Overview of DOE Fuel and Lubricant Technologies Subprogram

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API Detroit Advisory Panel

April 16, 2014
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Agenda

• Background
• Fuels
• Lubricants
• Summary
Greater focus needed on RDD&D for a range of technologies to displace the entire barrel of petroleum crude

- U.S. spends nearly $1B each day on oil imports*
- Only about 40% of a barrel of crude oil is used to produce petroleum gasoline
- Reducing dependence on oil requires replacing diesel, jet, heavy distillates, and a range of other chemicals and products

*American Petroleum Institute.
James V. Forrestal Building
1000 Independence Ave, SW
Washington, DC 20585
National Laboratory Emphasis

- National Labs also funded under Annual Operating Plan (AOP) funds.
- AOP funding is direct from DOE, doesn’t require a competitive solicitation.

Emphasis below is from Fuels and Lubes only, Advanced Combustion Engine Program not included.

- ANL: Tribology and lubricants, analysis, combustion
- LLNL: Chemical kinetics for combustion
- NREL: Heavy emphasis on biofuels, combustion, emissions
- ORNL: Combustion, emissions, tribology and lubricants
- PNNL: Unconventional fuels, catalysis expertise, lubricants
- SNL: Basic combustion research

Emphasis and funding is always changing so this is just a rough view.
Vehicle Technologies Office
Advanced Technologies for High Efficiency Clean Vehicles

Vehicles FY14 Budget: $289M
• VTO doesn’t work on production, BETO does
• VTO works on more than biofuels (e.g., natural gas), BETO doesn’t
• Joint activities with infrastructure activities in the past (esp. E15), more in the future?
Vehicle Technologies Office

\[\text{Decrease petroleum dependency} \quad \text{Reduce greenhouse gases}\]

Vehicle Technologies is primarily an R&D Program focused on removing market barriers through the development of transportation technology.

Lubricants added as a budget line item in FY2011
Mission
Enable advanced combustion through improved understanding of fuel-property impacts, evaluate next-generation biofuels & develop efficiency-improving lubricants

Activities
- Chemical and physical fuel property exploitation
- Next-generation biofuel fit-for-service evaluation
- Lubricant additives and base oil development
- Open, bench-scale lubricant testing methodology
- Fully-formulated oil fit-for-service evaluation
- Supporting analytical work

Goals
- By 2020, demonstrate expanded operational range of advanced combustion regimes to 75% of LD Federal Test Procedure
- By 2015, demonstrate cost effective lubricant with 2% fuel economy improvement

Funding in millions

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Budget & Accomplishment History 2003-2013

Years: 1998-2003
Diesel fuel sulfur effects on exhaust emission control testing program – resulted in diesel sulfur reduction to 15PPM – enables diesel engines to meet current emissions regulation

Years: 2008-2010
Critical research led to improved biodiesel ASTM standards – enables B20 approved engines

Years: 2011-2013
Developed CNG medium-duty engines. Began work on lubricants in 2011

2003
$19,164

2004
$15,887

2005
$12,419

2006
$13,356

2007
$18,413

2008
$17,376

2009
$19,560

2010
$23,421

2011
$11,000

2012
$18,500

2013
$17,500

Fuels Budget at a Glance

Years: 2007-2011
Developed and implemented DOE Intermediate Ethanol Blends Test Program – E15 approved for use in 2001 and newer vehicles – enables additional 7 bgy of ethanol use (additional 3% of light-duty petroleum use)
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Past Successes in Fuel Research had Monumental Impact on Efficiency and Emissions

• Removal of lead
  – Enabled catalytic emissions control technologies (1970s)
  – Further research for lead-free anti-knock replacements

• Re-formulated gasoline
  – Oxygenates further reduced CO and HC emissions (1990s)

• Reduced sulfur in diesel and gasoline
  – Enable aftertreatment systems for high-efficiency engines

• Codes and standards
  – Established the paths, requirements, and limitations to use of alternative fuels like biodiesel and ethanol in the legacy fleet
DOE Mid-Level ethanol blends studies cited by EPA in recent partial waiver for E15 (ORNL and NREL)

- Intermediate ethanol blends studied since 2007
  - $46M effort
  - SNREs, Vehicles, Infrastructure materials compatibility, etc

- Vehicle emissions testing and aging at three sites
  - 86 vehicles, >6.5 million miles
  - >300,000 gallons of fuel
  - Approximately 1000 emissions tests

