VEHICLE TECHNOLOGIES OFFICE

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Overview of the DOE Fuel and Lubricant Technologies R&D

June 16, 2014

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Outline

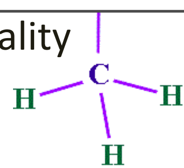
Outline of the talk

- Goals, strategy, budget request
- Fuels – what we do, why, examples/successes
- Lubes – what we do, why, examples/successes
- Directions for FY15
- Summary

Fuel and Lubricant Technologies

Accomplishments

- Demonstrated 2% fuel economy improvement with advanced addit (2015
- Dem range porti highw feder
- Full-s sales supp solicitation – “launch quality best to date” (CWI)



Funding in millions	**FY 2013** Enacted	**FY 2014** Enacted	**FY 2015** Request
Fuel and Lubricant Technologies	$17.0	$16.0	$27.4

Status

- On-track to meet goals for both fuels and lubricants

Future Directions

- Maintain lubricant research activities
  - Develop retrofittable, low-friction lubes for sting
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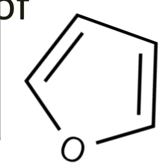


- Expand work in natural gas

FY 2020 Goals

Demonstrate cost effective lubricant with 4% fuel economy improvement relative to Mobil 1

Demonstrate expanded operational range of advanced combustion regimes to >95% of LD Federal Test Procedures

What is *end use* fuels R&D?

- Enabler of advanced combustion
  - Kinetically-controlled combustion regimes
  - Knock-resistant fuels for future SI engines
  - Improved fuel characterization for modern & future engines (i.e., beyond octane & cetane)
- Evaluation of suitability of new candidate fuels and fuel components for use as practical fuels
  - Alternative fuels, biofuels, other novel blendstocks
  - Adequacy or inadequacy of existing fuel production, distribution and refueling infrastructure w/r/t new fuels – e.g., technical incompatibilities & market barriers
  - Attempt to characterize (and avoid) negative, potentially-unforeseen, consequences
- Development (vs. Research) can include
  - Financial assistance for alternative fuel vehicle engines and platform integration – e.g., increasing availability of medium-duty natural gas engines
  - Specific technical problems seen as barriers – e.g., methodology or tool development, etc.

Why conduct *end use* fuels R&D?

- Identify and overcome <u>pre-competitive</u> barriers to use of new technologies
  - Assure alternative fuels have properties we want prior to major policy commitment
    - Just because you <u>can</u> make *something*, doesn't mean you should
  - Interface between development and deployment
  - Bridge the Valley of Death

- What It takes
  - Concerted, coordinated effort of government, autos, and energy companies
  - Though difficult… **there is ample precedent for this!**
  - A current (and rare) confluence of interests related to fuel effects – beginning with octane

Fuel Can Change: Historical Precedent

Effective dates

- 1974 Unleaded Gasoline
- 1979 E10 Ethanol Subsim Waiver
- 1989 Phase 1 Gasoline Summer RVP Limits
- 1991 Phase 2 Gasoline Summer RVP Limits (including 1-psi E10 waiver)
- 1992 Winter Oxyfuels Program (39 cities)
- 1993 Highway diesel fuel sulfur control (500 ppm)
- 1995 Phase 1 RFG and Anti-dumping
- 1996 Full prohibition on lead
- 2000 Phase 2 RFG
- 2002 Mobil Source Air Toxics (MSAT1)
- 2004 Tier 2 Gasoline Sulfur Control (30 ppm avg, 80 cap)
- 2006 Renewable Fuels Standard
- 2006 Removal of RFG Oxy Mandate
- 2006 Ultra Low Sulfur Highway Diesel Fuel (15 ppm)
- 2006 Boutique Fuels List
- 2007 Renewable Fuel Standard (RFS)
- 2010 Ultra Low Sulfur Nonroad Diesel Fuel (15 ppm)
- 2010 Renewable Fuel Standard 2 (RFS2)
- 2011 MSAT2 – Gasoline Benzene
- 2012 E15 Subsim Waiver
- 2017 Tier 3 Gasoline Sulfur Control (10 ppm avg)

Why conduct *end use* fuels R&D?

Regulation has driven past fuel changes

And it still will…

- e.g., CAFE increase – Possible entrée to <u>co-development of fuels & engines</u>?

But…

- Are there additional, non-regulatory drivers?

- *Is it possible to pursue GHG reduction as aggressively as criteria pollutant reductions have been (and are) pursued?*

What is engine/fuel co-development?

- What it traditionally meant…
  - "I have a nifty compound that I want to use as (or in) fuel!"
- What it increasingly means – and <u>should</u> mean…
  - "Let's explore and exploit potential synergies available from existing (or potential) technologies in engines and fuels!"
- Enables: pushing boundaries of what we can do – within constraints of infrastructure, sunken investment and market conditions
  - What do fuel properties enable? – e.g., expansion of speed-load map of RCCI, downsizing and higher power output
  - What are the constraints? What can & can't we do <u>with what we already have (or can have)</u>?

