Making *Better* Use of Ethanol as a Transportation Fuel With "Renewable Super Premium"

Brian West

Fuels, Engines, and Emissions Research Center

Oak Ridge National Laboratory

Biomass 2013 Meeting

August 1, 2013

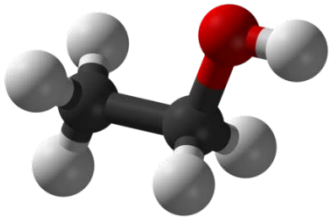
Work supported by DOE Biomass Energy Technology Office and Vehicle Technologies Office

U.S. DEPARTMENT OF ENERGY

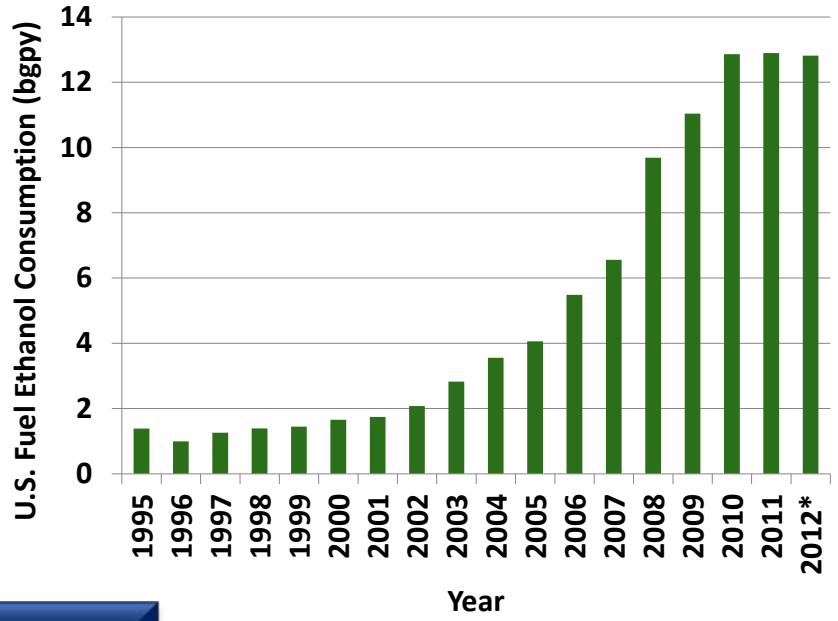
OAK RIDGE NATIONAL LABORATORY

MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Ethanol is currently largest volume biofuel



- **Dramatic growth in ethanol use in last 10 years (over 10 Bgpy)**
- **January 2007 – President launches 20-in-10**
- **December 2007 – EISA sets national goals for biofuel use**
  - 36 billion gal/yr by 2022
- **March 2009 – waiver application for E15**
- **Oct 2010, Jan 2011: EPA grants partial approval to E15 Waiver**
  - First E15 dispenser opened 1 year ago



U.S. Ethanol production.
Data from Energy Information Agency
http://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf
*estimated

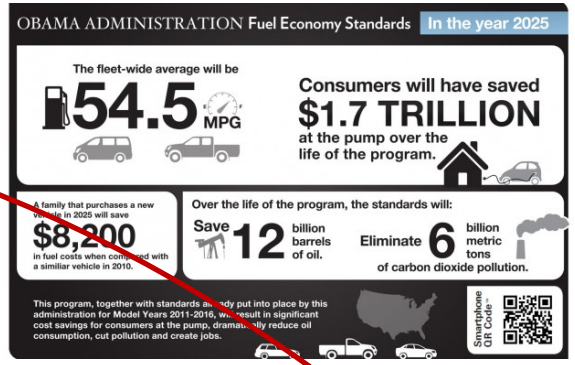
Over 99% of domestic ethanol use in E10 (<1% used in E85 and E15)

Three Major Challenges Facing the Transportation Industry Over the Next Decade

Can more sensible use of biofuels enable CAFE and RFS simultaneously?

54.5 mpg CAFE by 2025

-per U.S. EPA and U.S. DOT standards (2012 rule)



Fuel Economy Standards

Transportation Industry

EPA Tier 3 Emission Regulations

>70% less NOx

>85% less NMOG

Further reductions in vehicle emissions

-per proposed EPA Tier 3 regulations (2013)

