



CHAPTER 15: NONRENEWABLE ENERGY

2013

APES

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Energy Sources

- * 82% of commercial energy comes from nonrenewable sources
 - * 76% from fossil fuels (oil, natural gas, and coal)
 - * 6% from nuclear power
- * 18% from renewable resources
 - * biomass, hydropower, geothermal, wind, and solar

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Historical Energy Use

- * Over 12,000 years ago - fire used to cook, light, and heat
- * 12,000 years ago - domestication of animals, wind energy, flowing water
- * 275 years ago - machinery (mostly powered by firewood - steam engines)
 - * 1st energy crisis - deforestation
- * 200 years ago - burning coal (72%), wood (18%)
- * 100 years ago - oil (40%), coal (38%), natural gas (18%)
- * 50 years ago - nuclear power

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Commercial Energy Sources by Usage

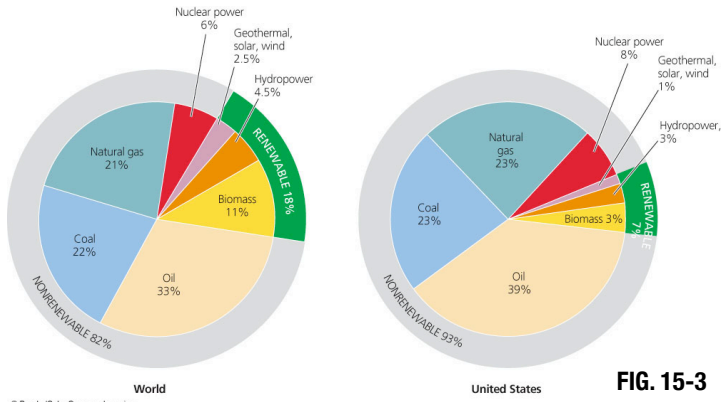
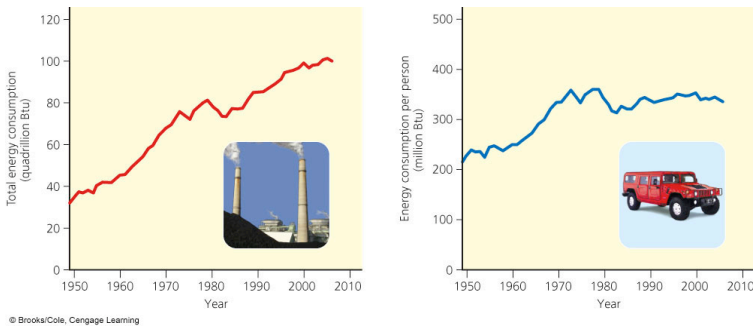


FIG. 15-3

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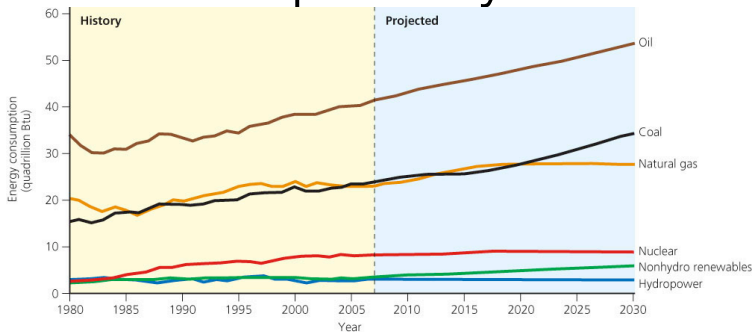
Energy Consumption (U.S.)



PG. S60

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U.S. Energy Consumption by Fuel



* Which energy source grew the most? How much?

