ENVIRONMENT

THE SCIENCE BEHIND THE STORIES

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Ch 21

New Renewable Energy Alternatives

Part 2: Environmental Issues and the Search for Solutions

PowerPoint® Slides prepared by
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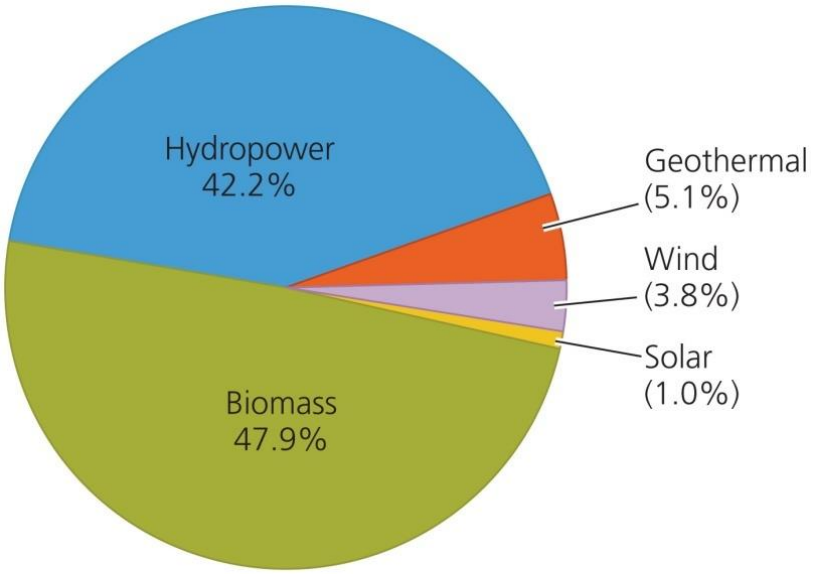
“New” renewable energy sources

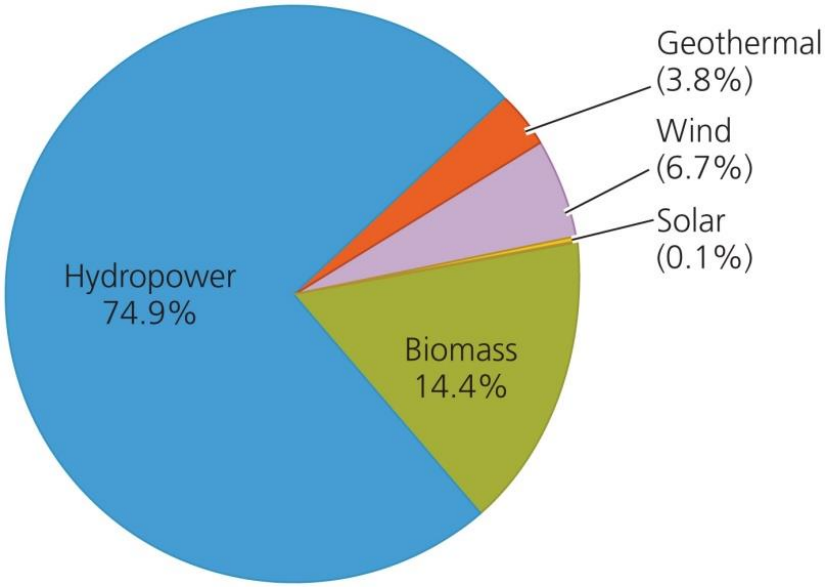
- “New” renewables are a group of alternative energy sources that include
  - Energy from the Sun, wind, geothermal heat, and movement of the ocean water
- They are commonly referred to as “new” because:
  - They are not yet used on a wide scale
  - Their technologies are still in a rapid phase of development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

Use has expanded quickly because of:

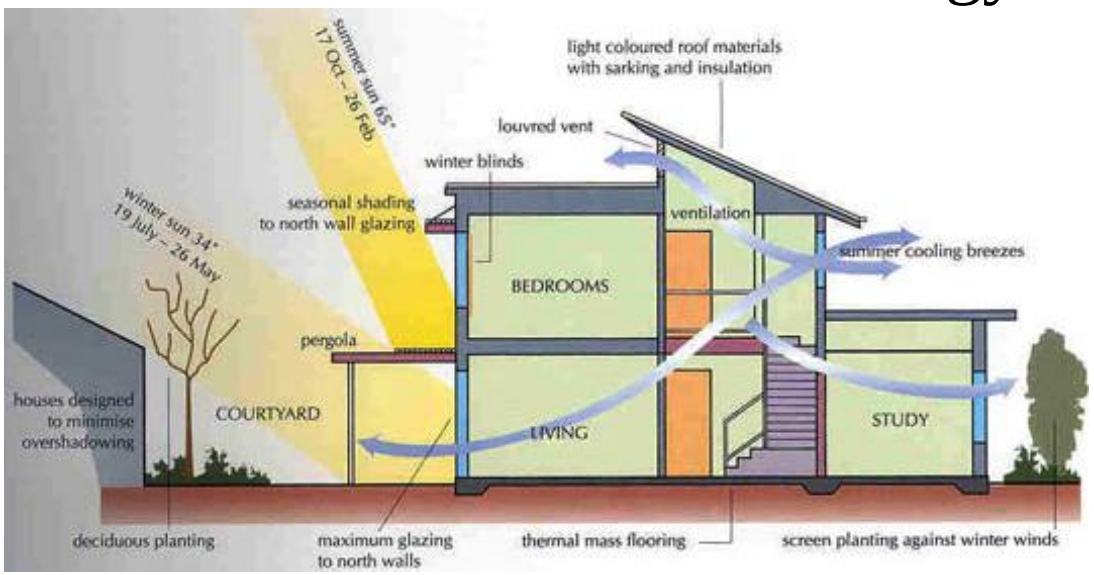
- Growing concerns over diminishing fossil fuels
- The environmental impacts of fossil fuel combustion
- Advances in technology make it easier and less expensive
- Benefits of the new renewables include:
  - They alleviate air pollution and greenhouse gas emissions that can cause climate change
  - They 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

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 light bulb
  - 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

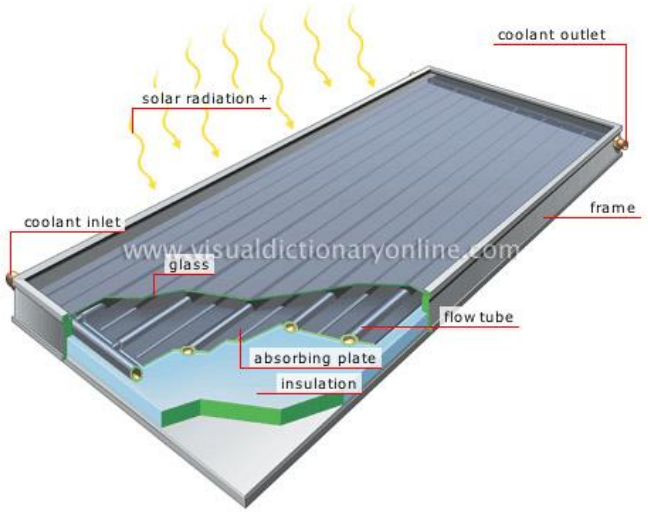
Passive solar heating is simple and effective

