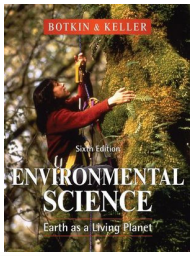

Environmental Science

Sixth Edition

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CHAPTER 19
Alternative Energy and the Environment

Introduction

- Fossil Fuels supply about 90% of energy
- All others are "Alternative Energy"
- Alternative energy can be either renewable or non-renewable (nuclear and geothermal)
- Most renewable energy sources can be said to be derived from the sun (see next slide)

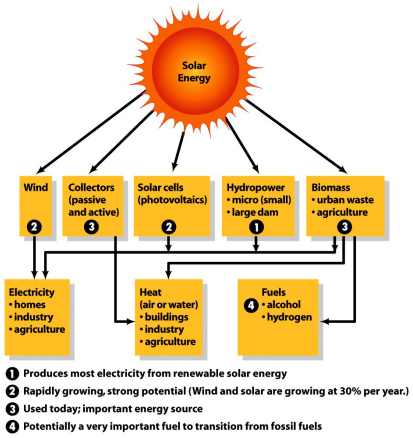

Figure 19-1 Botkin - Env. Sci. 6/e
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Table 19.1 • Global Resource-Based and Recoverable Energy for Selected Alternative Energy Sources

Source	Resource Base (TW)*	Recoverable Resource (TW)
Solar	90,000	1,000
Wind	300–1,200	10
Water	10–30	2
Biomass	30	10
Geothermal	30	3

* 1 TW = 10^{12} W; global energy production consumption is about 13 TW. This is equivalent to an annual consumption of approximately 425 exajoules.

Source: Modified from T. Jackson, and R. Lofstedt, "Royal Commission on Environmental Pollution, Study on Energy and the Environment," 1998. Accessed November 29, 2000, at http://www.rcep.org.uk/studies/energy/98-6061/jackson.html.

Table 19-1 Botkin - Env. Sci. 6/e
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More Basics

- Availability of alternative sources is potentially massive
- But - sources are not consistently available
- AND - not evenly distributed
- Alternatives are generally regarded as low impact and especially as being low in CO2

Alternative Energy Sources

- Solar: Passive, collectors, photovoltaics, largescale
- Hydrogen: Fuel Cells
- Water Power: Dams, small scale
- Tidal Power
- Wind Power
- Biofuels
- Geothermal

Solar Energy

- 10 weeks of sunlight equals all known reserves of fossl fuels
- 13% of light that reaches earth gets to surface
- Availability is site specific (see next slide)

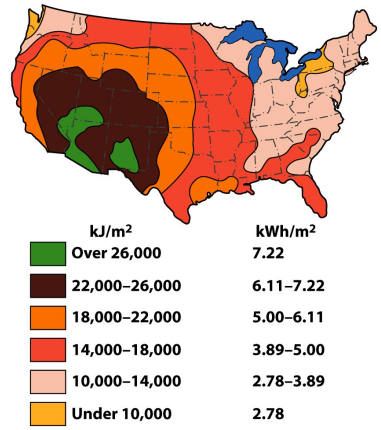

Figure 19-2 Botkin - Env. Sci. 6/e

Passive solar

- Passive Solar Energy Systems use design and materials to use the sun to heat in winter and warm in summer.
- Includes use of overhangs, trees, glass, and masonry

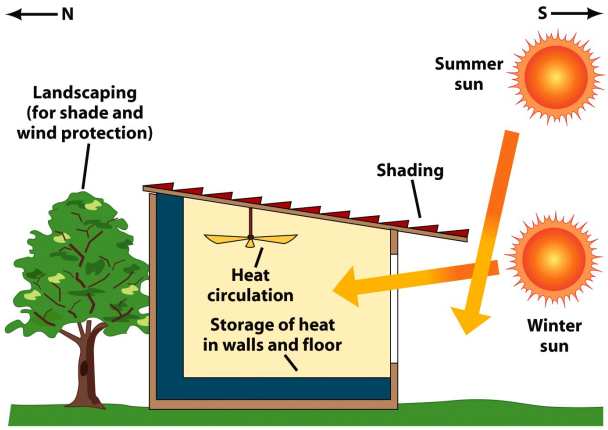

Figure 19-3a Botkin - Env. Sci. 6/e

Figure 19-3b Botkin - Env. Sci. 6/e

Solar Collectors

- Provide heat - usually hot water
- IMPORTANT PRINCIPLE
  - Light enters box through glass
  - light is absorbed by black surface
  - surface converts the energy to heat
  - heat warms air, which cannot escape the box
  - heat builds up, heating any fluids that flow through it

