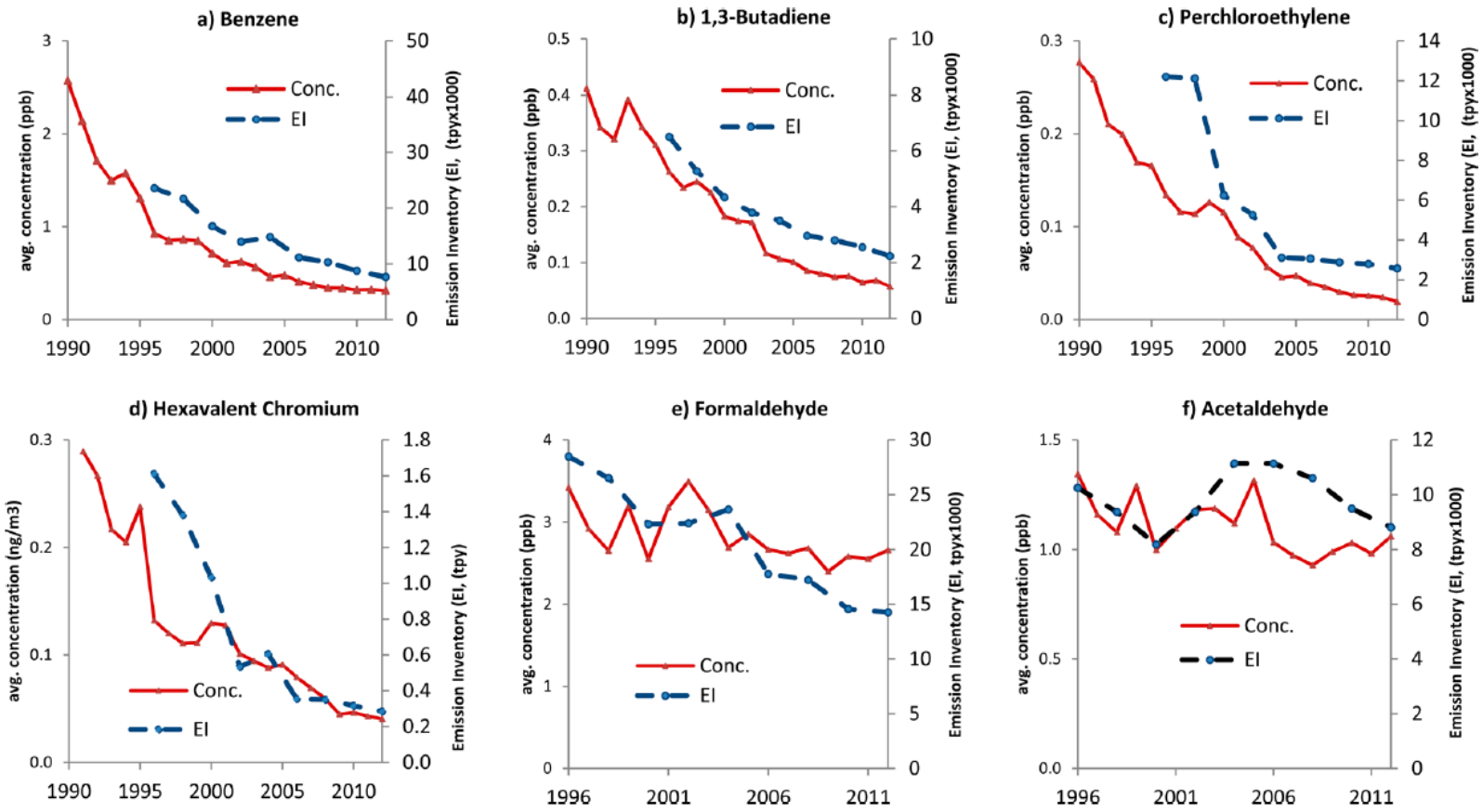


Figure 3. Statewide annual average concentrations and emissions inventory (EI) trends for six toxic air contaminants. EI data were available starting in 1996. (a) Benzene (1990–2012), (b) 1,3-Butadiene (1990–2012), (c) Perchloroethylene (1990–2012), (d) Hexavalent Chromium (1991–2012), (e) Formaldehyde (1996–2012), (f) Acetaldehyde (1996–2012).

