Chapter 13
Achieving Energy Sustainability

Renewable energy

can be rapidly regenerated, and some can never be depleted, no matter how much of them we use.

Potentially renewable- biomass energy, we don't consume faster than they can replenish.

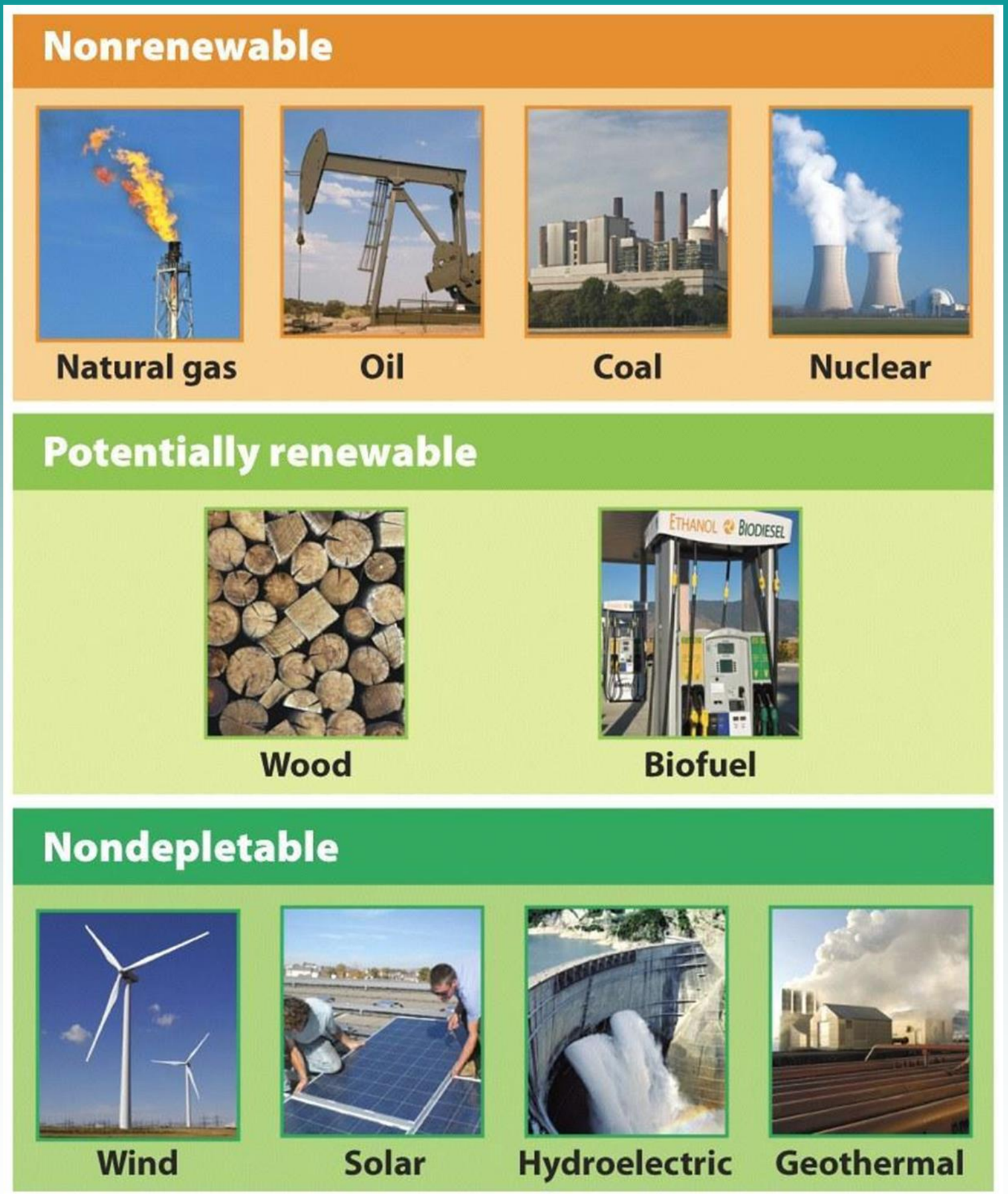

Figure 13.1
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How can we use less energy?

Energy conservation- finding ways to use less energy. For example, lowering your thermostat during the winter or driving fewer miles.

Energy efficiency- getting the same result from using a smaller amount of energy.

Home

- Weatherize (insulate, seal gaps).
- Turn thermostat down in winter, up in summer.
- Reduce use of hot water (do laundry in cold water/take shorter showers).
- Replace incandescent bulbs with compact fluorescents or LEDs.

Transportation

- Walk or ride a bike.
- Take public transportation.
- Carpool.
- Consolidate trips.

Electrical and electronic devices

- Buy Energy Star devices and appliances.
- Unplug when possible or use a power strip.
- Use a laptop rather than a desk-top computer.

Figure 13.4
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Benefits of Conservation and Efficiency

- Many energy companies have an extra backup source of energy available to meet the peak demand, the greatest quantity of energy used at any one time. (free incentives to improve/reduce energy use such as devices, tax breaks, reduction in bill...etc)
- **Variable price structure-** utility customers can pay less to use energy when demand is lowest and more during peak demand.

