Where We Are

Today: Finish up Chapter 4, hopefully!

Discussion:

- Alternative fuels, the benefits of conservation
- Where to go next?

Thursday: Start in on Chapter 5, “The Water We Drink”. Quiz!

NEXT Thursday: Exam 2!

In the U.S., fossil fuel combustion provides

- 70% of electricity
- 85% of total energy

Fossil fuels produce large amounts of CO_2

The supply of fossil fuels is finite, and may be running out (estimates vary)

- 150 years left for coal
- 50 years left for oil

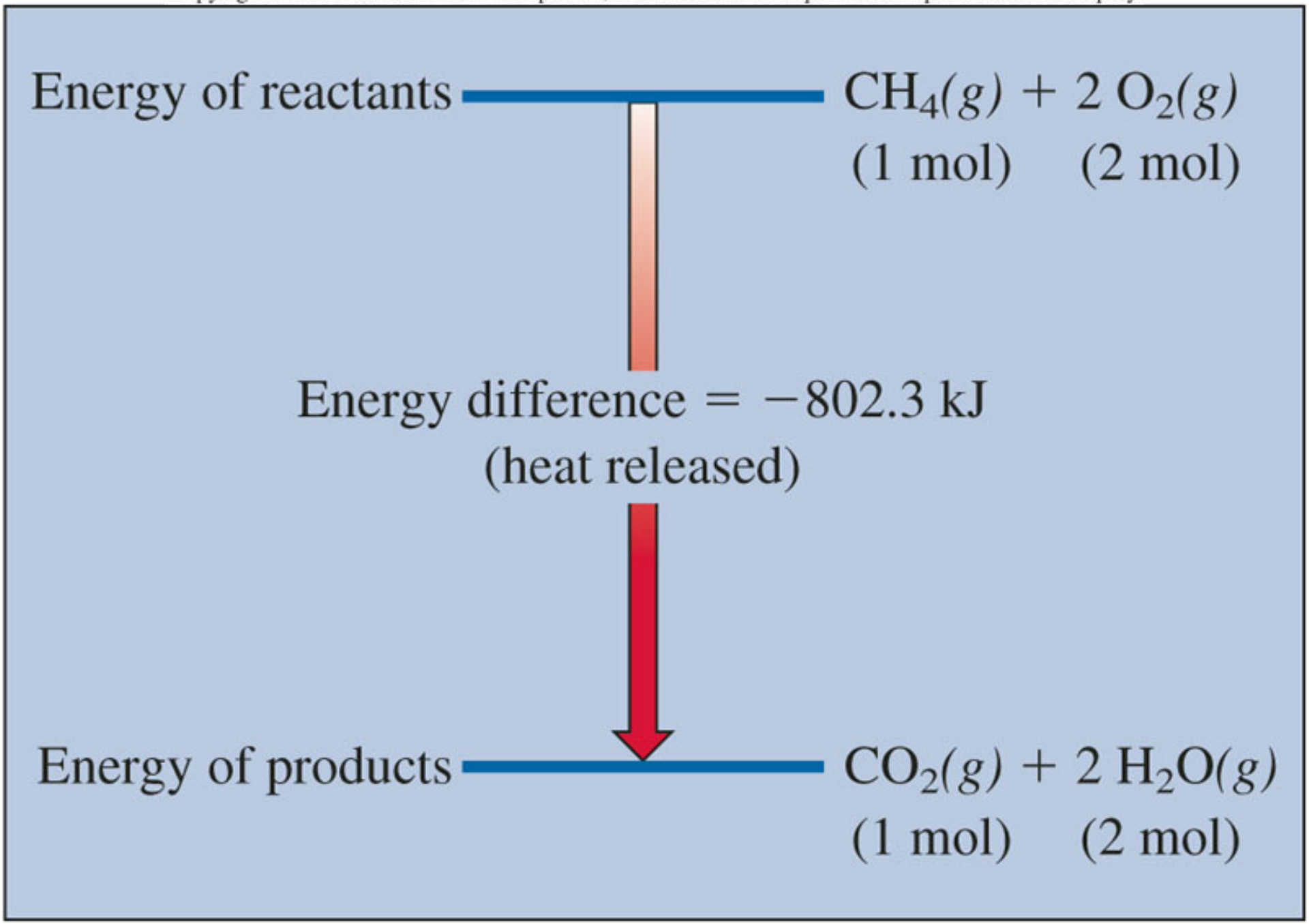
Energy Transformations

First Law of Thermodynamics:

Energy is neither created nor destroyed

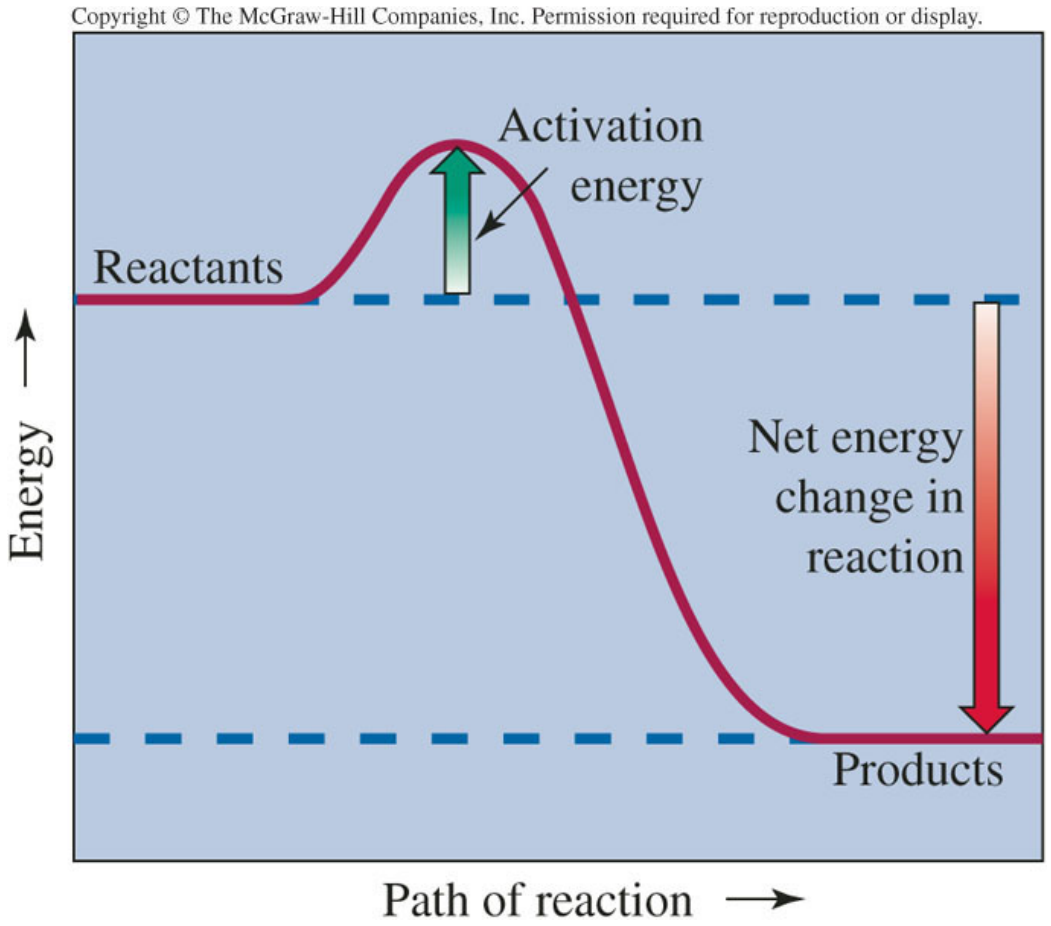
Second Law of Thermodynamics

The entropy of the universe always increases during a spontaneous process



Energy as a Barrier to Reaction

- Activation energy – the energy necessary to initiate a reaction



Fossil Fuels: Coal

- Drawback #1: Difficult to obtain
  - Underground mining dangerous and expensive
  - Since 1900 more than 100,000 workers killed in **American** mine disasters – but how many worldwide? And how many have been made sick, or died from “black lung”?
- Drawback #2: Coal is a dirty fuel
  - Soot
  - Sulfur and nitrogen oxides
  - Mercury
  - Carbon dioxide

Fossil Fuels: Coal

- The benefit of coal: the global supply is large
  - 20-40 times greater than petroleum
- Because of this, coal is expected to become a much more important fuel in the next 100-150 years
- It will become important to find ways to better use coal – more cleanly, more safely

