Nuclear Power in the World's Energy Future

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Outline of Talk

Nuclear power is still a miracle of nature, science, and technology.

Where we are. Where we might be to make a difference in the world.

The world's energy future.

Energy use, where. Energy use, how.

Current production not easy to maintain—production vs. resource.

Current production is not enough—Population; development and increasing living standards are even more important.

Energy field highly noncompetitive—e.g., OPEC, ENRON.

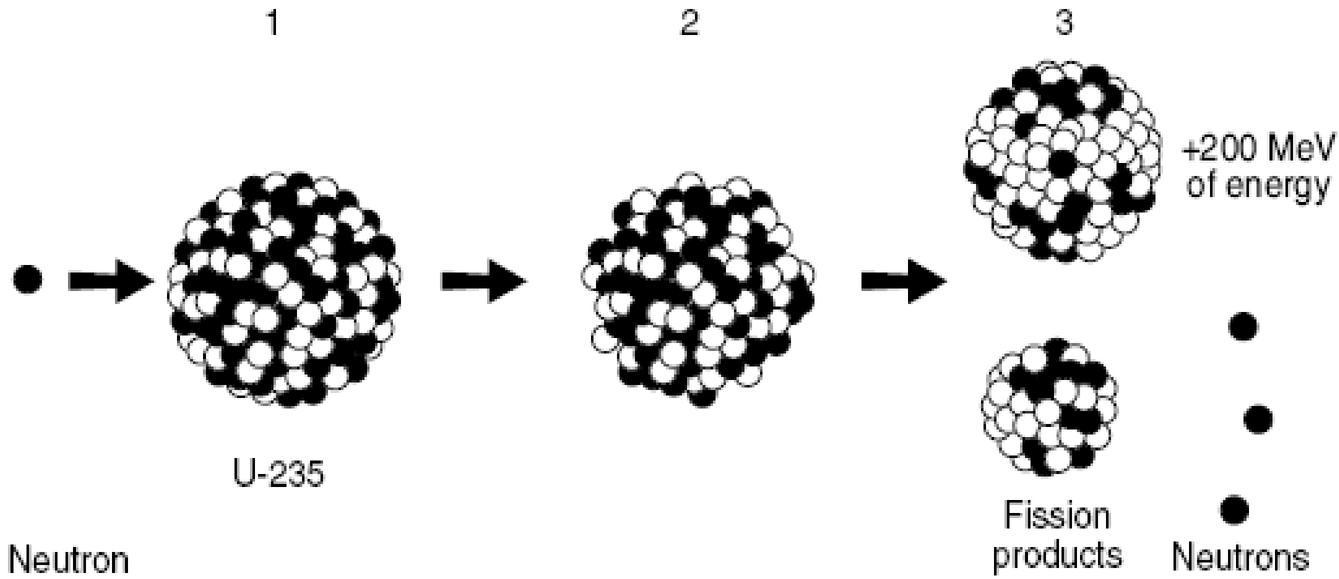
Not running out of energy. To quote John Holdren, Running out of:
cheap energy;   environment;   societal will; time.

Four nuclear reactors at the Cattenom nuclear power plant in France

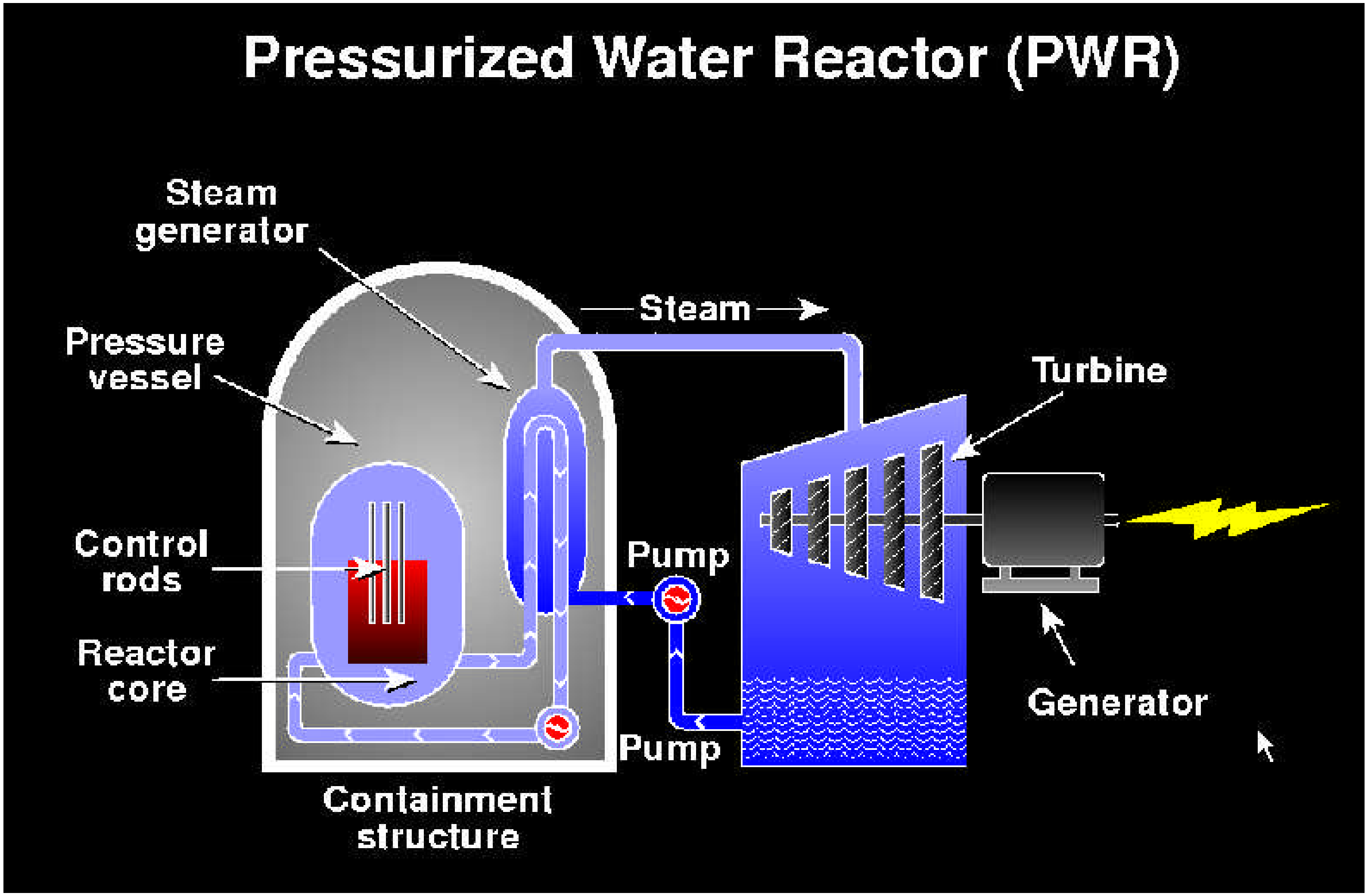
Three-reactor NPP at Itaka, Japan

NUCLEAR POWER IS A MIRACLE, ANALOGOUS TO FIRE

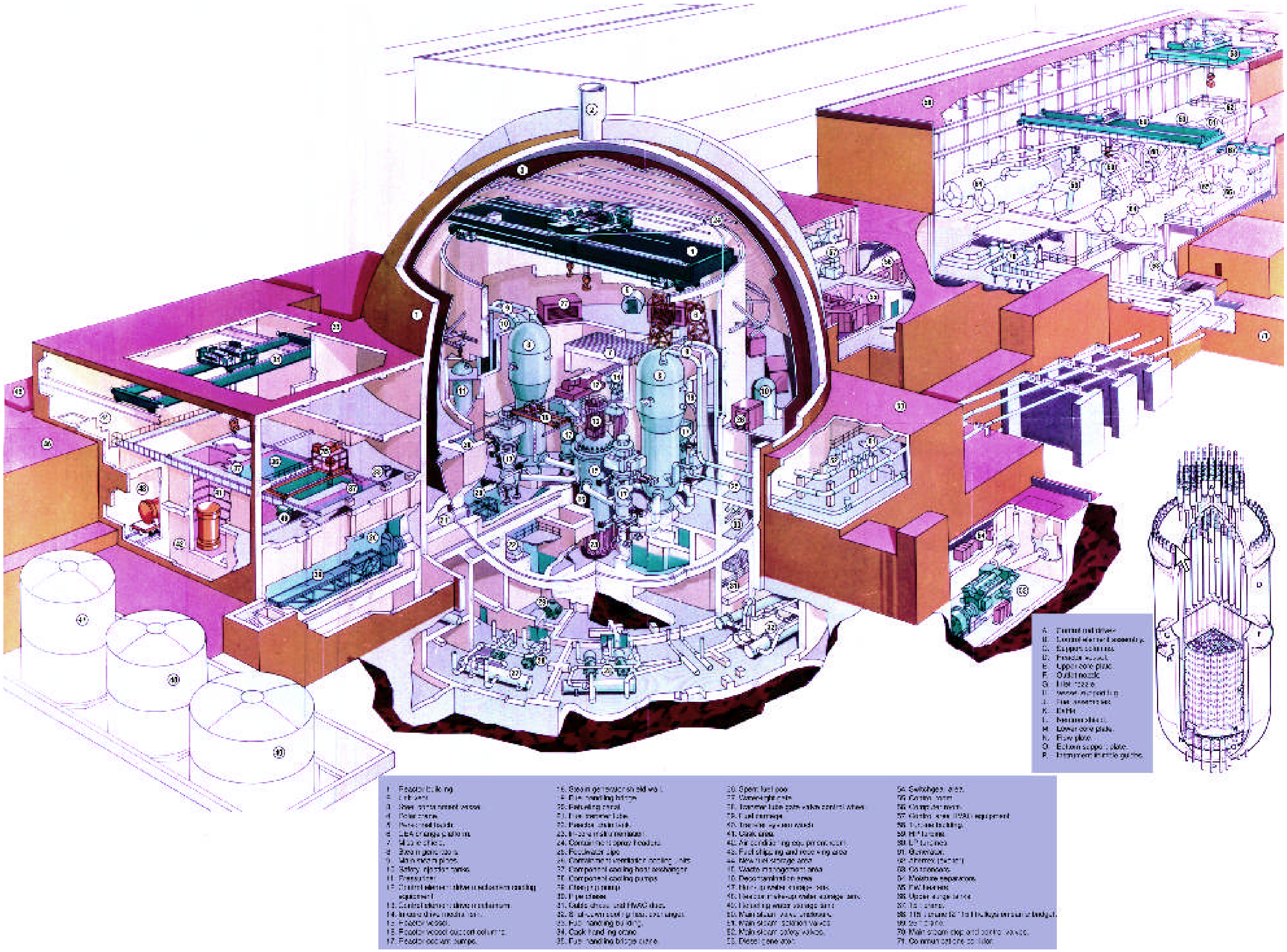
The fission chain reaction, with the neutron as carrier:



and with enough U-235, the fission neutrons provoke more fissions, and so on. With the help of a lot of science and engineering, one has a useful power reactor: neutronics, heat transfer, structure, and "balance of plant."



