Chapter 22
Energy Sources

Energy Sources
- As demand increased, reliable sources were required
- Oil, coal, and natural gas represent 90% of the world’s commercially traded energy
- These are non-renewable energy sources

Resources and Reserves
- Resource: a commodity that is useful to humans and can be extracted
- Reserve: resources that can be profitably extracted
- Resources change with amount used, reserves are subjected to market forces
Fossil Fuels

- Estimated 200 year supply at present rate of demand (based on reserves)
- Oil reserves, however, are estimated to last only 50 years, natural gas for 55 years
- Will current resources become tomorrow’s reserves? Will new resources be discovered?

Nonrenewable Energy

% of energy used worldwide

- Coal = 27%
  - (47% of electricity generated from coal)
- Oil = 40%
- Natural Gas = 21%

Formation of Fossil Fuels

- Approximately 300 million years ago, many wetlands occurred
- Plant and animal decomposition is inhibited under water
- Peat - first step
- When buried under seas, the weight of sediments and water coupled with high pressure - lignite coal

Fossil Fuels

- Lignite - hard, low grade. Less water and higher proportion of burnable material than peat
- If enough heat and pressure, bituminous coal is formed. Soft coal with low water content
- Given enough time at very high temperature and pressure - anthracite
Oil
- Formed from vast pool of bodies of microorganisms which release droplets of oil on decomposition
- Sediments trap oil in a shale formations, oil is not concentrated
- Sandstone layers above the shale allows oil pools to develop in pores of sandstone.
- Middle East has 90% of oil reserves

Natural Gas
- Similar to oil, but end products are more volatile.
- Usually found at the top of oil formation
- There are vast stores, but distribution is a problem.

Crude Oil and Natural Gas Pool

Extracting Coal
- Lignite - least desirable form
- Bituminous - easy to mine but not very clean ... supplies about 20 percent of the world's energy
- Anthracite - most energy per ton, but often deep and thus expensive to mine.

Coal Resources
- Bituminous and anthracite - estimated 618 billion tons.
- 1993: 3.5 billion tons produced (25% increase since 1980, mostly by United States and China.
- Note production versus known reserves!!!
Two Methods of Mining Coal

- **Surface mining or strip mining**
  - <100 meters deep
  - remove overburden
  - very efficient in terms of the percent of coal the mine recovers
  - can remove practically 100 percent of coal.

Other Method of Mining Coal

- **Underground mining**
  - Vertical shaft down to coal seam
  - Horizontal shaft sunk down through seam

Problems

- Land must be reclaimed after surface mining (costs passed to consumers)
- Land subsides (underground mines)
- Black lung disease (costs not passed to consumers - externality)
- transportation costs
- air pollution (dust and burning)
- Acid mine drainage

Extracting Oil

- Easy oil fields have been drained
- Cost (in US) is continually increasing
- 1993 - estimated 1000 billion barrels of reserves (3/4 in OPEC)
- About 66% of oil must be recovered by some means other than pumping - secondary recovery ... many methods

Crude Oil Refining

- Distillation tower allows various components to be separated
- Cracking (heat and pressure) produces more volatile chemicals
- Products are raw materials for many other products (e.g. plastics)
Problems with Oil

- Many similar to coal
- Oil spills in oceans is about 40% of the total pollution, 60% from routine handling
- Oil in soils contaminates underground water
- Photochemical smog

Extracting Natural Gas

- Supplies about 21% of the world’s energy
- Typically found by drilling wells, often found with oil
- Long pipelines are expensive, so much natural gas is burned as a waste product

Natural Gas

- Can be liquefied at cold temperature
- Can be converted to methanol
- Used to make fertilizers and various petrochemicals
- Russia and Middle East have 3/4 of the known reserves
- 1/3 of these reserves are in just 10 large fields

Natural Gas

- 100% increase in production in the last 25 years
- Many countries increase usage when oil prices increase
- Major obstacle for using natural gas (especially in developing nations) is in distribution.
Natural Gas - Problems

- Most environmentally friendly of the three major fossil fuels
- Some odor
- Some danger of explosion or fire
- Few known environmental problems if spilled
- Little air pollution when burned
Annual KWH Consumption per customer

- New York City: 4,696
- San Francisco: 6,753
- Chicago: 8,143
- Phoenix: 13,344
- Houston: 14,542
- Dallas: 16,116

Energy Consumption by state

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Energy Conservation
- Potential for 50% reduction in energy use
- Stoves versus open fires
- Fluorescent lights (lights and A/C account for 25 percent of U.S. electricity usage).
- Low emissive glass
- Automatic light shut-off
- Economics - short term vs. long term
Renewable Energy Sources

- Biomass
- Solid Waste (paper, plastic)
- Solar
- Geothermal
- Tidal
- Technological problems in replacing fossil fuels - currently 90% of world’s energy

