Nonrenewable Energy Resources

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   energy sources, criteria for evaluation, efficiency
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   what is natural gas? supplies, environmental issues
4. Coal
   what is natural coal? supplies, environmental issues
5. Nuclear Energy
   what happened to nuclear power? environmental issues

1. Evaluating Energy Resources

Most commercial energy comes from nonrenewable fossil fuels, though less developed countries (LDCs) use more renewable sources than more developed countries (MDCs).

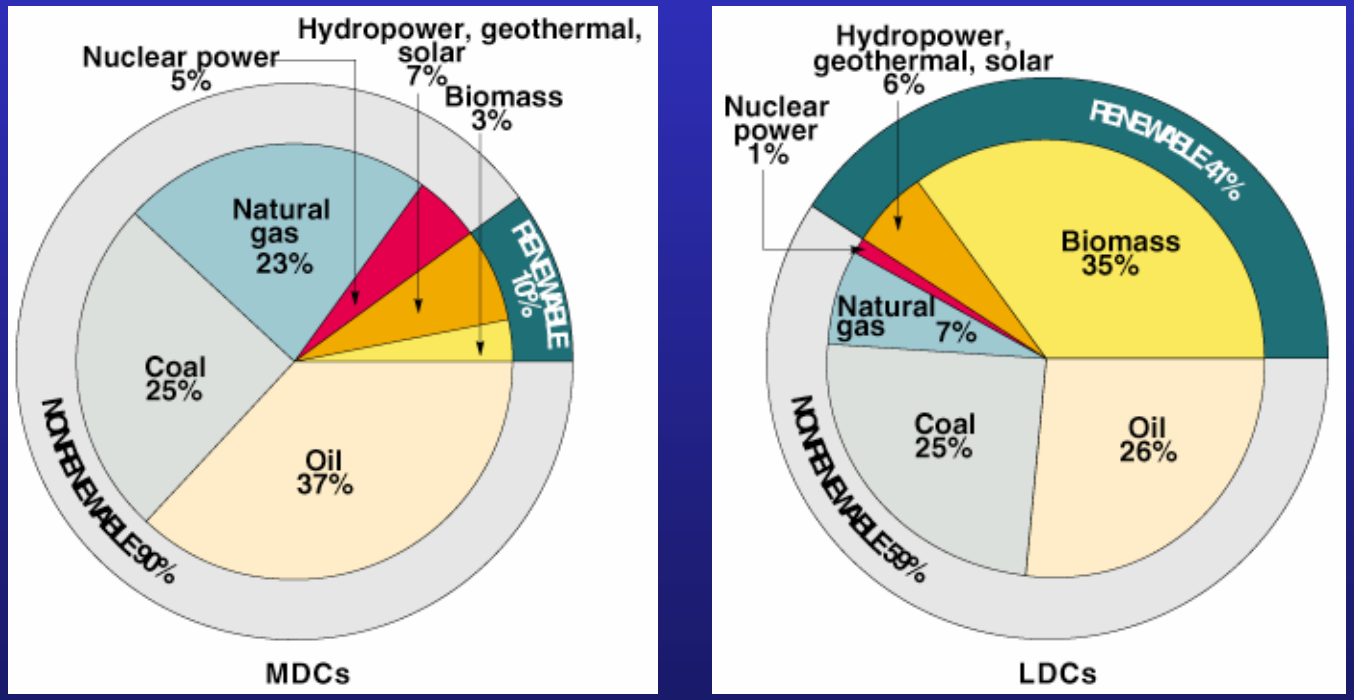


Fig.15–3

Energy Use in the U.S.

The United States is the largest user (& waster) of commercial energy.

- U.S. has 4.6% of world population, but uses 24% of the commercial energy;
- 84% of the U.S. commercial energy comes from nonrenewable fossil fuels (oil, coal, & natural gas);
- 7% of the U.S. commercial energy comes from nuclear power;
- only 9% of the U.S. commercial energy comes from renewable sources (hydropower, geothermal, solar, biomass).

Energy Use in the U.S.

Since the early 1800s, the sources of commercial energy used in the United States have shifted from wood to coal to a mix of oil, coal, natural gas, & nuclear.

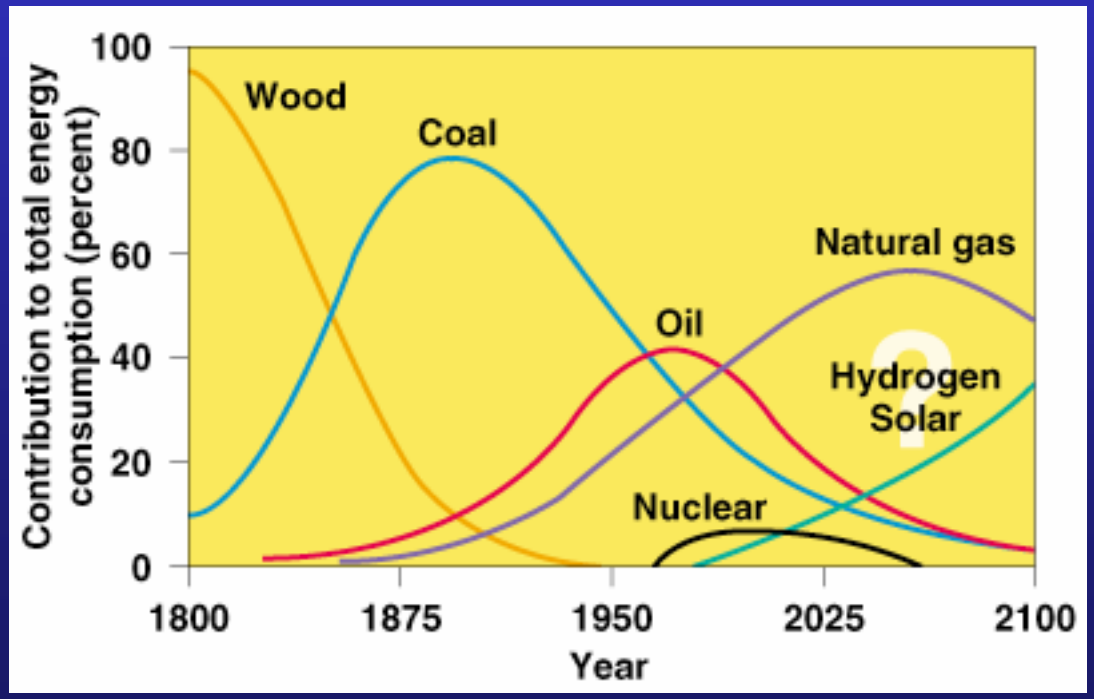


Fig.15–4

Evaluating Energy Resources

Criteria:

- How much of an energy source is available?
  - near future = next 15 years
  - intermediate future = next 30 years
  - long term = next 50 years
- How much does it cost to develop, phase in, & use?
- How does extraction, transport, & use affect the environment?
- What will using an energy source do to help sustain humans & other species living on Earth?
- What is the source's net energy yield?

What is Net Energy?

Net energy: the total useful energy available from a resource over its lifetime minus the amount of energy used, automatically wasted, & unnecessarily wasted to find, process, & transport it.

- example: if 8 units of energy are wasted for every 10 units extracted, then there is a net energy of 2 units;
- **net energy ratio** is the ratio of useful energy produced to the useful energy used to produce it; the higher the ratio the greater the net energy yield;
- for the above example the net energy ratio is 10/8 = 1.25.

Net Energy Ratios

Net energy ratios for various energy systems used for space heating.

