NON-RENEWABLE ENERGY

Chapter 9

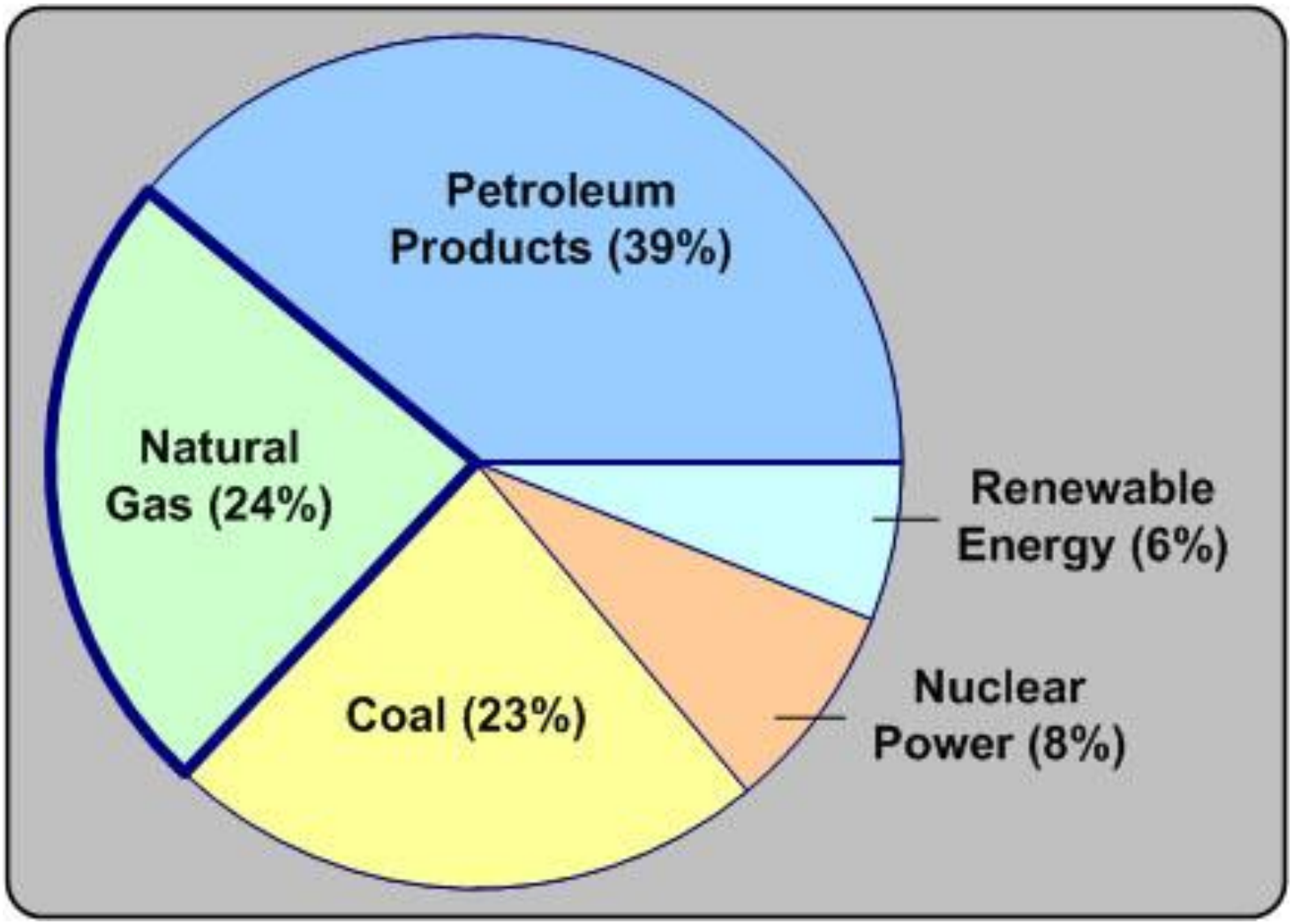
WHAT IS ENERGY?

Earlier this semester, we talked about energy and that energy is the capacity to do work.