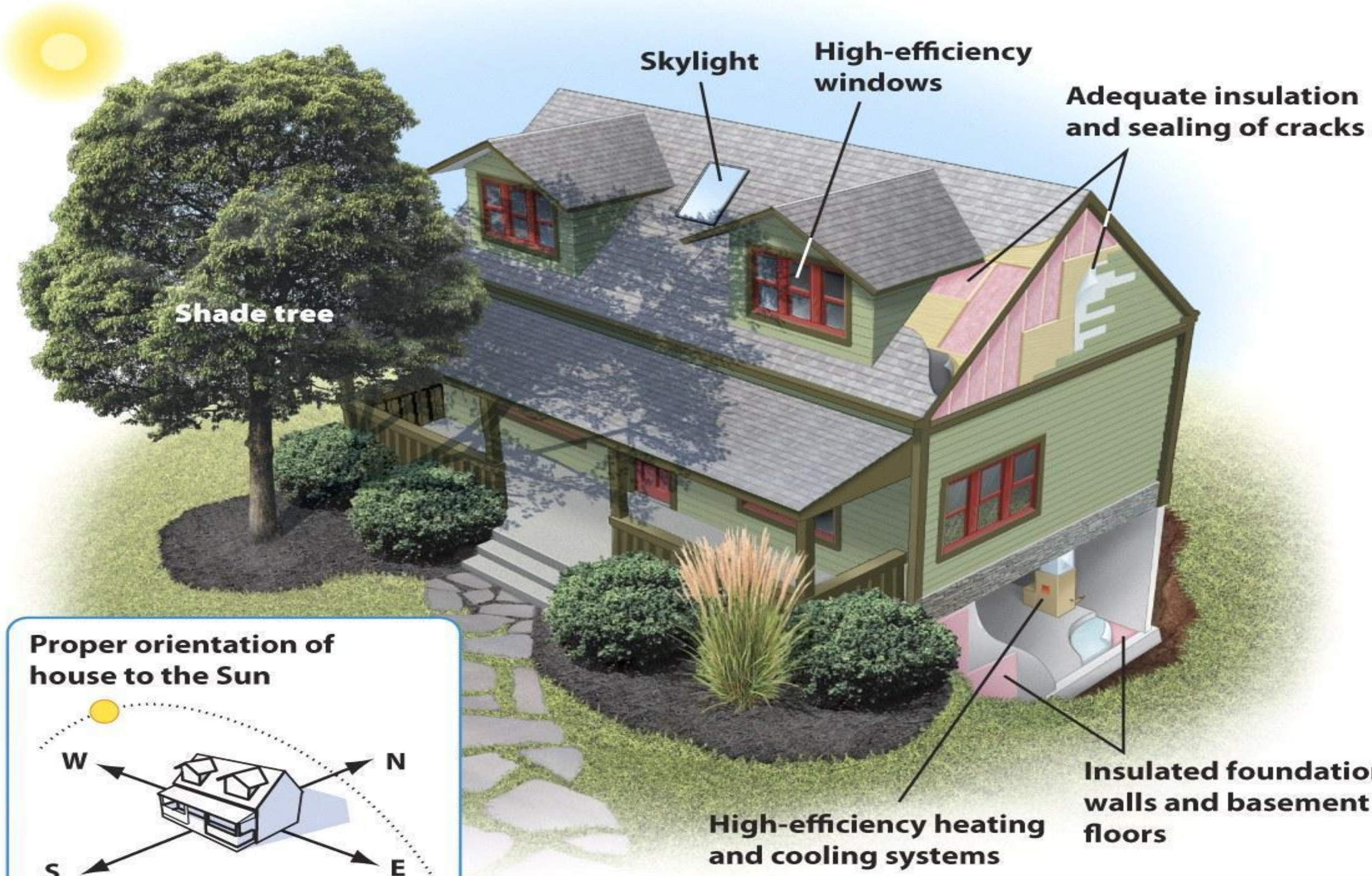


Figure 13.5
Environmental Science

A sustainable building design incorporates proper solar orientation and landscaping, as well as well insulated windows, walls, and floors

Sustainable Design

- Improving the efficiency of the buildings we live and work in.

Potential Consequences:

- **Biomass** can lead to overharvesting of wood leading to deforestation and degradation of the land.
- **Wind turbines** can unintentionally kill birds and bats.
- **Hydroelectric turbines** kills million of fish/marine life.
- **Photovoltaic solar panels** require heavy metals and great deal of water.

- All energy choices have environmental consequences…**best choice is to conserve and be efficient with our uses and choices in lifestyles.**

