Ethanol: Pathway to the Fuel of the Future

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As SI [spark ignition] engines are developed to become more efficient, knock will become more likely. Fuels of high anti-knock quality, and with high RON [research octane number] ... will enable future SI engines to reach their full potential. ... ethanol would be very important in making such fuels.”

Gautam Kalghatgi, PhD, head of Research at Saudi Aramco
Why Ethanol?

It’s a No Surprise Molecule

Naturally occurring
Manufactured for millennia
A vehicle fuel for a century
Used around the world today

It’s Safe

Non-toxic
Adds octane without carcinogens
Less polluting refineries

It’s Plentiful

Made from a variety of feedstock (including natural gas)
Production increased 300% in a decade

It Makes Gasoline Better

Lowest cost way to raise octane
Enhances combustion in direct injection engines
Co-Optima Evaluation Criteria
Adapted from 16JUN15 Presentation “Sustainable Transportation” By John Farrell

Impacts Depend on the:

**Engine / Fuel Combination**
1. Greenhouse gas reduction
2. Petroleum reduction
3. Vehicle performance
4. Incremental fuel cost
5. Incremental vehicle cost
6. Land/water use
8. Emissions/aftertreatment
9. Health effects

**Implementation Plan**
1. Greenhouse gas reduction
6. Land/water use
7. Infrastructure compatibility
10. Legacy fleet compatibility
11. Consumer acceptance
12. Scalability
13. Global harmonization
One Possible Engine / Fuel Combination vs E10
High Compression Engines Using a High Octane 25% Ethanol Fuel

**Petroleum Reduction**

- Compression Ratio
  - Low: 7% E10, 16% E25, 25% E25
  - High: 30% E10, 20% E25

**Vehicle Cost**

- Compression ratio = $0 cost
- Can replace < $1,000 worth of other technology

**Fuel Cost**

Fuel Prices Based on 05/14 to 07/16 OPIS Data

- E10 Reg.: $2.66
- E25: $2.65
- E10 Prem.: $2.90

**Vehicle Performance**

- Higher compression + charge cooling = 2X the torque
One Possible HOLC Fuel Implementation Plan
Slash Blend 25% Ethanol Fuel at the Blending Terminal

**Gasoline Blending Today**
- Ethanol Refinery
- Oil Refinery
- 84 AKI Blend Stock
- 91 AKI Blend Stock
- 110 AKI Ethanol
- 87 AKI E10
- 93 AKI E10

**Gasoline Blending 2026 +**
- Ethanol Refinery
- Oil Refinery
- 84 AKI Blend Stock
- 91 AKI Blend Stock
- 110 AKI Ethanol
- 87 AKI E10
- 93 AKI E10

Many Already E25 Compliant
Some Upgrade @ $400 a Pump
Implementation Requires Government and Industry

Regulations

Co-Optima Results .......... 2017?
EPA Mid-Term Review .. 2018
• Evaluation of HOLC fuels
EPA Regulations .......... 2019
• Minimum 98 RON octane standard by 2026
• E10 Premium and HOLC certification test fuels
• Test procedures that recognize low carbon fuels

Marketplace

Automobile Manufacturers
• Plan high compression engines for 2026 and later model years
• Begin to certify new vehicles on HOLC test fuels

Dispenser Producers / Retail Outlets
• Upgrade pumps to dispense E25
• Plan change-over to new labeling
Implementation Checklist

✅ Greenhouse Gases

- **Pump to Wheels**: 0%
- **Well to Pump**: -7.9%
- **Pump to Wheels** changes from 7/16 ORNL Report

- **Legacy Fleet Compatibility**

  Many 2018 – 25 vehicles could use either high octane fuel
  Vehicles requiring E10 will have high octane E10 available
  No chance of misfueling with 2026 + high compression engines

✅ Infrastructure

- Product flow changes at terminal
- Low cost pump upgrades at retailers

✅ Global Harmonization

- Manufacturers have choice of certifying on E10 or E25
Conclusions

Reducing Greenhouse Gases a National Priority
Meet our international obligations
Employ cost effective solutions

Ethanol Can Play an Important Role
Plays to our nation’s strengths
Makes gasoline better
Co-Optima looking for answers

Co-Optima
Evaluating multiple engine / fuel combinations
Results depend upon implementation as well

One Possible Combination
High compression engines
High octane E25 regular fuel

Government and Industry Must Work Together to Implement
So What About the Critics?