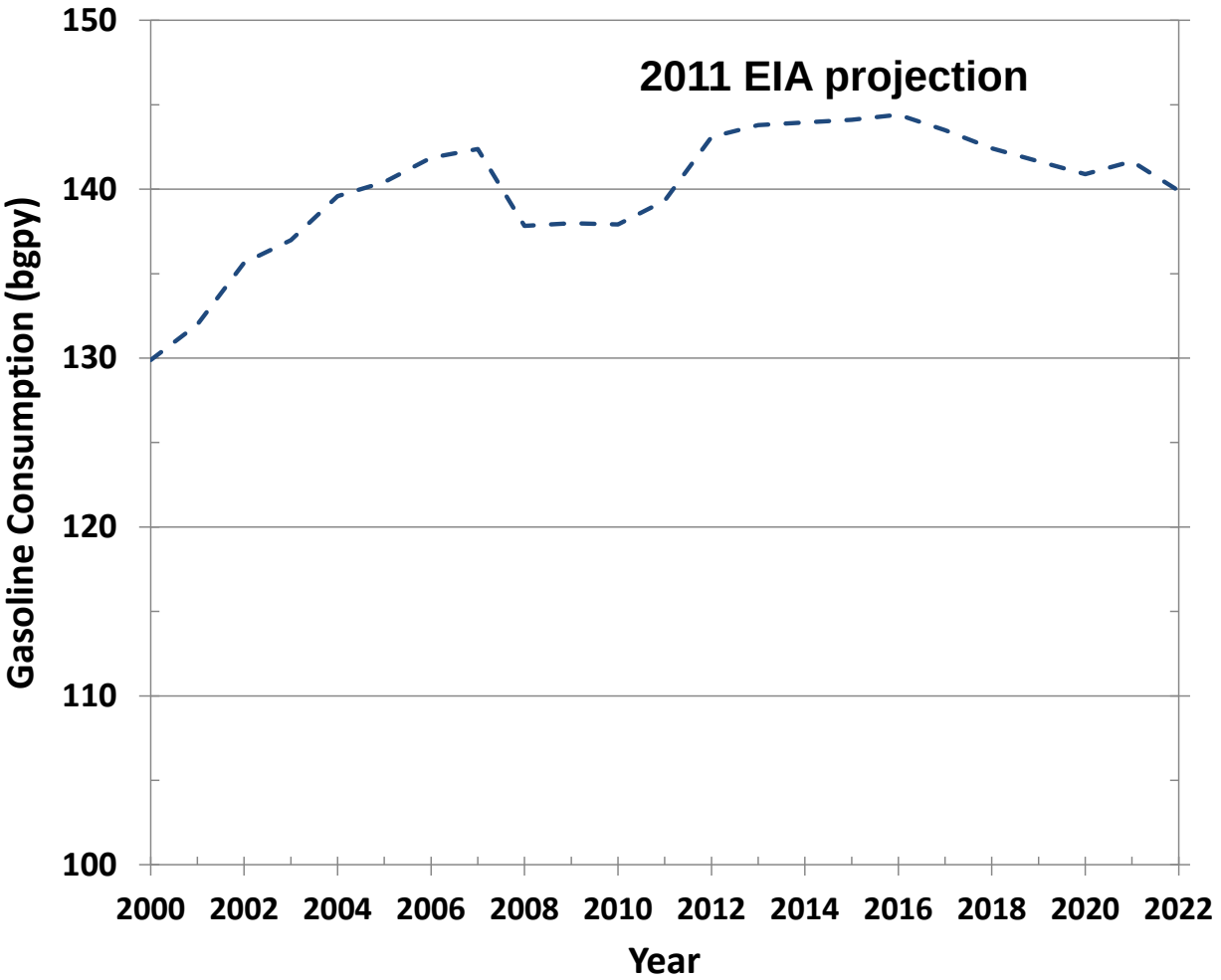
Renewable Fuel Standard

36 billion gallons /yr of renewable fuel by 2022

-per Energy Independence and Security Act of 2007

In 2011, Energy Information Agency projected relatively flat gasoline consumption for next decade