Recall that there are 2 types of energy:

- Potential – stored energy
- Kinetic – energy contained in moving objects

CURRENT US SOURCES OF ENERGY



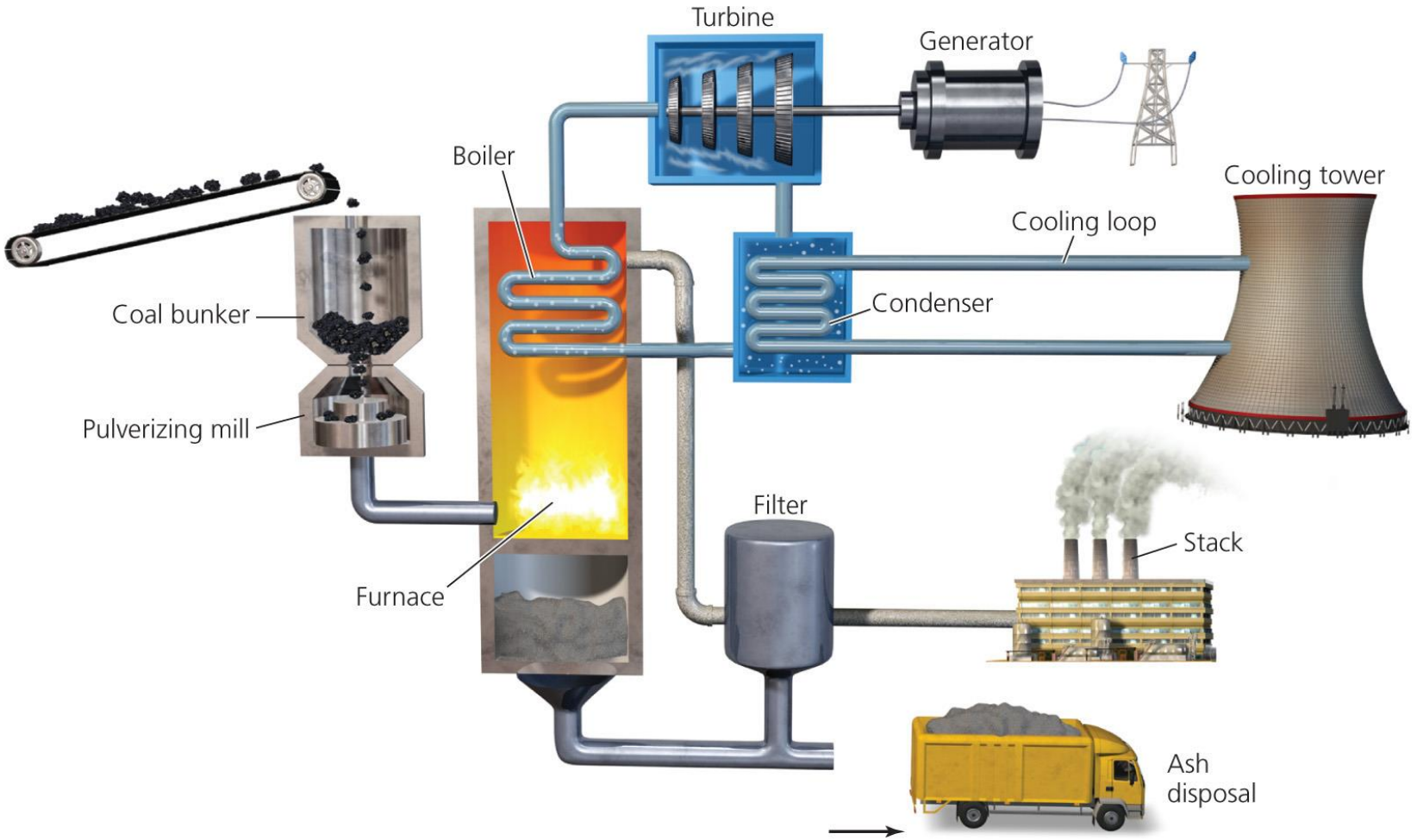
WHAT IS ELECTRICITY?

- From a basic physics perspective, an electric current is produced when electrons, that have been separated from their atoms, are excited. Their free movement creates an electric current.
- Electricity is a kinetic energy source that we create by converting primary potential energy sources.

