

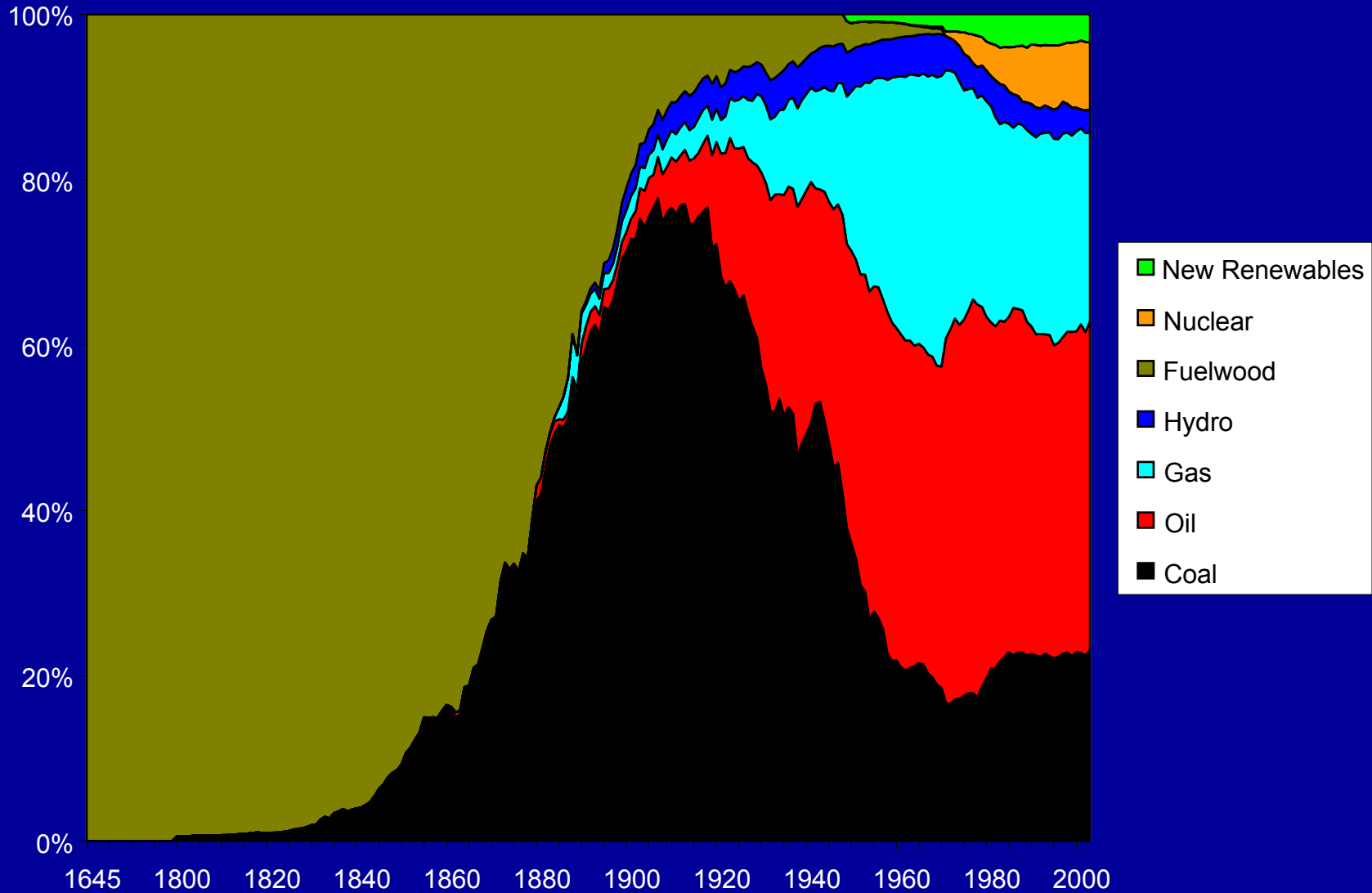
# A Future for Fossil Fuels?

**David G. Victor**

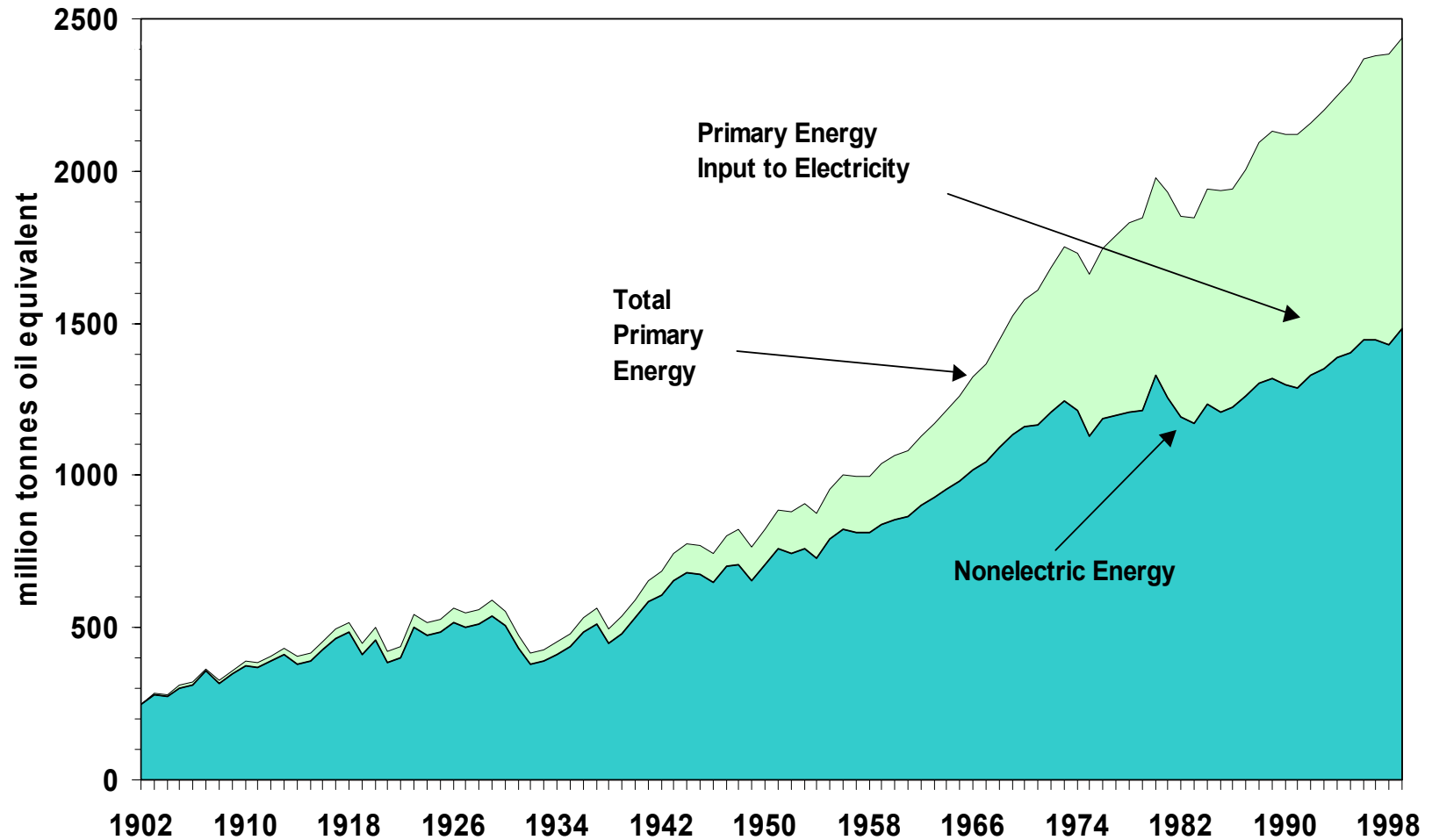
Director, Program on Energy &  
Sustainable Development  
Stanford University

<http://pesd.stanford.edu/>

# Primary Energy in the US, 1645-2003



# Electrification of the U.S. Economy



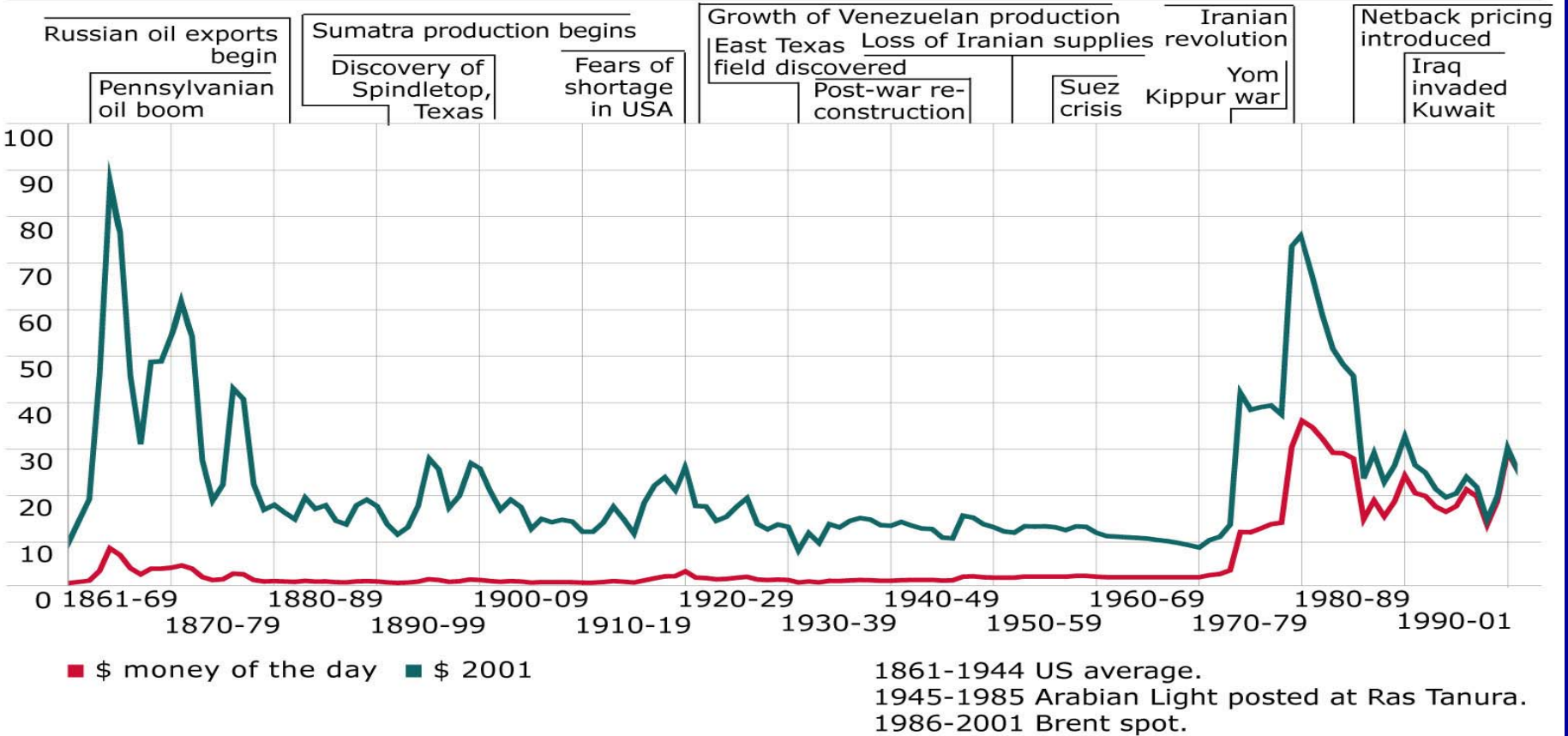
Sources: B.R. Mitchell, *International historical Statistics. The Americas, 1750-1988* (1993) and U.S. Department of Commerce, *Historical Statistics Colonial Times to the Present* (1975), updated with IEA, *Energy Policies of IEA Countries: 1999 Review* (2000); estimates for primary energy consumption from databases compiled at the International Institute for Applied Systems Analysis.

