

# Environmental Science A Study of Interrelationships

Twelfth Edition

Enger & Smith

## Chapter 9

### Energy Sources

# Energy Sources

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# Outline

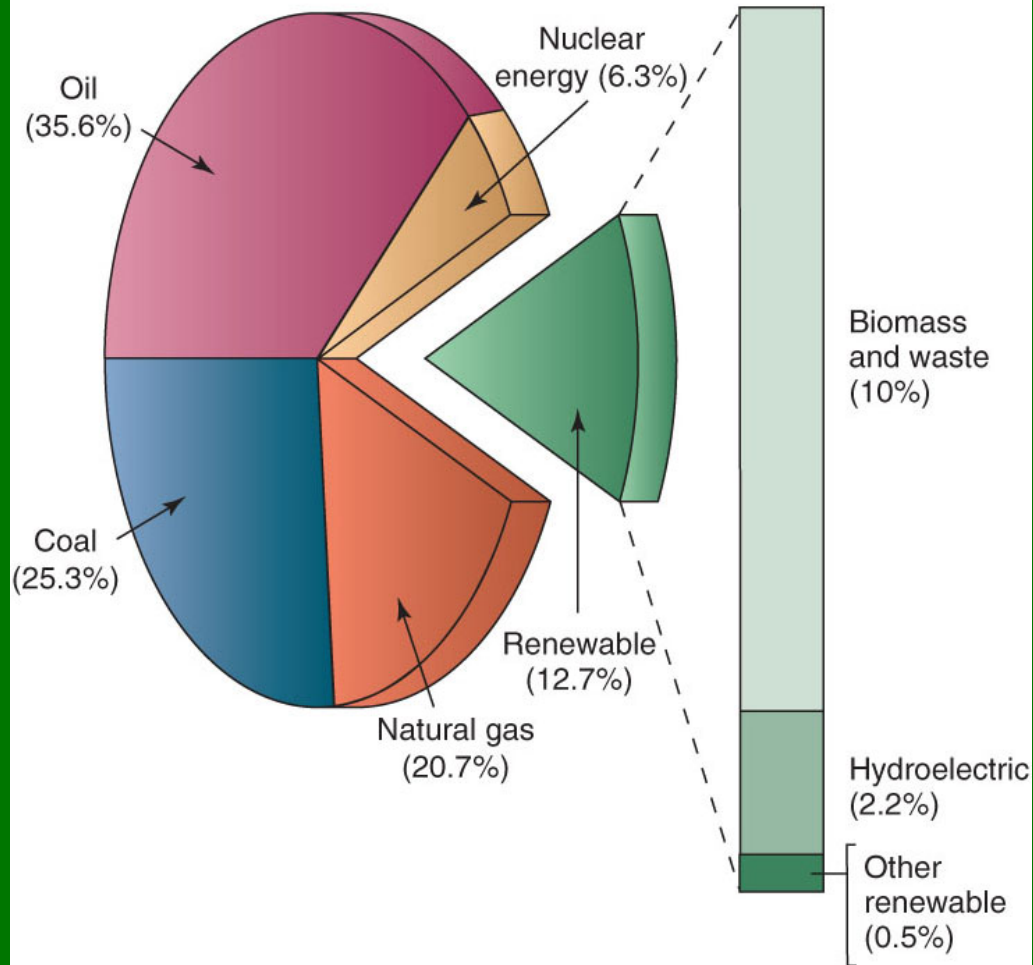
- Energy Sources
- Resources and Reserves
- Fossil-Fuel Formation
- Issues Related to the Use of Fossil Fuels
- Renewable Sources of Energy
- Energy Conservation
- Are Fuel Cells in the Future?

# Energy Sources

- **Nonrenewable energy sources** are those whose resources are being used faster than can be replenished.
  - Coal, oil, and natural gas
- **Renewable energy sources** replenish themselves or are continuously present as a feature of the environment.
  - Solar, geothermal, tidal, etc.
  - Some forms are referred to as perpetual energy.

# Energy Sources

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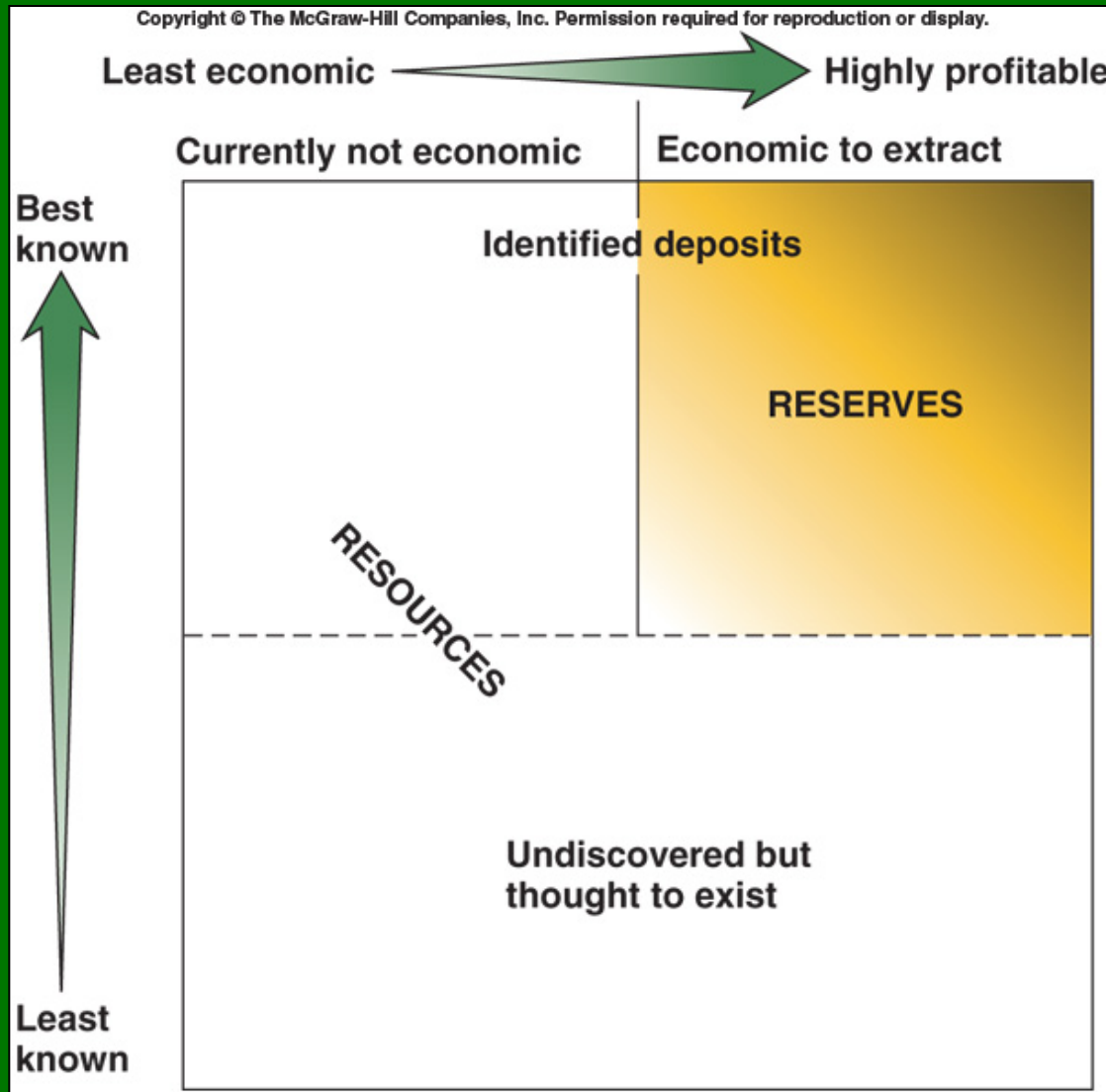
Data from International Energy Agency, 2007.

All energy sources

# Resources and Reserves

- A **resource** is a naturally occurring substance of use to humans that can potentially be extracted using current technology.
- A **reserve** is a known deposit that can be economically extracted using current technology, under certain economic conditions.
- Reserves are smaller than resources.
- Reserve levels change as technology advances, new discoveries are made, and economic conditions vary.