Toxic Air Contaminants (California Air Resources Board)

- "Toxic air contaminant" means benzene, 1,3-butadiene, formaldehyde, or acetaldehyde.
- “In each test, the emission rate of each toxic pollutant shall be multiplied by its relative potency, as shown in the following table, and the four products shall be summed.”

	Relative Potency
1,3-butadiene	1.0
benzene	0.17
formaldehyde	0.035
acetaldehyde	0.016

ATTACHMENT A-13; State of California; California Environmental Protection Agency; AIR RESOURCES BOARD; Stationary Source Division CALIFORNIA TEST PROCEDURES FOR EVALUATING SUBSTITUTE FUELS AND NEW CLEAN FUELS IN 2015 AND SUBSEQUENT YEARS; Adopted: March 22, 2012

Cancer Risk

- Ethanol generally decreases 1,3 Butadiene and Benzene, increases aldehydes but the weighted sum results in reduced cancer risk
- Stein et al./SAE In. J. Engines / Volume 6, Issue 1 (May 2013):
  - "Increased ethanol in gasoline should decrease emission of 1,3 butadiene and benzene and increase emissions of acetaldehyde and formaldehyde (later two due to incomplete combustion of ethanol). Due to much higher toxicity weighting factors, 1,3-butadiene and benzene dominate the weighted sum of these four toxics even in high ethanol content"
- "Unnasch and Henderson (2014) "Change in Air Quality Impacts Associated with the Use of E15 Blends Instead of E10".
  - Analysis of CRC Study E80 showed that "a change from E10 to E15 results in a 6.6% reduction in toxic risk. Furthermore, a "reduction in 1,3 butadiene and benzene produces a decrease in impacts that is greater than their relative decrease in mass emissions"