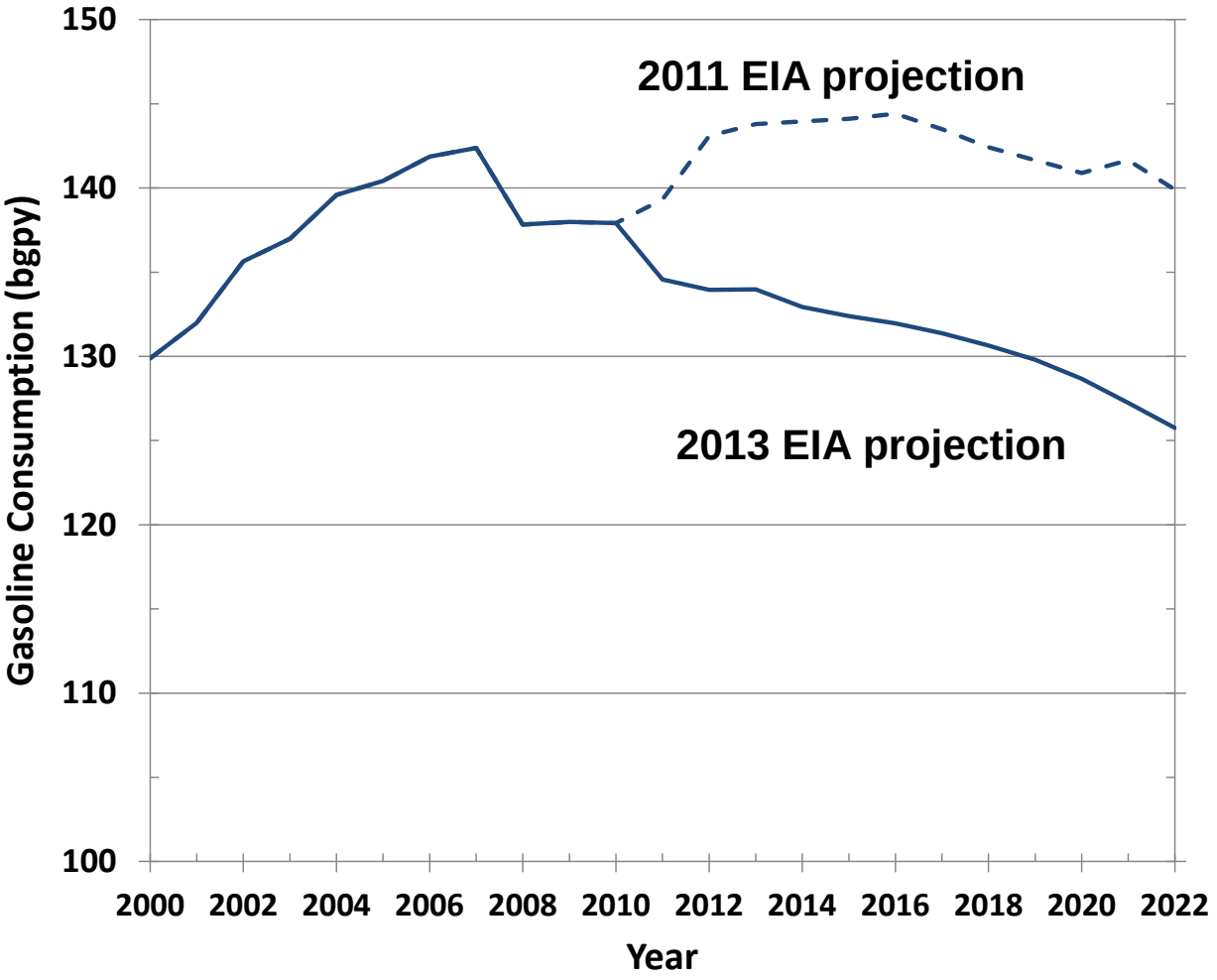
"Motor gasoline" includes E10. Flat demand at ~140bgpy led to projections of E15 allowing for *up to* 21bgpy ethanol. That was 2011….



http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2011&subject=0-AEO2011&table=11-AEO2011&region=0-0&cases=ref2011-d020911a

2013 Energy Information Agency projection shows declining motor gasoline consumption.

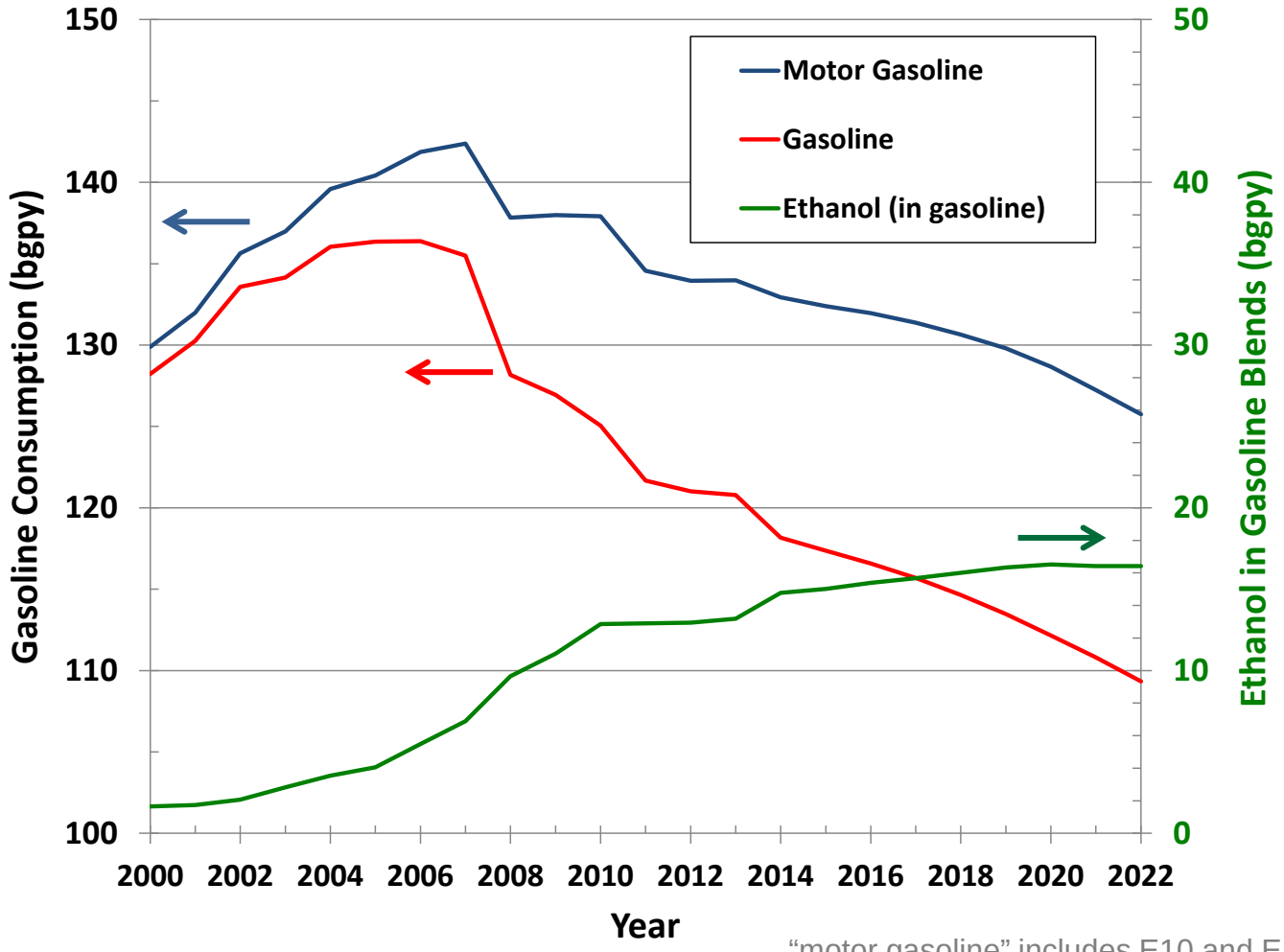
Fuel economy rule finalized in 2012.



