Nonrenewable Energy

Chapter 15

15-1 What Major Sources of Energy Do We Use?

- ***Concept 15-1A*** *About three-quarters of the world's commercial energy comes from nonrenewable fossil fuels and the rest comes from nonrenewable nuclear fuel and renewable sources.*
- ***Concept 15-1B*** *Net energy is the amount of high-quality usable energy available from a resource after the amount of energy needed to make it available is subtracted.*

Commercial Energy Use by Source for the World and the U.S.

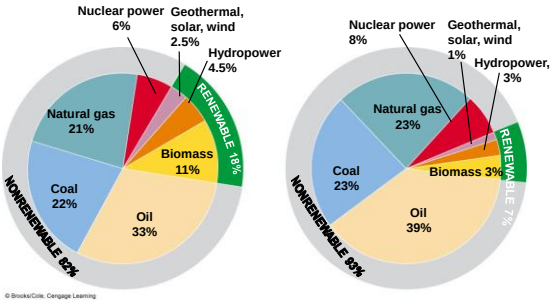


Fig. 15-3, p. 373

How Should We Evaluate Energy Resources?

- Supplies (limited **non**renewable)
- Environmental impact (mining and fracking; pollution; unintended consequences: oil spills, nuclear accidents)
- How much **useful** energy is provided (how much lost as heat?)? What is **efficiency** of resource?

Science Focus: Net Energy Is the Only Energy That Really Counts

- It takes energy to get energy
- Second Law of Thermodynamics
- **Net energy** expressed as **net energy ratio**
- Conventional oil: high net energy ratio
- Electricity produced by the **nuclear power fuel cycle**: low net energy ratio

Net Energy

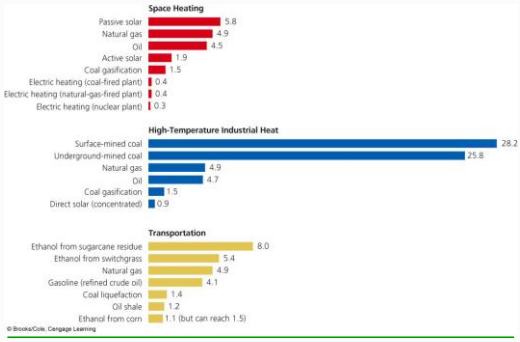
Net energy is the amount of high-quality usable energy available from a resource after subtracting the energy needed to make it available for use.

Net energy ration = useful energy produced:energy used to produce it

ie. 10:8 (10/8) for every 10 units of energy in oil we have to use and waste 8 units of energy. The net energy ratio is 10/8 or 1.25. The higher the ratio, the greater the net energy.

When the ratio is less than 1, there is a net energy loss.

Net Energy Ratios for Various Energy Systems over Their Estimated Lifetimes



15-2 What Are the Advantages and Disadvantages of Oil?

- ***Concept 15-2A*** *Conventional oil is currently abundant, has a high net energy yield, and is relatively inexpensive, but using it causes air and water pollution and releases greenhouse gases to the atmosphere.*
- ***Concept 15-2B*** *Heavy oils from oil sand and oil shale exist in potentially large supplies but have low net energy yields and higher environmental impacts than conventional oil has.*

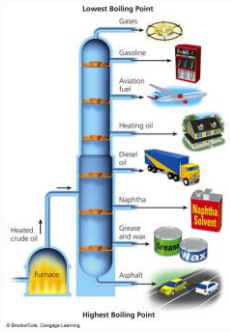
We Depend Heavily on Oil

- **Petroleum**, or **crude oil = conventional**, or **light oil**
- **Fossil fuels**: **crude oil** and **natural gas**
- Oil extraction and refining
- **Petrochemicals**: products of oil distillation
- World oil consumption http://www.eia.gov/countries/index.cfm?view=consumption

Per capita: http://www.indexmundi.com/map/?v=91000

Burning oil for transportation produces 43% of world's CO_2 emissions

Science: Refining Crude Oil



Fractional distillation done at oil refineries

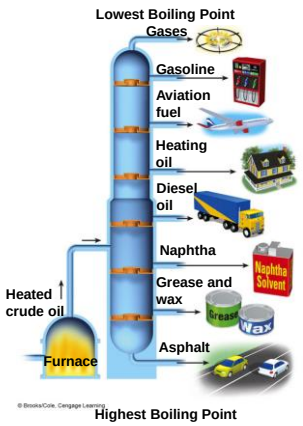


Fig. 15-4a, p. 375

OPEC Controls Most of the World's Oil Supplies (1)