# World Oil Prices

## chart of crude oil prices since 1861

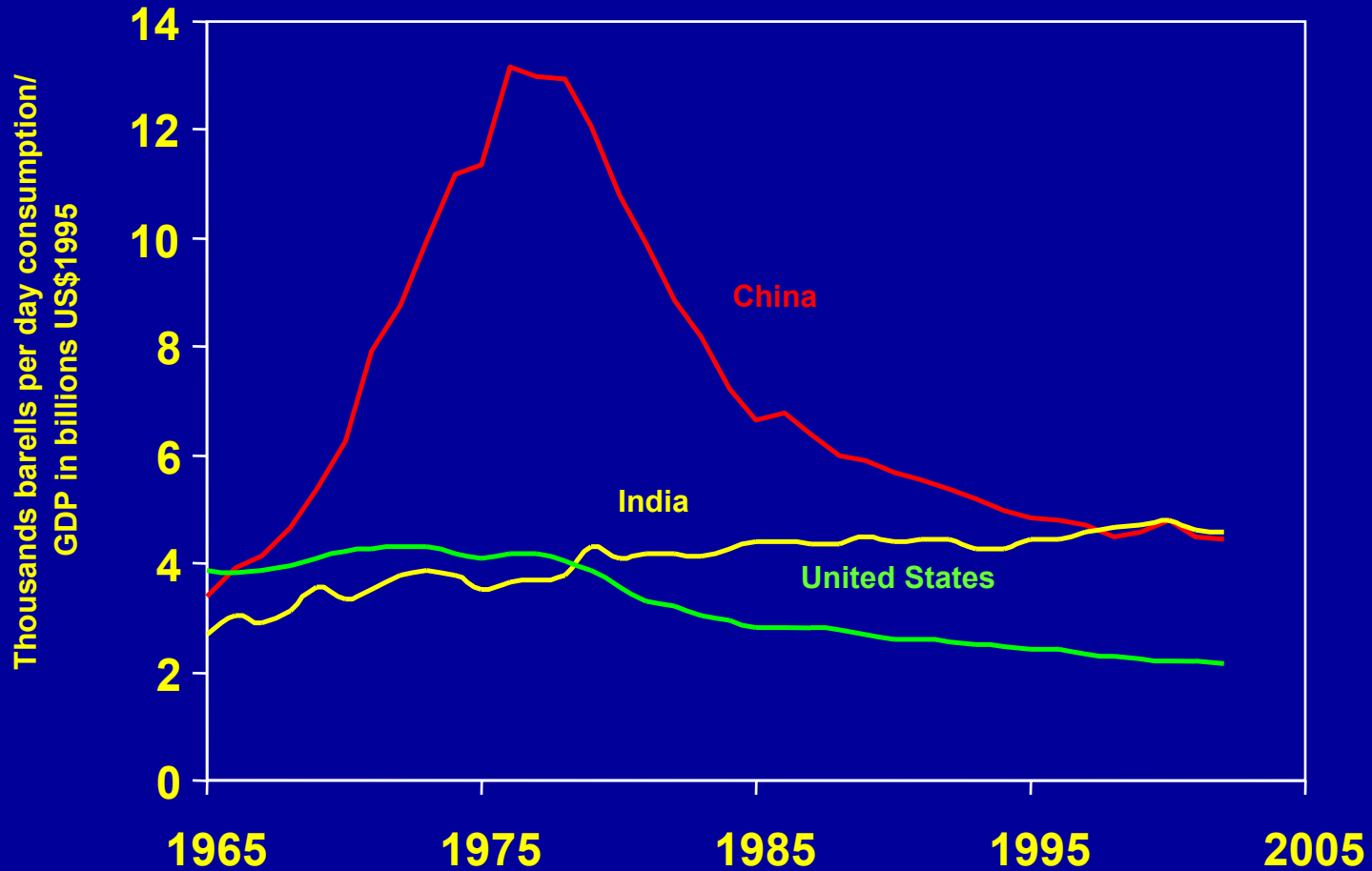
US dollars per barrel

### World events



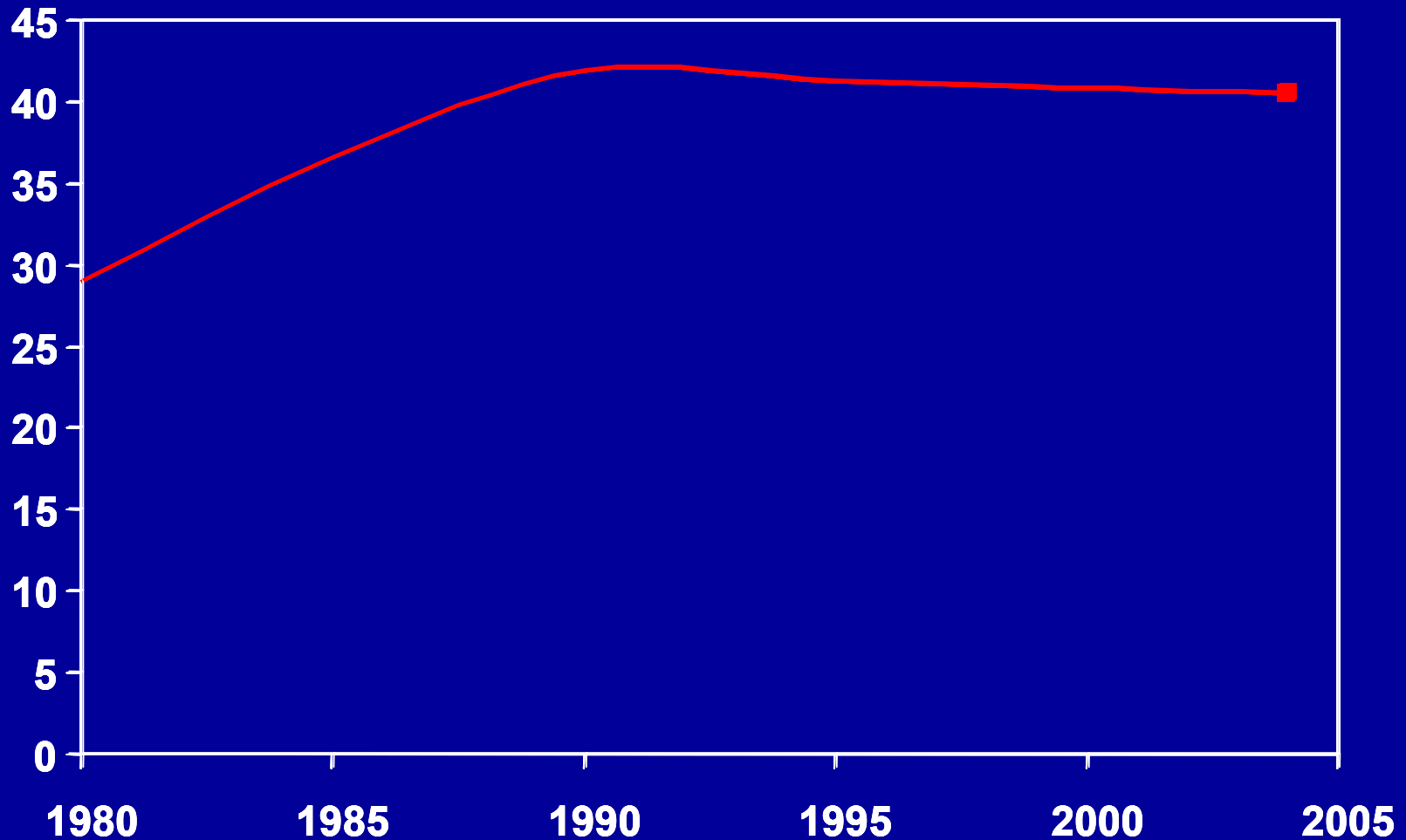
bp statistical review of world energy 2002

# Oil Intensity



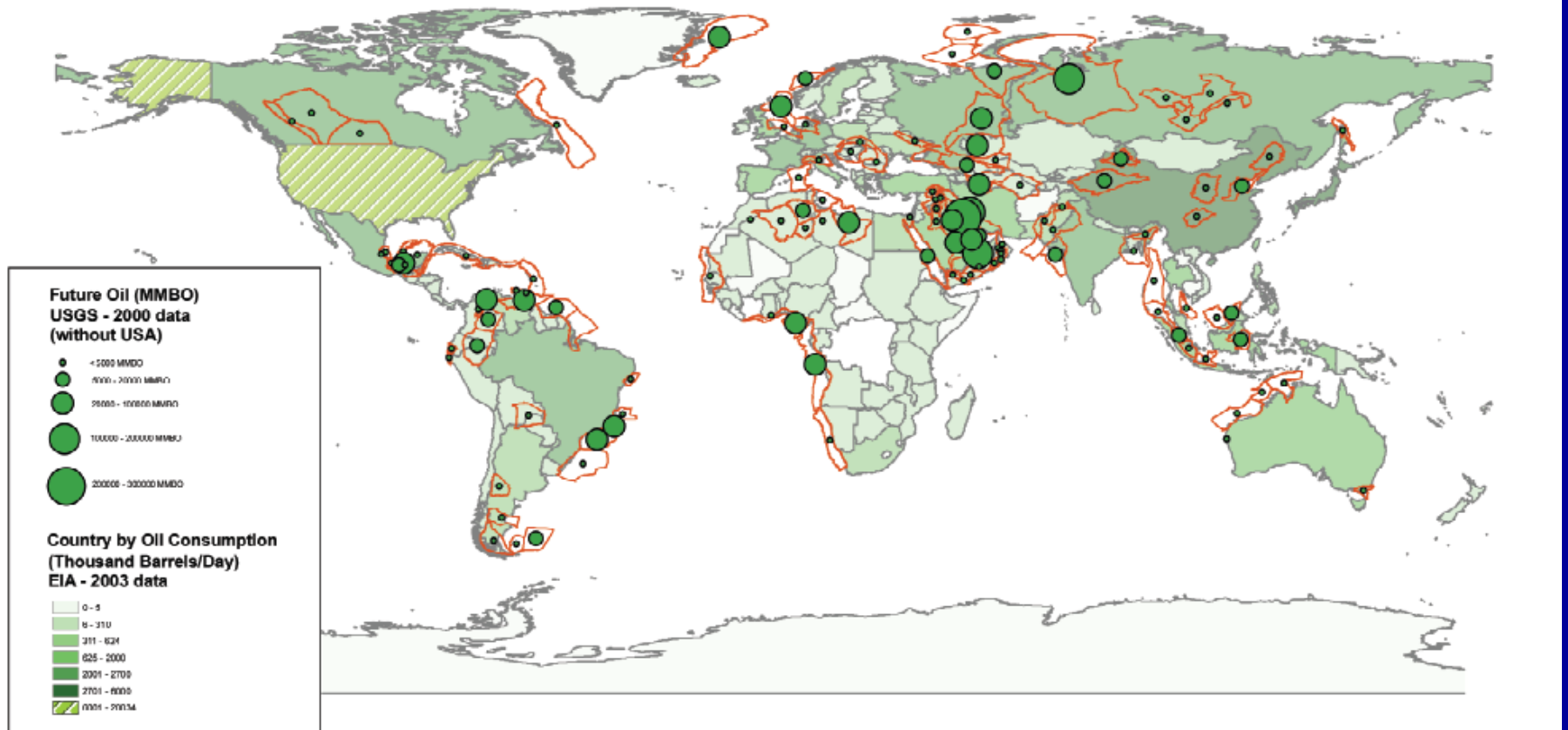
Data Source: WB-2004, BP-2005

# Proved Oil Reserves, 2004 (R/P ratio)



Source: BP Statistical Review of World Energy. 2005

## FUTURE OIL RESOURCES AND COUNTRY OIL CONSUMPTION (September, 2005)

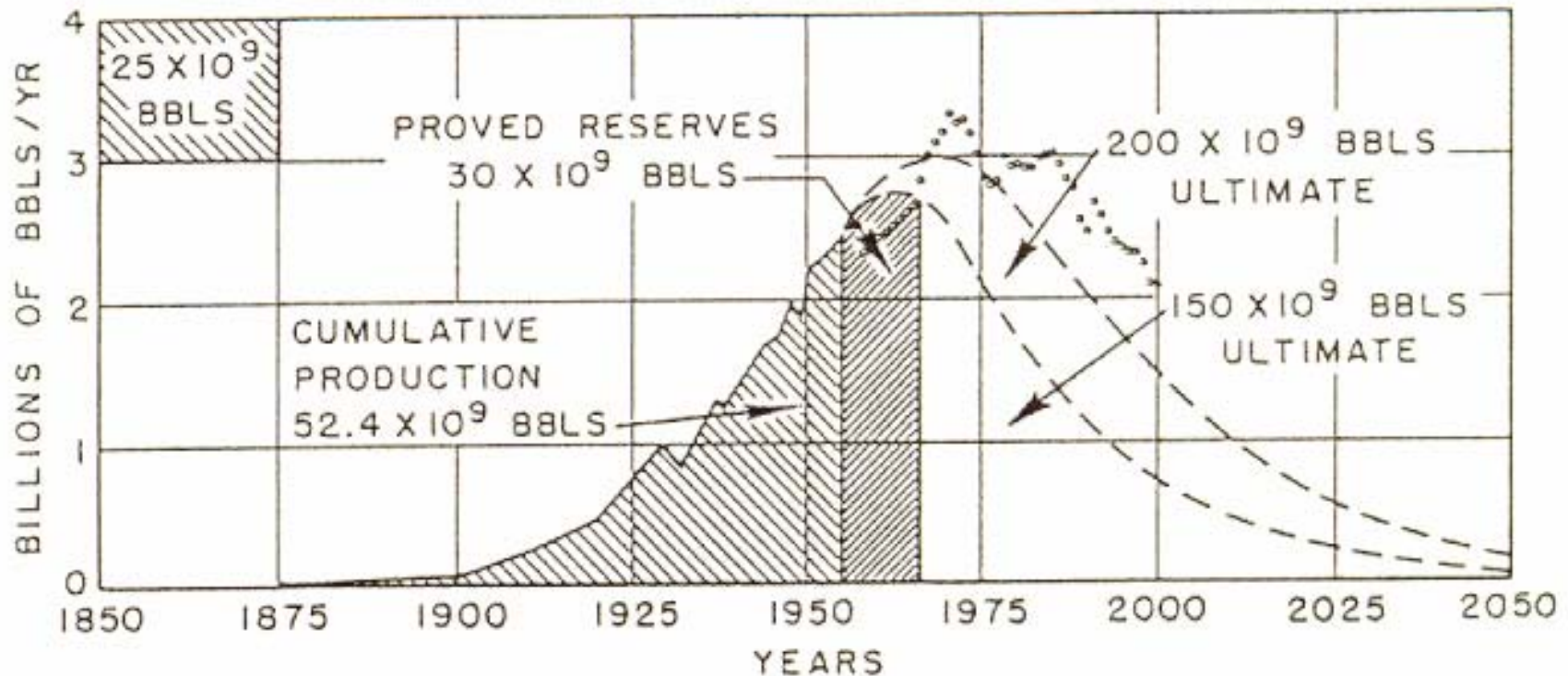


Future Oil = Remaining Reserves + Undiscovered Resources

Oil Consumption after  
Energy Information Administration (EIA) WEB site (2003 data)

Source: USGS

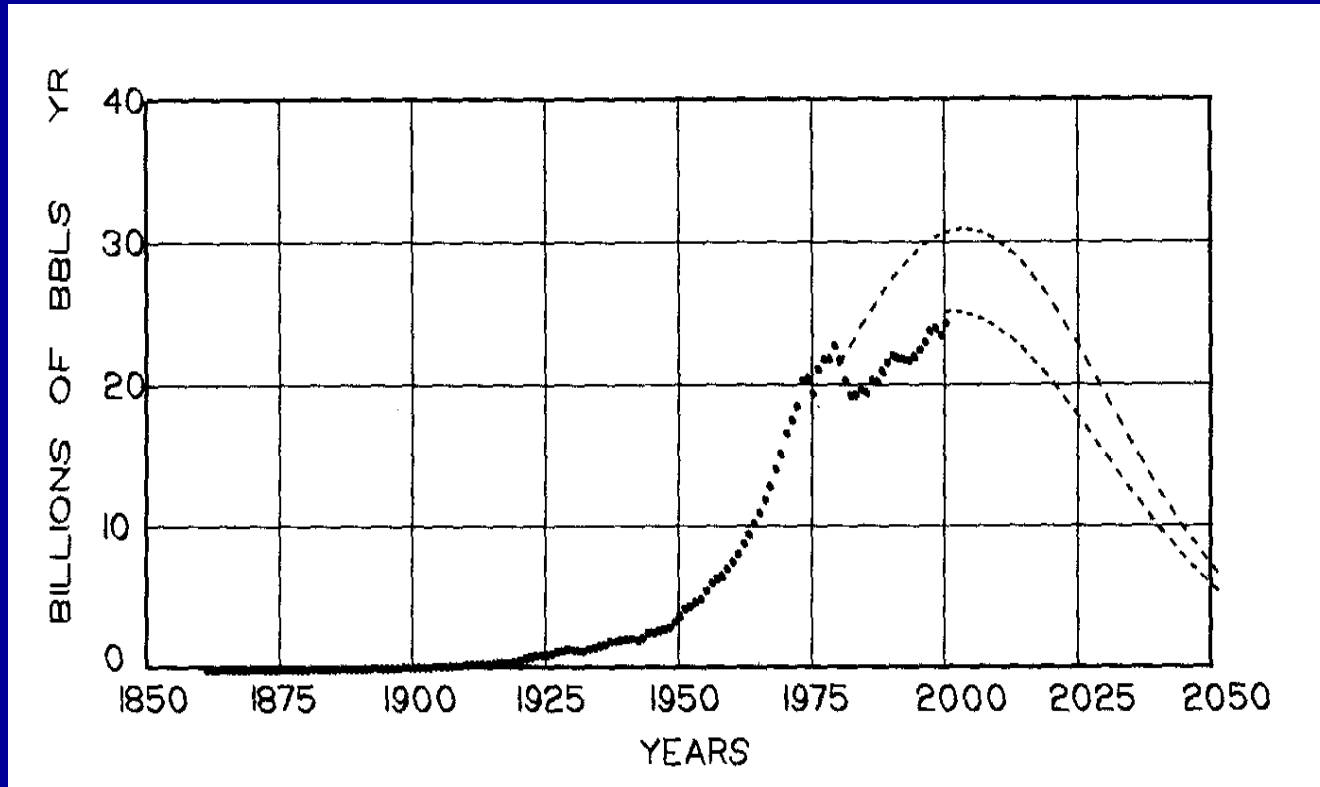
# Hubbert's Peak: United States



Source: Deffeyes, Kenneth S. Hubbert's Peak: The Impending World Oil Shortage. Princeton: Princeton University Press, 2001.



# Est. World Oil Production 1850-2020

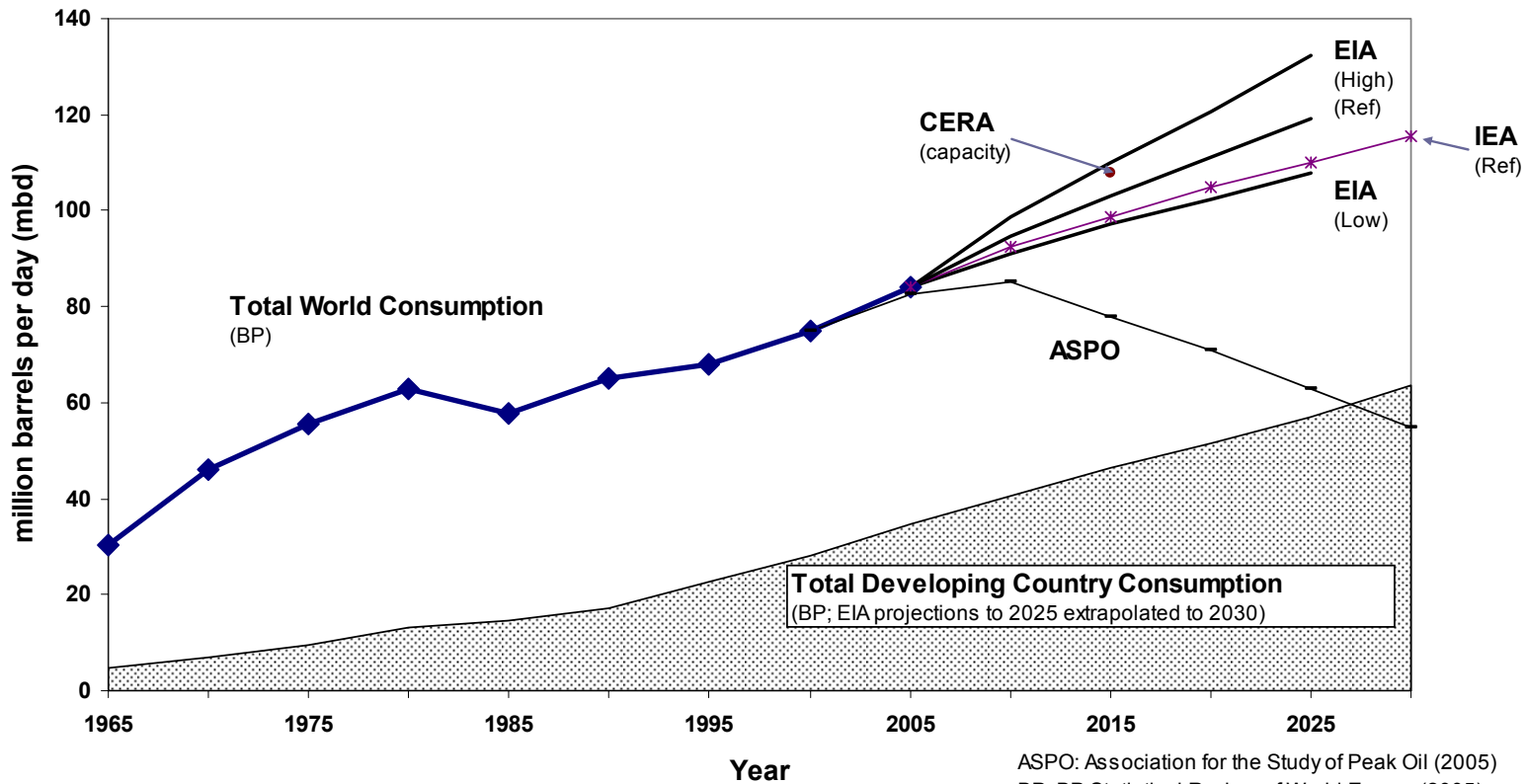


Lower Curve assumes 1.8 trillion barrels

Upper curve assumes 2.1 trillion barrels

Source: Deffeyes, Kenneth S. Hubbert's Peak: The Impending World Oil Shortage. Princeton: Princeton University Press, 2001.

