

Clean Automotive Technology ...  
... on the road to a sustainable future

<http://www.epa.gov/otaq/technology>

# *Future Automotive Fuels Options and Implications*

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**David Haugen**



**U.S. EPA  
National Vehicle & Fuel Emissions Laboratory**

<http://www.epa.gov/otaq/technology>

## **Abstract - *Future Automotive Fuels Options and Implications***

As we now reach the point of crude oil's global production matching global consumption, the economics of automotive fuels will soon see a new balance point in making personal transportation affordable. Either market or regulatory forces may make alternative fuels more attractive for use in the general automotive fleet, and the market's selection process will need to account for (source-to-sink) Green House Gas emissions and "traditional" tailpipe criteria pollutants associated with efficiently consuming using these alternative fuels. Adding challenge to the issue, all credible models are predicting a gap between the end of affordable crude oil and the availability of a hydrogen fuel distribution system as well as timing for affordable mass market fuel cell vehicles available being for sale. Understanding these factors and their influence on developing automotive technology options is critical to those in the automotive industry who are seeking to down-select alternate technology development pathways, as they plan their company's next generation engine and vehicle cycles.

### **Presenter – *Dr. David Haugen***

David Haugen is the Deputy Director of the Advanced Technology Division within the United States Environmental Protection Agency's Office of Transportation and Air Quality. He is also the Manager of the Technology Development Group at EPA's National Vehicle and Fuel Emissions Laboratory in Ann Arbor Michigan. Prior to joining EPA a little over four years ago, he held positions in industry that provided broad experience in diesel engine design, new engine development, engine manufacturing, as well as extensive experience in academia, research and the automotive service industry. He was educated at the University of Minnesota, earning degrees in Mechanical and Aerospace Engineering.

# *U.S. EPA's Office of Transportation & Air Quality National Vehicle & Fuel Emissions Laboratory*

## “Reconciling transportation and the environment”



### Focus of Efforts:

- Characterize emissions from mobile sources and related fuels;
- Assess & promote technologies capable reducing automotive emissions;
- Develop & implement regulatory programs for emissions control, including assessment of the status of control technology and in-use vehicle emissions;
- Ensure compliance with the regulations;
- Implementing programs for the integration of clean-fueled vehicles into the market.



# Factors that can result in Fuels changes for cars & trucks

- ◆ **Economic Dependence on Oil** (economic security)
  - a finite supply
- ◆ **Geopolitics of Oil Reserves** (energy security)
- ◆ **Global Climate Change** (environmental security)

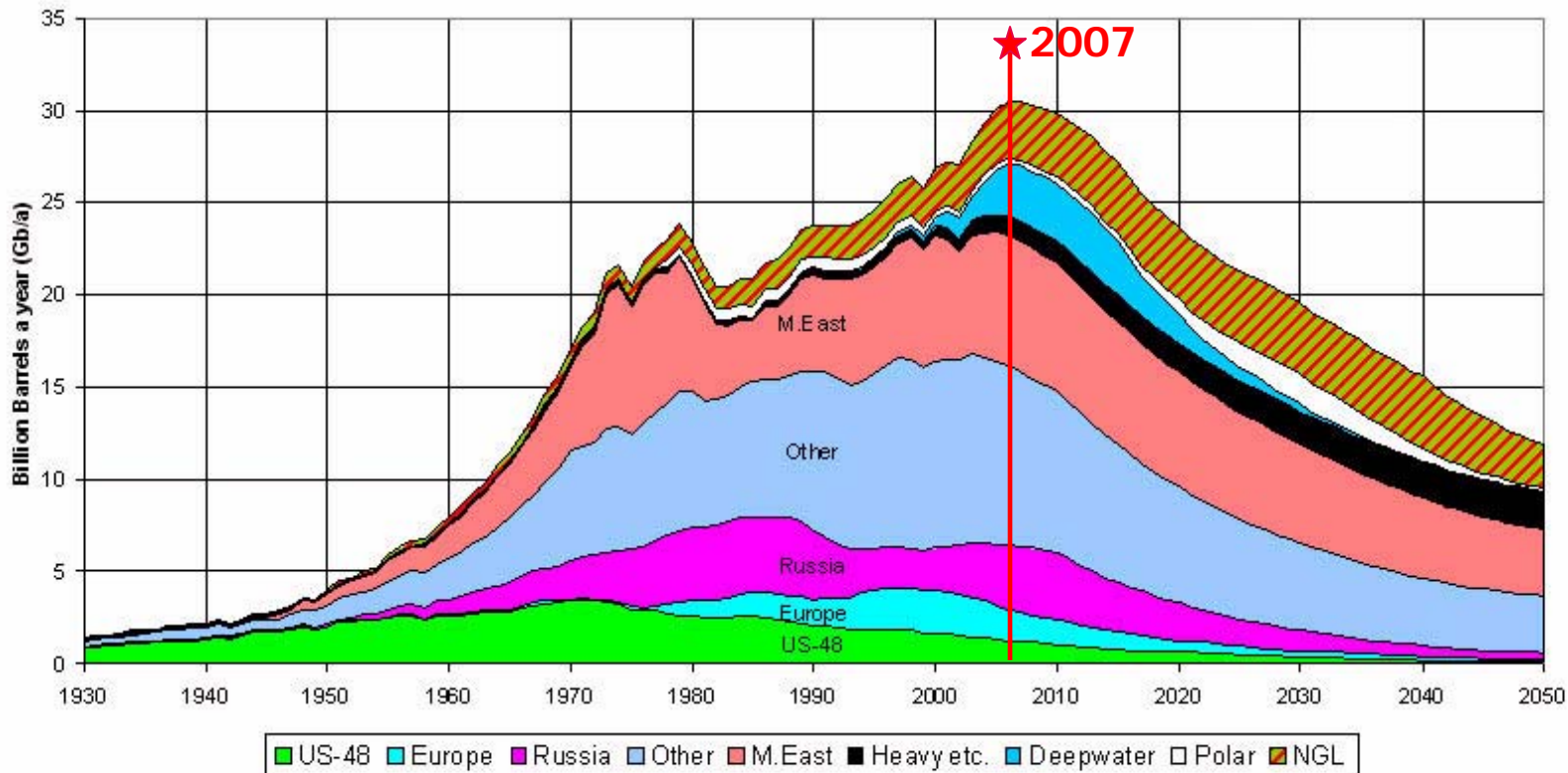
**Future transportation technology must be...**

