



# **Sustainable Mobility**

*Energy Efficiency and  
Advanced Technology Pathways*

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*Environmental and Safety Engineering  
Ford Motor Company*

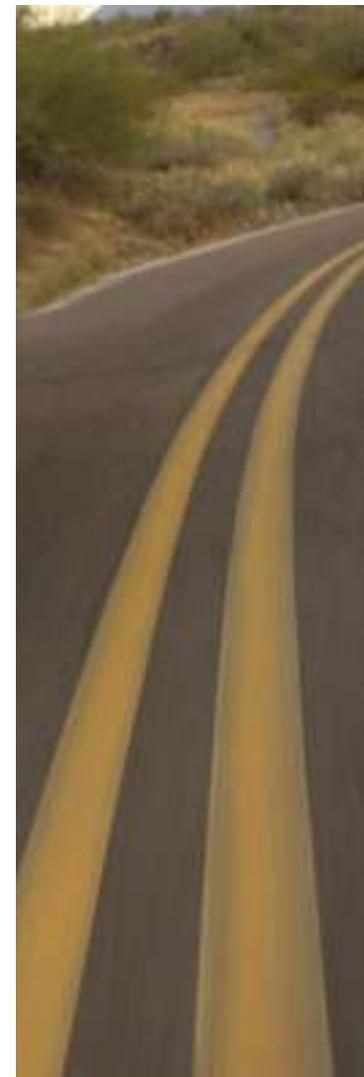
*Mobile Sources Technical Review Subcommittee*

*March 28, 2007*



# Overview

- Sustainable Mobility:  
Our Vision for the Future
- Auto Industry Progress to Date:  
Improvements in Product Efficiency
- Key Challenges Moving Forward
- Pathway for the Future:  
Advanced Technology Vehicles
- An Alternative Pathway For Today:  
Ethanol (E85) Flexible Fuel Vehicles
- The Role of Stakeholders:  
An Integrated Approach





# Sustainable Mobility

“Improved sustainable performance is not just a requirement, but a tremendous business opportunity.”

- *Bill Ford*

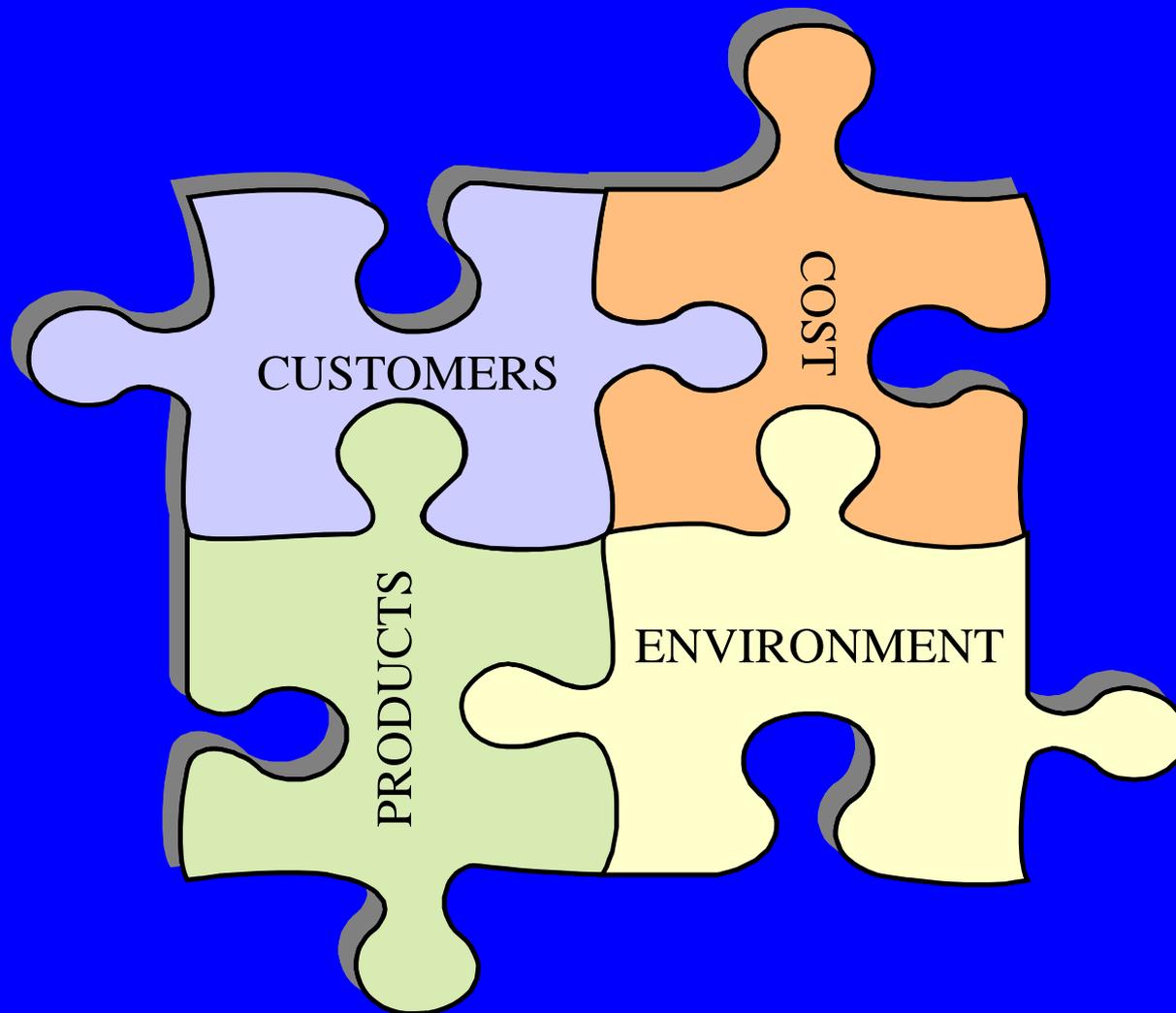


Our vision for the 21<sup>st</sup> century is to provide SUSTAINABLE transportation that is affordable in every sense of the word:

*Socially, Environmentally, & Economically*



# Maintaining a Critical Balance





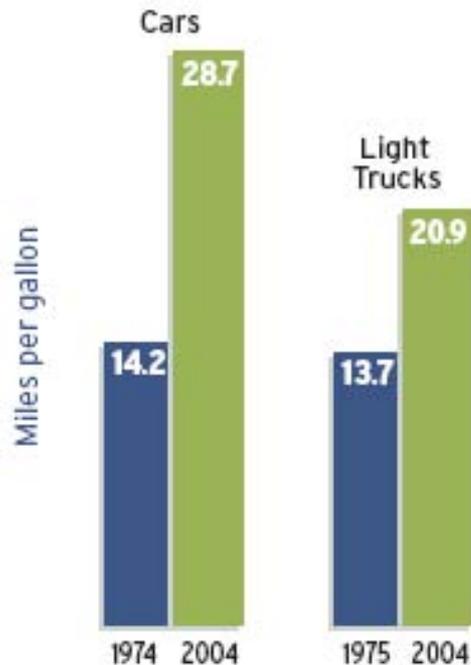
# Global Market Drivers



**Different needs drive different solutions. No Single Solution Fits All.**

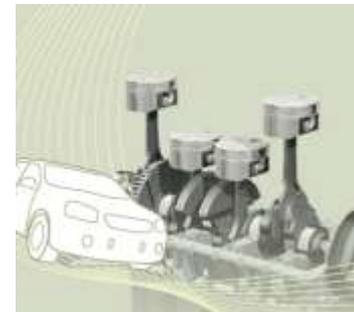


# Auto Industry Progress to Date: Fuel Economy has Increased



- Average fuel economy levels in the mid-1970s
- Average fuel economy levels in 2004

- Fuel economy rates in cars increased more than 100 percent since 1974.
- Fuel economy rates in trucks (minivans, vans, SUVs, and pickups) increased 53 percent since 1975.
- Today's average light truck gets better mileage than an average 1970s compact car.
- The average 2004 SUV gets 33 percent better mileage than the average car in 1975.





