

Chapter 13

Achieving Energy Sustainability

Module 37

Conservation, Efficiency, and Renewable Energy

After reading this module you should be able to

- describe strategies to conserve energy and increase energy efficiency.
- explain differences among the various renewable energy resources.

Thermodynamics Review

	1st Law of Thermodynamics	2nd Law of Thermodynamics
Definition	Energy is neither created nor destroyed, but can change from one form to another	When energy is converted from one form to another, some energy is lost
Example	The potential energy contained in firewood never goes away, but it is transformed into heat energy permeating the room when the wood is burned in a fireplace	When using an incandescent bulb, 5% of the energy entering the lightbulb is converted to useful light energy and the rest (95%) is lost to the environment as heat.

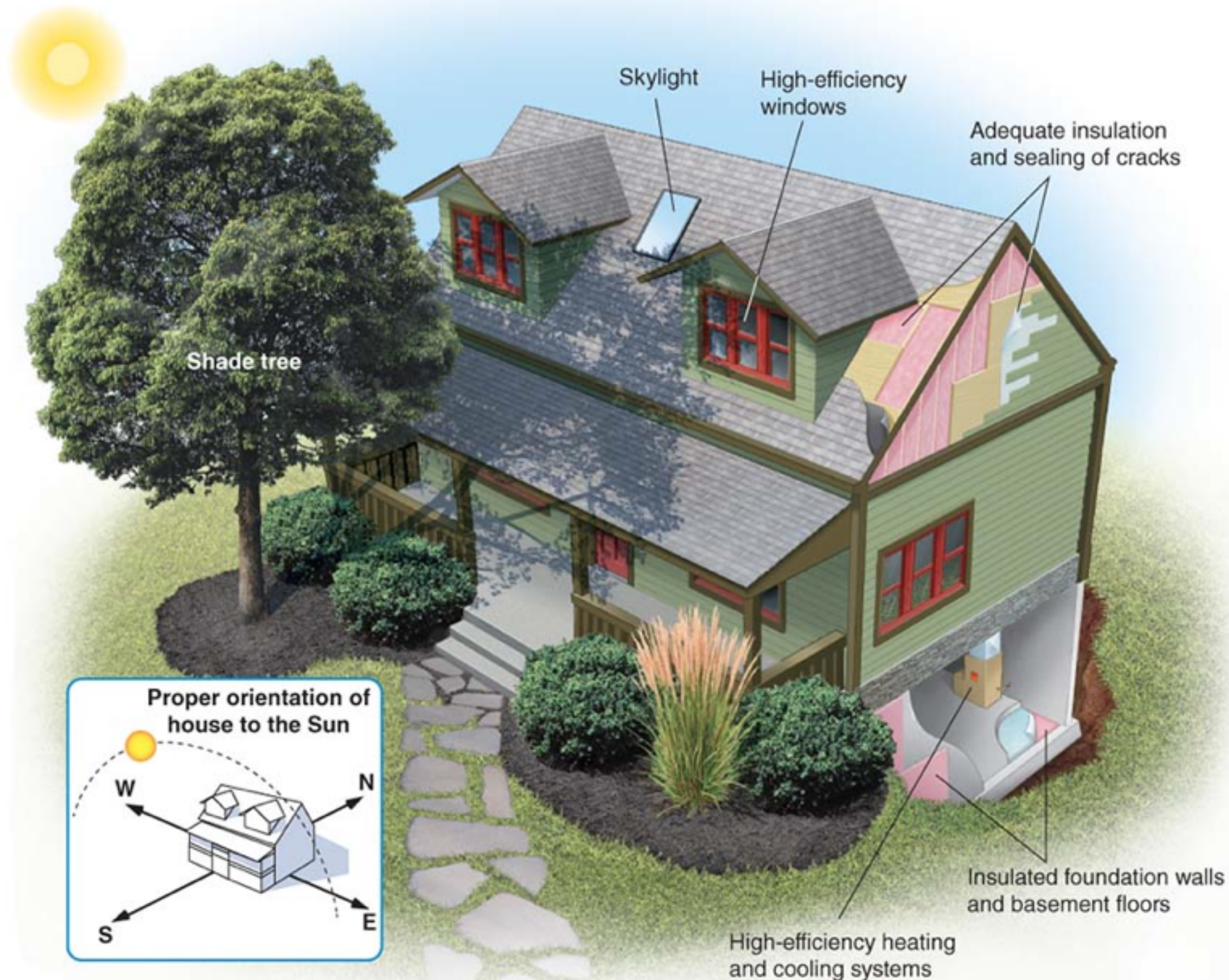
We can use less energy through conservation and increased efficiency

- Energy conservation and energy efficiency are the least expensive and most environmentally sound options for maximizing our energy resources.
- **Energy conservation** Finding and implementing ways to use less energy.
- **Tiered rate system** A billing system used by some electric companies in which customers pay higher rates as their use goes up.
- **Peak demand** The greatest quantity of energy used at any one time.

Sustainable Design

Sustainable design improves the efficiency of the buildings and communities in which we live and work.

An energy-efficient home. A sustainable building design incorporates proper solar orientation and landscaping as well as insulated windows, walls, and floors. In the Northern Hemisphere, a southern exposure allows the house to receive more direct rays from the Sun in winter when the path of the Sun is in the southern sky.



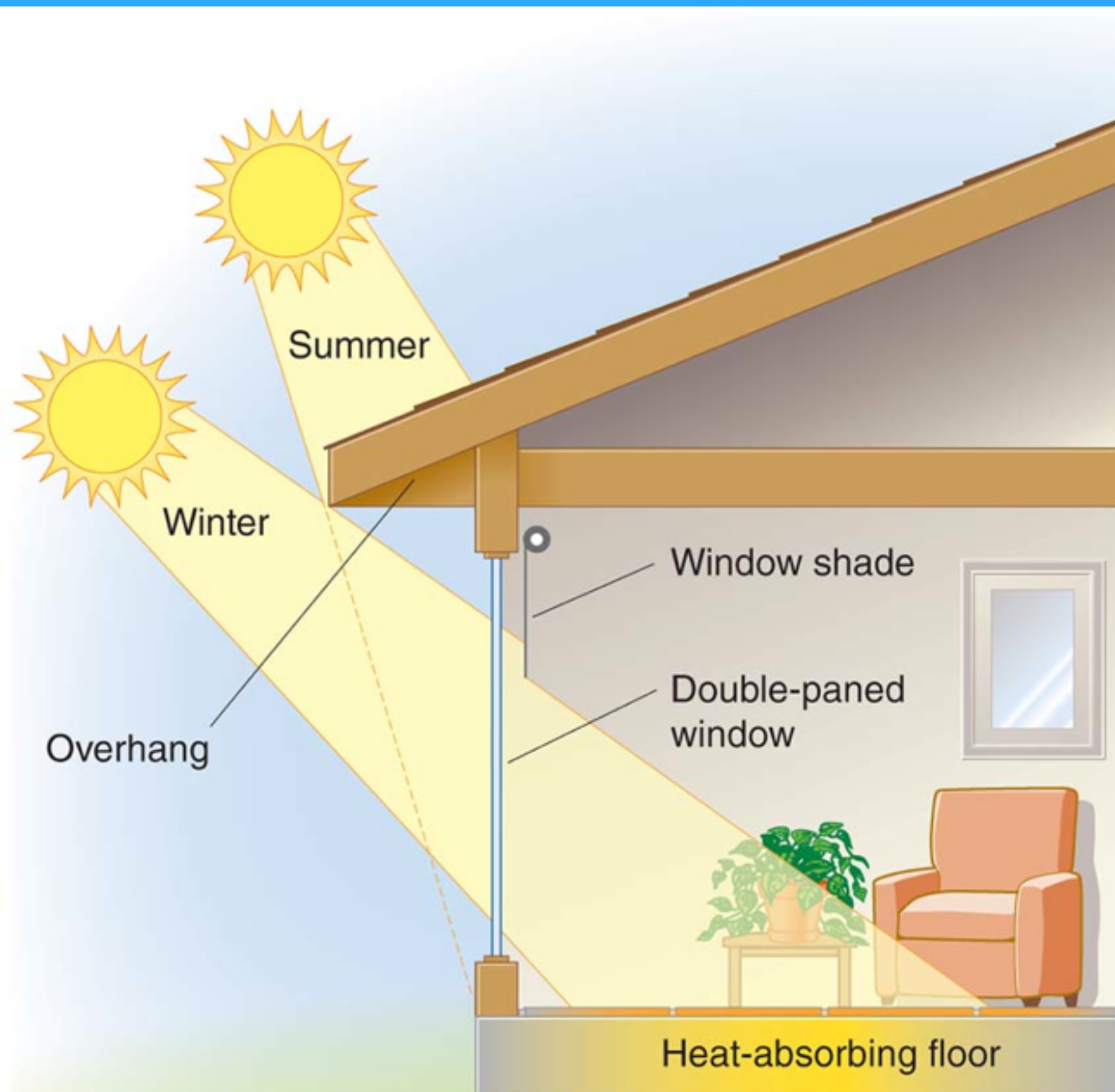
Sustainable Design

- **Passive solar design** Construction designed to take advantage of solar radiation without active technology.
- **Thermal mass** A property of a building material that allows it to maintain heat or cold.