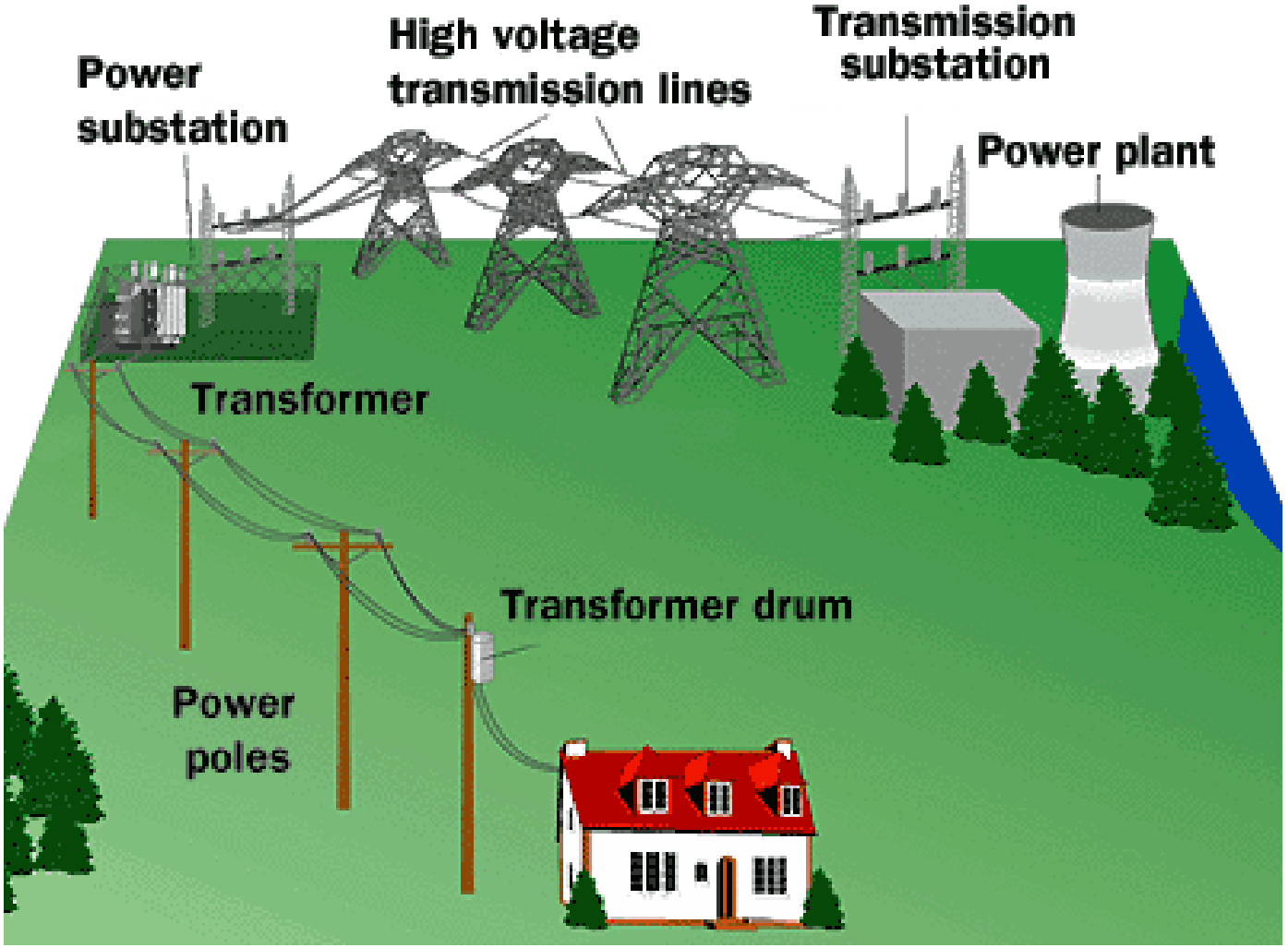
HOW DO WE PRODUCE ELECTRICITY?

- Typically, a potential primary source is burned in a giant furnace in order to heat water and create steam (kinetic).
- The pressure of the steam turns a turbine by pushing on its blades (mechanical energy).
- The steam turbine rotates a generator.
- Inside the generator, a magnet is rotated against a copper wire coil. Electrons in the copper wire get excited and produce a massive electric current.
- The electricity is delivered to homes, businesses and industry via distribution lines. (a.k.a. the grid)

