Energy Issues:
Demand, Supply, and Opportunities for Increased Efficiency

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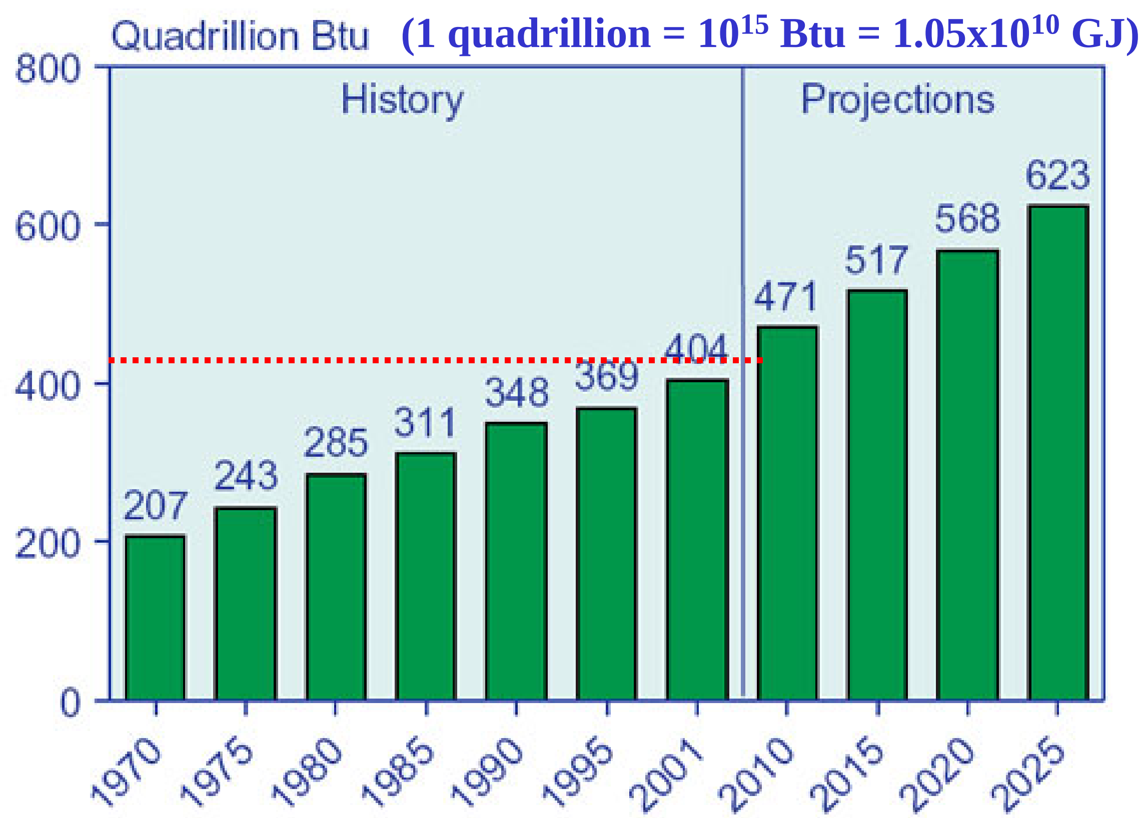
Organization

- Summary of World and U.S. Energy[1] Use
- Source and Reserves of Major Energy Sources
- Projections of Energy Supply Peak
- Purpose: Demonstrate the Extent of the Energy Problem
- Suggestions for Improved Efficiency for Buildings

[1] *Energy is the ability to do work or cause a change*

World Primary Energy Consumption

Source: EIA, U.S. DOE

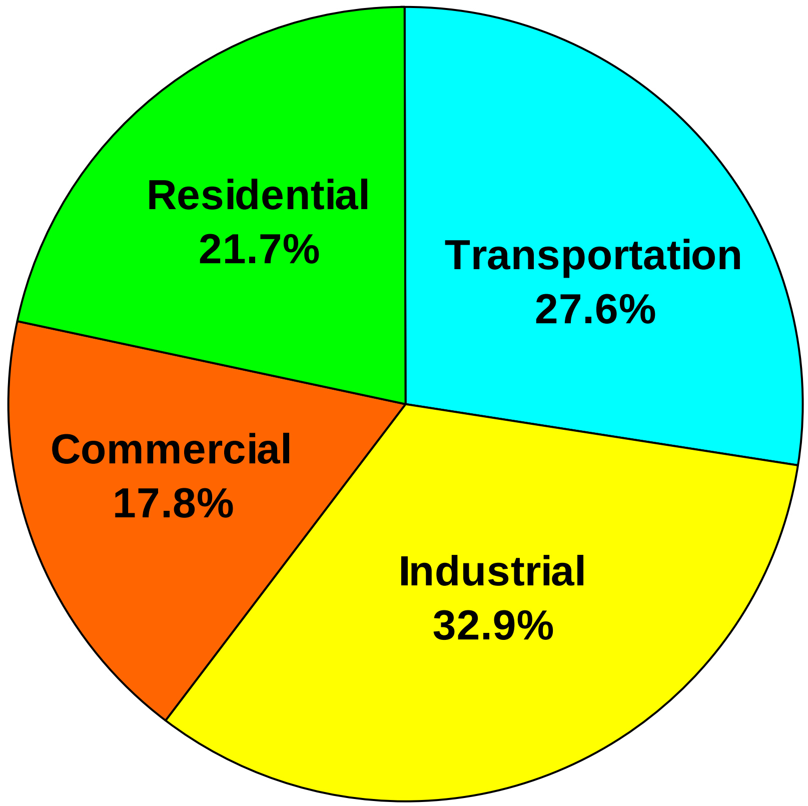


Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Energy Use in U.S.

Total Energy Use: 98×10^{15} Btu/yr = 1.03×10^{11} GJ

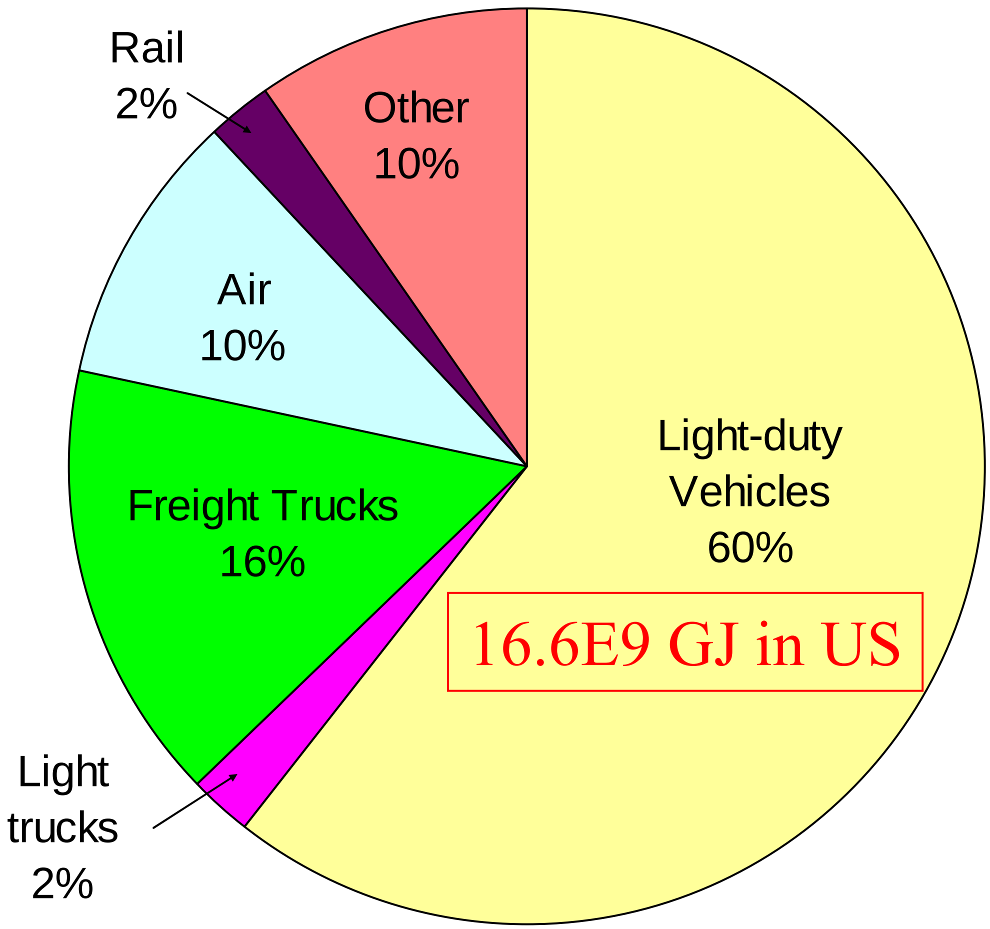
~24% of world energy use



Annual Energy Outlook 2005, U.S. DOE, Table A2 (2003)