Sustainable Design

- Using passive solar energy can lower your electricity bill without the need for pumps or other mechanical devices.
- Building the house with windows along a south-facing wall which allows the Sun's rays to warm the house is an example of passive solar design.

Sustainable Design



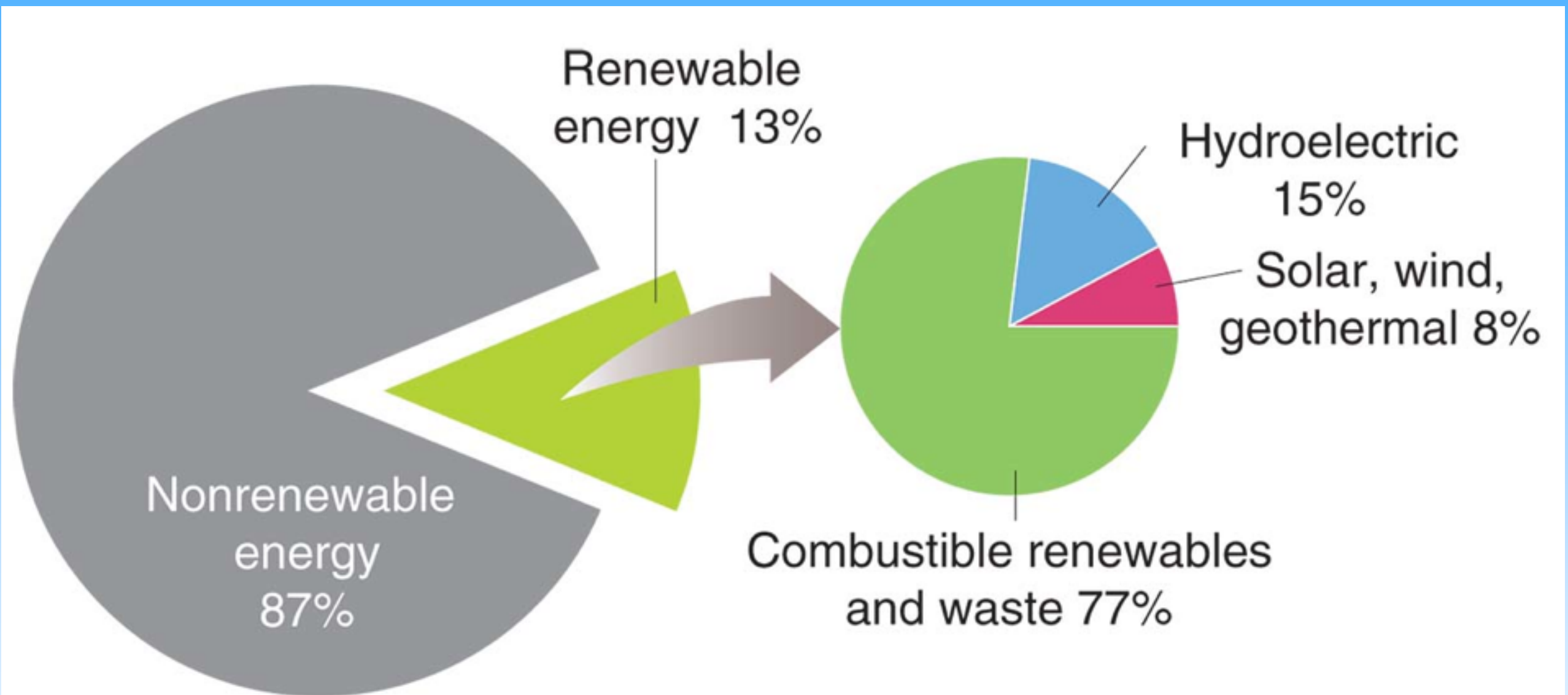
Passive solar design. Passive solar design uses solar radiation to maintain indoor temperature. Roof overhangs make use of seasonal changes in the Sun's position to reduce energy demand for heating and cooling. In winter, when the Sun is low in the sky, it shines directly into the window and heats the house. In summer, when the Sun is higher in the sky, the overhang blocks incoming sunlight and the room stays cool. High-efficiency windows and building materials with high thermal inertia are also components of passive solar design.

Renewable energy is either potentially renewable or nondepletable

- **Potentially renewable** An energy source that can be regenerated indefinitely as long as it is not overharvested.
- **Nondepletable** An energy source that cannot be used up.
- **Renewable** In energy management, an energy source that is either potentially renewable or nondepletable.

Renewable Energy

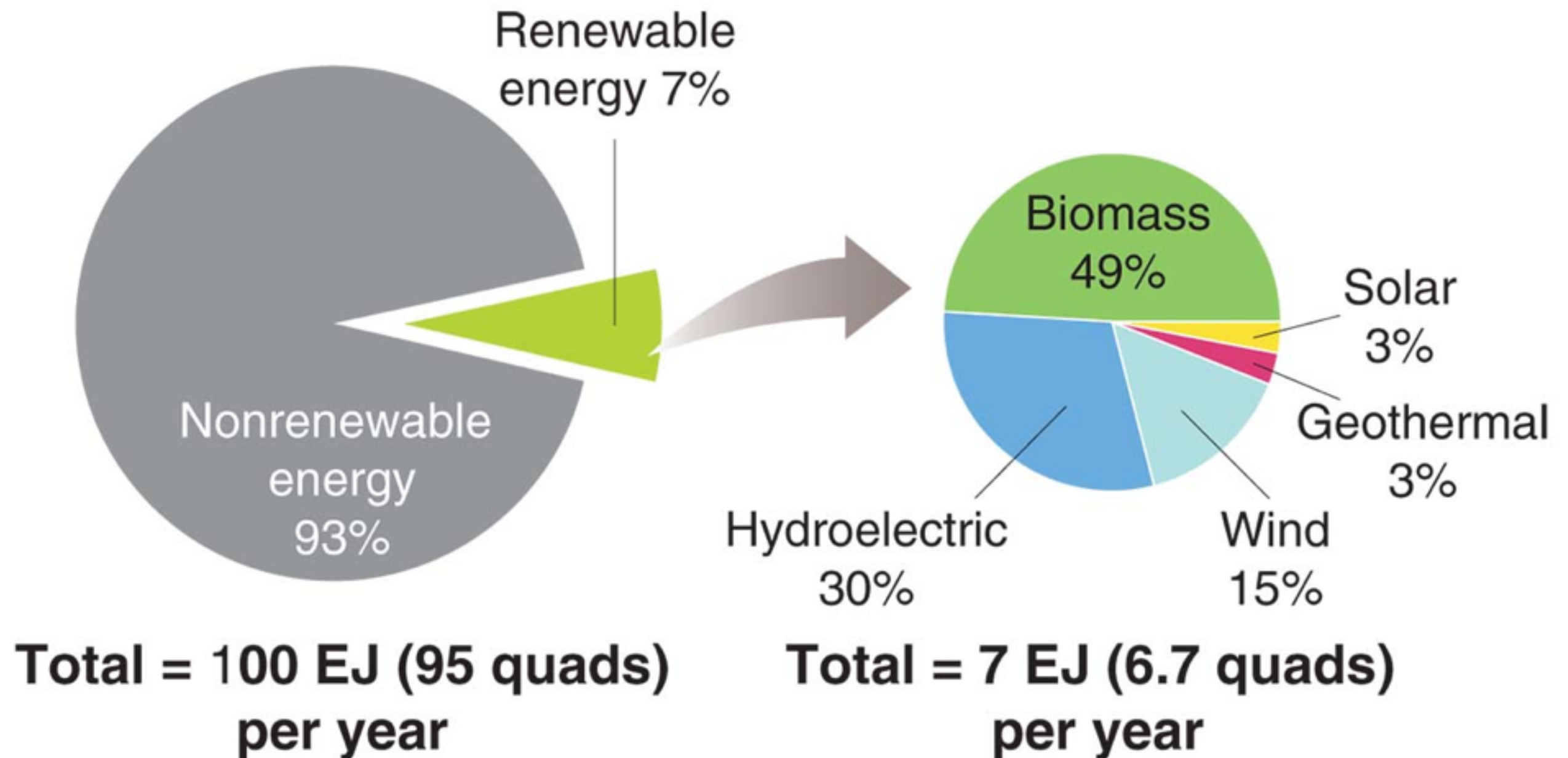
Global energy use. Renewable energy resources provide about 13 percent of energy worldwide



**Total = 550 exajoules per year
(520 quadrillion Btu, or “quads”) per year**

Renewable Energy

Energy Use in the United States. Only 7 percent of the energy used in the United States comes from renewable energy resources.



Module 38

Biomass and Water

After reading this module you should be able to

- describe the various forms of biomass.
- explain how energy is harnessed from water.

Biomass is energy from the Sun

Energy from the Sun. The Sun is the ultimate source of almost all types of energy.

How are fossil fuels related to the sun?

How are “other” fuels related to the sun?

