Intermediate Ethanol Blends

Plans and Status

Presented by: Wendy Clark

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DOE (Zia Haq, Pat Davis, Joan Glickman, Kevin Stork, Carolyn Clark)

NREL (Wendy Clark, Keith Knoll, Doug Lawson)

ORNL (Ron Graves, Brian West, Tim Theiss, John Thomas, Sean Huff)

and many others …
Ethanol markets cannot absorb the ethanol volume specified by the Energy Independence & Security Act (36B gallons)

- Today, blended gasoline used in standard vehicles (non-FFVs) is limited to 10 percent ethanol (E10).
- More than 99 percent of the fuel ethanol produced today is used in E10 blends; a tiny fraction is used to produce E85 for FFVs.
- E10 markets are likely to saturate by ~2012, as production capacity approaches 14B gallons (~10% of all gasoline sold).

There are two paths to increase ethanol markets >14B gallons:

- Path A: Saturate E10 markets, and significantly expand E85 markets at an accelerated pace
- Path B: Certify “intermediate blends” of gasoline to use up to 15 or 20% ethanol (E15, E20) and let market forces drive ethanol supply distribution

DOE is investigating ALL paths, but this project is designed to determine the impact of Path B on the existing “legacy” fleet of vehicles and non-road equipment
Nation has limited E85 Infrastructure

E85 Route to Solution:
For example, in order for E85 market to absorb 25 billion gallons of ethanol per year by 2017 we estimate that the US would need:
- 10 billion gallons per year of E85, 250X more than today.
- 100 million FFVs vs 6 million FFVs today.
- 60,000 E85 stations vs 1,200 today.
- DOE intermediate ethanol blend test plan development began March 2007
  - Organizational meetings – DOE, National Labs, EPA, USDA, State of MN – March & June 2007
  - Literature search April-July 2007
  - Small, non-road engines (SNRE) given priority in summer 2007 at EPA request
  - Established leveraging with CRC
  - Vehicle evaluations underway late CY 2007
  - Plans for other non-road in progress: ATVs, marine, motorcycles, snowmobiles
• Received input on vehicle testing from USCAR & incorporated into DOE plan (October 2007)

• Presented DOE test plans for vehicles and small engines to USCAR (January 2008)
  – Ongoing interactions between USCAR, Oil Cos. (CRC, ASTM) and National Labs on technical details

• Honda and the Automobile Importers of America to be briefed soon

• RFA being briefed today

• Ongoing discussions with representatives of the small / non-road engine manufacturers (December 2007– February 2008)
  – Planning a workshop for Spring 2008

• Industry interactions proving highly valuable
  – Provide input on test plans & vehicle/engine selections
  – All DOE tests at neutral sites
  – Coordinating Research Council (CRC) is main venue of collaboration and cost-share
Seven active vehicle tasks underway (11 total)

Addressing key questions on E15/20 impacts on legacy fleet
- Emissions
- Catalyst durability
- Driveability
- Materials compatibility
- Four fuels in most tests—E0, E10, E15, E20

Vehicle Test Fleet
- 46 vehicles today
- 100 by March
- 155 by May

5 of 7 vehicle tasks complete by end of CY 2008

Other 2 tasks are longer term, significant data available in CY 2008
- Full-useful life catalyst durability testing (with CRC)
- E0 to E20 speciated exhaust emissions study (with EPA)
• Plan developed in collaboration with EPA
• 11 late-model vehicles
  – Instrumentation: TCs, UEGO, ALDL/DLC/CAN
• E0, E10, E15, and E20 fuels
• Triplicate LA92 drive cycles on each fuel
  – NMOG, NO_x, CO, CO_2, ethanol, aldehydes, mpg
• CRC E-60 Wide Open Throttle protocol to assess open-loop fuel trim/catalyst protection
• Daily log to note driveability issues, MILs, etc.
• Testing is underway
MY2003 & 2007
Most popular
Cars & trucks
6 OEMs
• EPA/DOE Cooperation

• Objective: Establish effects of RVP,T50,T90, aromatic content and EtOH on exhaust emissions from Tier 2 vehicles

• Fuel matrix (computer-generated/optimal) includes 29 fuels
  – Fuel variables: T50 (4 levels); T90 (2 levels); EtOH (4 levels); RVP (2 levels); Aromatics (2 levels)

• 22 test vehicles in Phases 1 & 2; 19 vehicles in Phase 3

• Program Design (LA92) will be used throughout
  – Phase 1: RFS2 Pilot at 75°F (3 fuels tested in 22 vehicles, results => RFS2 NPRM)
  – Phase 2: RFS2 Pilot at 50°F (3 fuels tested in 22 vehicles)
  – Phase 3: Main Program (25 fuels tested in 19 Tier 2 vehicles, E85 tested in 4 FFVs)