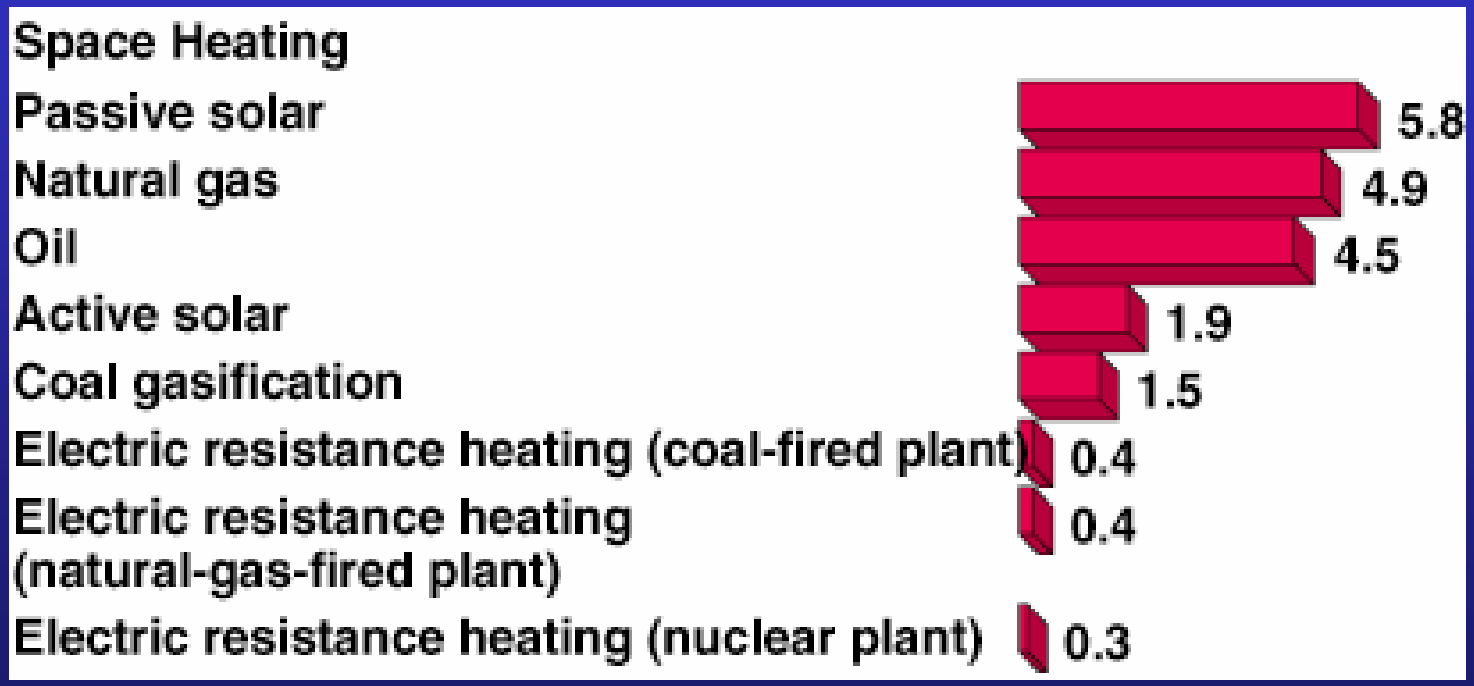
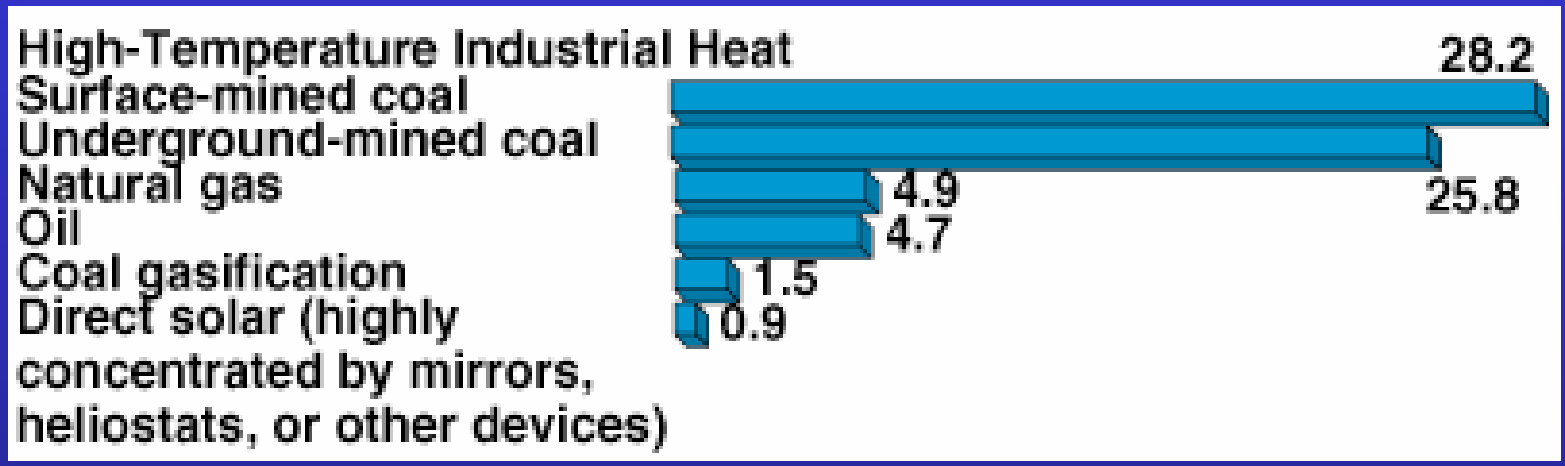
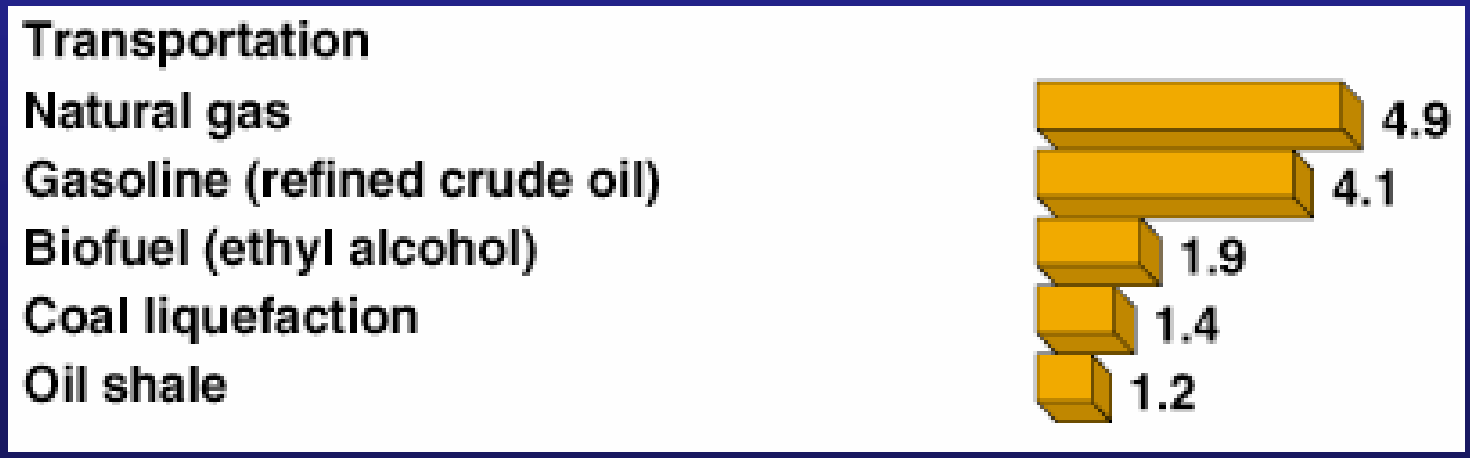


Fig.15–3

Net energy ratios for various energy systems used for industry.

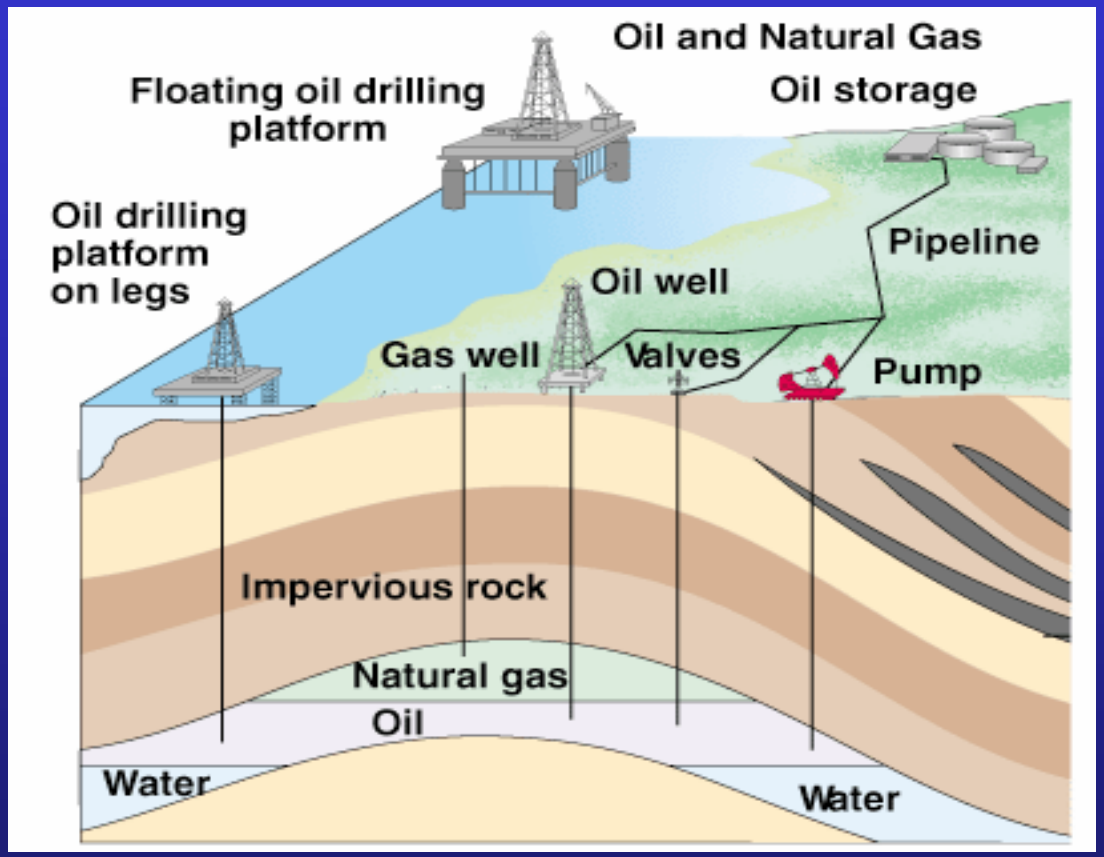


Net energy ratios for various energy systems used for transportation.



2. Oil

Petroleum or crude oil is a complex liquid mixture of hydrocarbons, with small amounts of sulfur, oxygen, & nitrogen impurities produced by the decomposition of deeply buried organic matter from plants & animals (fossil fuel).



Crude oil and natural gas are generally found together in sedimentary rock layers, with the oil dispersed in pores and cracks of the rock formation.

