Mining and Nonrenewable Energy

I. **Mining Law of 1872** – encouraged mineral exploration and mining.
   1. First declare your belief that minerals on the land. Then spend $500 in improvements, pay $100 per year and the land is yours
   2. Domestic and foreign companies take out $2-$3 billion/ year
   3. Allows corporations and individuals to claim ownership of U.S. public lands.
   4. Leads to exploitation of land and mineral resources.

II. Nature and Formation of Mineral Resources

A. **Nonrenewable Resources** – a concentration of naturally occurring material in or on the earth's crust that can be extracted and processed at an affordable cost. Non-renewable resources are mineral and energy resources such as coal, oil, gold, and copper that take a long period of time to produce.

1. **Metallic Mineral Resources** – iron, copper, aluminum
2. **Nonmetallic Mineral Resources** – salt, gypsum, clay, sand, phosphates, water and soil.
3. **Energy resource:** coal, oil, natural gas and uranium

B. **Ore:** rock containing enough minerals to be mined properly

C. **Identified Resources** – deposits of a nonrenewable mineral resource that have a known location, quantity and quality based on direct geological evidence and measurements

D. **Undiscovered Resources**– potential supplies of nonrenewable mineral resources that are assumed to exist on the basis of geologic knowledge and theory (specific locations, quantity and quality are not known)

E. **Reserves** – identified resources of minerals that can be extracted profitably at current prices.

E. **Other Resources** – resources that are not classified as reserves.

F. **Ore Formation**

1. **Magma (molten rock)** – magma cools and crystallizes into various layers of mineral containing igneous rock.
2. **Hydrothermal Processes**: most common way of mineral formation
   A. Gaps in sea floor are formed by retreating tectonic plates
   B. Water enters gaps and comes in contact with magma
   C. Superheated water dissolves minerals from rock or magma
   D. Metal bearing solutions cool to form **hydrothermal ore deposits**.
   E. **Black Smokers** – upwelling magma solidifies. Miniature volcanoes shoot hot, black, mineral rich water through vents of solidified magma on the seafloor. Support **chemosynthetic organisms**.
   F. **Manganese Nodules (pacific ocean)**– ore nodules crystallized from hot solutions arising from volcanic activity. Contain manganese, iron copper and nickel.
3. **Sedimentary Processes** – sediments settle and form ore deposits.

A. **Placer Deposits** – site of sediment deposition near bedrock or course gravel in streams
B. **Precipitation**: Water evaporates in the desert to form **evaporite mineral deposits**. (salt, borax, sodium carbonate)
C. **Weathering** – water dissolves soluble metal ions from soil and rock near earth's surface. Ions of insoluble compounds are left in the soil to form **residual deposits** of metal ores such as iron and aluminum (bauxite ore).

III. Methods For Finding Mineral Deposits

A. Photos and Satellite Images
B. Airplanes fly with radiation equipment and magnetometers
C. Gravimeter (density)
D. Drilling
E. Electric Resistance Measurement
F. Seismic Surveys
G. Chemical analysis of water and plants

IV. Mineral Extraction

A. **Surface Mining**: **overburden** (soil and rock on top of ore) is removed and becomes **spoil.**
   1. **open pit mining** – digging holes
   2. **Dredging** – scraping up underwater mineral deposits
   3. **Area Strip Mining** – on a flat area an earthmover strips overburden
   4. **Contour Strip Mining** – scraping ore from hilly areas

B. Subsurface Mining:
   1. dig a deep vertical shaft, blast underground tunnels to get mineral deposit, remove ore or coal and transport to surface
   2. disturbs less land and produces less waste
   3. less resource recovered, more dangerous and expensive
   4. Dangers: collapse, explosions (natural gas), and lung disease

