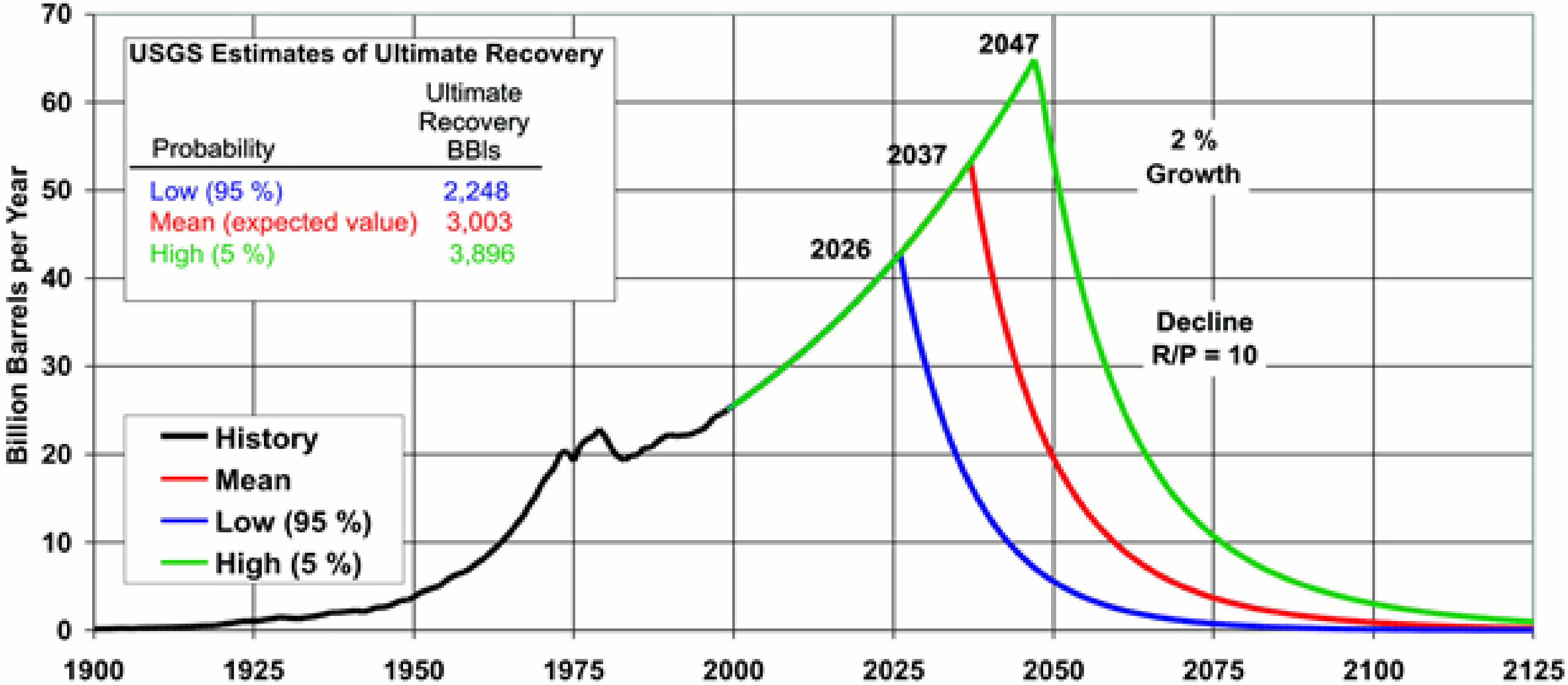
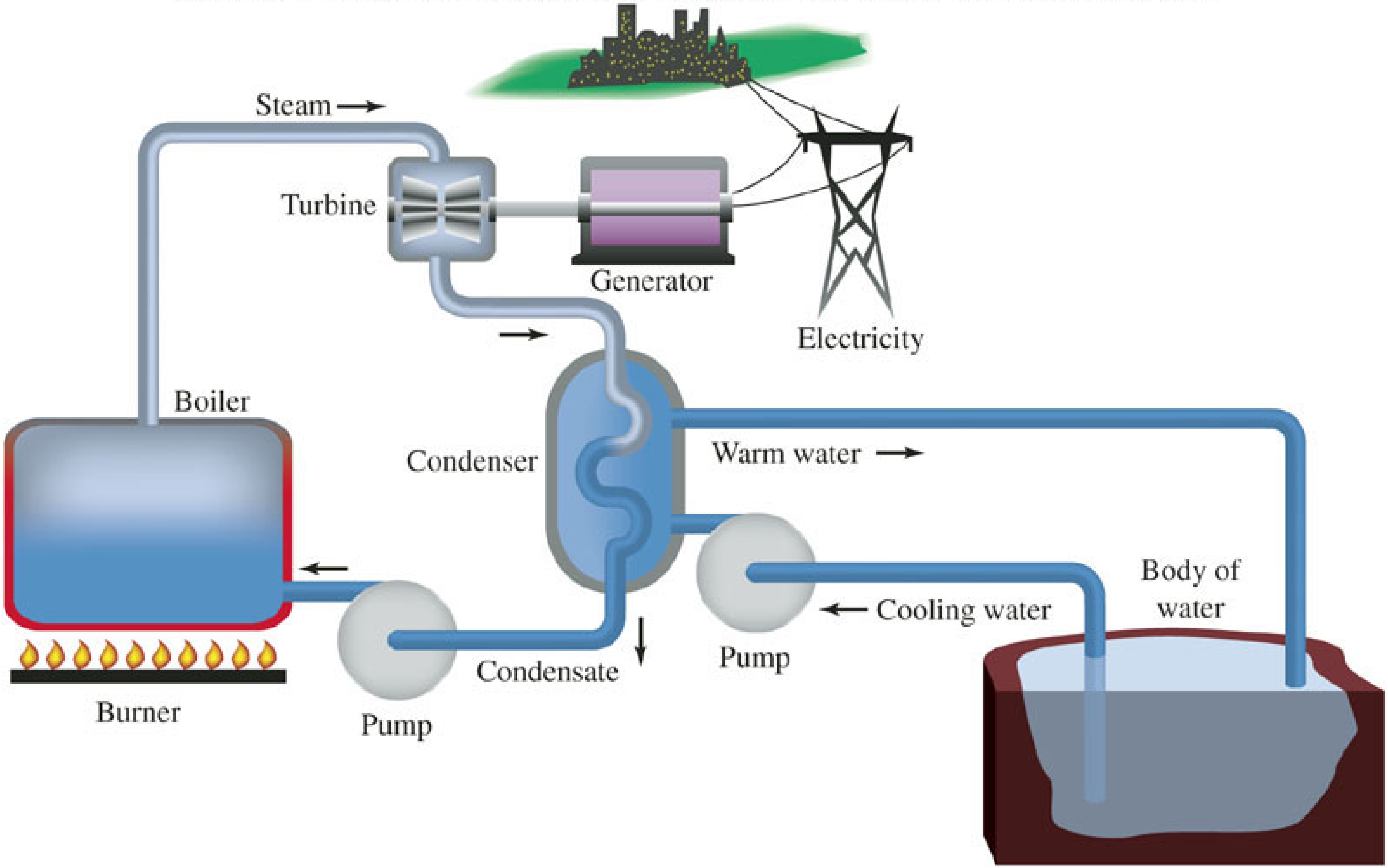
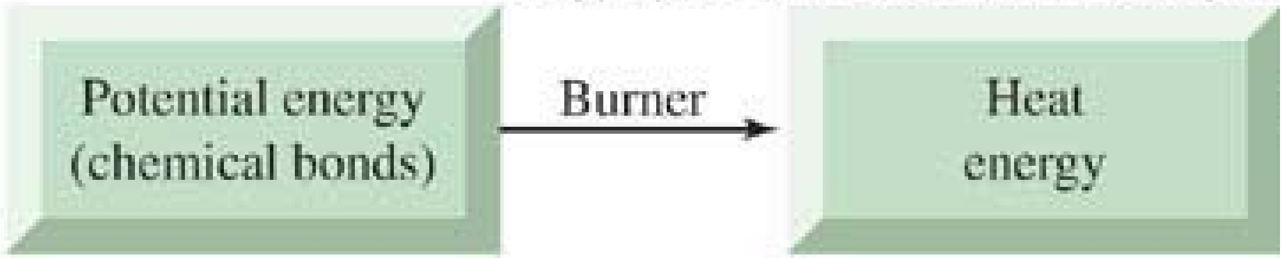
Figure 2. Annual Production Scenarios with 2 Percent Growth Rates and Different Resource Levels (Decline R/P=10)