2013 Energy Information Agency projection shows declining motor gasoline consumption.

Fuel economy rule finalized in 2012.

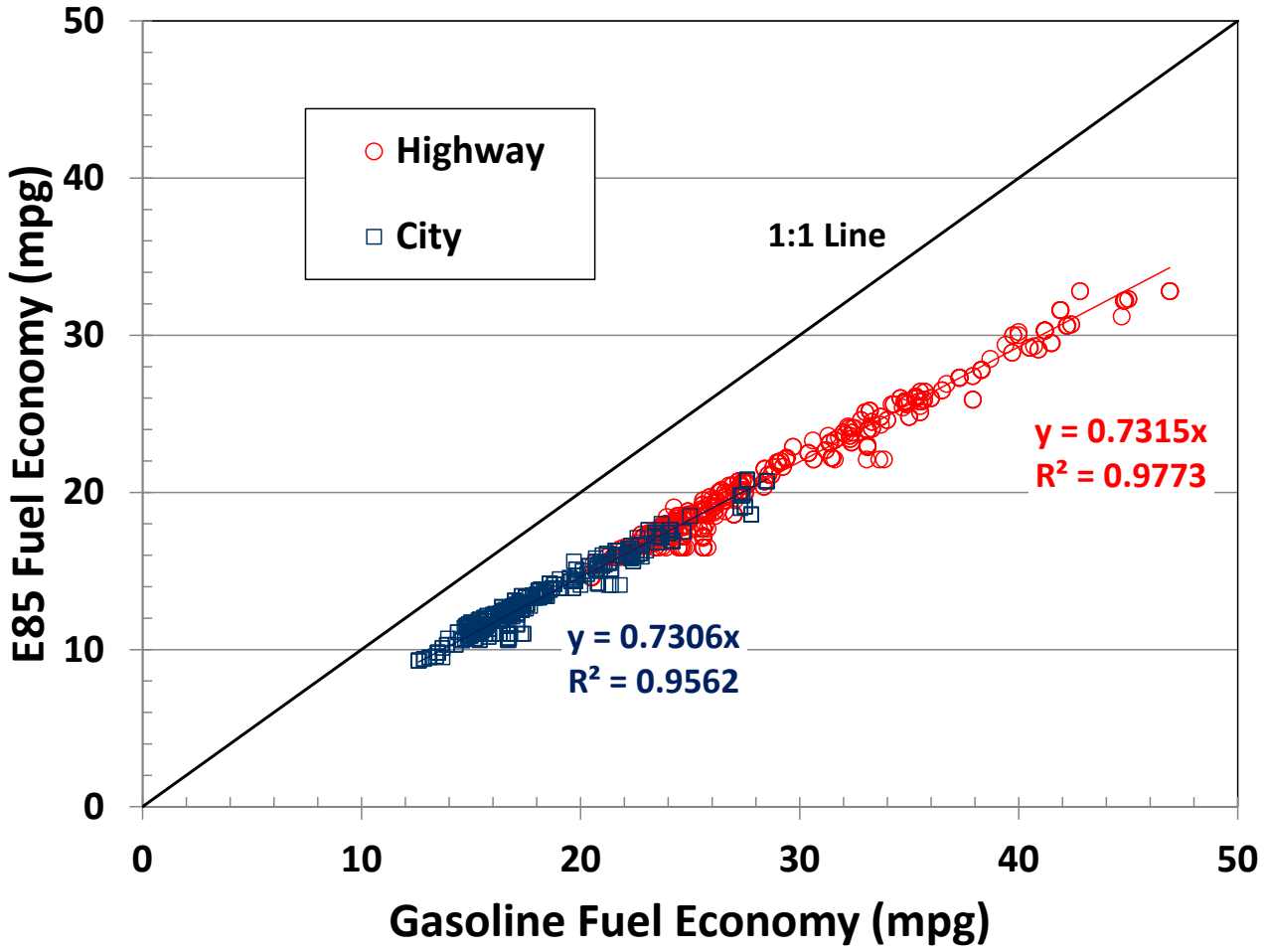
Note ethanol projection (assumes about half motor gasoline as E15 by 2022)



"motor gasoline" includes E10 and E15

Modern Flex Fuel Vehicles are "ethanol tolerant" gasoline vehicles. Fleet average shows 27% lower mpg with E85.