TYPICAL POWER PLANT

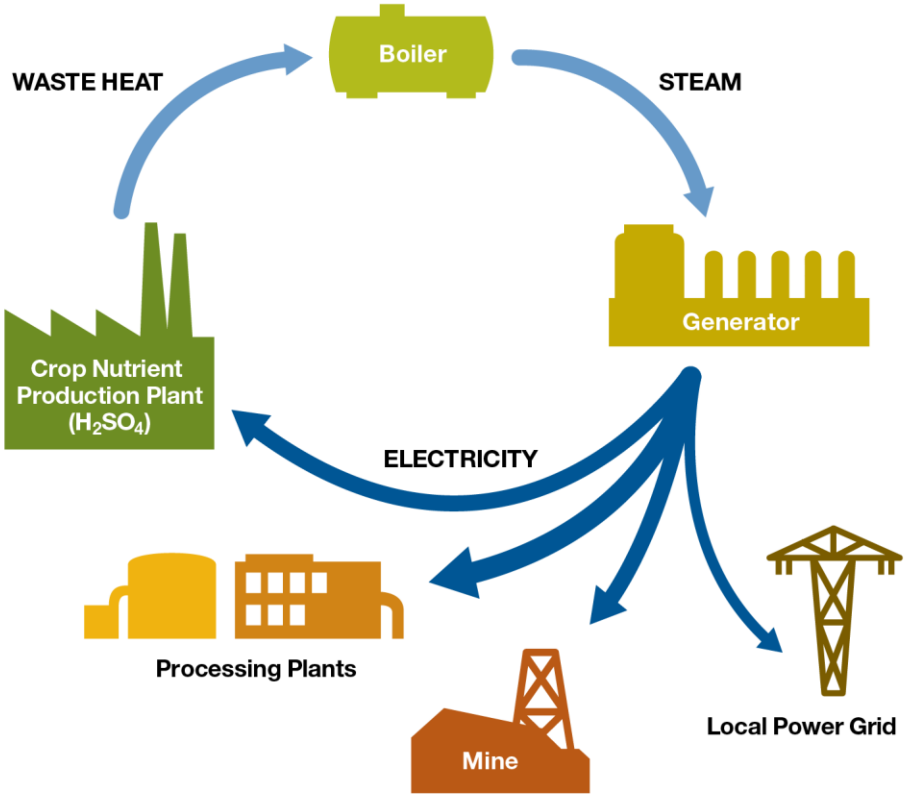


POWER GRID


Power substation
High voltage transmission lines
Transmission substation
Power plant
Transformer
Transformer drum
Power poles

COGENERATION

- When a fuel source is used to generate useful heat and electricity.
- Example: using the steam left over from electricity generation to produce heat.



PRIMARY POTENTIAL ENERGY SOURCES

- Fossil Fuels (coal, oil, natural gas)
- Nuclear

Non-renewable Sources

- Wind
- Hydro power
- Geothermal
- Biomass
- Solar
- Fuel Cells

Renewable Sources

This lecture discusses non-renewables

FOSSIL FUELS

- A fossil fuel is any organic fuel formed, over millions of years, from the remains of dead plants and animals. They are produced when organic material decomposes in an anaerobic environment (one that has little to no oxygen).
- The carbon-hydrogen bonds have been preserved, instead of broken down through decomposition.
- Different temperatures and pressures during fossilization create different fuels (either coal, oil, or natural gas).
- They are NON-RENEWABLE
- 75% of US energy needs are met by fossil fuels.

3 MAIN CATEGORIES OF USE

- Transportation (oil)
- Production of electricity (coal is major source)
- Other industries (more natural gas, some oil)

3 MAIN TYPES OF FOSSIL FUELS

- **Coal:** organic matter (woody plant material) that was compressed millions of years ago under very high pressure to form dense, solid carbon structures

- **Natural gas**: consists of methane (CH_4) and other volatile hydrocarbons

- **Crude oil (petroleum)**: a mixture of hundreds of different types of hydrocarbon molecules. Formed 1.5-3 km (1-2 mi) underground. Dead organic material was buried in marine sediments and transformed by time, heat, and pressure.

COAL

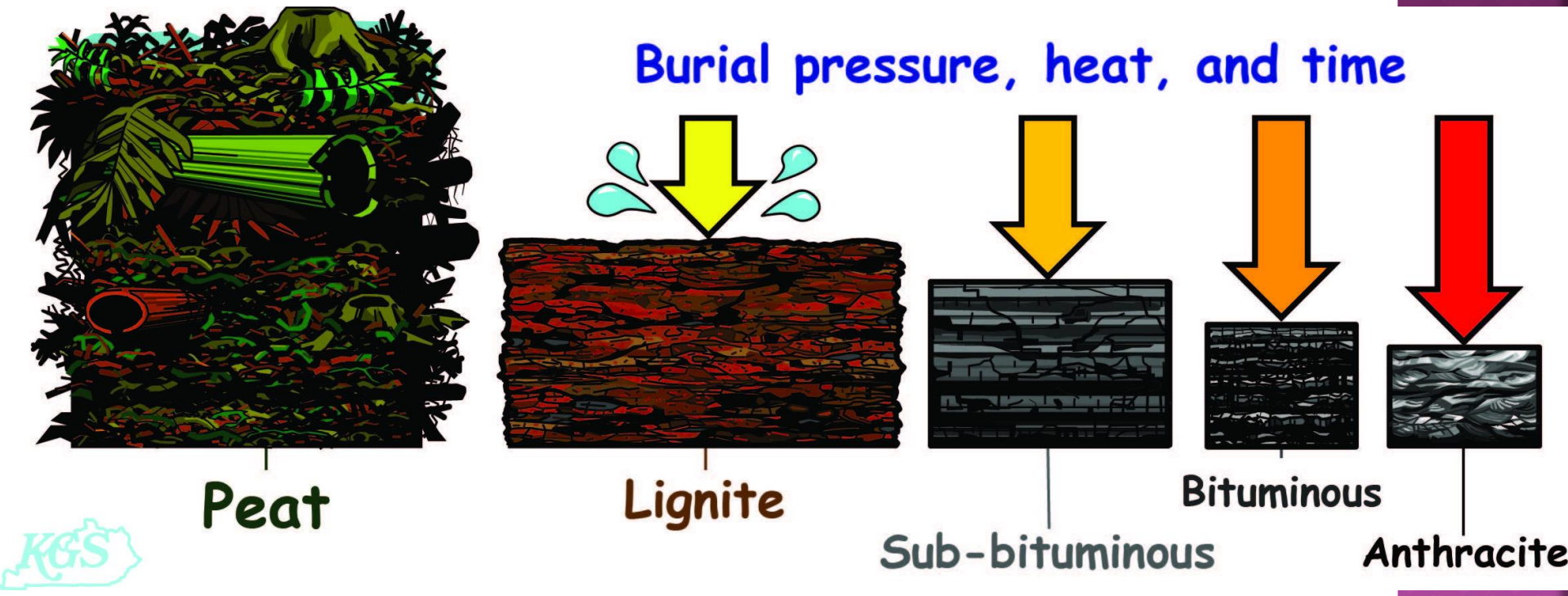
Pros:

- Vast reserves
- Very cheap

Cons:

- Takes millions of years to form.
- Must be mined from the earth (Wyoming and W. Virginia are top 2 producers)
- Emits CO_2 when burned
- Contributes to air pollution, acid rain.
- Emits mercury when burned which ends up in aquatic food chains via the water cycle.

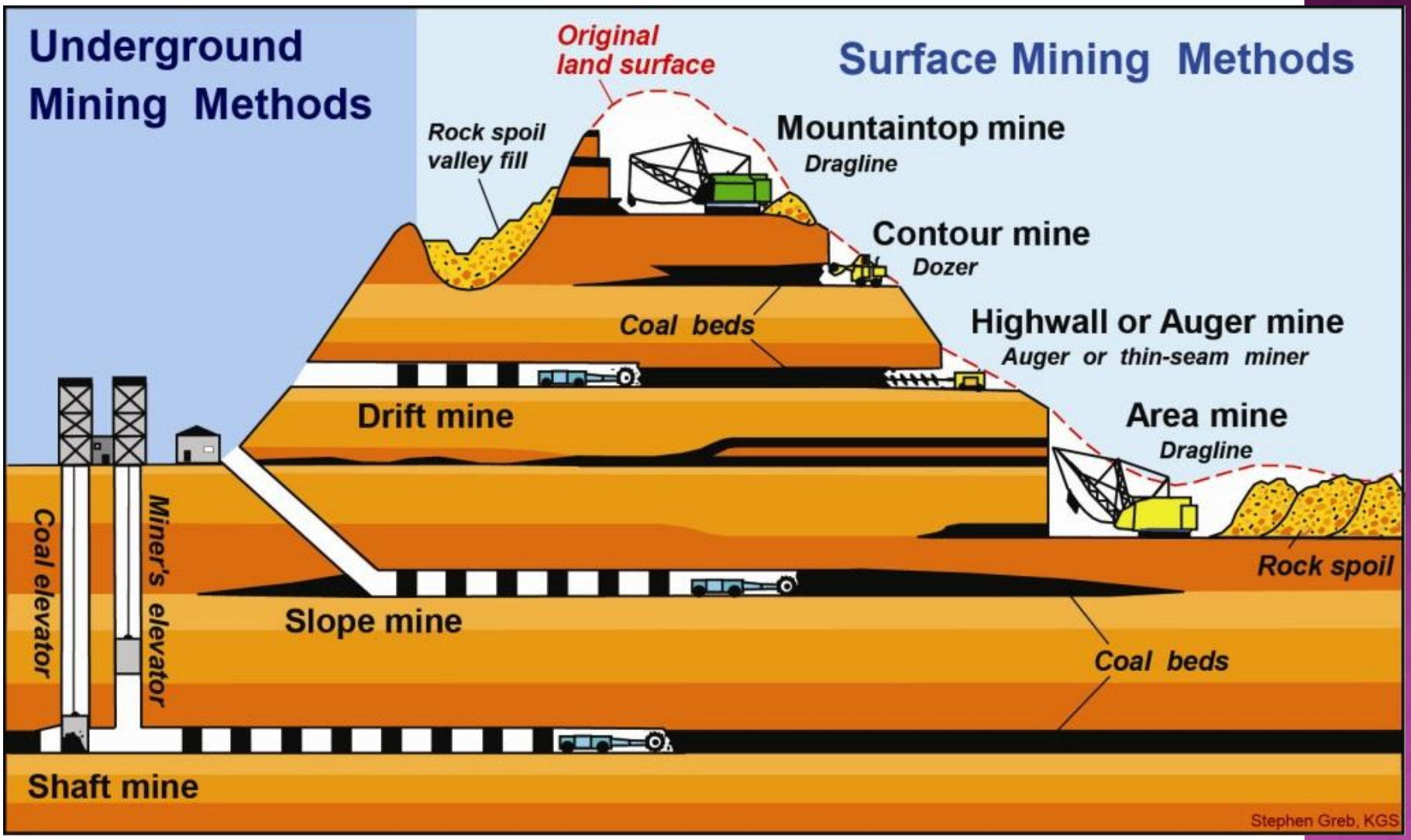
Coal Formation



- “It has been estimated that there are over 847 billion tonnes of proven coal reserves worldwide. This means that there is enough coal to last us around 118 years at current rates of production. In contrast, proven oil and gas reserves are equivalent to around 46 and 59 years at current production levels.” World Coal Association
  - One factor to consider is that most of this coal is located in the US, Russia, China, & India. So, it is not easily accessible to most of the world.
  - Another factor is that much of this coal may be inaccessible. It is not all proven to be recoverable.

Several mining methods are used to remove the rock layers and expose the coal seam for extraction.

