Climb the mountains and get their good tidings. Nature's peace will flow into you as sunshine flows into trees, The winds will blow their own freshness into you and the storms their energy, while cares will drop away from you like the leaves of autumn.

- John Muir

TOPICS INCLUDE:

- Energy
- Fossil Fuels
- Nuclear Energy

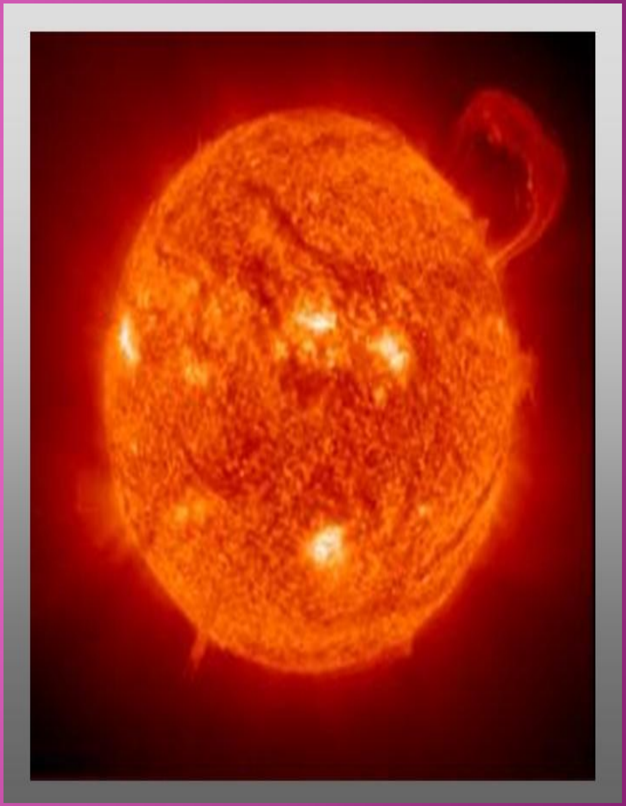
AP ENVIRONMENTAL SCIENCE

UNIT 5: ENERGY RESOURCES AND CONSUMPTION

(PART A)

V. ENERGY RESOURCES AND CONSUMPTION (10-15%)

A. **Energy Concepts –** energy forms, power units, conversions, and laws of thermodynamics
B. **Energy Consumption** – History (Industrial Revolution, exponential growth, and energy crisis), Present global energy use, future energy needs
C. **Fossil Fuels Resources and Use** – formation of coal, oil, and natural gas, extraction/purification methods, world reserves and global demand, synfuels, and environmental advantages/disadvantages of sources
D. **Nuclear Energy** – nuclear fission process, nuclear fuel, electricity production, nuclear reactor types, environmental advantages/disadvantages, safety issues, radiation and human health, radioactive waste and nuclear fusion
E. **Hydroelectric Power** – dams, flood control, salmon, silting and other impacts
F. **Energy Conservation** – energy efficiency, CAFÉ standards, hybrid electric vehicles, and mass transit
G. **Renewable Energy** – solar energy, solar electricity, hydrogen fuel cells, biomass, wind energy, small-scale hydroelectric, ocean waves and tidal energy, geothermal and environmental advantages/disadvantages



FORMS OF ENERGY

FORM	DESCRIPTION
Mechanical	Two types: potential (book sitting on a table) and kinetic (baseball flying through the air)
Thermal	Heat is the internal energy in substances – the vibration and movement of the atoms and molecules within substances
Chemical	Stored in bonds between atoms in a molecule
Electrical	Results from the motion of electrons
Nuclear	Stored in the nuclei of atoms; it is releases by either splitting or joining atoms
Electromagnetic	Travels by waves

POWER & UNITS

UNIT OR PREFIX	DESCRIPTION
BTU (British Thermal Unit)	Unit of energy used in the US (Joule in other countries) Amount of heat required to raise the temperature of 1 pound of water by 1^0F 1 watt = 3.4 BTU/hour 12,000 BTU/hr = ton (a/c applications)
Horsepower	Previously used in automobile industry 1 HP = 746 watts
Kilo-	= 1,000 = 10^3 1 kW = 10^3 watts
Mega- (M)	=1,000,000 = 10^6 1 MW = 10^6 watts
Watt (electrical)	Kilowatt-hour (kWh) = amount of energy expended by a 1 kilowatt (1000 watts) device over an hour Used by power plants & home energy bills
Watt (thermal)	Nuclear power plants produce heat measured in thermal watts

SCIENTIFIC NOTATION

$$5.67 \times 10^{5} = 567000$$

coefficient base exponent

In order for a number to be in correct scientific notation, the following conditions must be true:

1. The **coefficient** must be greater than or equal to 1 and less than 10.
2. The **base** must be 10.
3. The **exponent** must show the number of decimal places that the decimal needs to be moved to change the number to standard notation. A negative exponent means that the decimal is moved to the left when changing to standard notation.

SCIENTIFIC NOTATION CALCULATIONS

- MULTIPLYING
  - →When you multiply numbers with scientific notation, multiply the coefficients together and add the exponents. The base will remain 10.
- DIVIDING
  - →When dividing with scientific notation, divide the coefficients and subtract the exponents. The base will remain 10.
- ADDING or SUBTRACTING
  - →When adding or subtracting in scientific notation, you must express the numbers as the same power of 10. This will often involve changing the decimal place of the coefficient

ENERGY CONVERSIONS

Thorpeville is a rural community with a population of 8,000 homes. It gets its electricity from a small, municipal coal-burning power plant just outside of town. The power plants capacity is rated a 20 megawatts with the average home consuming 10,000 kilowatt hours (kWh) of electricity per year. Residents of Thorpeville pay the utility \$0.12 per kWh. A group of entrepreneurs is suggesting that the residents support a measure to install 10 wind turbines on existing farmland. Each wind turbine is capable of producing 1.5 MW of electricity. The cost per wind turbine is \$2.5 million dollars to purchase and operate for 20 years.

(a) The existing power plant runs 8,000 hours per year. How many kWh of electricity is the current plan capable of producing?

$$\frac{20\ \text{MW}}{} \times \frac{(1 \times 10^6\ \text{watts})}{1\ \text{MW}} \times \frac{1\ \text{kW}}{10^3\ \text{watts}} = 2 \times 10^4\ \text{kW}$$

$$\frac{(2 \times 10^4\ \text{kW})}{1} \times \frac{8{,}000\ \text{hours}}{1\ \text{yr}} = 16{,}000 \times 10^4\ \text{kWh/yr}$$

$$= 1.6 \times 10^6\ \text{kWh/yr}$$

Possible Point: 2

1 pt – correct setup

1 pt – correct calculation of electricity generated

Requirements:

- must correctly convert MW to kW
- no points awarded without showing work

(b) How many kWh of electricity do the residents of Thorpeville consume in one year?

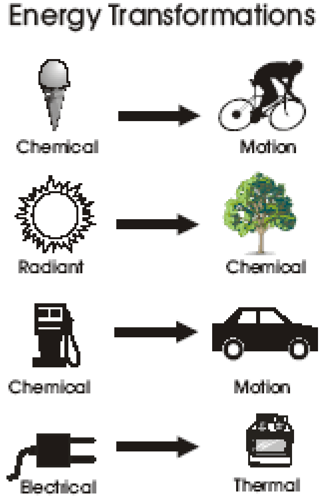
$$\frac{8 \times 10^3 \text{ homes}}{1} \times \frac{1 \times 10^4 \text{ kWh/home}}{1 \text{ yr.}} = 8 \times 10^7 \text{ kWh/yr}$$

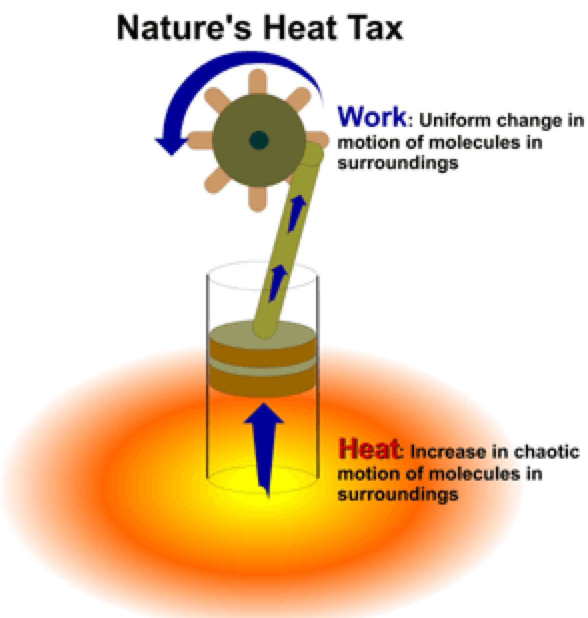
Possible Point: 2
1 pt – correct setup
1 pt – correct calculation of electricity generated
Requirements:
- must correctly convert MW to kW
- no points awarded without showing work

(c) Compare answers (a) and (b). What conclusion can you make?

Possible Point: 2 plus 1 elaboration point
1 pt – comparing answers (a) and (b)
1 pt – explanation of why the values are different
1 pt - explanations that go into great detail about why numbers are different (calculates surplus of energy, energy can be sold to other towns)

