Chapter 16:
Alternative Energy and the Environment

Sempra U.S. Gas & Power, LLC.

America's largest solar energy facility in 2012, at Copper Mountain, Nevada. It has a 55-megawatt electrical capacity.

Overview

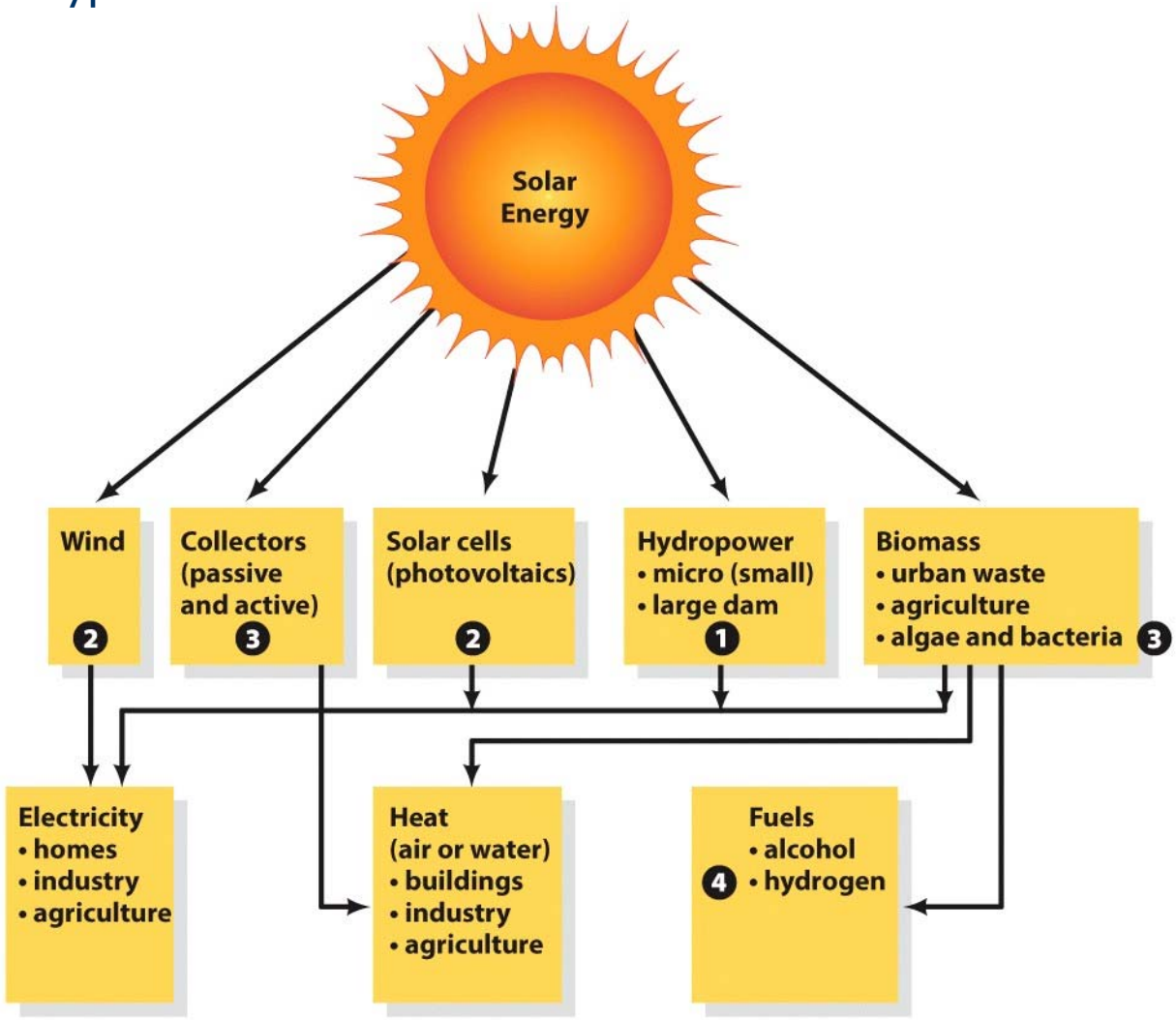
- Introduction to Alternative Energy Sources
- Solar Energy
- Converting Electricity from Renewable Energy into a Fuel for Vehicles
- Water Power
- Ocean Energy
- Wind Power
- Biofuels
- Geothermal Energy

A Joshua tree in Joshua Tree National Park, California. Is it a good idea to have a major solar energy installation near this park? Some environmentalists raise the question.

Introduction to Alternative Energy Sources

- Nonrenewable alternative energy
  - Nuclear
    - Requires a mineral fuel mined from Earth
  - Geothermal
    - Heat is extracted faster than it is replenished
- Renewable energy sources
  - Solar, fresh water, wind, ocean, and biofuels
    - All derive from the sun's energy
    - Biofuels-trees, grasses, peat, organic waste, landfill gases and ethanol-alcohol produced from algae or as by product of bacteria decomposition of organic wastes.

Routes of various types of renewable solar energy.



Solar Energy

- Ten weeks of solar energy equivalent to all known fossil fuel reserves
- Two types
  - Passive
  - Active

