Hydrogen and Fuel Cells: A Response to Earth's Challenge

Hydrogen & Fuel Cells 2007
Vancouver, BC
April 30, 2007

Bob Rose
US Fuel Cell Council
Breakthrough Technologies Institute, Inc.

Burning Carbon

Burning carbon has brought us (most of us) out of the darkness

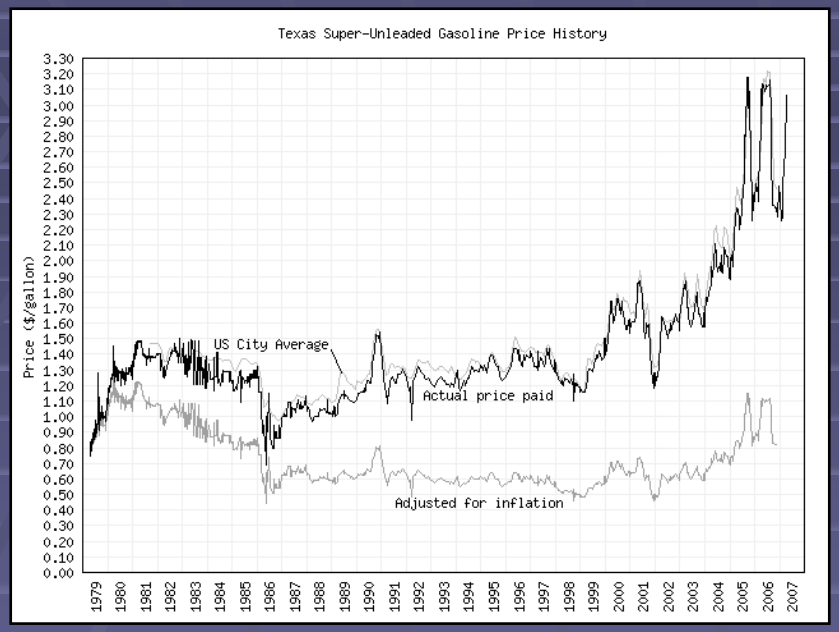
Burning Carbon

- Resource consumption
- Despoilation
- Resource waste
- Air pollution - sickness
- Water pollution
- Dirt and grime - costs
- Building damage - costs
- Damage to plants and animals
- Reduced crop yields
- Atmospheric warming

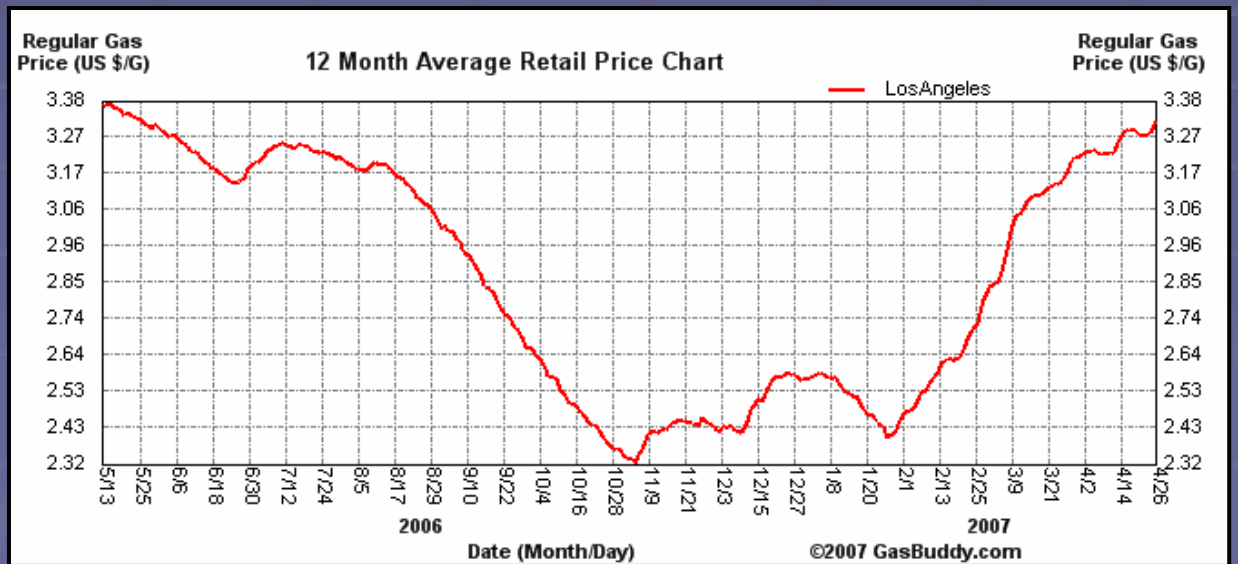
Geopolitical costs

- Resource competition among nations
- Unequal economic prospects
- Supply anxieties

Economic costs



- Wealth transfer
- Corruption
- Price insecurity
- Cost of mitigation



Our challenge

- Oil addiction*
  - US national security
  - Global Stability
  - Economic costs / energy competition
- Sustainable energy for growth
- Air, water and land pollution
- Global warming, climate instability

Not a cafeteria plan!

