**ENERGY RESOURCES**

I. Fossil Fuels

A. Oil

1. Largest reserves are found in the Mid-East

2. Largest reserve/producer in the U.S. - Texas ( %) of US oil, Alaska ( )

3. Formed from decaying animal matter

4. Only about 30% of the oil in a well is recovered

5. Current supplies of reserves may be depleted in the next 40 – 80 years

6. Pros of using oil

a. Relatively cheap

b. Easily transported - pipelines, oil tankers

c. Versatile

7. Cans of using oil

a. Carbon dioxide emissions

b. Water pollution from tanker spills (many pollutants are more soluble in oil than in water )

c. Habitat destruction from pipeline construction and oil spills

8. Major consumer - transportation sector

9. Oil Shale

a. Contains kerogen which may be refined to shale oil than to crude oil

b. Largest deposits ( ~80 %) on public lands

c. Very law net energy source – 1/3 barrel crude to produce 1 barrel of synfuel

d. Economically unfeasible

10. Tar Sands

a. Contain bitumen - high sulfur, heavy oil

b. Largest deposits in Canada

c. Very low net energy yield

d. Economically unfeasible

11. By 2025, the US may have to import ~70 % of the oil it consumes. (Currently import ~53%)

B. Natural Gas

1. Composed primarily of methane – CH4 (prod 19.05 import 3.59 from Canada 2002 trillion ft3) 2. Found in association with oil wells and coals mines

3. Clean burning, high energy content, high net energy yields

4. Can be recovered from landfills

5. Largest reserves in Russia

6. May be depleted in the next 40 - 100 years

C. Coal - Most abundant fossil fuel

1. Formed during the Carboniferous Period

2. Composed of anaerobically decomposed plant matter

3. Carbon, sulfur, nitrogen and moisture content may vary

4. Sequence of formation

PEAT 🡪 LIGNITE 🡪 SUBBITUMINOUS 🡪 BITUMINOUS 🡪

30 % C, low S, low heat, 30 – 90% C,

8300 Btu / lb Rocky Mtn. Region 15000 Btu / lb

2 – 4 % S, 45% of US coal

🡪 ANTHRACITE

Low S, low moisture, highest

Heat content, 2% of US coal

5. Coal use shot up in the seventies due to the interrupted flow of oil

6. Mining

a. Underground - 2nd most hazardous occupation in the world. leading cause of subsidence

b. Strip - intense habitat destruction, water pollution

c. Mine tailings are a source of acid pollution and may also contain other toxic elements

7. Supply

a. 150 - 200 years

b. Largest reserves - US (29%), USSR (28%), China (11%)

8. Major use - production of electricity; 30 - 40 % efficient

9. Pollutants - Major cause of acid rain; most pollutants are generated east of the Mississippi River

a. SO2 = precursor to acid rain

SO2 + 2O2 🡪 2SO3

SO3 + 2H2O 🡪 H2SO4 (sulfuric acid 66% of the acid in acid rain)

b. NO2 + H2O 🡪 HNO3 (nitric acid, 33% of the acid )

c. Particulate matter - particles less than 0.1 um in diameter are the most harmful and the most difficult to remove (lightest particles)

d. CO2 - released from any organic combustion process

10. Pollution Control Devices - required on plants built after 1978

a. Cyclone filter - removes only particulate matter

b. Electrostatic Precipitator - most effective at removing particulate matter, 99 % of the matter is removed

c. Wet Scrubbers - Utilize a spray containing CaO or CaCO3 -

Reduce SO2 emissions by 80 - 95%, reduce particulates by 99%

d. Selective Catalytic Reductions Units (SCR) – reduce NOx.

e. There are no pollution control devices to reduce CO2 emissions.

f. Pollutions Credits - EPA Program

1) SO2 credits (~200 / credit) $150 to $250 per ton between 2005 and 2025.