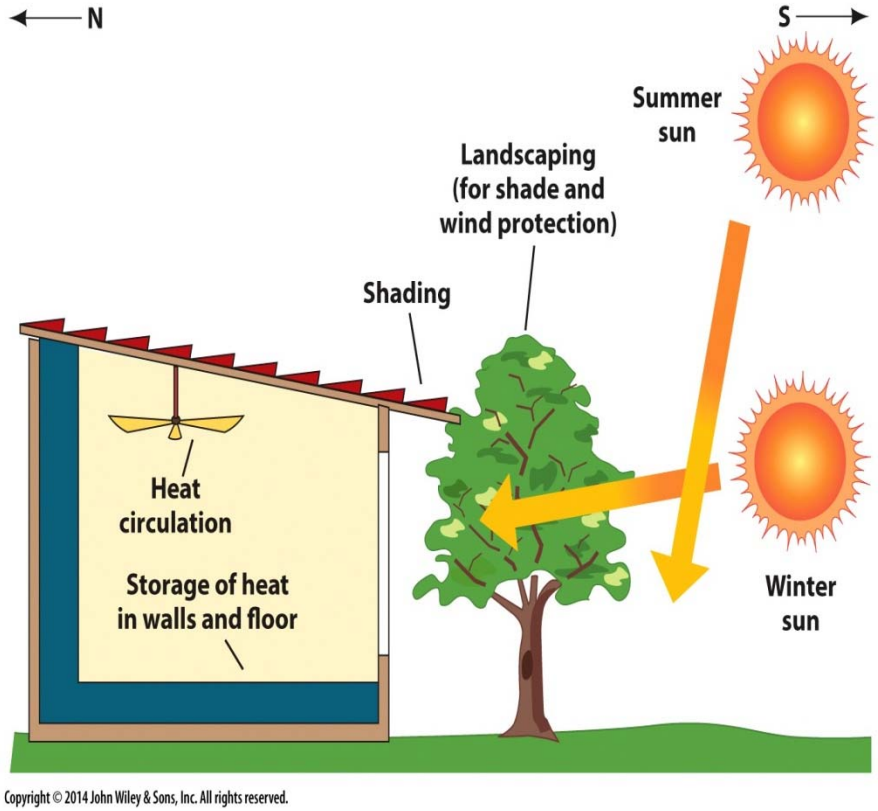


Figure 16.4 Essential elements of passive solar design. (a) High summer sunlight is blocked by the overhang, but low winter sunlight enters the south-facing window. Deciduous trees shade the building in the summer and allow sunlight to warm it in the winter. These are best located on the south side in the Northern Hemisphere. Other features are designed to facilitate the storage and circulation of passive solar heat.

Passive Solar Energy

- Promotes cooling in hot weather and retaining heat in cold weather
- Methods include:
  - Overhangs that block summer sun but allow winter sun
  - Walls in buildings that absorb heat during the day and release it at night
  - Deciduous trees as landscaping
  - Natural lighting to buildings through windows and skylights.
  - Window glass can have special glazing that transmits visible light, blocks infrared and provides insulation.

A Dugout: Homes cut into soils

http://www.finehomebuilding.com/2017/07/12/prairie-dugout-house

MARTIN BOND/stillpictures/Aurora Photos

Solar power, Holland.
Houses with passive solar design and solar collectors.

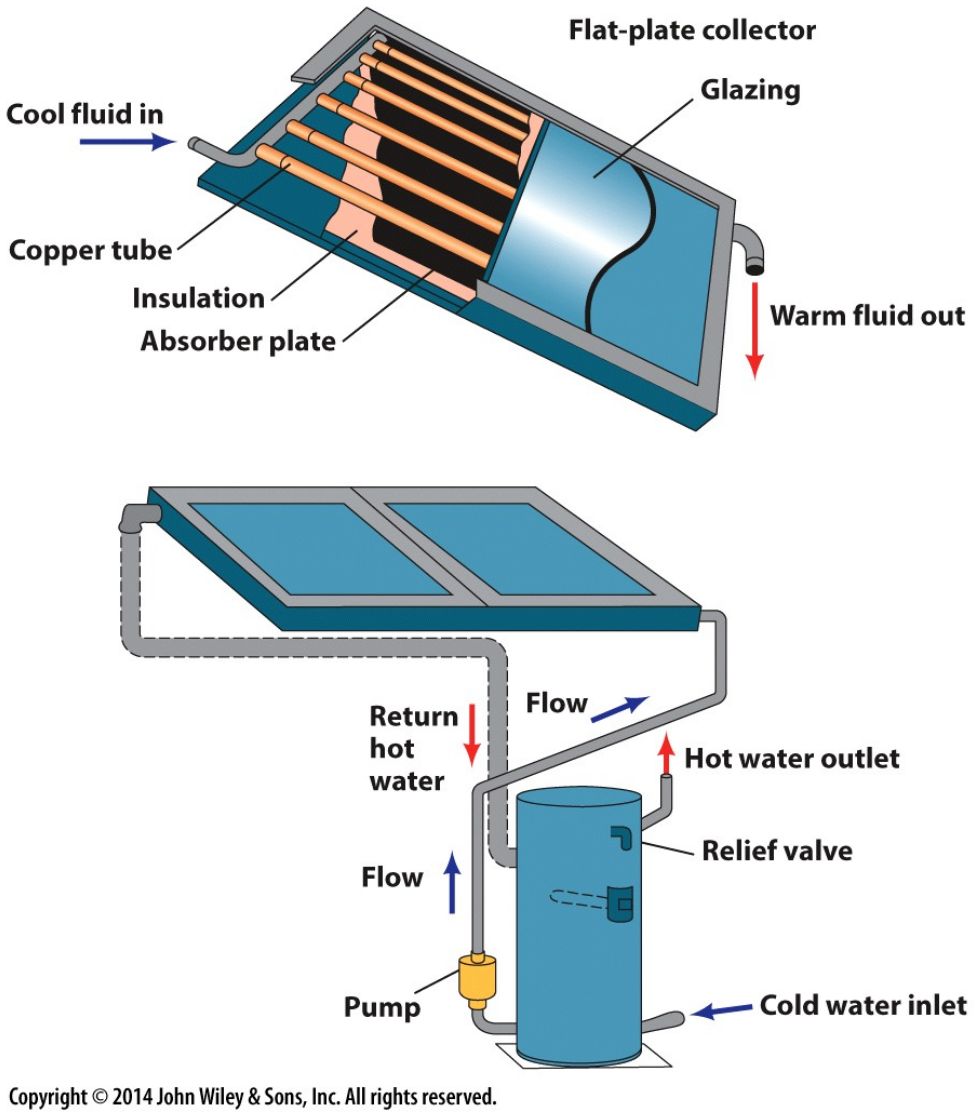
Active Solar Energy

- Energy systems that require mechanical power
  - Electric pump circulates air, water or other fluids from solar collectors to a location where heat is stored
  - Additional pumps move heat to location where energy is converted and used

Solar Collectors

- Provide space heating or hot water
  - Flat-plate collector
    - Flat, glass-covered plates over a black background where absorbing fluid is circulated through tubes
  - Evacuated tube collector
    - Each tube, filled with absorbing fluid, passes through a larger tube

Figure 16.6 Detail of a flat-plate solar collector and pumped solar water heater which is one kind of Active Solar energy.



Photovoltaics & Photovoltaic Cells

- Converts sunlight directly into electricity
  - Made from thin layers of semiconductors and solid-state electronic components with few or no moving parts
- The cells are constructed in standardized modules and encapsulated in plastic or glass.
- Electricity is produced when sunlight strikes the cell. The different electronic properties of the layers cause electrons to flow out of the cell through electrical wires.
- Large photovoltaic installations may be connected to an electrical grid. Off-the-grid applications can be large or small and include powering satellites and space vehicles, and powering electric equipment, such as water-level sensors, meteorological stations, and emergency telephones in remote areas.
- Off-the-grid photovoltaics are emerging as a major contributor to developing countries that can't afford to build electrical grids or large central power plants that burn fossil fuels.

