

Fuel Cells and the Energy Picture

Will Johnson

Gore Fuel Cell Technologies

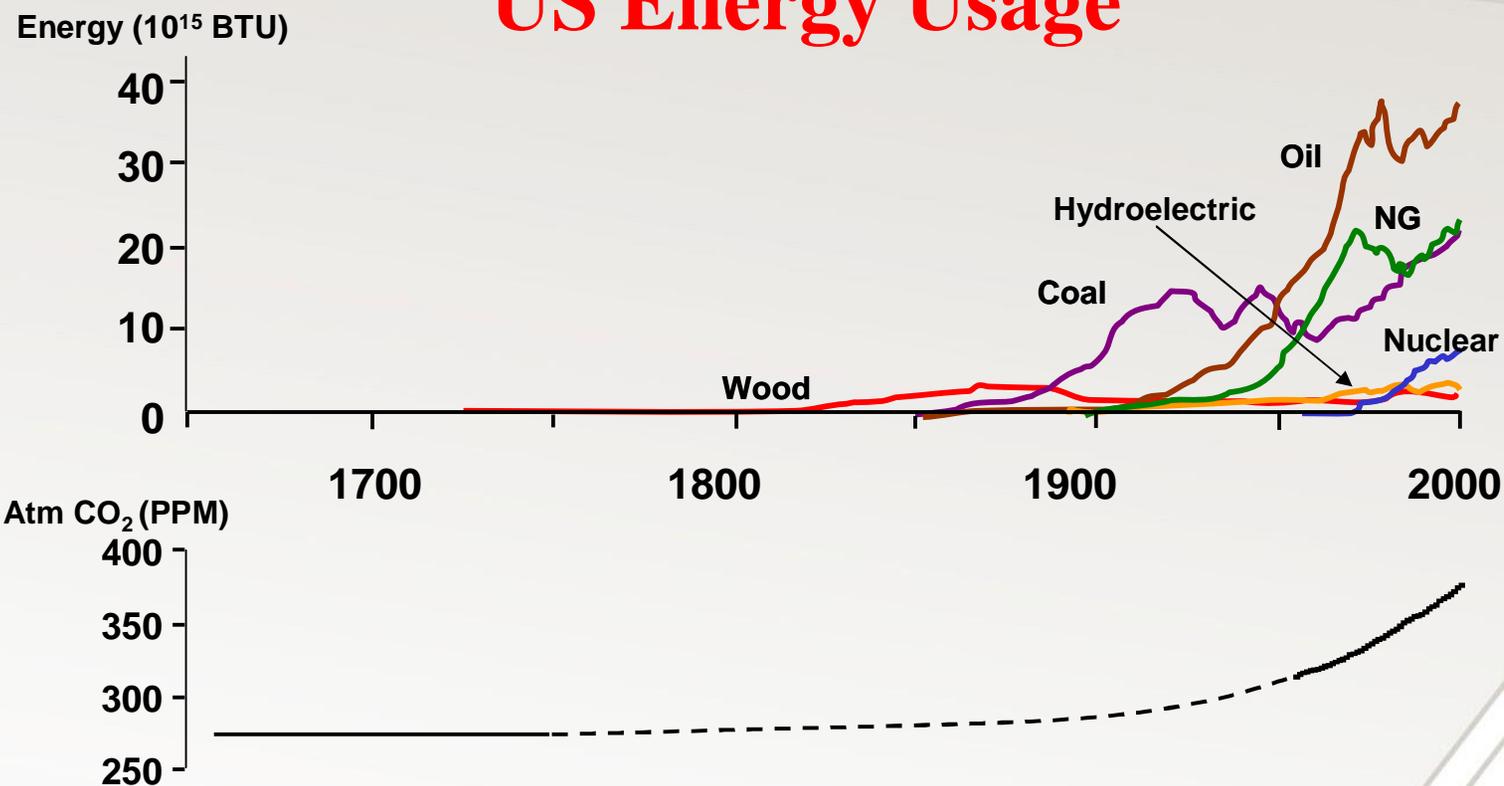
June 5, 2007



THINK GLOBALLY ...

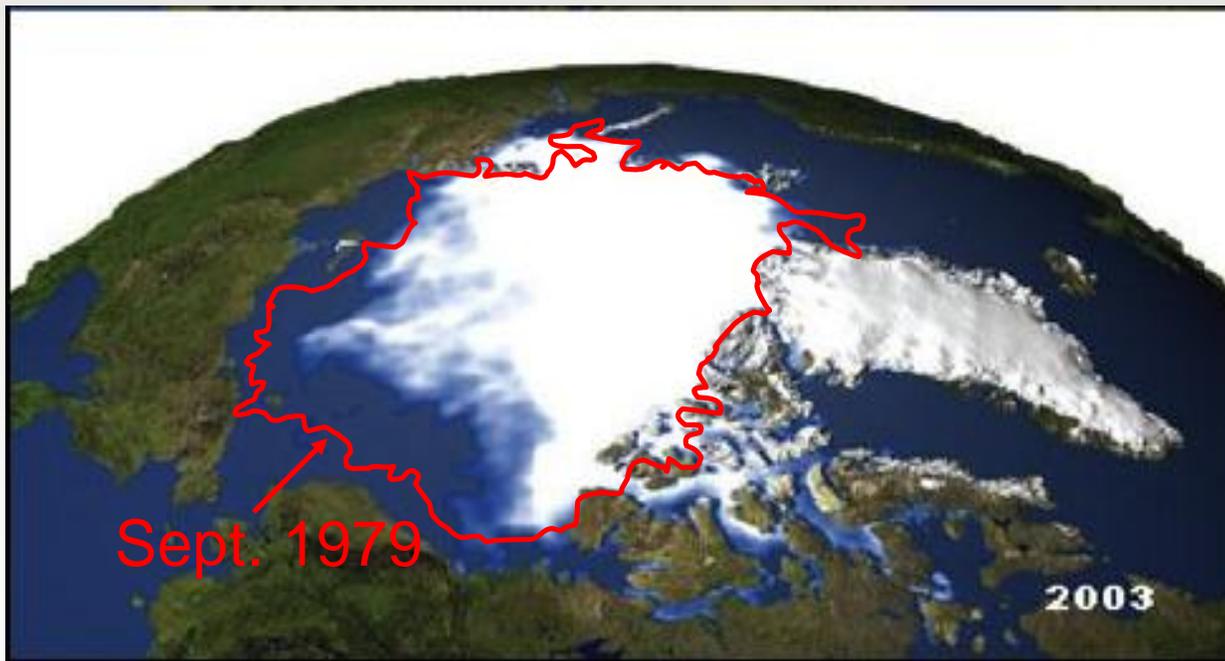
ACT LOCALLY!

