DOE DEER Conference
Panel Discussion on “Future of Internal Combustion Engines”
October 4, 2011

Drop In Fuels:
Where the Road Leads

Ken Wright
Chief Fuels Engineer
Fuels & Regulatory Affairs
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Outline

• Timeline of Fuels Transition
• Key Industry Drivers
• Renewable Fuels Mandate
• Drop-In Fuel Pathways
• Summary
To know where you are going, you have to understand where you are and where you’ve been!
Timeline of Fuels Transition - Historical Events

• 1970s – Gasoline Lead Removal

• 1980s – Volatility Controls

• 1990s – Reformulated Gasoline & Diesel Sulfur Reduction

• 2000s – Gasoline & Diesel Desulfurization and Renewable Fuels

• 2010+ - Benzene Reductions
  GHG and LCFS
Evolution of Fuel Quality Mandates

1970: Lead Removal

1975: Reduced RVP

1980: Low Sulfur Diesel

1985: CARB Diesel

1990: Ultra-Low Sulfur Diesel

1995: CaRFG 2

2000: RFG Phase I

2005: RFG Phase II

2010: CaRFG 3

2015: Biofuels Mandate

Tier 3 Fuels?

GHG Emissions

Benzene Reduction
KEY Industry Drivers

- Renewable Fuel Mandates
- Low Carbon Fuels Standard (LCFS) – California
- CAFÉ Standards: Current and Proposed
- U.S. Light-Duty Vehicle Sales – Rebound?
- Incremental Costs of Increased Fuel Efficiency
Renewable Fuels Mandates

2005/2007 – Renewable Fuels (RF) Standards

- EPAct05 – 7.5 Billion Gallons RF

- EISA07 - 36 Billion Gallons RF by 2022
  - 4 Categories of RF
    - Bio-massed Based Diesel
    - Non-Advanced
    - Other Advanced
    - Advanced Cellulosic

- Energy Differences
  - Neat Gasoline:
    - @ ~125,000* BTU/gallon
  - Ethanol
    - @ ~84,500* BTU/gallon
      (1/3 less than gasoline)

* Source: EIA AEO2011
EISA07 Renewable Fuel Standard (2007-2022)

Biomass-based Diesel: Biodiesel-ester
Standalone Renewable Diesel
Non-advanced Renewable Fuel: Conventional Corn-starch Ethanol
Co-processed Renewable Diesel
Advanced Cellulosic Biofuel
Non-cellulosic Advanced: Sugar Ethanol

Annual RF Volumes Are Mandated by Congress!
Estimated Volumetric Ethanol % of Gasoline Pool

Represented gasoline market saturation point with new RFS, i.e. E-10 with no E-85

Area of gasoline approved for today’s non-FFV rolling fleet.

Area of E10+ gasoline approved for any FFV.

Source: Base Gasoline demand from EIA AEO 2011 and DOE VISION model
Projected Impact on Hydrocarbon Fuels

Base Case: Finished Gasoline & E85 and AEO Proposed RFS2 Levels

Hydrocarbon in Base Case

3% CAFÉ Improvement:
Hydrocarbon

2017+ CAFÉ Proposed Rule

6% CAFÉ Improvement:
Hydrocarbon

Source: EIA AEO2011 & DOE VISION Model
What is a Drop-In Fuel?

• Fully compatible with current vehicles
• Fully compatible with current infrastructure
• Energy content same as traditional fuels
• Same molecules as in traditional fuels
Drop-in Fuel Pathways

Starches and Sugars
- Ethanol (EtOH)
- Higher Alcohols
- Sugar to Hydrocarbon

Biomass
- Cellulosic Ethanol (EtOH)
- Digestion
- Pyrolysis
- Hydrothermal

Fats & Oils
- Renewable Diesel
- Cracking
- FAME
Petroleum, Renewable & Biodiesel

\[ \text{Petroleum Diesel} \]

\[ \text{Renewable Diesel} \]

\[ \text{Biodiesel or Fatty Acid Methyl Ester (FAME)} \]
While the challenges of Corporate Average Fuel Economy and the Renewable Fuels Standard are imminent, hydrocarbon in motor vehicle fuels continue to have a viable future for decades to come!
The Road Ahead Will Be Challenging

ThankYou!

The Vehicle/Fuel Relationship Remains Strong!