- 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



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



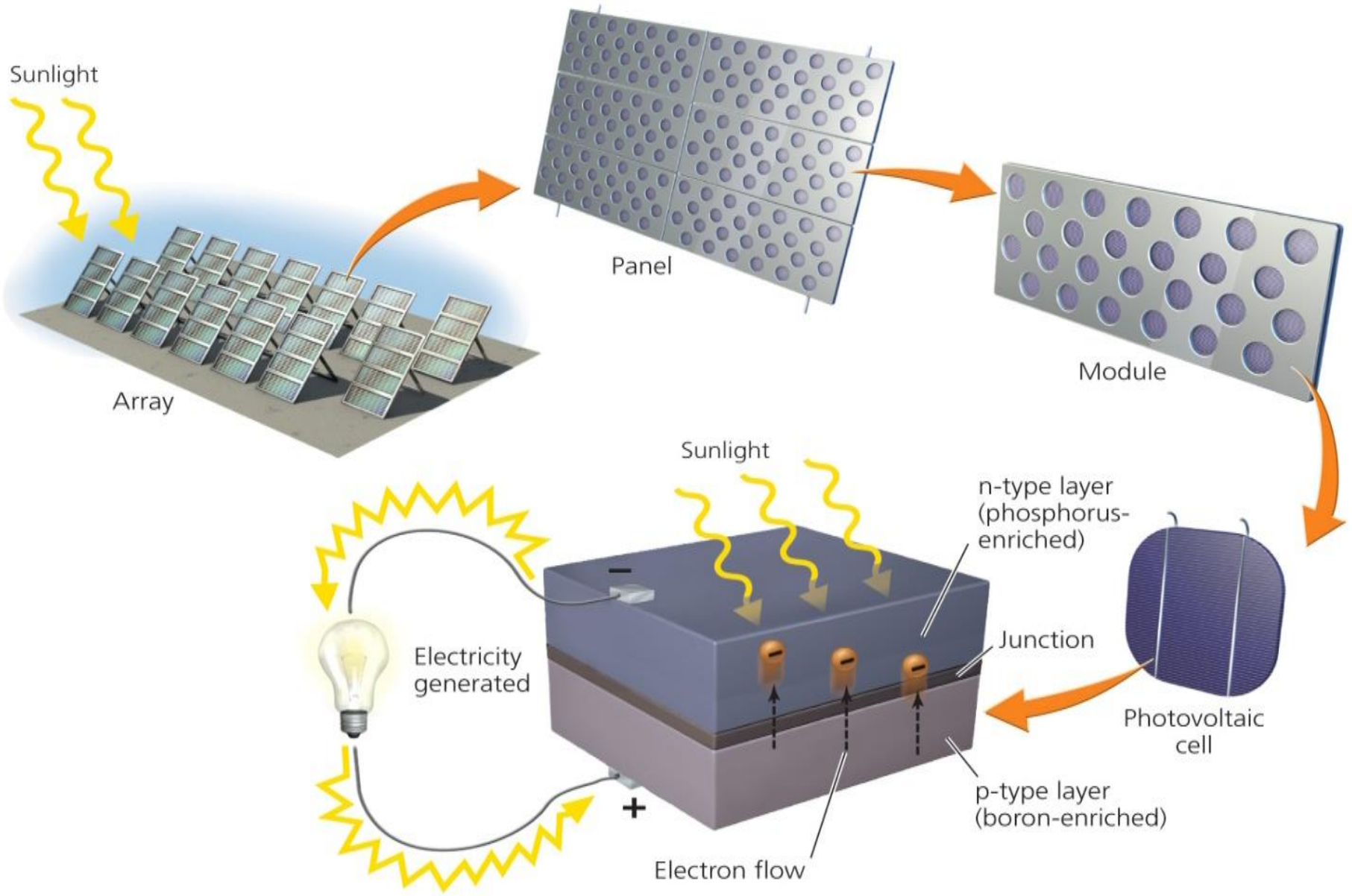
Concentrating solar rays magnifies energy