# Ford's Family of Brands:

## 13 Models at 30 mpg\* or Better!



**Mazda 3 Sedan**  
35 mpg



**Ford Focus Sedan**  
37 mpg



**Ford Focus Wagon**  
37 mpg



**Ford Fusion**  
31 mpg



**Mercury Milan**  
31 mpg



**Volvo S40**  
31 mpg



**Volvo V50**  
31 mpg



**Mazda 6 Sedan**  
32 mpg



**Ford Escape Hybrid (08)**  
30 mpg (34 mpg city)



**Volvo S60**  
30 mpg



**Mazda MX-5**  
30 mpg



**Mazda Tribute Hybrid (08)**  
30 mpg (34 mpg city)



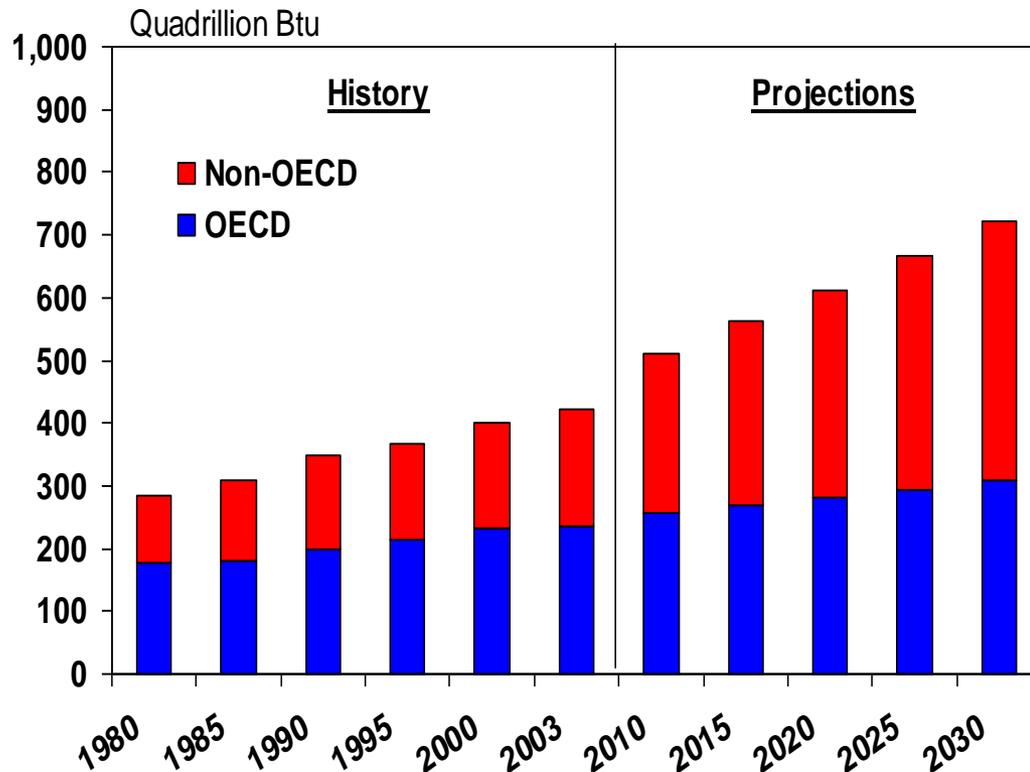
**Mercury Mariner Hybrid (08)**  
30 mpg (34 mpg city)

\* Source: 2007 MY EPA/DOE Fuel Economy Guide – Highway Estimates



# Key Challenges: Energy Demand

## World Marketed Energy Consumption



- World energy consumption is projected to increase 71% from 2003 to 2030
- Most rapid growth in demand from 2003-2030 is for Non-OECD nations including China and India
- Increases result from projected regional economic growth

Sources: History: Energy Information Administration (EIA), International Energy Annual 2003 (May – July 2005), Projections: EIA, System for the Analysis of Global Energy Markets (2006) – Organization for Economic Cooperation & Development.



# Key Challenges: Energy Security

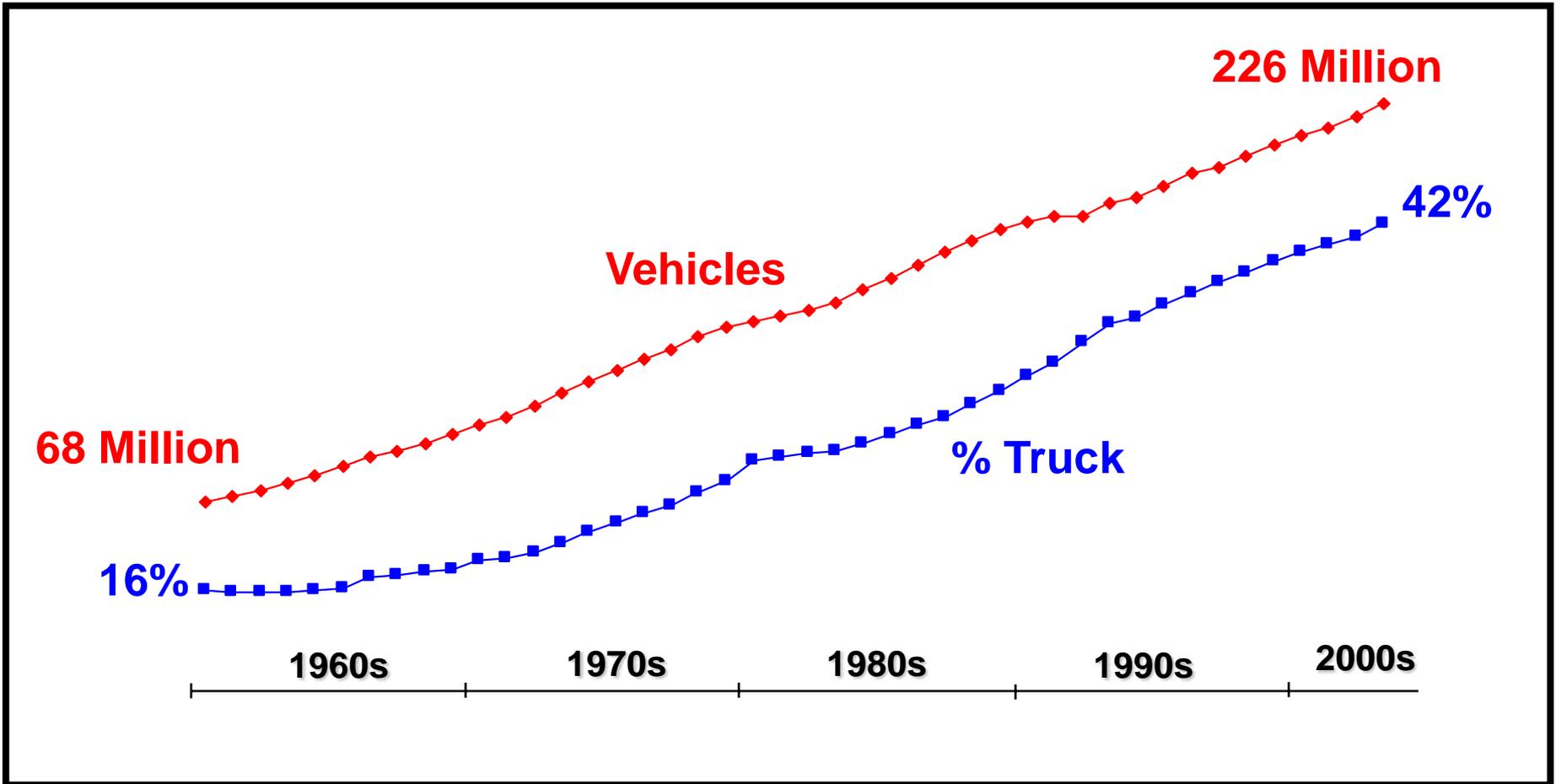
- More than 60% of U.S. oil is imported from foreign sources



