HYDROGEN ECONOMICS

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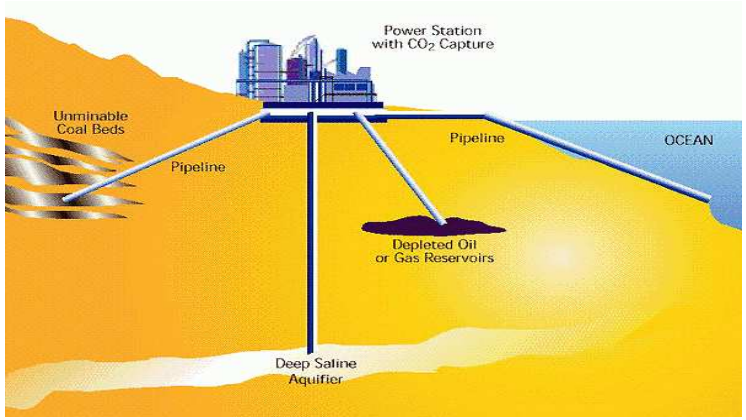
H_2 SUPPLY PATHWAYS

Like electricity, hydrogen is an **energy carrier** produced from **primary energy resources**

Wind

Solar

Biomass



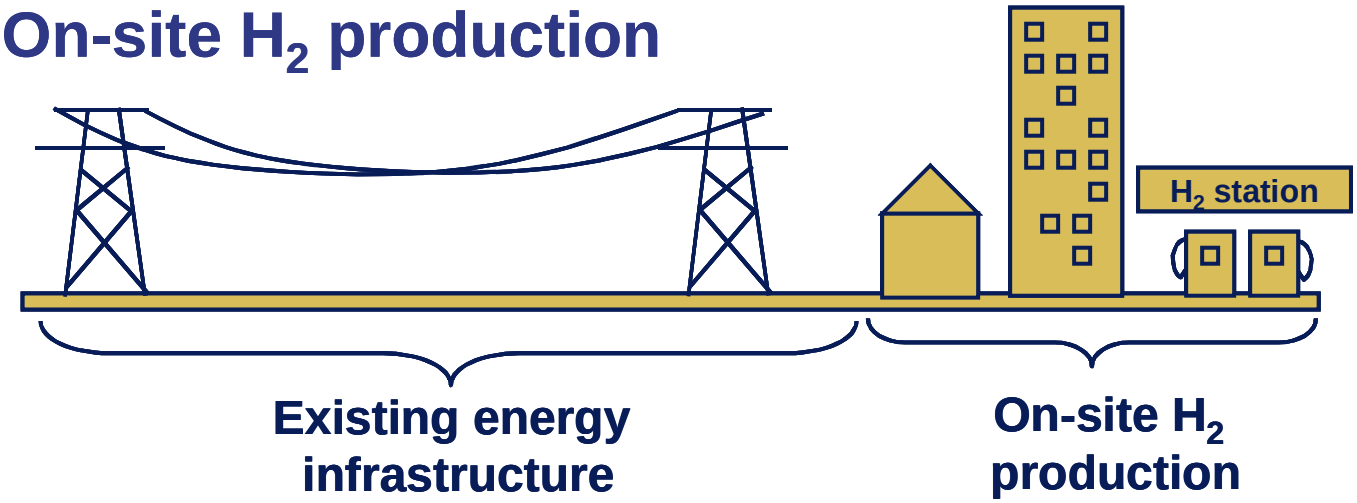
Coal w/CO2 Sequestration