# World Oil Consumption and Production



ASPO: Association for the Study of Peak Oil (2005)  
 BP: BP Statistical Review of World Energy (2005)  
 CERA: Cambridge Energy Research Associates (2005)  
 EIA: Energy Information Administration (2005)  
 IEA: International Energy Agency (WEO, 2005)

# Shares Of Liquid Reserves ordered by controlling firm (2003)

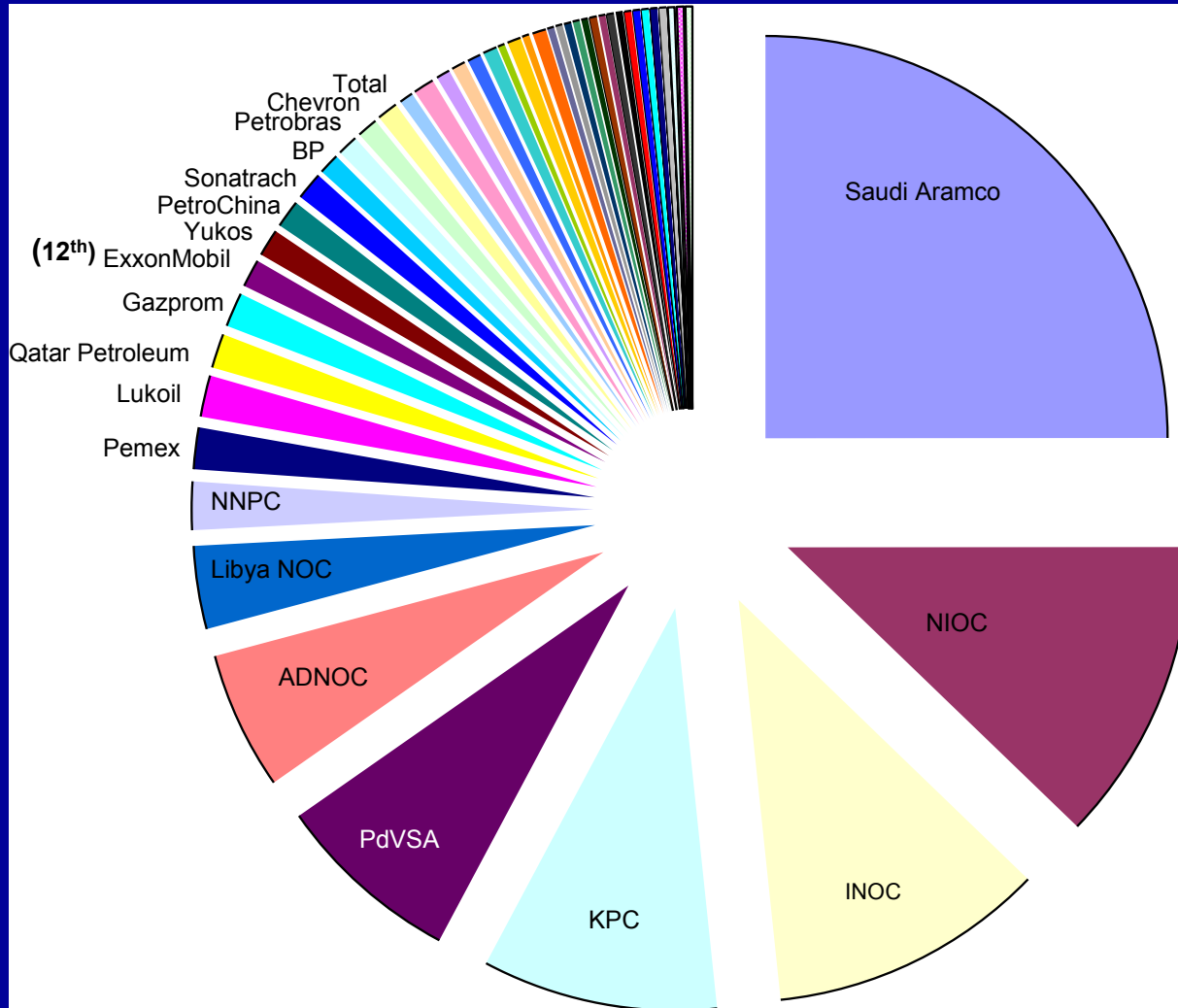


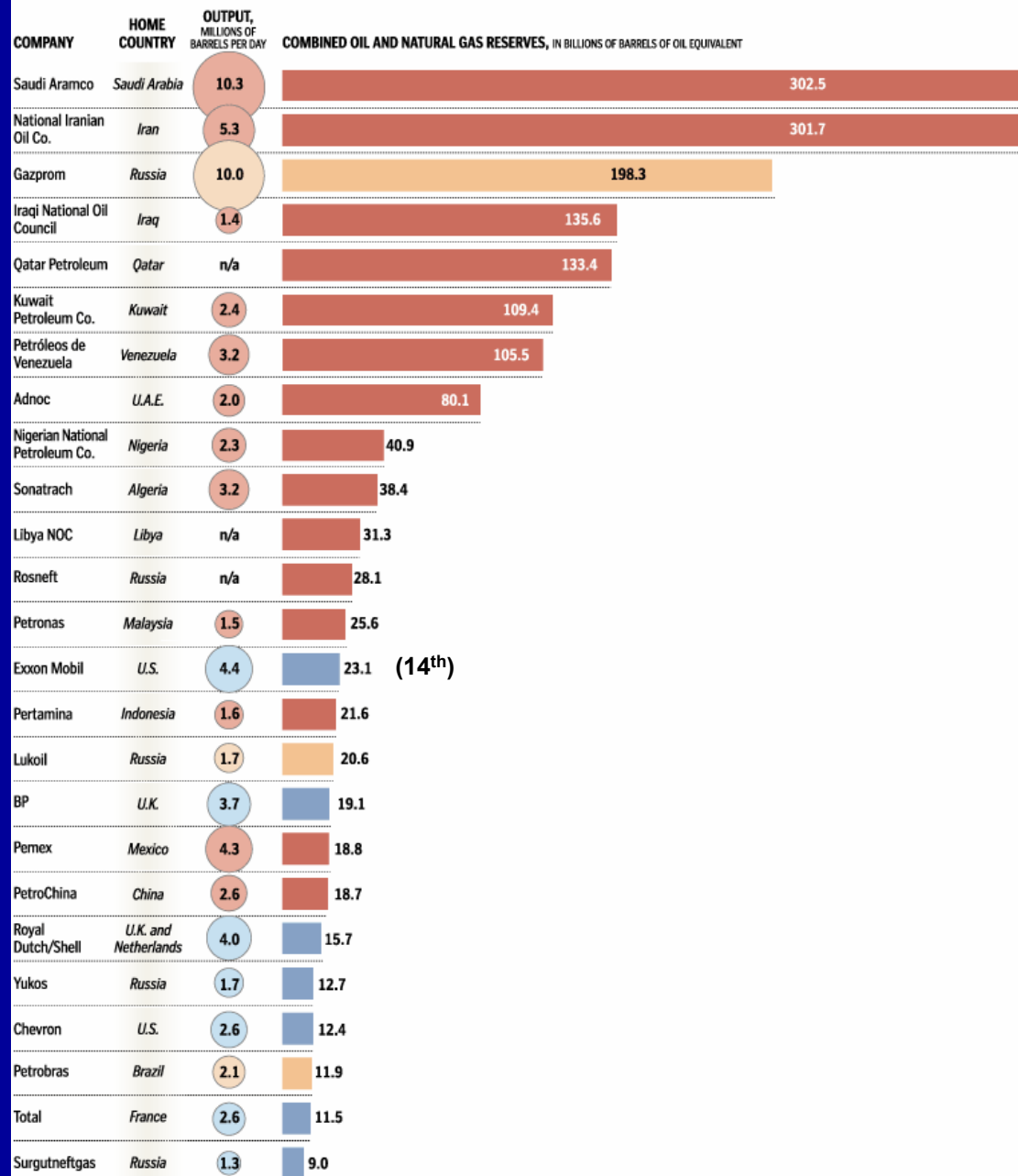
Figure 2. Data Source: Energy Intelligence (2005)

Colors represent ownership of the oil and gas companies.

90%-100% owned by state

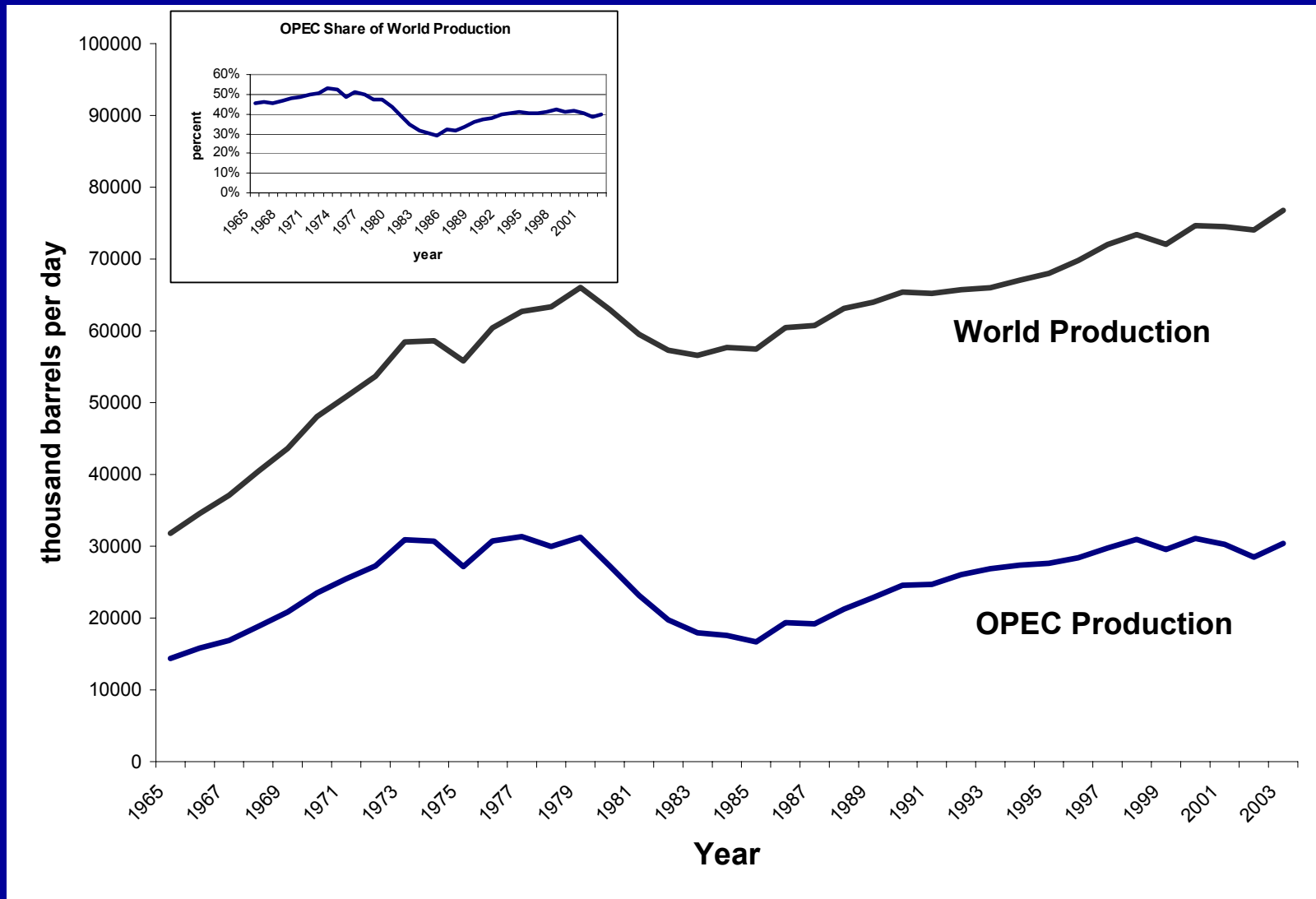
Up to 35% owned by state

Not owned by state

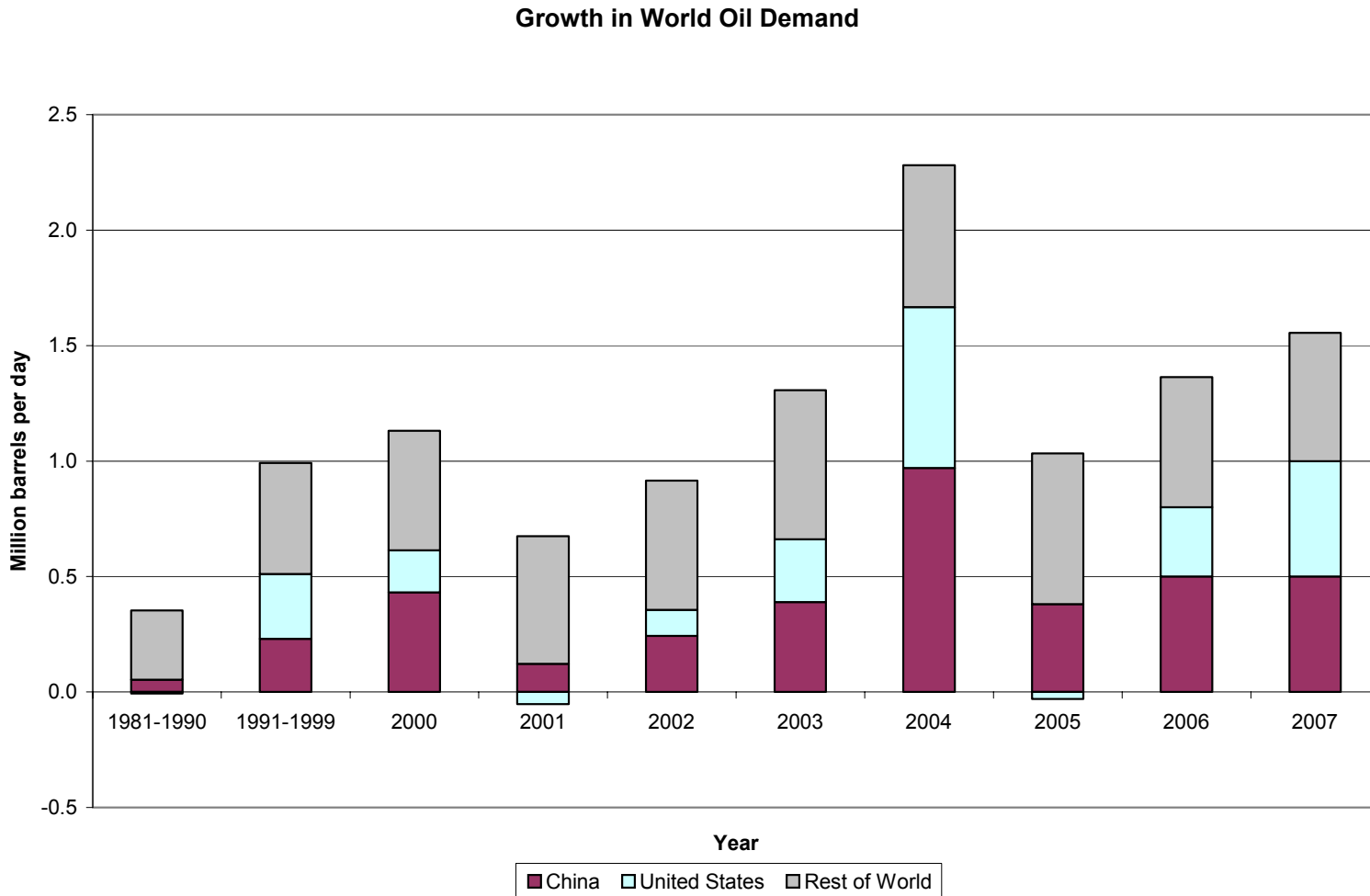


Figures are for 2003, the latest year available.