Recovering Oil

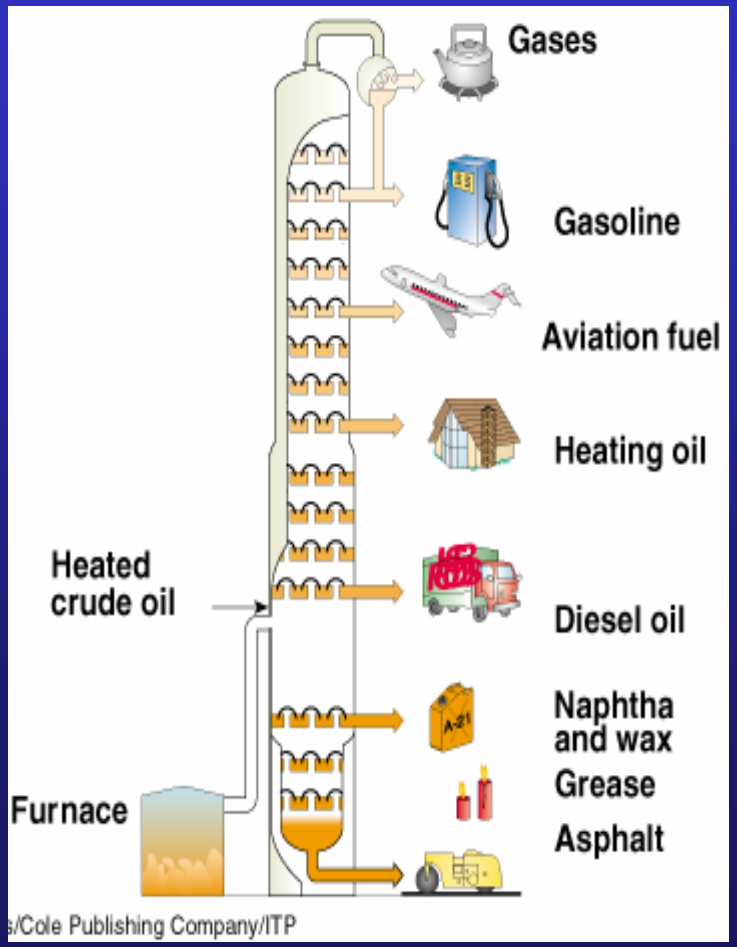
- **Primary Oil Recovery** involves drilling a well & pumping oil that flows by gravity into the bottom of the well;

- **Secondary Oil Recovery** involves injecting water in nearby wells to force remaining heavy oil to the surface;

- **Tertiary or Enhanced Oil Recovery** involves using steam or CO_2 gas to force still more oil into the well.

Processing Oil

Refining of crude oil involves separating components based on their boiling point.



- **Gasoline** & **aviation fuel** are among the most volatile components;
- **Heating oil** is less volatile, but still burns readily;
- **Diesel oil** is still less volatile, and is a common fuel for trucks, buses, & heavy machinery;
- **Grease**, **wax**, & **asphalt** are the least volatile, most dense materials separated;
- **Petrochemicals** derived from oil are used for synthesizing industrial organic chemicals, pesticides, plastics, synthetic fibers, paints, medicines, & many other products.

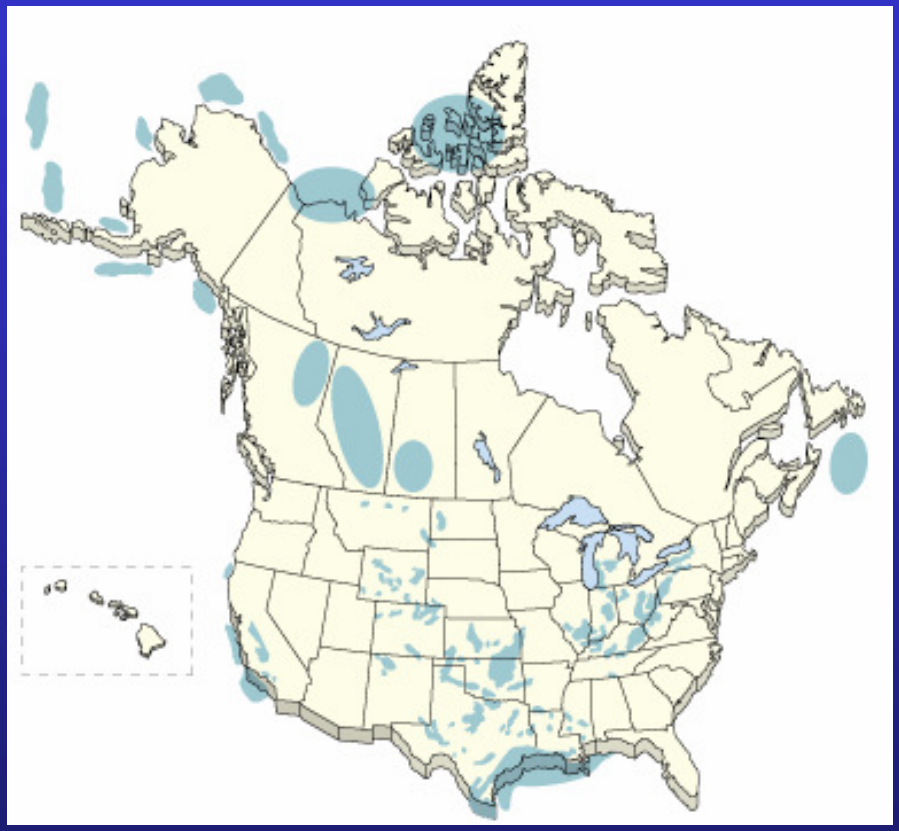
Crude Oil Sources

Thirteen countries that make up the Organization of Petroleum Exporting Countries (OPEC) have 67% of the world's reserves of oil.

- OPEC members: Algeria, Ecuador, Gabon, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates, & Venezuela;
- In 1997 OPEC produced 40% of the world's oil (down from 65% in 1973);
- By 2010 OPEC is expected to supply almost half of the world's oil;
- Other important oil producers include Alaska, Siberia, & Mexico.

Oil in the United States

- The U.S. has only 2.3% of the world's oil reserves, but uses nearly 30% of the oil;
- 65% of oil in the U.S. is used for transportation;
- Little new oil & natural gas are expected to be found in the U.S., leading to increasing dependence on imports.



Locations of the largest crude oil & natural gas fields in the United States & Canada.

Crude Oil Prices

When the price is adjusted for inflation, oil has remained cheap since 1975.

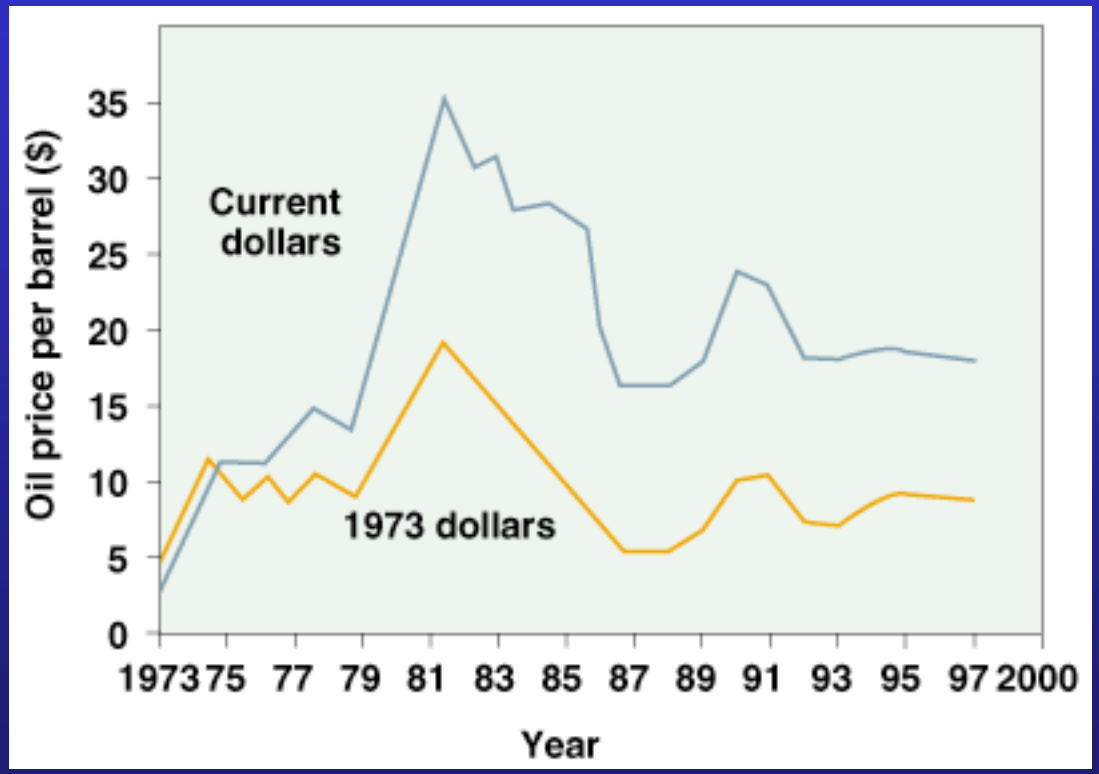


Fig.15–7

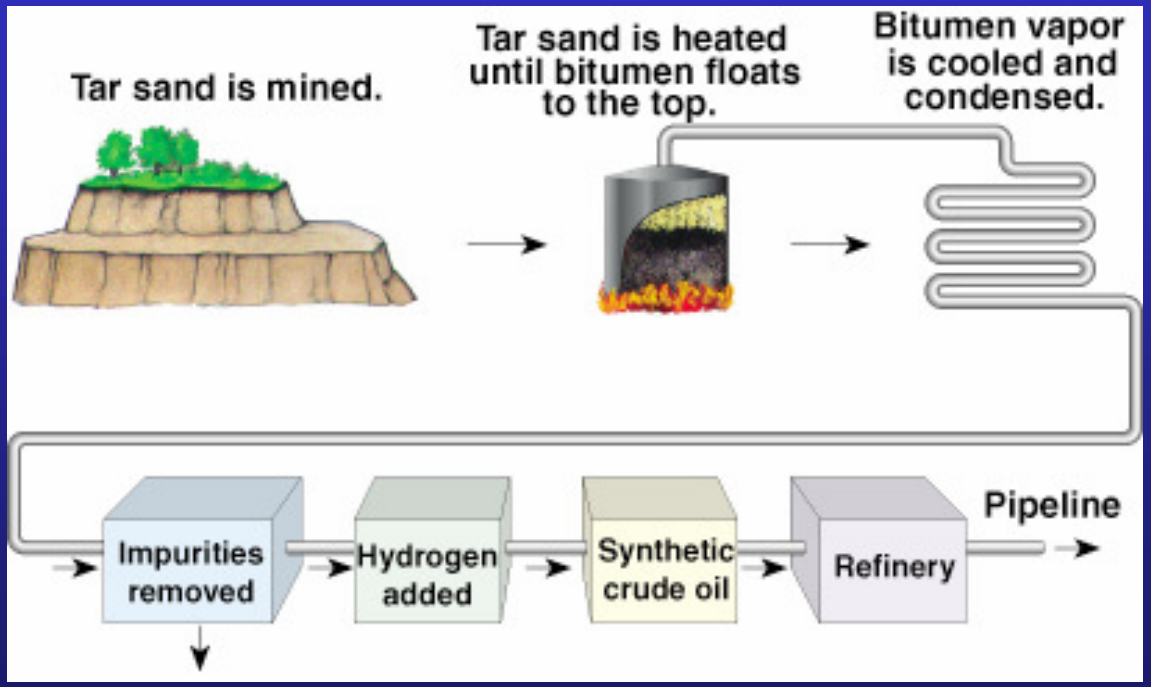
How Long Will Oil Supplies Last?