2) NOx credits(roughly $4,000 per ton in 2004 to $5,500 per ton in 2025)

3) CO2  credits - trial program proposed in Costa Rica

11. Cleaner Ways To Burn Coal

a. Coal Washing - prior to burning - economically unfeasible

b. Fluidized Bed Combustion

1) Coal is crushed and mixed with CaCO3 in boiler, CaCO3 reacts with

the SO2 to produce CaSO3 (a solid) which is then collected

(large amts. of solid waste are a drawback to this process)

2) About 40% efficient in generating electricity

3) Lower temperatures --> lower NO2 emissions

4) Reduce sulfur oxide emissions by 90 %

5) Other fuels can also be burned in the boiler, easy retrofit

6) Test plants are operating in the US

c. Magnetohydrodynamics -MHD

1) 2 stage process - direct and indirect production

2) About 60 % efficient in generating electricity

3) Reduce SO2 by 45% and lowers NO2 emissions

d. Coal Gasification and Liquefaction

1) Low net energy yields

2) Economically unfeasible at this time

II. Electricity

A. Electrical Current

1. Flow of electrons (negatively charged particles)

2. Maximum current is generated when the electrons flow is perpendicular to the magnetic field

through which it is flowing

3. Unit of charge = Coulomb = C

4. Current = I = Q / t (Q = charge, the no, of coulombs, t = time)

5. coulomb / sec = C/s = ampere = amp

6. Volt = V = J/C (joule / coulomb --> work / charge)

B. Electrical Resistance - resistance to the flow of electrons - R

1. Increase the length of the conductor - increase the resistance

2. Increase the diameter - decrease the resistance

3. Ohm’s Law : R = V/I

**C. Electrical Power**

1. Power = P = W / t = J/s = watt; 1000 watts = kilowatt

2. P = VI; P = I2R

3. Represents demand

**D. Electrical Energy**

1. E = P X t = watt hour(Wh, kilowatt hour = kWh)

2. Energy consumed

E. Transformers

1. Step-up transformers - increase voltage

2. Step-down transformers - decrease voltage

**F. Electricity**

6. Basic Scheme for the Production of Electricity

Generate heat to heat water 🡪 Produce steam 🡪 Turns blades in steam turbine that is connected

to an electrical generator

2. Av. efficiency - 33% (30 - 40 % for coal, 25 % for nuclear fuels)

2. Produced on demand, not stored.

3. New plants are built to accommodate peak demands, not average consumption levels

4. Base load - minimum load

5. Peak load - 3 to 4 times more expensive to generate than base load .

6. Load Management Utility Rate Structures - Demand -side management

a. Peak Load Rates or Time-of-use Rate (pay about 3X more for electricity

consumed during peak load hours)

b. Interruptible Rate Schedule - appliance may be turned off periodically during peak

hours to help reduce the peak load

III. Nuclear Resources

A. Nuclear Forces - much stronger and much more energetic than electrical forces

B. Basic Atomic Structure

1. Nucleus = protons + neutrons

a. Protons

1) Positively charged particles

2) Atomic mass is approximately 1

3) Atomic number = Z = # of protons

b. Neutrons

1) No charge

2) Approximately the same mass as a proton

c. Atomic mass = A = # protons + # neutrons

2. Electrons

a. Orbit the nucleus

b. Negatively charged, small particles

c. For an atom, the #of electrons = # of protons

3. Isotope = Same atomic no., different atomic mass (the number of electrons is the same,

the no. of neutrons is different)

4. Ion = a charged particle, a particle that has lost or gained electrons (e-)

5. Mass deficit = the mass of the atom is less than the individual p, n, and e-, that make

up the atom; this mass is converted into energy in nuclear reactions, E = mc2

C. Nuclear Reactions

1. Nuclear fission breaking down an atom into 2 smaller atoms

2. Nuclear fusion - combining smaller particles into a larger atom

3. Radioactivity - spontaneous decay of unstable nuclei

4. Half life

a. Disintegration rate

b. 10 half life decays are necessary for a radioactive substance to be considered harmless

c. Half-life of Pu = 24,000 yrs Extremely toxic material

5. Types of Decay

a. Alpha decay - kicks out the equivalent, of a helium nucleus.

