

Baseline Results
of the Saab 9-5
BioPower and
Comparison with
the U.S. Flex-Fuel
Vehicle Fleet



2007 Fuel Ethanol Workshop

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Department of Energy

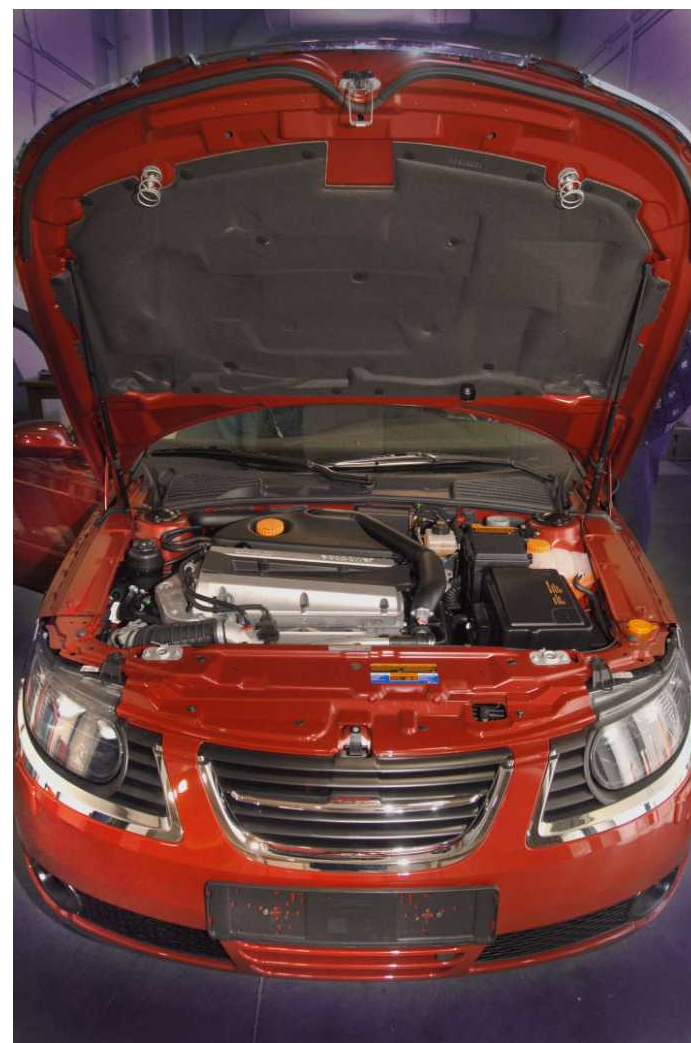
Biomass Program

Presentation Overview

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- **Project objective and background**
- **Baseline emissions and fuel economy on gasoline and E85**
 - FTP (city)
 - HFET (highway)
 - US06 (aggressive)
 - Acceleration
- **Measurements at TRC (Ohio) and ORNL**
 - Regulated and unregulated emissions
- **Comparison of fuel economy data to U.S. FFV Fleet**
- **Summary and Future Plans**



Why Evaluate a European Saab FFV?



- **U.S. legal FFVs are “ethanol-tolerant” gasoline vehicles**
 - Little or no performance benefit on ethanol fuel
 - Typically suffer ~30% drop in fuel economy (mpg) due to 30% reduction in energy content of E85 from gasoline
 - Little or no power/acceleration advantage
- **Saab 9-5 BioPower is reportedly optimized for ethanol use**
 - 20% increase in power with ethanol (150 to 180 hp)
 - Saab reports ~ 25% decrease in mpg... implies improved thermal efficiency on ethanol over what would be expected
 - No emissions certification data requirement on ethanol fuel in EU
 - Do performance, efficiency advantages come at expense of emissions?

Initial Saab Evaluations Conducted at TRC (Transportation Research Center) in Ohio

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- **TRC conducted a required 4000 mile break-in (catalyst de-greening) during Winter of 2007**
- **Performance evaluation on certification gasoline & E85**
 - Fuel economy
 - City (FTP), Highway (HFET), and Aggressive (US06) driving cycles used to test broad range of performance
 - Criteria emissions measured on both fuels (NO_x, CO, & HC)
 - Fixed gear acceleration