Current regulatory context justifies engine/fuel co-development

Current regulation is driving the necessary technology development for the joint optimization of (bio)fuels and engines

Fuel Economy Standards

2025 CAFE Standards

(U.S. EPA and U.S. NTSA standards)

Emissions Regulations

70% NOx, 85% NMOG

< 10 ppm sulfur in gasoline

(U.S. EPA Tier 3 regulations)

Renewable Fuels Standard

36 billion gallons by 2022

(EISA 2007)

Recent technology advances in sensors, onboard computers, and engine technologies are enabling new pathways

Current interest is high!

- Past year has seen some important industry-government dialogue on non-petroleum fuels – especially NG and biofuels
- It is clear that not all areas would fall under Fuels & Lubes at DOE
- Several topic areas of mutual interest have emerged:

Natural Gas:

- Pathways Modeling
- Codes and Standards
- On-board Storage
- Compressors
- Effects on Catalysts

Biofuels:

- Fuel Properties for Future Engines (!)
- Lifecycle Analysis
- Modeling tools for future/emerging combinations of engines and fuels

An <u>Example</u> of Engine-Fuel Co-development: High-Octane Fuel

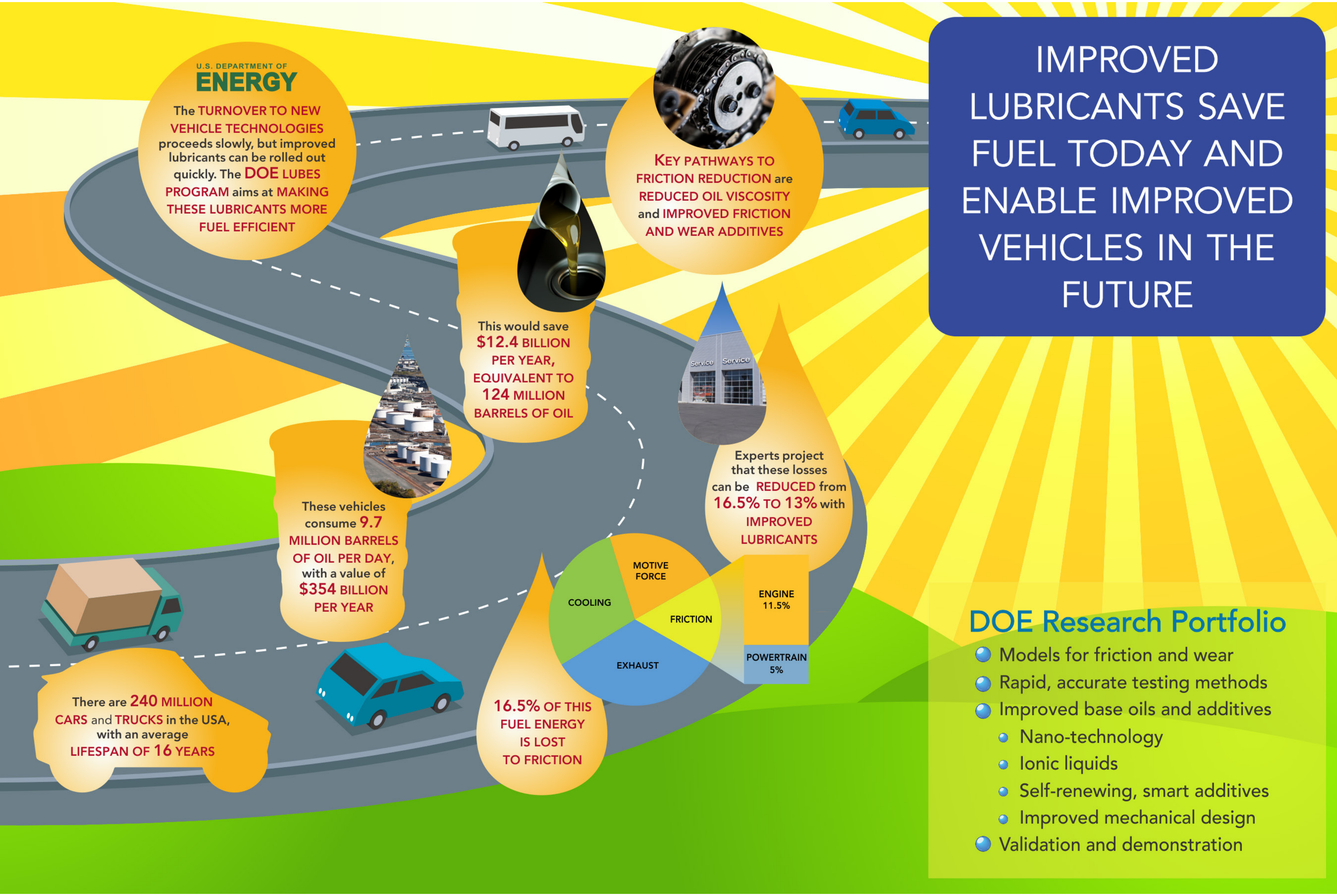
- Nearest-term opportunity for engine-fuel co-development
- Could provide route to CAFE standard attainment
- Builds on several years of work sponsored by both VTO and BETO at ORNL, NREL and ANL , and testing and analysis by industry
- Moving towards a more cohesive program in FY 2015
- Benefits of notional high octane fuel for future SI engines
  - Enables higher compression ratio directly
  - <u>Can</u> include additional benefits – e.g., charge cooling
  - May be a cost-effective route to improved fuel economy
  - Potential market for renewables
  - Potential carbon reductions