LAWS OF THERMODYNAMICS



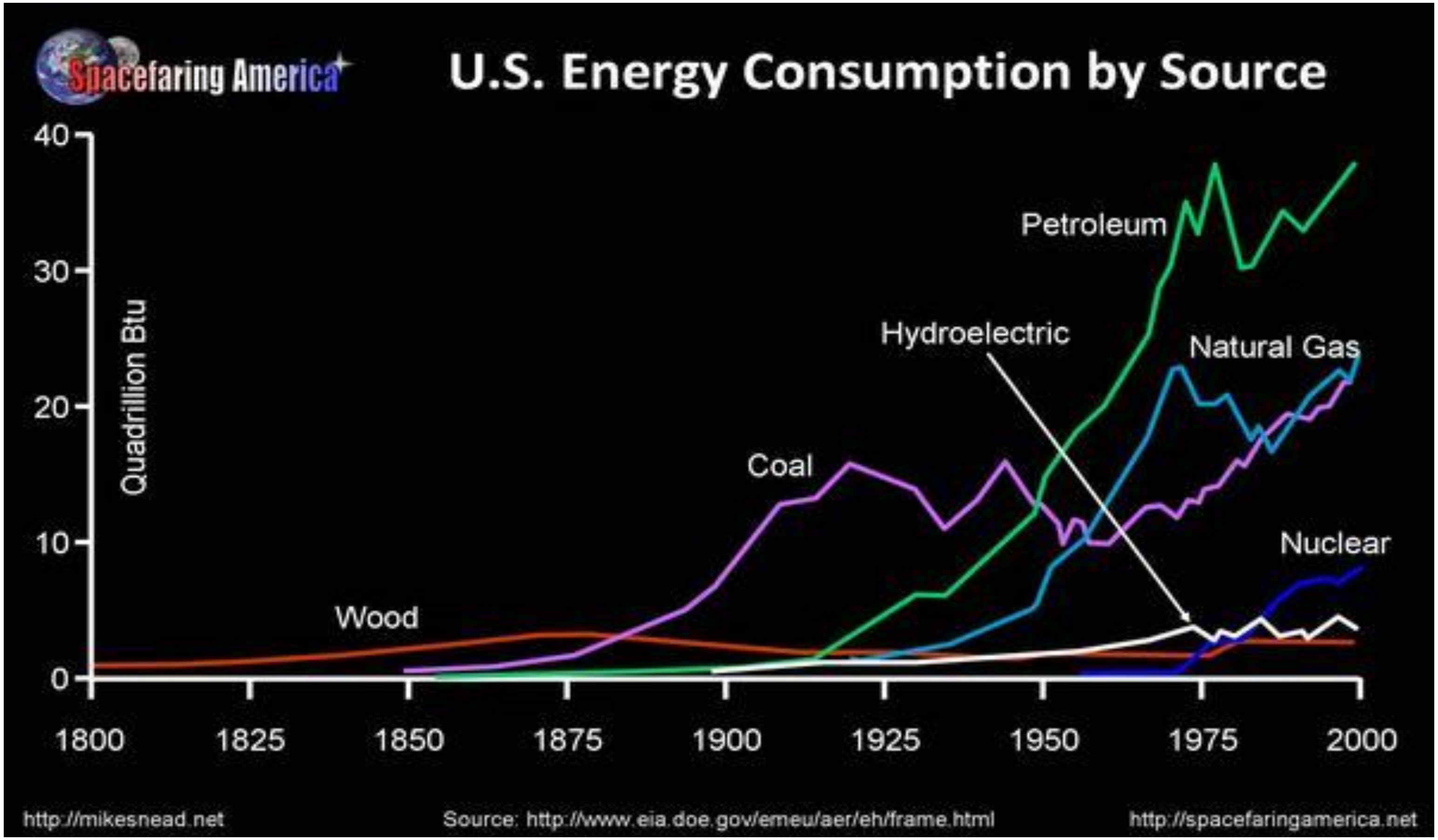


1st LAW: Conservation of Energy

- Energy cannot be created or destroyed

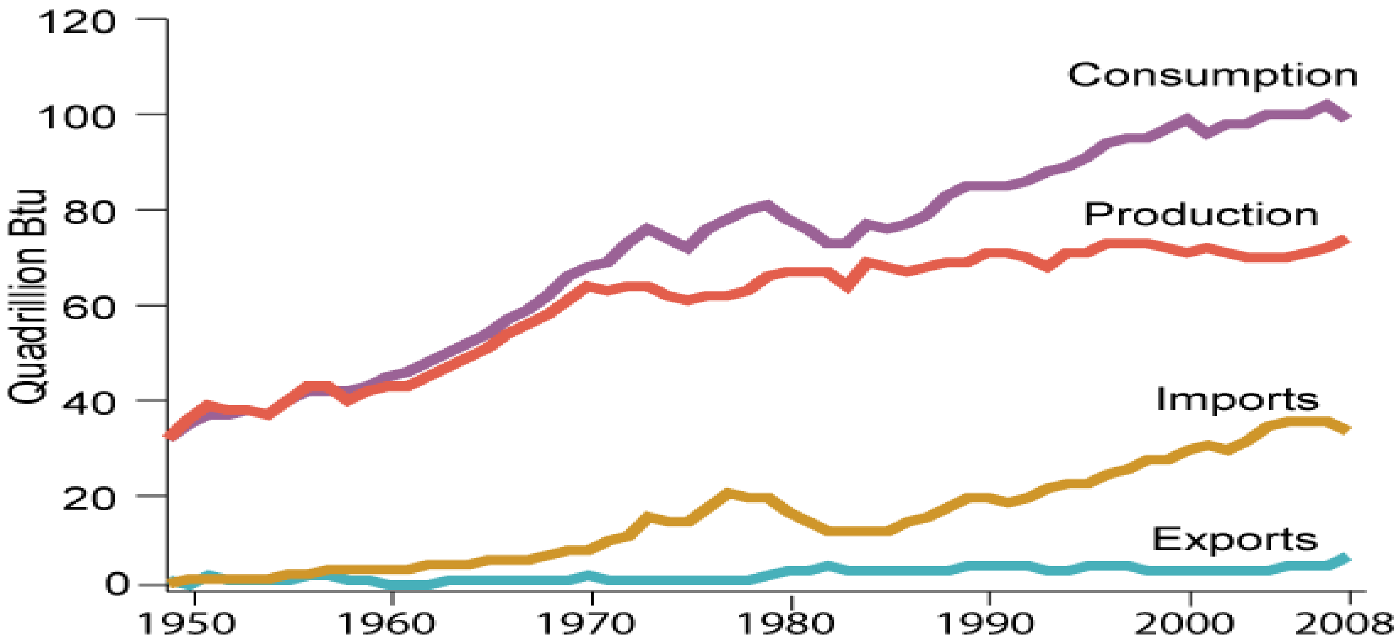
2nd LAW: Entropy

- When energy is converted from one form to another, a less useful form results (energy quality)
- EX: gasoline; only 20% of chemical energy is converted to mechanical, the rest is released as low-quality energy (heat)



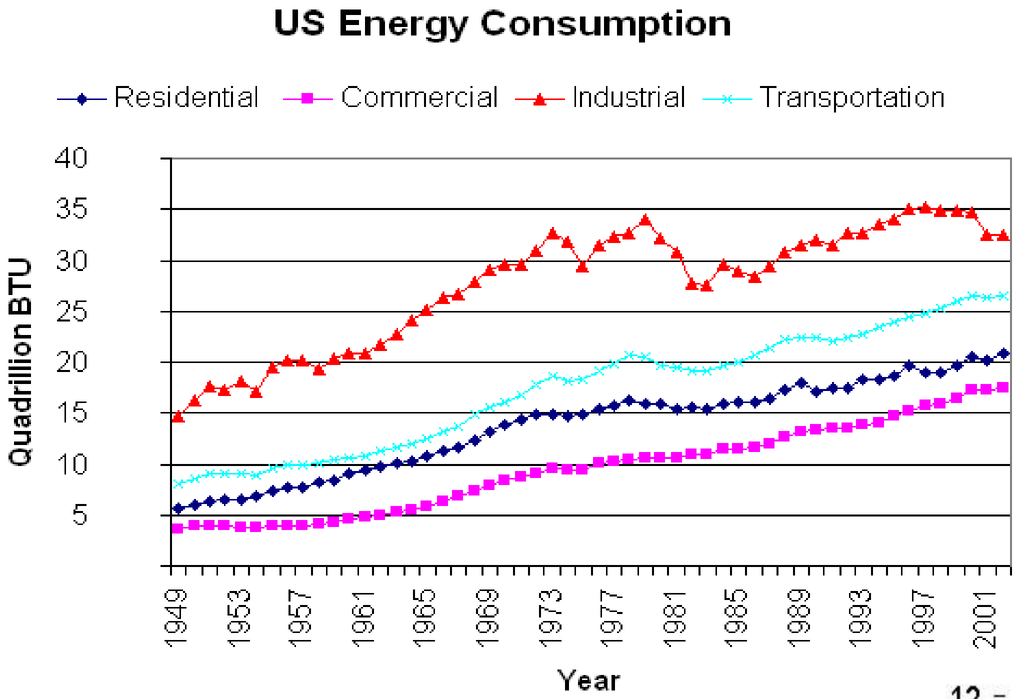
- Pre-Industrial Revolution: Wood
- Industrial Revolution: Coal
- Middle of 20th Century: Petroleum
- Late 20th Century: Natural Gas and Coal

U.S. Primary Energy Overview

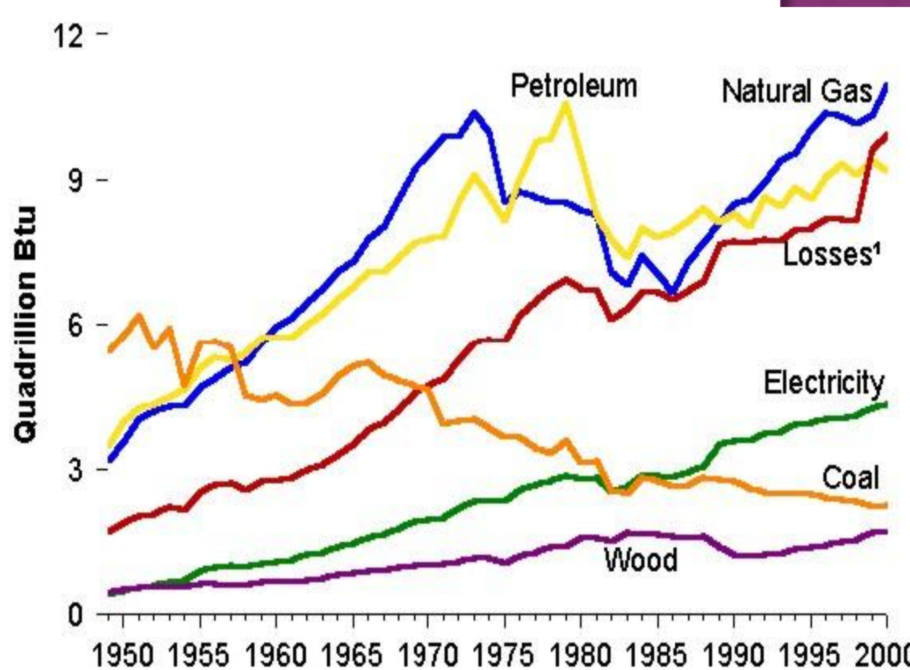


Source: Energy Information Administration, *Energy Perspectives*, Figure 1 (June 2009).

- Self-sufficient in energy until 1950s
- When consumption outpaced domestic production we needed oil to be imported



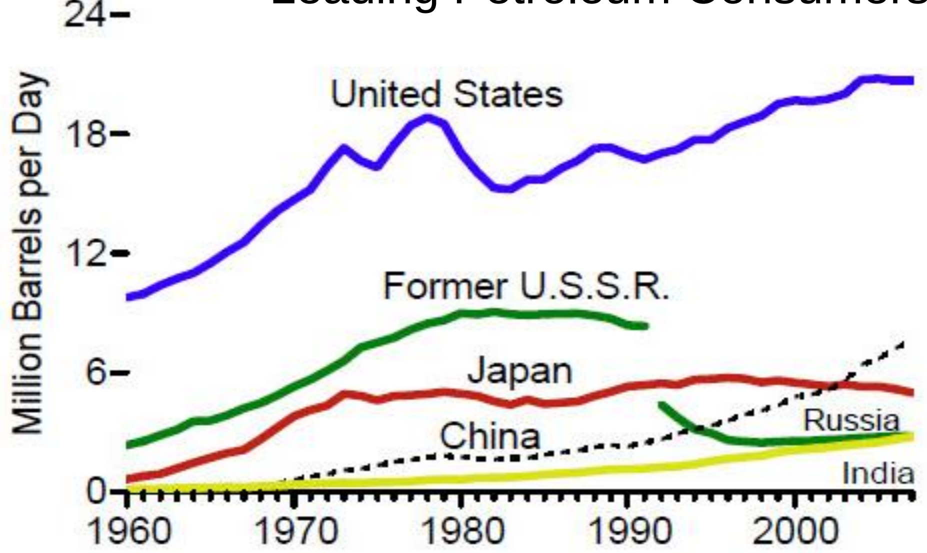
- Industrial is highest user (see above)
- Coal mostly used in 1950
- Late 1950's petroleum & natural gas use increases



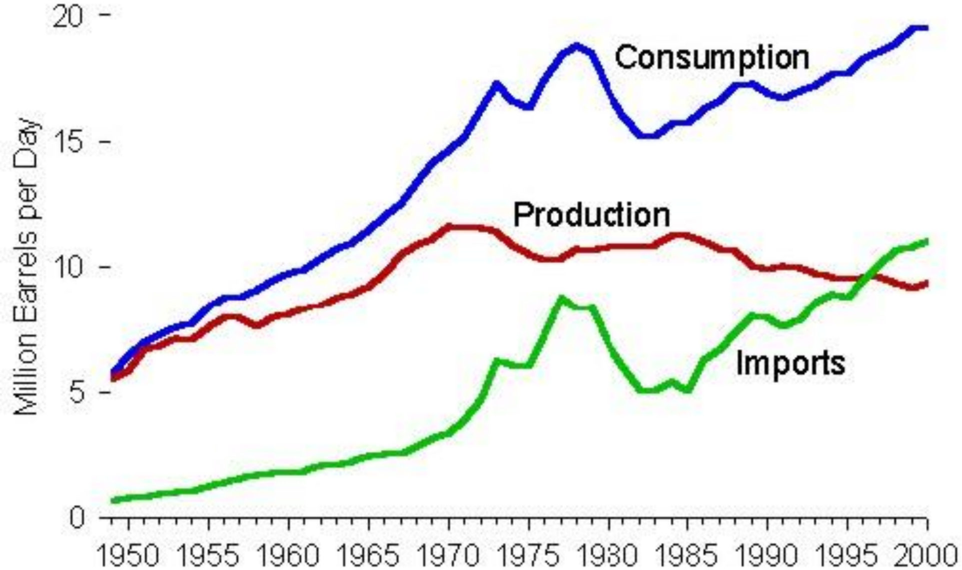
[1] Energy lost during generation, transmission, and distribution of electricity

- Beginning in 1998, net imports of oil surpassed the domestic oil supply in the U.S.
- The United States accounts for 25% of the world consumption of petroleum.