- Current volatility in gasoline fuel prices is expected to continue

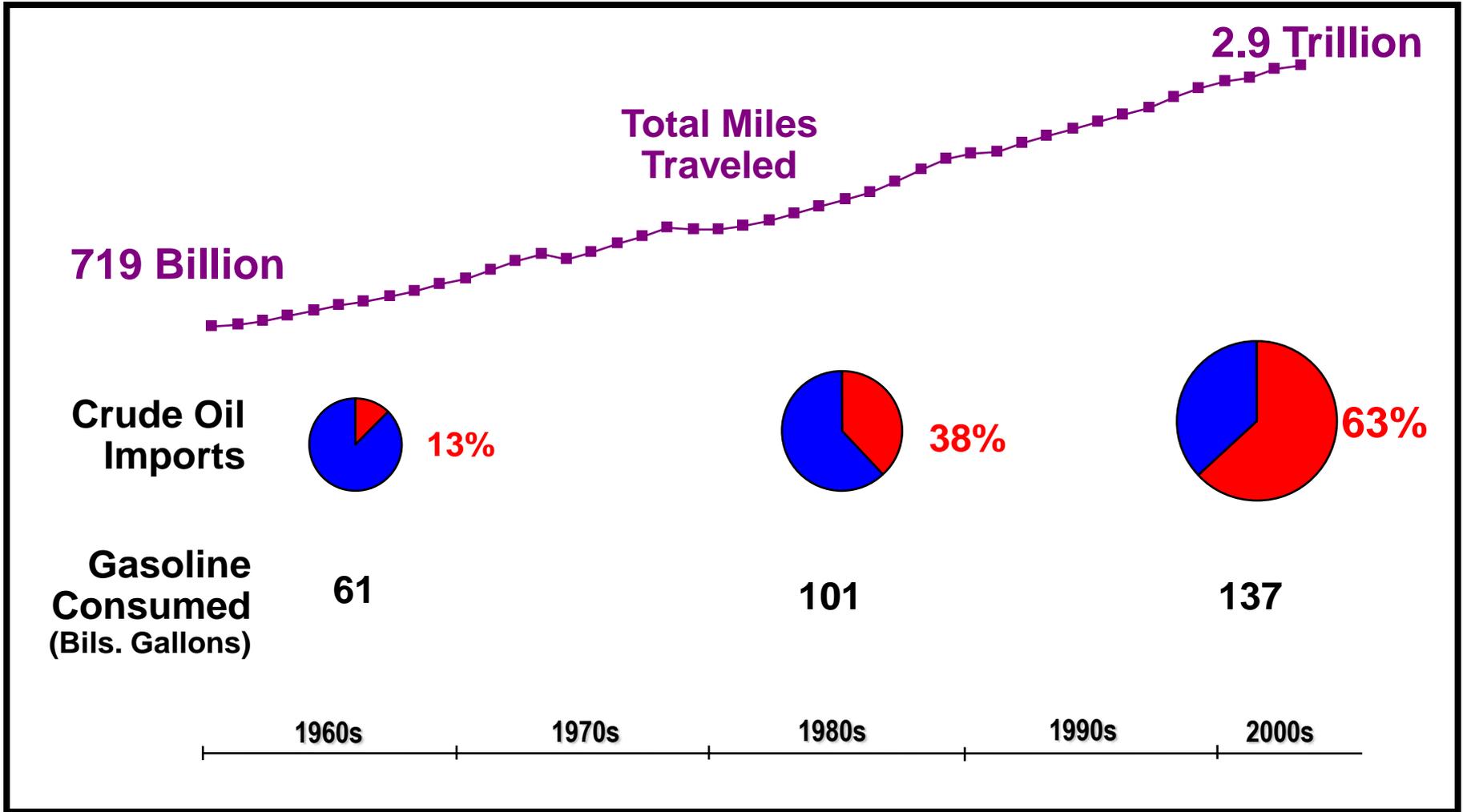


# Overall Fleet Fuel Consumption: Influenced by Vehicle Population & Mix



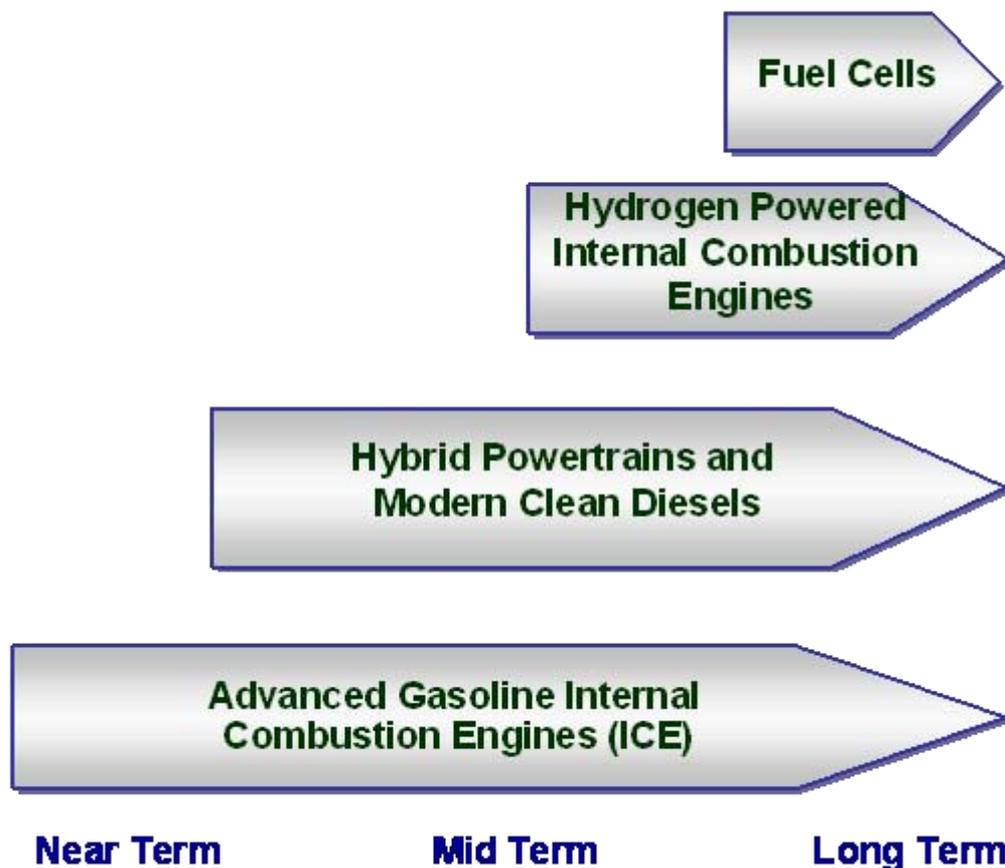


# Overall Fleet Fuel Consumption: Influenced by Vehicle Miles Traveled





# Pathway to the Future: Advanced Technology Vehicles



## **Fuel Cell: Impact in 20-30 yrs**

- Endgame for the hydrogen economy
- Environmentally neutral powertrain

## **Hydrogen Internal Combustion Engines: Bridging technology**

- Bridging action / enabler for H<sub>2</sub> Economy
- H<sub>2</sub> emissions benefits realized in near term

## **Hybrid Powertrain: 10-15% Mkt**

- Market driven niche solution
- Benefits realized in urban driving conditions

## **Modern Clean Diesel: Core for next 40+ yrs**

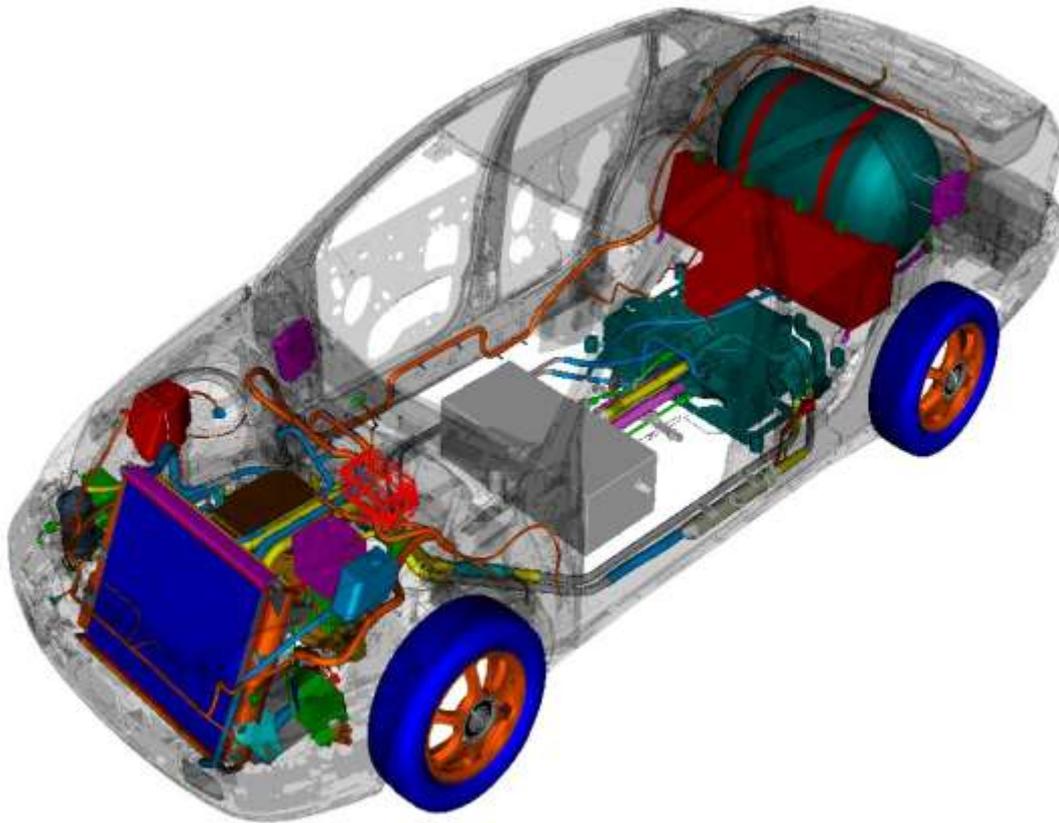
- Challenges – fuel quality, Tailpipe Emissions standards

## **Gasoline Engine Efficiency: Core for 30+ yrs**

- Low cost, reliable, familiar
- Existing capital & refueling infrastructure