Status of Renewable Energy

- Water Power
  - Long history of use (grain mills, sawmills, textile machinery)
  - Hydroelectric power plants built on mountain streams or included in dams
  - Now produces about 2.4 percent of world’s energy

Water Power - Problems

- Loss of farmland
- Loss of stream/river habitat — species lost, undesirable species appear - Schistosomes
- Relocation of people - Aswan dam in Egypt 80,000 people moved

Tidal Power

- Trap energy in moving water
- Only one large scale tidal generating station in the world - France. 240 megawatts capacity, 62 megawatts production.
- England is considering a 7200 megawatt plant (similar in cost to coal-fired plant)
Problems with Tidal Power

- Hydraulic disruption in estuary
- Pollutants can concentrate
- Areas for useful tidal power are hard to find.

Geothermal Power

- Earth’s core reaches temperatures of 4400°C - HUGE amount of energy
  - Volcanoes
  - Heated ground water vents in springs and geysers
  - Heat can turn water into steam ... hence geothermal energy

- Energy is tapped by drilling wells and using steam to turn turbines.
- U.S. has the world’s largest geothermal plant (California). Produces enough electricity to supply San Francisco (2.9 million people)

Geothermal Power

- Generates less air pollution than most other means of power generation.
- Typically less expensive than fossil fuel plants.
- Many plants are operating or are in the planning stages.
**Geothermal - Problems**

- Good sites often require habitat destruction
- Hydrogen sulfide production
- Minerals may be corrosive to pipes
- Minerals may be toxic to fish or other organisms.

**Wind Power**

- A form of solar energy
- Long history of use - grain mills, water pumps, sails on ships
- Recently used to generate electricity (stationary and portable units)
- California, the Netherlands, and India plan for 5 to 8 percent energy production from wind.

**Wind Resources**
Wind Power - Problems

- Need a steady, dependable source of wind.
- Aesthetic Impacts

Solar Energy

- Sun’s energy is steady, and far exceeds the world’s demands (600 times greater than that produced by all other forms)
- Passive systems - Light energy converted to heat energy
  - Maintenance free, but practical only in new buildings.
Active Systems
- Passively heat liquid, and actively transfer (pump) heat
- Pumps require maintenance, cost may be high
- Must store heat for times when sun energy is low
- Can recoup construction costs in 3-10 years.

Solar Generated Electricity
- Bell labs invented the photo-voltaic cell in 1954.
- Many small or remote location uses
- Can use solar energy to heat oil and then water to drive steam generators ... Can heat fluids to 390°C plus.
- Price is dropping for photo-voltaic cells and for steam generators.

Solar Energy Problems
- Currently provides less than 1% of total world energy
- Intermittent supply of solar energy - cloudy day = no energy
- Usually must supplement with some other form
- Still relatively expensive technology

Fuel Wood
- Provides 10 percent of the home heating energy in the US. Provides 3 percent of TOTAL energy in Canada.
- In many of the developing nations, fuel wood provides up to 75 percent of the total energy.

Problems with Fuel Wood
- Transportation
- Fuel is used at a faster rate than it can be grown.
- Desertification
- Air pollution (fly ash and carbon monoxide)
- Produces known carcinogens (75 organic compounds released - 25 known or suspected carcinogens
**Biomass**
- Derived energy from chemical energy stored in biomass
- Methane digesters
- Alcohol produced by fermentation
- Wood burning electrical generators

**Biomass - Problems**
- Most often used in countries with food shortages
- Nutrients removed from the soil
- More energy input than output.

**Solid Waste (Trash Power)**
- 1.8 Kg of solid waste per person discarded each day in New York. 80 percent of this material is combustible
- Reduces volume of waste and can generate electricity
- U.S. does little trash power

**Solid Waste - Problems**
- waste must be sorted
- waste stream must be steady
- air pollution
- toxic compounds released (very big concern ... dioxins).

**Hydrogen Fuel cells**
- Hydrogen molecules give up electrons and form hydrogen ions (protons) via a catalyst (platinum)
- Electrons travel from the anode (negative electrode) to the positive electrode (i.e., the cathode) through an external circuit. The electric current generated can power electric motors.
- Protons pass across the PROTON EXCHANGE MEMBRANE (PEM) to the positive electrode where they combine with oxygen from the air and with the electrons from the external circuit, to form water molecules
Efficiency and pollution

- Fuel cells are two-three times more efficient than the internal combustion engine in converting fuel to power.
- Since fuel is electrochemically converted rather than burned, there is no air pollution. The only byproducts are water and heat.
- If liquid fuels are reformed onboard the vehicle to produce hydrogen, carbon dioxide and hydrocarbon emissions are produced.