Leading Petroleum Consumers

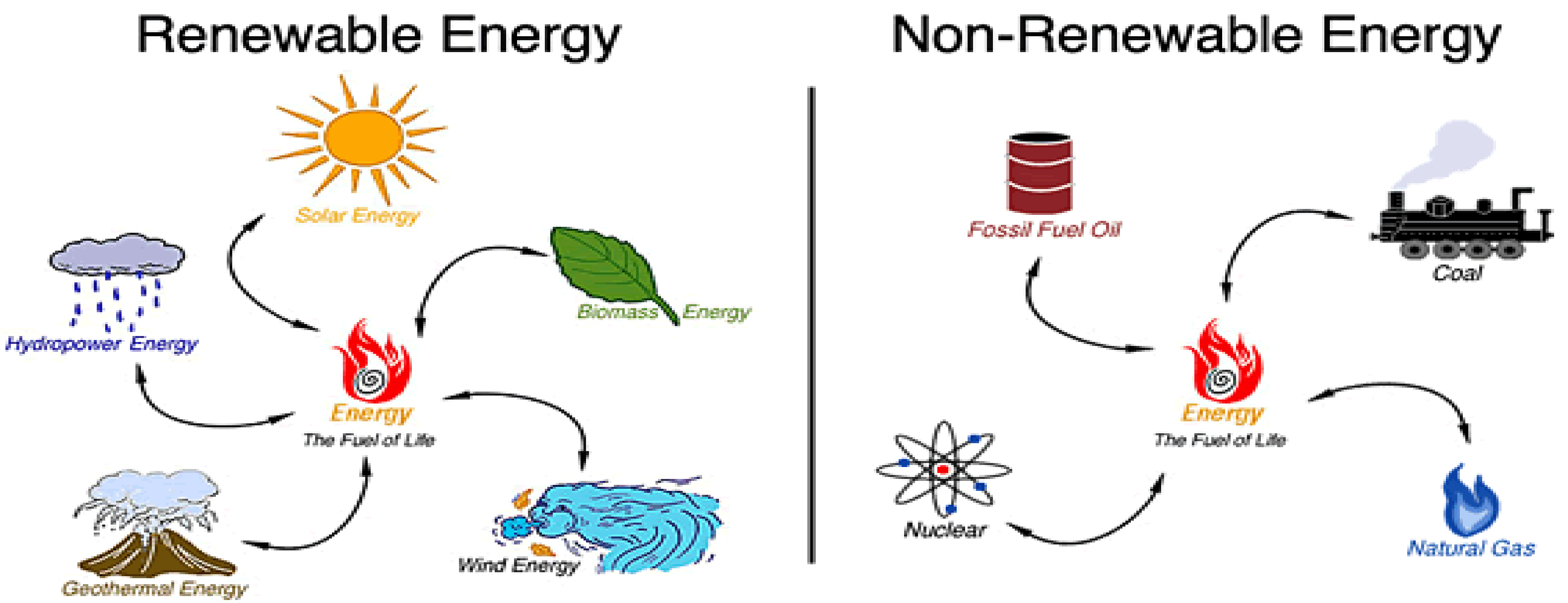


U.S. Petroleum Overview



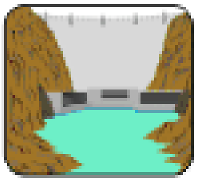
GLOBAL ENERGY USE

- <u>nonrenewable energy</u>: supplies are limited
  - →coal, petroleum, natural gas, propane, uranium
- <u>renewable energy</u>: replenished in a short period of time
  - → biomass, geothermal, hydropower, solar energy and wind



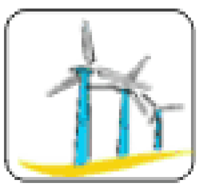
U.S. ENERGY CONSUMPTION BY SOURCE, 2007

BIOMASS 3.6%
renewable
Heating, electricity, transportation

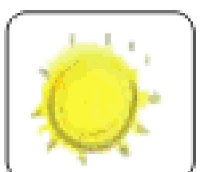


HYDROPOWER 2.4%
renewable
Electricity

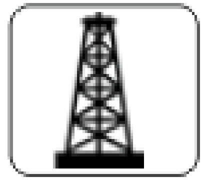
GEOTHERMAL 0.3%
renewable
Heating, electricity



WIND 0.3%
renewable
Electricity



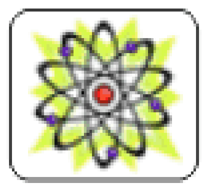
SOLAR & OTHER 0.1%
renewable
Light, heating, electricity



PETROLEUM 37.5%
nonrenewable
Transportation, manufacturing

NATURAL GAS 23.3%
nonrenewable
Heating, manufacturing, electricity

COAL 22.5%
nonrenewable
Electricity, manufacturing



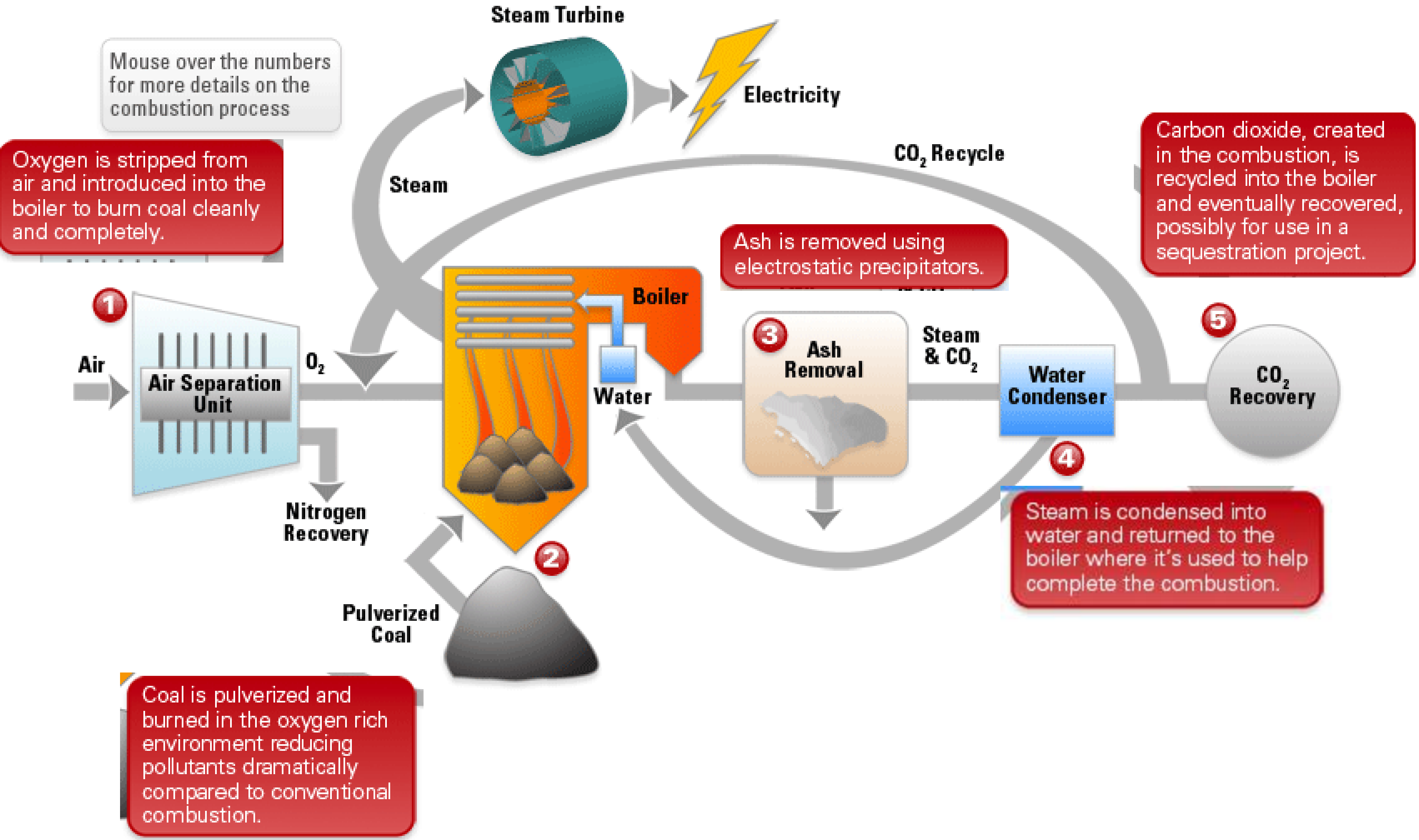
URANIUM 8.3%
nonrenewable
Electricity

PROPANE 1.7%
nonrenewable
Manufacturing, heating

FUTURE ENERGY NEEDS: COAL

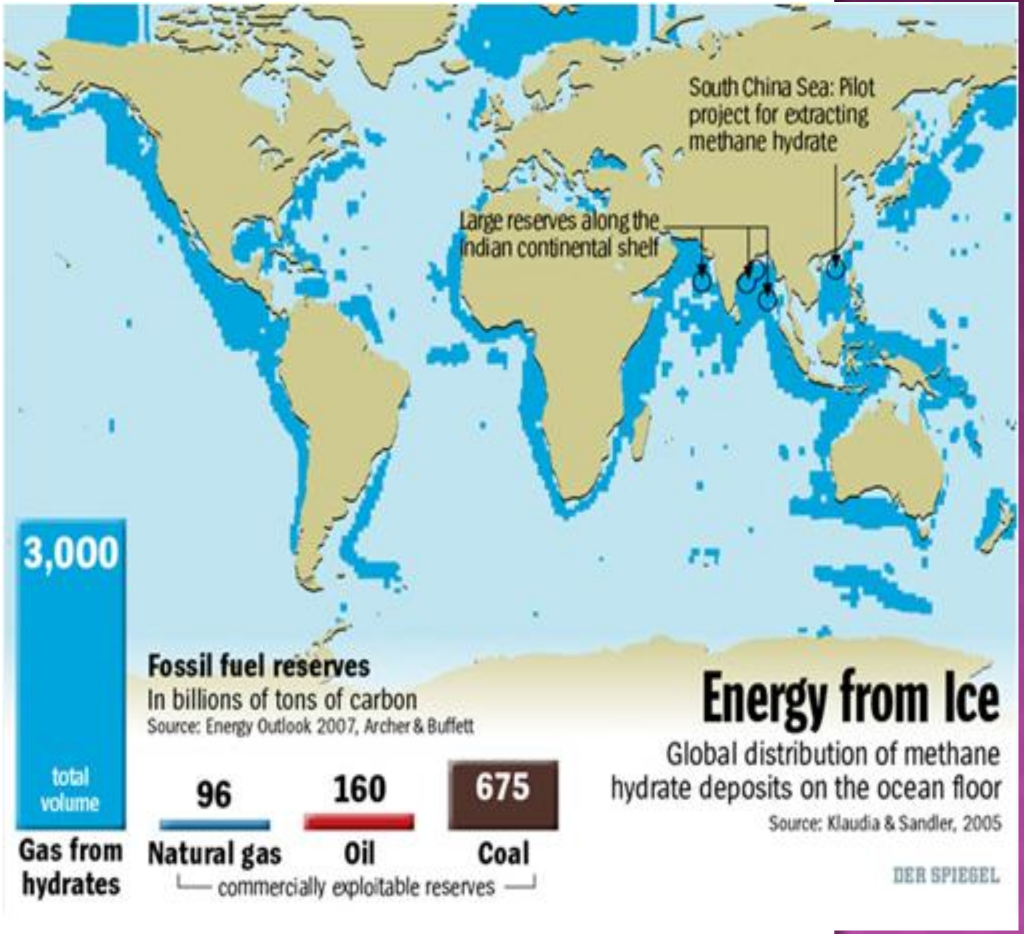
- Clean Coal Technology
  - →Processes that reduce negative environmental effects of burning coal
  - →Washing the coal to remove minerals & impurities
  - →Capturing the sulfur dioxide and carbon dioxide from the flue gases (gas exits atmosphere through pipe)

