Introduction to Environmental Geology, 5e

Chapter 16

Energy Resources

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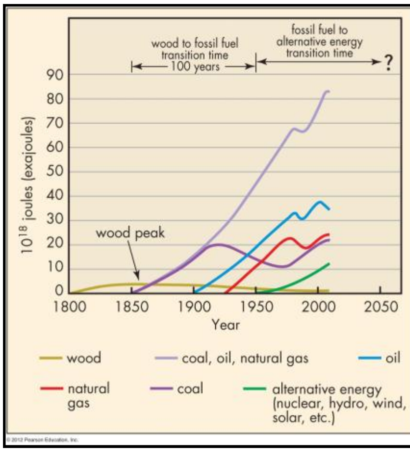
Chapter 16: Overview

- Understand peak oil and the impact to social and economic environment
- Know U.S. energy consumption
- Know types of fuel or energy: fossil, nuclear, and geothermal
- Know types of alternative, renewable energy
- Know issues regarding energy policy and the concept of sustainable energy development

Case History: Energy Transition 1800–Present

- The amount of fossil fuels in the Earth is finite
- Energy transformation in the United States from wood in the mid-1800s to fossil fuels in the mid-1900s
- Shortages of wood in 1812 in Philadelphia led to experiments of burning coal
  - The first oil well was completed in 1858
- Peak oil production (when about one-half of Earth's recoverable oil will have been produced and used) is likely to occur sometime between 2020 and 2050



Case History: Energy Transition 1800–Present

Figure 16.1

Energy Shocks Past and Present

- 2000 years ago, affluent Roman citizens had central heating that consumed vast amounts of wood—perhaps as much as 125 kg (275 lb) every hour
  - Romans had to import wood from up to 1600 km (995 mi)
  - They turned to solar energy as an alternative
- During the summer of 2008, U.S. citizens were shocked by the rapid price increase of gasoline
- "California energy crisis" with its rolling blackouts, in 2001 occurred ahead of the gasoline price increase
- Energy crisis: Not new, occurred in historic times

Peak Oil

- Benefits of oil: Undeniable
- Problems associated with oil: Unquestionable
- Peak oil: The time when half of Earth's oil extracted and used
- Oil: Nonrenewable and being consumed too fast
- Consequences: Growing demands, water pollution, air pollution, global warming; global, economic, and political instability

Peak Oil

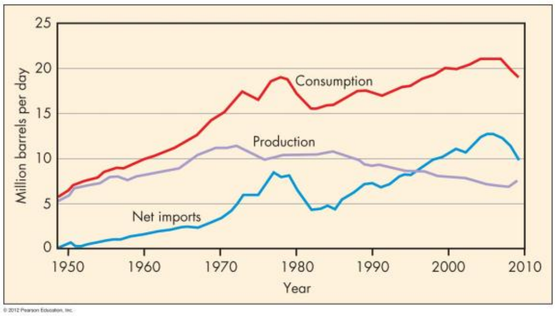
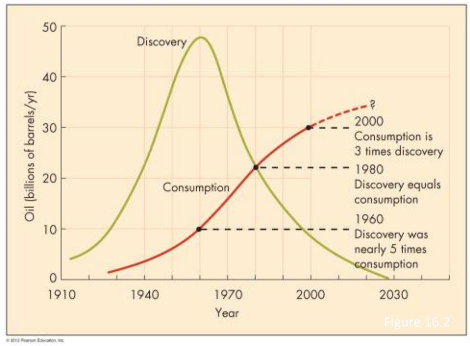


Figure 16.2

Peak Oil

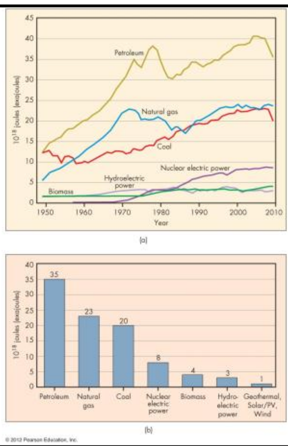


Energy Resources Introduction

- Fundamental lifeblood for industrialization
- Disproportionate amount of energy resources demanded and consumed in developed countries
- Growing challenges: How to break energy dependency, yet sustain development and high standard of living
- Energy shocks: constant worries from past to present and to the future over the price, dependency, power failures