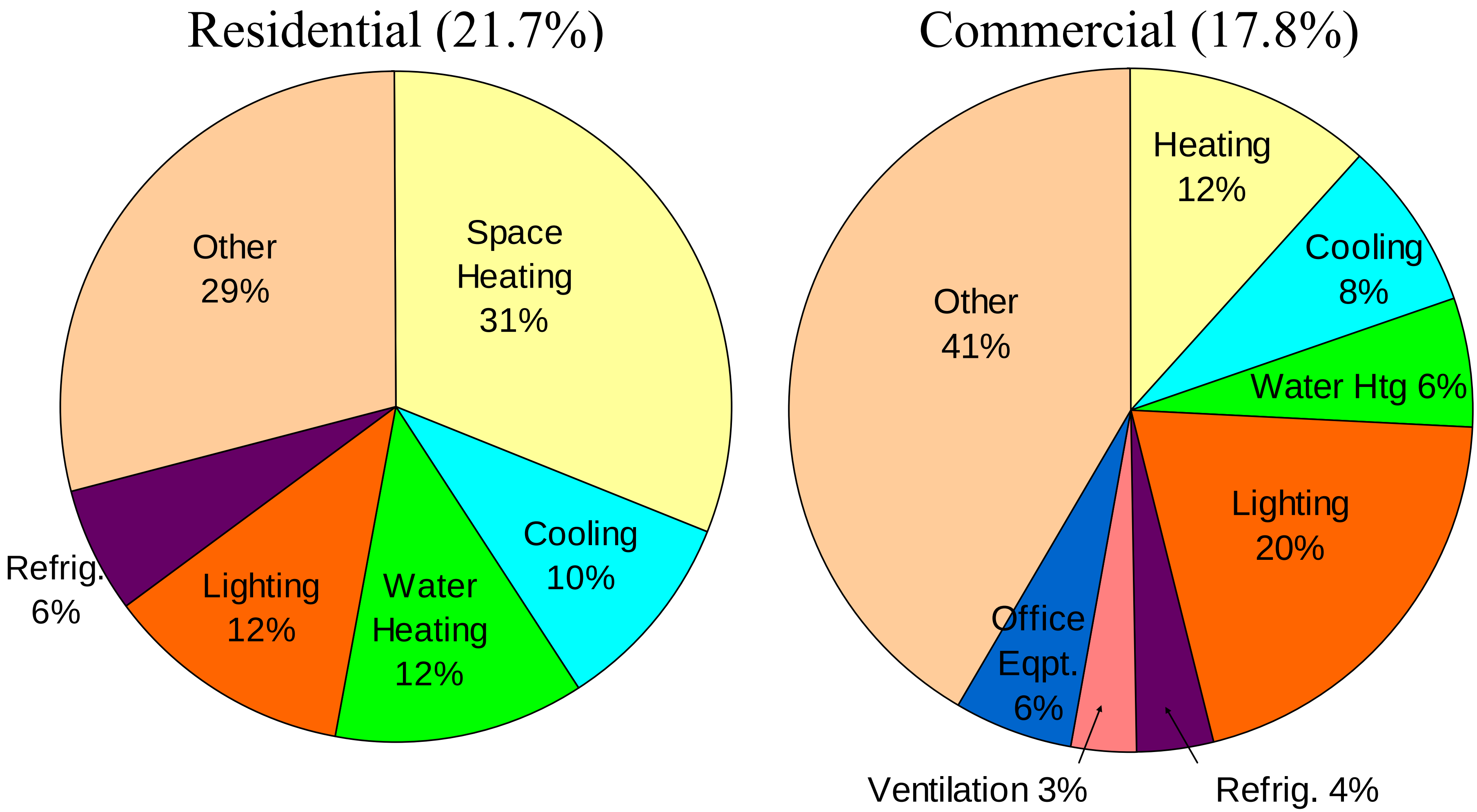
Transportation Energy Use (27.6%)

Over 60% is used for cars and privately owned light trucks



Annual Energy Outlook 2005, U.S. DOE, Table A7 (2003)

U.S. Energy Use Breakdown



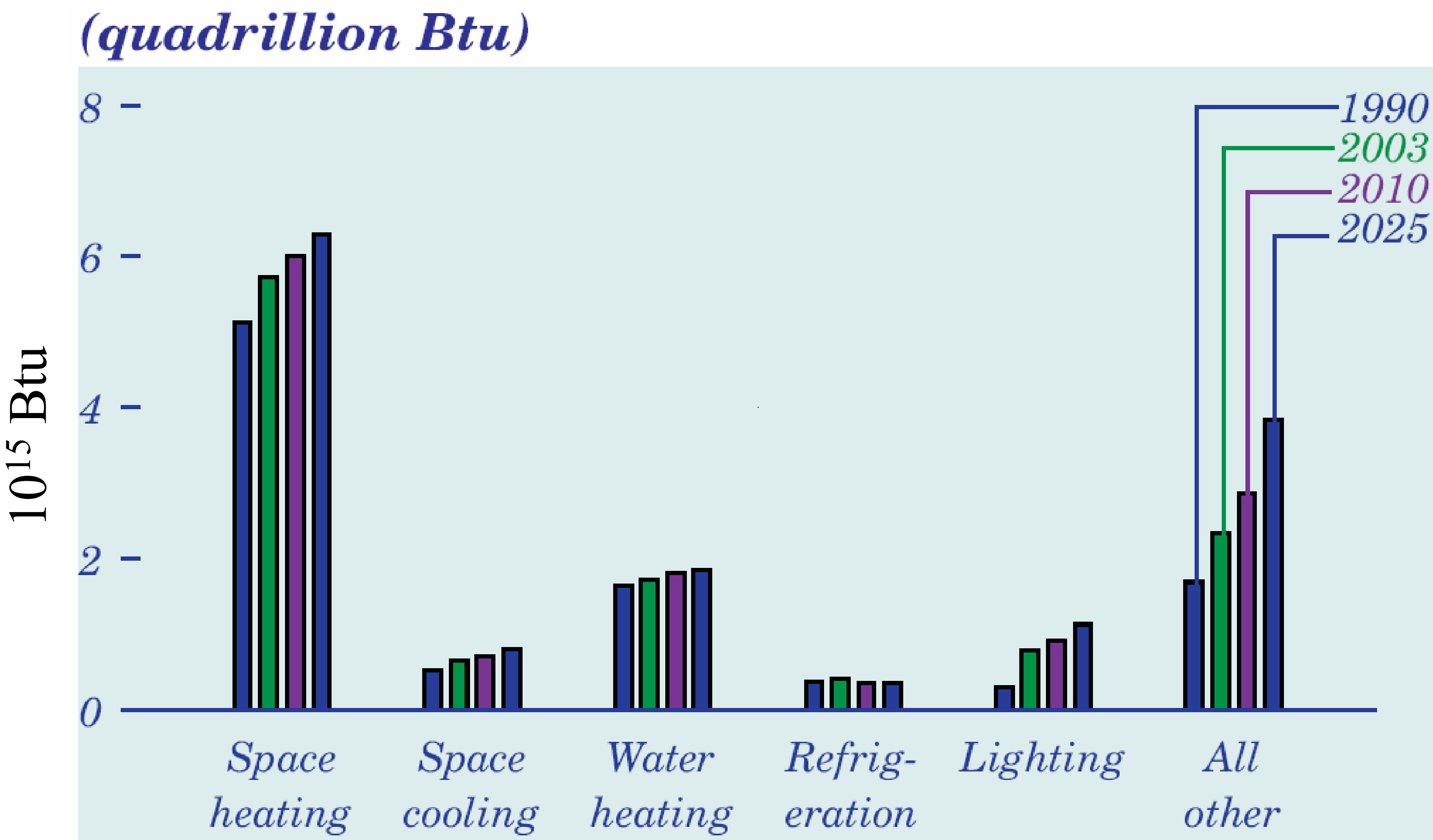
space & water heating: 43% space & water heating: 18%

43%*21.7E9 [GJ] + 18%*17.8E9 [GJ] = 12.5E9 [GJ] in US

Annual Energy Outlook 2005, U.S. DOE, Table A4 & A5 (2003)

U.S. Residential Energy Demand by End Use

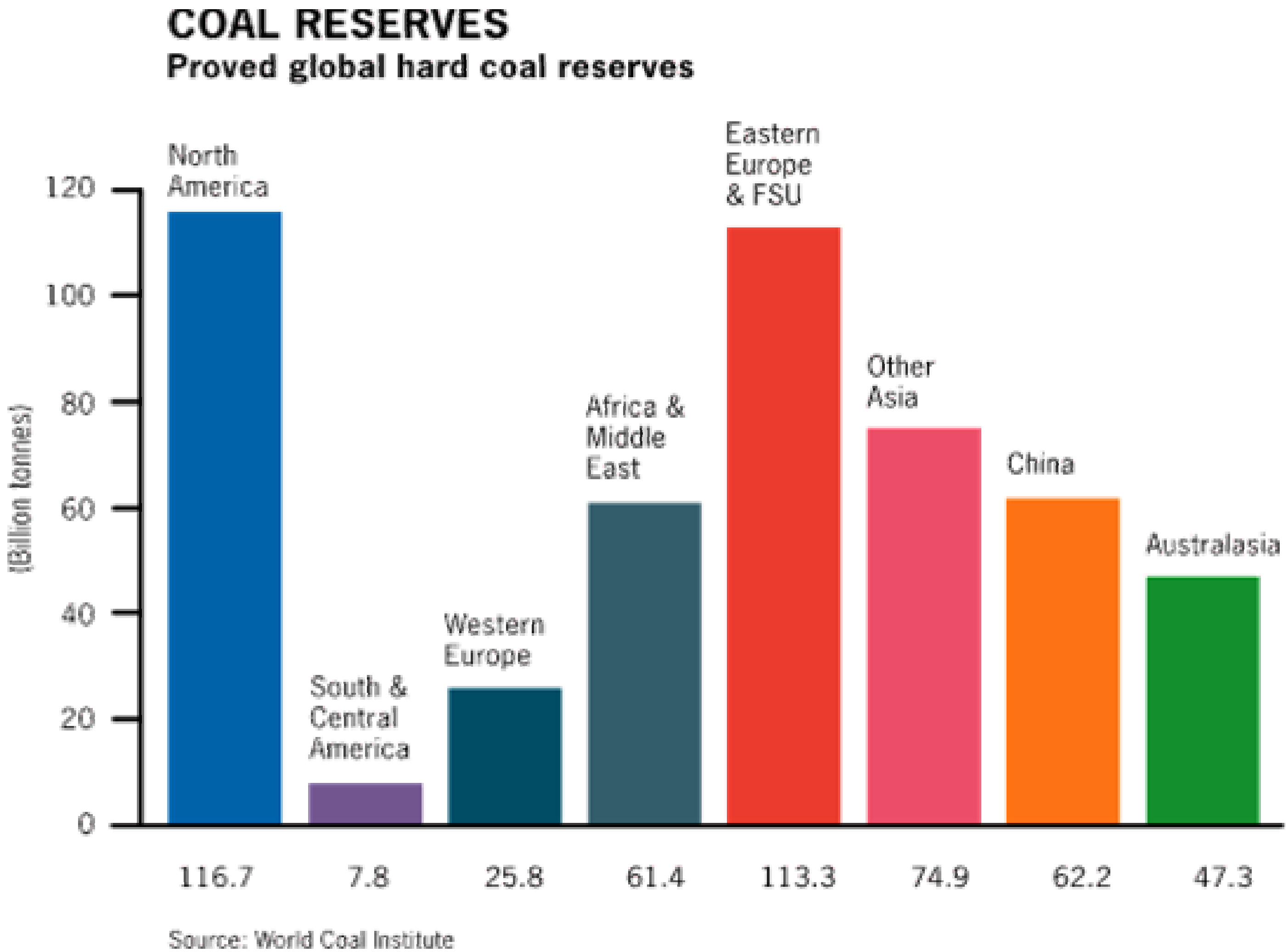
EIA Annual Energy Outlook, US DOE – 2005, Fig. 47



Primary Energy Supplies

What are they?
Where are they located?
What are the reserves?
How much do we use?