CLEANER COAL COMBUSTION

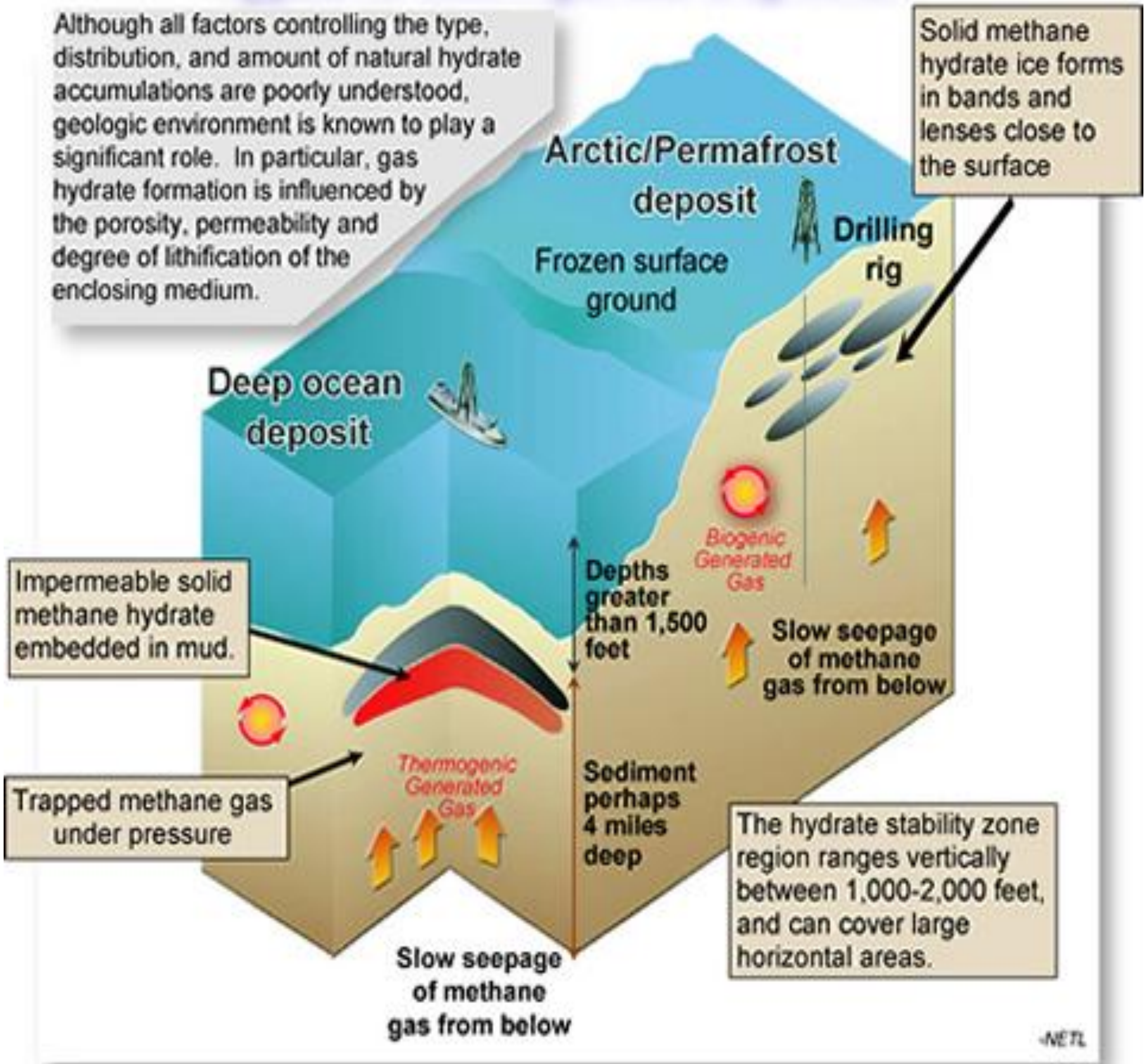


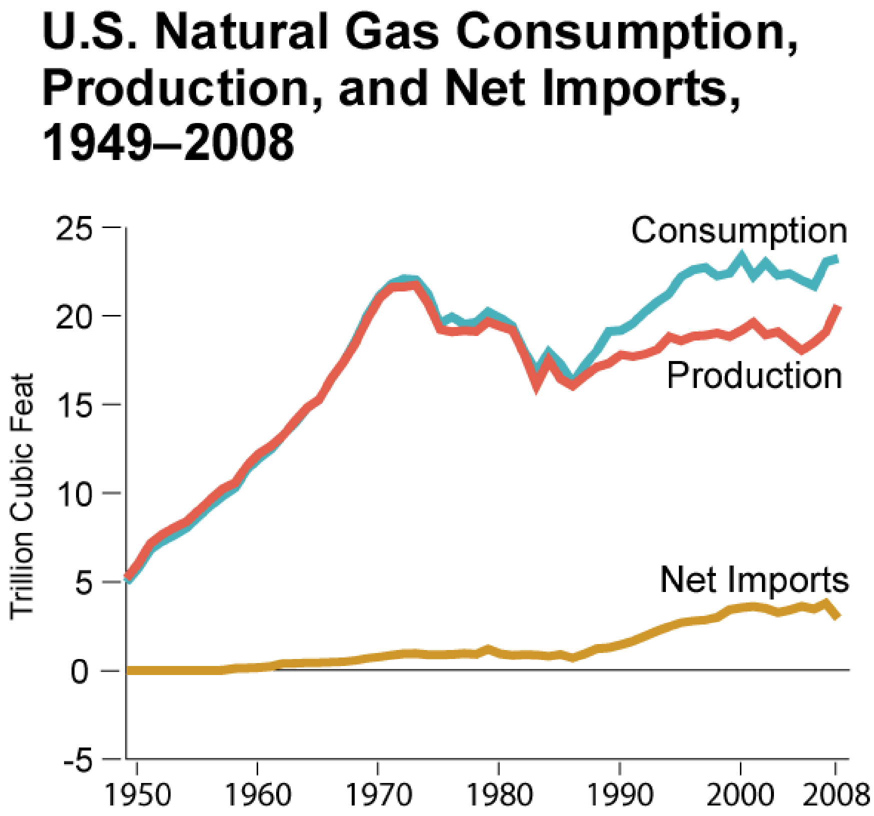
FUTURE ENERGY NEEDS: METHANE

- Methane Hydrates
  - Methane locked in ice; formed at low temperature & pressure (recent discovery)
  - Found on land in permafrost regions & beneath ocean floor
  - 3000X more than is found in atmosphere
  - Thought to be enough energy to supply for hundreds to thousands of energy

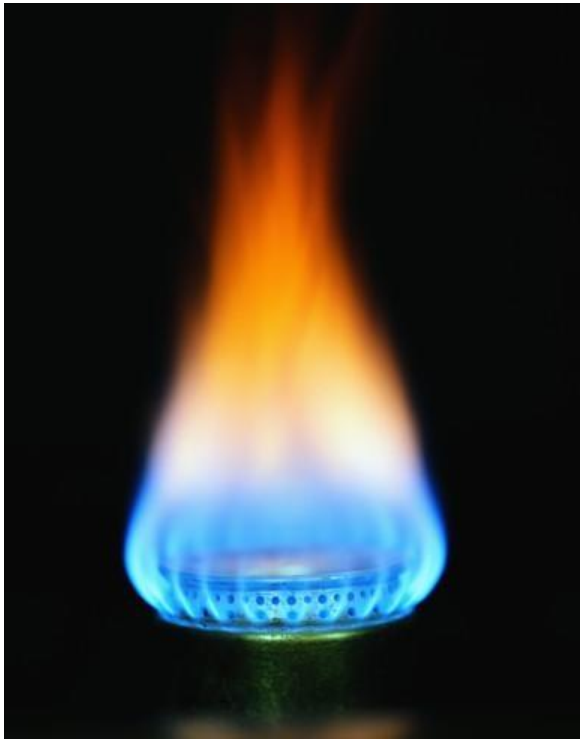


Types of Gas Hydrate Deposits





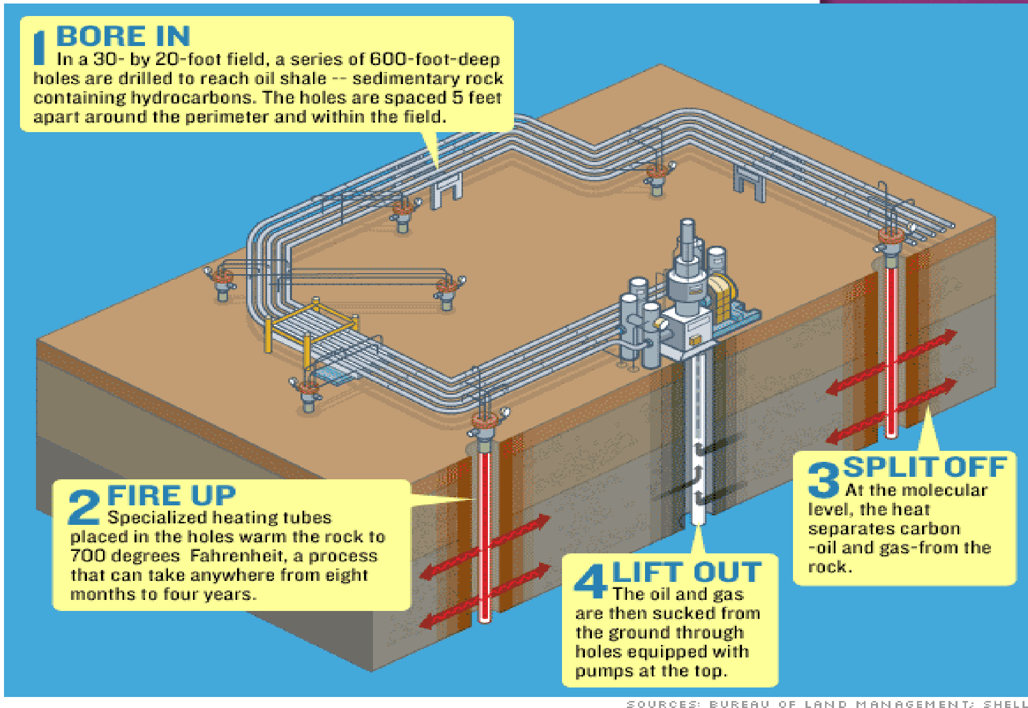
Source: Energy Information Administration, *Annual Energy Review 2008*, Table 6.1 (June 2009).



