Achieving Energy Sustainability

Chapter 13

V. Energy Resources and Consumption (10-15%)

F. Energy Conservation

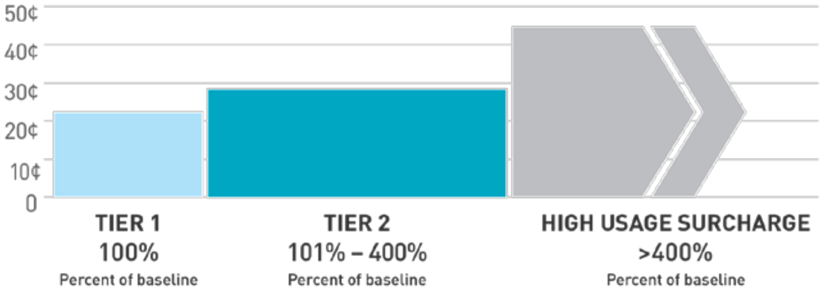
G. Renewable energy

Module 37: Conservation, Efficiency, and Renewable Energy

After this module you will be able to……

1) Describe strategies to conserve energy and increase energy efficiency
2) Explain differences among the various renewable energy resources

Conservation



Energy conservation means finding and implementing ways to use less energy. Energy conservation can be done on a household level or government level. You may choose to turn down your thermostat in colder months. The government may choose to increase public transportation options or offer tax rebates for retrofitting a home or business so it will operate on less energy.

Many electric companies bill customers with a **tiered rate system** in which customers pay a low rate for the first increment of electricity they use and a higher rate as their use goes up.

Conservation

The **peak demand** is the greatest quantity of energy used at any one time. Typically, companies keep backup generators of electricity available. These backups are usually fossil fuel-fired types, but may be batteries. An important aspect of energy conservation is the reduction of peak demand.

One way to reduce peak demand is by increasing the price of energy during high demand, but decreasing it during low demand. Remember that energy is lost during conversion, so the amount of energy we save is the sum of both the energy we did not use with the energy that would have been lost in converting that energy into the form in which we would have used it.

Conservation

Example:

If we can reduce our electricity use by 100 kWh, we may actually be conserving 300 kWh or an energy resource such as coal, since we save both the 100 kWh that we decide not to use and the 200 kWh that would have been lost during the conversion process to make the 100 kWh available to us.

Efficiency

Modern changes in electrical lighting have increased the efficiency of energy use. Compact fluorescent light bulbs use ¼ as much energy to provide the same amount of light as incandescent bulbs. LED light bulbs are even more efficient, using ⅙ the amount of energy.

Switching to products that meet standards of the Energy Star program set by the EPA.

Efficiency

Suppose you have a choice: an Energy Star unit for $300 or a standard unit for $200. The two units have the same cooling capacity but the Energy Star unit costs 5 cents per hour less to run. If you buy the Energy Star unit and run it 12 hours per day for 6 months of the year, how long does it take to recover the $100 extra cost?

$0.05/hour x 12 hours/day = $0.60/day

$0.60/day x 180 days = $108

Spending the extra $100 for the Energy Star unit saves $8 in one year of use. In three years you would more than pay for the initial cost of the unit.

Efficiency

Your turn…

You are about to invest in a 66-inch flat screen TV. These TVs come in both Energy Star and non-Energy Star models. The cost of electricity is $0.15 per kilowatt-hour and you expect to watch TV an average of 4 hours per day.

1) The non-Energy Star model uses 0.5 kW. How much will it cost you per year for electricity to run this model?
2) If the Energy Star model uses only 40 percent of the amount of electricity used by the non-Energy Star model, how much money would you save on your electric bill over 5 years by buying the efficient model?

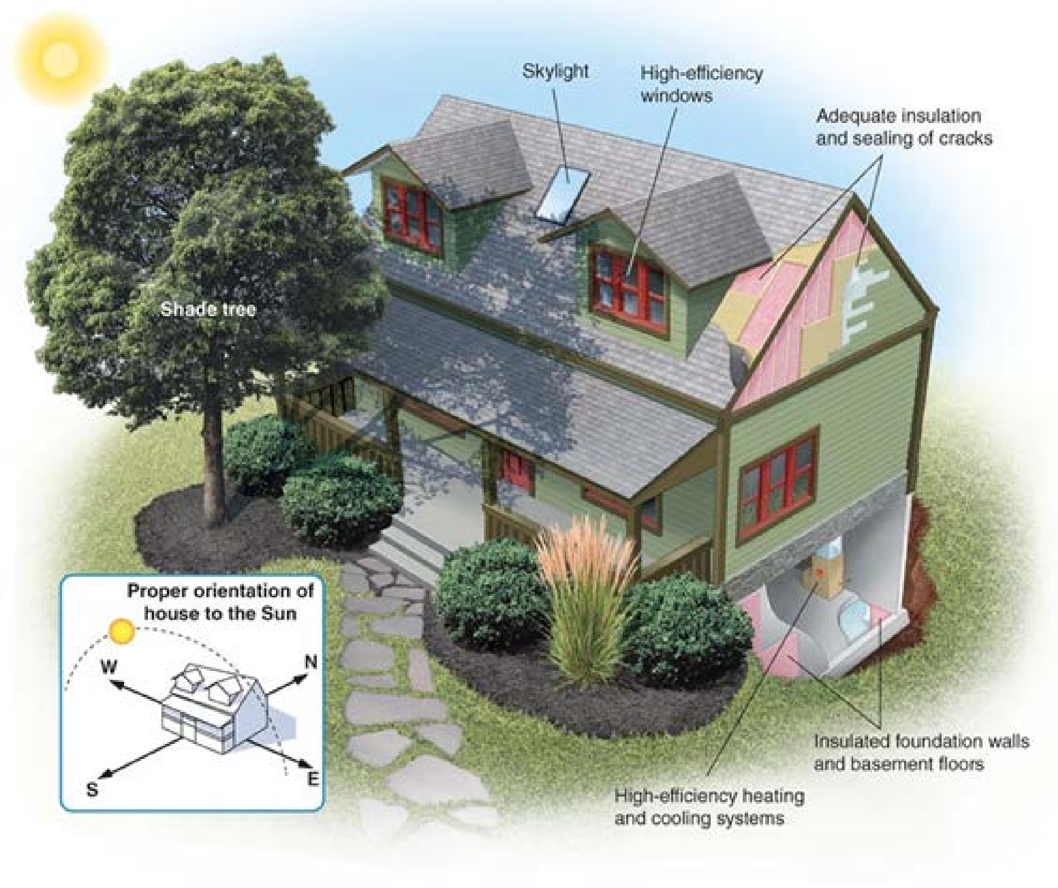


Figure 37.2
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Sustainable Design

Sustainable design can include:

- Insulating foundation walls and basement floors
- Orienting a house properly in relation to the Sun
- Planting shade in warm climates
- High efficiency windows

