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

Overview of the DOE Fuel and Lubricant Technologies R&D

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Mike Weismiller

Fuels R&D

Expanding the use of alternative fuels and fuel-controlled combustion

Fuel and Lubricant Technologies

Goals

By 2020, demonstrate expanded operational range of advanced combustion regimes covering >95% of LD Federal Test Procedure

By 2020, demonstrate at least a 4% real-world fuel economy improvement with novel formulations for powertrain and driveline lubricants

- Compatible with new and legacy vehicles

Baseline: 2015 powertrain with regular E10 gasoline

Accomplishments

Demonstrated with engine data that high RON biofuel plus high CR results in up to a 13% improvement in MPG

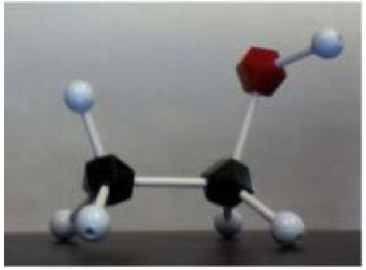
Demonstrated fuel effects can enable 36% BTE for RCCI at moderate load

FWG engine and WTW studies initiated

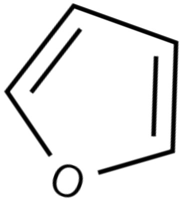
Showed 2.3% FE improvement with backward compatible advanced lubricant

New Technologies Developed

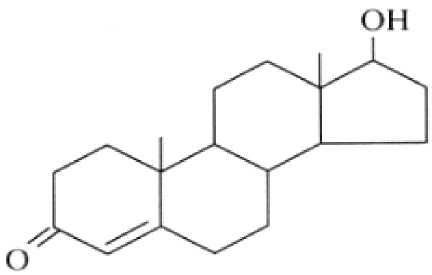
- **Friction modifiers for boundary lubrication**
- **Ionic Liquids synergy with ZDDP – anti-wear**



Ethanol Puppy: Ball-and-Stick Model



Fuel and Lubricant Technologies

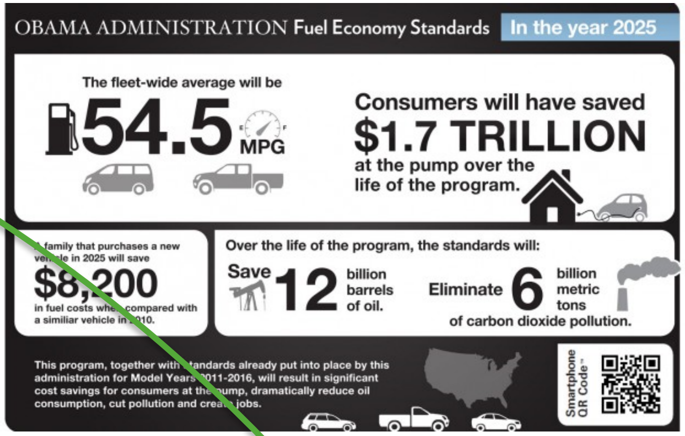


Funding in millions	**FY 2015** Enacted	**FY 2016** Enacted	**FY 2017** Request
Fuel and Lubricant Technologies	$20.0	$22.5	$20.5

Convergence of Three Automotive Challenges Underlines the Importance of Advanced Research

54.5 mpg CAFE by 2025

- per U.S. EPA and U.S. DOT standards
- Currently at 30.1 mpg for "cars"
- Gasoline dominating US light duty fleet



