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Conventional Energy Alternatives

Chapter Objectives

This chapter will help students:

Discuss the reasons for seeking alternatives to fossil fuels

Summarize the contributions to world energy supplies of conventional alternatives to fossil fuels

Describe nuclear energy and how it is harnessed

Outline the societal debate over nuclear power

Describe the major sources, scale, and impacts of biomass energy

Describe the scale, methods, and impacts of hydroelectric power

Lecture Outline

I. Central Case: Sweden's Search for Alternative Energy

A. In 1980 Sweden voted to phase out their country's nuclear power program, shutting down all nuclear plants by the year 2010.

B. Sweden today receives about one-third of its energy and nearly half its electricity from nuclear power.

C. Sweden does not favor expanding fossil fuel use, so to fill the gap the government has promoted research and development of renewable energy sources.

D. Hydroelectric power from running water supplies most of the other half of the nation's electricity, but it could not be expanded much more.

E. Renewables have taken longer to develop than hoped, so the government has repeatedly postponed the nuclear phaseout because of environmental concerns over what would replace it. If Sweden abandons nuclear power, it will be nearly impossible to meet carbon dioxide reduction goals.

II. Alternatives to Fossil Fuels

A. Nuclear power, biomass energy, and hydropower are conventional alternatives.

B. Conventional alternatives provide some of our energy and much of our electricity.

1. Today's economies are largely powered by fossil fuels, with 80% of all primary energy coming from oil, coal, and natural gas.
2. Fuelwood and other biomass provide 10.9% of our primary energy, nuclear energy 6.8%, and hydropower 2.2%, leaving the less-established renewable energy sources to account for only 0.5%.
3. Nuclear energy and hydropower each account for about one-sixth of the world's electricity generation, however.

III. Nuclear Power

1. Nuclear power is free of air pollution, but its promise has been clouded by nuclear weaponry, the dilemma of radioactive waste disposal, and the long shadow of Chernobyl and other power plant accidents.

A. Fission releases **nuclear energy.**

1. Nuclear energy is the energy that holds protons and neutrons together within the nucleus of an atom.
2. We convert this energy into thermal energy, which can then be used to generate electricity.
3. The reaction that drives the release of nuclear energy in power plants is **nuclear fission,** the splitting apart of atomic nuclei.

B. Nuclear energy comes from processed and enriched uranium.

1. **Nuclear reactors** are the facilities within nuclear power plants where we control fission and generate electricity.
2. Uranium ore is in finite supply, which is why nuclear power is generally considered a nonrenewable energy source.
3. Uranium is used for nuclear power because it is radioactive. Radioactive isotopes, or **radioisotopes,** emit subatomic particles and high-energy radiation as they decay into lighter and lighter radioisotopes, until they become stable isotopes.
4. Each radioisotope decays at a rate determined by that isotope's **half-life,** the amount of time it takes for one-half of the atoms to give off radiation and decay.
5. After several years in a reactor, enough uranium has decayed so that the fuel loses its ability to generate adequate energy, and it must be replaced. Some countries reprocess the spent fuel to recover more usable energy. Most of the fuel, however, is disposed of as radioactive waste.

C. Fission in reactors generates electricity in nuclear power plants.

D. Breeder reactors make better use of fuel, but have raised safety concerns.

1. **Breeder nuclear fission** makes use of ^{238}U, which in conventional fission goes unused as a waste product.

2. Because 99% of all uranium is ^{238}U, breeder fission makes much better use of fuel, generates far more power, and produces far less waste than conventional fission.
3. However, breeder fission is considerably more dangerous than conventional nuclear fission. This is because highly reactive liquid sodium, rather than water, must be used as a coolant, raising the risk of explosive accidents.
4. Breeder fission can potentially be used to supply plutonium to nuclear weapons programs.
5. Because of these reasons, nearly all of the world's breeder reactors have now been shut down.

E. Fusion remains a dream.
1. **Nuclear fusion**—the process responsible for the immense amount of energy that our sun generates and the force behind hydrogen or thermonuclear bombs—involves forcing together the small nuclei of lightweight elements under extremely high temperature and pressure.
2. The hydrogen isotopes deuterium and tritium can be fused together to create helium, releasing a neutron and a tremendous amount of energy.
3. Overcoming the mutually repulsive forces of protons in a controlled manner is difficult, and fusion requires temperatures of many millions of degrees Celsius. Despite decades of research, fusion experiments still require more energy to be input than is produced by the process.
4. Successful fusion in a reactor would produce vast amounts of energy using water as a fuel, with only low-level radioactive wastes and no risk of accidents, sabotage, or weapons proliferation.