Energy Supply and Demand

- Fossil fuels: 90% of U.S. energy consumption (10% from hydropower and nuclear power)
- Fossil fuels nonrenewable resources
- Fossil fuel peak discoveries in 1960s
- U.S. energy consumption increasing over time. Rate of increase variable: peak increase during 1950–74, then rate of increase rose again in late 1990s



Energy Supply and Demand

Figure 16.5

Energy and Energy Units

- Types of energy: Light, electrical, chemical, thermal, mechanical, and nuclear
  - Energy unit: Energy capacity to do work
    - Joules (J): 1 Newton force applied over 1 m
    - 1 gigajoule (GJ) = 10^9 J,
    - 1 exajoule (EJ) = 10^{18} J ,
    - 1 quad (10^{15} BTU) = 1.055 EJ
  - Power: Rate of energy transferred or used
    - Watt (W): 1 joule per second (1 J/sec)
    - MW (megawatt): 1000 W

Fossil Fuels

- Origin of fossil fuels is intimately related to the geologic cycle – stored in rock materials
- Fossil fuels are solar energy stored in the form of organic material transformed after burial
- Types: coal, petroleum, natural gas
- Environmental impact from exploration, production, processing, and distribution of fossil fuels should be weighed against benefits
  - Athabasca oil sands, Canada

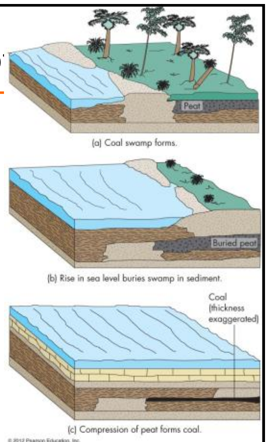
Coal Resources

- America has more coal than any other fossil-fuel resource
- 20% of total U.S. energy consumption
- The United States has more coal reserves than any other single country in the world
- 1/4 of all the known coal in the world is in the United States
- Large coal deposits can be found in 38 of the 50 states

Geology of Coal

- Coal: transformed plant matter from ancient swampland
  - Present environment: estuary, lagoon, low-lying coastal plains, delta
- Coal forming process:
  - massive dead plants →
  - buried in anaerobic (O-deficient) environment →
  - peat →
  - prolonged burial and transformation to increase carbon content → coal

Geology o

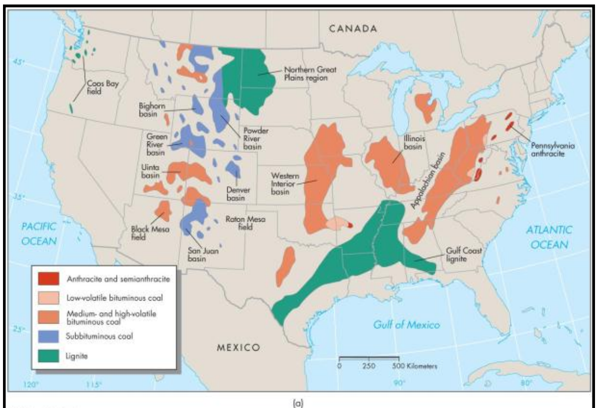


- Carbon content and caloric value- 4 types:
  - Lignite, subbituminous, bituminous, anthracite
- With the increase in rank-
  - Higher carbon content
  - Higher caloric values
  - Less volatile gas
  - Less moisture content
- Based on sulfur content: Low (<1%), medium (1–3%), and high (>3%)

*(see figure 16.7)

Coal Distribution and Consumption

- World reserves about 1000 BMT (billion metric tons)
- Evenly distributed throughout the world
- U.S. reserves: 25% of the world reserves
- Annual global consumption 5 BMT
- China, U.S., and Russia account for 50% of total CO_2 released from combustion of coal



(a)

Figure 16.8a

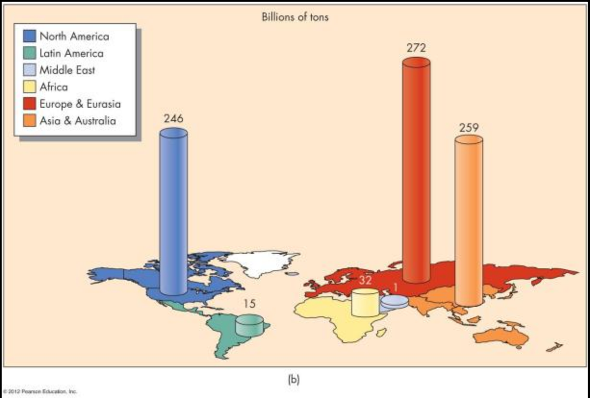


Figure 16.8b

Environmental Impact of Coal

- Land disturbance from open-pit and strip mining
- Acid mine drainage and sludge ponds
- Subsidence over subsurface mines
- Surface water and groundwater pollution
- Air pollution from processing plants
- Disposal of coal ash (5–20% of original coal)
- Area ecosystem degradation due to mining practices and inadequate land reclamation afterward