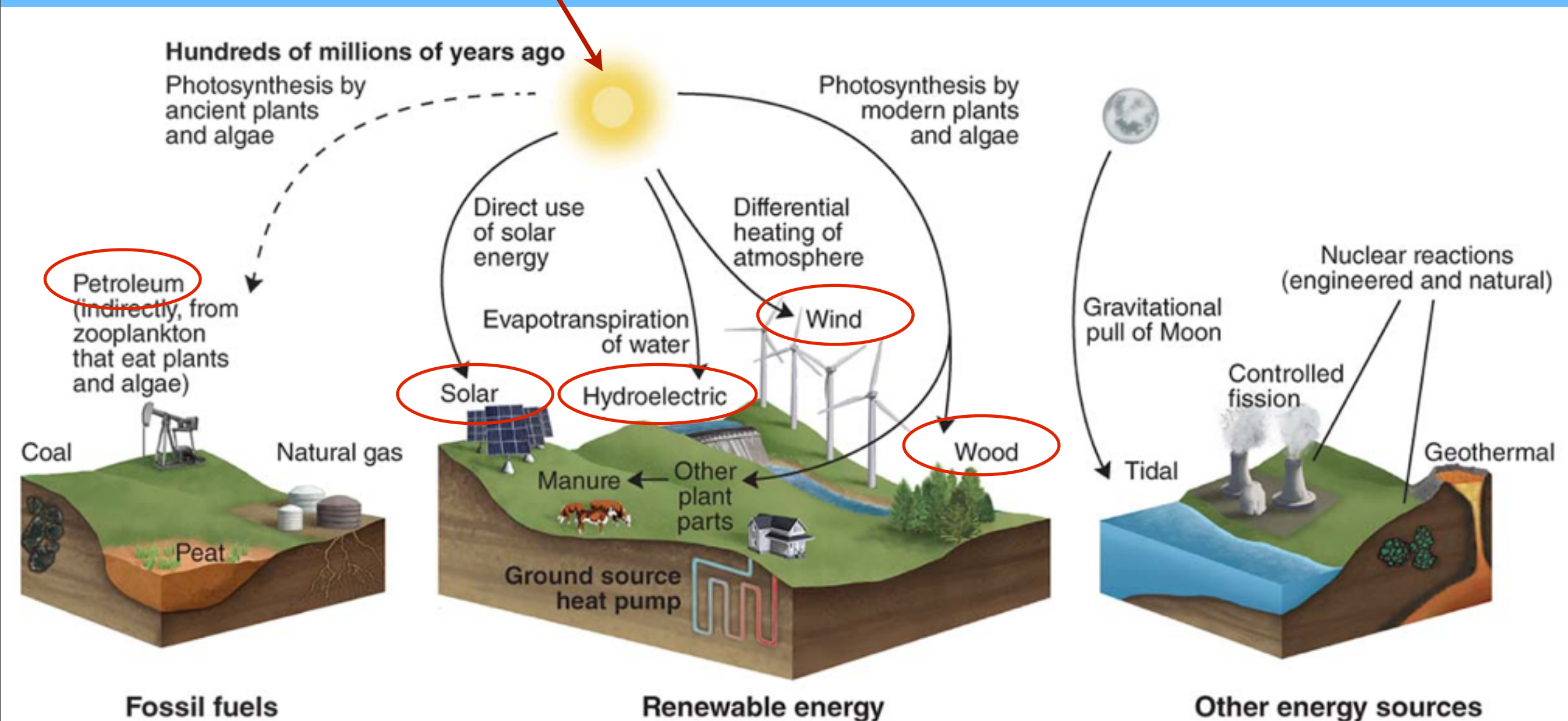


Figure 38.1

Modern Carbon Versus Fossil Carbon

- **Biofuel** Liquid fuel created from processed or refined biomass.
- **Modern carbon** Carbon in biomass that was recently in the atmosphere.
- **Fossil carbon** Carbon in fossil fuels.
- **Carbon neutral** An activity that does not change atmospheric CO₂ concentrations.

Solid Biomass: Wood, Charcoal, and Manure

- Wood, charcoal and manure are used to heat homes throughout the world.
- In the developing world, people often cannot afford fossil fuels or do not have access to them.
- **Net removal** The process of removing more than is replaced by growth, typically used when referring to carbon.

Solid Biomass

- Use of wood is unsustainable if forest growth does not keep up with forest use.
- Charcoal is lighter than wood and contains twice as much energy per unit of weight. It also produces less smoke.
- In regions where wood is scarce, people often use dried animal manure as a fuel for indoor heating and cooking. Burning manure indoors creates indoor air pollution.

Biofuels: Ethanol and Biodiesel

- Liquid biofuels can be used as a substitute for gasoline and diesel.
- Ethanol Alcohol made by converting starches and sugars from plant material into alcohol and CO₂.
- **Biodiesel** A diesel substitute produced by extracting and chemically altering oil from plants.
- **Flex-fuel vehicle** A vehicle that runs on either gasoline or a gasoline/ethanol mixture.

Class Work Review

- What are the different types of solid biomass and liquid biomass?
- How are the different types of solid biomass and liquid biomass used?
- Where are the different types of solid biomass and liquid biomass used?
- How are the different types of solid biomass and liquid biomass similar?
- Describe the environmental effects of using the different types of solid biomass and liquid biomass?
- What is the difference between Gasohol, E-85 and B-20?

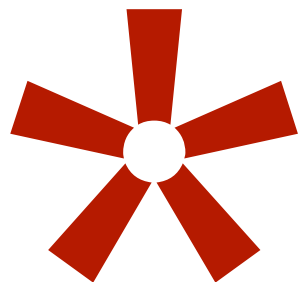
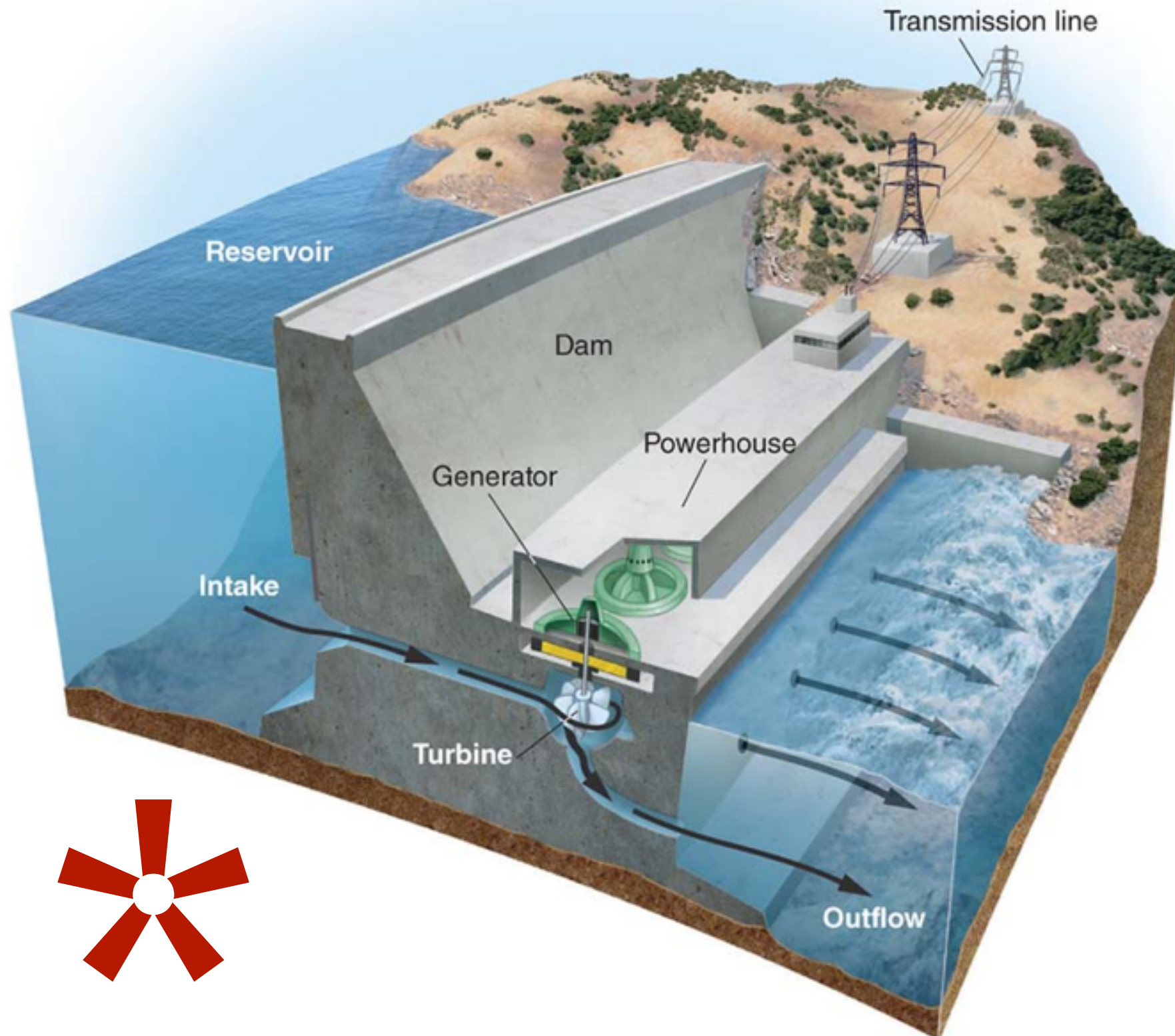
The kinetic energy of water can generate electricity

- **Hydroelectricity** Electricity generated by the kinetic energy of moving water.
- Worldwide, nearly 20% of all electricity comes from hydroelectric power plants with China the leading producer.