# Resources and Reserves



# Fossil Fuel Formation

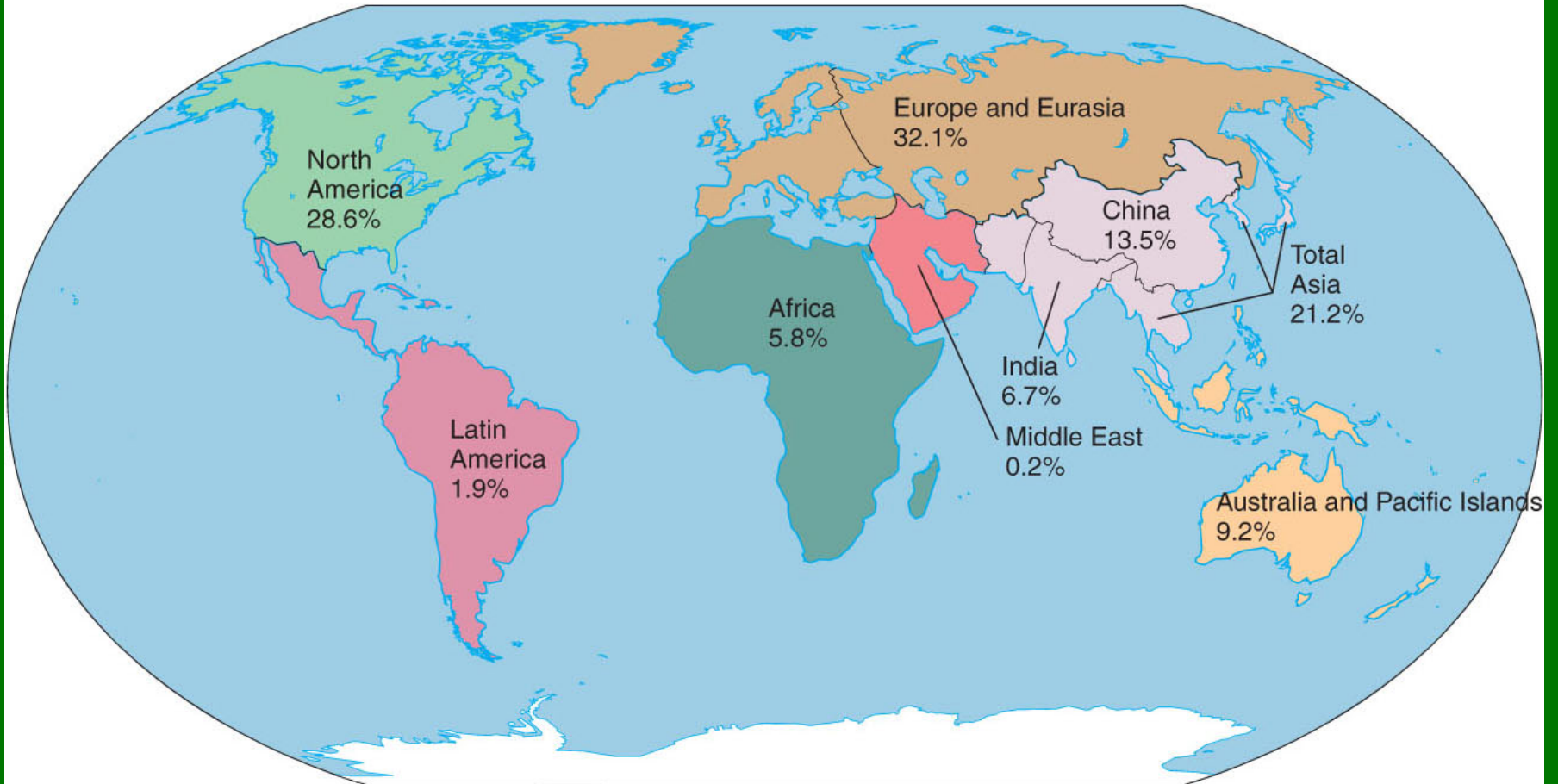
## ■ Coal

- 300 million years ago, plant material began collecting underwater, initiating decay, forming a spongy mass of organic material.
- Due to geological changes, some of these deposits were covered by seas, and covered with sediment.
- Pressure and heat over time transformed the organic matter into coal.



# Fossil Fuel Formation

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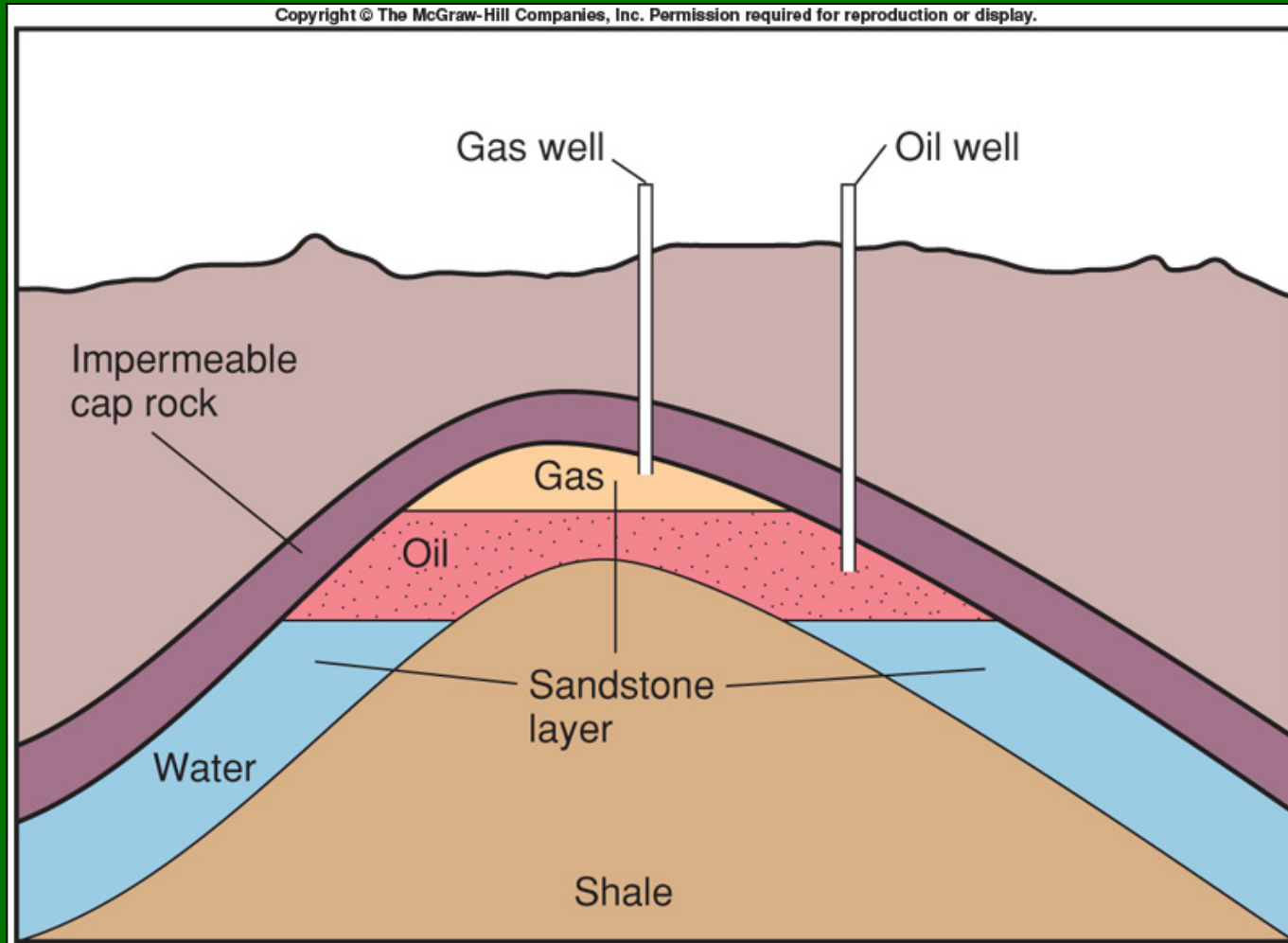
Source: Data from *BP Statistical Review of World Energy*, 2008.