# Oil Production: Worldwide and OPEC

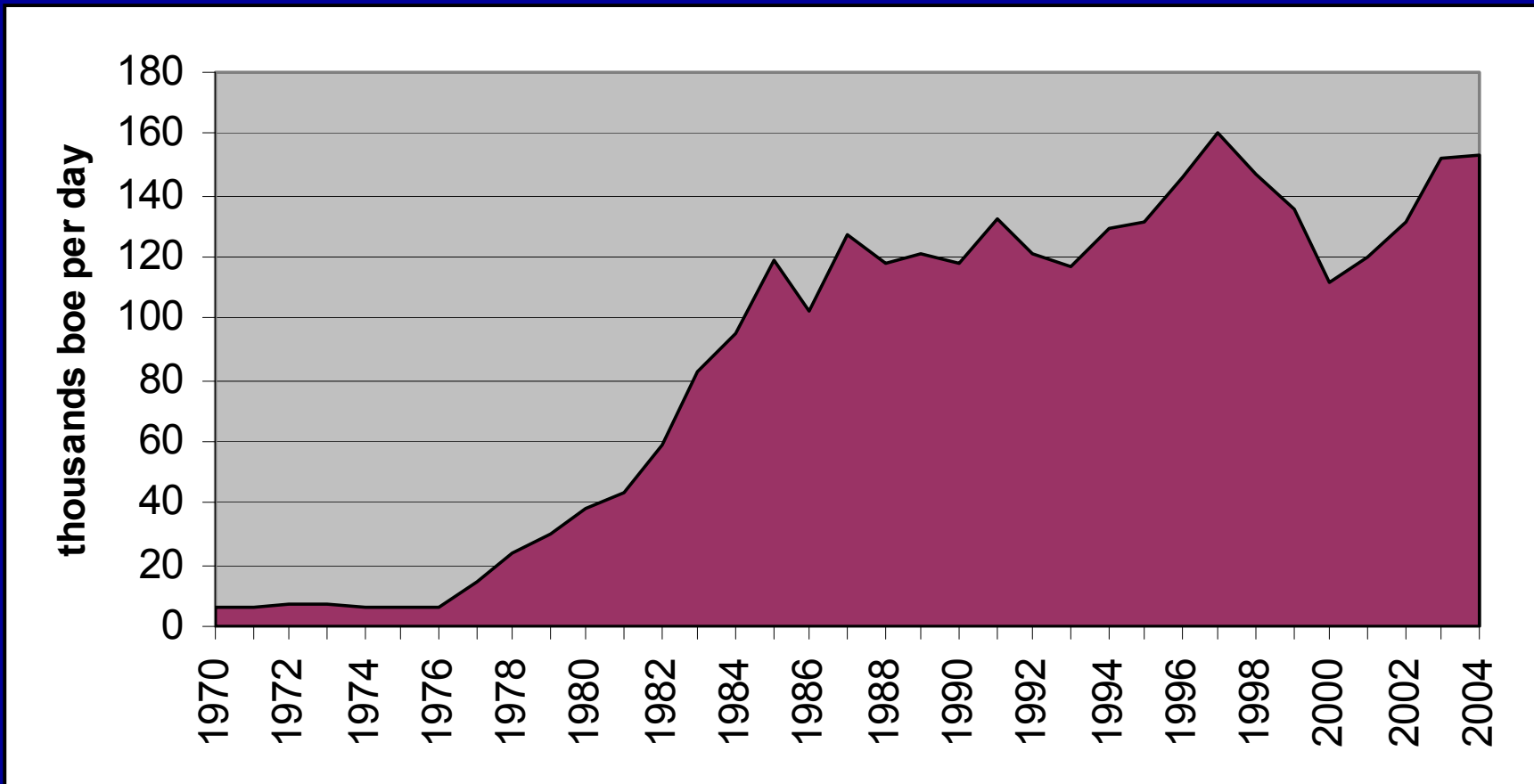


# Sources of Increased Demand



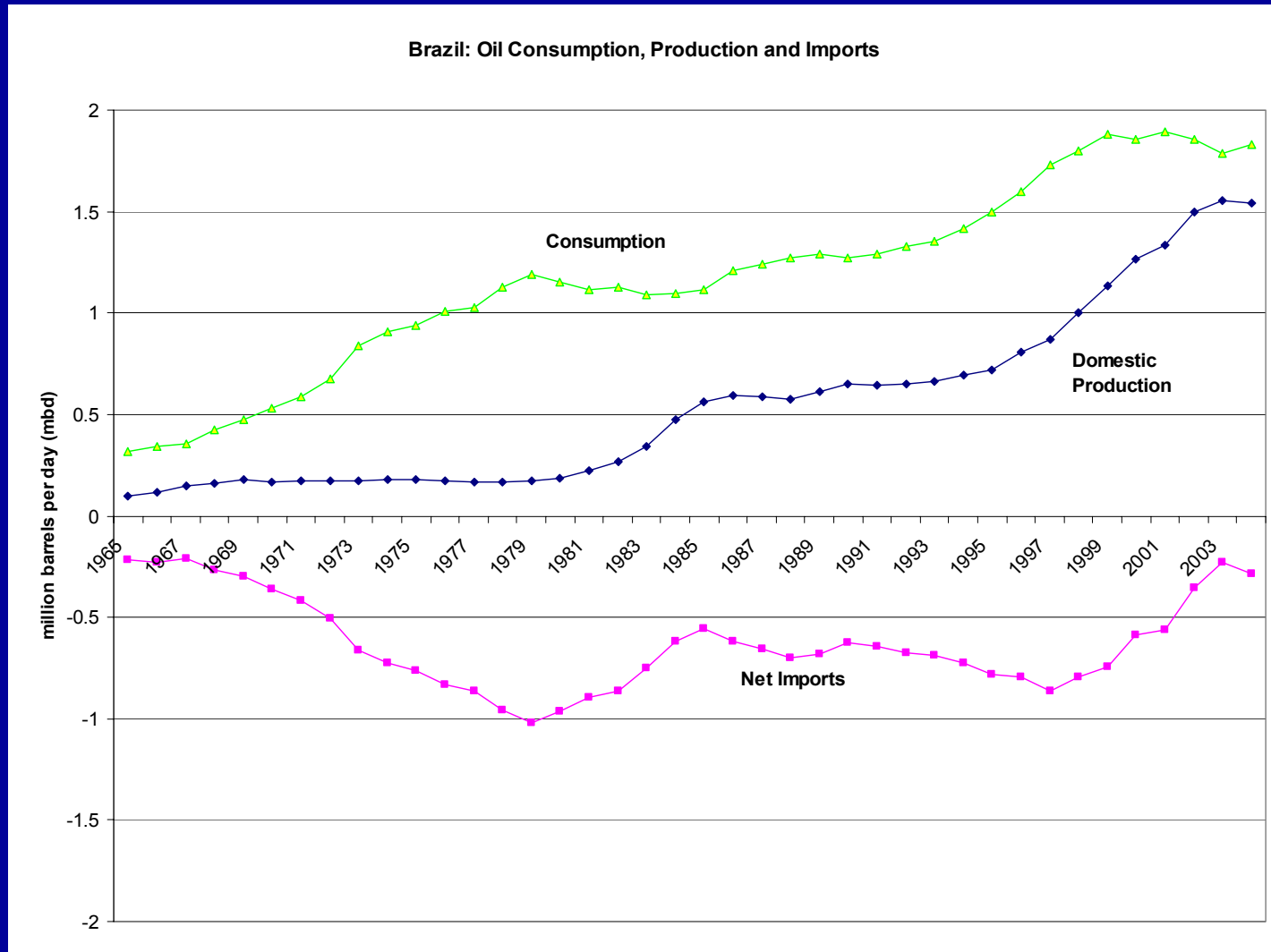
Source: EIA Short Term Energy Outlook, February 2006

# Alcohol Production from Sugar Cane (thousands of barrels of oil equivalent per day)



Source: MME Energy Balance

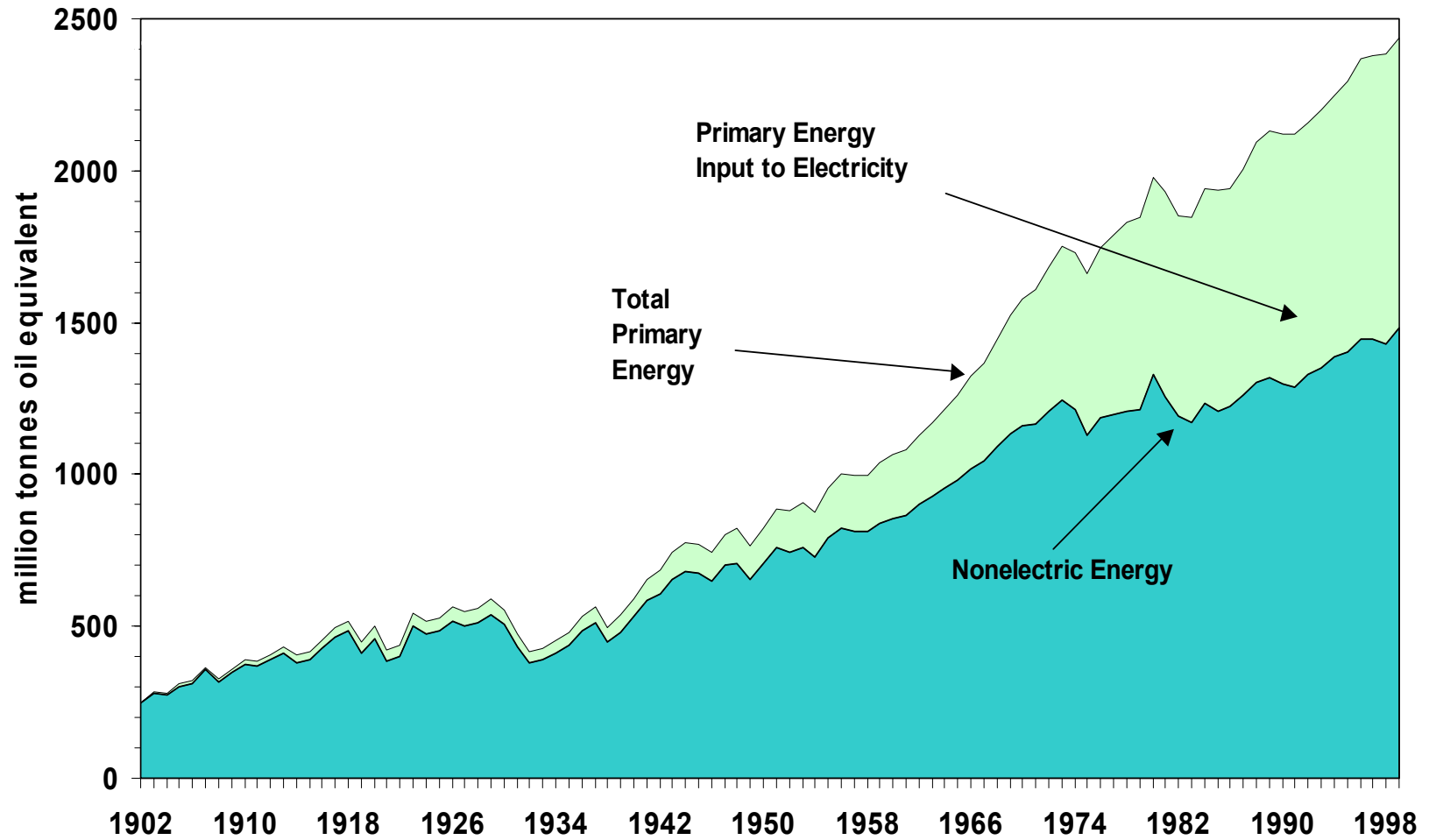
# Brazil's Oil Production & Consumption over time



Source: BP 2004

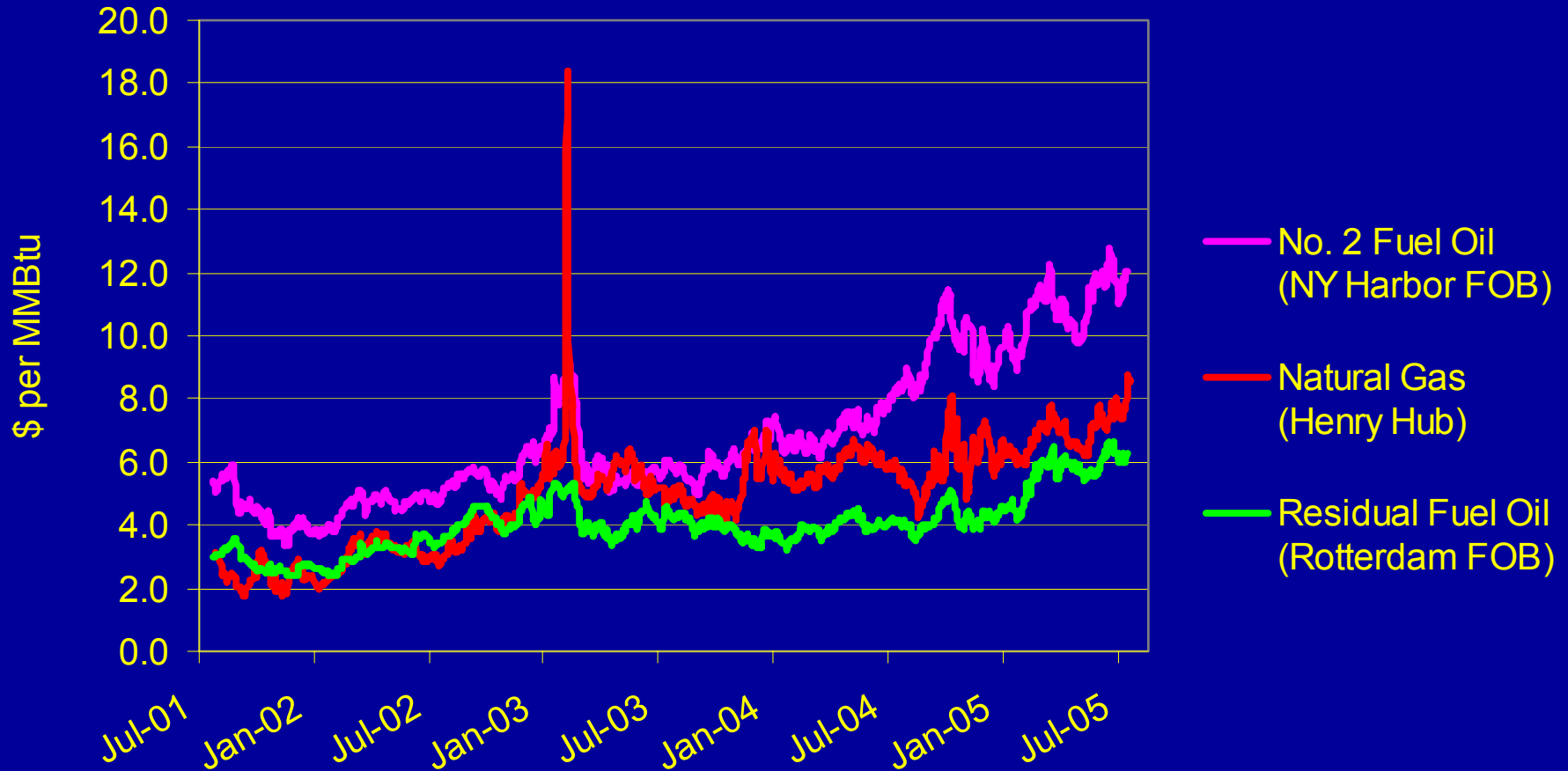


# Electrification of the U.S. Economy



Sources: B.R. Mitchell, *International historical Statistics. The Americas, 1750-1988* (1993) and U.S. Department of Commerce, *Historical Statistics Colonial Times to the Present* (1975), updated with IEA, *Energy Policies of IEA Countries: 1999 Review* (2000); estimates for primary energy consumption from databases compiled at the International Institute for Applied Systems Analysis.