- 13 countries have at least 60% of the world's crude oil **reserves**
  - Saudi Arabia: 25% (largest national reserves)
  - Canada: 15% (much in oil sand)
- Oil production peaks and flow rates to consumers (supply/demand; politics/wars)

OPEC

- **Organization of the Petroleum Exporting Countries (OPEC)**
  - founded in Baghdad, Iraq, with the signing of an agreement in September 1960 by five countries namely Islamic Republic of Iran, Iraq, Kuwait, Saudi Arabia and Venezuela. They were to become the Founder Members of the Organization.
  - These countries were later joined by Qatar (1961), Indonesia (1962), Libya (1962), the United Arab Emirates (1967), Algeria (1969), Nigeria (1971), Ecuador (1973), Gabon (1975) and Angola (2007).

OPEC Controls Most of the World's Oil Supplies (2)

- Possible **effects** of steeply rising oil prices
  - Reduce energy waste
  - Shift to non-carbon energy sources
  - Higher prices for products made with petrochemicals
  - Higher food prices; buy locally-produced food
  - Airfares higher
  - Smaller more fuel-efficient vehicles
  - Upgrade of public transportation

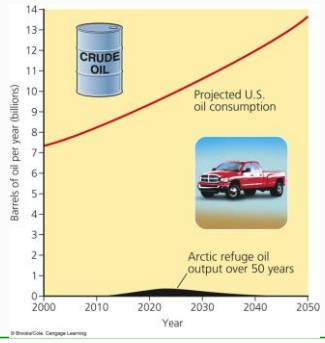
The United States Uses Much More Oil Than It Produces

- Produces 9% of the world's oil
- Imports 60% of its oil
- About One-fourth of the world's conventional oil is controlled by countries that sponsor or condone terrorism
- Should we look for more oil reserves?
  - Difficult, expensive and financially risky

Case Study: Oil and the U.S. Arctic National Wildlife Refuge

- The Arctic National Wildlife Refuge (ANWR)
  - Not open to oil and gas development
  - Fragile tundra biome
  - Would provide ca. 2 yr supply max for U.S.
- Oil companies lobbying since 1980 to begin exploratory drilling
  - Pros – decreased dependence on foreign oil…
  - Cons – only 2 yr supply; fragile ecosystem…

The Amount of Oil That Might Be Found in the ANWR



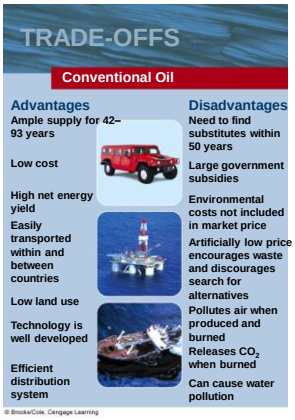


Fig. 15-6, p. 379

Bird Covered with Oil from an Oil Spill in Brazilian Waters

Will Heavy Oils from Oil Sand Be a Viable Option?

- **Oil sand, tar sand** contains **bitumen** (thick, sticky, heavy oil w/ high sulfur content)
- Canada and Venezuela: oil sand reserves have more oil than in Saudi Arabia
- Extraction
  - Serious environmental impact before strip-mining
  - Low net energy yield: Is it cost effective?

Will Oil Shales Be a Useable Resource?

- **Oil shales** contain **kerogen** (a mixture of hydrocarbons)
  - After distillation (removes impurities): **shale oil**
- 72% of the world's reserve is in arid areas of western United States; there is a catch!
  - Locked up in rock (fracking used to extract)
  - Lack of water needed for extraction and processing
  - Low net energy yield

Oil Shale Rock and the Shale Oil Extracted from It

15-3 What Are the Advantages and Disadvantages of Natural Gas?