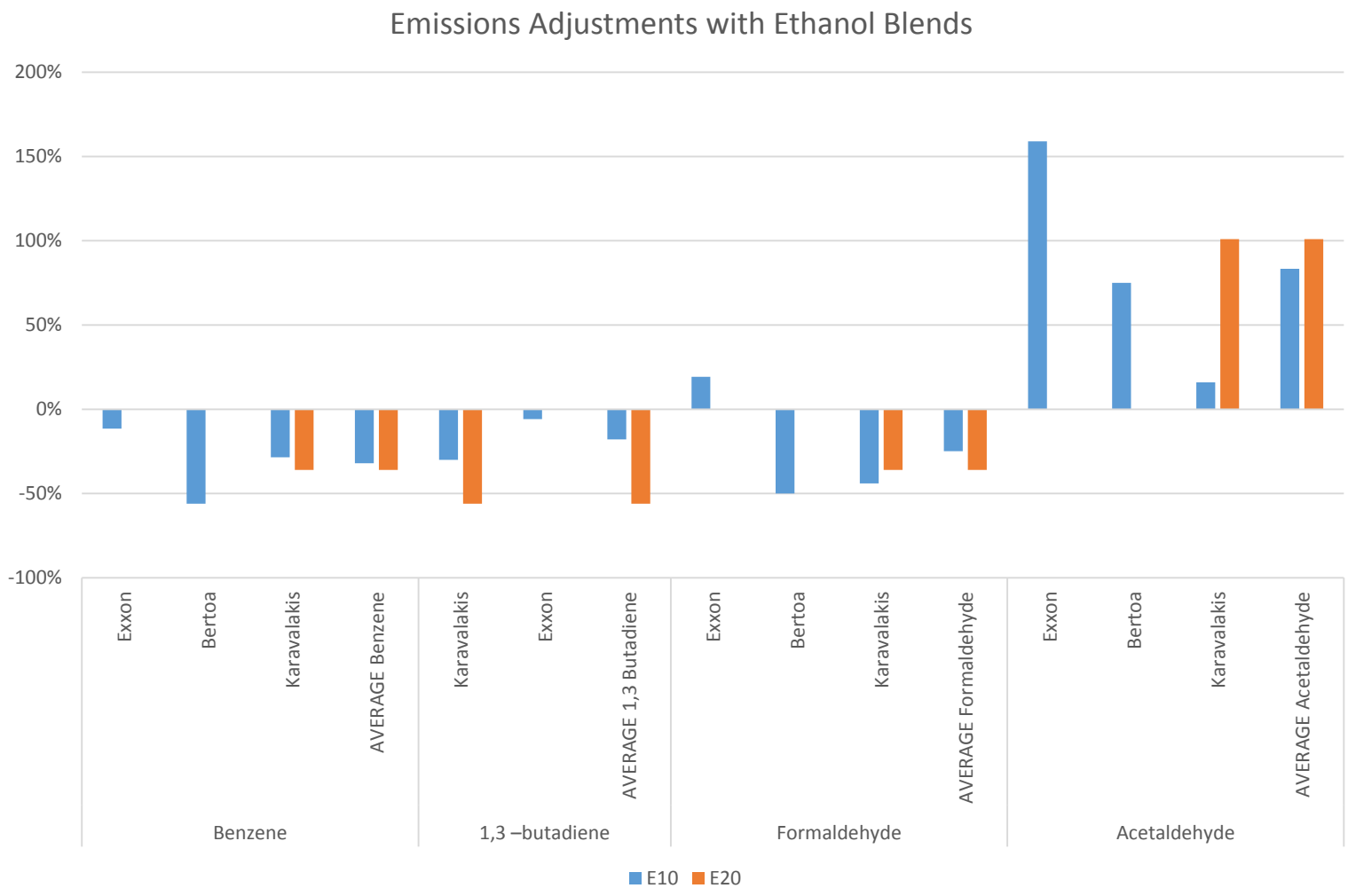
Citations

- Air Toxics Hot Spots Program Risk Assessment Guidelines; Part II; Technical Support; Document for Describing Available Cancer Potency Factors; May 2005; Secretary for Environmental Protection; California Environmental Protection Agency; Alan C. Lloyd, Ph.D.; Director Office of Environmental Health Hazard Assessment; Joan E. Denton, Ph.D.
  - Describes all underlying cancer studies for unit risk factors
- Air Toxic Emissions from On-road Vehicles in MOVES2014; Assessment and Standards Division; Office of Transportation and Air Quality; U.S. Environmental Protection Agency; EPA-420-R-16-016; November 2016
  - Describes that MOVES 2014 Air Toxic Analysis is based on Complex Model
- Unnasch at al. Refinement of Selected Fuel-Cycle Emissions Analyses; Final Report; Prepared for California Air Resources Board; April 20, 2001
- Ambient and Emission Trends of Toxic Air Contaminants in California; Ralph Propper,* Patrick Wong, Son Bui, Jeff Austin, William Vance, Álvaro Alvarado, Bart Croes, and Dongmin Luo*; California Air Resources Board, Environ Sci Technol, 2015.
  - Shows decreases of toxins over time in California

Literature Summary:
Vehicle Emissions Tests of Gasoline with Ethanol compared to Gasoline Without Ethanol

Toxic air contaminant	Citation	Emissions E10 vs E0 % Difference	Emissions E20 vs. E0 % Difference
Benzene	Exxon (citing 1992 data)	-12%	
	Bertoa et al. (2015)	-56%	
	Karavalakis (2012)	-29%	-36%
	AVERAGE Benzene	-32%	-36%
1,3 –butadiene	Karavalakis (2012)	-30%	-56%
	Exxon	-6%	
	AVERAGE 1,3 Butadiene	-18%	-56%
Formaldehyde	Exxon	19%	
	Bertoa et al. (2015)	-50%	
	Karavalakis (2012)	-44%	-36%
	AVERAGE Formaldehyde	-25%	-36%
Acetaldehyde	Exxon	159%	
	Bertoa et al (2015)	75%	
	Karavalakis (2012)	16%	101%
	AVERAGE Acetaldehyde	83%	101%

Most Publications: 1,3 Butadiene and Benzene Emissions go Down; some Aldehyde Emissions go Up with Ethanol Blends