ex. 238U 🡪 234Th + 4He

Not very penetrating, can be stopped by a thin sheet of foil or paper

b. Beta decay - equivalent to an electron -1e, more penetrating than alpha

particles. Ex. 3H 🡪 3He + 0e

c. Gamma decay - high energy particle similar to a photon

Planck's relationship : E = hf , h = 6.34 X 10-34 J s, f = frequency

D. Nuclear Fission Reactions

1. Fuel = U-235 (fissionable substance)

2. Nuclear Fuel Cycle

a. Mine U ore -- crush and treat to extract U3O8 (yellowcake) , composed of

0.7 % U-235 and 99.3 % U-238 -

b. Enrichment phase : Yellowcake 🡪 UF6(gas) 🡪 Gas diffusion process 🡪

UO2 pellets ( 3% U-235, 97 % U-238)🡪

c. Pellets are packed into rods 🡪 rods form fuel bundle 🡪 fuel bundle is placed into

the reactor core

3. Neutrons bombard the U-235 to begin the reaction and 3 neutrons are generated in this process

These neutrons can bombard other U-235 atoms.

4. Nuclear Fission Reactors - Design

a. Core - composed of the fuel assembly

b. Fuel Assembly - composed of fuel rods that are encased in stainless steel or a zirconium

alloy.

c. Fuel rods contain uranium oxide pellets - 3% U-235. Fuels rods become depleted and

must be replaced every three years.

d. Control rods - act to control the fission reaction, neutron absorbers, may be made of boron

If all the rods are in place, no reaction will occur.

e. Moderator fluid - controls the neutron flow, slows the neutrons down.

1) Light water - 73 % of reactors

2) Graphite - 20% of reactors (mostly in Russia and England)

Main drawback - flammable

3) Heavy water - 7% (can utilize (0.7% U-235 fuel)

f. Coolant - remove heat from rods

1) Water

2) He gas coupled with graphite as a moderator - can operate at higher temperatures

and produce electricity more efficiently - 38 % efficiency - Used in England.

g. Containment vessel - surrounds the reactor core, absorbs neutrons and gamma radiation

h. Heat from the reaction is used to produce steam 🡪 turbine 🡪 electrical generator 🡪

electricity

i. Cooling Towers help remove heat from the condenser

1) Once through cooling - requires on site cooling pond

2) Wet-type Cooling Tower - type used in the U.S.

3) Dry-type Cooling Tower - closed system, not used in the U.S.

5. Types of Nuclear Fission Reactors

a. PWR - pressurized water reactor, uses light water as a moderator common in the US,

higher temps obtained without boiling (~ 75% of reactors)

b. BWR - unpressurized, boiling -water reactor

c. HTGR - high temperature gas cooled reactor; graphite moderator,

He coolant 🡪 higher temps obtained, 38% efficient

d. CANDU - Canadian Deuterium Reactor - uses heavy water and (3.7% U-235)

6. Pollution and Nuclear Wastes

a. Low level wastes

1) Pre-1970, - disposed of in steel drums dumped in the ocean

2) Post 1970 - buried on-site

b. High level wastes - include spent fuel rods containing many radioactive isotopes

1) No waste facility exited, one had to be chosen by 1991 by the President. So

much waste is stockpiled that the first facility will be filled immediately and a

second facility will have to be opened. Yucca MTN is the proposed site.

2) Reprocessing - spent fuel is kept on site for 120 days in a pool to cool

down and then sent to a reprocessing facility. U-238, U-235 and Pu-239 are

recovered. (Hazardous materials)

3) Best option for disposal - deep geological disposal.

4) Impacts of thermal pollution

a) Increased metabolism , increased need for oxygen

b) Decrease in dissolved oxygen content of the water

c) Thermal shock

d) Concentration of pollutants due to increased evaporation

7. Pros and Cons of Using Conventional Nuclear Fission

a. Pros

1) Almost no air pollution is produced

2) Material is not bomb ready (not concentrated enough)

3) Lessens dependence on oil and coal

b. Cons

1) Waste Disposal

2) Thermal Pollution

3) High cost of building a plant

4) Low net energy yield

5) Short operating life 20 - 40 years

6) High Cost of decommissioning a plant

8. Use of Nuclear Energy to Produce Electricity

a. France - 80 %

b. US - 22 %

c. UK - 19%

d. former USSR - 11%

e. No new nuclear power plants have been ordered In the US since 1978.