Recoverable coal reserves of the world 2004

# Fossil Fuel Formation

- Oil and natural gas probably originated from microscopic marine organisms that accumulated on the ocean floor and were covered by sediments.
  - Muddy rock gradually formed shale containing dispersed oil.
  - Natural gas often forms on top of oil.

# Fossil Fuel Formation



Crude oil and natural gas pool

# Issues Related to the Use of Fossil Fuels

- Fossil fuels supply 80% of world's commercial energy.
  - Oil 36%
  - Coal 25%
  - Natural Gas 19%

# Issues Related to the Use of Fossil Fuels

- Coal is most abundant fossil fuel.
  - Primarily used for generating electricity.
- There are four categories of coal: Lignite, Sub-bituminous, Bituminous, and Anthracite.
  - Lignite
    - High moisture, low energy, crumbly, least desirable form.
  - Sub-bituminous
    - Lower moisture, higher carbon than lignite.
    - Used as fuel for power plants.

# Issues Related to the Use of Fossil Fuels

- Bituminous
  - Low moisture, high carbon content
  - Used in power plants and other industry such as steel making.
  - Most widely used because it is easiest to mine and the most abundant, supplying 20% of the world's energy requirements.
- Anthracite
  - Has the highest carbon content, and is relatively rare.
  - It is used primarily in heating buildings and for specialty uses.

# Issues Related to the Use of Fossil Fuels

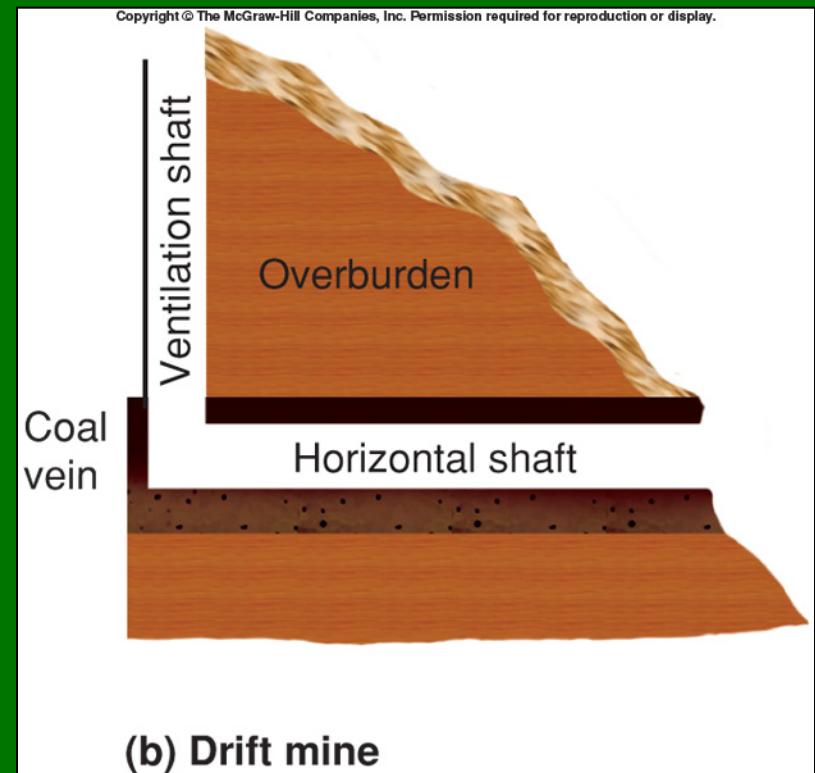
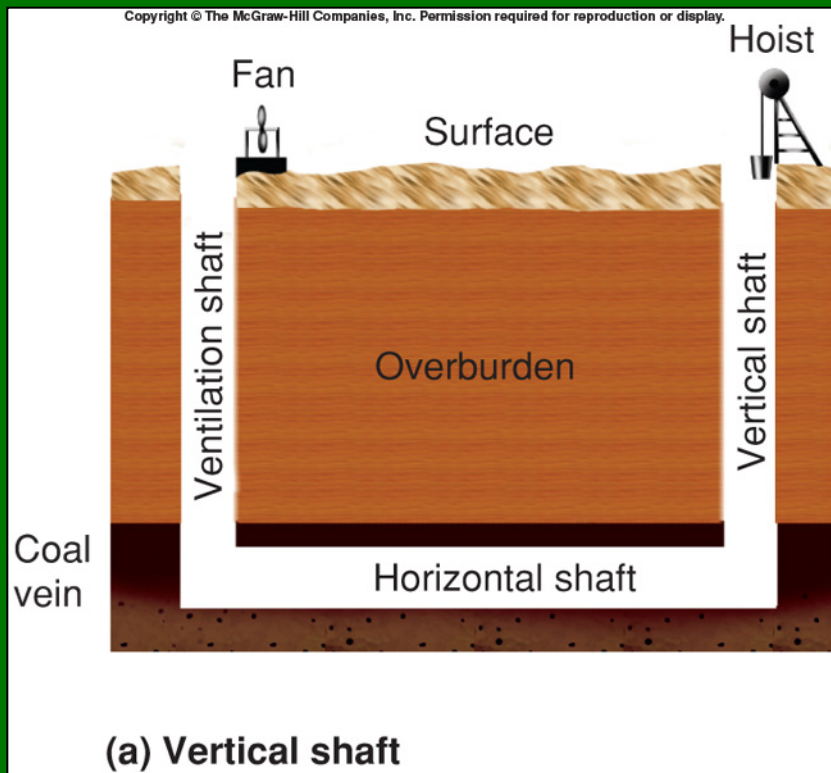
- There are two extraction methods:
  - **Surface mining (strip mining)**, which is the process of removing material on top of a vein, is efficient but destructive.
  - **Underground mining** minimizes surface disturbance, but is costly and dangerous.
    - Many miners suffer from black lung disease, a respiratory condition that results from the accumulation of fine coal-dust particles in the miners' lungs.

# Issues Related to the Use of Fossil Fuels

- Coal is bulky and causes some transport problems.
- Mining creates dust pollution.
- Burning coal releases pollutants (carbon and sulfur).
  - Millions of tons of material are released into atmosphere annually.
  - Sulfur leads to **acid mine drainage** and acid deposition.
  - Increased amounts of atmospheric carbon dioxide are implicated in global warming.



# Issues Related to the Use of Fossil Fuels



Underground mining

# Issues Related to the Use of Fossil Fuels

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**(a) Unreclaimed stripmine**



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**(b) Reclaimed stripmine**

Surface-mine reclamation

# Issues Related to the Use of Fossil Fuels

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U.S. Geological Survey

Acid mine drainage

# Issues Related to the Use of Fossil Fuels

- Oil is more concentrated than coal, burns cleaner, and is easily transported through pipelines.
  - These qualities make it ideal for automobile use.
  - It is difficult to find.
  - It causes less environmental damage than coal mining.

# Issues Related to the Use of Fossil Fuels

- Once a source of oil has been located, it must be extracted and transported to the surface.
- Primary Recovery methods
  - If water or gas pressure associated with the oil is great enough, the oil is forced to the surface when a well is drilled.
  - If water and gas pressure is low, the oil is pumped to the surface.
  - 5–30% of the oil is extracted depending on viscosity and geological characteristics.

