ENERGY RESOURCES

EM&SD lecture

Energy Resources

- Supplementing free solar energy
 - 99% of heat comes from the sun
 - Without the sun, the earth would be -240 °C (-400 °F)
- We supplement the other 1% with primarily non-renewable energy sources

Energy Resources

- Renewable (16%)
 - Solar
 - Wind
 - Falling, flowing water
 - Biomass

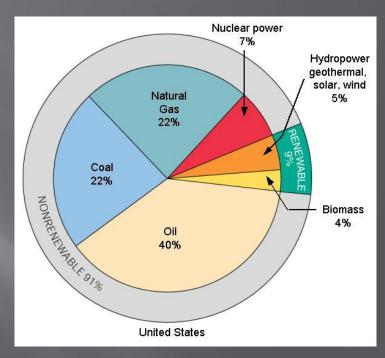
- Non-renewable (84%)
 - Oil
 - Natural gas
 - Coal
 - Nuclear power

Energy sources and uses

- Energy uses in developed countries
 - industrial
 - domestic
 - transportation
- Note: Electricity is not an energy source, converted from another source (coal, hydro, nuclear, etc.).
- 1st Law of Thermodynamics You can't get more energy out of something than you put in
- 2^{ond} Law In any conversion of heat energy to useful work, some energy is always degraded to a lower quality energy

Evaluating Energy Resources

- Renewable
- Future availability
- Net energy yield
 - It takes energy to get energy
- Habitat degradation
- Cost (initial and ongoing)
- Community disruption
- Political or international issues
- Suitability in different locations
- Polluting (air, water, noise, visual)



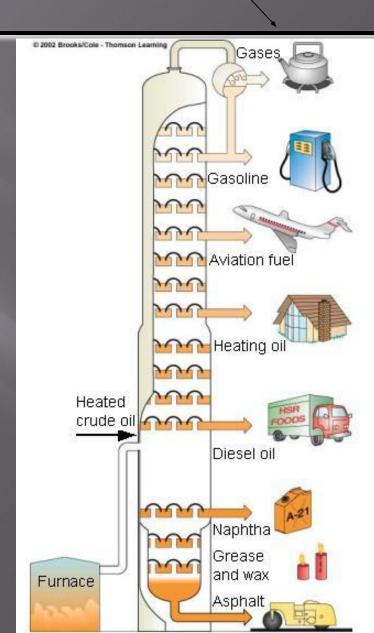
OIL and NATURAL GAS

- Accumulations of dead marine organisms on the ocean floor were covered by sediments.
- Muddy rock gradually formed rock (shale) containing dispersed oil.
- Sandstone formed on top of shale, thus oil pools began to form.
- Natural gas often forms on top of oil.
 - Primary component of natural gas is methane

Based on boiling points

- Petroleum (crude oil)
- Costs:
 - Recovery
 - Refining
 - Transporting Environmental
 - - Highest risks are in transportation
- Refining yields many products
 - Asphalt
 - Heating oil Diesel

 - Petrochemicals
 - Gasoline



Conventional Oil

Advantages

- Relatively low cost
- High net energy yield
- Efficient distribution system

Disadvantages

- Running out
 - 42-93 years
- Low prices encourage waste
- Air pollution and greenhouse gases
- Water pollution

Oil Shale and Tar Sands

Tar Sand:

Mixture of clay, sand water and bitumen a thick and sticky heavy oil.

Extracted by large electric shovels, mixed with hot water and steam to extract the bitumen.

Trade-Offs

Heavy Oils from Oil Shale and Oil Sand

Advantages

Disadvantages

Moderate cost (oil sand)

Large potential supplies, especially oil sands in Canada

Easily transported within and between countries

Efficient distribution system in place



High cost (oil shale)

Low net energy vield

Large amount of water needed for processing

Severe land disruption from surface mining

Water pollution from mining residues

Air pollution when burned

CO2 emissions when burned

Oil Shale:

Oily rocks that contain a solid mix of hydrocarbons.

Global supplies ~ 240 times conventional oil supplies.

Technology is well developed

@ 2005 Brooks/Cole - Thomson

Ritumen heated to

Natural Gas

- 50-90% methane
- Cleanest of fossil fuels
- Approximate 200 year supply
- Advantages and disadvantages

Trade-Offs

Conventional Natural Gas

Advantages

Disadvantages

Ample supplies (125 years)



Low cost (with huge subsidies)

Less air pollution than other fossil fuels

Lower CO₂ emissions than other fossil fuels

Moderate environmental impact

Easily transported by pipeline

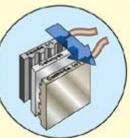
Low land use

Good fuel for fuel cells and gas turbines



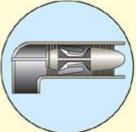
Nonrenewable resource

Releases CO₂ when burned



Methane (a greenhouse gas) can leak from pipelines

Difficult to transfer from one country to another



Shipped across ocean as highly explosive LNG

Sometimes burned off and wasted at wells because of low price

Requires pipelines

Coal - What is it?