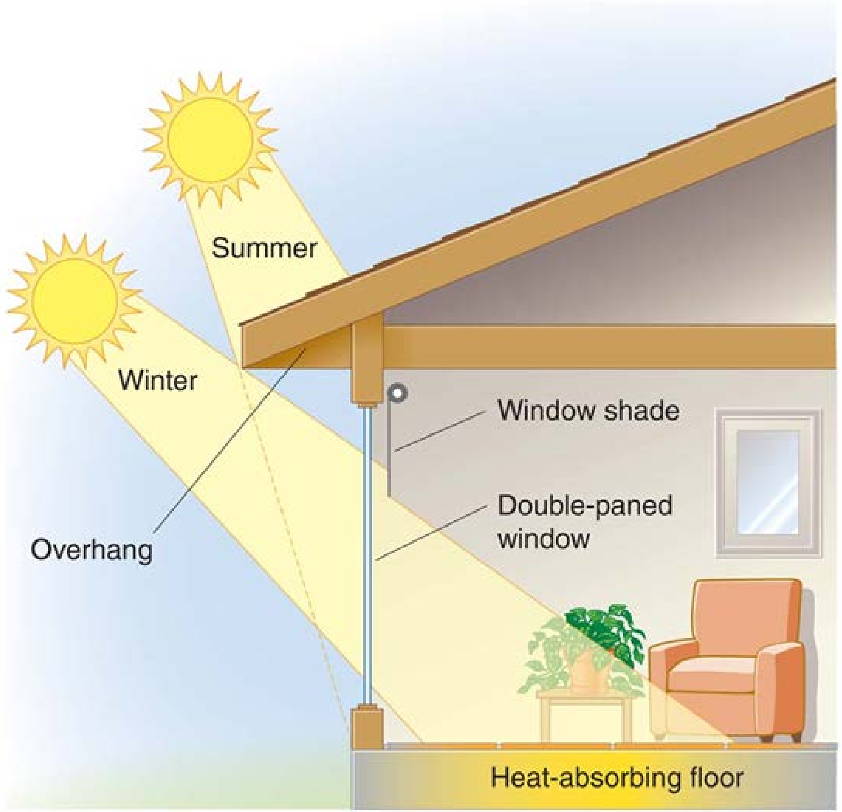

Figure 37.3
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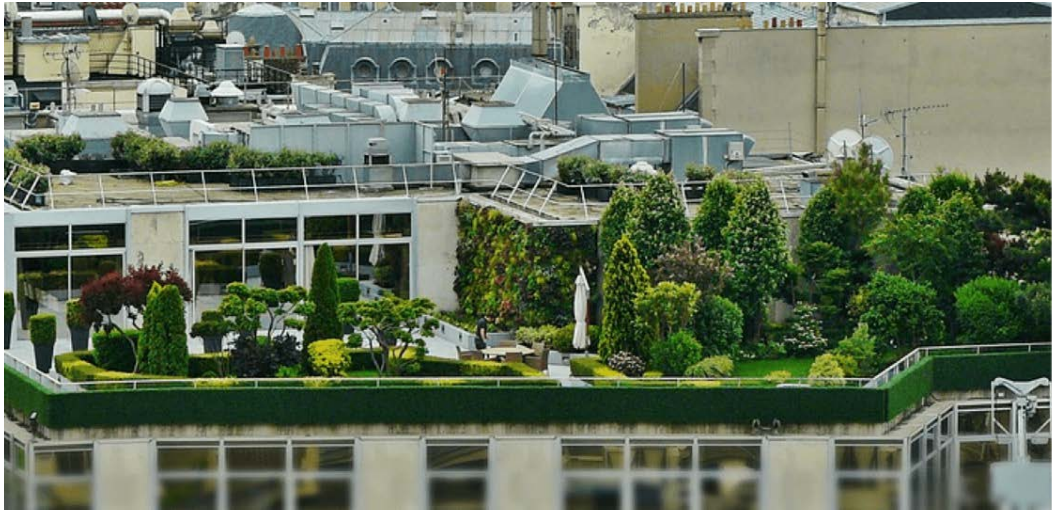
Sustainable Design

Passive solar design is a construction technique designed to take advantage of solar radiation without the use of active technology.

Thermal mass is a property of building material that allows it to maintain heat or cold. Examples of materials with high thermal mass is stone and concrete.

Sustainable Design

“Green roofs”--roofs with soil and growing plants--are uncommon in the United States, but many European cities, such as Berlin, have them on new or rebuilt structures. This helps cool and shade the building and improves overall air quality.



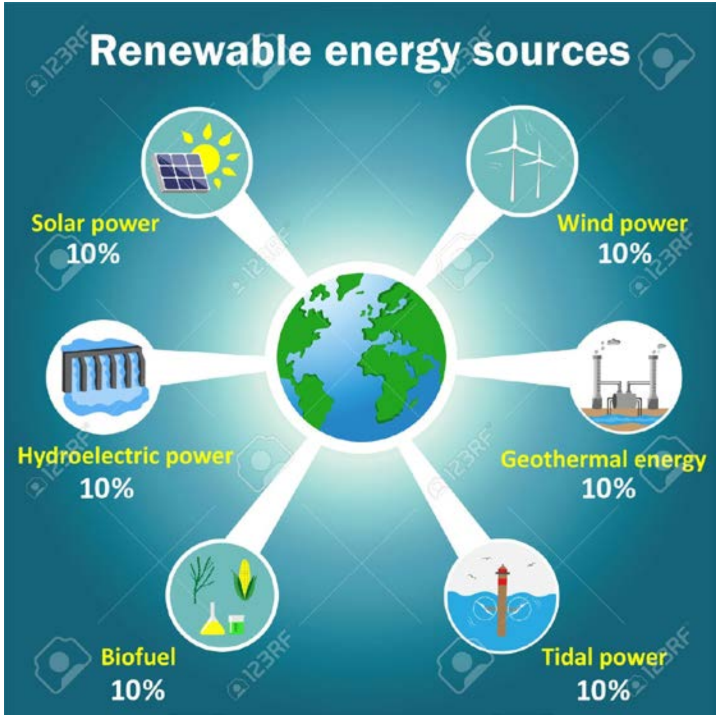
The California Academy of Sciences generates much of its own electricity with solar panels and captures water in its rooftop garden.

Potentially Renewable

Potentially renewable energy are energy sources that can be regenerated indefinitely as long as it is not overharvested. Examples include wood and biofuel.

Nondepletable energy is energy that cannot be depleted no matter how much we use them. Examples are wind, solar, hydroelectric, and geothermal.

Together, potentially renewable and nondepletable energy sources are considered **renewable** energy sources.



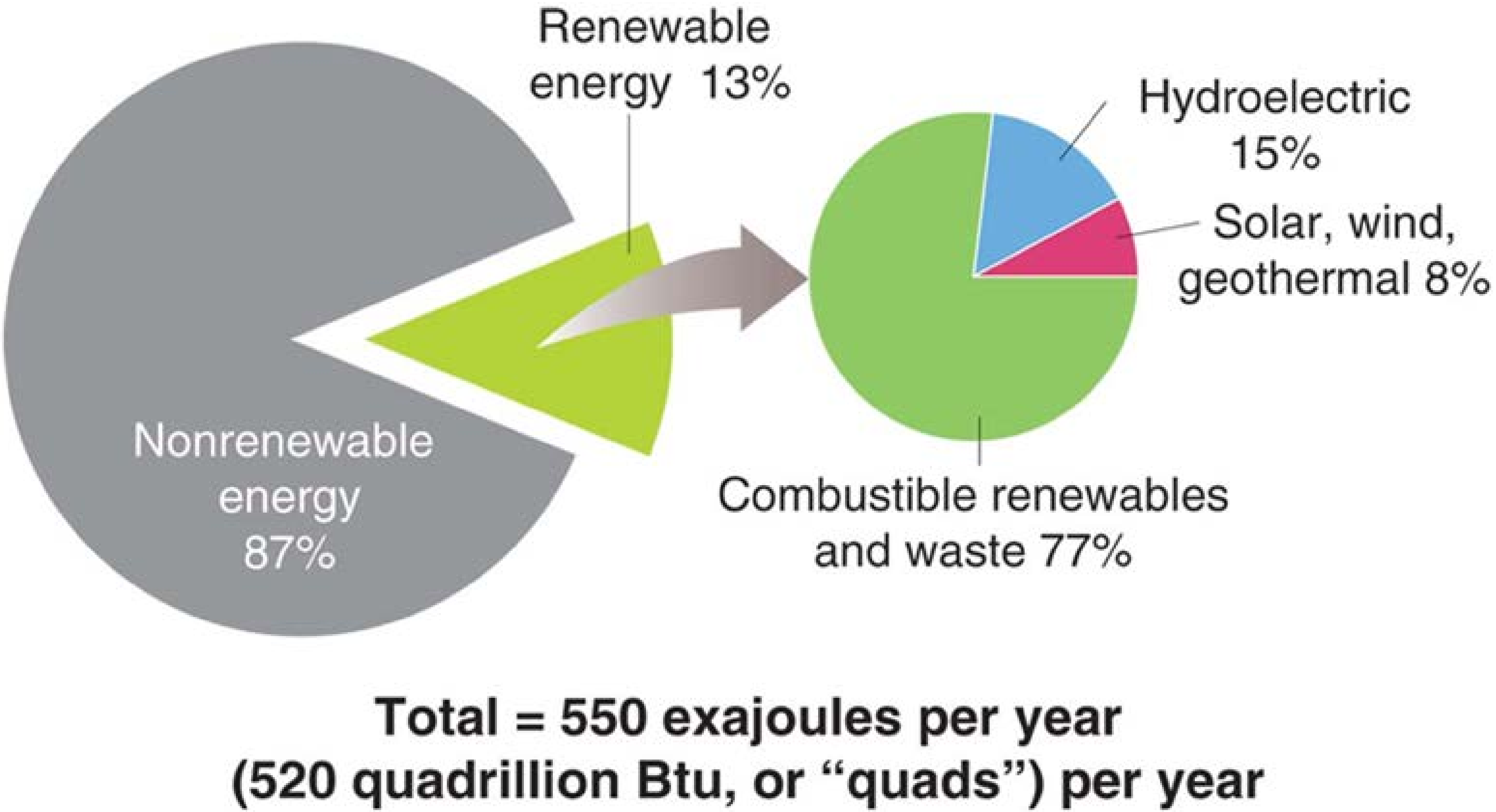


Figure 37.6
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Data from International Energy Agency for the 2011 calendar year, World Energy Outlook, 2013

