



DEER 2006
August 20-24, 2006
Detroit, Michigan

"The View from the Bridge"



John K. Amdall
Director of Engine R&D
Caterpillar Inc.

CATERPILLAR®

Caterpillar Inc.



- **Products:**

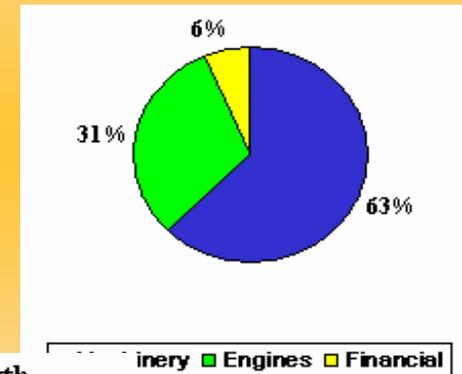
Construction & Mining Equipment
 Diesel & Natural Gas Engines, Industrial Gas Turbines
 Electric Power, Remanufacturing, Logistics & Financial Services



- **Global Company - 2005**

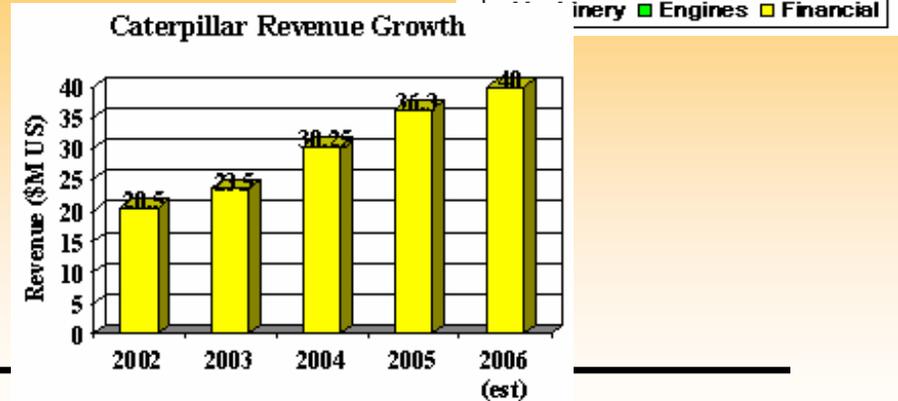
Corporate headquarters - Peoria, Illinois

- 278 company facilities
- 115 Manufacturing locations
 - 50 inside U.S.
 - 65 outside U.S. (23 countries)
- 92,000 Employees (50% U.S.)
- 2537 Patents in last 5 years