During the mining process, metals and toxic elements within the rock layers are exposed in amounts too large for nature to safely handle (mercury, arsenic, selenium). Normally erosion exposes these in very small amounts. In large amounts, they contaminate surrounding communities, water systems, and wildlife areas.


Underground Mining Methods
Surface Mining Methods
Original land surface
Rock spoil valley fill
Mountaintop mine
Dragline
Contour mine
Dozer
Coal beds
Highwall or Auger mine
Auger or thin-seam miner
Drift mine
Area mine
Dragline
Coal elevator
Miner's elevator
Rock spoil
Slope mine
Coal beds
Shaft mine
Stephen Greb, KGS

<u>Mining Method #1: Strip Mining</u> – Coal is removed that is near the surface

<u>Mining Method #2: Mountaintop Removal</u> (a type of strip mining) where tops of mountains are blasted away to reveal the coal beneath the surface.

Mining Method #3: Underground Coal Mining

Long-wall mining in an underground mine.

PETROLEUM

(PETRO = ROCK, OLEUM = OIL)

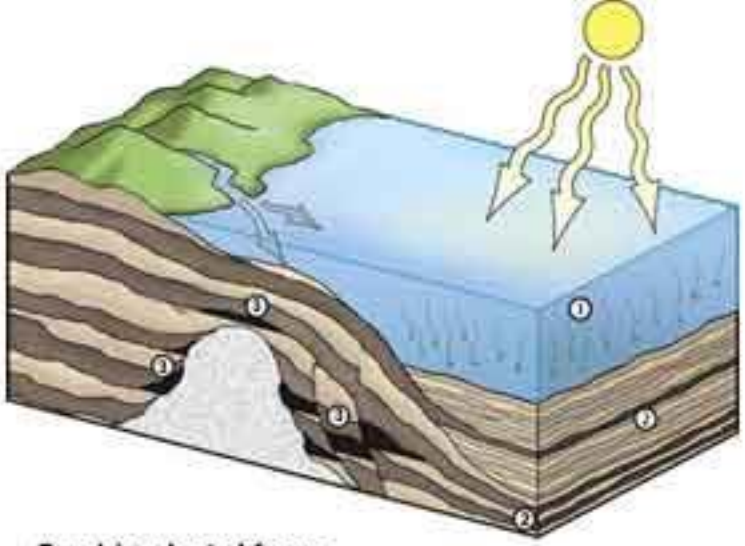
Pros:

- Cheap
- Many uses: transportation; heating homes; machine lubricants; ingredient in asphalt; ingredient in all plastics; manufacturing fertilizers, pesticides, herbicides, inks, paints, medicines, upholstery, synthetic fibers, and many other products.

