

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

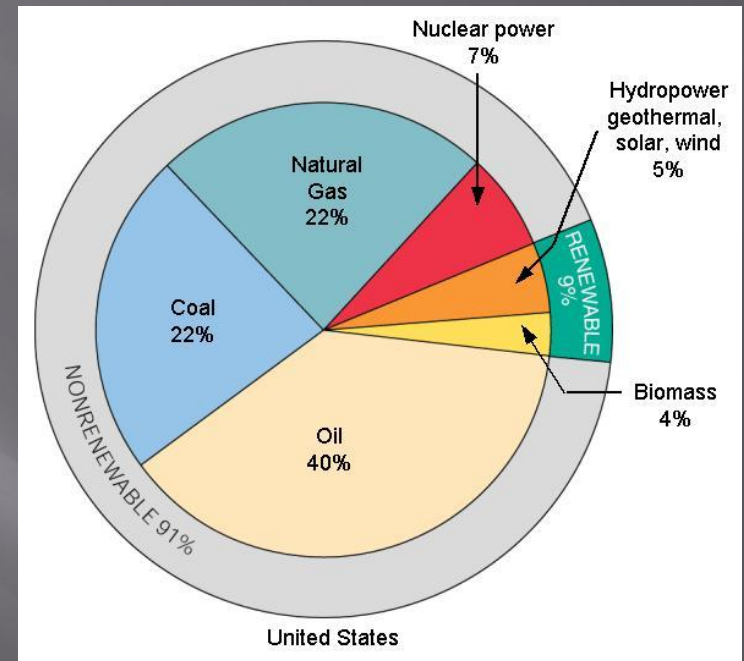
- ▣ Renewable (16%)
 - Solar
 - Wind
 - Falling, flowing water
 - Biomass
- ▣ Non-renewable (84%)
 - Oil
 - Natural gas
 - Coal
 - Nuclear power

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
- 2nd 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)



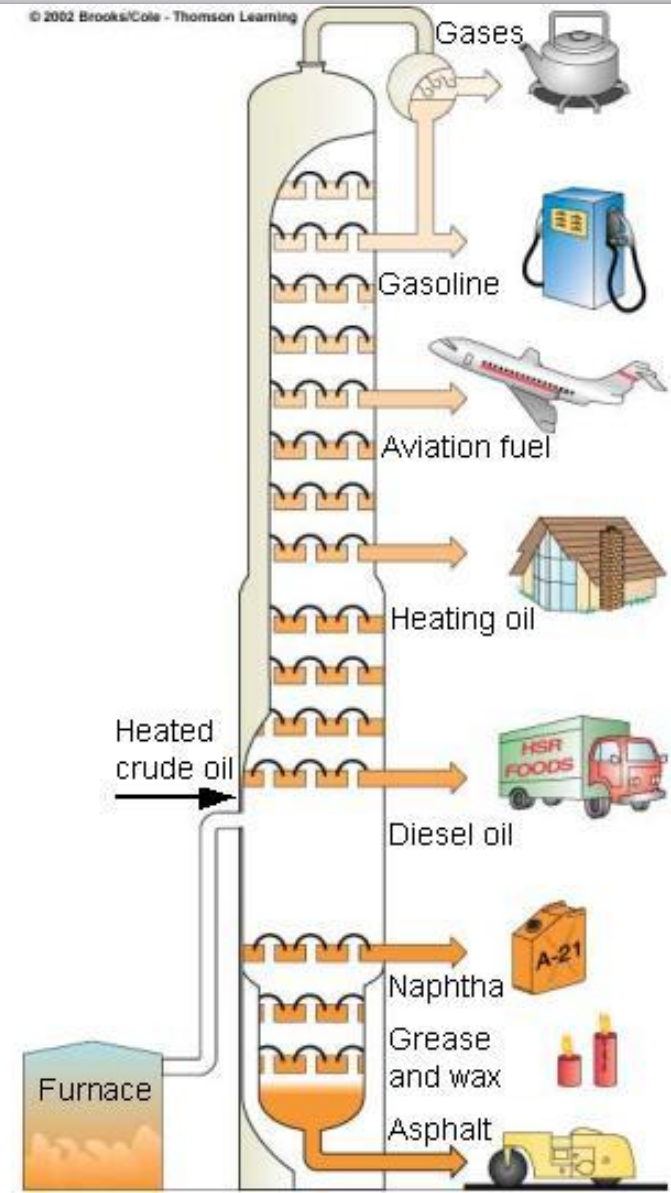
OIL and NATURAL GAS

- ▣ 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

Oil

- 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.