- **CLEAN** (local pollution) and
- **EFFICIENT** (CO<sub>2</sub>)

*Today's design & engineering decisions will constrain tomorrow's automotive product – Awareness is the start!*

# Economic Security – Finite Oil Reserves

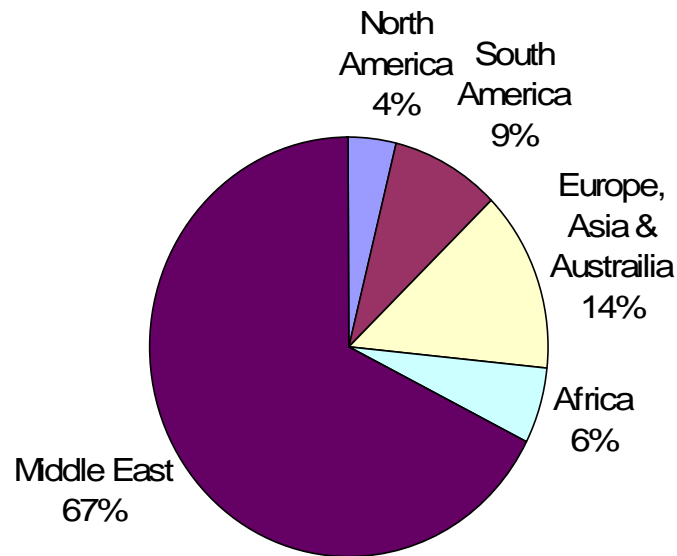
## OIL AND GAS LIQUIDS 2004 Scenario



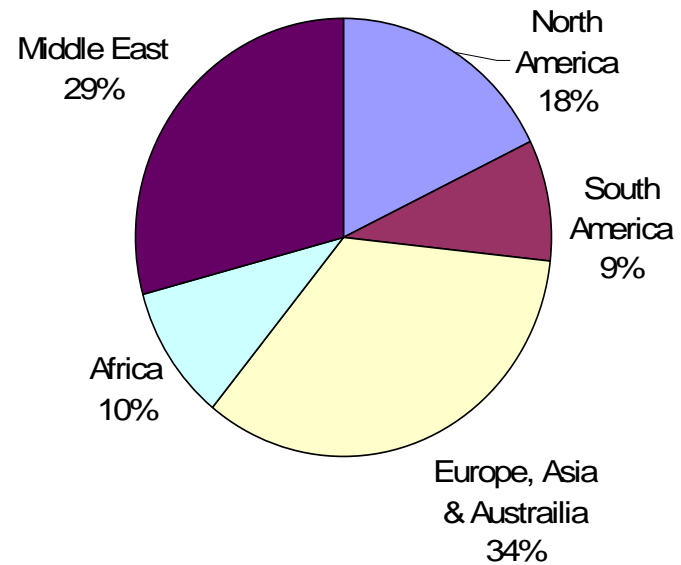
Compiled from EIA data – EPA analysis, 2004