- 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

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



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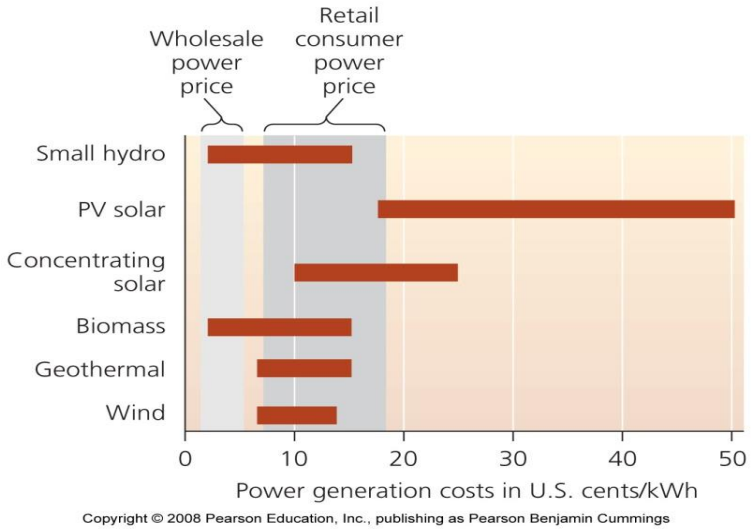
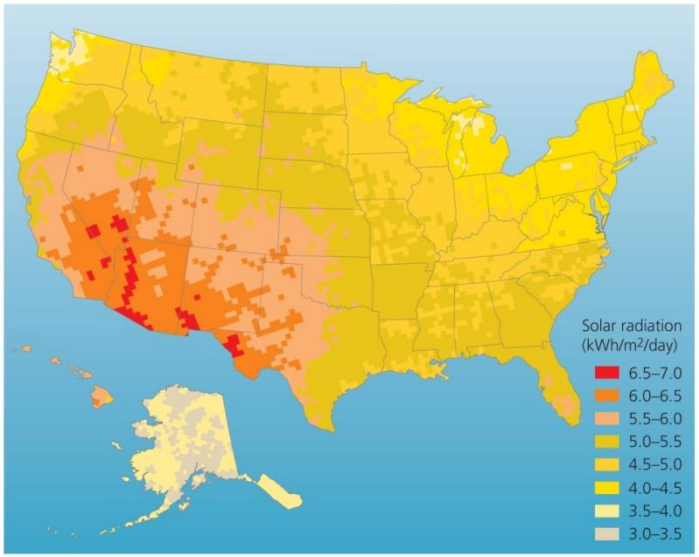
Solar power offers many benefits

- 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

Drawbacks to Solar

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



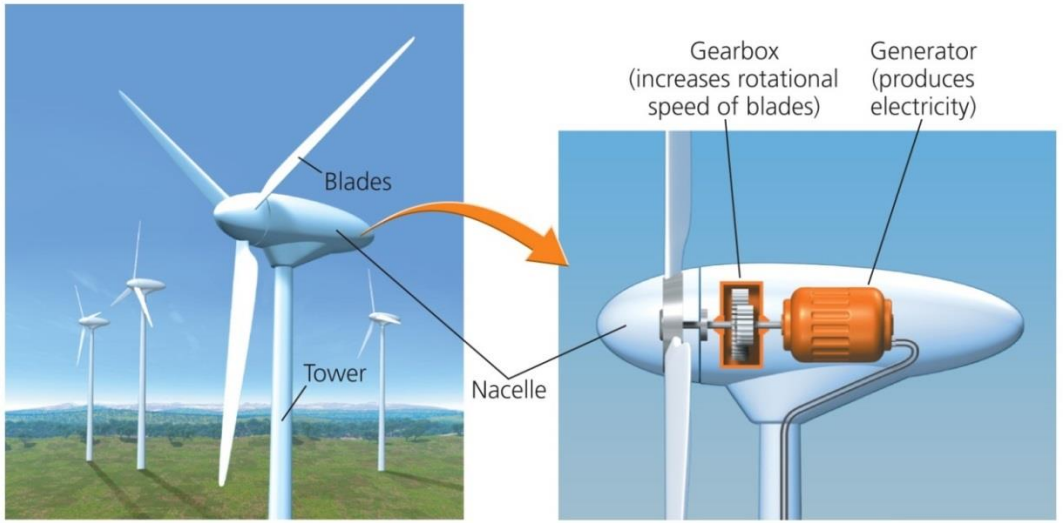


Wind has long been used for energy

- **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** = turbines erected in groups of up to hundreds of turbines