Manufacturers must protect for minimum available octane, so engines take little or no advantage of ethanol's properties to improve power or efficiency.

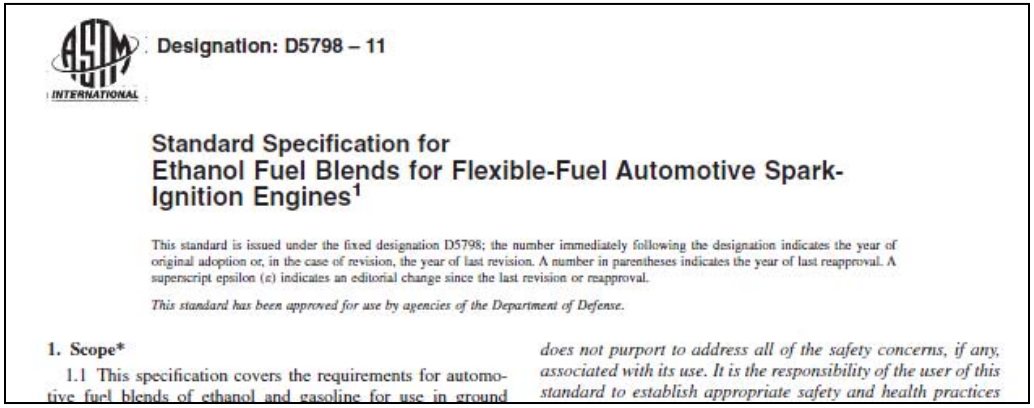


EPA certification data for U.S. legal FFVs, 2000-2012. 649 vehicle records.

Consumers shy away from E85

- **Gasoline/E10 dispensers average ~2400 gal/day**
- **E85 dispensers average <70 gal/day**
  - 14M FFVs on road – **consume 4 gal E85 per veh per year**
- **Lower Energy Density and higher $/BTU (compared to gasoline or E10)**
  - Shortened range
  - Higher cost per mile
- **How much ethanol is in my "E85?"**
  - New ASTM spec for "Fuel for FFVs" allows 51% to 83% ethanol
    - Specification addresses quality and volatility of blends
    - Potential for improved range *some of the time* (when HC portion is higher)
    - Contributes to consumer confusion

Consumer acceptance is key to success of any new fuel



Designation: D5798 – 11

Standard Specification for
Ethanol Fuel Blends for Flexible-Fuel Automotive Spark-Ignition Engines[1]

This standard is issued under the fixed designation D5798; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

