New Feedstocks and Replacement Fuel Diesel Engine Challenges

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Diesel Fuel Also Demands Innovation

Fossil Fuel Pathways

Petroleum

Ultra Low Sulfur Diesel

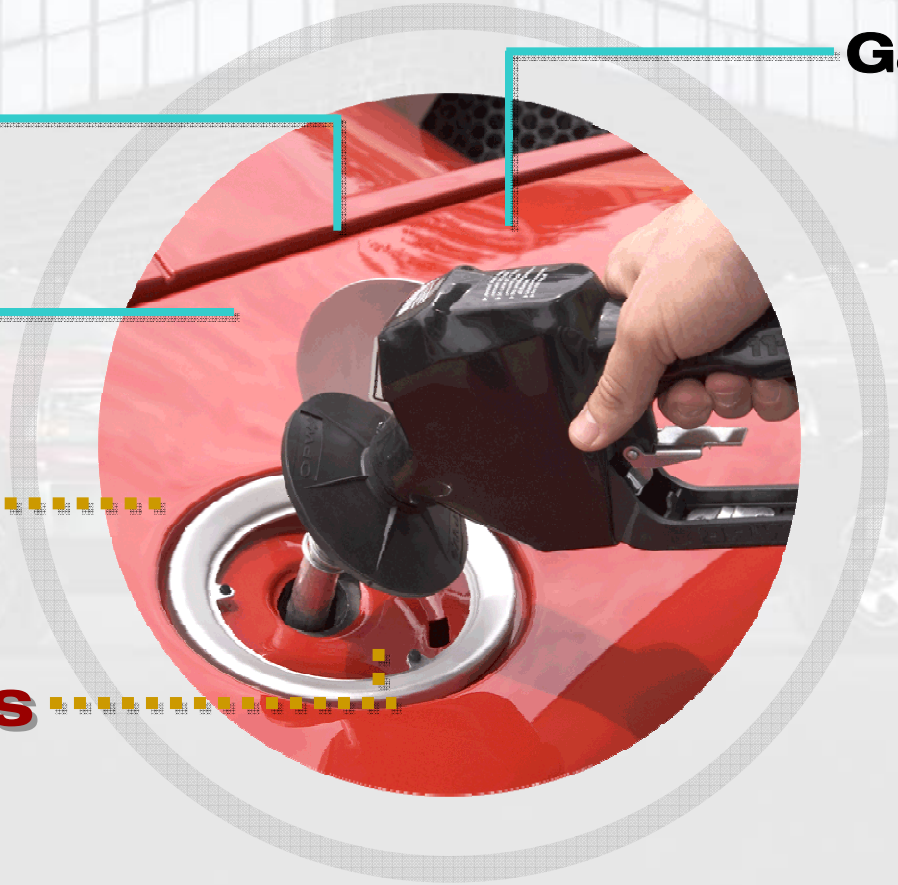
Tar Sands

Oil Shale

Coal Liquids

Synthesis

Gas to Liquid



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Current N.A. Diesel Engine Challenges

- **High Level of Performance**
  - Good Acceleration and Torque characteristics
  - Cold Start (No Smoke)
- **High Fuel Economy**
  - 30% or greater than our petrol counterparts
- **Engine Durability**
- **Quiet and Smooth Operation**
- **Meet Lower emissions standards**
  - 2007MY will require DOCs, DPFs, and Cooled EGR
  - 2010MY will require 2007MY enablers and some form of NOx aftertreatment
- **Engine Costs**

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Review of 2005 N. A. fuel properties

(2005 Alliance Survey Results)

- **Cetane Number**
  - US ranging from 38 – 58 cetane
  - Europe ranging from 50 – 60
- **Aromatics**
  - US ranging from 13 – 50% (ASTM D1319)
- **Water Content**
  - US fuels ranging from 40 – 180 ppm
- **Lubricity**
  - US fuels ranging from 200 – 600 μm wear scar with an average of ~ 490 μm

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Cetane and Aromatic Challenges

The overall wider and lower range of cetane numbers and higher Aromatic content in the US market creates a number of challenges from an engine development perspective

- **Cold Start and White Smoke**
  - Requires higher compression ratios
  - More cold starting aids
- **NOx Emissions**
  - More Cooled EGR
  - More complex turbocharger systems
- **Engine Deposits**
  - Injector Nozzles & Combustion Chamber
  - EGR / Intake / Exhaust Systems
- **Limited Synergies with European Diesel Technology**

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Water Content, Lubricity and Other Challenges

The water content of diesel fuel, the lubricity changes, and other fuel properties like sulfur content in off-road fuels creates significant challenges for engine developers

- **Fuel System Durability concerns**
  - Corrosion due to water content
  - Fuel system wear and durability challenges from reduced lubricity and increased operating pressures
- **Sulfur Content**
  - ULSD is required to support aftertreatment equipment and there is need to proceed with an off-road ULSD requirement.

