ENERGY AND THE ENVIRONMENT

Methane hydrate: potential energy source

- ⇒ Found all over the world
- ⇒ Located in marine sediments on continental slopes and rises
- ⇒ Conditions necessary for formation:
    1) High water pressure (depth > 530m in low latitudes, depth > 7250m in high latitudes
    2) Low temperatures (temp < 7ºC
- ⇒ Origin not exactly known, but may be a waste product of detritus munching bacteria
- ⇒ Methane (remember, it is a greenhouse gas) can be released if the water temperature rises

Energy: Capacity to do work

L = R+E+I/Population where: L = Quality of life or "standard of living"
R = Raw materials consumed
E = Energy consumed
I = Ingenuity

Examples:
Japan: High L, but with a low R and high E and I
U.S.: Low L, but good R, high E and I
Argentina: Low L, but good R, high E and low I

To a physicist, there is no energy shortage, since energy cannot be created or destroyed; only converted into another form of E, usually of lower quality.

Renewable Energy: Replenished at a rate equal to consumption

Nonrenewable Energy: Not replenished at a rate equal to consumption, so eventually it will run out

Renewable Sources: Solar, water, wood, wind, ocean and lake thermal gradients, geothermal and tidal energy

Nonrenewable Sources: Crude oil, coal, oil shales, tar sands, fissionable elements.

Usage of nonrenewable can be fast:

- ⇒ First gas engine – 1885 (Daimler and Benz) in U.S. – 1893 (Duryea)
- ⇒ Dust over 100 year later, look at our mess

<u>Petroleum</u>

Hydrocarbon: combinations of H and C

Petroleum occurs beneath the Earth's surface in liquid and gaseous forms and at the surface as oil seeps, tar sands, gilsonite, and oil shales.

- ⇒ Used for fuel of course
- ⇒ Also used for paints, plastics, fertilizers, insecticides, soaps, synthetic fibers and synthetic rubber

⇒ Carbon combines with H in at least 2 million different ways

Refining or Cracking: Process of separating crude oil into its various components

A. Origin and Accumulation of Hydrocarbon Deposits
   - → Hydrocarbons are the remains or chemical components of living organisms
   - → Majority of oil is found in sedimentary deposits
   - → Four conditions are necessary for the formation and accumulation of an exploitable petroleum deposit in nature:
     1) A source rock for oil
     2) A reservoir rock in which it can be stored
     3) A caprock to confine it
     4) A geologic structure or favorable strata to "trap" the oil

Source Rock: sedimentary shales or limestones, usually of marine or lacustrine origin
- ⇒ Almost all are dark (high organic content)
- ⇒ Typical organisms: diatoms (phytoplankton), zooplankton
- ⇒ Conservation to O.M. occurs @ 50ºC to 200ºC, with optimum occurring at 100-120ºC

Reservoir Rock: porous and permeable rock, like sandstone
- ⇒ Also porous limestone or fractured shales
- ⇒ Porosities range from 20-50%, yields 1ft^3 will be 1-4gallons of oil
- ⇒ Unit is a barrel = 42gallons

Caprock: Prevents oil from seeping upward and allows accumulation
- ⇒ Typically shales (clayey) and nonporous limestones

B. Geologic Traps – Oil and Gas Stop Here
   1. Structural Traps – gas on top of oil
      a. Anticline – upside down bowl shape
      b. Faults – form impermeable barriers
      c. Salt Domes – also form barriers, rise slowly in crust do to density
         - Found in Deep South – Havana salt.
   2. Stratigrpahic Traps – change in rock type
      a. Ancient coral reefs
      b. Ten times the productivity of structural traps
      c. Not a surprise that the Middle East has these

C. Oil Production
   First successful oil well: Titusville, PA in 1859

   Wildcat Well: New well that is productive
   - → 1 in 50 is successful through time
   - → Between 1970 and 2003, 1 in 4 chance

   Most successful wells require pumping
   - → Gusher – pressurized well
   - → Kuwait in Desert Storm: 749 gusher wells were set on fire

- Pro oil fighters brought in: Red Adair Company and Boots and Coots (with Kuwaiti roughnecks)

Slant Drilling – used to penetrate reservoir rocks far from drilling site, such as offshore or in developed land, like Beverly Hills