# US Gas Prices Linked to Oil Products



Source: US EIA, [energycentral.com](http://energycentral.com)

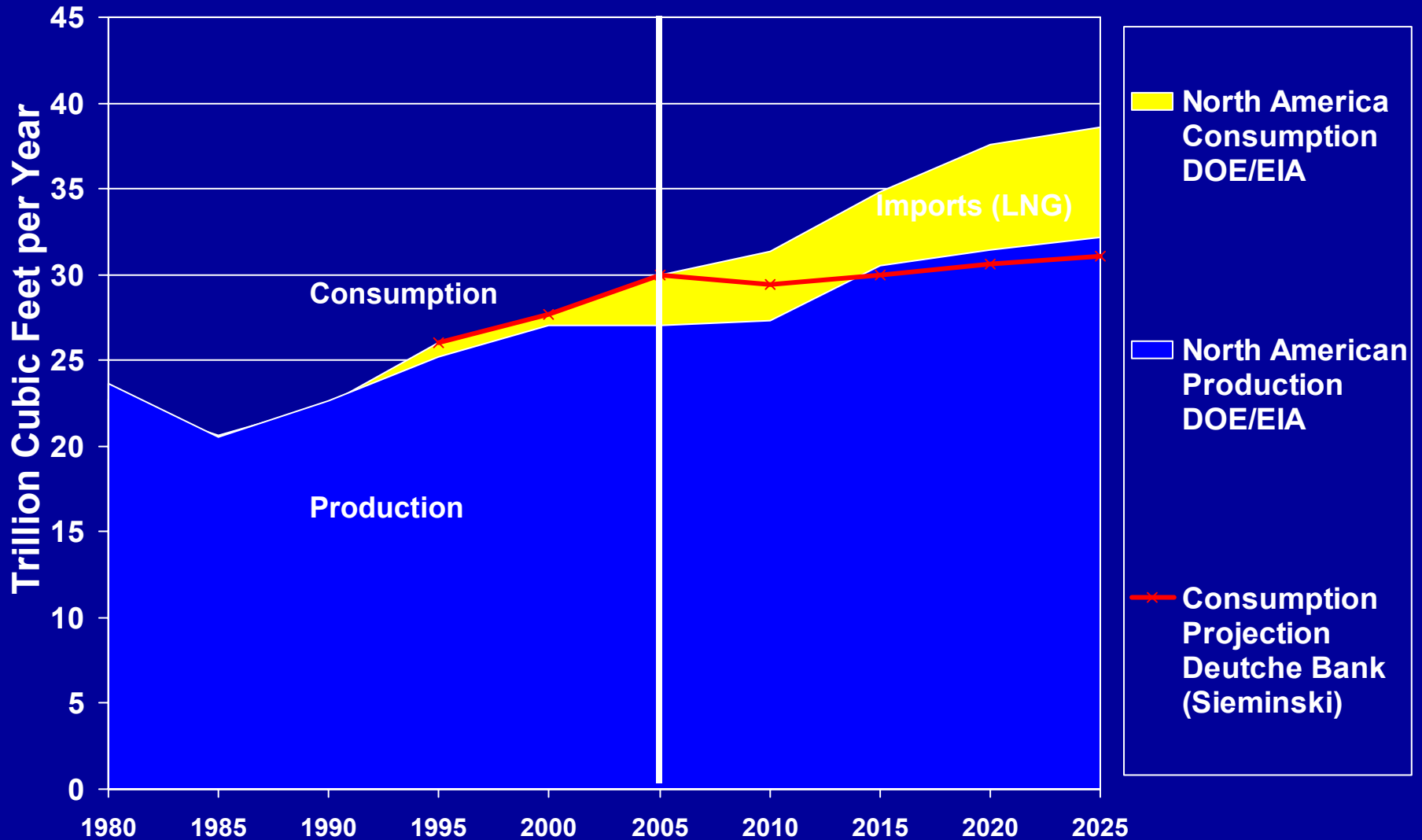
# Gas Resources and Potential Demand



**White: where the lights are on, satellite imagery**

**Blue → Red : Gas resources, with increasing size (USGS)**

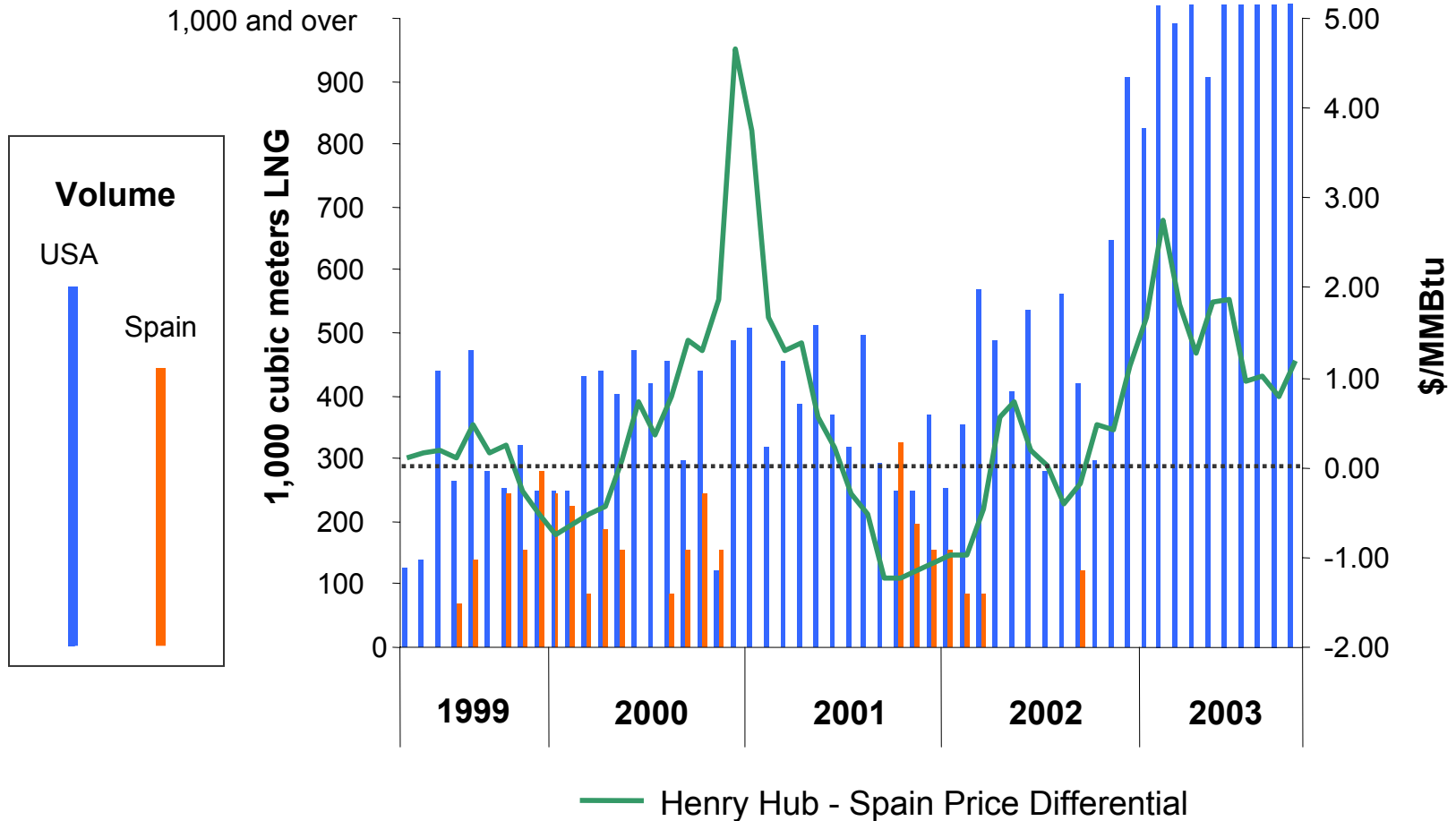
# North American Natural Gas Production & Consumption 1980 – 2025



# LNG Transport

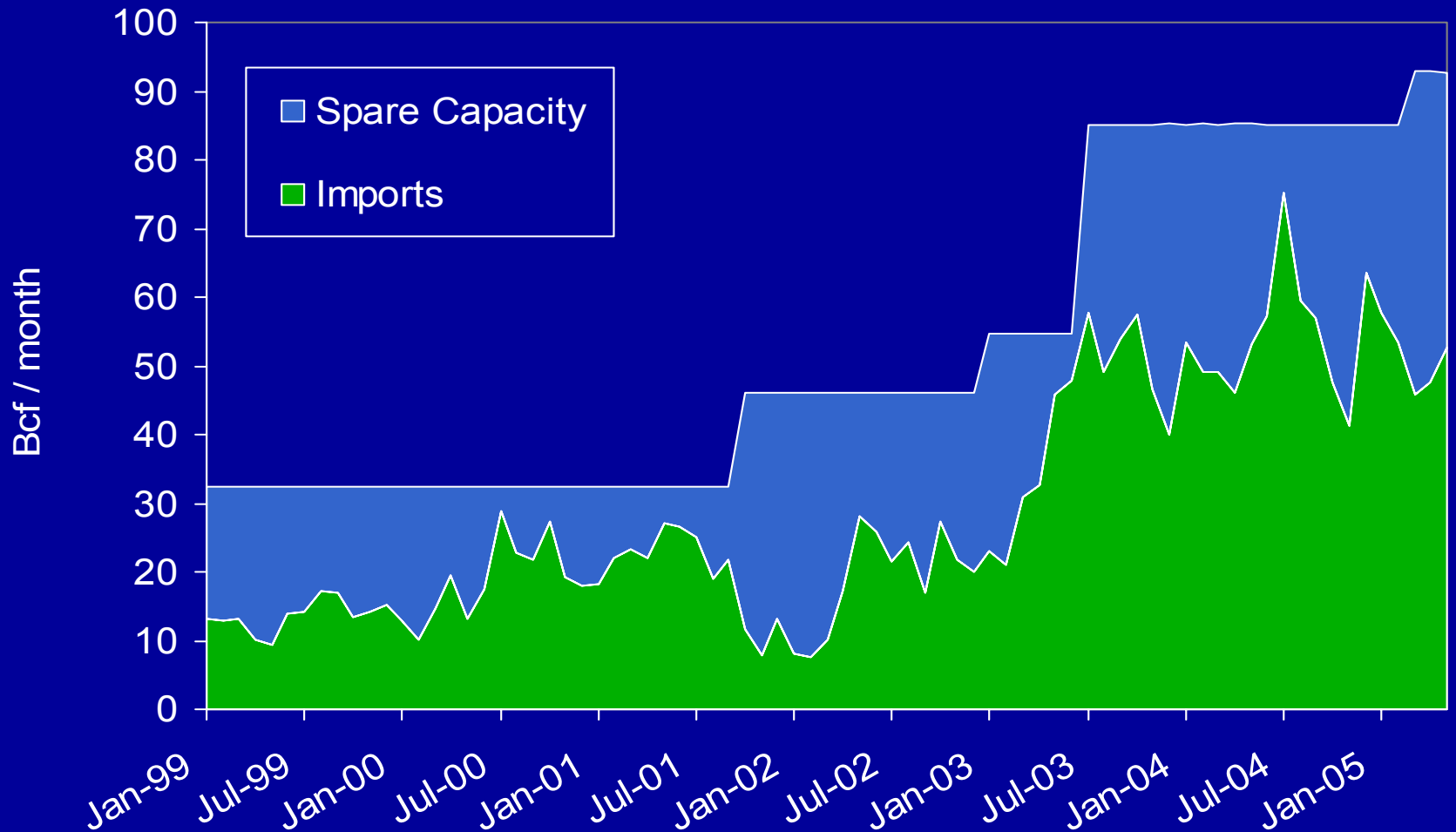


# Trinidad's Atlantic LNG Cargoes Already Follow US-Spain Price Differential



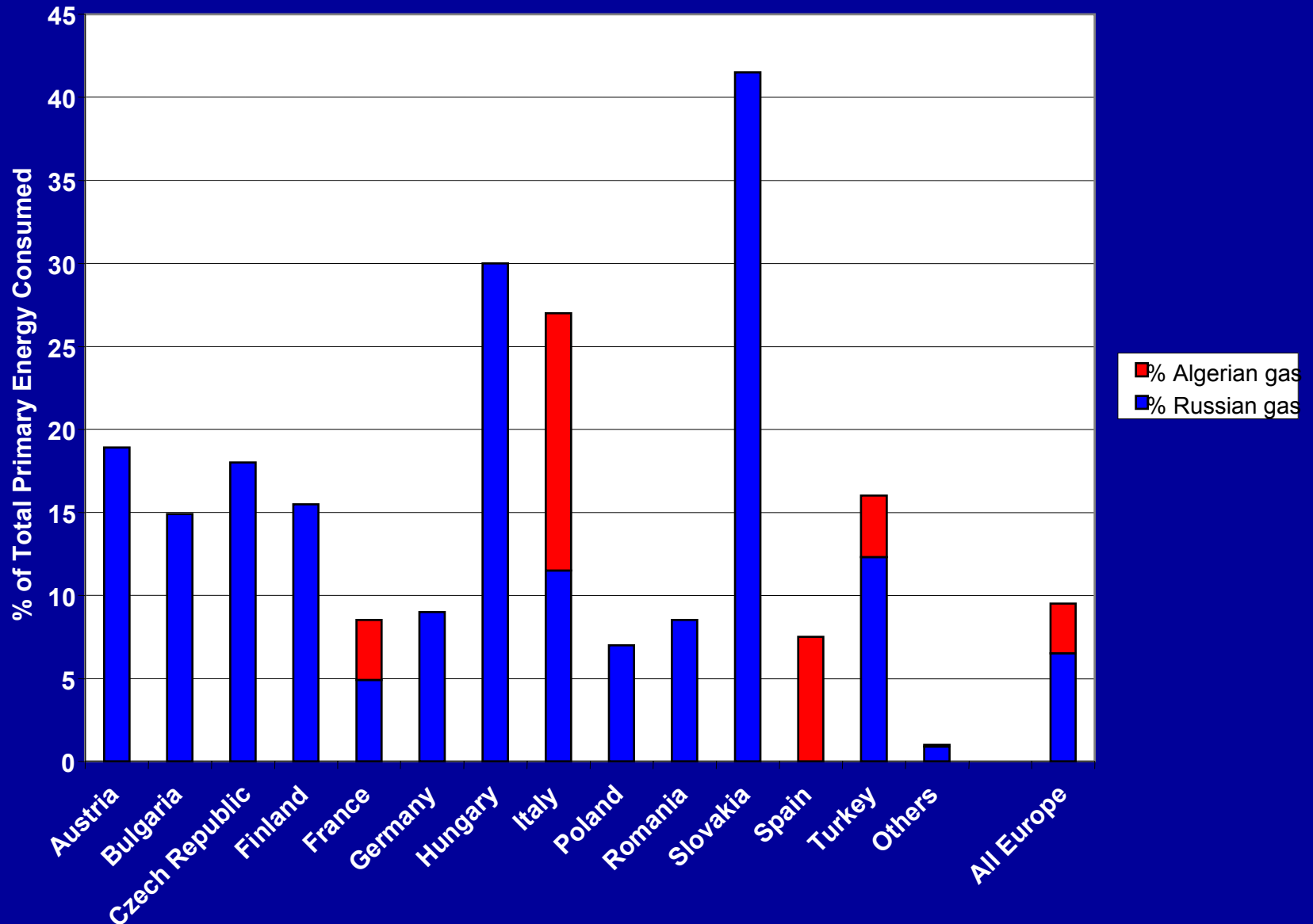
Source: Gas Strategies Consulting Ltd.