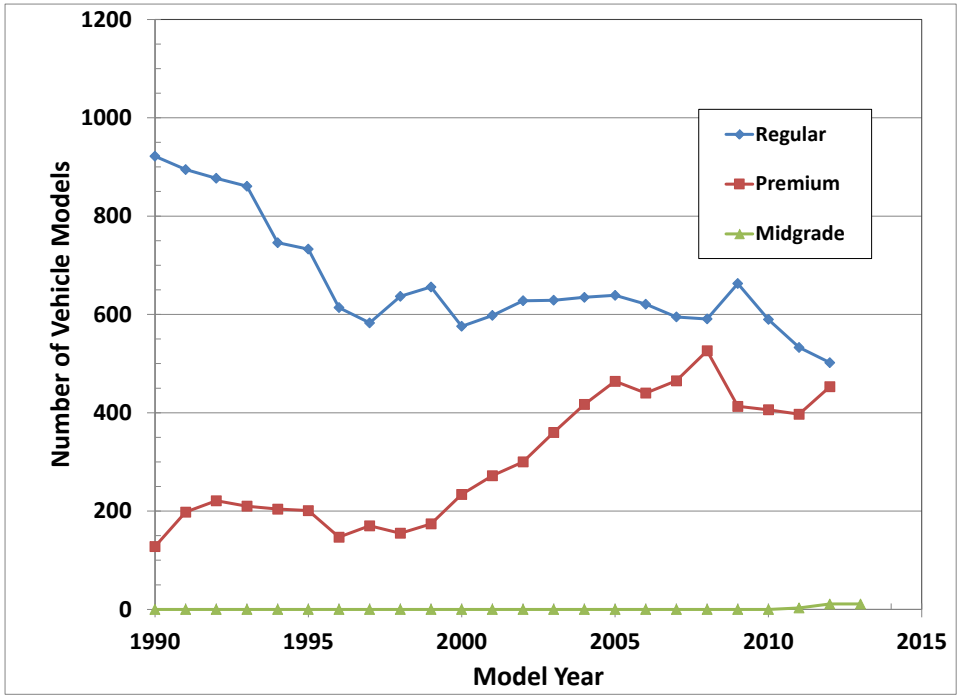
1. Scope*

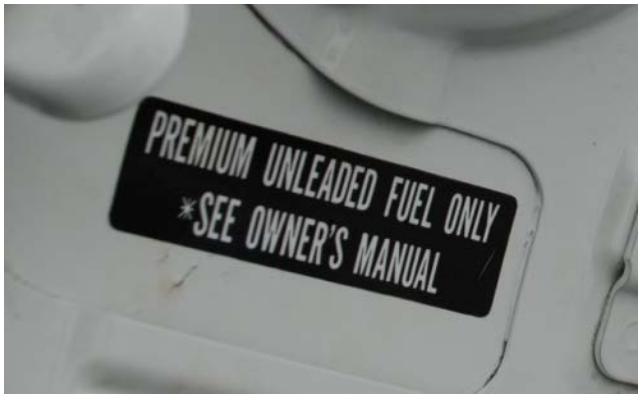
1.1 This specification covers the requirements for automotive fuel blends of ethanol and gasoline for use in ground

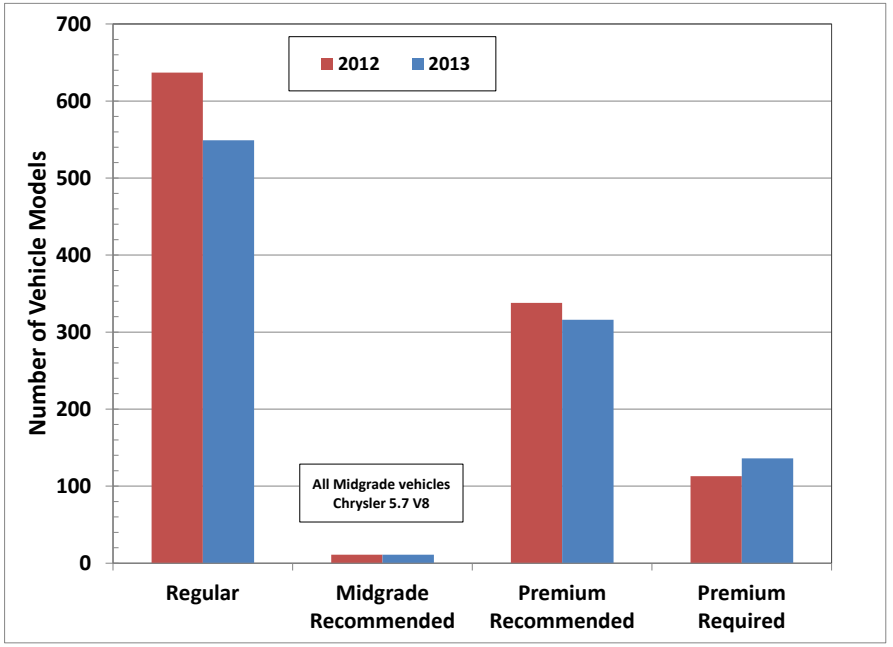
does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices

History of Fuel Recommendation/Requirement Shows Increase in "Premium Required" and "Premium Recommended"

Historically performance-oriented vehicles

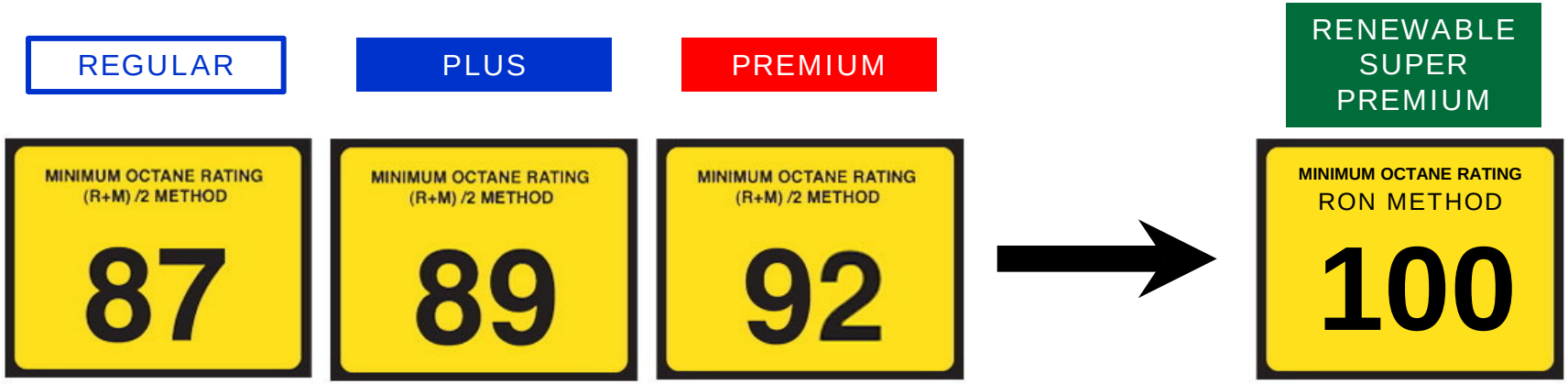






Data mined from www.fueleconomy.gov

IS A "*RENEWABLE SUPER PREMIUM*" A BETTER PATH FOR ETHANOL?