# Fuel Cell Powertrains



- ✓ Hydrogen fuel cells are the highest-efficiency technology
- ✓ Currently, Ford has 30 Focus Fuel Cell Vehicles (FCVs) on the road, helping to prove out, develop and demonstrate the technology
- ✓ To be competitive, fuel cell systems must have costs several orders of magnitude lower than today



# Hydrogen Powered Internal Combustion Engines (H<sub>2</sub>ICEs)



- ✓ Key “Bridge” Technology
- ✓ H<sub>2</sub>ICE Shuttle Bus Demonstration w/6.8L Supercharged H<sub>2</sub> Triton V10
- ✓ Holds up to 12 passengers plus luggage
- ✓ Worked with State of Florida, Dallas-Ft.Worth airport, Canadian government and others to launch a 2006 demo fleet



# Hybrid Electric Vehicles



- ✓ “No Compromise” Escape Hybrid delivers improved fuel economy and emissions while providing SUV functionality and utility
- ✓ Over 75% fuel economy improvement in City driving
- ✓ Over 400 mile range
- ✓ Efficiency benefits with engine downsize, regenerative braking, and electric launch and drive
- ✓ Acceleration performance similar to a V-6
- ✓ Meets strict SULEV and AT-PZEV (Advanced Technology PZEV) emissions standards