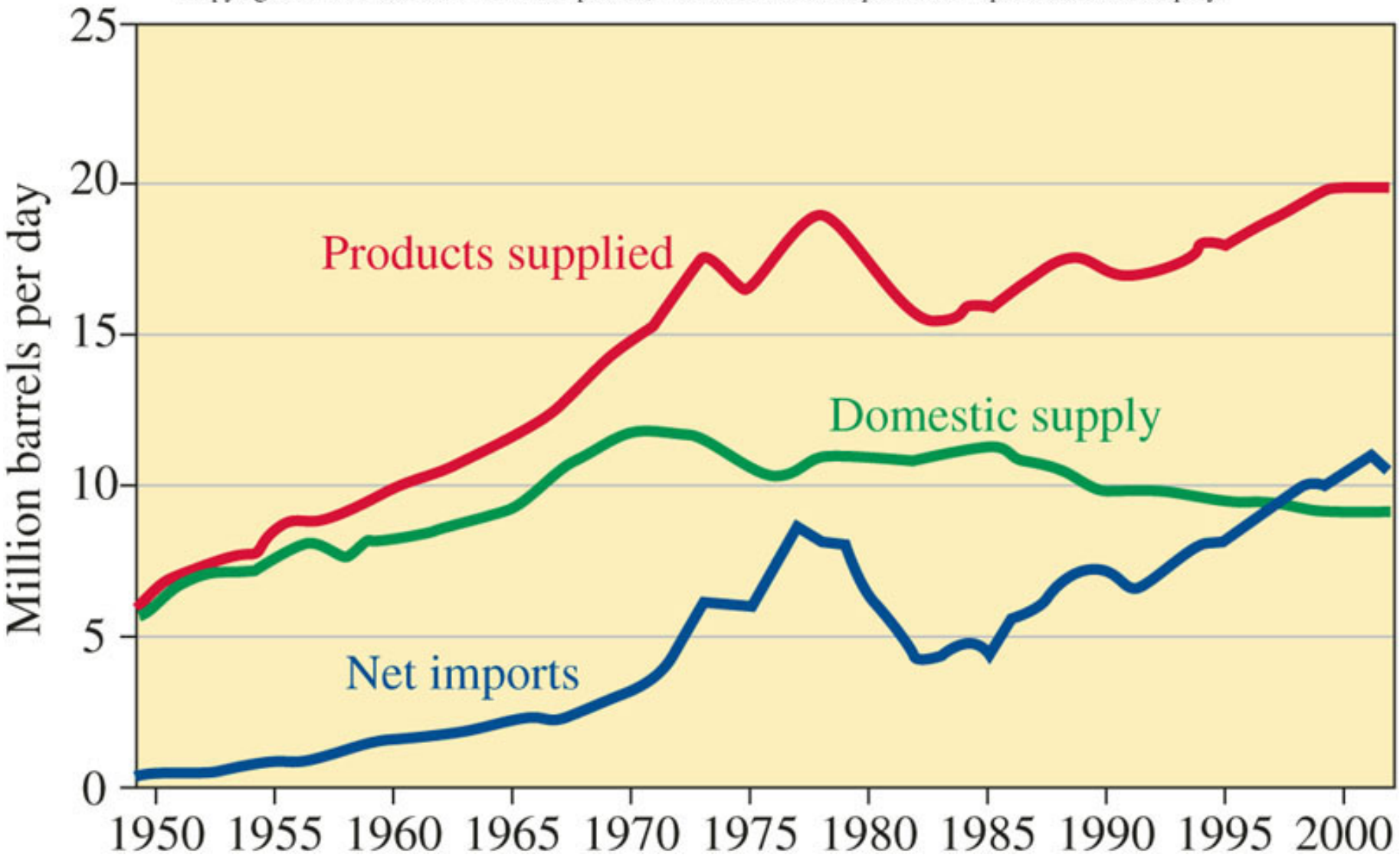
Calculations Concerning Coal

Compute the amount of energy released by burning 1.5 million tons of coal – the amount consumed at an average coal-burning plant in one year, assuming this coal produces 30 kJ per gram

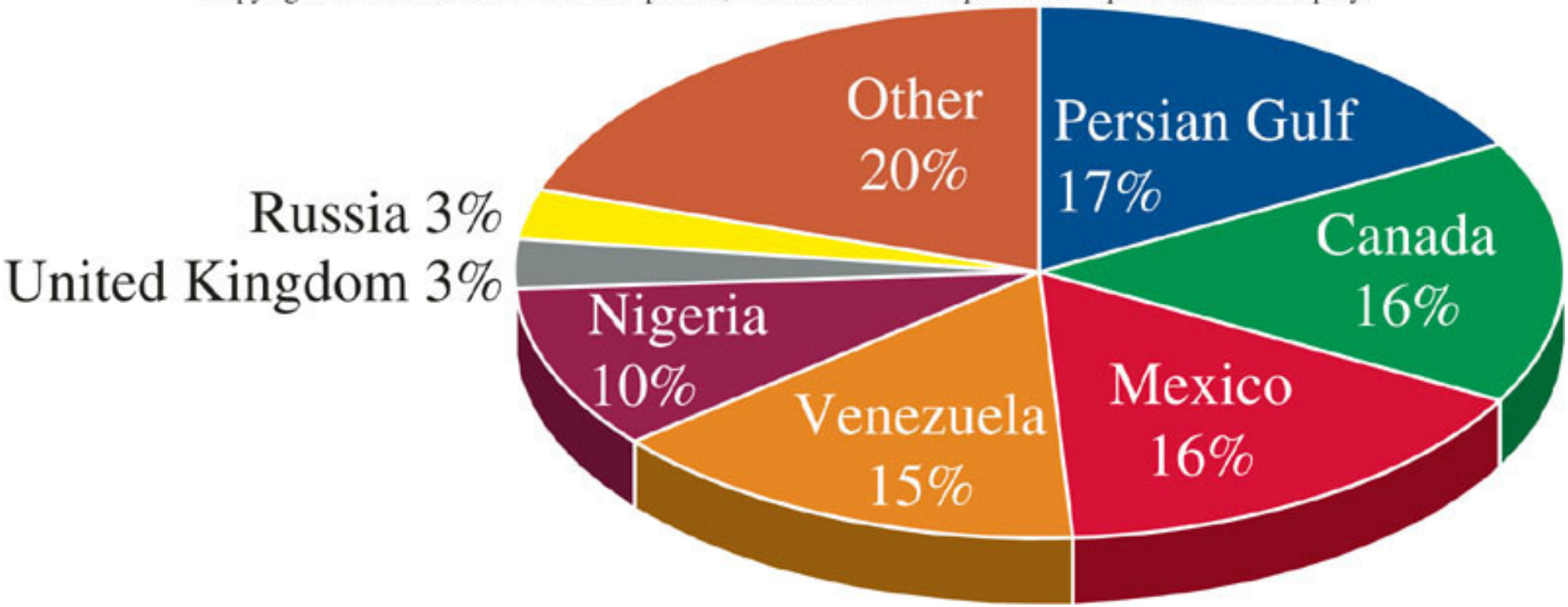
How much C is in 1.5 million tons of $C_{135}H_{96}O_9NS$? How much CO_2 would be produced from that combustion?