Schematic of the PWR, the most common power reactor



A PWR in the context of the nuclear power plant

One approach to the treatment of spent fuel before disposition in a mined geological repository

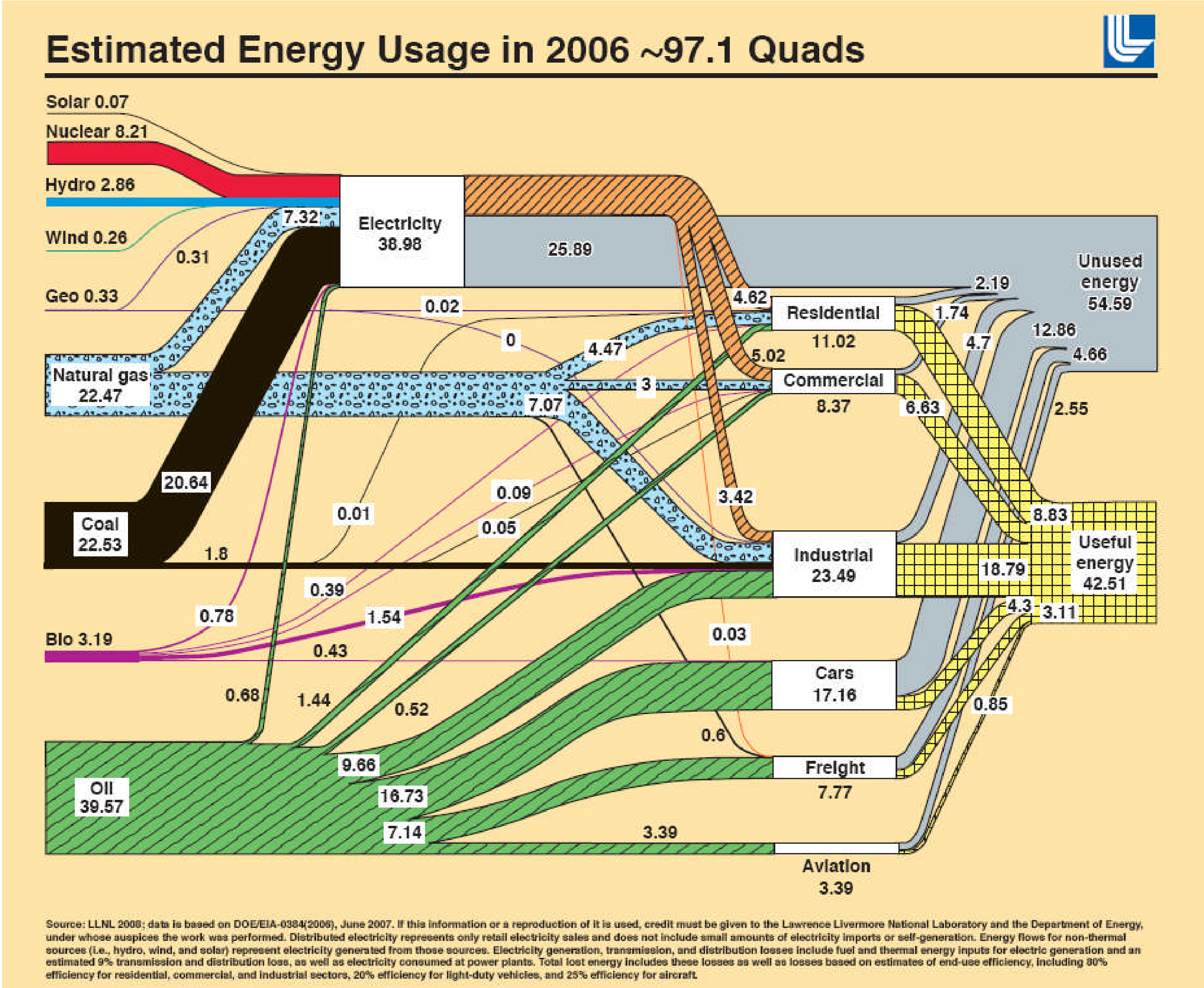
Figure 9. Dry cask storage of spent fuel. Two casks typically contain the equivalent of a year's spent fuel discharges from a 1000 MWe nuclear power plant. Comparison of the simplicity of interim spent fuel storage with the complexity of the huge reprocessing complex shown in Figure 6 makes it easier to understand the relatively low cost of interim storage.[87]

Dry-cask storage of spent fuel (Yankee site)

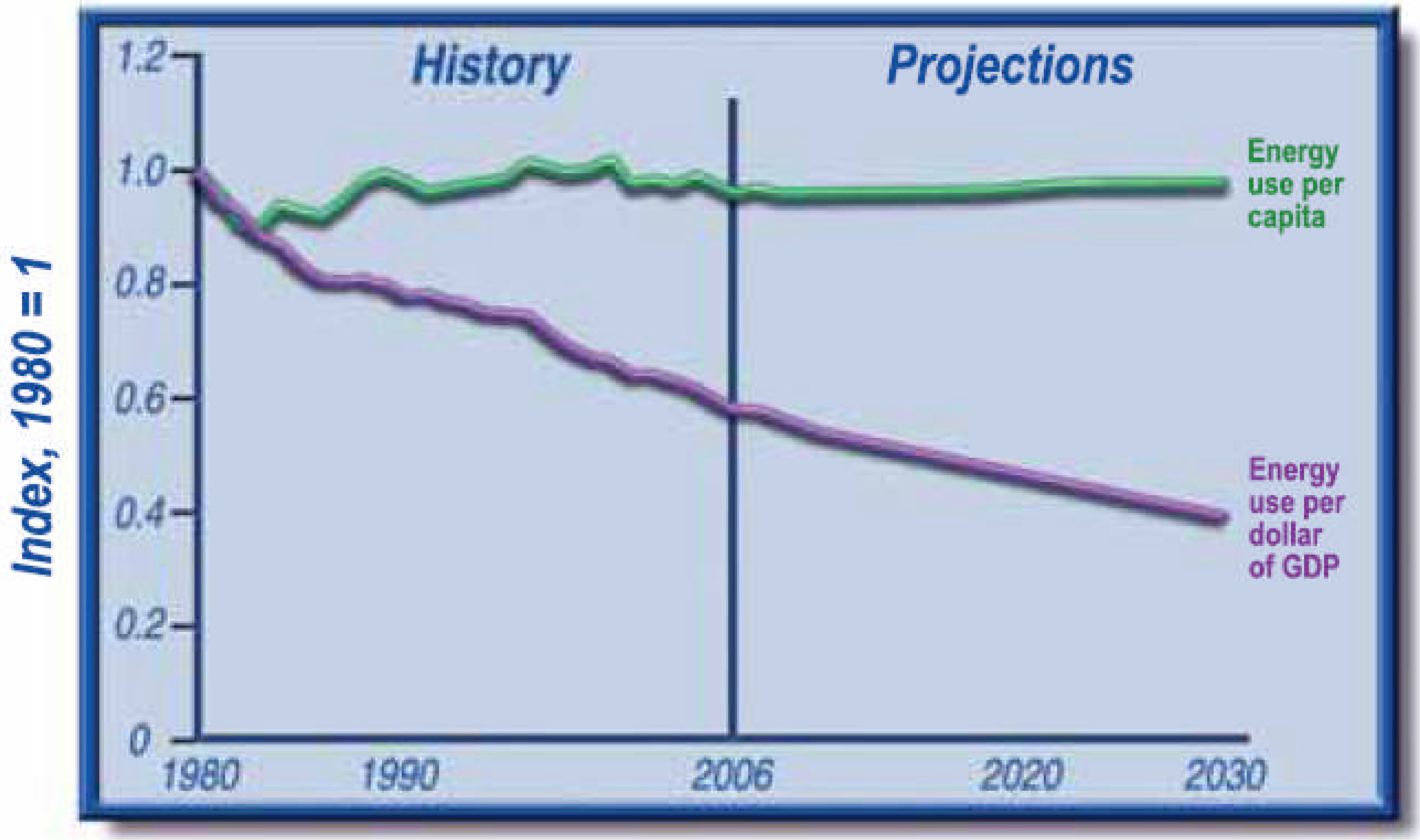
Another approach to the treatment of spent fuel before disposition in a mined geological repository

Figure 6. France's spent-fuel reprocessing complex on La Hague in northern France. Its plutonium fuel fabrication facility is in southern France, requiring regular long-distance truck shipments of separated plutonium.[49]