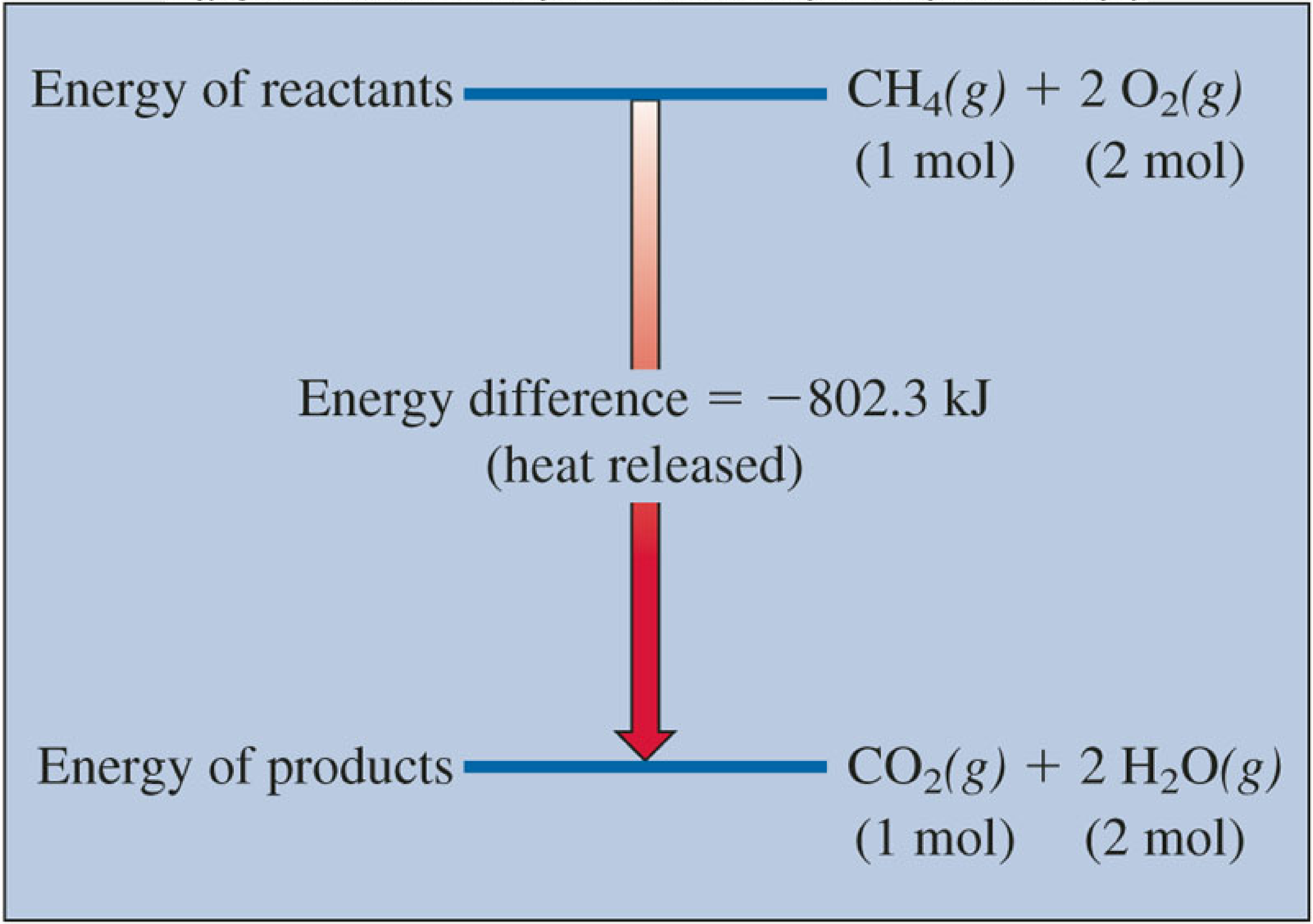
Source: Energy Information Administration
Note: U.S. volumes were added to the USGS foreign volumes to obtain world totals.


Steam
Turbine
Generator
Electricity
Boiler
Condenser
Warm water
Body of
water
Cooling water
Pump
Condensate
Pump
Burner


Potential energy (chemical bonds)
Burner
Heat energy


Heat energy
Gas turbine
Mechanical energy


Mechanical energy
Generator
Electrical energy


Energy of reactants
$CH_4(g) + 2\ O_2(g)$
(1 mol) (2 mol)
Energy difference = −802.3 kJ
(heat released)
Energy of products
$CO_2(g) + 2\ H_2O(g)$
(1 mol) (2 mol)

From Fuel Sources to Chemical Bonds

Endothermic Reaction	Exothermic Reaction
$Energy_{products} > Energy_{reactants}$	$Energy_{products} < Energy_{reactants}$
Energy change is positive.	Energy change is negative.
Energy is absorbed.	Energy is released.

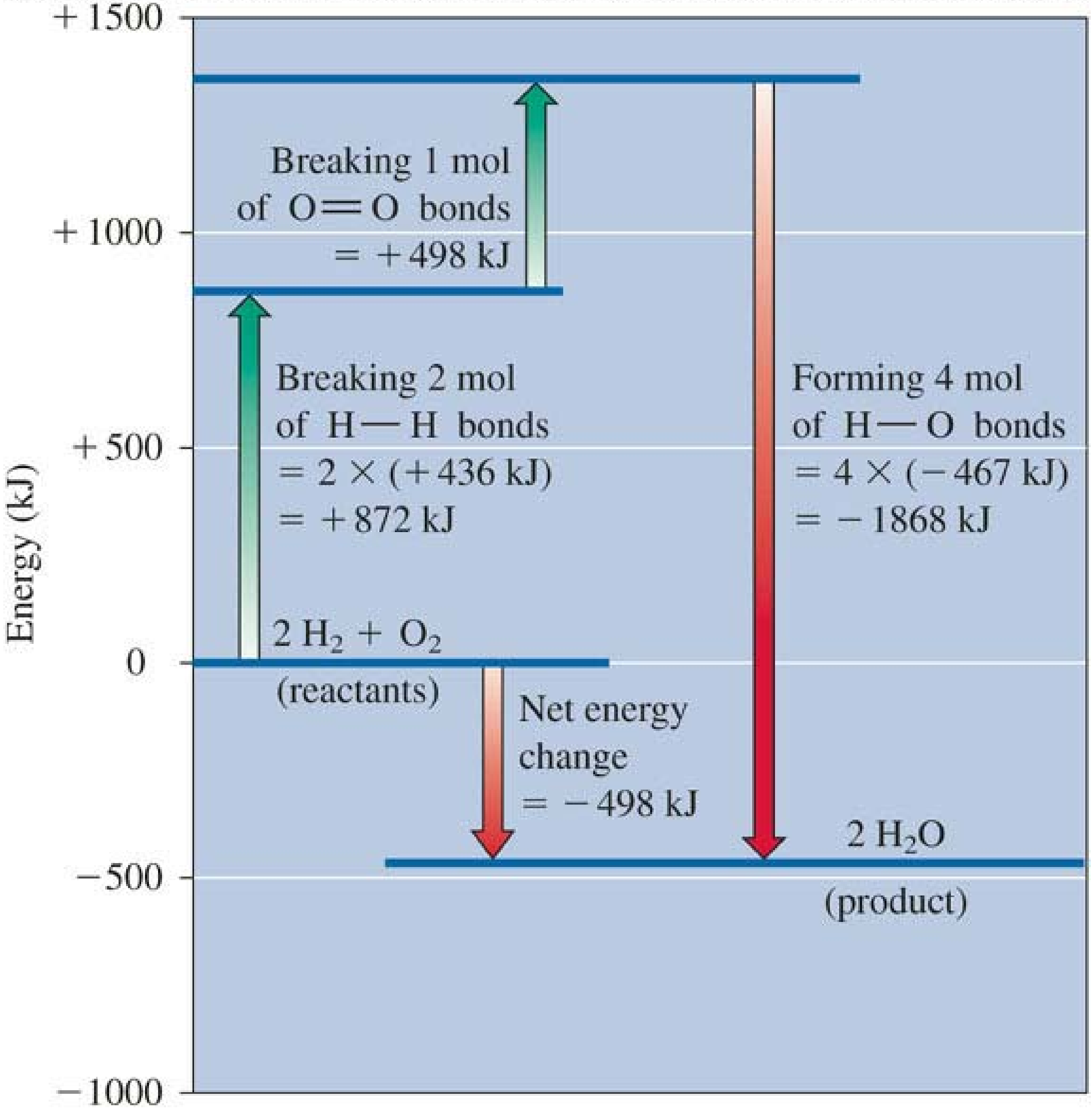
Table 4.2 Bond Energies (in kJ/mol)

