Chapter 16: Renewable Energy

APES 2013

1

Energy Waste

- Energy Conservation - decrease in energy use based on reducing unnecessary waste of energy
- Energy Efficiency - measure of how much work can be gained from each unit of energy
- 84% of all commercial energy used in the U.S. is wasted. 41% is unavoidable because of degradation (2nd Law of Thermodynamics). 43% is unnecessary waste because of inefficiency.
- Energy waste in the U.S. costs about $570,000 per minute.
- Reducing energy waste quickest, cleanest, and often the cheapest way to provide more energy, reduce pollution and environmental degradation, slow global warming, and increase economic and national security.

2

Major Energy Wasters

- Incandescent lightbulbs - use only 5-10% of the energy it draws to produce light (90-95% wasted as heat)
- Internal Combustion Engine - wastes 94% of energy in its fuel
- Nuclear Power Plant - wastes 83% of energy in nuclear fuel (92% when entire nuclear fuel cycle is included)
- Coal-fired Power Plant - wastes 66% of energy from coal (75-80% if energy to access and transport coal is included)

3

Industry

- Industry accounts for 30% of world energy consumption (38% for U.S.)
- Cogeneration (Combined Heat and Power) - producing heat and electricity from the same fuel source
    - This can increase energy efficiency from 30-40% to up to 80%. It also emits one third less CO_2.
- Energy-wasting electric motors - only run at full speed. Replacing could save the equivalent of 150 coal power plants of energy.
- Recycling - It takes 75% less energy to produce steel from recycled than from virgin ore. Cement industry could cut energy use by 42%.
- Lighting - from incandescent to fluorescent and LED

4

The Grid and Industry

- The Grid wastes huge amounts of energy. Converting to a digitally controlled network could save $100 billion a year.
- Dow Chemical is on track to cut its energy consumption in half by 2015. Their energy savings will equal the amount used by the entire nation of New Zealand.
    - These energy efficiency improvements cost Dow $1 billion dollars, but have saved about $5 billion already

5

Transportation

- Accounts for two-thirds of U.S. oil consumption, and is a major cause of air pollution and CO_2 emissions.

6

CAFE Standards

- Corporate Average Fuel Economy
  - Government mandated standards for fuel efficiency
- 1973-1985 fuel efficiency rose sharply
- Since 1985, average fuel efficiency for new vehicles has decreased by about 21 mpg
  - Government did not increase standards after 1985
  - SUVs and trucks became more popular

7

U.S. Average Fuel Economy

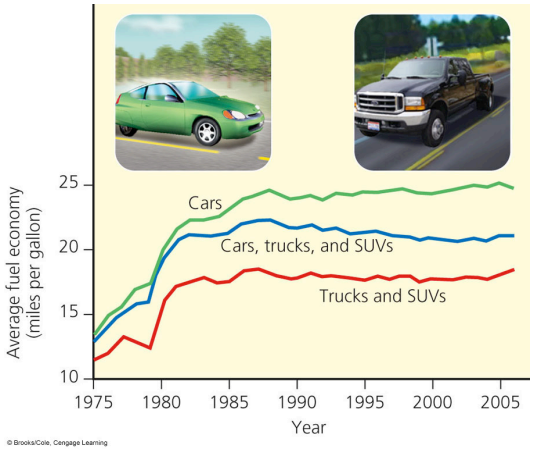


Fig. 16-5

8

International Standards

- Europe, Japan, China, and Canada have much higher fuel efficiency standards than the U.S.
- The U.S. raised CAFE standards to 35 mpg by 2020, but that will still keep them well below other countries

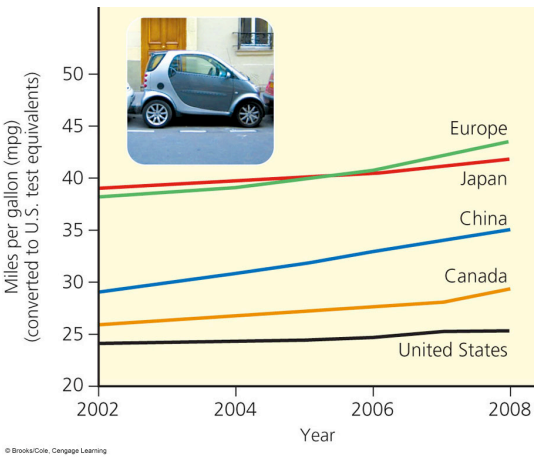


Fig. 16-5

9

Fuel Efficient Vehicles

- Should be at least 35 mpg
  - Ex. Toyota Prius (46 mpg)
- Fuel efficient cars are only 1% of new vehicle sales
- True cost of gas could be estimated at $16 per gallon when all factors are taken in to consideration
- Government does not incentivize fuel efficiency through subsidies and tax breaks.
  - Ex. Small business could buy a $50,000 Hummer and get a $25,000 tax deduction. Buying a $22,000 hybrid would only provide a $3,100 tax deduction.