- Greater role in power generation
- Expanded use for transportation fuel
- Future use of alternative liquid fuel & hydrogen for fuel cells
- Primary waste produce is CO_2

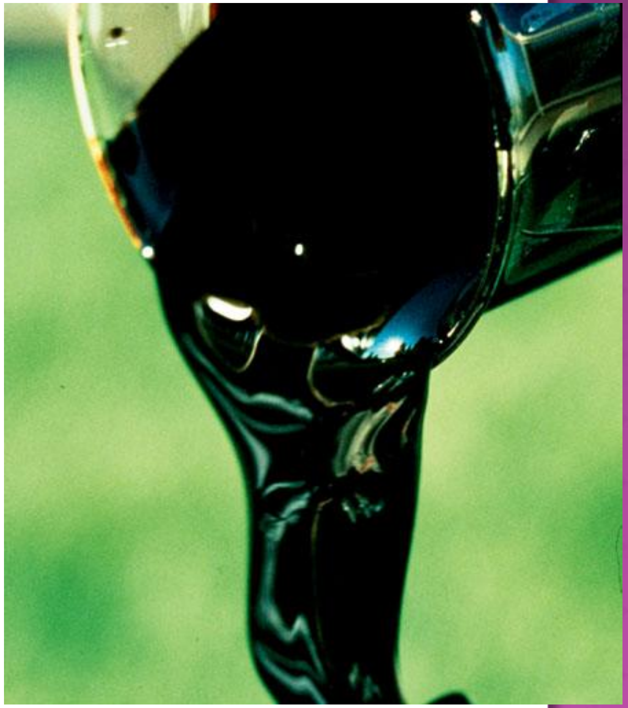
FUTURE ENERGY NEEDS: OIL SHALE

- Contains kerogen(organic material) which can be converted to oil
- 3 trillion barrels of recoverable oil (750 billion located in US)
- Largest world reserves in Estonia, Austrailia, Germany, Israel, and Jordan
- Moderate net energy yield
- Environmental Costs
  - →Surface mining
  - →Pollution
  - →Acid rain
  - →Global warming



FUTURE ENERGY NEEDS: TAR SANDS

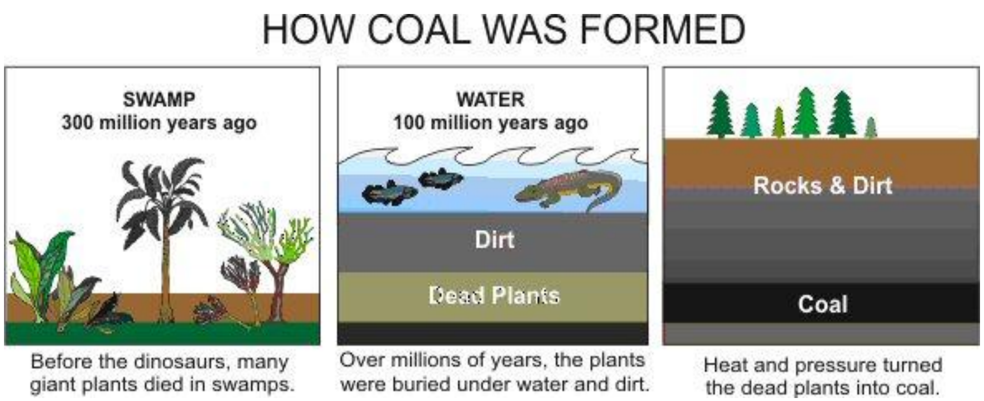
- Contain bitumen (semi-solid form of oil that does not flow)
- Specialized refineries can convert bitumen to oil
- Deposits are mined using strip-mining techniques
- Deposits located in Canada & Venezuela
- Represents 2/3 of the world's total oil reserves
- Moderate net energy yield
- Environmental Costs
  - →Pollution
  - →Acid rain
  - →Global warming



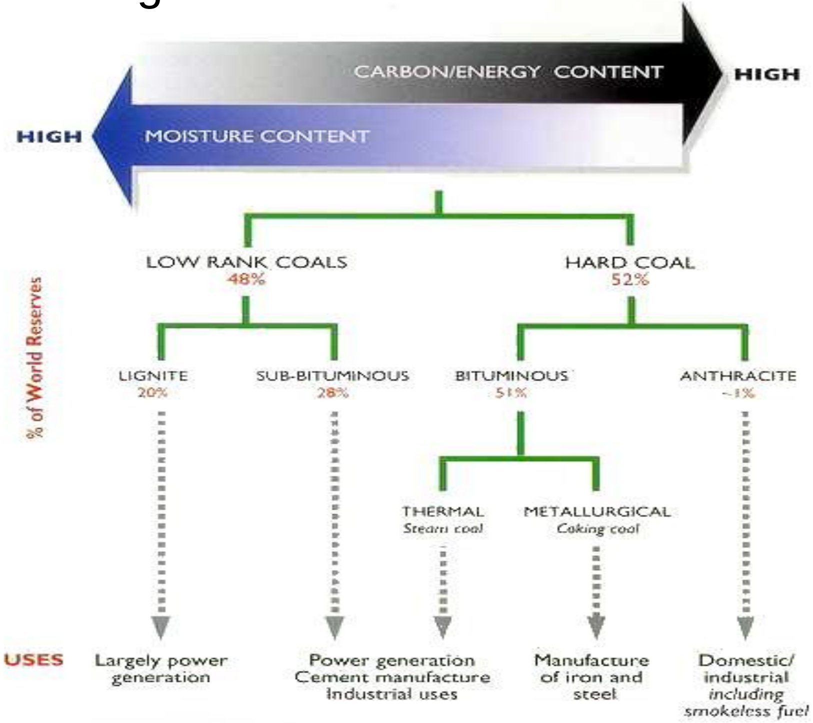
ENERGY CRISIS

- Price of energy is driven by the principle of supply & demand
- Oil supply is controlled by OPEC (Organization of Petroleum Exporting Countries) – such as Saudi Arabia & Venezuela
- Most of world's energy is supplied by burning oil
- At current rate of consumption world oil reserves are predicted to last 50 years
- As supplies decrease prices will increase (make other sources more economical)

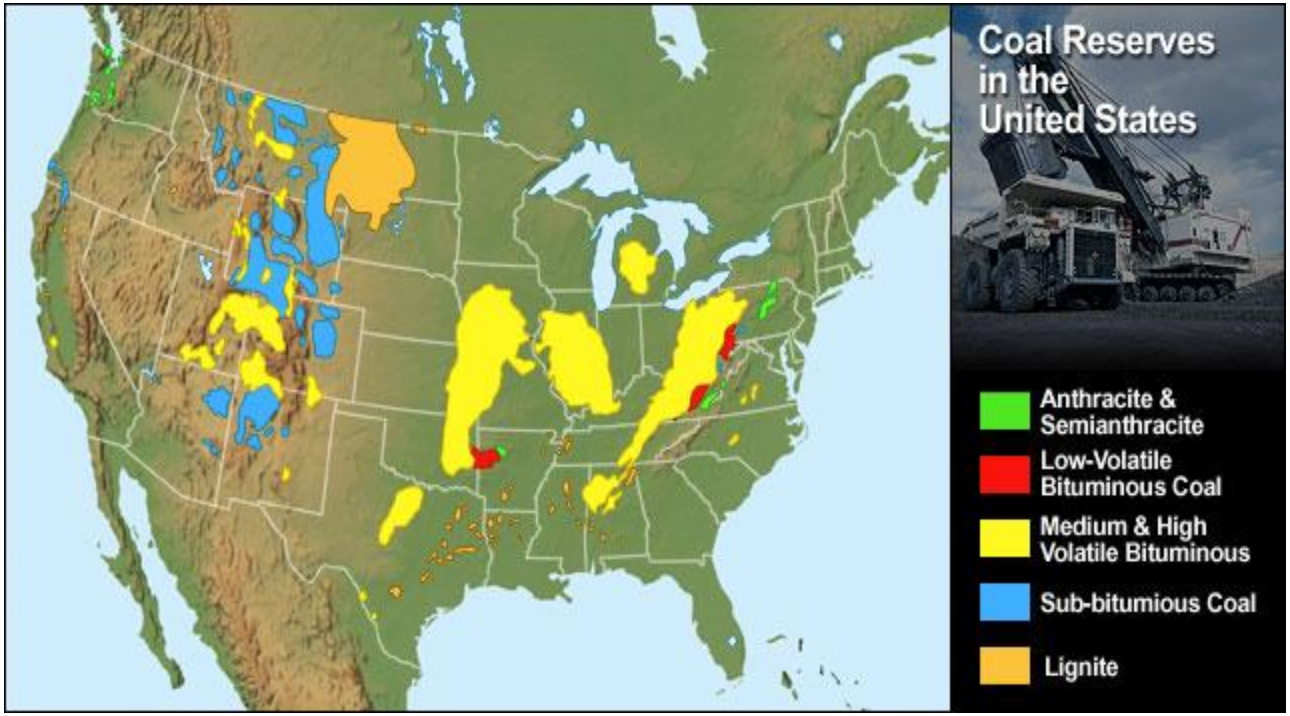
FOSSIL FUEL RESOURCES & USE



peat → lignite→ bituminous → anthracite

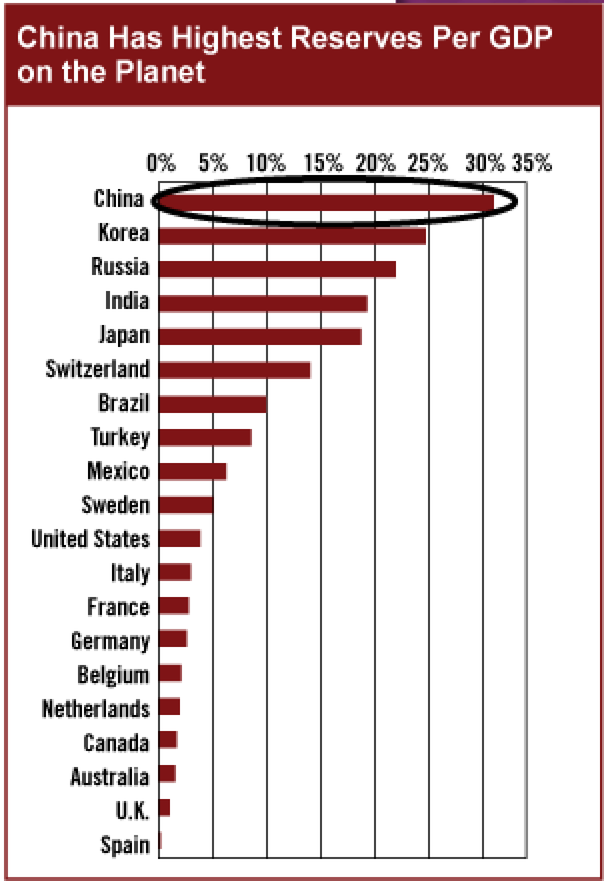


- Supplies 25% world's energy
- China and U.S. consume most
- U.S. 87% is used for power plant to produce electricity
- Clean Air Act requires reduction in release of sulfur-containing gases
  - → cleaning (washing) prior to burning coal
  - → redesigning boilers
  - → scrubbing or adding limestone or lime into the effluent