Fuel Economy Standards

EPA

>70% less NOx

>85% less NMOG

70% less PM

Automotive Industry

EPA Tier 3 Emission Regulations

Renewable Fuel Standard

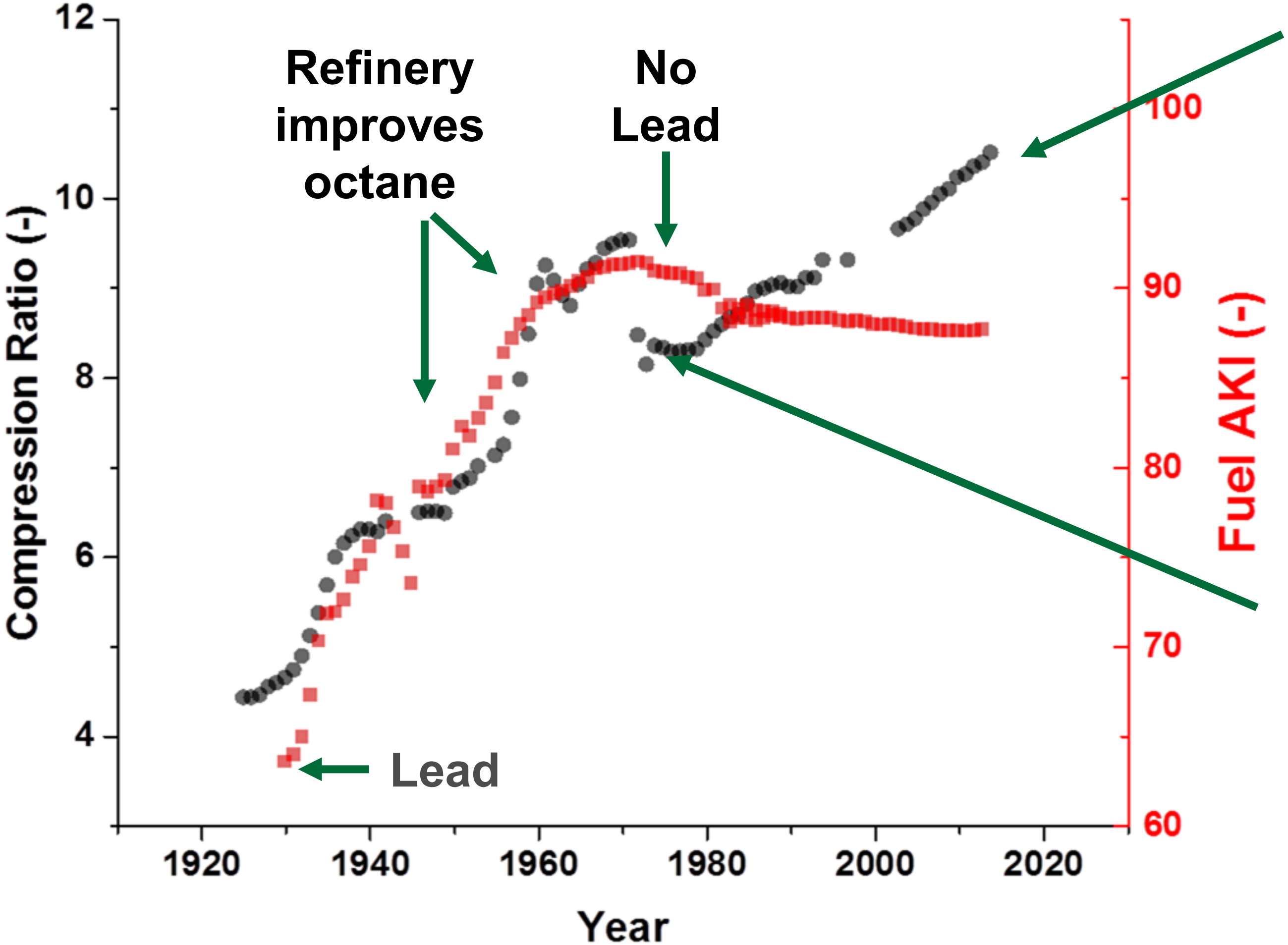
<70% less NOx, >85% less NMOG, and 70% less PM emissions by 2017-2025 (phased in)