The kinetic energy of water can generate electricity

- **Hydroelectricity** Electricity generated by the kinetic energy of moving water.
- **Run-of-the-river** Hydroelectricity generation in which water is retained behind a low dam or no dam.
- **Water impoundment** The storage of water in a reservoir behind a dam.
- **Tidal energy** Energy that comes from the movement of water driven by the gravitational pull of the Moon.

Hydroelectricity



A water impoundment hydroelectric dam.

Water impoundment, a common method of hydroelectricity generation, allows for electricity generation on demand. Dam operators control the rate of water flow by opening and closing the gates. This determines the amount of electricity generated. The arrows indicate the path of water flow.

Hydroelectricity and Sustainability

Hydroelectricity has many benefits:

- Hydroelectric projects bring renewable energy to large numbers of rural residents worldwide.
- Hydroelectricity does not create air pollution, waste products, or CO₂ emissions.
- Electricity generated from hydroelectricity is less expensive.
- Reservoirs create recreational opportunities.

Hydroelectricity and Sustainability

Hydroelectricity has some negative environmental consequences:

- Creating the reservoir may flood agricultural land or places of archeological significance, and force people to relocate.
- Impounding a river can interfere with organisms that depend on a free-flowing river.
- Downstream ecosystems are affected.
- **Siltation** The accumulation of sediments, primarily silt, on the bottom of a reservoir.

Module 39

Solar, Wind, Geothermal, and Hydrogen

After reading this module, you should be able to

- list the different forms of solar energy and their application.
- describe how wind energy is harnessed and its contemporary uses.
- discuss the methods of harnessing the internal energy from Earth.
- explain the advantages and disadvantages of energy from hydrogen.

The energy of the Sun can be captured directly

Geographic variation in solar radiation in the United States. This map shows the amount of solar energy available to a flat photovoltaic solar panel in kilowatt-hours per square meter per day, averaged over a year.