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Net Energy

- * It takes energy to make energy
- * Net energy - usable amount of high-quality energy available from a given quantity of an energy resource
 - * Net energy = (Total energy) - (cost to find, extract, process, and transmit to consumers)
 - * Ex. It takes 8 energy units to produce 10 energy units of coal. Thus, the net energy is 2 units.
 - * Net energy ratio - $10/8$ or 1.25 (higher the ratio, greater the net energy; ratio less than 1, energy loss)

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Oil

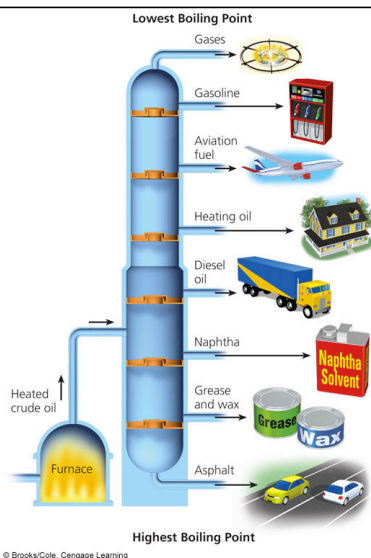
- * Petroleum - liquid and gas combustible hydrocarbons (also contain small amounts of sulfur, oxygen and nitrogen). Formed by the decaying remains of organisms that lived 100-500 million years ago.
 - * Crude Oil - liquid hydrocarbons
 - * Natural Gas - gas hydrocarbons
- * After extraction (from land or seafloor), crude oil is transported to a refinery and distilled into components
- * Petrochemicals - products of oil distillation (organic chemicals, cleaning fluids, pesticides, plastics, medicines...) (Ex. producing a computer requires 10 times its weight in fossil fuels)

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Refining Crude Oil

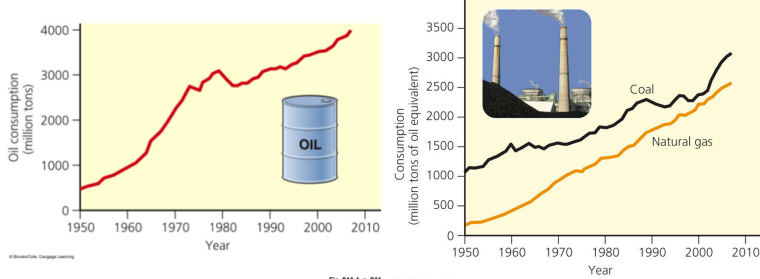


FIG. 15-4



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World Energy Consumption by Fuel



WORLD'S LARGEST OIL USERS

PG. S61

UNITED STATES - 24% OF ALL OIL PRODUCED
CHINA - 8%
JAPAN 7%

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OPEC

- * OPEC - Organization of Petroleum Exporting Countries
 - * Members - Algeria, Angola, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, UAE, and Venezuela
 - * 60% of the world's crude oil reserves
 - * Produce 43% of the world's oil
 - * OPEC revenue 2007 average = \$1.3 million per minute

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Oil Reserves

- * Largest = Saudi Arabia (25%)
- * 2nd Largest = Canada (15%) mostly in the form of oil sands
- * 75% of world oil reserves are controlled by government-owned companies
- * Oil production has exceeded oil discovery since 1984

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U.S. Oil Use

- * 89% of energy from fossil (39% from oil)
- * 25% of oil and 20% of natural gas come from offshore drilling
- * 17% from Alaska's north slope
- * Produces 9% of the world's oil, consumes 24%, has 2.4% of world's oil reserves

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ANWR

- * Arctic National Wildlife Refuge
 - * Contains one-fifth of all land in U.S. National Wildlife Refuge System
 - * Only stretch of Alaska's arctic coastline that is not open to oil development
 - * Very fragile, tundra ecosystem
- * Since 1980, oil companies have been lobbying to carry out exploratory drilling because they think there is oil there

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ANWR

- * Advocates for drilling:
 - * Decrease dependency on foreign oil
 - * Puts money into the economy (Alaskan citizens get dividend checks)
- * Opponents:
 - * Will only increase oil company profits without reducing dependence
 - * Geologists say there is only a moderate chance of finding enough oil to support the U.S. for 7-24 months
 - * Will damage ecosystem (ex. Prudhoe Bay)