- ***Concept 15-3*** *Conventional natural gas is more plentiful than oil, has a high net energy yield and a fairly low cost, and has the lowest environmental impact of all fossil fuels.*

Natural Gas Is a Useful and Clean-Burning Fossil Fuel

- **Natural gas:** mixture of gases
  - More than half (50-90%) is CH_4
- **Conventional natural gas**
  - Pipelines required to move
  - **Liquefied petroleum gas (LPG)**
  - **Liquefied natural gas (LNG)** – low net energy yield
- **Unconventional natural gas**
  - **Coal bed methane gas**
  - **Methane hydrate**

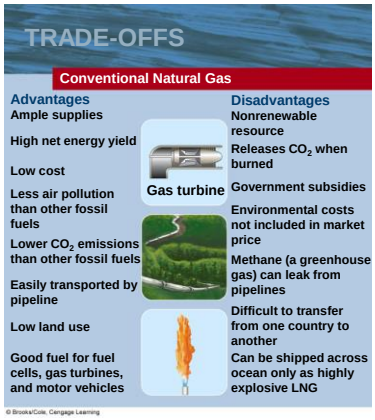


Fig. 15-10, p. 382

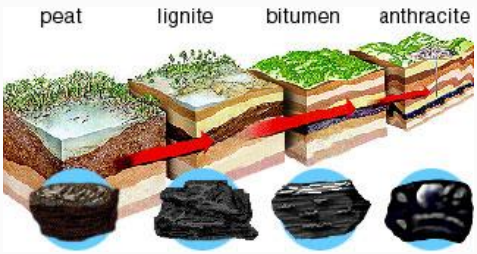
15-4 What Are the Advantages and Disadvantages of Coal?

- ***Concept 15-4A*** *Conventional coal is very plentiful and has a high net energy yield and low cost, but it has a very high environmental impact.*
- ***Concept 15-4B*** *Gaseous and liquid fuels produced from coal could be plentiful, but they have lower net energy yields and higher environmental impacts than conventional coal has.*

COAL

- **Coal is an abundant energy resource that is burned mostly to produce electricity and steel.**
- **Coal is the world's most abundant fossil fuel.**
- **Mostly in USA (25%), Russia (16%), and China (12%)**
- **US coal reserves could last up to 300 years, but an increase of just 4% per year could reduce that to 64 years!**

COAL FORMATION



Advantages of Coal

- ✓ Abundant known world reserves (200 years at current world consumption rate)
- ✓ Unidentified world reserves (1000 years at current consumption rate)
- ✓ USA (300 years at current consumption rate)
- ✓ High Net Energy Yield
- ✓ US subsidies keep prices low

Disadvantages of Coal

- ✓ 60 % surface mined (strip mining) in USA
- ✓ 40 % subsurface mined
- ✓ Occupational hazards include “black lung disease”, underground fires and collapse.
- ✓ 20% of coal becomes fly ash, boiler slag, and sludge. Releases mercury and radioactive particles into air.
- ✓ Expensive to process and transport

Environmental Impacts From Coal

- ✓ Releases CO into atmosphere
- ✓ Contributes 35% of all CO_2 into atmosphere (global warming)
- ✓ Contributes 70 % of all SO_2 (acid deposition)
- ✓ Contributes 30% of all NO and NO_2 (acid deposition)
- ✓ Produces more fly ash, toxic metals, and radioactive particles than a nuclear power plant.

Coal Comes in Several Forms and Is Burned Mostly to Produce Electricity

- **Coal**: solid fossil fuel
- Generates 40% of the world’s electricity
  - Inefficient [way to boil water]
- Three largest coal-burning countries
  - China
  - United States (for ca. 49 % of electricity here)
  - India

Stages in coal formation over millions of years

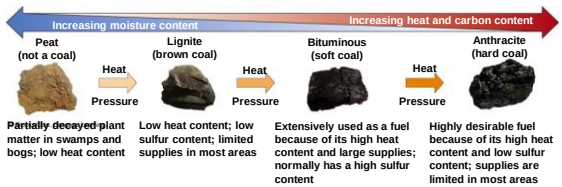


Fig. 15-11, p. 383

Electricity from coal

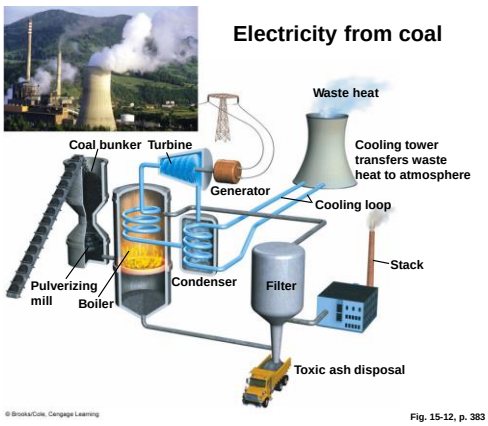


Fig. 15-12, p. 383

Coal Is a Plentiful but Dirty Fuel

- World’s most abundant fossil fuel
  - U.S. has 25% of proven reserves (>200 yr supply)
- Environmental costs of burning coal
  - Severe air pollution
    - Sulfur released as SO_2
    - Large amount of soot
    - CO_2
    - Trace amounts of Hg and radioactive materials
- Environmentalists call for
  - Taxation on CO_2 production by power plants
  - Cleaner coal-burning plants