- per U.S. EPA Tier 3 regulations

36 billion gallons of renewable fuel by 2022

- per Energy Independence and Security Act of 2007

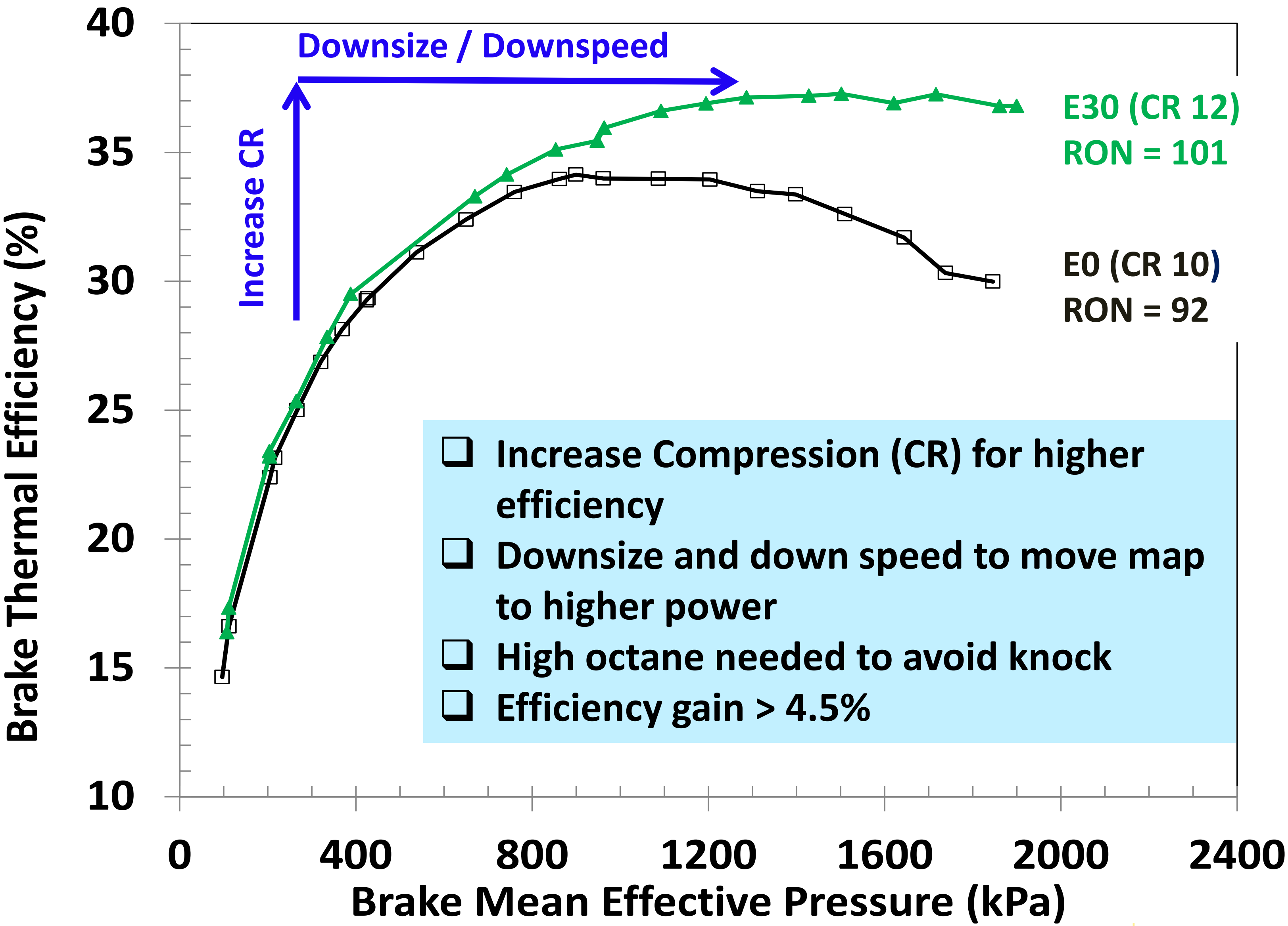
Historically There has Been a Very Tight Coupling between Engines and Fuels, in 1980 This Began to Diverge and Hasn't Recovered