# Energy Security – Where the Oil is Located

## Worldwide Proven Conventional Reserves (2004)

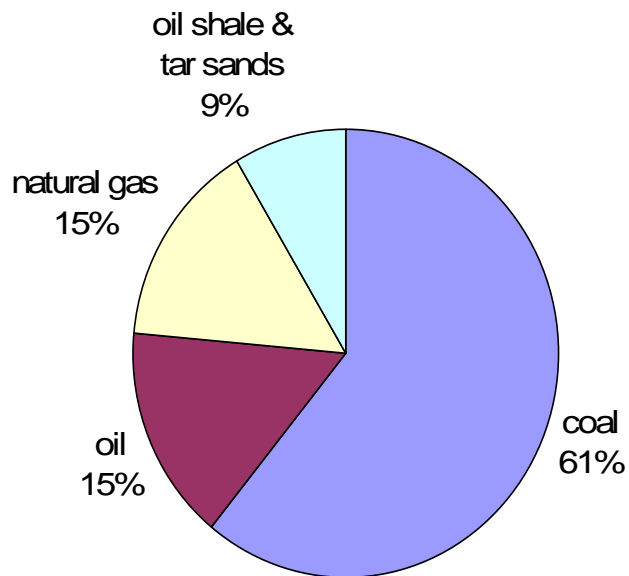


## Worldwide Production (2002)

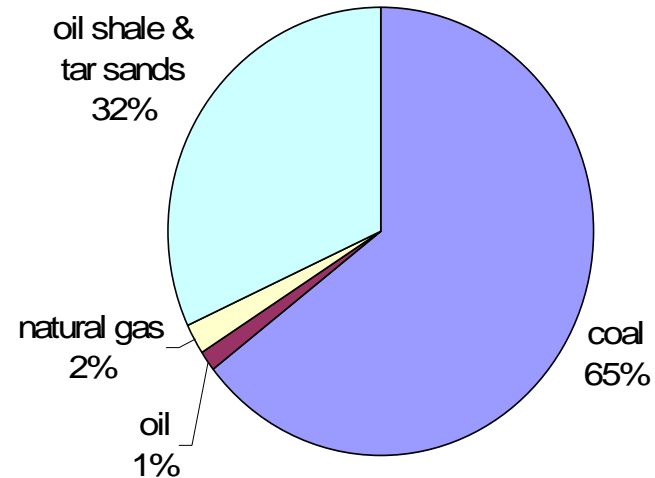


# Environmental Security - Source Availability of Energy Reserves

Worldwide Energy Reserves



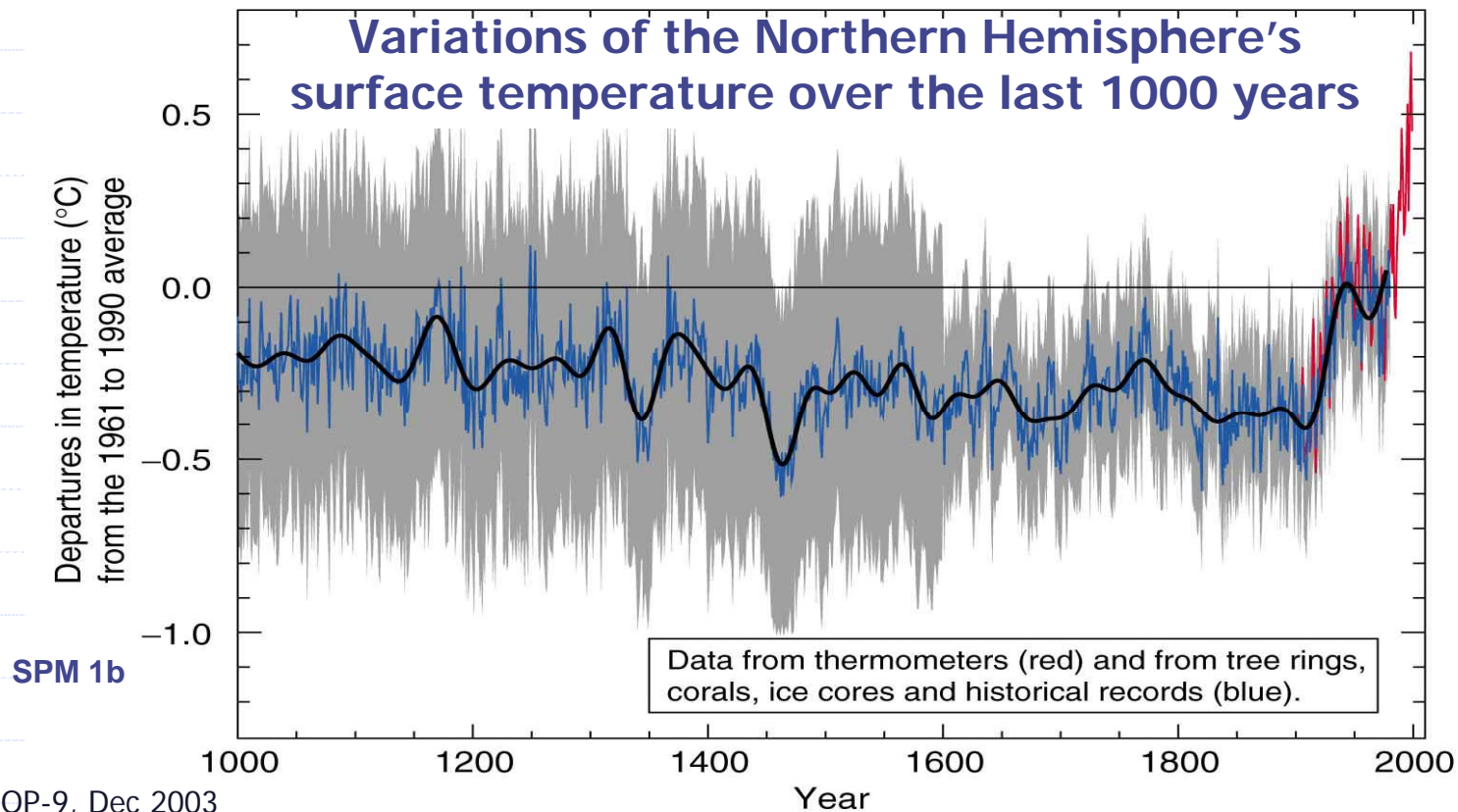
United States Energy Reserves



- EIA/DOE International Energy Annual 2002
- Oil shale data is from World Energy Council

# Global Environmental Security - Climate Change predictions increasing more confident

- ◆ In the U.S., the public's awareness of Climate Change is increasing
- ◆ Industry's growing concern of "risks" of delayed CC action, driven by unknown costs & schedules associated future crisis response

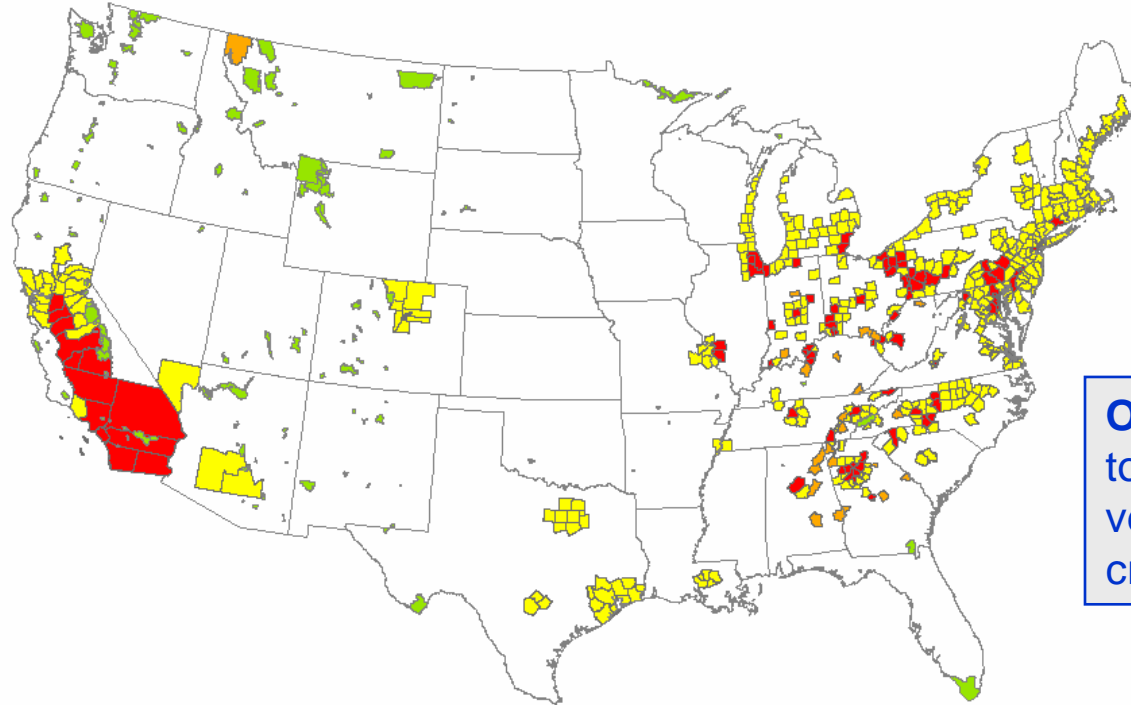


# Local Environmental Protection-

## Further progress in the U.S. is required

**65 million** people live in areas that violate the fine PM air quality standard; **159 million** people live in areas that are not in attainment for ozone

**Fine particles** from diesel exhaust can remain in the atmosphere for weeks, and carry over hundreds of miles



Diesel exhaust is likely to be **carcinogenic** to humans

**Ozone** has been shown to reduce yields of vegetables and field crops

- 8 Hour Ozone Nonattainment Areas
- Counties Exceeding PM<sub>2.5</sub> NAAQS
- 8 Hour Ozone Nonattainment AND PM<sub>2.5</sub> NAAQS Exceedances
- Federal Class I Areas (Visibility)

Clean Air Act requires EPA to take steps to remedy regional haze in **156 pristine "Class I" areas**