Example: High-Octane Fuel

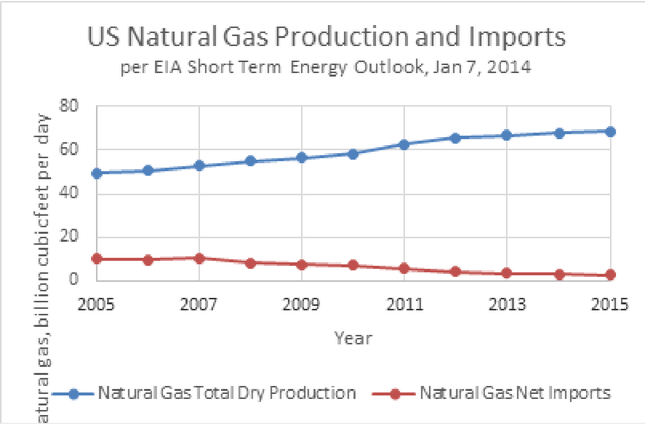
- Issues/barriers for high-octane fuels
  - <u>Some</u> octane sources are incompatible with current vehicles – e.g., ethanol greater than 10% or 15% in gasoline
  - Even for compatible octane, current vehicles largely waste the octane during normal operation – possible cost issue?
  - Currently, high-octane components are compensated with <u>sub-octane base fuel blendstock</u> – would this happen with higher ethanol levels (for example)?
  - <u>No uniform octane requirements</u> for gasoline across the U.S.
    - Regulation of AKI is at state level
    - Potential to call it a CAFE/GHG strategy, but controversial and would likely lead to big fight;
    - Tight timeline as mechanism for meeting current CAFE standards
  - Current *de facto* measure of octane (AKI or (R+M)/2) is lacking as a measure of what we are looking for in a fuel
    - <u>Research Octane Number more representative</u> of modern engines than is Motor Octane Number, <u>but fuel is regulated and sold according to AKI</u>
  - Uncertain impacts on: refineries, infrastructure, life-cycle GHGs, misfueling, etc.