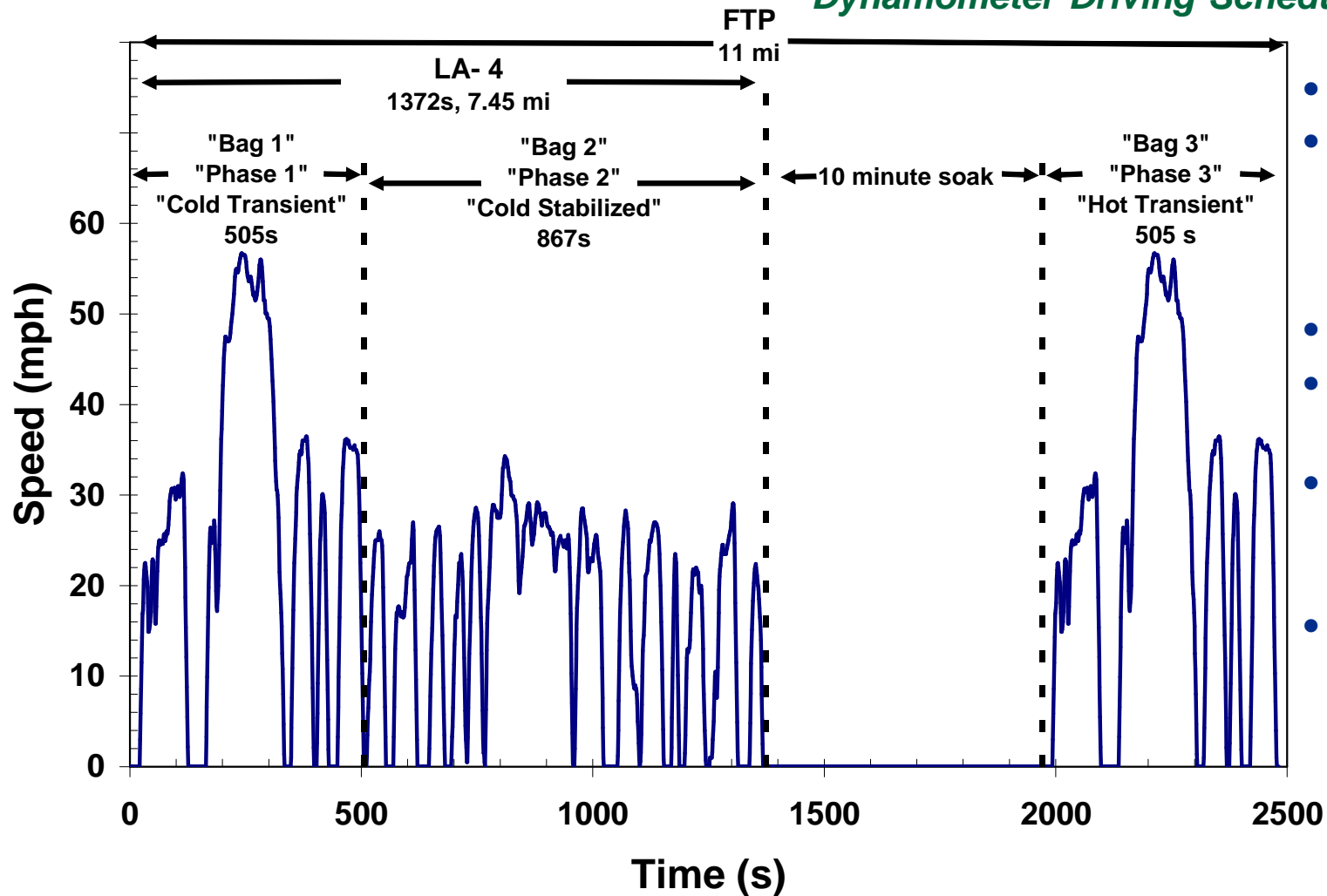


Federal Test Procedure (FTP) is used for Emissions Compliance Testing and for City Fuel Economy in U.S.

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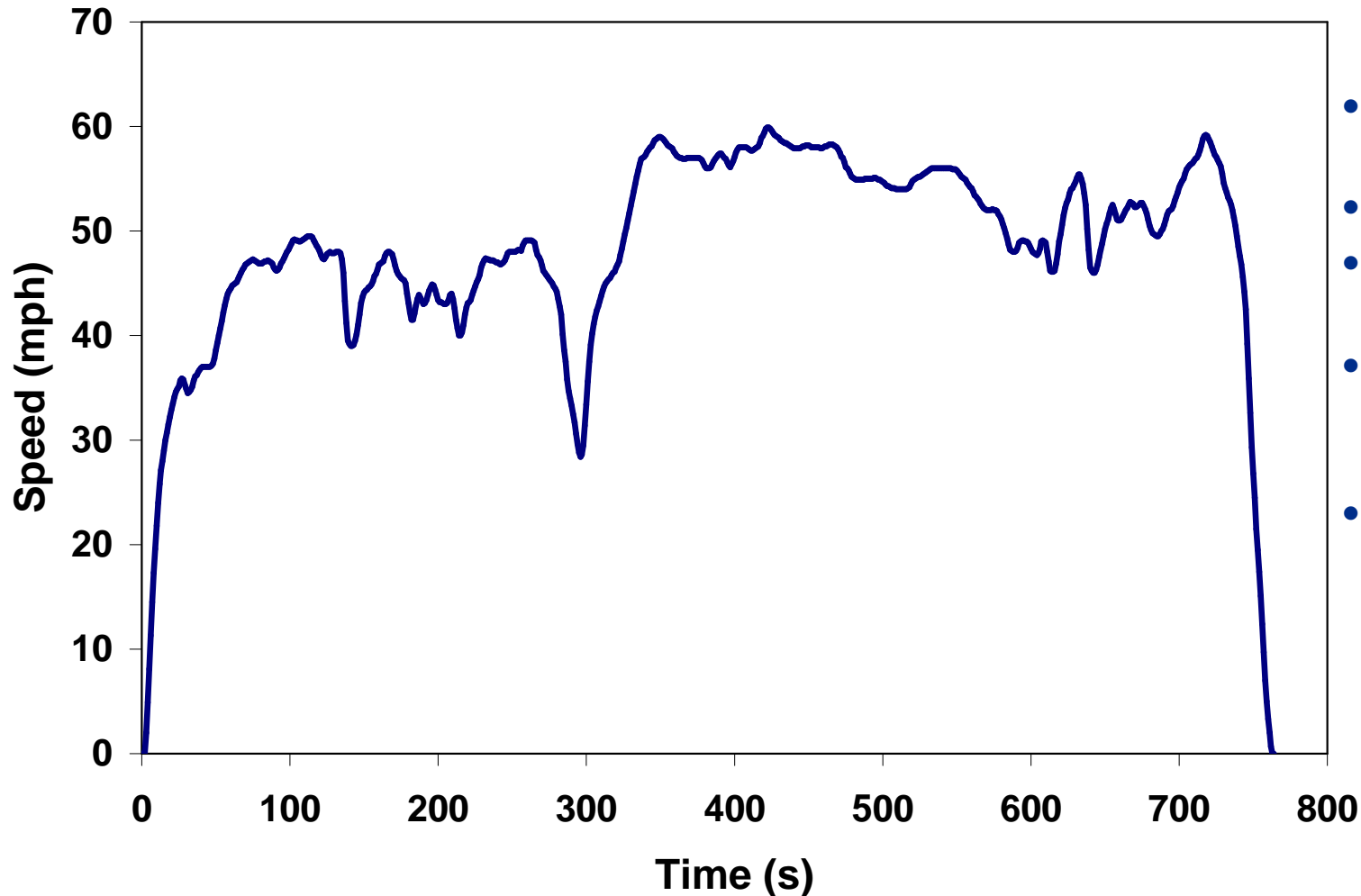
**FTP is also known as the City Test, the Urban Dynamometer Driving Schedule (UDDS)*