Bitumen heated to

Trade-Offs

Heavy Oils from Oil Shale and Oil Sand

Advantages		Disadvantages
Moderate cost (oil sand)		High cost (oil shale)
Large potential supplies, especially oil sands in Canada		Low net energy yield
Easily transported within and between countries		Large amount of water needed for processing
Efficient distribution system in place		Severe land disruption from surface mining
Technology is well developed		Water pollution from mining residues
		Air pollution when burned
		CO ₂ emissions when burned

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Oil Shale:

Oily rocks that contain a solid mix of hydrocarbons.

Global supplies ~ 240 times conventional oil supplies.

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)	Nonrenewable resource
High net energy yield	Releases CO ₂ when burned
Low cost (with huge subsidies)	Methane (a greenhouse gas) can leak from pipelines
Less air pollution than other fossil fuels	Difficult to transfer from one country to another
Lower CO ₂ emissions than other fossil fuels	Shipped across ocean as highly explosive LNG
Moderate environmental impact	Sometimes burned off and wasted at wells because of low price
Easily transported by pipeline	Requires pipelines
Low land use	
Good fuel for fuel cells and gas turbines	

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

World's most abundant fossil fuel
Mining and burning coal has a
severe environmental impact
Accounts for over 1/3 of the
world's CO₂ emissions

Trade-Offs

Coal

Advantages

Disadvantages

Ample supplies
(225–900 years)



Very high
environmental
impact

High net energy
yield



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?

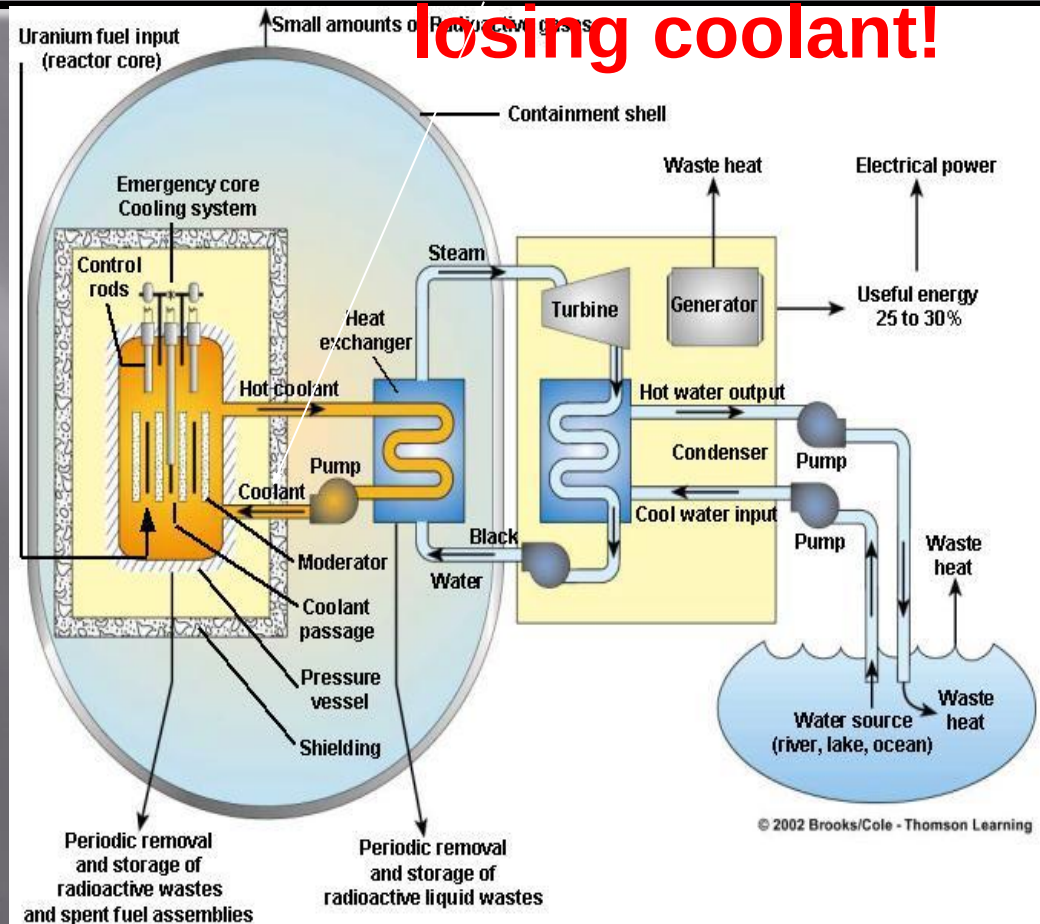
- ▣ A nuclear change in which nuclei of certain isotopes with large mass numbers are split apart into lighter nuclei when struck by neutrons.
 - Nuclei – center of an atom, making up most of the atom's mass
 - Isotopes – two or more forms of a chemical element that have the same number of protons but 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