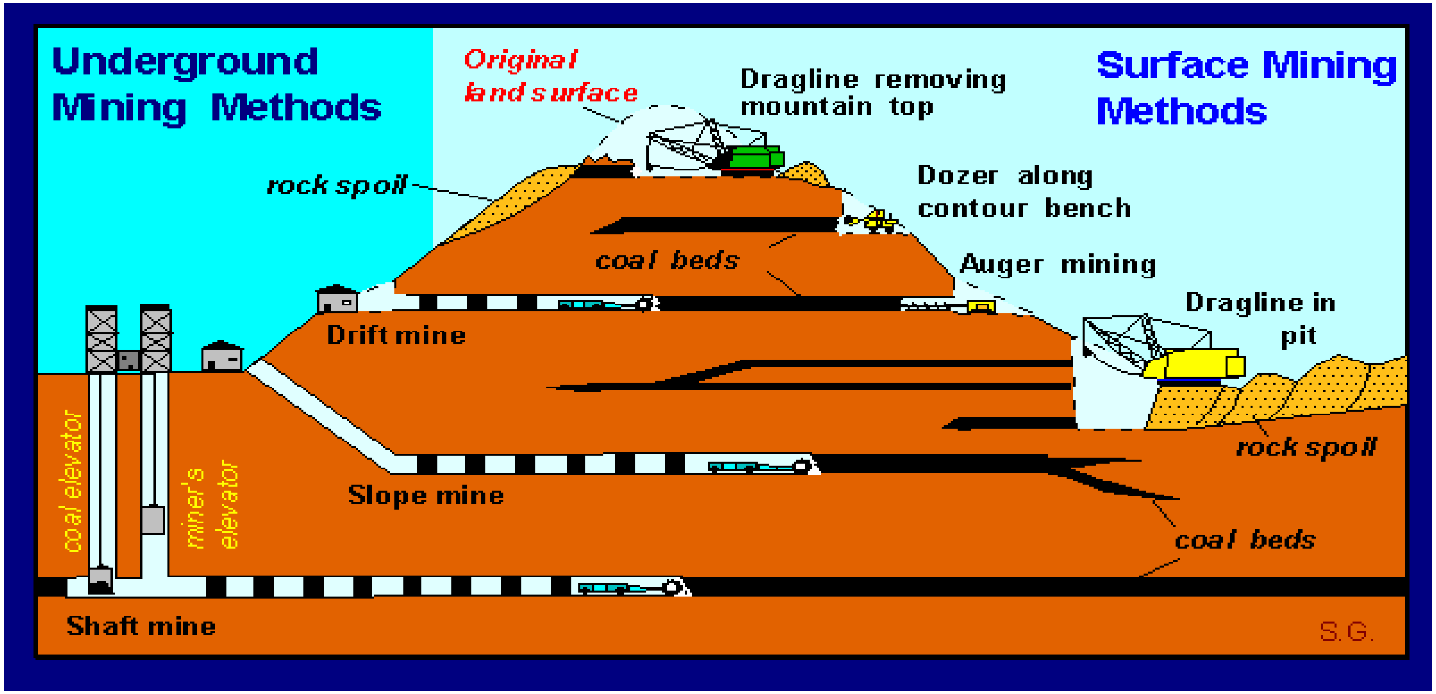


<u>Bituminous:</u> 50% of U.S. reserves

<u>Anthracite:</u> 2% of U.S. reserves



EXTRACTING COAL



- aka deep mining
- coal buried deep
- miners ride elevators deep down mine shafts
- machine dig out coal

- produces most coal in U.S.
- less expensive
- coal must be buried less than 200 feet underground
- machines remove top soil and layers of rock (overburden) to expose coal seam
- after mining, dirt & rock returned to the pit

COAL: PURIFICATION METHODS

PROCESSING COAL

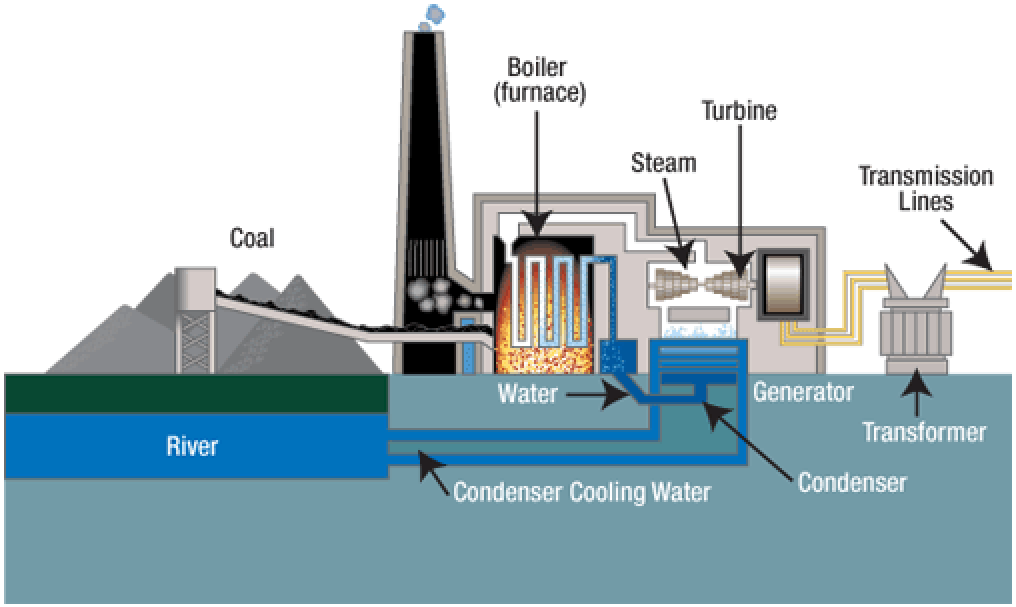
- taken to processing plant

- plant cleans & processes coal (increases heat capacity)

TRANSPORTING COAL

- cost of shipping may be greater than cost of mining

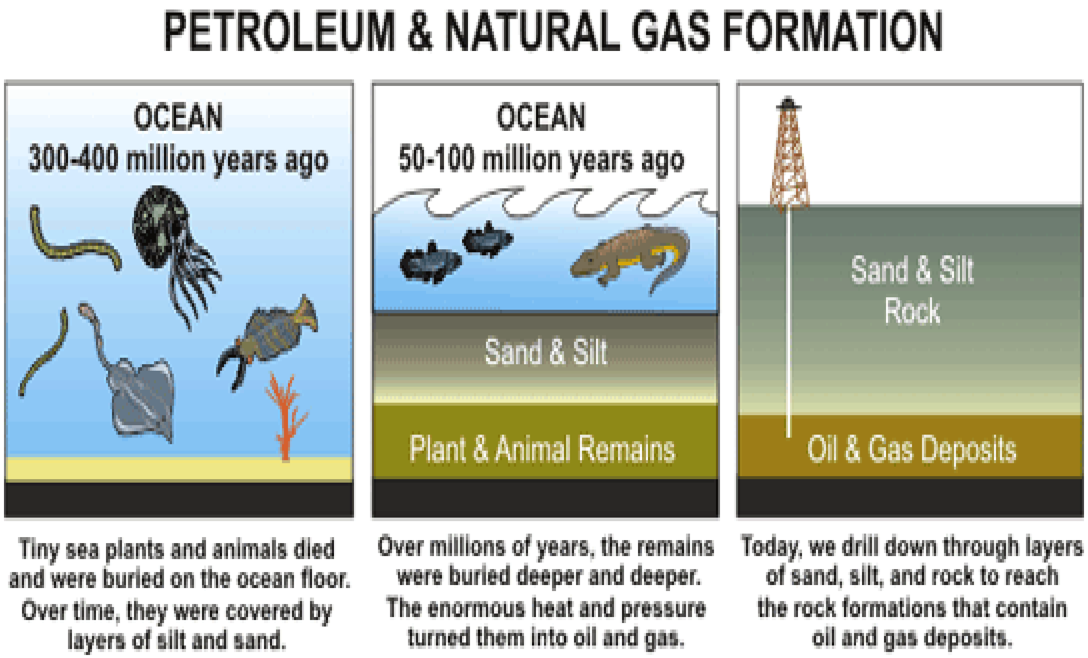
- 71% coal is U.S. is transported by train



COAL: PROS & CONS

PROS	CONS
Abundant, known world reserves will last approximately 300 years at current rate of consumption	Most extraction in U.S. is done through mining that disrupt land through erosion, runoff, and decrease in biodiversity
Unidentified world reserves are estimated to last 1,000 years at current rate of consumption	Up to 20% of coal ends up as fly ash, boiler slag or sludge; releases mercury, sulfur, radioactive particles in the air;
U.S. reserves are estimated to last 300 years at current rate of consumption	Underground mining is dangerous & unhealthy
Relatively high-net energy yield	Expensive to process & transport
U.S. government subsidies keep prices low	Can cause global warming; 35% of all CO_2 releases are due to burning of coal
Stable, non-explosive, not harmful if spilled	Scrubbers & other antipollution control devices are expensive

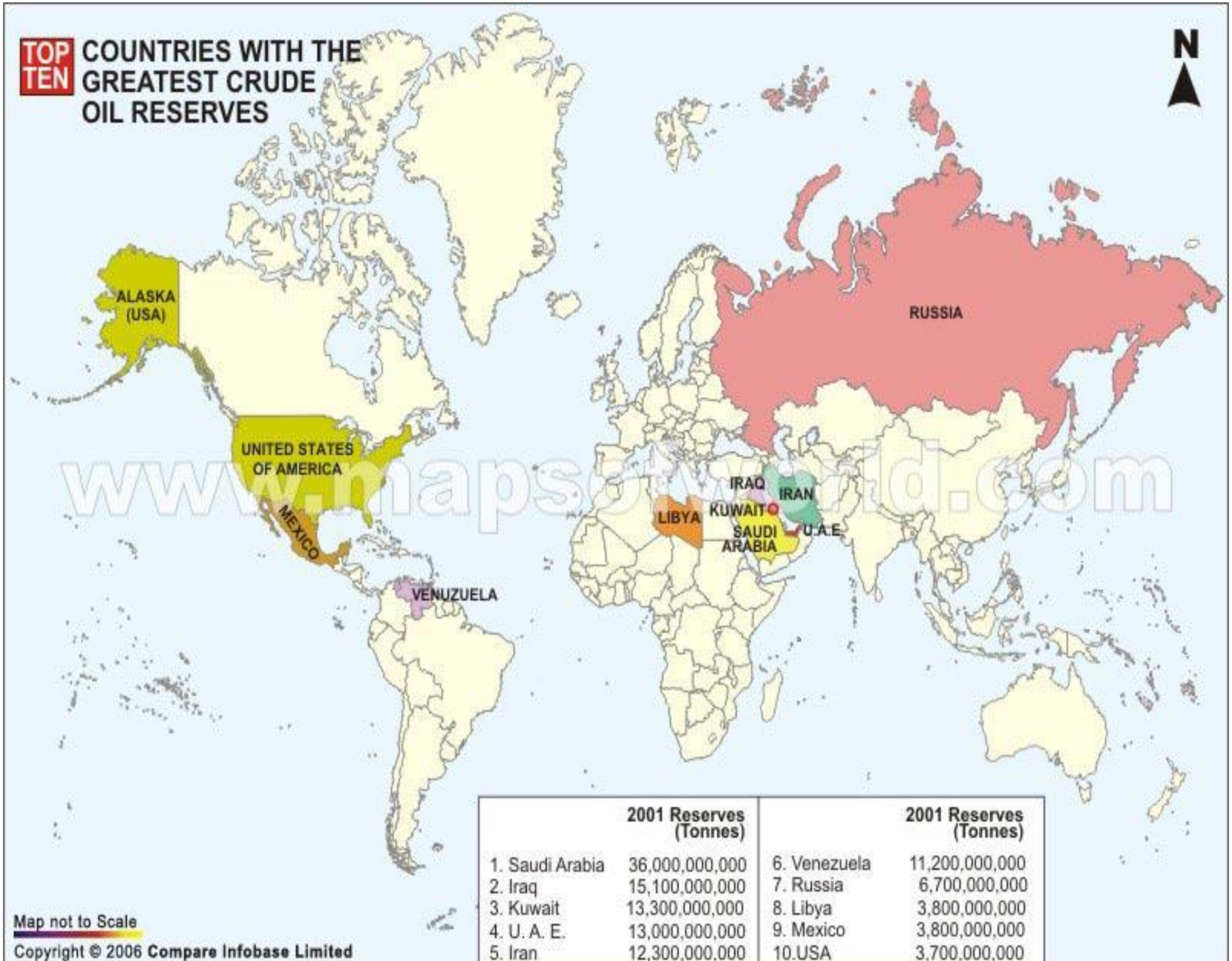
PETROLEUM: WORLD RESERVES & GLOBAL DEMAND