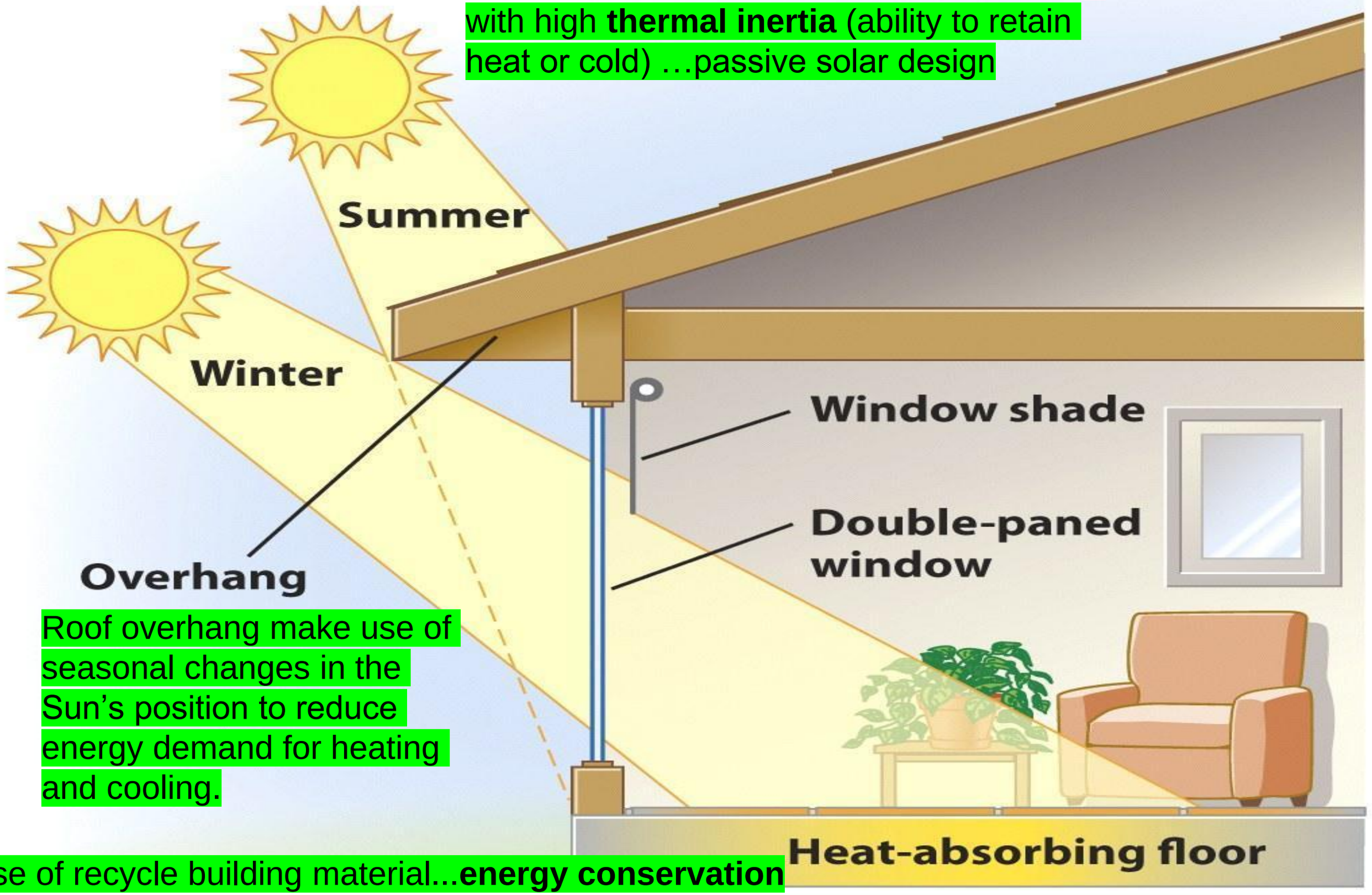
Passive Solar Energy

- **Passive solar design-** a technique that takes advantage of solar radiation to maintain a comfortable temperature in the building.

- Using passive solar energy can lower your electricity bill without the need for pumps or other mechanical devices and reduce deforestation.
  - Ex. Building the house with windows along a south facing wall which allows the Sun's rays to warm the house or covering building with dark roofing material (absorb max of heat)

- **Solar ovens** (technology to supply heat) – solar energy is absorbed by a dark based box lined with reflective material on the inside trapped with a glass top *("box cooker")* and is converted into heat energy *(on sunny days box can maintain temps at 350*F).*

High efficient windows & building materials with high **thermal inertia** (ability to retain heat or cold) …passive solar design



Roof overhang make use of seasonal changes in the Sun's position to reduce energy demand for heating and cooling.

Use of recycle building material...**energy conservation**

Building on the side of a hill or roofing with soil & plants **provide insulation** (reduce heating & cooling)

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Sustainable Design (San Francisco) maximizes the use of natural light & ventilation. This building generates much of its own electricity with solar panels on the roof and captures water in its rooftop garden.

The Sun's energy can be captured directly

- **Active solar energy-** capturing the energy of sunlight with the use of a pump or photovoltaic solar cell and generating electricity.
  - Solar water heating applications can provide energy to heat up a pool (most common) or any liquid within the household (water heater).

- **Photovoltaic solar cells** *–(contrast to solar water heating system)* captures energy from the Sun as light, not heat, and convert it directly into electricity.

- **Solar panels** (usually on roof) connect directly to appliances or lights or used to charge batteries for later use
  - *-photovoltaic systems are tied to the electrical grid…any extra electricity generated is sent to the electric company to buy or give customer credit for later use.*

Figure 13.19

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Solar thermal power plant “power tower’ uses sunlight to heat water and make steam for electricity

Benefits vs. Drawbacks

Benefits:

~Generate electricity w/o air pollution, water pollution or greenhouse gases emission.

~Economically feasible (credit for extra electricity generated during peak seasons)

~Tax breaks, rebates, and funding packages by various states

Drawbacks:

~Initial install and manufacture is expensive

~Low solar radiation....geography

~Manufacturing of cells require great deal of energy & water and a variety of toxic metals and industrial chemicals to be released into the environment *(working on better technologies and metals/chemicals used in the process)*

Biomass is energy from the Sun

- The Sun is the ultimate source of almost all types of energy (non-solar based energies are nuclear, geothermal & tidal)

- **Biomass** *(accounts for 10% of world energy consumption)* energy resource include *wood, charcoal, animal product & manure, plant remains, municipal solid waste (MSW)* used to heat homes throughout the world.

- **Biofuels**-*(accounts for 50% of the renewable energy, includes ALL biomass, mostly wood)* biomass that has been processed or refined into liquid fuels such as *biodiesel & ethanol* (used as substitutes for gasoline and diesel fuel).