	H	C	N	O	S	F	Cl	Br	I
Single bonds									
H	436								
C	416	356							
N	391	285	160						
O	467	336	201	146					
S	347	272	—	—	226				
F	566	485	272	190	326	158			
Cl	431	327	193	205	255	255	242		
Br	366	285	—	234	213	—	217	193	
I	299	213	—	201	—	—	209	180	151

Multiple bonds

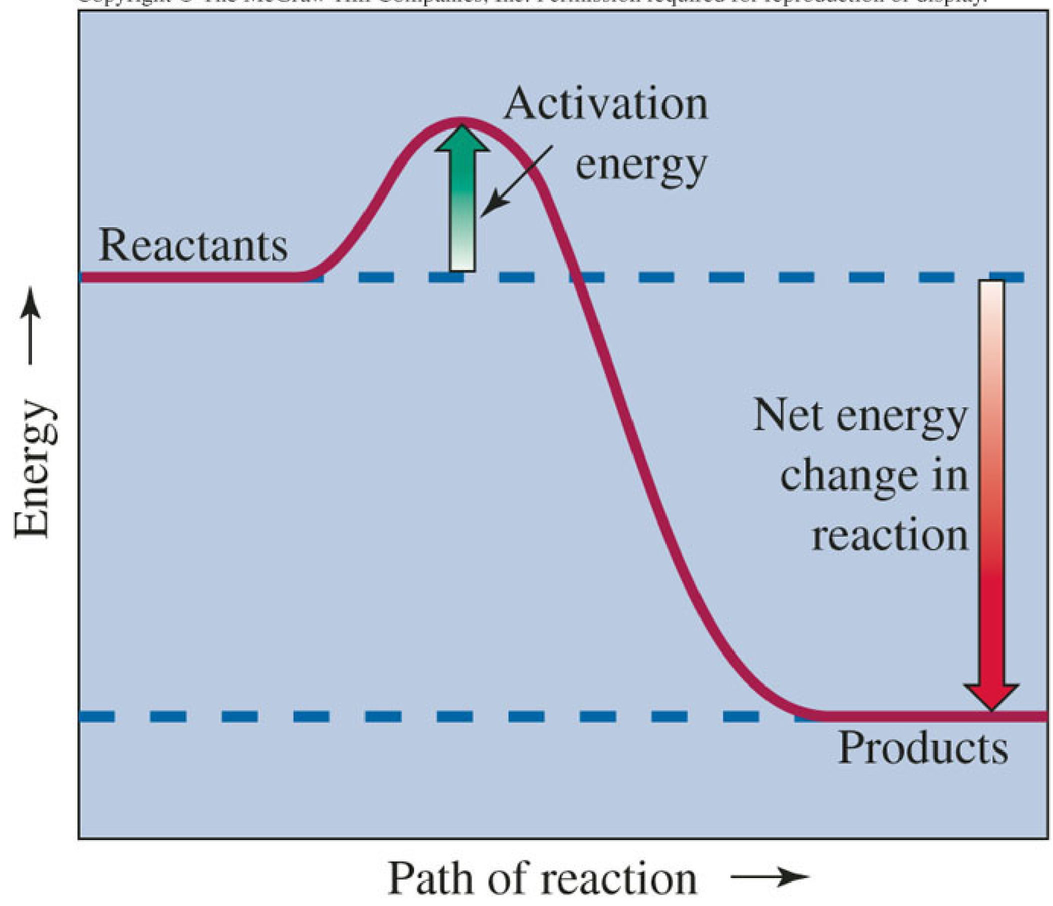
C=C	598	C=N	616	C=O	803 in CO_2
C≡C	813	C≡N	866	C≡O	1073
N=N	418	O=O	498		
N≡N	946				

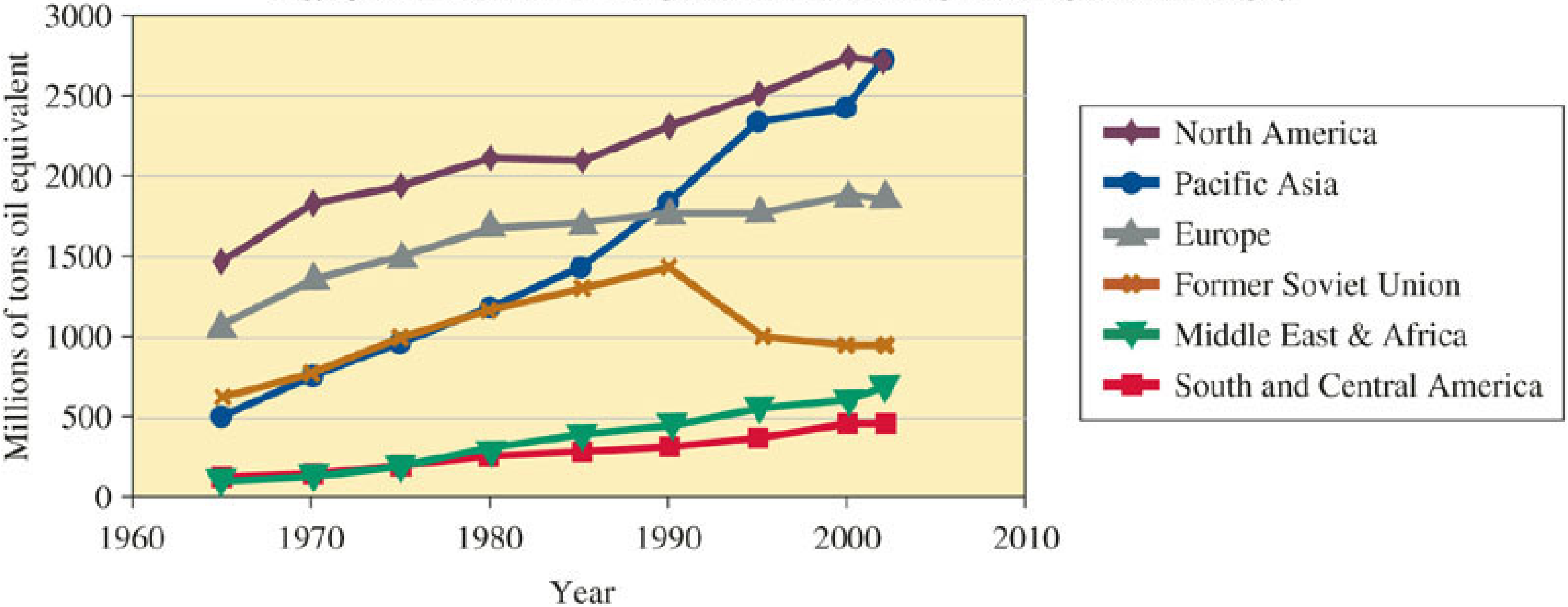
Source: Data from Darrell D. Ebbing, *General Chemistry,* Fourth Edition, 1993 Houghton Mifflin Co. Data originally from *Inorganic Chemistry: Principles of Structure and Reactivity,* Third Edition by James E. Huheey, 1983, Addison Wesley Longman.