V. Environmental Impacts of Mineral Resources

A. Scarring and disruption of land,
B. Collapse or subsidence
C. Wind and water erosion of toxic laced mine waste
D. Air pollution – toxic chemicals
E. Exposure of animals to toxic waste
F. Acid mine drainage: seeping rainwater carries sulfuric acid (acid comes from bacteria breaking down iron sulfides) from the mine to local waterway
G. Life Cycle of Metal Resources (fig. 14-8)
   1. Mining Ore
      A. Ore has two components: gangue(waste) and desired metal
      B. Separation of ore and gangue which leaves **tailings**
      C. **Smelting** (air and water pollution and hazardous waste which contaminates the soil around the smelter for decades)
      D. Melting Metal
      E. Conversion to product and discarding product

VII. Mineral Supplies

A. Future supplies depend on actual supply and rate of use
B. When they are economically depleted we can
   1. recycle or reuse
   2. waste less
   3. use less
   4. find substitute
   5. do without
C. **Depletion time** – time it takes to use up a certain proportion(80%) of a mineral at a given usage rate.

VIII. Economic Impact on Mineral Supplies

A. Mineral prices are low because of subsidies: depletion allowances and deduct cost of finding more
B. Mineral scarcity does not raise the market prices
C. Mining Low Grade Ore: Some analysts say all we need to do is mine more low grade ores to meet our need
   1. We are able to mine low grade ore due to improved technology
   2. The problem is cost of mining and processing, availability of fresh water, environmental impact
D. Mining Oceans
   1. Minerals are found in seawater, but occur in too low of a concentration
   2. Continental shelf can be mined
   3. Deep Ocean are extremely expensive to extract (not currently viable)
E. Substitutes for metals
   1. Materials Revolution
   2. Ceramics and Plastics
   3. Some substitutes are inferior (aluminum for copper in wire)
   4. Will be difficult to find substitutes for helium, manganese, phosphorus and copper

IX. Evaluating Energy Sources

A. What types of energy do we use?
   1. 99% of our heat energy comes directly from the sun (renewable fusion of hydrogen atoms)
   2. Indirect forms of solar energy (renewable)
   3. wind
   4. hydro
   5. biomass
B. 1% of our energy comes from commercial energy produced by nonrenewable organic fossil fuels (petroleum, natural gas and coal)
   1. 75% fossil fuels
   2. 6% nuclear
C. 1% of commercial energy consumed comes from nonrenewable energy resources
D. 20th Century Trends
   1. Coal use decreases from 55% to 22%
   2. Oil increased from 2% to 30%
   3. Natural Gas increased from 0% to 25%
   4. Nuclear increased from 0% to 6%

E. Evaluating Energy Resources; Take into consideration the following:
    a. Availability
    b. net energy yield
    c. Cost
    d. environmental impact
F. **Net Energy** – total amount of energy available from a given source minus the amount of energy used to get the energy to consumers (locate, remove, process and transport)
    G. **Net Energy Ratio** - ratio of useful energy produced to the useful energy used to produce it.

X. Oil
    A. **Petroleum/Crude Oil** – thick liquid consisting of hundreds of combustible hydrocarbons and small concentrations of nitrogen, sulfur, and oxygen impurities.
    B. Produced by the decomposition of dead plankton that were buried under ancient lakes and oceans. It is found dispersed in rocks.

C. Oil Life Cycle
1. Primary Oil Recovery
    a. drill well
    b. pump out light crude oil
2. Secondary Oil Recovery
    a. pump water under pressure into a well to force heavy crude oil toward the well
    b. pump oil and water mixture to the surface
    c. separate oil and water
    d. reuse water to get more oil
3. Tertiary Oil Recovery
    a. inject detergent to dissolve the remaining heavy oil
    b. pump mixture to the surface
    c. separate out the oil
    d. reuse detergent
4. Transport oil to the refinery (pipeline, truck, boat)
5. Oil refining – heating and distilling based on boiling points of the various petrochemicals found in the crude oil. (fractional distillation in a cracking tower)
6. Conversion to product
    a. Industrial organic chemicals
    b. Pesticides
    c. Plastics
    d. Synthetic fibers
    e. Paints
    f. Medicines
    g. Fuel

