Alternative Fuels

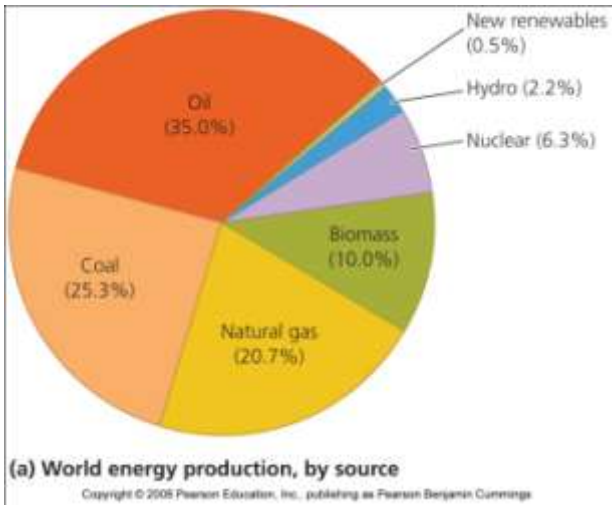
Reduce our dependence on the fossil fuels.

News Article

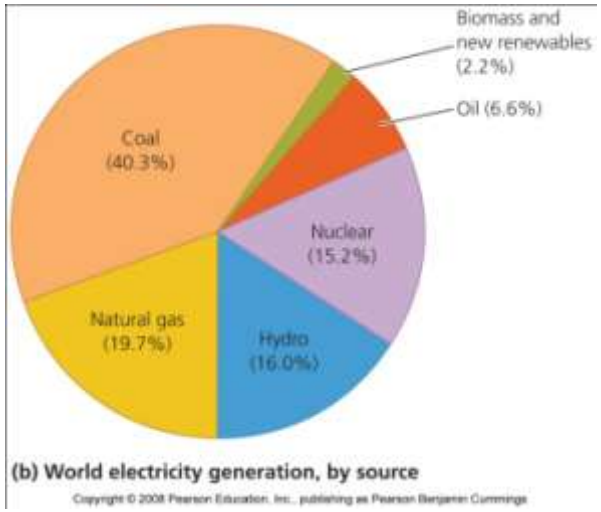
- http://news.nationalgeographic.com/news/2009/09/090904-farm-energy.html

Alternatives to Fossil Fuels

- 80% of our energy comes from oil, coal, and natural gas
  - These three fuels also power two-thirds of the world's electricity generation
- Given fossil fuel's substantial drawbacks, many people believe we need to shift to using less easily depleted and environmentally gentler fuels



(a) World energy production, by source



(b) World electricity generation, by source

Video Clip

- ABC news clip, “The Rising Gallon”
- What are the reasons why we need to find an alternative fuel according to this news clip?
  - Economic
  - Political
  - Geological (supply)

The Rising Gallon

Conventional alternatives

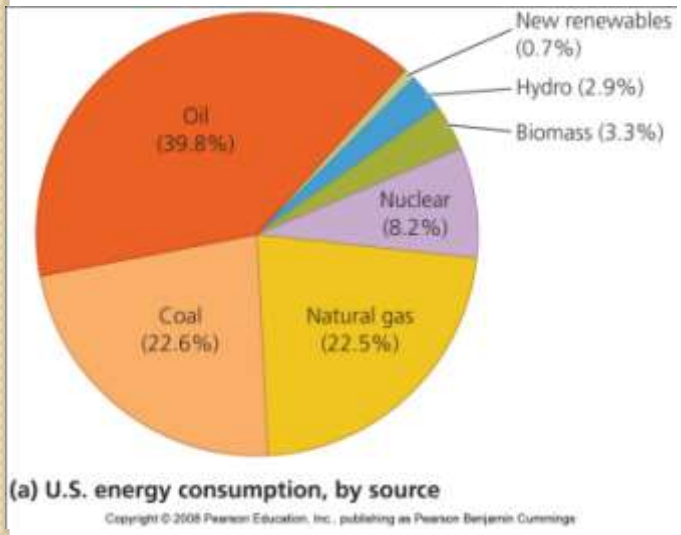
- Three alternative energy sources are currently the most developed and most widely used: nuclear energy, hydroelectric power, and energy from biomass
- These are all “conventional alternatives” to fossil fuels
  - They exert less environmental impact
  - Each has benefits and drawbacks
  - These are best viewed as intermediates along a continuum of renewability

Conventional alternatives provide energy

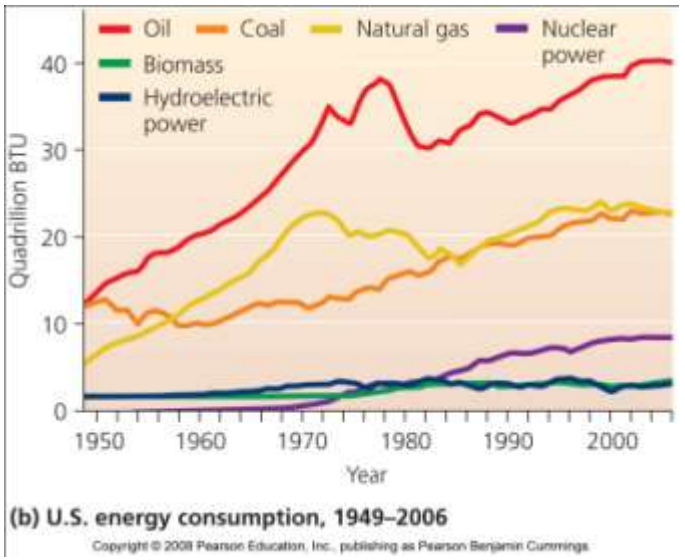
- Fuelwood and other biomass sources provide 10% of the world's energy, nuclear power provides 6.3%, and hydropower provides 2.2%
- Nuclear energy and hydropower each account for nearly one-sixth of the world's electricity generation

The U.S. relies on fossil fuels

- The U.S. relies more on fossil fuels and nuclear power than other countries
  - Conventional alternatives play minor, yet substantial roles, in energy use
  - The use of conventional alternatives has been growing more slowly than fossil fuels



(a) U.S. energy consumption, by source



(b) U.S. energy consumption, 1949–2006

Biomass energy

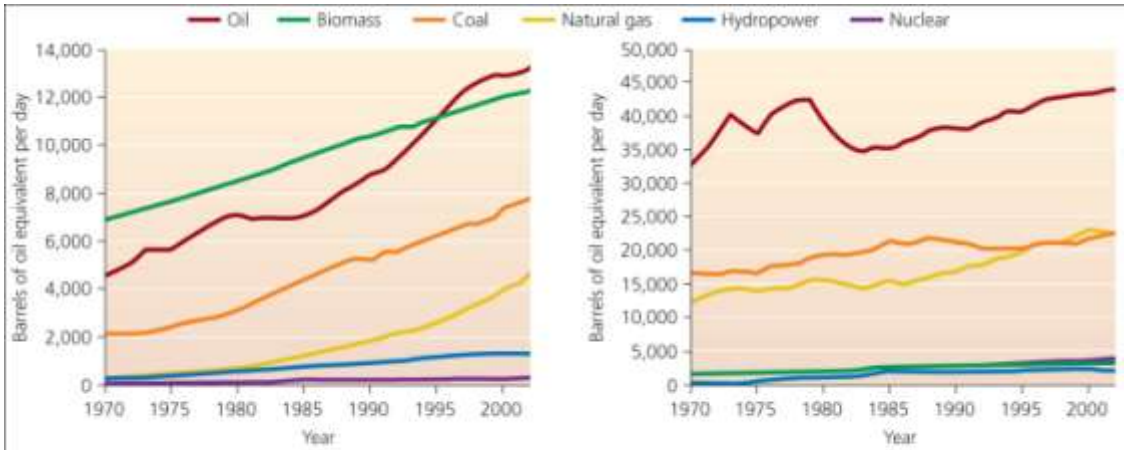
- Biomass energy has great potential for addressing our energy challenges
- **Biomass** = organic material that makes up living organisms
- People harness biomass energy from many types of plant matter
  - Wood from trees, charcoal from burned wood, and matter from agricultural crops, as well as combustible animal waste products

Biomass sources are widely used

- More than 1 billion people use wood from trees as their principal energy source
- In developing nations, families gather fuelwood for heating, cooking, and lighting
- Fuelwood, charcoal, and manure account for 35% of energy use
- Fuelwood and other biomass sources constitute 80% of all renewable energy used worldwide

Biomass can be overharvested

- Biomass is only renewable when it is not overharvested
  - With rapid deforestation, soil erosion, and forest failures to regrow, biomass is not replenished
- As developing nations industrialize, fossil fuels are replacing traditional energy sources
- Biomass use is growing more slowly than overall energy use



(a) Energy consumption in developing nations

(b) Energy consumption in industrialized nations

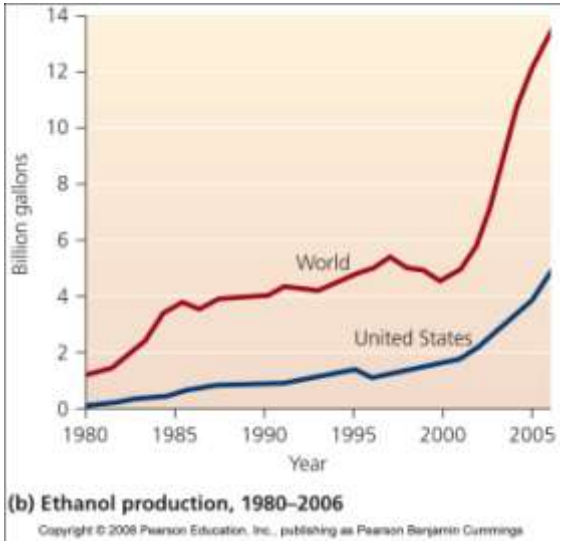
New biomass strategies

- Biomass sources include a variety of materials
- **Biopower** = produced when biomass sources are burned in power plants, generating heat and electricity
- **Biofuels** = biomass sources converted into fuels to power automobiles

Biofuels can power automobiles

- Ethanol = produces as a biofuel by fermenting carbohydrate-rich crops
  - Ethanol is widely added to U.S. gasoline to reduce emissions
  - Any vehicle will run well on a 10% ethanol mix

(a) Corn grown for ethanol



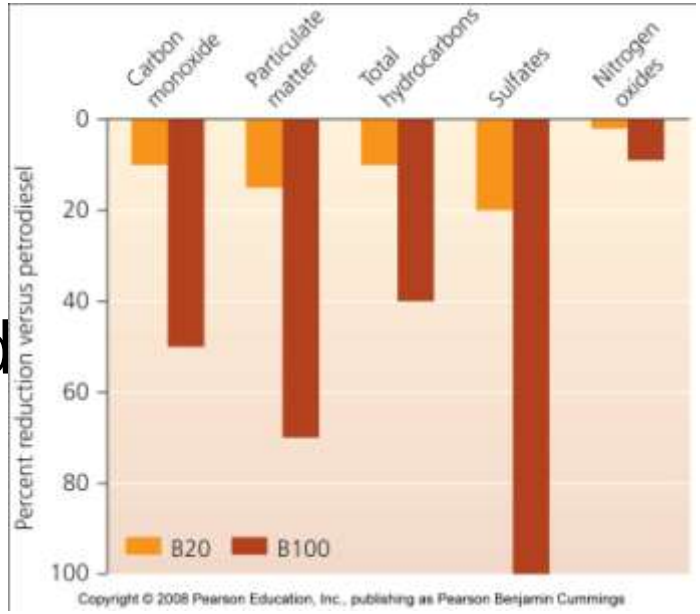
(b) Ethanol production, 1980–2006

Cars can run on ethanol

- **Flexible fuel vehicles** = run on 85% ethanol
  - But, very few gas stations offer this fuel
- Researchers are refining techniques to produce ethanol from cellulose, so ethanol could be made from low-value crops, instead of high-value crops

Biodiesel is produced from vegetable oil

- U.S. biodiesel producers use soybean oil
  - Animal fats, used grease, and cooking oil can also be used
  - Vehicles can run on 100% biodiesel, but the engine needs to be modified
  - Biodiesel cuts down on emissions; its fuel economy is almost as good and costs slightly more than gasoline



Video Clip

- “Alternative Fuel Sources”
- http://video.nationalgeographic.com/video/player/environment/energy-environment/alternative-energy.html

Biopower generates electricity

- Many sources of biomass can be used
  - Waste products of existing industries or processes
  - Woody debris from logging operations and sawmills
  - Crops can be specifically grown, such as fast-growing willow trees or bamboo
  - **Co-firing** combines biomass with coal
  - Bacterial breakdown of waste to produce methane

Biomass energy brings benefits

- It is essentially carbon-neutral, releasing no net carbon into the atmosphere
  - Only if biomass sources are not overharvested
  - Capturing landfill gases reduces methane emissions
- Economic benefits include
  - Supporting rural communities
  - Reducing dependence of fossil fuel imports
  - Improved energy efficiency
  - Reduces air pollutants such as sulfur dioxide

Drawbacks of biomass energy

- Health hazards from indoor air pollution
- Rapid harvesting can lead to deforestation
- Growing crops exerts tremendous impacts on ecosystems
  - Fertilizers and pesticides
  - Land is converted to agriculture
- Biofuel is competing with food production
- Substantial inputs of energy are required