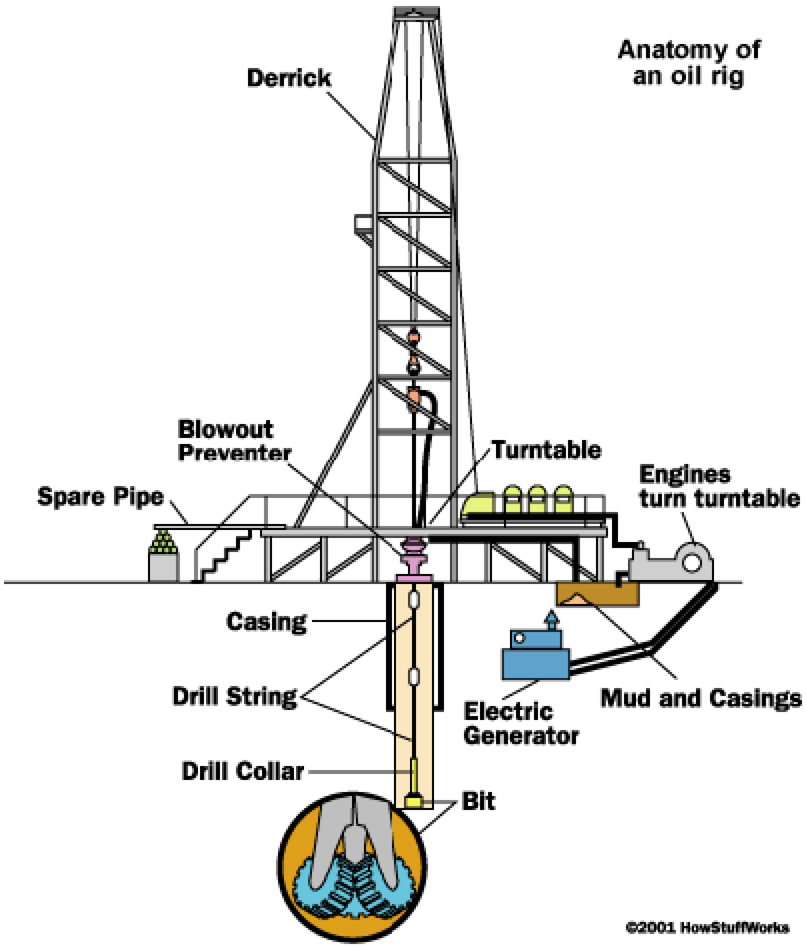
Petroleum = “rock oil” = “oil from the earth”

Crude oil is found in underground reservoirs

→ must be extracted



	2001 Reserves (Tonnes)		2001 Reserves (Tonnes)
1. Saudi Arabia	36,000,000,000	6. Venezuela	11,200,000,000
2. Iraq	15,100,000,000	7. Russia	6,700,000,000
3. Kuwait	13,300,000,000	8. Libya	3,800,000,000
4. U. A. E.	13,000,000,000	9. Mexico	3,800,000,000
5. Iran	12,300,000,000	10.USA	3,700,000,000


Anatomy of an oil rig
Derrick
Blowout Preventer
Turntable
Spare Pipe
Engines turn turntable
Casing
Drill String
Electric Generator
Mud and Casings
Drill Collar
Bit
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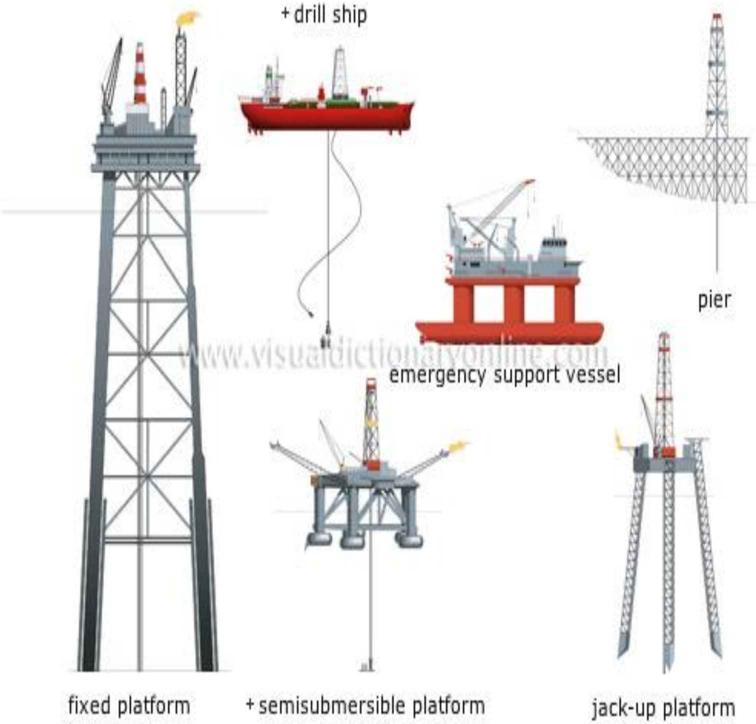
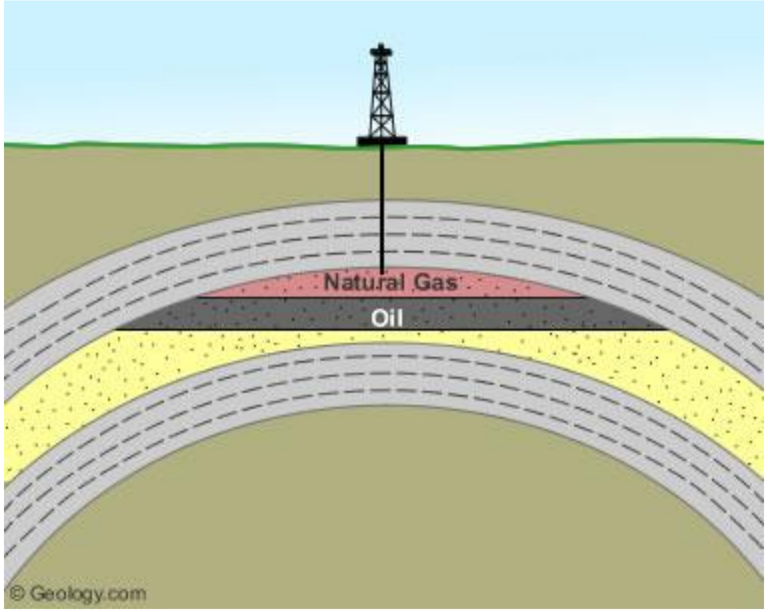

+ drill ship
pier
www.visualdictionaryonline.com
emergency support vessel
fixed platform
+ semisubmersible platform
jack-up platform

OIL: PROS & CONS

PROS	CONS
Inexpensive; however prices are increasing	World oil reserves are limited & declining
Easily transported through pipelines and distribution networks	Produces pollution (SO_2, NO_x and CO_2) Pollution releases contaminated wastewater & brine
High-net energy yield	Causes land disturbances in drilling process (accelerates erosion)
Amply supply for immediate future	Oil spills both on land & ocean from platform & tankers
Large U.S. government subsidies	Disruption to wildlife habitats (Arctic Wildlife Refuge)
Versatile – used to manufacture many products (paints, medicines, plastics, etc.)	Supplies are politically volatile

NATURAL GAS: WORLD RESERVES

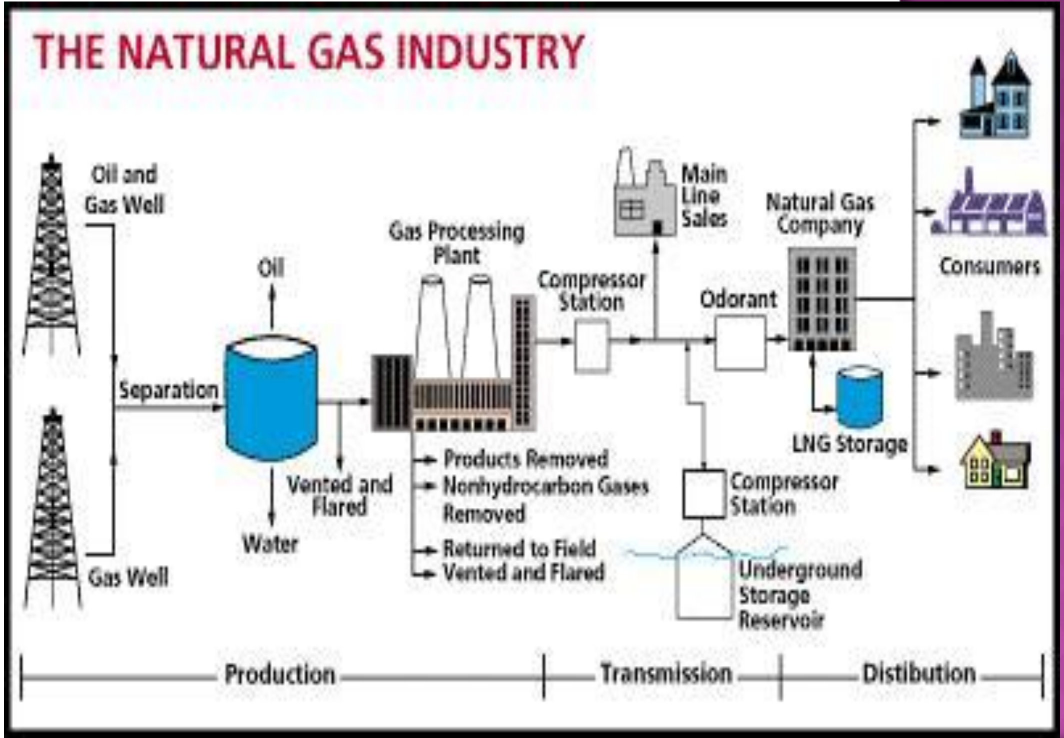


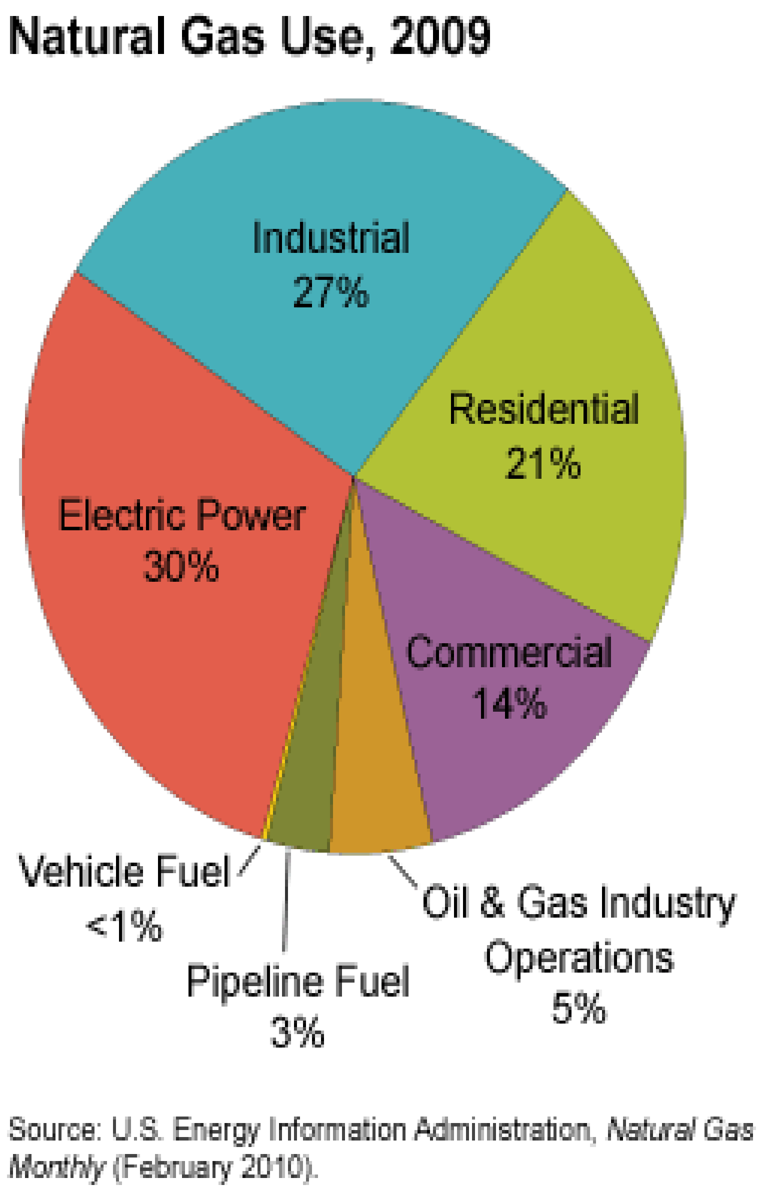
Flows from wells under its own pressure

Collected by small pipelines that feed into the large gas transmissions pipelines

