1 **Introduction to**
Environmental Geology, 5e
Chapter 16
Energy Resources

2 **Energy Resources: summary in haiku form**
Petroleum, gas,
coal, uranium, et al.
There's only so much...

3 **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 failure

4 **Case History: Energy Transition 1800–**
- 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, the peak in use of wood was approximately 1870
- It took something like 100 years for the full transition
- Shortages of wood in 1812 in Philadelphia led to experiments of burning coal, and 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
- Another transition is in the making, from oil to alternative energy sources

5 **Case History: Energy Transition 1800–**
Figure 16.1

6 **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
- To combat the shortages, the Romans had to import wood from distances as far away as 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

7 **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

8 **Peak Oil**

Figure 16.2

9 **Energy Supply and Demand**

- Fossil fuels: 90 percent of U.S. energy consumption (10 percent from hydropower and nuclear power)
-
- Fossil fuels nonrenewable resources
-
- Fossil fuel peak discoveries in 1960s
-
- U.S. energy consumption increasing over time. The rate of increase variable: Peak increase during 1950–1974, since then it has slowed down

10 **Energy Supply and Demand**

Figure 16.5

11 **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 (megawatts): 1000 W

12 **Fossil Fuels**

- Transformed from the solar energy originally stored in organic matter
-
- Organic matter buried and preserved as fossil fuels
-
- Geologically: Stored in subsurface rock materials
-
- Types: Coal, petroleum, natural gas
-
- Environmental impact: Significant impact from exploration, production, processing, and distribution

13 **Coal Resources**

- America has more coal than any other fossil-fuel resource.
-
- 20 percent of the total U.S. energy consumption
-
- The United States has more coal reserves than any other single country in the world
-
- One-quarter 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

14 **Geology of Coal**

- Coal: Transformed plant matter in ancient swamps
  - Estuaries, lagoons, low-lying coastal plains or delta environment
  -
- Coal forming process

  - Massive dead plants→ buried in an anaerobic (O-deficient) environment→ peat→ prolonged bury and transformation to increase carbon content→ coal

15 **Geology of Coal**

Figure 16.6

16 **Classification of Coal**

- Based on carbon content and calorific value on combustion
  - Lignite, subbituminous, bituminous, anthracite
  -
- With the increase in rank, generally higher carbon content, higher calorific values, less volatile gas, and less moisture content
-
- Based on sulfur content: low (< 1 percent), medium (1 to 3 percent), and high (> 3 percent)

17 **Coal Distribution and Consumption**

- World reserves about 1000 BMT (billion metric tons)
-
- Relatively evenly distributed throughout the world
-
- U.S. reserves: 25 percent of the world reserves
-
- Annual global consumption 5 BMT
-
- China, United States, and Russian account for 50 percent of total CO_2 released

18 **Distribution of Coal (2)**

Figure 16.7

19 **Impact of Coal Mining**

- Land disturbances from open-pit and strip mining
-
- Mining area acid drainage
-
- Subsidence over subsurface mines
-
- Surface water and groundwater pollution
-
- Air pollution from thermoelectric power plant
-
- Area ecosystem degradation due to mining practice and afterward inadequate land reclamation

20 **Future Use and Environmental Impacts of Coal**

- More and more land will be strip mined
- Disposal of coal ash (5–20 percent of original coal)
- Mining, processing, disposal of mining waste, shipping, burning, and disposing of ash: All potentially adverse to environment
- Fly ash, from burning finely ground coal in a power plant, hazardous
- The use of coal releasing huge amounts of carbon dioxide (CO_2) into the atmosphere
- China, the United States, and Russia: The major carbon dioxide contributors

21 **Hydrocarbon: 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 matters
- Heavily mined through production wells
- Other forms: Oil shale and tar sands

22 **Geology of Oil and Gas (1)**

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

23 **Geology of Oil and Gas (2)**

Figure 16.13

24 **Geology of Oil & Gas (3)**

Geologic conditions for O&G fields

- Source rock: Fine-grained organic-rich sedimentary rocks, then O&G migrating upward to the reservoir rocks
- Reservoir rock: Porous and permeable rocks
- Cap rock: Impermeable rock as a barrier to trap O&G in place, forming oil fields

25 **Oil & Gas Production**

Production: Commonly through wells

- Types of production
  - Primary recovery: Pump no more than 25 percent of the petroleum in the field under natural reservoir pressure
  - Enhanced recovery: Manipulate reservoir pressure by injecting gases and liquids, 50 to 60 percent of the petroleum