# Issues Related to the Use of Fossil Fuels

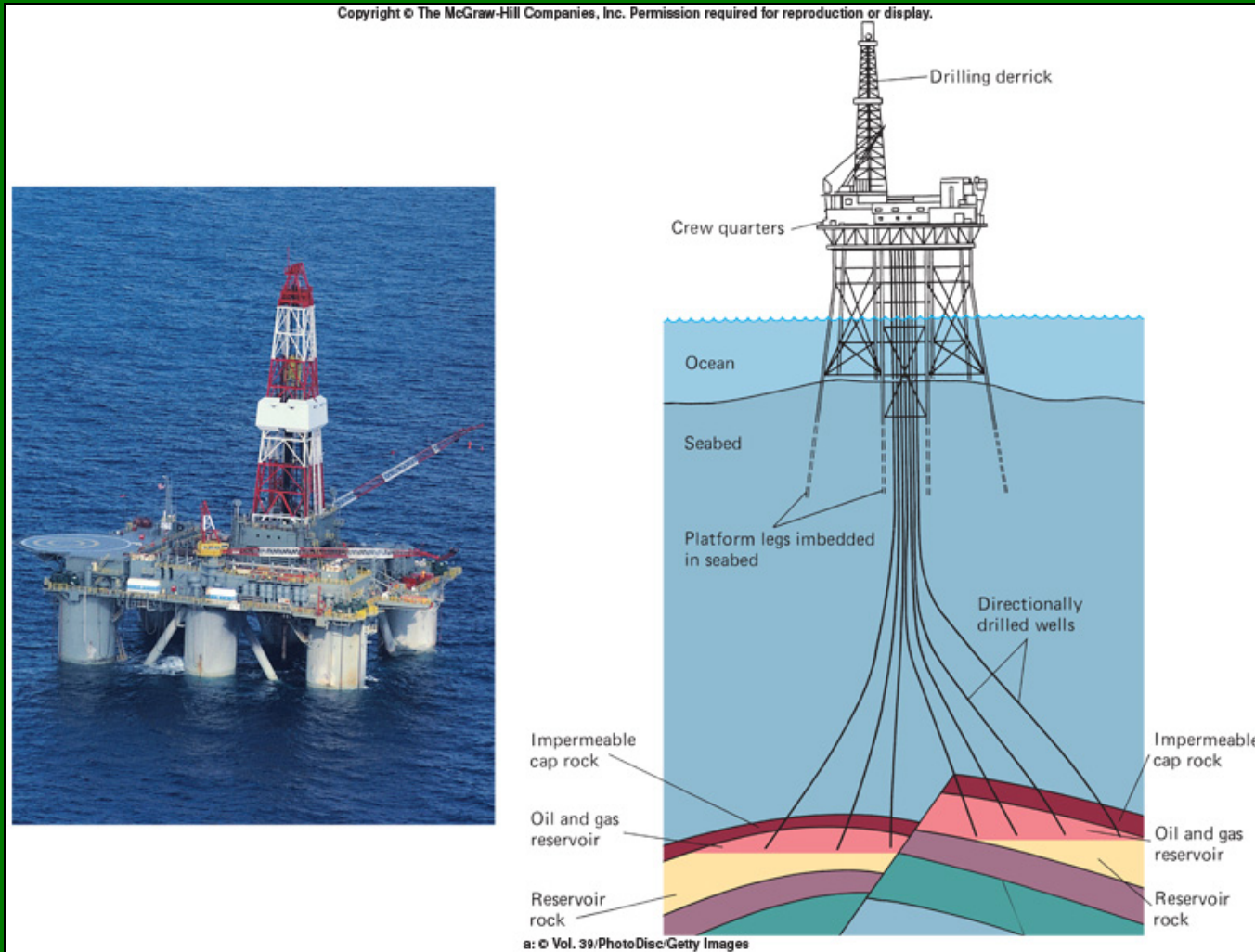
## ■ Secondary Recovery

- Water or gas is pumped into a well to drive the oil out of the pores in the rock.
- This technique allows up to 40% of the oil to be extracted.

## ■ Tertiary Recovery

- Steam is pumped into a well to lower the viscosity of the oil.
- Aggressive pumping of gas or chemicals can be pumped into a well.
- These methods are expensive and only used with high oil prices.

# Issues Related to the Use of Fossil Fuels



# Issues Related to the Use of Fossil Fuels

## ■ Processing

- As it comes from the ground, oil is not in a form suitable for use, and must be refined.
- Multiple products can be produced from a single barrel of crude oil.

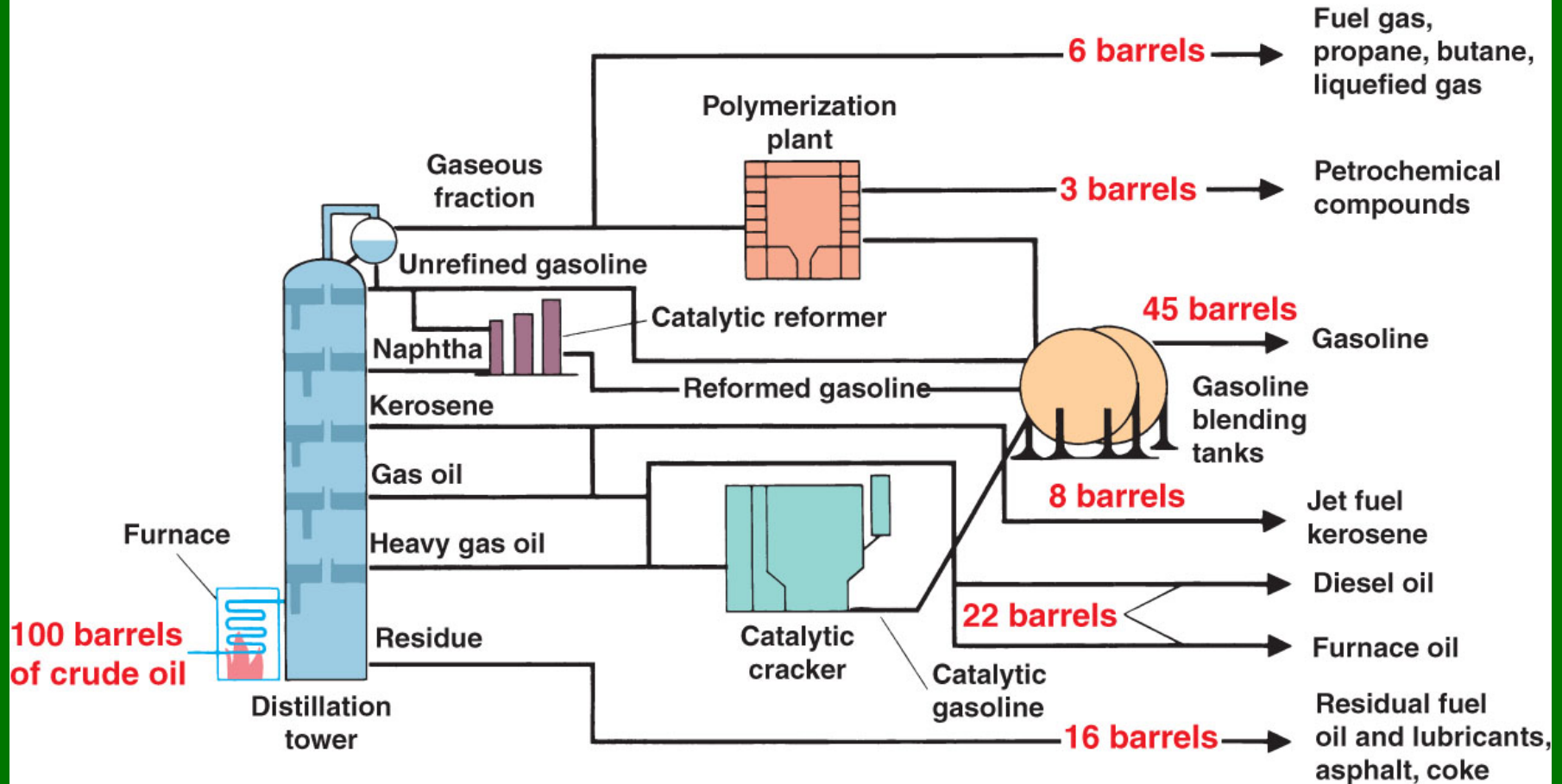
## ■ Oil Spills

- Accidental spills only account for about 1/3 of oil pollution resulting from shipping.
- 60% comes from routine shipping operations.