Solution:
Stop Burning Carbon

The Fuel Cell/Hydrogen Solution

Power Generation

High Efficiency

- 80%+ in combined heat and power
- 35-60% electrical
  - Higher in hybrid configurations
  - Validated by US EPA in 2005: 93.8%
    - PAFC, anaerobic digester gas

Emissions

- Annual Emissions (1650 MWH)
  - UTC PC 25 = 75 pounds
  - Average U.S. fossil plant = 41,427 pounds
  - CO_2 reduction ~ 45%

Low CO_2

- ~ 4 tons/kW/year (natural gas) =
  - 4,000 Tons per MW
  - x 40 MW installed =
  - 160,000 tons/year
- Vehicle = 6 tons/year (US EPA)
  - 2/3 vehicle/kW/year
  - 107,000 vehicles/year

3 PAFC fuel cell kW/years = 2 vehicle years

CO_2 Emissions Reduction by DFC and SOFC Power Plants

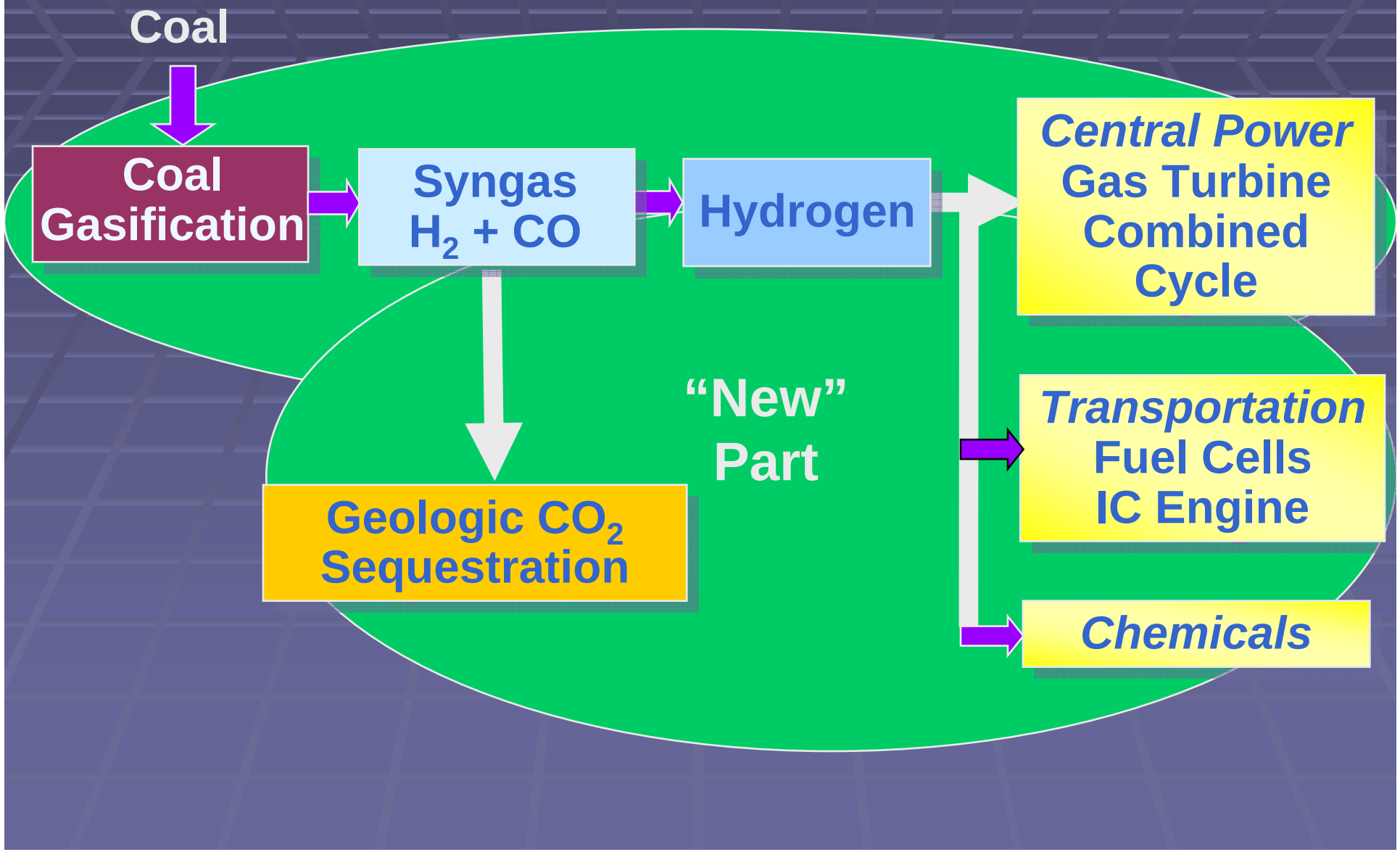
Fuel Cell System	Electrical Efficiency	CO_2 (lb/kWh)	Reduction
Current DFC Plant	45%	0.982	-41%
DFC/Turbine Hybrid	56%	0.789	-52.70%
Coal-based SECA Target	>50%	<0.0884**	-80%