10

Fuel Efficient Future

- Superefficient and Ultralight cars that could get 80-300 mpg
- Conventional Hybird - invented in 1900 by Ferdinand Porsche, improved by Japanese automakers
  - Up to 46 mpg and 65% less CO_2 emissions
- Plug-in Hybrid - hybrid with a more powerful battery that can be plugged into a standard outlet to recharge
  - Up to 100 mpg for standard drivers
  - Up to 1,000 mpg for those who only make trips less than 40 miles between recharges

11

Hybrid Vehicles

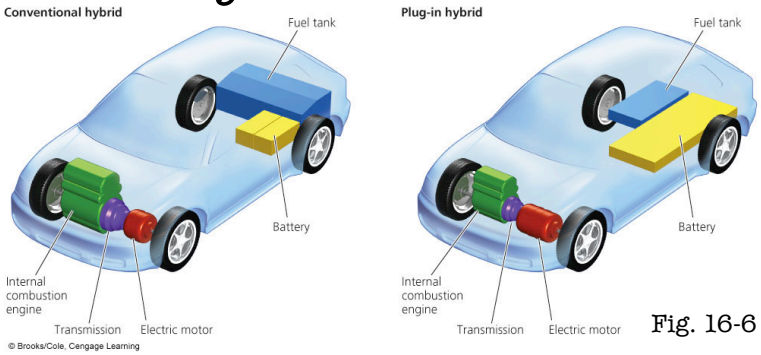


Fig. 16-6

- Replacing the U.S. fleet would cut U.S. oil consumption by 70-90% (eliminate need for foreign oil imports) and reduce CO_2 emissions by 27%
  - If the vehicles were recharged by wind, solar, or hydropower CO_2 emissions would drop by 80-90%

12

Diesel

- Energy efficient diesel - 30% more fuel efficient, 20% less CO_2
- Diesel fuel can be made from coal, plant material, and cooking oil
- Hybrid-electric diesel cars would be more efficient than gasoline hybrids

Fuel Cells

- Twice as efficient as internal combustion engines
- Use hydrogen gas as a fuel to produce electricity with no carbon dioxide emissions

13

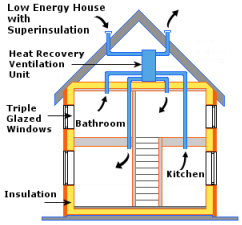
Green Architecture

- Better architecture and energy saving building practices could save 30-40% of global energy
- Green architecture takes advantage of: natural lighting, passive solar heating, geothermal heat pumps, cogeneration, solar hot water heaters, natural ventilation, recycled building materials, energy efficient lighting, rainwater collection, efficient water use

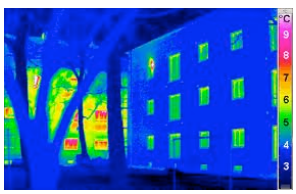
14

Superinsulation

- When a house is so heavily insulated and airtight that heat from direct sunlight, appliances, and human bodies can warm it with little or no use of a heating system.



- Air-to-air heat exchangers prevents indoor air pollution
- Costs 5% more to build (this cost is made up within 5 years). Can save $50,000-100,000 over a 40 year period



- Superinsulated houses in Sweden use 90% less energy than similar American homes

15

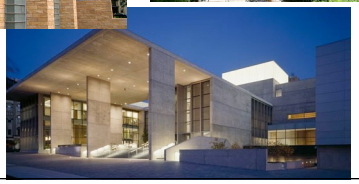
Straw Bale Houses

- Type of superinsulated house
- Made by stacking compact bales of straw (renewable resource) then covering the outside with plaster

16

Green Building Certifications

- U.S. Green Building Council's - Leadership in Energy and Environmental Design (LEED)
  - Accredited more than 25,000 buildings
  - Four levels: Certified, Silver, Gold, and Platinum