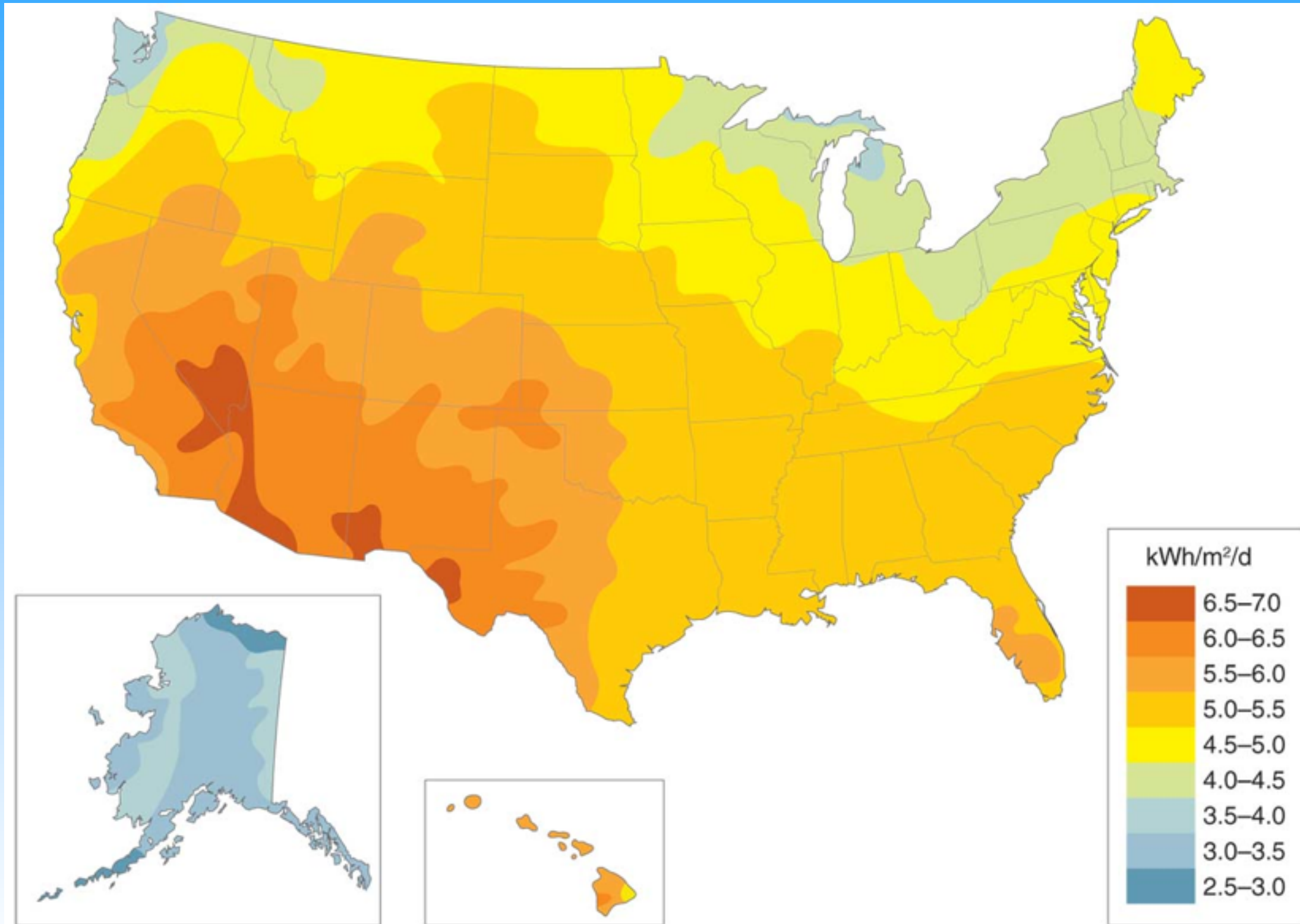


Figure 39.1

Passive Solar Energy

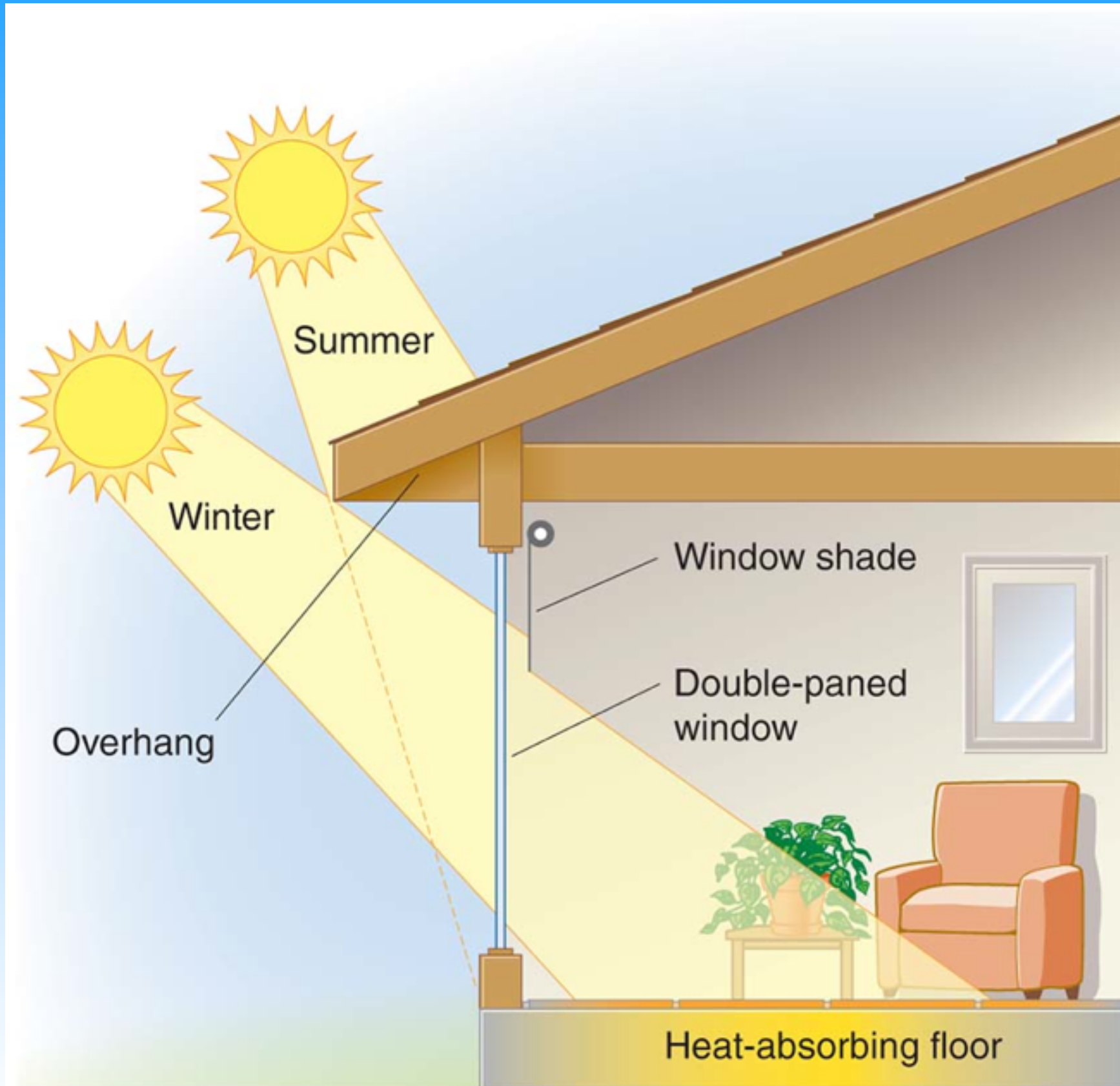


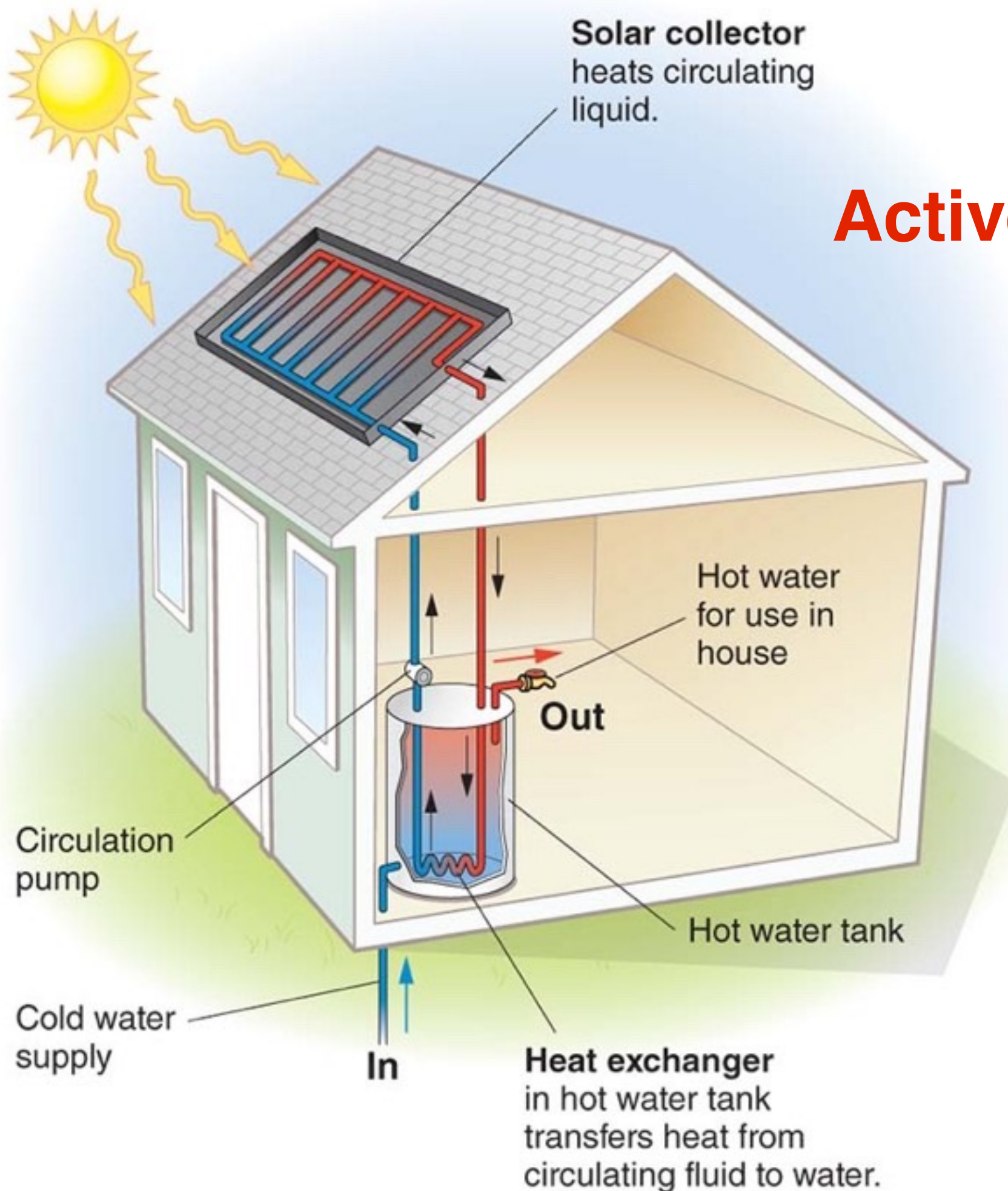
Figure 37.3

Active Solar Energy

- **Active solar energy** Energy captured from sunlight with advanced technologies.

Technologies that employ active solar energy include:

- Solar water heating systems
- Photovoltaic systems
- **Photovoltaic solar cell** A system of capturing energy from sunlight and converting it directly into electricity.
- Large-scale concentrating solar thermal systems for electricity generation (CST)



Active Solar Energy

What equipment do passive solar heating and active solar heating use?

What is the primary use of a passive solar heating system?

What is the relative costs of passive and active solar heating systems?

Benefits of Active Solar Energy Systems

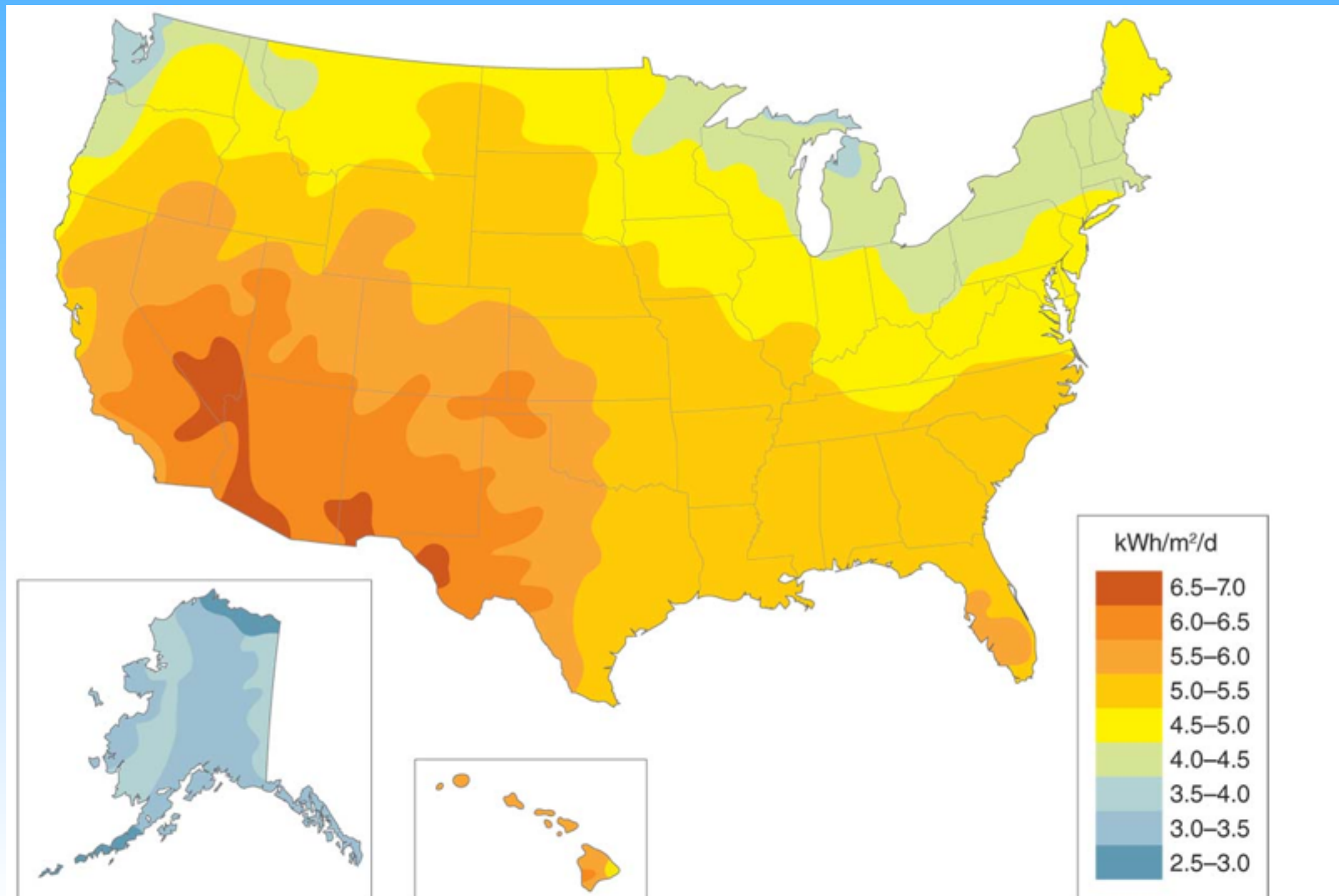
Active solar energy systems offer many benefits:

- Generating hot water or electricity without producing CO₂ or polluting the air or water during operation.
- Producing electricity on hot, sunny days when demand for electricity is high.
- Producing electricity during peak demand hours helps reduce the need to build new fossil fuel power plants.
- A photovoltaic system may be less expensive than running electrical transmission lines to some home sites.

What do the colors on the map indicate?