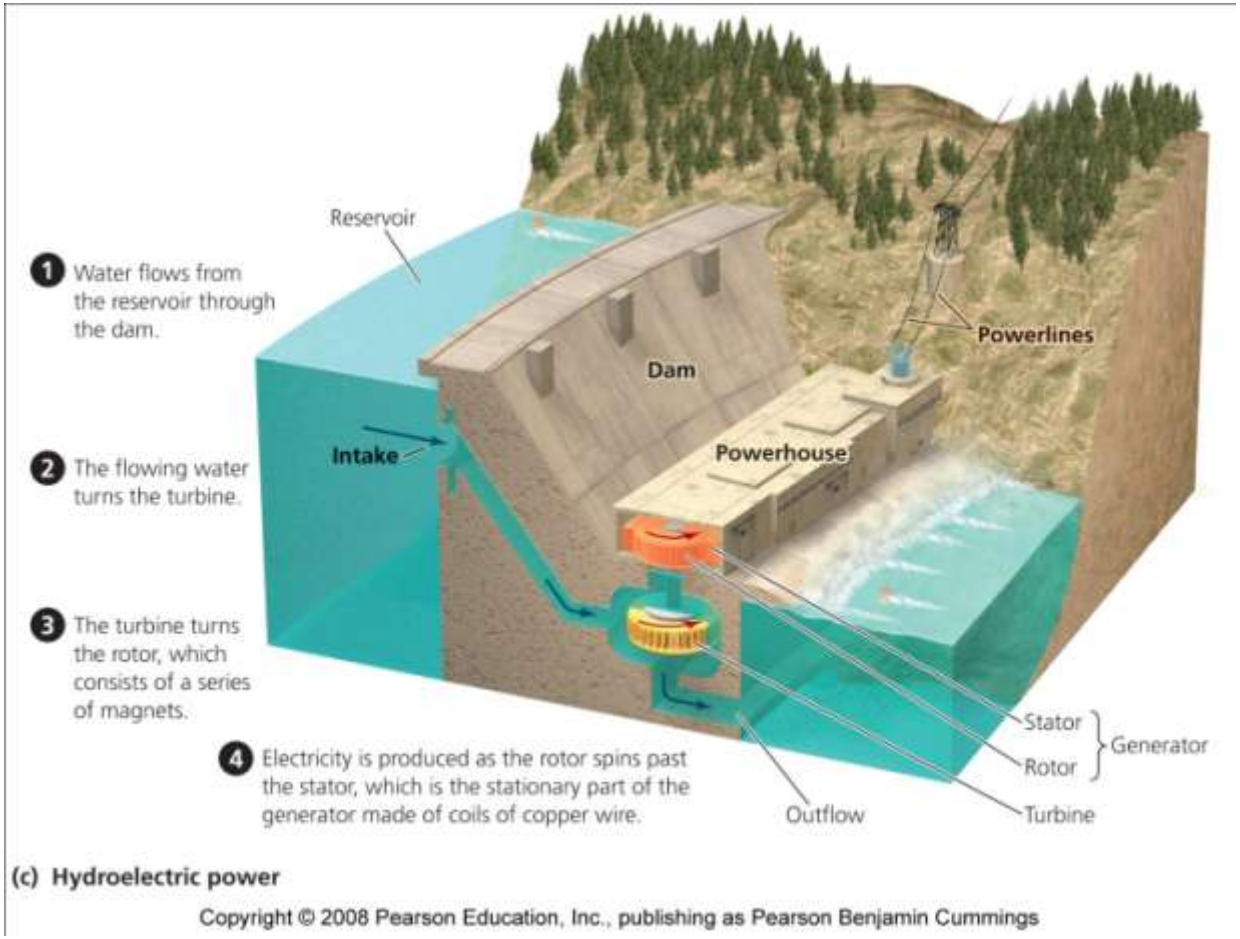
Hydroelectric power

- **Hydroelectric power** = uses the kinetic energy of moving water to turn turbines and generate electricity
- **Storage technique** = impoundments harness energy by storing water in reservoirs behind dams
  - Water passing through the dam turns turbines
- Run-of-river approaches generates energy without greatly disrupting the flow of river water

(a) Ice Harbor Dam, Snake River, Washington

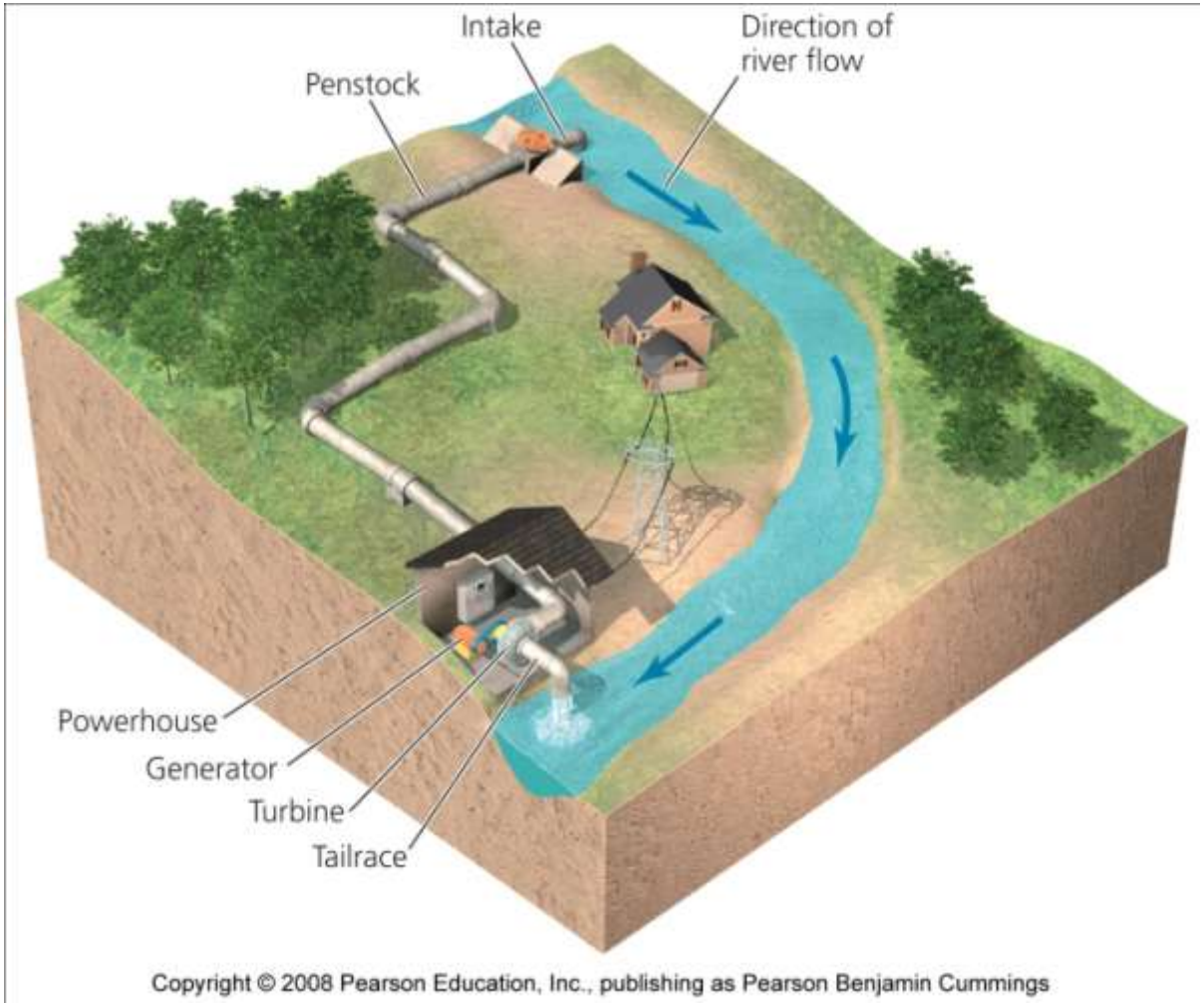
(b) Turbine generator inside McNary Dam, Columbia River

A typical dam



(c) **Hydroelectric power**

A run-of-river system



Hydroelectric power is widely used

- Hydropower accounts for 2.2% of the world's energy supply
  - And 16% of the world's electricity production
- Nations with large rivers and economic resources have used dams
  - However, many countries have dammed their large rivers
  - People want some rivers left undammed

Hydropower is clean and renewable

- Hydropower has two clear advantages over fossil fuels for producing electricity:
  - It is renewable: as long as precipitation fills rivers we can use water to turn turbines
  - It is clean: no carbon dioxide is emitted
- Hydropower is efficient
  - It has an EROI of 10:1, as high as any modern-day energy source

Hydropower has negative impacts

- Damming rivers destroys habitats
  - Upstream areas are submerged
  - Downstream areas are starved of water
- Natural flooding cycles are disrupted
- Thermal pollution of downstream water
- Periodic flushes of cold reservoir water can kill fish
- Dams block passage of fish, fragmenting the river and reducing biodiversity

Hydropower may not expand much more

- China's Three Gorges Dam is the world's largest dam
- Most of the world's large rivers have already been dammed
- People have grown aware of the ecological impact of dams
- Developing nations will probably increase hydropower if they have rivers

Three Gorges

- http://video.nationalgeographic.com/video/player/environment/energy-environment/alternative-energy.html

Conclusion

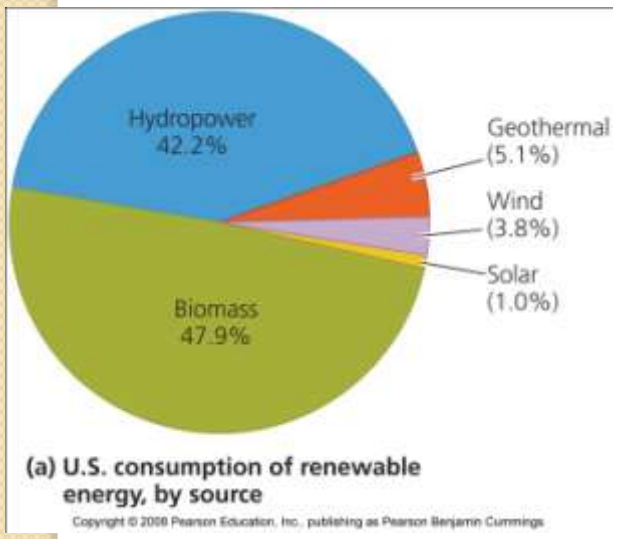
- With limited fossil fuel supplies, nations are trying to diversify their energy portfolios
- Nuclear power showed promise, but high costs and public fears stalled its growth
- Biomass energy sources include traditional wood and newer biofuels
- Hydropower is a renewable, pollution-free alternative, but it can involve substantial ecological impacts

“New” renewable energy sources

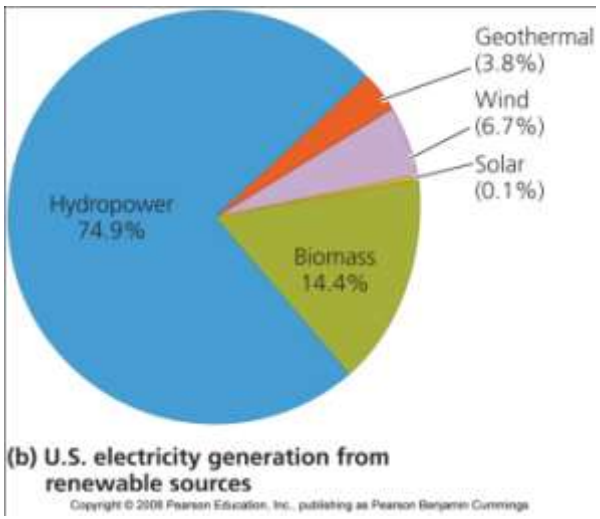
- “New” renewables are a group of alternative energy sources that include
  - Energy from the Sun, wind, geothermal heat, and movement of the ocean water
- They are commonly referred to as “new” because:
  - They are not yet used on a wide scale
  - Their technologies are still in a rapid phase of development
  - They will play a much larger role in our energy use in the future

New renewables provide little of our power

- We obtain only one half of 1 percent from the new renewable energy sources
- Nations and regions vary in the renewable sources they use
- In the U.S., most renewable energy comes from hydropower and biomass



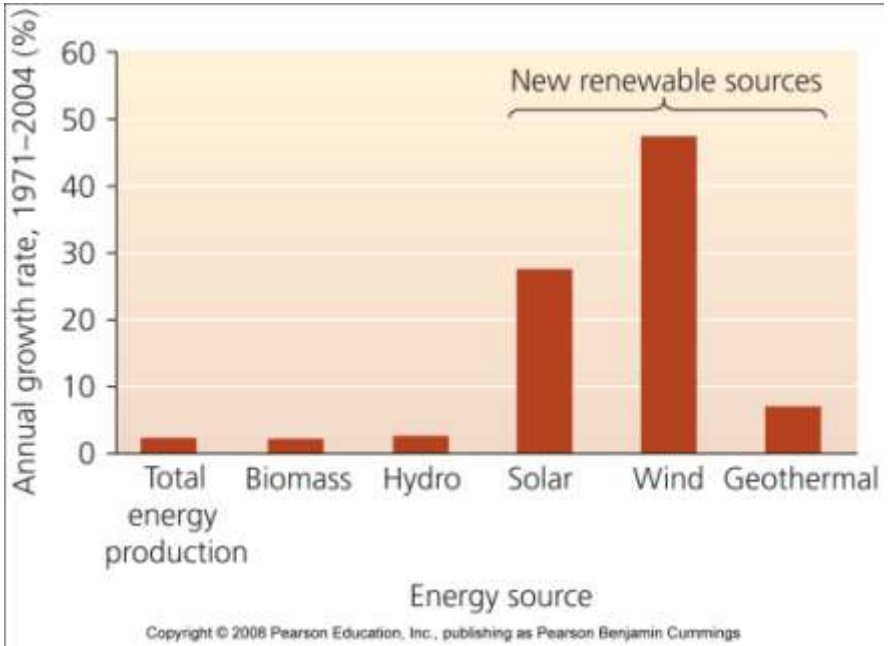
(a) U.S. consumption of renewable energy, by source