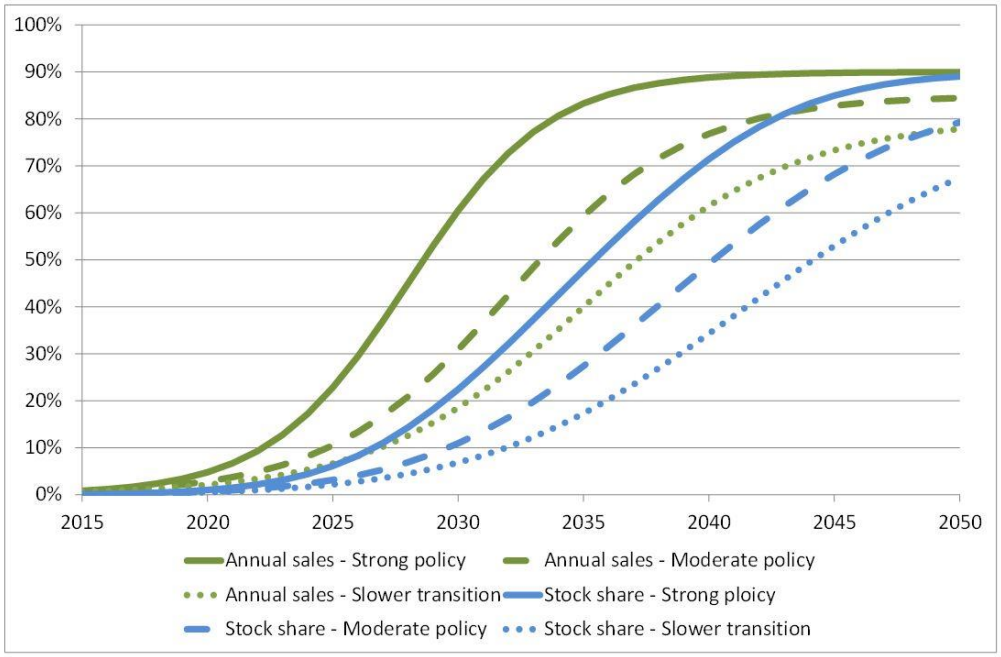


After Applying Relative Toxicity Weights: Large Toxicity reductions from Blending Ethanol

Can Global Cities Rely on Electric Vehicles ONLY to Solve Pollution Problems?

Relatively Slow Vehicle Population (Stock) Change Towards Electric Vehicles even with high annual new Electric Vehicle Sales

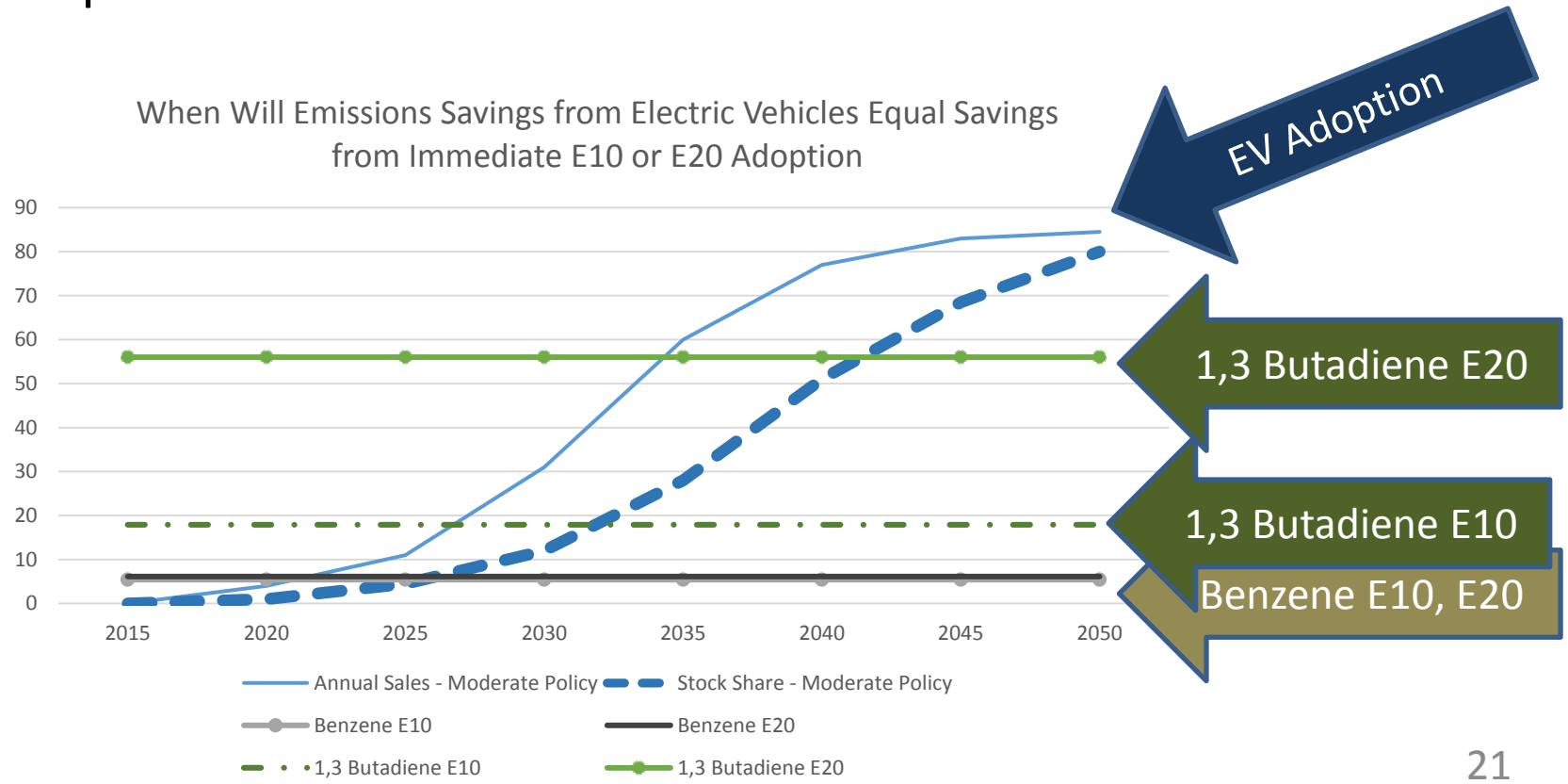
- For 2030, the study cites that Electric Vehicles will account for between 20% to 60% of annual vehicle sales converting to 7% and 22% of total vehicle population (stock) depending on the policy scenario.
- A Roland Berger report cites annual new vehicle sales of EVs by 2030 of 19% which would correspond more closely with the slower adoption scenario by Whitmore



