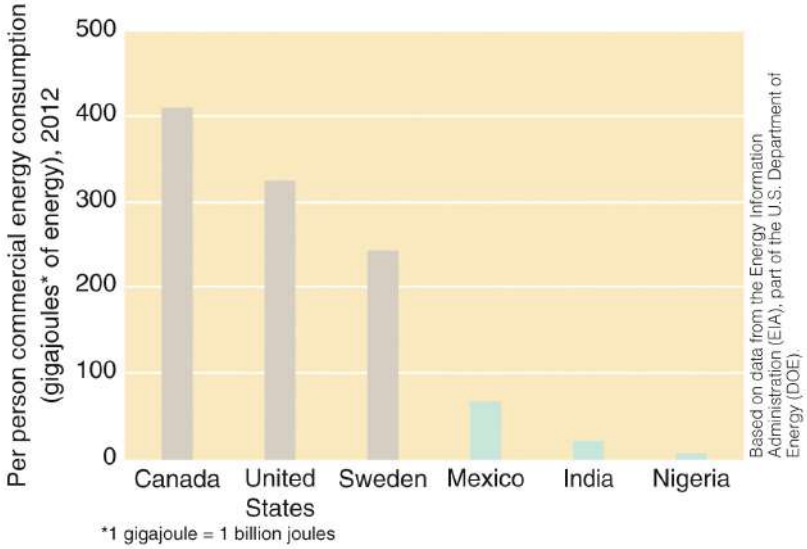
Visualizing Environmental Science

Nonrenewable Energy Resources

Chapter 17

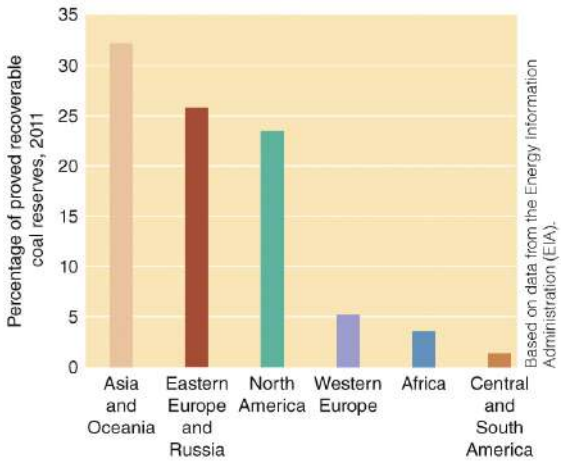
Energy Consumption

- Human society depends on energy
  - Grow, store, cook food; warm/cool homes; extract/process natural resources, manufacture items; transportation
- Per capita consumption of energy is much higher in developed than developing countries
  - In developing countries, industrial energy use is lower, and household use higher
  - Developed nations use more but consumption is not increasing/relatively stable



Coal

- Coal is the most abundant fossil fuel on Earth
  - U.S. has 25% of world's coal deposits
  - Used to produce electricity and steel
- Two basic types of coal mines
  - Surface mining
    - Coal within 30 m of the surface
    - 60% of U.S. coal is obtained this way
    - Usually safer for miners, less expensive
    - Disrupts the land extensively
  - Subsurface mining (deep underground)
    - Approximately 40% of coal is mined this way in the U.S.



Environmental Impacts of Coal

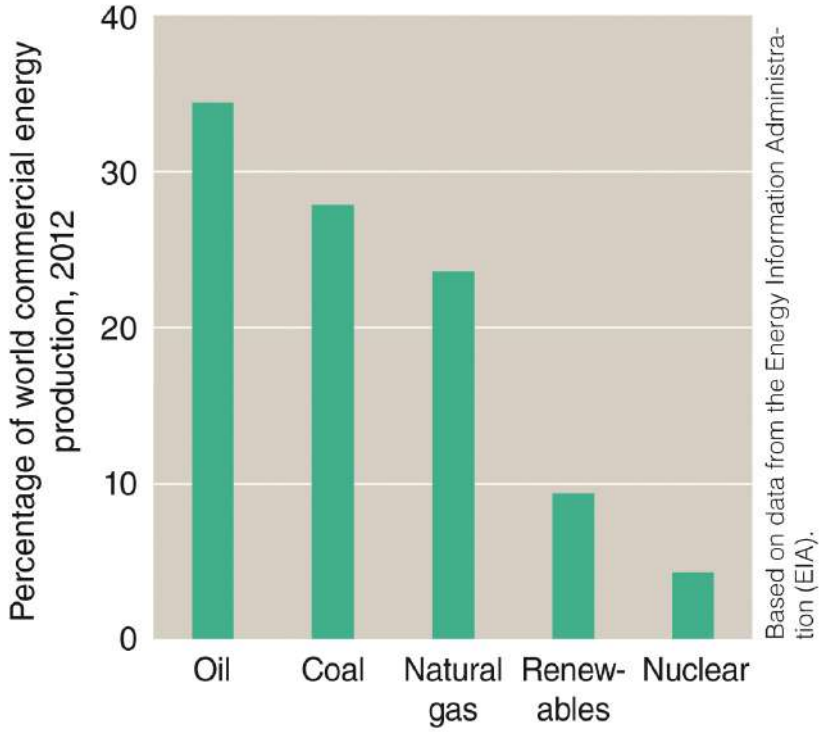
- Substantial effects on the environment
  - Topsoil loss (from erosion or removal during mining)
    - Prevents restoration of site
  - Acid and toxic mineral drainage leaches from minerals exposed in mine waste
  - Streams become polluted with silt runoff and acid mine drainage
  - Mountaintop removal
    - One of the most destructive mining methods
    - Has leveled 15–25% of mountains in southern West Virginia
      - Half the peaks in that area will be gone by 2020
    - Valleys and streams between mountains are obliterated; filled in with tailings and debris