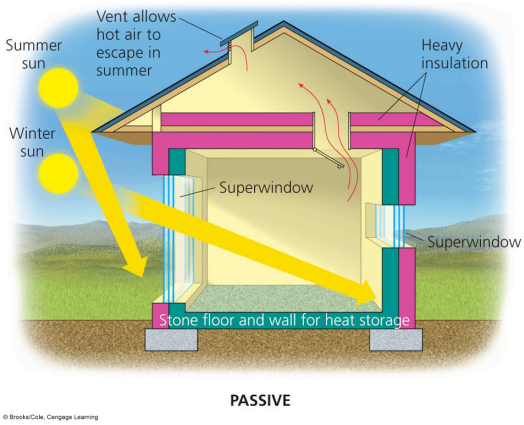
17

Existing Buildings

- Insulate and plug leaks - up to one third of all heated air escapes
- Energy-efficient windows -
- Other heating and cooling losses
- Heat houses more effectively - passive solar heating, geothermal heat pumps
- Heat water more efficiently - solar water heaters, tankless water heater
- Energy efficient appliances
- Energy efficient lighting

18

Passive Solar Heating



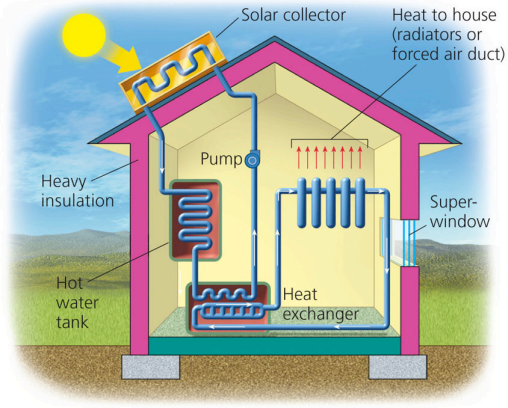
- Absorbs and stores heat from the sun directly within a well-insulated structure without the need for pumps or fans to distribute

Fig. 16-10

19

Active Solar Heating

- Absorbs energy from the sun by pumping heat-absorbing fluid (such as water) through collectors on the roof



20

Solar Thermal System

- Transform energy from the sun into high-temperature thermal energy which can be used to heat water and produce steam and generate electricity
- Central Receiver System - mirrors (heliostats) track the sun and focus sunlight on a central heat collection tower (power tower)
- Sunlight can also be focused on oil filled pipes
- These systems have high costs, low energy yields, and few sustainable sites

21

Solar Cookers

- Small scale
- Focuses and and concentrates sunlight to cook food
- Cost only $2-10 to build
- Zero pollution way to cook

22

Photovoltaic (PV) Cells

- Often called “solar cells”
- Thin wafers of purified silicon with trace amounts of metals that allows them to focus as semiconductors to produce electricity
- Can be connected to the grid (earn money back from power company) or to batteries (store energy)
- Safe, quiet, little maintenance, produce no pollution, last as long as a commercial power plant
- Good tool for developing countries not connected to an electrical grid

23

Small and Large Scale

Fig. 16-18 Largest Solar Energy Producers Germany, Japan, and China Fig. 16-19

24

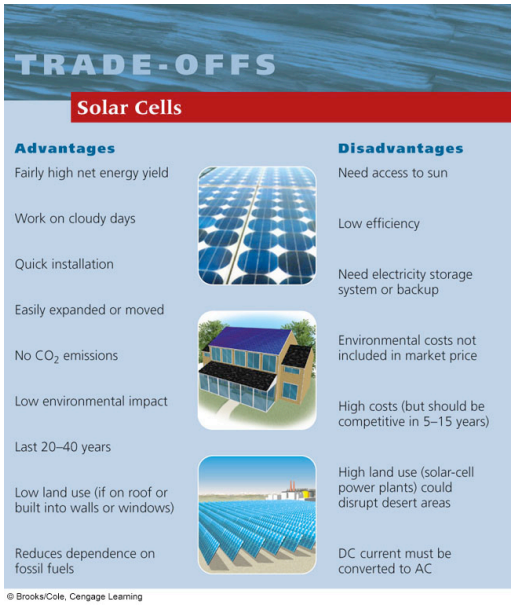


Fig. 16-20

25

Cost of Solar Energy

- Costs are expected to go down as mass production begins

Table 16-1

Total Costs of Electricity from Different Sources in 2004
(in U.S. cents per kilowatt-hour)