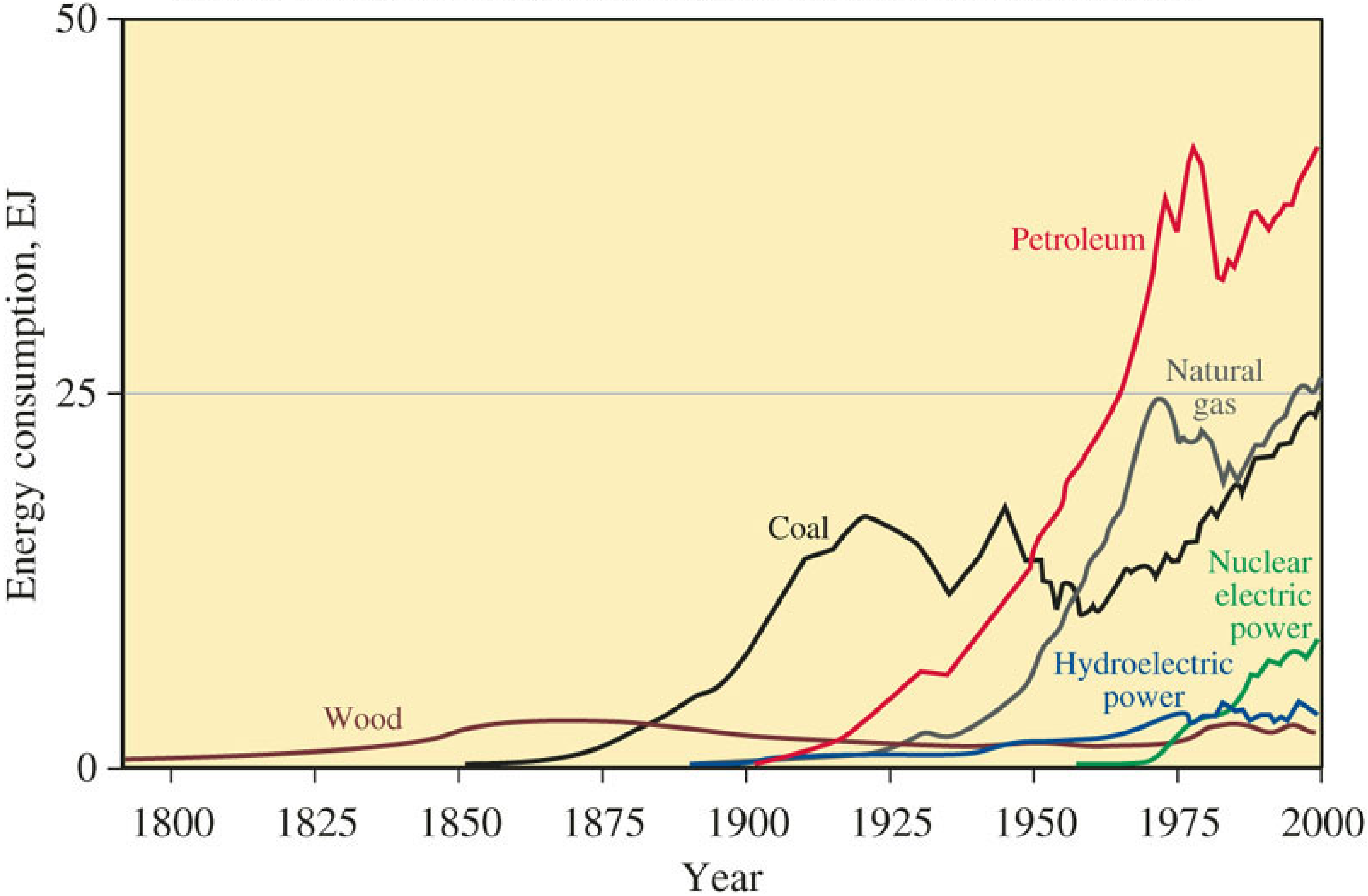

+1500
+1000
+500
0
−500
−1000
Energy (kJ)
Breaking 1 mol of O═O bonds = +498 kJ
Breaking 2 mol of H—H bonds = 2 × (+436 kJ) = +872 kJ
Forming 4 mol of H—O bonds = 4 × (−467 kJ) = −1868 kJ
2 H₂ + O₂ (reactants)
Net energy change = −498 kJ
2 H₂O (product)

Energy as a Barrier to Reaction

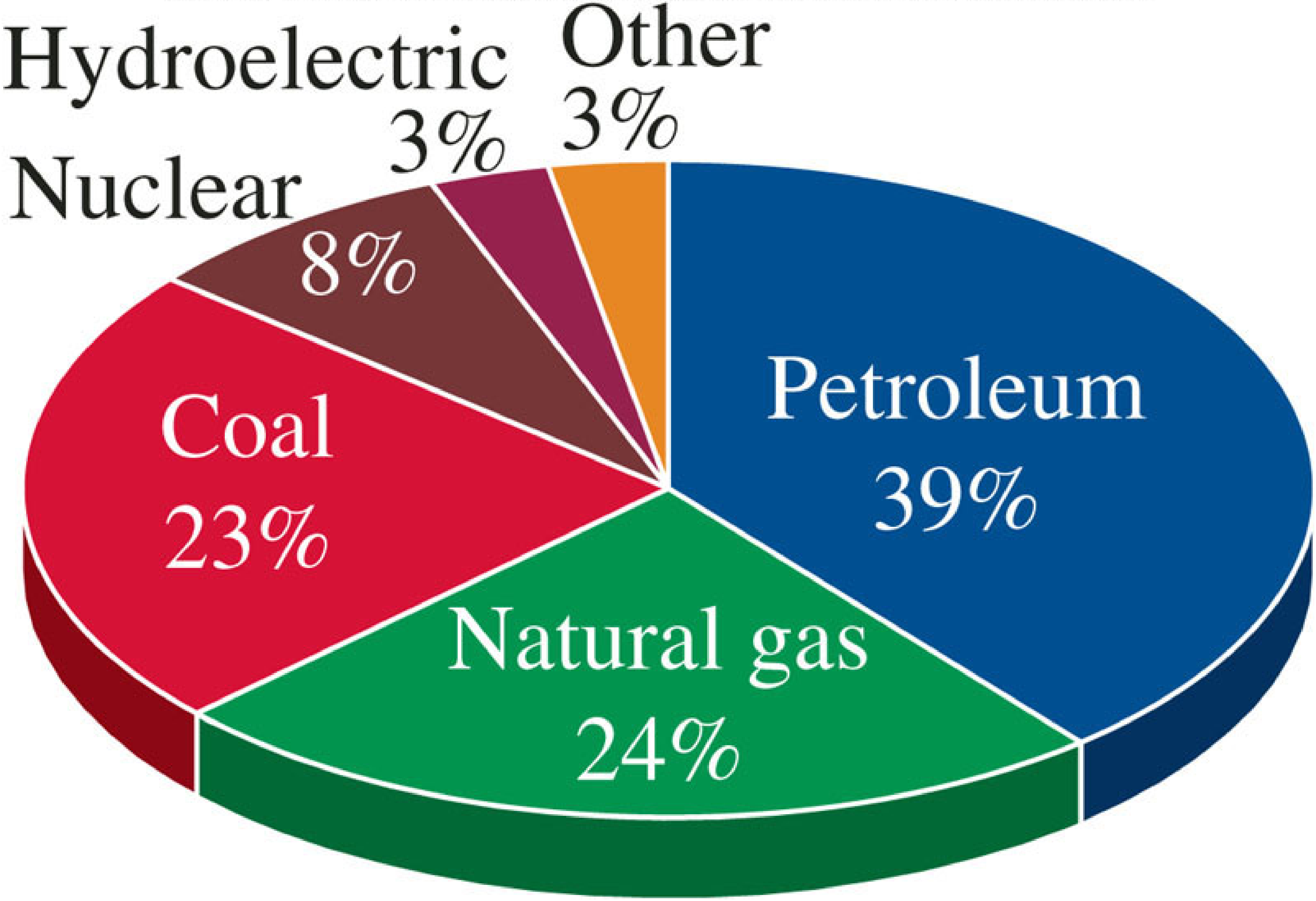
- Activation energy – the energy necessary to initiate a reaction