- Three phases
- Phase 1 and 3 are identical except for engine temperature
- 11 miles total
- 19.5 mph average speed
- 57 mph maximum speed
- 3.3 mph/s maximum acceleration

Highway Fuel Economy Test (HFET) is Basis for Highway Fuel Economy on Vehicle Window Stickers in U.S.

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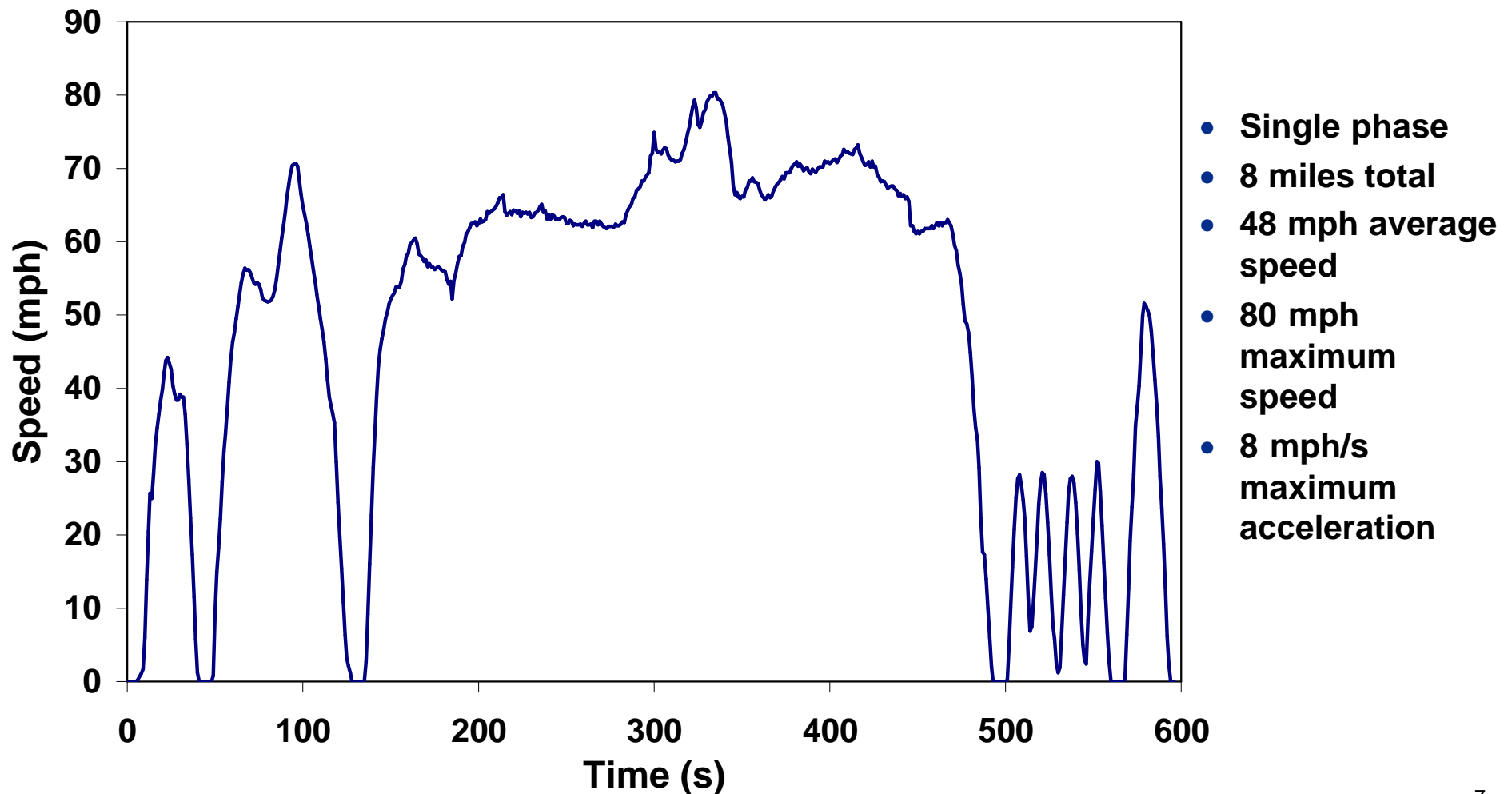
- Single phase with no stops
- 10.25 miles total
- 48 mph average speed
- 60 mph maximum speed
- 3.2 mph/s maximum acceleration