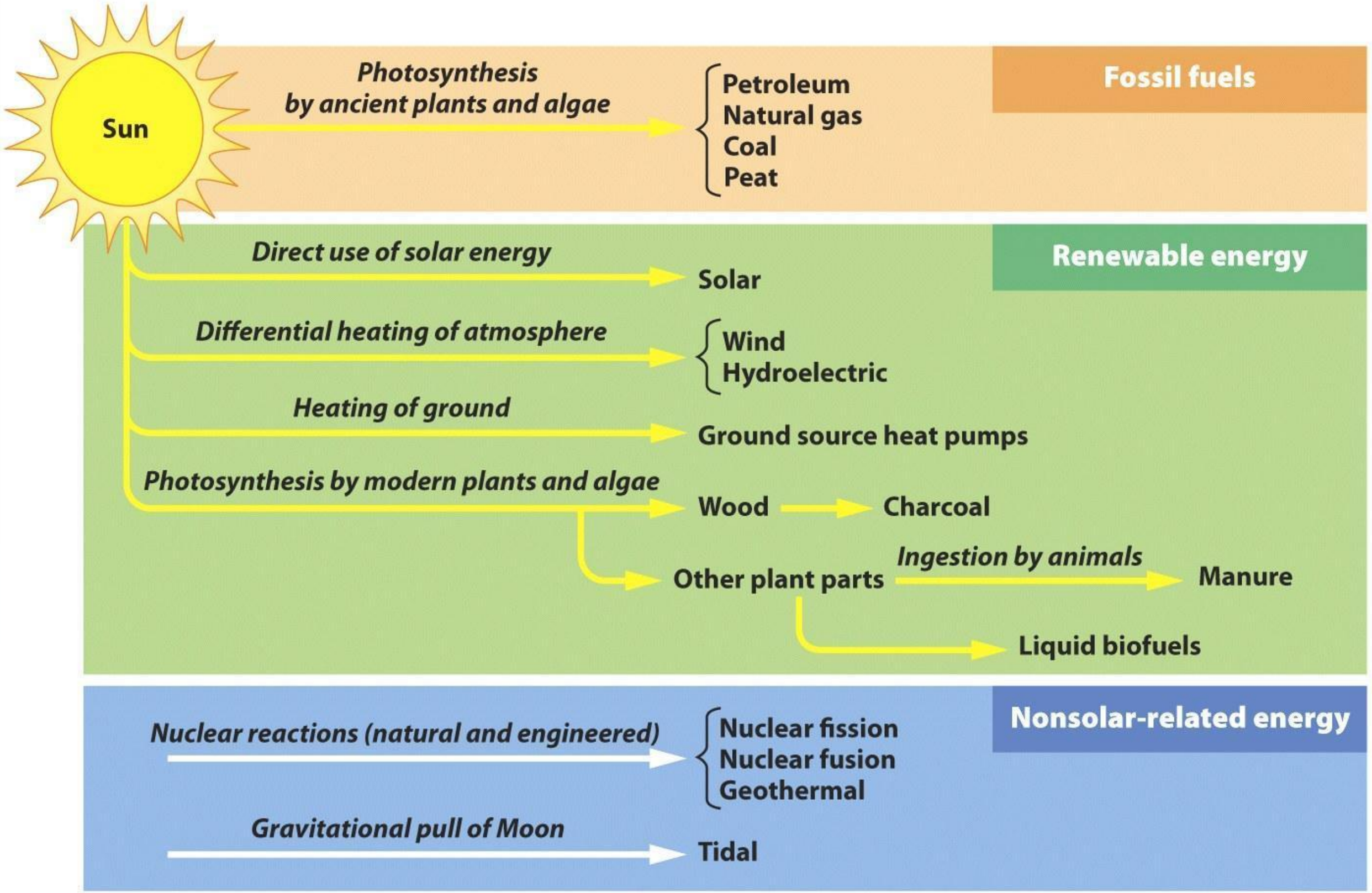

Figure 13.8
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Modern Carbon vs. Fossil Carbon

- Many people are confused how burning biomass such as wood is *better* then burning coal (both put Carbon into atmosphere).
- **Modern Carbon** – the carbon found in biomass was in the atmosphere as carbon dioxide, taken in by the tree, and by *burning it we put it back into the atmosphere*
  - *In theory, modern carbon should not result in a net increase in atmospheric carbon dioxide*
- **Fossil Carbon** – Burning coal is carbon that has been buried for millions of years and was out of circulation until we began to use it. This results in a *rapid increase in the concentration of carbon dioxide in the atmosphere* (release of stored Carbon that has been "buried for millions of years)