What is the kilowatt hours per square per day for: Houston, New York City, Phoenix and Cleveland? And Delray Beach?

If you were the Governor of Arizona, what type of incentive would you recommend to increase the number of photovoltaic cells used in residential homes?



Drawbacks of Active Solar Energy Systems

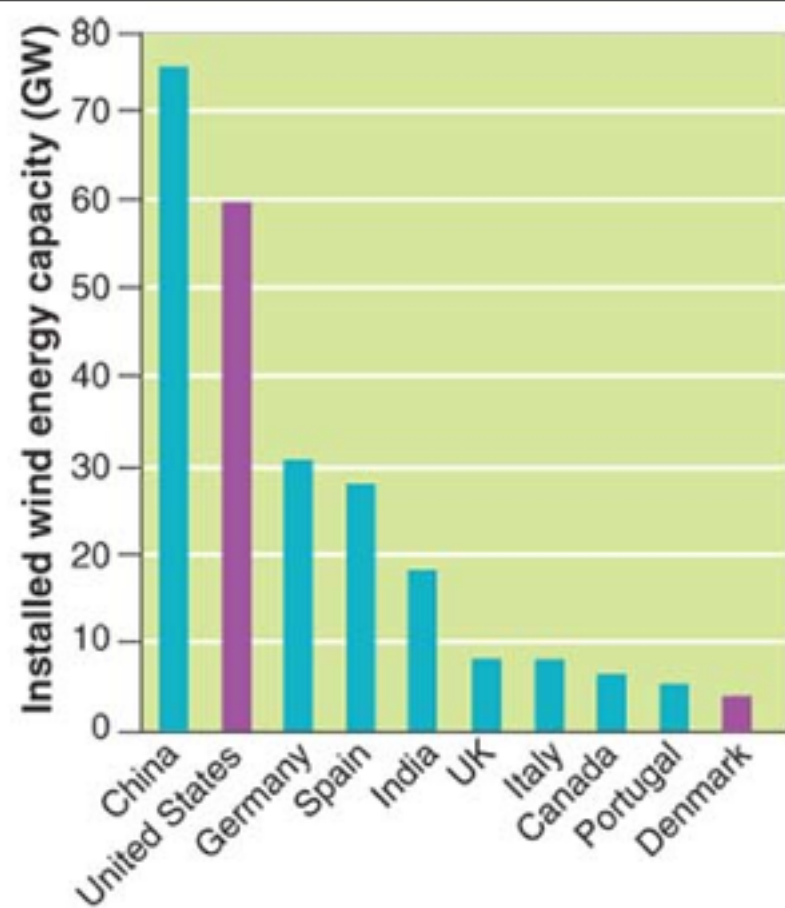
Drawbacks have inhibited the growth of solar energy use in the United States:

- Photovoltaic solar panels are expensive to manufacture and install.
- Manufacturing requires energy and water, and involves a variety of toxic metals and industrial chemicals.
- There are environmental costs associated with the batteries for systems that use batteries for energy storage.
- The end-of-life reclamation and recycling is another potential source of environmental contamination.

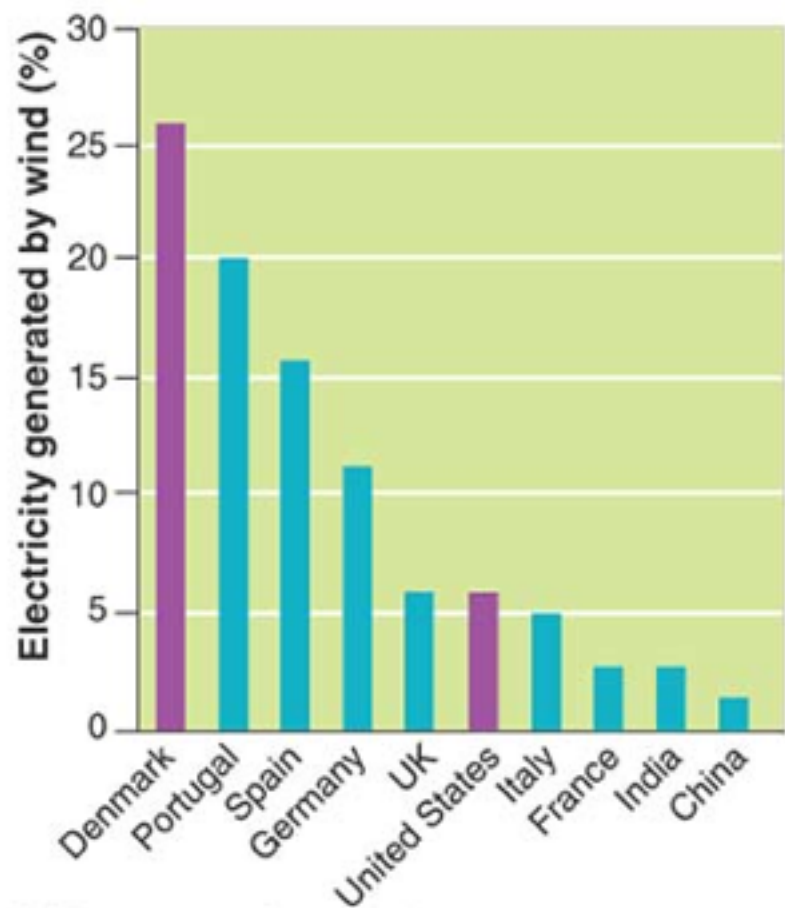
Wind energy is the most rapidly growing source of electricity

- **Wind energy** Energy generated from the kinetic energy of moving air.
- Wind energy is the fastest growing major source of electricity in the world.
- Ultimately the sun is the source of all winds!

Wind Energy



(a) Wind capacity



(b) Percentage from wind

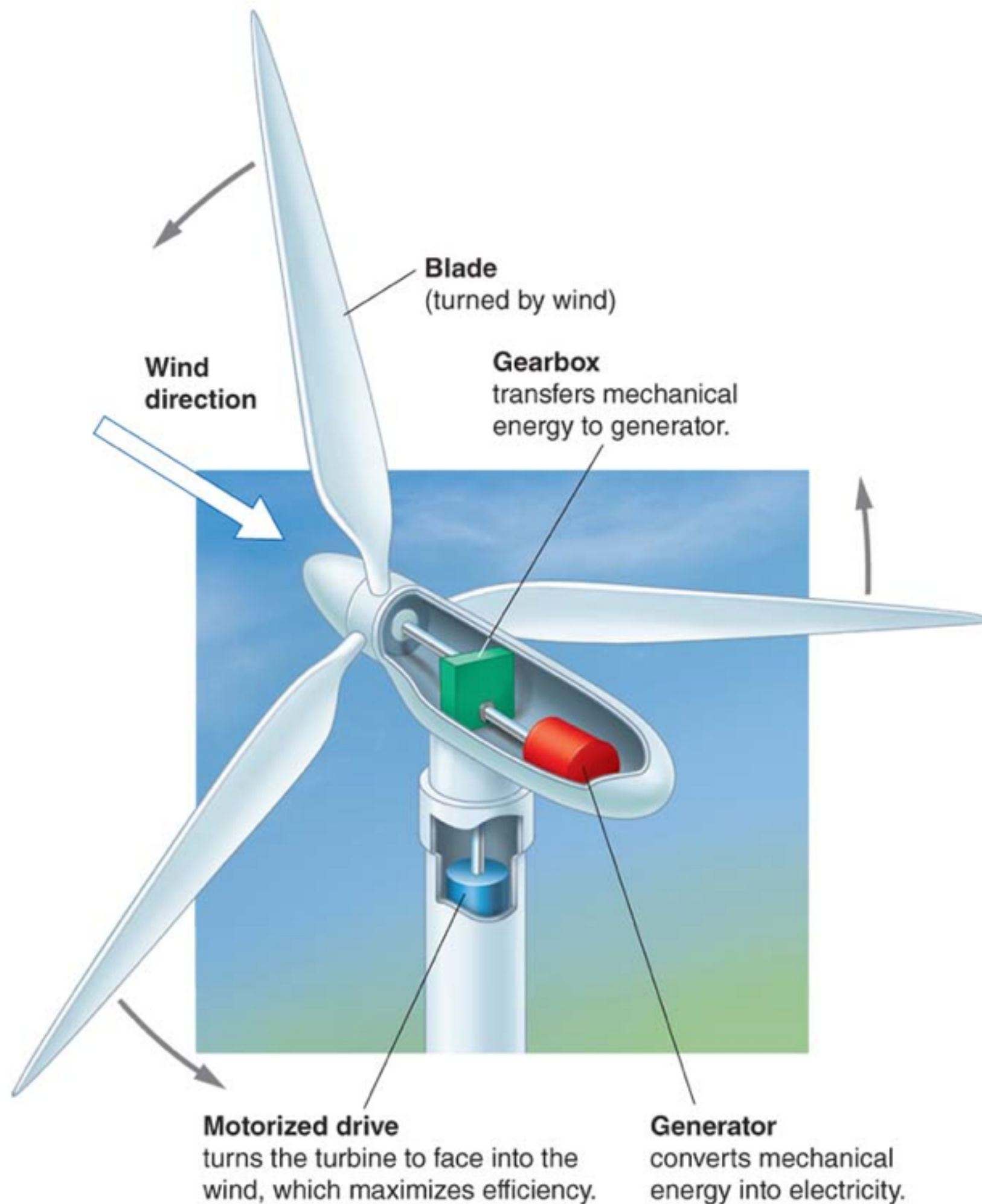
Installed wind energy capacity by country.

