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New Renewable Energy Alternatives

Chapter Objectives

This chapter will help students:

Outline the major sources of renewable energy and assess their potential for growth

Describe solar energy and the ways it is harnessed, and evaluate its advantages and disadvantages

Describe wind energy and the ways it is harnessed, and evaluate its advantages and disadvantages

Describe geothermal energy and the ways it is harnessed, and evaluate its advantages and disadvantages

Describe ocean energy sources and the ways they could be harnessed, and evaluate their advantages and disadvantages

Explain hydrogen fuel cells and assess future options for energy storage and transportation

Lecture Outline

I. Central Case: Iceland Moves toward a Hydrogen Economy

A. Iceland is a hunk of lava the size of Kentucky that has risen out of the North Atlantic from the rift between tectonic plates known as the mid-Atlantic ridge.
B. The magma that gave birth to the island heats its groundwater, giving Iceland some of the world's best sources of geothermal energy.
C. Iceland has also dammed some of its many rivers for hydropower.
D. Iceland also depends on fossil fuels, and has one of the highest per capita rates of greenhouse gas emissions in the world.
E. In the 1970s, Bragi Árnason, a University of Iceland professor, began arguing that Iceland could break its reliance on fossil fuel

imports, boost its economy, and serve as a model to the world by converting to a renewable energy economy based on hydrogen.

F. In the late 1990s, the interest of international energy companies in his ideas and the nation's "Kyoto dilemma" finally forced Árnason's countrymen to pay attention.
G. Those planning the shift to a hydrogen economy sketched a stepwise transition, with fossil fuels phased out over 30–50 years.
H. To make this happen, in 1999 Icelanders teamed up with corporate partners who were looking to develop technology for the future.
I. In 2003, the first hydrogen-based public filling station was opened in Reykjavic, followed in 2008 with improved hydrogen buses, prototype cars, and boats. Iceland plans to convert the fishing fleet to hydrogen in the future.
J. A global hydrogen economy could be closer than we suspect.

II. "New" Renewable Energy Sources

1. The new renewables include energy from the sun, from wind, from Earth's geothermal heat, and from the movement of ocean water.
2. They are called "new" because they are not yet used on a wide scale.
3. They are harnessed by using technologies that are still in development.
4. It is widely believed that they will come to play a larger part in our energy use in the future.
5. Considering economic costs, impact to the environment, and security risks of fossil fuels, many nations are seeking alternatives.

A. The new renewables currently provide little of our power.
   1. The new renewables presently provide only one-half of one percent of our global primary energy supply.
      a. Fossil fuels provide nearly 80% of the world's primary energy.
      b. U.S. electricity generation from renewables is 75% hydropower, followed by biomass at 17.5%. As of 2005, geothermal provided 4.2%, wind provided 4.1%, and solar contributed 0.1%.

B. The new renewables are growing fast.
   1. The new renewables are growing at much faster rates than conventional energy sources.
   2. The leader in growth is wind power, expanding at nearly 50% each year.
   3. The rapid growth of the new renewables has been motivated by concerns over diminishing fossil fuel supplies, the environmental impacts of fossil fuel combustion, and national security concerns.

C. The transition cannot be immediate, but it must be soon.
   1. Many renewables are expensive, lack adequate technological development, or lack the infrastructure necessary to transfer energy on the required scale.

2. The best hope may be for a gradual transition from fossil fuels to renewable energy sources.
3. The new technologies tend to be more labor intensive so job growth is an anticipated outcome of renewable energy sources as well.
4. Transition to renewable energy is also slow because development is underfunded because fossil fuels appeared less expensive due to government policies.

III. Solar Energy

1. The sun provides energy for almost all biological activity on Earth by converting hydrogen to helium in nuclear fusion.
2. The potential for using sunlight to meet our energy needs is tremendous. If it could be captured, there is enough sun striking Earth each day to power human consumption for a quarter of a century.
3. In **passive solar** heating, buildings are designed and building materials are chosen to maximize their direct absorption of sunlight in winter.
4. **Active solar** energy collection makes use of technological devices to focus, move, or store solar energy.