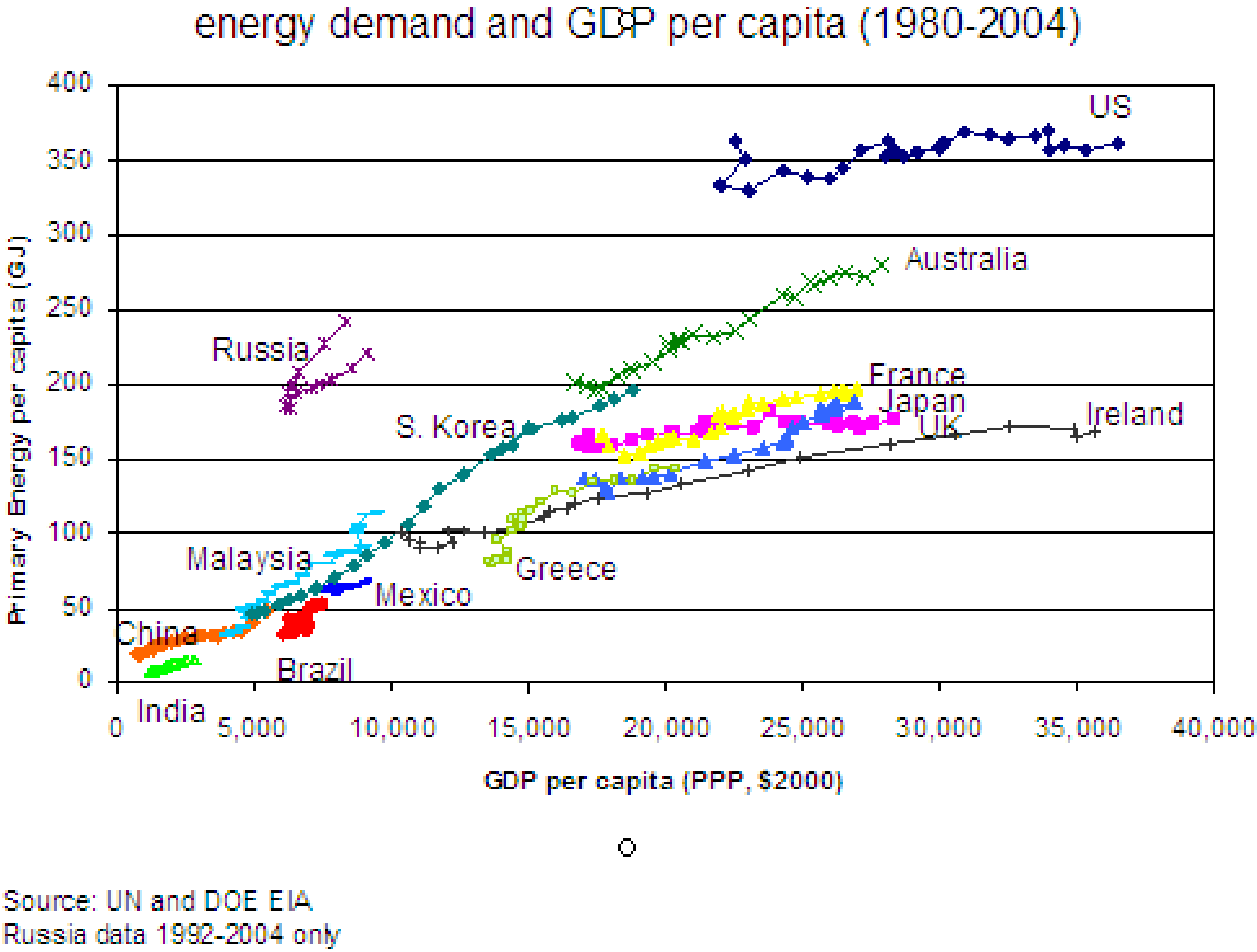
France's spent-fuel reprocessing complex at La Hague



U.S. energy usage in 2006 (1 quad = 1.055 exajoule)

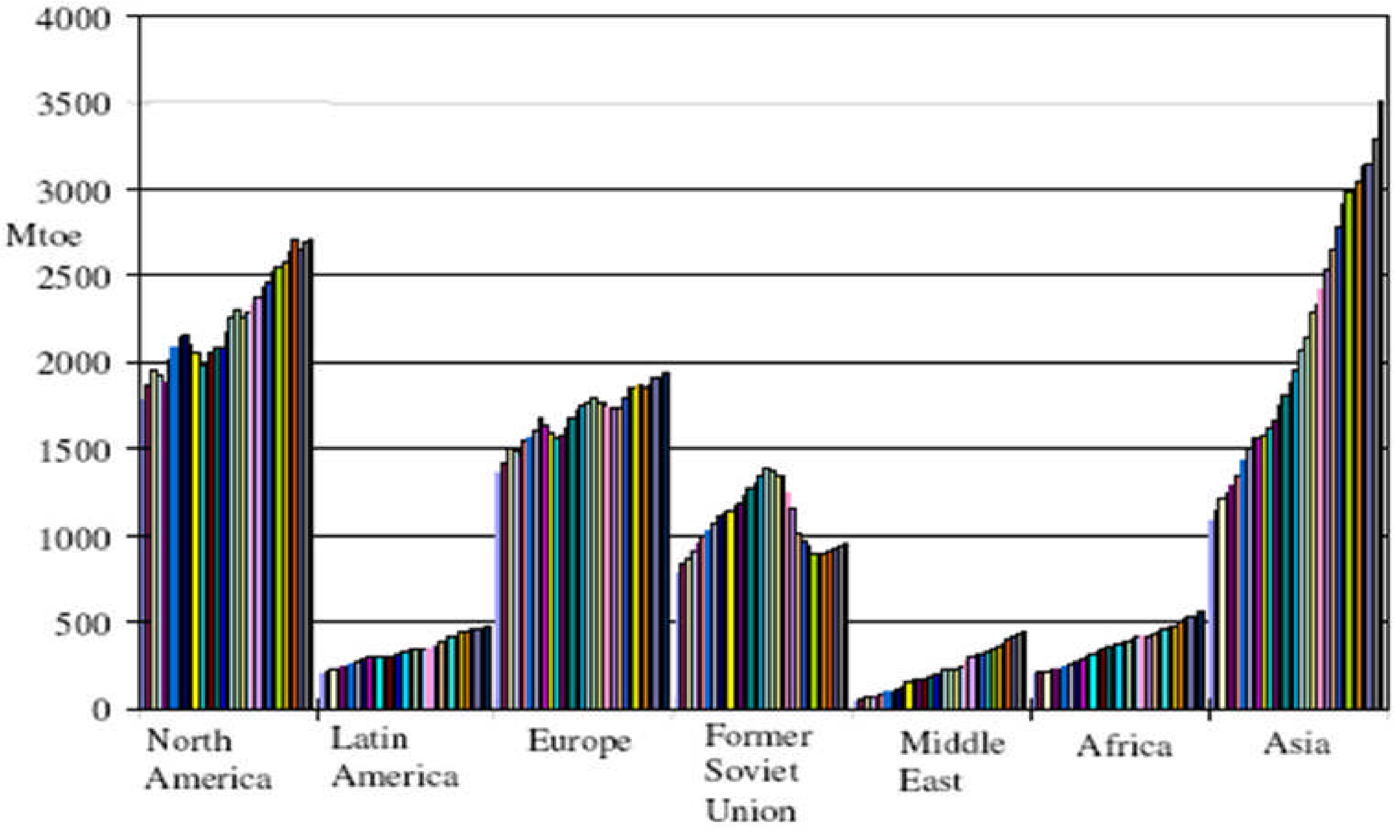


U.S. energy use per capita and per dollar of GDP from 1980 to 2030



(Courtesy of Dr. Steve Koonin, BP)

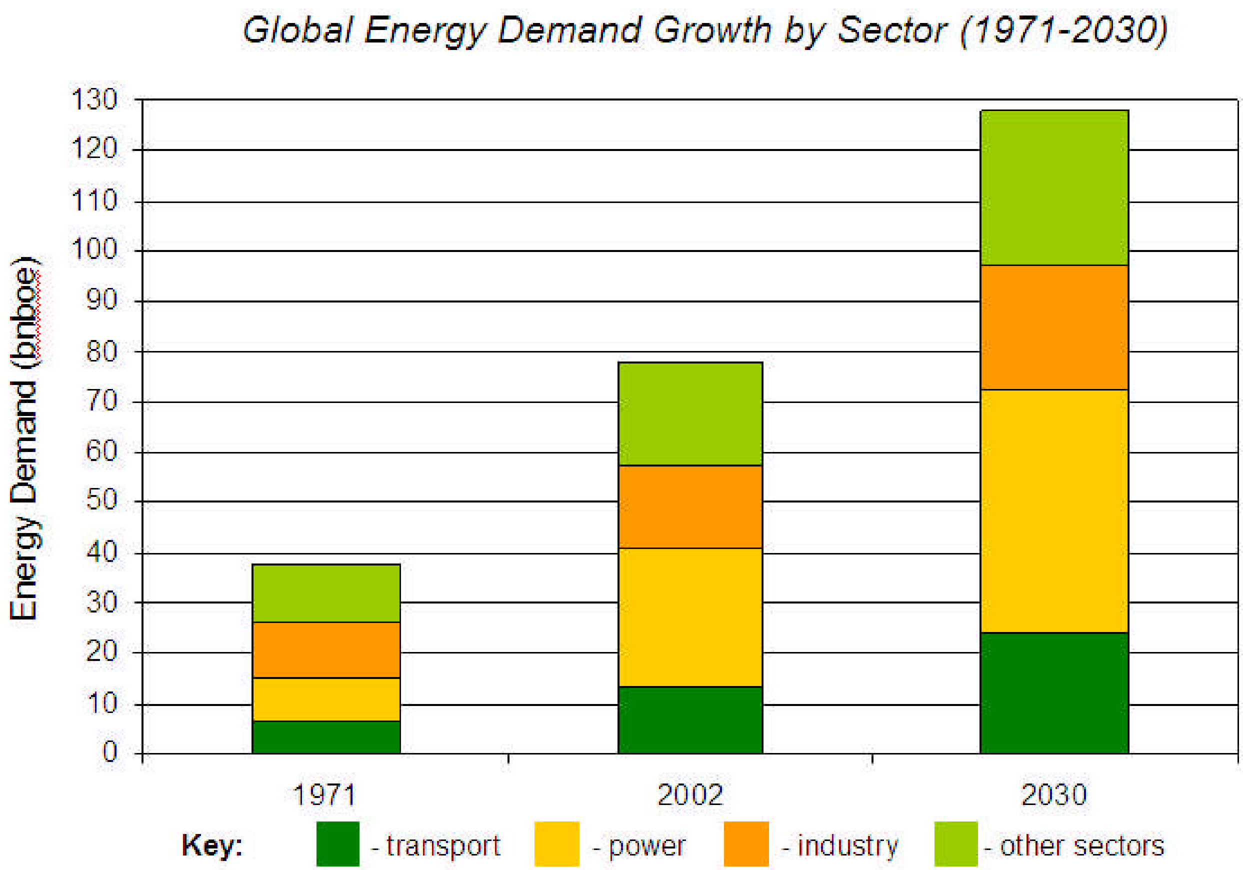
annual primary energy demand 1971-2003



Source IEA, 2004 (Excludes biomass)