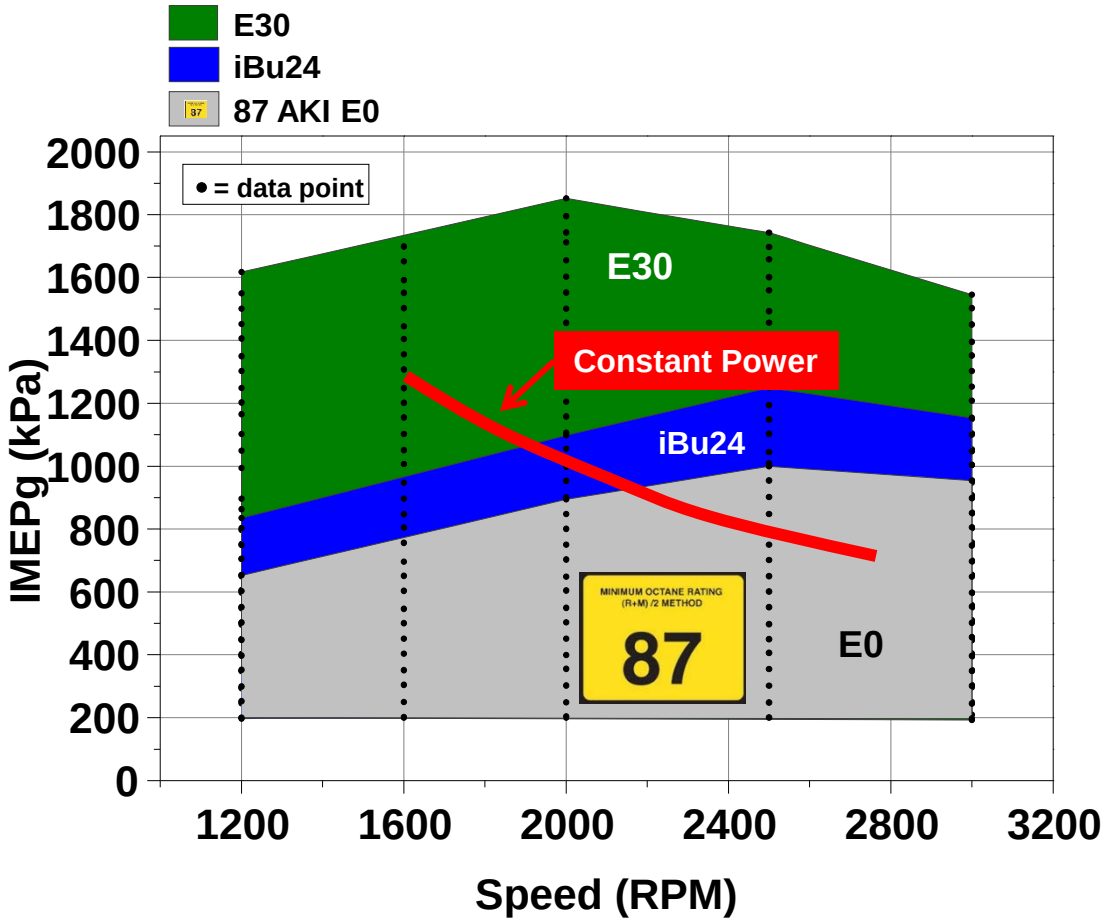


- **Engine efficiency can improve with increasing ethanol (in properly designed future engines/vehicles)**
  - Chemical octane number + latent heat of vaporization permit higher CR, optimized combustion phasing, increased power (downspeeding/downsizing)
- **Likely that optimum blend is ~E20-E40**
  - Energy density penalty is *linear* with ethanol concentration, power and efficiency gains are *non-linear*
  - Tradeoff in efficiency, cost, and MPG
  - Ideal blend in optimized vehicles could enable CAFE (fuel economy) compliance and RFS compliance simultaneously
  - **Also legal to use in ~14M legacy FFVs**

High Octane E30 Enables Doubling of Engine Torque over 87 AKI Gasoline in High CR, Boosted, DI Engine

(ORNL single-cylinder engine data)