A. Passive solar heating is simple and effective.
   1. Passive solar design techniques include using heat-absorbing construction materials and installing low, south-facing windows to maximize sunlight capture in winter in the Northern Hemisphere.
   2. Passive solar design can also involve using vegetation around a building.

B. Active solar energy collection can heat air and water in buildings.
   1. Solar panels or flat-plate solar collectors generally consist of dark-colored, heat-absorbing metal plates mounted in large, flat boxes covered with glass panes.

C. Concentrating solar rays magnifies the energy received.
   1. The strength of solar energy can be magnified by gathering sunlight from a wide area and focusing it on a single point.
   2. The principle of concentrating the sun's rays has also been put to work by utilities in large-scale, high-tech approaches to producing electricity from solar energy.

D. Photovoltaic cells produce electricity directly from sunlight.
   1. **Photovoltaic (PV) cells** collect sunlight and convert it to electrical energy directly by making use of the photoelectric effect.
   2. The plates of a PV cell are made primarily of silicon, enriched on one side with phosphorus and on the other with boron.
   3. Multiple PV cells are arranged in modules, which can comprise panels that are gathered together in flat arrays.

E. Solar power is little used but fast growing.
   1. Although solar technology dates from the 19th century, solar power was pushed to the sidelines as fossil fuels gained a stronger foothold in our energy economy.

2. Largely because of the lack of investment, solar power presently contributes only a minuscule portion of our energy production.
3. Sales of PV cells are growing fast—by 28% per year in the United States.

F. Solar power offers many benefits.
1. The fact that the sun will continue burning for another 4–5 billion years makes it practically inexhaustible as an energy source for human civilization.
2. PV cells and other solar technologies use no fuel, are quiet and safe, contain no moving parts, require little maintenance, and do not require a turbine or generator.
3. Another advantage of solar systems is that they enable local, decentralized control over power.
4. A major benefit of solar power over fossil fuels is that it does not pollute the air with emissions, and thus greatly reduces the level of greenhouse gases and pollutants released into the atmosphere relative to fossil fuels.

G. Location and cost can be drawbacks for solar power.
1. Not all regions are sunny enough to provide adequate power with the technology currently available.
2. The up-front cost of investing in the equipment is high.
3. Decreases in price and improvements in the energy efficiency of solar technologies have been encouraging.
4. Governments are enacting economic incentives to spur investment. California invested $3.5 billion in programs in 2006.

IV. Wind Energy

A. Wind energy can be thought of as another form of solar energy.
1. Differential heating of air masses causes wind to blow.
2. We use **wind turbines** to convert wind's kinetic energy into electrical energy.

B. Wind has long been used for energy.
1. Today's wind turbines have their historic roots in Europe, where wooden windmills have been used for 800 years.
2. The first wind turbine or windmill built for the generation of electricity was constructed in the late 1800s by inventor Charles Brush.
3. Wind energy in the United States is languishing due to inaction by Congressional failure to provide long-term tax credit for wind energy development.

C. Modern wind turbines convert kinetic energy to electrical energy.
1. Wind turbines use the motion of wind passing through their blades to create electricity.
2. Turbines can be erected singly, but are most often erected in groups called *wind parks* or *wind farms*.
3. In order to harvest wind power as efficiently as possible, engineers have designed turbines to begin turning at specific wind speeds.

D. Wind power is the fastest-growing energy sector.

E. Offshore sites can be promising.
1. Wind speeds over water are often greater than those over land.

F. Wind power has many benefits.
    1. Like solar power, wind produces no emissions once the necessary equipment is manufactured and installed.
    2. Wind power appears considerably more energy-efficient than conventional power sources.
    3. Wind turbine technology can be used on many scales, from a single tower for local use to fields of thousands of towers for utilities to supply large regions.
    4. Another societal benefit of wind power is that landowners can lease their land for wind development.
    5. Wind energy involves up-front costs for the erection of turbines and the expansion of the infrastructure, but over the lifetime of the project requires only maintenance costs.
G. Wind energy has some downsides.
    1. Humans have no control over the wind.
    2. Good wind resources are not always near population centers that need the energy, so the transmission networks will need to be greatly expanded.
    3. Wind turbines are known to pose a threat to flying birds, which can be killed by the rotating blades. The mortality rate, however, is far lower than for those killed by other types of towers, tall buildings, and other human causes. Placing wind farms away from major bird flyways can avoid much of the fatalities associated with wind generators.
    4. Wind is an intermittent source of energy, not always available when it is needed. However, this drawback can be overcome with the ability to store through new technologies.