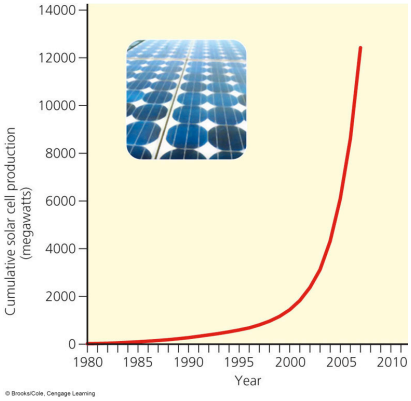
Electricity Source	Generating Costs	Environmental Costs	Total Costs
Wind	4.7–6.3	0.1–0.3	4.8–6.6
Geothermal	4.8	1.0 (approximately)	5.8
Hydropower	4.9–8.5	0.3–1.1	5.2–9.6
Natural gas	5.2–6.5	1.1–4.5	6.3–11.0
Biomass	5.5–6.4	1.0–3.4	6.5–9.8
Nuclear*	5.9–12.0	0.2–0.7	6.1–12.7
Coal	4.5–5.4	3.0–17.0	7.5–22.4
Solar cells	12.4–26.0	0.7	13.1–26.7

*Plant only. Costs are much higher if entire nuclear fuel cycle is included.

26

Future of Solar

- Currently 0.2% of electricity, but if tax breaks and other subsidies are used, it could eventually provide 16% by 2040.
- Can now print cells like printing a newspaper (flexible, light) at half the cost of rigid panels
- Could become most widely used form of energy within two decades



Pg. S67

27

Future of Solar

- Estimates are that if solar cells are put on just 4% of the world's desert, it could supply the entire world with energy
- Solar industry could become one of the world's largest
- Germany (even though it is cloudy and rainy) is the world's largest producer of solar energy.
  - Huge governmental investment

28

Hydropower

- Relies on the water cycle (Indirect from of solar energy)
- Most common means of production is to build a dam and create a reservoir
- Third cheapest way to produce energy (when environmental costs are considered)
- Global warming could have an impact on this
- Micro-hydropower - small and placed in stream (low cost, almost zero environmental impact)

29

Ocean Tides and Waves

- Turbines placed in tidal zones to harness the power of the tides
- Chains of floating steel tubes can be installed along coasts with continuous waves that get energy from up and down motion (In Portugal this produces enough electricity for 15,000 homes)

30

Wind Power

- Indirect form of solar energy (difference in heating between equator and poles combined with Earth's rotation)
- Today's turbines can generate 20 times more energy than those produced in the 1980s
- 2nd fastest growing source of energy
- Germany hopes to get 30% of its electricity from wind by 2030
- Capturing only one-fifth of the wind energy at the world's best sites would generate more than seven times the amount of electricity currently used in the world

31

Offshore Wind Farms

- Wind speeds are often stronger and steadier over water
- Installation costs are higher
- Critics site "visual pollution"
  - Cape Cod, Massachusetts
  - Lake Michigan

32

Wind Energy Challenges

- Locations with greatest wind potential are often located far away from heavily populated areas (need to expand the current grid system)
- If winds die down, it requires a back up energy source.
  - Could store wind energy with plug-in hybrids or passing it through water to make hydrogen fuel cells
  - Could store it in the form of compressed air.

33

Wind Energy Challenges

- Does occasionally result in the death of birds (40,000 bird a year) but other sources like windows, buildings, and electrical transmission towers kill over 1 billion birds a year
- Perceived as noisy and ugly
    - Farmers can earn $3,000-$10,000 per turbine per year

34

Biomass

- Plant materials and animal wastes that can be directly burned or converted into gas or liquid biofuels
- Supplies 10% of world's energy (35% in developing countries and 95% in poor countries)
- Wood chips and waste can be burned to produce electricity and heating systems (half of the heating in Sweden, 80% of downtown St. Paul, Minnesota)
- Wood is renewable as long as it is not harvested faster than it is grown (choose fast growing plants/trees)
- Can also use waste materials from crop harvests

35

Biodiesel and Ethanol

- Produced from plants and plant waste
- Reduces dependence on imported oil
- Crops not used faster than they are replenished (no net increase in carbon dioxide emissions)
- Can be distributed through existing networks
- Problems: Decreases biodiversity (monocultures), soil degradation (erosion, nutrient leaching), raise food prices

36

Is Biodiesel the Answer?

- Vegetable oil from soybeans, sunflowers, etc.
- Type of plant used impacts how much biodiesel can be produced
- 40% more efficient than conventional gasoline engines
- Could produce 10% of U.S. diesel fuel needs

37

Is Ethanol the Answer?