Global Energy Use

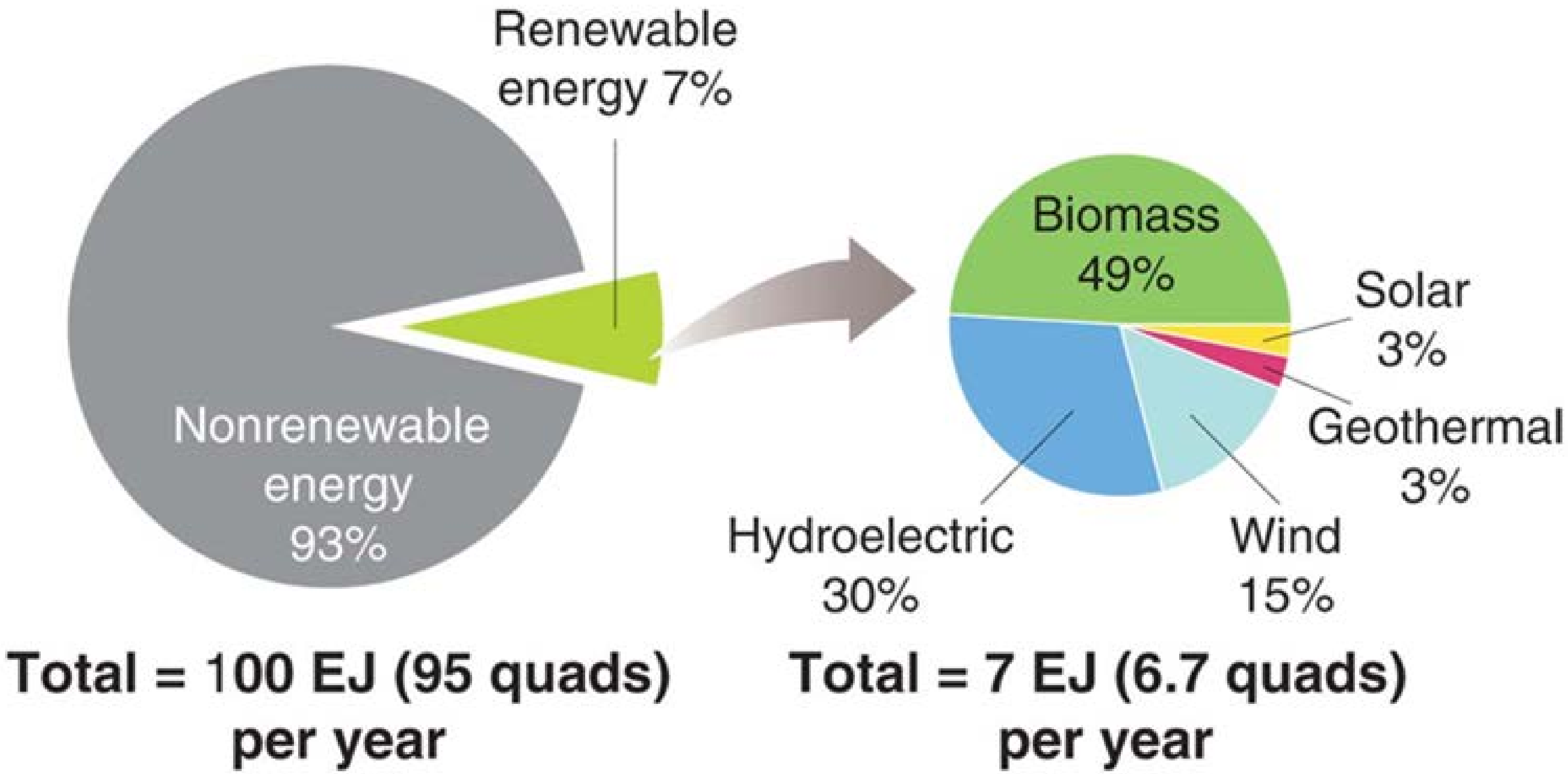

Figure 37.7
Environmental Science for AP®, Second Edition
Data from U.S. Department of Energy for the 2012 calendar year, EIA, 2013

Energy use in the United States

Module 38: Biomass and Water

After this module you will be able to……

1) Describe the various forms of biomass
2) Explain how energy is harnessed from water

Biomass is energy from the Sun

All fossil fuels and most renewable energy sources ultimately come from the Sun. Biomass is a term for a multiple type of energy sources such as wood and charcoal, animal products and manure, plant remains, municipal solid waste (MSW), and liquid fuels such as ethanol and biodiesel.

Biodiesel is liquid fuel created from processed or refined biomass.

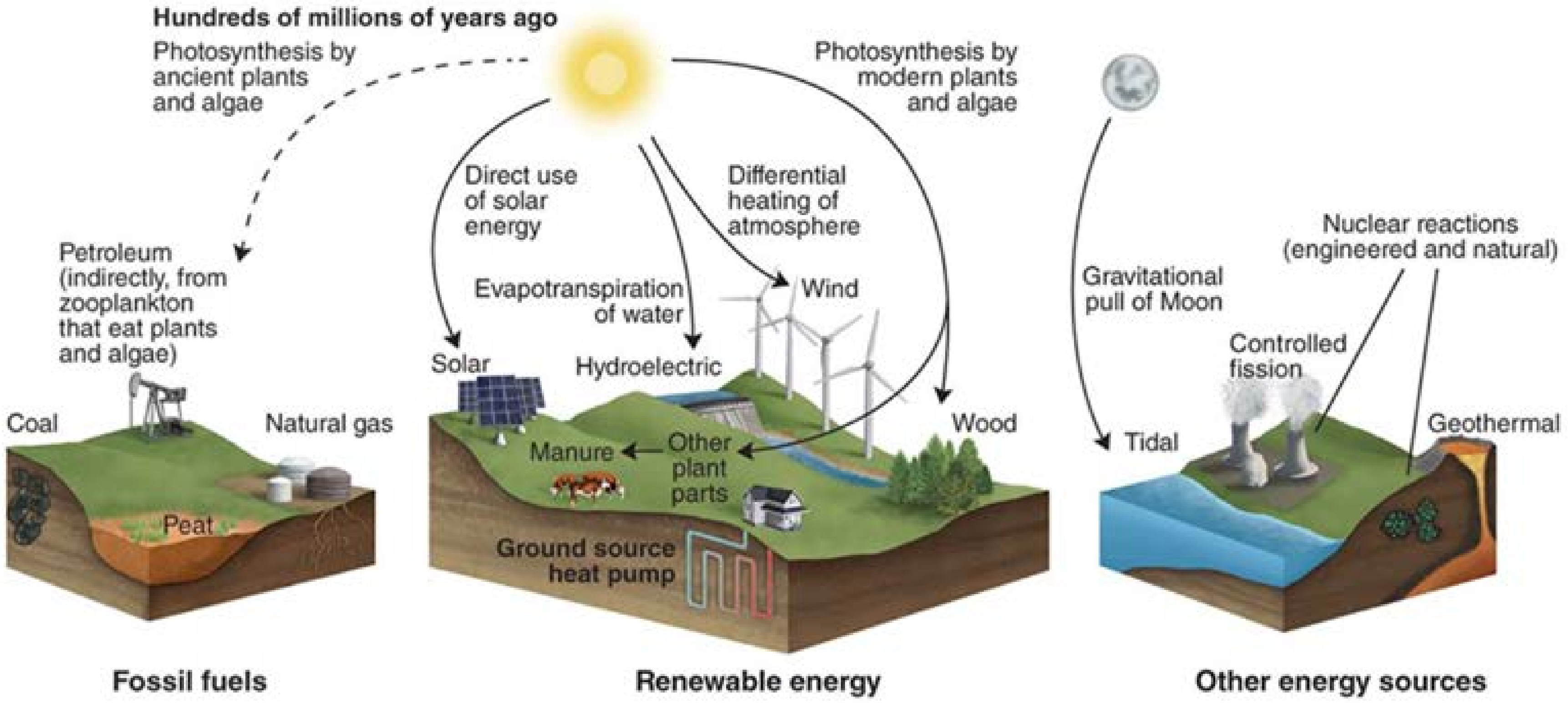

Figure 38.1
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Energy from the Sun

Modern Carbon vs Fossil Carbon

Modern carbon is carbon in biomass that was recently in the atmosphere. Examples include plants that are fairly young and have taken in the carbon from the air around it.