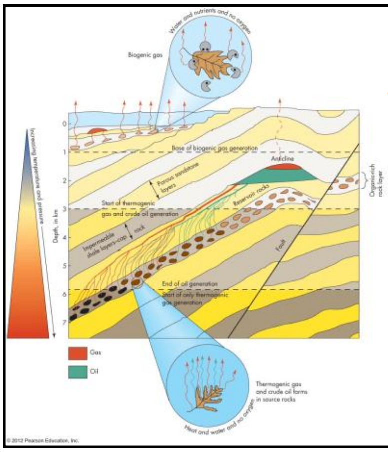
Hydrocarbons: Oil and Gas

- Oil and gas (O&G): Hydrocarbons due to chemical composition of C, H, and O
- Natural gas: Mostly methane (CH_4)
- O&G: Formed from transformation of organic matter
- Heavily mined through production wells
- Other forms: oil shale and tar sands

Geology of Oil and Gas

Formation of oil and gas:

- ⦿ Rapid burial →
- ⦿ Anaerobic environment →
- ⦿ Biogenic or thermogenic transformation →
- ⦿ Oil window (approximately 3–6 km depth)
- ⦿ Formation of oil and gas →
- ⦿ O&G trapped over geologic time in certain structures



Geology of Oil and Gas

Figure 16.13

Geology of Oil and Gas

Geologic conditions:

- Source rock: fine-grained organic-rich sedimentary rock
  - O & G migrate up
- Reservoir rock: porous and permeable rock
- Cap rock: impermeable rock as barrier to trap O & G

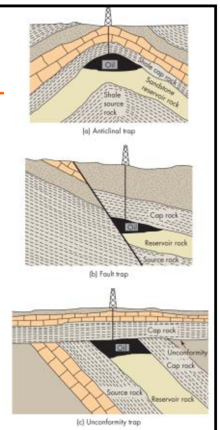
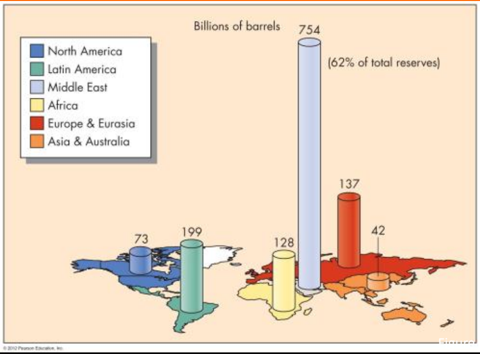


Figure 16.14

Distribution of Oil and Gas

- Almost exclusively from sedimentary rocks younger than 500 MY
- ~85% of the total production in less than 5% of production fields
- ~65% of the total production from about 1% of the giant fields
- Most giant O&G fields near recently active plate boundaries in the last 70 MY

Distribution of Oil and Gas



Natural Gas

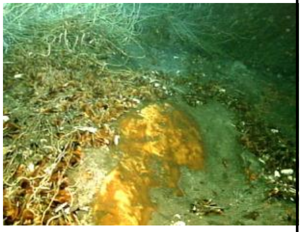
- Larger global reserves, lasting 100 years at current rate of consumption
- Most reserves in Russia and Middle East
- Cleaner fuel than oil and coal
- Coal-bed methane: stored in surfaces of organic matter in coal beds
- Methane hydrate: ice-like material made of molecules of CH_4 'caged' by frozen H_2O
  - may be future alternative energy source

Coal-Bed Methane

- Coal containing a large amount of methane
- The methane reserves in WY sufficient for U.S. natural gas use for 5 years
- Most coal-bed methane shallow and more economical to drill
- Concerns over extraction processing and transportation
- Environmental problems associated with production: disposal of salty water, a flammable process, erosion

Methane Hydrate

- Potential good source of natural gas
- Exists at depths of 1000 m (3300 ft) beneath the sea and under perma-frost land areas
- Complicated processes for exploration and production due to highly pressurized conditions
- More studies need to be done for exploiting it