Oil supplies will be 80% depleted within 35–84 years, depending on the consumption rate.

- At current consumption rates, world reserves will last at least 44 years;
- At current consumption rates, the U.S. reserves will last about 24 years;
- Consumption rates are increasing & are expected to increase about 25% by 2025;
- Some projections expect production to peak within the next 10–20 years, at which time oil prices are expected to rise sharply.

Other Sources of Oil

Synthetic crude oil can be produced from oil shale (involving grinding large quantities of rock) or from tar sand (shown below). However, quality is lower, environmental impact higher, & energy yield lower than for oil from conventional sources.



See **Digging for Oil** at http://www.washingtonpost.com/wp-dyn/content/article/2005/06/14/AR2005061401533.html, http://www.hydrocarbons-technology.com/projects/athabasca/ and http://www.oilsandsdiscovery.com/oil_sands_story/resource.html

Pros & Cons of Oil

Pros:

- Oil is still cheap;
- Economy is set up around use of oil;
- Many useful products can be readily synthesized from oil;

Cons:

- Supply is limited & will be depleted within 35–84 years;
- Pollution & environmental degradation result from extraction, processing, transport, & use.

3. Natural Gas

Conventional natural gas *is trapped above oil deposits.*

Unconventional natural gas *is found in coal beds, tight sands, & dissolved in deep hot water.*

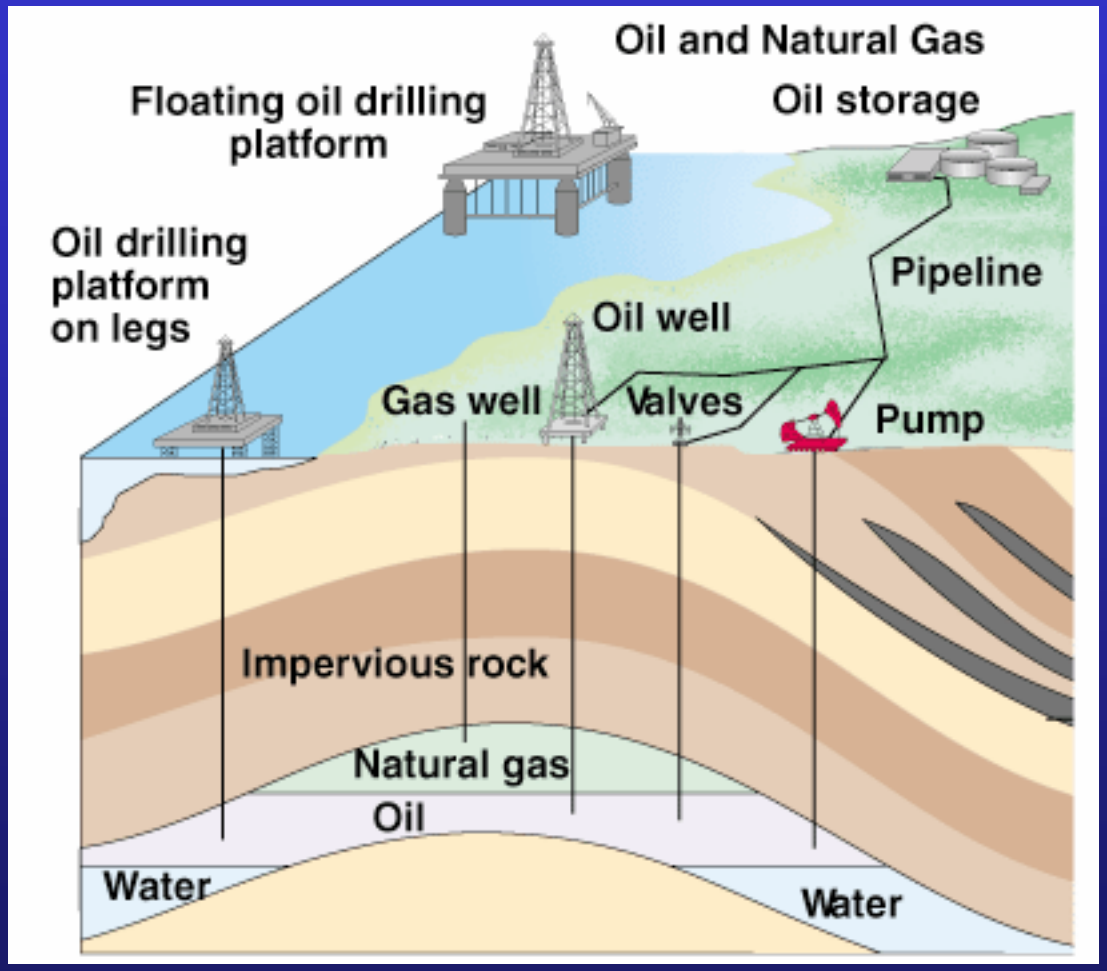


Fig.15–2a

Natural gas *is a fossil fuel, produced by decomposition of deeply buried organic matter from plants & animals.*

- Natural gas is a mixture of 50–90% methane (CH_4), with smaller amounts of ethane (C_2H_6), propane (C_3H_8), & butane (C_4H_{10}), and the toxic gas hydrogen sulfide (H_2S);
- When a natural gas field is tapped, propane & butane gases are removed as **liquefied petroleum gas (LPG)**;
- Natural gas is typically transported in pipelines from oil fields to users;
- Since many oil wells are isolated, much of the natural gas is either burned or pumped back into the ground because it is not economically feasible to transport it.

Natural Gas Sources

Russia and Kazakhstan have almost 40% of the world's natural gas supply.

- Other countries with large reserves: Iran (15%), Qatar (5%), Saudi Arabia (4%), Algeria (4%), United States (3%), Nigeria (3%), Venezuela (3%);
- 90–95% of natural gas used in the U.S. is domestic & the remaining 5–10% is from Canada (estimated 411,00 km = 255,00 miles of pipeline).

Pros & Cons of Natural Gas

Pros:

- cheaper than oil;
- reserves are more abundant than oil: 65–80 years for U.S., 125 years for world at current consumption rates;
- easy to transport over land by pipeline;
- burns hotter, cleaner, & produces less carbon dioxide than other fossil fuels;

Cons:

- transport overseas requires conversion to liquid natural gas (LNG), pressurized & highly flammable;
- pollution & environmental degradation result from extraction, processing, transport, & use (though less than other fossil fuels).

4. Coal

Coal *is mostly carbon, with smaller amounts of water, sulfur & trace amounts of radioactive materials. It is typically extracted by strip mining or underground coal mining.*