US Energy Usage



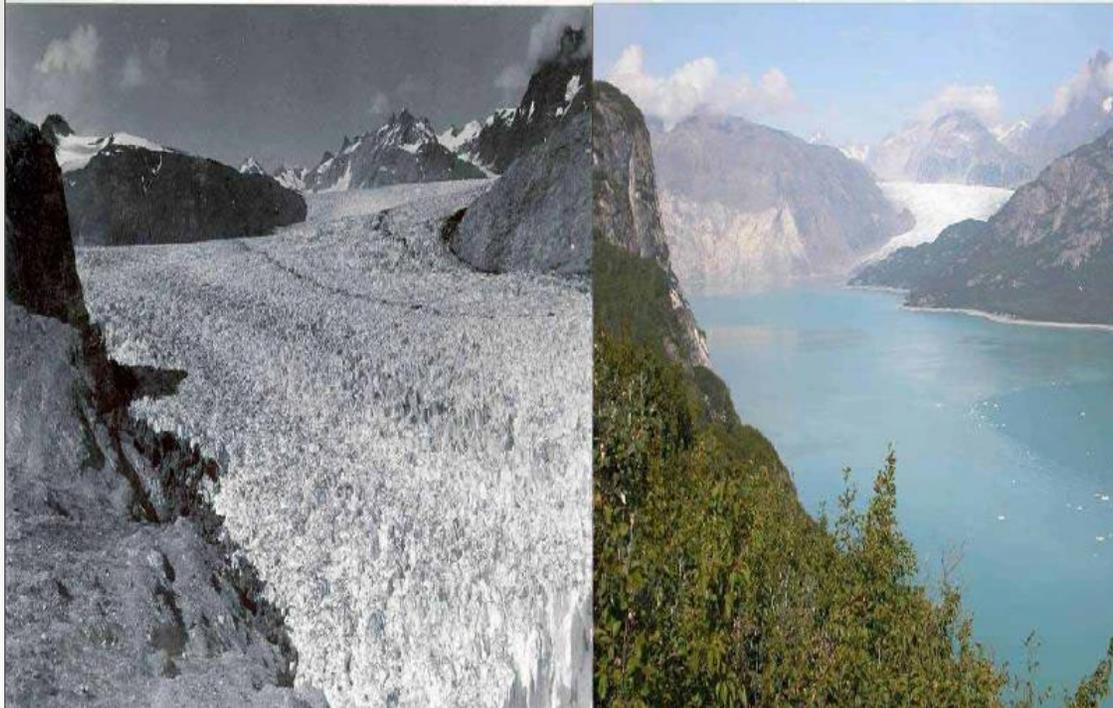
Energy Data: Annual Energy Review 2003, Energy Information Administration, Report No. DOE/EIA-0384(2003), September 7, 2004
 See original at < <http://www.eia.doe.gov/emeu/aer/eh/frame.html> > and at < <http://www.eia.doe.gov/emeu/aer/eh/frame.html> >.
 CO₂ Data 1959-2004: C.D. Keeling, T.P. Whorf, and the Carbon Dioxide Research Group, Scripps Institution of Oceanography, Univ. of CA, May, 2005; Data available at
 < <http://cdiac.ornl.gov/ftp/trends/co2/maunaloa.co2> >

Arctic Ice Cap Retreat



Original Data: Hassol, Susan J, ACIA, *Impacts of a Warming Arctic Climate Impact Assessment*, Cambridge University Press, 2004, Pg. 25.
Available from <http://www.acia.uaf.edu>.

Global Changes



Muir Glacier, SE Alaska, 1941-2004

Source: Arctic Global Climate Change, L. G. Thompson at www.eesi.org/briefings/2006/Energy&Climate/6.15.06_ClimateSymposium/Lonnie%20Thompson_6.15.06.pdf



Healthy and “bleached” coral

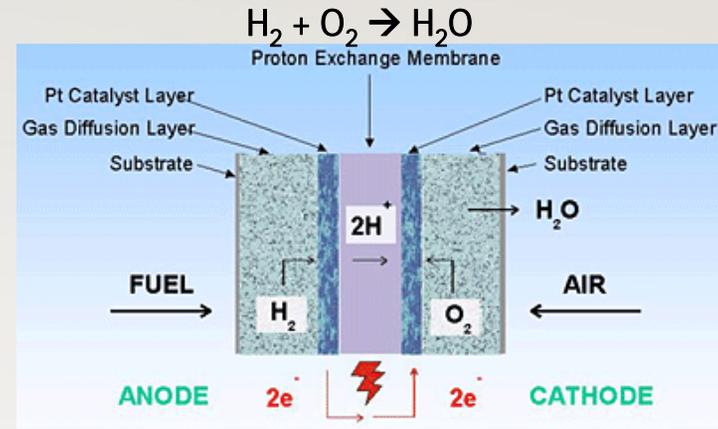
Source:
<http://www.oceansalive.org/explore.cfm?subnav=article&contentID=4709>