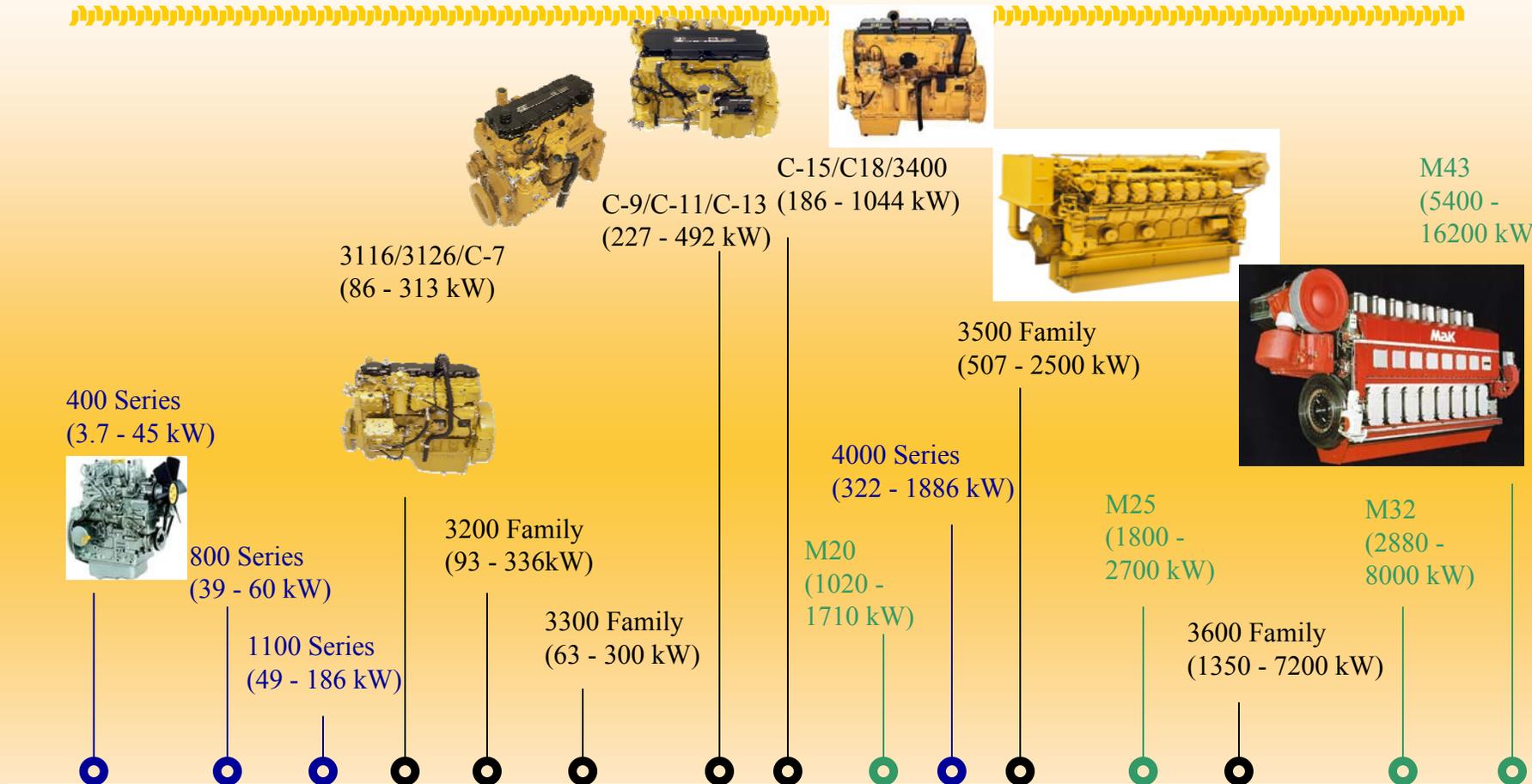


- **2005 Sales & R&D:**

\$36.3B Revenue (50% Outside the U.S.)
 \$1.1B Corporate R&D



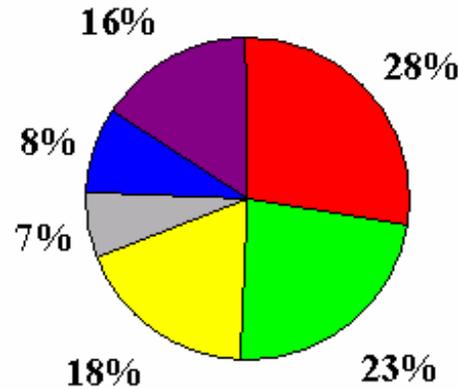
Caterpillar® Diesel Engines



Caterpillar: Non-confidential

Technology & Solutions Division
Caterpillar Engine Research

Caterpillar Engine Applications



- On-Highway
- Electric Power
- Oil & Gas
- Marine
- Industrial/OEM
- Cat Machine

Technology for ...



Caterpillar's Future

Emissions is only one of the issues!

What is the Technology Strategy?



- What are the **critical technologies** for our future?
- What is the **technology roadmap**?
- What is the **future of Petroleum**?
- What about **Hydrogen**?
- When will Caterpillar equipment use **fuel cells**?
- When will **CO2** become a product requirement?
- What about **renewable energy**?

What about Game Changers?



- **Health effects**, including Sound & Ergonomic requirements
- **GHG regulations** and Kyoto implementation
- Petroleum, as the primary energy source, replaced by:
 - **Coal, Tar Sands, Solar, Nuclear, Bio-Mass, Wind**
- Breakthroughs in energy conversion and/or energy carrier:
 - **Photovoltaic, Fuel Cell, Thermal Electric, Hydrogen, Battery**
- **Recycling / Reuse** requirements
- **Dust Management** requirements
- **Internet / Wireless** -- everywhere, free, unlimited bandwidth
- **Policy shift** from energy invulnerability to energy survivability



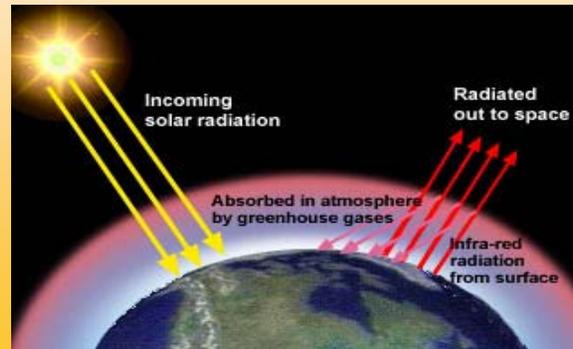
**I wish I had an answer to that, because
I am tired of answering that question.**

Yogi Berra

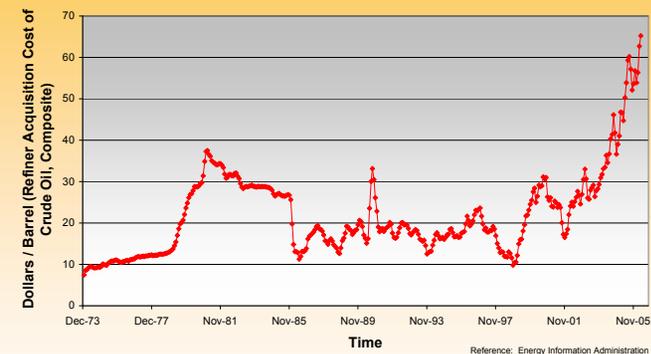
Energy Drivers for Our Future



- **CO₂**



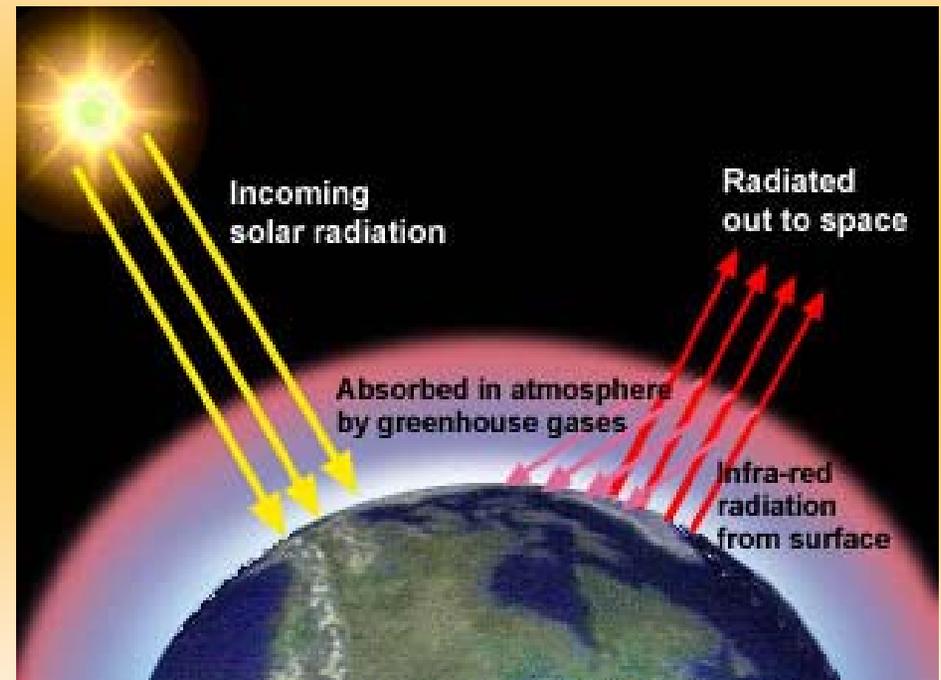
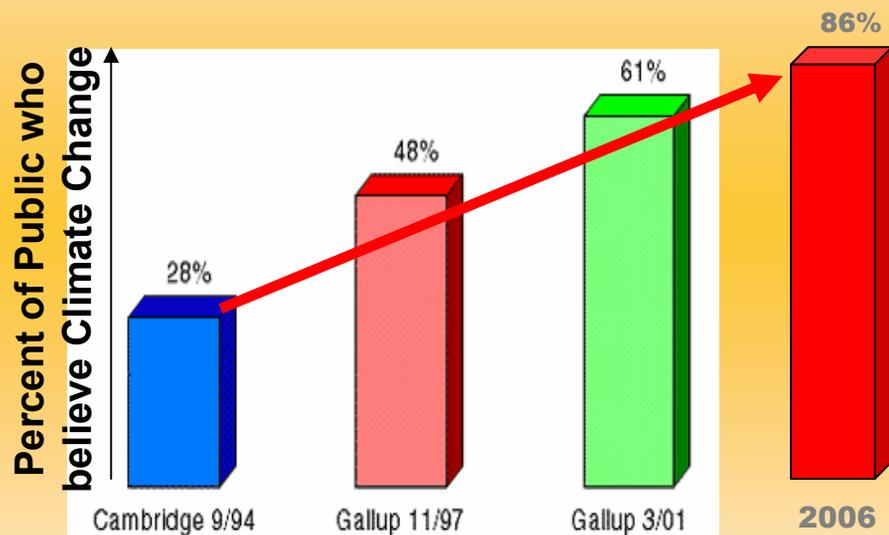
- **Price of Oil**