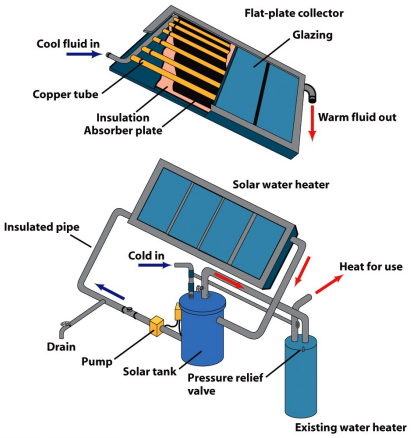

Figure 19-4 Botkin - Env. Sci. 6/e

Photovoltaics

- Convert sunlight directly to electricity
- Common in space
- Good in remote locations
- Becoming important in developing nations

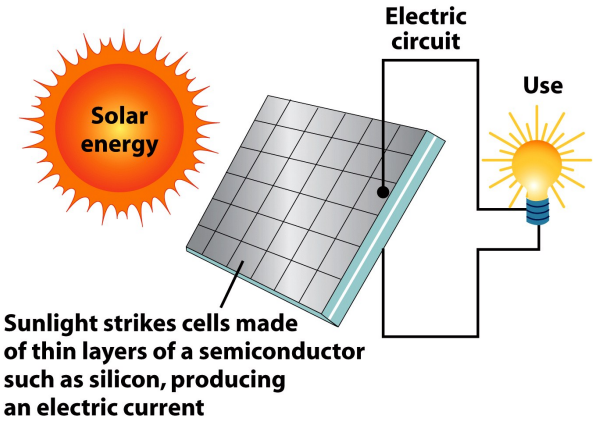

Figure 19-5 Botkin - Env. Sci. 6/e

Figure 19-6a Botkin - Env. Sci. 6/e

Figure 19-6b Botkin - Env. Sci. 6/e

Power Towers and other centralized Solar Power Designs

- Large power plants hooked to the grid like coal, gas or nuclear plants
- Focus sunlight from a large area onto a single point to create heat
- Working fluid is liquid sodium or oil
- Requires large areas of land
- The "Luz" design used long trough shaped mirrors and a pipe of oil

Figure 19-7 Botkin - Env. Sci. 6/e

Power Block Assembly
1. Solar collector assembly
2. Natural gas boiler
3. Turbine generator
4. Steam generator and solar superheater
5. Control building
6. Cooling tower
7. Southern California Edison interconnect

Figure 19-8a Botkin - Env. Sci. 6/e

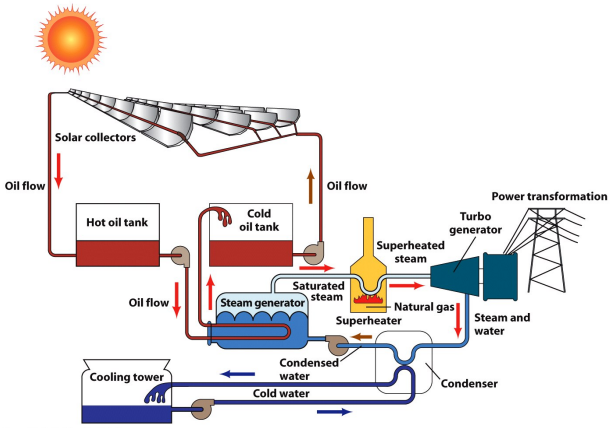

Figure 19-8b Botkin - Env. Sci. 6/e

Pros and Cons - Solar

- relatively low impact
- Sun is persistent
- Takes up a lot of space
- Location dependent
- materials and processes can be hazardous