Units of energy! 1 Mtoe (million tonnes of oil equivalent) = 0.042 EJ (exajoule = 10^{18} J); 1 quad = 1 quadrillion BTU = 10^{15} BTU = 1.055 EJ; 1 boe (barrel of oil equivalent) = 6.12 GJ; 1 Mbpd (million barrels of oil per day) x 365 days = 2.24 EJ/year

growing energy demand is projected

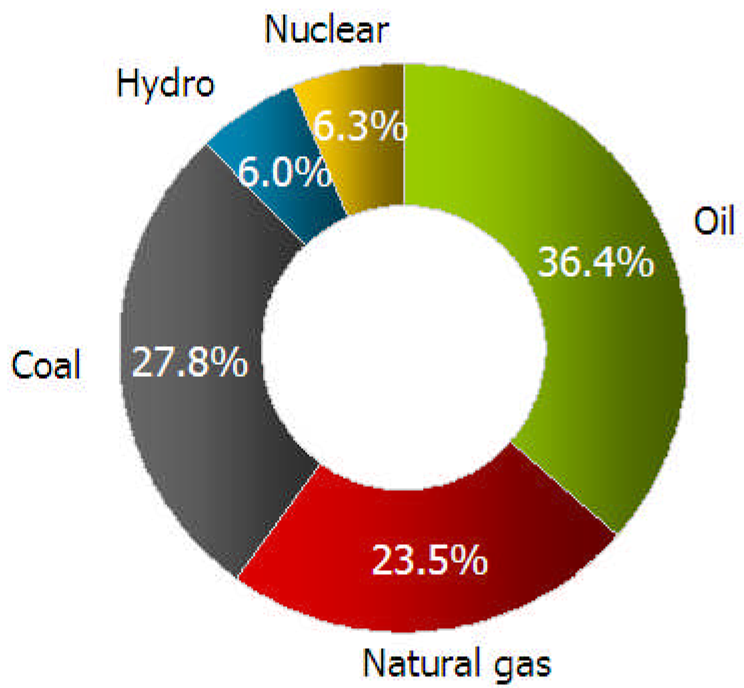


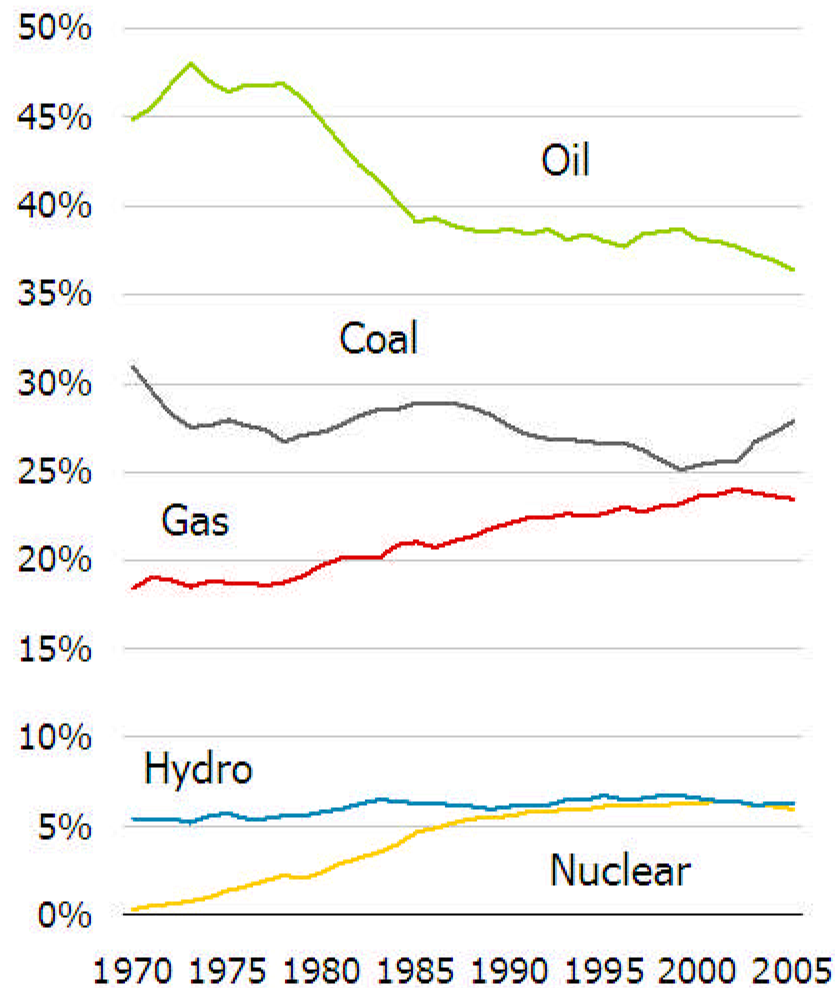
Notes: 1. Power includes heat generated at power plants
2. Other sectors includes residential, agricultural and service

Source: IEA WEO 2004

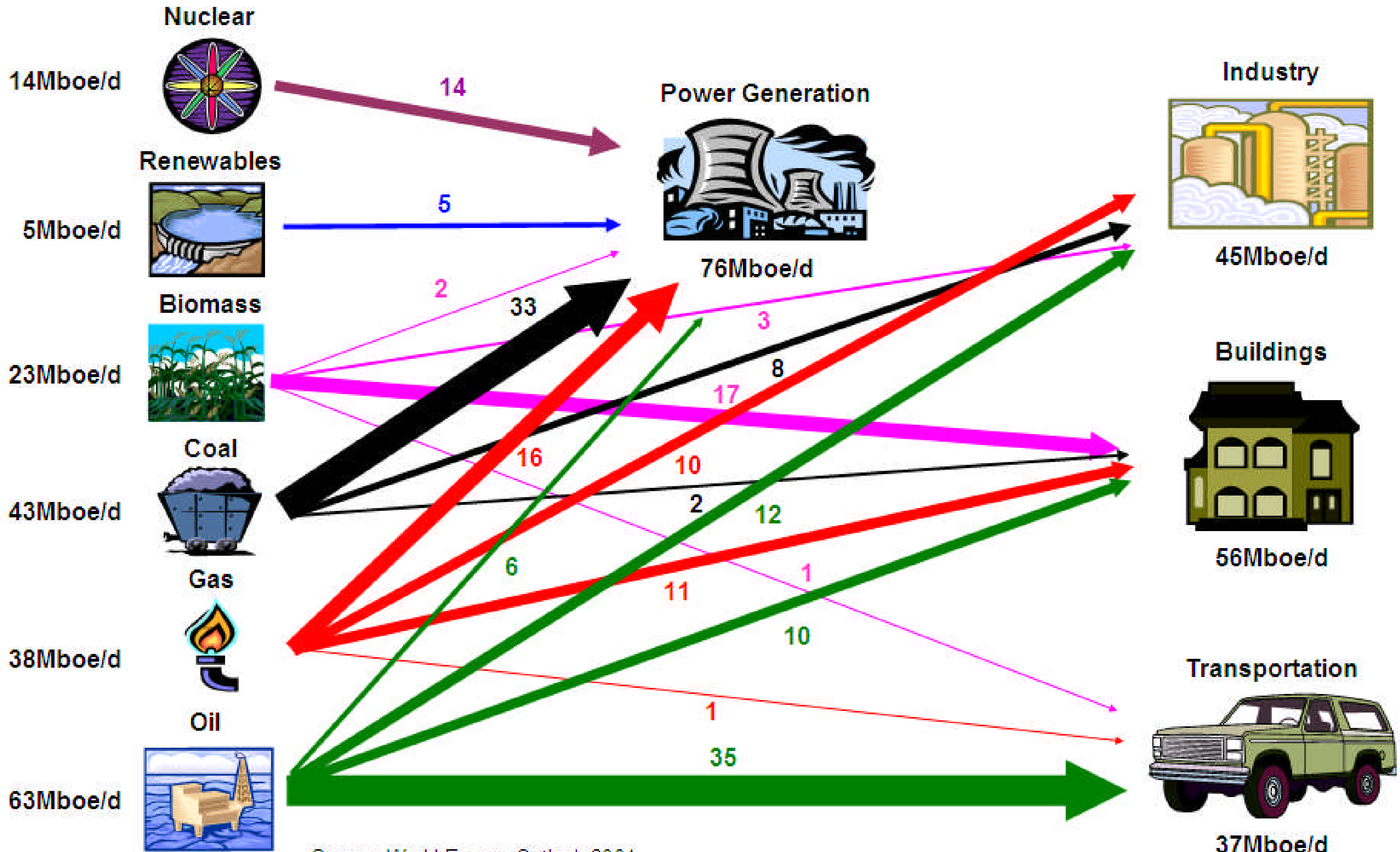
1 bnboe = 1Gboe = 6.12 GJ x 10^9 = 6.12 EJ; 2002 total about 477 EJ, of which U.S. is 102 EJ.