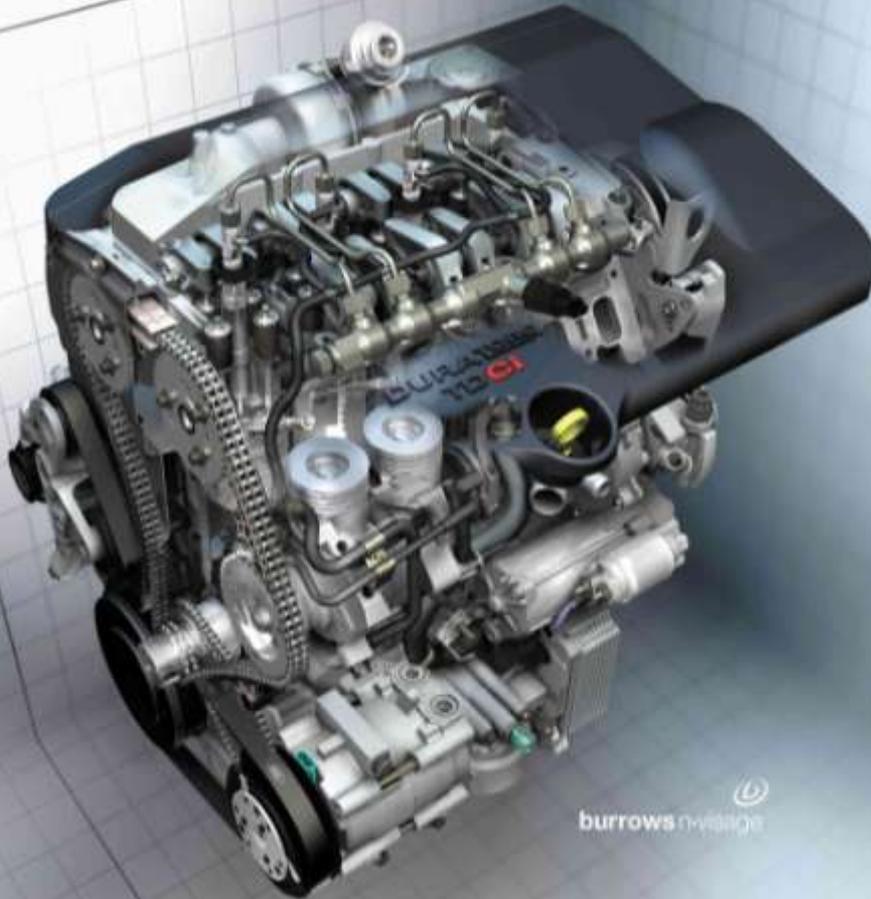
# HySeries Drive™ Technology with Plug-In Capability



- ✓ First drivable fuel cell HEV with plug-in capability
- ✓ Operates using a fuel cell, small gasoline or diesel engine connected to an electric generator
- ✓ Powered by a 336-volt lithium-ion battery pack (refreshed by an on-board charger from a standard home outlet)
- ✓ Drives first 25 miles on stored electricity, after which the fuel cell kicks in to keep battery charged (provides additional 200 miles range)
- ✓ Significant technical hurdles to overcome before commercialization – including fuel cell and lithium-ion battery costs



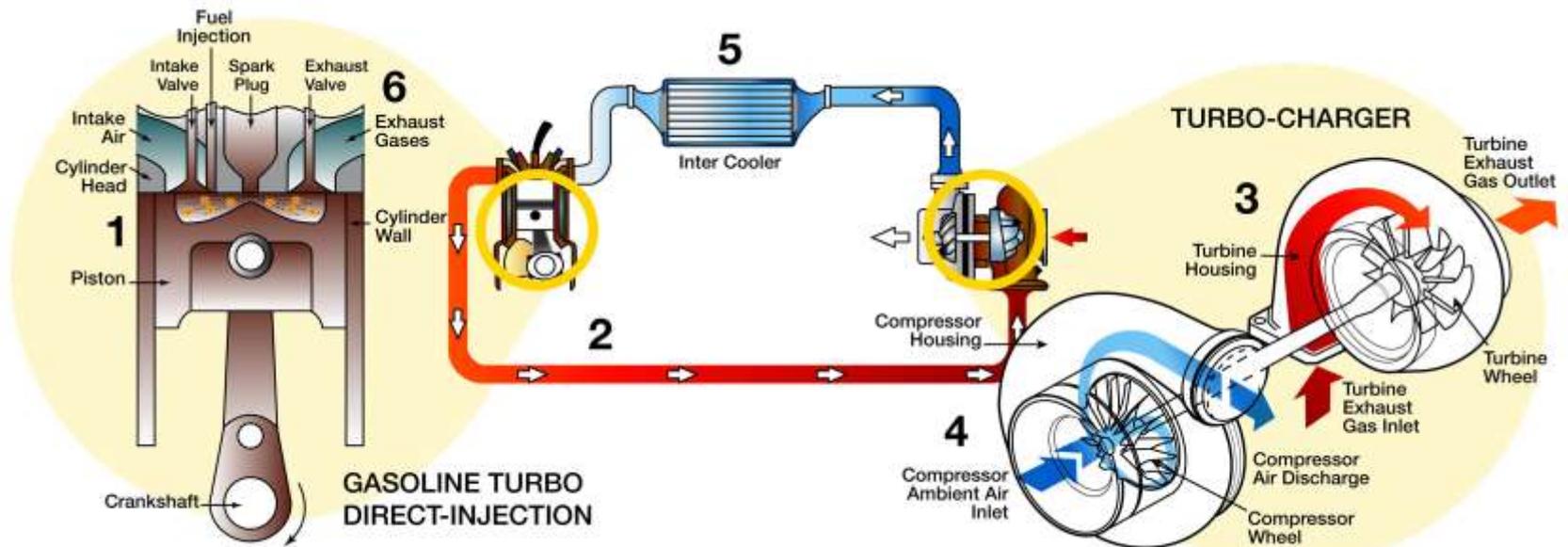
# Modern Clean Diesels



- ✓ Significant increase in fuel economy (20-30%)
- ✓ Higher performance, less noise, less odor
- ✓ Improved emissions performance



# Advanced Gasoline Internal Combustion Engines (ICEs)



Below is how Ford's gasoline, turbocharged, direct-injection system operates:

- 1: A precisely controlled amount of gasoline is directly injected into the engine's cylinders at high pressures.
- 2: Exhaust gas from the engine is routed to a turbocharger.
- 3: The exhaust air drives the turbine, which drives the compressor.
- 4: The compressor then compresses the intake air.
- 5: The compressed intake air is then routed through the inter cooler and to the engine. Cooling the intake air before it reaches the engine improves combustion.
- 6: The air is then forced at high pressure into the engine cylinder mixing with high pressure gasoline.