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

Wind power has many benefits

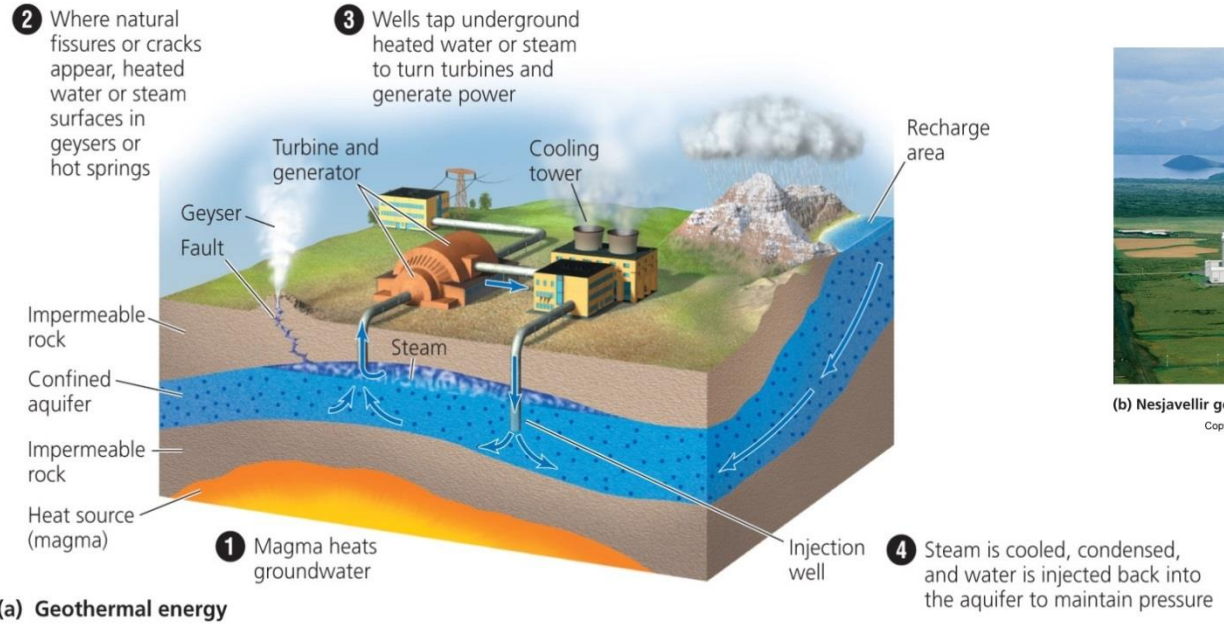
- Wind produces no emissions once installed
- It prevents the release of CO_2
- It is more efficient than conventional power sources
- Turbines also use less water than conventional power plants
- Farmers and ranchers can lease their land
  - Produces extra revenue
  - Landowners can still use their 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