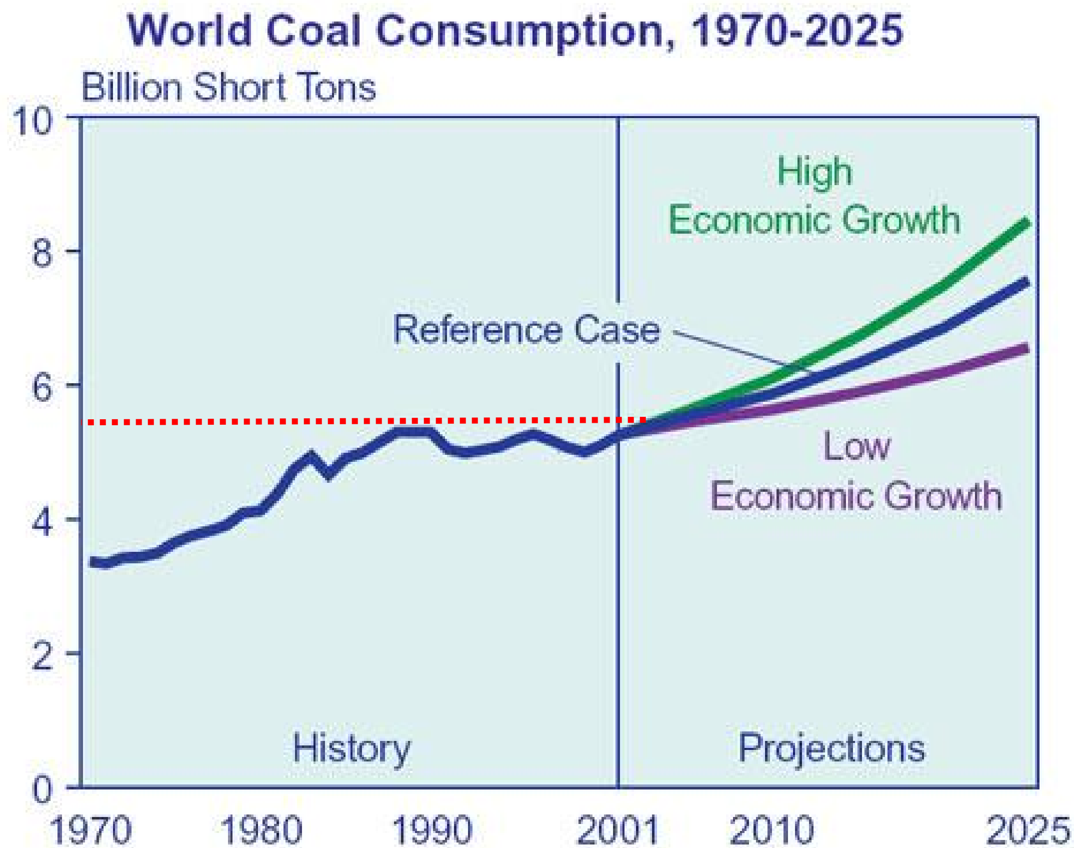
Proven Coal Reserves



Total Coal Reserves = 510 Billion Tons = 4.63E11 kg

World Use of Coal

Total Coal Consumed in 2002: 5.26 Billion Tons



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Coal Use in Other Measures

- 2002 world use = 5,262 million tons
- Density of Solid Coal:

  1300-1500 kg/m^3 (80-95 lb_m/ft^3)
- Volume of Annual Coal Use (using 1500 kg/m^3):

  3.41×10^9 m^3 = 3.41 km^3

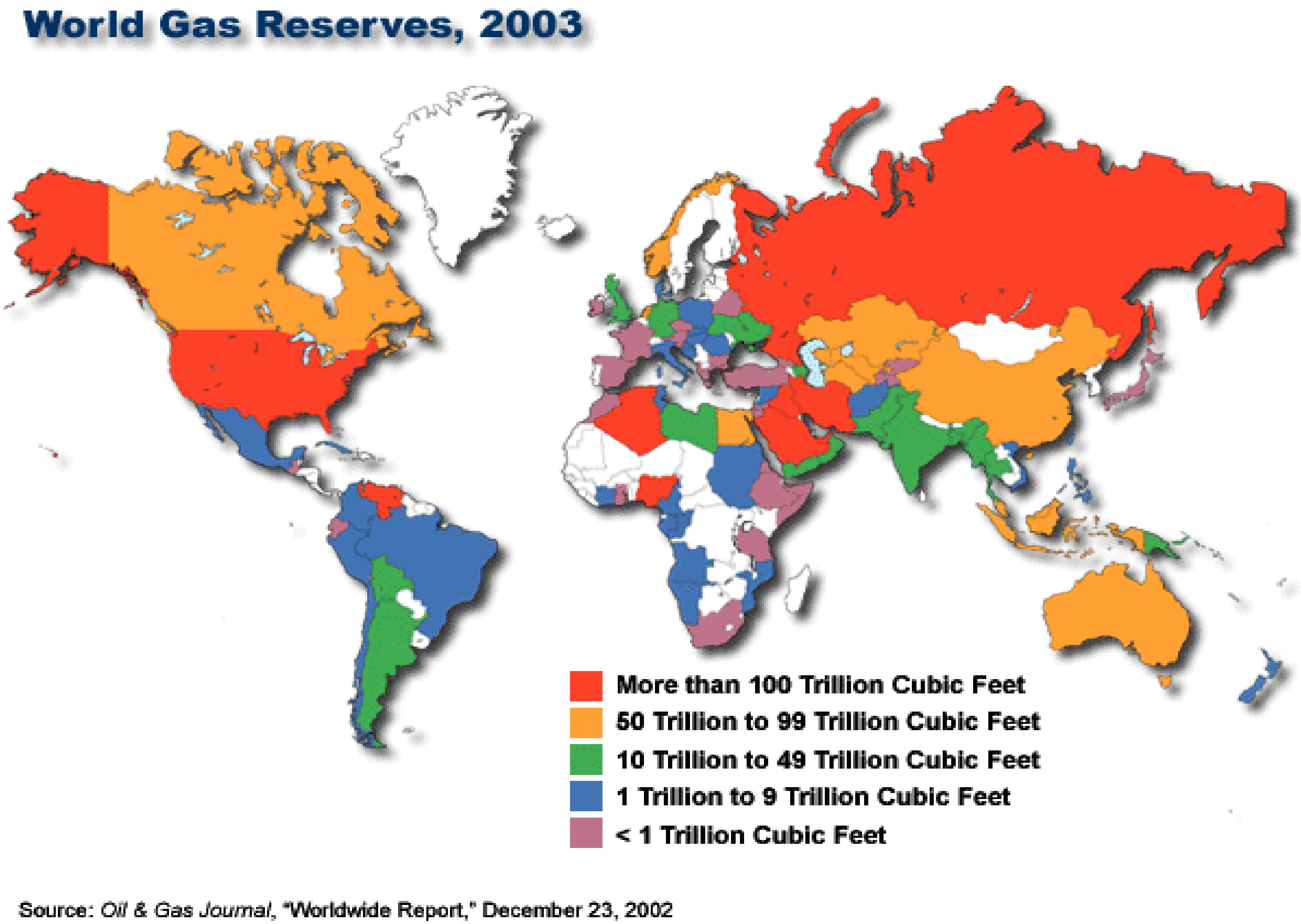
  4.46×10^9 yd^3 = 0.82 $mile^3$
- Area Use for 10 m (32.8 ft) depth

  340 km^2 = 130 $mile^2$
- Annual Mass of CO_2 produced:

  1.75×10^{13} kg

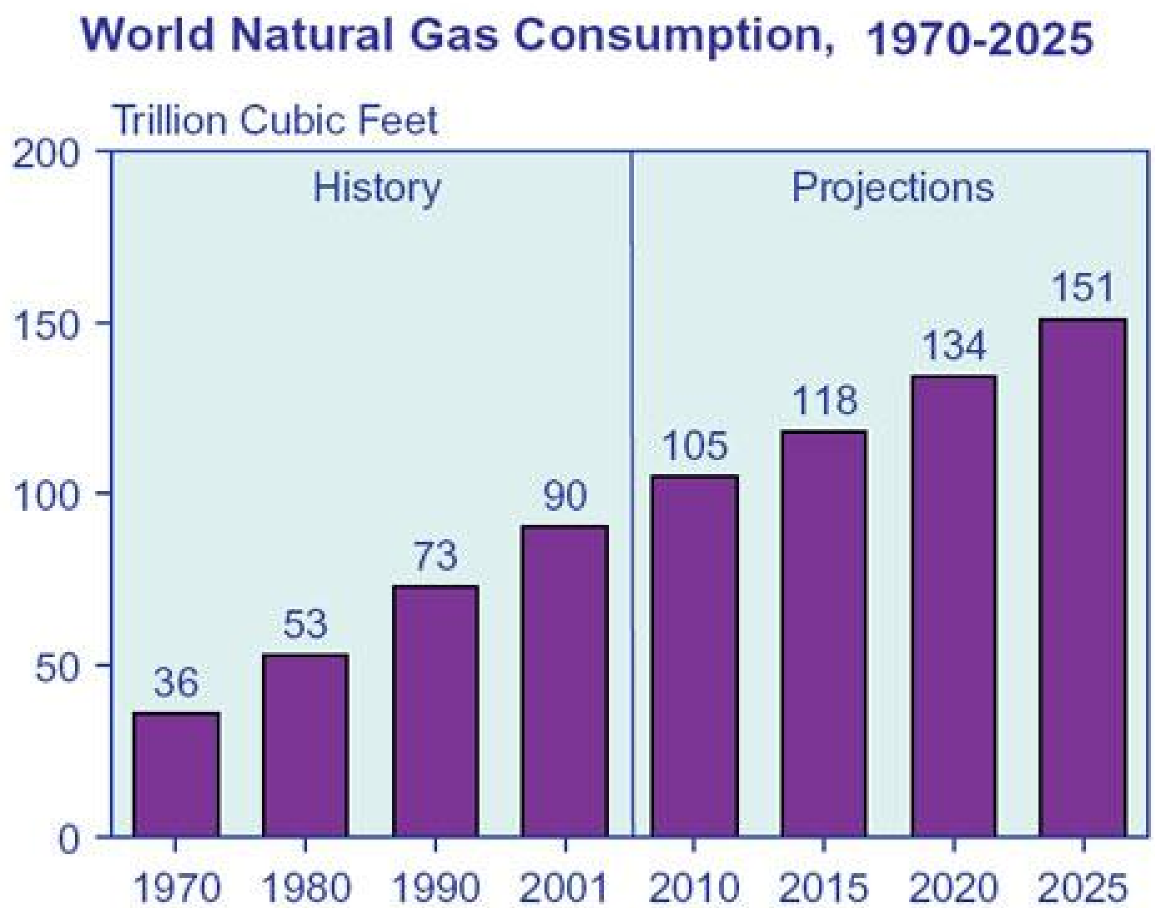
  1.93×10^{10} ton

Total Gas Reserves



World Use of Natural Gas

Total Gas Consumed in 2002: 91.76 Trillion Cubic Feet

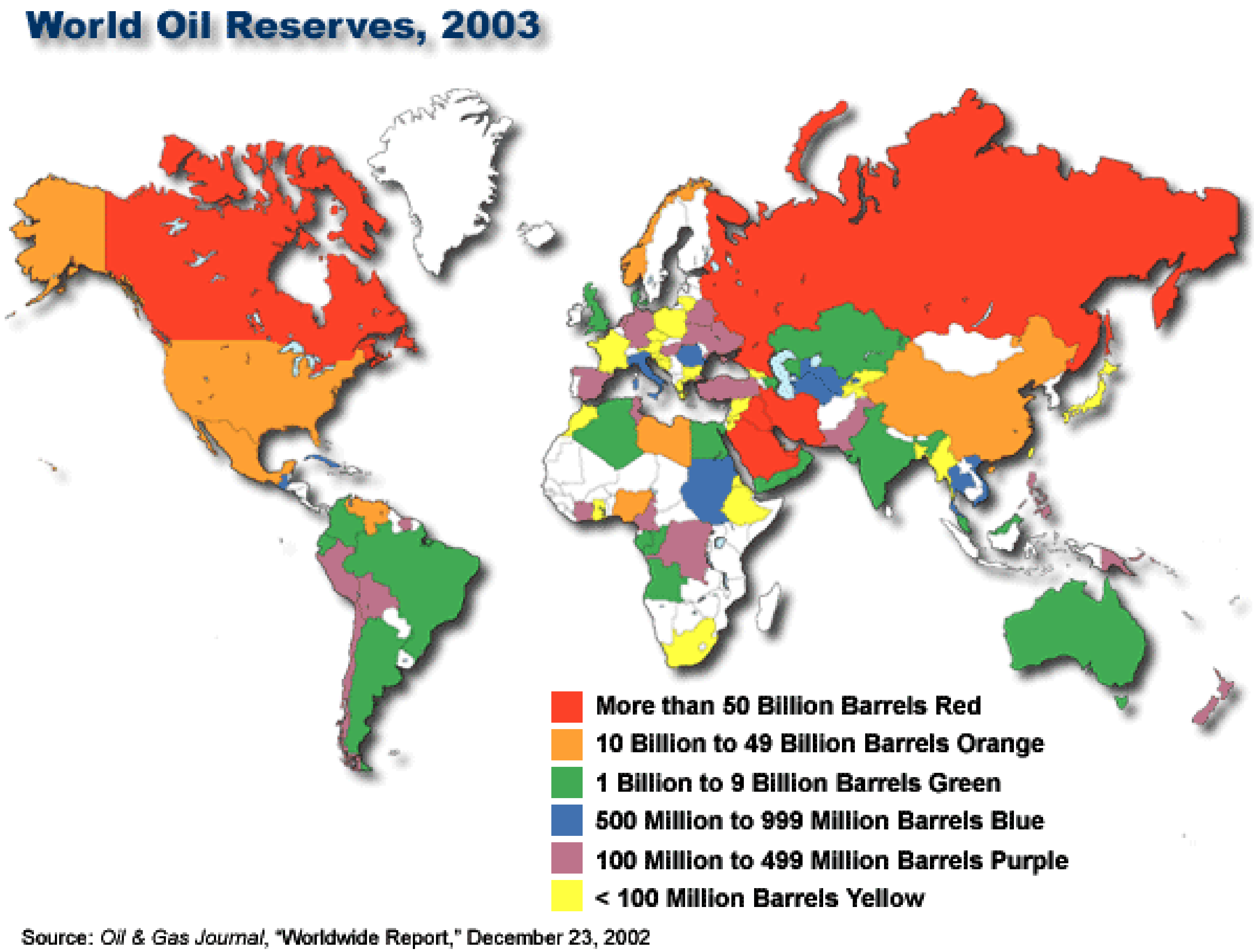


Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Just How Much is 90 trillion ft^3?

- **Lake Michigan**
  - Length - 307 miles / 494 km
  - Width - 118 miles / 190 km
  - Ave. Depth - 279 ft. / 85 m
  - Max. Depth - 925 ft. / 282 m
  - Volume - 1,180 cubic miles / 4,920 km^3 / 1.3×10^{15} gal
  - Water Surface Area - 22,300 sq. miles / 57,800 sq. km
- 90 trillion ft^3 = 2550 km^3
- The yearly gas use would occupy about ½ the volume of Lake Michigan
- Energy in 90 trillion $ft^3 \approx 9.0 \times 10^{11}$ therms $\approx 95 \times 10^9$ GJ
- Energy could boil: 1.0×10^{13} gal or ~1% of Lake Michigan

Total Oil Reserves



World Use of Oil

Total Oil Consumed in 2001: 78.1 Million Barrels

Source:BP 2003 Statistical Review
http://production.investis.com/bp2/ia/stat/

How Much is 80 Million Barrels?

- 1 barrel = 42 gallons
- In 2003, the world used about 80 million barrels per day
  - 80 million barrels/day × 365 days × 42 gallons/barrel

    = 1.23 trillion gallons
- Lake Mendota = 126 billion gallons
  - Average depth = 41 feet = 12.5 m
  - Diameter ≈ 4.4 mile = 7 km
  - 9,847 acres = 40 km^2

1.23 trillion/126 billion ~ 10

The annual world oil use would fill Lake Mendota 10 times!

Effect of Combustion on Global Warming

- Global warming concerns usually related to CO_2
- Consider the effect of the heat release from:
  - Coal: 5,262×10^6 tons (4.775×10^{12} kg) ⇒ 140×10^9 GJ
  - Gas: 90 trillion ft^3 (9.0×10^{11} therms) ⇒ 95×10^9 GJ
  - Oil: 80 million barrels/day 4.0×10^7 m^2 ⇒ 190×10^9 GJ
- Mass of air in atmosphere = 5×10^{18} kg (*just the air*)
- Specific heat of air = 1.0 kJ/kg-K

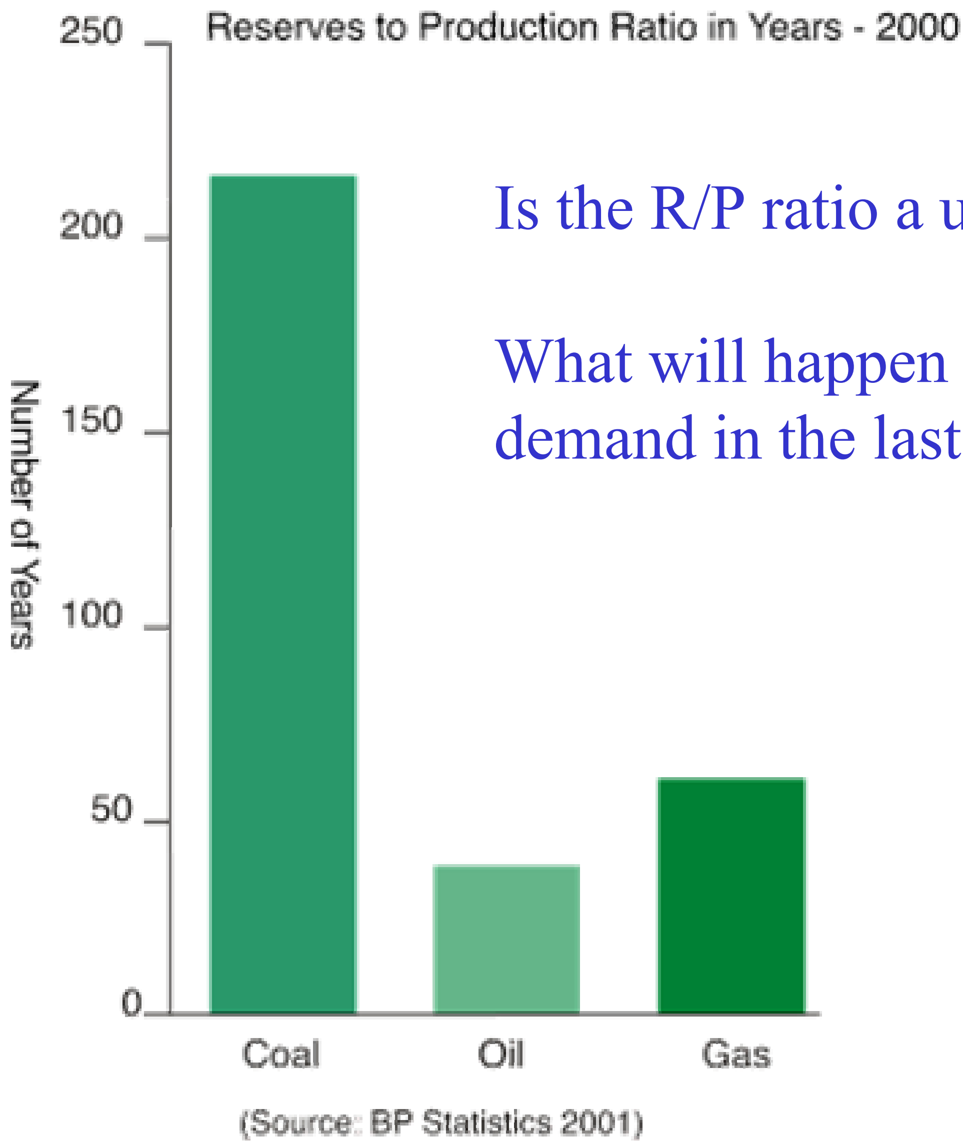
Resulting temperature Rise = 0.085 K

(*independent of the 'greenhouse' effect*)

The energy release in itself is not a concern

Are We Running Out of Primary Energy Supplies?