D. Location of World Oil Supplies
1. 64% Middle East (67% OPEC – 11 countries)
    a. Saudi Arabia (26%)
    b. Iraq, Kuwait, Iran, (9-10% each)

2. Latin America (14%) (Venezuela and Mexico)
3. Africa (7%)
4. Former Soviet Union (6%)
5. Asia (4%) (China 3%)
6. United States (2.3%) we import 52% of the oil we use
7. Europe (2%)

E. How long will the oil last

1. Identified Reserve will last 53 years at current usage rates
2. Known and projected supplies are likely to be 80% depleted within 42 to 93 years depending on usage rate
    1. US oil supplies are expected to be depleted within 15 to 48 years depending on the annual usage rate

F. Heavy Oils

1. **Oil Shale** – fine grained sedimentary rock containing solid organic combustible material called **kerogen**
2. **Shale Oil** – kerogen distilled from oil shale.
    a. could meet U.S. crude oil demand for 40 years at current usage rates (Colorado, Utah and Wyoming public lands)
3. **Tar Sand** – mixture of clay sand and water containing bitumen (high sulfur heavy oil)

XI. Natural Gas

A. Natural Gas is a mixture of 50-90% methane (CH_4) by volume; contains smaller amounts of ethane, propane, butane and toxic hydrogen sulfide.B.

1. **Conventional natural gas** - lies above most reservoirs of crude oil
2. **Unconventional deposits** - include coal beds, shale rock, deep deposits of tight sands and deep zones that contain natural gas dissolved in hot hot water.
3. **Gas Hydrates** - an ice-like material that occurs in underground deposits (globally)
4. **Liquefied Petroleum Gas (LPG)** - propane and butane are liquefied and removed from natural gas fields. Stored in pressurized tanks.
5. Liquefied Natural Gas (LNG) - natural gas is converted at a very low temperature (-184^{o}C)

B. Where is the world's oil?

Russia and Kazakhstan - 40%
Iran - 15%
Qatar - 5%
Saudi Arabia - 4%
Algeria - 4%
United States - 3%
Nigeria - 3%
Venezuela - 3%

C. Pros and Cons of Oil of Natural Gas

I. Advantages:

Cheaper than Oil
World reserves - >125 years
Easily transported over land (pipeline)
High net energy yield
Produces less air pollution than other fossil fuels
Produces less CO2 than coal or oil
Extracting natural gas damages the environment much less that either coal or uranium ore
Easier to process than oil
Can be used to transport vehicles
Can be used in highly efficient fuel cells

Disadvantages:

When processed, H_2S and SO_2 are released into the atmosphere
Must be converted to LNG before it can be shipped (expensive and dangerous)
Conversion to LNG reduces net energy yield by one-fourth
Can leak into the atmosphere; methane is a greenhouse gas that is more potent than CO_2.

XII. Coal

A. Coal is a solid, rocklike fossil fuel; formed in several stages as the buried remains of ancient swamp plants that died during the Carboniferous period (ended 286 million years ago); subjected to intense pressure and heat over millions of years.

B. Coal is mostly carbon (40-98%); small amount of water, sulfur and other materials

C. Three types of coal
1. lignite (brown coal)
2. bituminous coal (soft coal)
3. anthracite (hard coal)
4. Carbon content increases as coal ages; heat content increases with carbon content.