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

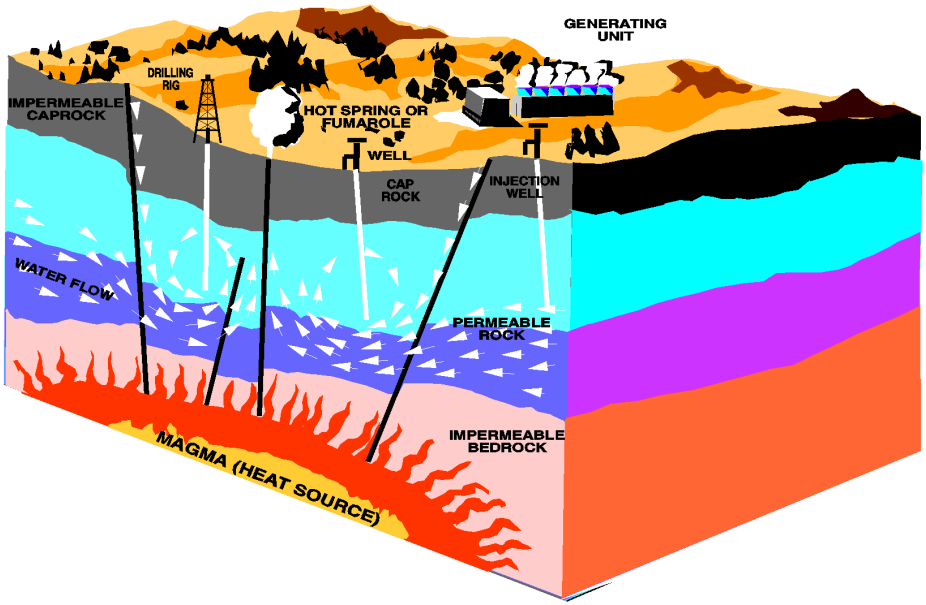


(a) Geothermal energy

(b) Nesjavellir geothermal power station, Iceland

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

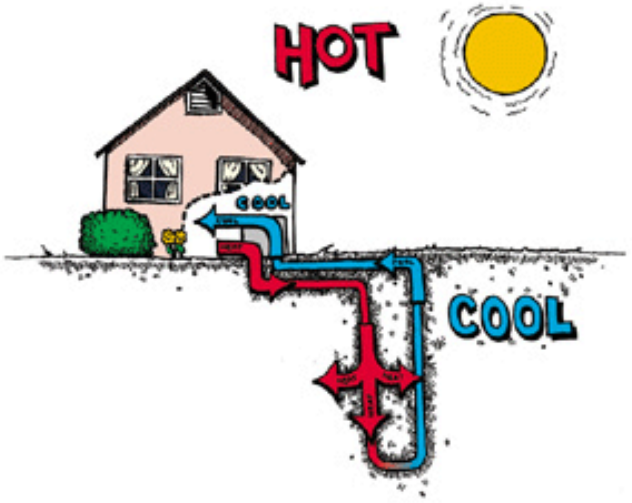


Geothermal energy produces heat and electricity

- 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

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



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

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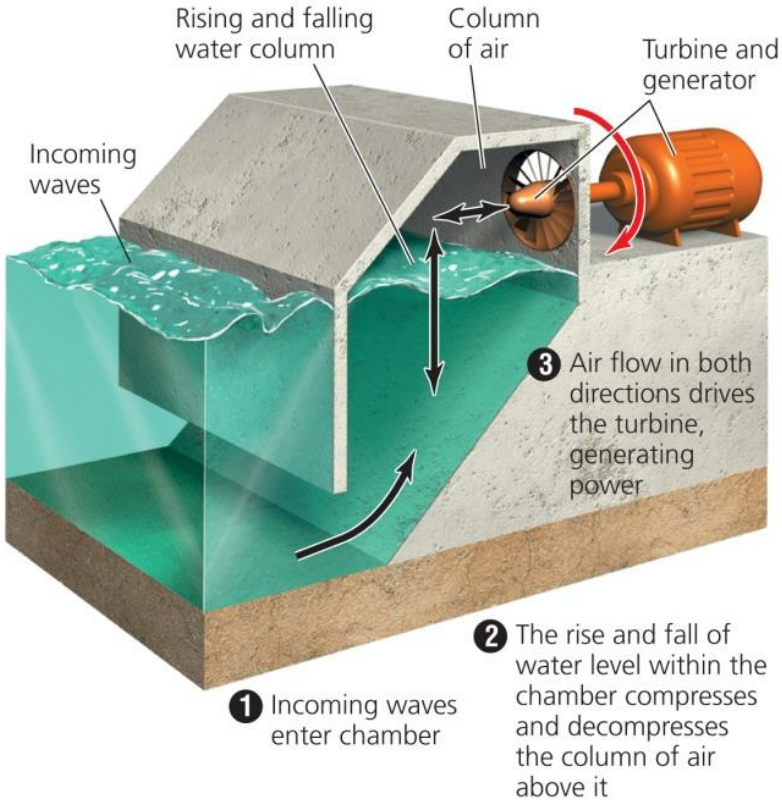
Wave energy

- 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 channels and elevated reservoirs; electricity is generated when 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