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Future N. A. Diesel Fuel Trends

- Shipping of diesel fuel from N. A. to Europe
- Tar Sand Liquids are becoming apart of the current diesel fuel pool
- Oil Shale Liquids may enter in future diesel fuels
- The development of these new source into the diesel fuel stock must not increase the CO2 burden
- Entry of these alternative sources also must not compromise current fuel quality levels for Cetane, Aromatics, Water Content and Lubricity
- Changes to fuel sources or feedstock base may radically change ash content, this may require an ash specification compatible with new diesel aftertreatment systems

Fossil Fuel Summary

Current fossil fuel properties present increased technological challenges for meeting customer performance expectations and still have an engine that meets emissions requirements.

These challenges are being overcome but at an already high price of complexity and cost to the customer

- Increased compression ratios
- Addition of cold starting aids
- Increased EGR system size and complexity
- Increased Boosting system complexity and costs
- Increased fuel system complexities and costs
- Duplicated development efforts (Europe vs. N.A.)
- Inability to migrate already refined diesel engines from Europe to North America

Fossil Fuel Recommendations

Verify and regulate any new fossil fuel feedstocks and sources so that their entry into the North American diesel fuel pool does not reduce or compromise current fuel quality levels

Select key diesel fuel properties to better align with our European market fuel properties. The primary example would be better alignment of cetane levels between US and European markets. This would facilitate the migration of already developed diesel engines and technology to the North American markets.

This alignment would also allow the trend of shipping diesel fuel from North America to Europe to not dilute the current fuel quality in the North American market

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Biofuel Pathways

Bio Diesel

DOE Bio Refinery

Biomass to Liquids

Biodiesel Status - Ford

- North American Biodiesels are primarily soybean methyl ester based
- European Biodiesels are primarily rape seed methyl ester based
- There are many public and private initiatives for biodiesel use greater than 5%, but manufacturer acceptance is limited and then only under controlled fuel conditions.
  - B20 is included as an alternative fuel for EPA fleet use
  - Biodiesel that meets ASTM D975 for aromatic and sulfur content, CARB considers that fuel a “diesel” fuel

Biodiesel Status – Ford continued

- Ford and most other manufacturers accept the use of biodiesel fuels up to 5% (B5) blends
  - Ford does not recommend the use of biodiesel fuel blends > 5% in current products
  - Ford is currently studying the possible use of blends > B5 in the future products
- The key issue with operation of biodiesel fuels in current engines is fuel quality and consistency

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Biodiesel vs. Fossil Fuels

Biodiesel fuels have both superior and inferior fuel qualities and properties compared to US Fossil Fuels

- **Cetane Number (Biodiesel > US Fossil Fuel)**
- **Aromatic % (Biodiesel < US Fossil Fuel)**
- **Water Content (Biodiesel > US Fossil Fuel)**
- **Lubricity (Biodiesel > US Fossil Fuel)**
- **Cold Properties (Biodiesel > US Fossil Fuel)**
- **Oxidation Stability (Biodiesel < US Fossil Fuel)**
- **Biological Growth (Biodiesel > US Fossil Fuel)**

Biodiesel challenges increase the technical challenge already encountered with fossil fuel development

Biodiesel Summary

Ford Motor Company recognizes the potential benefits associated with the use of biodiesel fuel blends. Ford and biodiesel producers must evaluate biodiesel fuels to verify these fuel blends do not decrease performance, durability, or the ability of modern diesel engines to meet emissions requirements.

Ford and other OEMs may be able to design robust biodiesel compatible fuel systems, but depending upon fuel quality and specifications, this can drive significant costs into the system.

Biodiesel Recommendations

Biodiesel fuel producers and regulating agencies can expand biodiesel fuel usage and help the development of engines compatible to operating higher biodiesel fuel blends by improving the consistency and quality of current and future biodiesel fuels.

- Biodiesel Fuel Specification development
  - Oxidation Stability Limits
  - Water Content Limits
  - Cold Property Limits
  - Biological Growth Monitoring Requirements
- Biodiesel Production Infrastructure Regulation
  - Improve regulation of the biodiesel industry to verify that the producers and distributors are selling fuel that meets a proper specification

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Parting thought

The real discussion for this panel is the balance between fuel specification and quality requirements vs. engine and fuel system design requirements. Essentially what is the trade-off that allows a robust engine and fuel system design to current and future market fuels with manageable fuel and engine costs for producers and consumers alike.