Hydrogen (Fuel Cells)

- Hydrogen is the lightest, most abundant element in the universe
- Abundant on earth - especially as two thirds of water.
- Releases a lot of energy when H2 forms bonds with O2 to form H2O (combustion)
- Can generate electricity in Fuel Cells
- Relatively east to store and transport

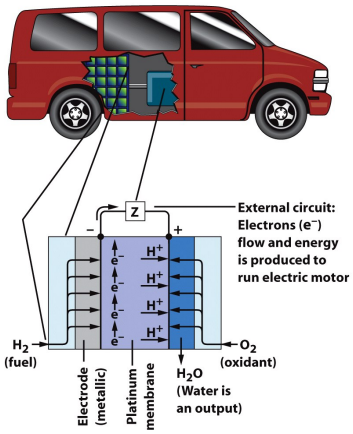

Figure 19-9 Botkin - Env. Sci. 6/e

Water Power

- Dams - Potential energy is stored by letting water "pile up" behind the dam
- Falling or flowing water turns turbines to make electricity

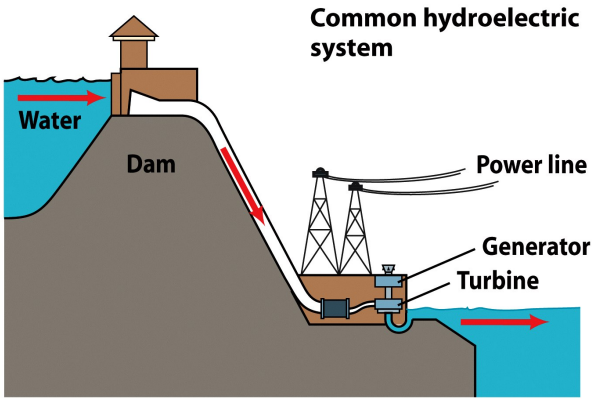

Figure 19-10a Botkin - Env. Sci. 6/e

Pump Storage

- A sort of "water battery" that stores excess energy by pumping water uphill, so that it can later fall to generate electricity during peak demand

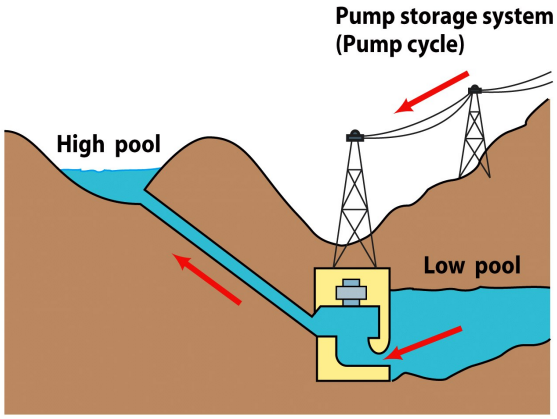

Figure 19-10b Botkin - Env. Sci. 6/e

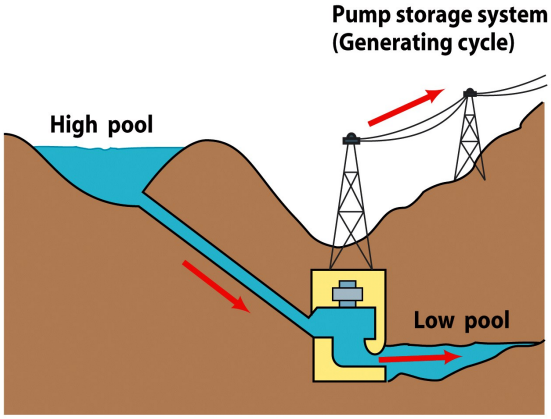

Figure 19-10c Botkin - Env. Sci. 6/e

Small-Scale systems

- Large scale no likely to increase in developed nations - all good sites are taken.
- Small plants produce 100kW
- used for individual homes, farms, or small industries
- can produce electricity or power machinery

Water Power - Pros and Cons

- Hydropower is very clean - But
- Dams fill valleys
- Dams block movement of wildlife
- Water can become saturated in nitrogen
- sediment build up
- evaporation increase
- Downstream flow is affected