- Solid fossil fuel formed in several stages
- Land plants that lived 300-400 million years ago
- Subjected to intense heat and pressure over many millions of years
- Mostly carbon, small amounts of sulfur

Coal - what do we use it for?

- Stages of coal formation
 - 300 million year old forests
 - peat > lignite > bituminous > anthracite
 - Primarily strip-mined
- Used mostly for generating electricity
 - Used to generate 62% of the world's electricity
 - Used to generate 52% of the U.S. electricity
- Enough coal for about 200-1000 years
 - U.S. has 25% of world's reserves
- High environmental impact
- Coal gasification and liquefaction

Coal: Trade-offs

Advantages

Disadvantages

World's most abundant fossil fuel Mining and burning coal has a severe environmental impact Accounts for over 1/3 of the world's CO, emissions

Ample supplies (225-900 years)



Very high environmental impact

High net energy vield



Severe land disturbance, air pollution, and water pollution

Low cost (with huge subsidies)



High land use (including mining)

Mining and combustion technology well-developed



Severe threat to human health

High CO2 emissions when burned

Air pollution can be reduced with improved technology (but adds to cost)



Releases radioactive particles and toxic mercury into air

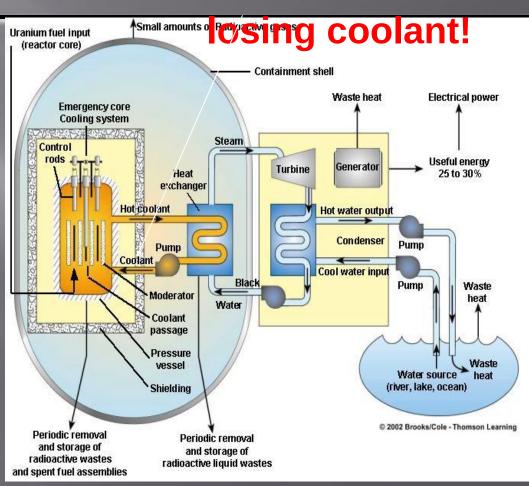
Nuclear Energy – What is it?

- A nuclear change in which nuclei of certain isotopes with large mass numbers are split apart into lighter nuclei when struck by neutrons.
 - Nuclei center of an atom, making up most of the atom's mass
 - Isotopes two or more forms of a chemical element that have the same number of protons but different mass numbers because they have different numbers of neutrons in their nuclei.
 - Neutron elementary particle in all atoms.
 - Radioactivity Unstable nuclei of atoms shoot out "chunks" of mass and energy.

Nuclear Energy

Great danger of

- Fission reactors
- Uranium-235
- Fission
 - Resulting heat
 used to produce
 steam that spins
 turbines to
 generate
 electricity
 - Produces radioactive fission fragments



Light water generator – used in all U.S. and 85% world wide.

Conventional Nuclear Power: Trade-offs

No new plants in U.S. since 1978 and in Germany as well

All 120 plants ordered in 1973 have been cancelled.

Cost over-runs High operating costs

Trade-Offs

Conventional Nuclear Fuel Cycle

Advantages

Disadvantages

Large fuel supply

Low environmental impact (without accidents)

Emits 1/6 as much



High cost even with large subsidies

Low net energy yield

High environmental impact (with major accidents)

Moderate land disruption and water pollution (without accidents)

CO2 as coal

Moderate land use

Low risk of accidents because of multiple safety systems (except in 35 poorly designed and run reactors in former Soviet Union and eastern Europe)



Catastrophic accidents can happen (Chernobyl)

No widely acceptable solution for long-term storage of radioactive wastes and decommissioning worn-out plants



Subject to terrorist attacks

Spreads knowledge and technology for building nuclear weapons

Chernobyl – Ukraine (Former USSR)

- April 26, 1986
- One of four reactors explodes.
- 31 immediate deaths.
- 116,000 people evacuated.
- 24,000 evacuees received high doses of radiation.
- Thyroid cancer in children.
- Damaged reactor entombed in concrete, other reactors returned to service within months.
- Eventually, remaining reactors out of service.