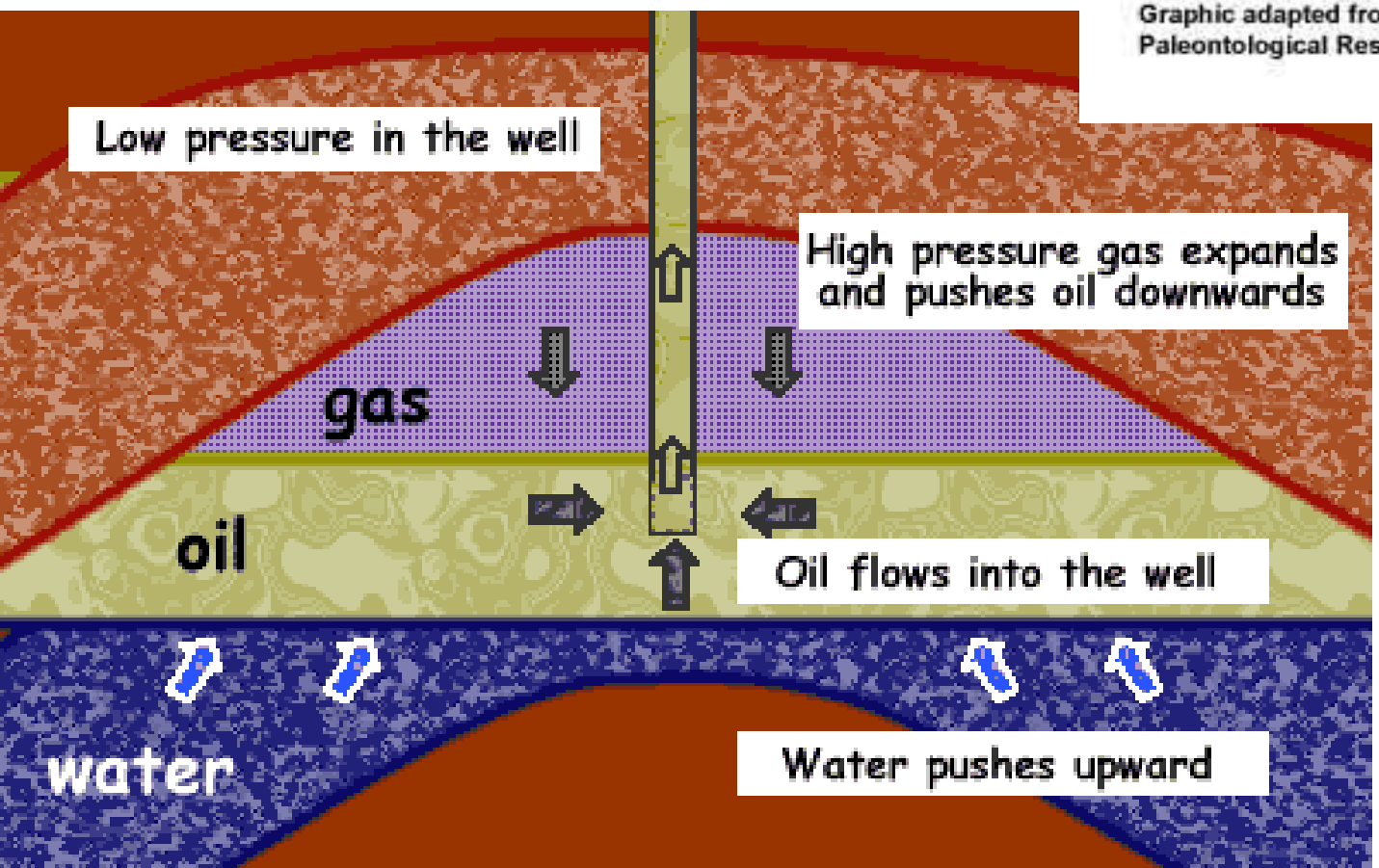
Cons:

- Reserves not nearly as vast as coal
- Oil spills and seeps from current and past drills cause vast damage to drinking water sources, rangelands, as well as to the natural environment.