# Issues Related to the Use of Fossil Fuels

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Processing crude oil

# Issues Related to the Use of Fossil Fuels

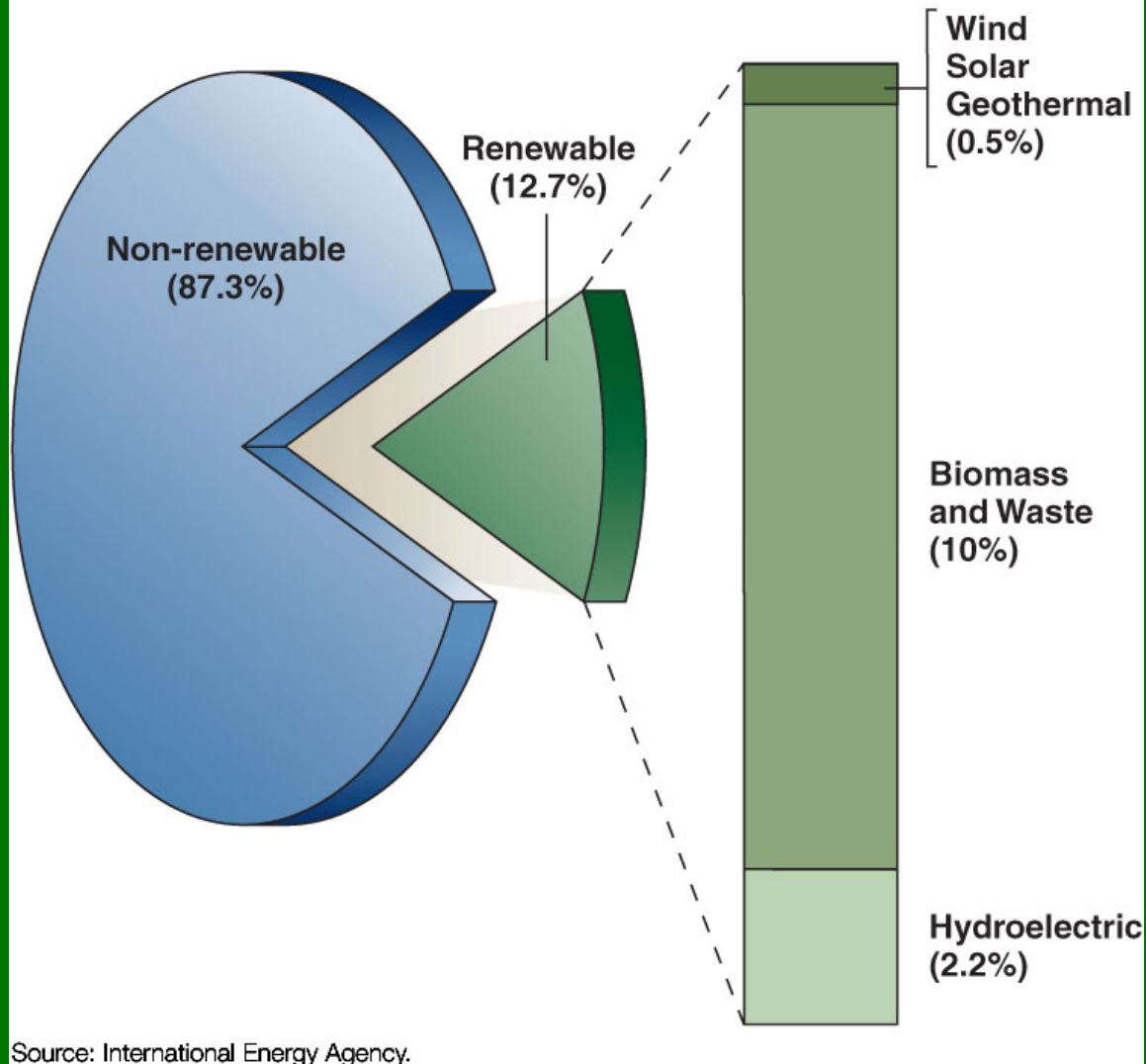
- The drilling operations to obtain natural gas are similar to those used for oil.
- It is hard to transport and in many places is burned off at oil fields, but new transportation methods are being developed.
  - Liquefaction at  $-126^{\circ}$  F (1/600 volume of gas)
  - The public is concerned about the safety of LNG loading facilities so they are located off shore.
- It is the least environmentally damaging fossil fuel.
  - It causes almost no air pollution.

# Renewable Sources of Energy

- Currently, alternative energy sources supply almost 13.5% of the world's total energy.
  - Some studies suggest these sources could provide half of the world's energy needs by 2050.
  - Renewable sources will become much more important as fossil fuel supplies become more expensive.
    - Biomass conversion
    - Hydroelectric power
    - Solar energy
    - Wind energy
    - Geothermal energy
    - Tidal power

# Renewable Sources of Energy

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Source: International Energy Agency.

Renewable energy as a share of total energy consumption (World 2006)

# Renewable Sources of Energy

## ■ Biomass Conversion

- All biomass is produced by green plants that convert sunlight into plant material through photosynthesis.
- Biomass is still the predominant form of energy used by people in less-developed countries.
- It accounts for 10% of world energy use.

# Renewable Sources of Energy

- There are several sources of biomass energy:
  - Fuel wood
  - Municipal and industrial wastes
  - Agricultural crop residues and animal wastes
  - Energy plantations

# Renewable Sources of Energy

- In less-developed countries, fuel wood has been a major energy source for centuries.
- Fuel wood is the primary energy source for nearly half the world's population.
- Due to intense population growth, an estimated 1.3 billion people cannot get enough fuel wood, or are using it faster than rate of regeneration.
- It is a source of air pollution and particulate matter.

# Renewable Sources of Energy

- Solid waste is a major source of biomass and other burnable materials produced by society.
- The burning of solid waste only makes economic sense when the cost of waste disposal is taken into account.
- Using municipal waste as a source of energy:
  - Reduces landfill volume.
  - Requires large volume and dependable supply, and must be sorted.
  - Produces air pollution, including pollutants not found in other forms of biomass.



# Renewable Sources of Energy

- Crop residues and animal wastes:
  - Materials left over following the harvest of a crop (e.g., straw and stalks) can be used as biomass fuel.
  - Animal dung is dried and burned or processed in anaerobic digesters to provide a burnable gas.

# Renewable Sources of Energy

- Energy plantations:
  - Many crops, including sugar beets, sugar cane, corn, grains, kelp, and palm oil can be grown for the express purpose of energy production.
  - Two factors determine whether a crop is suitable for energy use:
    - Good energy crops have a very high yield of dry material per unit of land.
    - The amount of energy that can be produced from a biomass crop must be more than the amount of energy required to grow a crop.

# Renewable Sources of Energy

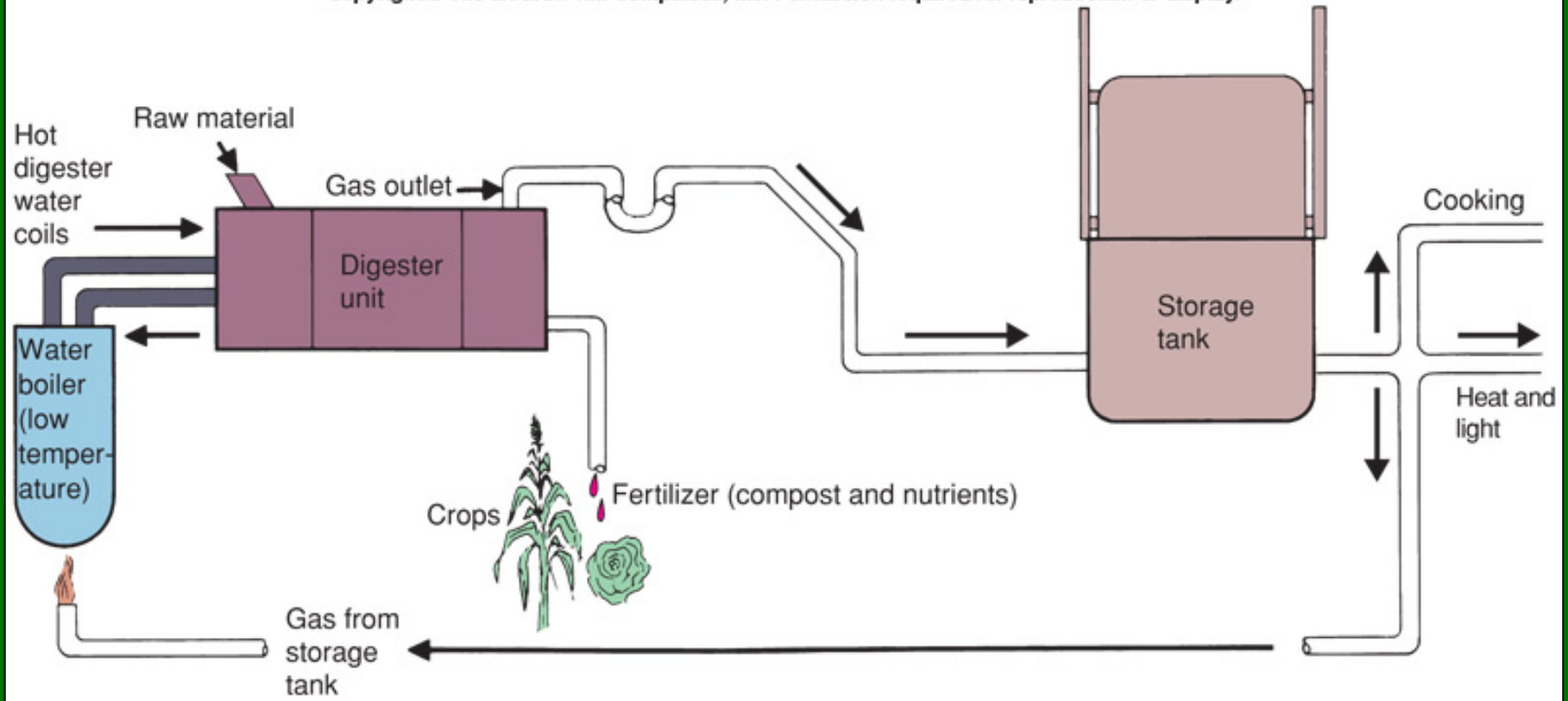
- There are several technologies capable of converting biomass into energy.
  - **Direct combustion**
    - Burning biomass in fires to cook food or heat homes.
  - **Biofuels production**
    - Fermentation converts plant sugars to ethanol, which is used as an energy source.
  - **Anaerobic digestion**
    - Green, wet biomass and animal waste is broken down by anaerobic bacteria, producing methane and CO<sub>2</sub>.
  - **Pyrolysis**
    - A thermo chemical process that converts biomass to a more useful fuel such as charcoal.