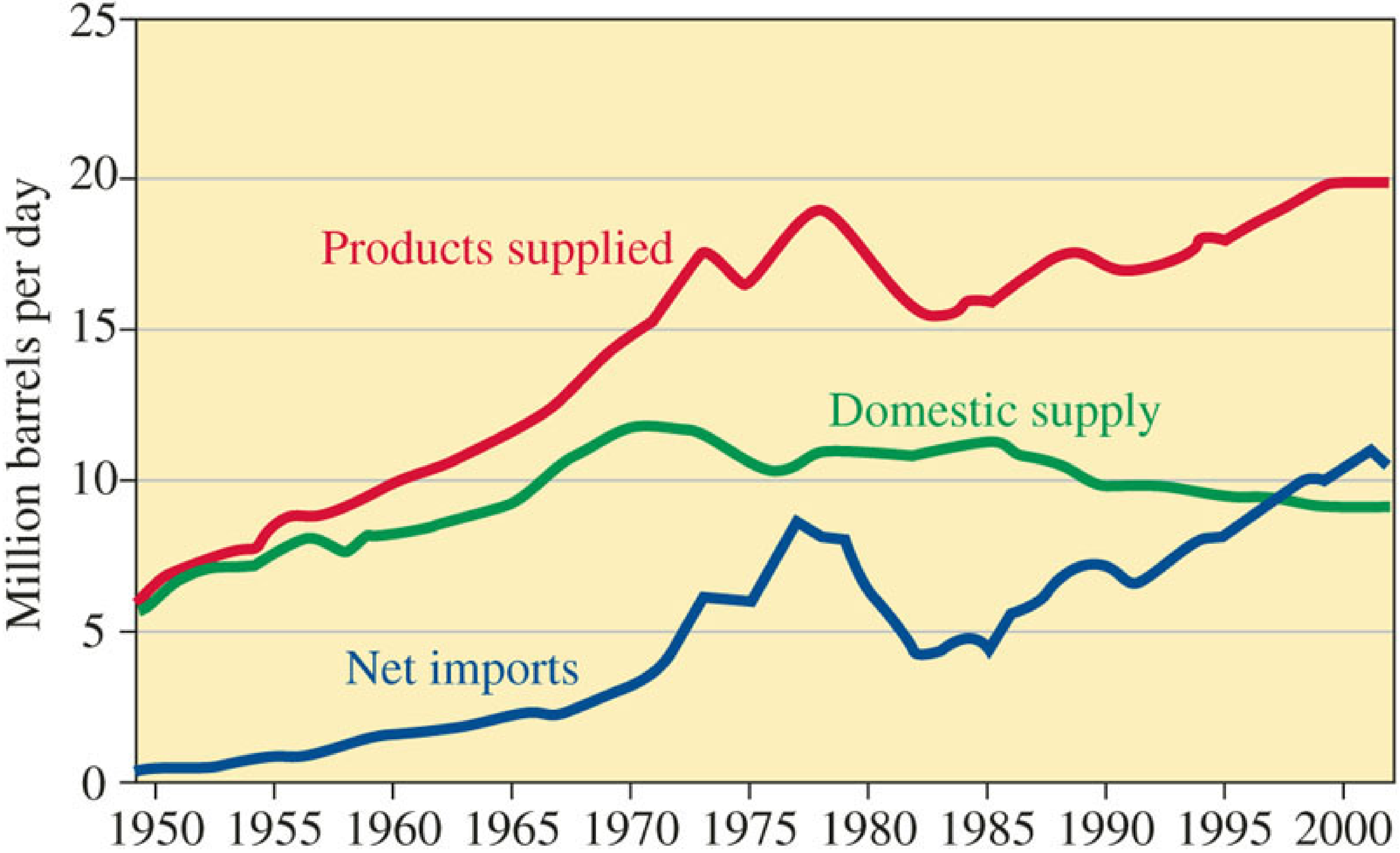

3000
2500
2000
1500
1000
500
0
Millions of tons oil equivalent
1960
1970
1980
1990
2000
2010
Year
North America
Pacific Asia
Europe
Former Soviet Union
Middle East & Africa
South and Central America



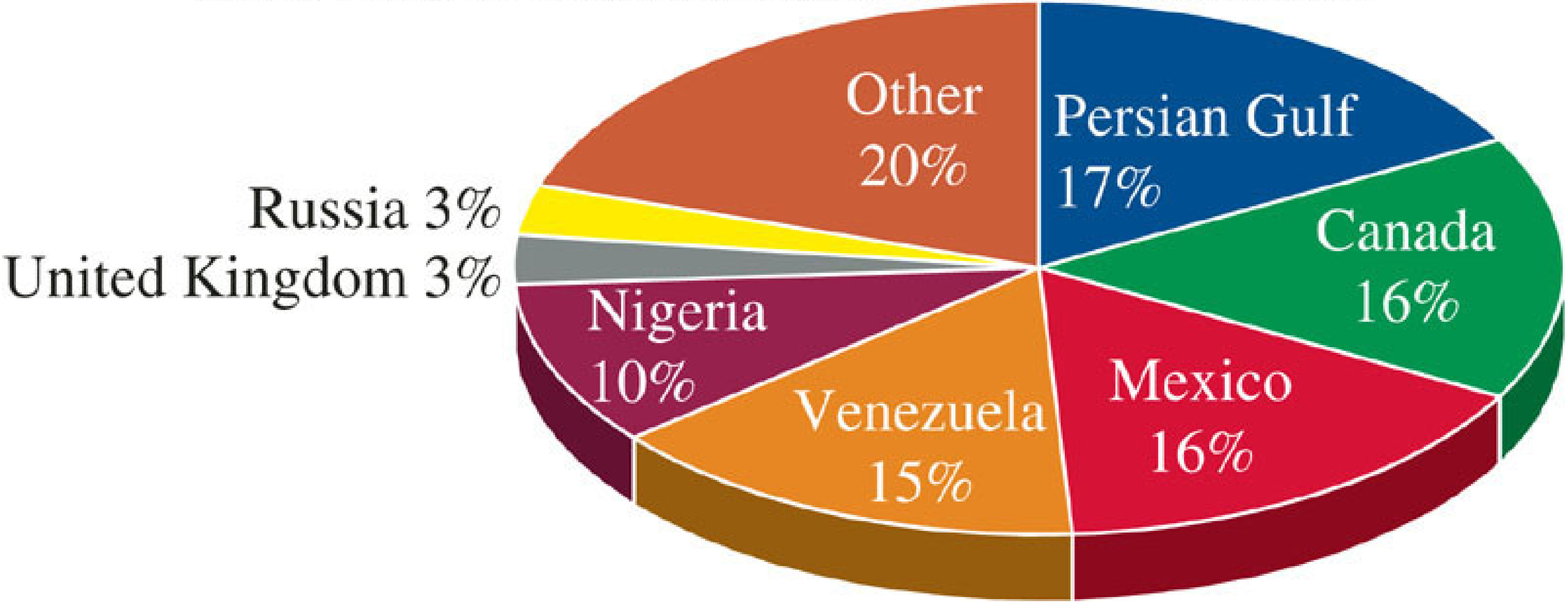
History of US energy consumption by source, 1 EJ = 10^{18} J



Annual US energy consumption by source, 2002
'other' includes wood, waste, alcohol, geothermal, wind and solar

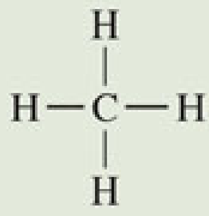


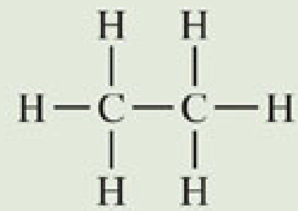
US petroleum product use, domestic production, and imports. In 2002, more than 50% of total oil used in US is imported.