174 hp, 1.5 L disp
0-60 in 6.6 s
31/41 MPG

90 hp, 3.6 L disp
0-60 in 15.5 s
15/21 MPG

Engine Data + Vehicle Modeling can Estimate the Benefits Enabled by High Octane

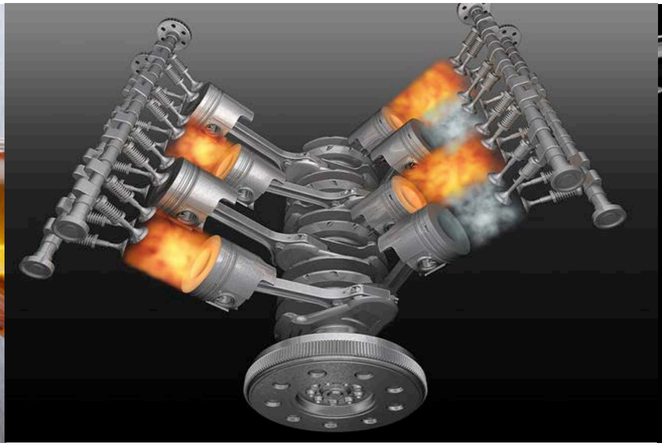


- ❑ Increase Compression (CR) for higher efficiency
- ❑ Downsize and down speed to move map to higher power
- ❑ High octane needed to avoid knock
- ❑ Efficiency gain > 4.5%

Co-Optimization of Fuels and Engines

- ❑ Need better fuels and engines to meet goals.
- ❑ Current fuels constrain engine design.
- ❑ Co-optimization for near and long-term fuel economy gains.

Presents an opportunity for low-carbon fuels!

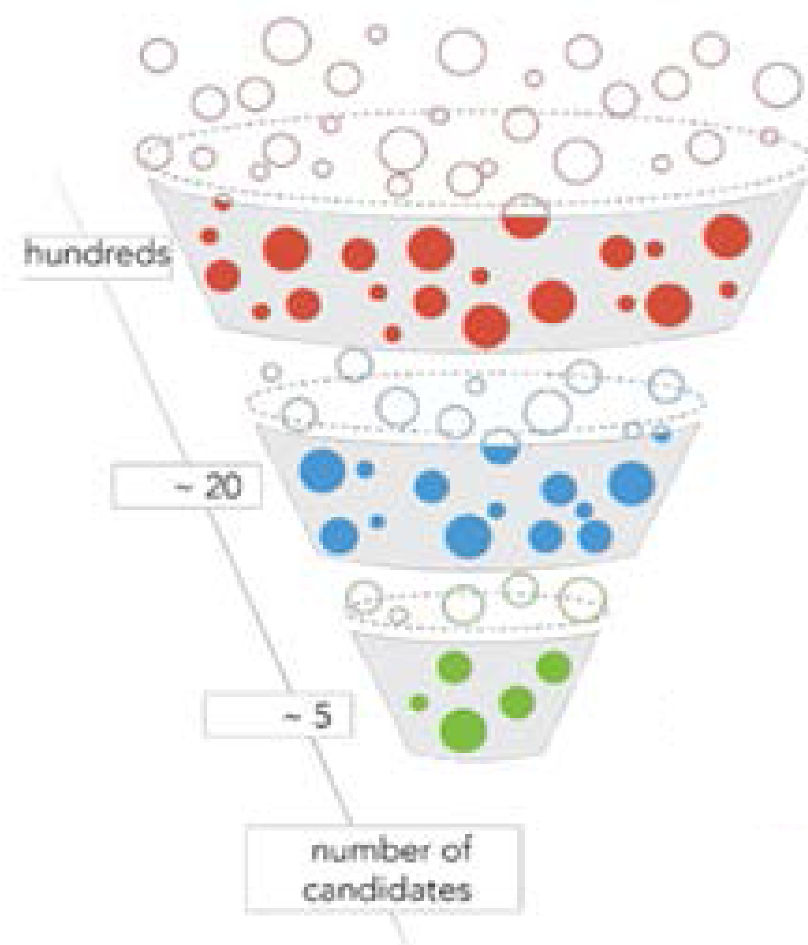


Convergence of alternative fuels and powertrain development

Goals

- Reduce per-vehicle petroleum consumption 30% vs. 2030 base case
  - Additional 7-15% reduction in engine fuel consumption.
  - 20% reduction in fuel WTT emissions.
  - GHG emissions reduction of the light-duty vehicle fleet by 9-14% relative to BAU within 10 years of market introduction.
- Develop new fuels and engines that:
  - Have better performance.
  - Can be produced affordably, sustainably, and at scale.
  - Reduce GHG emissions.

