Overview of High Octane Fuel Engine and Vehicle Efforts

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** General Motors

Auto/Ag/Ethanol Meeting
USCAR
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Work supported by
DOE Bioenergy Technologies Office
DOE Vehicle Technologies Office
Coordinating Research Council
Industry Partners

ORNL is managed by UT-Battelle for the US Department of Energy
Industry and DOE Investing In Programs to Quantify Benefits of High Octane Fuels in Turbo GDI Engines

DOE Work supported by

• Vehicle Technologies Office
• Bioenergy Technologies Office

Industry Cost-Share, Funds-in, and Technical Support

• Ford
• General Motors
• Coordinating Research Council

• Thermal Efficiency of Ford EcoBoost

*(data from Sluder, ORNL)*

![Graph showing brake thermal efficiency vs. brake mean effective pressure for different fuel octane ratings and ethanol blends.](image-url)
## Engine-Based Projects

Summary slides on each project to follow

<table>
<thead>
<tr>
<th>Test Program Attribute:</th>
<th>AVFL-20</th>
<th>AVFL-20A</th>
<th>AVFL-26</th>
<th>&quot;open&quot; DOE Project (Sluder)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modified 1.6L GTDI engine (modified near/mid-term engine design)</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Modified 2.0L GTDI engine (Advanced design, DOE FOA project)</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Current production 1.4L FIRE NA engine</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Long-term engine design (2 stage turbo, high energy ignition and EGR)</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Modify compression ratios on engine (inc. CR = inc. efficiency)</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Quantify higher octane impacts on gaseous/PM emissions</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Quantify higher octane impacts on particulate number emissions</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Determine ethanol impacts on gaseous/PM emissions (E10-E30)</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Determine ethanol impacts on PN emissions (E10-E30)</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Quantify E0 gasoline impacts on gaseous/PM/PN emissions</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Determine PMI fuel impacts on gaseous/PM/PN emissions</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Evaluate gasoline and ethanol interactions and the effects on engine efficiency on near to mid term engine design</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Study of effects of sensitivity on gasoline-ethanol fuel blending to achieve target RON and effect of sensitivity on engine efficiency</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Understand and quantify fuels effects (PMI) on future (long-term) engine technologies with respect to engine efficiency, gaseous/particulate emissions and fuel economy</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Engine mapping with various compression ratios and octane levels to support vehicle modeling for estimating Fuel Economy benefits of HOF in downspeeded/boosted GDI engines</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>
AVFL-20 and DOE Project Using Ford 1.6 Liter EcoBoost To Explore High Octane Fuels and Engine Compression Ratio Synergies

• Turbo-charged, direct-injection engine
  – Full engine control provided by Ford
  – High compression pistons have been designed and machined
  – Supporting both DOE and CRC projects

• Fuel blends will span various octane levels with different sources of octane number

• Full Engine maps with emissions and efficiency to support vehicle modeling

DOE work supported by Vehicle Technologies Office, with engine and technical support from Ford

CRC funds-in effort underway (AVFL-20)*

CRC Project AVFL20a

Objective:
Expand the results of AVFL20 to include impacts on port-fuel injected platforms that may exhibit different responses to changes in fuel formulation compared with GTDI platforms.

Approach:
Develop engine maps for a PFI platform followed by vehicle modeling to assess fuel economy impacts.
- Fuels same as those for AVFL20 phase 3.
- Chrysler FIRE 1.4L NA PFI
- Baseline CR plus one higher CR

Status and Timing:
Contract with CRC and funding in place; awaiting engine delivery.
Completion estimated for calendar year 2016.
AVFL-26, DOE Funding Opportunity (Competitive), FOA991 Awarded 2015
Gasoline Engine and Fuels Offering Reduced fuel Consumption and Emissions

- GM 2.0 LTG Engine
- Cost share with CRC
- Technical support from GM
- Target 25% reduction in petroleum consumption

Work supported by DOE Vehicle Technologies Office, engine and technical support from GM/CRC

**CRC project AVFL-26**

## Vehicle-Based Projects. Summary slides on each project to follow

<table>
<thead>
<tr>
<th>Test Program Attribute:</th>
<th>BETO HOF Vehicle Demo</th>
<th>Fiesta EcoBoost Demo</th>
<th>Flex Fuel Vehicle Performance Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM 2.0 Turbo GDI (LTG Platform)</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Current production 1.0L EcoBoost engine</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Current production Normally Aspirated FFVs (4).</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Modify compression ratios on engine (inc. CR = inc. efficiency)</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Quantify higher octane impacts on acceleration performance</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Quantify higher octane impacts on whole vehicle fuel economy (mpg)</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Examine HOF ranging from 87 AKI to 100 RON with various levels of ethanol</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Compare E10 to E30</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Compare E0 to E15</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Determine PMI fuel impacts on gaseous/PM/ PN emissions</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Simulate downspeeding and downsizing via vehicle changes and vehicle test weight</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Combustion analysis being conducted to quantify CA50</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Criteria pollutants measured and reported</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Work completed and published?</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>
BETO Project Demonstrating High Octane Fuel Benefits at the Vehicle Level

• Late model vehicle with TGDI engine
  – Turbo-charged GDI engine, manual transmission
  – Baseline Experiments Completed
    • Factory compression ratio
    • 87 AKI to 100 RON
    • E0 to E30
    • Downsped and downsized
    • Cylinder pressure data collected
  – Compression ratio change imminent
    • High compression pistons acquired

Work supported by DOE Bioenergy Technologies Office, GM providing technical support (vehicle uses same engine as DOE FOA project [CRC AVFL-26])
Vehicle Study to Determine Potential Performance Improvement of Legacy FFVs with High Octane Blends

**Motivation:** Measureable performance improvement in legacy FFVs could enable early adoption of “High Octane Fuel for Your FFV”

- Acquired 4 “ethanol tolerant” FFVs
  - GMC Sierra
  - Chevrolet Impala
  - Ford F150
  - Dodge Caravan

- Prep and Baseline “wide open throttle” (WOT) test with Regular E10

- Prep and WOT test with ~100 RON E30

- **Report available:**
  - 3 of 4 FFVs show acceleration improvement with E30
    - ORNL’s Sierra results with E30 similar to Car and Driver test with E85

If half FFVs on road today filled up with E30 half the time, consume half-billion gallons more ethanol
Benefits of Engine Downsizing with High Octane E-Blend Demonstrated on Late-Model Turbo GDI Vehicle

- **E15-Compatible Ford EcoBoost Fiesta**
  - 1.0 liter, 3-cylinder turbo GDI engine
- **Owner’s Manual:** “Regular unleaded gasoline...is recommended....premium fuel will provide improved performance and is recommended for severe duty usage...”
- **Experiment:**
  - Blend regular 87 octane E0 with 15% Ethanol
    - Boosts octane, lowers energy content
  - Test on City, Highway, and US06 (high-load cycle)
  - *No Changes* to engine, vehicle, calibration or shift schedule
  - Results within 1% of Volumetric Fuel Economy Parity with E15 on US06

![Graph showing fuel economy and performance comparisons between E0 and E15 fuel.](image)

**Addition of 15% ethanol boosts octane, improves engine performance & efficiency.**