Fossil Fuels: Petroleum

- Liquid - easy to pump to surface
- Transported via pipelines
- Higher energy content than coal
  - 48 kJ/g for petroleum
  - 30 kJ/g for coal
- Petroleum (crude oil) easily converted to gasoline
- Around 1950, oil surpassed coal as the primary fuel in the U.S.
- In 1998, the U.S. burned 125 billion gallons in more than 203 million vehicles
- The U.S. consumes 25% world's oil … for 5% of the population



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

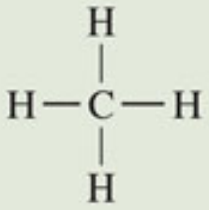


Sources of crude oil and petroleum products imported by US (August 2003)

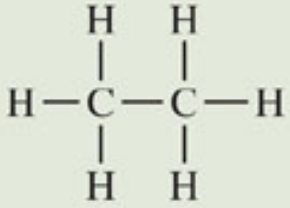
Fossil Fuels: Petroleum

- Crude oil must be refined
- Mostly hydrocarbons – molecules consisting of hydrogen and carbon atoms
  - Range from 1 to 60 carbon atoms per molecule
- Mostly alkanes – hydrocarbons with only single bonds between carbons

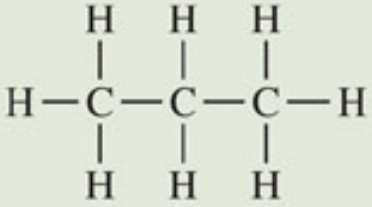
Table 4.5 Alkanes with One to Eight Carbons