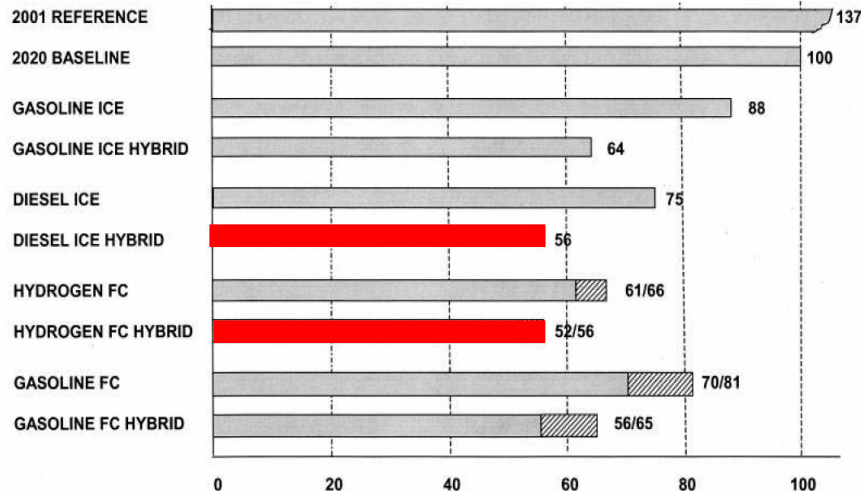
# Fuel Cells - Potential & Timing

## Relative Consumption of Life-Cycle Energy and CO2

## Time Scales for Significant U.S. Fleet Impact

FIGURE 2. RELATIVE CONSUMPTION OF LIFE-CYCLE ENERGY

- Total energy (LHV) from all sources consumed during vehicle lifetime
- Shown as percentage of baseline vehicle energy consumption
- Total energy includes vehicle operation and production of both vehicle and fuel



Implementation Stage	Gasoline DI Spark-Ignition Boosted Downsized Engine	High Speed DI Diesel with Particulate Trap, NO <sub>x</sub> Catalyst	Gasoline SI Engine/Battery-Motor Hybrid	Fuel Cell Hybrid Vehicle On board Hydrogen Storage
Market competitive vehicle	~ 5 years	~ 5 years	~ 5 years	~ 15 years
Penetration across new vehicle production	~ 10 years	~ 15 years	~ 20 years	~ 25 years
Major fleet penetration	~ 10 years	10 - 15 years	10 - 15 years	~ 20 years
Total time required	~ 20 years	~ 30 years	~ 35 years	~ 55 years

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# Beyond Conservation, what are the Choices... Decisions...

## Fuels

- Low Sulfur Gasoline
- Low Sulfur Diesel
- Bio-Diesel
- Fischer-Tropsch Diesel
- DME (Dimethyl Ether)
- Methanol
- Ethanol
- Natural Gas/CNG/LPG
- Hydrogen
- Electricity

*The key is to select powertrains that are exciting to the consumer and are simultaneously cost-effective and ultra-efficient.*

## Engines

- Incremental improvements to Gasoline Engines
- Clean Diesel
- Variable Displacement
- Variable Compression
- DI Gasoline
- HCCI engine
- Fuel Cell
- Free Piston Engine

## Drivetrains

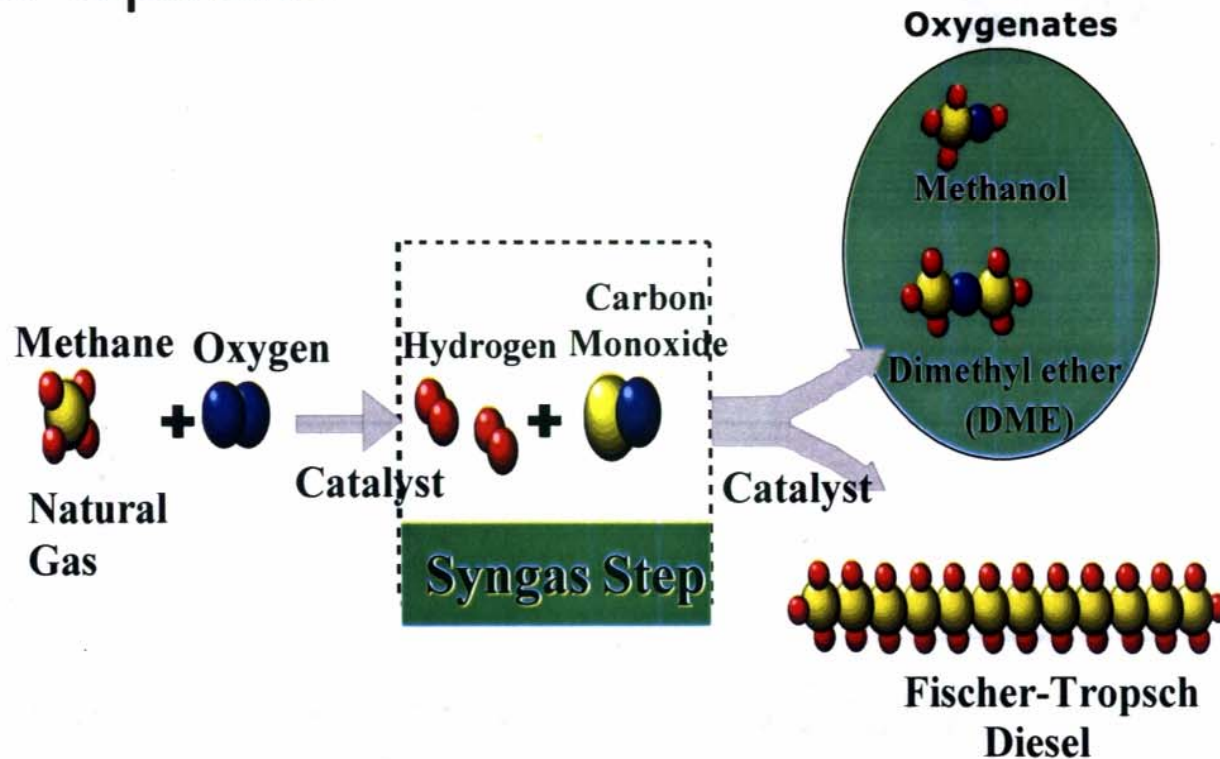
- CVT
- Electric Hybrids
- Hydraulic Hybrids