Natural Gas

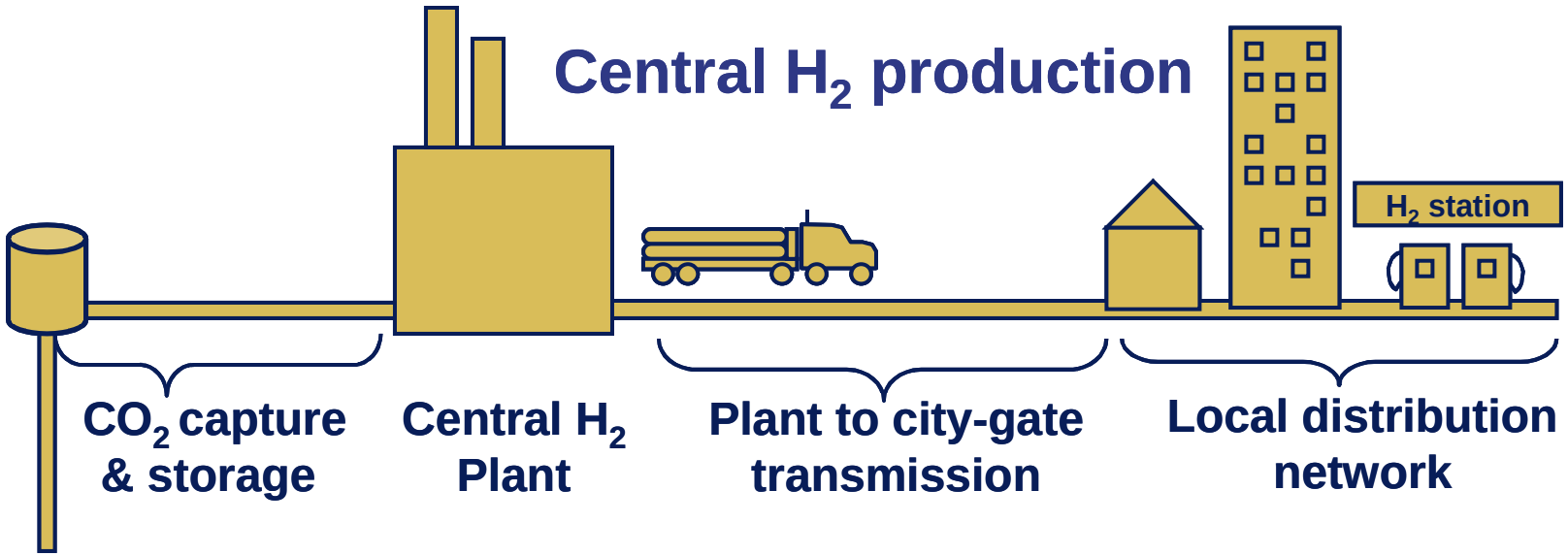
Nuclear

H_2 INFRASTRUCTURE

On-site H_2 production



Central H_2 production



H_2 ECONOMICS: Measuring Cost

Energy Content

1 kg H_2 ~ 1 gallon gasoline

Fuel Cost

$1/kg H_2 ~ $1/gallon gasoline

Fuel Economy

H_2 FCV ~ 1.5-2.5 x Gasoline Car

Fuel cost per mile ($/mi)