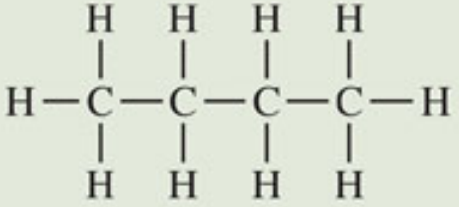
methane



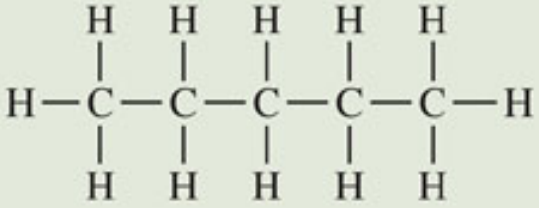
ethane



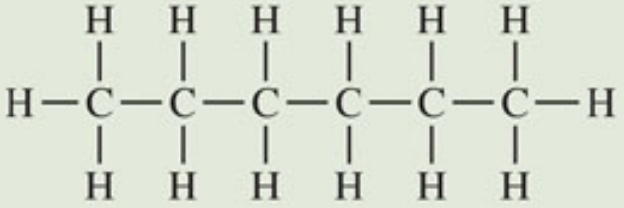
propane



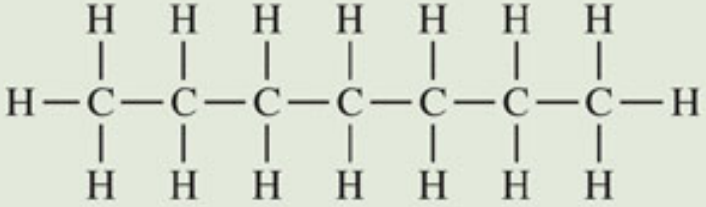
butane



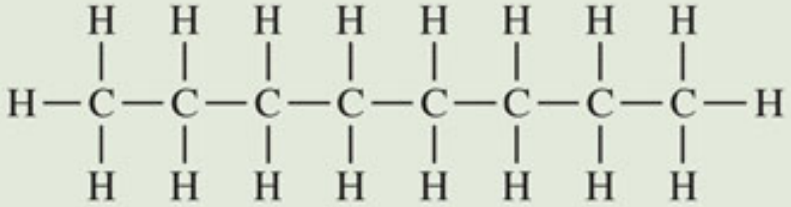
pentane



hexane



heptane



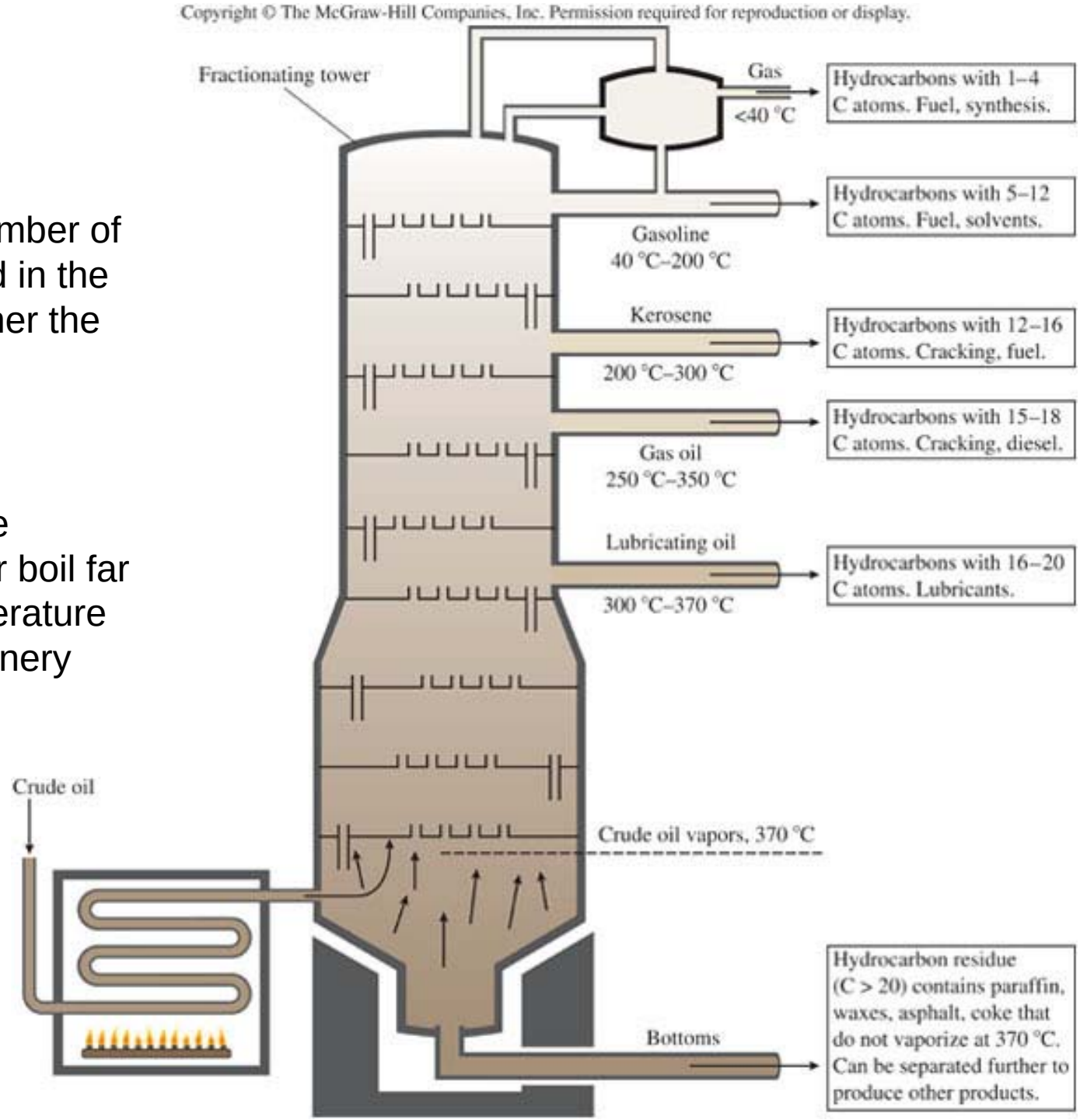
octane

Oil Refinery

- Distillation – purification, or separation, process in which a solution is heated to its boiling point and the vapors are condensed and collected