Fuel Candidate Screening



U.S. DRIVE FWG Primary Objective

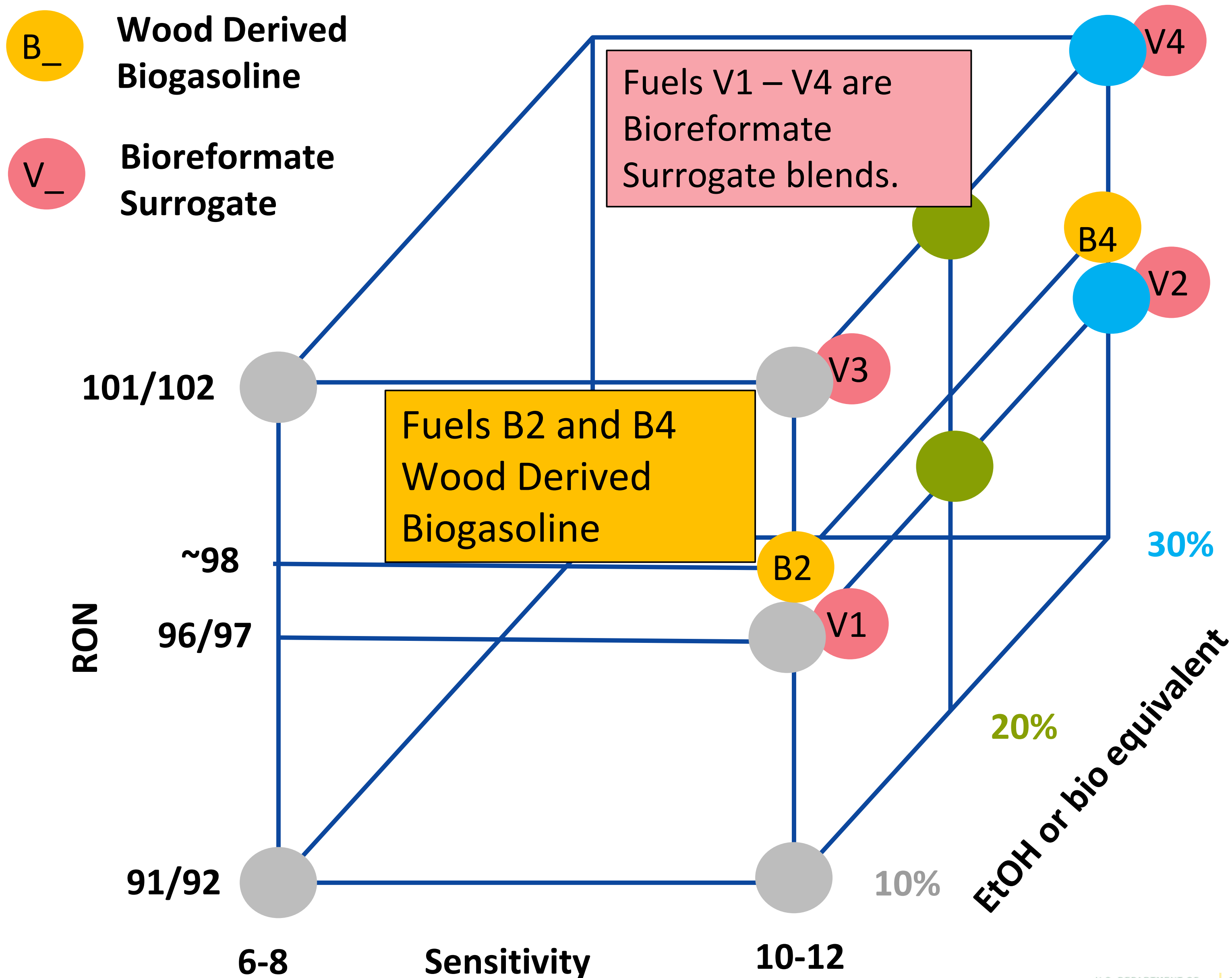
- Evaluate potential properties of lower carbon fuels* for future, high efficiency engines and combustion regimes meeting U.S. DRIVE ACEC targets.