- E15 now legal for 2001 and newer vehicles

The latest fuel to market – E15 (15% ethanol, 85% gasoline)
New Emphasis: Drop-In Biofuels

• “Drop-ins” are biofuels that look and act like the conventional fuel they displace
  – Require no changes to existing fuel infrastructure or engines
  – Longer time horizon for commercialization

• Several potential pathways being researched
  – Biological (microorganisms: algae, fungi, bacteria)
  – Thermochemical (heat and catalysis)
  – Combined (e.g., ethanol to HC conversion)
  – May produce “finished fuel” ready for engine, “blending streams” that can be readily blended with conventional fuels, or “biocrude” ready for upgrading in refinery

• EERE role in R&D
High-Octane Fuel Projects

- Fundamental studies at DOE labs to investigate combustion impacts of high-octane biofuel blends
- BETO projects at ORNL, NREL, and ANL to investigate GHG and infrastructure aspects of a “renewable super premium” fuel
- Low-octane fuels (gasoline-range naphtha) also of interest but not currently a research area
Gaseous Fuels

• **CNG**
  – Proven fuel for centrally-refueled fleets (transit buses, etc.)
  – Infrastructure problems for light-duty, “pipe-in, bi-fuel” possibility
  – Low energy density more challenging for heavy-duty, long-haul

• **LNG**
  – Suitable for some long-haul fleets that travel regular routes (UPS, etc)
  – High energy density is advantageous
  – Refueling is problematic for public applications

• **EERE and ARPA-e role in natural gas R&D**

• **Propane, DME, other**
  – Interesting but no major EERE activities at this time
Industry active in DME research

- Liquid at low pressures (similar to propane) making storage more manageable than CNG
- **Volvo has a prototype heavy-duty truck designed to run on DME**
  - Recently evaluated by DOE to collect benchmarking data
  - Data included fuel consumption (via carbon balance), gaseous emission, and particulate emissions
Alcohols

- **Methanol**
  - Lots of interest due to low natural gas prices
  - Infrastructure problems with legacy equipment in the U.S.

- **Butanol**
  - Too early to tell possibilities
  - Looks promising on initial tests
  - Currently no fuel-scale supplier

- **Biobutanol**
  - More attractive than current production methods
  - Greater GHG and petroleum reduction
  - Technical issues for production are similar to other biofuels
  - Market issues with production cost
  - Potential savings at refinery – can use light compounds typically removed for E10 BOB

- **EERE role in R&D**
Gas to Liquids (GTLs)

- Promoted as the panacea by some advocates
- Produces a great fuel but not cost-effectively
- Prohibitively high capital expense
  - Barely works even with free gas (as in Qatar)
  - Current projects have multi-billion dollar cost overruns and long delays
    - Oryx: spec was $4B; currently $16B+
  - We are unaware of any breakthrough technology on the horizon
  - If there is a breakthrough, it will not be brought to market by government
- No major EERE role at this time
  - Office of Fossil Energy continues to work on production synthetic fuels from coal and natural gas, but has very little funding
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**Lubricants**

**Base Oil:** Carrier for additives, cooling
- High VI for efficiency
- Low viscosity with improved additives

**Additives:** Why engine oil works
- Current additives “poison” aftertreatment systems
- Push for low SAPS oil (low sulphated ash, phosphorus, sulfur)
- Anti-Wear
- VI and Friction Modifiers
- Extreme-pressure
- Anti-oxidants
- Anti-foam
- Pour-point depressants
- Dispersants
- Detergents
Studies of lubricant formulations to enhance engine efficiency:
- Ionic Liquids (ORNL)
- Hyperbranched Polymers (PNNL)
- Polyalkylene Glycol (Ford)
- Boric Acid (ANL)
- Novel formulations (MIT, Ashland, Northwestern)

Demonstrating impacts of lubricants at the vehicle level in terms of MPG

Also investigating fuel and lubricant effects on pre-ignition phenomena and particulate matter
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Summary

Fuels
• Exhaust emissions will remain the key factor in fuel requirements
• Fuel chemistry may enable more efficient combustion modes
• Future R&D work will have less emphasis on alcohol fuels
• Future R&D work will involve octane/cetane studies
• Future R&D work with natural gas to improve efficiency

Lubricants
• Lubricants have huge potential due to retrofit capacity
• R&D on vehicle powertrain lubricants is a relatively new activity
• Future emphasis areas for lubricants is a bit unsure
DOE

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