Photovoltaics

- Off-the-grid applications
- Emerging as a major contributor to developing countries
  - Don’t have ability to build electrical grids
  - Systems can power lights and televisions in small villages

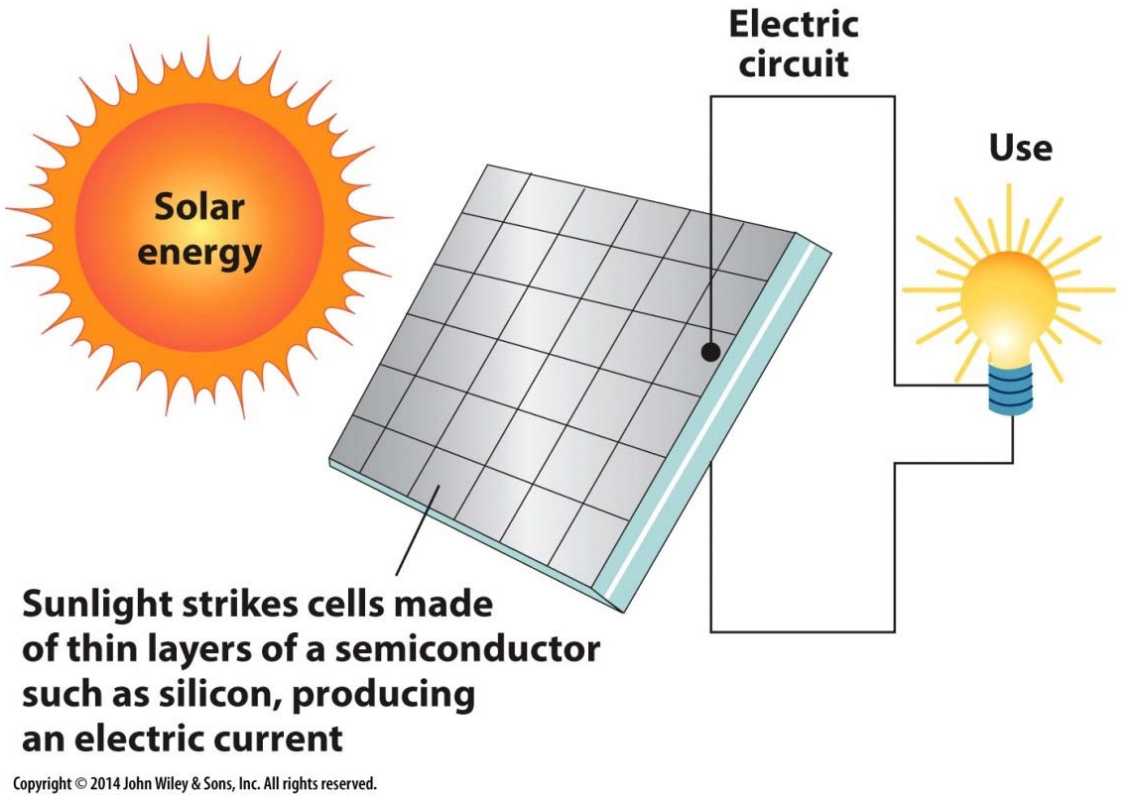


Figure 16.7 Idealized diagram illustrating how photovoltaic solar cells work.

H. Gruyaeart//Magnum Photos, Inc.

Prof. Ed Keller

Figure 16.8 (a) Panels of photovoltaic cells are used here to power a small refrigerator to keep vaccines cool. The unit is designed to be carried by camels to remote areas in Chad.

(b) Photovoltaics are used to power emergency telephones along a highway on the island of Tenerife in the Canary Islands.

Solar Thermal Generators

- Focus sunlight onto water-holding containers
  - Traditionally built using solar power towers
  - Water boils and is used to run conventional steam-driven electrical generators
  - Built with very large output
  - Previously, mirrors used to reflect the light placed on the top of the tower.
  - Recently, solar devices that heat a liquid and produce electricity from steam have used many mirrors without a tower, each mirror concentrating sunlight onto a pipe containing liquid (simpler, cheaper and reliable).

Photo by Daniel B. Botkin

Solar power tower at Barstow, California.

Sunlight is reflected and concentrated at the central collector, where the heat is used to produce steam to drive turbines and generate electric power.

Solar Thermal Generators

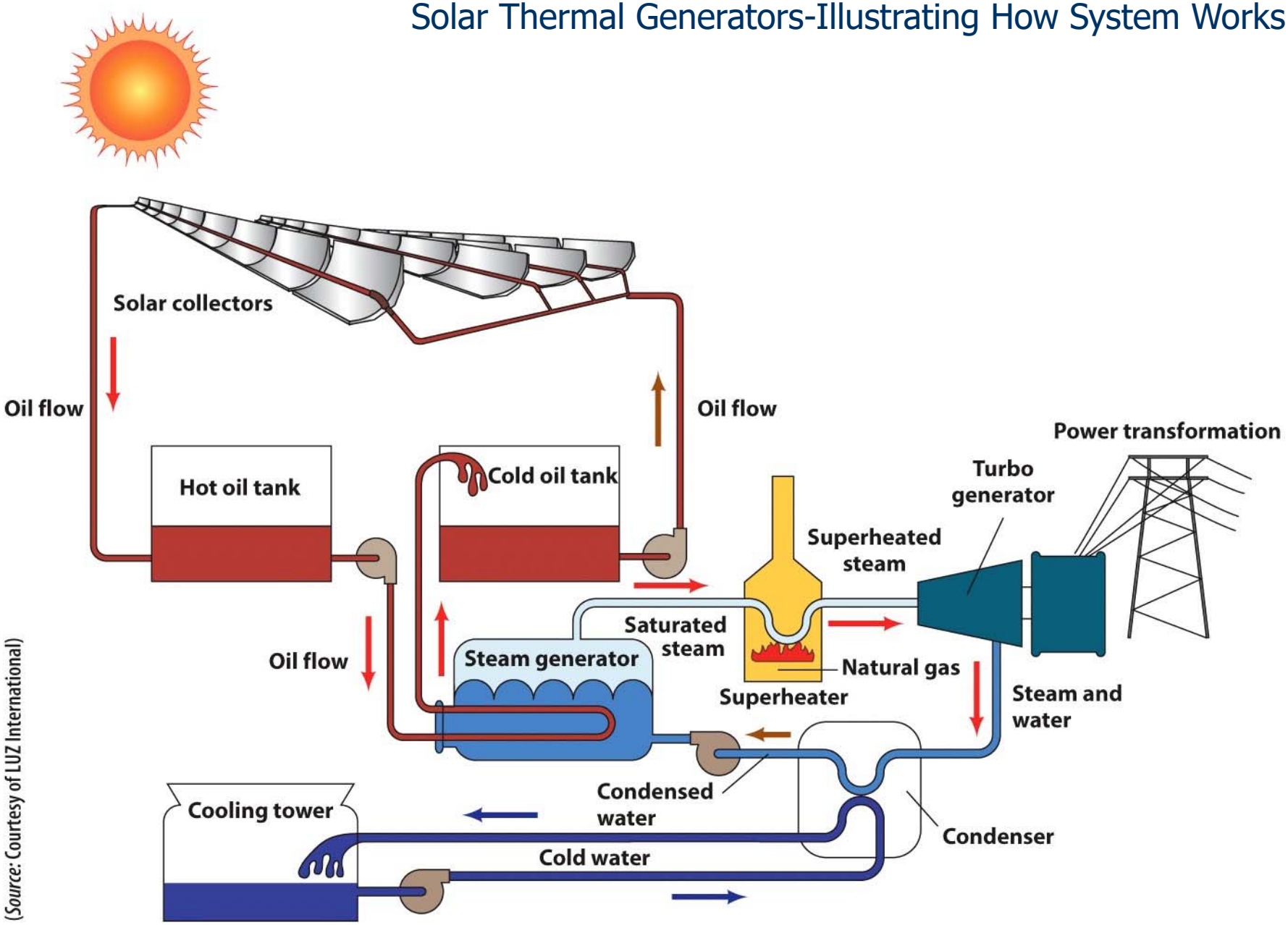
- In newer facility
  - Mirrors focus solar energy onto pipes with heat-absorbing fluid