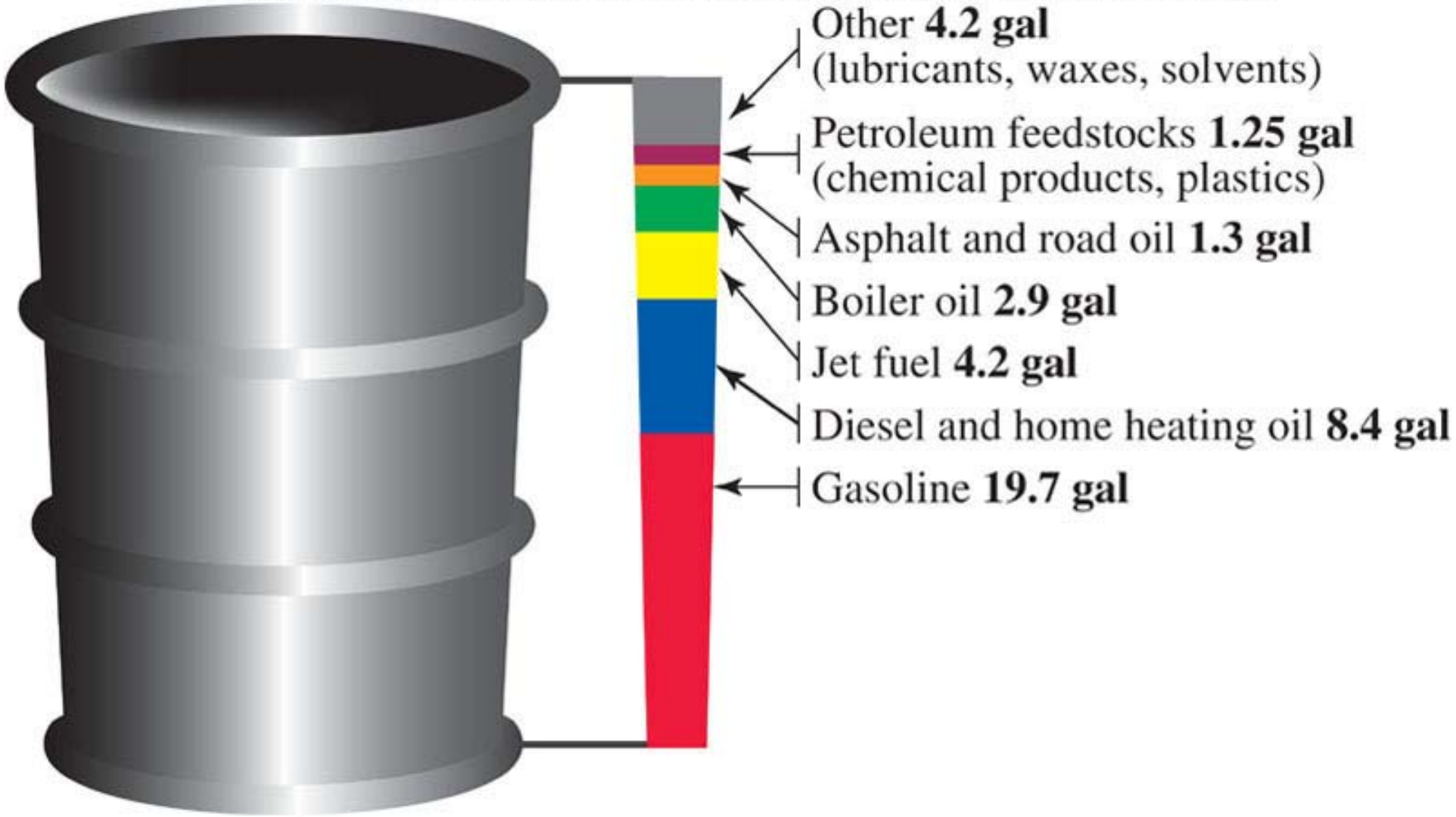
The higher the number of carbons contained in the molecule, the higher the boiling point.

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



Petroleum

- The gasoline fraction contains hydrocarbons with 5 to 12 carbon atoms per molecule
- One barrel of crude oil contains **42 gallons**
- 35 gallons of this is used for heating and transportation



Manipulating Molecules

- Gasoline that comes directly from the fractionating tower represents less than 50% of the original crude
- Heavier and lighter fractions can undergo chemical reactions to form more gasoline

Manipulating Molecules

- Cracking - a chemical process by which large molecules are broken into smaller ones suitable to be used in gasoline
  - $C_{16}H_{34} \rightarrow C_8H_{18} + C_8H_{16}$
  - $C_{16}H_{34} \rightarrow C_5H_{12} + C_{11}H_{22}$
- Thermal cracking – heat crude oil to high temperature so it decomposes
- Catalytic cracking – lower temperature process using a catalyst

