Transportation Fuels—

Future Options and Opportunities

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University of Wisconsin ERC Research Symposium: Future Fuels for IC Engines
Topics

- The new energy equation
- Future scenarios
- Biofuels and other advanced fuels
- Concluding remarks
Global energy perspectives

- Growing energy demand globally, especially in China, India and Latin America
- Increasing competition and investments for resources
- Developing cleaner fuels and technologies
- Improving energy efficiency
- Diversify supply – integrate sustainable resources
- Growing expectations surrounding climate change
New energy equation

Through 2025

- Total world energy consumption is expected to grow by over 40%
- Global oil demand will increase 1.4% annually
- Demand for natural gas is projected to rise at >2% annually

Source: EIA/DOE International Energy Outlook 2005
Meeting increased demand

- Develop and deploy technologies that will allow us to produce hydrocarbons in complex environments such as ultradeep waters and heavy oil
- Research technologies for conversion of other heavy hydrocarbons to liquid transportation fuels
- Deployment of gas to liquids technologies
- Develop more diverse energy sources/carriers (such as biofuels, hydrogen, etc.)
- Become more efficient in our energy use
Diversification of fuel for Transportation: How big will it really be? What will it be?

Source Data: Chevron & Consultant Consensus
Switching to an alternative fuel vehicle - Three transition criteria for the customer

Energy companies will provide whatever fuels customers demand.

*For a customer to demand an alternative fuel vehicle, they want to see three criteria fulfilled:*

- Equal or improved driving performance, safety, reliability and comfort
- Equal or lower vehicle and fuel costs
- Improved fuel economy & environmental benefits

*How do alternative fueled vehicles fit into this picture?*

*Which fuel and powertrain combinations?*
Future Scenarios Considered

GHG Value

High $/Tonne CO2e

Base Case

Oil Price Low$/bbl

High $/bbl

Low $/tonne CO2e

START

END
Highlighting Favored Fuels/Technologies in Future Scenarios

Some key elements:

Focus on customer economics

Model economics with two key inputs—oil price and CO₂ value—corresponding to scenario

- Key fuel prices (natural gas, coal, biofuels, etc.) are correlated to oil prices
- If mitigated, CO₂ values are considered as a customer credit
- Fuel and technology options are ranked by relative customer cost

This modeling allows transparent “level playing field” comparisons, among many options, on a consistent basis
Some General Observations—
from Scenario Results—20 Year Time Frame

If oil prices and CO2 mitigation values increase to very high, sustained levels:

- Diesels, hybrids, biofuels, and some natural gas based options (eg, GTL diesel) show increasingly favorable customer economics

- Plug-in hybrids, battery-electric vehicles, and fuel cell vehicles remain in a higher customer cost range

The fuel economy option is a critical one
Advanced Engine Technologies are a Key

--They are cost-effective and improving substantially

Advanced technology gasoline and diesel powered vehicles coupled with cleaner burning fuels can meet extremely stringent requirements.

Numerous options available for improving fuel economy and emissions performance.

- Downsizing and Boosting
- Direct Injection Gasoline
- Common Rail Injection
- Increasing EGR
- Cylinder Deactivation
- Advanced Valve trains
- Advanced Control Systems
- HCCI/CAI Combustion

Several dozen vehicle makes and models offered in California meet AT-PZEV or PZEV emissions levels (list at website below)

Evolutionary engine efficiency improvements of about 1%/year

http://www.driveclean.ca.gov/en/gv/vsearch/cleansearch_result.asp
Biofuels Objectives

- Build a focused biofuels organization that coordinates enterprise efforts while actively engaging the emerging biofuels market segment
- Improve the performance of first-generation product quality assurance
- Develop next-generation processing technology to open up the choice of feedstocks, including cellulosic materials
- Improve small-scale distributed manufacturing.
Feedstock to Pump Energy for Gasoline and Ethanol