D. Subsurface Mining - labor intensive; world's most dangerous occupation (accidents and black lung disease)

E. Surface Mining - three types
1. Area strip mining
2. contour strip mining
3. open-pit mining

F. How is coal used?
1. Coal provides 25% of world's commercial energy (22% in US).

2. Used to make 75% of world's steel
3. Generates 64% of world's electricity

G. Remainder of world's electricity is produced by:

1. hydroelectric dams - 18%
2. nuclear energy - 17%
3. other renewable sources (wind, solar, etc.)
4. In US electricity is produced by coal (57%), nuclear energy (19%), natural gas (11%), hydroelectric power (9%), oil (3%) and renewable resources (1%)

H. Coal-Fired Electric Power Plant

1. Coal is pulverized to a fine dust and burned at a high temperature in a huge boiler. Purified water in the heat exchanger is converted to high-pressure steam that spins the shaft of the turbine. The shaft turns the rotor of the generator (a large electromagnet) to produce electricity.
2. Air pollutants are removed using electrostatic precipitators (particulate matter) and scrubbers (gases). Ash is disposed of in landfills. Sulfur dioxide emissions can be reduced by using low-sulfur coal.

I. World's Coal Supplies

1. US - 66% of worlds proven reserves
   Identified reserves should last 220 years at current usage rates.
   Unidentified reserves could last about 900 years

J. Pros and Cons of Solid Coal

Advantages: World's most abundant and dirtiest fossil fuel,
High net energy yield

Disadvantages:

- harmful environmental effects

-mining is dangerous (accidents and -black lung disease)
-harms the land and causes water pollution
-Causes land subsidence
-Surface mining causes severe land disturbance and soil erosion
-Surface mined land can be restored - involves burying toxic materials, returning land to its original contour, and planting vegetation (Expensive and not often done)
-Acids and toxic metals drain from piles of water materials
-Coal is expensive to transport
-Cannot be used in sold form in cars (must be converted to liquid or gaseous form)
-Dirtiest fossil fuel to burn releases CO, CO_2, SO_2, NO, NO_2, particulate matter (flyash), toxic metals and some radioactive elements.
-Burning Coal releases thousands of times more radioactive particles into the atmosphere per unit of energy than does a nuclear power plant
-Produces more CO_2 per unit of energy than

other fossil fuels and accelerates global warming.

-A severe threat to human health (respiratory disease)

K. Clean Coal Technology

1. **Fluidized-bed combustion -** developed to burn coal more cleanly and efficiently.
2. **Use of low sulfur coal -** reduces SO_2 emission
3. **Coal gasification** – uses coal to produce synthetic natural gas (SNG)
4. **Coal liquefaction -** produce a liquid fuel - methanol or synthetic gasoline
5. **Synfuels -** can be transported by pipeline inexpensively; burned to produce electricity; burned to heat houses and water; used to propel vehicles.
6. **Coal gasification and coal liquefaction -** low net energy yield; 30-40% of energy content would be lost in the energy conversion
7. **Synfuels -** requires huge amount of water, release more CO_2 than coal.

XIII. Nuclear Energy

A. Three reasons why nuclear power plants were developed in the late 1950s:

1. Atomic Energy Commission promised electricity at a much lower cost than coal
2. US Gov't paid ~1/4 the cost of building the first reactors
3. Price Anderson Act protected nuclear industry from liability in case of accidents

B. Globally, nuclear energy produces only 17% of world's electricity (6% of commercial energy)
Why is nuclear power on the decline?

- huge construction overruns

-high operating costs
-frequent malfunctions
-false assurances
-cover-ups by government and industry
-inflated estimates of electricity use
-poor management
-Chernobyl
-Three Mile Island
-public concerns about safety, cost and disposal of radioactive wastes

C. How a Nuclear Reactor Works

Nuclear fission of Uranium-235 and Plutonium-239 releases energy that is converted into high-temperature heat. This rate of conversion is controlled. The heat generated can produce high-pressure steam that spins turbines that generate electricity.