# US LNG Import Capacity Utilization



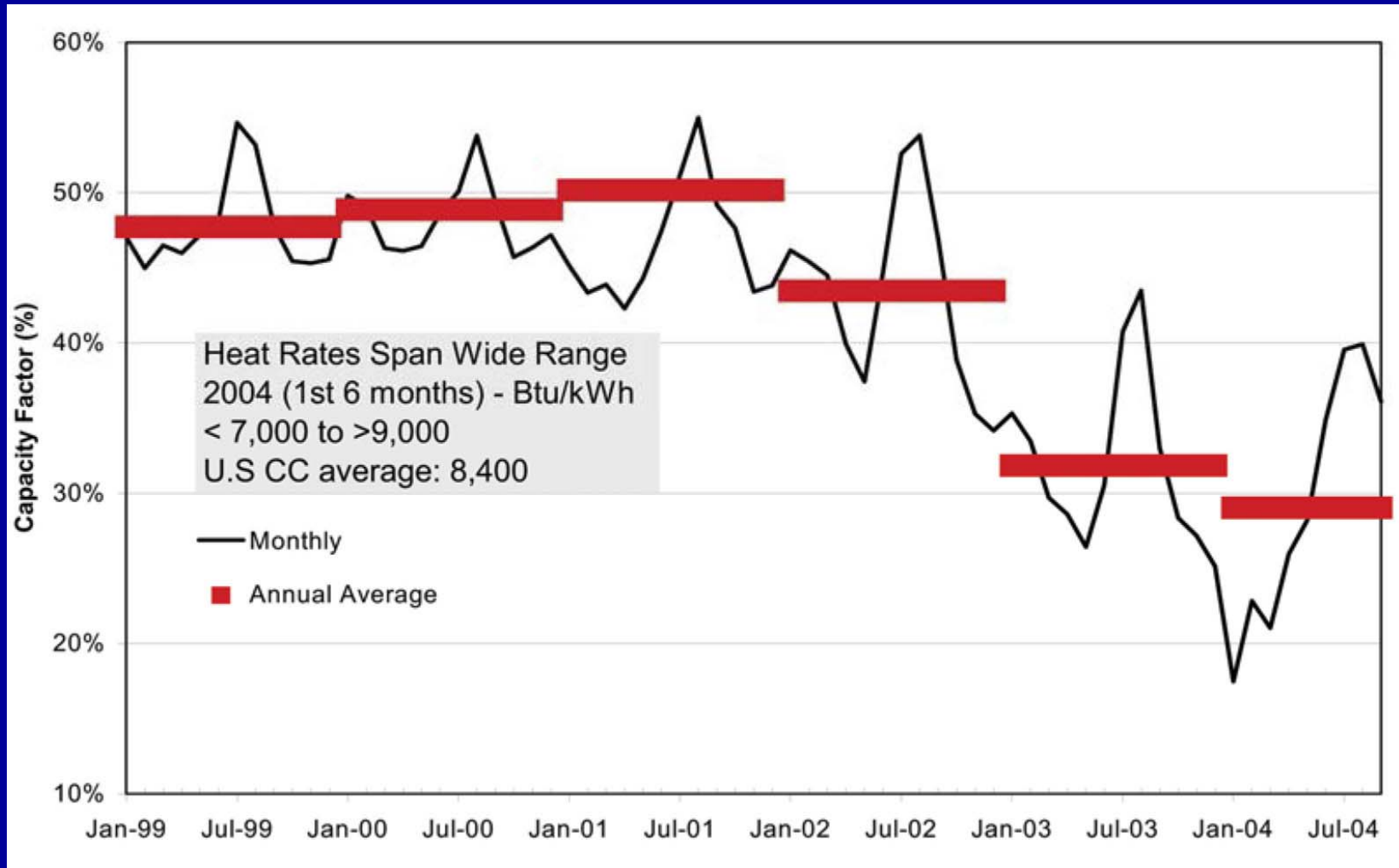
Source: US EIA

# European Gas Imports: Russia & Algeria





# US Combined Cycle Capacity Factors: Impact of Overbuilding and High Fuel Prices



Source: EPRI Reference: Report 1008329, forthcoming Gas Market Transition: Impacts of Power Generation on Gas Pricing Dynamics [EPRI Program 67A]; update in March P67 newsletter on new power plants

# A Coal Mine in Wyoming

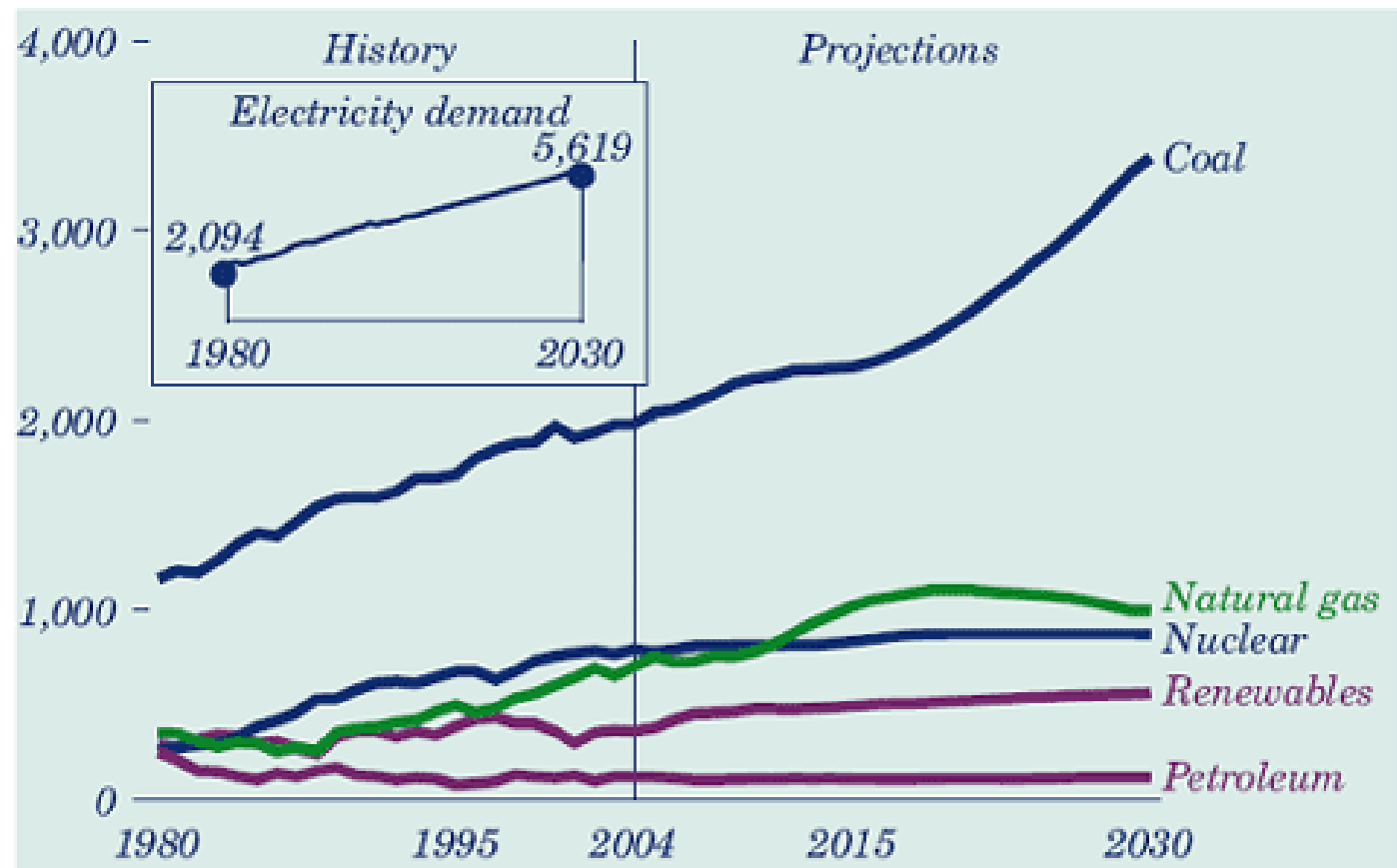




The Navajo power plant, Page, AZ

# Growth in Electricity from Coal: United States

*Figure 5. Electricity generation by fuel, 1980-2030  
(billion kilowatthours)*



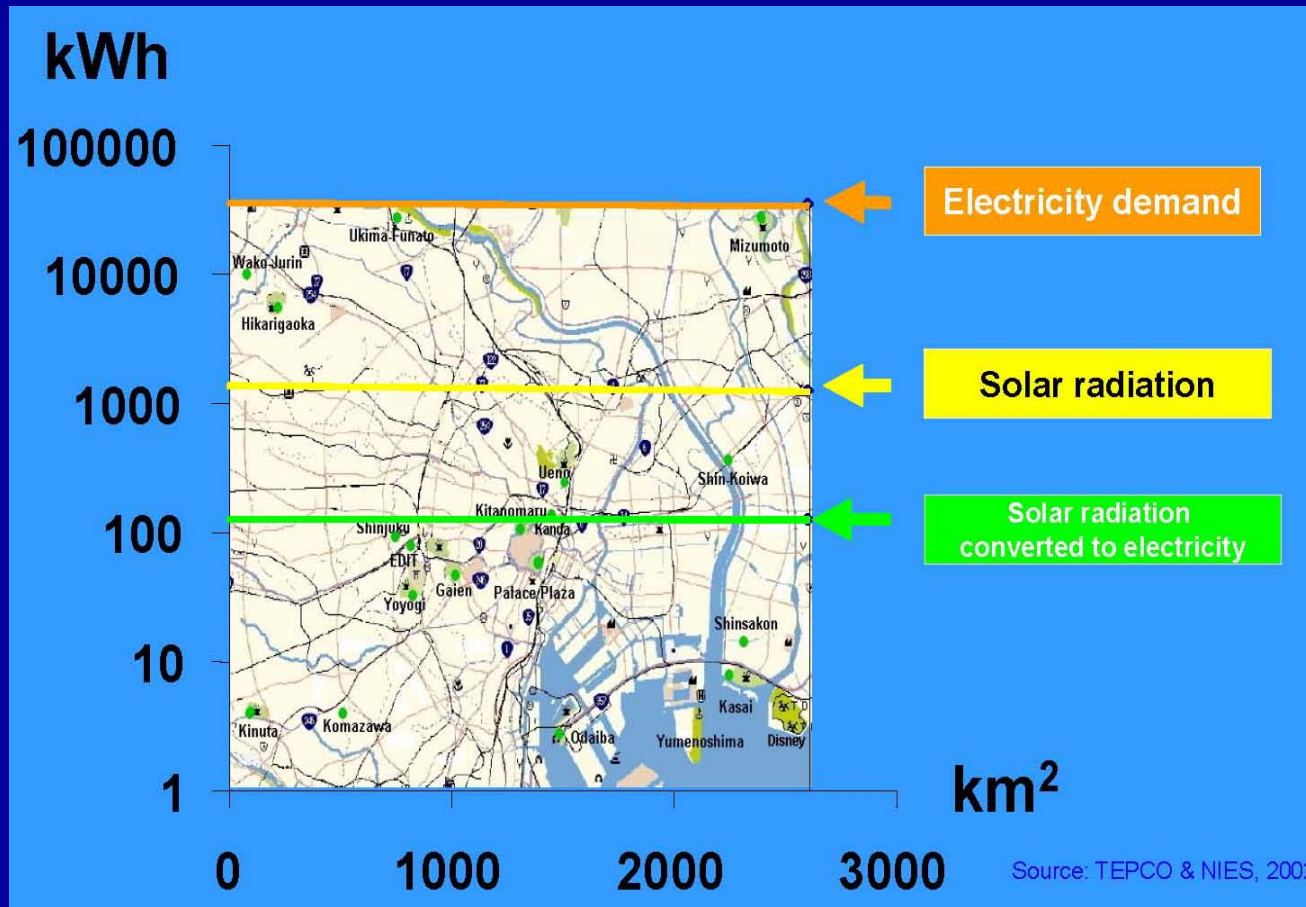
Source: U.S. EIA Annual Energy Outlook 2006