(b) U.S. electricity generation from renewable sources

The new renewables are growing fast

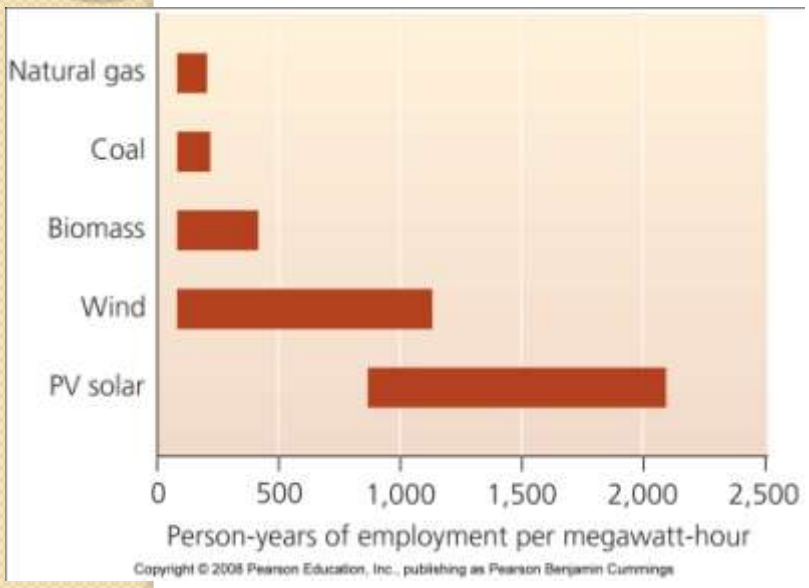
- They are growing at much faster rates than conventional sources
  - Wind power is the fastest growing
  - However, since these sources began at low levels, it will take time to build them up



Use has expanded quickly because of:

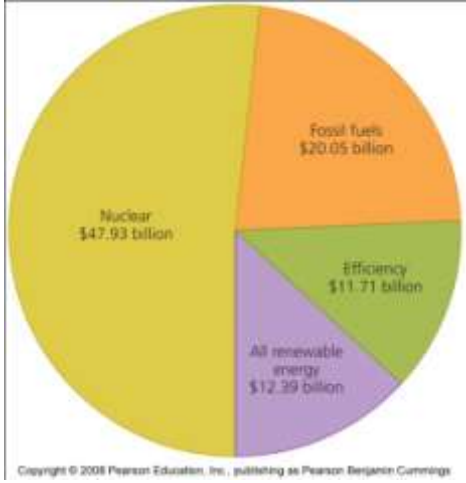
- Growing concerns over diminishing fossil fuels
- The environmental impacts of fossil fuel combustion
- Advances in technology make it easier and less expensive
- Benefits of the new renewables include:
  - They alleviate air pollution and greenhouse gas emissions that can cause climate change
  - They are inexhaustible, unlike fossil fuels
  - Help diversify a country's energy economy
  - They create jobs and are sources of income and taxes, especially in rural areas

New energy sources create jobs



- New technologies require more labor per unit of energy output
  - More jobs will be generated than remaining with a fossil fuel economy
- Rapid growth will continue as:
  - Population and consumption grow, energy demand increases, fossil fuel supplies decline, and people demand a cleaner environment

Our transition must begin soon



- Technological and economic barriers prevent a quick switch to renewables
  - Renewables receive little government help
  - Need infrastructure for renewables
  - Transition needs to be gradual; companies are unwilling to rapidly change
- Transitioning too slowly will cause fossil fuel depletion, and renewables will not be able to compensate
  - We could have disrupted economies and a degraded environment

Solar energy

- Sun provides energy for almost all biological activity on Earth
- Each square meter of Earth receives about 1 kilowatt of solar energy = 17 times more than a lightbulb
  - There is great potential in solar energy
- **Passive solar energy** = the most common way to harness solar energy
  - Buildings are designed to maximize direct absorption of sunlight in winter and keep cool in summer
- **Active solar** energy collection = uses technology to focus, move, or store solar energy
- Solar energy has been used for hundreds of years

Putting Solar Energy to Work

Rooftop Water Heaters

Figure 14-2 Environmental Science, 10/e

Solar Thermal Power in Southern California

Figure 14-3 Environmental Science, 10/e

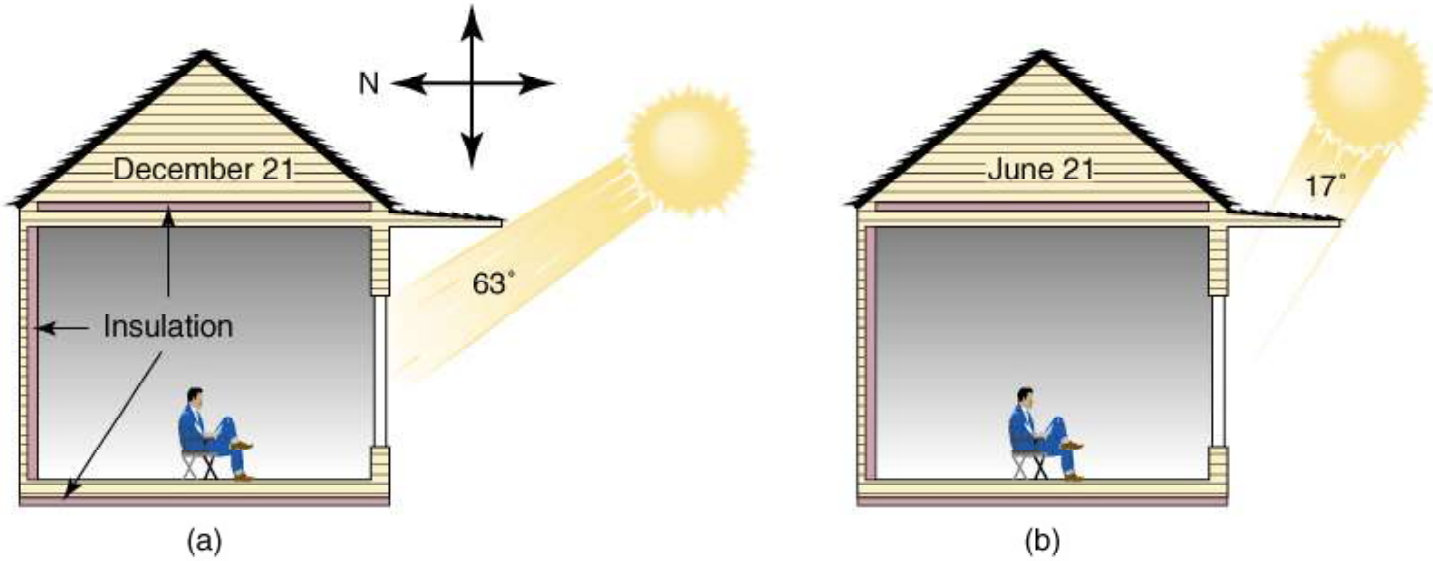
Solar energy use is increasing

- 1.5 million homes and businesses heat water with solar panels, mostly for swimming pools
- Solar panels are used far from any sort of electrical grid to help boil water and power rural hospitals
- Solar power need not be expensive or in regions that are always sunny

Passive solar heating is simple and effective

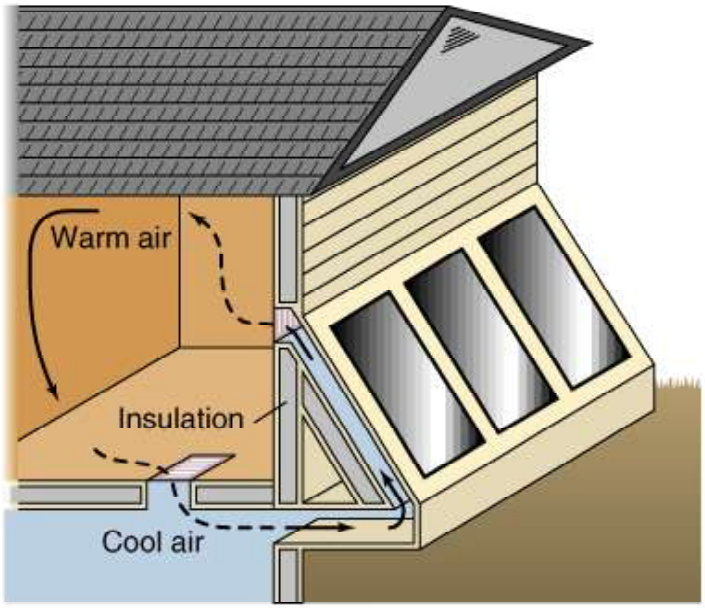
- Low south-facing windows maximize heat in the winter
  - Overhangs on windows block light from above in the summer
- **Thermal mass** = construction materials that absorb, store, and release heat
- Planting vegetation in strategic locations
- By heating buildings in winter and cooling them in summer, passive solar methods conserve energy and reduce costs

Solar Building Siting



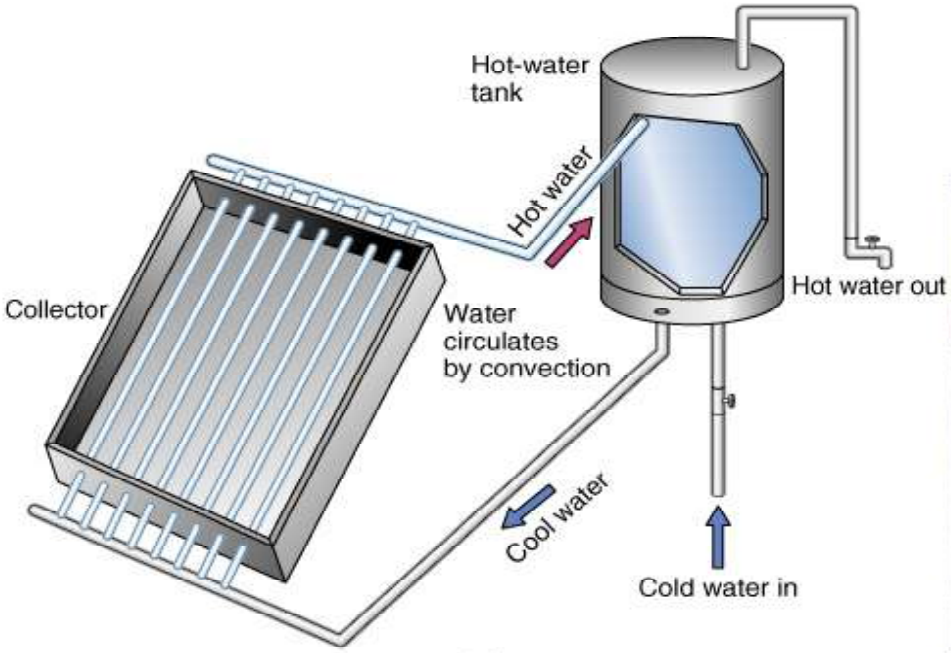
Solar Space Heating

(a)



(b)

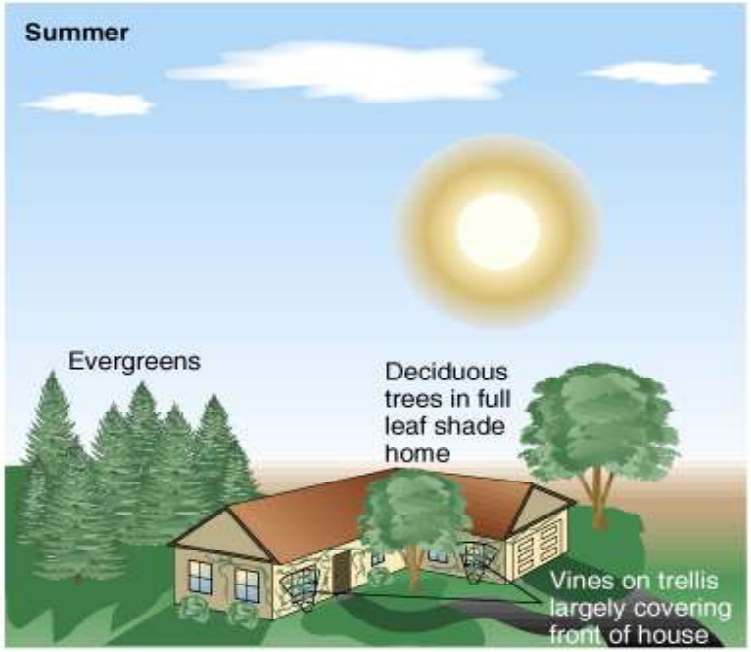
Solar Water Heaters



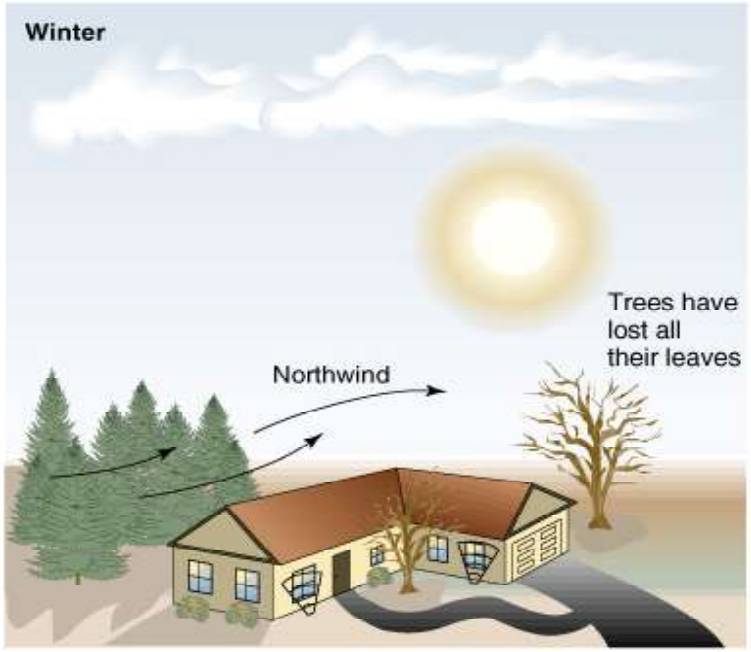
(a)