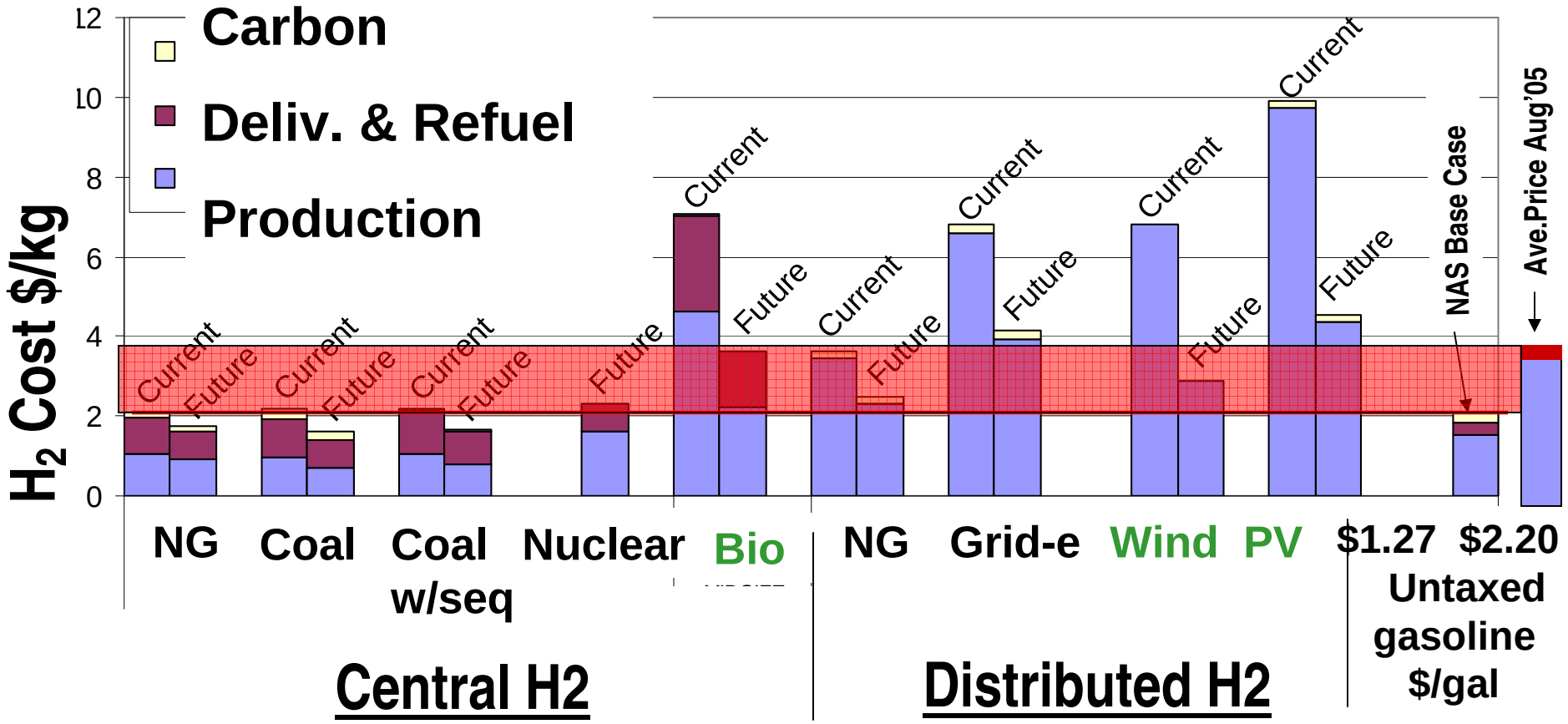
= Fuel cost ($/gallon)/Fuel economy (mi/gallon)

=> H_2 can cost 1.5-2.5 X as much as gasoline and give the same fuel cost per mile!

National Academies "Hydrogen Economy" Study (2004):

DELIVERED H_2 COSTS

W/CURRENT AND FUTURE TECH



Gasoline

scaled by hybrid fuel economy

Source: http://books.nap.edu/books/0309091632/html/53.html

HOW MUCH WILL H_2 COST?