Whitmore, Adam; "How fast could the market for electric vehicles grow? June 21, 2016 by Adam Whitmore; http://energypost.eu/fast-market-electric-vehicles-grow/

Biofuels Need to Bridge the Adoption Gap and Then Complement Benefits of Electric Vehicles

- Graph shows that it will take until 2032 for Electric Vehicles to produce annual emissions savings equal to immediate E10 adoption



New Emissions Study for Beijing

New Study for Beijing

1. University of Illinois at Chicago commissioned to sample actual Beijing/Tianjin gasoline samples
2. Calculated Air Toxins Emissions using the US Environmental Protection Agency Complex Model

   The Complex Model is a computer model used to determine whether gasoline complies with reformulated gasoline (RFG) and emissions performance standards.
3. Adjusted fuel samples for E10 and E20 ethanol blends based on the adjustments in distillation properties.
4. Recalculated Air Toxins Emissions for ethanol blends to show different emissions with ethanol

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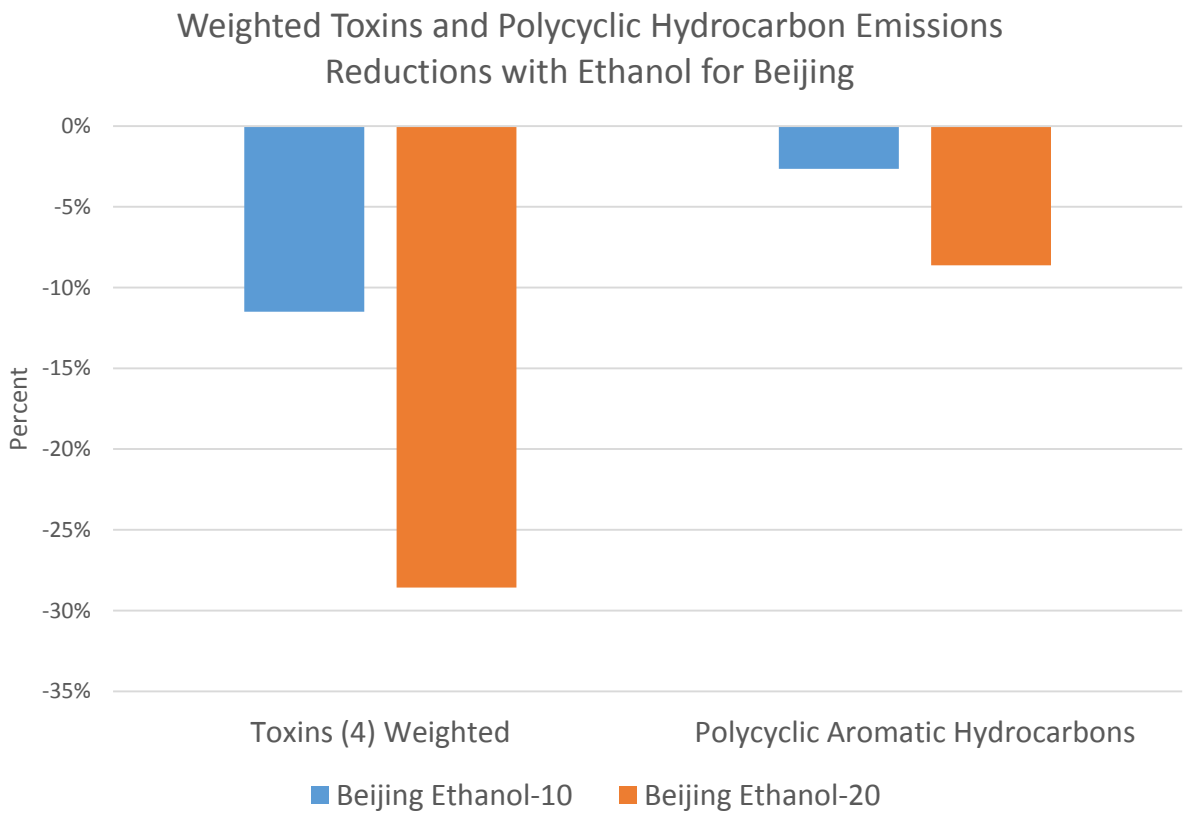
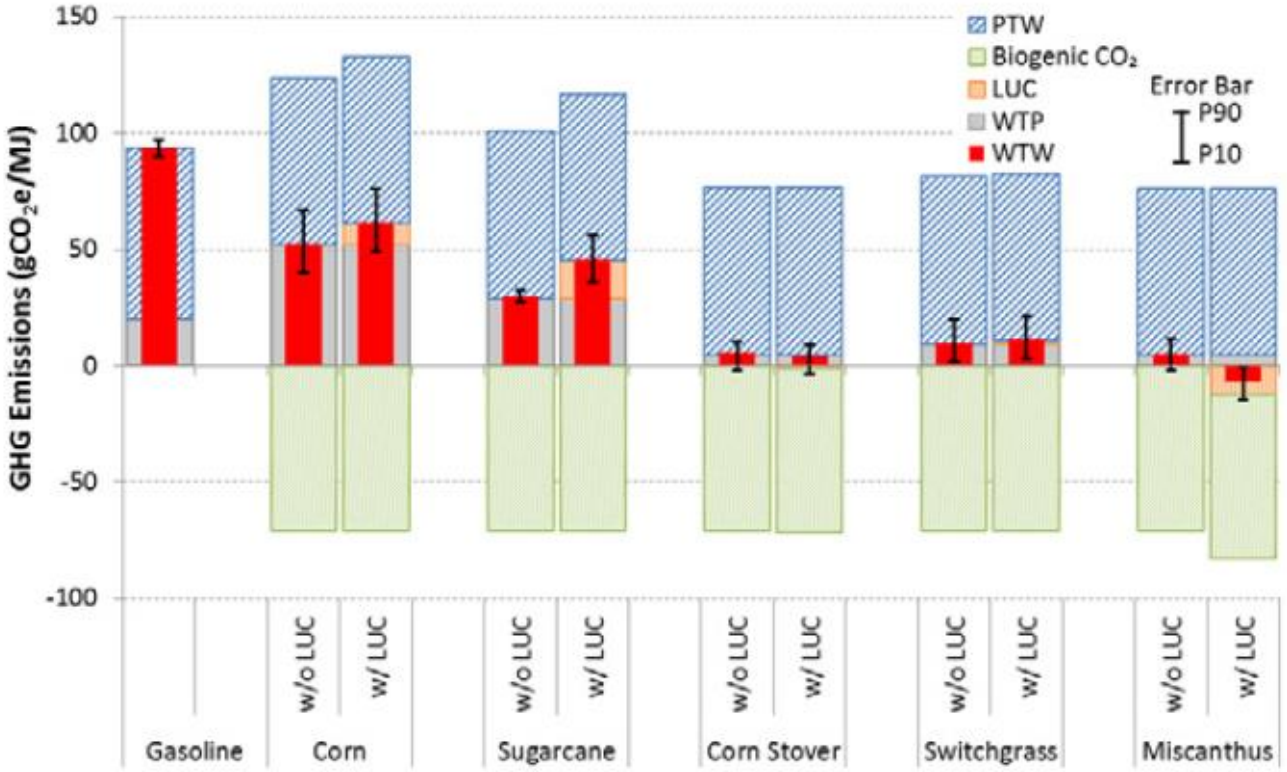
Beijing/Tianjin Air Toxins Reductions with Ethanol