Fossil carbon is carbon in fossil fuels or wood cut from a large tree several hundred years ago. Burning fossil carbon releases CO_2 that was hasn't been in the atmosphere for millions of years.

An activity that does not change atmospheric CO_2 concentrations is referred to as **carbon neutral**.

Solid Biomass

When we cut down more trees than we can replace by growth we have a **net removal** of forest. This net removal combined with burning of wood leads to a net increase in atmospheric CO_2. Tree removal can be sustainable if we allow time for forests to regrow. It's also possible to increase the biodiversity if you remove select trees from heavily forested areas.

Solid Biomass

Many people in the developing world use wood to make charcoal, which is a superior fuel.

Charcoal...

- is lighter than wood and contains approximately twice as much energy per unit of weight
- produces much less smoke
- is more expensive than wood

Solid Biomass

In areas where wood is scarce, people often use dried animal manure as a fuel for indoor heating and cooking. This is beneficial because it removes harmful microorganisms from surrounding areas. However, it also releases PM and other pollutants that cause a variety of respiratory illnesses.

Burning biomass fuels produce a variety of pollutants, including PM, CO, and NO_X.

Biofuels

The liquid biofuels, ethanol and biodiesel, can be used as substitutes for gasoline and diesel, respectively. **Ethanol** is an alcohol made by converting starches and sugars from plant material into alcohol and carbon dioxide.

Biodiesel is a diesel substitute produced by extracting and chemically altering oil from plants.

Ethanol

The United States is the world leader in ethanol production, followed by Brazil. Brazil manufactures ethanol from sugarcane which only needs to be replanted every six years as opposed to every year with corn.

Usually, ethanol is mixed with gasoline, resulting in gasohol that is 10% ethanol. **Flex-fuel vehicles** can run on either gasoline or E-85 (85% ethanol, 15% gasoline).

Ethanol does provide a lower MPG than 100% gasoline. Growing corn also uses a significant amount of fossil fuel energy and land.

Biodiesel

Biodiesel acts as a direct substitute for petroleum-based diesel fuel, although it is usually more expensive. Biodiesel is typically diluted to “B-20”, a mixture of 80 percent petroleum diesel and 20 percent biodiesel. It’s possible to modify your engine to run on 100 percent straight vegetable oil (SVO), typically as a waste product from restaurants and filtered for use as fuel.

Biodiesel

In the United States, most biodiesel comes from soybean oil or processed vegetable oil. However, scientists are working on ways to produce large quantities of biodiesel directly from wood or other forms of cellulose.

Some species of algae appear to have great potential for producing biodiesel. Algae can be grown almost anywhere and produce the greatest yield of fuel per hectare of land area per year and utilize the least amount of energy and fertilizer per quantity of fuel. In theory, biodiesel should be carbon neutral.

Hydroelectricity

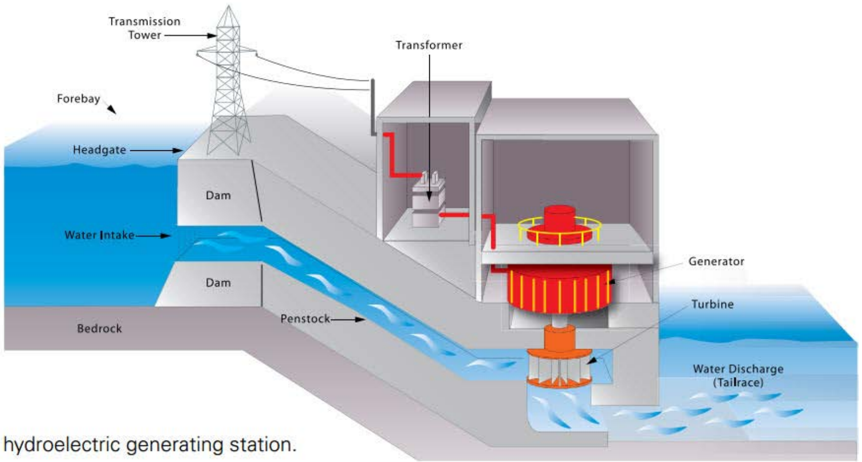


Diagram of a hydroelectric generating station.

Hydroelectricity is electricity generated by the kinetic energy of moving water. It is the second most commonly used form of renewable energy in the United States and in the world.

Water is used to turn a turbine which can be used to generate electricity and exported to the electrical grid. The amount of energy generated depends on flow rate and height of the waterfalls.

Run-of-the-river

Water is retained behind a low dam and runs through a channel before returning to the river

- Little flooding upstream
- Seasonal changes in river flow are not disrupted
- Generally small, thus can produce intermittent electricity generation
- Heavy runoff from rains cannot be stored, limiting generation during hot, dry periods

Water Impoundment

Storage of water in a reservoir behind a dam

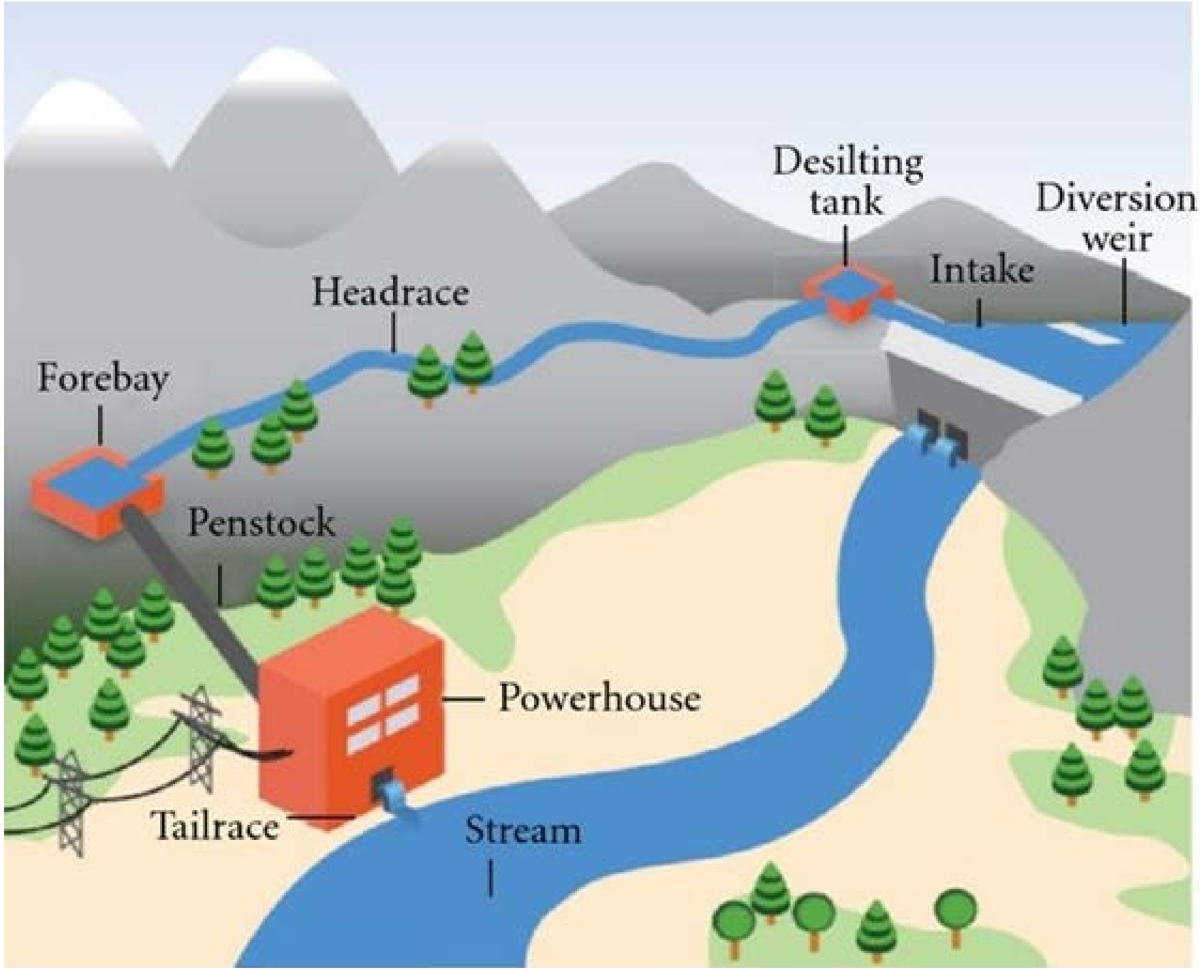
- Most common method
- Allows for generation of electricity on demand
- Largest in the U.S. is Grand Coulee Dam in Washington State
- Largest in the world is the Three Gorges Dam on the Yangtze River in China