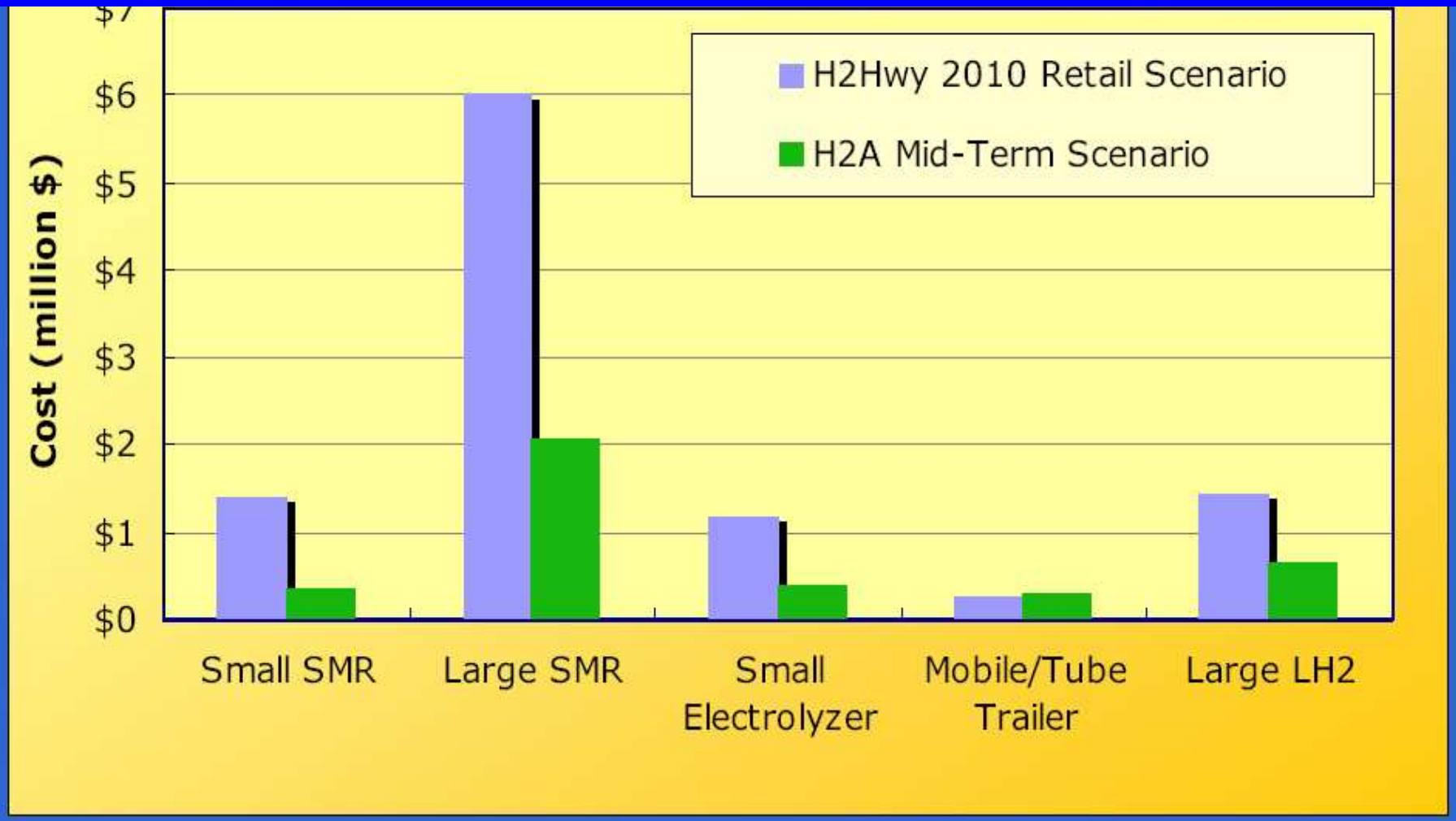
- **Long Term**:

  Delivered H_2 cost range
  ~$2-5/kg for **mature, large scale** H_2 economy.

	H_2 FCV	Gasoline Hybrid	Gasoline ICEV
Fuel economy	**60 mi/kg**	**40 mpg**	**27 mpg**
Fuel cost (untaxed)	**$2-3/kg (fossil)** **$3-5/kg (renewable)**	**$1.27/gal (oil=$30/bbl)** **$2.20/gal (Aug 2005)**	**$1.27/gal (oil=$30/bbl)** **$2.20/gal (Aug 2005)**
Fuel cost per mile (cent/mi)	**3-5 (fossil)** **5-8 (renewable)**	**3.2 ($30/bbl)** **5.5 (Aug 2005)**	**4.5 ($30/bbl)** **8 (Aug 2005)**

- **Near term H_2 costs higher**

NEAR TERM STA. CAPITAL COST ~ $0.3-5 MILLION DECREASE W/ MASS PRODUCTION AND TECHNOLOGY IMPROVEMENT



Source: S. Lasher, Tiax, Study for California H2 Highway Blueprint Plan, http://www.hydrogenhighway.ca.gov/implement/pubmeetings/economy/091404meeting/tiax.pdf