26 **Distribution of Oil and Gas (1)**

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

27 **Distribution of Oil and Gas (2)**

Figure 16.15

28 **Natural Gas**

- Larger global reserve, lasting 100 years at current rate of consumption
- The most reserves in Russia and Middle East
- Cleaner fuel than oil and coal
- Methane hydrate: May be future alternative energy source

29 **Coal-Bed Methane**
- Coal containing a large amount of methane
-
- The methane reserves in WY sufficient for the 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, such as disposal of salty water, a flammable process, erosion

30 **Methane Hydrate**
- Potential good source of natural gas
-
- Exist at depths of 1,000 m (3,300 ft) beneath the sea and under permafrost land areas
-
-
- White, ice-like compound of methane gas capsulated by frozen water
-
- Complicated processes for exploration and production due to highly pressurized conditions
-
- More studies need to be done for exploiting it

31 **Impact of Exploration & Production**
- Land disturbance: Access, drilling
-
- Environmental impact: Production, transportation, and emissions from refinery
-
- By-products: Salty brine water, evaporation, and waste disposal problems
-
- Oil field development in sensitive areas
-
- Blow-outs or fire at oil and gas wells
-
- Acid rain

32 **Oil Shales and Tar Sands**
- Best-known oil shale in the United States found in Green River Formation
- Approximate 44,000 km^2 in CO, UT, and WY
- ~ 2 trillion (MMBOL) in United States, two-thirds of the world's oil shale
- 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)

33 **Future of Oil**
- Approaching the peak oil time
- About 3 trillion barrels of oil be recovered
- World current consumption rate: 30 billion barrels/yr
- Estimated peak production 2020 to 2050
- Significant oil production in the United States not extend beyond 2090
- Planning, education, research and development on alternative energy sources: Gasification and liquefaction of coal, other renewable sources

34 **Fossil Fuel and Acid Rain**
- Acid rain: A regional to global environmental problem

- Both wet and dry acid deposition:
- Sulfur dioxide (SO_2) and nitrogen oxides (NO_x)
- In the United Sates, about 17 million tons of NO_x and 13 million tons of SO_2 into the atmosphere
- Geology, climate patterns, type of vegetation, and composition of soil affected

35 **Fossil Fuel and Acid Rain**

Figure 16.22

36 **Nuclear Energy**

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

37 **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

38 **Reactor**

- 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 in design and gravity-influenced cooling system (passively safe)
-
- Gas-cooled reactor, “pebble-bed reactor,” to be available in the next few years, preventing the risk of core meltdown and providing optimal energy production

39 **Risks with Fission Reactors**

- Various amounts of radiation to environment, from mining, processing, transportation, and before transportation
-
- Potential nuclear reactor accidents, TMI and Chernobyl
-
- Nuclear weapons, terrorist activity, and possibly war
-
- Disposal of nuclear wastes

40 **Nuclear Energy from Fusion**

- Combining lighter elements to produce heavier ones, releasing energy
-
- The Sun and other stars: Huge nuclear fusion reactors
-
- Nuclear fusion: Research objective, not a commercial reality yet
-
- Environment: Little radioactive waste, unlimited supply
-
- Technology: Under the development

41 **Geothermal Energy**
- Extracting energy associated with heat and pressure from natural hot water and steam
- Generating electricity at many sites of world or heating energy for buildings, etc.
- Vast amount of geothermal energy resources (500 times of oil and gas resources), only 1 percent could be captured from upper 10 km

42 **Risks with Geothermal Energy**
- Overall, environmentally friendly with a great potential for the future energy
- Expensive production process
- Thermal pollution from hot waste waters
- Land subsidence
- At present, relatively local and regional operations

43 **Renewable Energy Sources**
- Solar energy: Rapid growing
- Hydropower: Hydroelectric, tidal power
- Biofuels: Wood, charcoal, burning of municipal
  waste, currently only 1 percent U.S. municipal wastes recovered for energy and 10 percent can be extracted, 30 to 50 percent of wastes for energy in western Europe
- Wind power: Less than 1 percent global electricity demand, but 10 percent potential in a few decades

44 **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

45 **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 United States
- Soft path: Emphasis on energy alternatives
  - Renewable, flexible, decentralized, and environmentally more benign than those of the hard path

46 **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 to soft path involving continued use of fossil fuel

-
- Energy path: Satisfying modern society needs
  without endangering the planet

47 **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

48 **Chapter 16 figures follow…**

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104 **End of Chapter**