Figure 16.10 (a) Acciona solar thermal power plant, south of Las Vegas, which uses more than 180,000 parabolic mirrors to concentrate sunlight onto pipes containing a fluid that is heated above 300ºC.

The heated fluid, in turn, boils water, and the steam runs a conventional electrical generating turbine.

Paul Harris/NewsCom

Figure 16.10 (b)
Solar Thermal Generators-Illustrating How System Works



Fuel Cells—An Attractive Alternative

- Fuel cells are highly efficient power-generating systems that produce electricity by combining fuel and oxygen in an electrochemical reaction.
- Hydrogen is the most common fuel type, but fuel cells that run on methanol, ethanol, and natural gas are also available.
- Traditional generating technologies require combustion of fuel to generate heat, then conversion of that heat into mechanical energy (to drive pistons or turbines), and conversion of the mechanical energy into electricity.
- With fuel cells, however, chemical energy is converted directly into electricity.
- Fuel cells are efficient and clean, and they can be arranged in a series to produce the appropriate amount of energy for a particular task.
- For example, they power buses at Los Angeles International Airport and in Vancouver.

Fuel Cells: conversion of more useful form of energy

- Both hydrogen and oxygen are added to the fuel cell in an electrolyte solution.
- The hydrogen and oxygen remain separated from one another, and platinum membrane prevents electrons from flowing directly to the positive side of the fuel cell.
- Instead, they are routed through an external circuit, and along the way from the negative to the positive electrode, they are diverted into an electrical motor, supplying current to keep the motor running.

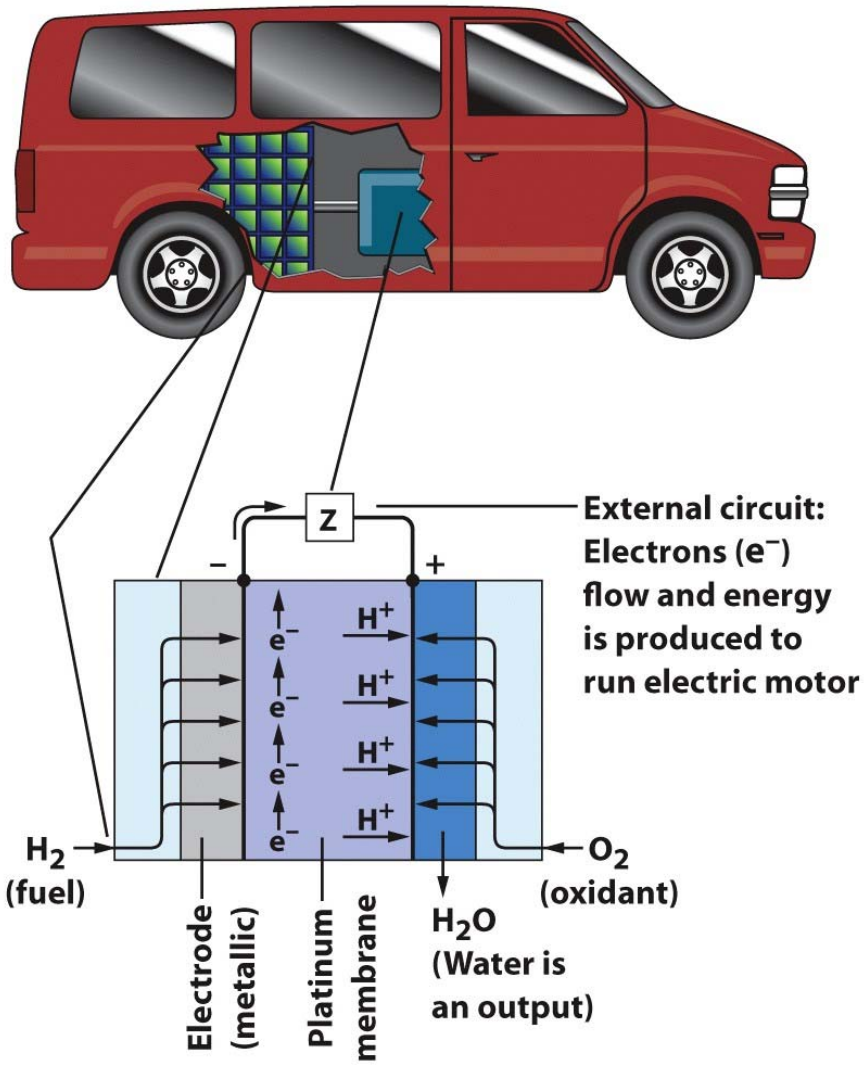


Figure 16.11Idealized diagram showing how a fuel cell works and its application to power a vehicle.