British Petroleum Predictions



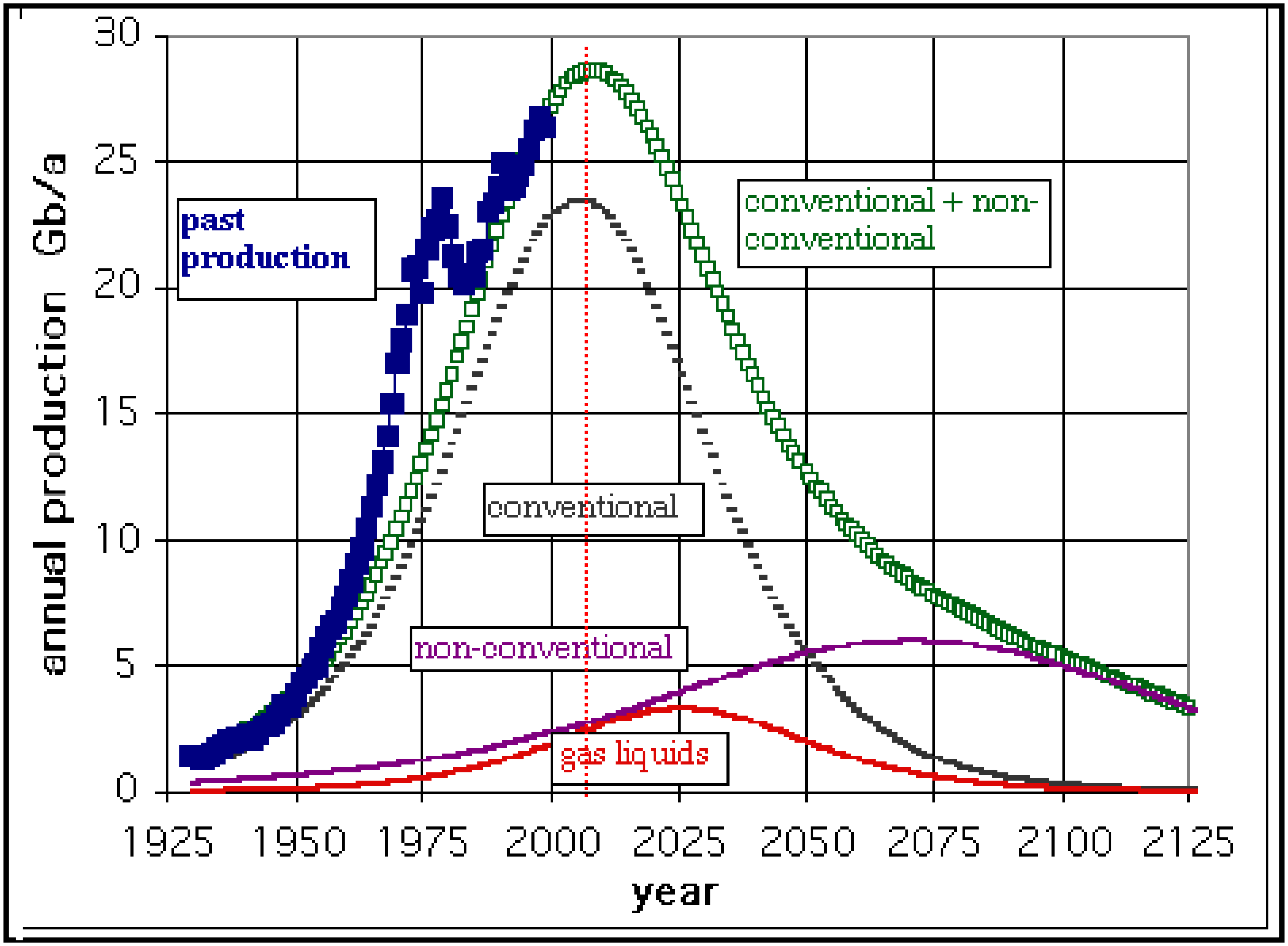
Is the R/P ratio a useful metric?

What will happen to the cost and demand in the last year?