global primary energy sources

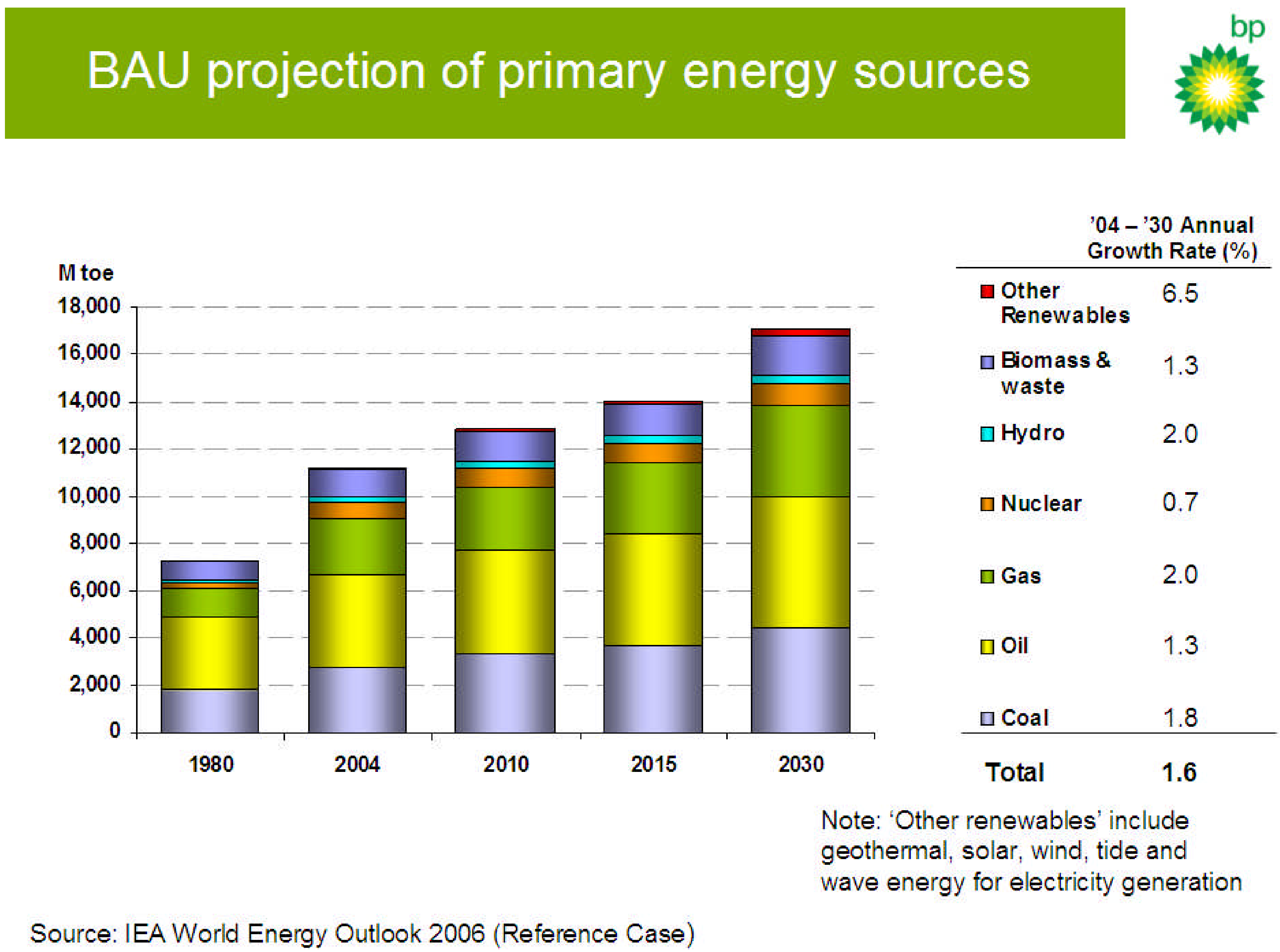




global energy supply & demand (total = 186 Mboe/d)

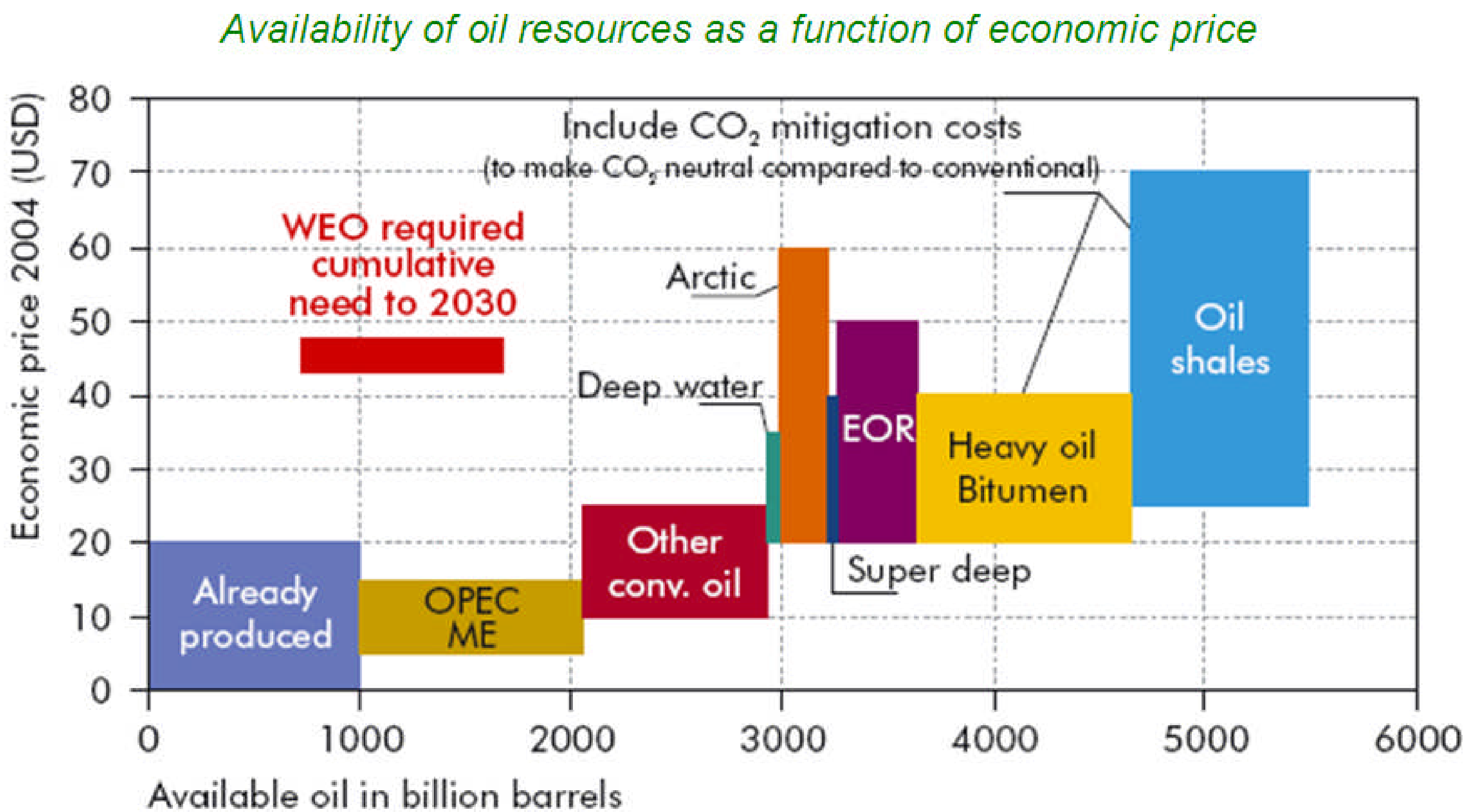


Source: World Energy Outlook 2004



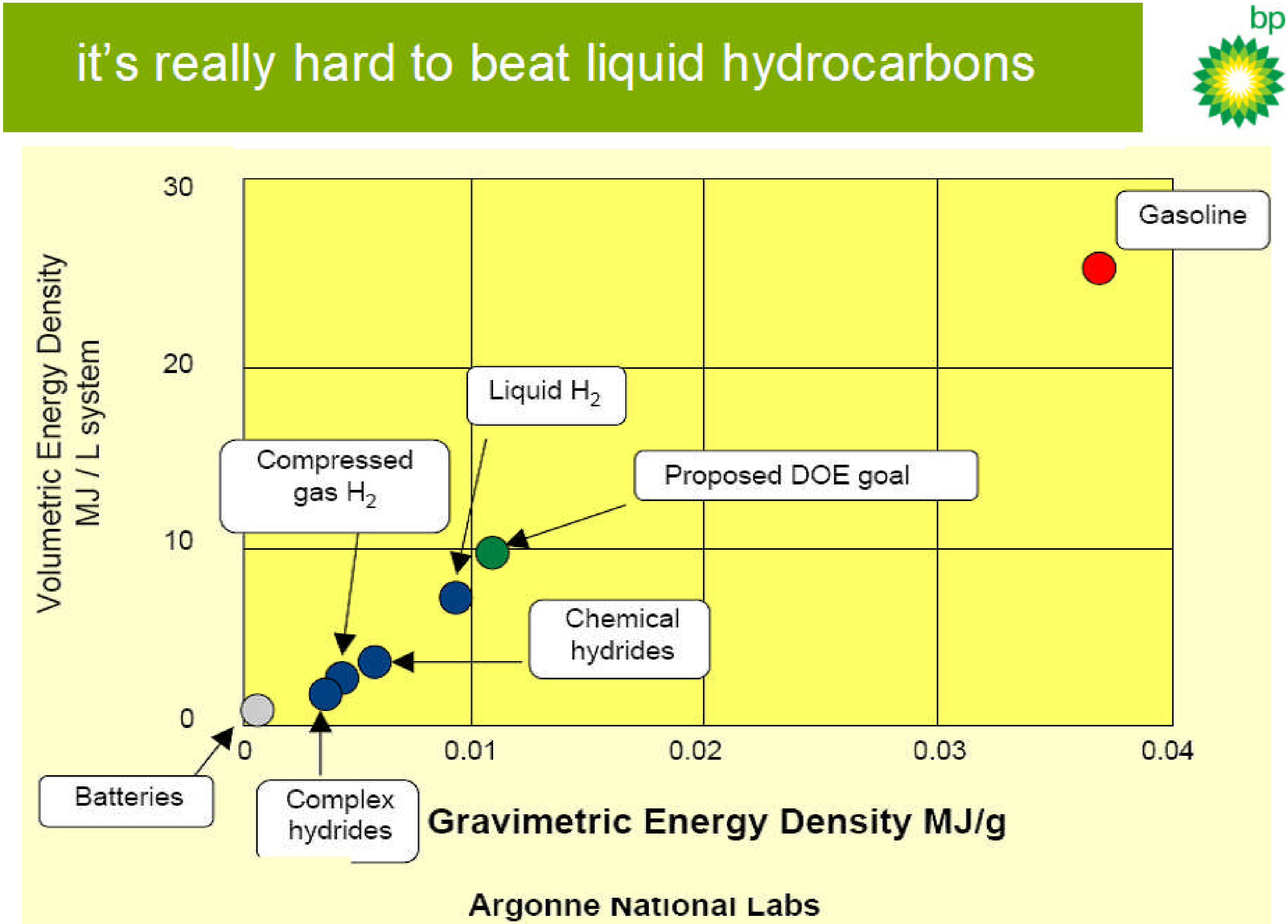
"BAU" is "business as usual"