Air Pollution from a Coal-Burning Industrial Plant in India

Coal Has Advantages and Disadvantages

- Single biggest air polluter in coal-burning countries
- One-fourth of the annual world CO_2 emissions
- Advantages and disadvantages (see next slide)

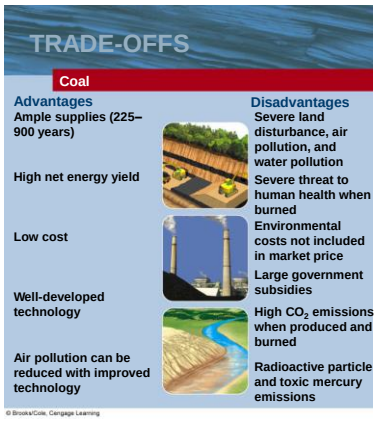


Fig. 15-15, p. 385

We Can Convert Coal into Gaseous and Liquid Fuels

- **Conversion of solid coal to**
  - **Synthetic natural gas (SNG)** by **coal gasification**
  - Methanol or synthetic gasoline by **coal liquefaction**
- Are there benefits to using these synthetic fuels?

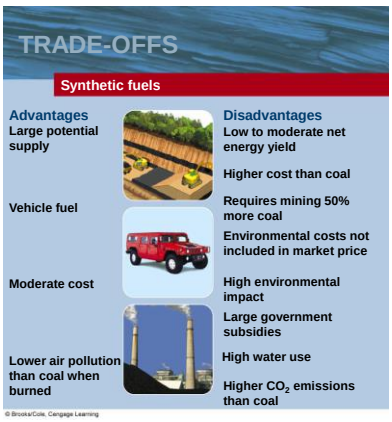
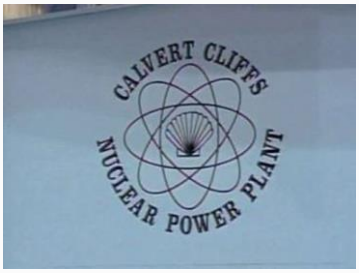


Fig. 15-16, p. 386

15-5 What Are the Advantages and Disadvantages of Nuclear Energy?

- ***Concept 15-5*** *Nuclear power has a low environmental impact and a very low accident risk, but high costs, a low net energy yield, long-lived radioactive wastes, vulnerability to sabotage, and the potential for spreading nuclear weapons technology have limited its use.*

Video: Nuclear energy



How Does a Nuclear Fission Reactor Work?

- Controlled nuclear fission reaction in a **reactor**
  - **Light-water reactors**
- Fueled by uranium ore and packed as pellets in **fuel rods** and **fuel assemblies**
- **Control rods** absorb neutrons
- Water is the usual **coolant**
- **Containment shell** around the core for protection
- **Water-filled pools or dry casks** for storage of radioactive spent fuel rod assemblies

Light-Water-Moderated and –Cooled Power Plant

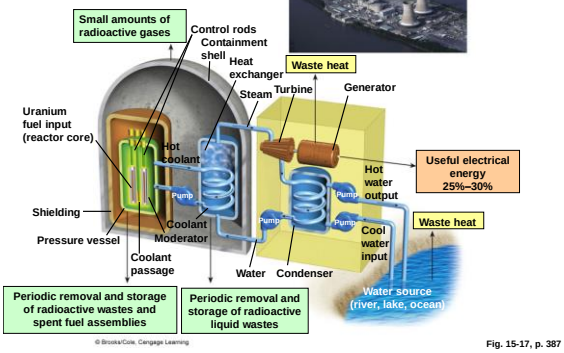
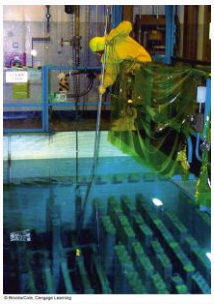


Fig. 15-17, p. 387

After 3 or 4 Years in a Reactor, Spent Fuel Rods Are Removed and Stored in Water



What Is the Nuclear Fuel Cycle?