US06 Test is used for Emissions Compliance Testing in U.S.

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**US06 is part of the Supplemental FTP, also known as the aggressive driving test, characterized by high speeds and hard accelerations*

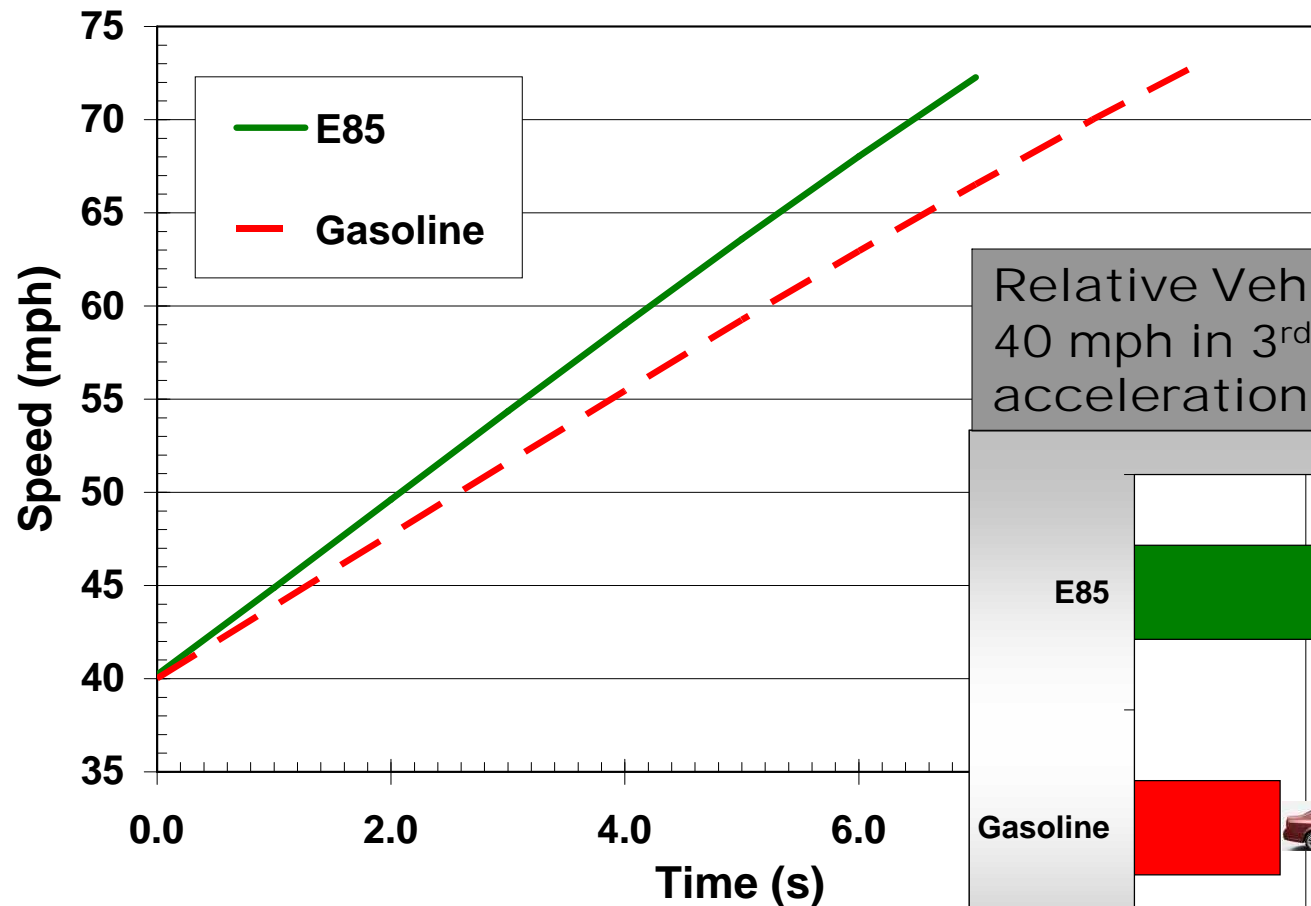


Increased Power and acceleration on E85 is significant...a key consumer preference