BRINGING DOWN THE COST OF H_2

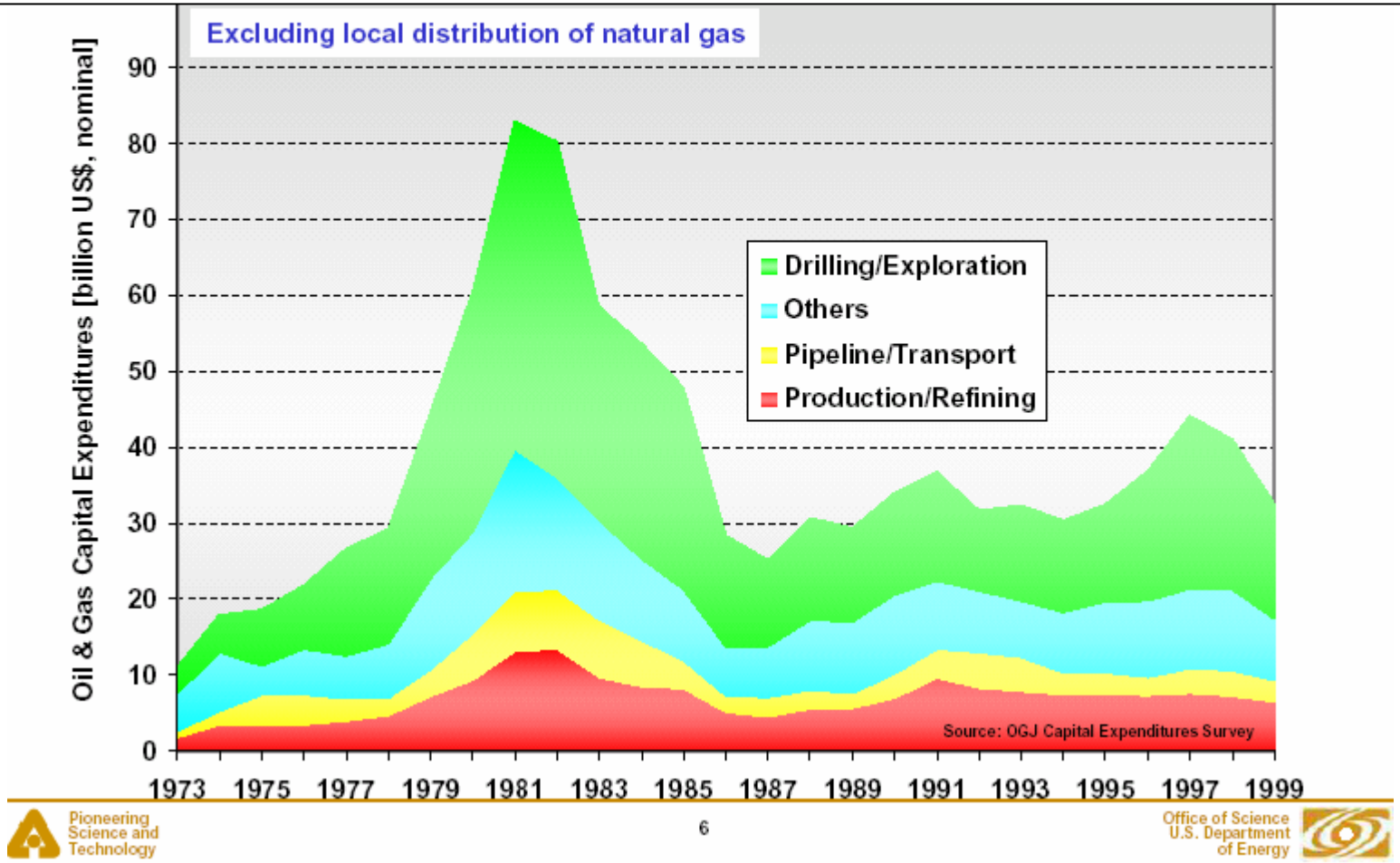
- Technical maturity
- Mass production of H_2 technologies
- Larger station
- Higher Capacity Factor
- Siting

H_2 ECONOMY INVESTMENT COSTS

- Current demonstration H_2 refueling stations cost ~$1 million each.
- Shell estimates 11,000 H_2 stations needed nationwide to serve **early** market (1 million H_2 vehicles); initial cost $12 B (~$12,000/car)
- Several hundred to several thousand $ per vehicle for **mature** H_2 refueling infrastructure.
- Full implementation of US H_2 infrastructure cumulative investment of $100sB
- BUT conventional fuels are also costly.

Oil & Gas: Cum. Investment 1973-1999 ~ $1 Trillion;

Transport, Pipelines, Refining ~$300 B, not incl local distrib, refuel



Source: M. Mintz, G. Conzelman. R. Cirillo, C. Macal, M. North, Argonne National Laboratory, "Hydrogen Infrastructure: Investments and Issues," presented at the Windsor Workshop Transportation Technologies Fuel Forum, Windsor, Ontario, June 2004.