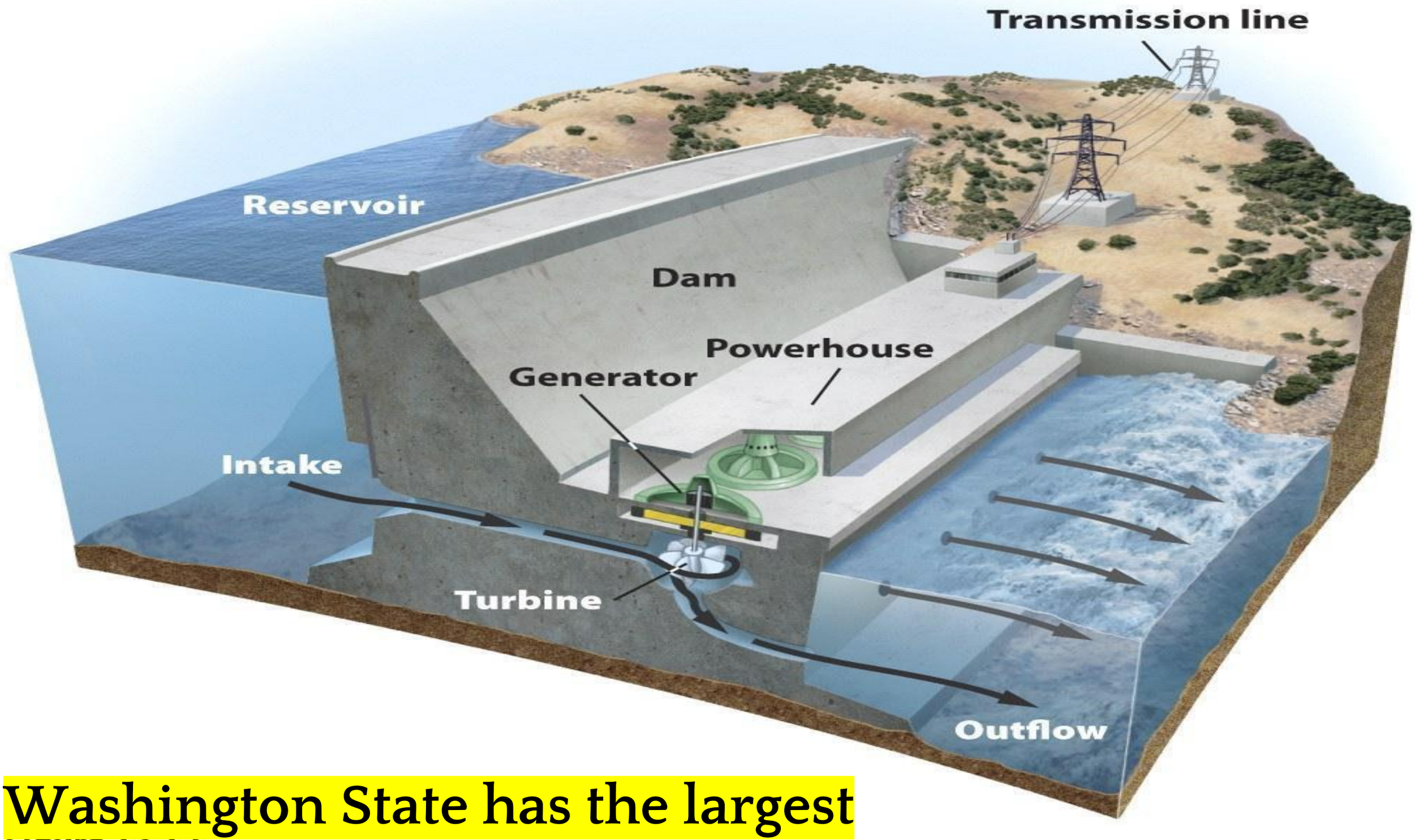
The kinetic energy of water can generate electricity

- **Hydroelectricity**- electricity generated by the kinetic energy of moving water *(falling over vertical distance, flowing with a river or tidal)*.
  - This is the second most common form of renewable energy in the world (China #1 producer, followed by Brazil & U.S).

~A hydroelectric power plant captures the kinetic energy (flowing water) and uses it to turn a turbine, the turbine transforms the kinetic energy of water into electricity (just like the kinetic energy of steam turns turbines in a coal-fired power plant), exported to the electrical grid via transmission lines.

~The amt. of electricity generated depends on the flow rate, the water travels at (higher rate, more spinning of the turbine, more electricity)

Water impoundment System



Washington State has the largest

one generating 6,800MW at peak capacity

Types of hydroelectric power systems

- **Run-of-the-river systems-** water is held behind a dam and runs through a channel before returning to the river (not controlled).

  ~Natural water flows (small), not a reservoir. Dry, hot period, flow of water is low….little electricity generated.

- **Water impoundment** (most common method)- water is stored behind a dam and the gates of the dam are opened and closed *controlling the flow of water.*

- **Tidal systems-** the movement of water is driven by the gravitational pull of the Moon (not a major energy source).

  - ~Uses gates & turbines underwater to capture KE of water flowing through estuaries, rivers and bays & convert it into electricity.

Hydroelectricity Sustainable

- Require minimal fossil fuels
- Generate large quantities of electricity w/o creating air pollution, waste products, or Carbon dioxide emissions
- Less expensive for the consumers *(than electricity generated using nuclear or natural gas - $.5 to $.11/kW)*
- Reservoir behind a dam can provide recreational & economic opportunities *(generate millions of dollars and visitors)* as well as downstream flood control for flood-prone areas

Negative Consequences

- Hydroelectric dams are expensive to build
- Flooding prime valley agricultural land or canyons
- Large reservoirs of standing water hold more heat, contain less oxygen & release greenhouse gases (*to build & fill reservoirs*) than free-flowing rivers
- Regulating water flow, & flooding, dams can alter dynamics of ecosystem
- accumulation of sediments **(siltation)**, over time (hundreds of years, or decades depending on geology of area), reservoir fills with sediment, water is impounded, generating electricity is reduced…major reason to *dismantle dams*

Earth's internal heat produces geothermal energy

- **Geothermal energy-** is heat that comes from the natural radioactive decay of elements deep within Earth (Sun has no point in this process).

- Whenever magma comes close enough to groundwater (heats up), pressure builds up from the hot liquid…drives to the surface causing a geyser or hot spring to occur.

- Electricity-generating process is like thermal power plant, steam run the turbines come from water evaporated by Earth's internal heat instead of burning fossil fuels

- Unfortunately, long periods of harvesting groundwater from a site may deplete it to a point of no return…returning the water to the ground to be reheated is needed for sustainably.