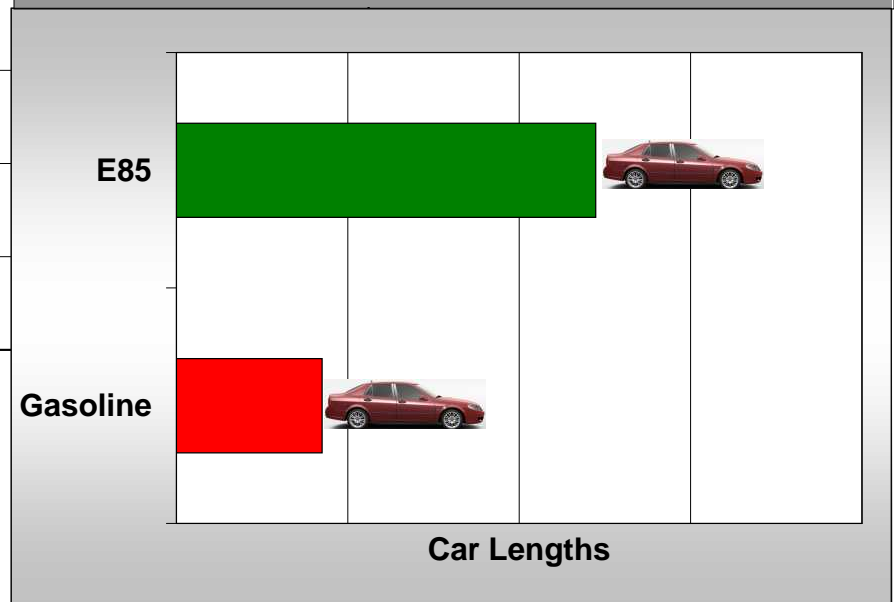
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**40-70 mph full throttle acceleration in 3rd gear is 2 seconds faster on E85. Equates to ~20% more power*



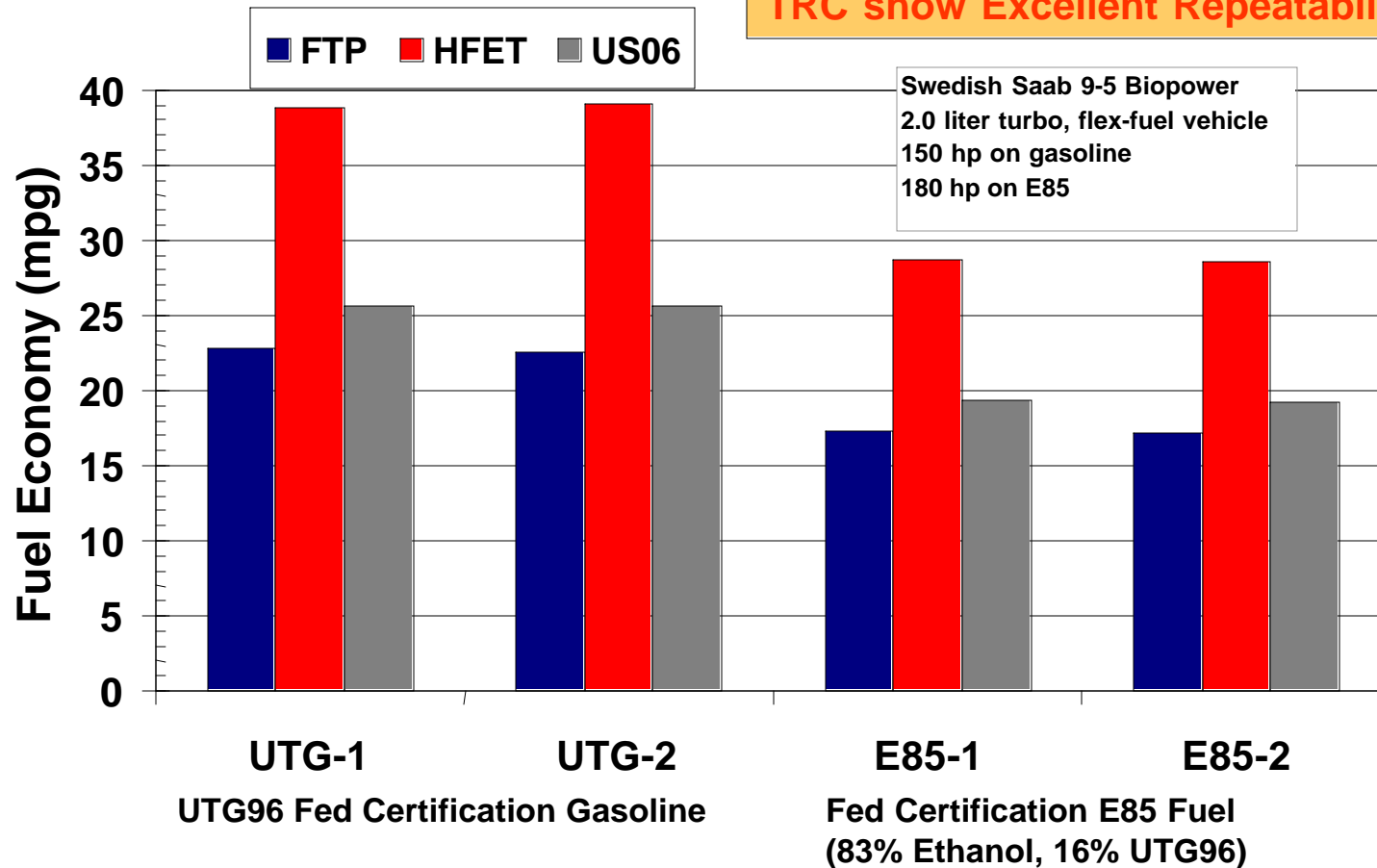
Relative Vehicle Position, start at 40 mph in 3rd gear, WOT acceleration, 500 feet for E85



Saab BioPower Fuel Economy Data Shows that E85 Fuel Economies 25-30% lower than Gasoline.