# Renewable Sources of Energy

- Environmental impact of biomass
- Habitat and biodiversity loss
  - 1.3 billion people cannot obtain wood, or harvest it faster than it grows.
  - Much forest has been destroyed in Asia and Africa.
  - Desertification has increased in these regions.
- Air pollution
  - Burning wood produces air pollution.
  - Smoke, particulates, carbon monoxide, and hydrocarbons contribute to ill health.

# Renewable Sources of Energy

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Methane digester

# Renewable Sources of Energy

- **Hydroelectric power** is created when flowing water is captured and turned into electricity.
  - Damming a river and storing water in a reservoir is the most common method.
  - Pumped storage plants use two reservoirs separated by a significant elevation difference.
  - The potential for developing hydroelectric power is best in mountainous regions and large river valleys.
  - The World Energy Council estimates that it would be technically possible to triple the electricity produced by hydropower with current technology.

# Renewable Sources of Energy

- Hydroelectric power currently supplies 16% of world's electricity.
  - In South and Central America, 65% of electricity used comes from hydroelectric power.
  - Norway gets 99% of its electricity and 65% of all its energy from hydroelectric power.
  - Construction of “mini hydro” (less than 10 megawatts) and “micro hydro” (less than 1 megawatt) plants is increasing; these plants can be built in remote places and supply electricity to small areas.

# Renewable Sources of Energy

- Reservoir construction causes significant environmental and social damage.
  - Loss of farmland or forest land due to flooding
  - Community relocation
  - Prevention of fish migrations
  - Trapping of silt fills in reservoir and stops flow of nutrients downstream
  - Mercury accumulation

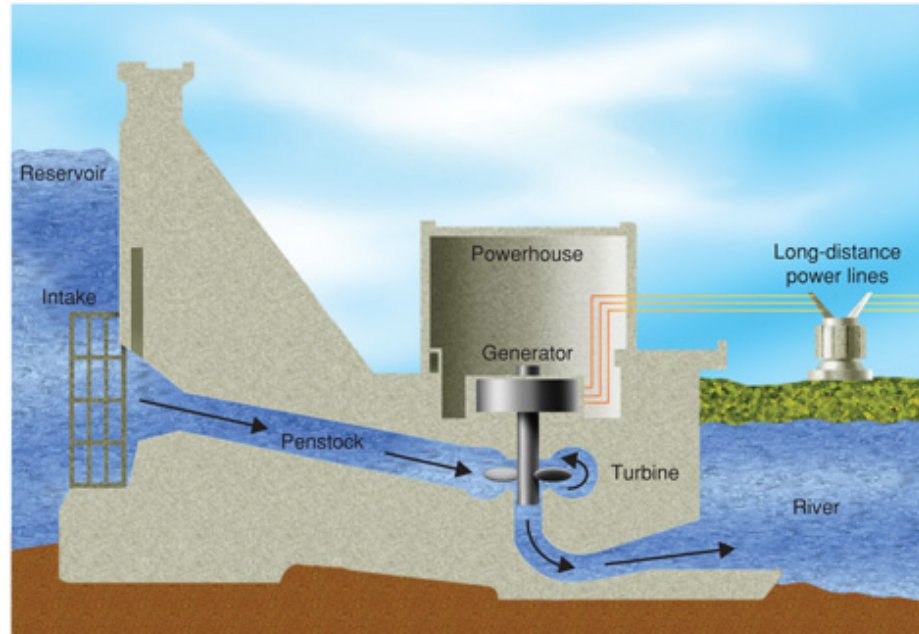


# Renewable Sources of Energy

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(a) Glen Canyon Dam



(b)

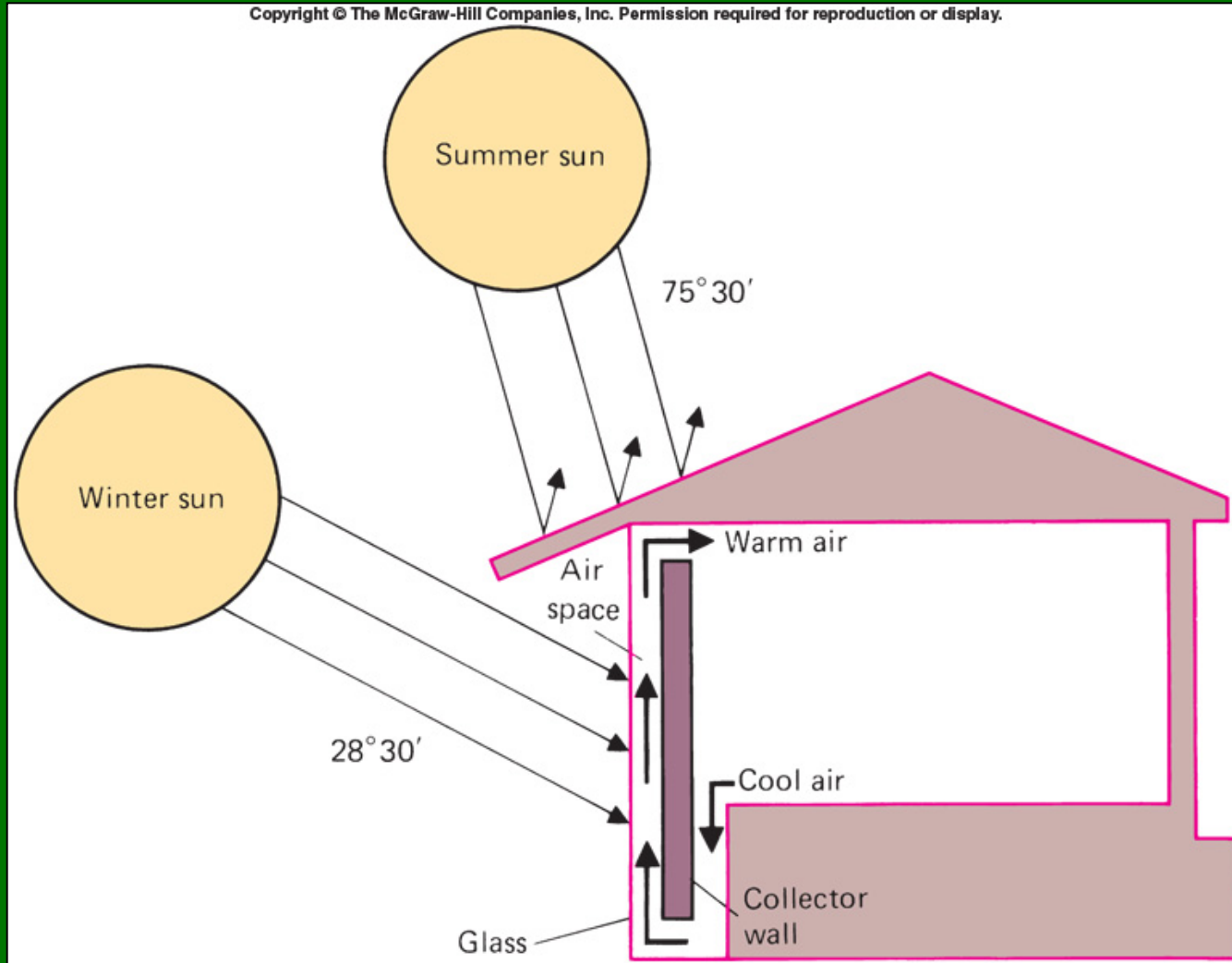
a: © Corbis Royalty Free

Hydroelectric power plant.