* **The average U.S power plant CO2 emission of 1.668 lb**

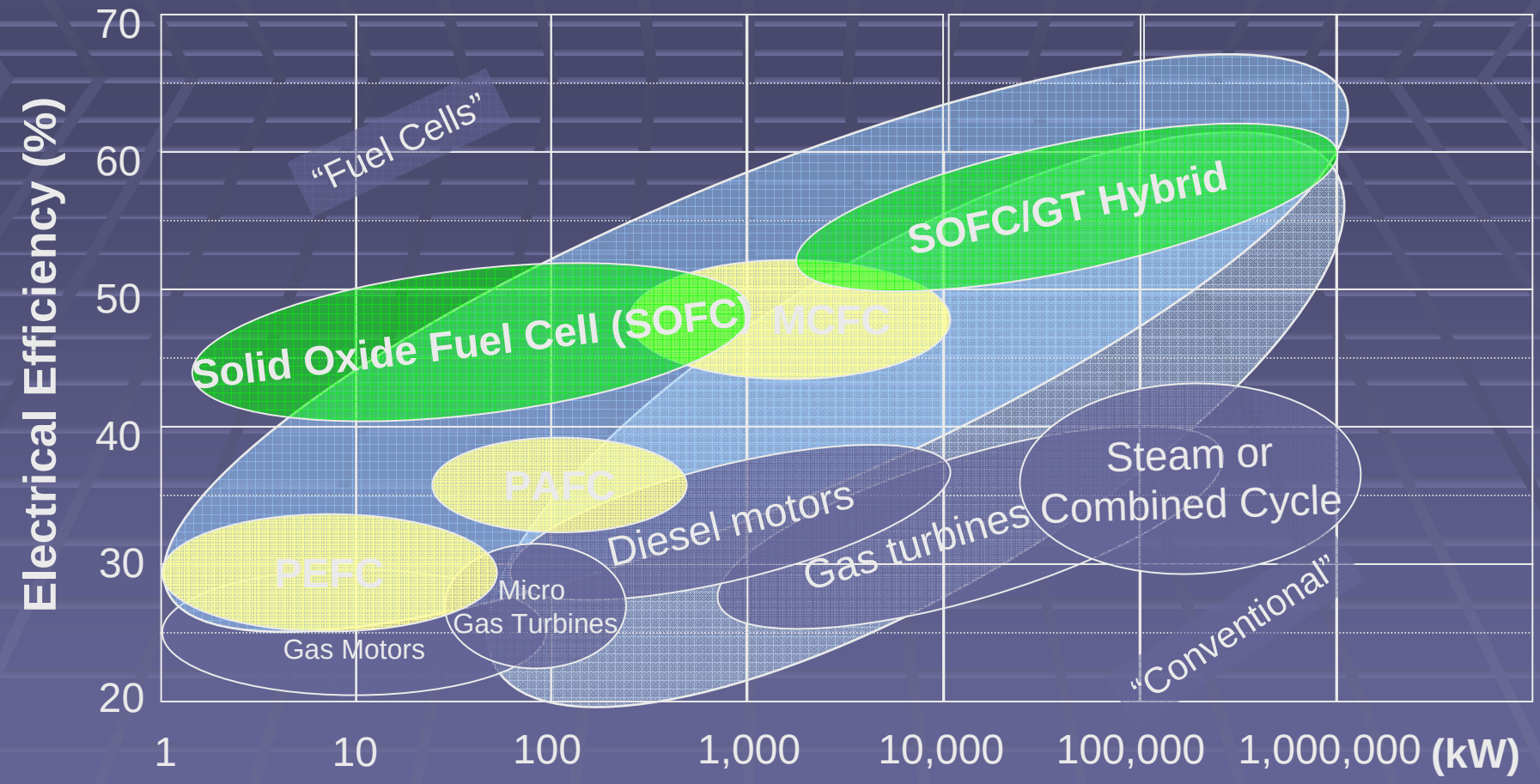
Co-gen heat was not taken into calculation

** With >90% CO_2 Sequestered

IGCC in FutureGen (USDOE)



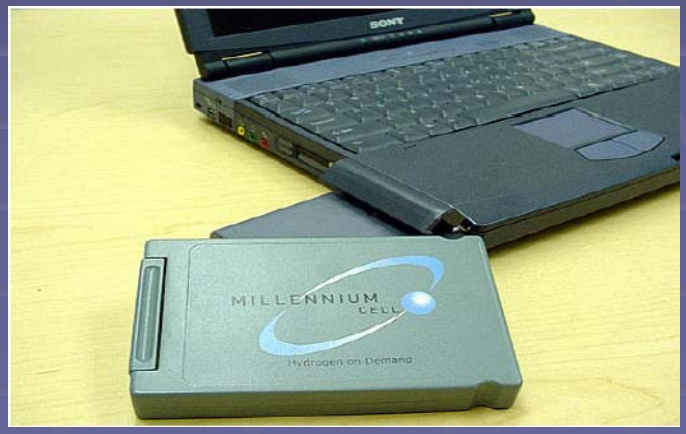
Why Fuel Cells?



Why Fuel Cells in a Coal Plant? (*FutureGen*)

- High Performance with low carbon fuel i.e., Hydrogen
- Easily adapted for CO2 sequestration (>90%)
- High Power Station Efficiency (55 - 60% HHV)
- Near Zero Emissions of NOx
- Negligible Impact on Cost of Electricity
- Meet environmental regulations
- Able to site and produce energy from coal in any state in the U.S.

Micro Fuel Cells



Potential benefits

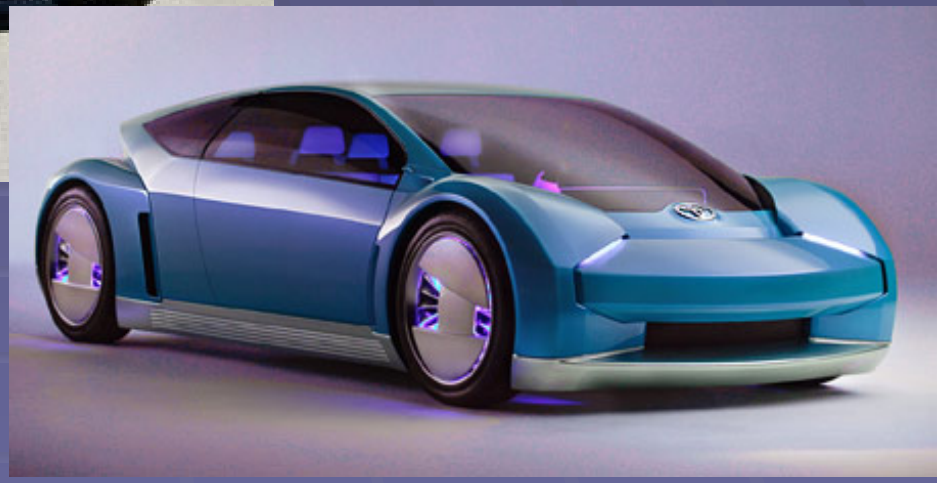
- Efficiency
  - 6% of US energy demand (2002)
- Life cycle environmental benefits
- Safety