# Petroleum Alternatives

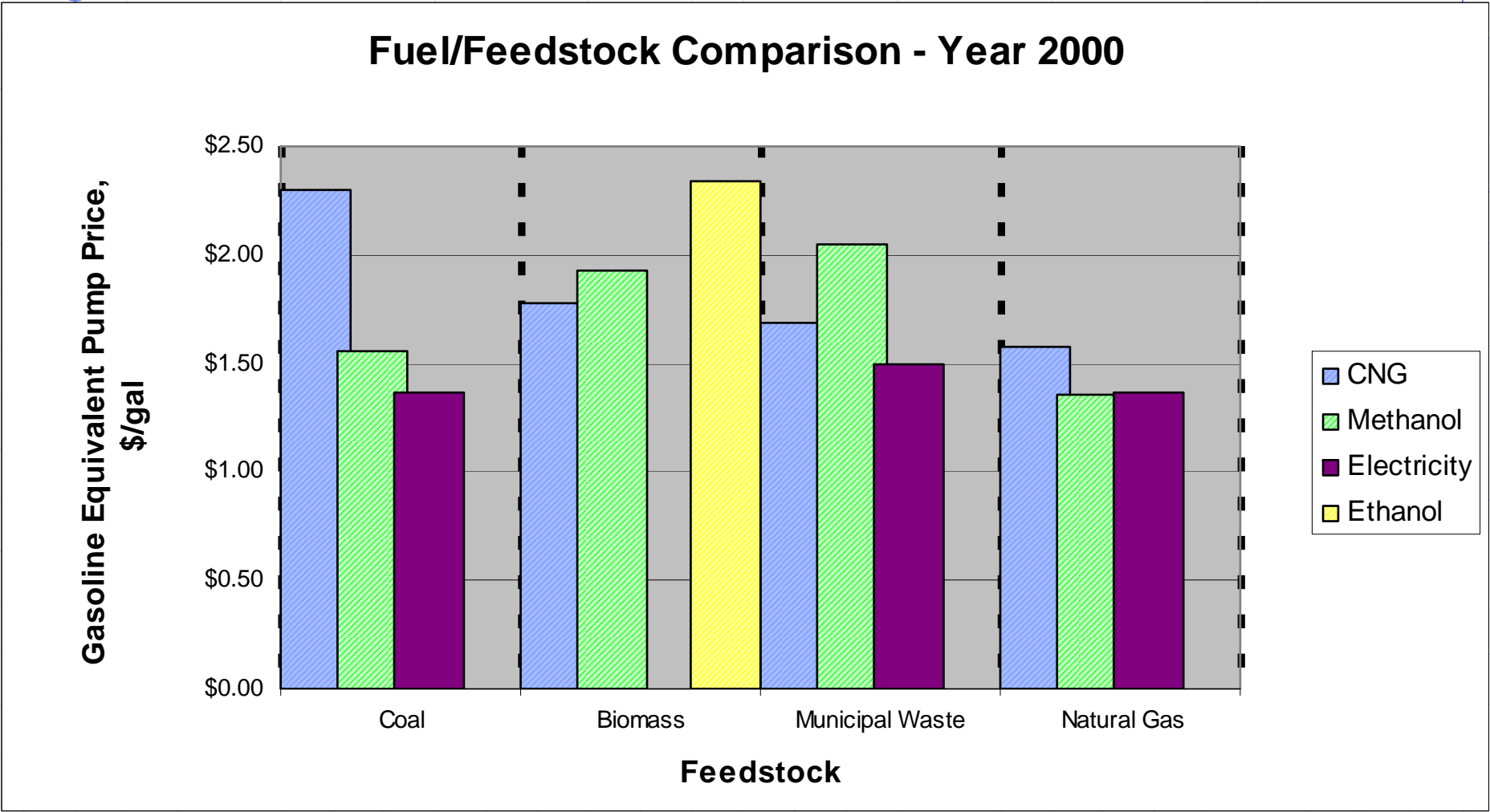


## Low Cost Gas-to-Liquids

Two Options