losing coolant!

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



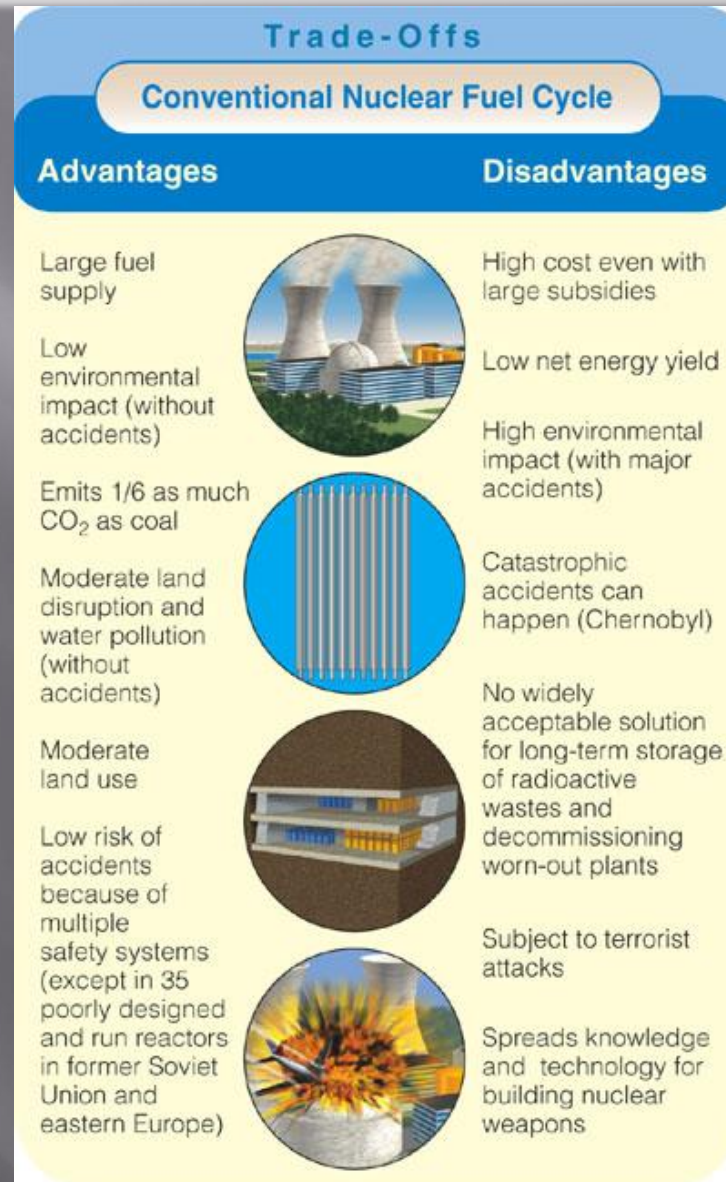
Light water generator – used in all U.S. and 85% world wide.