The Role of Fuel Cells in our Energy Future

- Effective, efficient converters of hydrogen fuel to electrical energy
 - Environmentally cleanest alternative for transportation uses
 - Very high efficiency for stationary CHP applications
- Challenges
 - Hydrogen storage for transportation applications
 - Cost for all applications
 - Durability (life)
 - Materials challenge – need materials that will survive 5000 – 60,000 hours in harsh conditions

Polymer Electrolyte Membrane Fuel Cells

- Membrane is both separator and electrolyte
- Desirable membrane properties:
 - High ionic conductivity and zero electronic conductivity
 - Low gas permeability
 - Thin with high mechanical strength
 - Dimensional stability (resistance to swelling)
 - Resistant to chemical degradation in fuel cell operating conditions
 - Both highly oxidizing and highly reducing conditions at the same time
 - Thermally stable to high temperatures
 - High water transport characteristics
 - Inexpensive to manufacture

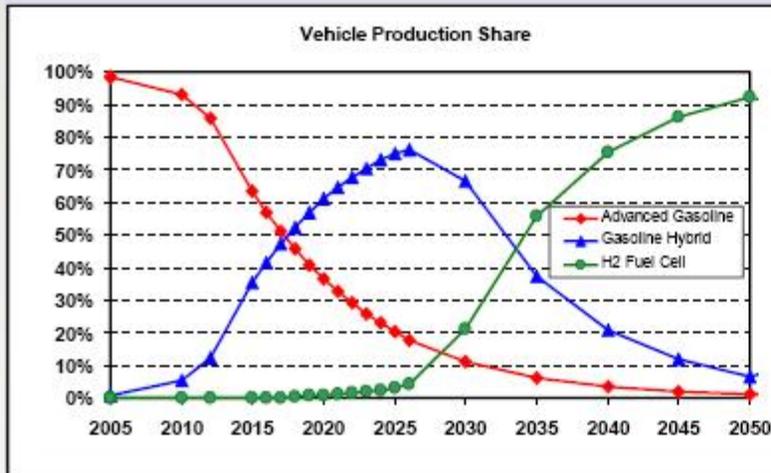


Markets

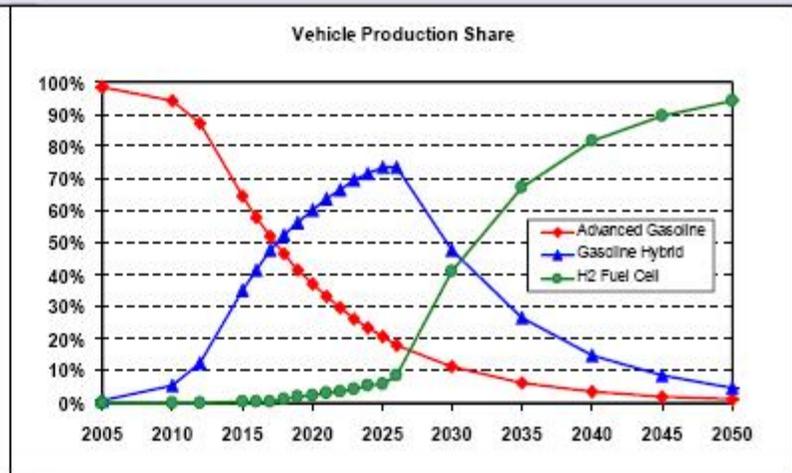
- Transportation
 - Global light vehicle auto production is ~60MM vehicles
 - IF even 10% go fuel cell, and each vehicle requires 100 MEAs @ \$25 each = \$15 BILLION DOLLARS
 - Other segments also viable – forklifts, buses, trucks, etc.
- Stationary
 - Backup power (e.g., cell phone towers) – longer time desired, more reliable, and less “messy” than current GenSets
 - Home and/or industrial
 - METI announcement in JAPAN
- Portable
 - Portable electronics

Fuel Cell Future in Automobiles

Scenario 1



Scenario 3



- Policies will almost certainly be required for early transition period (2012-2025).
- Assumes EIA Hi Oil case and the Hydrogen and FreedomCar Programs achieve full success.
- Does not consider impact of uncertainty on willingness to invest.

Source:

U.S. Department of Energy
Hydrogen Program

*Analysis of the Transition to Hydrogen
Fuel Cell Vehicles & the Potential
Hydrogen Infrastructure Requirements*

David L. Greene
Oakridge National Laboratory
2008 DOE Hydrogen Program
Merit Review and Peer Evaluation Meeting

June 9, 2008



W. L. Gore & Associates

W. B. Johnson, DE State Energy Plan Meeting, 08/26/2007



Japanese Government is strongly pushing household stationary use ...

Friday, August 22, 2008

METI To Subsidize Home Fuel-Cell Cogeneration Systems

Source: Nikkei English News

↵

Nikkei English News via NewsEdge

TOKYO (Nikkei)--The Ministry of Economy, Trade and Industry hopes to provide subsidies to partly cover the cost of installing fuel-cell cogeneration systems in homes, one of several measures to reduce greenhouse gas emissions.

The ministry plans to request funding for these measures in the fiscal 2009 budget. It hopes to secure more money for anti-global-warming programs than the 416 billion yen in fiscal 2008.

And fuel cell industry is responding ...

Friday, August 22, 2008

Nippon Oil To Mass-Produce Household Fuel Cells From April

Source: Nikkei English News

↵

Nikkei English News via NewsEdge

TOKYO (Nikkei)--Nippon Oil Corp. (5001) said Thursday it will begin mass production of household fuel cells in April 2009, manufacturing 10,000 units in fiscal 2010 and raising output to 40,000 by fiscal 2015.

Fuel Cell Industries Locally

- Delaware (today, employment in hundreds?)
 - Du Pont: materials, MEA, & membrane supplier
 - Gore: membrane & MEA supplier
 - Ion Power: MEA, materials supplier
 - Air-Liquide: hydrogen supplier
- Regionally (today, employment of ??)
 - Johnson-Matthey (PA): catalyst & MEA supplier
 - BASF (NJ): catalyst supplier
 - Arkema (PA): membrane supplier
 - Air Products (PA): hydrogen supplier

What can we do locally at state level?