Tidal

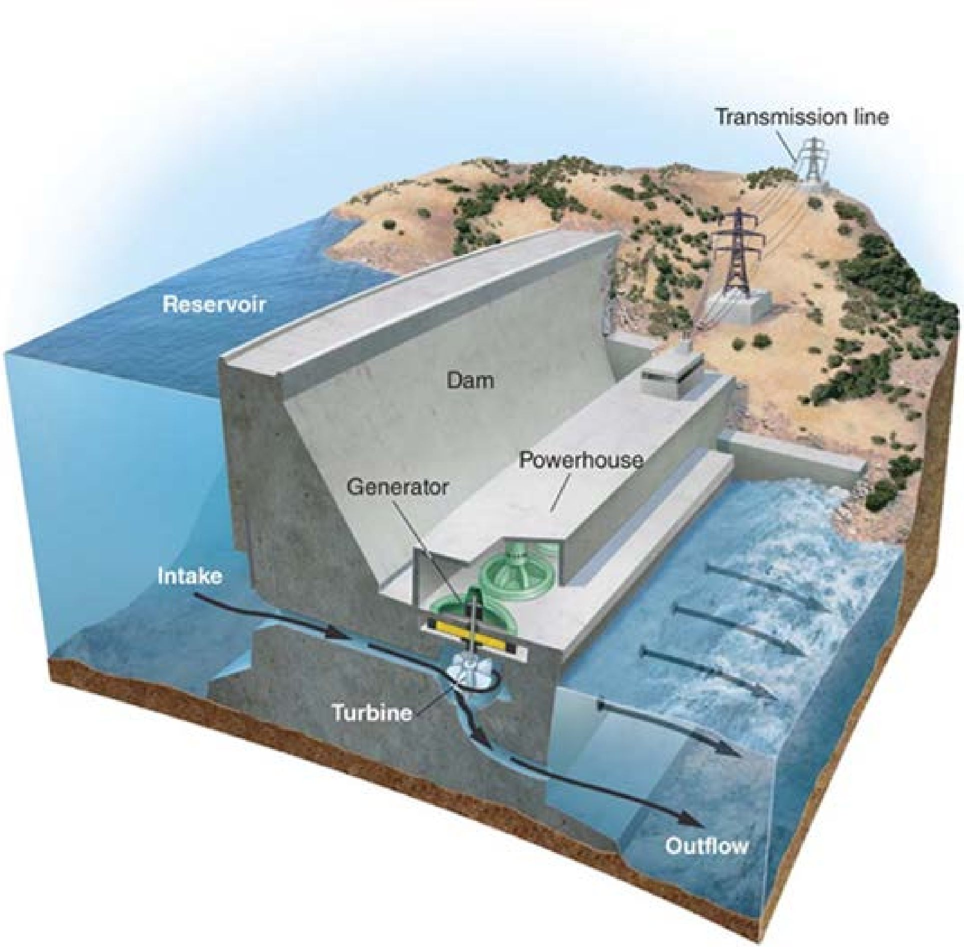
Energy that comes from the movement of water driven by the gravitational pull of the moon

- Uses gates and turbines to capture kinetic energy of water flowing
- Does not have a potential to become a major energy source due to a low difference in water level between high and low tides
- Transmission lines must be constructed near a coastline or estuary

Methods of generating hydroelectricity



Run-of-the-river System



Water Impoundment System

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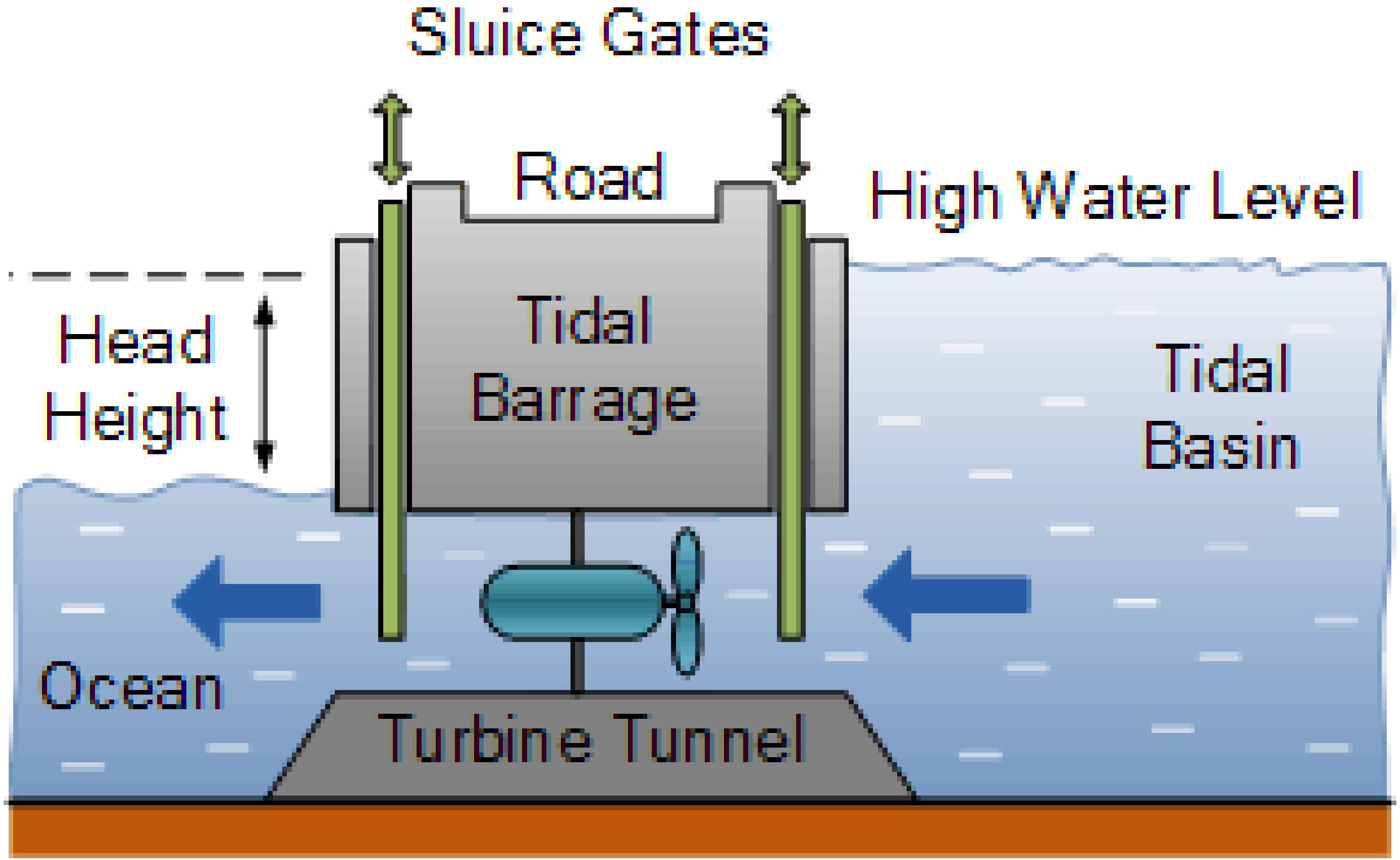


Tidal System

Hydroelectricity and Sustainability

Although it’s expensive to build a hydroelectric dam, they require minimal amount of fossil fuel for operation. In general, electricity from hydroelectric dams are cheap for the consumer, ranging from 5 cents to 11 cents per kilowatt-hour. They also provide recreational and economic opportunities as well as flood control.