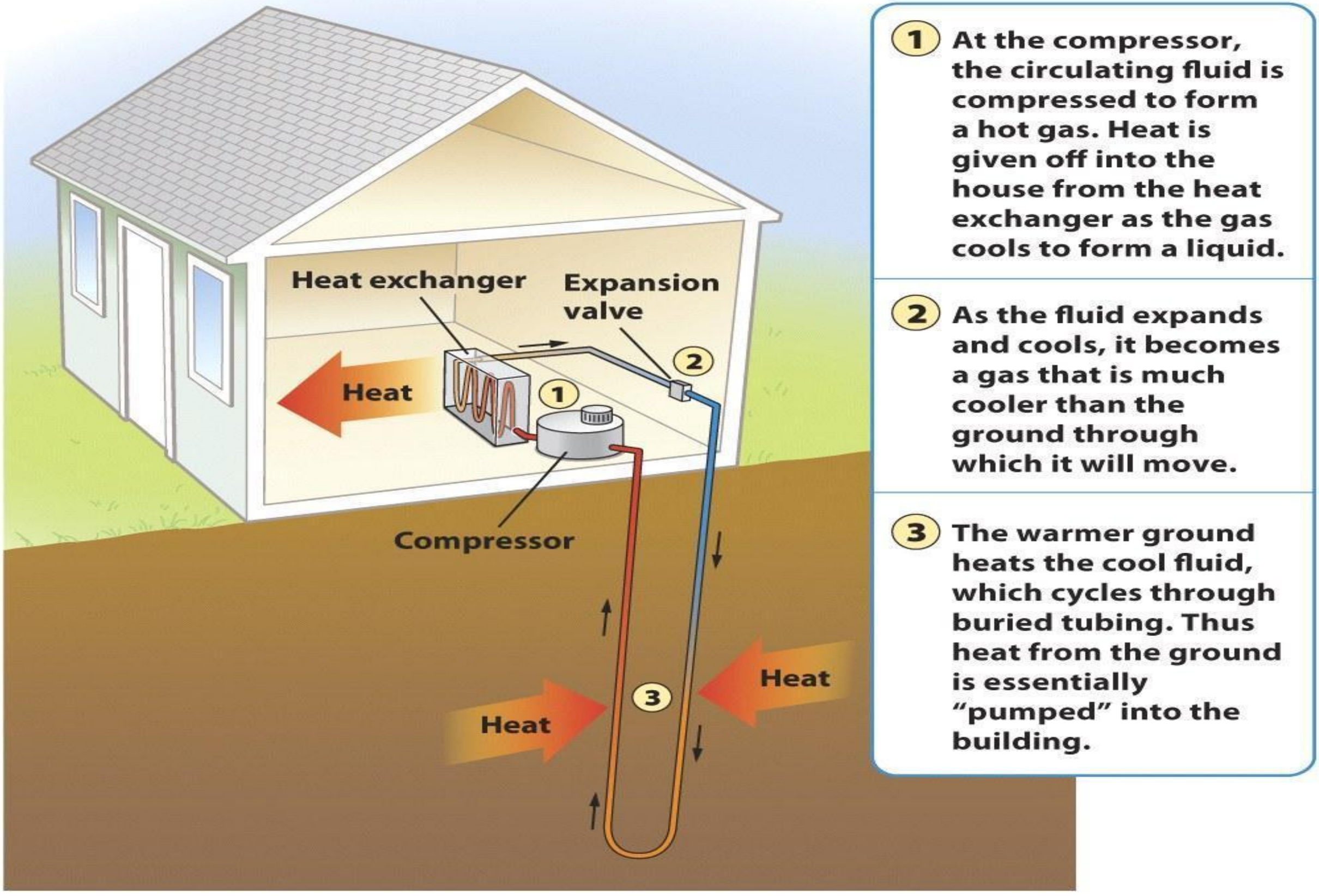


Figure 13.20
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A ground source can heat & cool a building using 30 to 70% less energy than traditional furnaces & air conditions

Wind energy is the most rapidly growing source of electricity

- **Wind energy-**(less than 1% generated electricity) using a wind turbine to convert kinetic energy of moving air into electrical energy
  - *Sun is the source of all winds...solar radiation & ground surface heating drives air circulation.*
- Offshore wind parks (in or near coastline water) generated more electricity. Typically installed in rural locations, away from buildings & population centers