(b)

Landscaping in Solar Heating and Cooling



(a)

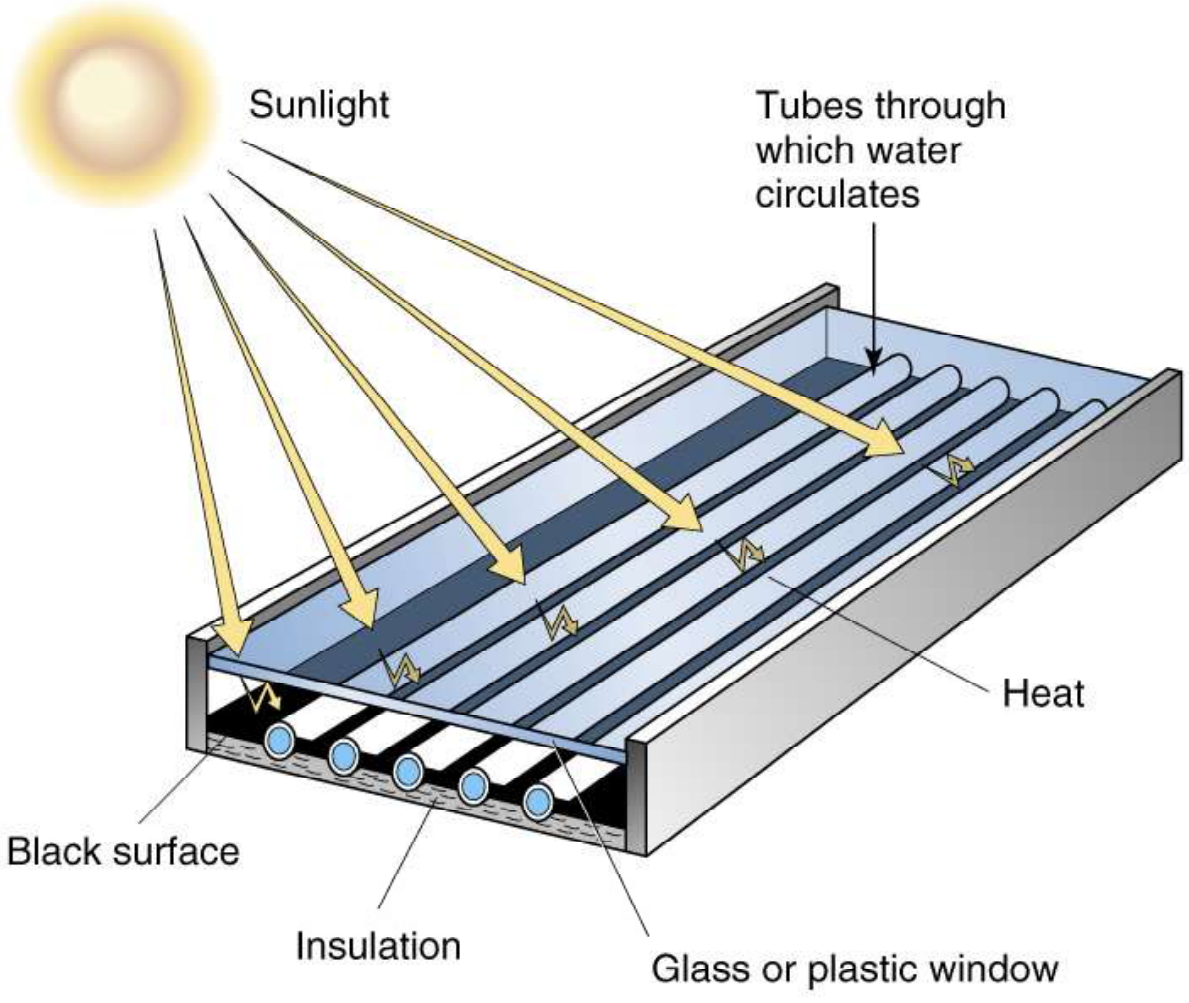


(b)

Active solar energy collection

- **Flat plate solar collectors (solar panels)** = one active method for harnessing solar energy
  - Installed on rooftops
  - Dark-colored, heat-absorbing metal plates
    - Water, air, or antifreeze pass through the collectors, transferring heat throughout the building
    - Heated water is stored and used later

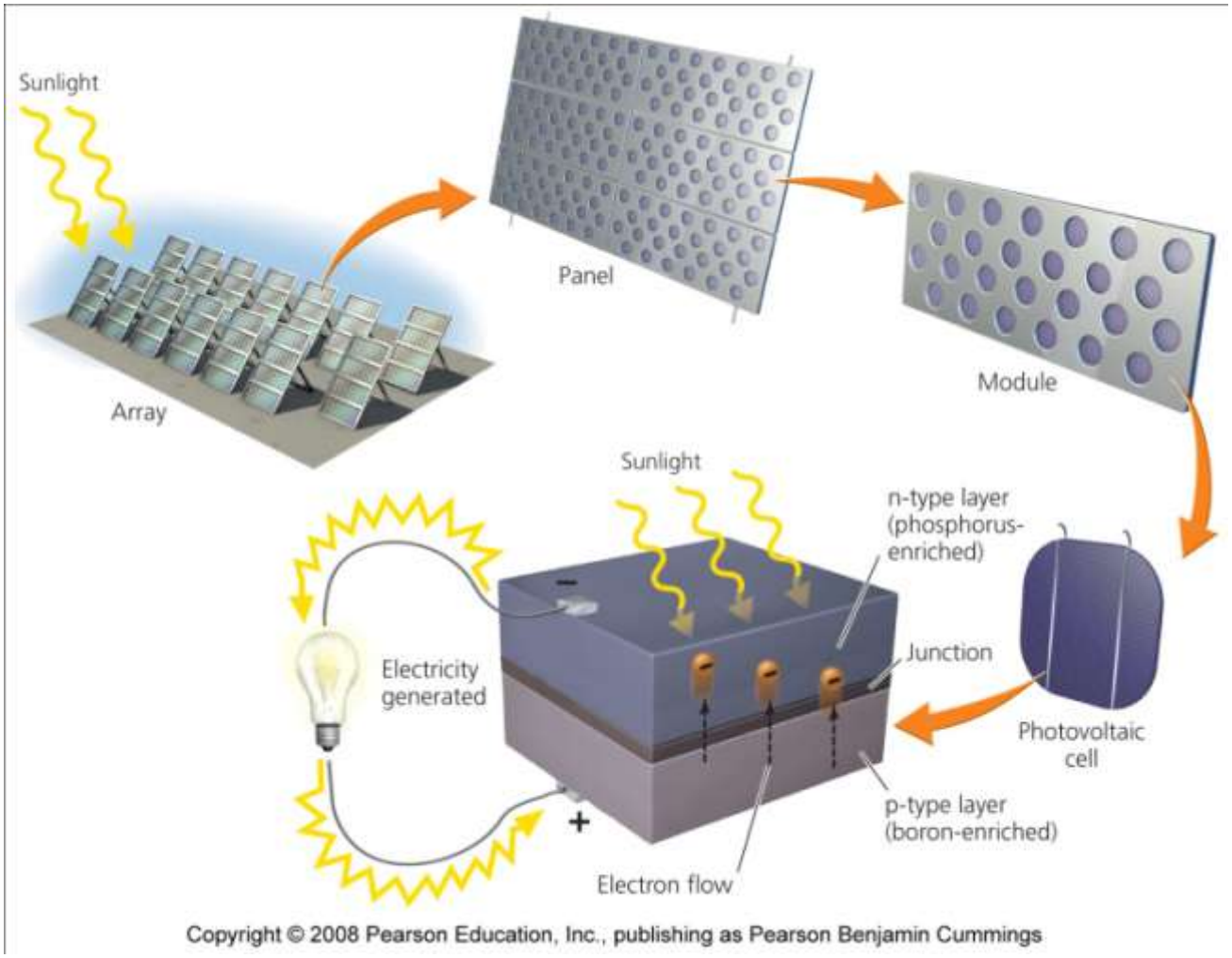
Solar Heating of Water: Flat-plate Solar Collector



Photovoltaic cells generate electricity

- **Photovoltaic cells** = collect sunlight and convert it into electrical energy
  - These are used with wind turbines and diesel engines
- **Photovoltaic (photoelectric) effect** = occurs when light strikes one of a pair of metal plates in a PV cell, causing the release of electrons, creating an electric current
- A PV cell has two silicon plates, the n-type layer (rich in electrons) and the p-type layer (electron poor)
  - Sunlight causes electrons to flow from the n-type to the p-type layer, generating electricity

A typical photovoltaic cell



Required Components?

- Flat-plate collector
- Water pump
- Blowers
- Heat exchanger
- Improved insulation

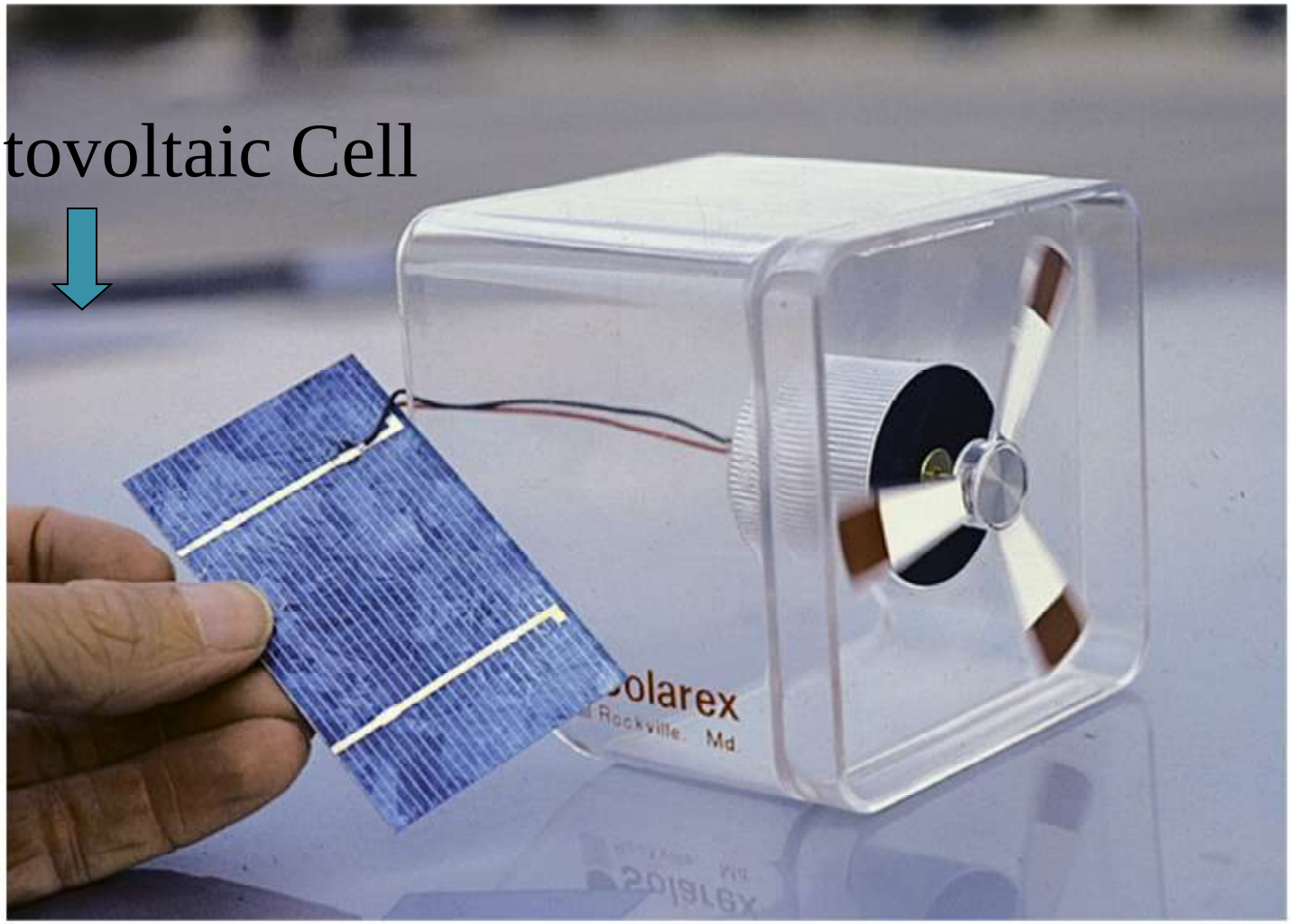
✓Solar hot water

✓Solar space heater

✓Both

Solar Production of Electricity

Photovoltaic Cell



How Photovoltaic Cells Work: Part 1

- Each cell consists of two thin mylar layers.
- Lower layer has atoms with single electron in outer orbit – easily lost.
- Upper layer has atoms lacking one electron in outer orbit – easily accepts electrons.

How Photovoltaic Cells Works: Part 2

- Kinetic energy from sunlight dislodges electrons from lower layer – creates an electric potential between the two layers.

How Photovoltaic Cells Works: Part 3

- The potential provides the energy for an electrical current through the rest of the circuit.
- Electrons from lower layer flow through a device back to upper side.