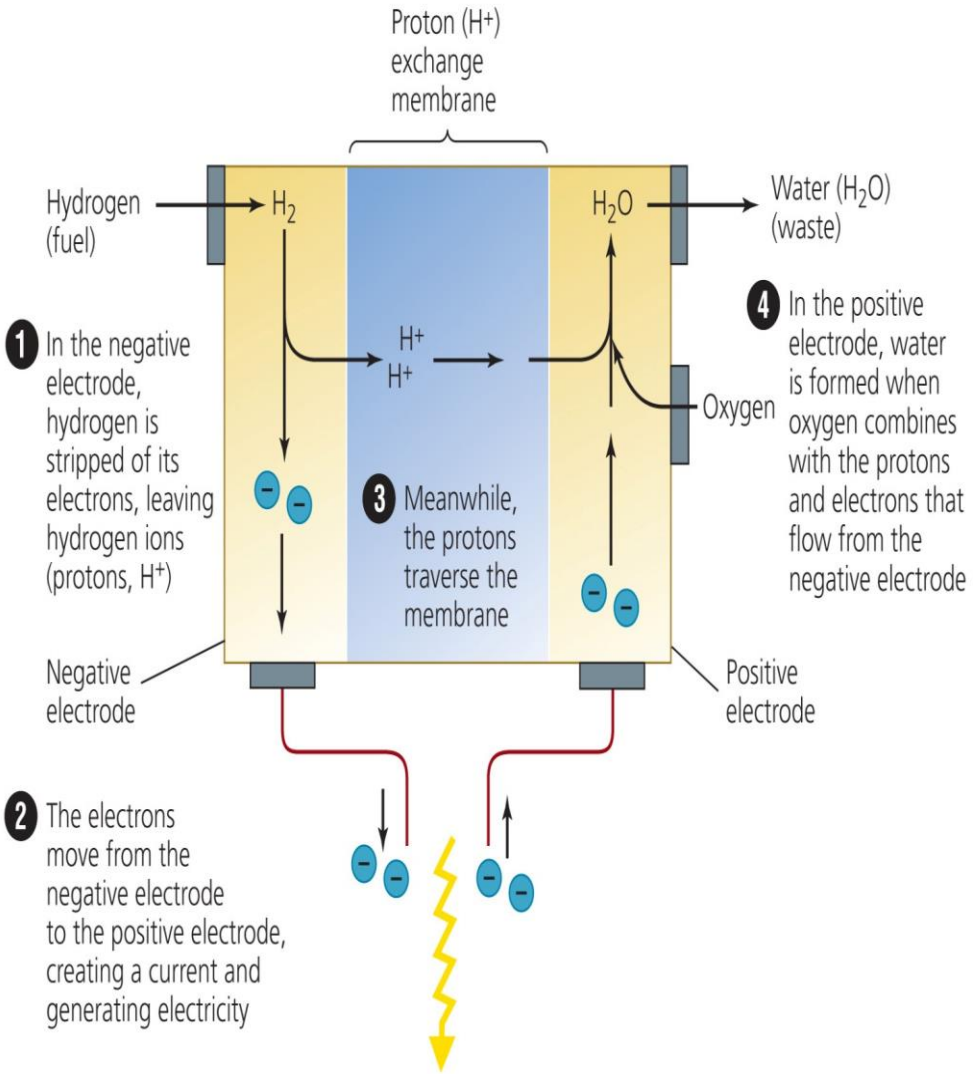


The ocean stores thermal energy

- 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



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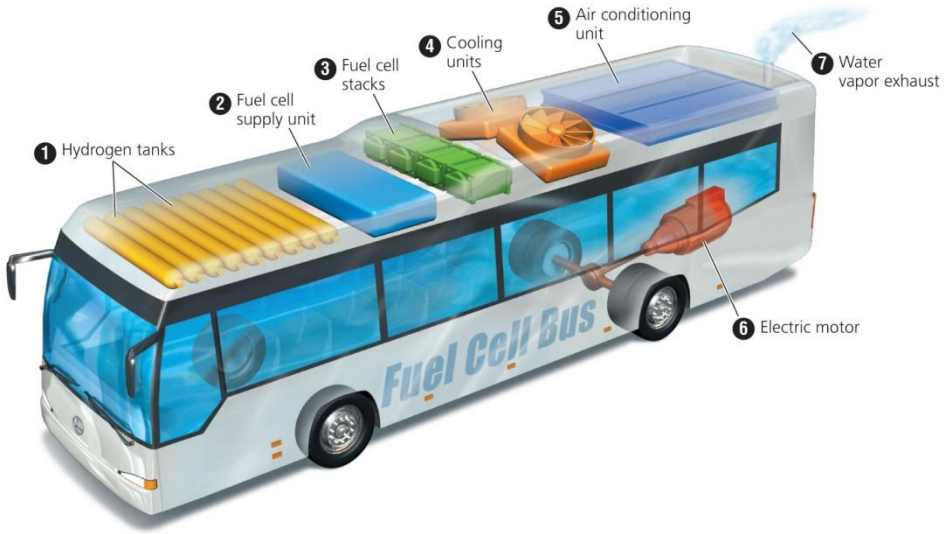
An energy system based on hydrogen