- Central hydrogen fueling stations
 - Fuel cell buses running in Wilmington, Newark and Dover?
 - Hydrogen filling station on Rt. 95?
- State tax incentives?
 - For industrial investment?
 - For investment in fuel cell vehicles?
- Organize regionally for larger political clout
- Financially support fuel cell R&D, fuel cell manufacturing, and equipment purchases with clean energy funds (and follow through on existing commitments)

I just want to say one word to you - just
one word **FUEL-CELLS**

“...fuel cells are the energy engine of the 21st century. When using hydrogen as the fuel, a fuel cell produces heat, power and remarkably, no polluting by-products”.

“Just as the internal combustion and diesel engines displaced the steam engine around the turn of the 20th century, the fuel cell will replace the internal combustion engine in the 21st century”.

**W. B. Johnson, Statement to Congressional R&D Caucus,
Rayburn House Office Building, Sept. 15, 2005.**

EXTRA SLIDES

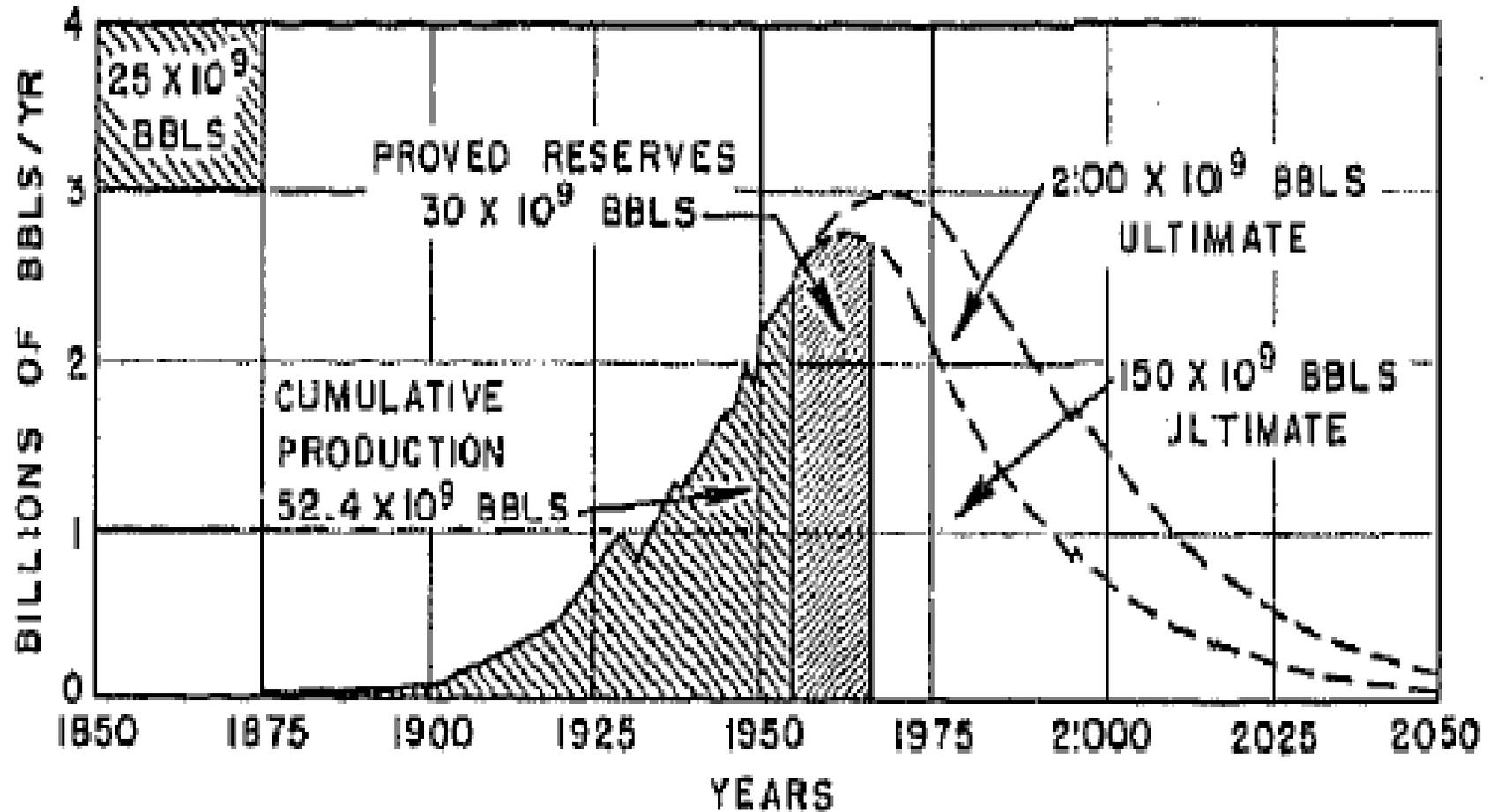


Our Energy Future

- **“... these fuels [fossil fuels] represent an accumulation over 500 million years of geologic time, and any additional accumulation that may be expected within the next 10,000 years is negligible. When these fuels are burned, their material content remains upon the earth in a relatively useless form, but the precious energy, after undergoing a sequence of degradations, finally leaves the earth as spent, long-wavelength, low temperature radiation. Hence, we deal with an essentially fixed storehouse of energy which we are drawing upon at a phenomenal rate. The amount**