Analysis Needed

Vehicles

GM Hy-wire

Honda FCX



Toyota FINE-S

We CAN Kick the Habit

- Hybrids and biofuels may buy time, but . . .
- Only hydrogen fuel cells can break the cycle of oil dependence
- Hydrogen fuel cell vehicles offer the best *combination* of benefits

Options: Policy

- Gas tax: 50 cents? $1?
- Price Controls
- Curbs on speculating (trading limits)
- Enforced conservation
  - No drive days
  - No trucks during rush hours
  - Staggered work hours – mandatory

Options: Policy

- Excess profits tax
- Jawboning
- Release more reserves
- CAFE
- Market stimulus
  - Gas guzzler tax / gas sipper rebate
  - Increase credits for hybrids and other hi-tech cars

Majority Support has been elusive

Options: Technology and Fuels

- Vehicles
  - Battery EV's
  - Gas-Electric Hybrids
  - "Plug In" Hybrids
- Fuels
  - "Traditional" Alt Fuels
  - Biofuels
    - Ethanol
    - Biodiesel
- Fuel Cells
  - Hydrogen fuel cells

The Good News

- Better batteries mean better fuel cell vehicles
- Better hybrid technologies mean better fuel cell vehicles
- Best plug-in hybrids may be fuel cell hybrids
- Biofuels are good hydrogen carriers
- With sequestration, we can draw carbon from the atmosphere

Benefits from all pathways

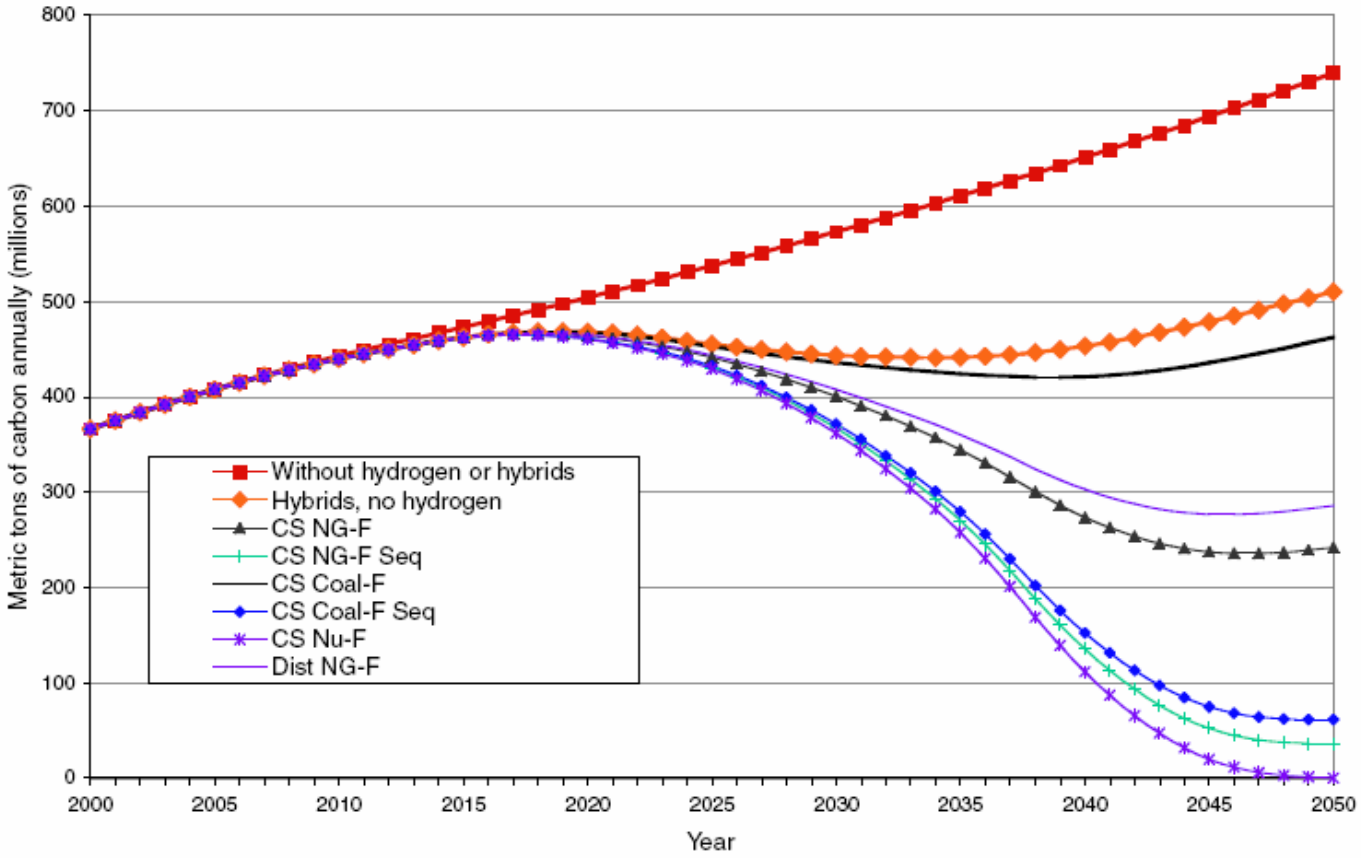


FIGURE 6-8 Estimated volume of carbon releases from passenger cars and light-duty trucks: possible future hydrogen production technologies (fossil fuels and nuclear energy), 2000–2050. See Table 5-2 in Chapter 5 and discussion in text.