9. Nuclear Accidents 1957 - 1986

a. Winter 1957 - Soviet Union (Kyshtym)

1) Center For Pu production -

2) About 30 towns and cities wiped out

b. Oct. 7, 1957 - Liverpool, England

1) Water cooled, graphite moderated system

2) Pu produced

3) 200 mi2 contaminated

4) Graphite caught fire

c. March 22, 1975 - Alabama

1) Fire caused by flame from worker checking leaks

2) 5 emergency cooling systems knocked out

3) Back-up prevented contamination

4) 1978 - Boot fell into reactor - - - $ 2.8 million search unsuccessful

d. March 28, 1979 - Three Mile Island - Pennsylvania

1) Coolant lost, 1 % meltdown of rods

2) More than $1.5 billion spent on clean-up

3) Plant is still not totally decommissioned

e. March 8, 1981 - Japan - Radioactive wastewater leakage

f. June 9, 1985 - Ohio

1) Loss of coolant - similar to TMI

2) Caught in time - no release of radioactive substances

g. April 26, 1986- Chernobyl

1) Graphite-moderated, water- cooled reactor

2) No containment vessel

3) Graphite fire

4) Explosion blew the roof off the reactor (reaction) building

5) Operators had turned off auto and safety equipment for an unauthorized

safety experiment

6) More than 20 countries were threatened with radioactive fallout

7) Took 10 days to get the fire under control

8) Initial impact - 31 dead, 200 people with acute radiation sickness, 1000 mi2 con-

taminated, most people were not evacuated for at least 10 days after the accident

9) 5000 - 100,000 premature deaths from cancer due to radiation contamination

4 million people may suffer health impacts due to exposure to low level radiation

10) As much as $358 billion spent on clean-up effort

11) 1994 study - 80 % of radioactive materials from the core were released, not the

3 % originally reported

10. Methods of Decommissioning a Plant

a. Entombment

b. Dismantlement - preferred by the US

c. Mothball- preferred by France, Germany and England

E. Breeder Reactors - convert spent fuel, such as Pu-239 and U-235, by use of fast neutrons, into fissionable

substances

1. Fuel is bomb ready

2. More difficult to control if an accident occurs

3.No moderator fluid, liquid sodium is used as the coolant

4. LMFER = liquid metal fast breeder reactor

5. France - one plant on-line, two - three as expensive to operate compared to a conventional

fission reactor, heavily subsidized by the government

F. Fusion Reaction

1. Favored scheme - Deuterium-Tritium reaction ( H-2 and H-3)

D + T 🡪 He-4 + 1n 17.6 MeV

2. Gram for gram 10 times more energetic than fission (mass deficit)

3. Relatively non-polluting

4. Source of deuterium - sea water

5. Critical Parameters

a. Ignition temperature > 100 million degrees centigrade

b. Density of ions

c. Confinement time

d. Lawson Criteria - must be met for- a reaction to occur and have a positive net energy.

1014 particles for 1 sec per cm3. The Lawson Criteria has not been met at this time.

6. Proposed Confinement Structures - can not have a physical wall

a. Magnetic Confinement - Tokamak design

b. Inertial Confinement

7. Cold fusion - has not been able to be duplicated.

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**ALTERNATE ENERGY RESOURCES**

I. Solar Energy

A. Solar Insolation = rate at which solar energy fall on a square meter of the earth's surface.

B. Means of transferring Energy

1. Convection

2. Conduction

3. Radiation

C. Active Systems

1. Solar water heating / space heating

a. Solar collector

b. Storage / distribution system

2. Solar electricity

a. Photovoltaics

1) Direct conversion of sunlight to electricity

2) First observed by Becquerel in 1839

3) First practical application - 1954 - Bell Labs

4) Composed of Si

5) Life expectancy - ~30 yrs.