The Changing Perception of Greenhouse Gas

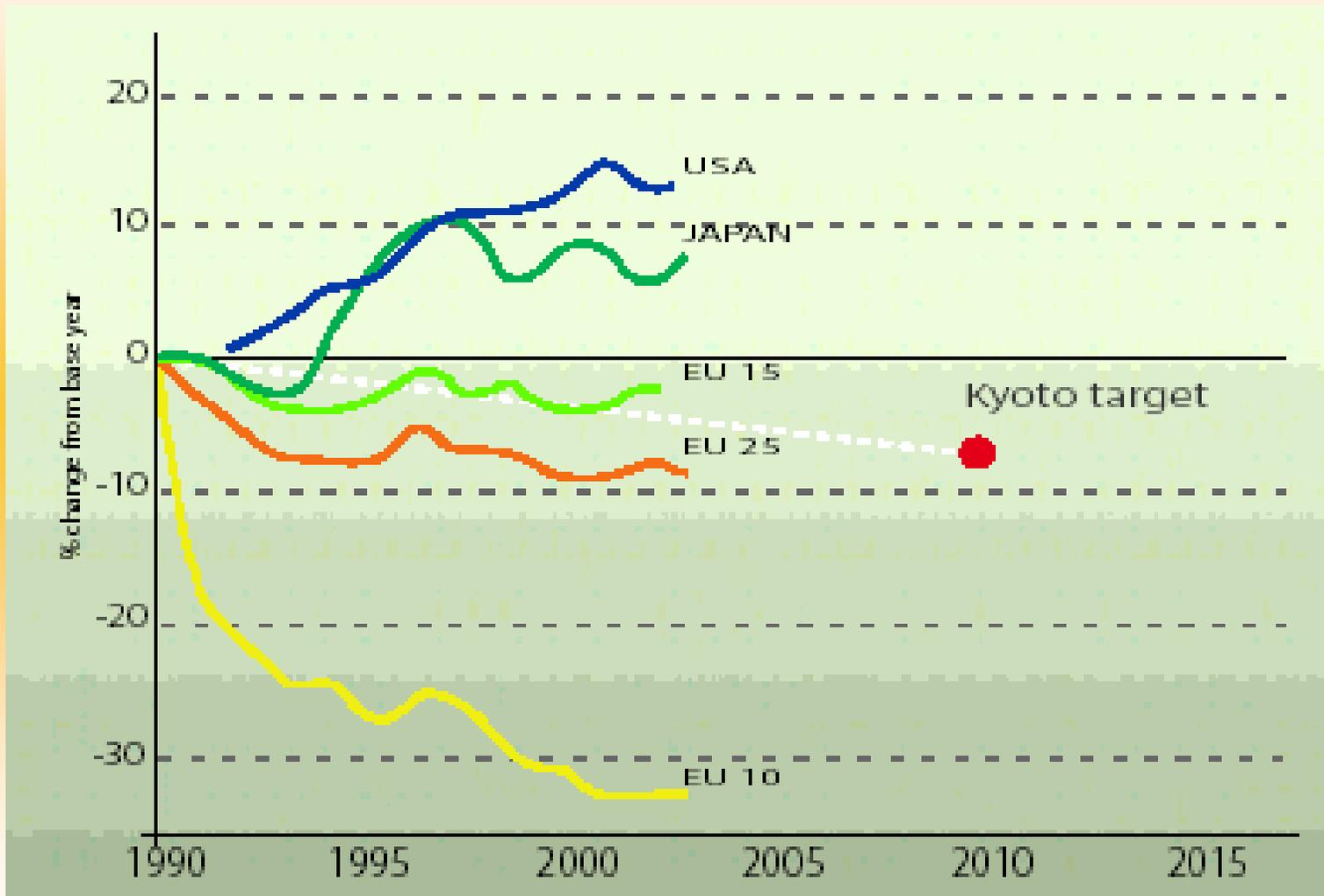


Growing public perception that climate change is a real issue.