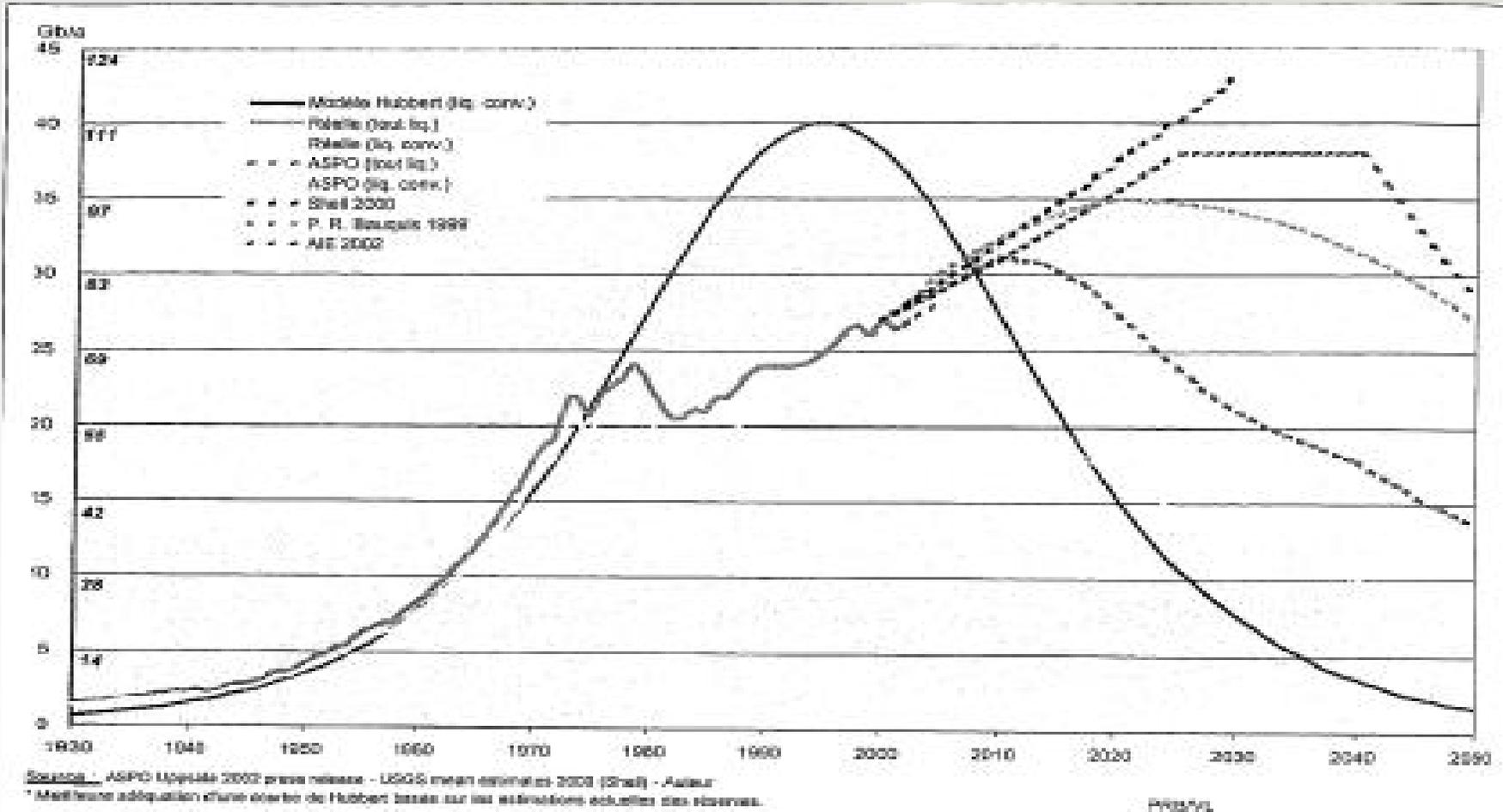
M. King Hubbert, "Energy from Fossil Fuels," *Science*, Vol. 109, 2/4/1949, pg. 105.