H_2 OFFERS MULTIPLE SOCIETAL BENEFITS

H_2 is one of the only long term fuel options that offers radical reductions in:

- **GHG emissions**
- **Air pollutant emissions**

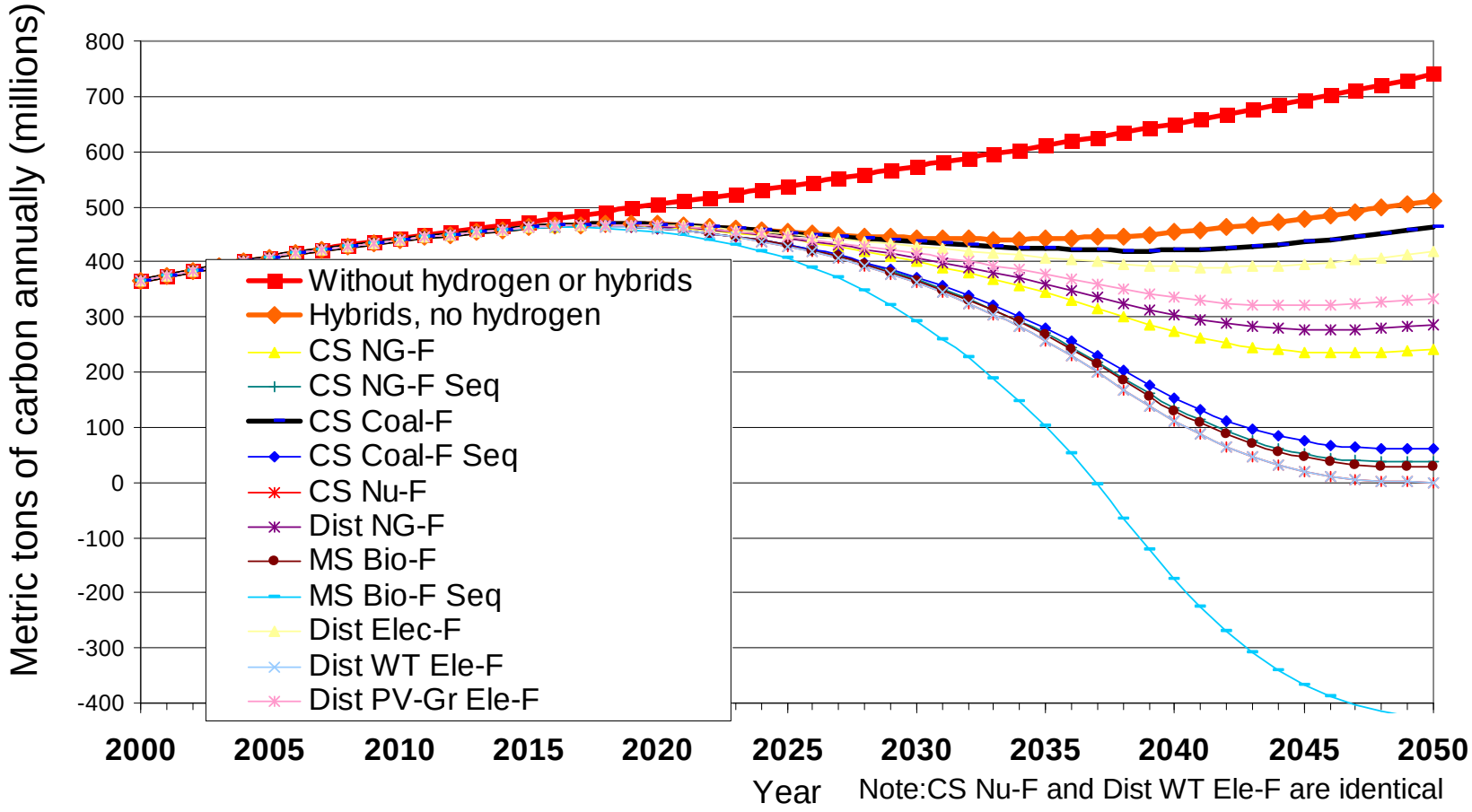
and

- **Diverse primary supply for fuels**

H_2 ECONOMICS II

Economic valuation of hydrogen's societal benefits is complex and uncertain, but several studies suggest that these could be significant. H_2 FCVs will have lower emissions and societal costs than other options.