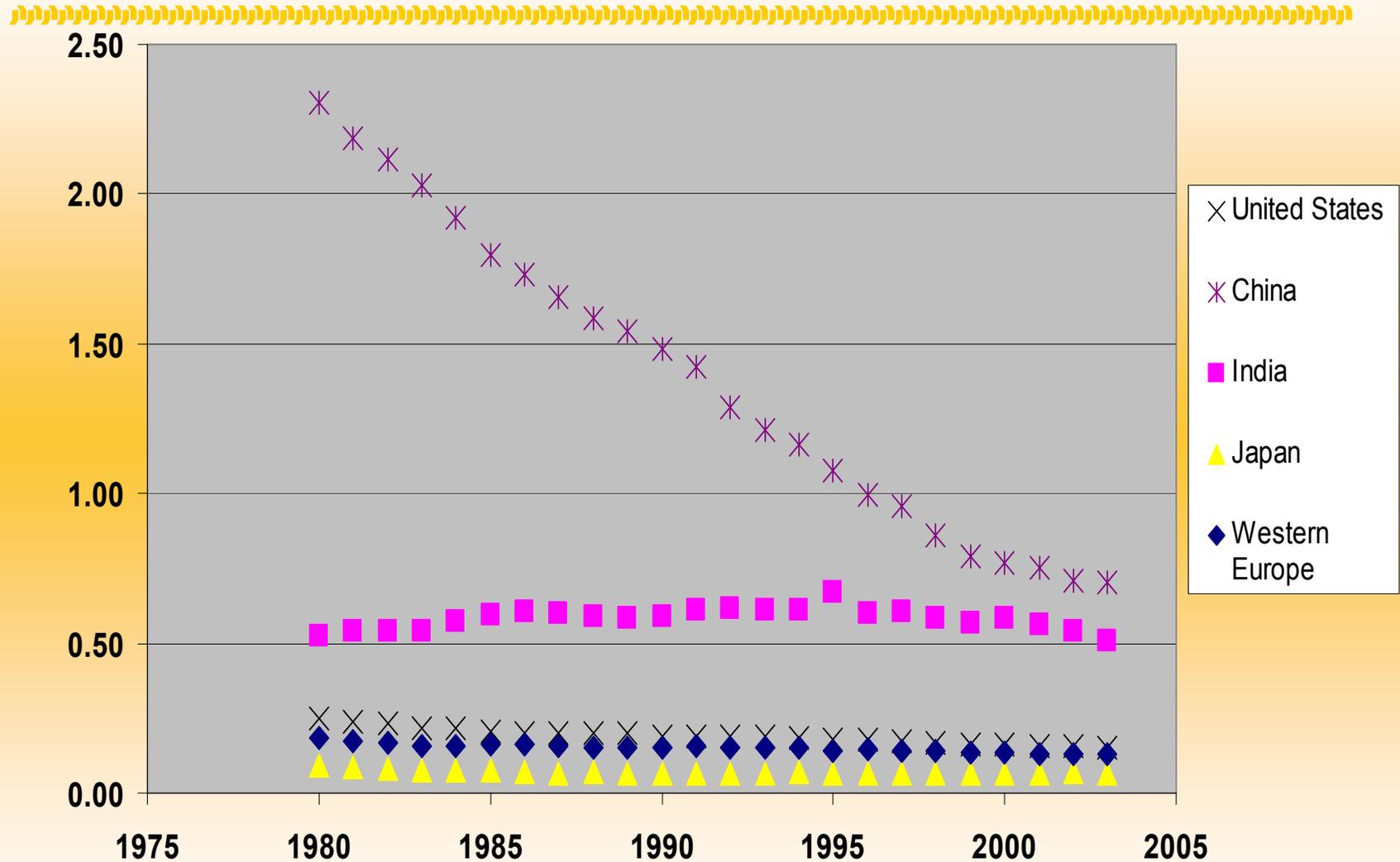


Public perceptions drive political and legislative agendas.