# A Pathway for Today: Ethanol (E85)



- Ethanol has been a transportation alternative fuel choice for more than 10 years
- About 3.5 billion gallons of ethanol were sold for transportation purposes in 2005
- Most U.S. ethanol is currently derived from corn
- Ethanol produced from cellulosic feedstocks planned for the future





# Why Ethanol Now?

*Opportunity for Immediate Impact*

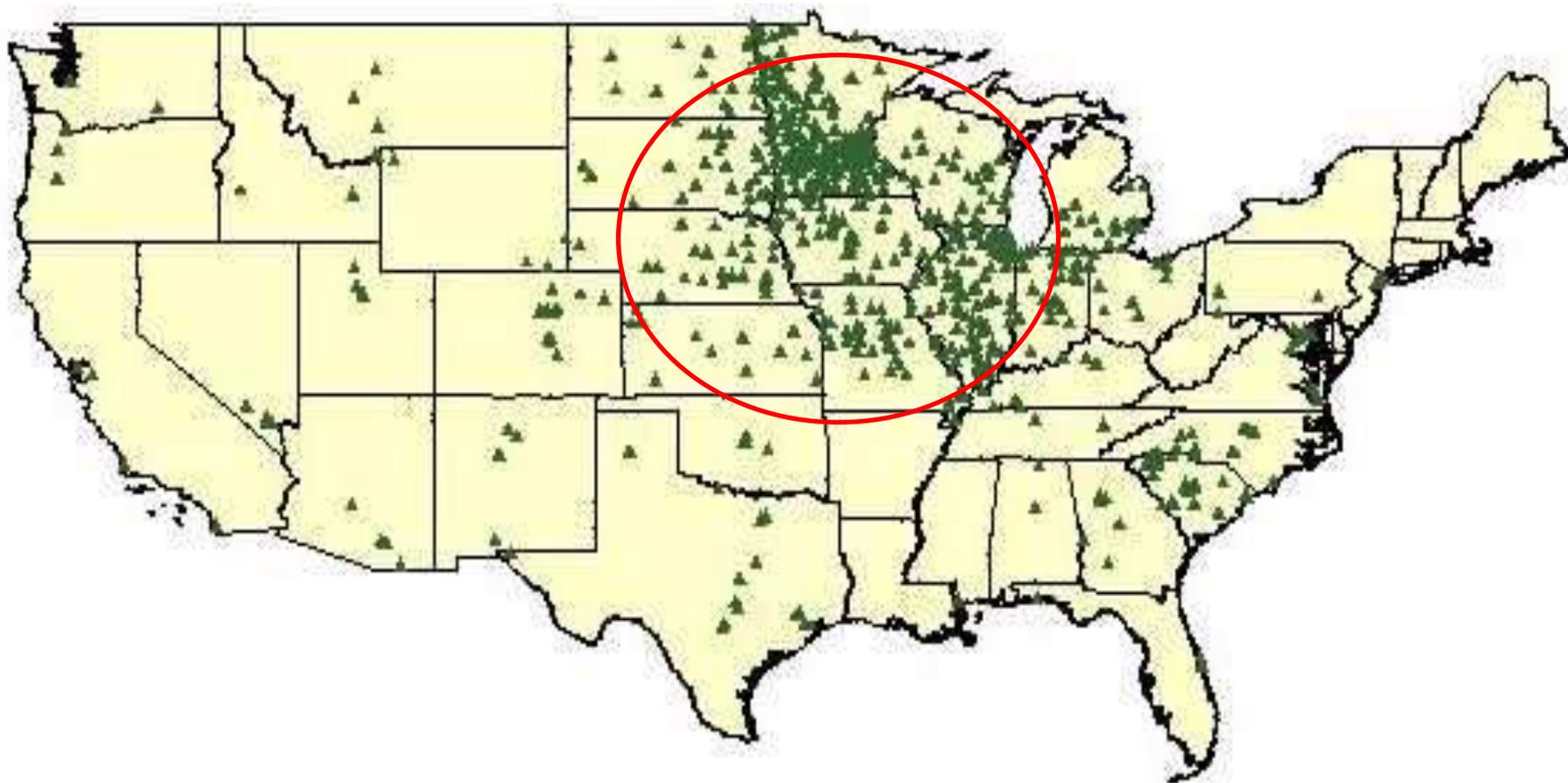
- Ford has placed over 2 million E85 FFVs on America's roads
- As a whole, U.S. automakers have produced more than 6 million E85 flexible fuel vehicles
- If all of these vehicles were operated on E85, over 3.6 billion gallons of gasoline a year could be displaced.
  - ✓ That's like saving a full year of gasoline consumption in a state like Missouri or Tennessee.
- Ford, GM and DaimlerChrysler voluntarily committed to doubling our production of FFVs by 2010.
  - ✓ We expanded that commitment to include half our vehicles each year by 2012, provided sufficient infrastructure is in place



# What Is Needed?

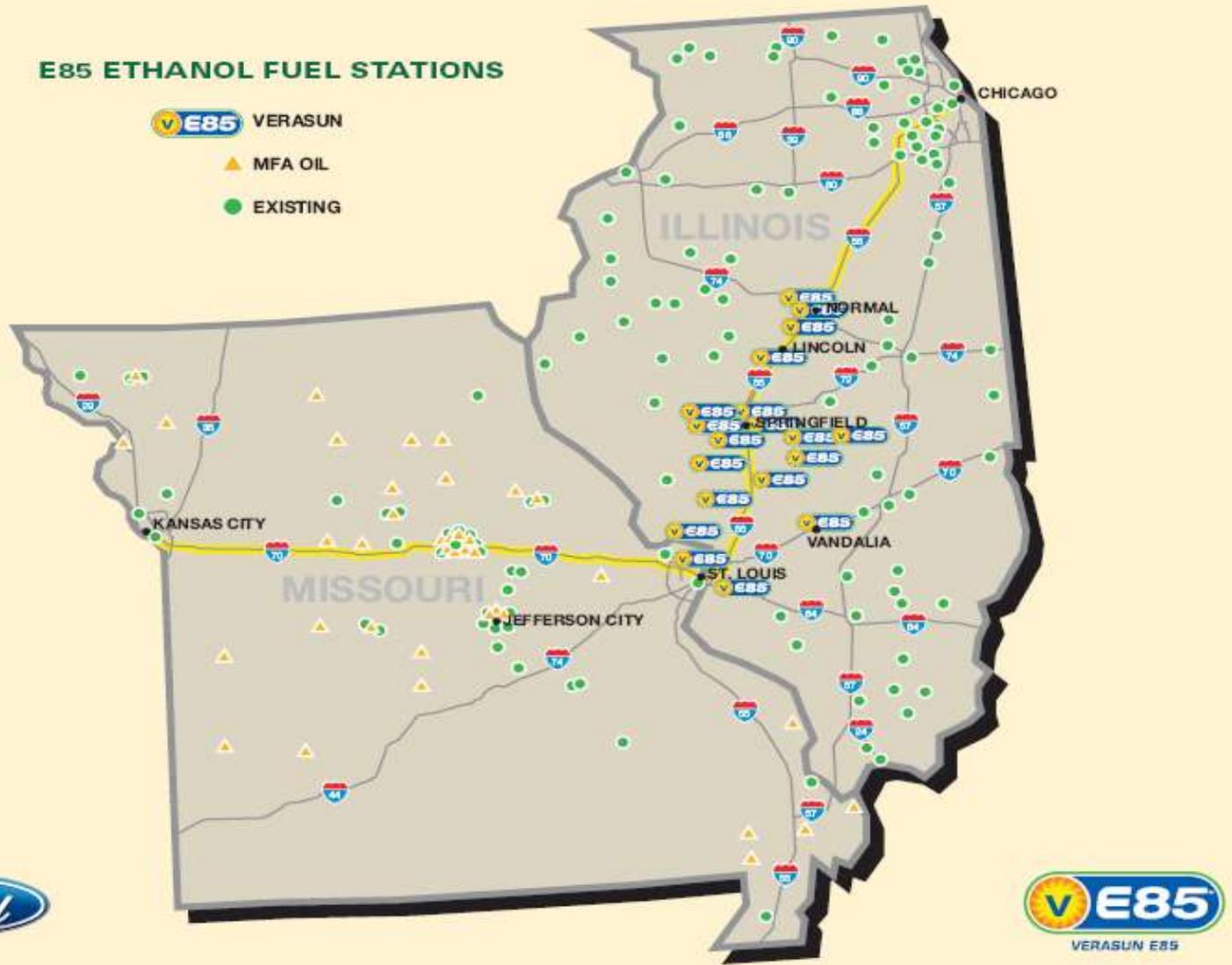
*More E85 Stations Will Solve The "Chicken & Egg" Problem*