6) World shipments have nearly doubled since 1995

7) US - #1 global producer of solar cells (export ~70% of production)

8) Japan - designed roof tiles that incorporate solar cells

9) Cost is about 30 cents / kWh

10) Drawbacks - cost and storage

11) Flywheel storage - close to 90 % efficient – virtually frictionless

b. Solar Thermal Plants

c. Stand alone systems

d. Connected to the grid systems

D. Passive / hybrid Systems

1. Latent / sensible heats

2. Solar space heating

a. Trombe wall

b. Greenhouses

c. Thermal mass - walls and/or floors

d. Landscaping and microclimates

3. Solar water heating

4. Passive cooling - much harder to accomplish because heat flow is against the thermal gradient.

(Heat moves along the thermal gradient from warmer bodies to cooler bodies.)

a. Radiant Cooling = heat radiates from the hotter to cooler object

1) Nocturnal Radiant Cooling

2) Flat Roofs

3) Skytherm

b. Evaporative Cooling = from the hotter surface to the surrounding air; due to latent heats

of vaporization

1) Swamp cooler

2) Roof ponds

3) Intermittent roof spray

c. Convection and Ventilation

1) Natural convection accounts for 30 - 50% of the heat transferred from a warm surface

to its surroundings

2) Effective strategy in warm, humid climates

3) Stack Effect

a) Solar Chimney

b) Clerestory windows

c) Attic fans, turbines

4) Nocturnal venting

5) Cross ventilation

d. Conduction = hotter to cooler via direct contact

1) Earth berms

2) Cooling tubes

e. Peak load landscaping

1) Maximum shading during the warmest periods of the day

2) Addresses the east and south walls

3) Create a cooler microclimate

II. Wind

A. Pros

1. Fastest growing energy resource to produce electricity

2. Largest producers - US (majority in CA, FP&L- 40%) and Denmark

3. Average wind speeds > 25 km/hr

4. Egg beater design - wind speeds of > 19 km/hr

5. Cost competitive with coal, less air pollution

B. Cons

1. Visual pollution (wind farms)

2. Noise Pollution

3. Migratory bird disruption

C. Storage

1. Attach to the electrical grid for back up

2. Sell excess electricity to power companies

III. Geothermal

A. Types of Geothermal

1. Dry Steam

2. Wet steam

3. Hot Water

B. Uses

1. Direct heat - ex. Iceland - most buildings are heated by geothermal steam

2. Produce electricity - CA Geysers Project

C. Pros

1. Virtually renewable

2. Reduces CO2 emissions by 96%

3. Competitive cost

D. Cons

1. Relative availability - site specific

2. Environmental impacts

IV. Biomass - ~12% of the world's energy

A. Wood

1. Major source in US until ~1850.

2. Can be highly polluting

a. Wood burning stoves and fireplaces are banned in Vale, Aspen and

Telluride, CO

b. Can be very inefficient

3. LDCs

a. Major source of fuel ( up to 95 %)

b. Fuel wood crisis

B. Methane digesters - biogas

1. Convert organics into methane by anaerobic decomposition (dung, food

scrapes, plant residues)

2. Sludge remaining can be used as fertilizer

3. Municipal landfills are also a source of methane

C. Liquid fuels - alcohols

1. From fermenting gains

2. Can be combined with gasoline to produce gasohol

3. Oxygenated fuels often contain methanol or ethanol-reduces air pollutants,

decreases knocking

D. Crop residues - best not to use for fuel, left in place it can help prevent soil erosion

E. Food processing residues - Bagasse - responsible for 10 % of the electricity

generated in Hawaii and Brazil

V. Hydrogen

VI. Hydroelectric (SEE Water notes for major pros and cons)

A. About 20 % of the world's electricity, about 6 % of the total global commercial

energy

B. Leading countries

1. Norway - 99% of its electricity

2. Canada - largest hydroelectric producer

3. South America - 75 % of electricity from hydroelectric

C. Dams

1. Largest - Itaipu Dam

a) Parana River between Brazil and Paraguay

b) Destroyed tropical rainforest (1300 km2 lake created)

c) Displaced indigenous people

2. Tellico Dam - TN- construction almost halted due to the snail darter

3. Small scale

4. Pumped Storage - water is pumped up during off peak times and then

released to produce peak electricity

VII. Ocean Energy

A. Tidal

1. Minimum tide difference of 6 km

2. La Rance, France - first plant - opened in 1966 - produces 62 MW

3. Anapolis Royal, Nova Scotia - first North American Plant - 16 MW

4. Bay of Fundy - large and small-scale projects have been proposed

B. OTEC - Ocean Thermal Energy Conversion

1. Closed System

2. Open System

VIII. Resource Recovery Plants - trash to electricity

IX. Net metering

X. Conservation and Increasing Efficiencies