Hubbert Peak: US Production

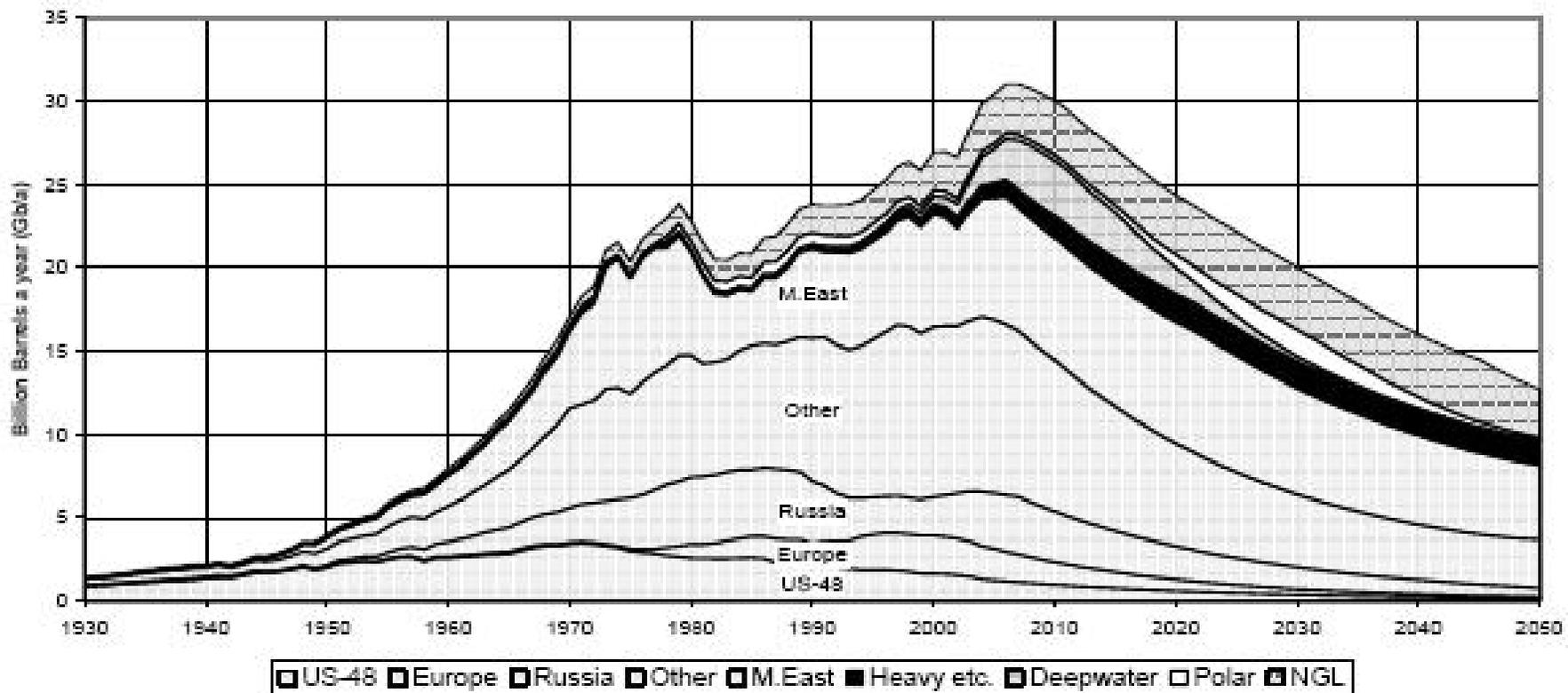


Hubbert, M. King, "Nuclear Energy and the Fossil Fuels, American Petroleum Institute, Drilling and Production, 1956, pg. 17.

Worldwide Oil Production: Recent Predictions

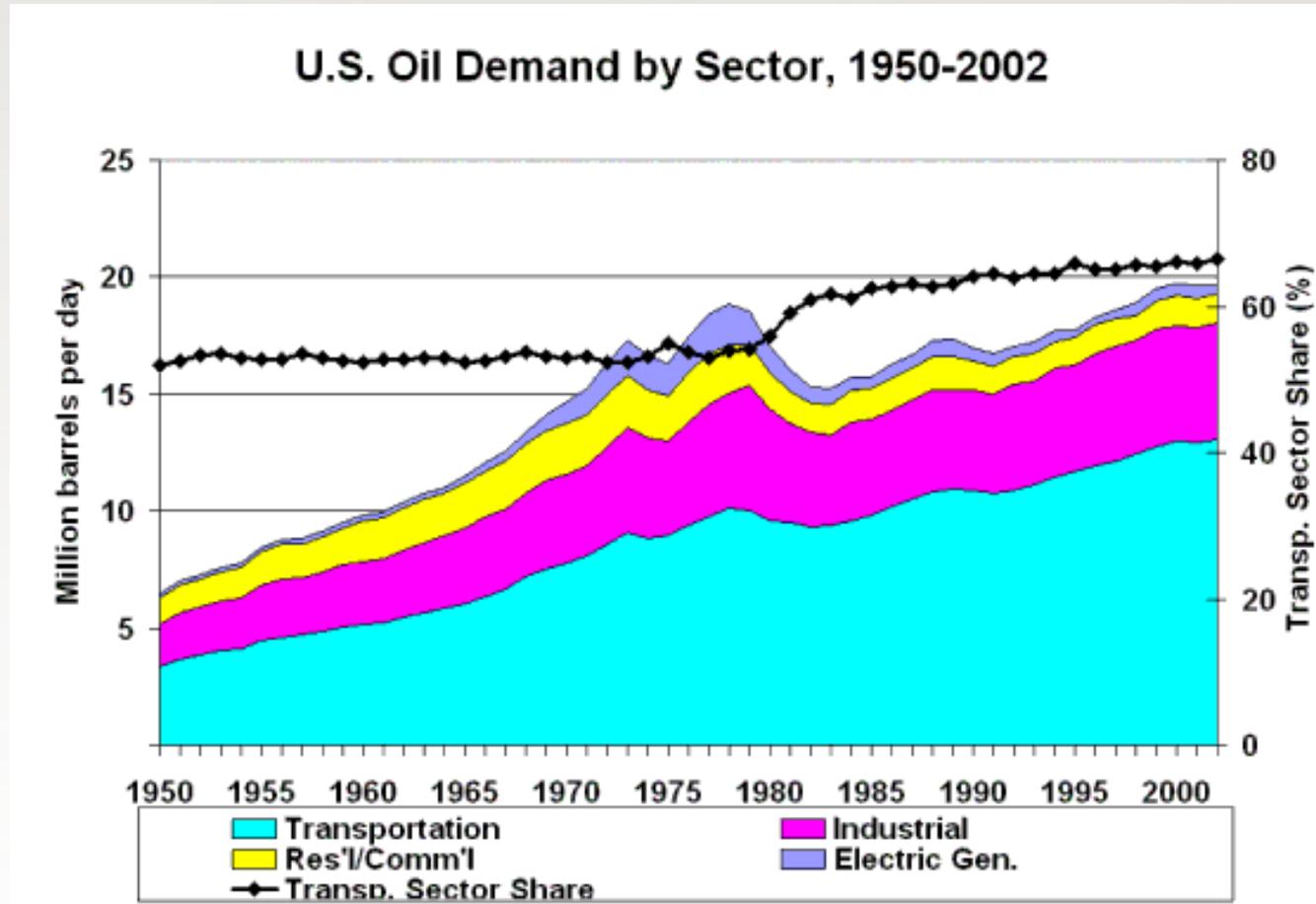


Worldwide Oil Production: Recent Predictions



Association for the Study of Peak Oil & Gas Newsletter, downloaded 9-30-05 from http://en.wikipedia.org/wiki/Image:ASPO_2004.png#file

So What?



Source: DOE table from <http://www.eia.doe.gov>, downloaded 9-30-05

W. L. Gore & Associates

W. B. Johnson, DE State Energy Plan Meeting, 08/26/2007



How about that Malthus?