Negative environmental consequences include population relocation, flooding of agricultural land or canyons at the reservoir, and creating unsuitable living conditions for specific organisms.

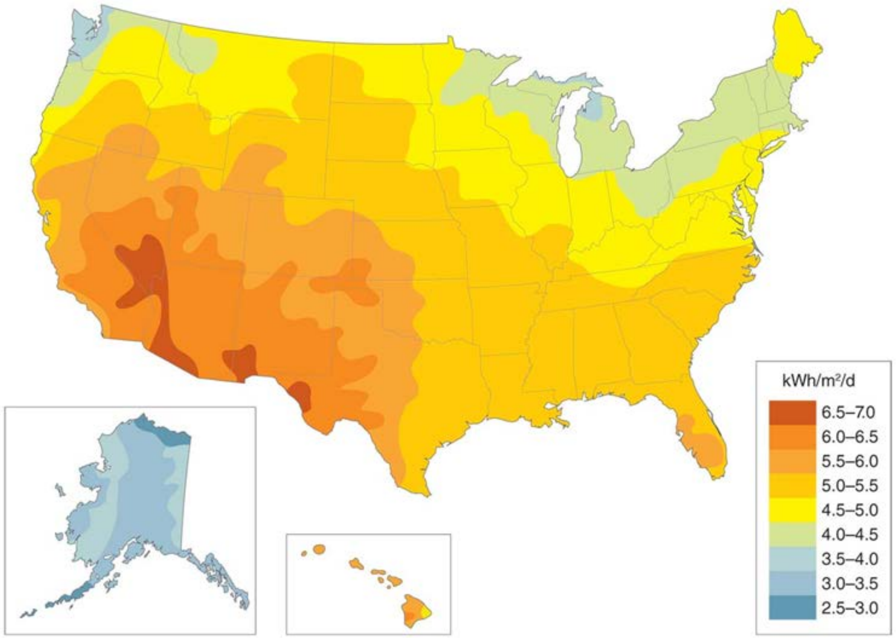
Siltation, or the accumulation of sediments at the bottom of a reservoir, can occur due to dam construction. This can reduce the lifespan of the dam. Many dams have been removed and increased the biodiversity of the species in that area.

Module 39: Solar, Wind, Geothermal, and Hydrogen

After this module you will be able to……

1) List the different forms of solar energy and their application
2) Describe how wind energy is harnessed and its contemporary uses
3) Discuss the methods of harnessing the internal energy from Earth
4) Explain the advantages and disadvantages of energy from hydrogen

Solar Energy



Passive solar heating includes positioning windows on south-facing walls to admit solar radiation in winter, covering buildings with dark roofing material to absorb heat, and building homes on the side of a hill.

Solar ovens allows us to cook food with only using the sun for heat. These are often used in western Africa.

Solar Energy

Active solar energy is energy captured from sunlight with advanced technology. These include small-scale solar water heating systems, photovoltaic solar cells, and large-scale concentrating solar thermal systems for electricity generation.

Solar Energy

Solar water heating systems range from providing domestic hot water and heating swimming pools to a variety of heating purposes for business and home. In the United States, heated swimming pools is the most common application of solar water heating and pays for itself the most quickly.

Heat from the sun is transferred directly to water or another liquid and the circulation of the liquid is driven by a pump or natural convection.

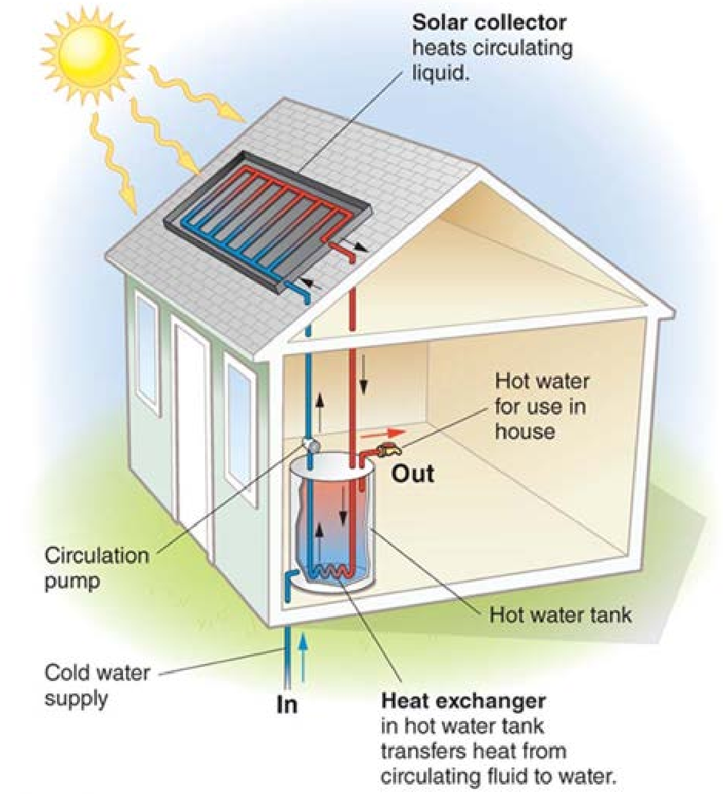


Figure 39.3
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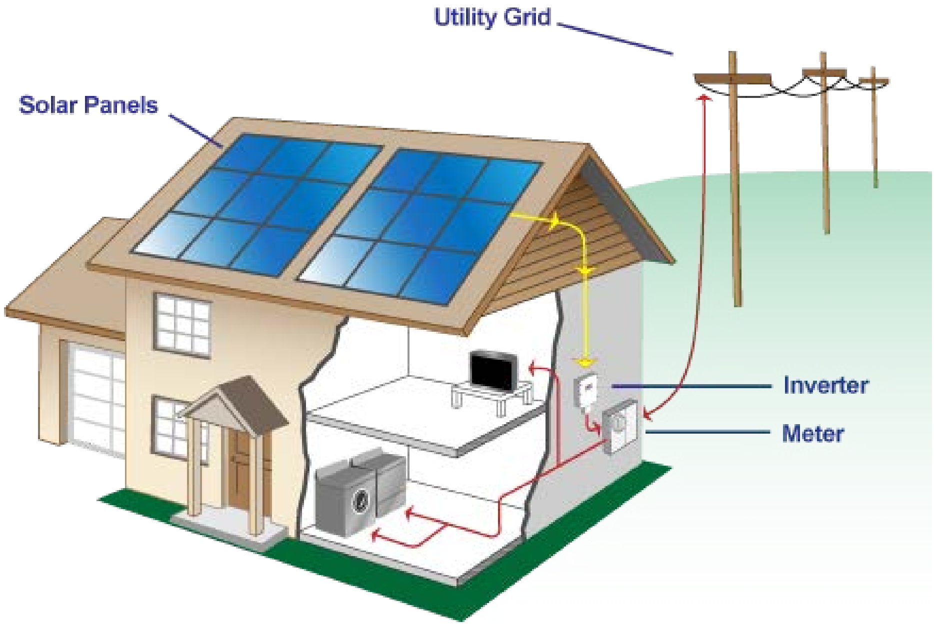
Solar Energy

Photovoltaic (PV) solar cells are used to capture energy from the sun as light as opposed to heat and convert it to electricity. Certain semiconductors generate a low-voltage electric current when exposed to sunlight. This current is converted to a higher-voltage alternating current for use in homes or businesses. Typically, PV cells are 12 to 20 percent efficient.



Solar Energy

Concentrating Solar Thermal Electricity Generation (CST) systems are a large-scale application of solar energy to electricity generation. CST systems use lenses or mirrors and tracking systems to focus the sunlight falling on a large area into a small beam. The beam evaporates water and produces steam that turns a turbine to generate electricity. Unfortunately, a large amount of land is required to use this method and no electricity is generated at night.

Solar Energy

A 3 MW wind turbine was installed in an on-land location where the capacity factor was measured to be 22 percent.

1. How much electricity will this wind turbine generate in a year?
2. How much revenue would a utility receive if they were paid $0.05/kwh for this electricity?