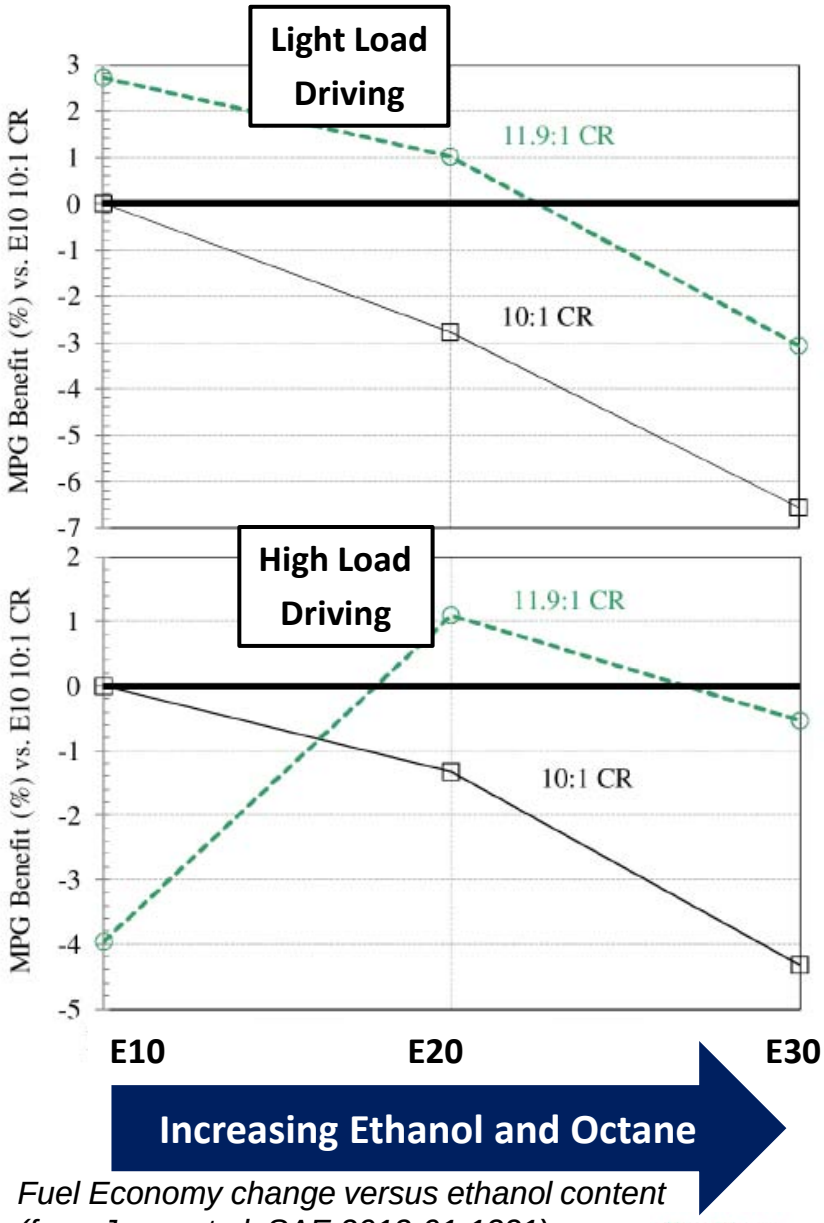
- **Engine map shows available torque as function of speed for 3 fuels**
  - Isobutanol and ethanol added to same base gasoline
- **Isobutanol (24%) provides modest performance improvement over E0**
- **Ethanol (30%) *doubles* available torque**
- **Enables downspeeding and downsizing for improved fuel economy and lower GHG emissions**
  - Supports RFS and CAFE Compliance



Splitter and Szybist, submitted to *Energy and Fuels* 2013

Ford Data Shows Improved Fuel Economy with High Octane Ethanol Blends

- **Ford developed engine maps with three ethanol blends at 2 compression ratios**
- **Modeled vehicle fuel consumption**
- **At light load (highway test)**
  - Higher compression boosts fuel economy with all fuels
  - Fuel economy tracks ethanol content
- **At higher loads (US06 aggressive test)**
  - Higher compression boosts fuel economy with higher octane blends
- **Ethanol can do so much more than bring sub-octane gasoline (BOB) up to 87 AKI and displace 2/3^{rds} of a gallon of gasoline**



Fuel Economy change versus ethanol content (from Jung, et al, SAE 2013-01-1321)

Realizing The RSP Vision Has Significant Potential Benefits And Challenges

Benefits

- **Improved Fuel Economy and GHG**
- **Increased Ethanol Utilization**
- **High Performance Vehicles**

Challenges

- **Infrastructure (production, distribution, retail)**
- **"Regulatory Thicket"**
- **Benefits lost in certification?**
  - Tier 3 proposal "opens door" for a new fuel…
- **Fuel Specifications**
  - D4814, D4806, D5798, new one for RSP?
    - RON, MON, AKI= (R+M)/2
    - Latent heat of vaporization
- **Consumer acceptance and concerns over misfueling in the field**
- **. . .**

Acknowledgements

- **DOE Bioenergy Technologies Office**
  - Alicia Lindauer and Chris Ramig (EPA)
- **DOE Vehicle Technologies Office**
  - Kevin Stork and Steve Przesmitzki
- **Several ORNL Colleagues**

Contact Information

Brian West

westbh@ornl.gov

865-946-1231

Questions?