Greenhouse Gas Life Cycle Emissions: MTBE vs Corn Ethanol

GREET 2012: GHG Life Cycle Emissions

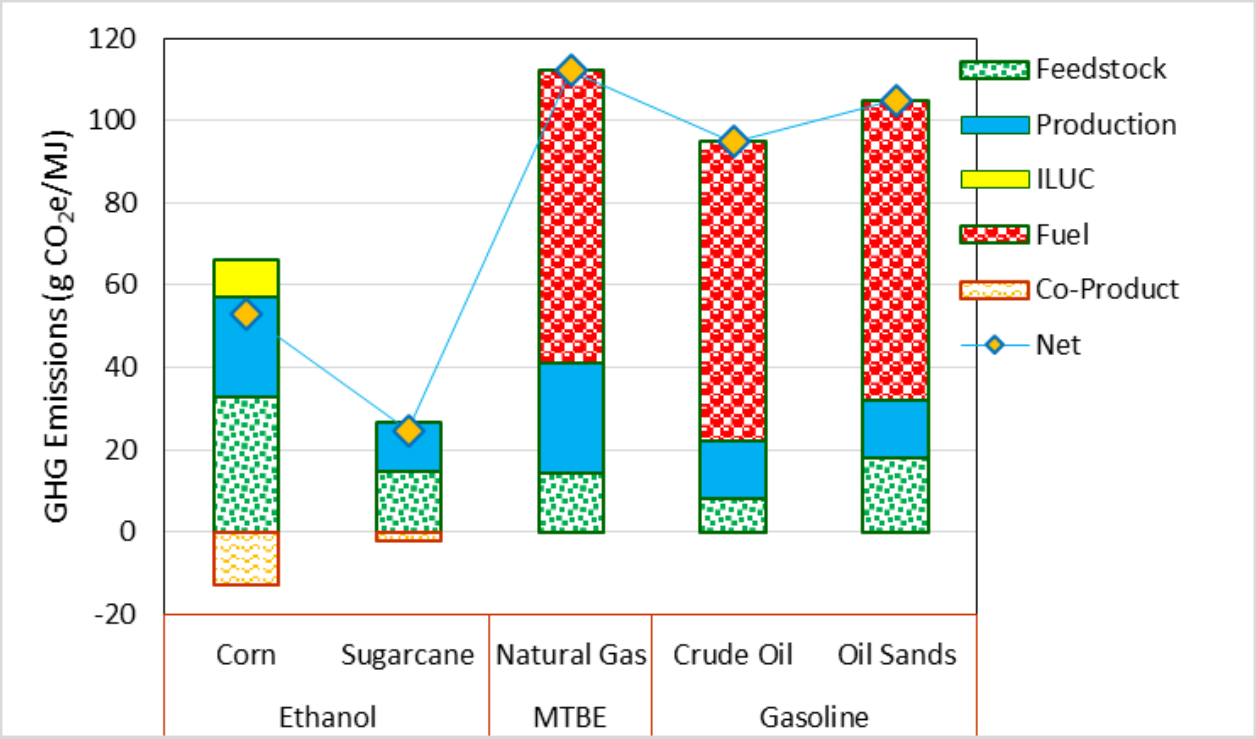
- Argonne GREET Model 2012



Source: Wang 2012

GHG Emissions

- Ethanol provides large GHG reductions over gasoline
- Reductions are even more significant when we compare oxygenate components only since MTBE has very high GHG emissions profile (worse than oil sands)



Summary

- E10 is standard in the US fuel supply. Dramatic emissions reductions for pollutants/toxins under the Clean Air Act
- Ethanol reduces toxicity and cancer risk by diluting **and substituting** for 1,3 Butadiene and Benzene.
- Even high annual sales will only slowly change electric vehicle stock: Ethanol for the current vehicle stock and electrification of future vehicle sales provide a combined solution to the pollution problem
- Upcoming study for Beijing documents the immediate emissions reductions with ethanol blended gasolines
- Ethanol provides significant greenhouse gas reductions relative to gasoline and even higher reductions relative to the currently used oxygenate MTBE

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