Renewable hydrogen is even better

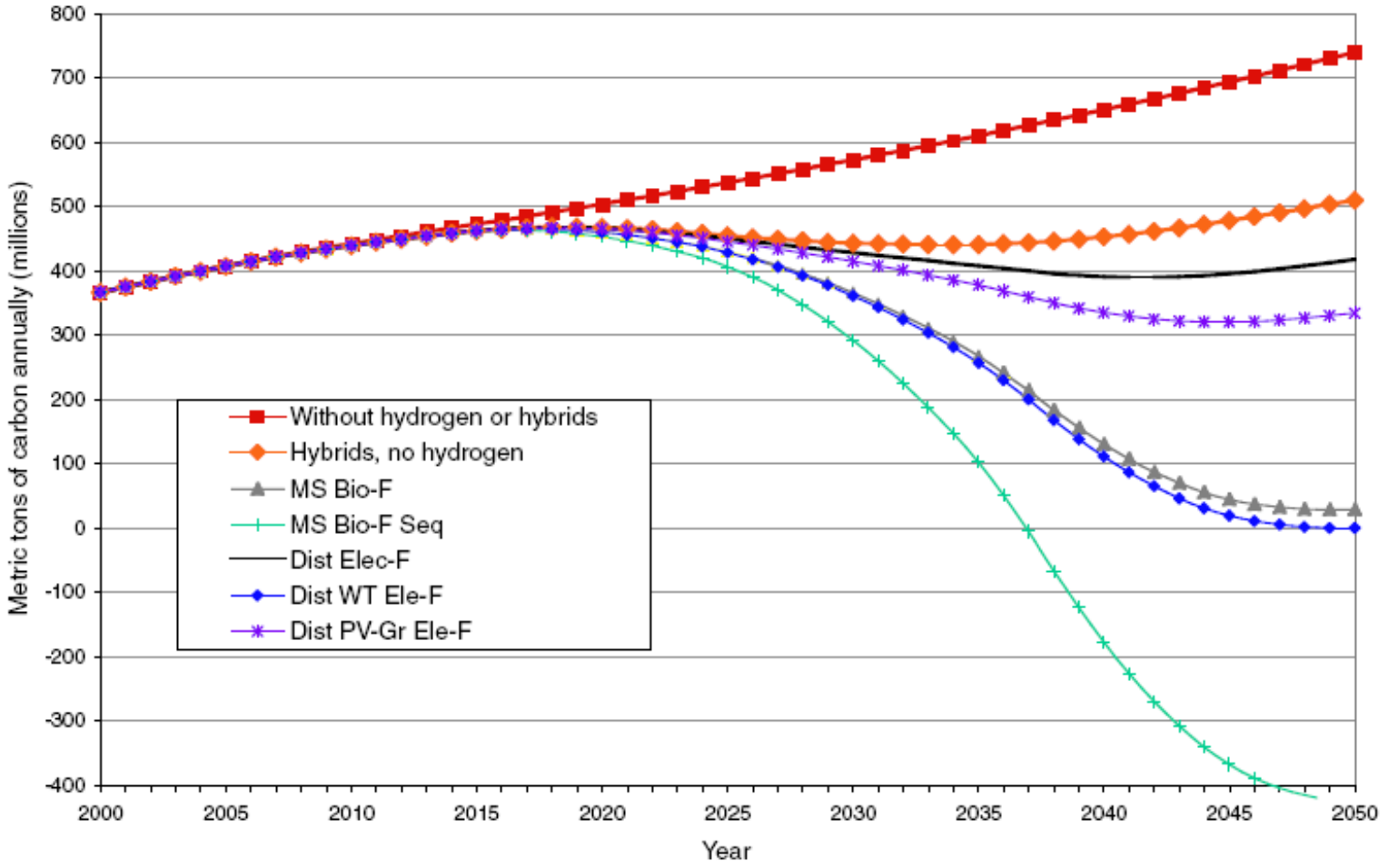
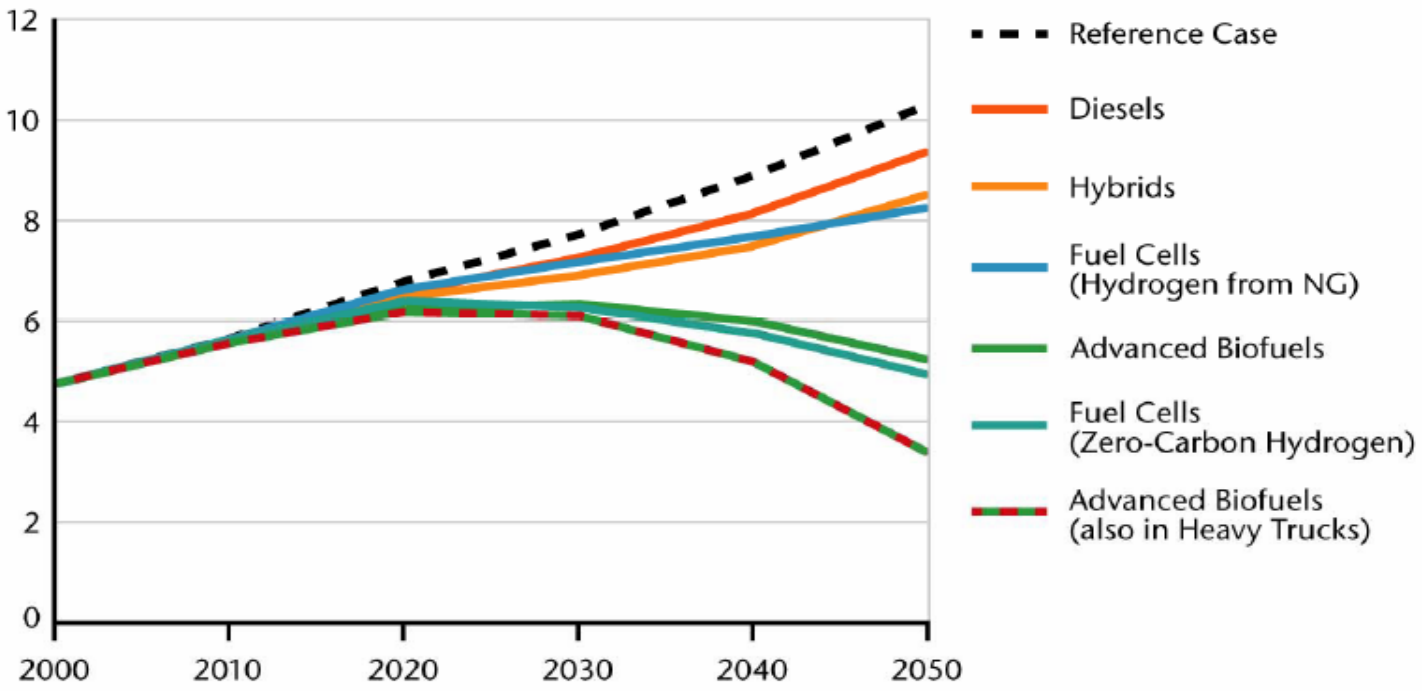