Environmental Impacts of Coal

- Coal burning
  - Contributes more air pollutants than oil or natural gas
  - When coal is burned it produces sulfur and nitrogen oxides, which react with water in the atmosphere and cause acid deposition
  - Releases more CO_2 into the atmosphere (per unit of heat produced) than other fossil fuels
  - Scrubbers and other technologies can be used to remove sulfur and particulates from emissions released during coal burning

Oil and Natural Gas

- Provide 56% of world's energy
- In U.S., also supplies approximately 56% energy
- Other U.S. sources:
  - Coal 23%
  - Nuclear power 9%
  - Renewables 11% (hydropower, wind, solar)
  - Liquid biofuels 1%



World commercial energy sources

Oil and Natural Gas

- Petroleum, or crude oil
  - Liquid composed of hundreds of hydrocarbon compounds
  - Petrochemicals
    - Oil is also used to produce fertilizers, plastics, paints, pesticides, medicines, synthetic fibers
- Natural gas
  - Only a few hydrocarbons
    - Methane is used primarily for heating residential and commercial buildings, and generating electricity
    - Ethane, propane, and butane
  - Liquefied petroleum gas
    - Propane and butane are separated and stored in pressurized tanks as a liquid

Oil and Natural Gas

- Natural Gas Uses
  - Electricity generation
  - Transportation
    - Fuels for cars, trucks, buses
    - Environmental advantages over gasoline/diesel
      - 33% less CO_2; 80–93% fewer hydrocarbons; 70% less CO; 90% fewer toxic emissions, almost no soot
  - Commercial cooling
  - Plastics and fertilizer production

Oil and Natural Gas

- Main disadvantage
  - Deposits are located far from where gas is needed
  - Costs four times more to transport through pipelines than crude oil
    - Must be compressed to form liquefied natural gas (LNG) and carried in specially constructed refrigerated ships
    - Reserves are found on every continent, but have uneven distribution
- Hydraulic fracturing (fracking) techniques have changed estimates of natural gas resources
  - Environmental impacts of fracking different than other extraction methods

Environmental Impacts of Oil and Natural Gas

- Oil
  - CO_2 production contributes to global warming
  - Acid deposition
  - Photochemical smog
  - Nitrogen oxides (almost no sulfur oxides)
- Natural gas
  - Relatively clean
  - No sulfur
  - Releases far less CO_2 and hydrocarbons
  - Almost no particulates compared to oil and coal
- Risks associated with transport
  - Leaks and spills

Major US Oil Spills

- *Deepwater Horizon* drilling platform explosion—2010, Gulf of Mexico
  - 11 workers died
  - 4 million barrels of crude oil spilled from the damaged ocean floor well
  - Fisheries disrupted, wildlife killed, extensive ecological damage occurred