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



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

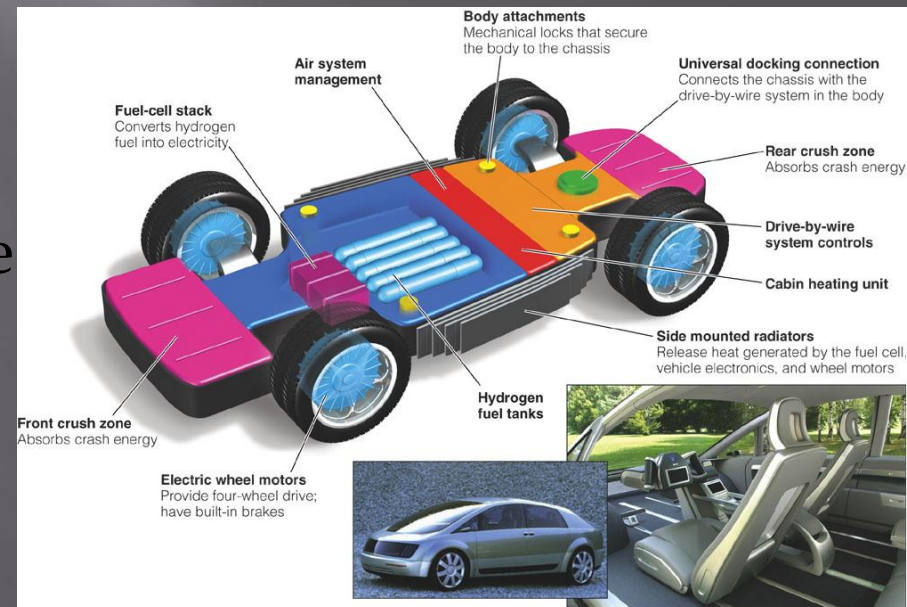
- ▣ 84% of energy is wasted in the United States
 - 41% degradation (2nd law of Thermodynamics)
 - 43% unnecessary
 - Fuel wasting vehicles
 - Furnaces
 - Poorly insulated buildings
- ▣ U.S. unnecessarily wastes 2/3 of the energy that the rest of the world's population consumes!

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



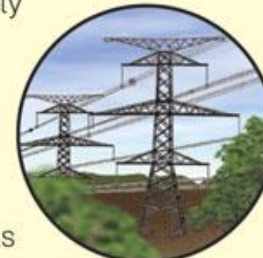
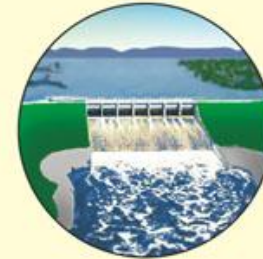
Renewable energy sources

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

Producing Electricity from Moving Water

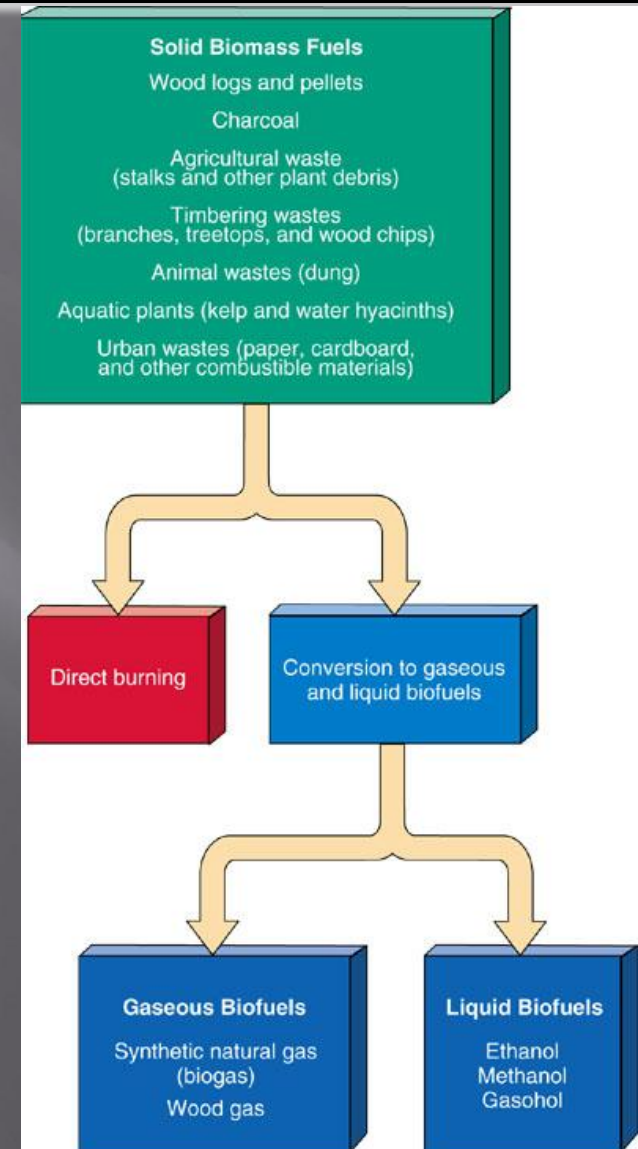
- Large-scale hydropower
- Small-scale hydropower
- Tidal power plant
- Wave power plant