FIGURE 6-10 Estimated volume of carbon releases from passenger cars and light-duty trucks; possible future hydrogen production technologies (electrolysis and renewables), 2000–2050. See Table 5-2 in Chapter 5 and discussion in text.

“Cleaning” is possible

Hypothetical potential of individual technologies to lower road transport Well-To-Wheels CO2 emissions



Note:
The cases represent very high hypothetical levels of technology penetrations, thus they cannot be added together.

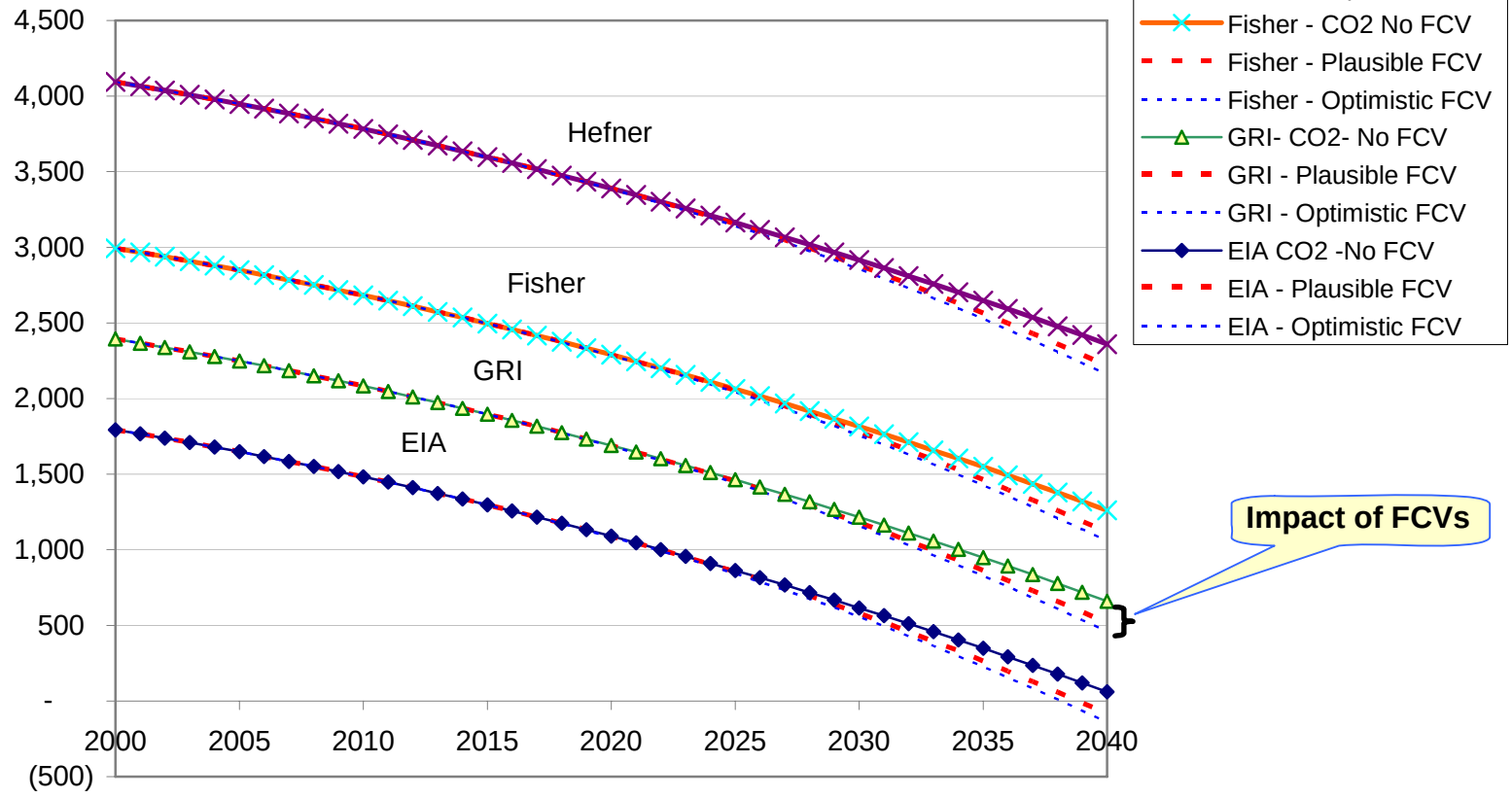
Natural gas is a good interim hydrogen feedstock

- Low carbon fuel (not low enough!)
- Mixed with water today to produce hydrogen – 50% renewable fuel
- 2x times cheaper than gasoline on energy equivalent basis
- Efficiency and emissions benefits in a fuel cell vehicle

Efficiency/Natural gas derived hydrogen FCV

- NAE/NSC (2004):
  - 2.4x as efficient as ICE
    - $3 hydrogen ~ $1.25 gasoline
  - 65% better than Prius
- ANL (2005):
  - Diesel and gasoline hybrids 10% to 20% better than best conventional ICE's
  - FCVs ~ 50% better
  - E85 net loser

Impact of FCVs on NG Resources



The Industry's Pursuit of ZEVs

If we accelerate hydrogen/fuel cell commercialization

and . . .