Impact of Exploration and Production

- Land disturbance: Access, drilling
- Environmental impact: Production, transportation, and emissions from refineries
- By-products: Salty brine water, evaporation, and waste disposal problems
- Oil field development in sensitive areas
- Blow-outs or fires at oil and gas wells
- Acid rain from air pollutants
- Combustion releases greenhouse gases

Shales and Tar Sands

- Marcellus Shale in NE USA holds ~500 trillion cubic feet of natural gas
- Best-known oil shale in the United States found in Green River Formation
  - Approximate 44,000 km^2 in CO, UT, and WY
- Tar sands contain tar oil and asphalt and other semi-solid or solid petroleum products
- Tar sands not necessarily sandstone, can be shale, limestone, or unconsolidated sediments
- Largest tar sands: the Athabasca Tar Sands in Alberta, Canada, ~ 78,000 km^2 (2 trillion BOL)

Future of Oil

- Approaching the peak oil time
- About 3 trillion barrels of oil may be recovered
- World current consumption rate: 30 billion barrels/yr
- Estimated peak production 2020–2050
- Significant oil production in the U.S. may not extend beyond 2090
- Planning, education, research & development on alternative energy sources

Fossil Fuels and Acid Rain

- Regional to global problem related to fossil fuel burning and generation of acid rain
  - Reaction of sulfur and nitrogen oxides with water
- Effects of acid rain:
  - Effects depend upon bedrock, soils, and water characteristics
  - Damage to vegetation, lake ecosystems, human structures

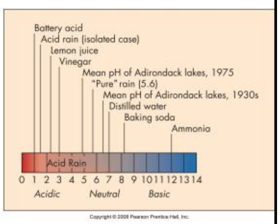


Figure 16.20

Fossil Fuel and Acid Rain

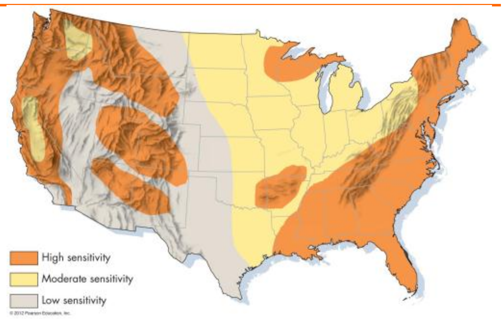


Figure 16.22

Nuclear Energy

- 440 nuclear reactors provide 16% global electricity needs
- Mostly from fission of U-235, 0.7% concentration naturally, enriched to 3% before used ir reactor
- Fission of 1 kg of uranium equivalent to the burning of 1 metric tons of coal

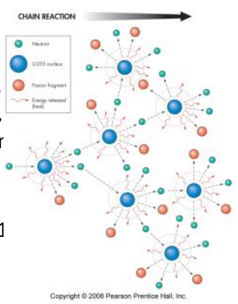


Figure 15.20

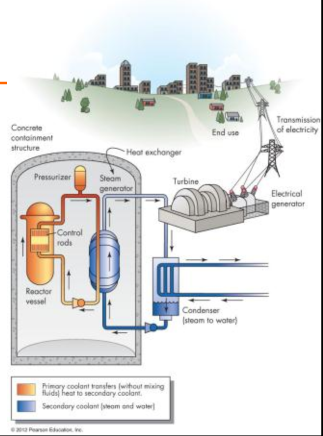
Geology and Distribution of U

- Average natural concentration 2 ppm
- Must have a concentration factor of 400 to 2500 times to be mined at a profit
- Three types of common deposits: Sandstone impregnated with U, veins of U-bearing materials, and old placer deposits
- U-235: only naturally occurring fissile material
- U-238 not fissionable, but neutron bombardment converts it to fissionable Plutonium-239

Reactors

- Most of the reactors: burner reactors
- Four main components of burner reactors: Core, control rods, coolant, and reactor vessel
- Trend of smaller reactors with less complex design and gravity-influenced cooling system (passively safe)
- Pressurized water reactors gaining popularity in Europe with improved safety measures.