Solar Energy and the Environment

- Generally low impact
- Some concerns—
  - What might be the effects of installing solar energy near national parks and on public lands that have other important environmental uses and benefits?
  - Variety of metals, glass, plastics, and fluids used in the manufacture and use of solar equipment
  - Production and accidental spills could release toxic materials

Converting Electricity from Renewable Energy to a Fuel that Can Be Burned and Can Power Vehicles

- Two choices
  - Store electricity in batteries and use electric vehicles
  - Transfer the energy in the electricity to a gaseous or liquid fuel
    - Hydrogen

Producing Liquid and Gaseous Fuels from Electricity

- Hydrogen as power for fuel cells
  - Electric current separates water into hydrogen and oxygen
  - When H recombines with O, electrons flow between positive and negative poles—an electric current
  - H can be transported via pipeline
- Hydrogen burned as a clean fuel
  - Combustion product is water
  - We can combine hydrogen with carbon to form methane CH_4, the major constituent of natural gas.
  - Or, the methane can be combined to form ethanol (C_2H_6O)-the alcohol already used as part of standard gasoline in the United States.

Water Power

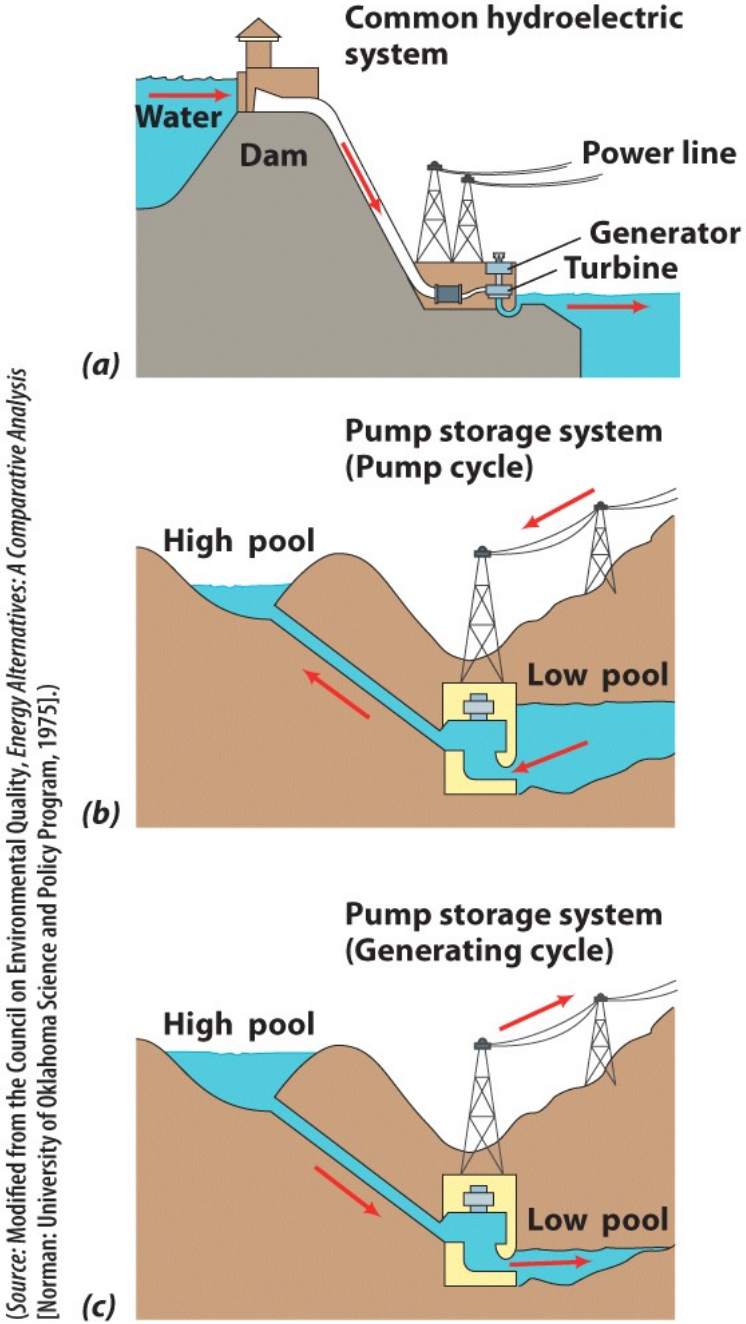
- Long history, Roman Empires used
- Waterwheels convert water power to mechanical energy.
- Used in grain-mills, sawmills and other machinery.

- Today's hydroelectric power plants
  - Use water stored behind dams
  - Also produced through the process of pump storage
  - Advantage of pump-storage lies in the timing of energy production and use.
  - However, pump storage facilities are considered ugly, especially at low water times.

Figure 16.12 (a) **Basic components of a hydroelectric power station.**

(b) A pump storage system. During light power load, water is pumped from low pool to high pool.

(c) During peak power load, water flows from high pool to low pool through a generator.



(*Source:* Modified from the Council on Environmental Quality, *Energy Alternatives: A Comparative Analysis* [Norman: University of Oklahoma Science and Policy Program, 1975].)

Small-Scale Systems

- They have potential
  - In mountainous areas along streams
  - Horizontal turbines in larger rivers.
  - Small dams cause little environmental degradation beyond the specific sites, but a large number of dams can have an appreciable impact on a region.
  - Hydroturbines – interesting development and are being in use as testing.
  - These work like the large turbines that operate in hydroelectric dams, but are smaller and lie horizontally within a river.
  - They are fixed in place, but are not part of a dam, so they allow the normal river flow and migration of fish.

Kris Unger/Verdant Power, Inc.

Figure 16.13 An experimental electric-generating horizontal turbine tested in New York City's East River.

Water Power and the Environment

- Advantages
  - Water power is clean and efficient power
  - No burning of fuel, no radioactive waste
- Disadvantages
  - Flood large tracts of land
  - Block fish migration
  - Trap sediment that would replenish beaches
  - Evaporative loss of water from reservoirs

Ocean Energy-Tidal Power

- High energy in motion of waves, currents and tides in the ocean
  - Difficult to harness
    - Storms destructive and water corrosive
  - Most successful: tidal power since Roman and Great Britain times.
  - Very few areas with the right topography

Tidal power station on the river Rance near Saint-Malo, France.

Tidal Power

- Dam built across the entrance to a bay or estuary, creating a reservoir.
- Water held in or out of bay until significant difference in water level provides substantial force when allowed to enter or exit (flood tide or ebb tide)
- Dam opens/closes related to either flood tide or ebb tide to turn-on the blades of the turbines.
- This runs turbines turning generators

Tidal Power

- Environmental impacts
  - Changes hydrology of bay affecting vegetation and wildlife
  - Restricts passage of fish
  - Changes habitat for birds and other organisms

A **bay** is a recessed, coastal body of water that directly connects to a larger main body of water, such as an ocean, lake, or another **bay**.