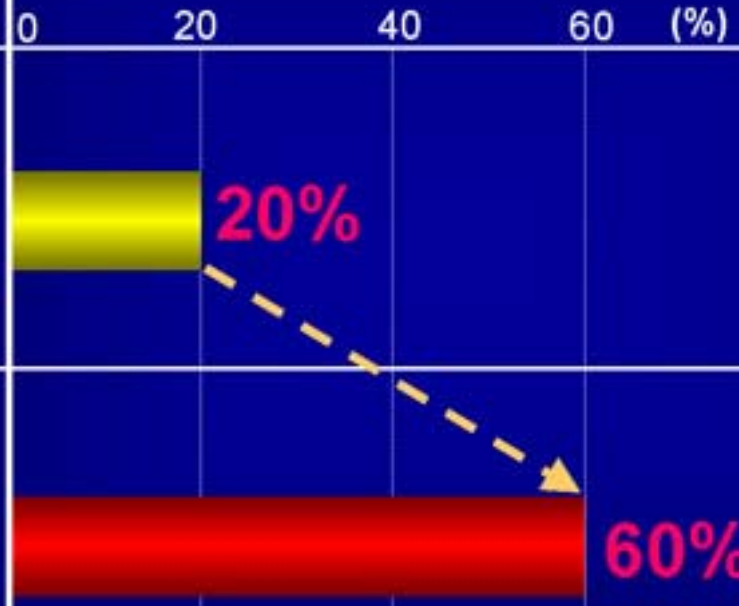
We'll have a partner in the auto industry!

Why?

- Only Fuel Cells can enable the low impact vehicles that auto makers need to achieve their commercial goals

Future Mobility Forecast

Year	World Population (Billion)	Availability of Automobile	World Vehicle Ownership (Billion)	Environmental Impact
2000	6.1	20%	0.74	1.0
2050	8.9	60%	3.24	4.4



→ Factor 4～5

Benefit Estimates

An unmatched combination of benefits

1. Health, environmental, energy security, global warming benefits
2. Natural gas or wind powered fcv's:

- save 3,700 to 6,400 lives
- 1 to 3 million fewer asthma cases
- ~ 2x health benefit compared to hybrids
- Hybrids: "a rough tie for third" overall of five options
  - Assumes hybrid ~ 45% + efficiency

Jacobson et al. 2005

LCA Confirms the Benefit v. ICE

(comp. of two scenarios)

ICE/low sulfur diesel	-28%	+4%
ICE/CNG	-28%	-28%
ICE/Ethanol (corn)	+11%	+13%
ICE Ethanol (cellulose)	-62%	-57%
Battery EV (coal)	-12%	-22%
Battery EV (NG)	-62%	-64%
FCEV (NG)	-58%	-60%
FCEV (water)	-91%	-90%

DeLucchi 2005

One Scenario

- Short term: Efficiency
  - Hybrids
  - Natural gas fuel cells
  - LED’s
  - IGCC
  - Green buildings

One Scenario

- Mid term: Transitional fuels and strategies
  - Biofuels
  - Nuclear + hydrogen??
  - IGCC + fuel cells
  - Renewable electricity