E85 Availability Primarily in the Midwest (presently about 1,100 stations – out of about 170,000 retail gasoline stations nationwide)





# Ford, with VeraSun, developed the Midwest Ethanol Corridor adding 50 E85 stations





# Ford's 2007 Ethanol (E85) Flexible Fuel Vehicles





# Flexible Fuel Vehicle Features

## FFVs Provide Fueling Options:

They operate on gasoline, E85, or any blend in between

## FFV Operation is Transparent to Drivers:

Engine operating parameters are constantly adjusted for optimum performance regardless of fuel blend

## Typical Upgraded FFV Engine Components:

Valves and Valve Seats, Spark Plugs, Fuel Injectors, Cylinder Head Gaskets

## Engine Control Computer:

Adjusts engine calibration for proper performance and to meet emission requirements on all fuel blends

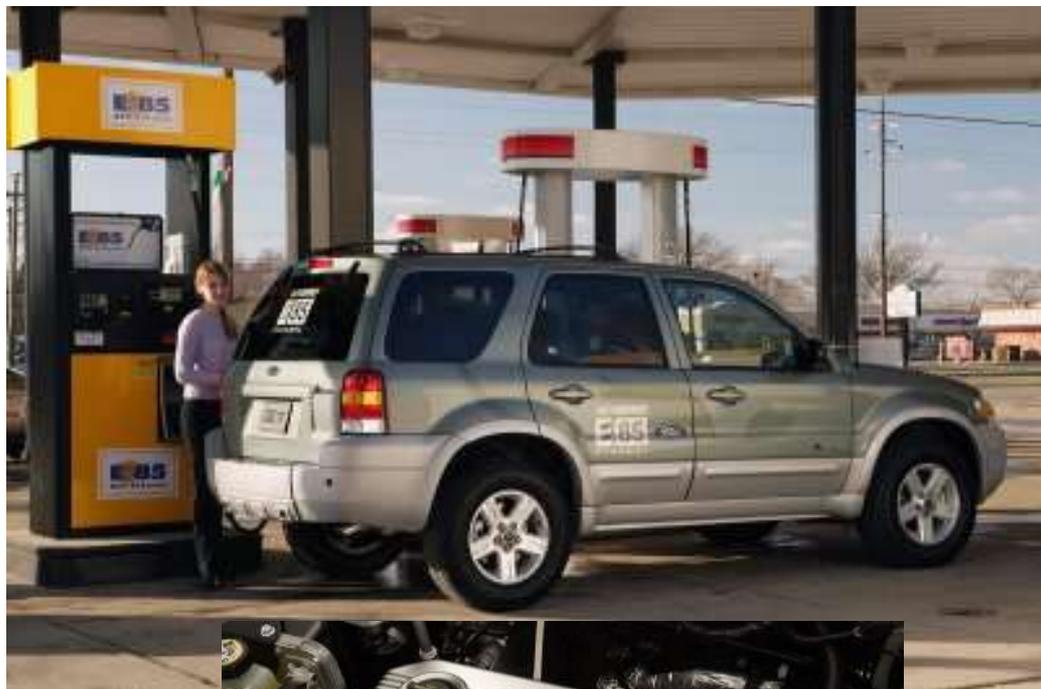
## Typical Upgraded FFV Fuel System Components:

Low Permeability Fuel Tank, Higher Flow Fuel Pump, Fuel Delivery Lines





# Escape Hybrid E85 Demonstration Fleet



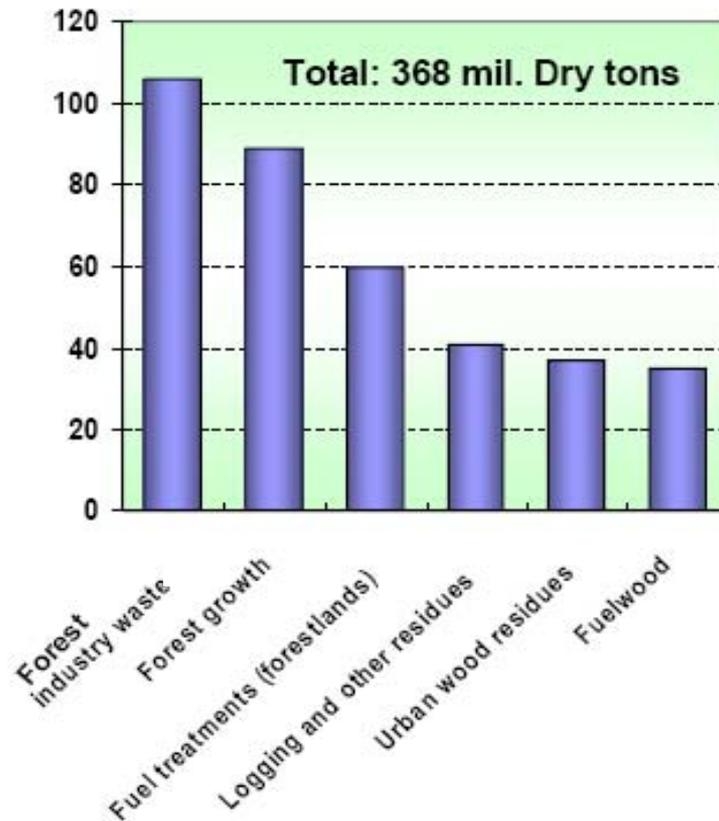
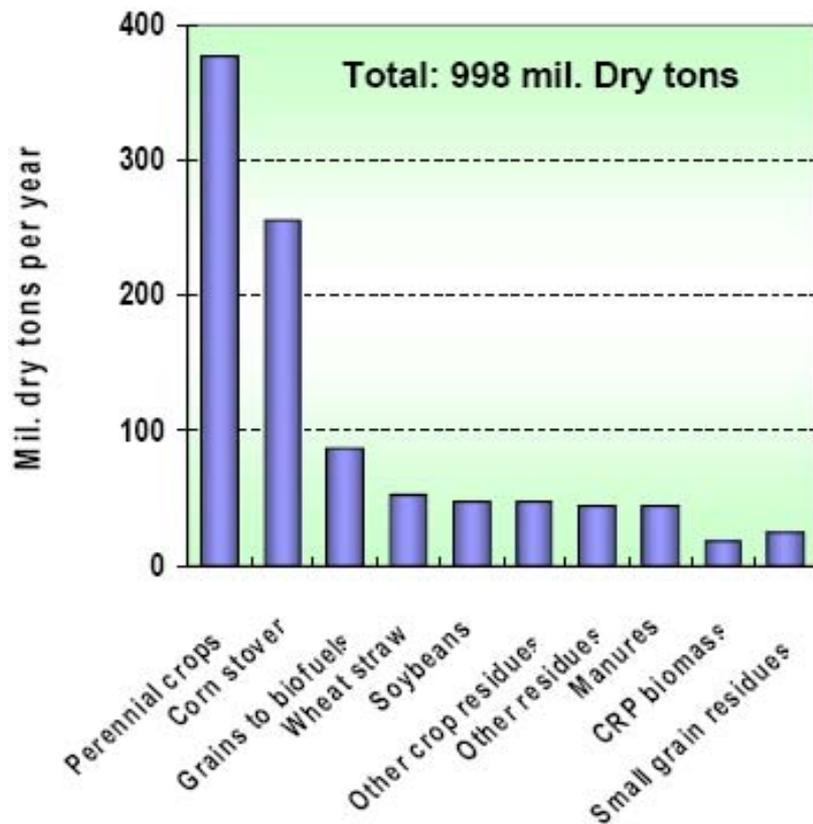
- ✓ Demonstration program marrying two petroleum-saving technologies – hybrid electric power and flex-fuel capability
- ✓ 20 vehicles will be delivered later this year
- ✓ Helps reduce dependence on imported oil
- ✓ Produces about 25% less carbon dioxide than a gasoline-fueled Escape Hybrid