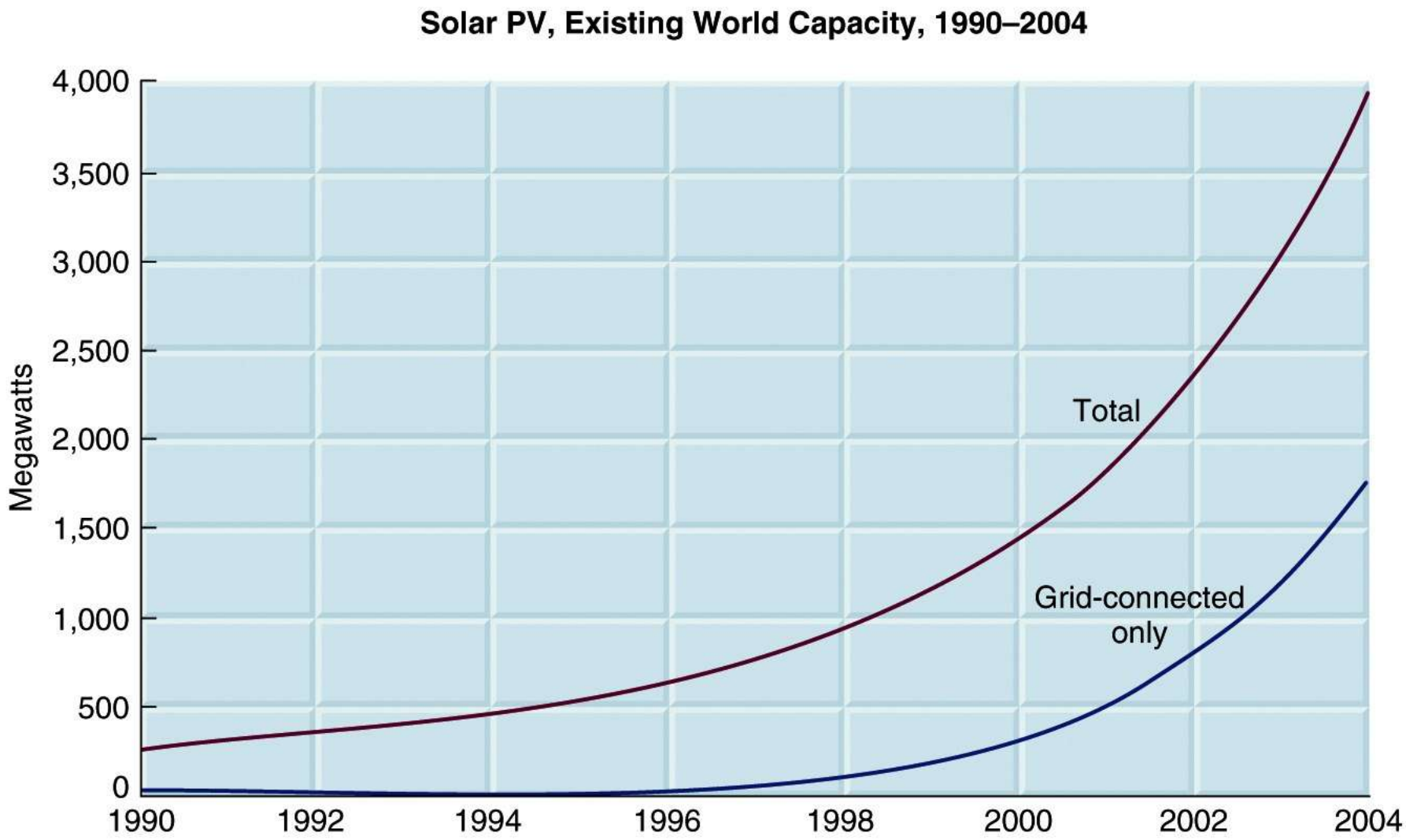


Figure 14-13 Environmental Science, 10/e

PV Power Plant

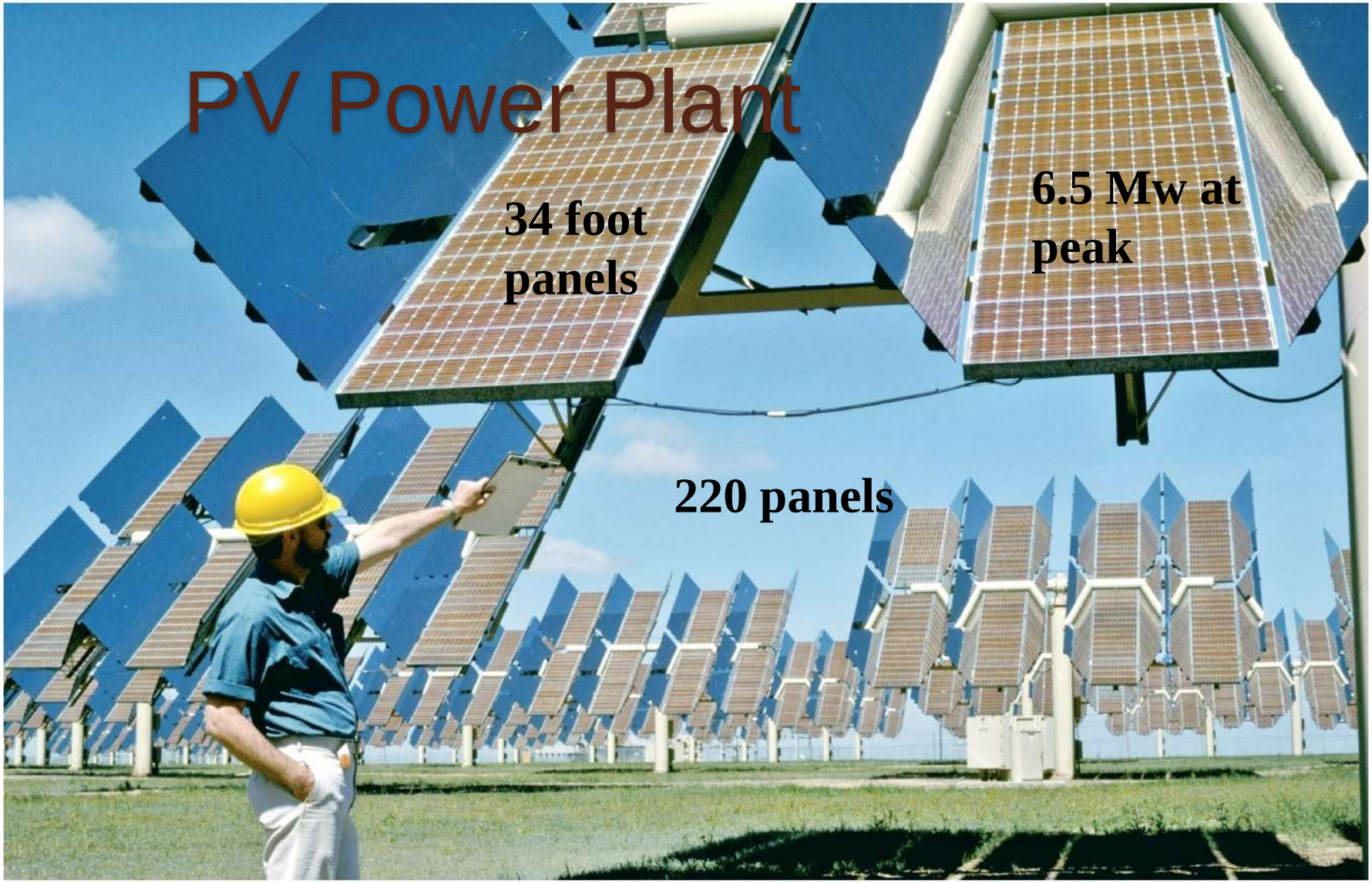


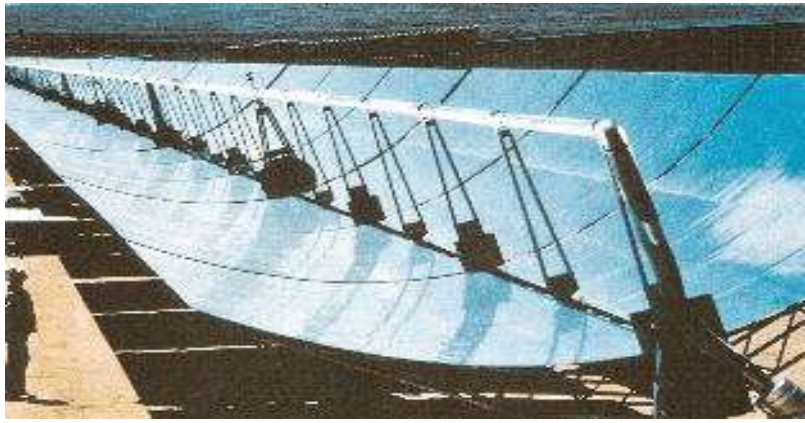
Figure 14-15 Environmental Science, 10/e

Concentrating solar rays magnifies energy

- Focusing solar energy on a single point magnifies its strength
- **Solar cookers** = simple, portable ovens that use reflectors to focus sunlight onto food
- **Power tower** = mirrors concentrate sunlight onto receivers to create electricity
- **Solar-trough collection systems** = mirrors focus sunlight on oil in troughs
  - Superheated oil creates steam to produce electricity

Concentrating Solar Power

- PV power plants
- Solar-trough collectors
- Power towers
- Dish-engine system



Power Tower

Disadvantages of Solar Energy Technologies

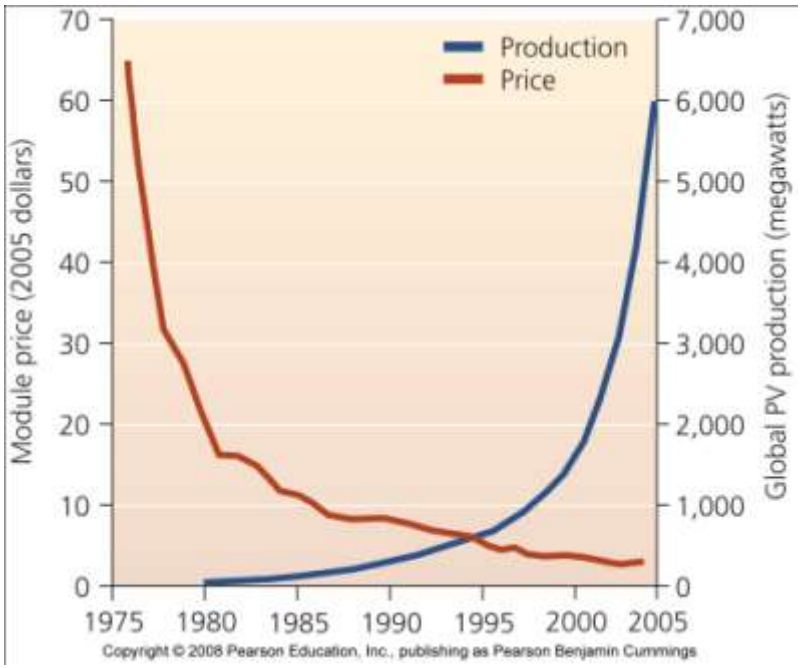
- Expense
- Only works during the day
- Requires back-up energy sources, e.g., batteries
- Some climates not sunny enough

Solar power is little used but fast growing

- Solar energy was pushed to the sidelines as fossil fuels dominated our economy
  - Funding for research and development has been erratic
  - Because of a lack of investment, solar energy contributes only a miniscule amount of energy
- Solar energy is attractive in developing nations
  - Hundreds of millions don’t have electricity
- Some multinational companies are investing in solar energy

Solar energy will continue to grow

- Japan and Germany lead the world in PV installation
- The U.S. may recover its leadership, given a 2005 federal tax credit and some state initiatives
- Solar energy use should increase
  - As prices fall, technologies improve and governments enact economic incentives

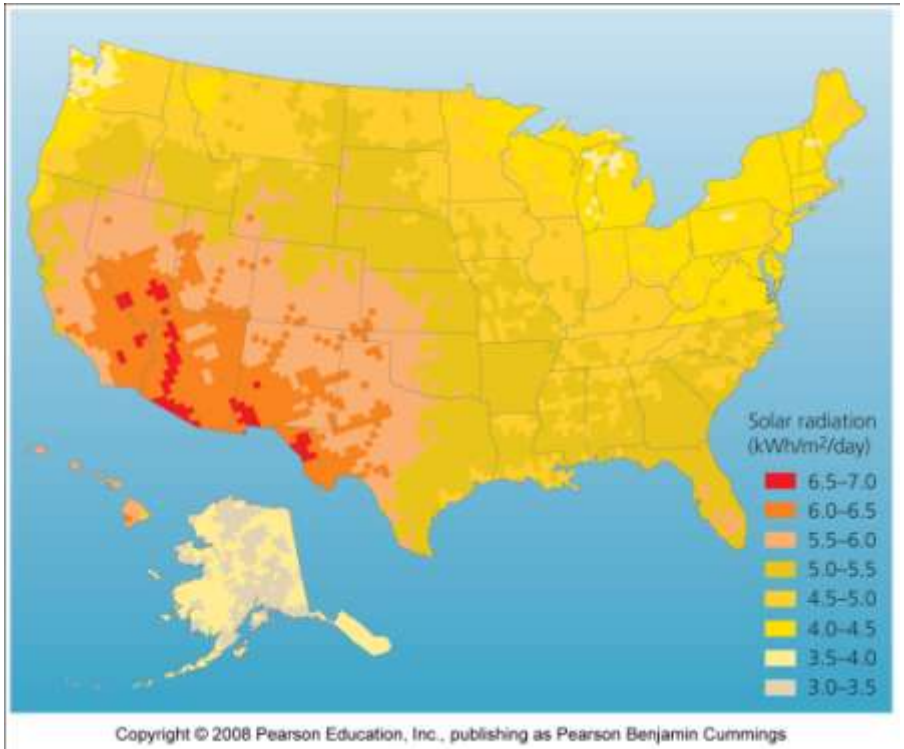


Solar power offers many benefits

- The Sun will burn for 4 - 5 billion more years
- Solar technologies are quiet, safe, use no fuels, contain no moving parts, and require little maintenance
- They allow local, decentralized control over power
- Developing nations can use solar cookers, instead of gathering firewood
- **Net metering** = PV owners can sell excess electricity to their local power utility
- New jobs are being created
- Solar power does not emit greenhouse gases and air pollution