- Made through distillation of sugars from sugarcane, corn, and switchgrass
- Gasohol - 10-23% ethanol with gasoline can be burned in conventional engines
- E85 - 85% ethanol (flex-fuel)
- Brazil is the 2nd largest ethanol producer (behind U.S.)
  - 45% of Brazil's vehicles run on ethanol
  - Saved $50 billion in oil costs since 1970s (10 times investment in ethanol

38

Is Ethanol the Answer?

- In the U.S., ethanol is made from corn
- Huge government subsidies
- Net energy is only 1.1-1.5 units per unit of fossil fuel
- May increase climate change because of huge amounts of nitrogen fertilizers used to produce corn (greenhouse gas nitrous oxide)

39

Geothermal

- Heat stored in soil, underground rocks, and fluids
- Used to heat and cool buildings as well as produce electricity
- Estimated that using 1% of the heat in the upper 5km of Earth's crust could provide 250 times more energy than oil and natural gas reserves

40

Geothermal Heat Pump

- Loop of pipes
- In winter extracts heat from ground
- In summer deposits heat in ground

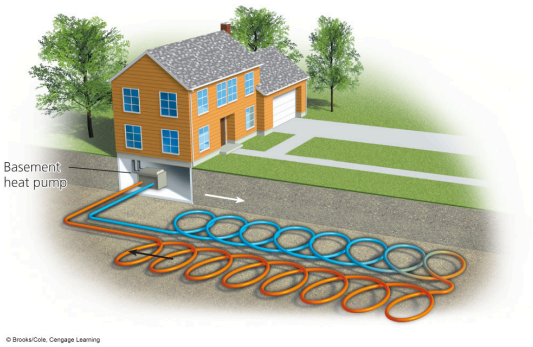


Fig. 16-28

41

Hydrothermal Reservoirs

- Iceland has done this for decades
- Drill wells into reservoirs to extract steam and hot water which is used to heat buildings and produce electricity
- Cool water is pumped back to be reheated
- U.S. is the largest producer of geothermal energy (mostly in California, Nevada, Utah, and Hawaii)
- Releases one-sixth as much carbon dioxide as a natural gas power plant

42

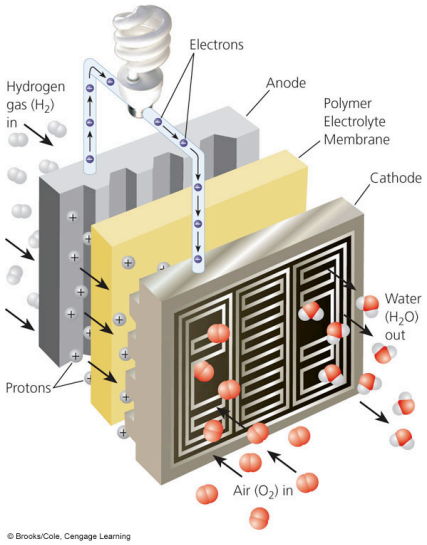


Fig. 16-30

Hydrogen

- Fuel cells that combine hydrogen gas and oxygen to produce electricity and emit water
- Would eliminate air pollution problems and reduce climate change (produces no carbon dioxide)

43

Problems with Hydrogen

- Hydrogen is chemically locked up in water and organic compounds - takes energy to separate it (net energy yield will always be negative)
- Fuel cells are very expensive
- Produces no carbon dioxide directly, but the energy to separate hydrogen uses conventional energy sources
- Pure hydrogen and pure oxygen are explosive

44

Energy Transition

- Need to: improve efficiency, use a mix of renewable energy resources, and include environmental costs into market prices
- Supply-side (hard-path) - finding more nonrenewable resources
- Demand-side (soft-path) - reducing energy waste and depending on a mix of renewable resources
- Make a shift from centralized macropower systems to smaller, decentralized micropower systems

45

Governmental Controls

- To ensure a sustainable future:
  - Keep prices of selected energy resources low to encourage use
    - Currently R &D (2007) $159 million for solar energy, $303 million for nuclear energy, and $427 million for coal
  - Keep prices high for selected resources to discourage use
  - Emphasize consumer education
    - Inform about incentives and advantages

Californian Model

- Very powerful/influential (On its own, it would be the world's 6th largest economy.)
- Uses less energy per person than any other U.S. state.
  - Average U.S. citizen uses 12,000 kWh of energy per day
  - Californians use less than 7,000 kWh (save $800 per person)
- Higher electricity rates (promotes energy efficiency)
- California has decreased carbon dioxide emissions by 30%