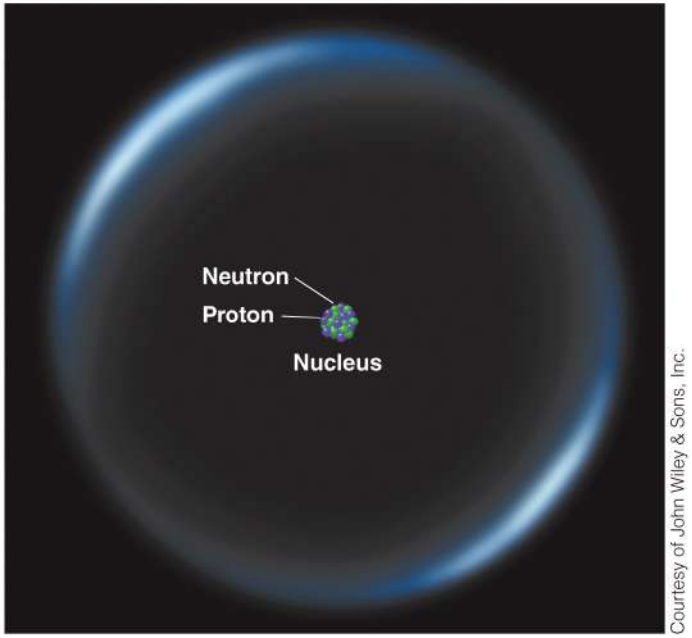
Year	Amount spilled (million barrels of oil)	Event	Location
1910	9	Drilling rig hits pressured oil pocket	Kern County, California
1991	6	Oil dumped by Iraqi army during first Persian Gulf War	Kuwait
2010	4 to 5	*Deepwater Horizon* oil rig fails	Gulf of Mexico, south of Louisiana
1979	2.5 to 3.5	Exploratory well Ixtoc I fails	Bay of Campeche, Gulf of Mexico
1979	2.1	Oil tankers *Atlantic Empress* and *Aegean Captain* collide	Trinidad and Tobago

Compiled from Casselman, A., (2012). "10 Biggest Oil Spills in History" *Popular Mechanics*. Moss, L., (2010). "The 13 Largest Oil Spills in History" *Microsoft News Network* July 12, 2010; Harvey, S. (2010). "California's Legendary Oil Spill". *Los Angeles Times*, June 13, 2010.

Nuclear Energy

- Atoms are composed of
  - Protons (+)
  - Neutrons (0)
  - Electrons (–)
  - Protons and neutrons are in the nucleus, and electrons orbit the nucleus
- With fossil fuels, combustion releases energy from changes in the chemical bonds between atoms
- Nuclear energy comes from changes within the nuclei of atoms

Atomic structure



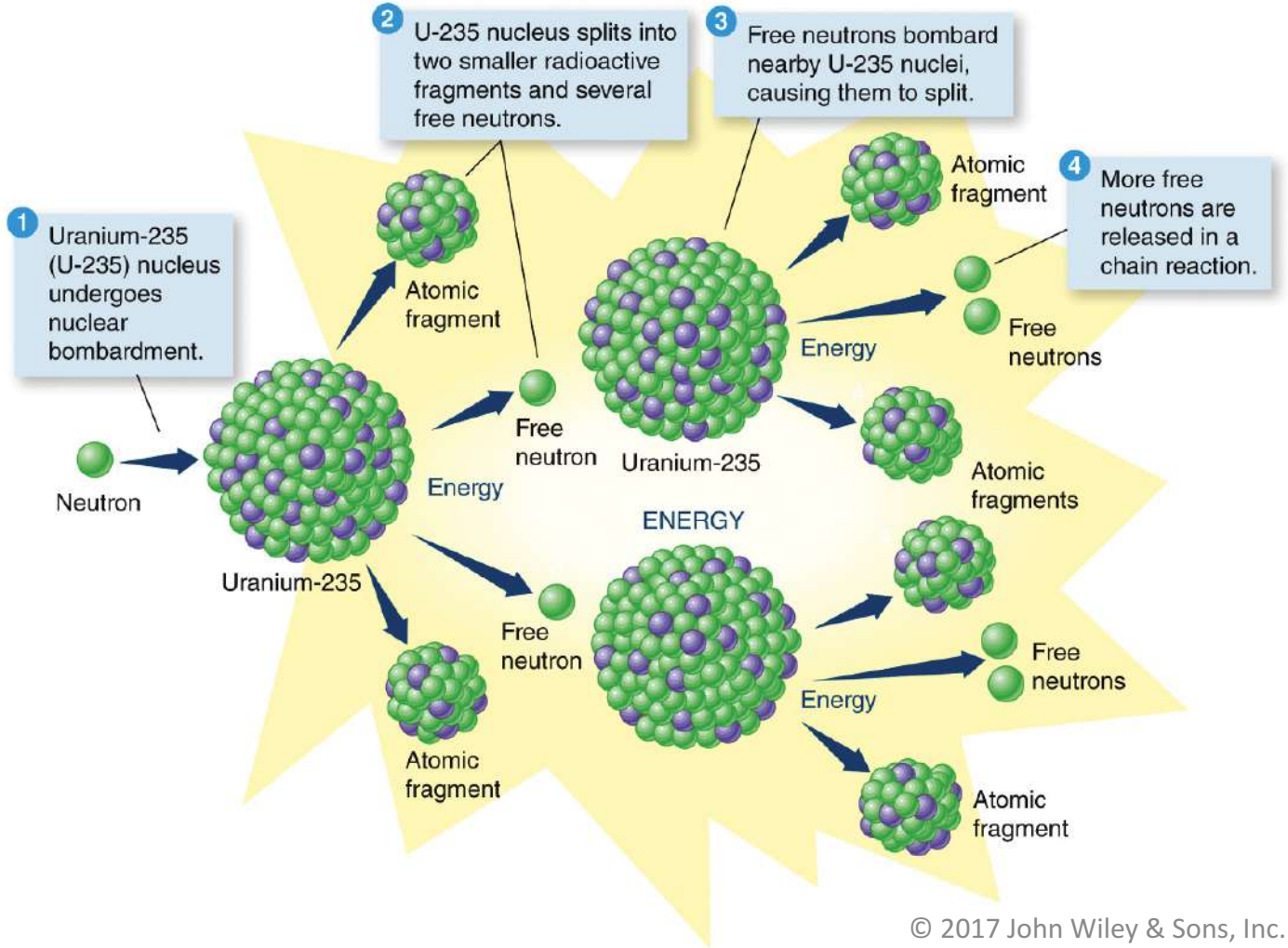
An atom contains a nucleus made of protons and neutrons. Circling the nucleus is a “cloud” of electrons