Dealing with Nuclear Waste

- High- and low-level wastes
- Terrorist threats storage casks hold 5-10 X more long-lived radioactivity than the nuclear power plant
- Disposal proposals
 - Underground burial
 - Disposal in space (illegal under international law)
 - Burial in ice sheets
 - Dumping into subduction zones
 - Burial in ocean mud
 - Conversion into harmless materials (no way to do this with current technology)

Low - Level Waste – (materials other than the radioactive isotopes)

- Includes cooling water from nuclear reactors, material from decommissioned reactors, protective clothing, and like materials.
 - Prior to 1970, US alone placed 50,000 barrels of low-level radioactive waste on the ocean floor.
 - Moratorium in 1970, Ban in 1983.

Energy Efficiency and Renewable Energy

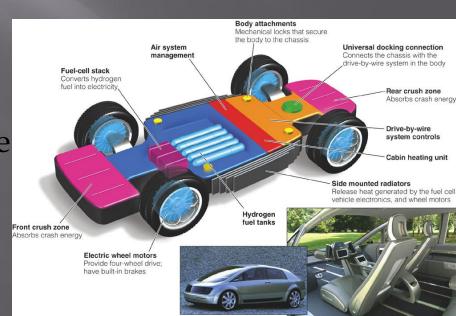
- 84% of energy is wasted in the United States
 - 41% degradation (2nd law of Thermodynamics)
 - 43% unnecessary
 - ☐ Fuel wasting vehicles
 - Furnaces
 - Poorly insulated buildings
- U.S. unnecessarily wastes 2/3 of the energy that the rest of the world's population consumes!

Ways to Improve Energy Efficiency

- Cogeneration combines heat and power
 - Two forms of energy (ex. steam and electricity) are provided from the same fuel source. Used in Western Europe, U.S. produces 9% of electricity using cogeneration plants)
- Efficient electric motors
- High-efficiency lighting
- Increasing fuel economy
- Alternative vehicles
- Insulation
- Plug leaks

Hybrid and Fuel Cell Cars

- Hybrid cars still use traditional fossil fuels
 - Energy otherwise wasted charges battery which assists acceleration and hill climbing
 - More efficient than internal combustion engine alone, but still uses non-renewable resources
- Fuel cell cars not yet available
 - Hydrogen gas is fuel
 - Very efficient
 - Low pollution
 - Major infrastructure change needed for fueling stations



Renewable energy sources

- Solar
- Flowing water
- Wind
- Biomass
- Geothermal
- Hydrogen

Producing Electricity from Moving Water

Trade-Offs

Large-Scale Hydropower

- Large-scale hydropower
- Small-scale hydropower
- Tidal power plant
- Wave power plant

Advantages

Moderate to high net energy

High efficiency (80%)

Large untapped potential

Low-cost electricity

Long life span

No CO₂ emissions during operation in temperate areas

May provide flood control below dam

Provides water for year-round irrigation of cropland

Reservoir is useful for fishing and recreation

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Disadvantages

High construction costs

High environmental impact from flooding land to form a reservoir

High CO₂ emissions from biomass decay in shallow tropical reservoirs

Floods natural areas behind dam

Converts land habitat to lake habitat

Danger of collapse

Uproots people

Decreases fish harvest below dam

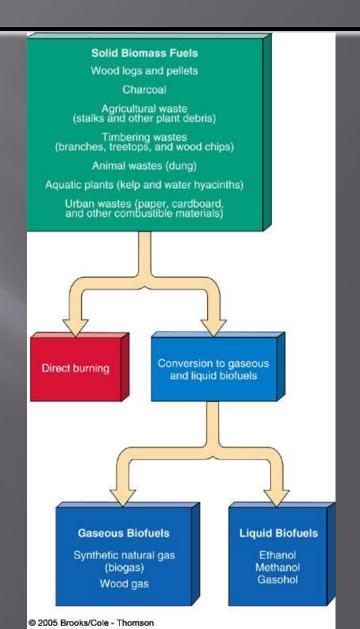
Decreases flow of natural fertilizer (silt) to land below dam





Producing Energy from Biomass

- Biomass and biofuels
- Biomass plantations
- Crop residues
- Animal manure
- Biogas
- Ethanol
- Methanol



Geothermal Energy

- Geothermal heat pumps
- Geothermal exchange
- Dry and wet steam
- Hot water
- Molten rock (magma)
- Hot dry-rock zones

Trade-Offs

Geothermal Energy

Advantages

Disadvantages

Very high efficiency

Moderate net energy at accessible sites

Lower CO₂ emissions than fossil fuels

Low cost at favorable sites

Low land use

Low land disturbance

Moderate environmental impact



Scarcity of suitable sites

Depleted if used too rapidly

CO₂ emissions

Moderate to high local air pollution

Noise and odor (H₂S)

Cost too high except at the most concentrated and accessible sources



The Hydrogen Revolution

- Environmentally friendly
- Extracting hydrogen efficiently
- Storing hydrogen
- Fuel cells