- **Personal energy usage**
 - Hunter-gatherer: 3 kcal/person/day
 - Agrarian: 15 kcal/person/day
 - Developed countries today: 150-300 kcal/person/day
- **Food production in developed countries**
 - 10 cal of energy for 1 cal of food to your table!
 - 31% fertilizer
 - 19% machines
 - 16% transportation

Energy Alternatives

- **Oil [42% today]**
 - Production peaking, will become expensive & too precious to burn
- **Other Fossil Fuels [coal (24%) & gas (20%)]**
 - Larger reserves left, BUT coal very dirty; less global reserves of gas than coal, but more than oil - may be a good “bridge” energy source, but transport not easy
- **Nuclear [8%]**
 - Can we as a society (race) accept long-term effects of highly toxic waste??

Regardless of energy source, we need a

way to “carry” the energy → HYDROGEN

Renewables [4%]
Wind [2%], Solar [2%], Geothermal, Wave, ...
currently expensive, BUT will become increasingly



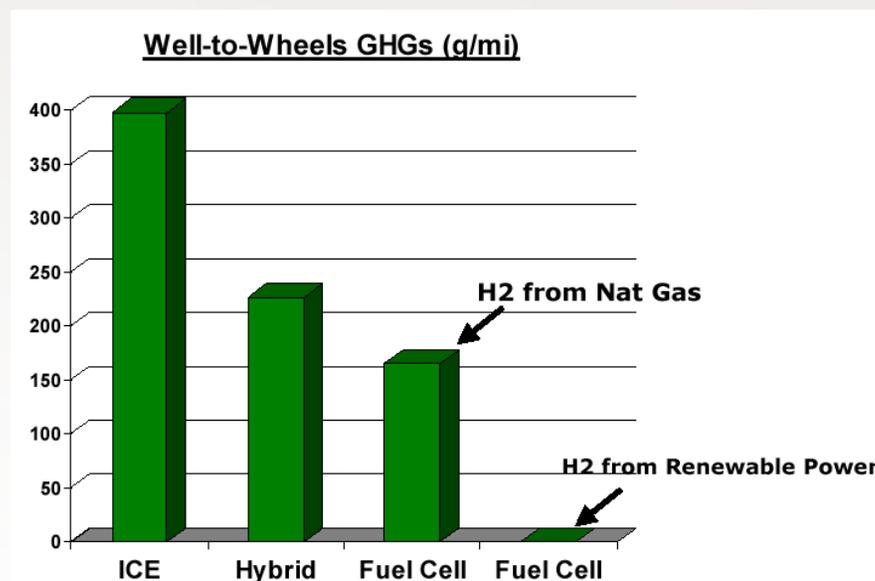
Hydrogen as Fuel

- Cost “at pump” today for hydrogen from renewable energy is ~ \$5/kg
- 1 gal gasoline \equiv 1 kg Hydrogen and fuel cells 2x more efficient than ICE

•• **\$2.50/gal gas \equiv \$5/kg hydrogen from renewables!**

AND ...

YOU GET TRULY ENVIRONMENTALLY CLEAN FUEL!!



W. B. Johnson, DE State Energy Plan Meeting, 08/26/2007

Hydrogen Infrastructure: A Red Herring?

