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Fossil Fuels, Their Impacts, and Energy Conservation

Chapter Objectives

This chapter will help students:

- Identify the energy sources that we use
- Describe the nature and origin of coal, and evaluate its extraction and use
- Describe the nature and origin of petroleum, and evaluate its extraction, use, and future depletion
- Describe the nature and origin of natural gas, and evaluate its extraction and use
- Outline and assess environmental impacts of fossil fuel use
- Evaluate the political, social, and economic impacts of fossil fuel use
- Specify strategies for conserving energy and enhancing efficiency

Lecture Outline

- I. Central Case: Oil or Wilderness on Alaska's North Slope?**
 - A. For some U.S. citizens, Alaska's North Slope is the last great expanse of wilderness in their sprawling industrialized country.
 - B. For millions of others, this land represents a source of petroleum, the natural resource that fuels our society and shapes our way of life.
 - C. Ever since oil was found in this area a century ago, these two visions for Alaska's North Slope have competed and now exist side by side across three regions of this vast swath of land.
 1. The westernmost portion was set aside in 1923 by the U.S. government as an emergency reserve for petroleum.
 2. In the central portion are state lands that have experienced widespread development and extraction since 1997.
 3. The Arctic National Wildlife Refuge (ANWR) lies in the eastern region of the North Slope, on federal lands set aside in 1960 and

1980 to protect wildlife and preserve pristine tundra, mountain, and coastal ecosystems.

- D. ANWR has been the focus of debate for decades as advocates of oil drilling have tried to open its lands for development while advocates of wildlife preservation have fought for its protection.
- E. In a compromise in 1980, the U.S. Congress passed legislation that put most of the refuge off-limits to oil drilling but reserved for future decision making a 600,000-hectare area of coastal plain.
- F. Throughout the noisy policy debate over the ANWR, scientists have attempted to inform the dialogue through research.
- G. In 2006, heedless to objections of wildlife biologists, environmentalists, and hunters, the Bush Administration opened for development an ecologically sensitive area in the National Petroleum Reserve-Alaska, (NPR-A) that holds strategic breeding ground for caribou and many migratory waterfowl species.

II. Sources of Energy

- A. We use a variety of energy sources.
 - 1. Earth receives energy from several sources; most comes from the sun.
 - a. We can harvest the sun's radiation directly.
 - b. Sunlight drives the growth of plants, from which we take wood as a fuel source.
 - c. After their death, plants may impart their stored chemical energy to **fossil fuels**, which are highly combustible substances formed from the remains of organisms from past geological ages.
 - d. Solar radiation also helps drive wind patterns and the hydrologic cycle, making possible other forms of energy, such as wind power and hydroelectric power.
 - 2. A great deal of energy also emanates from Earth's core, enabling us to harness geothermal power.
 - 3. A much smaller amount of energy results from the gravitational pull of the moon and sun; we are beginning to harness the ocean tidal power generated by these forces.
 - 4. An immense amount of energy resides within the bonds in atoms.
 - 5. Energy sources such as sunlight, geothermal energy, and tidal energy are considered perpetually renewable because their supplies will not be depleted by our use of them.
 - 6. Some sources, such as timber, are renewable if we do not harvest them at too great a rate.
 - 7. Energy sources such as oil, coal, and natural gas are considered nonrenewable, because at our current rates of consumption we will use up Earth's accessible store of them in a matter of decades to centuries.
- B. It takes energy to make energy.
 - 1. When evaluating the value of an energy source, it is important to subtract costs in energy invested from benefits in energy received.

2. **Net energy** expresses the difference between energy returned and energy invested.
- C. Developed nations consume more energy than developing nations.
- D. Fossil fuels are indeed fuels created from fossils.
 1. The fuels we burn today in our cars and electric power plants were formed from the tissues of organisms that lived 100–500 million years ago.
 2. Most organisms that die fall and decay, undergoing **aerobic** decomposition, breaking down into molecules that are recycled through the ecosystem.
 3. Fossil fuels are produced only when organic material is broken down in an **anaerobic** environment, one that has little or no oxygen.
- E. Fossil fuel reserves are unevenly distributed.