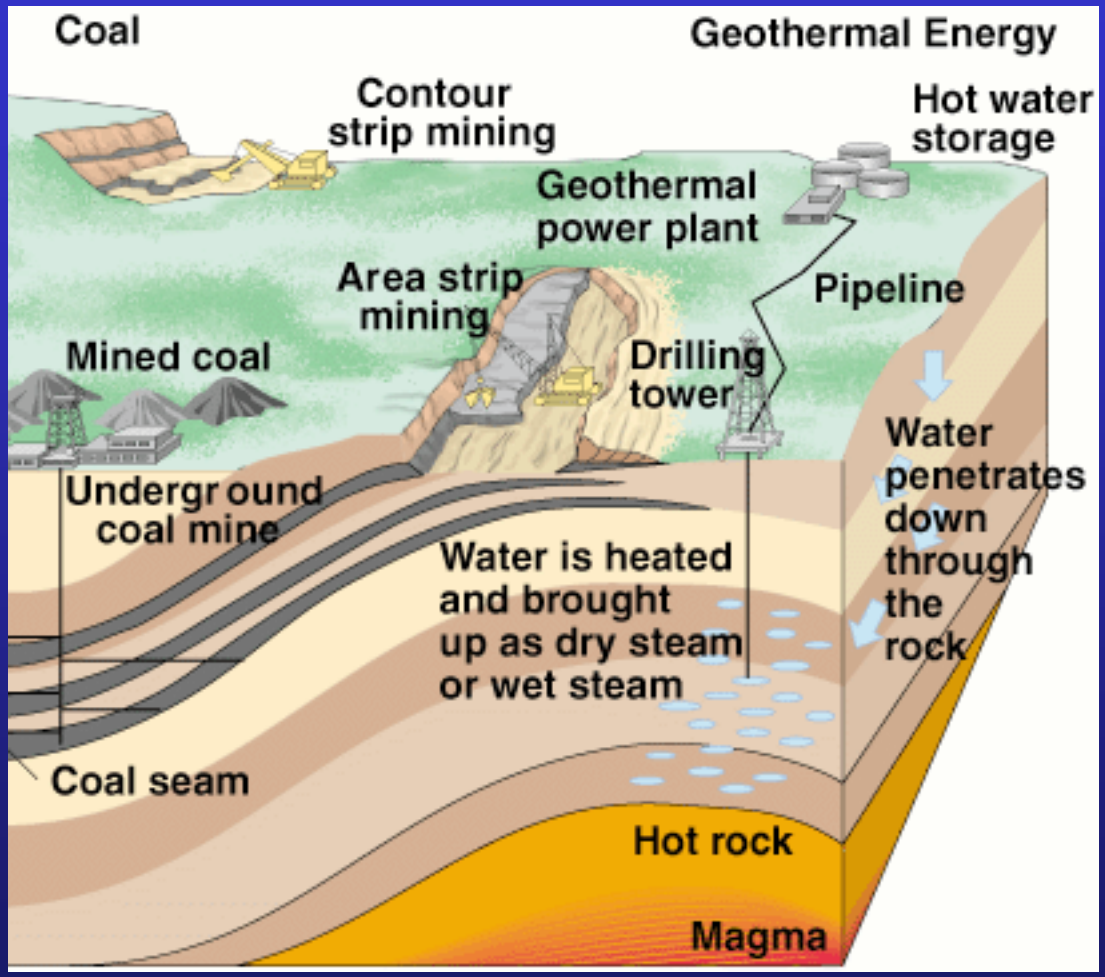
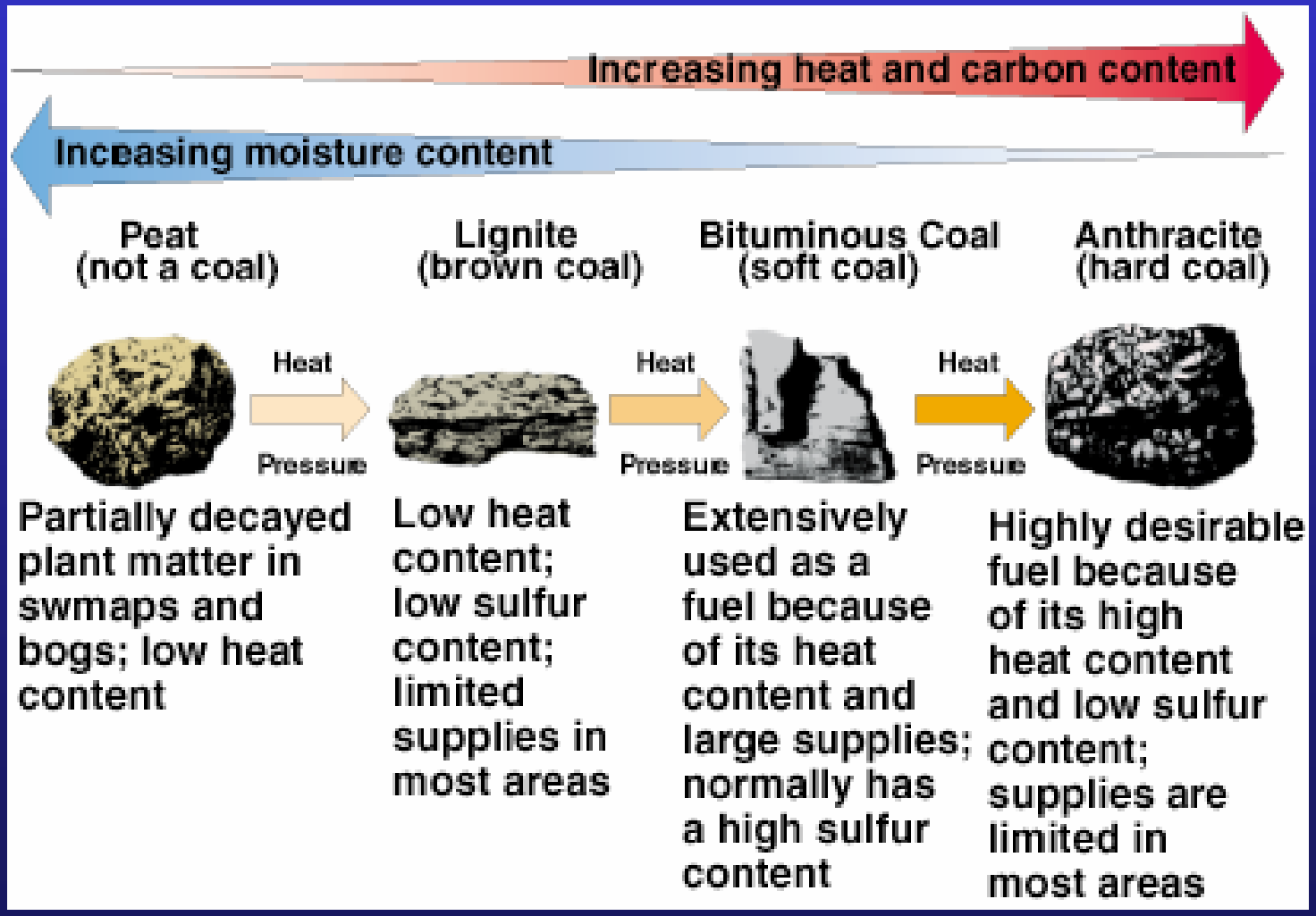


Fig.15–2b

Coal *is a fossil fuel, produced from the buried remains of swamp plants that died during the Carboniferous period (geologic era ending 286 million years ago).*

Stages in the formation of coal over millions of years. Note the three types of coal.



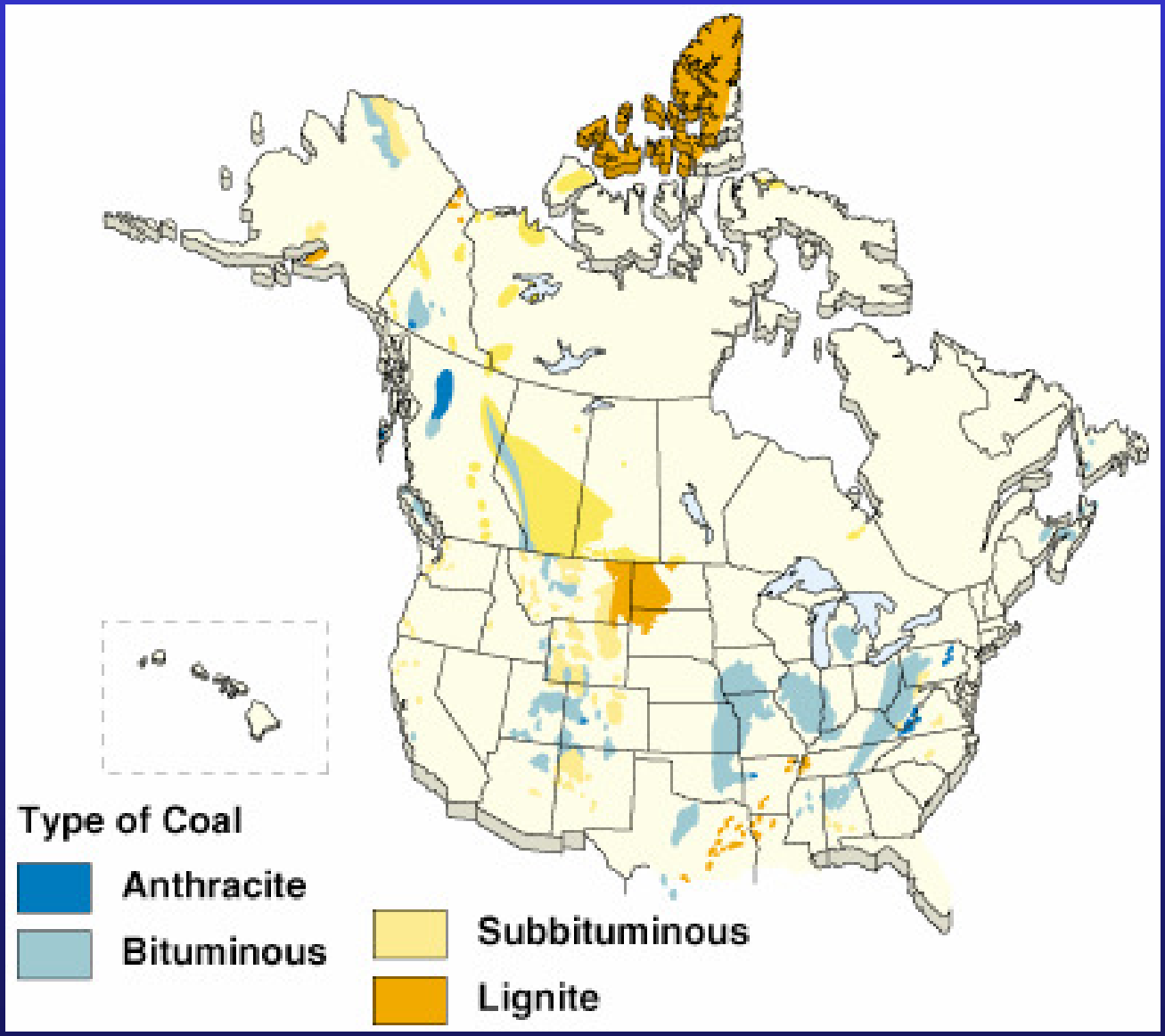
Coal Sources & Uses

About 66% of the world's proven coal reserves and 85% of the estimated undiscovered deposits are in the United States, the former Soviet Union, and China.

- Coal provides about 25% of the world's commercial electricity (22% in U.S.);
- Used to generate 64% of world's electricity (57% in U.S.);
- Used to make 75% of world's steel;
- China gets 76% of energy from coal, largest user;
- U.S. second largest user, close behind China.