Solar Energy

Benefits

- Generates hot water or electricity without producing CO_2
- Can produce electricity when it's needed the most (hot, summer days) when demand is high
- Economically feasible

Drawbacks

- PV solar panels are expensive to manufacture and install
- The payback period can be long for areas that have access to electrical lines
- Takes a great deal of energy and water to manufacture PV solar cells, involving many chemicals and toxic metals to be released into the air
- Environmental factors with disposing of batteries

Wind Energy

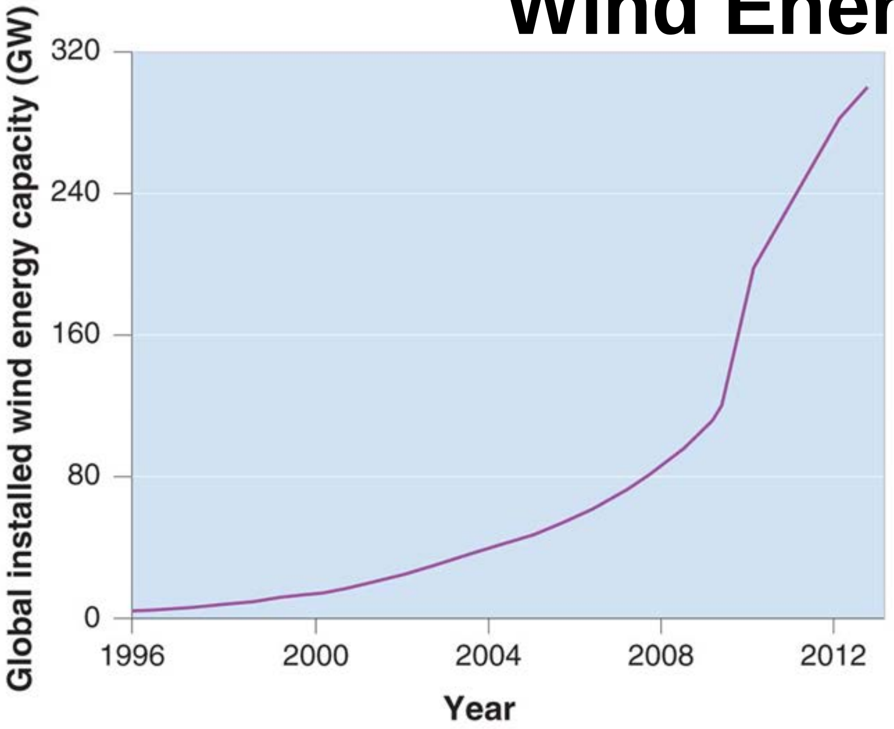


Figure 39.6
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Data from Global Wind Energy Council

Wind energy is generated from the kinetic energy of moving air. Wind energy is currently the fastest-growing major source of electricity in the world, although the United States contains less than 6 percent of its energy from wind.

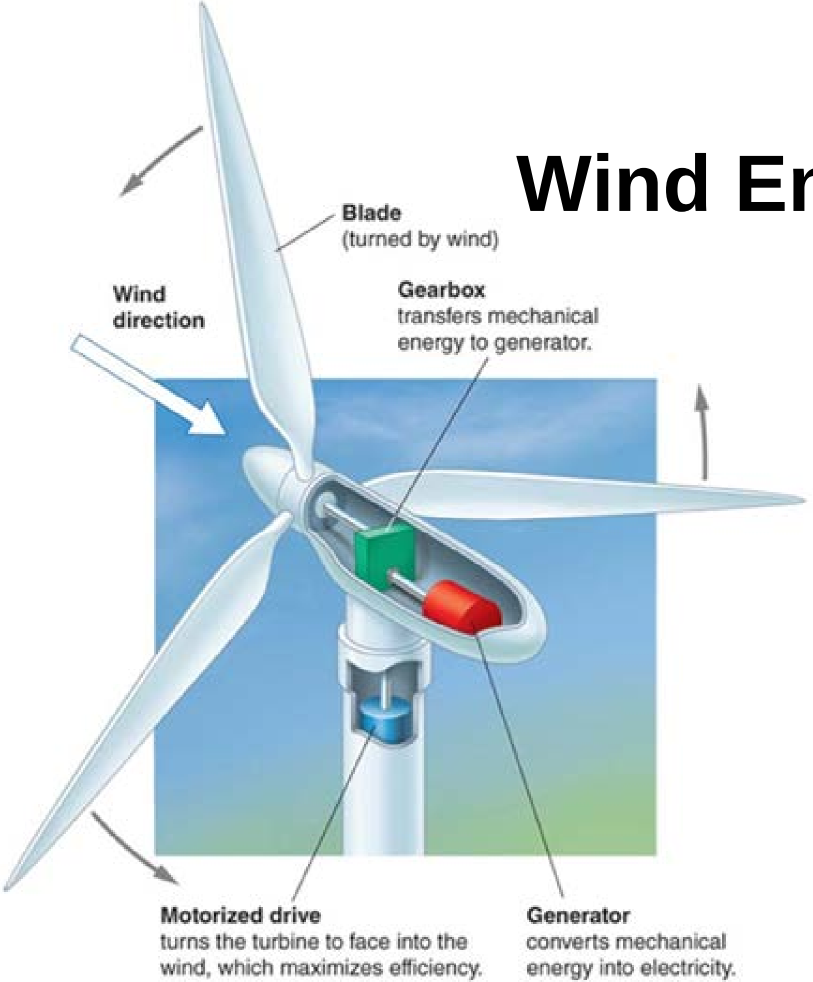

Figure 39.8
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Wind Energy

A **wind turbine** is used to convert the wind energy into electricity. Average wind conditions may have a capacity factor of 25 percent. However, offshore wind conditions can increase that capacity to 50 percent.

In order to increase the effectiveness of capacity and location for windmills, they are usually grouped into wind farms or wind parks.

Solar Energy

Benefits

- Nondepletable, clean, and free energy resource
- No pollution
- No greenhouse gases
- Only fossil fuels used are to help workers travel to maintain the equipment
- Can share land with other uses (e.g. grazing cattle)

Drawbacks

- Most off -grid residential systems rely on batteries to store electricity
- Birds and bats are killed by collisions with the turbine blades (approximately 4 bird deaths per turbine)
- Some vocal people find wind farms visually objectionable
- Can cause bothersome sound

Geothermal Energy

Geothermal energy, unlike other renewable energy sources that come from the Sun, comes from the heat produced by natural radioactive decay of elements deep within the Earth. When magma travels towards the surface of the Earth due to convection currents it may come close enough to groundwater. This can create geysers and hot springs, like those in Yellowstone National Park.

Geothermal Energy

There are a number of ways to harvest geothermal energy. Hot groundwater can be piped directly into household radiators to heat a home or homes can use heat exchangers (see The Heating Engineers of Winterfell). Geothermal energy can also generate electricity. Steam is created from the evaporation of water to turn a turbine, much like a traditional thermal power plant.

Although radioactive elements are depletable, we consider it renewable and nondepletable since they decay would last longer than the span of human time. However, the groundwater used *can* be depleted.

Geothermal Energy

Ground source heat pumps is a technology that transfers heat from the ground to a building. Note that we refer to this informally as "geothermal," but the source of heat actually originates from solar energy and *not* geothermal energy.

Steam or hot water is not removed from the ground, but water is cycled through the ground and house using pipes. The advantage to ground source heat pumps is that they can be installed anywhere in the world, whether or not actual geothermal energy exists or not.

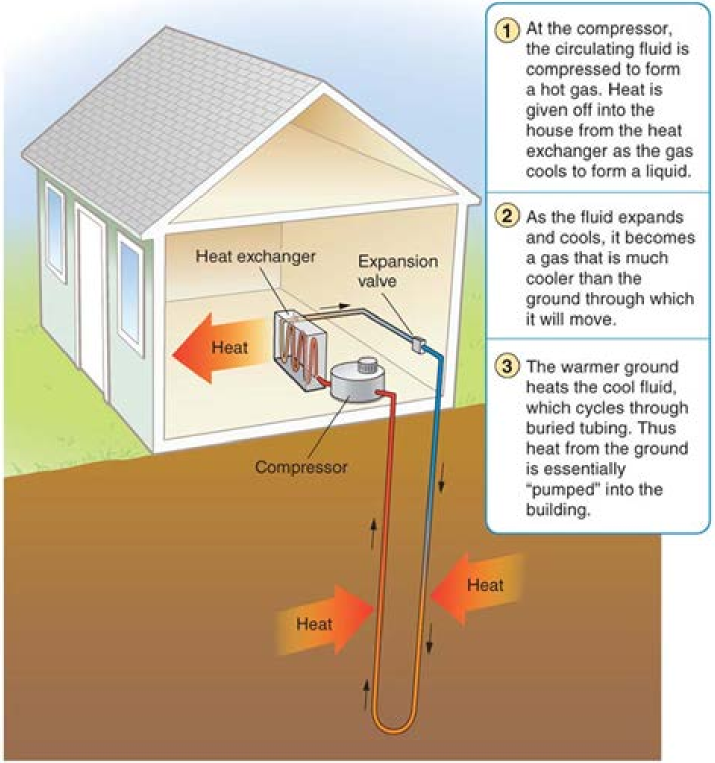

Figure 39.10
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Hydrogen Fuel Cells

A **fuel cell** is an electrical-chemical device that converts fuel, such as hydrogen, into an electrical current. A few cell acts as a battery, but with one key difference. In a battery, electricity is generated by a reaction between two chemical reactants. This reaction occurs in a closed container and the battery dies once it’s complete.