Focus Areas (Fuel Effects Studies Aligned with ACEC)

1. Premixed, Flame Propagation, Spark Ignition Combustion Mode (SI)
2. Mixing/Diffusion Compression Ignition Combustion Mode (CI)
3. Chemical Kinetics Dominated Low Temperature Combustion Modes (LTC)
4. New Combustion Quality Metrics
   a. Anti Knock for SI
   b. Ignition Delay for LTC

** Lower carbon as measured by well-to-wheels greenhouse gas emissions measured in g/mi, compared to a baseline case (reference fuel and vehicle)*

FWG Fuel Set Compares Octane Effects for Bio-Gasolines

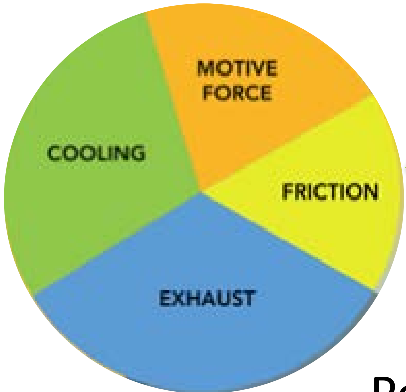


Well-to-Wheels (WTW) Activities

Do tailpipe GHG reductions from increased octane outweigh refinery GHG increases?

- ❑ Quantify net GHG impacts of increased engine efficiency enabled by higher octane ratings, refinery actions, and/or biofuel content
- ❑ Refinery Linear Program Modeling – Analyzes GHG for the blendstock
  - Basis: EIA 2014 data for regions and refineries across the US
- ❑ Compare multiple potential fuel/engine combinations, with and without renewables
  - Basis: GREET Model (augmented by additional analyses)
- ❑ Supported through Argonne National Laboratory and Jacobs Engineering