--Representative Published Values; Conclusions Can Depend on What’s Counted

Btu Spent for One Btu Available at Fuel Pumps

<table>
<thead>
<tr>
<th></th>
<th>Total Energy (Fossil + Renewable) Includes Energy in Feedstock</th>
<th>Fossil Energy Added (NG + Coal + Petroleum)</th>
<th>Petroleum Energy Added</th>
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</thead>
<tbody>
<tr>
<td><strong>Gasoline</strong></td>
<td><img src="image1" alt="Renewable BTU" /> <img src="image2" alt="Fossil BTU" /></td>
<td><img src="image1" alt="Renewable BTU" /> <img src="image2" alt="Fossil BTU" /></td>
<td><img src="image1" alt="Renewable BTU" /> <img src="image2" alt="Fossil BTU" /></td>
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<td><strong>Corn Ethanol</strong></td>
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<td><img src="image1" alt="Renewable BTU" /> <img src="image2" alt="Fossil BTU" /></td>
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<td><strong>Cellulosic Ethanol</strong></td>
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Technology Ventures
Biofuels “Wells to Wheels”
Greenhouse Gas Emissions
--Representative Published Values

<table>
<thead>
<tr>
<th>Per Gallon Gasoline Equivalent</th>
<th>Per Gallon Diesel Equivalent</th>
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</thead>
<tbody>
<tr>
<td>Lb CO₂ Equivalent Per Gallon</td>
<td></td>
</tr>
<tr>
<td>Gasoline</td>
<td>25</td>
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<tr>
<td>Corn Ethanol</td>
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<td>Cellulosic Ethanol</td>
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<tr>
<td>Diesel</td>
<td>30</td>
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<tr>
<td>Soy FAME Biodiesel</td>
<td>10</td>
</tr>
<tr>
<td>Biomass FT Biodiesel</td>
<td>5</td>
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</tbody>
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Current Research Alliances

Georgia Tech - Advanced distributed manufacturing technologies
- Chemical characterization of feedstocks; impact of pretreatment technologies on chemical structure and reactivity of biomass resources
- Analysis of chemical constituents impacting fermentation of enzyme hydrolyzed biomass to bio-ethanol
- Integration of chemical analysis into a systems model for biomass to bio-ethanol production.

UC Davis – Agricultural sciences, biotech, transportation policy
- California-based; biomass identification and development of technologies to grow, harvest and process into transportation fuels
- Potentially includes a demonstration facility

NREL – U.S. National Lab devoted to renewable energy
- Identification, evaluation and development of second-generation biofuels production from biologic pathways (e.g., algae)
- Identification, analysis and characterization of biomass and feedstock

Colorado Center for Biorefining and Biofuels
- The research focus of the center is on the identification and characterization of biomass energy crops and the development of advanced biofuel production technologies.
- Participating research institutions in C2B2 include the University of Colorado at Boulder, Colorado School of Mines, Colorado State University and NREL.

Lincoln University – New Zealand
- Research into developing viable biodiesel crops of commercial value to NZ farmers.

Several other strategic relationships being developed
- Focused on feedstock, conversion technology and logistics.
From Refining to Molecular Design

Improving current fuel performance:
- Very low sulfur levels and other attributes
- Converting heavier crude slates

Creating options for advanced fuels:
- Opening access to new resources, including bio-feedstocks
- Developing fuels and blendstocks that enable maximum benefits from advanced engines
Hydrogen Infrastructure Demonstrations

Public-private partnerships
- Multi-year cost-sharing programs with Federal and State Agencies, industry partners

Objective
- To demonstrate safe, practical hydrogen technologies in real-world settings
- Identify and overcome key technical challenges

Distributed Chevron Hydrogen energy stations
- Designed to fuel demonstration fuel cell vehicles and stationary power applications
- Currently located with strategic partners in California, Florida and Michigan

Limited access
- Not available for public use
- Early-stage applied R&D, reflective of the state of technology
Hydrogen Refueling Station - Oakland

Dual Steam Methane Reforming
Total 150 kg/day generation capacity
- Low Pressure - 75 kg/day
- High Pressure - 75 kg/day

Zero Safety Incidents
360 kg storage
Dual dispensers, 5000 psig
Fill rate – up to 3.6 kg/min
Finding and Encouraging the Best Options

*Enable the winners, don’t pick them*

**There is no silver bullet**
- Issues of dependency, reliability of supply, environmental footprint and cost apply to all fuels to some degree

**All economic fuels - plus conservation - will be needed to meet future demand**
- The government should support conservation and technology development
- Market-based competition amongst technologies should not be inhibited
- Consumers have the means to conserve and are beginning to respond

**Allow time for technology to advance**
- New technologies must offer tangible benefits to consumers and real-world wells-to-wheels benefits to the environment
- Progress on new technologies is like a journey, with lots of unknowns