U.S. produces about 20 trillion cubic feet per year

Russia & Kazakhstan have 40% of world reserves



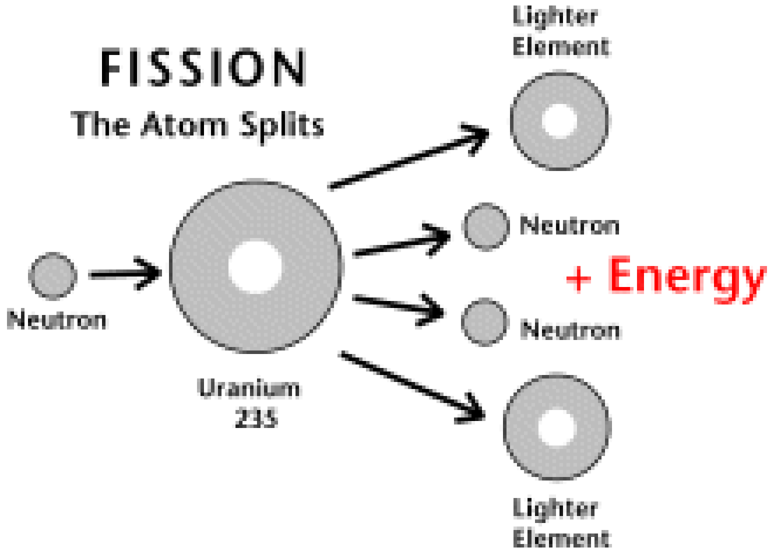


- **24% of energy used in U.S. came from natural gas in 2008**
- **Used to produce steel, glass, paper, clothing, brick, electricity**
- **Some products use natural gas as a raw material such as paints, fertilizer, plastic, dyes, medicines, explosives**
- **Half the homes in U.S. use natural gas as heating fuel**

NATURAL GAS: PROS & CONS

PROS	CONS
Pipelines & distribution networks are in place; easily processed and transported as LNG over rail or ship	H_2S and SO_2 are released during processing
Relatively inexpensive, but prices are increasing (viewed by many as a transitionary fossil fuel)	LNG processing is expensive & dangerous (results in lower net energy)
World reserves are estimated to be 125 years at current rate of consumption	Leakage of CH_4 has a greater impact on global warming than does CO_2
High net energy yield	Disruption of areas where it is collected
Produces less pollution than any other fossil fuel	Extraction releases contaminated wastewater and brine
Extraction is not as damaging to the environment as either coal or oil	Land subsidence

NUCLEAR ENERGY: FISSION



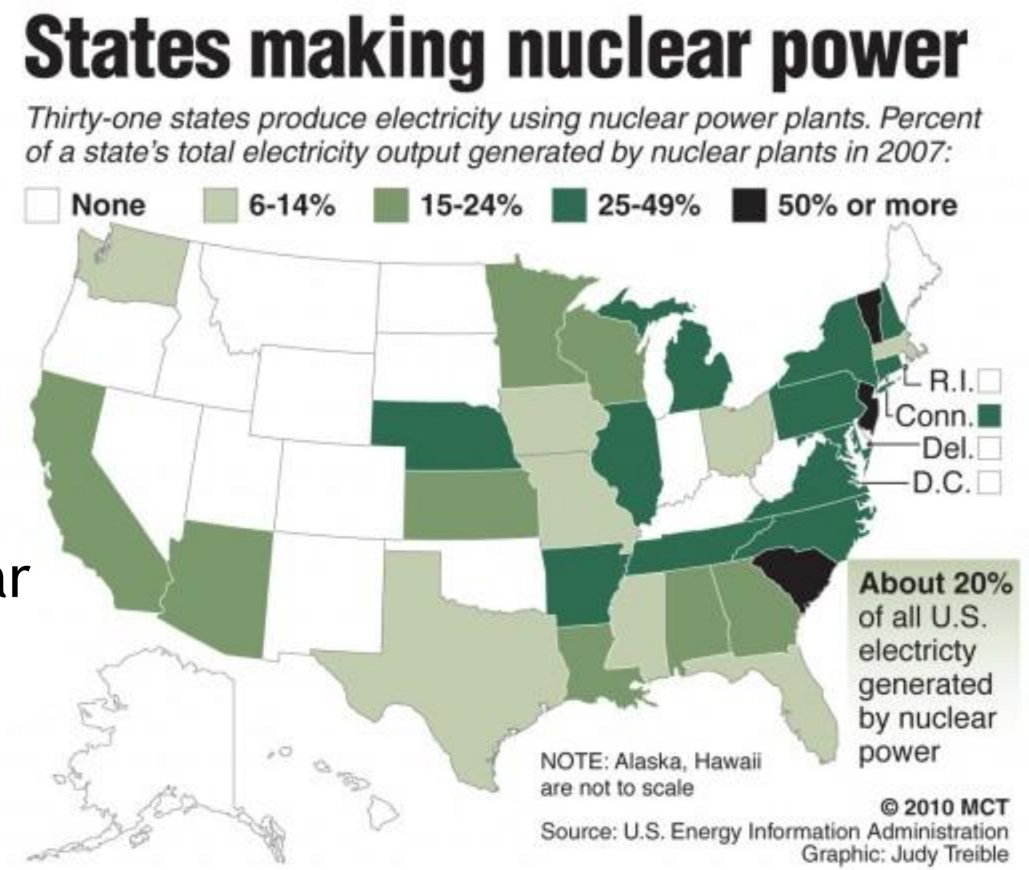
- Atom splits into 2 or more smaller nuclei
- Exothermic reaction
- If controlled,

  heat produced → produces steam → turns generators → produce electricity
- If NOT controlled, nuclear explosion can occur

NUCLEAR FUEL

- U-235
  - Minimum amount needed is called critical mass
  - Half-life = 700 million years
  - Nuclear weapons contain 85%
  - Nuclear power plants contain 3%
- U-238
  - Most common isotope of uranium
  - Half-life = 4.5 billion years
  - When hit by neutron decays into Pu-239 (fuel used in fission reactors)
- PU-239
  - half-life = 24,000 years
  - Produced in breeder reactors
  - Provides 1/3 of the total energy produced in typical commercial nuclear power plant
  - Control rods in power plant need to be changed frequently (buildup)
  - International inspections regulate the amount produced

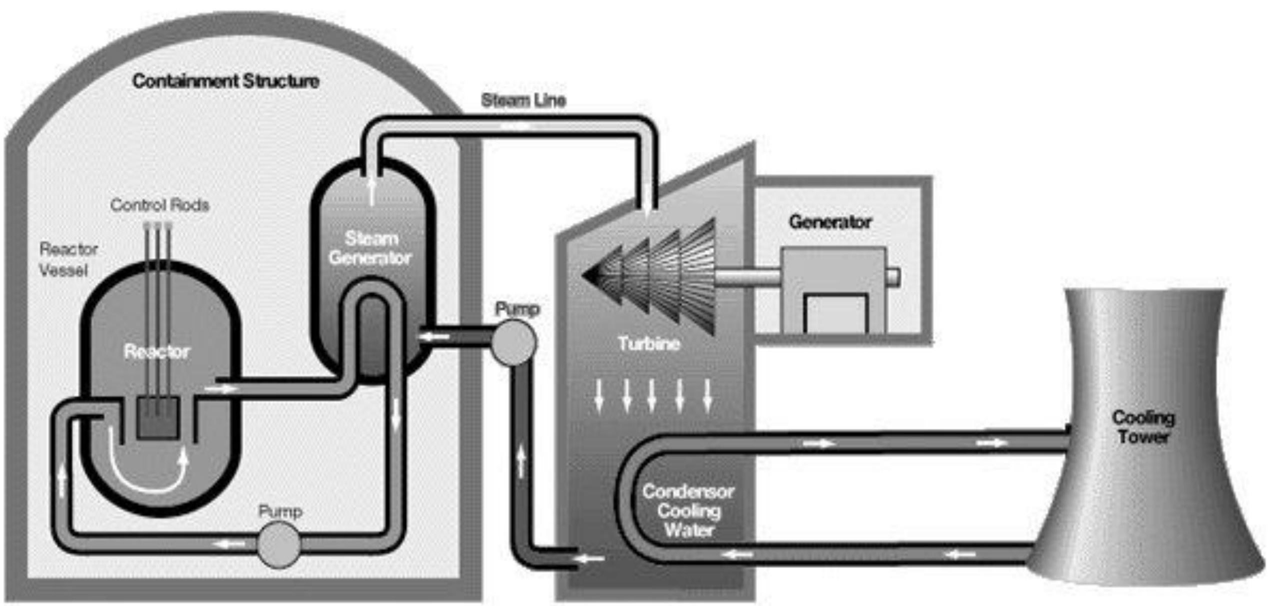
- Decline in worldwide nuclear power
  - → Cost overruns
  - → Higher-than expected operating costs
  - → Safety issues
  - → Disposal issues of nuclear wastes
  - → Perception as risky investment



- China building 50 new reactors by 2020
- France receives 75% of energy needs from nuclear energy

NUCLEAR POWER PLANT

- Core: contains 50,000 fuel rods (each pellet has energy equivalent of 1 ton of coal)
- Fuel: Uranium oxide 97% U-238 3% U-235
- Control Rods: made of boron; move in and out of the core to absorb neutrons and slow down the reaction
- Moderator: reduces the velocity of the fast neutrons; can be water, graphite, one deuterium oxide (heavy water)
- Coolant: removes heat & produces steam to generate electricity



NUCLEAR ENERGY: PROS & CONS

PROS	CONS
No air pollutants if operating correctly	Nuclear wastes takes millions of years to degrade; problem of where to store them and keeping them out of hands of terrorists
Releases about 1/6 of the CO_2 as fossil fuel plants (reduces global warming)	Current facilities have a lifespan of only 15-40 years
Water pollution is low	Low net-energy yield (energy required for mining Uranium, processing ore, building & operating plant, storing waste)
Disruption of land is low to moderate	Safety & malfunction issues

NUCLEAR ENERGY: LEGISLATION & CASE STUDIES

- Price-Anderson Nuclear Indemnity Act (1957)
  - → Covers all nonmilitary nuclear facilities constructed before 2026
  - → Indemnifies the nuclear industry against all liabilities claims arising from nuclear accidents
  - → Compensation coverage for general public (first $10 billion comes from nuclear industry; above that from U.S. government)
- Chernobyl, Ukraine (1986)
  - → Explosion in nuclear power plant sent highly radioactive debris throughout northern Europe
  - → Estimated 32,000 deaths, 62,000 square mile contamination
  - → 500,000 people exposed to dangerous levels of radiation
  - → Cost estimates $400 billion
  - → Cause determined to be design & human error