Lubrication Research Motivation and Strategy



16.5% of fuel energy is lost to friction

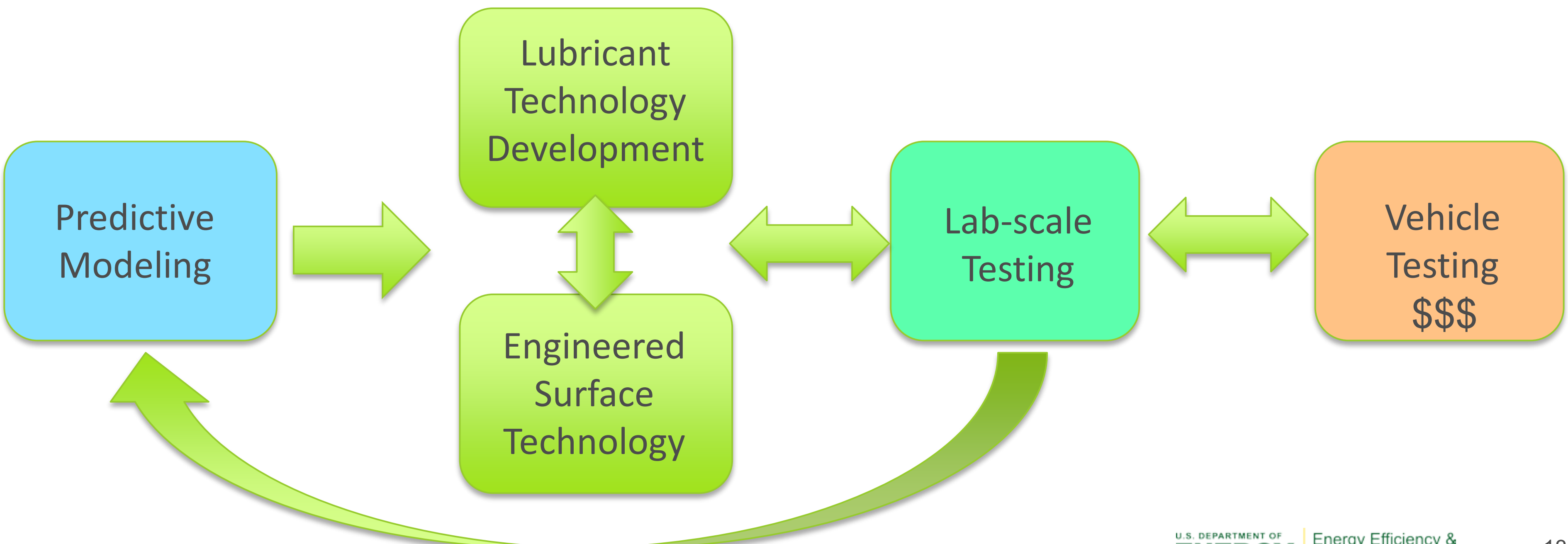
- **11.5%** Engine
- **5%** Powertrain

Reducing Friction has a direct effect on

- Petroleum consumption
- GHG emissions

Potential to have 'drop-in' replacement for legacy vehicles

Many Vehicles **x** Small per Vehicle Savings **=** Large Benefit

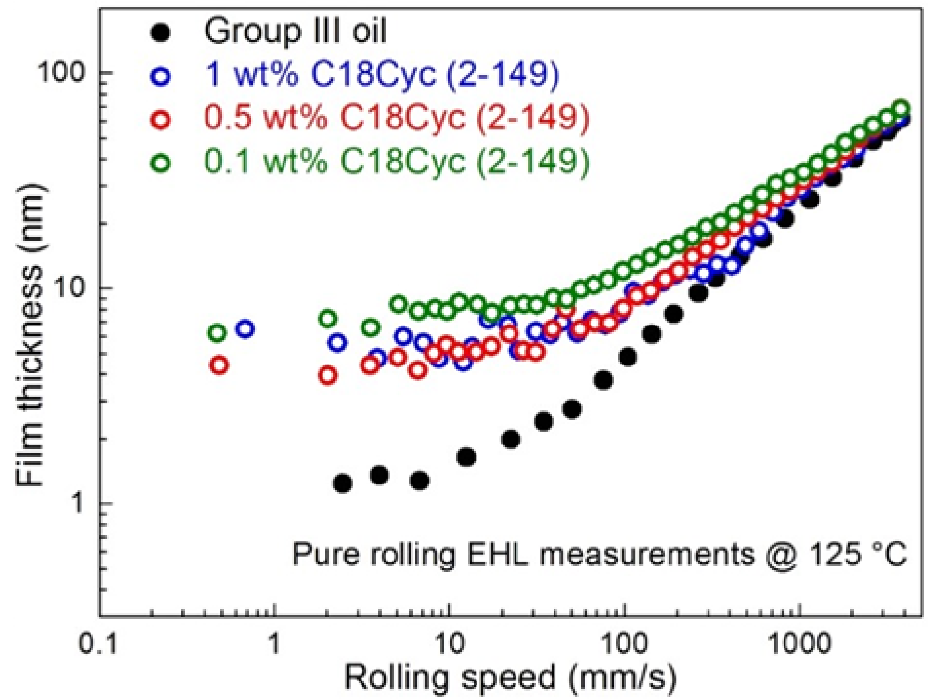


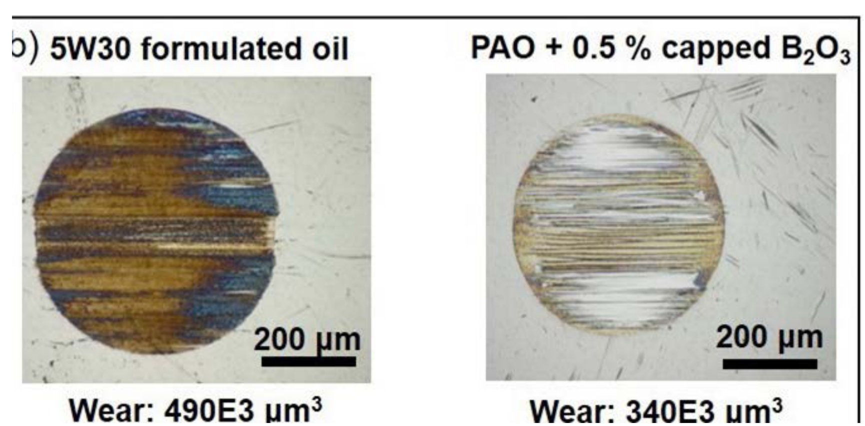
A Novel Lubricant Formulation Scheme for 2% Fuel Efficiency Improvement