- Mine the uranium
- Process the uranium to make the fuel
- Use it in the reactor
- Safely store the radioactive waste
- **Decommission** the reactor

What Happened to Nuclear Power?

- Slowest-growing energy source and expected to decline more
- Why?
  - Economics
  - Poor management
  - Low net yield of energy of the nuclear fuel cycle
  - Safety concerns
  - Need for greater government subsidies
  - Concerns of transporting uranium

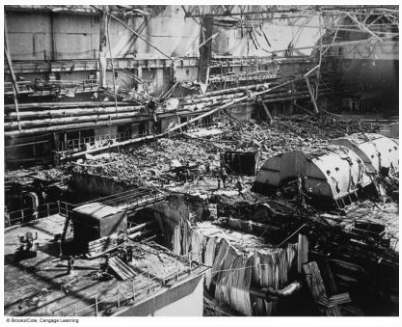
Case Study: Worst Commercial Nuclear Power Plant Accident in the U.S.

- Three Mile Island
  - March 29, 1979
  - Near Harrisburg, PA, U.S.
  - Nuclear reactor lost its coolant
  - Led to a partial uncovering and melting of the radioactive core
  - Unknown amounts of radioactivity escaped
  - Increased public concerns for safety
    - Led to improved safety regulations in the U.S.

Case Study: Worst Nuclear Power Plant Accident in the World

- Chernobyl
  - April 26, 1986
  - In Chernobyl, Ukraine
  - Series of explosions caused the roof of a reactor building to blow off
  - Partial meltdown and fire for 10 days
  - Huge radioactive cloud spread over many countries and eventually the world
  - 350,000 people left their homes

Remains of a Nuclear Reactor at the Chernobyl Nuclear Power Plant



Animation: Chernobyl fallout

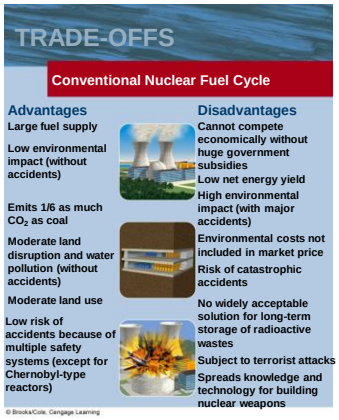


Fig. 15-21, p. 391

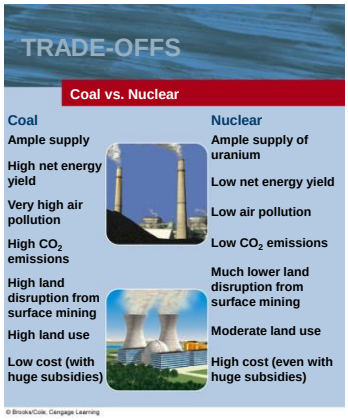


Fig. 15-22, p. 392

Dealing with Radioactive Wastes Produced by Nuclear Power Is a Difficult Problem

- **High-level radioactive wastes**
  - Must be stored safely for 10,000–240,000 years
- Where to store it
  - Deep burial: safest and cheapest option
  - Would any method of burial last long enough?
  - **There is still no facility**

Case Study: Experts Disagree about What to Do with Radioactive Wastes in the U.S.

- 1985: plans in the U.S. to build a repository for high-level radioactive wastes in the Yucca Mountain desert region (Nevada)
- Problems
  - Cost: $58–100 billion
  - Large number of shipments to the site: protection from attack?
  - Rock fractures
  - Earthquake zone
  - Decrease national security

What Do We Do with Worn-Out Nuclear Power Plants?

- Decommission or retire the power plant
- Some options
  - Dismantle the plant and safely store the radioactive materials
  - Enclose the plant behind a physical barrier with full-time security until a storage facility has been built
  - Enclose the plant in a tomb
    - Monitor this for thousands of years

Will Nuclear Fusion Save Us?

- "**Nuclear fusion** is the power of the future and always will be"
- Still in the laboratory phase after 50 years of research and $34 billion dollars
- 2006: U.S., China, Russia, Japan, South Korea, and European Union
  - Will build a large-scale experimental nuclear fusion reactor by 2040

Experts Disagree about the Future of Nuclear Power

- Proponents of nuclear power
  - Fund more research and development
  - Pilot-plant testing of potentially cheaper and safer reactors
  - Test breeder fission and nuclear fusion
- Opponents of nuclear power
  - Fund rapid development of energy efficient and renewable energy resources