Then in late 1990's, horizontal drilling and multilateral drilling

Offshore rigs can drill through a mile of water and several miles into the Earth
→ looking into doubling water depth

Secondary Recovery: Extract oil that remains in the reservoir rock after normal withdrawal methods have ceased
Three categories of S.R.:

1) Thermal – steam injection and fire flooding
2) Chemical – water injection (larger molecules are added to water to move more oil)
3) Miscible – fluid mixing with water, propane or ethane

All methods require injection wells for injecting fluids or gas and extraction wells for removing the remobilized oil

D. Quality and Price
Price varies with its grade, quality and market demand

Light Crude: very fluid and yield a high percentage of gas and diesel fuel

Heavy Crude: thick, lubricating oils

E. The Future for Oil
Petroleum: 40% Energy needs, 90% transportation needs

Reserves: amount of an identified resource that can be extracted economically
→ Saudi Arabia – 25%
→ 72% in Middle East nations

U.S. the most energy deficient of the largest oil-producing countries

At the current rate of production, the U.S. reserves will last about ten years

F. Arctic National Wildlife Refuge (ANWR)
→ Between 5.7 and 16 billion barrels
→ Price of crude needs to be $25-30/barrel to make it economical

U.S. Citizen:
→ 4 tons of oil, 2.5 tons of coal, 2 tons of natural gas and our weight in oil in 7 days!
→ 5% population but 33% worlds energy consumption

G. Energy Gases and The Future
    - → "Affordable oil" could decline soon, but probably by 2040-2050
    - → Move to natural gas
    - → Coal Bed methane, methane hydrate
    - → Hydrogen: although right now it is produced using fossil fuels

Coal

Coal: carbonaceous residue of plant matter that has been preserved and altered by heat and pressure

- ⇒ Deposits are known from every geologic period since the Devonian

Permian: Antarctica, Australia, India
Carboniferous: North America, England and Europe
Tertiary: Western U.S., Japan, India, Germany, Russia, Spits Bergen Island

A. Coalification and Rock
    - → First Stage: plant accumulation in a low 0 environment like a swamp
        - Peat → Lignite → Sub bituminous → Bituminous → Anthracite
          Increasing Btu, fixed carbon →
          Decreasing amount of burned volatiles →
    - → Anthracite is essentially metamorphic, produced in convergence
    - → WV, KY, PA leading coal producers
    - → Wyoming now the biggest producer of low-sulfur coal

B. Reserves and Production
    - → 80% of U.S. energy stores but only 18% of present usage
    - → However, it depends on our energy demands - how long it lasts (200-300yrs at present rates, only 50 years if consumption continues to increase
    - → Synthesis Gas – conversion of coal to methane
    - → Methanol – higher octane, but higher CO_2
    - → Coal to liquid synthetic fuels or synfuels

Non-Conventional Fossil Fuels

A. Tar Sands: contain thick oil (too viscous) to flow at normal temperatures
    - → Found in Canada, Venezuela, Madagascar and U.S.
    - → Athaba Sea Sands in Canada are the largest
        - More oil then Saudi Arabia (1.7 trillion barrels)
        - → Some are too deep to mine from the surface – Cold Lake area

B. Oil Shales: sedimentary rocks that yield petroleum when they are heated
    - ⇒ Found on all continents, originally produced in lakes, marshes, or oceans
    - ⇒ Green River Shale
    - ⇒ Kerogen is the source
    - ⇒ Water is the limiting factor for extraction:
        - o 3-4 x the amount of water is needed
        - o Plus it destroys the landscape

Problems of Fossil Fuel Combustion

1) Air Pollution

- ⇒ Co to CO_2 – global warming
- ⇒ Other oxides: S, N, as well as ash
- ⇒ SO_x: form sulfuric acid (acid rain)
- ⇒ NO_x: precursors to PAN (Peroxyacetyl Nitrate) and ozone (O_3) which are associated with smog, or HNO_3 – nitric acid
- ⇒ Clean Air Act of 1963 (amended in 1970, 1990)
  - o By 1980 cars were 90% cleaner then 1970s cars
- ⇒ RFG – Reformulated Gasoline
  - o MTBE – Methyl Tertiary Butyl Ether: add as much as 2.5% oxygen to the fuel
  - o Stored in underground tanks (that can leak)
- ⇒ Due to leaks, EPA (Barbara Brosner) recommended:
  1) Remove clean air act Requirement for 2% reduction in RFG
  2) Enhance Underground Storage
  3) Reduce MTBE use