D. Light-water reactors (LWR)

1. Core containing 35,000-40,000 fuel rods containing pellets of uranium oxide fuel. Pellet is 97% uranium-238 (nonfissionable isotope) and 3% uranium-235 (fissionable).
2. **Control rods -** move in and out of the reactor to regulate the rate of fission
3. **Moderator -** slows down the neutrons so the chain reaction can be kept going [liquid water in pressurized water reactors; solid graphite or heavy water (D_2O)].
4. **Coolant -** water to remove heat from the reactor core and produce steam
5. 1/3 of fuel rod assemblies must be replaced every 3-4 years. They are placed in concrete lined pools of water (radiation shield and coolant).
    - A. Nuclear wastes must be stored for 10,000 years
    - B. After 15-40 years of operation, the plant must be decommissioned by
        1. dismantling it
        2. putting up a physical barrier, or
        3. enclosing the entire plant in a tomb (to last several thousand years)

F. Advantages of Nuclear Power:

1. Don't emit air pollutants
2. Water pollution and land disruption are low

G. Nuclear Power Plant Safety

1. Very low risk of exposure to radioactivity
2. Three Mile Island - March 29, 1979; No. 2 reactor lost coolant water due to a series of mechanical failures and human error. Core was partially uncovered
3. Nuclear Regulatory Commission estimates there is a 15-45% chance of a complete core meltdown at a US reactor during the next 20 years.
4. US National Academy of Sciences estimates that US nuclear power plants cause 6000 premature deaths and 3700 serious genetic defects each year.

H. Low-Level Radioactive Waste

1. Low-level waste gives off small amounts of ionizing radiation; must be stored for 100-500 years before decaying to levels that don't pose an unacceptable risk to public health and safety

2. 1940-1970: low-level waste was put into drums and dumped into the oceans. This is still done by UK and Pakistan
3. Since 1970, waste is buried in commercial, government-run landfills.
4. Above-ground storage is proposed by a number of environmentalists.
5. 1990: the NRC proposed redefining low-level radioactive waste as essentially nonradioactive. That policy was never implemented (as of early 1999).

I. High-Level Radioactive Waste

1. Emit large amounts of ionizing radiation for a short time and small amounts for a long time. Must be stored for about 240,000
2. Spent fuel rods; wastes from plants that produce plutonium and tritium for nuclear weapons.

J. Possible Methods of Disposal and their Drawbacks

1. Bury it deep in the ground
2. Shoot it into space or into the sun
3. Bury it under the Antarctic ice sheet or the Greenland ice cap
4. Dump it into descending subduction zones in the deep ocean
5. Bury it in thick deposits of muck on the deep ocean floor
6. Change it into harmless (or less harmful) isotopes
7. Currently high-level waste is stored in the DOE $2 billion Waste Isolation Pilot Plant (WIPP) near Carlsbad, NM. (supposed to be put into operation in 1999)

K. Worn-Out Nuclear Plants

1. Walls of the reactor's pressure vessel become brittle and thus are more likely to crack.
2. Corrosion of pipes and valves
3. **Decommissioning a power plant** (3 methods have been proposed)

A. immediate dismantling
B. mothballing for 30-100 years
C. entombment (several thousand years)

4. Each method involves shutting down the plant, removing the spent fuel, draining all liquids, flushing all pipes, sending all radioactive materials to an approved waste storage site yet to be built.

L. Connection between Nuclear Reactors and the Spread of Nuclear Weapons

1. Components, materials and information to build and operate reactors can be used to produce fissionable isotopes for use in nuclear weapons.

M. Can We Afford Nuclear Power?

1. Main reason utilities, the government and investors are shying away from nuclear power is the extremely high cost of making it a safe technology.
2. All methods of producing electricity have average costs well below the costs of nuclear power plants.

N. Breeder Reactors

1. Convert nonfissionable uranium-238 into fissionable plutonium-239
2. Safety: liquid sodium coolant could cause a runaway fission chain reaction and a nuclear explosion powerful enough to blast open the containment building.
3. Breeders produce plutonium fuel too slowly; it would take 1-200 years to produce enough plutonium to fuel a significant number of other breeder reactors.

O. Nuclear Fusion

1. D-T nuclear fusion reaction; Deuterium and Tritium fuse at about 100 million degrees
2. Uses more energy than it produces