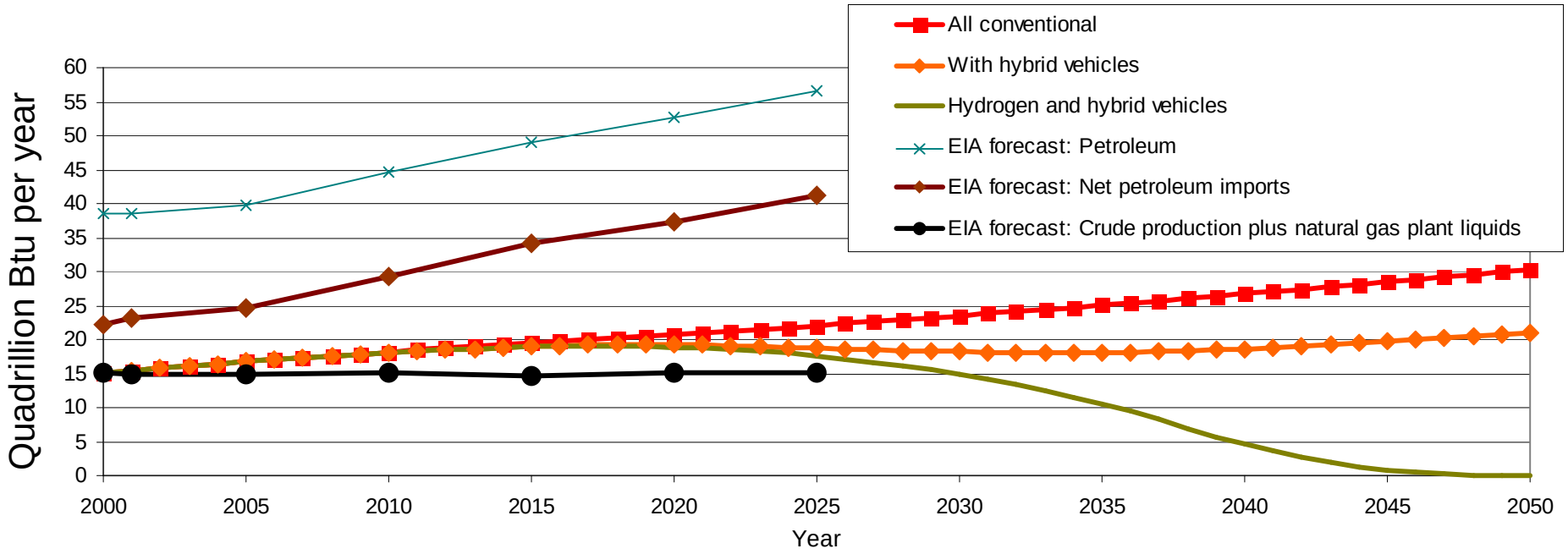
National Academies "Hydrogen Economy" Study (2004): IMPACT ON CARBON EMISSIONS



- *Curves show emissions due to H_2 supply chain for each production technology, assuming each is sole supplier of vehicles in fleet – future technology*

Source: http://books.nap.edu/books/0309091632/html/71.html

National Academies "Hydrogen Economy" Study (2004):
SECURITY IMPACTS
Petroleum Use Decreases with Penetration of FCV versus HEV or Conventional ICE



- *EIA reference projections of U.S. consumption, production, and imports of oil also shown*

Source: http://books.nap.edu/books/0309091632/html/69.html

Question: How soon can H_2 reach costs projected by NAS?

Early market strategies for introducing H_2 energy

- H_2 already used in energy industry at large scale
- Buses and other fleet vehicles
- Co-production of H_2, electricity and heat

H_2 ECONOMICS

In the long term,

H_2 FCV, fuel cost per mile $\leq$ today's gasoline vehicles.

\$3/kg H_2/ (60 mi/kg) ~ \$0.05/mi

\$2/gallon gasoline/(30 mpg) ~ \$0.07/mi

H_2 refueling infrastructure will be expensive initially. But cumulative costs for building large scale H_2 infrastructure may be comparable to maintaining and expanding conventional fuel infrastructure.