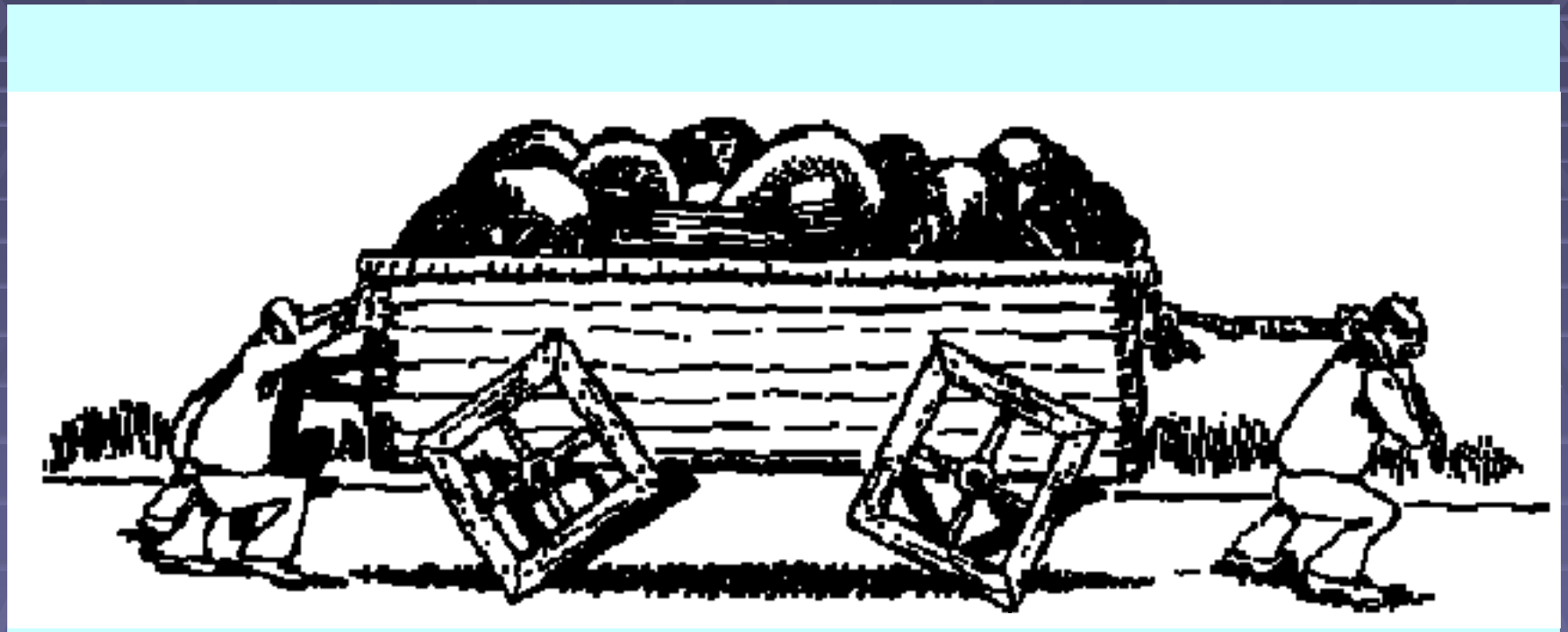
One Scenario

- Long term: Innovation
  - Renewable hydrogen
  - Coal with Carbon sequestration + fuel cells
  - Biofuel-hydrogen with sequestration
  - Nuclear + hydrogen??

"Hydricity"

Are we a wrist radio?

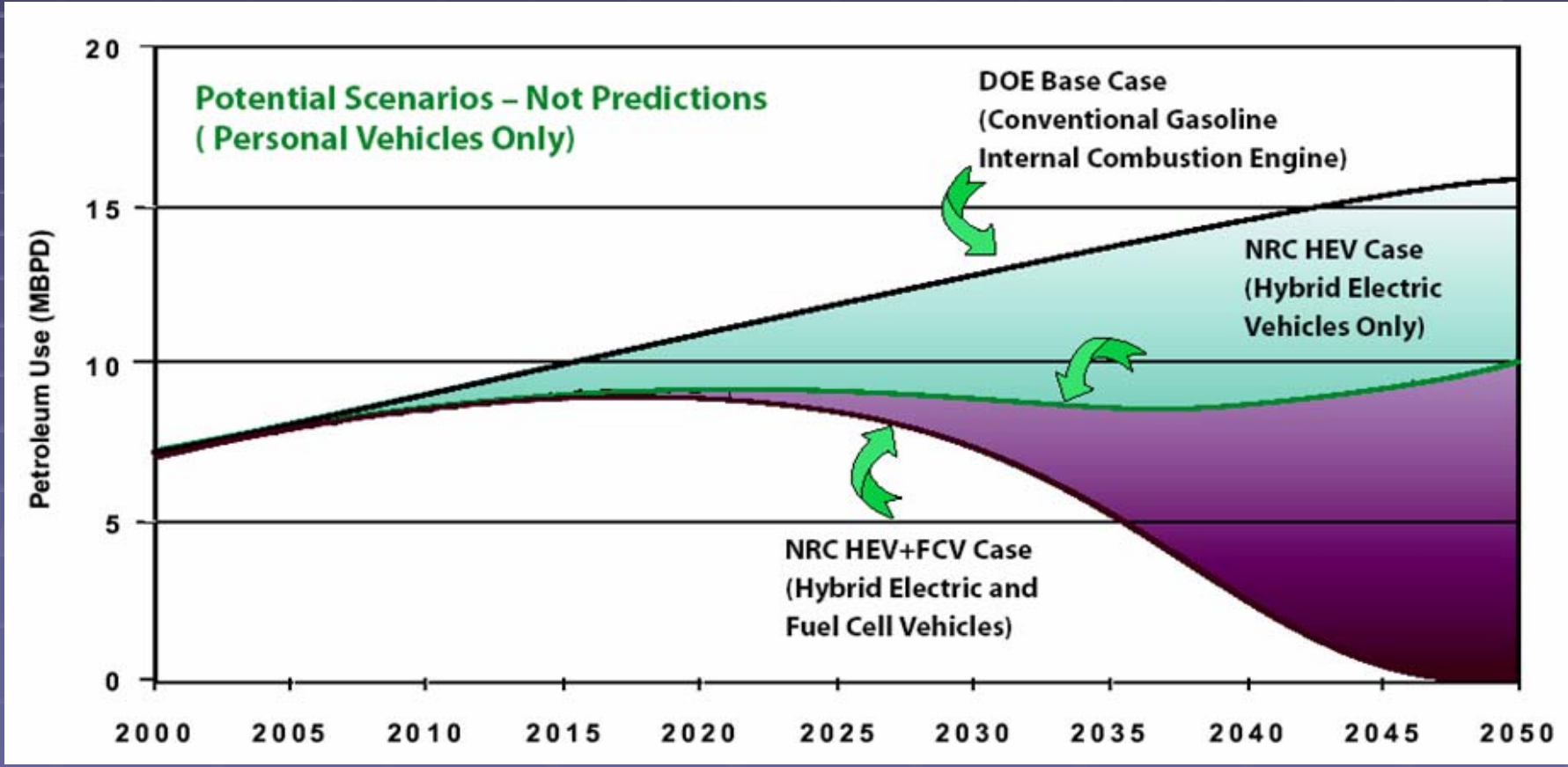
Or a square wheel?



Don’t underestimate the human imagination

May the road rise to meet you . . .

H+ and e^- Get Us There (The Brass Ring)



Near term: hybrid vehicles for improved efficiency
Long term: Hydrogen substitution in Fuel Cell Vehicles