3 Year Study for MN Corn

Five former auto industry experts
Over a century of experience
Must believe in our projects
Looked at major concerns

Land Use Change
Federal labs quantified impact
Not a significant problem

Food vs Fuel
False dichotomy refuted by experts

Environmental Impact
Greenhouse gas emissions
Minor part of ag pollution

Economics
No corn ethanol subsidies since ‘11
Reduced the cost of driving
Neither Oil Nor Ethanol is Perfect

Octane Rating

- Measure of fuel’s resistance to pre-ignition
- Low octane rating limits ability to design high efficiency engines

Gasoline

- High energy density (BTU per gallon)
- Low octane rating

Ethanol

- Lower energy density
- Much higher octane rating

### Ethanol in Gasoline Blends

<table>
<thead>
<tr>
<th>Boost the Octane Rating of Gasoline</th>
<th>Replace Gasoline – e.g., E85 in Flex-Fueled Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>E10 Saved Drivers $0.06 per Gallon in 2013</td>
<td>Drivers Paid $0.32 per Gallon More for E85 than E10 in 2013</td>
</tr>
</tbody>
</table>

- Ethanol’s Octane Fully Utilized
- Ethanol’s Octane Benefit Wasted

Provides Energy Security Benefit = $0.46 per Gallon of Ethanol Used
The Intersection of Vehicles and Fuels

**Fuel Properties**

**Energy Density (BTU/Gall)**

Higher Energy Density =
More Power per Gallon

Higher Octane Rating =
- Higher Compression Ratio
- Greater Thermal Efficiency
- More Power With Less Fuel

Greater Thermal Efficiency \times \text{BTU per Gallon} = \text{More Power Output}
Data Used in Presentation
What is the Automotive Industry Perspective?

To Ensure that the Benefits of Individual Personal Transportation Outweigh Its Cost

- Purchase Price
- Operating Cost
- Social Externalities
- Performance
- Utility
- Convenience
The Impact of Ethanol Gasoline Blends Today

10% Gasoline – Ethanol Blend (E10)
- In the market since 1970’s
- Nearly all gasoline today is E10

Refineries: Blend Stock, not Pump Gas
- Blend stock: 84 AKI octane rating
- Ethanol added to boost octane
- Resulting pump gas = 87 AKI octane

Question: What is the Public Impact?
- Cost to consumer
- Environmental

![Graph showing the increase in use of ethanol in gasoline from 1980 to 2020.](chart.png)
EPAct and the EPA MOVES Model

EPAct Test Program

Used Blends not Sold to Public

EPA: “different [results] if splash blends of ethanol in gasoline were utilized”

Particulate Matter Increases

No: 5 Vehicles

EPA: “fuel properties interact ... with vehicle and engine design, controls, and/or calibrations.”

Yes: 10 Vehicles

EPA’s MOVES Model

Vehicle Emissions in Real World

- Problems using MOVES data
- Does not properly represent splash blended fuels like E15

State Implementation Plans

Required by Clean Air Act

Deprives States Tools like E15
E10 vs E0

Adapted MOVES to Compare:
- 87 octane E10
- 87 octane pure gasoline

E10 has much lower:
- Toxic emissions
- CO emissions

Higher HC, NOx and PM
- Calibration not fuel?
- Addressed in Tier 3 by adding an E10 test fuel
High Efficiency Engine Needed

Greater Engine Efficiency = Higher Engine Pressure
- Engine knock limits pressure
- Higher octane reduces knock

New Engine and Fuel Last Low Cost Way to Reduce CO₂
- Higher octane fuel required
- Current “premium” gasoline too expensive

MY 2025 Propulsion Technologies

- High Efficiency Engine
- Fully Utilized Technologies
- Hybrid (Prius)
- Plug-In Hybrid (Volt)
- Battery Electric Vehicle (Tesla)