• Species measured (continuous and bag): Regulated emissions, CO₂, NO₂, VOCs, ethanol, carbonyl compounds

• Fuel blending began in February; Phase I testing to begin on April 1
- Led by EPA
- E-77 Pilot, Draft Report under review by committee (10 older cars, all E0 fuels)
- E-77-2 Current test program at ATL (4 Tier 2 vehicles, 4 Tier 1, all “enhanced” evaporative systems; E0, E10, E20)
- E-77-2b EPA testing at SwRI (8 vehicles – E0, E10, possibly E20)
- E-77-3 EPA field testing study with ERG – looking for leakers
• Planned in collaboration with CRC and USCAR

• 80 vehicles (10 vehicle types x 8 each)
  – Vehicle selection based on CRC E-87

• E0, E10, E15, and E20 fuels

• CRC E-60 Wide Open Throttle protocol to assess open-loop fuel trim / catalyst protection

• Status: RFP to be issued in Q1 2008
Task V4: Catalyst Durability and Aging Protocol

- Acquire vehicles, run single FTP and CRC E-60 WOT
  - Confirm open-loop characteristics observed in CRC E-87
- 10 vehicle types
  - Baseline FTP emissions on E0 (all vehicles)
  - Baseline on E10, E15, E20 (2 vehicles per fuel)
- Age vehicle 25,000 miles using EPA Standard Road Cycle
  - Splash blended retail gasoline (RE0, RE10, RE15, RE20)
- Duplicate FTPs on E0 and Exx (4 tests per vehicle)
- Repeat until 50,000 miles driven or vehicle reaches full useful life
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Initiated as FFV E85 Cold-Start / Driveability program to update ASTM volatility class vapor pressure (RvP) requirements for Flexible-Fuel Vehicles (FFVs)

- Targets volatility classes 1 and 2
- Uses industry accepted CRC protocols/raters
- Intermediate blends added to address Exx-fueled vehicle performance in same volatility classes
Task V5: CRC Cold-Start & Driveability Program Summary

- **Exx Fuel Matrix:**
  - E0 at 5.7 & 7.9 psi RVP
  - E15 at 6.7 & 10.0 psi RVP
  - E20 at 6.7 psi RVP

- **Exx Temperature Matrix**
  - Class 1: 30°F to 40°F
  - Class 2: 20°F to 30°F

- **Exx Program Schedule**
  - Testing completed February 2008
  - Full data analysis complete November 2009
  - Interim results should be available earlier
• Evaluate durability impacts of wetted fuel system components when exposed to E20
  – Fuel system designs selected with the most E20 susceptibility for testing using new fuel system components
  – Targeting suspected vulnerable parts and test processes
  – Complete fuel system test rigs to be constructed instead of complete vehicle testing to reduce cost
  – Accelerate aging via raised temperatures, ‘aggressive’ alcohol
  – Functional part testing to aid in wear determination
  – Material compatibility to be evaluated based on wear analyses

• Fuels: E0, E10 (base fuel), and aggressive E20

• Project start 1st Quarter 2008, 15 months in length

• Working with Transportation Research Center, Inc.
Task V6: Program Approach

- **Fuel Pump**
  - Initial Phase: Soak fuel pump components in E20
  - Testing on E20; affected designs retested using E10
    - Endurance Test (SAE J1537)
    - Extended fuel soak with periodic operation
      - Soak E20 components in E0 and retest

- **Fuel Injector**
  - Durability Test (SAE J1832)
  - Test on E20, then select designs on E10

- **Complete Fuel System Fuel Exposure**
  - 11 month soak at elevated temperature using fuel circulation with fuel refreshed periodically and analyzed for material degradation
  - E20 and E10 are tested in parallel for each selected system
Tasks V7-V11

- Tasks V7 & V8: Materials Compatibility (MN/RFA and UL)
  - Monitor ongoing activities
  - Assess need for parallel or follow-on efforts

- Task V9: OBD and operations issues
  - Plans contingent on issues observed during V1-V5

- Task V10: Health Impacts – TBD

- Task V11: Monitor and Assist Rochester Institute of Technology in E20 Test and Evaluation Program

Task V11: Monroe County Pickup in the Delphi emissions test facility
• Small, non-road engines study well underway (accelerated schedule requested by EPA)
  – Emissions and durability

• Small-engine industry advising on test plans, procedures, test devices
  – Workshop in March 2008

• Additional engine studies will follow, pending resource availability
  – Marine engines
  – ATVs, snowmobiles, motorcycles
  – Heavy-duty gasoline engines
• Open Loop, non-road SI engines expected to be very sensitive to increased ethanol content

• Wide range of displacement and full useful life. DOE study examining engine classes I (lawnmower), II (small tractor), and IV (string trimmers, chainsaws, etc.)