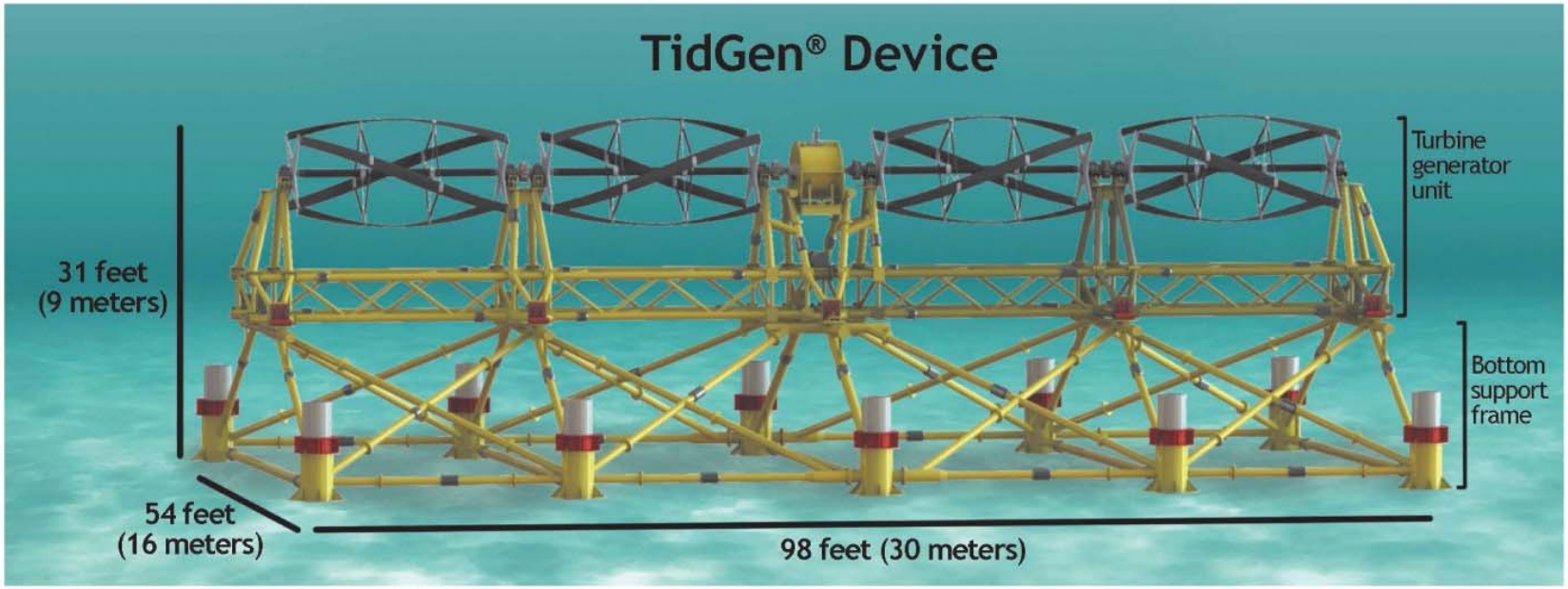
An **estuary** is where a river meets the sea. There, saltwater mixes with freshwater. The river becomes wider and wider and flows slowly to the ocean.

New Ocean Energy Technologies

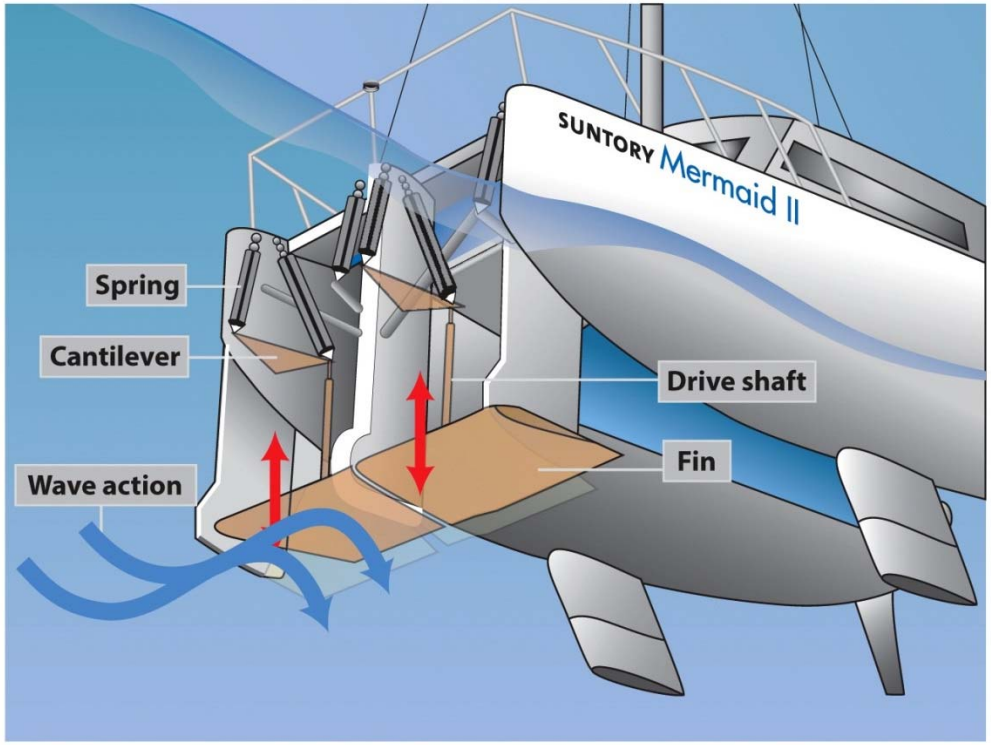
- Horizontal turbine generates electricity from the movement of tidal waters in Cobscook Bay, Maine
- The use of ocean waves to power ocean-going vessels
- Robotic boat using wave and solar energy

Figure 16.15 The first ocean turbine providing electricity to a U.S. grid began operation in September 2012. (a) the turbine being readied (b) For installation; (b) a diagram of the turbine.

Photo courtesy of Ocean Renewable Power Company



(*Source:* Ocean Renewable Power Company's TidGen® Device)



(Source: KEVIN HAND/POPULAR SCIENCE)

REUTERS/Shigeo Yamada/Landov Photographers

Figure 16.16 Wave energy propels boats.

(a) On the Suntory Mermaid, the up-and-down wave motion is transferred mechanically to two fins mounted side by side beneath the bow, which use dolphin-like kicks to propel the boat;

(b) the Suntory Mermaid sailing.