oil supply and cost curve

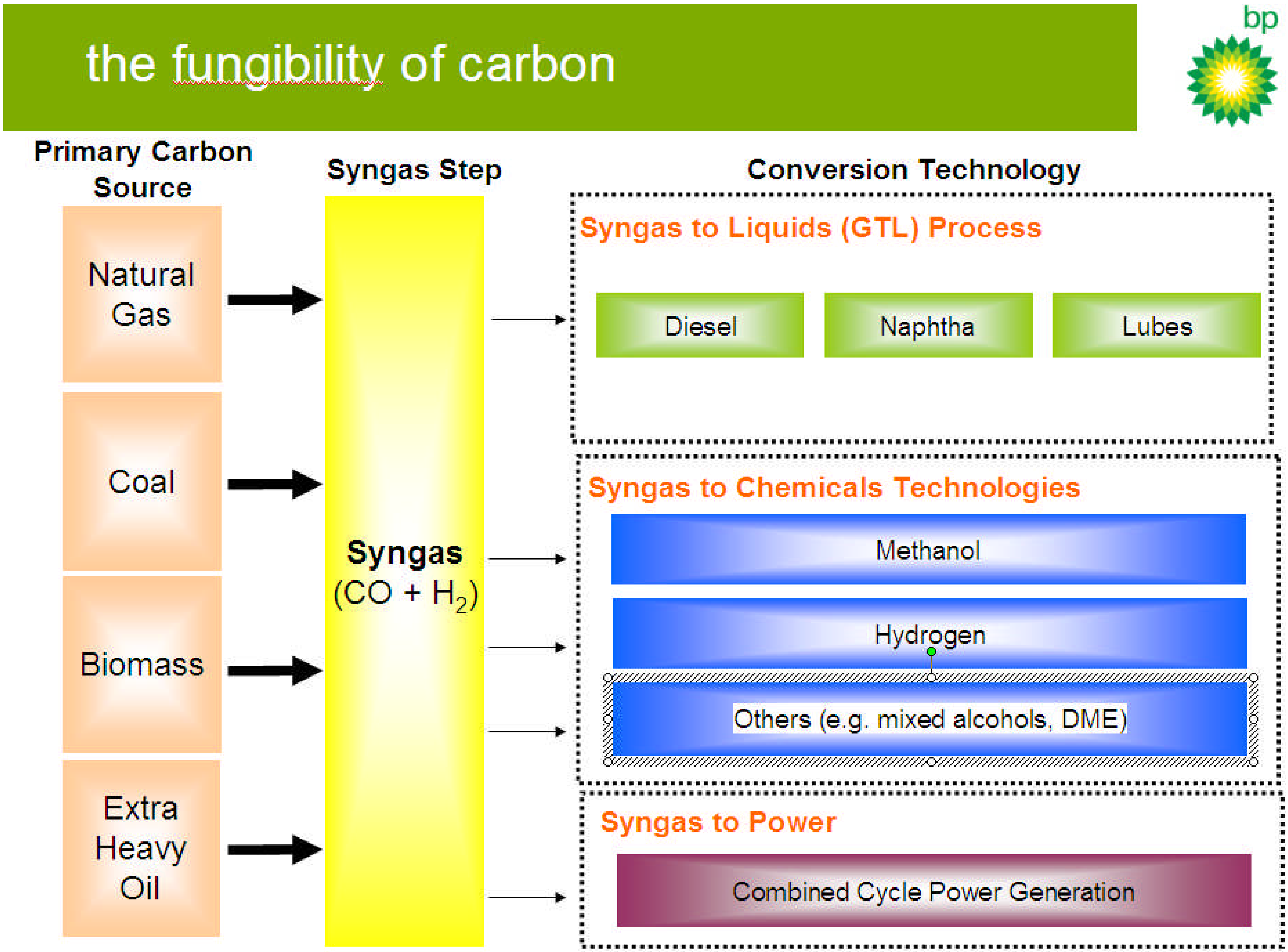


Source: IEA (2005)

Compare 2008 $130/barrel price with max $25/bbl cost.