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Oil Sand

- * Mix of clay, sand, water, and bitumen(thick, heavy oil with high sulfur content)
- * Oil sands in Canada and Venezuela combined contain more oil than Saudi Arabia
- * 20% is close enough to surface to be strip-mined, but removal damages the environment
 - * Boreal forest needs to be clear-cut, wetlands drained, rivers and streams diverted, overburden removed (4 tons removed to produce 1 ton of bitumen)
 - * Wastes from overburden and processing are very toxic
 - * Creates three times as much CO₂ as conventional oil in processing
 - * Uses four to five barrels of water for each barrel of bitumen produced
 - * Estimated takes 0.7 barrels of oil energy to produce one barrel of bitumen

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Oil Shale

- * "Oily rocks"
- * Oil extracted by heating
- * Huge deposit in Colorado, Wyoming, and Utah (four times Saudi Arabia's reserves) (110 years of U.S. oil use)
- * Most of it is low grade (would take huge amounts of energy to get it out)
- * Takes huge amounts of water (already not much water in the West)
- * Takes 0.8 metric tons of rock for one barrel of oil



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Natural Gas

- * Mixture of gasses (50-90% methane)
- * Lies above most oil reserves
- * Liquefied Petroleum Gas (LPG) - propane and butane removed from natural gas
- * Russia has 27% of the world's natural gas [Iran (15%) and Qatar (14%)]
- * U.S. only has 3% of the world's natural gas supply but uses 27%

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Natural Gas Use

- * Efficiency - Coal (24-35%), Natural Gas (50-60%)
- * Cheaper than coal to maintain
- * Produces much less CO₂ than coal

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Coal

- * Solid fossil fuel made from remains of plants that were buried 300-400 million years ago and subjected to intense heat and pressure
- * 2,100 power plants (40% of world's power)
- * Process is a complex (and inefficient) way to boil water
- * Coal is also used in industry. Ex. bituminous coal is converted to coke which is burned in a blast furnace to make iron

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Coal Formation

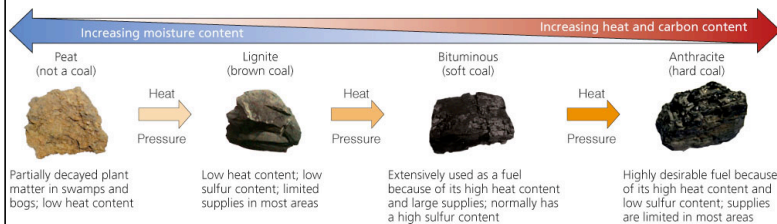


FIG. 15-11

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Top Coal Burners

- * China (expected to burn twice as much as the next country by 2025)
- * United States (49% of electricity produced this way)
- * India (from 2006 to 2031 use is expected to quadruple)

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Coal as Fuel

- * World's most abundant fossil fuel (USGS estimates coal supplies could last from 225-1000 years)
- * United States has 25% of the world's coal [Russia (15%), India (13%), China (13%), Australia (8%)]
- * U.S. coal supplies could last from 100 more years
- * Pollutes the air severely
 - * Mostly made of carbon so releases CO₂ into the air as burned (25% of world CO₂ emissions; 40% of U.S. emissions)
 - * Contains sulfur so releases SO₂ (causes acid rain)
- * Environmentally damaging mining techniques

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China and Coal

- * Used to produce 70% of China's energy (80% of its electricity)
- * Adds equivalent of three large coal power plants a week
- * As of a 2007 study, only has about 37 years of coal left (only 10-15 if consumption rates keep increasing)
- * World's leading producer of sulfur dioxide
 - * Causes respiratory and cardiovascular diseases
 - * Acid rain

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China and Coal (con.)