III. Coal

- A. Coal is the world's most abundant fossil fuel. **Coal** is organic matter compressed under very high pressure to form dense, solid carbon structures.
- B. Coal use has a long history.
 1. Coal has been used longer than any other fossil fuel.
 2. The Romans used coal in the second and third centuries, as have people in parts of China for 2,000–3,000 years.
 3. Beginning in the 1880s, people began to put coal to use in generating electricity.
- C. Coal varies in its qualities.
 1. **Peat** is the precursor to coal. It is broken down anaerobically but remains wet, near the surface, and not well compressed.
 2. Scientists classify coal into four types, from the least to most energy rich: lignite, sub-bituminous, bituminous, and anthracite.
 3. In each of these coal types there are various impurities, including sulfur, mercury, arsenic, and other trace metals.
 4. Sulfur content varies depending on whether the coal was formed in freshwater or saltwater sediments.
- D. Coal is mined from the surface and from belowground.
 1. To reach underground deposits we use **subsurface mining**; shafts are dug deep into the ground and networks of tunnels are built to follow coal seams.
 2. When deposits are at or near the surface, **strip mining** is used; huge amounts of earth are removed by heavy machinery to expose the coal, which is dug out directly.

IV. Natural Gas

- A. Natural gas is a much cleaner-burning fuel than coal or oil, produces less pollution, and is the fastest-growing fossil fuel in use today.
- B. Natural gas is formed in two ways.
 1. **Natural gas** consists primarily of methane, and typically includes varying amounts of other volatile hydrocarbons.

2. Thermogenic gas is formed at great depths as geothermal heating separates hydrocarbons from organic materials.
 - Natural gas is also found in association with coal mines and represents a potential fuel source, but often goes to waste.
 - If not captured for use, the **coalbed methane** becomes a waste product and leads to increased global warming when it escapes.
 3. Biogenic gas is created at shallow depths by the anaerobic decomposition of organic matter by bacteria.
- C. Natural gas has only recently been widely used.
1. The Greek essayist Plutarch wrote the earliest known description of natural gas around 100 A.D., describing its “eternal fires.”
 2. During much of the 19th century, its use was localized because the technology did not exist to pipe gas safely over long distances.
 3. During the 1950s and 1960s, thousands of miles of underground pipelines were laid throughout the United States.
 4. Today, natural gas is favored because it burns more cleanly than coal or oil and emits less global warming gas.
 5. By compressing natural gas, it can be cooled and liquefied so that long distance transport is possible. Liquefied natural gas (LNG) presents catastrophic explosion potential and is controversial.
- D. Natural gas extraction becomes more challenging with time.
1. In order to access some natural gas deposits, prospectors need only drill an opening to allow gas to flow to the surface, because pressure drives the gas upward naturally.
 2. Most fields remaining today require that gas be pumped to Earth’s surface.
- E. Offshore drilling produces much of our gas and oil.

V. Oil

- A. Heat and pressure underground form petroleum.
1. The sludgelike liquid we know as **crude oil**, or **petroleum**, tends to form within a window of temperature and pressure conditions often found 1.5–3 km below the surface.
- B. The age of oil began in the mid-19th century.
1. People used solid forms of oil as long ago as 4000 B.C., taking them from deposits that were easily accessible at Earth’s surface.
 2. The modern use of petroleum began in the 1850s.
- C. Petroleum geologists infer the location and size of fossil fuel deposits.
1. Geologists use a number of techniques to map underground rock formations, understand geologic history, and predict where fossil fuel deposits might lie.
 2. Some portion of this amount of oil will be impossible to extract using current technology and may have to wait for future technological advances.
 3. Oil companies will not be willing to extract this entire amount because some oil will be so difficult to extract and transport that it will not be economically feasible.