F. Nuclear power delivers energy more cleanly than fossil fuels.
1. Researchers calculate that nuclear power lowers emissions 4–150 times below those of fossil fuel combustion.
2. Uranium generates far more power than coal by weight or volume, requiring less of it to be mined, causing less damage to landscapes, and generating less solid waste.
3. A drawback to nuclear power is the radioactive waste that must be disposed of in a way that minimizes danger to present and future generations.
4. A second main drawback is that if an accident occurs at a power plant, or if a plant is sabotaged, the consequences can be potentially catastrophic.
5. Most governments, although not necessarily most citizens, have judged the good to outweigh the bad, and today there are 439 operating nuclear plants around the world.

G. Nuclear power poses small risks of large accidents.
1. Two events were influential in shaping public opinion about nuclear energy. The first was at a nuclear plant in Pennsylvania.
   a. In 1979, the **Three Mile Island** plant in Pennsylvania experienced the most serious nuclear power plant accident in the United States.

b. Through a combination of mechanical failure and human error, metal surrounding the uranium fuel rods began to melt, releasing radiation.
c. This process, a **meltdown,** proceeded through half of one reactor core at Three Mile Island.
d. The accident was brought under control within days, the damaged reactor was shut down, and multi-billion-dollar cleanup efforts stretched on for years.
e. Although no significant health effects to residents have been proven in the years since, the event put safety concerns squarely on the map for U.S. citizens and policymakers.

H. **Chernobyl** saw the worst accident yet.
1. In 1986, an explosion at the Chernobyl plant in Ukraine caused the most severe nuclear power plant accident the world has yet seen.
2. Human error, combined with unsafe reactor design, resulted in explosions that destroyed the reactor and sent clouds of radioactive debris billowing into the atmosphere.
3. There is now a gigantic concrete sarcophagus around the demolished reactor, but the landscape for at least 30 km around the plant remains contaminated.
4. Atmospheric currents carried radioactive fallout from Chernobyl across much of the Northern Hemisphere.

I. Waste disposal remains a problem.
1. Even if nuclear power generation can be made completely safe, we still must dispose of the spent fuel rods and other material and equipment in a location where radiation will not escape to harm the public.
2. This waste remains dangerous for thousands of years.
3. Currently, nuclear waste from power generation is being held in temporary storage at nuclear power plants around the world.
4. In the United States, Yucca Mountain, Nevada, has been chosen for nuclear waste storage beginning in 2010.

J. Multiple dilemmas have slowed nuclear power's growth.
1. Almost every nuclear plant has turned out to be more expensive than expected.
2. Plants have aged more quickly than expected because of problems that were underestimated. Well over 100 plants around the world have been shut down, having served on average for less than half their expected lifetimes.
3. Shutting down a plant can be more expensive than the original construction.
4. These issues make nuclear-power-generated electricity more expensive than electricity from other sources.
5. Asian nations are adding generating capacity, but in Western Europe there are no reactors under construction today and 75% of the current capacity will be retired by 2030.
6. Nearly half of the U.S. nuclear plants ordered since 1957 have been cancelled.

IV. Biomass Energy

1. *Biomass* consists of the organic material that makes up living organisms. **Biomass energy** involves burning many types of plant and animal matter, including wood, charcoal, and combustible animal waste products.

A. Fuelwood and other traditional biomass sources are widely used in the developing world.
   1. Fuelwood and other traditional biomass energy sources constitute nearly 80% of all renewable energy used worldwide.
   2. In reality, biomass is renewable only if it is not overharvested.

B. New biomass sources are being developed in industrialized countries.
   1. Biomass sources that can be burned efficiently in power plants can produce **biopower,** generating electricity in the same way that coal does.
   2. Biomass sources that can be converted into fuels to power automobiles are termed **biofuels.**
   3. Many of the new biomass resources are actually the waste products of preexisting industries or processes, such as woody debris from logging and mills.
   4. Organic components from municipal landfills, animal waste from feedlots, and agricultural residue could also become major bioenergy sources.

C. Biofuels can power automobiles.
   1. **Ethanol** is the alcohol in beer, wine, and liquor. It is produced by fermenting biomass.
   2. Ethanol is added to gasoline in the United States to reduce automotive emissions.
   3. Many vehicles now run either entirely on ethanol or on E-85, a mix of 85% ethanol and 15% gasoline.
   4. **Biodiesel** is produced from vegetable oil, used cooking grease, or animal fat. The oil or fat is mixed with small amounts of ethanol or methanol in the presence of a chemical catalyst.
   5. Traditional diesel engines can run on 100% biodiesel.
   6. Research that would use algae as a source of ethanol production is underway. If this becomes feasible, it may be possible to produce substantial amounts of energy in small spaces at reduced costs.