# Renewable Sources of Energy

- Daily energy from the sun is 600 times greater than energy produced each day by all other energy sources combined.
  - The major problems with solar energy are its intermittent and diffuse nature.
- Solar energy is utilized in three ways:
  - In passive heating, the sun's energy is converted directly to heat and used at collection site.
  - In an active heating system, the sun's energy is converted into heat, but transported elsewhere to be used.
  - Solar energy is also transformed into electrical energy.

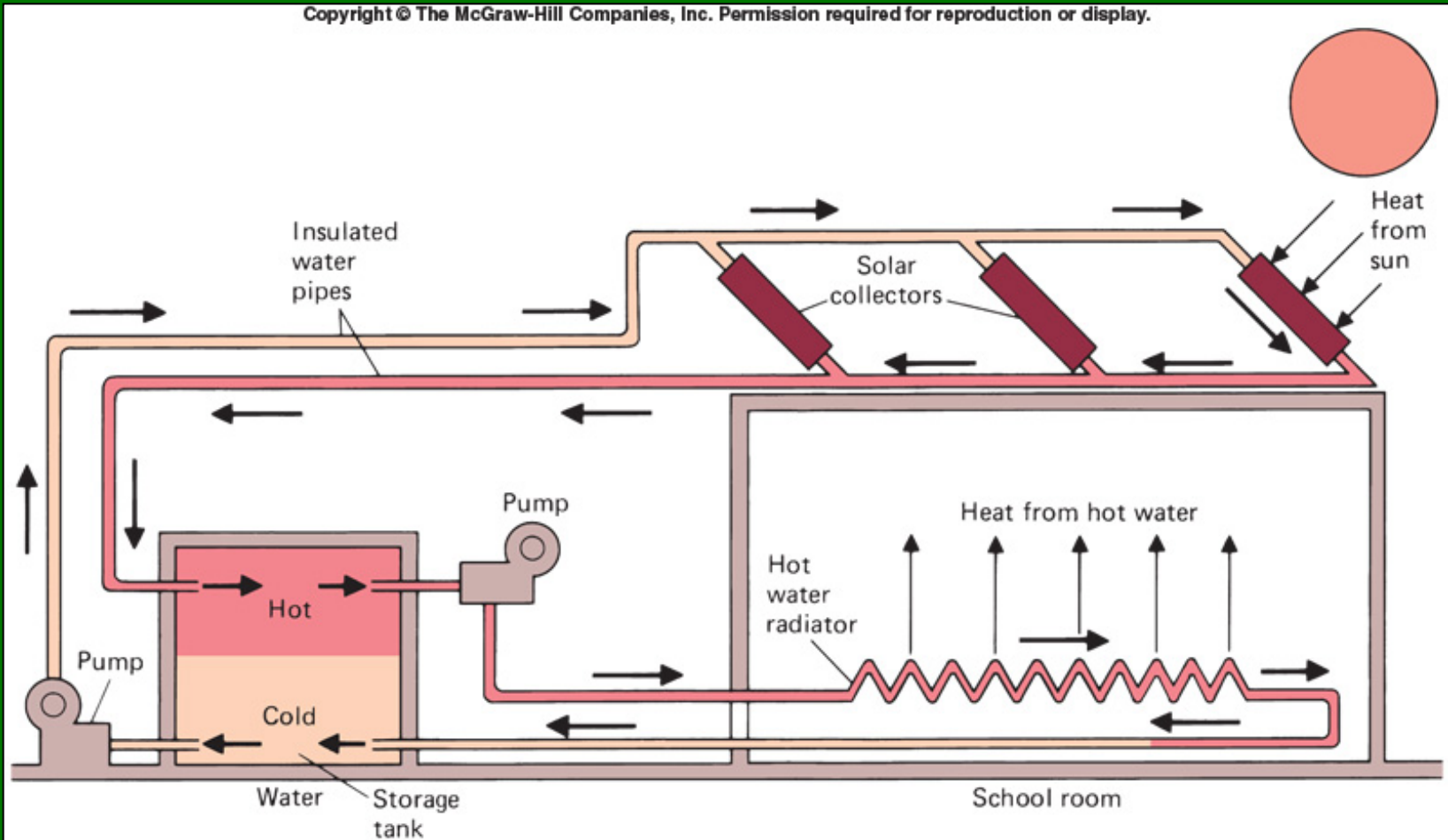
# Renewable Sources of Energy



Passive solar heating

# Renewable Sources of Energy

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Solar heating designs

# Renewable Sources of Energy

- In a passive solar system, light energy is transformed to heat energy when it is absorbed by a surface.
- Buildings designed for passive solar heating in the Northern Hemisphere usually have large, south-facing windows.
- Floors and walls, made of materials that absorb and store the sun's heat during the day, slowly release heat at night when it is needed most. This feature is called **direct gain**.

# Renewable Sources of Energy

- Solar energy can generate electricity in two different ways.
  - Steam can be created to drive a turbine.
  - Photovoltaic cells can generate electricity directly.
  - Currently the most successful design is the parabolic trough which heats oil in pipes. The heat is transferred to water to make steam and run a turbine.
  - The Nevada Solar One plant which opened in 2007 is currently the world's largest solar generation facility in the world.
  - Several plants are under construction in Spain.