http://production.investis.com/bp2/ia/stat/

Oil and Natural Gas Supply Predictions

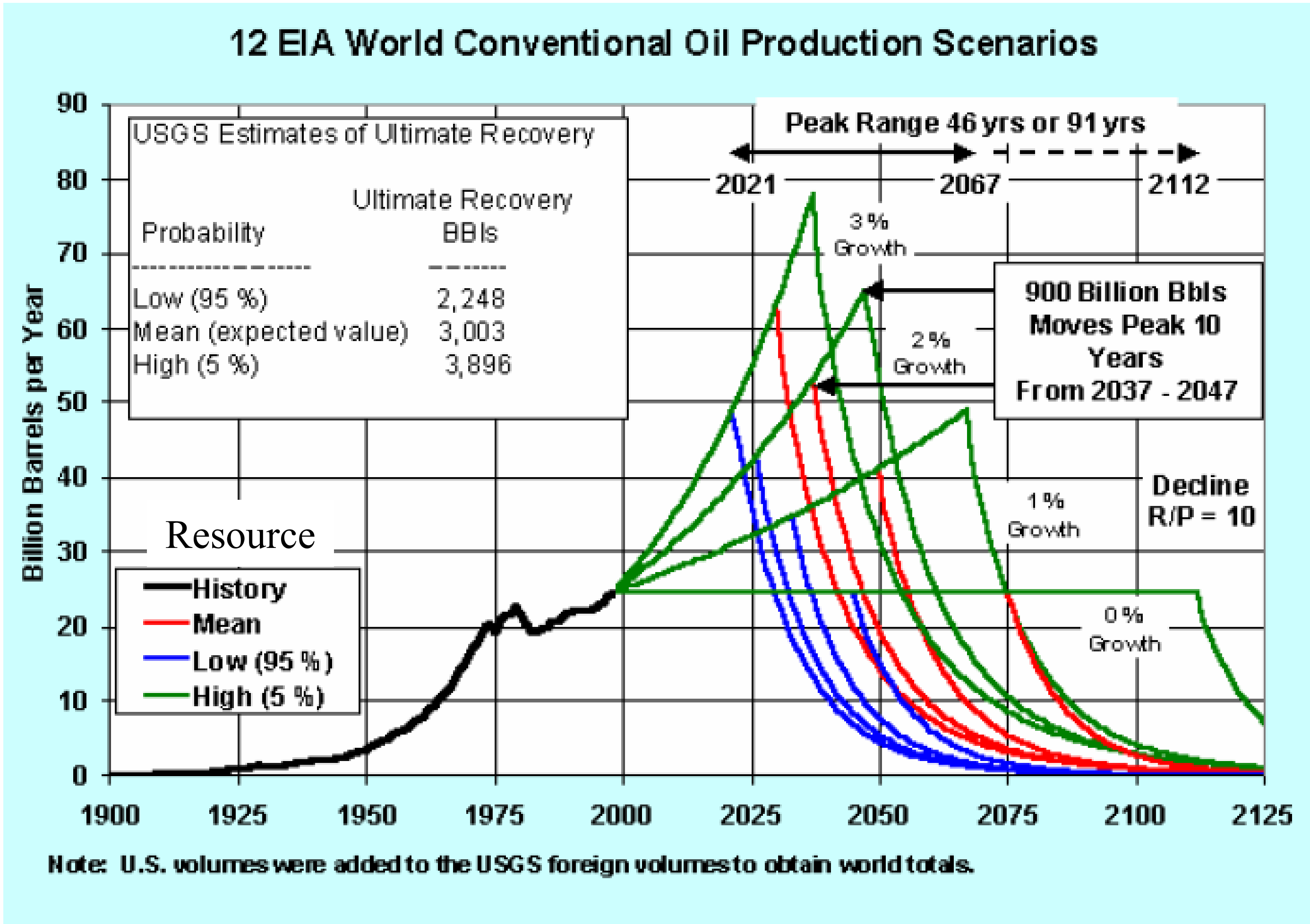
Jean H. Laherrère, 2000



Source: http://www.hubbertpeak.com/midpoint.htm

See also: Kenneth Deffeyes, Hubbert's Peak, Princeton

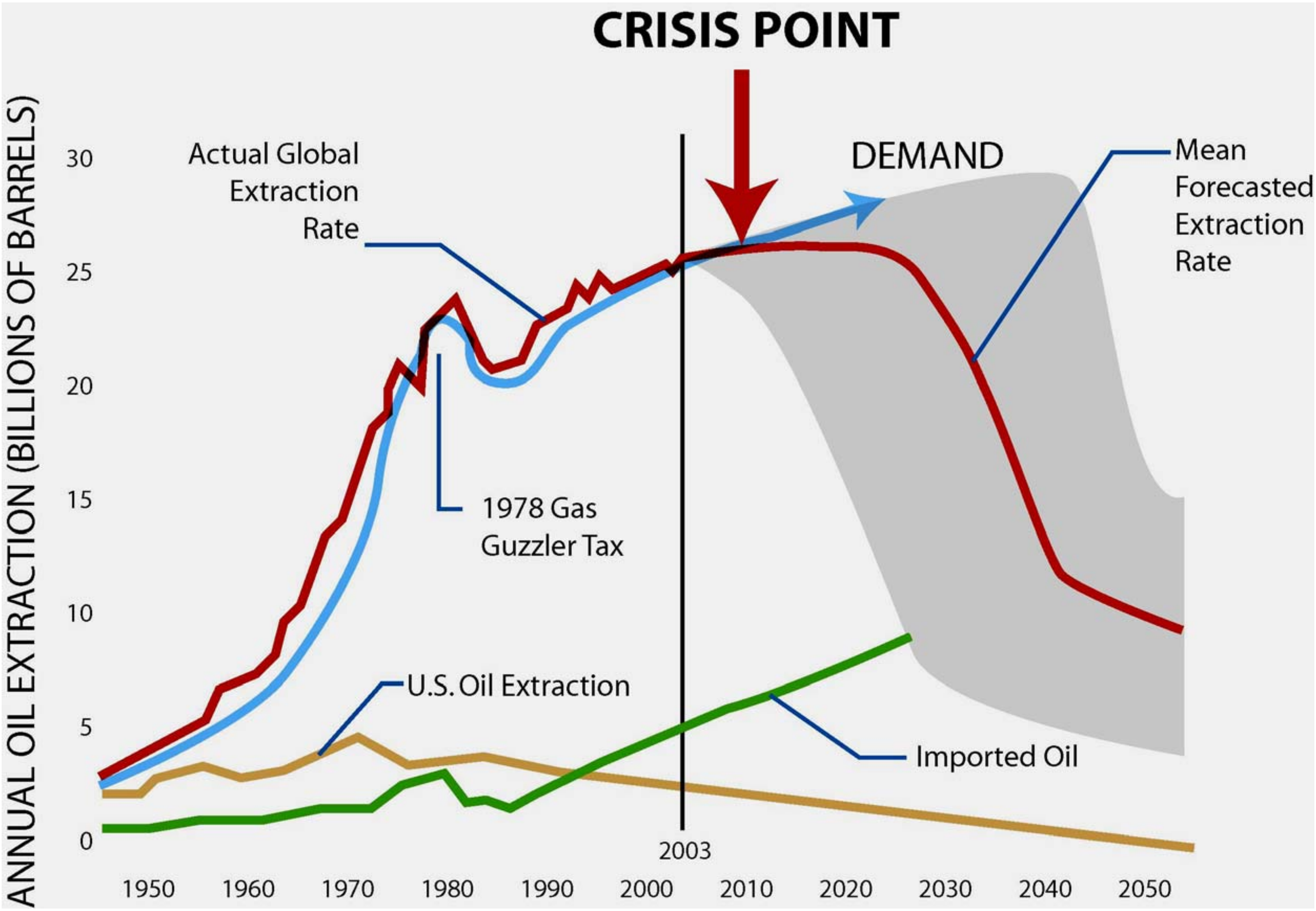
USGS Reserve Estimates



http://tonto.eia.doe.gov/FTPROOT/features/longterm.pdf

Note: Oil may run out before the U.S. Social Security is broke!

Hubbert's Peak



Slide courtesy of Don Aitkens

What can we do to extend our reserves?

U.S. DOE Energy Policy

http://www.eere.energy.gov/hydrogenandfuelcells/presidents_initiative.html

President's Hydrogen Initiative: A Clean and Secure Energy Future

"A simple chemical reaction between hydrogen and oxygen generates energy, which can be used to power a car producing only water, not exhaust fumes. With a new national commitment, our scientists and engineers will overcome obstacles to taking these cars from laboratory to showroom so that the first car driven by a child born today could be powered by hydrogen, and pollution-free. Join me in this important innovation to make our air significantly cleaner, and our country much less dependent on foreign sources of energy."

— President Bush, State of the Union Address, January 28, 2003

...Bush has already proposed $1.2 billion in research funding so that America can lead the world in developing clean, ***hydrogen****-powered automobiles*

The Bush Administration's fiscal year 2005 budget request includes $227 million for research to support the President's Hydrogen Fuel Initiative

Hydrogen Economy Opinions

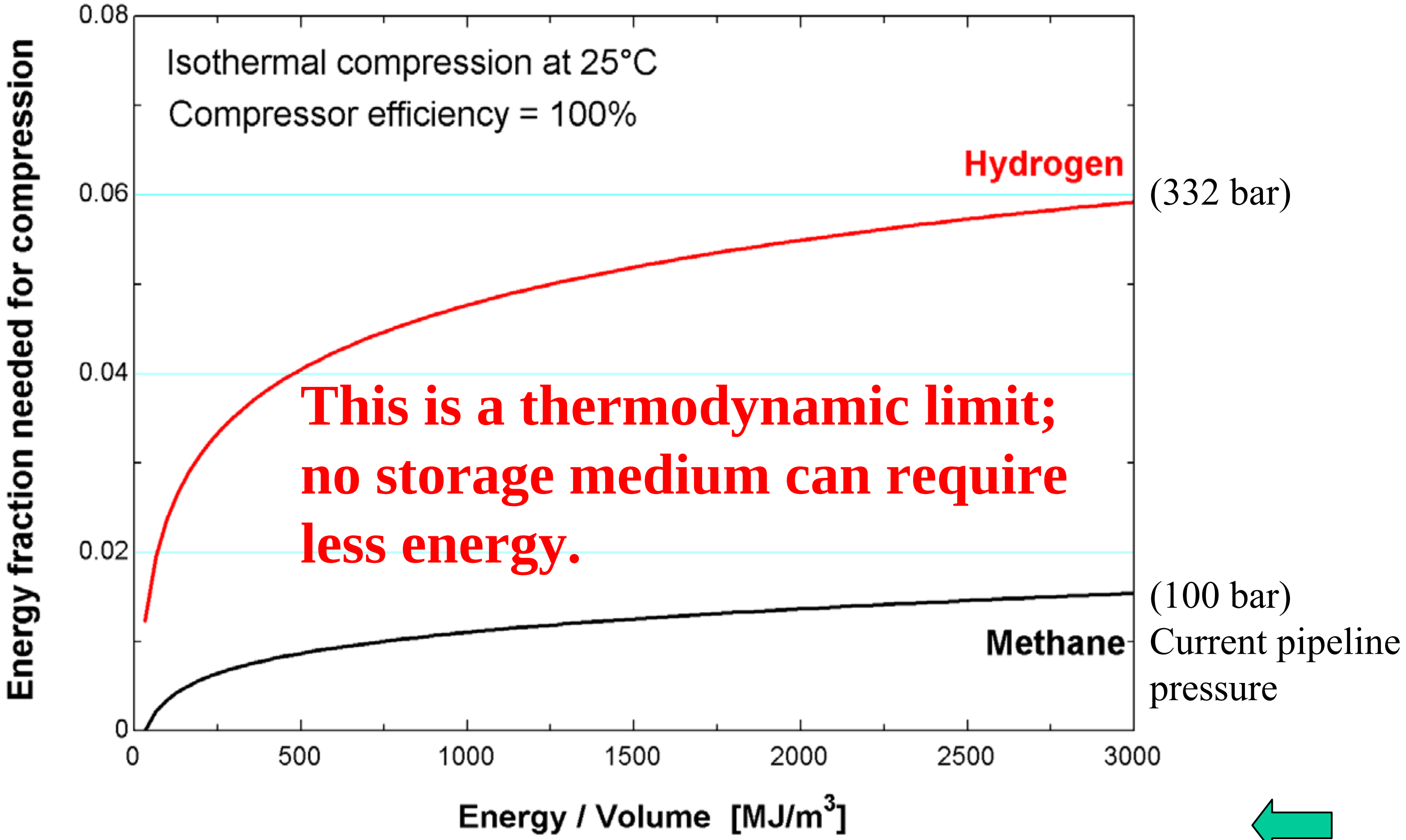
- Hydrogen is difficult to store
- Hydrogen is not easily transported over long distances
- Hydrogen must be generated from renewable or non-renewable fuels (with an efficiency penalty)
- Hydrogen is an energy transport/storage medium – not a fuel

Use of hydrogen with fuel cells for transportation will not solve our energy dilemma – it may make it worse.