Wind turns blade, connected to the generator, generates electricity

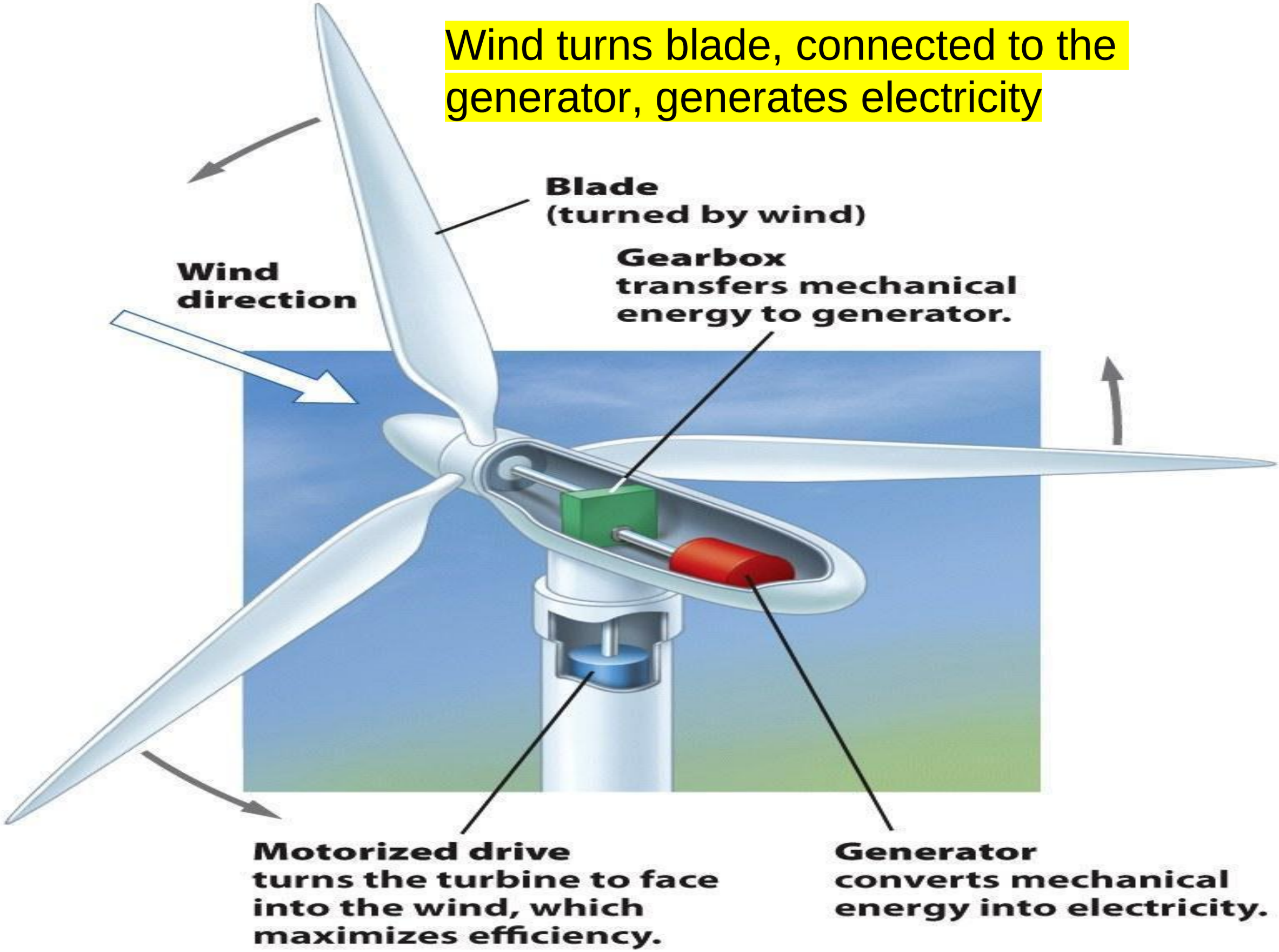

Figure 13.22
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Benefits:

- Like sunlight, wind is nondepletable, clean, and free energy resource (subjective on climate)
- Produces no pollution or greenhouse gases once installed and manufactured

Drawbacks:

- Wind energy systems rely on batteries, which are expensive to produce and hard to dispose of or recycle
- Noise pollution
- Killing of organisms (placement in non-migration paths)

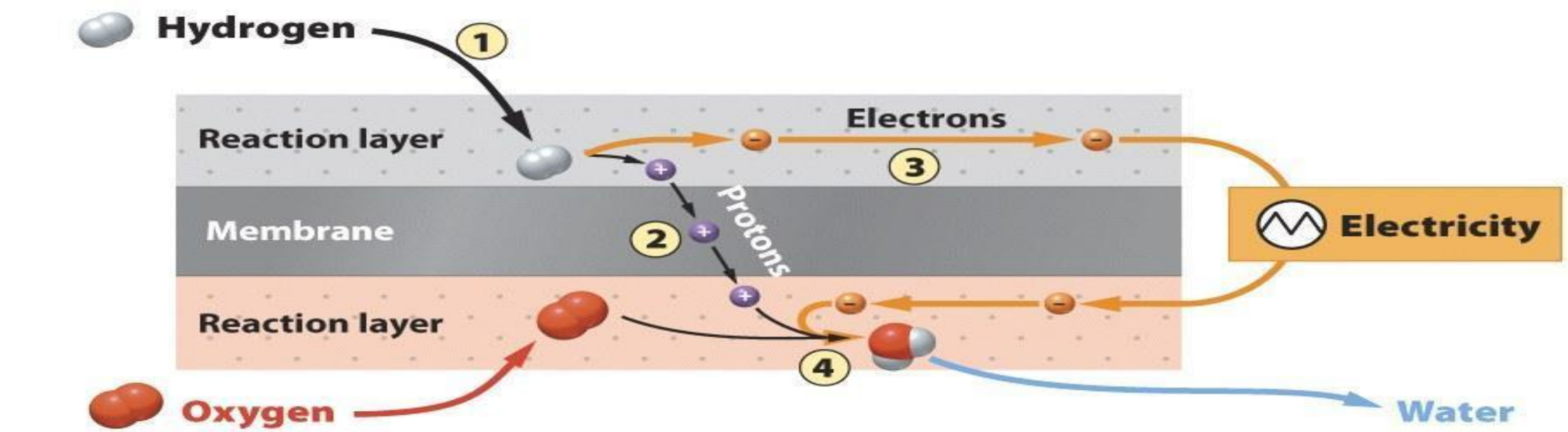
Hydrogen fuel cells have many potential applications

- **Fuel cell-** a device that operates like a common battery (nickel & cadmium) where electricity is generated by a reaction between two chemicals but will not deplete as long as supplied with fuel (hydrogen & oxygen).

- **Electrolysis-** electric current is applied to water to "split" it into hydrogen & oxygen gas.