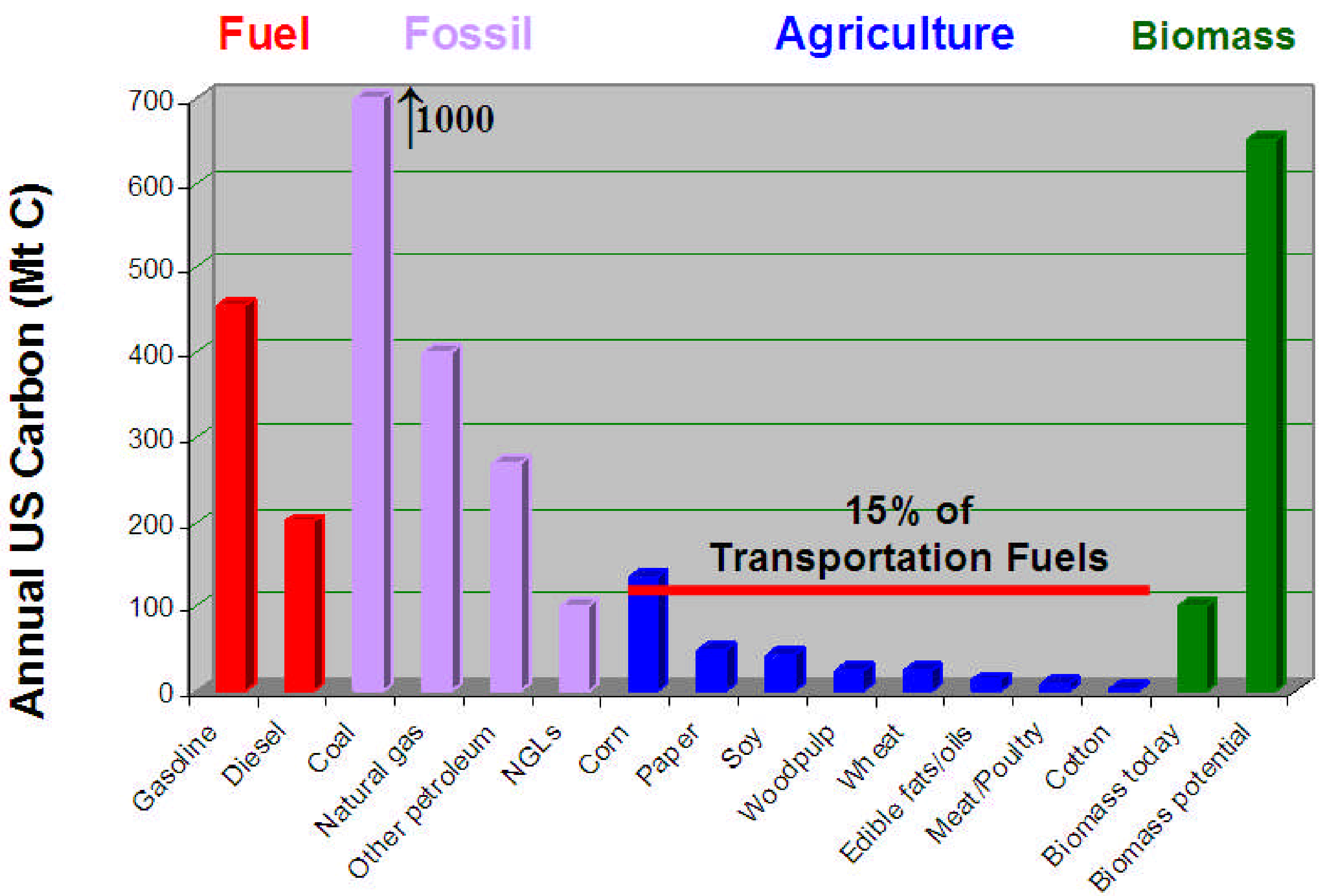


Gasoline or diesel fuel is an efficient energy carrier



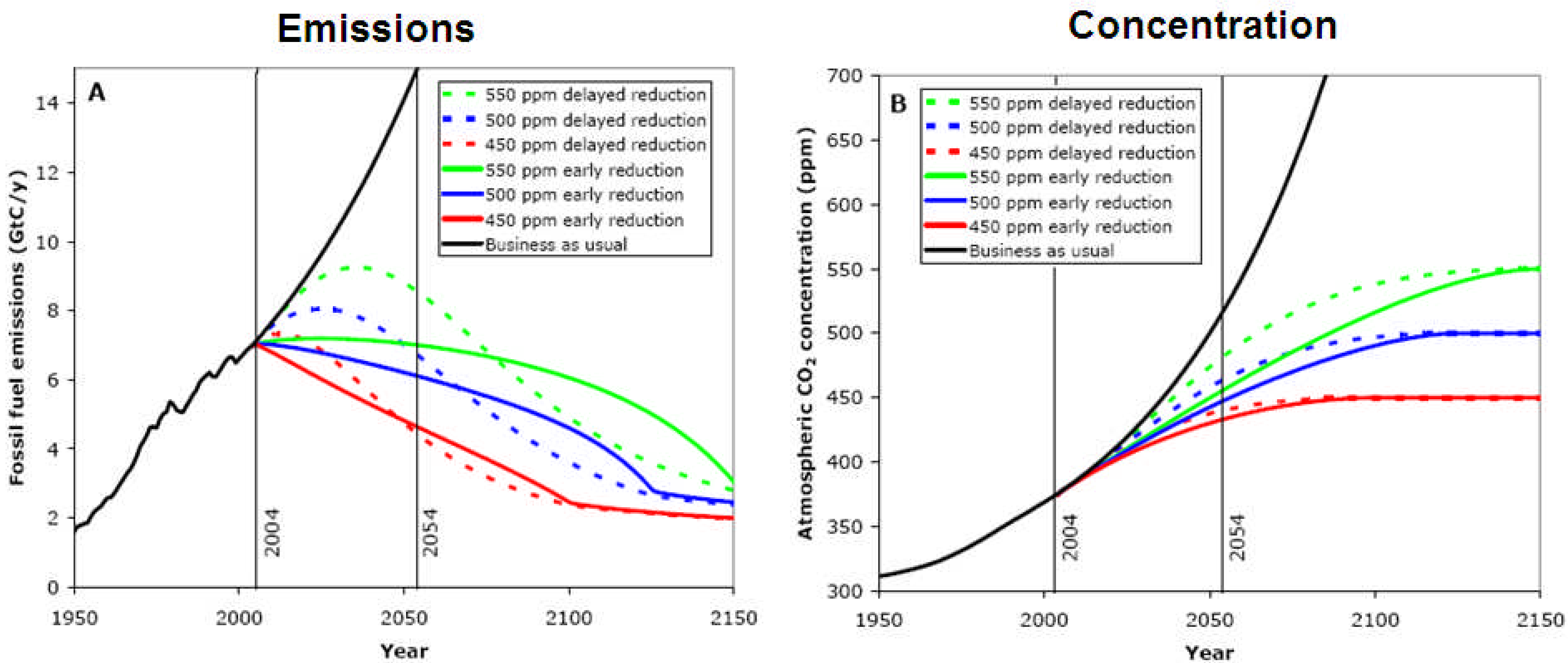
Can supply major amounts of transport fuel, but even more CO_2 emission

what carbon "beyond petroleum"?

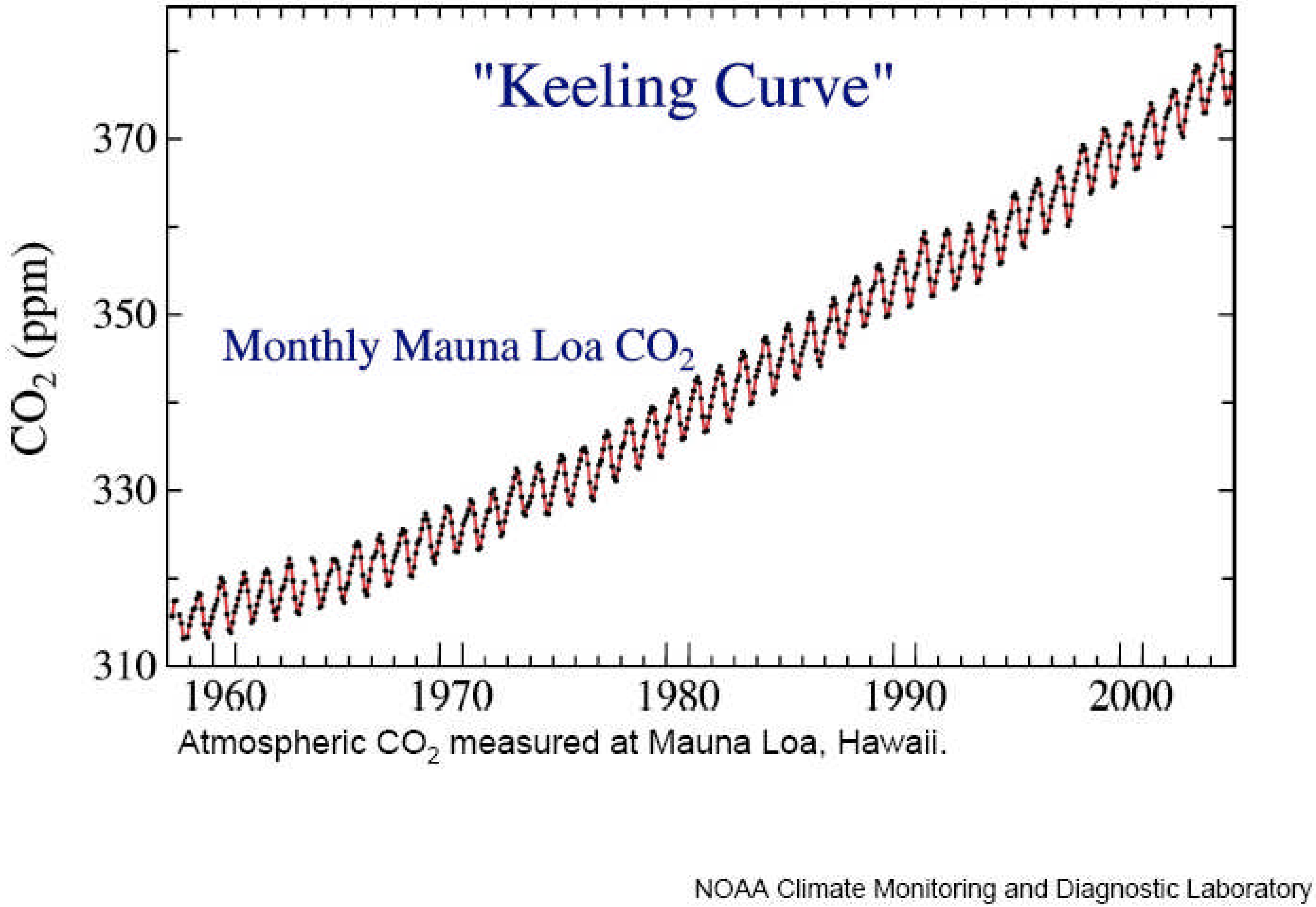


Biomass for transport fuel can provide energy without net CO_2 emission

crucial facts about CO_2 science



Strong measures are required to hold atmospheric CO_2 concentration to 450 or 550 ppm, compared with pre-industrial 280 ppm



The "energy problem" would be severe without regard to CO_2; the "CO_2 problem" would be severe by itself. Together they may be the largest problem the world faces.

Emissions from energy are 65% of the problem, above all CO_2 from fossil-fuel combustion

The emissions arise from a 4-fold product…

$$C = P \times GDP / P \times E / GDP \times C / E$$

where C = carbon content of emitted CO_2 (kilograms), and the four contributing factors are

P = population, persons

GDP / P = economic activity per person, \$/pers

E / GDP = energy intensity of economic activity, GJ/\$

C / E = carbon intensity of energy supply, kg/GJ

For example, in the year 2000, the world figures were…

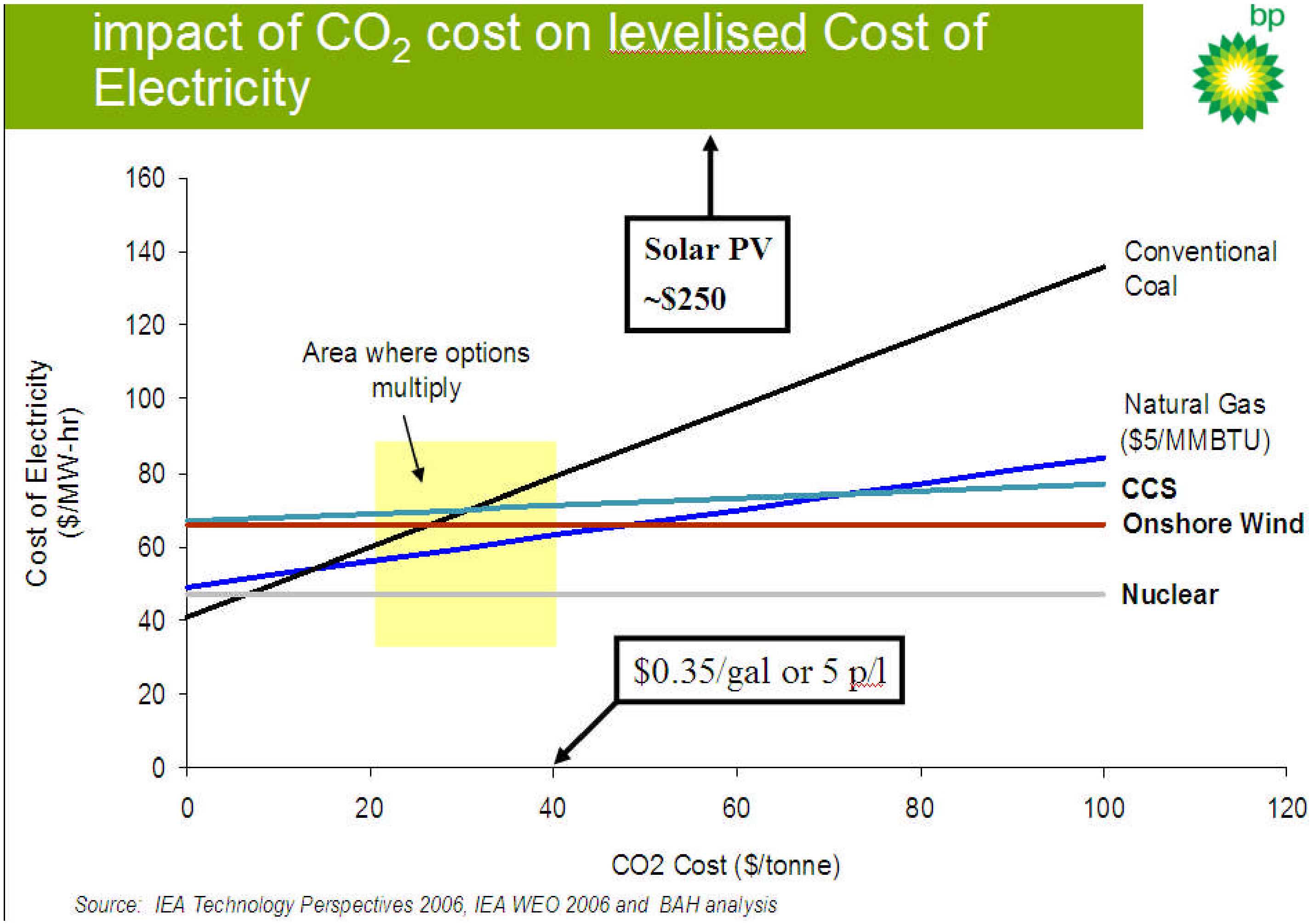
6.1×10^9 pers x \$7400/pers x 0.01 GJ/\$ x 14 kgC/GJ