- 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

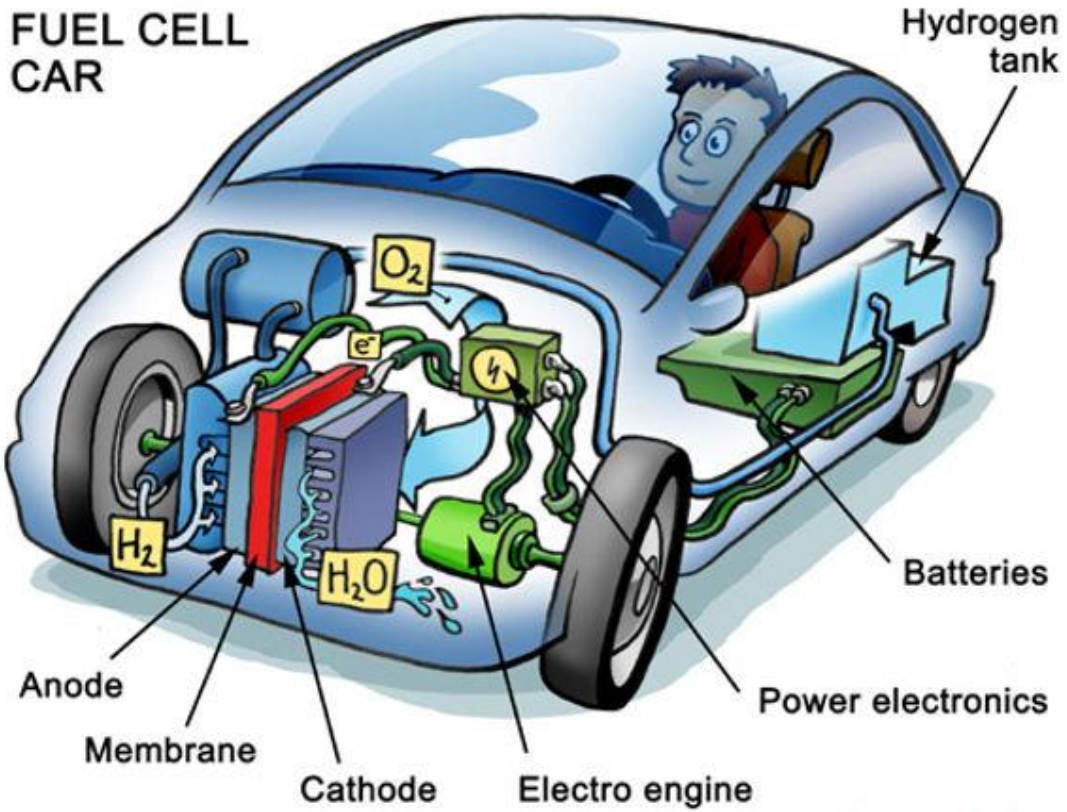


Production of hydrogen fuel

- **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 other processes
- 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