- Estimate of the cost to build hydrogen infrastructure

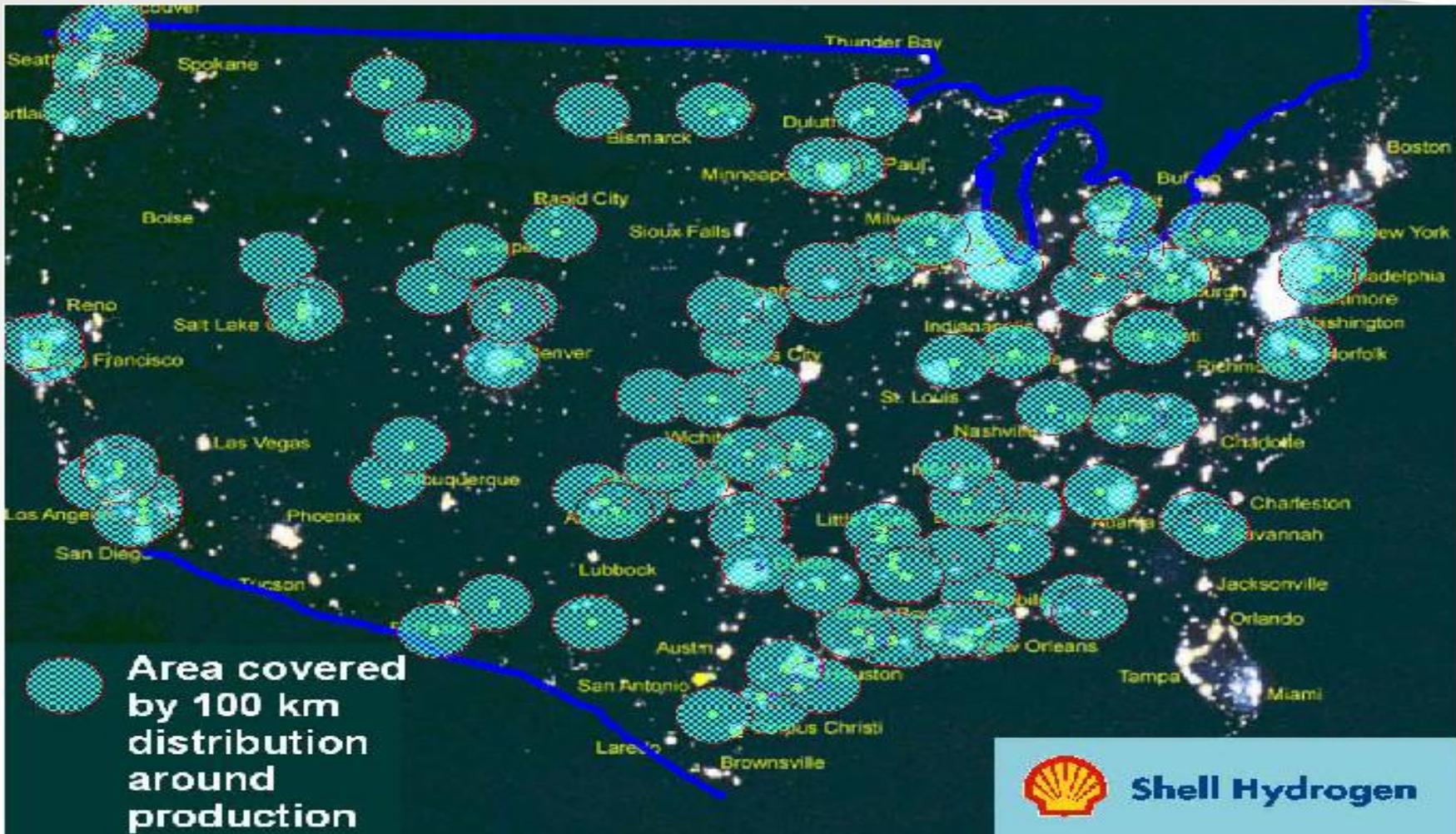


\$12 Billion (12,000 stations @ \$1MM each reach 80% + 1/25 miles on Hwy)

– \$19 Billion

- Current cost to maintain existing gasoline infrastructure: \$11 Billion per year by private industry

US Hydrogen Production Today



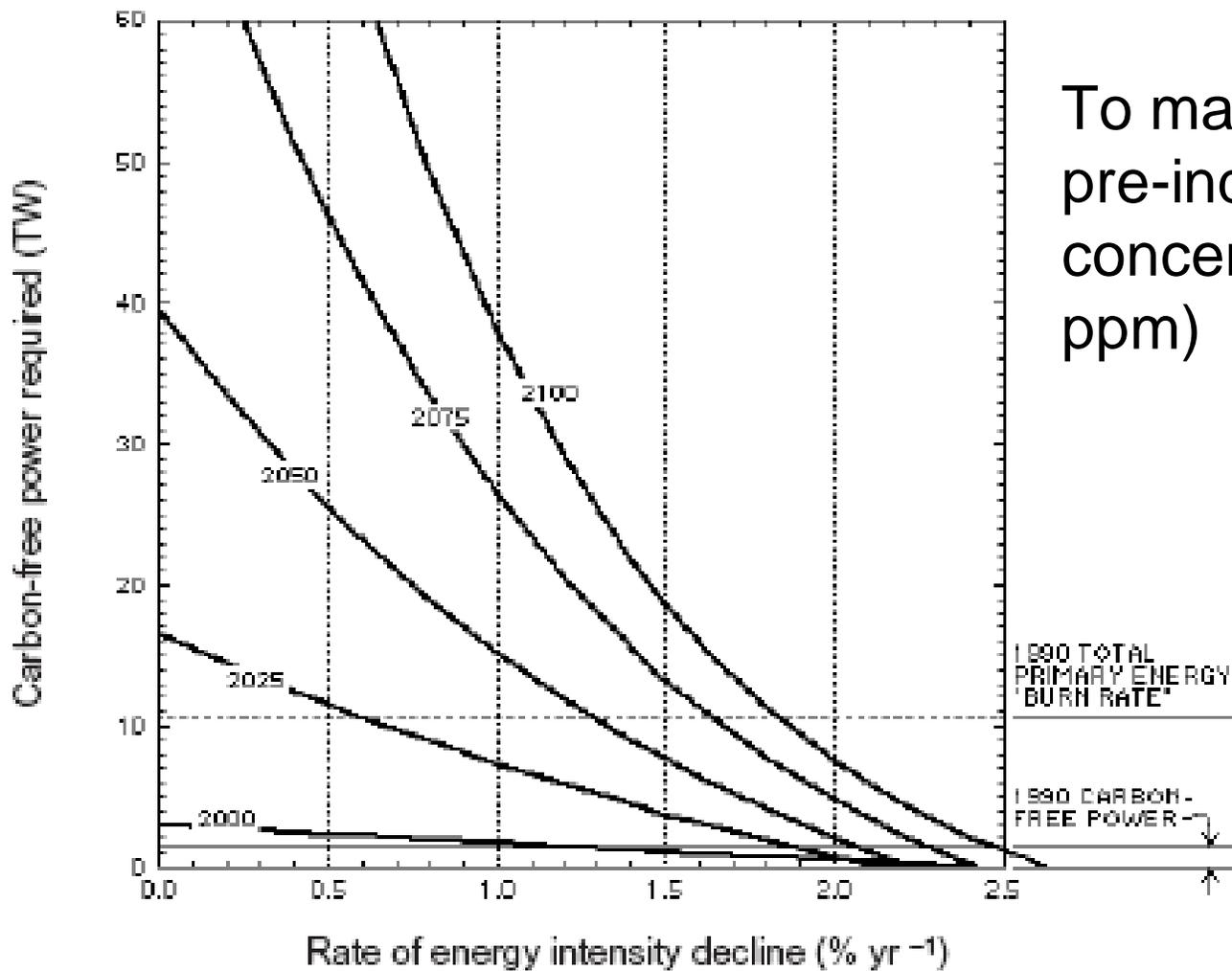
Source: Dennis Campbell, Ballard Power Systems, presentation to Joseph Priestly Society Meeting, Feb. 10, 2005.

Summary

- **Oil production will reach its peak in our lifetime, leading to dramatic changes in our economy**
 - **Failing to recognize this fact now, and preparing for it may have severe, unpleasant consequences**
- **Hydrogen fuel from renewable resources, i.e., wind, solar, geothermal, hydro. (and nuclear)**

Summary

- **Fuel cells offer a clean, efficient means to convert hydrogen to electricity, but we (i.e., humanity) are still developing the technology**
- **W. L. Gore & Associates is committed to developing the technology and products to make fuel cells a reality**



To maintain 2x pre-industrial CO₂ concentration (550 ppm)

Hoffert, M.I., et. al., *Nature*, 1998, 395, 881, "Energy Implications of Future Atmospheric Stabilization of CO₂ Content"

W. L. Gore & Associates

W. B. Johnson, DE State Energy Plan Meeting, 08/26/2007