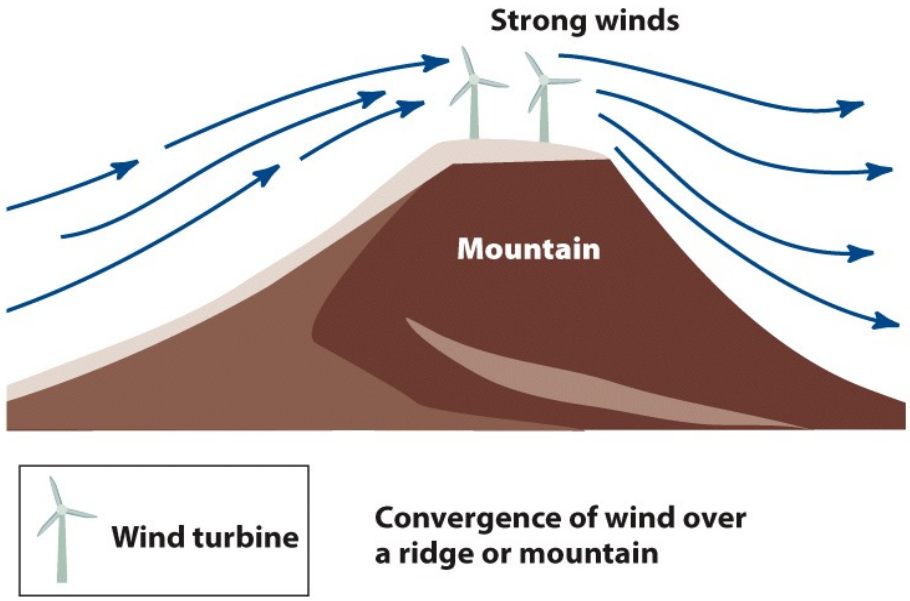
Wind Power-Alternative Energy

- Evolved over long time, from early Chinese and Persian civilizations
- Wind produced when differential heating of Earth's surface creates air masses with differing heat contents and densities
- Wind energy is the cheapest form of alternative energy
  - Less than natural gas and coal
  - Now used in many places including offshore
  - Used in propelling ships, grinding grains and water pumping for ranchers
  - Can generate electricity
  - A site with average wind velocity 18km/h is considered a good prospect for development of wind energy.

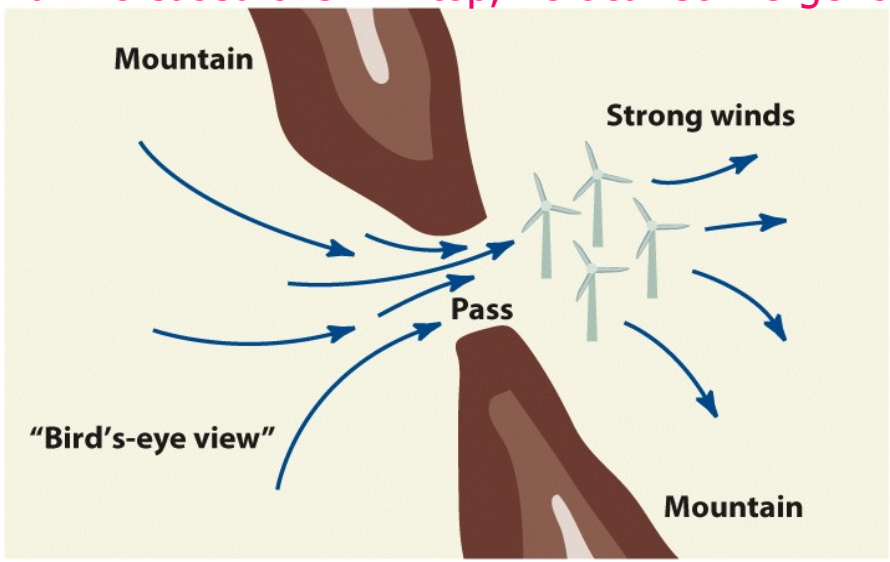
Wind Power

- Problems
  - Wind highly variable in time, place, and intensity, depends on local topography and temperature differences
  - Wind velocity often increases over hill tops or funneled through a mountain pass

Figure 16.18 Idealized diagram showing how wind energy is concentrated by topography.



Wind increased over hill top, Vertical Convergence



Wind Funneled or pass increases due to Horizontal Convergence

Wind Power and the Environment

- Wind energy does have a few disadvantages
  - Kills birds, especially large birds of prey
  - Uses large areas of land
  - May degrade area's scenic resources
- Everything considered, though, wind energy has a relatively low environmental impact

Future of Wind Power

- Growing at a rapid rate each year
  - Could supply 10% of the world's electricity in the coming decades
  - Has created thousands of jobs and investment opportunities
  - Technology producing more efficient wind turbines

Biofuels

- Energy recovered from biomass (organic matter)
- Five categories
  - Unmanaged growth harvested by people, including firewood (wood fuel), grasses, and peat
  - Organic wastes used directly, including cooking oil, which can fuel diesel engines, and methane, emitted from bacterial decomposition of waste
  - Agrifuels, which are crops grown to be converted into liquid fuels
  - Ethanol produced by algae as a by-product of photosynthesis
  - Ethanol produced by bacteria as a by-product of bacteria's decomposition of organic wastes

Biofuels and Human History

- Energy from biomass is the oldest fuel used by humans
  - Until end of 19th century major fuel source in the U.S. was wood
  - 1 billion people in the world still use wood as primary source of energy for heat and cooking
- Includes: firewood, cattle dung, peat

Wood Pellets

Pellet fuels are biofuels made from compressed organic matter or biomass. Pellets can be made from any one of five general categories of biomass: industrial waste and co-products, food waste, agricultural residues, energy crops, and virgin lumber.

Pellets can be used in stream-generating electric power plants.

Could be a new energy source?

There is a controversy in the less/high emissions of carbon dioxide.

http://www.renewableenergyworld.com/ugc/articles/2016/05/how-to-make-wood-pellets--wood-pellet-manufacture-steps.html

Biofuels and the Environment

- Certain types of crops (nuts) produced by trees, may provide a net energy benefits in environment.
- Fewer pollutants like SO_2
- Can pollute the air and degrade the land
  - World's forests will decrease if our need for forest products and forest biomass fuel exceeds the productivity of the forests
- Combustion of biomass-derived fuel generally releases fewer pollutants then combustion of coal/gasoline
  - But burning urban waste can release heavy metals

Geothermal Energy- Nonrenewable Energy

- Deep earth—high density
  - Energy from interior of earth
  - Mined and used to heat buildings and generate electricity
  - May be considered nonrenewable when rates of extraction are greater than rates of natural replenishment
- Shallow earth—low density
  - Solar energy that has traveled to shallow depths-at much lower temperatures and not used for electricity production. Can be used to heat buildings, swimming pools and soils for crop production. E.g., systems in Iceland.