Nuclear Energy

- Nuclear energy- the energy released by fission or fusion nuclear reactions
  - Fission
    - Splitting of nucleus into two smaller fragments, accompanied by the release of large amounts of energy
      - E.g., a neutron crashes into a nucleus of uranium
    - Used in nuclear power plants
  - Fusion
    - Two small atoms are combined to form a large atom of a different element
      - E.g., process that powers the sun and other stars

Nuclear Fission

Fission process in U-235 atoms



Conventional Nuclear Fission

- Uranium ore is used in nuclear power plants
  - Nonrenewable resource, 11% of global resources of uranium are located in U.S.
- Fission of U-235 releases an enormous amount of heat
  - In nuclear reactors, this heat is used to convert water into steam
  - Steam then drives a turbine, generating electricity
- Nuclear reactors use controlled nuclear fission chain reactions to produce energy
  - Bombs are uncontrolled nuclear reactions

Nuclear Energy and Fossil Fuels

- Nuclear power production has plateaued after a decade of growth
  - In 201, 438 nuclear power plants in 30 countries operating; 67 more under construction in 15 countries
- Supporters claim we need more nuclear energy
  - Affects the environment less than fossil fuels
    - Less pollution, no CO_2
    - Decreases demand on foreign oil
- Nuclear energy generates radioactive waste
  - Spent fuel, coolant fluids and gases
  - Special measures necessary for safe storage and disposal

Safety and Accidents in Nuclear Power Plants

- Nuclear power plants cannot explode like bombs. However, accidents can cause radiation release
  - Meltdown—metal encasing uranium fuel can melt
  - Water can boil off and release radioactivity
- Nuclear industry considers major accidents low probability risks, but public's perception of risk is much higher
  - Involuntary and potentially catastrophic
  - People are distrustful of nuclear industry
  - Consequences of accidents are drastic and long-lasting
- Worldwide, three major nuclear accidents have occurred since 1970

Radioactive Wastes

- Low-level
  - Solids, liquids, or gases that give off small amounts of radioactive energy
  - Produced by power plants, nuclear medical facilities, university research labs
- High-level
  - Solids, liquids, or gases that give off large amounts of radiation
  - Produced during nuclear fission in reactors
    - Fuel rods and assemblies, coolants, air and gases from reactor, reprocessing of spent fuel
  - Among the most dangerous human-made hazardous wastes
    - Difficult to store; toxic and produce considerable amounts of heat

Radioactive Wastes

- Recommended storage
  - Stable rock formations deep in the ground
    - People object to having it stored under their homes/cities
- Currently no long-term centralized storage in U.S.
- Commercial nuclear power plants store spent fuel on-site, but none are designed for long-term storage
- No countries have successfully selected or developed long-term storage facilities for high-level nuclear waste as of 2016

Case Study

- The Arctic National Wildlife Refuge (ANWR)—1980
  - "America's Serengeti"
    - Biologically rich - home to many species
    - Fragile ecosystem
  - Environment vs. economy conflict
    - Proposed opening of area to oil exploration
    - Supporters—economic considerations are main reason for drilling; make U.S. less dependent on foreign oil
    - Detractors—money spent on exploration would be better spent on developing alternative, renewable fuel sources, and energy conservation
    - Permanent threats to balance of nature in Alaskan wilderness