# Feedstocks for alternative fuels

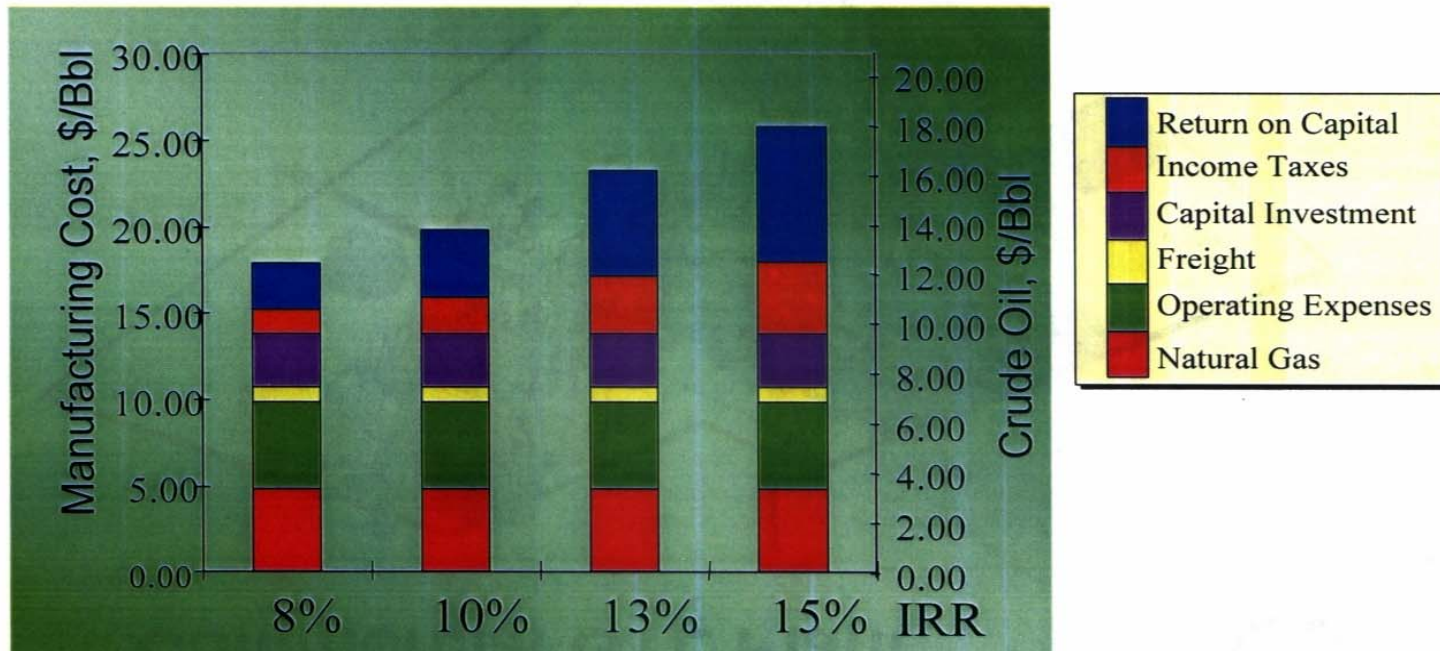


EPA staff study – calculated in 2000 dollars.