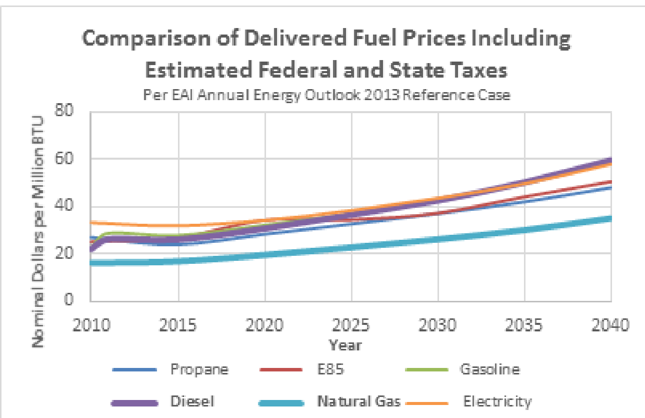
Lubrication Strategies/Activities

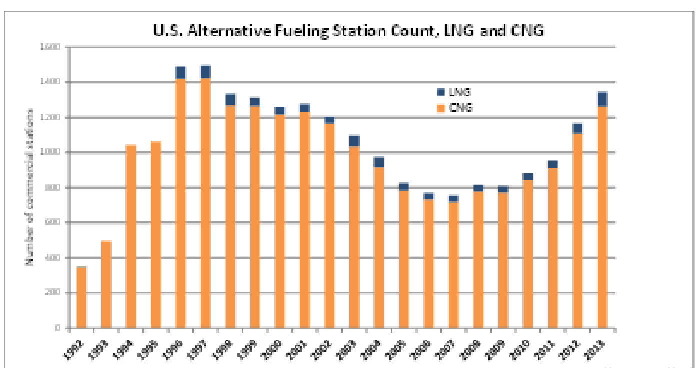
1. **Predictive modeling -** Integration of (continuum) component parasitic friction loss models into subsystems and vehicle level packages – 'what if' parametric studies
2. **Develop Science/Mechanistic Based Models** of Parasitic Losses and Durability/Reliability and friction and wear
3. **Lubricant Technology Development** – Develop advanced lubricants (base fluids and additives) that reduce frictional losses while maintaining or exceeding other performance metrics (durability, reliability, corrosion, deposits, etc.)
4. **Engineered Surface Technology** Development – Develop advanced engineered surfaces (textures, designs, materials and coatings) that mitigate parasitic losses from a systems approach. Go beyond current ferrous based tribological systems.
5. **Validation of Modeling and Technologies** – Develop protocols to improve the fidelity of models and technologies. Improve correlation between lab-scale tests and engine/vehicle tests. Develop high fidelity databases for models and simulation of parasitic losses. Lab-Rig-Engine-Vehicle Validation Studies


IMPROVED LUBRICANTS SAVE FUEL TODAY AND ENABLE IMPROVED VEHICLES IN THE FUTURE
U.S. DEPARTMENT OF ENERGY
The TURNOVER TO NEW VEHICLE TECHNOLOGIES proceeds slowly, but improved lubricants can be rolled out quickly. The DOE LUBES PROGRAM aims at MAKING THESE LUBRICANTS MORE FUEL EFFICIENT
KEY PATHWAYS TO FRICTION REDUCTION are REDUCED OIL VISCOSITY and IMPROVED FRICTION AND WEAR ADDITIVES
This would save $12.4 BILLION PER YEAR, EQUIVALENT TO 124 MILLION BARRELS OF OIL
Service
Service
Experts project that these losses can be REDUCED from 16.5% TO 13% with IMPROVED LUBRICANTS
These vehicles consume 9.7 MILLION BARRELS OF OIL PER DAY, with a value of $354 BILLION PER YEAR
MOTIVE FORCE
COOLING
FRICTION
EXHAUST
ENGINE 11.5%
POWERTRAIN 5%
16.5% OF THIS FUEL ENERGY IS LOST TO FRICTION
There are 240 MILLION CARS and TRUCKS in the USA, with an average LIFESPAN OF 16 YEARS
DOE Research Portfolio
Models for friction and wear
Rapid, accurate testing methods
Improved base oils and additives
Nano-technology
Ionic liquids
Self-renewing, smart additives
Improved mechanical design
Validation and demonstration

The opportunity for natural gas







- U.S. is approaching zero net imports of natural gas
- Natural gas expected to remain the low-cost fuel on an energy basis through 2040
- Use of natural gas is growing in transportation – driven by bus and municipal fleets
- Many groups have identified similar barriers to further expansion of use:
  - Lack of refueling infrastructure
  - Lack of choice in engines and trucks that use natural gas
  - Limited driving range of trucks between refueling
  - Heavy, bulky, expensive on-board fuel storage
  - Potential hazards and lack of familiarity with gaseous fuel
  - Many competing markets for natural gas: Can’t use same BTU twice!
- Many barriers have pre-competitive aspects

Directions for FY 2015

- High performance, low carbon fuels for high efficiency engines
  - Emphasis on high-octane fuel study – low-hanging fruit
    - Renewable Super Premium (co- w/ BETO)
    - Refinery-based fuels and blendstocks
  - Co-optimization of fuel properties and combustion
  - Natural Gas
    - Heavy duty trucks, marine, rail
    - Removal of barriers to expanded use

- Next-Generation Lubricants
  - Evaluation methods development, correlation to end use
  - New base oils and VI behavior
  - Friction and wear reducing additives
    - Liquid, solid, nano

Summary

- Now is the time for <u>beginning</u> serious co-development of engines & fuels
  - Regulatory climate
  - The will to act
  - Octane may be a good starting point, advanced combustion a close second

- Natural gas likely to be the low cost fuel choice at least through 2040
  - How best to use it?

- Lubricants provide a potential drop-in retrofit for existing vehicles in many cases (depends on vehicle class and part lubricated – e.g., engine oil, but perhaps not light-duty automatic transmission fluid)
  - Many Vehicles **x** Small per Vehicle Savings **=** Large Benefit
  - May be low-hanging fruit
  - May be necessary for meeting future CAFE
  - Opportunities for co-evolution of lubricant and engines/vehicles

Summary, cont'd.

Fuels

- Exhaust emissions will remain the key factor in fuel requirements
- Fuel chemistry can enable more efficient combustion modes
- Octane will play a role
- Ethanol and natural gas aren't used optimally with today's engines

Lubricants

- Lubricants have huge potential due to retrofit capacity
- High-VI base oil will help on cold starts
- Improved additives required for lower viscosity base oils
- Co-development of the engine and lubricant will yield the greatest benefit

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