See: *Eliasson and Bossel*, http://www.efcf.com/reports/

Energy Needed to Compress Hydrogen

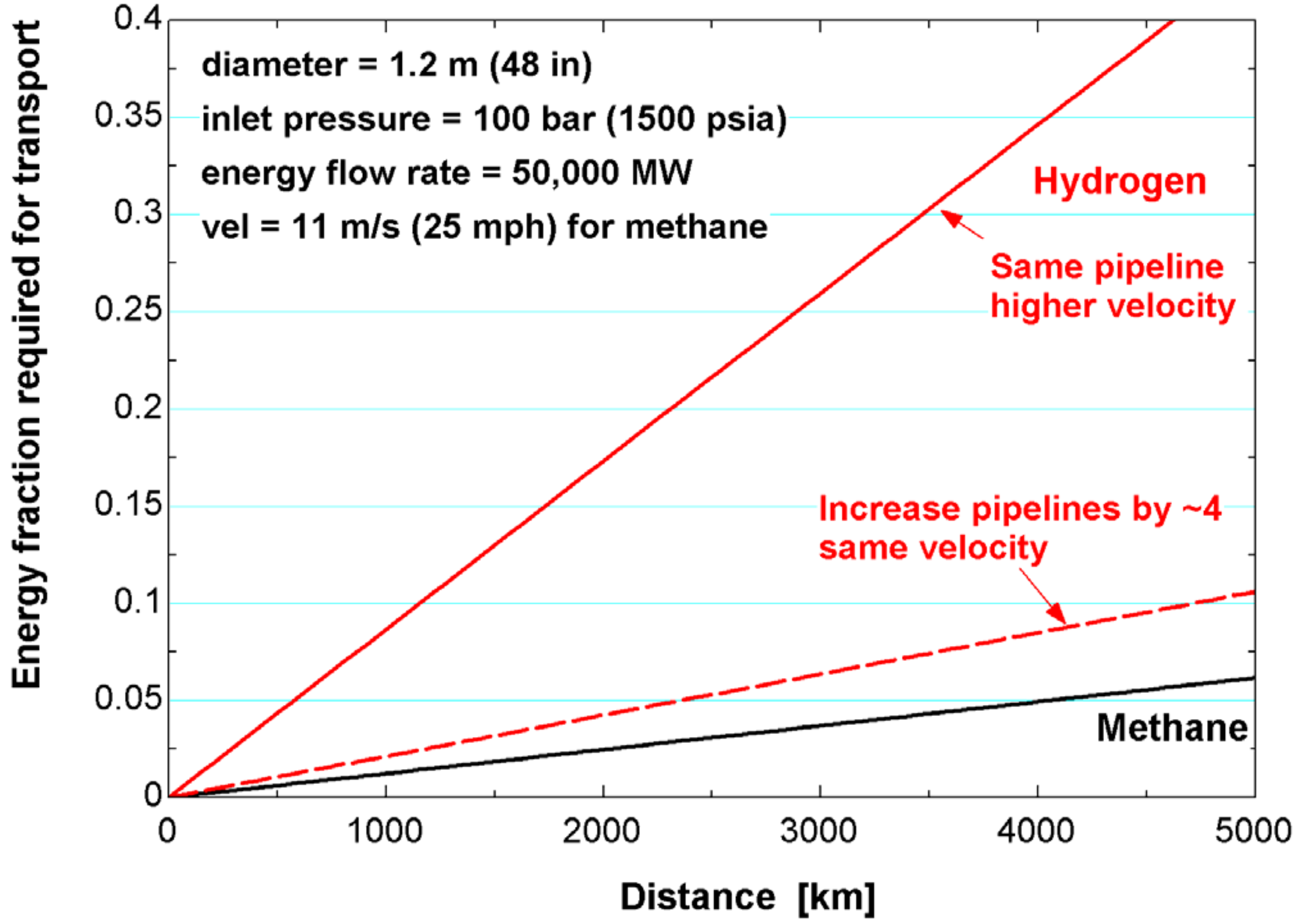
Compress to same energy density for storage and transport



Hydrogen requires 3 to 4 times as much energy as methane for compression.
The energy storage density is ~10 x greater than gasoline.

Energy Needed for Pipeline Transport

for equivalent energy flow rates



$$\Delta P = f \frac{L}{d}\frac{\rho v^2}{2} \qquad \dot{W} = \dot{V}\Delta P$$

Hydrogen requires ~ 2-7 times as much transport energy

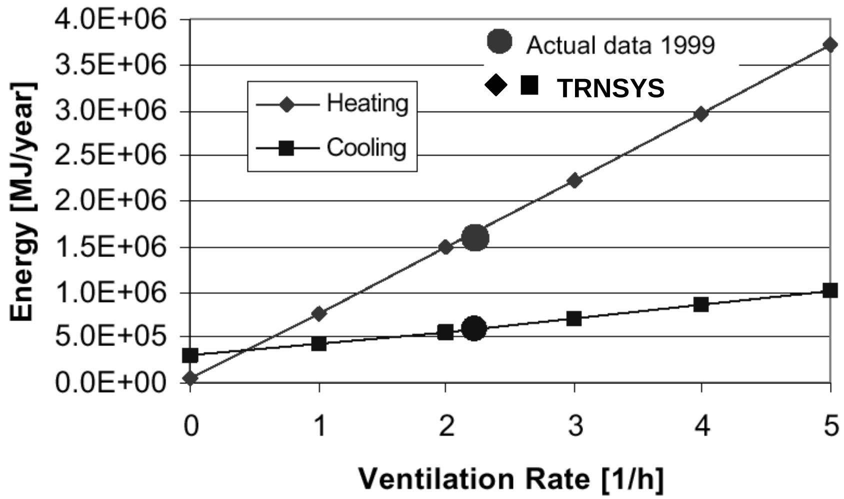
Opportunities for Increased Efficiency related to Buildings

- 39.5% of U.S. energy use is in the residential and commercial sectors
- 32% of this energy is used for low efficiency space and water heating applications
- What can we do to reduce energy use?
  - Reduce the load
  - Utilize Energy Recovery
  - Increase Space/Water Heating Efficiency
  - Displace Conventional Fuels

Energy Recovery Application

Henry Vilas Zoo – Madison WI

Zones: 1) cats 2) primates,
3) viewing, 4) visitor area.
Total floor area: 1,516 m^2

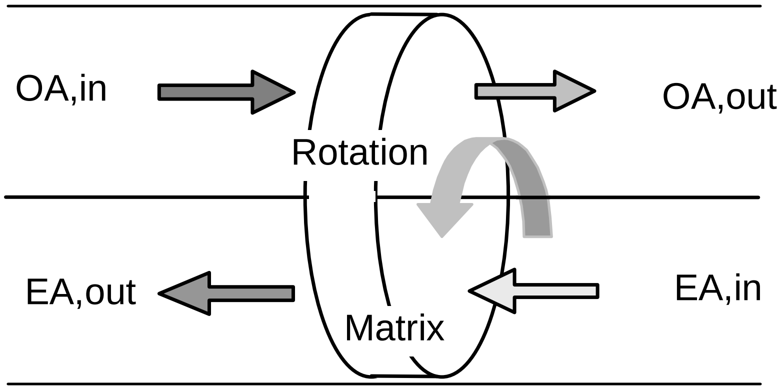


Applicable codes call for 2-15 air changes/hr.

Ref: Freund, Klein, and Reindl, *Energy Savings Potential of Energy Recovery Ventilation in an Animal Housing Facility*, ASHRAE Transactions, Vol. 110, Pt. 1, 2004