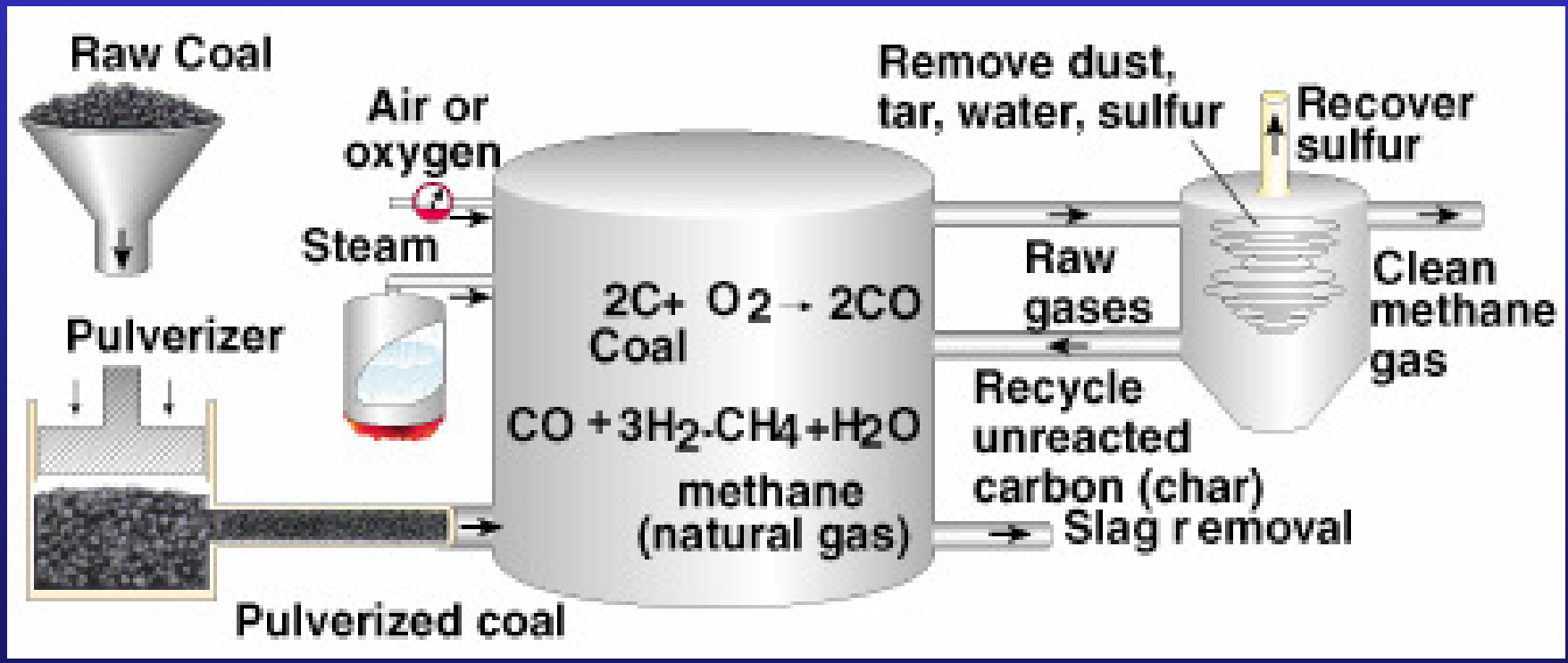
Coal Sources

Locations of the major coal fields in the United States & Canada.



Coal

*Coal can be converted into gaseous & liquid fuels. However, production of these **synfuels** leads to low net energy yield. The process of coal gasification is shown below.*



Coal Pros & Cons

Pros:

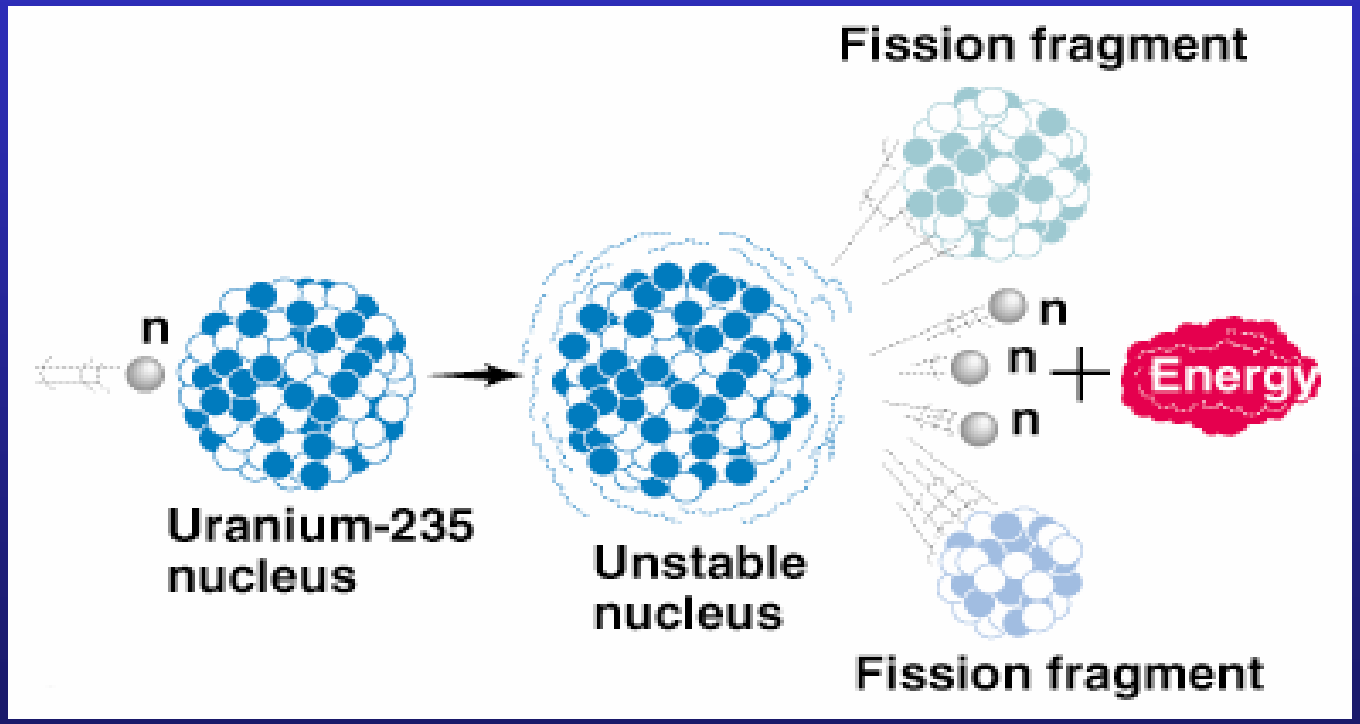
- most abundant fossil fuel;
- U.S. has major reserves, will last 300 years at current consumption rates;
- high net energy yield;

Cons:

- dirtiest fossil fuel, in terms of air pollution & carbon dioxide released;
- major environmental degradation that result from extraction, processing, transport, & use;
- burning coal is major threat to human health — estimated to kill or cause chronic respiratory disease for large numbers of people.

5. Nuclear Energy

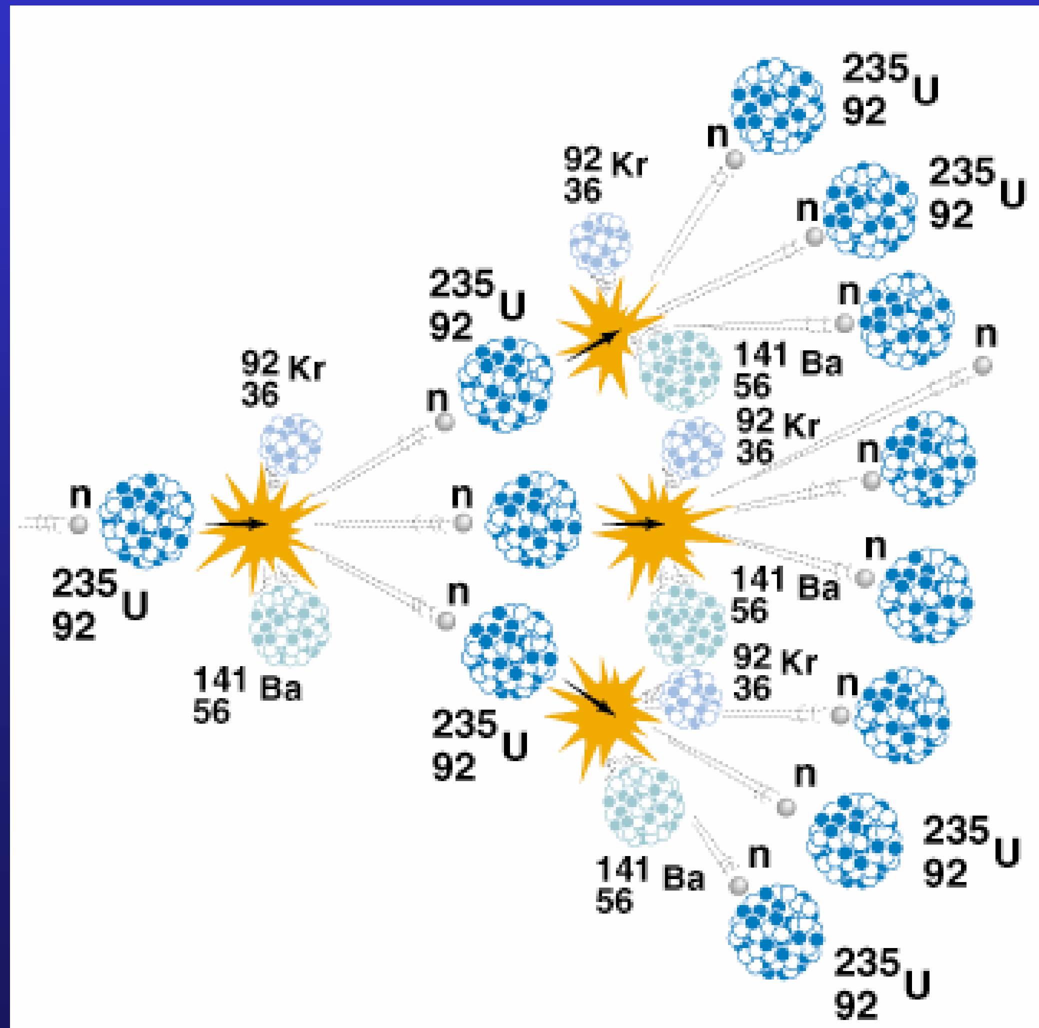
Nuclear fission: a nuclear change in which certain unstable isotopes of high mass numbers split into lighter nuclei & release energy in the process.