Tidal Power

- Uses daily tidal range to drive turbines
- Highly dependent on many arrangements of seafloor topography and coastal shape
- At the Bay of Fundy, Canada, the tides have a range of up to 49 feet!
- A dam is built across a bay, turbines are turned as water flows in, and also as it flows out

Figure 19-11 Botkin - Env. Sci. 6/e

Wind Power

- One of the oldest kinds of human harnessing of power to run machines (windmills)
- Air moves when the earth experiences "differential heating"
- Highly variable in distribution, and even variable in teh places where it is most frequently available.
- Depends greatly on topography (see next slide

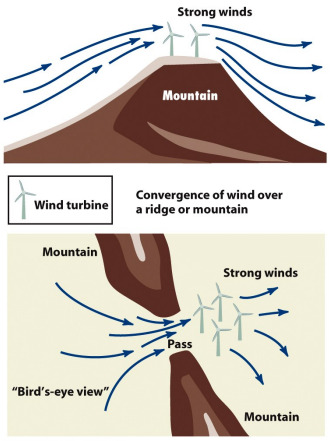

Figure 19-12 Botkin - Env. Sci. 6/e

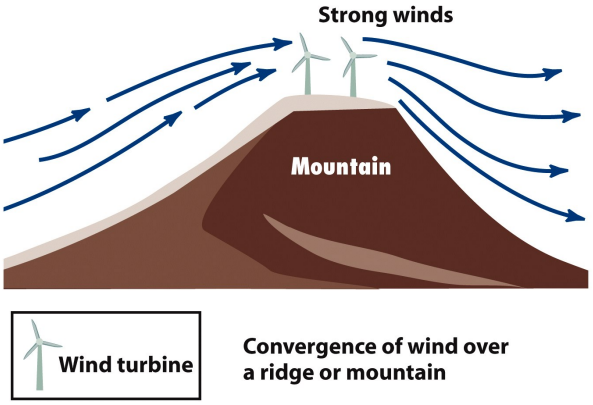

Figure 19-12 part 1 Botkin - Env. Sci. 6/e

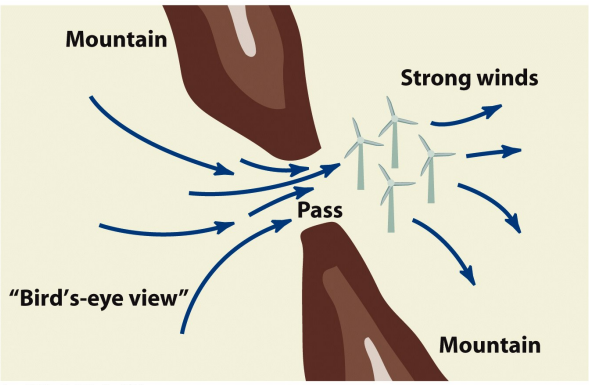

Figure 19-12 part 2 Botkin - Env. Sci. 6/e

More on wind

- Widely available on Eastern seaboard, Texas, northern California, and near Palm Springs CA
- Could be utilized small scale on homes, farms, etc....(see case study)
- Negative impacts include: kills birds, aesthetic impacts, sound, land use