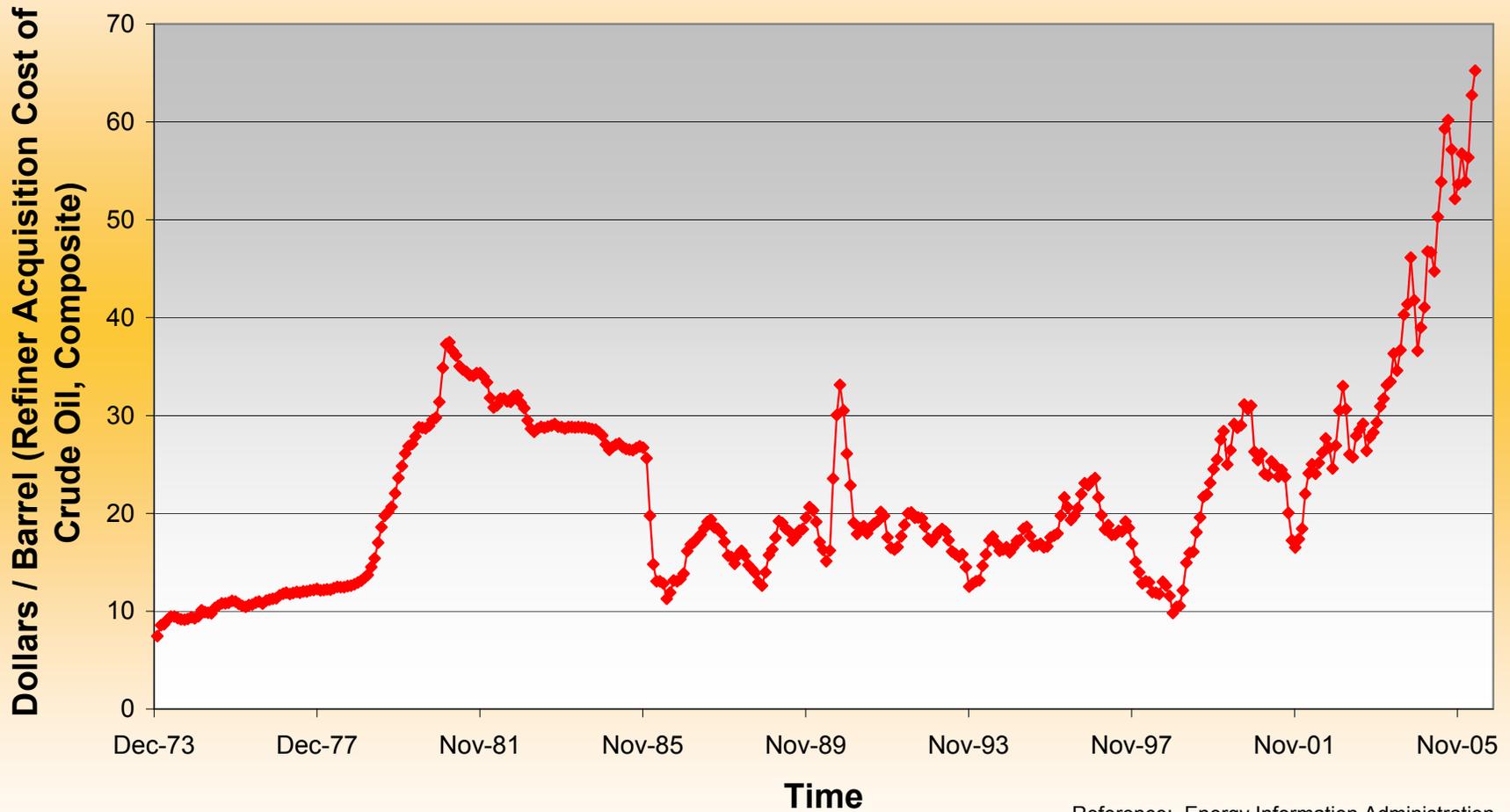
Greenhouse Gas Emissions Since 1990



Greenhouse Gas per GDP (Million Metric Tons CE vs. Billions \$'s GDP)