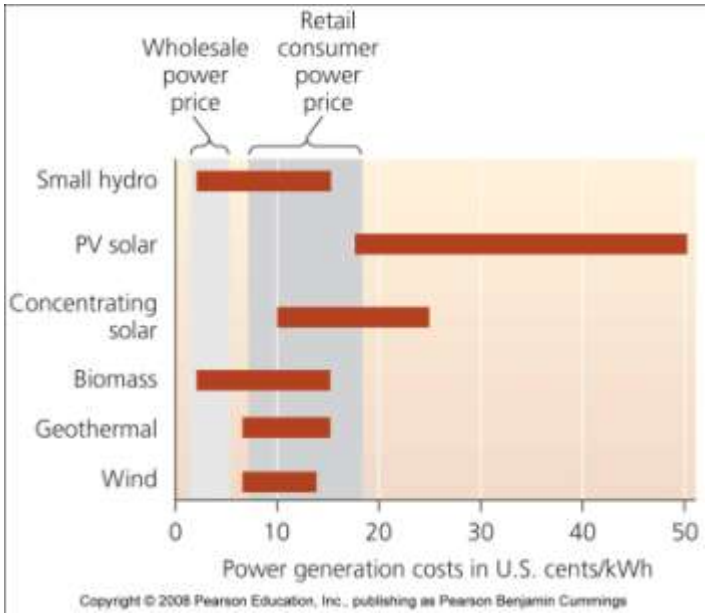
Location is a drawback

- Not all regions are sunny enough to provide enough power, with current technology
  - Daily and seasonal variation also poses problems



Cost is a drawback

- Up-front costs are high and solar power remains the most expensive way to produce electricity
  - The government has subsidized fossil fuels and nuclear energy at the expense of solar energy

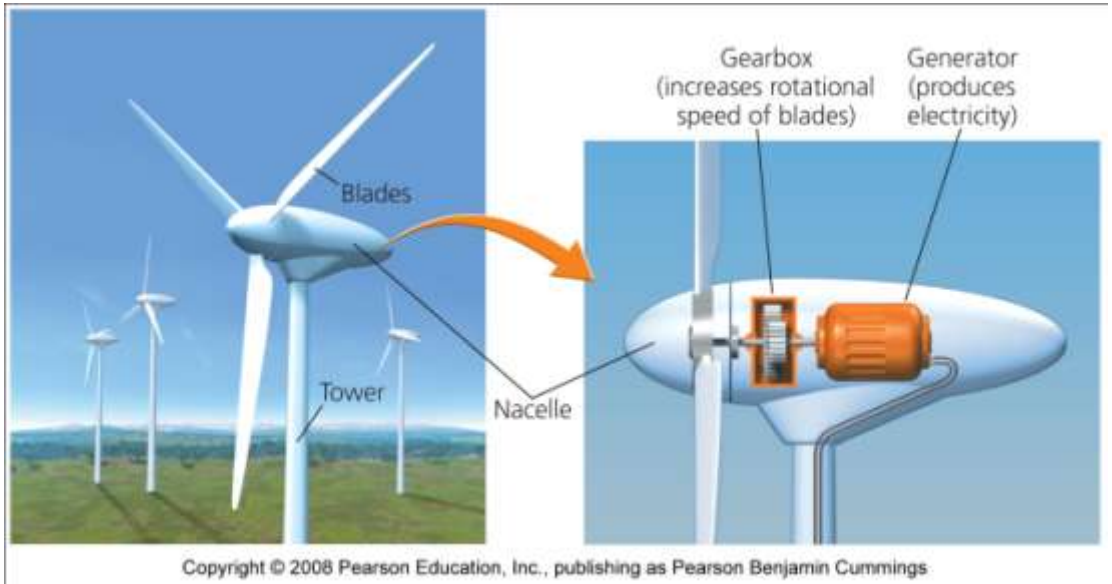


Wind has long been used for energy

- **Wind turbines** = devices that harness power from wind
- Windmills have been used for 800 years to pump water
- The first windmill to generate electricity was built in the late 1800s
- After the 1973 oil embargo, governments funded research and development
- Today, wind power produces electricity for the same price as conventional sources

Modern wind turbines convert kinetic energy

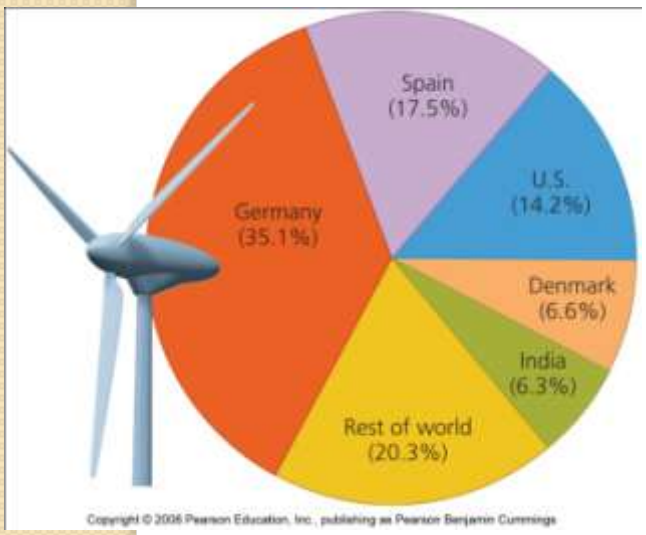
- Wind blowing into a turbine turns the blades of the rotor, which rotate machinery inside a compartment (**nacelle**) on top of a tall tower
- Towers are 40 - 100 m (131 - 328 ft) tall
  - Higher is better to minimize turbulence and maximize wind speed



Wind farms

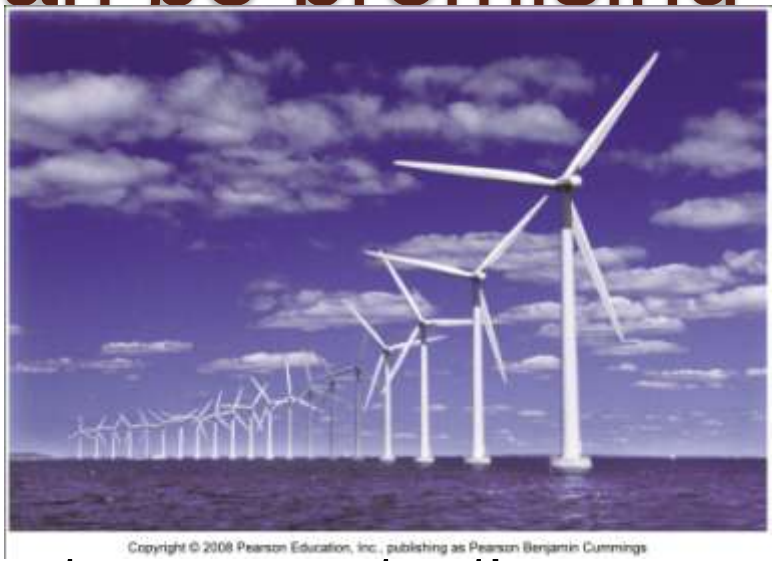
- **Wind farms** = turbines erected in groups of up to hundreds of turbines
- Turbines harness wind as efficiently as possible
  - Different turbines turn at different speeds
  - Slight increases in wind velocity yield significant power output

Wind is the fastest-growing energy sector



- Wind power grew 25% per year globally between 2000 and 2005
  - Five nations account for 80% of the world's wind power
- California and Texas produce the most wind power in the U.S.
  - Wind power could be expanded to meet the electrical needs of the entire U.S.

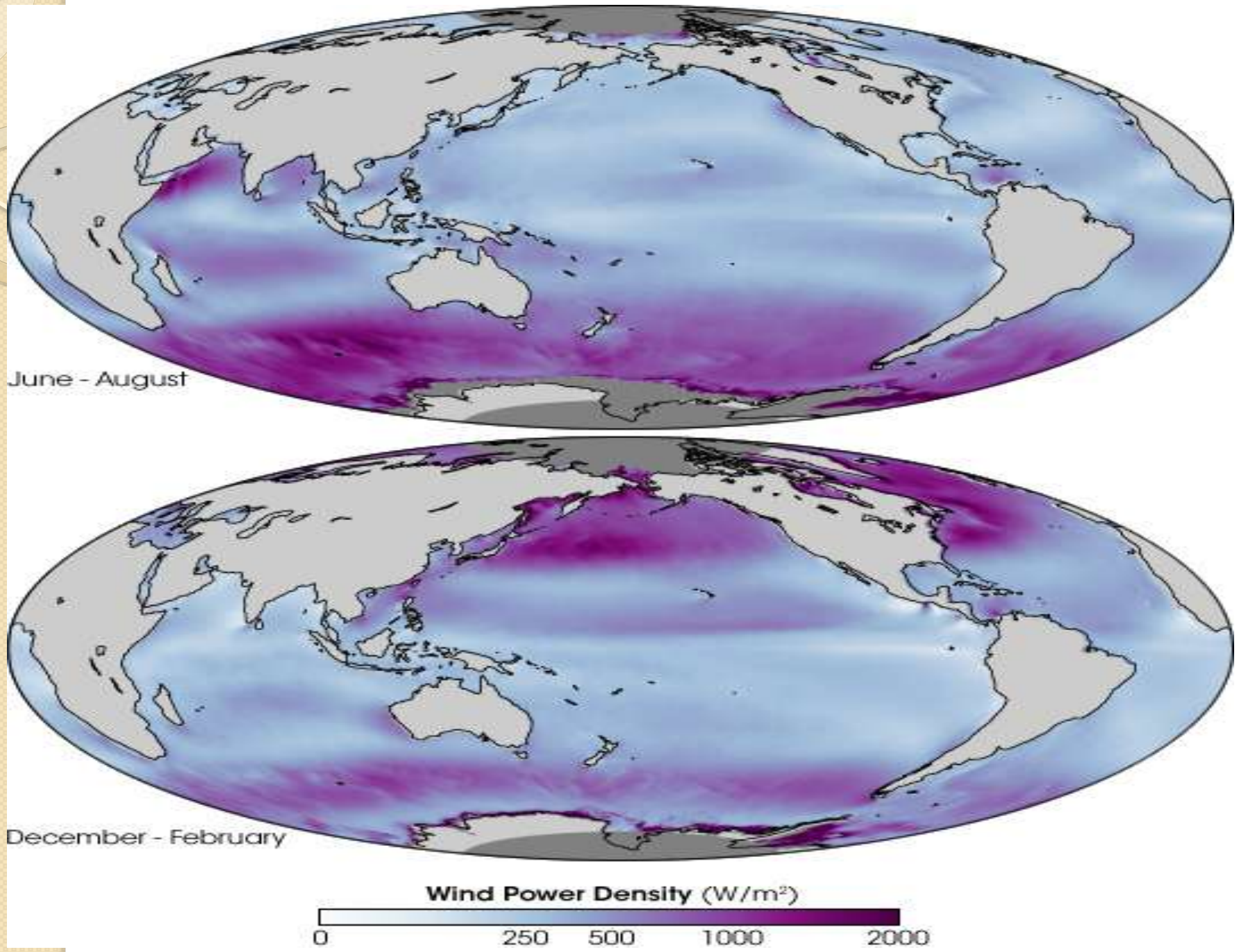
Offshore sites can be promising



- Wind speeds are 20% greater over water than over land
- There is less air turbulence over water than land
- Costs to erect and maintain turbines in water are higher, but the stronger, less turbulent winds produce more power and make offshore wind more profitable
- Currently, turbines are limited to shallow water

Global Ocean Wind Energy Potential

- Wind energy has the potential to provide 10 to 15 percent of the world's future energy. NASA
- Once windmills are installed, wind can be converted to electricity inexpensively.
  - mars scenic views and
  - can kill birds and bats
  - wind tends to blow stronger over the ocean than over land


June - August
December - February
Wind Power Density (W/m²)
0
250
500
1000
2000

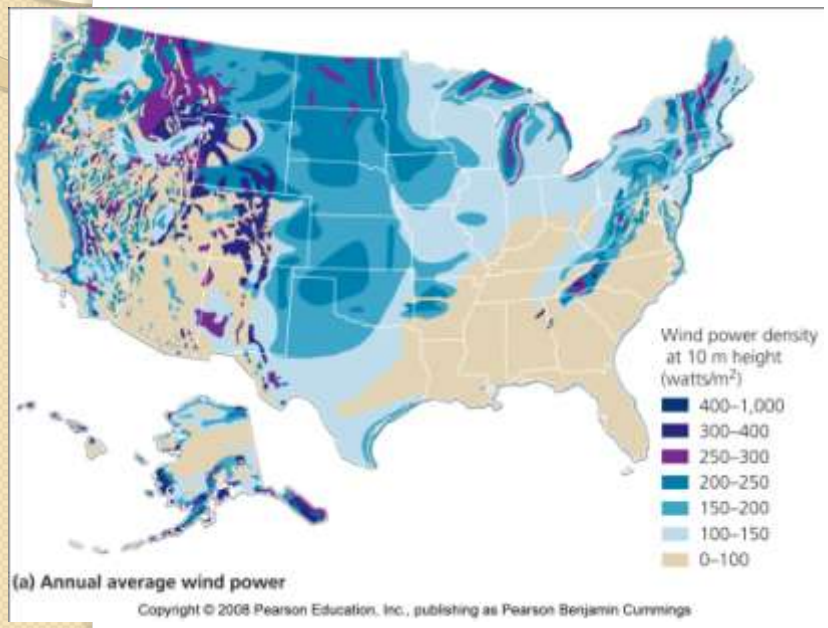
Wind power has many benefits

- Wind produces no emissions once installed
- It prevents the release of CO_2
- It is more efficient than conventional power sources
- Turbines also use less water than conventional power plants
- Farmers and ranchers can lease their land
  - Produces extra revenue
  - Landowners can still use their land for other uses
- Advancing technology is also driving down the cost of wind farm construction