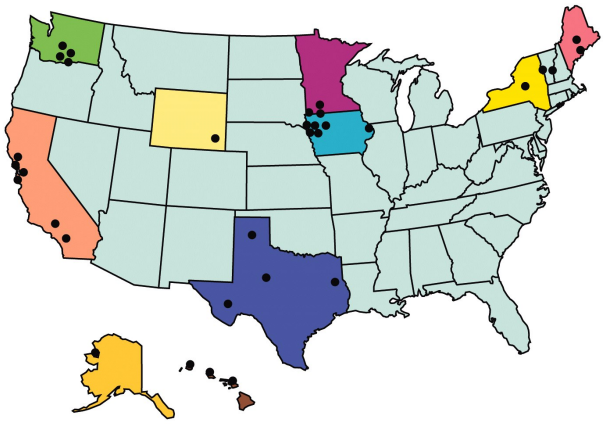

Figure 19-13a Botkin - Env. Sci. 6/e

Figure 19-13b Botkin - Env. Sci. 6/e

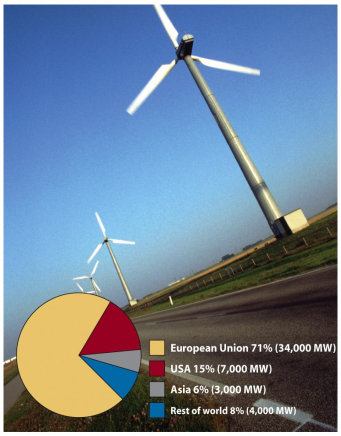

Figure 19-14 Botkin - Env. Sci. 6/e

Biomass (biofuels)

- Firewood, Dung, Peat,
- "Digestion" of organic matter can also generate methane
- Ethanol can be produced by sugarcane and corn, as well as from "switchgrass" and other plants
- Ethanol from corn is controversial
- Ethanol from Algae is cutting edge

Table 19.2 • Selected Examples of Biomass Energy Sources, Uses, and Products

Sources	Examples	Uses/Products	Comment
Forest products	Wood, chips	Direct burning,[a] charcoal[b]	Major source today in developing countries
Agriculture residues	Coconut husks, sugarcane waste, corncobs, peanut shells	Direct burning	Minor source
Energy crops	Sugarcane, corn, sorghum	Ethanol (alcohol),[c] gasification[d]	Ethanol is major source of fuel in Brazil for automobiles
Trees	Palm oil	Biodiesel	Fuel for vehicles
Animal residues	Manure	Methane[e]	Used to run farm machinery
Urban waste	Waste paper, organic household waste	Direct burning of methane from wastewater treatment or from landfills[f]	Minor source

[a]Principal biomass conversion.

[b]Secondary product from burning wood.

[c]Ethanol is an alcohol produced by fermentation, which uses yeast to convert carbohydrates into alcohol in fermentation chambers (distillery).

[d]Biogas from gasification is a mixture of methane and carbon dioxide produced by pyrolytic technology, which is a thermochemical process that breaks down solid biomass into an oil-like liquid and almost pure carbon char.

[e]Methane is produced by anaerobic fermentation in a digester.

[f]Naturally produced in landfills by anaerobic fermentation.

Table 19-2 Botkin - Env. Sci. 6/e

Figure 19-15 Botkin - Env. Sci. 6/e

Energy Source	U.S. Recoverable Resource[a] (exajoule/yr)	Costs in 1998 Cents[b] (per KWh) 1988	2000	Land Use[c] (m^2/GWh for 30 years)	Carbon Reduction (%)	Carbon Avoidance Cost[d] ($/ton)	Number of Jobs[e] (per thousand GWh/yr)	Environmental Impact
Wind	10–40	8	5	1,355	100	95	542	
Geothermal	Small	4	4	404	99	110	112	
Photovoltaic	35	30	10	3,237	100	819	—	
Solar thermal	65	8	6	3,561	84	180	248	
Biomass	13–26	5	NA	—	100[f]	125	—	
Combined-cycle coal	—	6[g]	—	3,642	10	954	116	
Nuclear	—	15[h]	—	—	86	535	100	

[a]*Recoverable resource* is a measure of how much of the energy can be captured or exploited. From M. Brower, *Cool Energy* (Washington, D.C.: Union of Concerned Scientists, 1990), p. 19.

[b]L. R. Brown, C. Flavin, and S. Postel, *Saving the Planet* (New York: Norton, 1991), p. 27.

[c]Ibid., p. 60.

[d]Based on comparison with existing coal-fired plants. From C. Flavin, "Slowing Global Warming," in *State of the World* (New York: W.W. Norton, 1990), p. 27.

[e]Brown et al., p. 62.

[f]Assumes that the amount of carbon dioxide released in combustion will be consumed by replanted vegetation.

[g]C. Flavin, "Building a Bridge to a Sustainable Future," in *State of the World* (New York: Norton, 1992), p. 35.

[h]A. K. Reddy and J. Goldenberg, "Energy for the Developing World," *Scientific American* 263 (3)(1990):116.

Unnumbered table 19 pg 404 Botkin - Env. Sci. 6/e