In a fuel cell the reactants are added continuously to the cell so it can produce electricity indefinitely as long as fuel is added.

$$2H_2 + O_2 \rightarrow \text{energy} + H_2O$$

Hydrogen Fuel Cells

When H_2 is added through a membrane the electrons take a different pathway. The movement of protons in one direction and electrons is another is what generates an electric current. This means we need a high supply of $H_{2,}$, which is an issue because free hydrogen gas is not only rare in nature, but also highly explosive.

Currently, most hydrogen is produced by an energy-intensive process of burning natural gas in order to extract its hydrogen leaving CO_2 as a waste product. **Electrolysis** is the application of an electric current to water molecules to split them into hydrogen and oxygen.

Hydrogen Fuel Cells

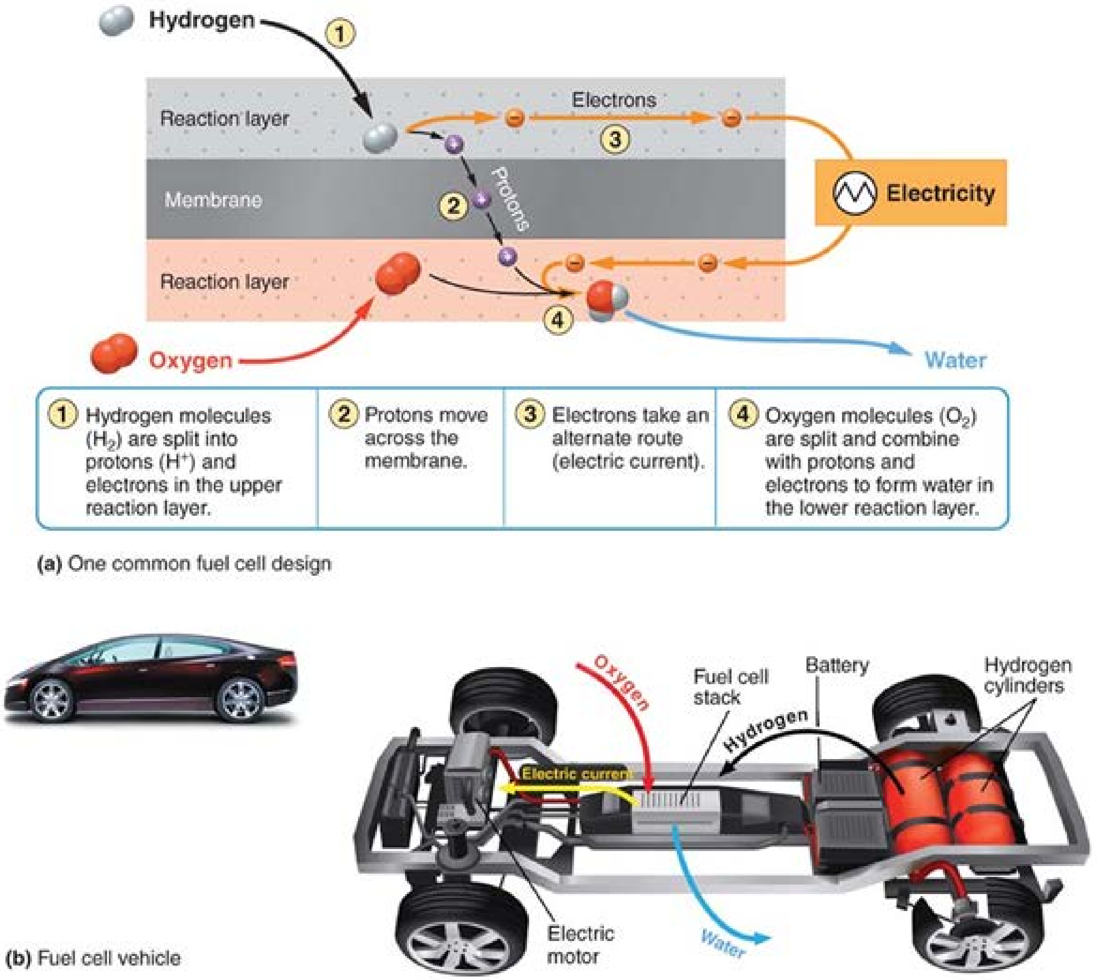

Figure 39.11
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Solar Energy

Benefits

- 80 percent efficient
- Water is the only by-product

Drawbacks

- Scientists need to learn how to obtain hydrogen without expending too many fossil fuels
- Suppliers will need a distribution network to safely deliver hydrogen to consumers
- Vehicles would need bigger tanks and tanks could explode if ruptured

Module 40: Planning Our Energy Future

After this module you will be able to……

1) Discuss the environmental and economic options we must assess in planning our energy future
2) Consider the challenges of renewable energy strategy

Energy Future

Each renewable energy source has their own advantages. They also come with their own disadvantages. There is no single renewable energy source (that we are aware of!) that can completely replace the use of our nonrenewable energy resources. This means we need a strategy that combines energy efficiency, energy conservation, and the development of renewable and nonrenewable energy resources, taking into account the costs, benefits, and limitations of each.

Renewable Energy Challenges

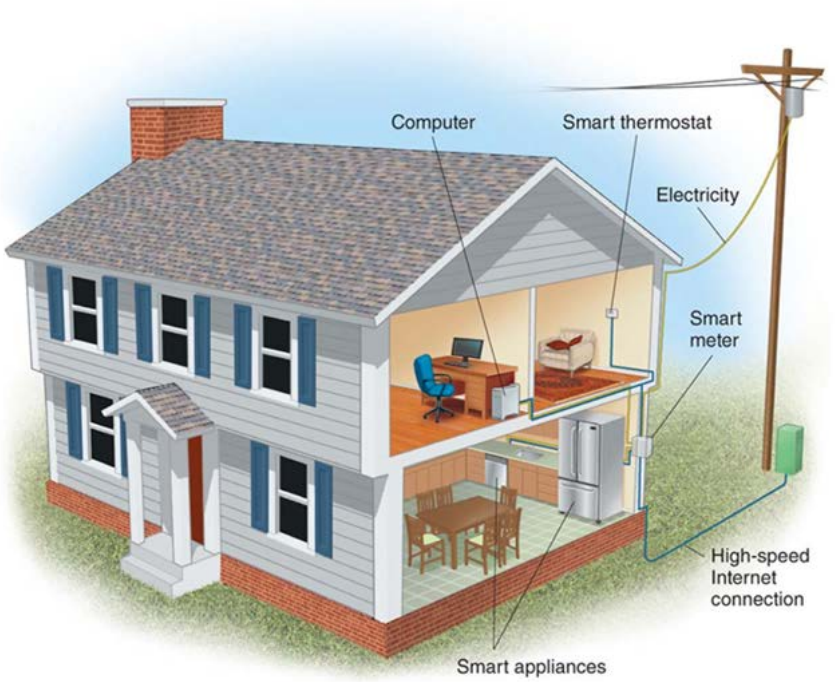

Figure 40.1
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One large issue with renewable energy is that energy will need to be obtained in many locations and then delivered to other locations. This can lead to problems for urban areas that need to obtain their energy from rural locations. Our current electrical grid was not designed for this purpose.

One possible solution is the **smart grid**, an efficient, self-regulating electricity distribution network that accepts any source of electricity and distributes it automatically to end users.

Renewable Energy Challenges

The major concern for widespread use of wind, solar, and tidal energy are the costs and limitations associated with energy storage technology. However, we have seen a decrease in the total cost and some markets even have wind energy that is cost-competitive with natural gas and coal. Tesla has been making advances with products such as the Tesla Powerwall, which is a lithium ion battery that can be hung on a wall.