A. Sulfur Emissions and Acid Rain
- Occurs in coal as pyrite (FeS_2), and organic sulfur
- SO_2 can travel great distances
- SO_2 (near facility) will be dry and kill plants
- Mobile Sources (cars): 4% of total
- SO_2 (in atmosphere) will produce acid rain
- Scrubbers are used: bond with SO_2 and absorbs or neutralizes it
- Fluidized-Bed Combustion: burn with limestone
  - → Takes sulfur out, but increases CO_2

B. Nitrogen Oxides and Smog
- NO_x: significant from coal burning and vehicular sources
- Produce photochemical smog: LA, Mexico City, Denver
- NO_x and O_3 cause respiratory problems
  - → 6 ppm of O_3 can kill lab critters
  - → Catalytic converters help

C. Domestic Coal Burning
- China – 25% global output, 76% of China's use
- Fluorine – also in Guizhou – dental and skeletal fluorosis

2) Mine Collapse

- ⇒ Lignite and bituminous coals
- ⇒ "Room and Pillar" methods
- ⇒ Subsidence: Pittsburgh, Scranton, Wilkes-Barre as well as WY, MT, SD

Energy for the Future

Our primary fuel energy source has always been at least indirectly the sun.

1) Direct Solar Power

- ⇒ Very diffuse, hard to concentrate easily
- ⇒ There are two ways potentially:
    - a) Solar-Thermal methods utilize collectors to warm a fluid which heats or is used for generating electricity
    - b) Photovoltaic Cells – use Si to convert light energy to electricity
- ⇒ Right now: cost (See Table)
- ⇒ Solar one and Solar two in Barstow
    - ■ Solar One → used water
    - ■ Solar Two → nitrate salt → heat transfer
- ⇒ PU – photovoltaic cells – 80% reduction of costs
    - ■ Need to fall another 50-75% to compete with fossil fuels

2) Indirect Solar Energy

A. Wind Energy

- o fastest growing for the last 20 years
- o small increases in velocities can increase power greatly (14 to 16 mi/hr, 50% more energy)
- o size matters too: 10m to 50m gives 55 fold increase
    - → Off the ground: faster winds too
- o (A is leader: Tehachapi Pass (SE of Balers Field), Altamont Pass (E of San Jose), Banning Pass
- o Produced by movement from H → L pressure systems
- o Wind Power Potential – Figure – 12 states could produce 90% of total US need
    - → Problems: visual blight, noise, TV interference, land acquisition
    - → Some people like them just fine

B. Hydroelectric Energy

- o Falling water, largest renewable resource next to wood
- o 25% worlds electricity
- o Norway: 99% electricity, 50% total energy
- o Aitupu Dam between Paraguay/Brazil: 12,600 MW
- o No more deal, but retrofits may occur
- o Clean, but requires creative management

3) Geothermal Energy

- ⇒ Best near plate boundaries
- ⇒ US, Japan, N.Z., Mexico, Russia, Iceland
- ⇒ Energy fields are of two types:
    - a) Steam-Dominated – Napa geysers – great sources
    - b) Hot Water-Dominated
- ⇒ Problems: geothermal waters typically have toxins, such as As, Se, Ag, Au, Ca
- ⇒ Increasing in popularity

4) Nuclear Energy

- ⇒ 16% worldwide, 19% in US
- ⇒ At one time – it was the solution
- ⇒ ^{238}U: most stable, ^{235}U: unstable, easy to split, but hard to control

A. Geological Considerations
  - NRC – watch for faults
  - Reactors are programmed to shut down

B. Nuclear Waste Disposal
  - Biggest deterrent

<u>Energy from the Sun</u>

1) OTEC: Ocean Thermal Energy Conversion
   - → Still too costly
2) Wave Energy
   - → Also diffuse and hard to concentrate
3) Tidal Currents
   - → Flood (landward) and Ebb (seaward)
   - → France (30-46 feet difference) – Rance River
   - → N.A. – Annapolis Royal in Nova Scotia – taps Bay of Fundy

<u>Case Studies</u>

14.1: Rock Oil and the Colonel – Edwin Drake

14.2: Tragedy in the Sound

14.3: Baking Soda, Vinegar and Acid Rain