4. Technology sets a limit on the maximum that can be extracted, whereas economics determines how much will actually be extracted. The amount that is both technologically and economically feasible to extract under current conditions is termed the **proven recoverable reserve**.
- D. We drill to extract oil.
1. Once geologists have identified a likely deposit, an oil company will typically conduct exploratory drilling.
 2. The oil in rocks is typically under pressure from one of several sources.
 3. Once pressure is relieved, oil becomes more difficult to extract and may need to be pumped out.
 4. As much as two-thirds of the total deposit may remain after **primary extraction**, the initial drilling and pumping.
 5. **Secondary extraction**, in which solvents are used or underground rocks are flushed with water or steam, is more expensive than primary extraction.
- E. Petroleum products have many uses.
1. Once crude oil is extracted, it is put through refining processes.
 2. Because crude oil is a complex mix of hydrocarbons, we can create many types of products by separating its different components.
 3. Transportation represents the largest share of the ways in which oil is used.
- F. We may have already depleted half our oil resources.
1. Analysts calculate the **reserves-to-production ratio**, or **R/P ratio**, by dividing the amount of total remaining reserves by the annual rate of production.
 2. At current levels of production, most analysts estimate that world oil supplies will last about 40 more years.
 3. However, when production declines as demand continues to increase, we will experience an oil shortage immediately. Most experts calculate that this crisis will likely occur within the next several years.
 4. U.S. oil production peaked in 1970 and has fallen since then. This peak has come to be known as **Hubbert's peak**, after the geologist who first calculated it.
 5. Hubbert also calculated that global oil production would peak in 1995; others, using newer data, predict that production will peak within the next decade.
 6. Discoveries of new oil fields peaked 30 years ago. Since then, we have consumed more oil than we have been discovering.
 7. China and India are industrializing rapidly and are increasing the demand for oil.

VI. Other Fossil Fuels

- A. Oil sands can be mined and processed.
1. Oil sands or tar sands are deposits of moist sand and clay containing **bitumen**, a thick and heavy form of petroleum.

2. Most of the oil sands are in Alberta, Canada, and Venezuela. Separating the bitumen from the sand and clay requires steam pressure.
- B. Oil shale is abundant in the U.S. West.
1. Oil shale is sedimentary rock filled with **kerogen** (organic matter) that was not buried deeply enough to form oil.
 2. We strip mine to retrieve oil shale. Once mined, it can be directly combusted like coal or baked in the presence of hydrogen and in the absence of air to extract liquid petroleum. This process is called **pyrolysis**.
- C. Methane hydrates show potential.
1. Methane hydrates occur under the seafloor.
 2. These sources are abundant, but the technology for extracting them is largely undeveloped and expensive. The extensive mining that would be required would further the severe environmental impacts, because methane is a potent global warming gas.
- D. These alternative fossil fuels have downsides.
1. Their net energy yields are low and they are expensive to produce.
 2. They have significant environmental impact.
 3. Their collective use would emit as much carbon dioxide, methane, and other air pollutants as other fossil fuels do now.

VII. Environmental Impacts of Fossil Fuel Use

- A. Fossil fuel emissions cause pollution and drive climate change.
1. Carbon dioxide released from the burning of fossil fuels has been inferred to warm our planet and drive changes in global climate.
 2. Fossil fuels release more than carbon dioxide when they burn, and air pollution from the combustion of fossil fuels can have serious consequences for human health and the environment.
- B. Coal mining affects the environment.
1. Surface strip mining can destroy large swaths of habitat and cause extensive soil erosion.
 2. **Acid drainage** occurs when sulfide minerals in newly exposed rock surfaces react with oxygen and rainwater, which can leach metals from the rocks and drain into waterways. This leachate is toxic to organisms in high concentrations.
 3. Coal mining continues to remain inexpensive because of government subsidies.
- C. Oil and gas extraction can alter the environment.
1. Drilling activities themselves have fairly minimal impact, but much more than drilling is involved in the development of an oil or gas field.
 2. Road networks must be constructed, which fragments habitats; many sites may be explored during prospecting.
 3. The extensive infrastructure necessary to support a full-scale drilling operation includes housing for workers, access roads, pipelines, and waste piles.