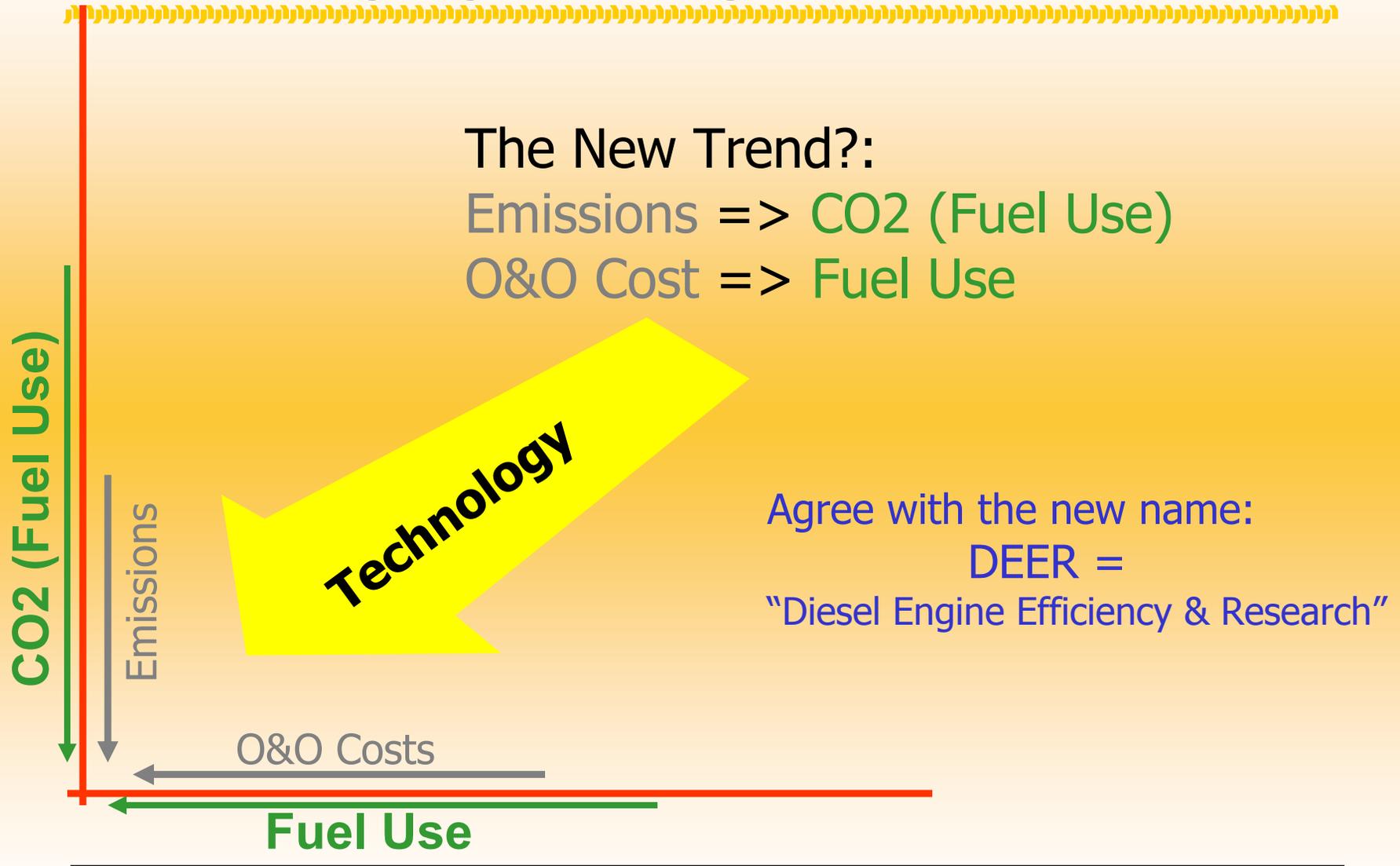


Oil Price (inflated \$) vs. Time



Reference: Energy Information Administration

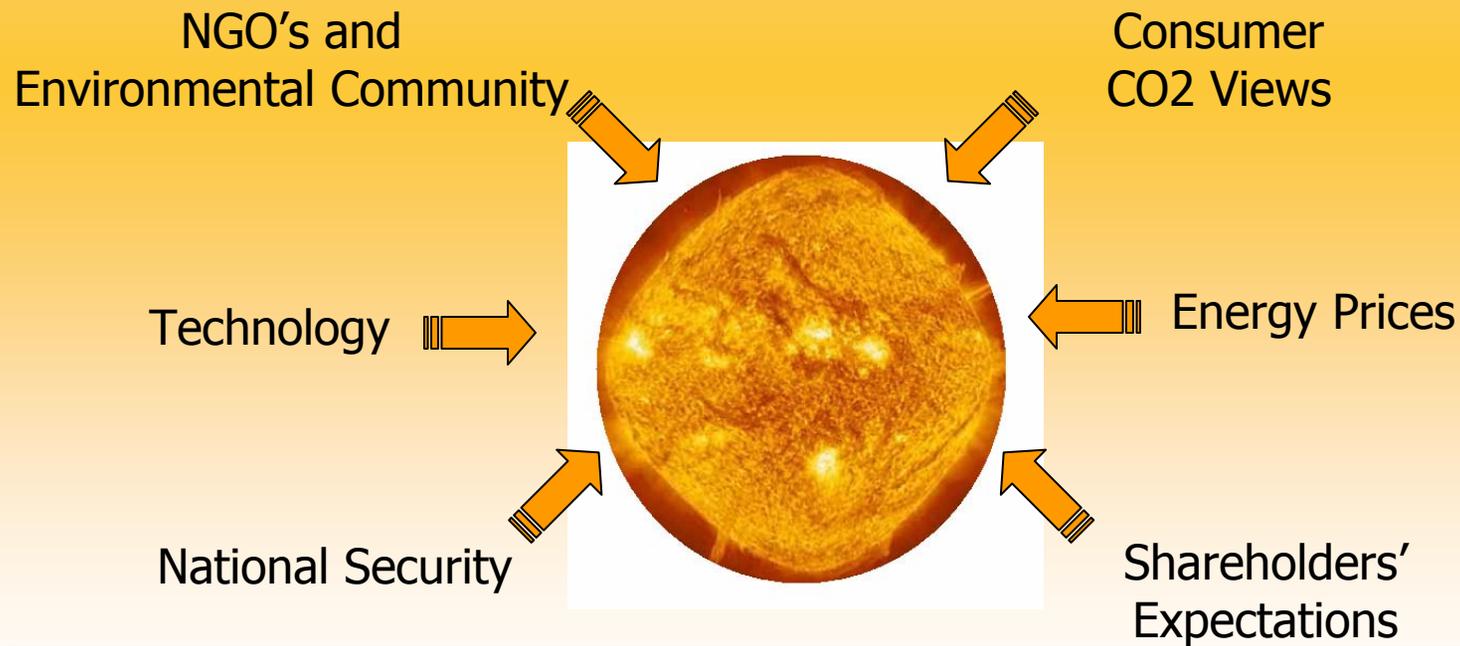
GHG and High Fuel Costs are Changing our Engine Research Drivers



Energy/CO₂ Scenarios

Caterpillar's products must align with the future energy/CO₂ strategies and policies.

Energy's future depends on outside pressures...



2020 Energy Scenario 1 - No Basic Change



Current Energy Supplies last 250 years or more

Continued oil field development:

- A “dry well” only removes 20% of available petroleum
- Oil reserves have been 20 years for the past 50 years
- Long term oil prices at \$50 to \$60 per barrel
- Ultra clean fuels
- CO2 concerns die down

Petroleum supplemented with:

- Coal
- Tar Sands & Oil Shale
- Natural Gas

“US DOE says CO2 injection could quadruple oil reserves”

Rueters, Friday, March 3, 2006



2020 Energy Scenario 2 - Shift to Coal

Coal Supplies last 250 years or more

Continued developments for

- Clean coal power
- Carbon sequestration
- Hydrogen from coal

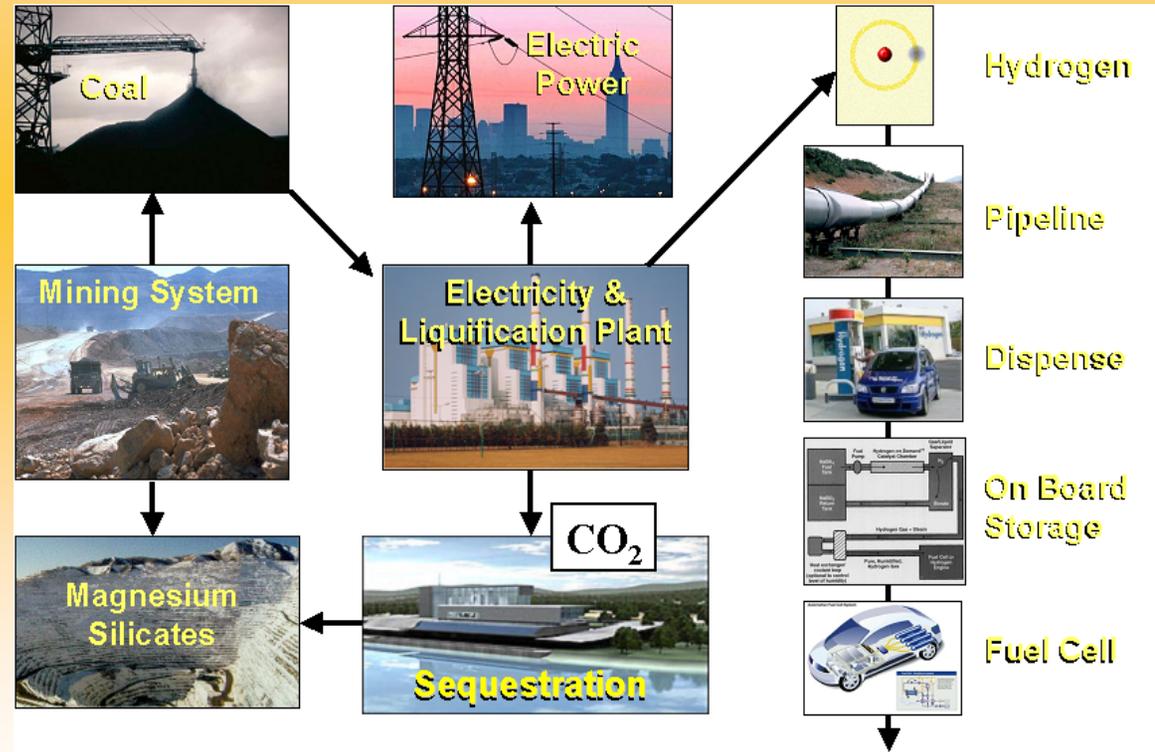
“Virtually all projections show coal continuing to supply around half of the nation's electricity for the next 20 years” DOE – Office of Fossil Energy

“... U. S. will sponsor a \$1 Bil, 10-year demo project to create the world's first coal-based, zero-emissions electricity and hydrogen power plant...”