# Key Driver is Economics



## GTL-FT Economics - Generic



Source: Gradassi, BP

# Fuels options affect \enable better Advanced Engine Options

## EPA Clean Diesel Combustion

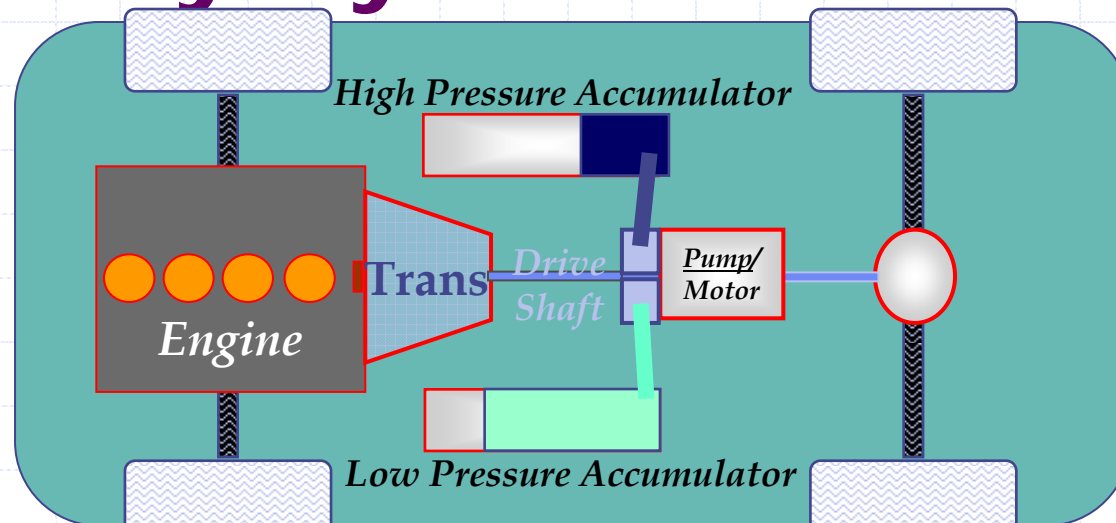
- 4 cylinder engine working, installed in mini-van
- Meets levels of Tier 2/bin5 NOx (without NOx aftertreatment)
- Maintains high diesel efficiency
- Working with industry on application to larger engines
- Public Announcement with *International Truck and Engine Corp.* – May 2004
- Public Announcement with *Ford* – January 2005

## Methanol Engine

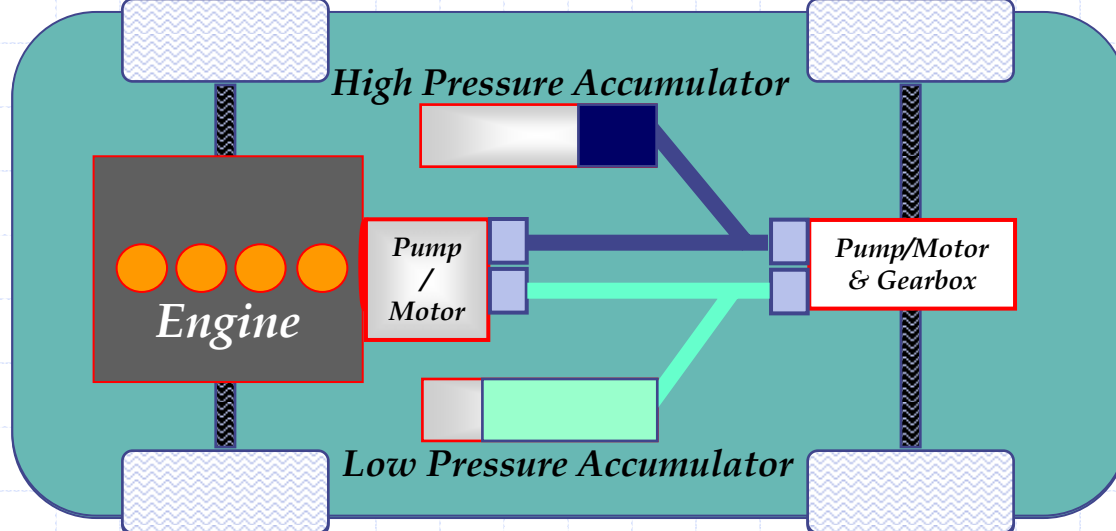
- Great efficiency → 40+%
- Paper in March 2003 SAE World Congress

# Advanced Engines better enabled by Hybrid Drivetrains

**Mild**  
*Hydraulic Hybrid  
(Parallel)*



**FULL**  
*Hydraulic Hybrid  
(Series)*



# More Advanced Engine Options

## leveraging the power of advanced drivetrains

### Full-map HCCI Combustion

- 4 cylinder engine working, installed in truck
- Virtually “no” NOx or PM emissions
- Diesel like efficiency from gasoline
- Excellent engine for a series hybrid
- Paper in March 2004 SAE World Congress

### Free-Piston Engine

- Great efficiency -Hydraulic power directly from engine for series hybrids
- Clean 4-stroke cycle or High Power 2-stroke cycle
- Capable of Clean Diesel or HCCI combustion
- High Reliability/Low Cost potential: fewer moving parts
- Paper in April 2005 SAE World Congress

# Emerging Engine Technologies...

## HyTEC – Hybrid Thermal Energy Converter

- Recovers energy from engine exhaust heat
- Works best with series hybrids or long haul trucks

## Variable Displacement Engine

- Hybrid “peak shaving” allows high efficiency use of smaller displacement engines while retaining the option for sustained high power when needed

## Variable Compression Engine

- Allows low power, very efficient engines to also provide high power performance

# In Conclusion -

## ADVOCATE & PREPARE

- ◆ Have an awareness that Fuel Changes are closer than we might have hoped
- ◆ Know the options & trends as you work on today's products, designs & features
- ◆ Use this knowledge to reduce the legacy design impact, when soon the affects of fuel changes are being incorporated into products you support