Nuclear fission reactors *produce electricity from heat released by the fission of atoms such as uranium–235 & plutonium–239.*

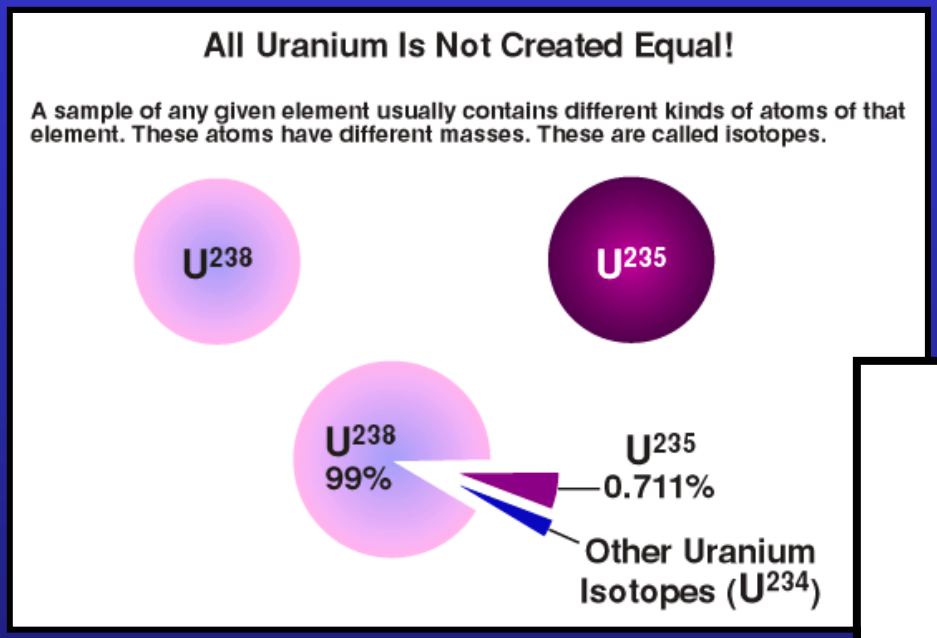
Nuclear Chain Reaction: multiple fissions resulting from a positive feedback loop in which each fission releases neutrons that cause more fissions to occur.

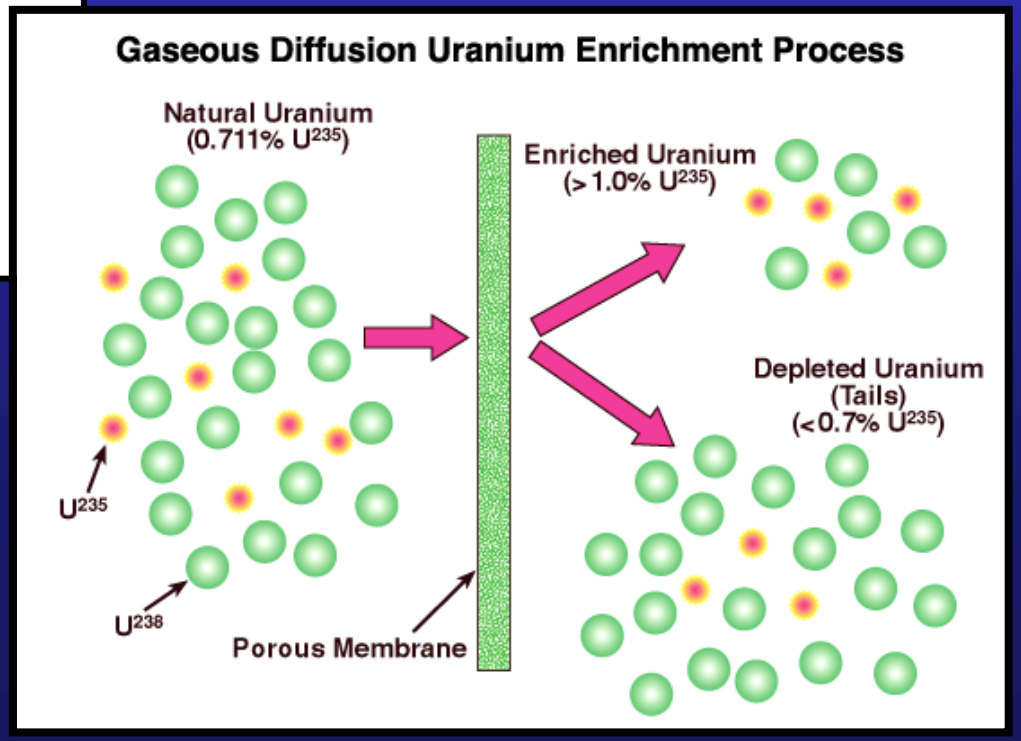
A nuclear chain reaction leads to major release of energy in the form of heat.



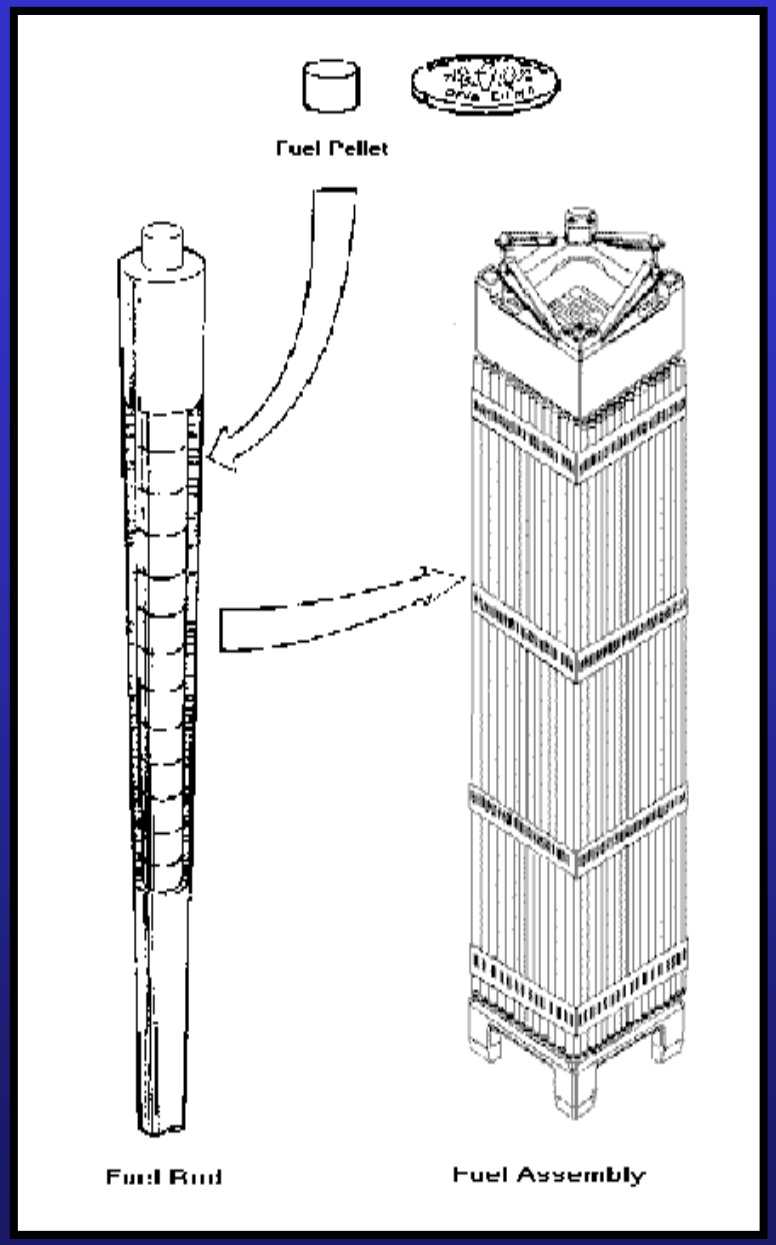
Controlled fission is achieved by:

#1 - bringing fissionable atoms to critical mass (see below)