(a) China generates more electricity from wind energy than any other country.

(b) However, some relatively small countries, such as Denmark, generate a much higher percentage of their electricity from wind.

Generating Electricity from Wind

- **Wind turbine** A turbine that converts wind energy into electricity.
- The blades of the wind turbine transfer energy to the gear box that transfers energy to the generator.
- Wind turbines on land are typically installed in rural locations, away from buildings and population centers.
- Turbines are typically grouped into wind farms or wind parks.



Generating electricity with a wind turbine.

The wind turns the blade, which is connected to the generator, which generates electricity.

The number of wind farms in the U.S. and around the world is increasing, it is the fastest growing renewable source of energy.

Wind Energy

Advantages of wind energy include:

- It is a nondepletable and free energy resource.
- After manufacturing and installation, little energy input other than wind is required.
- Wind-generated electricity produces no pollution and no greenhouse gases.
- Wind farms can share the land with other uses.

Wind Energy

Disadvantages of wind energy include:

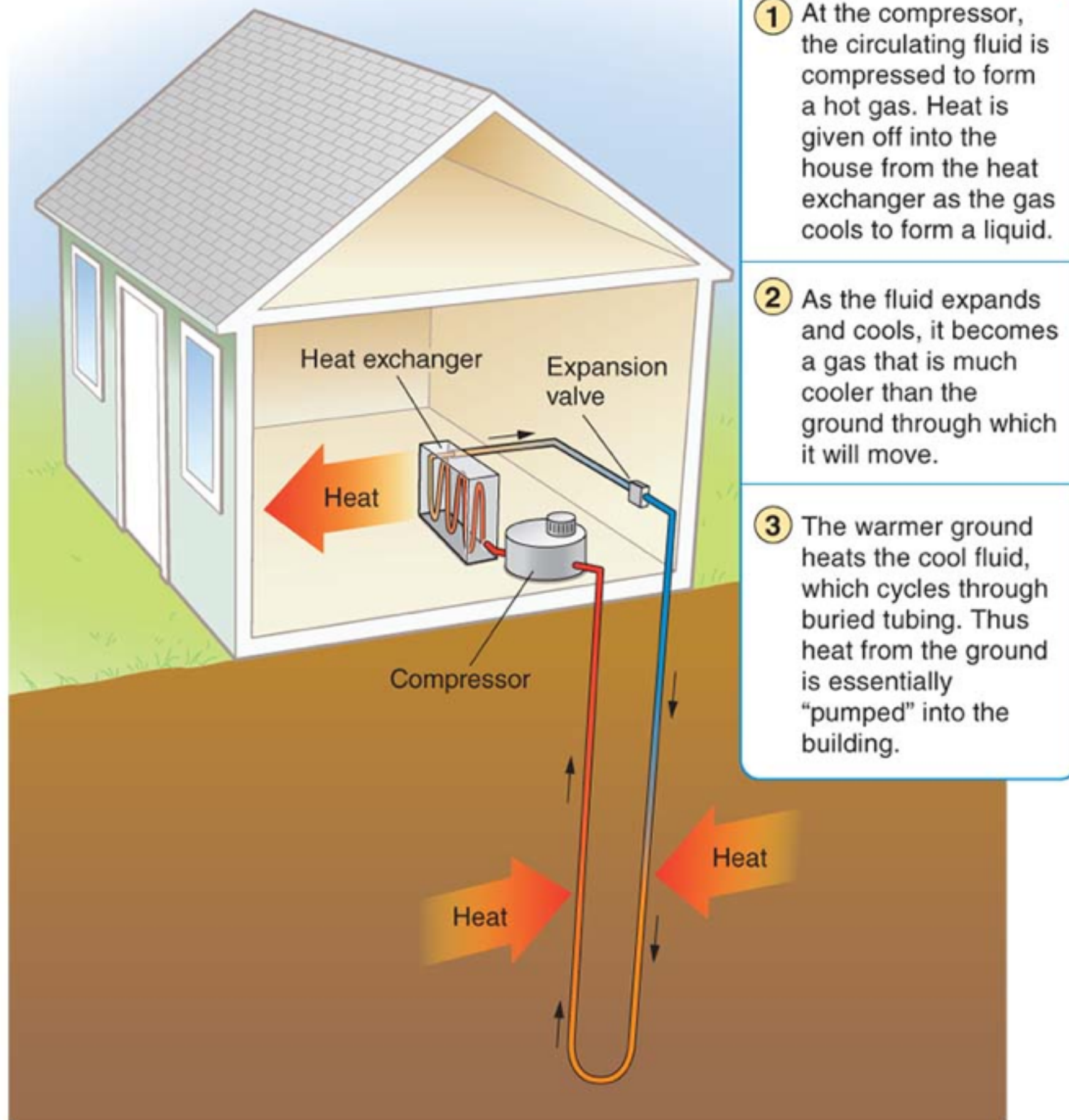
- Most off-grid residential wind energy systems rely on batteries to store.
- Wind turbines can be noisy and unattractive.
- As many as 40,000 birds are killed by wind turbine blades in the United States each year.
- Bats are also killed by wind turbines.

Earth's internal heat is a source of nondepletable energy

- **Geothermal energy** Heat energy that comes from the natural radioactive decay of elements deep within Earth.
- Geothermal energy can be used directly as a source of heat.
- Many countries obtain clean, renewable energy from geothermal resources.
- The United States, China, and Iceland, all of which have substantial geothermal resources, are the largest geothermal energy producers. Overall however it has the less potential for growth than solar or wind because it is not easily accessible everywhere and hazardous gases could potentially escape from power plants.

Ground Source Heat Pumps

- **Ground source heat pump** A technology that transfers heat from the ground to a building.
- Although the heat tapped by ground source heat pumps is often informally referred to as “geothermal,” it comes from solar energy.



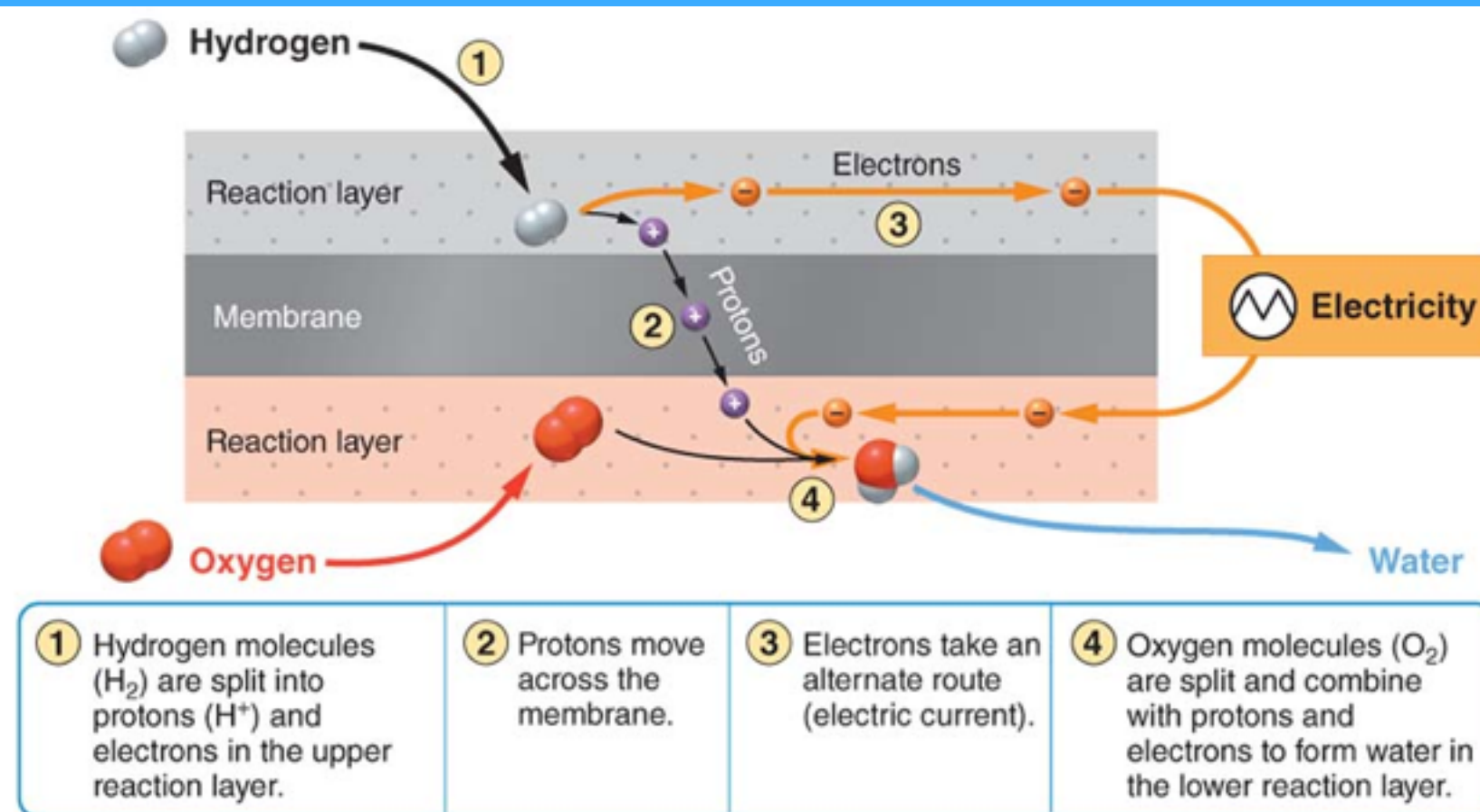
Heating and cooling with a ground source heat pump. By exchanging heat with the ground, a ground source heat pump can heat and cool a building using 30 to 70 percent less energy than traditional furnaces and air conditioners.