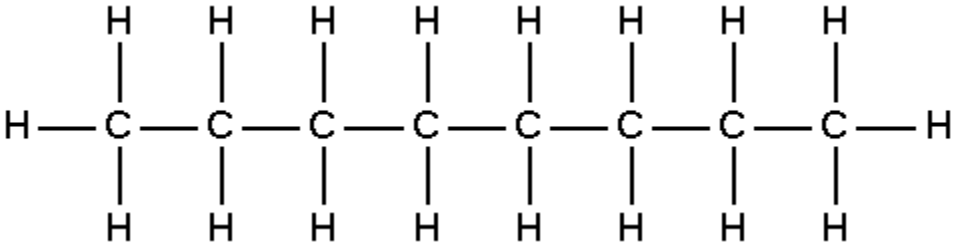
Manipulating Molecules

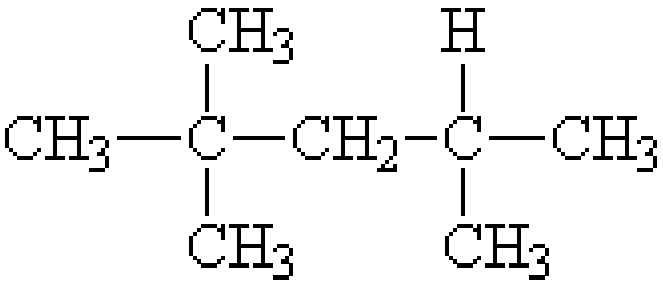
- Catalytic combination – use a catalyst to join smaller molecules together to form intermediate sized ones

  $4\ C_2H_4 \rightarrow C_8H_{16}$

Manipulating Molecules

- Isomers –compounds with the same chemical formula but different chemical structures.
  - C_8H_{18}
  - Octane – boiling point 125^oC
  - Isooctane – boiling point 99^oC – ignites more readily.





Internal Combustion Engine

http://auto.howstuffworks.com/engine1.htm

http://auto.howstuffworks.com/engine4.htm

Knocking

- Premature ignition during the compression stroke
- Noisy and can damage the engine
- Octane rating of gasoline

  The higher the number, the less likely the gas will cause knocking

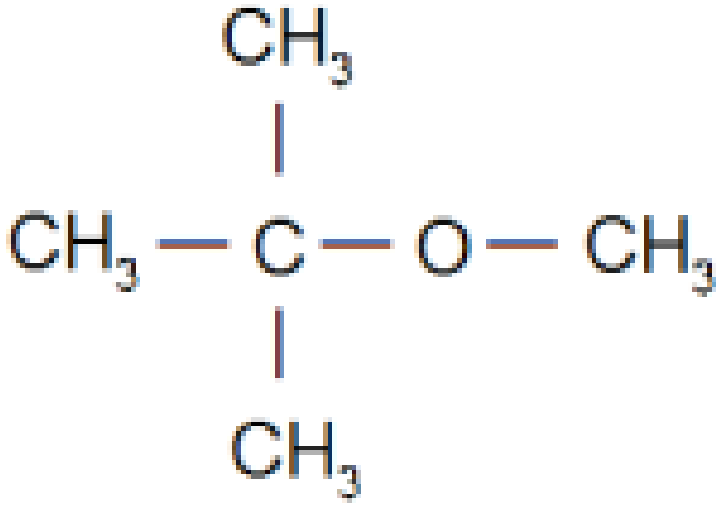
Table 4.6 Octane Ratings of Several Substances

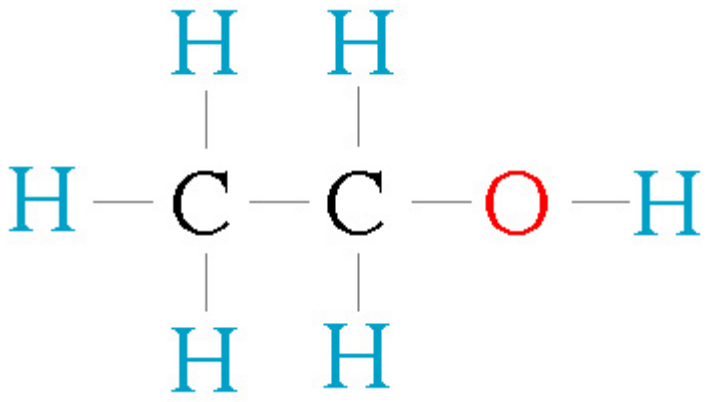
Compound	Octane Rating
Octane	−20
Heptane	0
Isooctane	100
Methanol	107
Ethanol	108
MTBE	116

- Octane can be reformed to isooctane
- Oxygenated fuels are octane boosters

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.