# Nuclear Power: A Fresh Start?



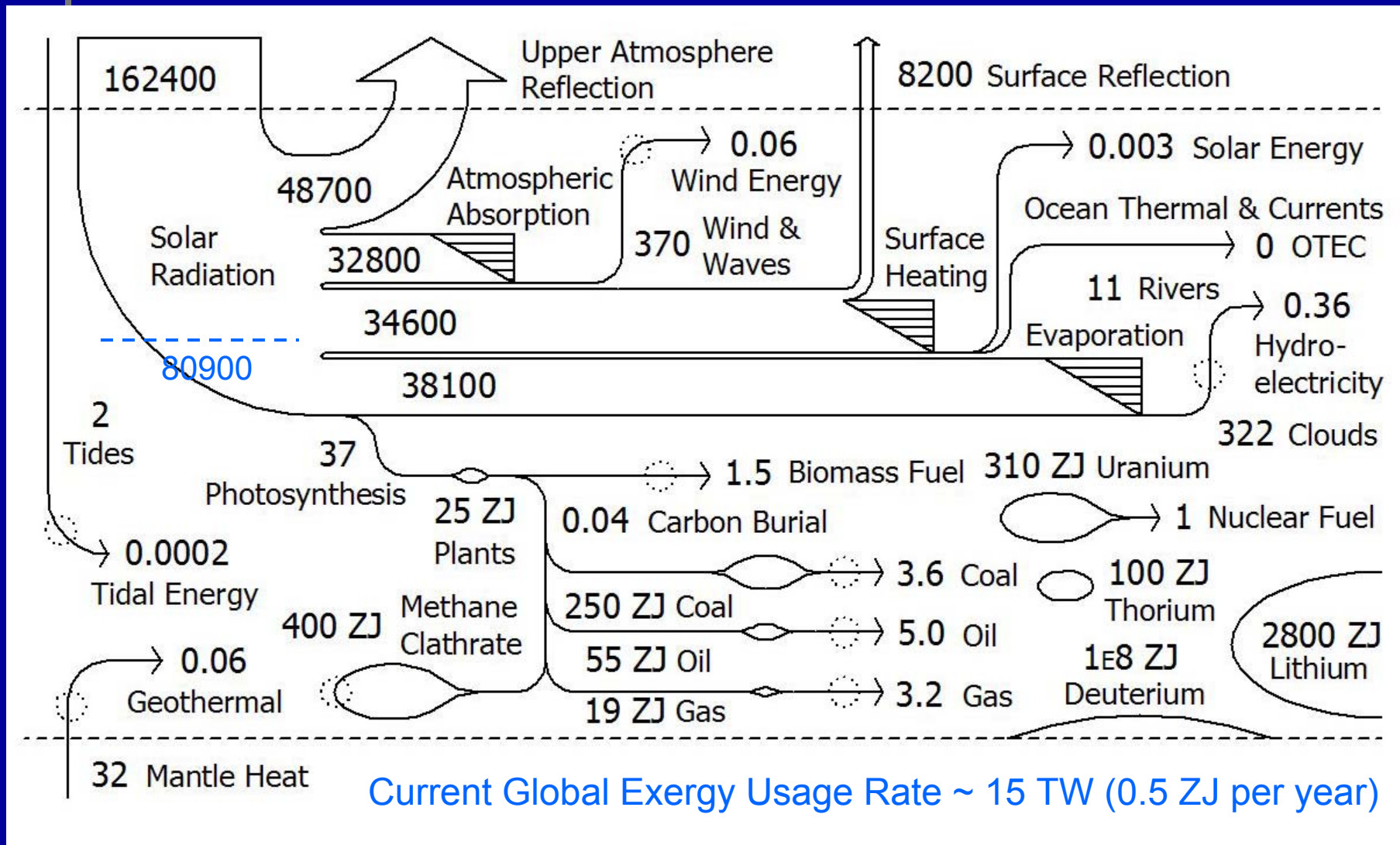
Cattenom, France

# Tokyo Electricity Demand & Solar Supply Potential



Additional source: Arnulf Gruebler

# Exergy Flow of Planet Earth (TW)



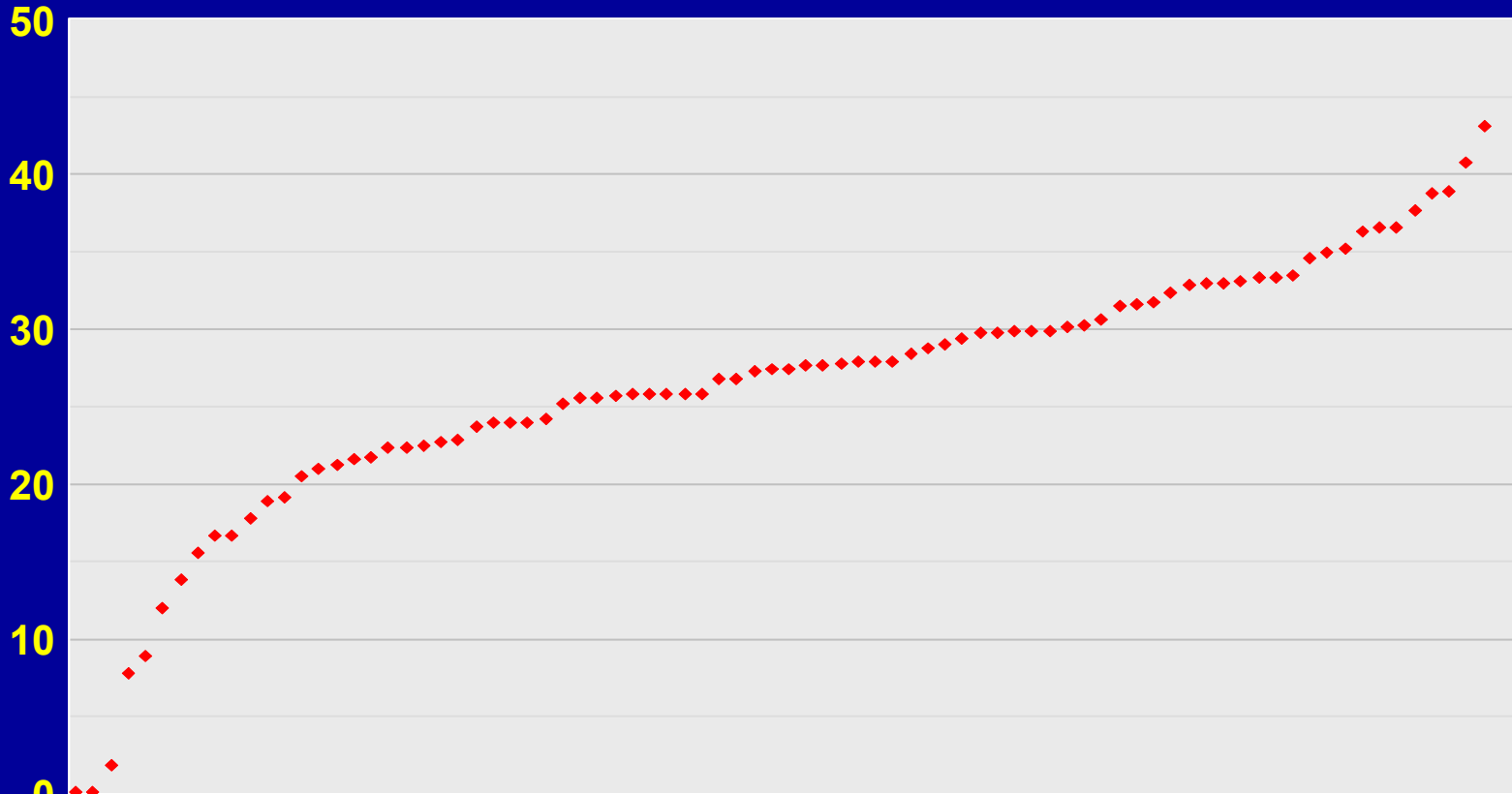
(1 ZJ =  $10^{21}$ J)

80900/15 = 5393

Source: W. Hermann, GCEP Systems Analysis Group 2004.

# U.S. Wind Plant Capacity Factors, 2004

Capacity Factor, %

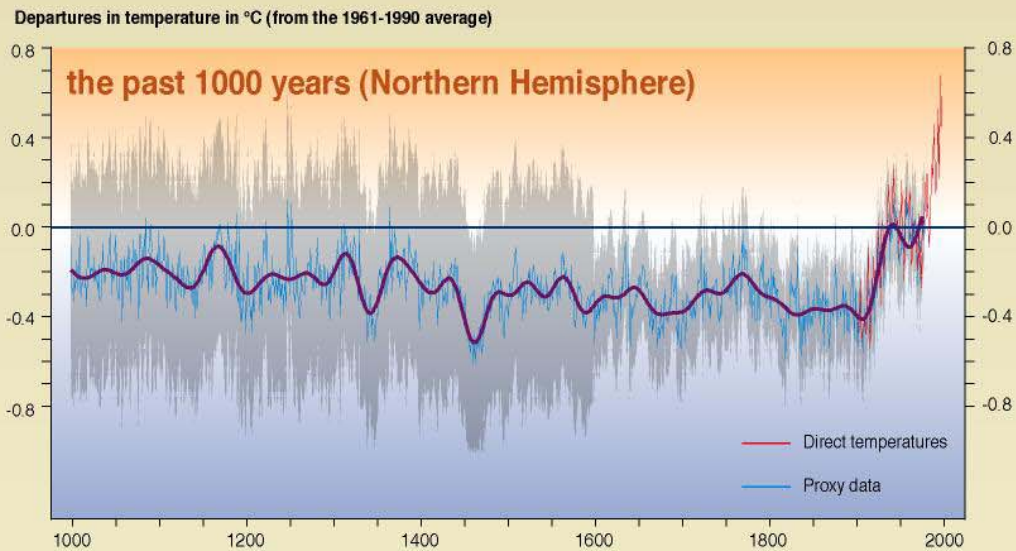
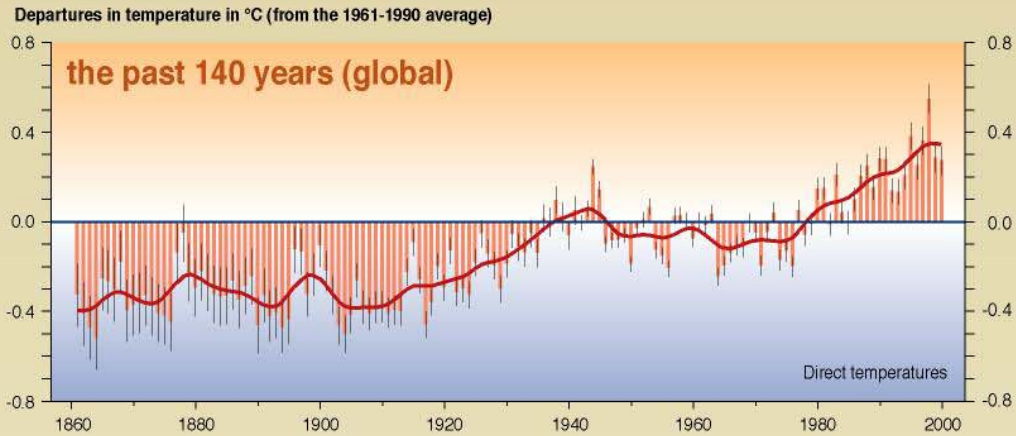


Sites Ranked by Increasing Capacity Factors

Source: EIA; EPRI Program 67 Newsletter, Energy Markets and Generation Response – Update on New Power Plants, September 2005