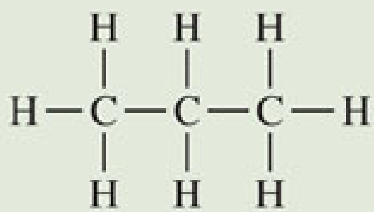


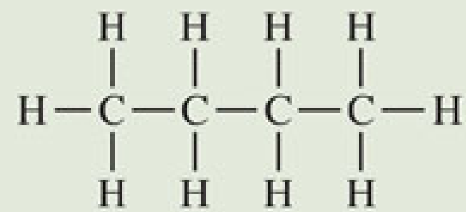
Sources of crude oil and petroleum products imported by US (August 2003)

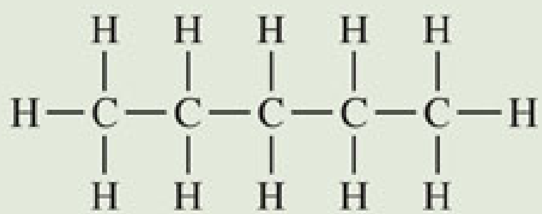
Table 4.5 Alkanes with One to Eight Carbons

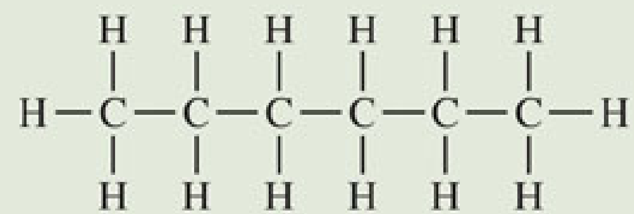

methane

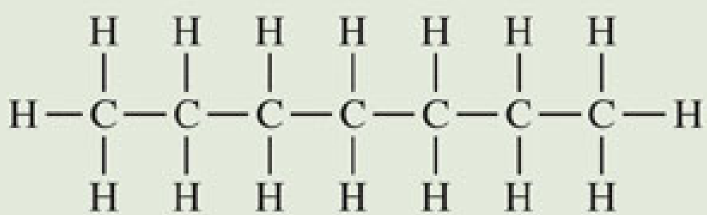

ethane

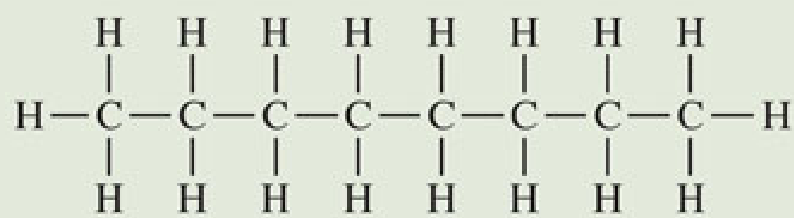

propane


butane


pentane

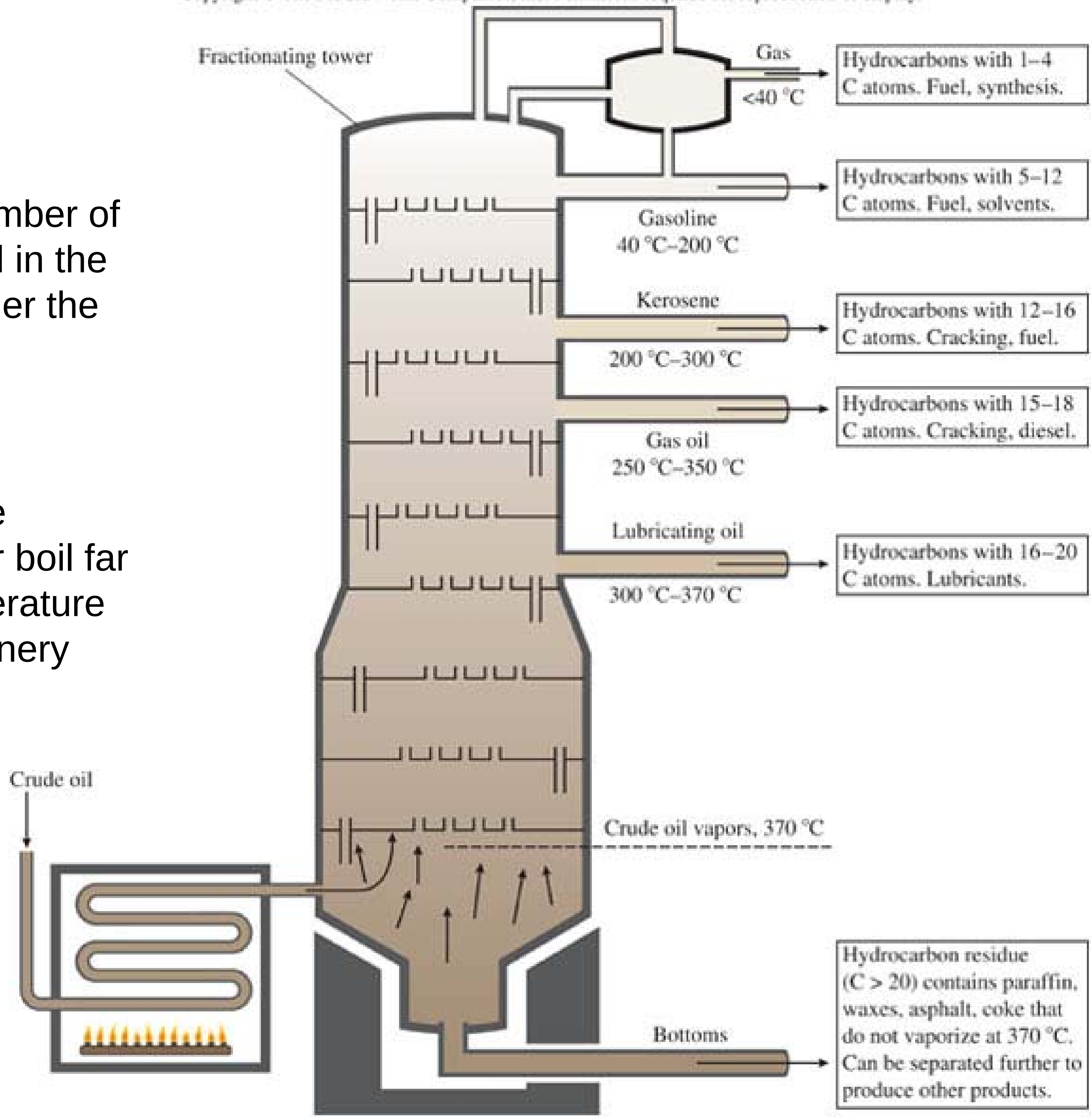

hexane

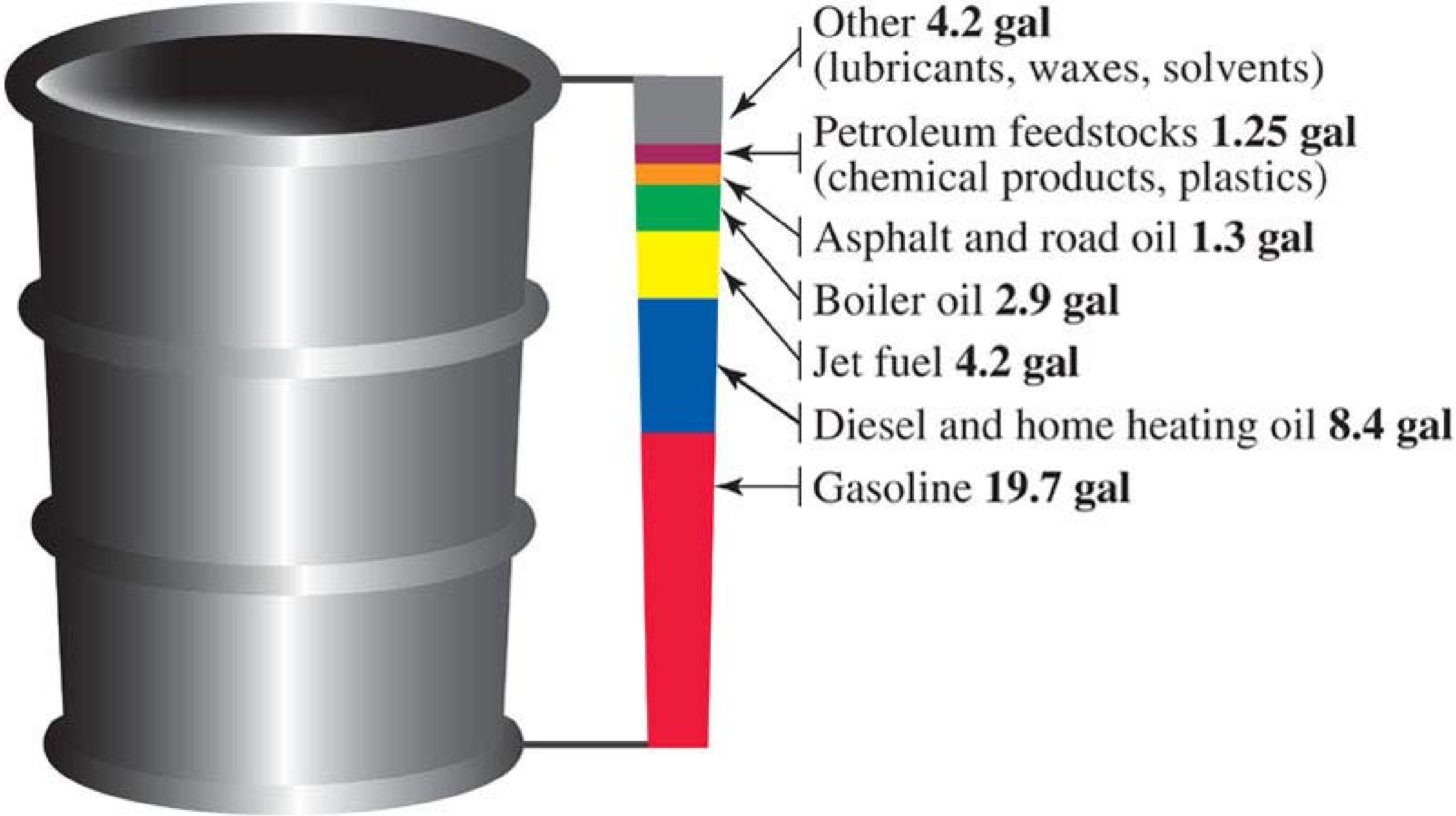

heptane


octane

The higher the number of carbons contained in the molecule, the higher the boiling point.

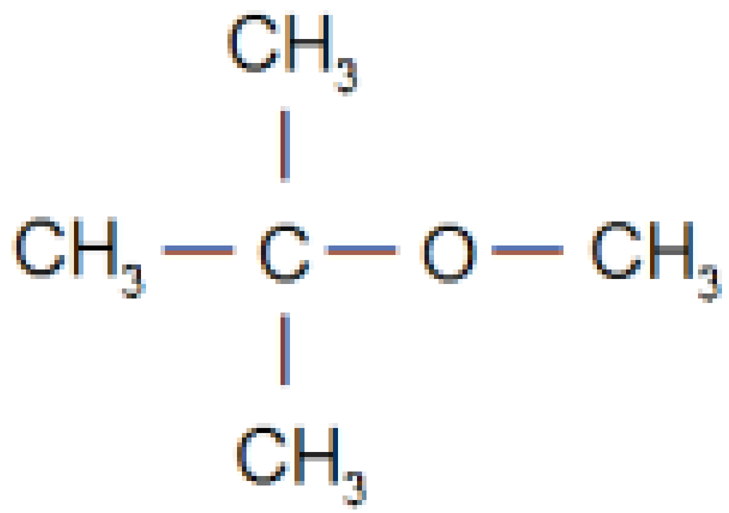