D. Biopower generates electricity from biomass.
   1. Burning biomass in air is the most common method of use.
   2. Biomass is increasingly being combined with coal in existing coal-fired power plants in a process called *co-firing*.
   3. Decomposition of biomass by microbes produces gas that can be used to generate electricity.

E. Biomass energy brings environmental and economic benefits.
   1. One major environmental benefit is that biomass is essentially carbon-neutral, releasing no net carbon into the atmosphere.
   2. Biomass is the product of recent photosynthesis, so the carbon released in combustion is balanced by carbon taken up in the photosynthesis that created it.
   3. This holds only if biomass sources are not overharvested, leaving less vegetation to continue carbon uptake.

4. Capturing landfill gas for biofuels also reduces greenhouse gas emissions.
5. Adding ethanol and biodiesel to traditional petroleum fuels helps them to combust more completely, reducing pollution.
6. Economic benefits include the fact that biomass is geographically widespread and should help support rural economies and reduce dependence on imported fuels.
7. Biomass is less expensive than traditional fuels and should lower energy prices.
8. Biomass also has benefits for human health. By replacing coal, it reduces emissions of nitrogen oxides and sulfur dioxide.

F. Biomass energy also brings drawbacks.
1. Burning biomass in traditional ways for cooking and heating leads to health hazards from indoor air pollution.
2. Harvesting fuelwood at an unsustainably rapid rate leads to deforestation, soil erosion, and desertification, which in turn damage landscapes, diminish biodiversity, and impoverish human societies.
3. Growing biofuel crops establishes monoculture agriculture, with all its impacts, on land that might otherwise be used to grow food, be developed for other purposes, or be left as wildlife habitat.
4. Growing bioenergy crops requires substantial inputs of energy, including fossil fuels for farm equipment, pesticides, and fertilizers.

V. Hydroelectric Power

1. In **hydroelectric power,** or **hydropower,** the kinetic energy of moving water is used to turn turbines and generate electricity.

A. Modern hydropower uses dams and "run-of-river" approaches.
1. Most of our hydroelectric power today comes from impounding water in reservoirs behind dams and then letting that water pass through the dam. Because immense amounts of water are stored behind dams, this is called the **storage technique.**
2. An alternative is the **run-of-river** approach, in which electricity is generated without greatly disrupting the flow of river water. This approach sacrifices the reliability of water flow across seasons, but minimizes many of the environmental impacts.

B. Hydroelectric power is widely used.
1. For nations with large amounts of river water and the economic resources to build dams, hydroelectric power has been a keystone of their development and wealth.

C. Hydropower is clean and renewable.
1. Hydropower is renewable as long as rain still falls and fills rivers and reservoirs.
2. Hydropower is cleaner than power from fossil fuels.
3. Recent evidence indicates that large reservoirs may release the greenhouse gas methane as a result of anaerobic decay.

D. Hydropower has negative environmental impacts.

1. Damming rivers destroys habitat for riverside wildlife as riparian areas above dam sites are submerged and those below dam sites often become starved of water.
2. Because water discharge is carefully controlled to optimize electricity generation, the natural flooding cycles of rivers are disrupted.
3. Sediments become trapped behind dams, where they begin filling the reservoir.
4. Dams also cause thermal pollution, because water downstream from dams may become unusually warm if water levels are kept unnaturally shallow, and then may experience periodic flushes of cold water from the lower depths of the reservoir.
5. Dams generally block the passage of fish and other aquatic creatures, effectively fragmenting segments of the river and reducing biodiversity in each segment.

E. Hydropower may not expand much more.
1. Most of the world's rivers that offer excellent opportunities for hydropower have been dammed.
2. Moreover, in developed nations, awareness of the environmental impacts of dams is causing people to propose dismantling and removing many of the dams that exist to restore river habitats.
3. In the United States, 98% of the rivers appropriate for dam construction are already dammed, and many of the remaining 2% are protected from dam building.
4. Hydropower will likely continue to increase in developing nations, but in developed nations growth will likely slow or stop.

VI. Conclusion

A. Many nations have sought to diversify their energy portfolios with alternative energy sources.
B. The three most developed and widely used alternatives so far are nuclear power, biomass energy, and hydropower.
C. It appears that we will need further renewable sources of energy.