Energy Recovery Equipment

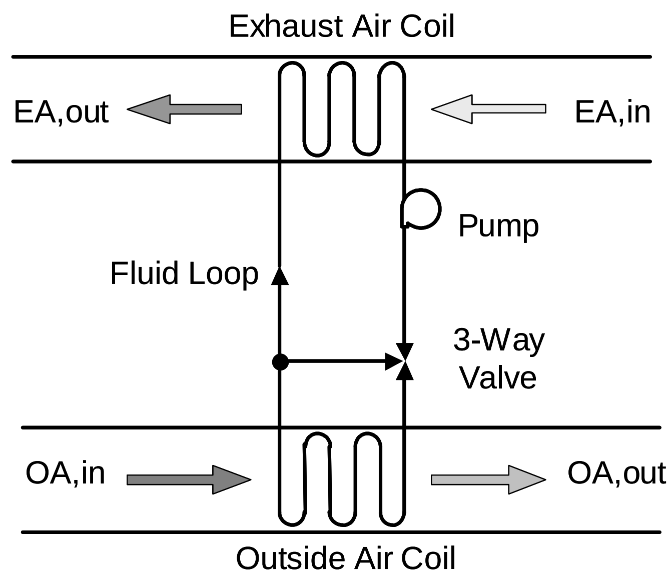
Enthalpy Exchanger



	Heating	Cooling
% Energy Savings	76	23
% Peak Reduction	66	47

Savings: $9,400/yr heating
$1,400/yr cooling

Run-around loop

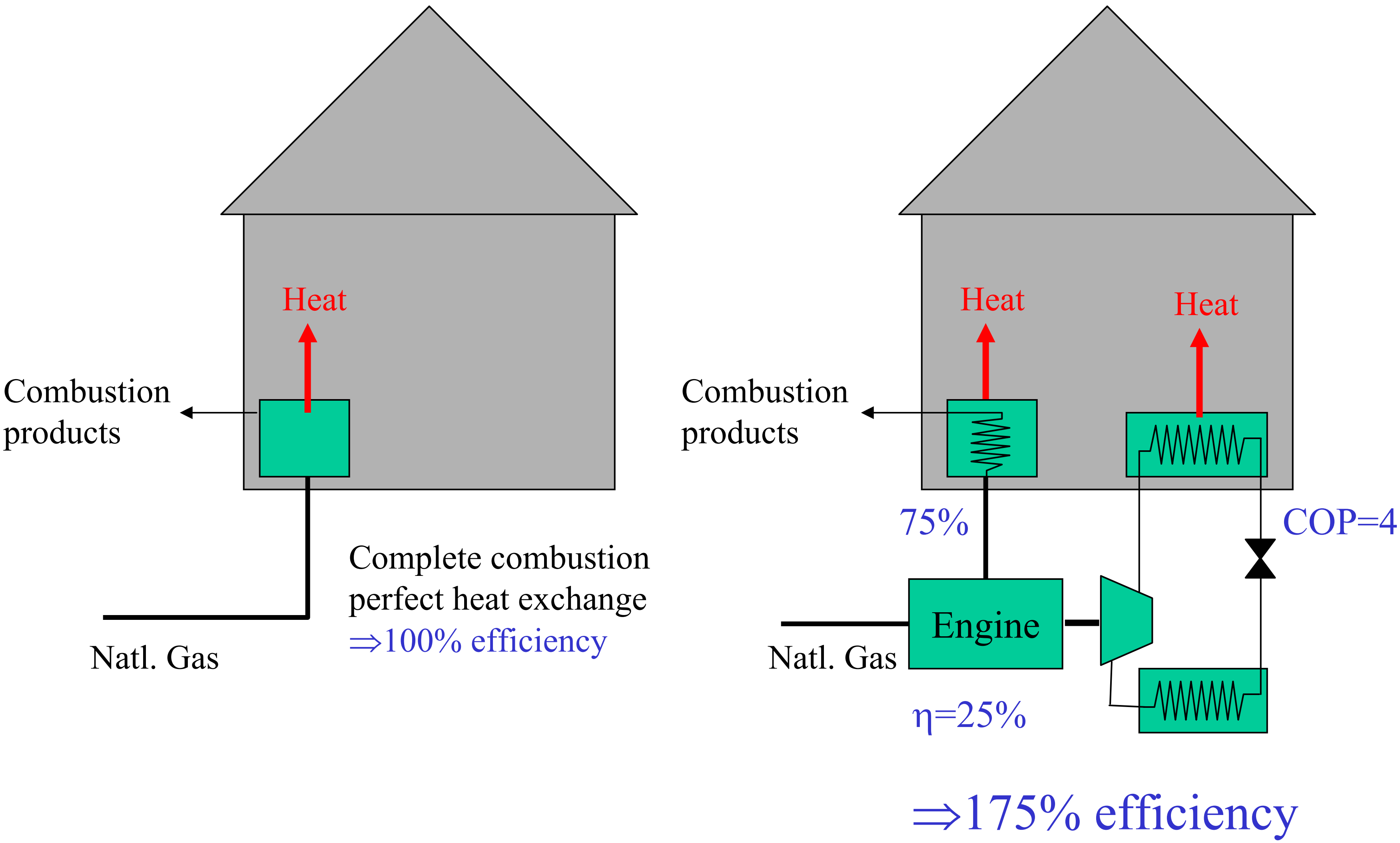


	Heating	Cooling
% Energy Savings	56	3
% Peak Reduction	46	10

Efficiency of Space Heating

- Efficiency: $\frac{\text{Energy provided to building}}{\text{Energy supplied to furnace}}$
- Electric resistance furnaces are 100% efficient
- Natural gas furnaces are available with efficiencies greater than 90%
- Efficiency for space heating is not limited to 100%
- True (2nd Law) efficiency: $\frac{\text{Exergy provided to building}}{\text{Exergy supplied to furnace}}$
- 2nd Law efficiency (space heating) is less than 10%
- The low efficiency provides *opportunities*

How to Achieve > 100% Efficiency



Alternatives – but higher efficiency requires greater equipment cost

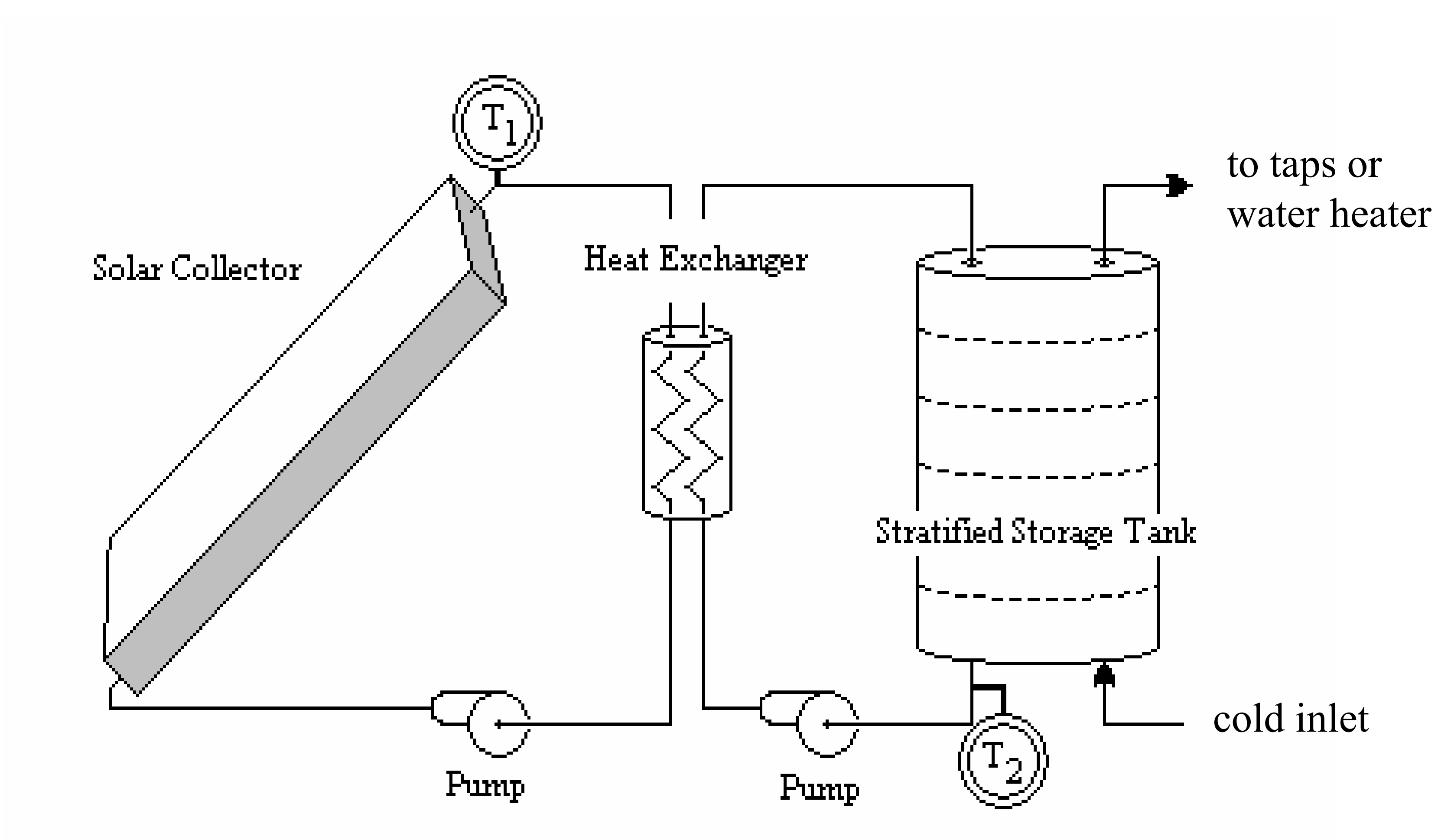
Quiz

How much energy does a typical U.S. family use for water heating in one year compared to that used to power the family car?

A. Water heating uses much less energy
B. Water heating uses about the same energy
C. Water heating uses much more energy
D. These applications are not comparable

Reducing energy use for water heating is easier and less expensive than increasing mileage. Both result in a reduction of CO_2 production.

Typical Solar Water Heating System



Solar water heating is more cost effective than PV electricity

Solar Water Heating System - Madison WI

Space and Water Heating System

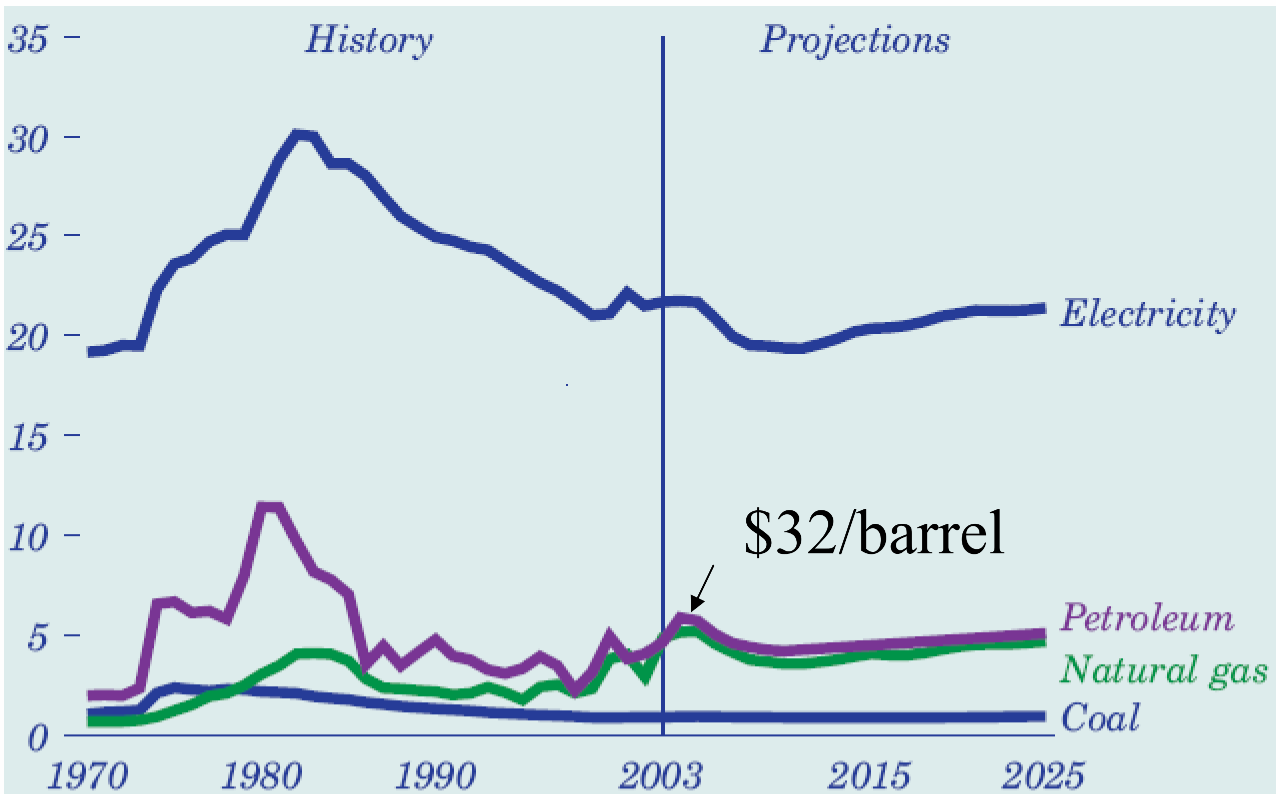
McKay Center University of Wisconsin - Madison

U.S. Energy Price Projections

Annual Energy Outlook, 2005 (EIA/DOE)

http://www.eia.doe.gov/oiaf/aeo/

Figure 1. Energy prices, 1970-2025 (2003 dollars per million Btu)



Concluding Comments

- There is increasing demand for conventional energy sources
- There is evidence supporting global climate change induced by extensive use of these energy sources
- Energy reserves are finite
- Available information indicates that the reserves of oil and gas may be depleted within a relatively short time (10-50 yrs)
- The proposed hydrogen economy will not help this energy problem and in fact may make it worse
- Buildings utilize a significant fraction of the total energy use

\+ Energy is used inefficiently in building applications

\+ Relatively simple changes can significantly reduce building energy use

\+ Most systems that reduce energy use have increased first costs

Clearly – challenges lie ahead