V. Geothermal Energy

A. Geothermal energy is one form of renewable energy that originates not from the sun, but rather from deep within Earth.
    1. The radioactive decay of elements amid the extremely high pressures and temperatures deep within Earth generates heat, which rises to the surface in magma and through cracks and fissures.
    2. Geothermal power plants use the heat energy of naturally heated water to generate power.
B. Geothermal energy is harnessed for heating and electricity.
    1. Tapping the energy of geothermal sources usually requires that wells be drilled down hundreds or thousands of meters toward the heated groundwater.
    2. Hot groundwater can also be used directly for heating homes, offices, and greenhouses.
    3. Thermal energy from either water or solid earth can also be used to drive a heat pump to provide energy. Geothermal ground source heat pumps (GSHP) use thermal energy from near-surface sources of earth and water. Compared to conventional heating and cooling systems, GSHPs are 50–70% more efficient.
C. Use of geothermal power is growing.
D. Geothermal power has benefits and limitations.

1. Geothermal power greatly reduces emissions relative to fossil fuel combustion.
2. The water of many hot springs is laced with salts and other minerals that corrode equipment and pollute the air.
3. Geothermal power is limited to being used in the particular areas in which it occurs.

VI. Ocean Energy Sources

A. We can harness energy from the tides and from ocean waves.
B. The ocean is a storehouse of thermal energy.
   1. Other oceanic energy sources that we have not yet effectively tapped include the motion of ocean currents, chemical gradients in salinity, and the immense thermal energy contained in the oceans.
   2. The concept of **ocean thermal energy conversion (OTEC)** has been developed the most.

VII. Hydrogen

1. The development of fuel cells and hydrogen fuel shows promise as a vehicle to store electricity conveniently and in considerable quantities, and to produce electricity at least as cleanly and efficiently as with renewable energy sources.
2. In this system, electricity generated from wind or solar can be used to produce hydrogen and then be stored in fuel cells until it is needed.

A. Hydrogen fuel may be produced from water or from other matter.
   1. Hydrogen atoms tend to bind to other molecules, becoming incorporated in everything from water to organic molecules.
   2. **Electrolysis** produces pure hydrogen without emitting carbon- or nitrogen-based pollutants.
B. Fuel cells produce electricity by joining hydrogen and oxygen.
   1. Once hydrogen gas has been isolated, it can be used as a fuel to produce electricity within fuel cells.
C. Hydrogen and fuel cells have many benefits.
   1. Hydrogen is the most abundant element in the universe—we will never run out of it.
   2. It is clean and nontoxic to use, and may produce few greenhouse gases and other pollutants, depending on the source of the hydrogen and the source of electricity used for its extraction.
   3. Fuel cells are silent, are nonpolluting, and allow energy to be stored in the form of hydrogen.
   4. Hydrogen and its use in fuel cells is energy-efficient.

VIII. Conclusion

A. The coming decline of fossil fuel supplies and increasing concern over air pollution and global climate change have convinced many people that we will need to shift our energy use to renewable energy sources that will not run out and will not pollute.
B. Biomass and hydropower have been playing major roles so far, and solar, wind, geothermal, and ocean energy sources are promising for the future.

C. Electricity from hydrogen fuel can help convert our transportation sector to a nonpolluting, renewable basis.
D. Most renewable energy sources have been held back for a variety of reasons, including a lower level of funding for research and development relative to nonrenewable resources, and artificially cheap market prices for nonrenewable resources, which do not include external costs.