Some 40 million people today receive their electricity from geothermal energy at a cost competitive with that of other energy sources.
In El Salvador, geothermal energy is supplying 25% of the total electric energy used.

Geothermal Systems

- Areas of high heat flow occur at plate boundaries
  - Divergent and convergent plate boundaries
- Hydrothermal convection—transfers heat from depths to surface
  - Using steam or hot water
- Such natural heat flow at Yellowstone National Park. On the basis of geologic criteria, several types of hot geothermal systems (with temperatures greater than about 80°C) have been defined.

The average heat flow from the interior of the Earth is very low, about 0.06 watts per square meter (W/m^2). This amount is trivial compared with the 177 W/m^2 from sunlight at the surface, but in some areas the heat flow is high enough to be useful.

Figure 16.20 Geysers Geothermal Field, north of San Francisco, California, is the largest geothermal power operation in the world and produces energy directly from steam.

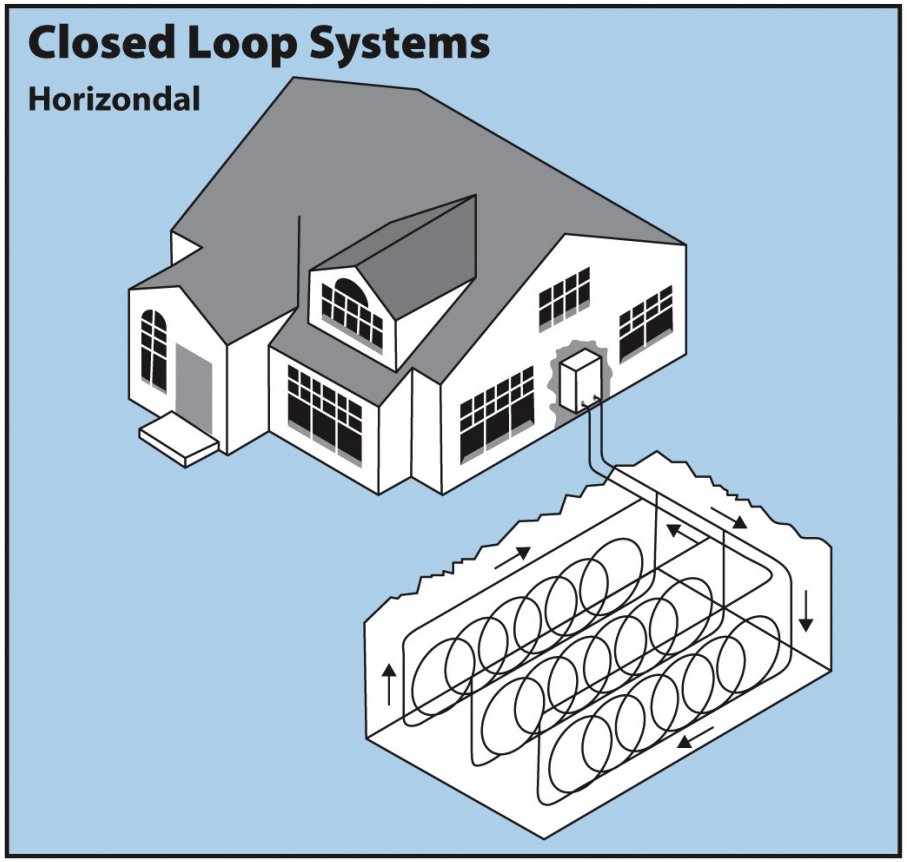
Kim Steele/Getty Images, Inc.

Geothermal Energy

- Most groundwater can be considered a source of geothermal energy
  - Groundwater at a depth of 100m is 13^{o}C or 55^{o}F
  - In summer, heat can be transferred to the cool water
  - In winter, heat can be transferred from the water to the air

Figure 16.21
Heat and cooling right under your feet. How a geoexchange system works.

"Heat pumps" for this kind of heat transfer are used in warm locations such as Florida and as far north as Juneau, Alaska, but are limited by extreme temperatures and can't function in the cold winters of northern New Hampshire or interior Alaska, such as in Fairbanks.



(*Source:* DOE EIA)

Geothermal Energy and the Environment

- Problems
  - Considerable thermal pollution from hot wastewaters
  - Water may be saline or highly corrosive
  - On-site noise
  - Emissions of objectionable gas
  - Disturbance of land and habitats

90% less CO_2 and SO_2
No large scale transportation of raw chemicals

Hawaii, where active volcanoes provide abundant near-surface heat, some argue that the exploration and development of geothermal energy degrade the tropical forest as developers construct roads, build facilities, and drill wells.

In Hawaii, geothermal energy also raises religious and cultural issues.

Some people, for instance, are offended by the use of the "breath and water of Pele," the volcano goddess, to make electricity.

Future of Geothermal Energy

- Globally, the likelihood is that high-density, deep-earth geothermal can be only a minor contributor to world energy demand
- Low-density, shallow-earth geothermal can be a major source of alternative and renewable energy

Chapter Summary

- Use of renewable alternative energy sources is growing rapidly
- These energy sources do not cause
  - Air pollution
  - Health problems
  - Climate changes
- They offer our best chance to replace fossil fuels and develop a sustainable energy policy

Chapter Summary

- Passive solar energy systems involve architectural designs that enhance absorption of solar energy without requiring mechanical power or moving parts
- Active solar energy systems use solar collectors to heat water for homes
- Systems to produce heat or electricity include power towers and solar farms

Chapter Summary

- Photovoltaics convert sunlight directly into electricity
- Hydrogen gas may be an important fuel of the future, especially when used in fuel cells
- Water power today provides about 10% of the total electricity produced in the United States
  - Water power is clean
  - Several environmental concerns must be considered

Chapter Summary

- Wind power has tremendous potential as a source of electrical energy in many parts of the world
  - Environmental impacts of wind installations include loss of land, killing of birds, and degradation of scenery
- Biofuels include firewood, wastes, and crops grown to produce fuels
  - Involve considerable environmental costs
  - At present not considered a good option

Chapter Summary

- Geothermal energy, natural heat from Earth's interior, can be used as an energy source
- The environmental effects of developing geothermal energy relate to specific site conditions and the type of heat—steam, hot water, or warm water
- Potential environmental impacts
  - On-site noise, industrial scars, emissions of gas, and disposal of saline or corrosive waters