Trade-Offs	
Large-Scale Hydropower	
Advantages	Disadvantages
Moderate to high net energy	High construction costs
High efficiency (80%)	High environmental impact from flooding land to form a reservoir
Large untapped potential	High CO ₂ emissions from biomass decay in shallow tropical reservoirs
Low-cost electricity	Floods natural areas behind dam
Long life span	Converts land habitat to lake habitat
No CO ₂ emissions during operation in temperate areas	Danger of collapse
May provide flood control below dam	Uproots people
Provides water for year-round irrigation of cropland	Decreases fish harvest below dam
Reservoir is useful for fishing and recreation	Decreases flow of natural fertilizer (silt) to land below dam



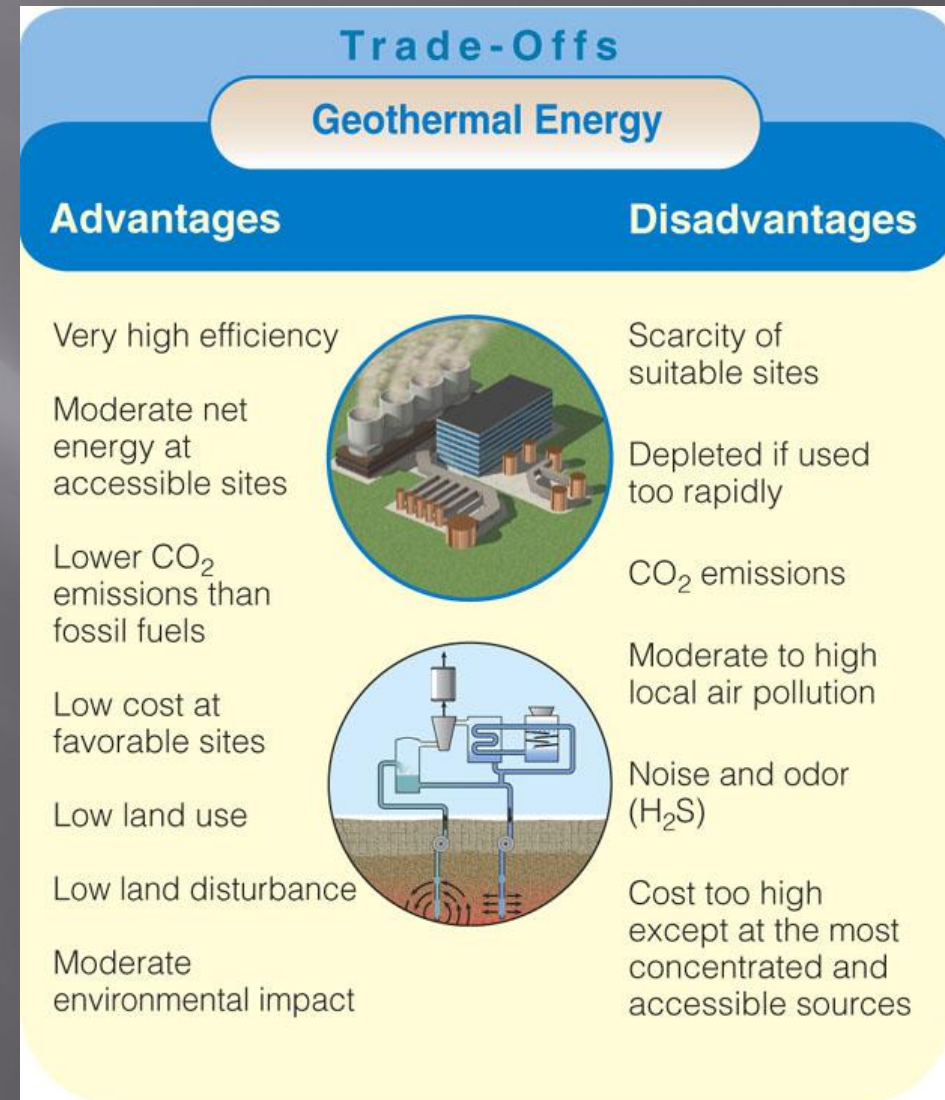
Producing Energy from Biomass

- 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



The Hydrogen Revolution

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