Newer Fuels and Other Sources

- Winter Oxyfuel Program (1992)
  - Part of the Clean Air Act
  - Reduce CO emissions
  - During winter months, gasoline must contain 2.7% oxygen by weight
  - Typically ethanol

Newer Fuels and Other Sources

- Year-round Reformulated Gasoline Program (1995)
  - Part of clean air act
  - Reformulated gasolines (RFGs) are oxygenated gasolines that also contain a lower percentage of certain more volatile hydrocarbons, such as benzene found in non-oxygenated conventional gasoline

Reformulated gasolines

- <1% benzene
  - Benzene is a carcinogenic compound
- >2% oxygenates
  - Burn cleanly
- Evaporate less easily than conventional gasoline
  - Fewer smog-forming pollutants
- 30% US gasolines are RFGs – with 90% containing MTBE

MTBE

- In January 2004, the National Institute of Environmental Health Sciences reported the human health effects of short-term exposure to large or small amounts of MTBE are not known.
- MTBE is very soluble in water and is finding its way to drinking water
- Little likelihood that MTBE will cause adverse health effects at concentrations of 40 ppb or below – above this concentration one can taste it in the water
- California has phased out the use of MTBE in gasoline, and many local governments in the Northeast have started the same process
- Because this represents a huge market, most gasoline providers have stopped using MTBE and have replaced it with other additives – particularly ethanol

Newer Fuels and Other Sources

- Coal supply bigger than petroleum supply
- Convert coal into gaseous and liquid fuels

$$\underset{coke}{C(s)} + H_2O(g) \rightarrow \underset{water\ gas}{CO(g)} + H_2(g)$$

$$\underset{water\ gas}{CO(g)} + H_2(g) \xrightarrow{catalyst} hydrocarbons$$

Newer Fuels and Other Sources

- Biomass
  - Materials produced by biological processes
  - Wood
  - Ethanol, CH_3CH_2OH
    - Produced by fermentation of starch and sugars in grains such as corn
    - Can also be prepared commercially by the reaction of water with ethylene (C_2H_4)
  - Biodiesel

Newer Fuels and Other Sources

- Gasohol
  - Mix 10% ethanol with 90% gasoline
  - Can be burned in a standard car engine
- Ethanol produces 29.7 kJ/g of energy
- Octane produces 47.8 kJ/g of energy

Newer Fuels and Other Sources

- Flexible Fuel Vehicles
  - Detect what the fuel actually is, and adjust engine performance to match
  - Can use E85 – 85% ethanol and 15% gasoline
  - It is believed that most FFV owners (4 million as of 2006) are not aware that their vehicles can run on E85: fewer than 1% of the consumed fuel is E85

Partial List of Vehicles Capable of E85 Fueling

Make & model	Engine
Chevrolet S10 2WD pickup	2.2L
Chevrolet Silverado pickup	5.3L
Chevrolet Suburban	5.3L
Chevrolet Tahoe	5.3L
Chrysler Sebring sedan and convertible	2.7L
Chrysler Town and Country	3.3L
Chrysler (formerly Plymouth) Voyager	3.3L
Dodge Caravan	3.3L
Dodge Cargo minivan	3.3L
Dodge Grand Caravan	3.3L
Dodge Stratus	2.7L
Ford Explorer (4 door)	4.0L
Ford Explorer Sport	4.0L
Ford Explorer Sport Track	4.0L
Ford Ranger pickup (2WD and 4WD)	3.0L
Ford Ranger Supercab 2WD pickup	3.0L
Ford Taurus sedan	3.0L
Ford Taurus wagon	3.0L
GMC Sierra pickup	5.3L
GMC Sonoma 2WD pickup	2.2L
GMC Suburban	5.3L
GMC Yukon	5.3L
Isuzu Hombre 2WD pickup	2.2L
Mazda B3000 pickup	3.0L
Mercury Mountaineer	4.0L
Mercury Sable	3.0L

For full list, see www.afdc.doe.gov.

Drawbacks of Ethanol as Fuel

- Not as much energy (gram per gram) as gasoline
- How much farmland would need to be diverted from food production to get ample fuel production?
- How much is needed? Estimates are that California alone will consume 20% of the ethanol produced in the U.S.
- Expense ($$ and Energy)
  - Energy required to plant, cultivate and harvest corn
  - Production and application of fertilizers
  - Distillation of alcohol
  - Tractors used in farming
  - More energy to produce a gallon of ethanol than obtained from burning?

Biodiesel

- Can be used in any **standard diesel** engine
- Natural and renewable resources
  - New and used vegetable oils and animal fats
- Burn more cleanly and more efficiently than traditional diesel

Garbage Power

- 140 U.S. power plants use garbage as fuel source
  - Hennepin Energy Resource Company in Minneapolis converts 365,000 tons of garbage per year into enough energy to provide power to 25,000 homes
  - One truckload of solid waste generates the same amount of energy as 21 barrels of oil
  - They've since built a second facility that processes another 235,000 tons
- Simultaneously addresses two major problems: Energy and Waste
- Downside? Incineration process is efficient but produces CO_2

Garbage Power

- Methane Generators
  - Animal and vegetable wastes are fermented to form “biogas”
    - 60% methane
    - Can be used for cooking, heating, lighting, refrigeration, electrical generation
    - The manure from 2 cows provides enough energy to support a farm family
  - Prevalent in China and India. In China, 2/3 of rural families use biogas as their primary fuel