The most volatile components of the fractionating tower boil far below room temperature and are called refinery gases.

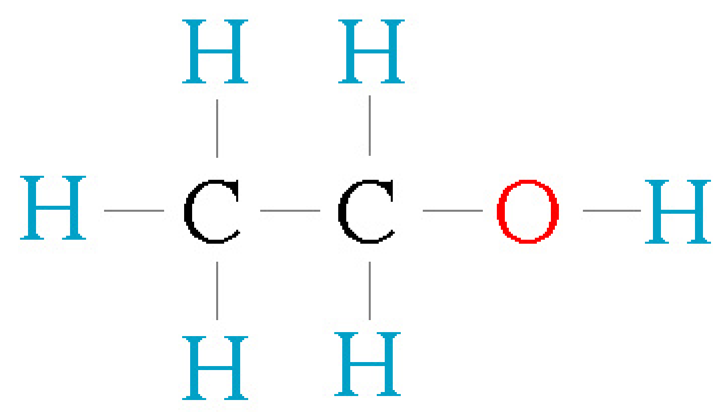


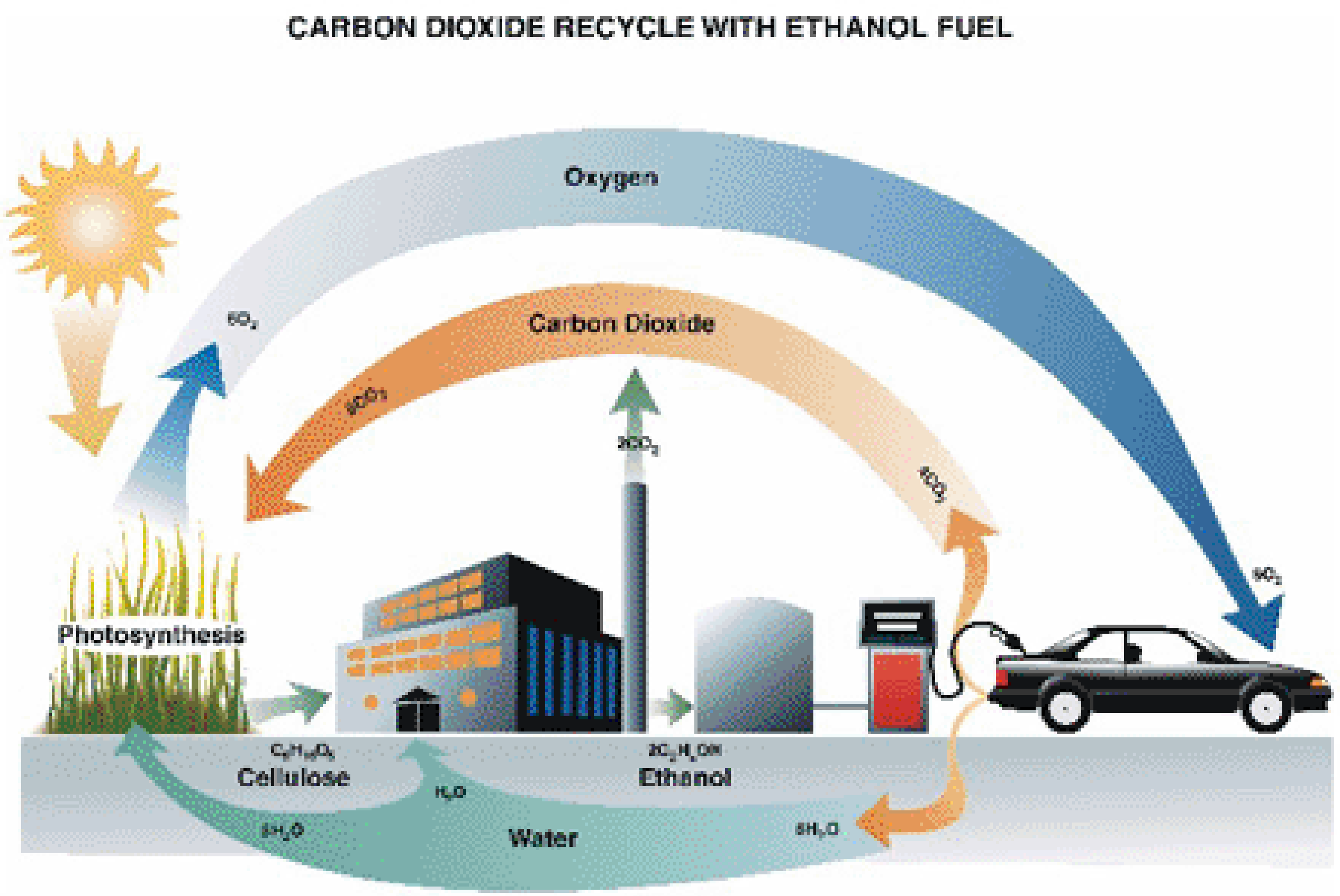

Other **4.2 gal**
(lubricants, waxes, solvents)
Petroleum feedstocks **1.25 gal**
(chemical products, plastics)
Asphalt and road oil **1.3 gal**
Boiler oil **2.9 gal**
Jet fuel **4.2 gal**
Diesel and home heating oil **8.4 gal**
Gasoline **19.7 gal**

Newer Fuels and Other Sources

- Oxygenated gasolines – blends of petroleum-derived hydrocarbons with oxygen-containing compounds such as MTBE (methyl tertiary butyl ether) and ethanol.
- They reduce the carbon monoxide emissions, since fuel contains oxygen.