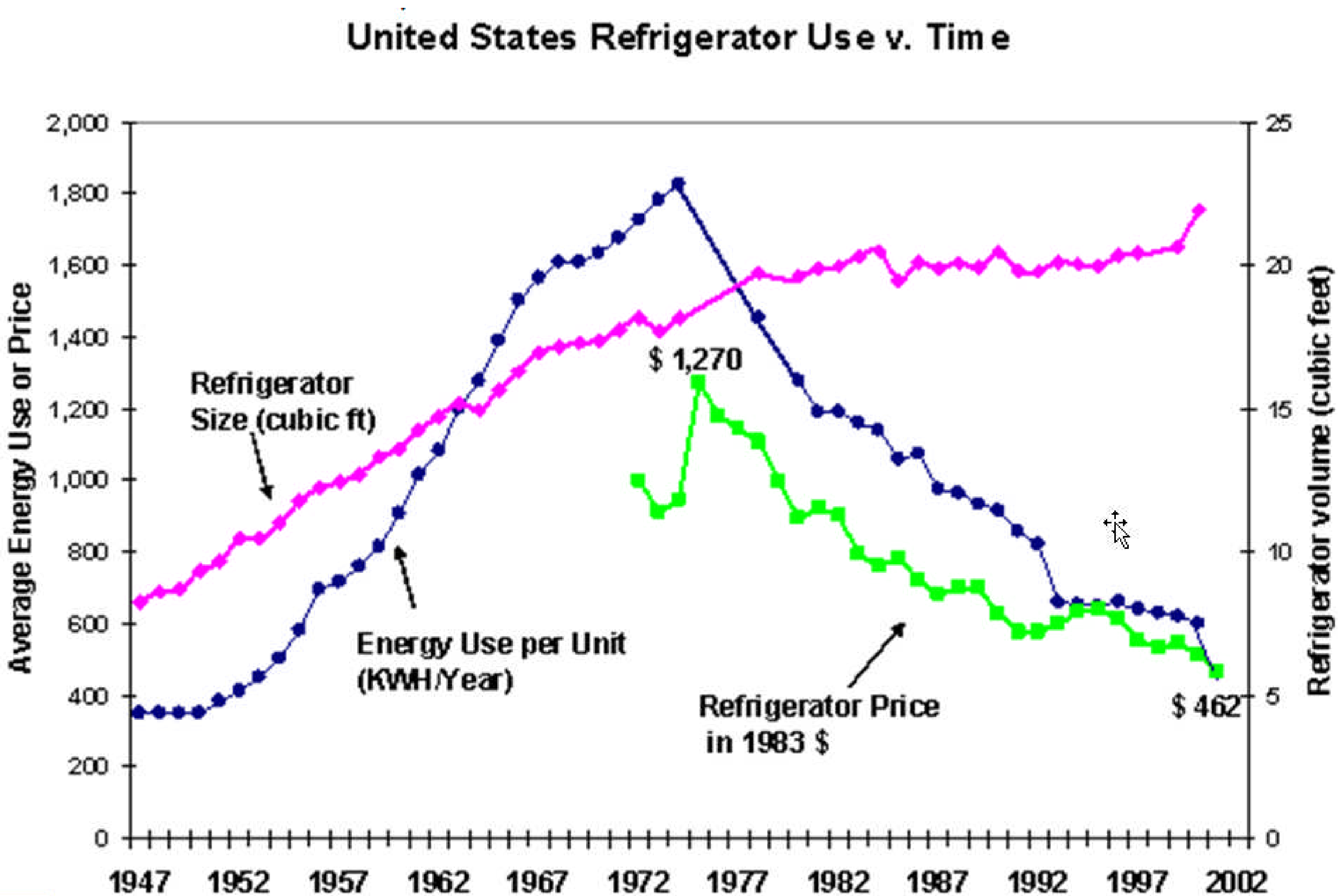
$= 6.4 \times 10^{12}$ kgC = 6.4 billion tonnes C

[From John Holdren]

Near-term tools

- **A carbon tax to move toward low-carbon or no-carbon solutions**

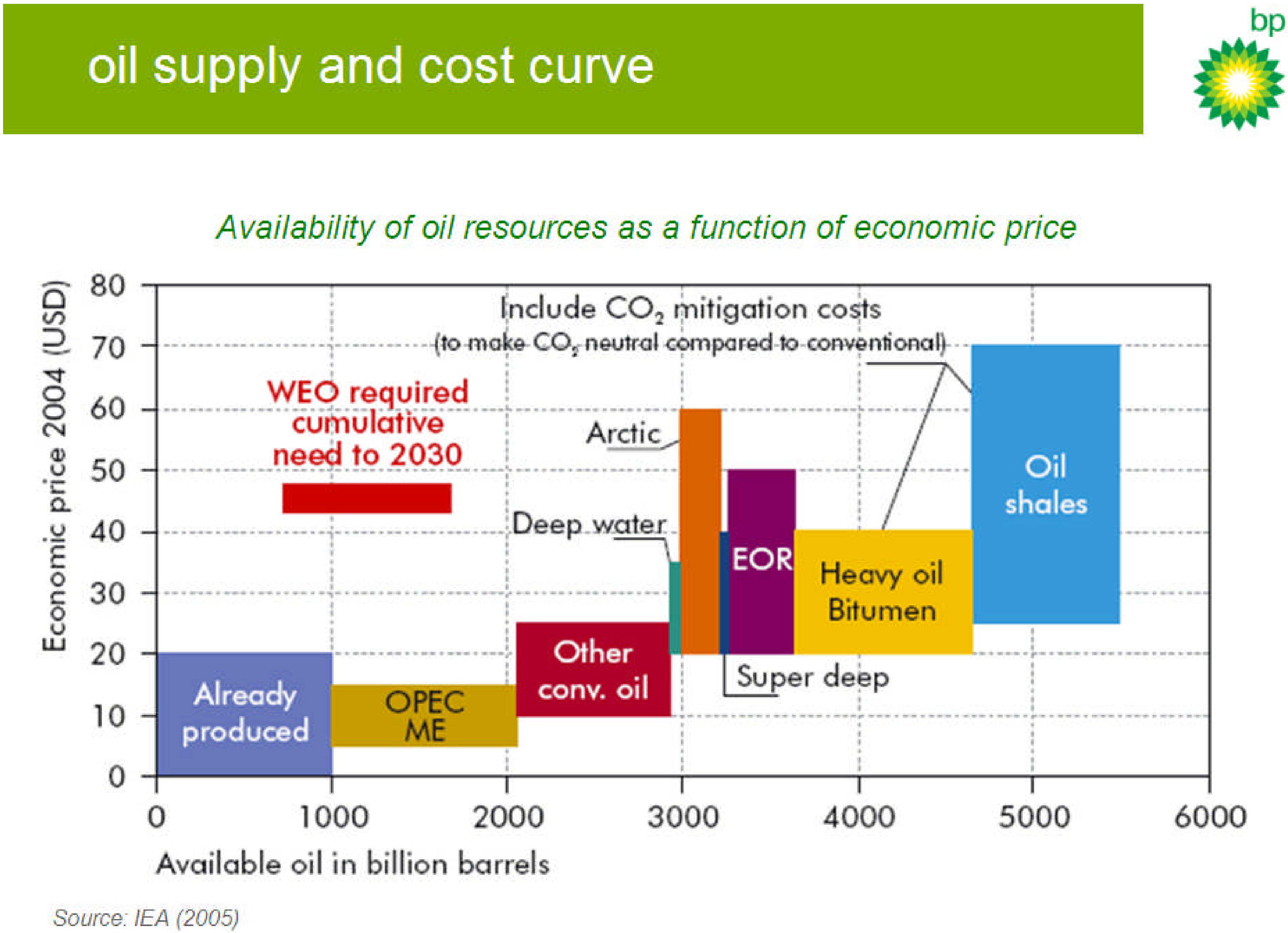




Spectacular results in response to a government prize/incentive program

Near-term tools

- **More efficient use of energy, e.g., U.S. refrigerators.**
- **Major push for at-scale demonstration of "carbon capture and storage". A single coal-fired 1000 MWe plant burns 2 million tonnes of carbon per year, generating 2 x 44/12 = 7.3 MT CO_2 per year. Dispose in aquifers, deep-sea pools, sea-bed sediment.**
- **Develop and deploy cellulose-to-ethanol plants for transport fuel, using waste plant material for zero-C fuel.**
- **Low-cost exploration to determine availability and cost of extraction of uranium for nuclear power—the "supply curve" of uranium.**
- **Explore the production of clathrate methane from ocean margins, and define the resource (perhaps 2000 Gt of carbon, but a dilute, non-flowing resource)**



Compare 2008 $130/barrel price with max $25/bbl cost.
What to do about the price?

Getting serious

- **Create an Organization of Petroleum Importing States.**
- **Establish a virtual world energy laboratory—not necessarily centralized like CERN because no enormous machine would be involved. But perhaps a central nuclear-power laboratory.**
- **Support alternatives to conventional petroleum by contracting for their product at a fixed price, compensating for inflation, not by guaranteed profit.**
- **Since the effect of high petroleum prices is not increased production but reduced demand, the OPIS countries should impose taxes to produce comparable high prices—e.g. a tax of $60/bbl equal to $1.50 per gallon or Euro 0.35 per liter.**

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