Northwestern Univ. – Q. Jane Wang

Achieve improvements by:

- ❑ Reducing boundary friction at start-up and low speed
- ❑ Reducing lube viscosity at medium- and high-speed
- ❑ Plot shows additive maintains film thickness at low and medium speed
- ❑ Anti-wear additives successfully tested
  - – Photo shows lower wear with additive than without
  - – Can enable lower viscosity lubes





Power Cylinder Friction Reduction through Coatings, Surface Finish

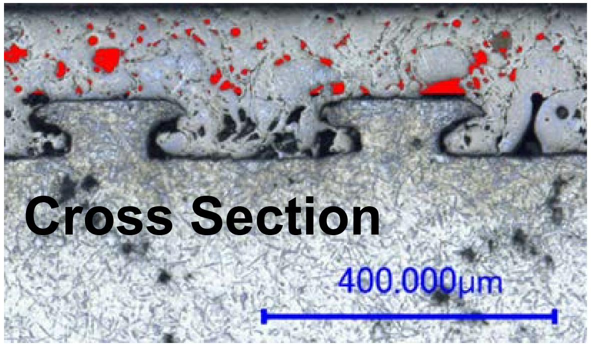
Ford – Arup Gangopadhyay

- ❑ High porosity cylinder <u>bore coatings</u> using Plasma Transfer Wire Arc (PTWA)
  - – Allows oil retention → reduced friction
- ❑ Optimized PTWA process to control porosity level (2-8%) and developed procedure for characterizing porosity on the micro-scale.

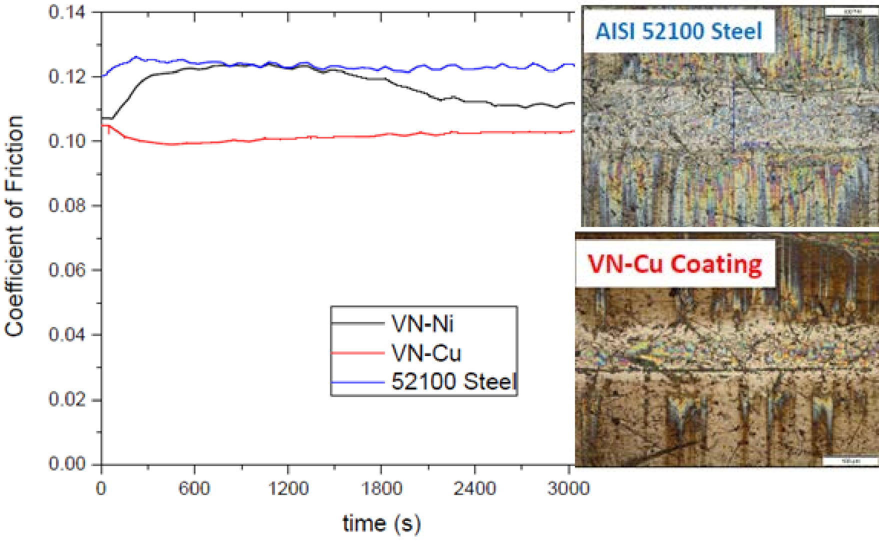
ANL – Ali Erdemir

- ❑ Coated liners will be paired with ANL's low-friction/low-wear nanocomposite <u>coated piston-rings</u>
  - – Despite harsh testing conditions, low wear was observed and friction was reduced by 10-15%.

PTWA Coating with 6-8% Porosity



red = pores



Directions for FY 17

- Co-Optima Project
  - Decision Point for SI fuel (Spring 2017)
  - Continued examination of fuel properties (RON, HoV, etc.) to enable high efficiency SI engines
  - Thrust 2 (Advanced CI, Low-Temp. Combustion) emphasis increases
- Continued Lubricants R&D Activity
  - Coordination of multiple capabilities (surface analysis, emissions, bench-testing, chemical synthesis) at labs and with Industry
  - Understand effects on wear – ensure compatibility with both new and legacy vehicles to maximize impact

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