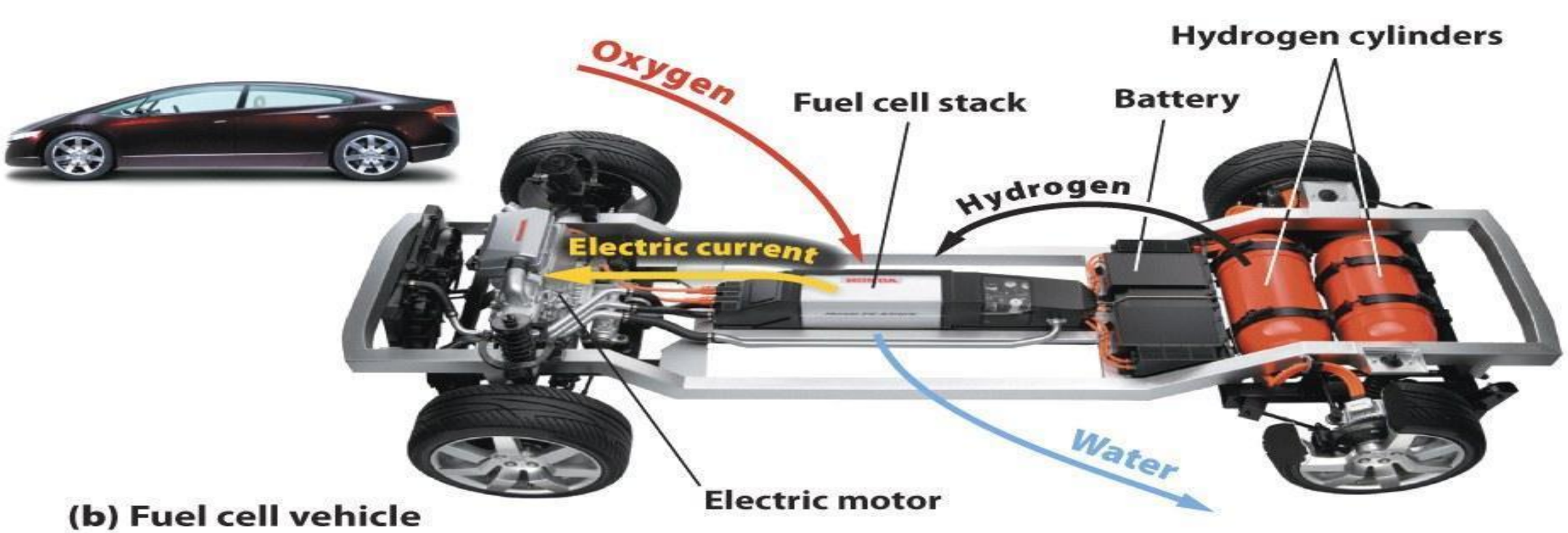
- Electricity is generated by the reaction of

$$2H_2 + O_2 \longrightarrow 2H_2O$$



1 Hydrogen molecules (H_2) are split into protons (H^+) and electrons in the upper reaction layer.	2 Protons move across membrane	3 Electrons take alternate route (electric current)	4 Oxygen molecules (O_2) are split and combine with protons and electrons to form water in the lower reaction layer.

(a) One common fuel cell design



(b) Fuel cell vehicle

Figure 13.25
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Benefits:
~Hydrogen fuel cells are 80% efficient in converting potential energy of hydrogen and oxygen into electricity
~Byproduct is water (no carbon monoxide)
~Electric motors *(60% is converted into motion)* are more efficient than internal combustion engines *(20% is converted into motion)*

Drawbacks:
~Be able to obtain Hydrogen w/o expending more fossil fuel energy
~Safety – driving and suppling hydrogen gas to consumers
~Redesigning of vehicles with fuel tanks much larger

TABLE 13.1 Comparison of renewable energy options

Energy type	Advantages	Disadvantages	Pollution and greenhouse gas emissions	Electricity cost (cents/kWh)	Energy return on investment
Liquid biofuels	Potentially renewable Can reduce our dependence on fossil fuels Reduces trade deficit Possibly more environmentally friendly than fossil fuels	Loss of agricultural land Higher food costs Lower gas mileage Possible net increase in greenhouse gas emissions	Carbon dioxide and methane		1.3 (from corn) 8 (from sugarcane)
Solid biomass	Potentially renewable Eliminates waste from environment Available to everyone No technology required	Deforestation Erosion Indoor and outdoor air pollution Possible net increase in greenhouse gas emissions Less energy content per liter of fuel	Carbon monoxide Particulate matter Nitrogen oxides Possible toxic metals from MSW Danger of indoor air pollution		
Hydroelectric power	Nondepletable resource Low cost to run Flood control Recreation	Limited amount can be installed in any given area High construction costs Threats to river ecosystem Loss of habitat, agricultural land, and cultural heritage; displacement of people Siltation	Methane from decaying flooded vegetation	0.05–0.11	12
Tidal energy	Nondepletable resource After initial investment, no cost to harvest energy	Potential disruptive effect on some marine organisms Geographically limited	None during operation		15
Photovoltaic solar cells	Nondepletable resource After initial investment, no cost to harvest energy	Manufacturing materials requires high input of metals and water No plan in place to recycle solar panels Geographically limited High initial costs Storage batteries required for off-grid systems	None during operation Some pollution generated during manufacturing of panels	0.20	
Solar water heating	Nondepletable resource After initial investment, no cost to harvest energy	Manufacturing materials requires high input of metals and water No plan in place to recycle solar panels Geographically limited High initial costs	None during operation Some pollution generated during manufacturing energy	0.05–0.11	
Geothermal energy	Nondepletable resource After initial investment, no cost to harvest energy Can be installed anywhere (ground source heat pump)	Emits hazardous gases and steam Geographically limited (deep well geothermal)	None during operation	0.05–0.30	8 (to electricity)
Wind energy	Nondepletable resource After initial investment, no cost to harvest energy Low up-front cost	Turbine noise Deaths of birds and bats Geographically limited to windy areas near transmission lines Aesthetically displeasing to some Energy storage can be difficult	None during operation	0.04–0.06	18
Hydrogen	Efficient Zero pollution	Energy-intensive process to extract hydrogen Lack of distribution network Hydrogen storage challenges	None during operation		18