# Why Ethanol in the Future?

*Biofuels Further Enhance Our Energy Security*

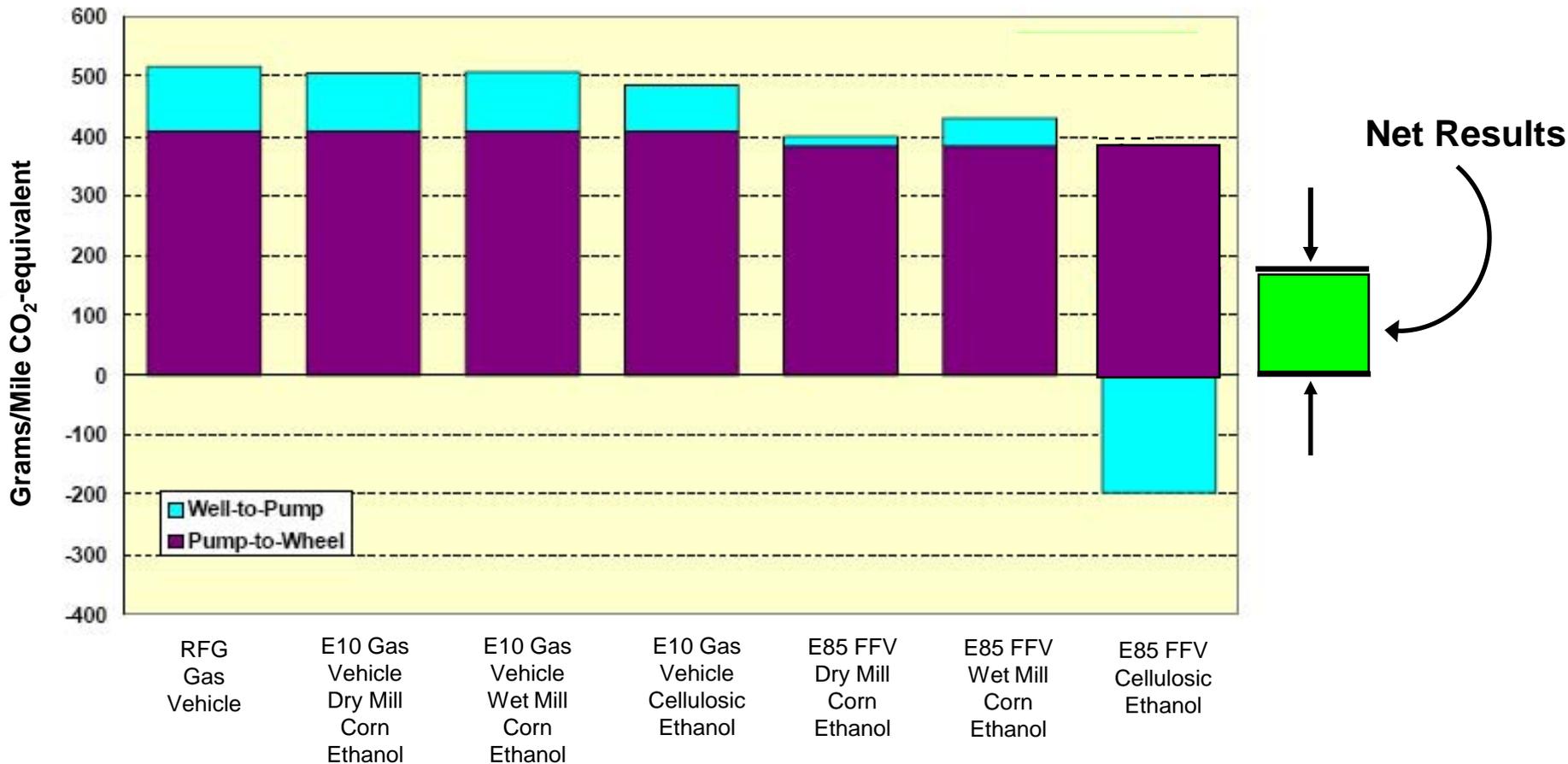
**2005 ORNL Study: 1.3 Billion Tons of Biomass Available Per Year  
Enough to Displace 30% of Petroleum Consumption for Transportation**





# Why Ethanol in the Future?

*Significantly Lower Greenhouse Gas Emissions*



Source: Argonne National Laboratory; Michael Wang, September 2005



# The Role of Stakeholders: An Integrated Approach

Automotive Industry	<ul style="list-style-type: none"><li>✓ Accelerate advanced technology vehicle deployment</li><li>✓ Continue to improve the efficiency of our products</li><li>✓ Educate consumers/provide “eco-driving” training</li></ul>
Fuel Industry	<ul style="list-style-type: none"><li>✓ Invest in developing and marketing E85</li><li>✓ Increase R&amp;D into advanced low carbon bio-fuels (including cellulosic ethanol)</li></ul>
Government	<ul style="list-style-type: none"><li>✓ Incentives for advanced technology vehicles &amp; E85 fueling infrastructure development</li><li>✓ Investment in improved road traffic management infrastructure</li><li>✓ Public awareness and education</li></ul>
Consumers	<ul style="list-style-type: none"><li>✓ Drive vehicles in an energy-conscious fashion</li><li>✓ Vehicle choice and miles traveled ultimately determines how much fuel is consumed</li></ul>