Duplicate Tests of Each Cycle at TRC show Excellent Repeatability.



FTP: City Test

HFET: Highway Fuel Economy Test

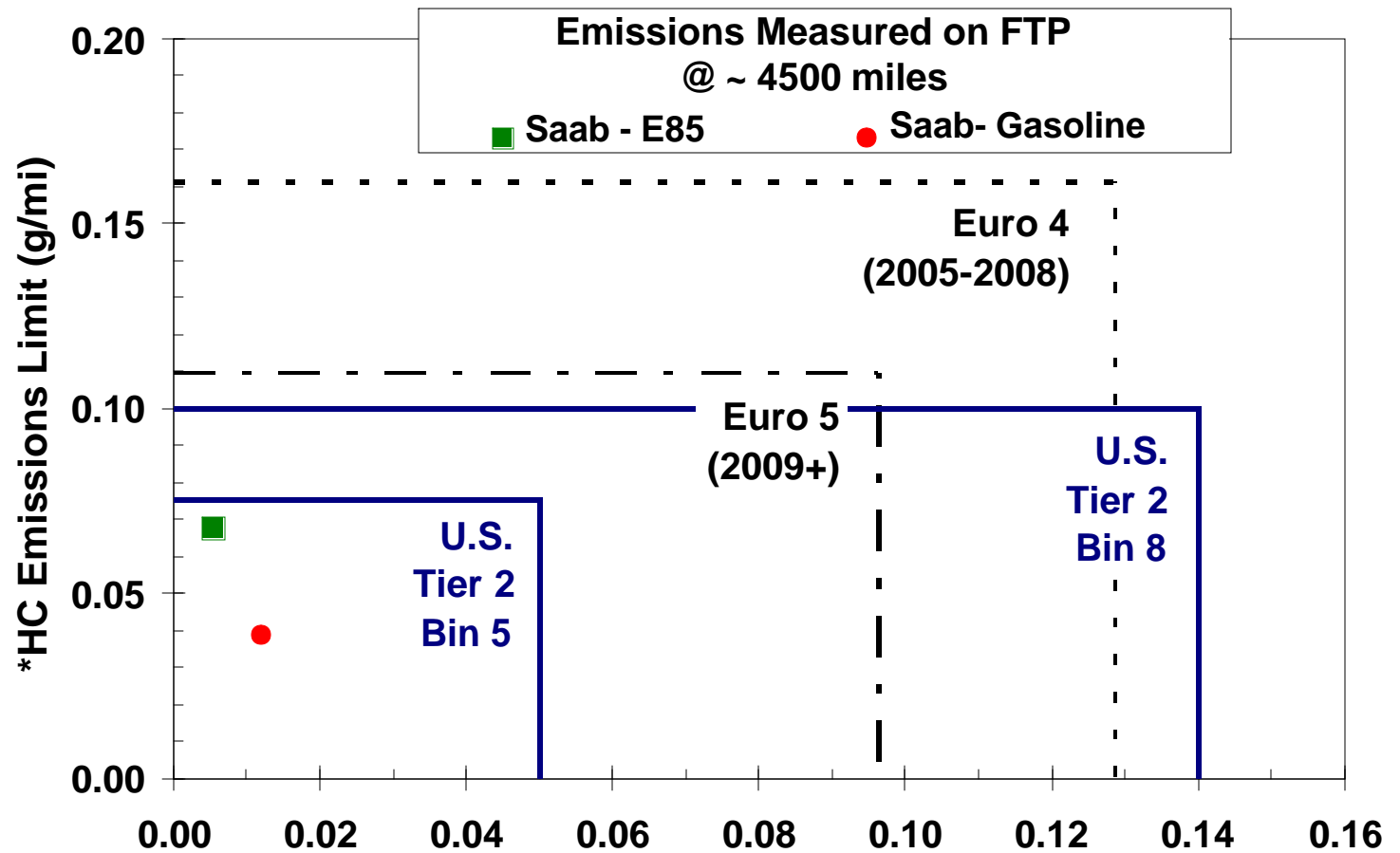
US06: Aggressive driving Test

ORNL Results show Saab BioPower Below U.S. Standards for Tier 2, Bin 5 Compliance (50,000 mile std.)