Hydrogen fuel cells have many potential applications

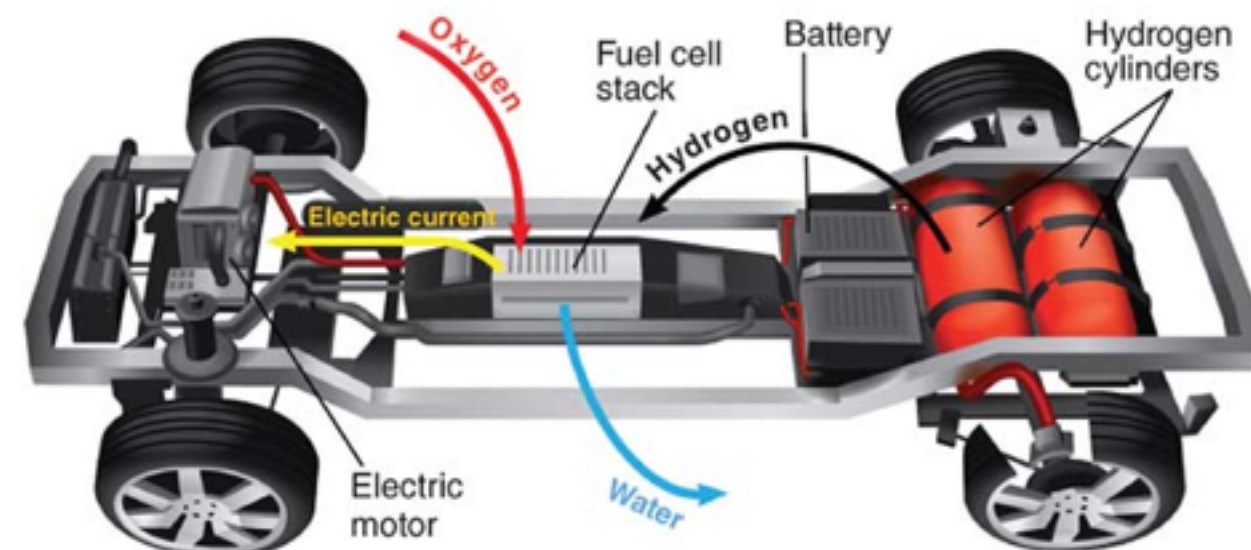
- **Fuel cell** An electrical-chemical device that converts fuel, such as hydrogen, into an electrical current.
- **Electrolysis** The application of an electric current to water molecules to split them into hydrogen and oxygen.

Power from a hydrogen fuel cell.

- (a) Hydrogen gas enters the cell from an external source. Protons from the hydrogen molecules pass through a membrane, while electrons flow around it, producing an electric current. Water is the only waste product of the reaction.
- (b) In a fuel cell vehicle, hydrogen is the fuel that reacts with oxygen to provide electricity to run the motor.



(a) One common fuel cell design



(b) Fuel cell vehicle

Module 40

Planning Our Energy Future

After reading this module, you should be able to

- discuss the environmental and economic options we must assess in planning our energy future.
- consider the challenges of a renewable energy strategy.

Our energy future depends on efficiency, conservation, and the development of renewable and nonrenewable energy resources

- No single energy can replace nonrenewable energy resources in a way that is completely renewable, nonpolluting, and free of impacts on the environment.

A sustainable energy strategy must combine:

- Energy efficiency
- Energy conservation
- Development of renewable and nonrenewable energy resources

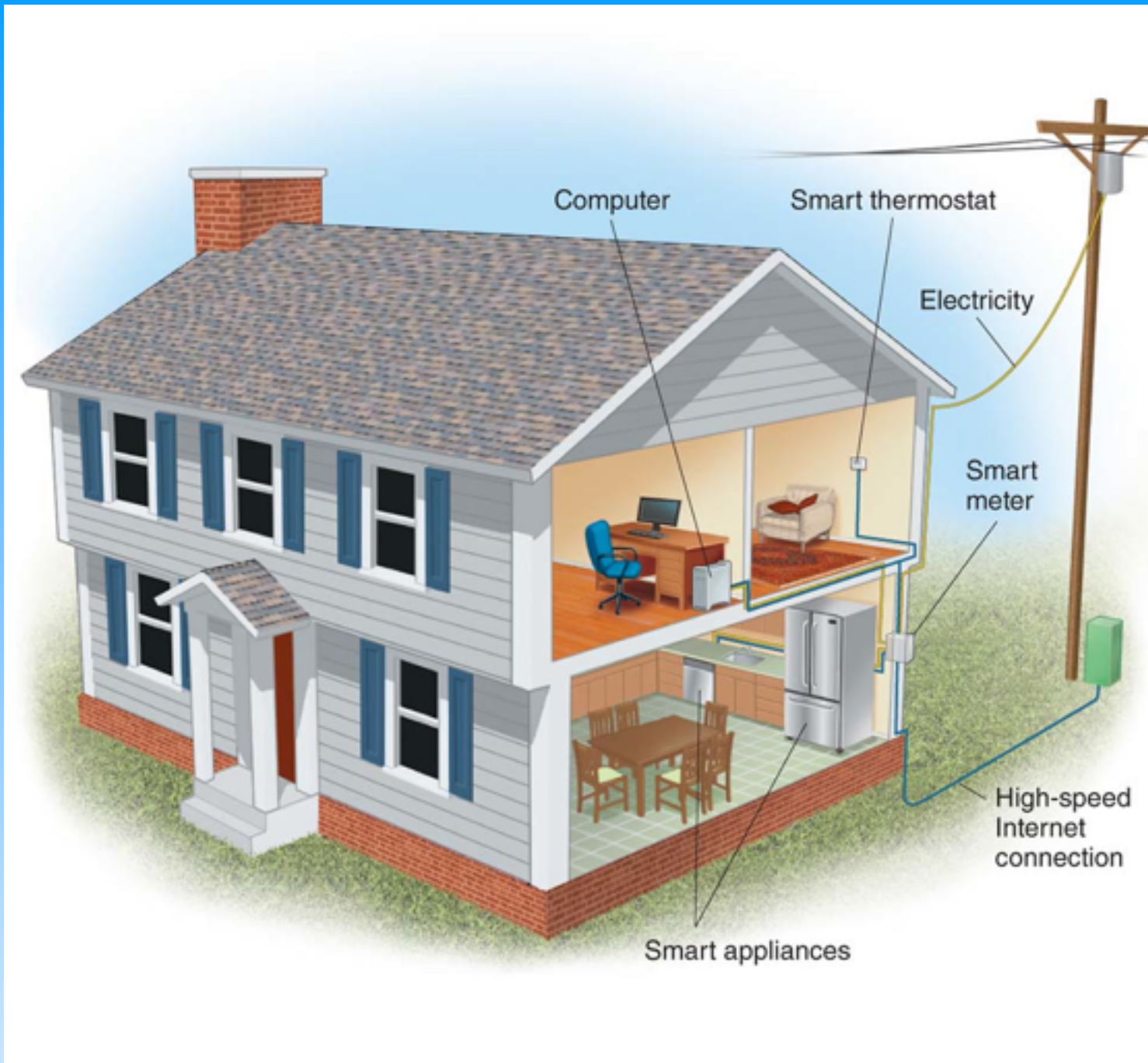
Our Energy Future

- A sustainable energy strategy must consider the costs, benefits, and limitations of each energy source.
- Convenience, reliability, and logistical considerations are also important.
- **Smart grid** An efficient, self-regulating electricity distribution network that accepts any source of electricity and distributes it automatically to end users.

Renewable energy strategy presents many challenges

- Renewable energy sources will not likely replace fossil fuels in the near future unless: tax incentives are put in place, consumer rebates, direct funding and other financial incentives.
- Government funding and other sources of capital are needed to support research to overcome the current limitations of many renewable energy sources.

Our Energy Future



Using a smart grid. So in addition to investing in new energy sources, the U.S. will have to upgrade its existing electrical infrastructure- its power plants, storage capacity, and distribution networks.

Using a smart grid. A smart grid optimizes the use of energy in a home by continuously coordinating energy use with energy availability.

Smart Grid

- Improving the electrical grid can make moving electricity from place to place more efficient, thereby reducing the need for storage capacity.
- A smart grid uses computer programs and the internet to move energy around thereby distributing the energy more evenly during peak times and low times.
- Some experts argue for increase the number of power plants and decrease there size. In other words, have lots of small power plants with a mixture of energy sources