• SE1: In-house evaluations at ORNL and NREL
  – Temperature and emissions on 4 fuels. (Full useful life testing on 50 hour leafblower at NREL)
  – Class I (5-10 hp) and Class II (10-25 hp) generators (ORNL)
  – Class IV line trimmer and leaf blower (NREL)

• SE2: Full useful life evaluations at TRC on all four fuels
  – Residential and Commercial - Class I & Class IV engines
  – Emissions and temperatures at break-in, half life, and full useful life
  – E0 baseline on all engines at beginning and end. Exx emissions at each testing interval

• SE3: Class II: Larger equipment (e.g. tractors) - deferred at this time; hope to leverage EPA program in FY08

• SE4: Motorcycles, ATVs, marine - planning stages, no funding yet
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• Very limited observations from ongoing tests with new vehicles confirm prior studies that drivers may not notice any immediate impact of E20 on vehicle driveability.

• Cannot extrapolate this result to older vehicles, so new data are required.

• Longer-term performance effects on new vehicles are not known.

• Preliminary data is insufficient to assess intermediate-blend impacts on key concerns of vehicle catalyst durability, emissions.

• For small, non-road engines, $\text{NO}_x$ and operating temperatures increase with increasing ethanol content, and CO and HC decrease.
  – Regulated emissions standard ($\text{NO}_x + \text{HC}$) still met; EPA and states may be more concerned about $\text{NO}_x$ increases, regardless.
Supplemental Slides
• Dispenser component tests underway

• Second apparatus constructed for elastomer and metal-based coupon studies
  – More fundamental material study
  – Dynamic test (stir tank)
  – Temperature control (60°C)
  – Coupons periodically removed for analysis
  – Apparatus potentially available for evaluation of automotive materials
Goal: To determine the impact of E20 on existing, conventional vehicles (Non-FFV)

Monroe County, NY has dedicated 10 older vehicles (1998-2004 models, wide range of mileages)

E20 from dedicated tank at Monroe County Fleet Center: fueling beginning week of 28 Jan 08; test duration 1yr.

Emissions testing baseline on unleaded complete (Delphi-Henrietta facility, FTP 75 protocol, three reps/vehicle)
• Follow up testing will be done after E20 implementation (late spring-summer '08)
• All ten vehicles have Networkcar vehicle monitoring system w/GPS
• Driver comment cards for subjective driveability evaluations
• Fuel and oil will be sampled periodically (some to NREL)
• Will track maintenance data, mileage, OBD/MILs, failures (due to fuel), performance/driveability
• Life cycle analysis using GREET model to determine predicted emissions deltas for these vehicles for comparison with test data

<table>
<thead>
<tr>
<th>Fleet Number</th>
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SNRE Program Summary
to date

• ORNL generator set testing complete
  – Honda GX200 engine - Class I commercial
  – 1999 Honda generator –Class I (used)
  – Briggs and Stratton engine - Class II residential
  – Kohler V-twin- Class II commercial

• NREL Class IV tests complete
  – Stihl line trimmer - Class IV commercial
  – Poulan leaf blower - Class IV residential

• TRC underway - full useful life data planned
  – Briggs & Stratton pressure washer - Class I residential
  – Poulan leaf blower - Class IV residential
  – Honda generator - Class I commercial
  – Stihl line trimmer - Class IV commercial
ORNL evaluated 4 small engines at Fuels, Engines, Emissions Research Center

- Engines Instrumented for
  - Temperatures
    - Exhaust Manifold
    - Cylinder Jug
    - Engine Oil
    - Cylinder Head
  - Emissions
  - Air:fuel ratio
  - Gravimetric fuel consumption
- Resistive Load Bank used to simulate 6-mode emissions test
- Engine-Driven Generators:
  - 200 cc Honda (new, Class I, commercial)
  - 249 cc Briggs and Stratton (new, Class II residential)
  - 163 cc Honda (used 1999 model)
  - 725 cc Kohler V-twin (new, Class II commercial)
- Test Fuels (E0, E10, E15, E20)
NREL Evaluated Two Class IV Small Engines at its ReFUEL Engine Test Facility

- Engines Instrumented for
  - Temperatures (Exhaust Manifold, Cylinder Jug, Engine Oil, Cylinder Head)
  - Emissions
  - Air:fuel ratio

- Automated throttle actuator used to follow CFR-specified 2-mode cycle.
  - 4.25 minutes at 100% Load
  - 0.75 minutes at idle
  - Emissions and Durability Cycles

- Two Engines Evaluated:
  - 25 cc Poulan Leaf Blower (2-stroke Class IV residential)
  - 28.4 cc Stihl Line Trimmer (4-stroke Class IV commercial – uses fuel/oil mix)

- Test Fuels (E0, E10, E15, E20)