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- Euro and U.S. emissions measured on different cycles
 - Cycles do differ but typically result in similar fuel economies
- *HC in U.S. is NMOG, Euro 4 is THC, Euro 5 is NMHC
- No E85 emissions test requirement in Europe!
- Saab 9-5 biopower is “cleaner than it needs to be”



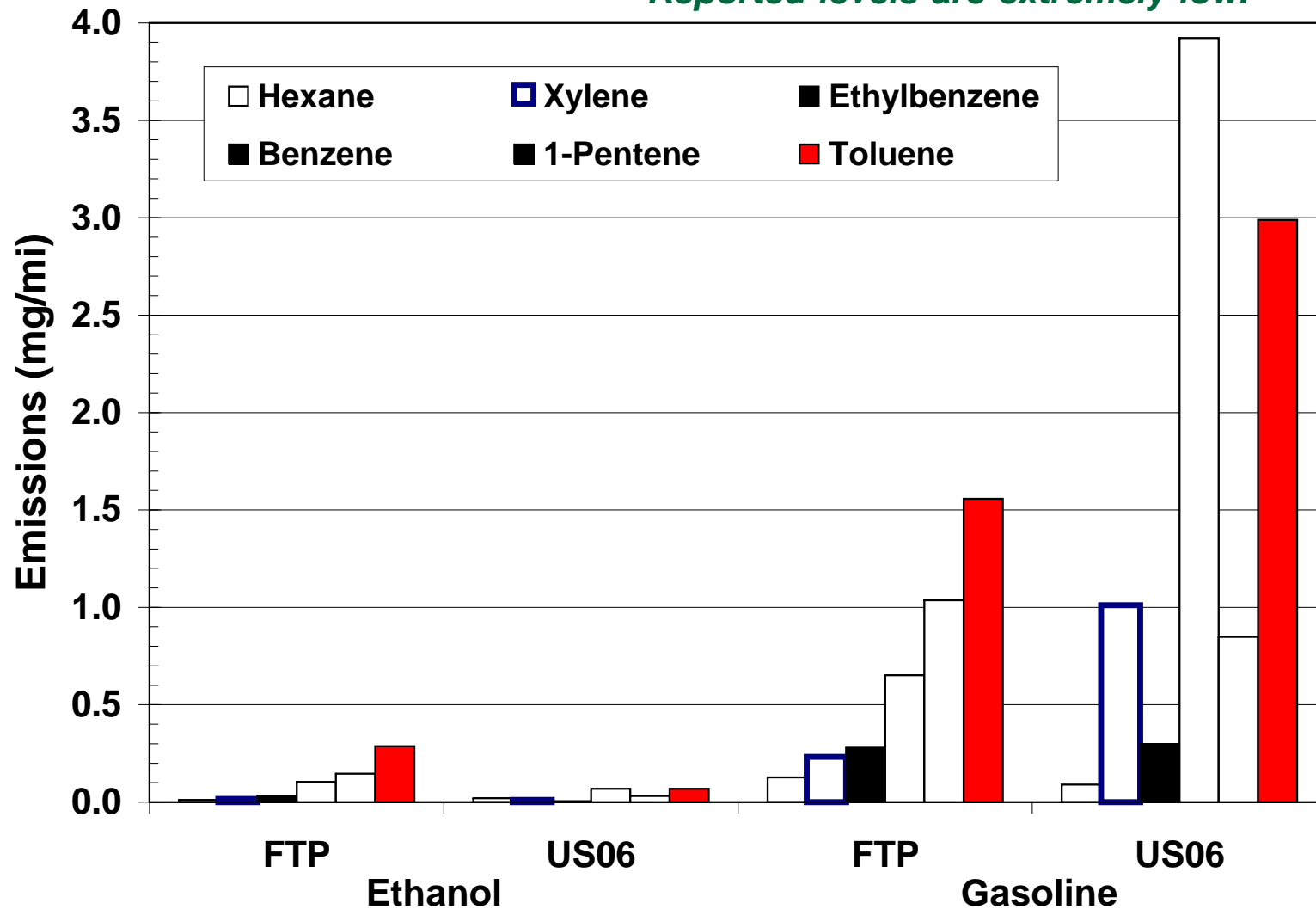
HC: Hydrocarbons NOx Emissions Limit (g/mi)
 NMHC: Non-Methane hydrocarbons
 NMOG: Non-methane Organic Gases
 FTP: Federal Test Procedure

Saab Biopower produces more gasoline-derived HC species on gasoline fuel (ORNL Results).

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**Hazardous Air Pollutants measured via GC/MS. Reported levels are extremely low.*