# Renewable Sources of Energy

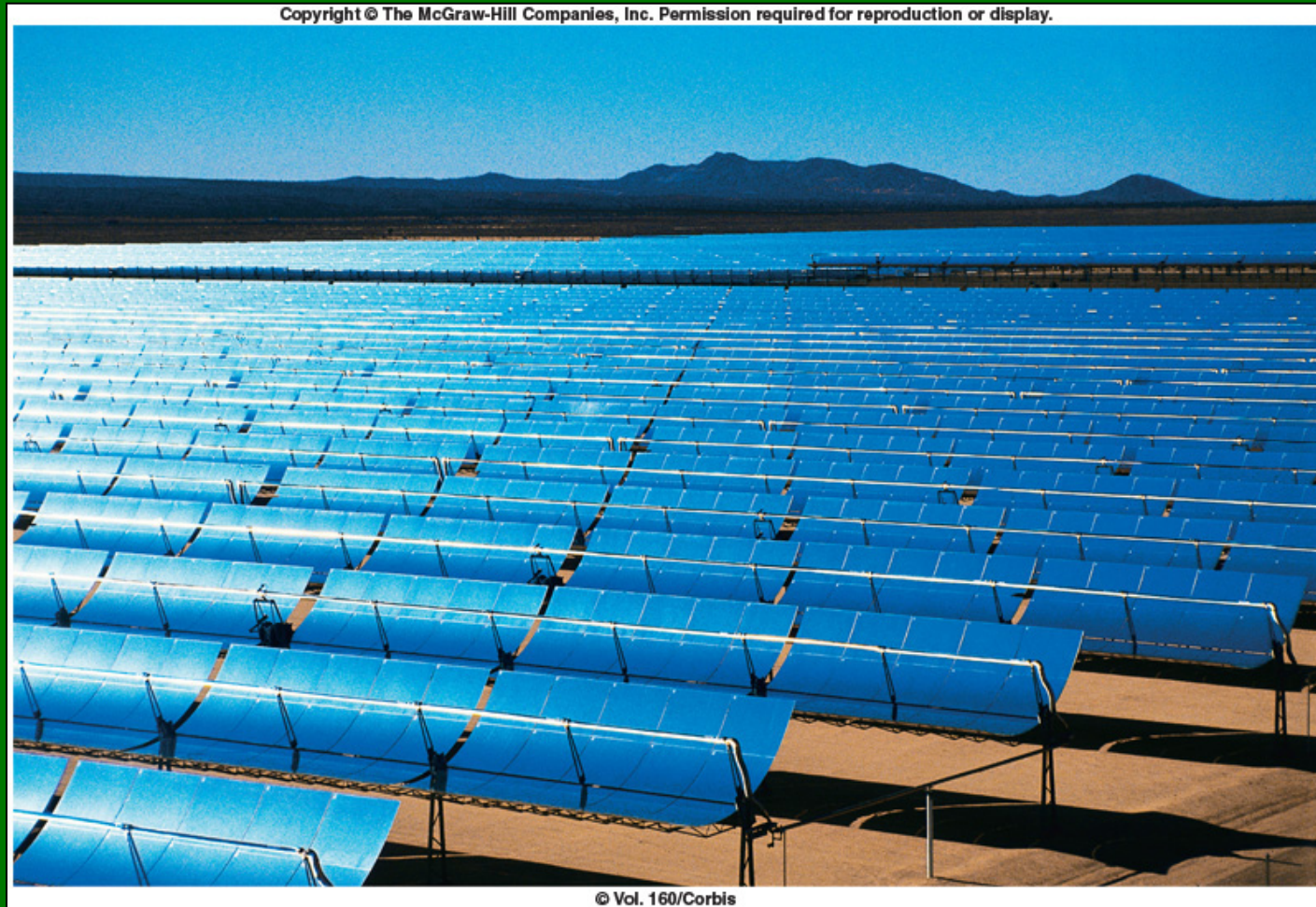
- A photovoltaic cell (PV) is a solid-state semiconductor that converts sunlight directly into electricity.
- The amount of PV power installed worldwide has increased from 314 megawatts in 1997 to 5700 megawatts in 2006.
- Thin-film technology has made it possible to build solar cells into roof shingles and tiles, building facades, and the glazing for skylights and atria.

# Renewable Sources of Energy

- Improving solar cell efficiency while holding down the cost per cell is an important goal of the growing PV industry.
  - Solar electricity is 20 cents per kilowatt-hour, more than electricity from the power plant.
- Photovoltaics are probably the most benign method of power generation known.
- They are silent, produce no emissions, and use no fuel other than sunlight, but thermal systems use large amounts of land to position the mirrors.



# Renewable Sources of Energy



Solar generation of electricity

# Renewable Sources of Energy



Photovoltaic shingles

# Renewable Sources of Energy

## ■ Tidal Power

- The gravitational forces of the moon and sun cause ocean water to bulge out. Tides form as the Earth rotates through this bulge.
- As water flows from a higher level to a lower level, it can be used to spin an electricity-generating turbine.
- Since tidal changes of roughly 16 feet are needed to produce practical amounts of power, suitable sites are limited.
- A new style, submerged turbine tidal generator is being developed in the Philippines.

# Renewable Sources of Energy

## ■ Geothermal Power

- In geologically active areas hot magma moves to the surface and heats water.
  - The hot water can heat buildings or generate electricity through a steam turbine.
- Wells are drilled to obtain steam trapped underground, and the steam powers electrical generators.
- The U.S. produces 30% of world's geothermal electricity, with the world's largest plant in San Francisco.
- However, this accounts for less than 1% of U.S. electrical consumption.

# Renewable Sources of Energy

- Heat pumps can be used in areas that are not geologically active.
- The pump extracts heat from the Earth, and deposits it in a building.
- Environmental Issues
  - Steam contains hydrogen sulfide gas.
    - It smells like rotten eggs.
    - Minerals in the steam corrode pipes and equipment.
    - The minerals are toxic to fish.

# Renewable Sources of Energy



Geothermal power plant

# Renewable Sources of Energy

## ■ Wind Power

- As warm air becomes less dense and rises, cooler, denser, air flows in to take its place. This flow of air is wind.
- Wind has ground grain and pumped water. Now is it used to generate electricity.
- Some areas are better suited than others, and winds are variable. Wind energy must be coupled with other sources of energy.
- Only 0.5% of total worldwide electrical production is from wind.
- Only 1% of U.S. electricity is from wind. 20% could be generated by 2030.

# Renewable Sources of Energy

- There are some negative effects from wind generators:
  - The moving blades produce noise and some consider the windmills visual pollution.
  - Moving blades are hazardous to birds, although newer windmills have slower-moving rotors that many birds find easier to avoid.
  - Vibrations from generators can cause structural damage.



# Energy Conservation

- Conservation is not a way of generating electricity, but a way of reducing need for additional energy production/consumption and saving money for the consumer.
- Much of the energy we consume is wasted.
  - The amount of energy wasted through poorly insulated windows and doors alone is about as much energy as the U.S. receives from the Alaskan pipeline each year.
- Electrical utilities have recently become part of the energy conservation picture.

# Energy Conservation

- Many conservation techniques are relatively simple and highly cost-effective.
  - Highly efficient fluorescent light bulbs give the same amount of light as incandescent bulbs for 25% of the energy, and produce less heat.
  - Lighting and air conditioning (removing the heat from inefficient incandescent lighting) account for 25% of U.S. electricity consumption.
  - Automatic dimming or light-shutoff devices are being used in new construction.

# Are Fuel Cells in the Future?

- Hydrogen is abundant and generates heat and pure water when it reacts with air.
- Hydrogen fuel cells are beginning to rise in popularity due to their high efficiency and low emissions.
  - They do not need to be recharged, unlike batteries.
  - They run continuously if provided with adequate fuel input—anything from which hydrogen can be extracted.

# Are Fuel Cells in the Future?

- The most common form is the proton exchange membrane (PEM) fuel cell.
  - Pressurized hydrogen gas enters the fuel cell and contacts a catalyst that causes the hydrogen molecules to split into hydrogen ions and electrons.
  - A proton exchange membrane allows the hydrogen ions, but not electrons, to flow through it.
  - The electrons flow through an electric circuit to do work, such as powering motors or generating lights.
  - The hydrogen ions flow through the membrane and recombine with electrons that have passed through the circuit and with oxygen to form water.

# Are Fuel Cells in the Future?

- Obstacles delaying the development of fuel cells include:
  - Hydrogen used to power the cell is difficult to obtain in a pure state.
  - Hydrogen gas is highly flammable, difficult to store, and not available to consumers as readily as oil-derived fuels.
  - Fuel reformation results in impure hydrogen, decreasing fuel cell efficiency; it also releases carbon dioxide, nitrous oxide, and particulate matter.

# Are Fuel Cells in the Future?

- Advantages of fuel cells include:
  - Low operating temperature and minimal noise generation make them safe to install in semi-exposed areas.
  - Cells are self-sustaining, making them ideal for remote locations.
  - They operate separately from power lines associated with electrical distribution systems, so weather-related power outages are diminished.
  - They are nonpolluting.

# Are Fuel Cells in the Future?

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Courtesy DaimlerChrysler AG, Stuttgart

Experimental fuel cell bus

# Summary

- Resources are naturally occurring substances of use to humans.
- Reserves are known deposits from which materials can be extracted profitably with existing technology under present economic conditions.
- Coal is the world's most abundant fossil fuel.
- The supply of oil is limited.
- Natural gas is another major source of fossil-fuel energy, but transport of natural gas to consumers is problematic.



# Summary

- Fossil fuels are nonrenewable.
- Fuel wood is the major source of energy in less-developed countries.
- Biomass can be burned to provide heat or electricity, or can be converted to alcohol or used to generate methane.
- Hydroelectric power can be increased significantly but may displace people.
- Solar energy can be collected and used in either passive or active systems and can also generate electricity.

# Summary

- Geothermal and tidal applications are limited by geographic locations.
- Wind power may be used to generate electricity but requires wide, open areas and a large number of wind generators.
- Energy conservation can reduce energy demands without noticeably changing standards of living.