President George W. Bush
February 27, 2003

“Carbon sequestration is the ultimate solution to stabilizing global carbon emissions.”

DOE – Office of Fossil Energy
Vision 21 - The Ultimate Power Plant Concept



2020 Energy Scenario 3 - Natural Gas



“More than 90 percent of the power plants to be built in the next 20 years will likely be fueled by natural gas.”

DOE - http://www.energy.gov/engine/content.do?BT_CODE=ELECTRICPOWER

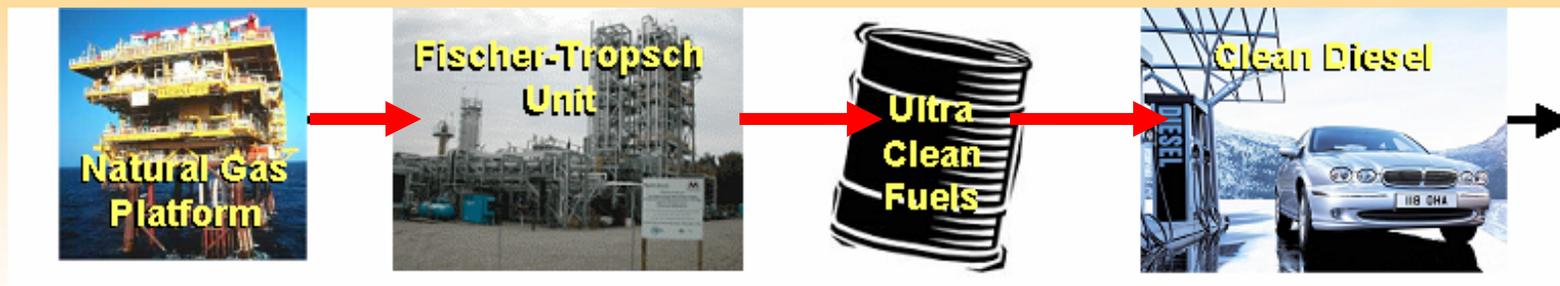
“Annual U.S. natural gas consumption is projected to rise from 22.1 trillion cubic feet (Tcf) in 2004 to 30.7 Tcf in 2025.”

DOE - http://www.fossil.energy.gov/programs/oilgas/publications/Ing/LNG_080505.pdf



Methane Hydrate – “Worldwide estimates of the natural gas potential of methane hydrate approach 400,000,000 Tcf vs. 5,500 Tcf of proven gas reserves.”

DOE - <http://www.fe.doe.gov/programs/oilgas/hydrates/index.html>



2020 Energy Scenario 4 - Nuclear

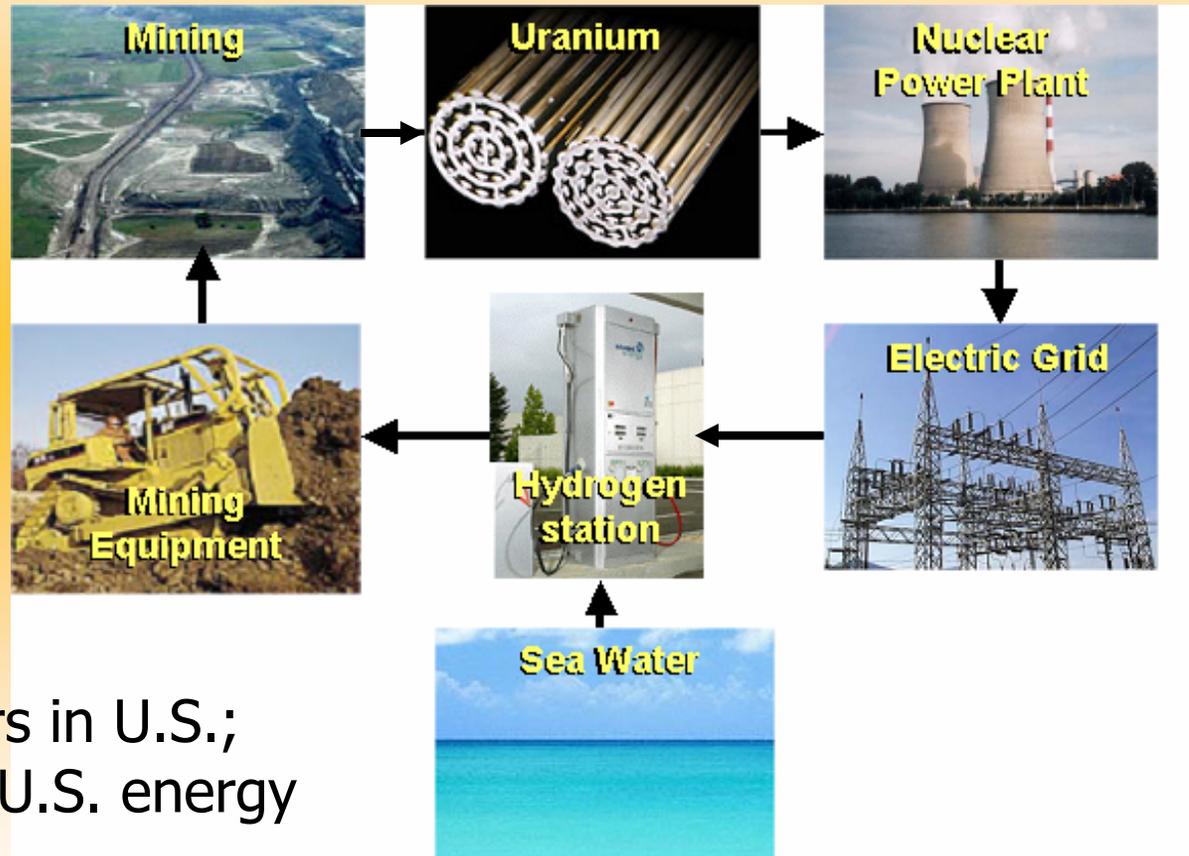


2005 Energy Bill includes provisions for 6 new nuclear power plants.

“Only nuclear power plants can generate massive amounts of electricity without emitting an ounce of air pollution or greenhouse gases.”