- * Pollution (ex. SO₂ and CO₂) impacts: China, Korea, Japan, and U.S.
- * Mercury has been found in fish caught in Oregon
- * CO₂ emission (largest emitter since 2008)
- * Has 20 of 30 most polluted cities
- * Estimated that pollution causes 650,000 - 700,000 premature deaths in China every year

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Synthetic Natural Gas

- * Solid coal can be converted to SNG by coal gasification and liquid fuel (methanol) by coal liquefaction
- * Requires 50% more coal (pollutes 50% more)



FIG. 15-16

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Nuclear Energy

- * Nuclear Power Plant
 - * Complex system used to boil water that produces steam to spin turbines to generate electricity
 - * Complexity because it is a nuclear fission reaction that provides the heat
 - * Produced in a reactor ex. Light water reactor (85% of nuclear energy)
 - * Inefficient
 - * loses about 83% of available energy as heat (75% in the plant, 8-9% in lost in mining and processing)

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Nuclear Energy Fuel

- * Uranium ore from the earth's crust (U-235)
- * Ore must be enriched to increase concentration (from normal 0.7% to 3%)
- * Enriched uranium is processed into pellets of uranium dioxide. Each eraser sized pellet contains the energy equivalent of one ton of coal
- * Pellets are packed into pipes called fuel rods, which are placed into the reactor

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Nuclear Energy Controls

- * Control rods are moved in and out of the reactor as needed to absorb neutrons (thus controlling the reaction rate)
- * Coolant (usually water) circulates through the reactor core to remove heat. This keeps the fuel rods from melting and releasing large amounts of radioactivity.
- * Containment shell - thick, steel-reinforced, concrete walls surrounds the reactor core to keep radioactive materials from escaping into the environment if an explosion or meltdown occurs. It also protects the core from outside forces

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Refueling/Storage

- * Reactors are shut down and refueled about once a year
- * Hot, radioactive, spent fuel rod assemblies are removed and stored in water filled pools or in dry casks
- * Goal is to take this spent material and store it in a secure underground storage facility for 10,000 to 240,000 years (depending on the radioactive isotopes present)
 - * Even 60 years after use of nuclear energy started, no country has created such a facility

FIG. 15-18



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Nuclear Fuel Cycle

**ABOUT 92%
OF THE
AVAILABLE
ENERGY IN
NUCLEAR FUEL
IS WASTED
IN PRODUCTION**

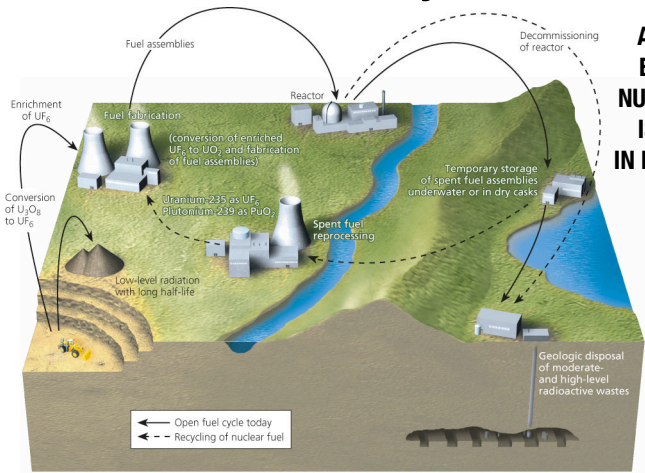


FIG. 15-19

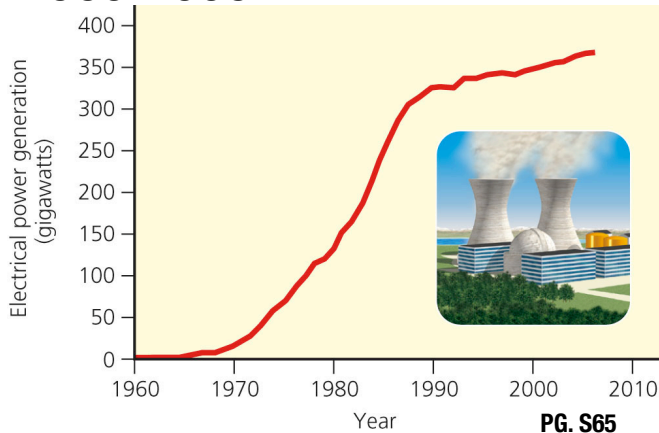
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Energy of the Future?