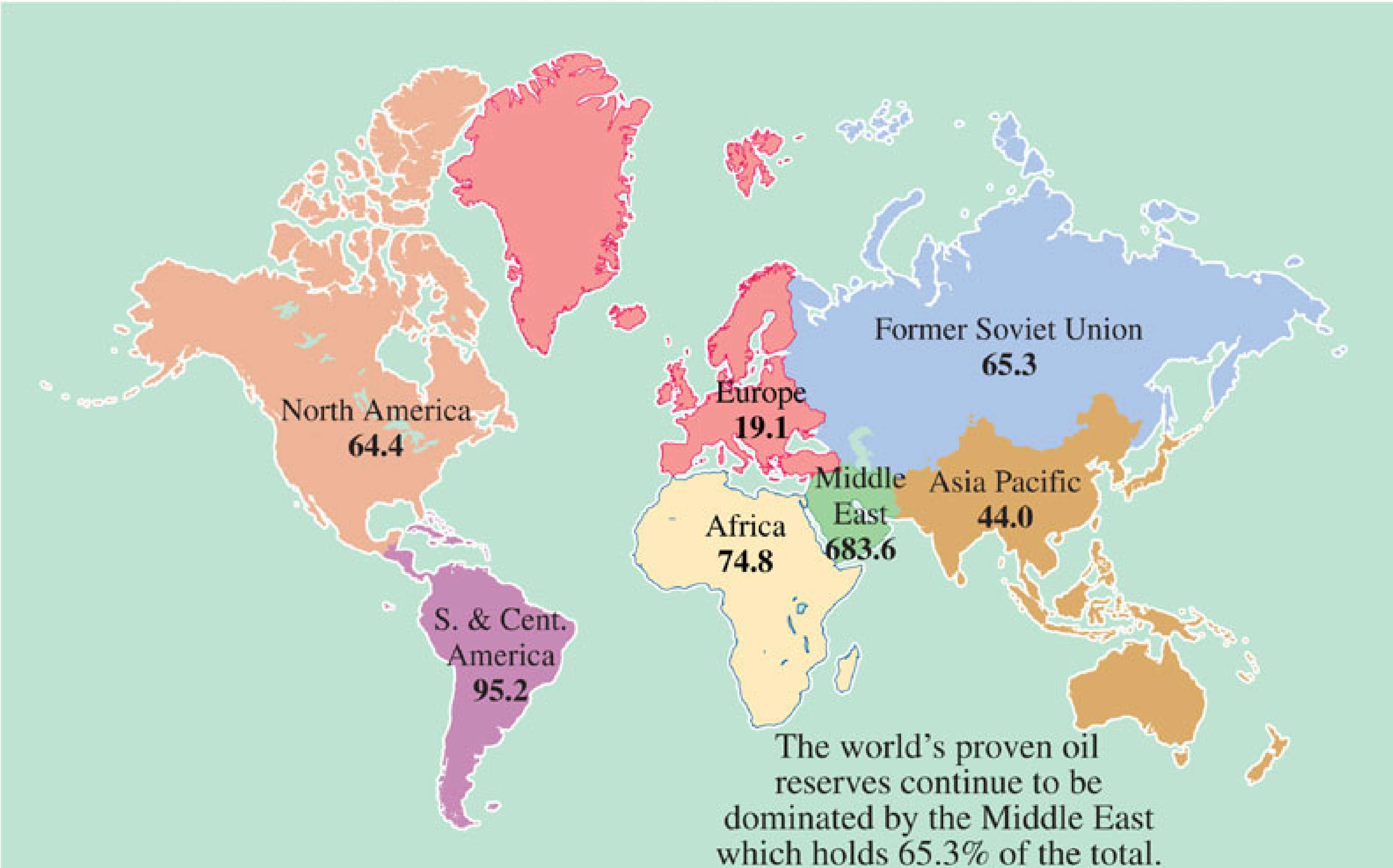




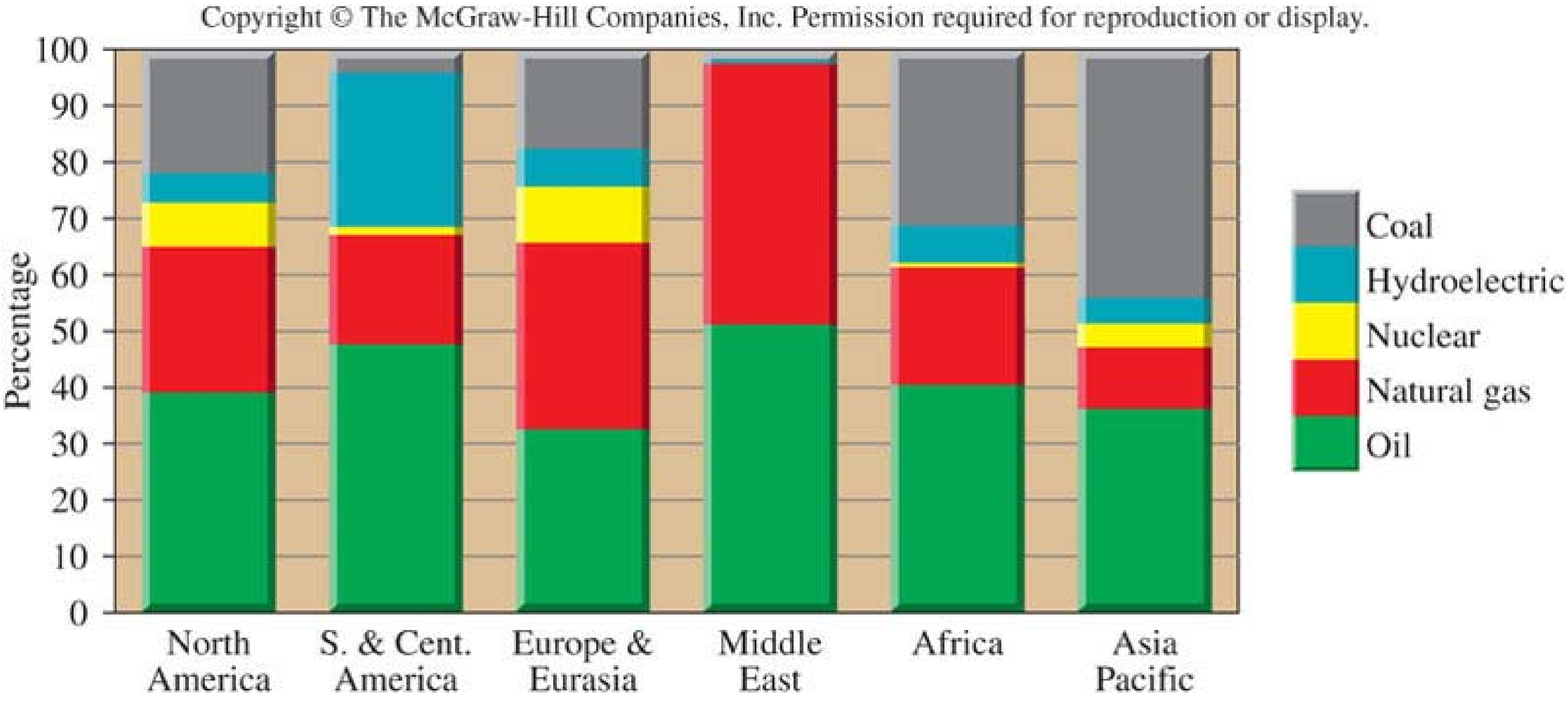
$$6CO_2(g) + 6H_2O(l) \xrightarrow{\text{chlorophyll}} \underset{\text{glucose}}{C_6H_{12}O_6}(s) + 6O_2(g)$$

$$\underset{\text{glucose}}{C_6H_{12}O_6}(s) \xrightarrow{\textit{Yeast Enzymes}} 2C_2H_5OH + 2CO_2$$

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O + 1367kJ$$


North America
64.4
Europe
19.1
Former Soviet Union
65.3
Middle East
683.6
Asia Pacific
44.0
Africa
74.8
S. & Cent. America
95.2
The world's proven oil reserves continue to be dominated by the Middle East which holds 65.3% of the total.

The Case for Conservation



The Case for Conservation