President George W. Bush
August 8th, 2005

Currently 103 reactors in U.S.;
400 needed to meet U.S. energy needs.



2020 Energy Scenario 5 - Renewable

Bio-diesel, Biomass to liquids:

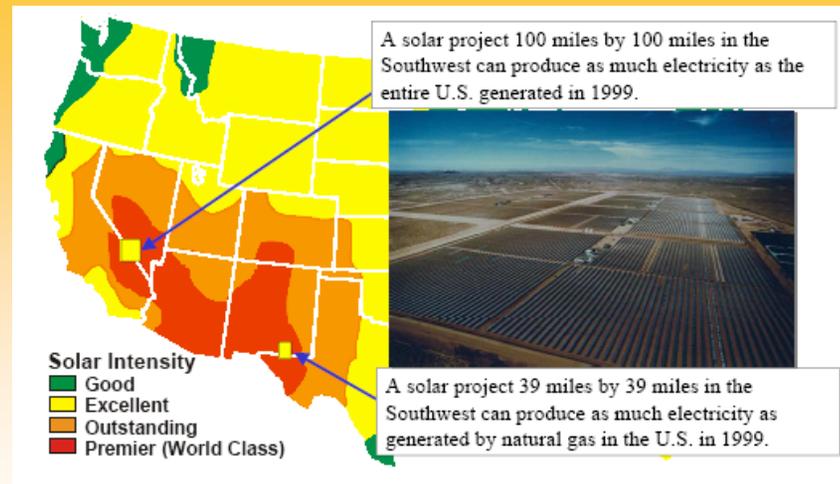
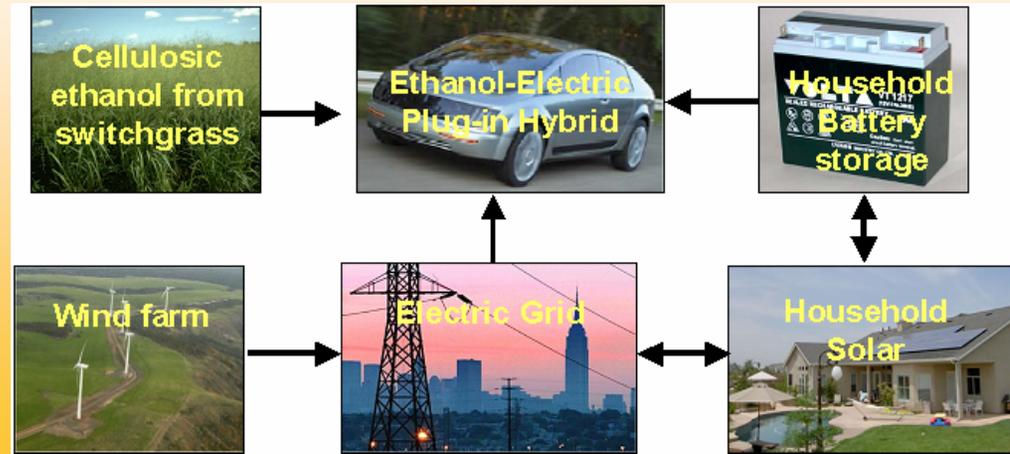
1 billion dry tons of biomass could displace 30% of US oil use. Supply "potential exceeds 1.3 bil. dry tons per year." U.S. Dept. of Ag. & U.S. Dept of Energy, Feb. 2005

"U.S. ethanol consumption has a CAGR of 28% over last four years"
American Coalition for Ethanol, August 2005

Solar photovoltaic U.S. market has a CAGR of 30% over last 7 years and "may reach 10-15 GW ... by 2015" (a 40% CAGR through 2015). Energy Information Administration, Nov. 2005 and the "Solar America initiative" June, 2006

"Wind turbines now generate over 17 GW, currently the world's fastest growing source of energy."

Woodard, C. 2001. "Wind Turbines Sprout from Europe to US," Christian Science Monitor 93(75):7.



Energy System View (the matrix multiplies!)



- Energy Systems – Source, Transport, Carriers, and Compact Power



Energy Source

Fossil
Renewable
Nuclear
Etc.

Energy Distribution

Power Lines
Pipeline
Tankers
Etc.

Energy Storage

Batteries
Hydrogen
Refined fuels
Etc.

Energy Conversion

Engines
Motors
Fuel cells
Etc.

With the more likely scenarios, the need is even greater for clean, fuel efficient & cost effective energy converters.

- Expect clean, higher efficiency diesels to have a major role.
- With much more emphasis on efficiency, the following DOE programs and key enabling technologies will become even more important :
 - "Heavy Truck Engine"* Adv. combus. w/ adv. A.T.
 - "High Efficiency Clean Combustion"* HCCI combus. w/o A.T.
 - "Waste Heat Recovery"* Adv turbo m/c, Thermo-electrics
 - "Advanced Propulsion Materials."* High-temp strength mtls.
 - "Advanced Petroleum & Renewable Fuels"* Fuel chem. opt., Bio-diesel
- To apply our collaborative strength more effectively, and take advantage of fundamental discoveries and progress in existing programs to address the critical issues of Oil Dependence, Climate Change and overall System Sustainability, a new DOE engine program is needed, such as:

"Ultra High Efficiency Engines"

Summary

- Caterpillar is well positioned for future energy developments.
- Energy policies are only one of many challenges.
- High energy efficiency technology is of increasing importance.
- Key technology development is needed and DOE can greatly accelerate it.
- Government/industry collaboration is critical.