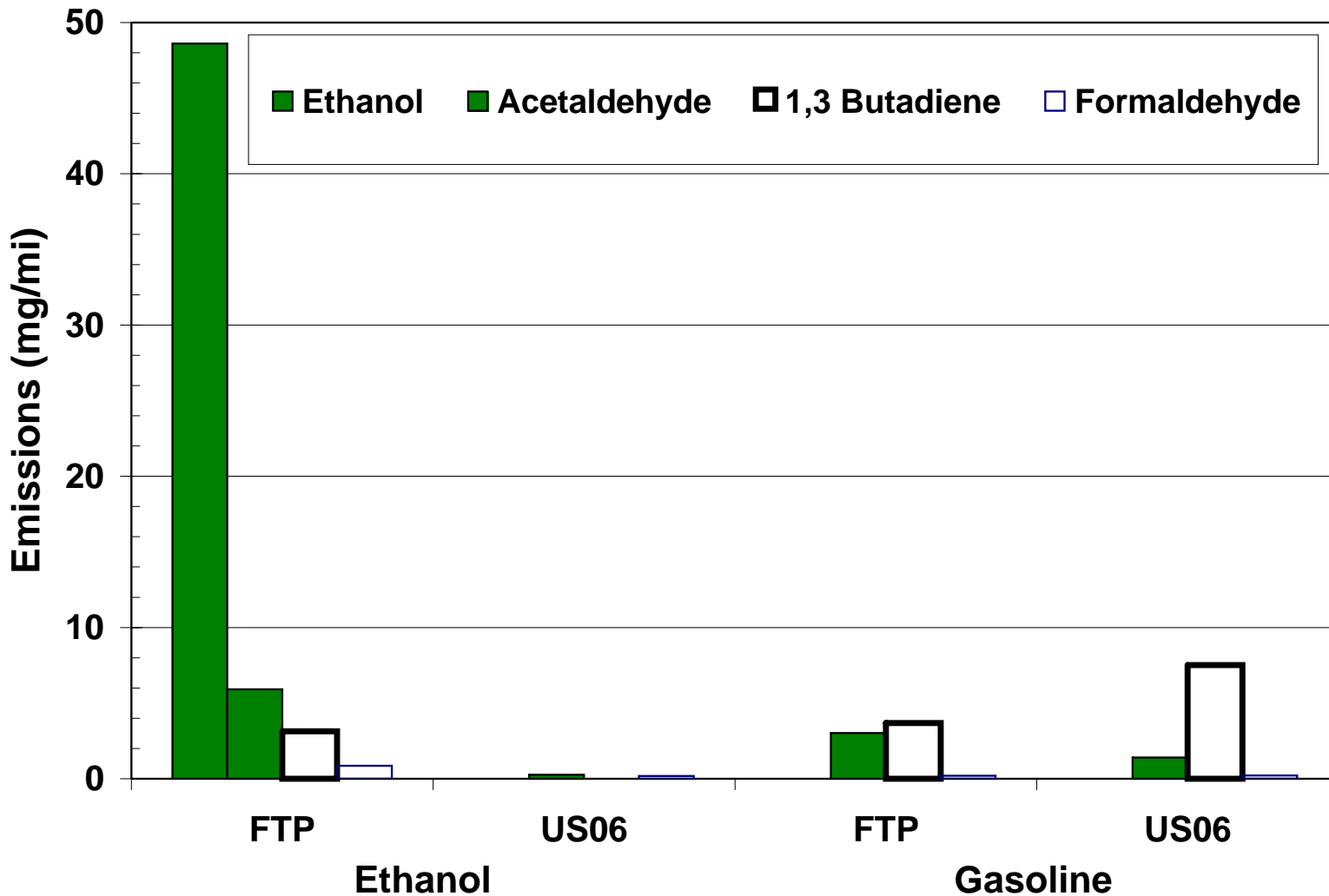


With E85 fuel, Saab produces more ethanol, acetaldehyde and formaldehyde (ORNL Results).

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**Compounds measured with photoacoustic sensor, FTIR, and DNPH cartridges.*



Summary of Emissions Evaluations



- **Saab BioPower appears to be capable of meeting stringent U.S. Tier 2, Bin 5 emission standards, despite**
 - Not certified on U.S. cycles
 - No E85 certification requirement in EU
 - 20% higher power output on E85
 - No sacrifice of emissions for performance
 - Increased power results in lowered CO emissions on aggressive US06 cycle
- **Note that Full Useful Life (120,000 miles) Emissions not measured**
 - Saab measurements conducted at ~4500 miles

Summary of Saab BioPower Benchmarking

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- **Saab BioPower produces 20% more power on ethanol (E85) than on gasoline**
 - Provides a measurable performance advantage
 - May provide additional consumer incentive
 - Leads to lower CO emissions on aggressive US06 driving cycle
- **Saab BioPower emissions on U.S. cycles are below stringent Tier 2, Bin 5 levels** (Note that full useful life emissions have not been measured)
 - Results are significant in that
 - Europe does not require emissions certification on E85
 - Applicable Euro 4 emissions requirements are less stringent than the comparable Tier 2 levels
 - Validates the BioPower as reasonable benchmark for U.S.
- **Detailed exhaust speciation reveals**
 - Ethanol and aldehyde emissions higher on E85
 - Hydrocarbon-based hazardous air pollutants are higher on gasoline
 - Levels of these compounds on either fuel are very low
- **Saab BioPower fuel economy is very good compared to the US FFV fleet**
 - Among higher fuel economy vehicles available in the U.S.
 - Gasoline equivalent fuel economy on E85 on par with U.S. fleet on the highway test (~3% better than on gasoline)
 - Gasoline equivalent fuel economy on E85 is slightly better on the city test (~7% better than on gasoline versus 3% for U.S. Fleet)

Future Plans for Saab BioPower

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- **Additional, more detailed evaluations at ORNL**
 - Engine out and tailpipe exhaust sampling
 - Unregulated compounds
 - Monitoring of engine parameters (Exhaust and catalyst temperatures, RPM, boost, etc)
 - Acceleration performance
- **Follow-on comparisons (FY08) should compare several U.S.-legal FFVs tested at common location on known fuels**
 - Ford Taurus, Chev Impala, Chrysler Sebring, Mercedes C-class available in U.S. as FFVs, have similar rated power and curb weight
- **Evaluation on Intermediate blends of gasoline and E85 may reveal interesting trends in relative fuel economy (FY08)**
- **Butanol and other alcohols are also of interest**
- **Investigate technologies for improving fuel economy (OFCVT project) (FY07-08)**