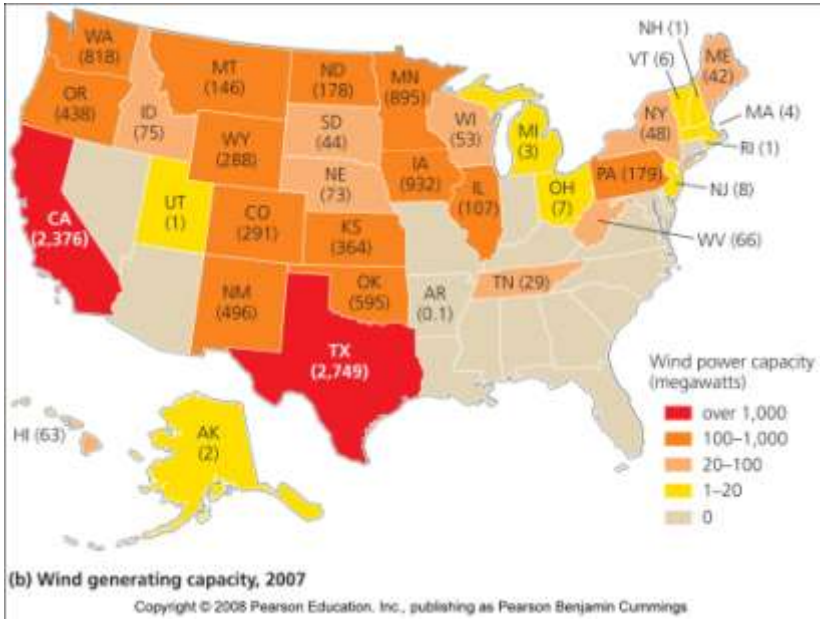
Wind power has some downsides

- We have no control over when wind will occur
  - Causes major limitations in relying on it for electricity
- Companies have to invest a lot of research before building a costly wind farm
- Good wind sources are not always near population centers that need energy
- When wind farms are proposed near population centers, local residents often oppose them
- Wind turbines also pose a threat to birds and bats, which can be killed when they fly into rotating blades

U.S. wind-generating capacity



(a) Annual average wind power



(b) Wind generating capacity, 2007

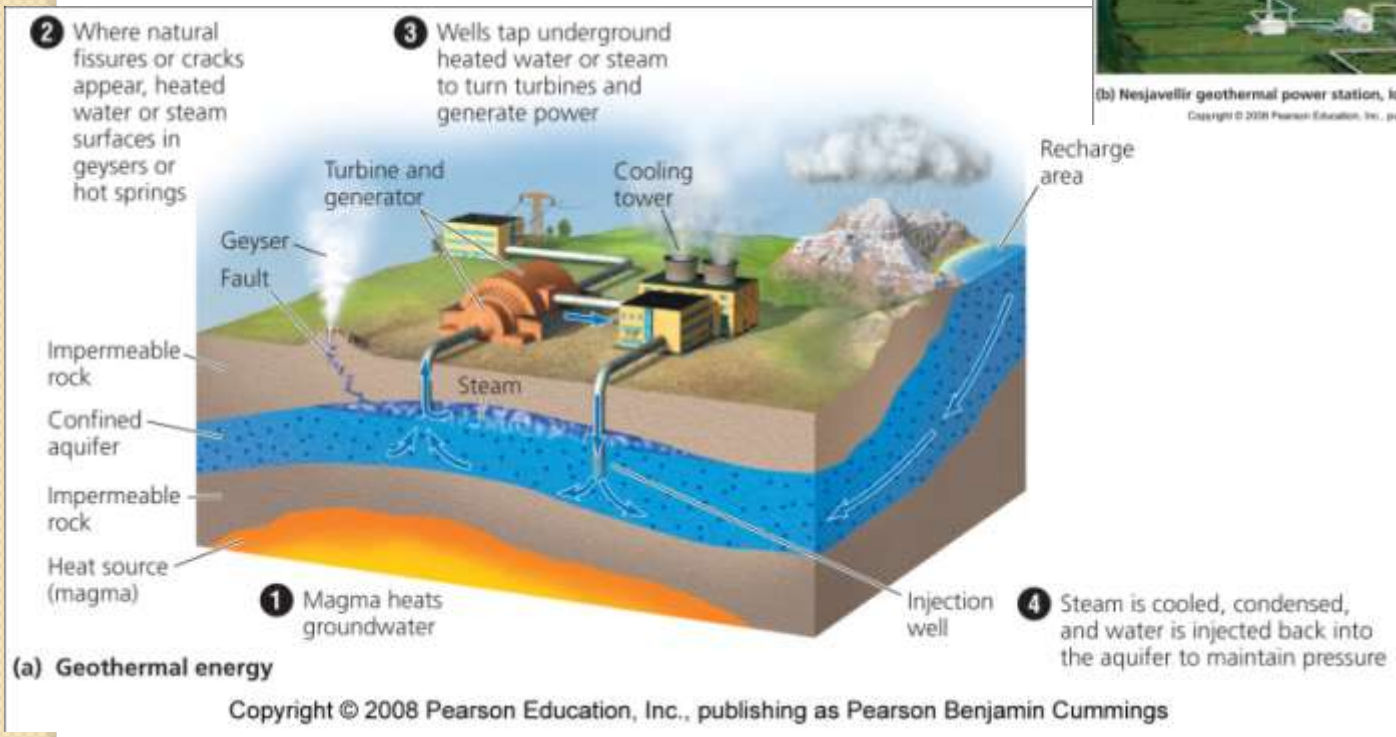
Wind's capacity to generate power varies according to wind speed

Geothermal energy

- Renewable energy that does not originate from the Sun
  - It is generated from deep within the Earth
- Radioactive decay of elements under extremely high pressures deep inside the planet generates heat
  - This heat rises through magma, fissures, and cracks
- Geothermal power plants use heated water and steam for direct heating and generating electricity

The origins of geothermal energy

(b) Nesjavellir geothermal power station, Iceland



(a) Geothermal energy

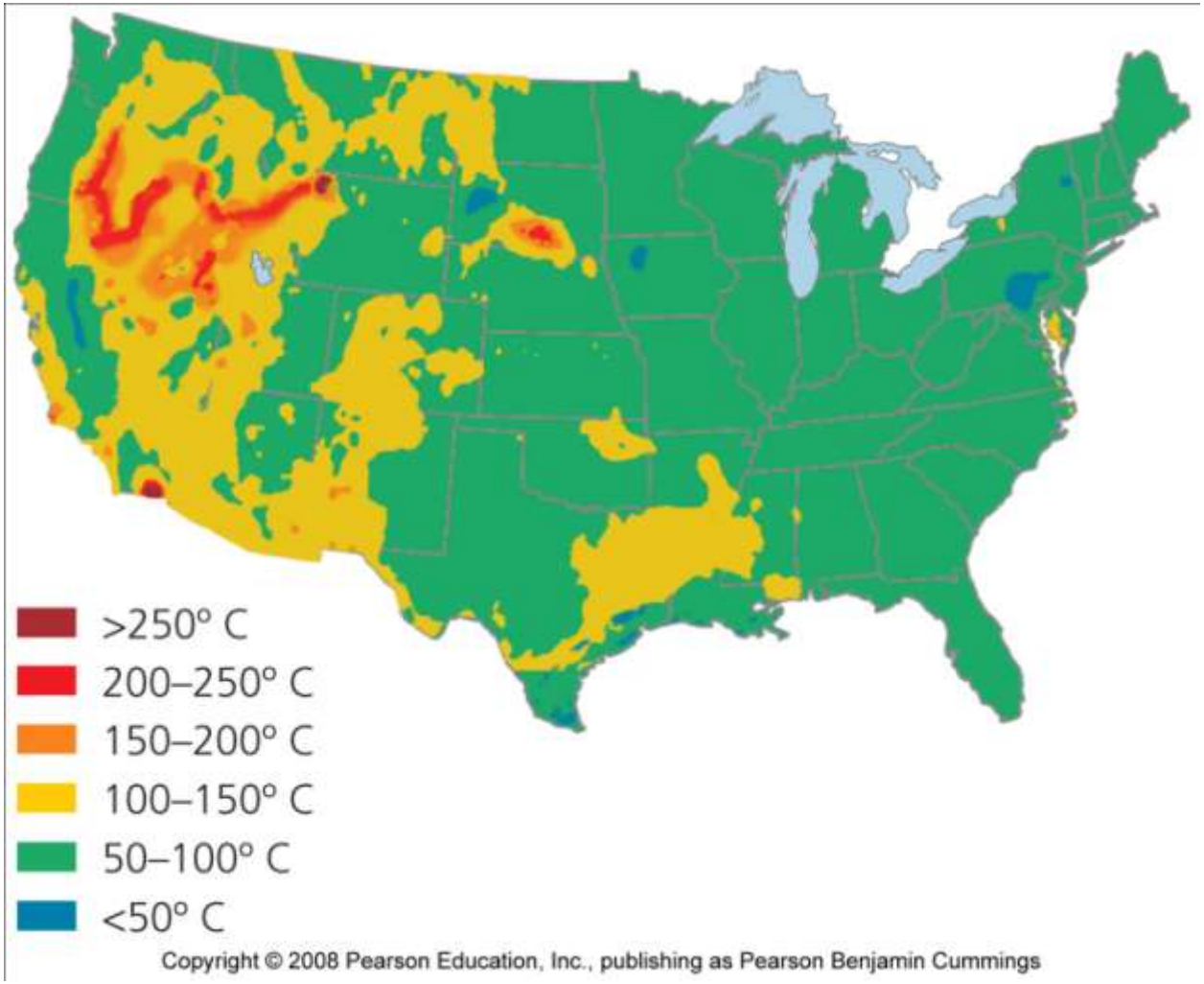
Geothermal energy is renewable in principle

- But if a geothermal plant uses heated water faster than groundwater is recharged, the plant will run out of water
  - Operators have begun injecting municipal wastewater into the ground to replenish the supply
- Patterns of geothermal activity shift naturally
  - An area that produces hot groundwater now may not always do so

Geothermal energy produces heat and electricity

- Most often wells are drilled hundreds or thousands of meters toward heated groundwater
  - Water at temperatures of 150 – 370 degrees Celsius is brought to the surface and converted to steam, which turns turbines that generate electricity
- Hot groundwater can be used directly to heat buildings
  - Cheap and efficient

Geothermal energy is greatest in the U.S. west



Heat pumps are highly efficient

- Geothermal ground source heat pumps (GSHPs) use thermal energy from near-surface sources of earth and water
  - The pumps heat buildings in the winter by transferring heat from the ground into buildings
  - In the summer, heat is transferred through underground pipes from the building into the ground
  - Highly efficient, because heat is simply moved

Use of geothermal power is growing

- Currently, geothermal energy provides less than 0.5% of the total energy used worldwide
  - It provides more power than solar and wind combined
  - But, much less than hydropower and biomass
- Geothermal energy in the U.S. provides enough power to supply electricity to more than 4 million people
- The U.S., Japan, and China lead the world in geothermal power use

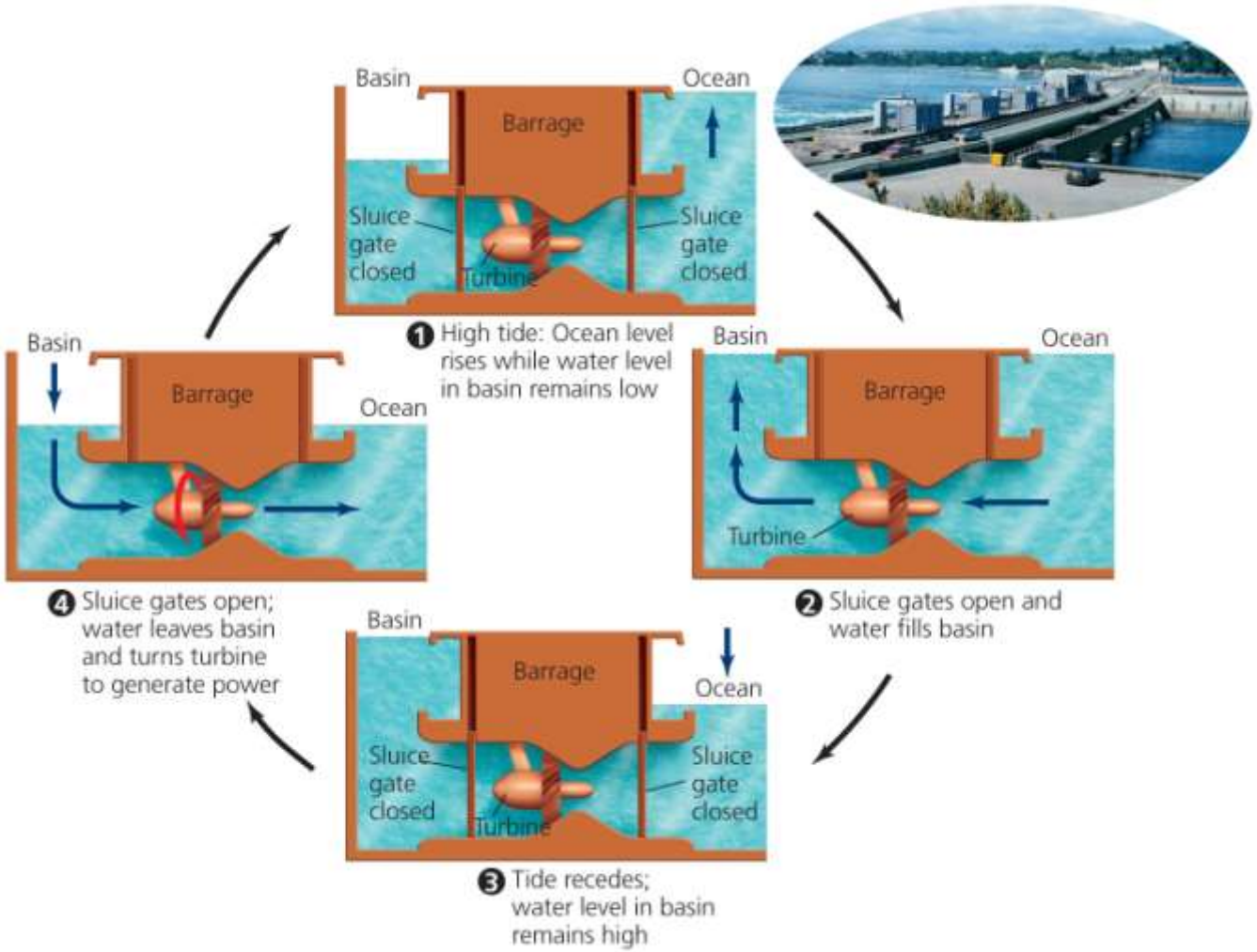
Geothermal power has benefits and limits