- * Nuclear energy was expected to produce most of the world's energy
 - * Today it is only about 16% of the world's electricity
 - * Exceptions: France (77%), Japan and South Korea (39%)
- * Currently the slowest-growing energy source and is expected to drop as old plants are decommissioned faster than new ones are built
- * Government provides huge subsidies, tax breaks, loans, and insurance (totaling about \$9 billion a year), which keeps the industry alive
- * In 2007, Congress offered an additional 10.1 billion to build new reactors by 2015 or 2020

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Worldwide Generating Capacity 1960-2006



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Causes for Failure

- * Multibillion dollar construction costs
- * High operating costs
- * Malfunctions
- * Low net energy yield of the nuclear fuel cycle
- * Public safety concerns
- * Governmental regulations
- * Even with subsidies, it costs more to produce than coal, natural gas, or wind power
- * Water availability

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Nuclear Accidents

- * Three Mile Island, Harrisburg, PA (1979)
- * Lost coolant water because of mechanical failures
 - * Water level dipped below the top of the core causing a partial core meltdown, but the containment building kept most of the radioactivity from being released
 - * 50,000 people were forced to evacuate and 50,000 more voluntarily evacuated
 - * So far studies have shown no higher cancer rates
 - * Cleanup and lawsuits have cost \$1.2 billion (reactor cost \$700 million to build)

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Nuclear Accidents

- * Chernobyl, Ukraine (then Soviet Union) (1986)
 - * Explosion blew the roof off the reactor building
 - * Reactor had a partial meltdown
 - * Graphite moderator caught fire and burned for 10 days
 - * Released 100 times the radiation generated by the atomic bombs dropped on Hiroshima and Nagasaki
 - * Radioactive cloud produced eventually encircled the entire planet
 - * Still areas of Ukraine and Northern Europe that are dangerously contaminated

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Nuclear Accidents

- * Chernobyl (con.)
 - * By 2006 at least 56 people have died from the radiation (WHO projects this number will reach 9,000)
 - * Russian Academy of Medical Sciences estimates the number will be closer to 212,000
 - * 350,000 people had to abandon their homes because of contamination and fallout
 - * Still some areas where the water is unsafe to drink and foods produced are unsafe to eat
 - * Cancer rates are significantly higher

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Nuclear Wastes

- * Every part of the nuclear power fuel cycle produces radioactive waste
- * High-level radioactive wastes - spent fuel rods and assemblies, nuclear weapon production materials must be stored for 10,000-240,000 years
 - * Ex. plutonium-239 must be stored for 240,000 years before decaying to a safe level
 - * 10 years after removal from a reactor a fuel assembly would emit enough radiation to kill a person 1 meter away in three minutes

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Yucca Mountain

- * 100 miles northwest of Las Vegas
- * 1985 DOE announced plans to build an underground repository for high-level nuclear waste on federal land
- * Cost to build would be \$58-100 billion
- * Projected opening date is 2017 (probably 2020 because of problems with the site, legal battles, and insufficient funding)
- * Plan: Store material in zircon, seal it in steel canisters, store in underground tunnels that should be unaffected by earthquakes and rising water table for at least 10,000 years

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Yucca Mountain

* Problems:

- * Located in the third most seismically active part of U.S., zircon may degrade faster than once thought, rock fractures may allow water to leak (any water that percolates through could contaminate for thousands of years)
- * Transport of nuclear materials to the site
- * Site would be filled in 38 years
- * The government will have to pay nuclear power plants for every year they do not provide a storage facility (This will cost \$7 billion by 2017. This is in addition to the \$58 billion already spent on the facility.)

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Decommissioning

- * When plants are old, they need to be retired.
- * Option 1: They can be dismantled and stored in a high-level nuclear waste facility (no such facility currently exists)
- * Option 2: Physical barrier built around the facility and full time security for 30-100 years until it can be dismantled (safer but still dangerous level)
- * Option 3: Enclose plant in a tomb that must be monitored for several thousand years
- * Decommissioning costs 2-10 times more than building the plant

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