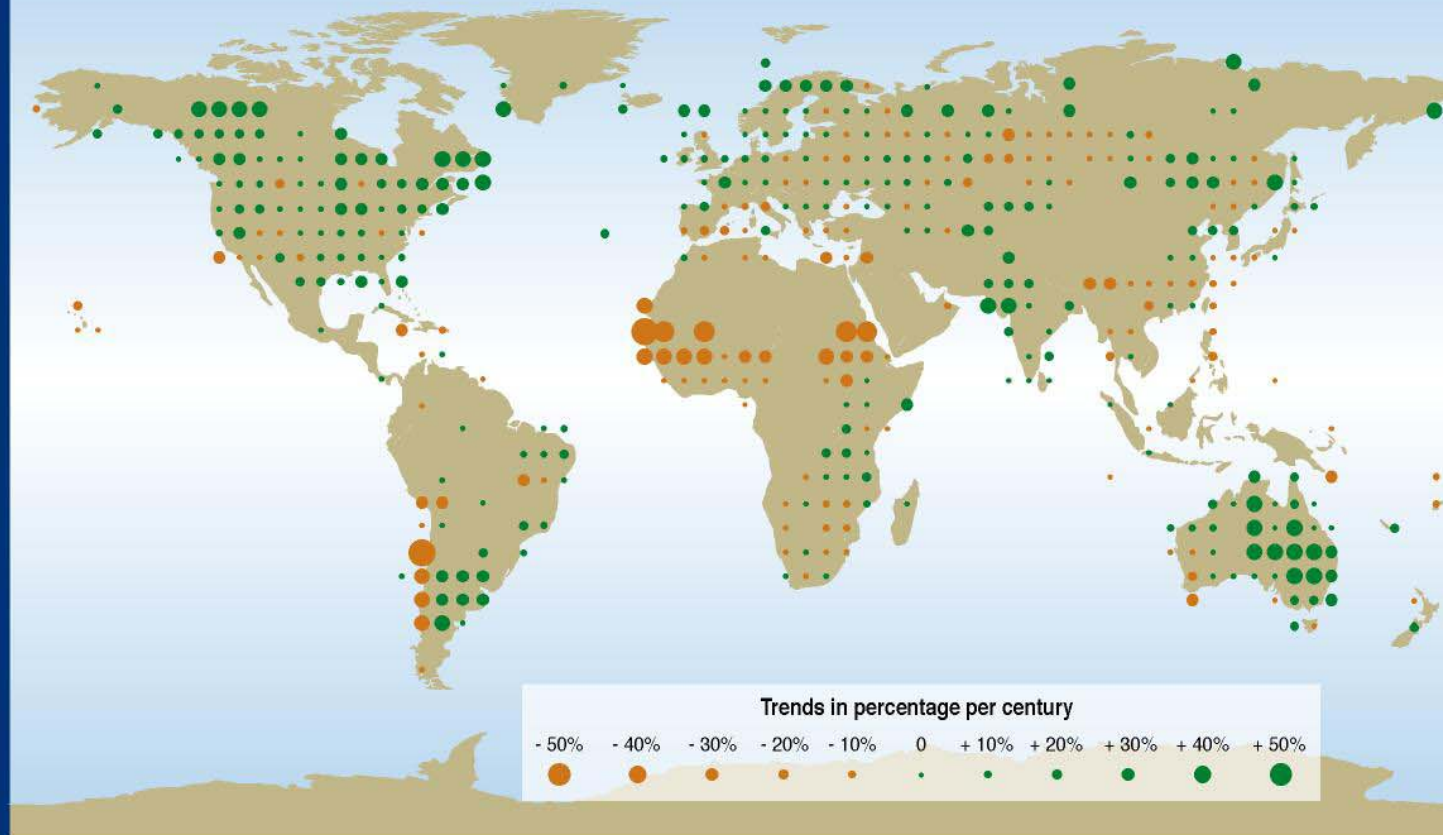


## Variations of the Earth's surface temperature for...



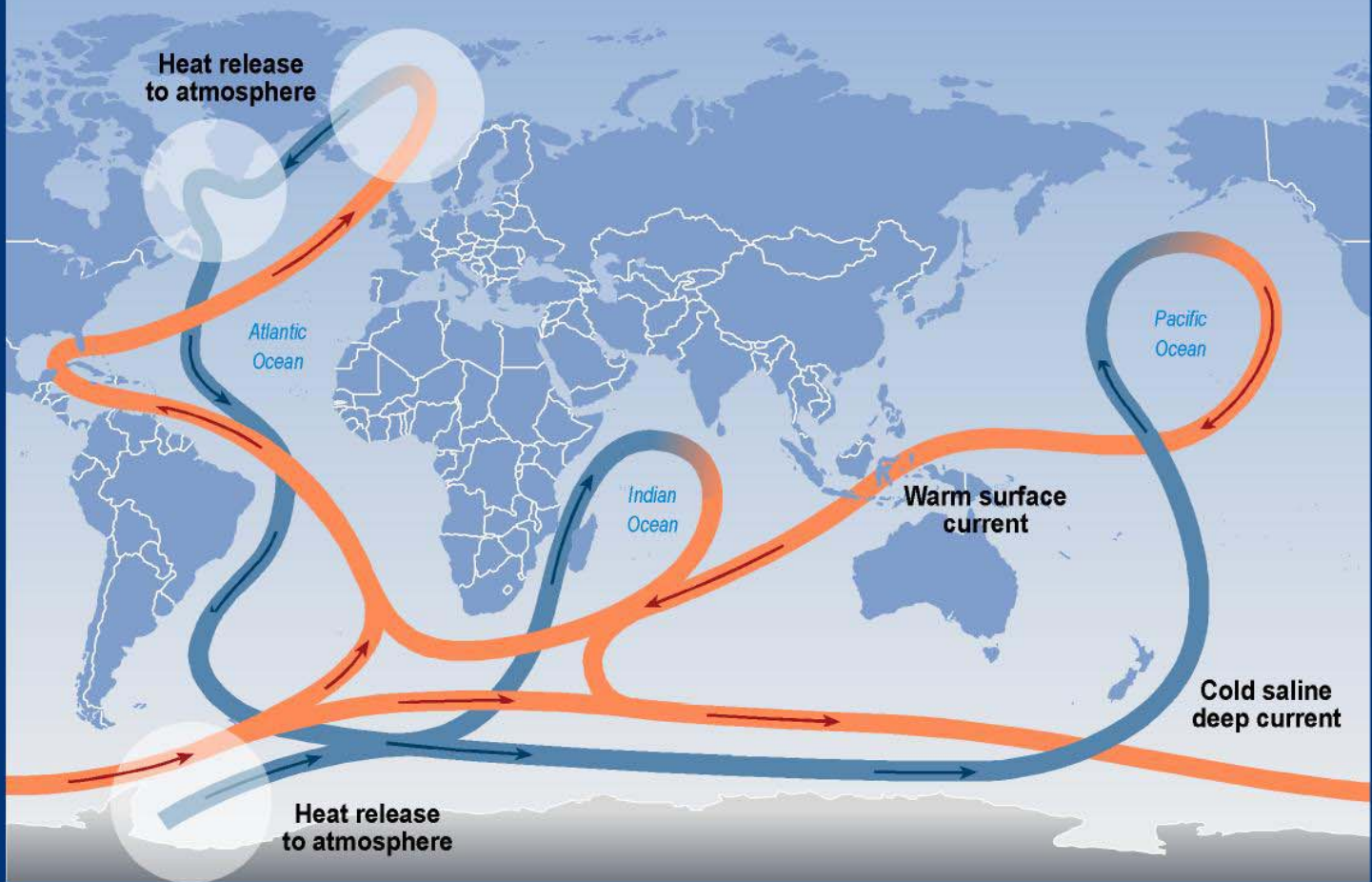
SYR - FIGURE 2-3

## Annual precipitation trends: 1900 to 2000



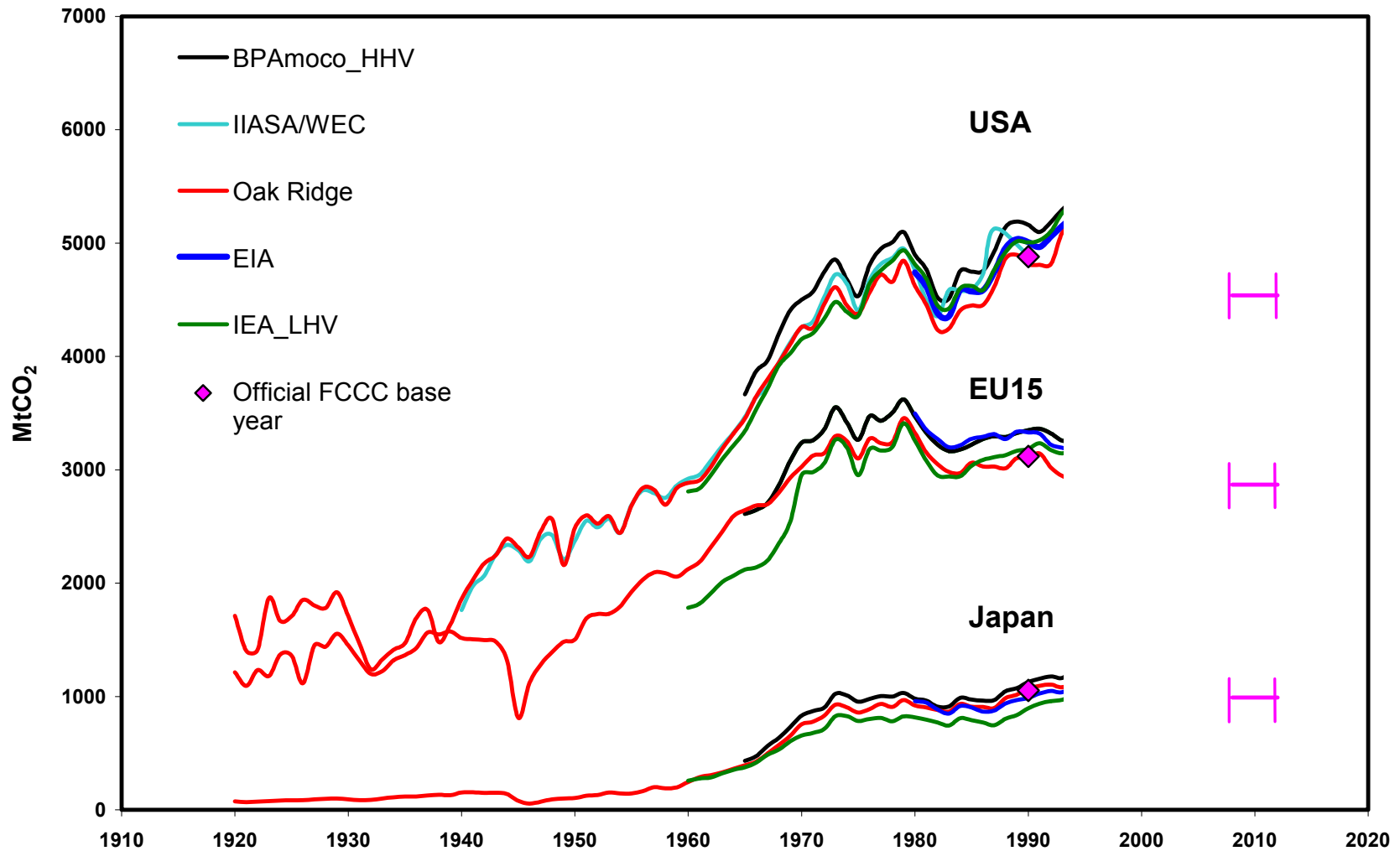
SYR - FIGURE 2-6a

# Great ocean conveyor belt

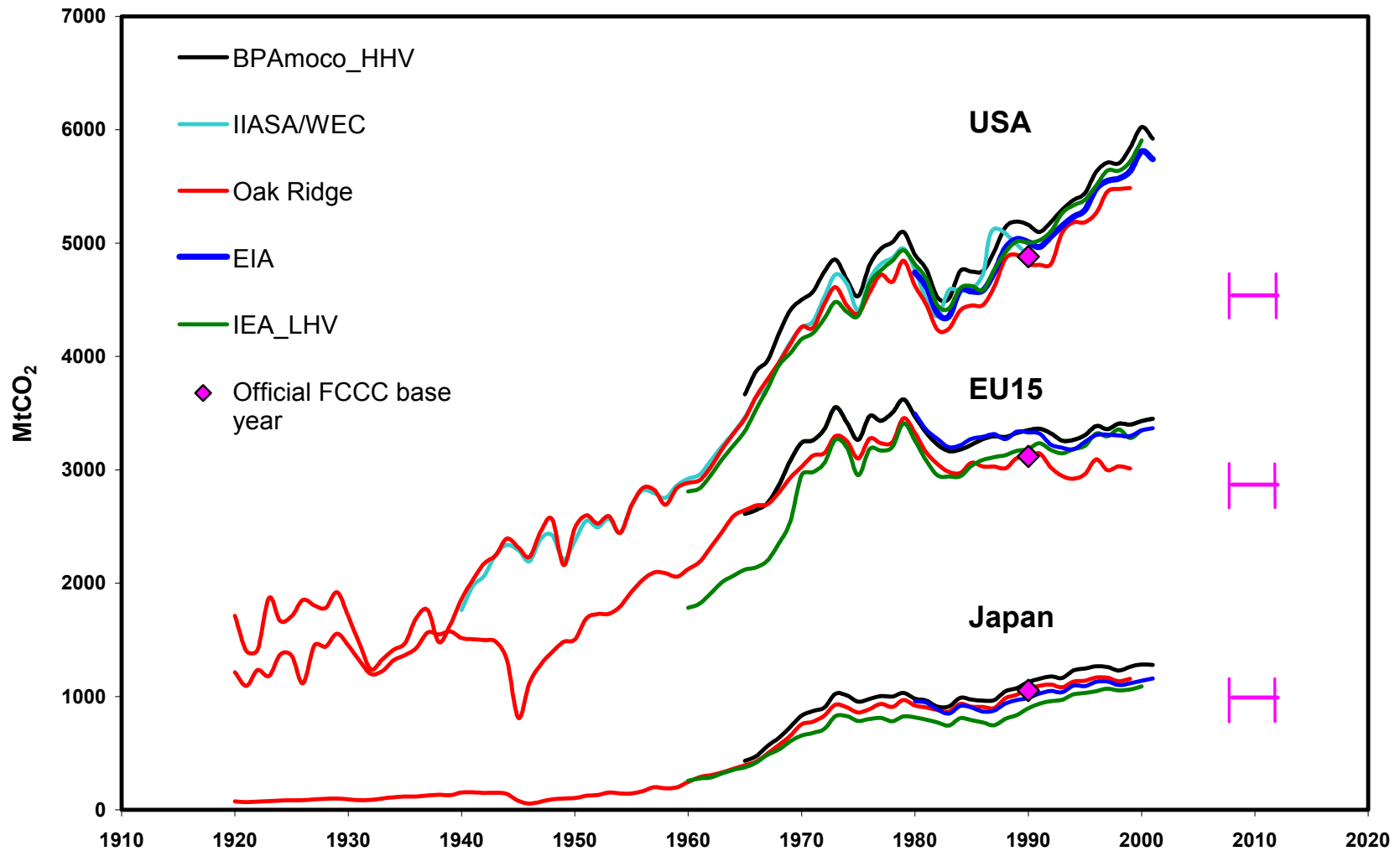


SYR - FIGURE 4-2

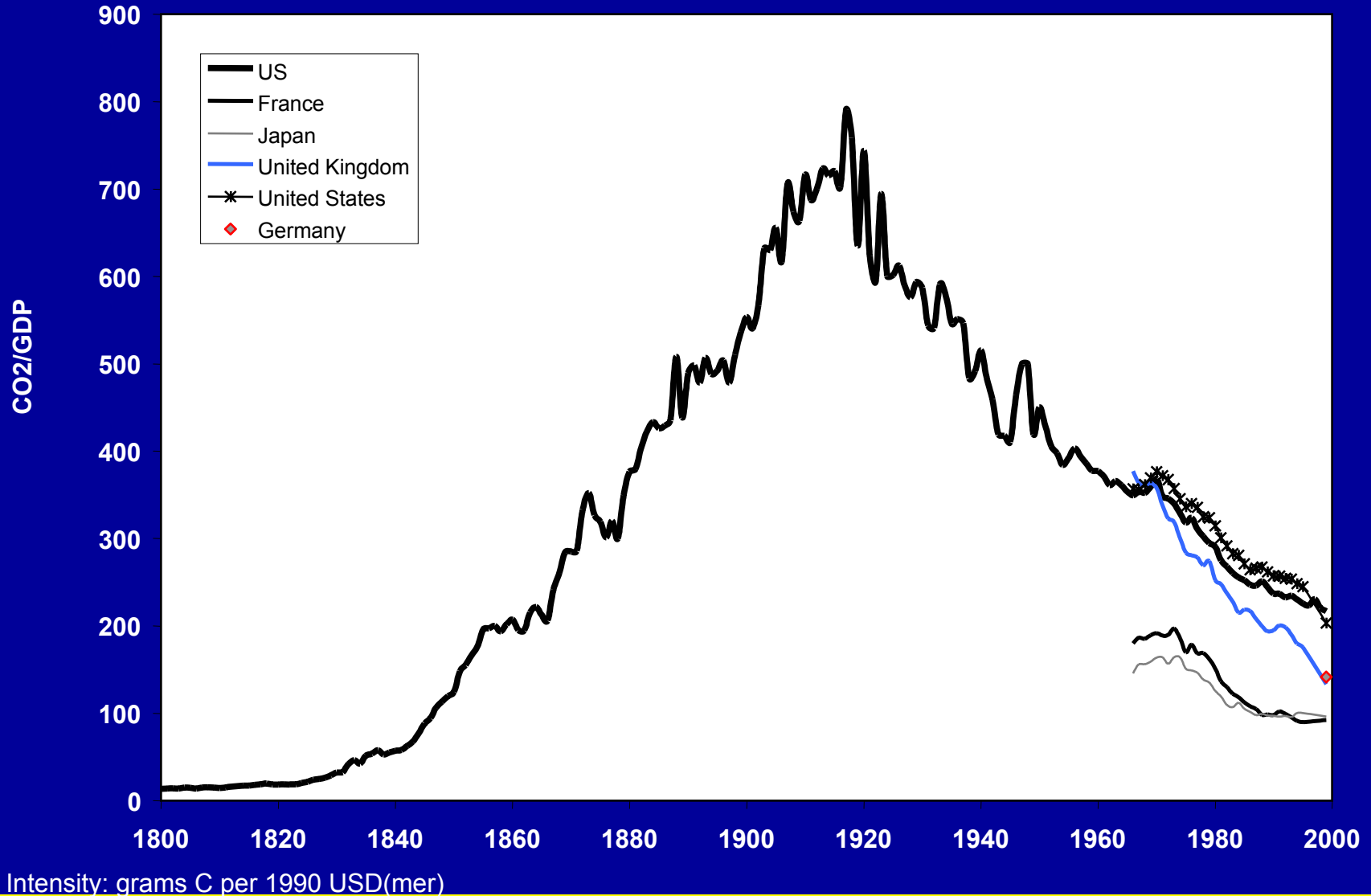
# Trends in Fossil Carbon Emissions (Trajectories and Kyoto Commitments)



# Trends in Fossil Carbon Emissions (Trajectories and Kyoto Commitments)

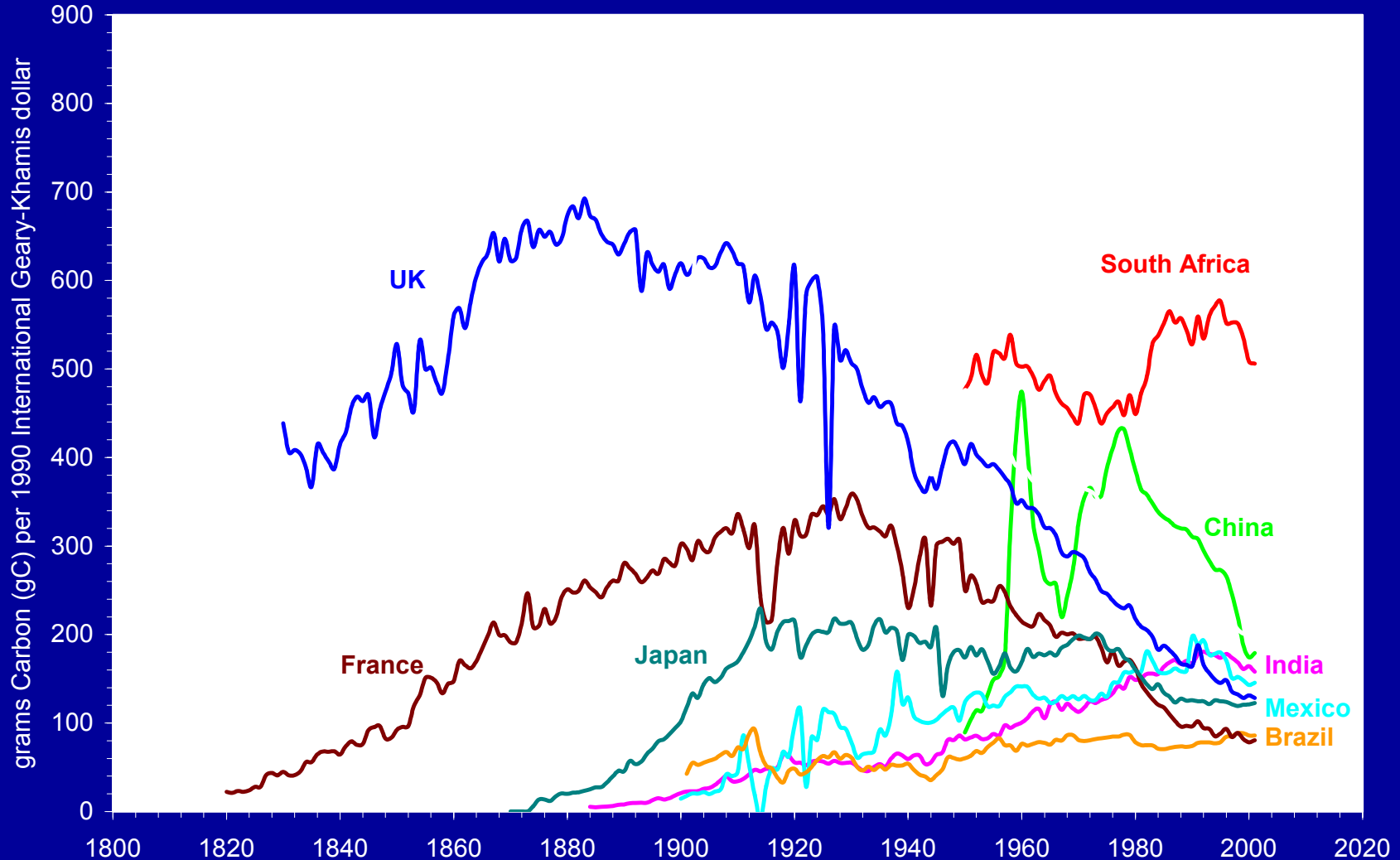


# “Carbon Intensity” of the U.S. Economy (1800-1999)



# Carbon Intensity of Major Economies

## Carbon Intensity of Major Economies



Data Source: Oak Ridge National Laboratory, Maddison, A. (2004)

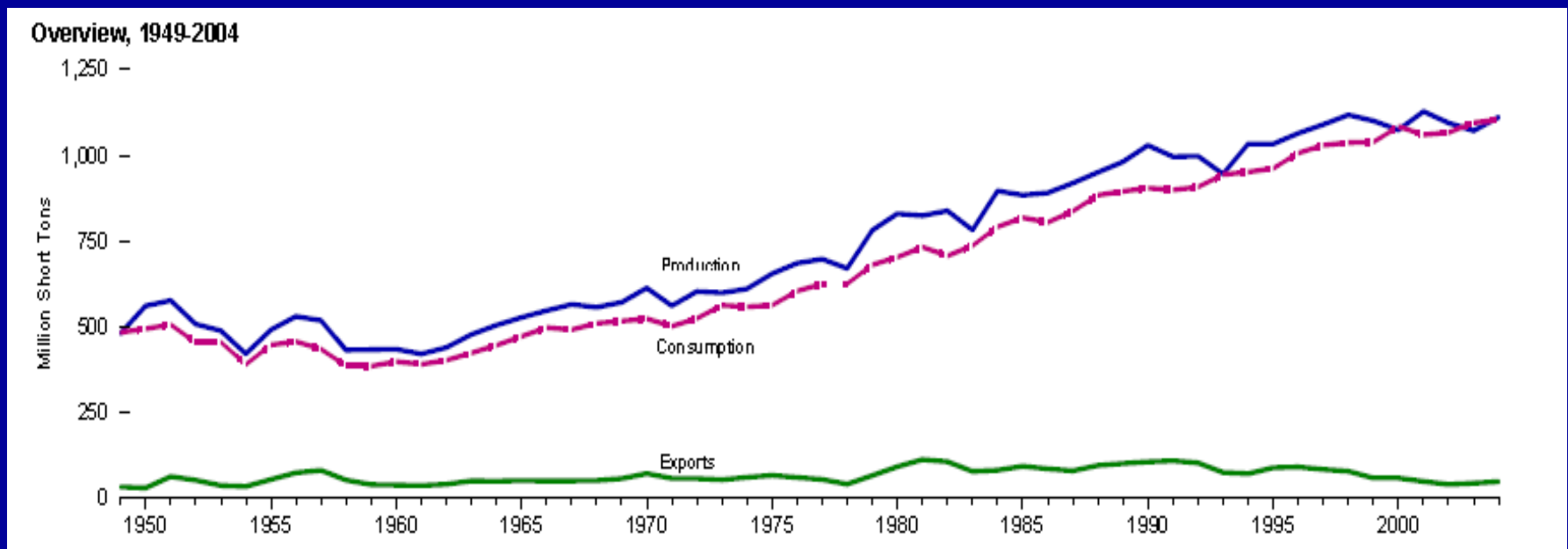
# Integrated Gasification Combined Cycle (IGCC)



Wabash River Integrated Gasification Combined-Cycle Plant



# Coal: Production & Consumption: 1949-2004



Source: EIA