4. Many onshore North American oil and natural gas reserves are located in arctic or semi-arid areas. These ecosystems are sensitive to minor changes.
- D. Many scientists anticipate negative environmental impacts of drilling in ANWR.
1. Scientists have examined the effects of development on arctic vegetation, air quality, water quality, and wildlife.

VIII. Political, Social, and Economic Impacts

- A. Nations can become dependent on foreign oil.
1. Economies tied to the use of fossil fuels are vulnerable if oil supplies become suddenly unavailable or extremely costly.
 2. In the United States, concern over reliance on foreign oil sources has repeatedly driven the proposal to open the ANWR to drilling.
 3. To counter foreign oil dependence, the United States has diversified its sources of oil, and now receives much of its oil from non–Middle Eastern nations.
- B. Oil supply and prices affect the economies of nations.
1. We have experienced “oil shocks” such as the “energy crisis” of 1973–1974, when the predominantly Arab nations of the Organization of Petroleum Exporting Countries (OPEC) resolved to stop selling oil to the United States.
 2. In response to the embargo, the U.S. government enacted a series of policies designed to reduce reliance on foreign oil.
- C. Residents may or may not benefit from their fossil fuel reserves.
1. The extraction of fossil fuels can be extremely lucrative; many of the world’s wealthiest corporations deal in fossil fuel energy or in related industries.
 2. Alaska’s distribution of oil revenue among its citizenry is a rare example of local residents seeing the benefits of oil production.
 3. In Nigeria, oil was discovered in 1958 in the territory of the Ogoni, one of Nigeria’s native peoples, and the Shell Oil Company moved in to develop oil fields. Although Shell extracted \$30 billion worth of oil, the Ogoni still live in poverty, with no running water or electricity.
- D. How will we convert to renewable energy?
1. One option is to commit to using fossil fuels until they are no longer economically practical, and to develop other energy sources only after supplies have dwindled.
 2. A second option is to fund development of alternative energy sources now, and attempt to reduce our reliance on fossil fuels gradually.
 3. Alternatively, as many environmentalists advocate, we could try to end our fossil fuel use as soon as possible and hasten a switch to renewable sources such as wind, solar, hydroelectric, biomass, and geothermal energy.

IX. Energy Conservation

- A. Energy conservation has followed economic need.

1. The policies enacted in the U.S. in response to events in 1973 also included conservation measures.
 2. Thirty years later, many of the conservation policies developed after the 1973 oil crisis have been abandoned.
 3. Without the immediate threat of shortages, people lack the motivation to conserve.
 4. Many critics of oil drilling in the ANWR point to the vast amounts of oil wasted by fuel-inefficient automobiles, and argue that a small amount of conservation would save the nation far more oil than it would obtain from drilling in ANWR.
 5. The U.S. has kept taxes on gasoline artificially low. European countries pay two-and-a-half times as much per gallon as Americans do. The price at the pump does not reflect the external costs that oil consumption places on society.
- B. Personal choice and increased efficiency are two routes to conservation.
1. As individuals, we can make conscious choices to reduce our own energy consumption.
 2. As a society, we can make our energy-consuming devices and processes more efficient.
 3. The efficiency of power plants can be improved through **cogeneration**, in which excess heat produced during the generation of electricity is captured and used to heat workplaces and homes and to produce other kinds of power.
- C. Both conservation and renewable energy are needed.
1. Until we are using solely renewable energy sources, we will face the gradual depletion of nonrenewable fossil fuel resources and will need to practice **energy conservation**—reducing energy use to extend the lifetimes of our nonrenewable energy supplies.
 2. The only way to assure ourselves long-term energy supplies is to rapidly develop renewable energy sources.

X. Conclusion

- A. Fossil fuels have helped us build complex industrialized societies.
- B. Our production of fossil fuels will begin to decline just as we become increasingly aware of the negative impacts of their use.
- C. We can respond by encouraging conservation and developing alternative energy sources, or we can continue our current path until our energy sources are nearly depleted before trying to develop new technologies. Our choice will have far-reaching consequences.