Pressurized Water Reactor

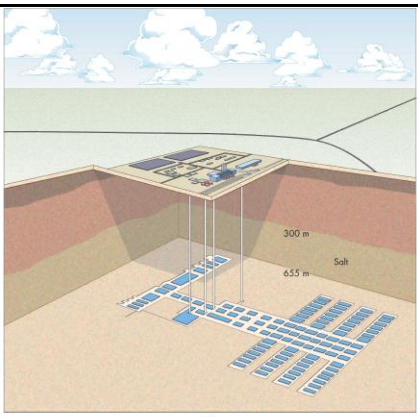


Risks with Fission Reactors

- Various amounts of radiation to environment, from mining, processing, transportation, and before transportation
- Potential nuclear reactor accidents, Three Mile Island & Chernobyl
- Nuclear weapons, terrorist activity, and possibly war
- Disposal of nuclear wastes
- Critical placement – Japanese tsunami

Radioactive Waste Management

- Safe disposal of nuclear waste a significant environmental issue
- Low-level radioactive waste
- Transuranic waste
- High-level radioactive wastes
  - The scope of the high-level disposal problem
  - Disposal of high-level waste in the geologic environment
  - Long-term safety



(b)

Figure 16.26

Geothermal Energy

- Extracting energy associated with heat and pressure from natural hot water and steam
- Generating electricity at many sites in the world or heating energy for buildings, etc.
- Vast amount of geothermal energy:
  - If only 1% could be captured from upper 10 km it would equal about 500 times oil and gas resources

Geology of Geothermal Energy

- Concentrations largely associated with tectonic processes
- Especially prevalent at divergent and convergent boundaries
- Geothermal gradient – avg 30-45° per 1km
- Two common systems:
  - Hydrothermal convection systems
  - Groundwater systems

Geothermal Energy Risks

- Overall, enviro-friendly with a great potential for energy
- Expensive production
- Thermal pollution from hot wastewaters
- Land subsidence
- At present, relatively local and regional operations

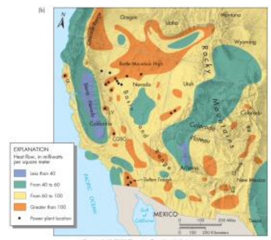
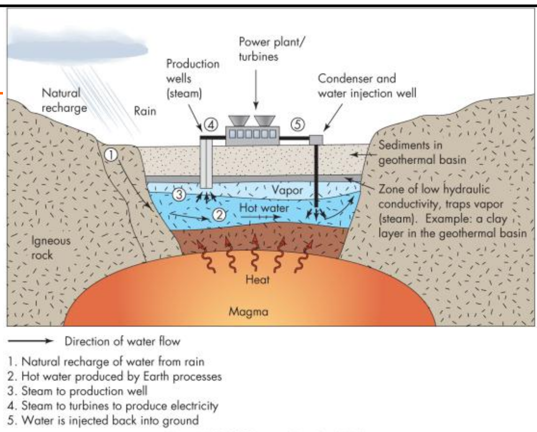


Figure 16.27



Renewable Energy Sources

- Solar energy: Growing rapidly
- Hydrogen: fuel cells
- Hydropower: hydroelectric, tidal power
- Biofuels: wood, charcoal, burning of municipal waste, currently only 1% of U.S. municipal wastes recovered for energy and 10% can be extracted, 30–50% of wastes used for energy in western Europe
- Wind power: Less than 1% global electricity demand, but 10% potential in a few decades

Conservation, Efficiency, and Cogeneration

- Highly variable future supply of and demand for energy
- Need to minimize energy demand and adjust energy uses
- Increase energy efficiency through improved or new technologies
- Cogeneration: Capture and use some of the waste heat, rather than direct release to the atmosphere

Energy Policy for the Future

Hard path: Continuing "business as usual":

- Environmental problems due to use of local resources, and industrialization and technology bringing solutions to the problems
- Dominate energy planning in the U.S.

Soft path: Emphasis on energy alternatives:

- Renewable, flexible, decentralized, and environmentally more benign than those of the hard path

Sustainable Energy Policy

- Energy planning for the future is complicated
- Necessary to find useful long-term sources of energy without causing atmospheric pollution
- Transition from the hard path to the soft path involving continued use of fossil fuel
- Energy path: Satisfying needs of modern society without endangering the planet

Critical Thinking Topics

- Sustainable energy development means an energy policy and energy sources without harming the environment. Do you think this is possible?
- Is it possible that new technology will be able to make fossil-fuel burning a clean process? Explain
- Speculate the possibility of power plants in space
- List specific actions that an individual citizen can take to conserve energy and reduce environmental impact