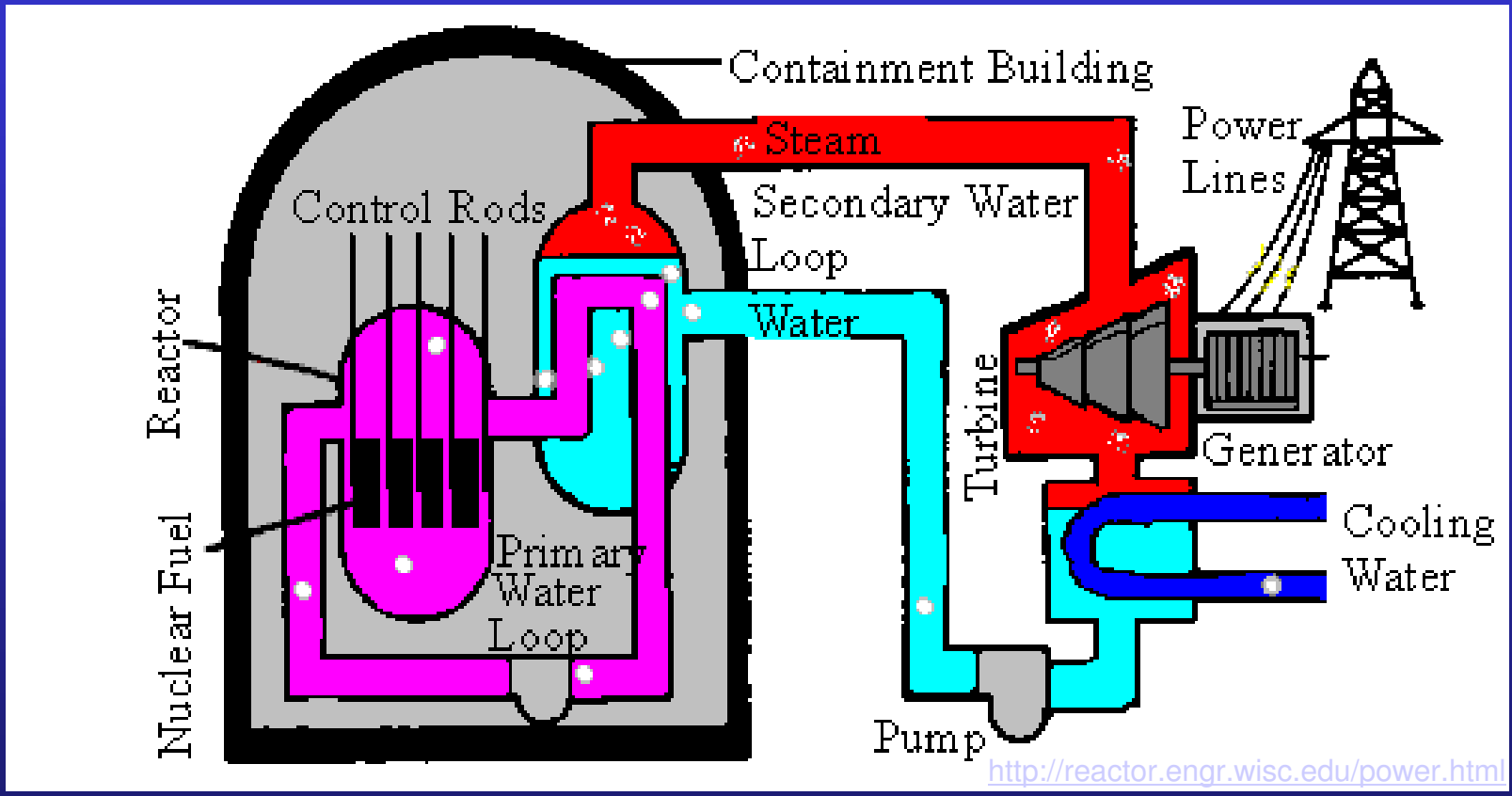
•http://www.nrc.gov/materials/fuel-cycle-fac/ur-enrichment.html#1



#2 – converting enriched uranium into fuel pellets which are then stacked into fuel rods, grouped into fuel assemblies, and lowered into the reactor

•http://www.nucleartourist.com/basics/construct.htm

#3 - controlling rate of fission by absorbing excess neutrons with control rods & surrounding the reaction core with coolant.



See http://www.cookinfo.com/pdfs/howplantworks.pdf

Built–in safety features are *supposed* to minimize the risk of release of radioactive substances or an out-of-control fission reaction.

Nuclear Fuel Cycle

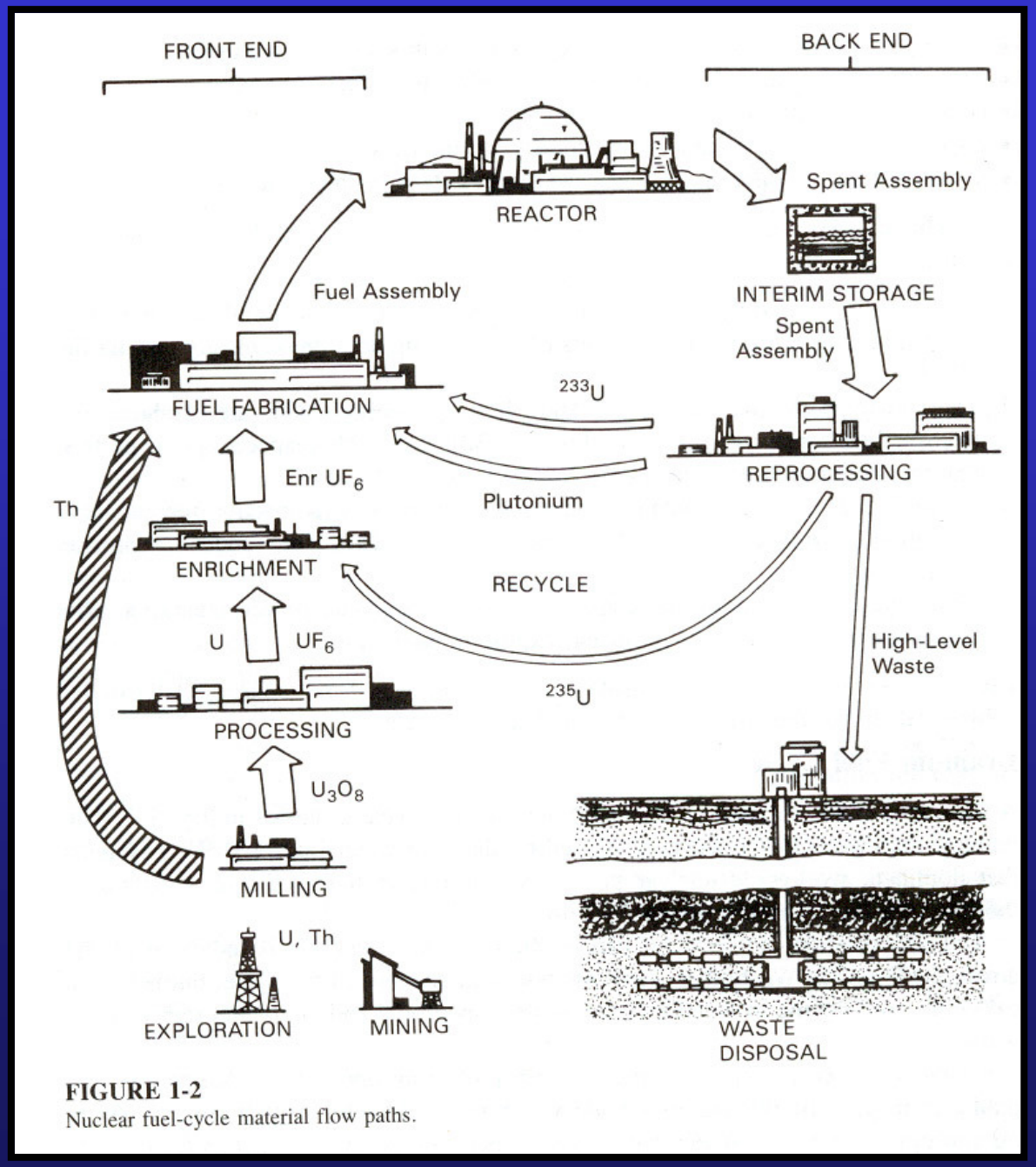


FIGURE 1-2
Nuclear fuel-cycle material flow paths.

www.if.uidaho.edu/~gunner/Nuclear/Fuel%20Cycle%20Intoduction.doc

Nuclear Energy Risks

On March 29, 1979, the number 2 reactor at the Three Mile island nuclear plant near Harrisburg, Pennsylvania lost its coolant & the core suffered a partial meltdown.

- 50,000 people evacuated & another 50,000 fled area;
- unknown amounts of radioactive materials were released;
- partial cleanup & payment of damage claims cost $1.2 billion so far;
- 1997 concluded that increased cancer rates were caused by released radiation.

Video: http://www.history.com/media.do?action=clip&id=tdih_0328

See “Three Mile Island: What Happened” at http://www.pbs.org/wgbh/amex/three/sfeature/tmihow.html

*On April 26, 1986, in what is known as the **Chernobyl** disaster, a series of explosions in one of the reactors of a nuclear power plant in the Ukraine flung radioactive debris into the atmosphere.*

•http://www.uic.com.au/nip22.htm

Video: http://www.history.com/media.do?action=clip&id=tdih_0426

- In 1998 the Ukrainian health ministry reported 3,576 deaths. However, Greenpeace estimates a total death toll of about 32,000;
- about 400,000 people were forced to leave their homes;
- according to a UN report, some 160,000 sq kilometers (62,00 sq miles) remain contaminated;
- over half a million people were exposed to dangerous levels of radioactivity;
- the cost of the incident is estimated in excess of $358 billion.

See Chernobyl Legacy at
http://todayspictures.slate.com/inmotion/essay_chernobyl/

Nuclear Energy Use

The United States is phasing out the use of nuclear energy; while some countries, mostly in western Europe (notably France) are investing increasingly in nuclear energy.

- U.S. currently only gets about 7% of energy from nuclear power;
- no new power plants ordered since 1978; of 105 commercial nuclear power plants in U.S., 40% expected to be retired by 2015 & all by 2030;
- France gets about 78% of its energy from nuclear power plants, & views nuclear energy as essential for their future.

What happened to nuclear energy?

- crippled by high & uncertain construction & operating costs, billion dollar overruns;
- frequent malfunctions;
- false assurances and cover–ups by government & industry officials;
- overproduction of energy in some areas;
- poor management;
- lack of public acceptance.

Pros & Cons of Nuclear Energy

Pros:

- U.S. has major reserves of uranium;
- lower mining impacts than coal;
- no carbon dioxide emission;
- no air pollution/acid-forming emissions;
- lower quantity of solid wastes;

Cons:

- cost high & recently rising;
- possible major release of radioactive contaminants;
- mining & processing impacts;
- radioactive wastes: short–term containment of short–lived isotopes (now water–filled tanks); transport & long–term containment of long–lived isotopes;
- thermal pollution.