- Benefits:
  - Reduces emissions
  - It does emit very small amounts of gases
- Limitations:
  - May not be sustainable
  - Water is laced with salts and minerals that corrode equipment and pollute the air
  - Limited to areas where the energy can be trapped

We can harness energy from the oceans

- Scientists are devising ways to use kinetic energy from the natural motion of ocean water to generate electrical power
- The rising and falling of ocean tides twice each day throughout the world moves large amounts of water
  - Differences in height between low and high tides are especially great in long narrow bays
  - These areas are best for harnessing **tidal energy** by erecting dams across the outlets of tidal basins

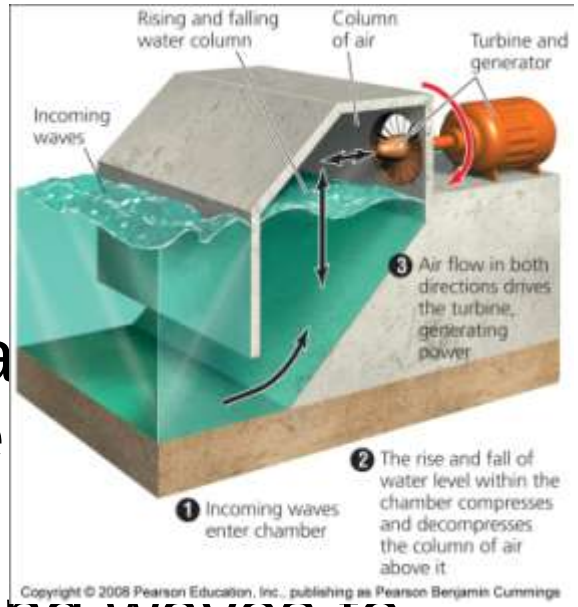
Energy can be extracted from tidal movement



Wave energy

- Can be developed at a greater variety of sites than tidal energy
- The motion of wind-driven waves at the ocean's surface is harnessed and converted from mechanical energy into electricity
- Many designs exist, but few are adequately tested
- Some designs are for offshore facilities and involve floating devices that move up and down the waves
  - Wave energy is greater at deep ocean sites, but transmitting electricity to shore is very expensive

Coastal onshore facilities



- Waves are directed into narrow cha
  elevated reservoirs; electricity is ge
  water flows out
- Another design uses rising and falling waves to push air in and out of chambers, turning turbines to generate electricity
  - No commercial wave energy facilities are operating
- A third design uses the motion of ocean currents, such as the Gulf Stream
  - Currently being tested in Europe

The ocean stores thermal energy

- Each day, the tropical oceans absorb an amount of solar radiation equal to the heat content of 250 billion barrels of oil
- The ocean's surface is warmer than deep water
  - **Ocean thermal energy conversion (OTEC)** is based on this gradient in temperature
  - Closed cycle approach = warm surface water evaporates chemicals, which spin turbines
  - Open cycle approach = warm surface water is evaporated in a vacuum and its steam turns turbines
  - Costs remain high and no facility is commercially operational

A hydrogen economy

- The development of fuel cells and hydrogen fuel shows promise to store energy in considerable quantities
  - To produce clean, efficient electricity
- A hydrogen economy would provide a clean, safe, and efficient energy system
  - By using the world's simplest and most abundant element as fuel

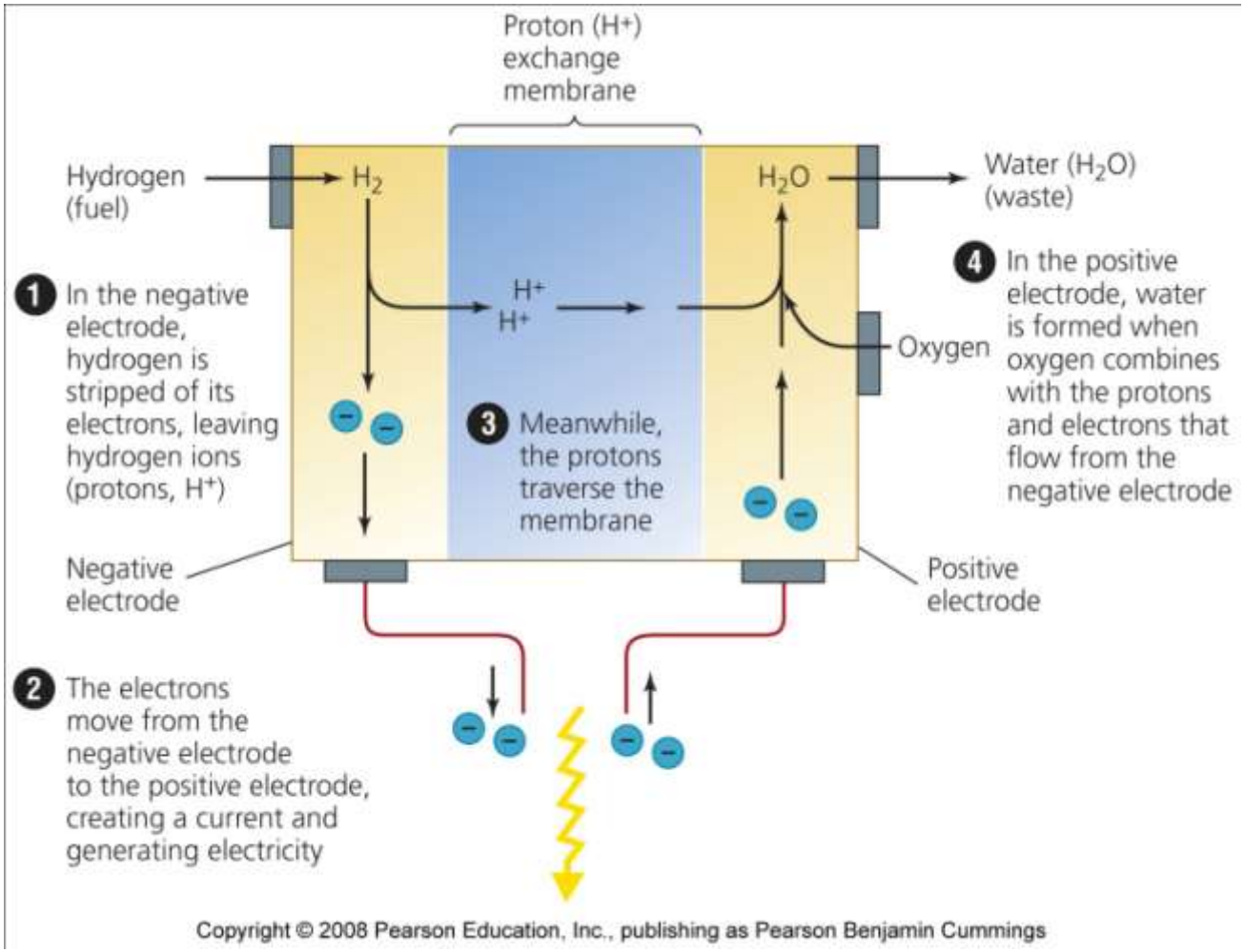
Fuel Cells

- http://video.nationalgeographic.com/video/player/environment/energy-environment/alternative-energy.html

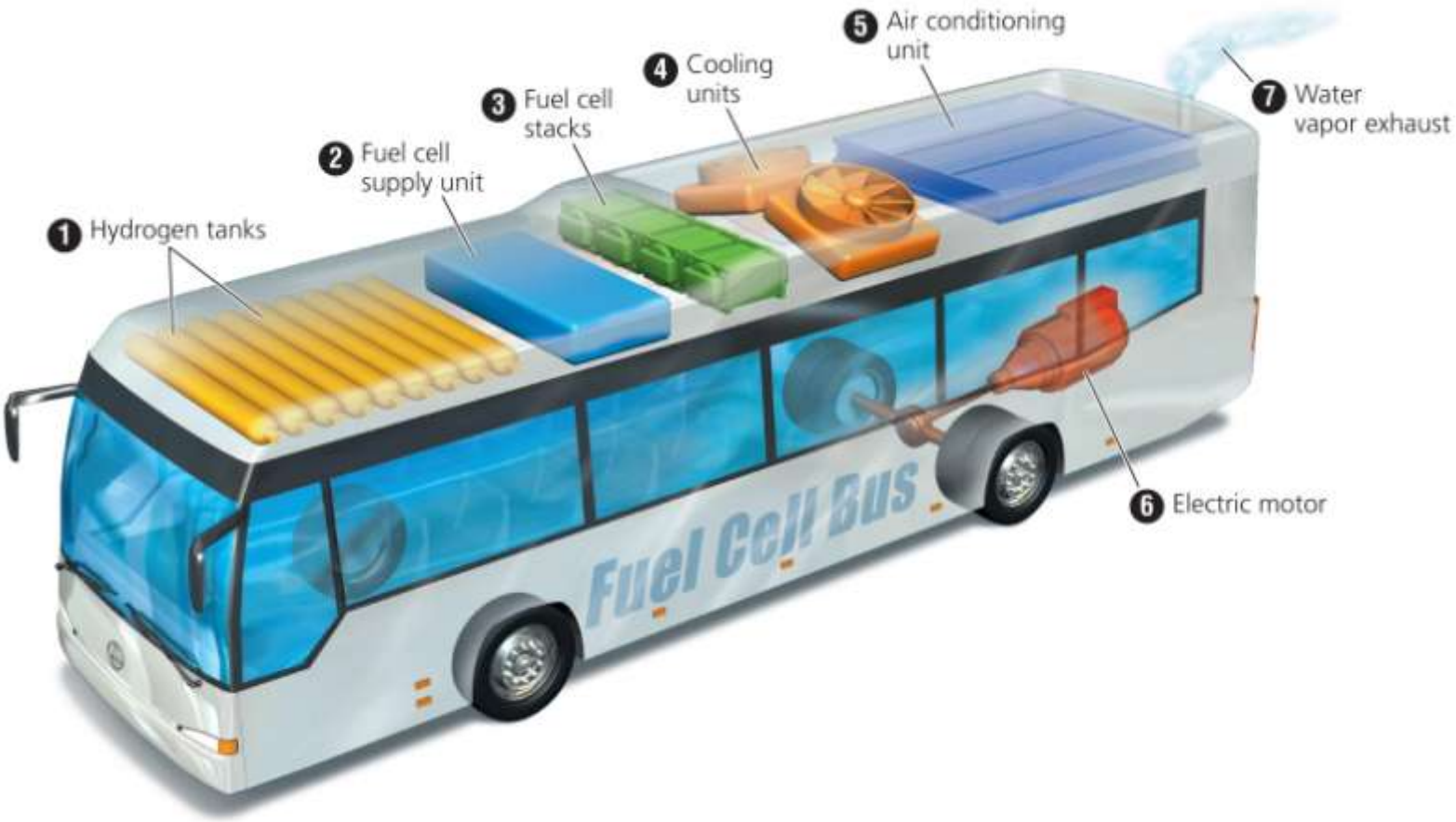
An energy system based on hydrogen

- Electricity generated from renewable sources could be used to produce hydrogen
- Vehicles, computers, cell phones, home heating, and countless other applications could be powered
- Basing an energy system on hydrogen could alleviate dependence on foreign fuels and help fight climate change
- Governments are funding research into hydrogen and fuel cell technology to produce vehicles that run on hydrogen

A typical hydrogen fuel cell



A hydrogen-fueled bus



Production of hydrogen fuel

- **Electrolysis** = electricity is input to split hydrogen atoms from the oxygen atoms of water molecules:
  - $2H_2O \Rightarrow 2H_2 + O_2$
  - Produces pure hydrogen
  - Will cause some pollution depending on the source of electricity, but less than than other processes

Other ways of obtaining hydrogen

- Hydrogen can also be obtained from biomass and fossil fuels, such as methane (CH_4)
  - $CH_4 + 2H_2O \Rightarrow 4H_2 + CO_2$
- Results in emissions of carbon-based pollution
- Whether a hydrogen-based energy system is environmentally cleaner than a fossil fuel system depends on how the hydrogen is extracted
- Leakage of hydrogen could deplete stratospheric ozone

Fuel cells produce electricity

- Once isolated, hydrogen gas can be used as a fuel to produce electricity within fuel cells
- The chemical reaction involved in that fuel cell is the reverse of electrolysis
  - $2H_2 + O_2 \Rightarrow 2H_2O$
- The movement of the hydrogen's electrons from one electrode to the other creates electricity

Hydrogen and fuel cells have many benefits

- We will never run out; hydrogen is the most abundant element in the universe
- Can be clean and nontoxic to use
- May produce few greenhouse gases and other pollutants
- Can be no more dangerous than gasoline in tanks
- Cells are energy efficient
- Fuel cells are silent and nonpolluting and won’t need to be recharged

Conclusion

- The coming decline of fossil fuels and the increasing concern over global climate change has convinced many people we need to shift to renewable energy
- Renewable sources include solar, wind, geothermal, and ocean energy sources and hydrogen fuel
- Renewable energy sources have been held back by inadequate funding and by artificially cheap prices for nonrenewable resources