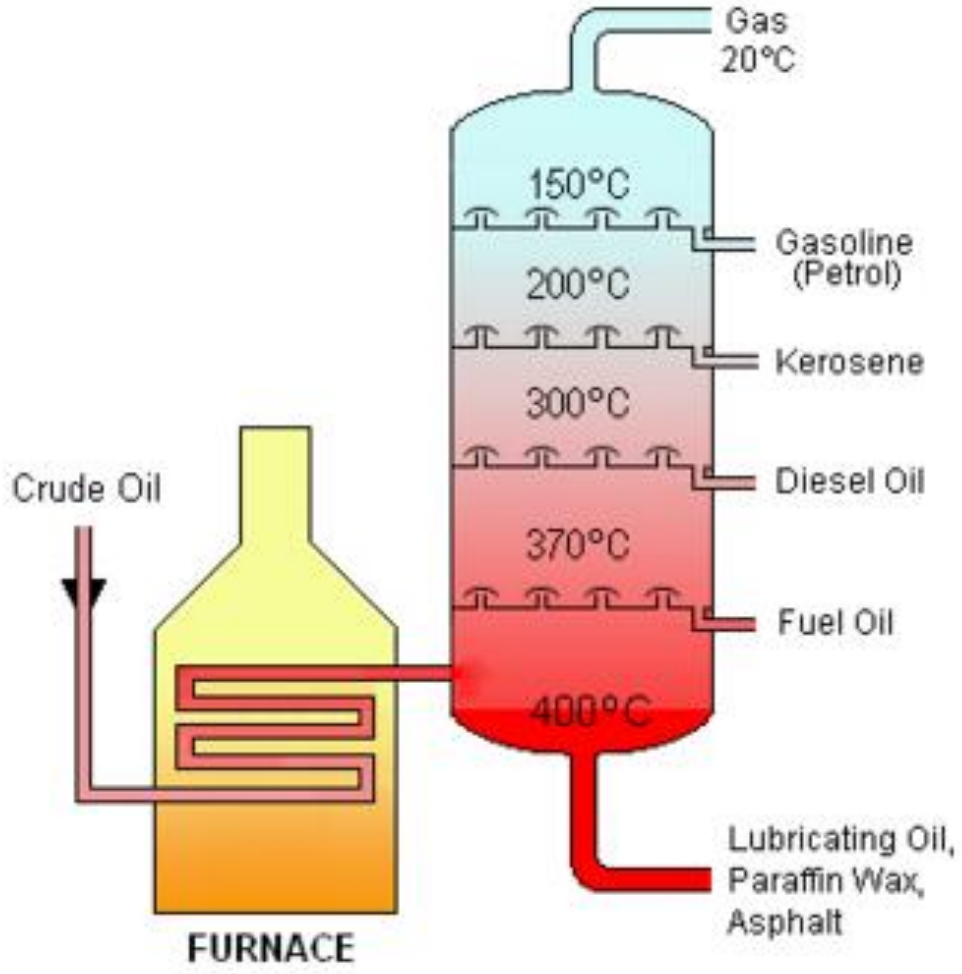
Oil is located in pockets deep underground. Much of it is offshore under oceans. Some is located onshore. It was formed from ancient marine organisms.

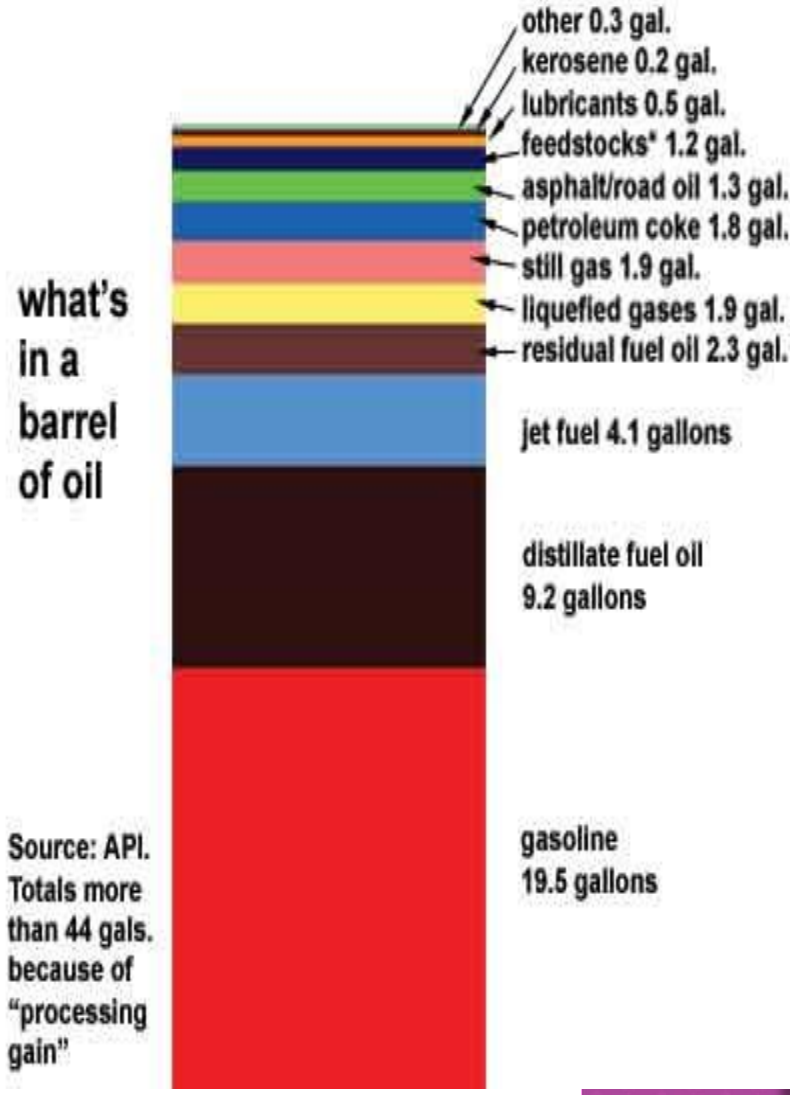


Graphic adapted from:
Paleontological Research Institution

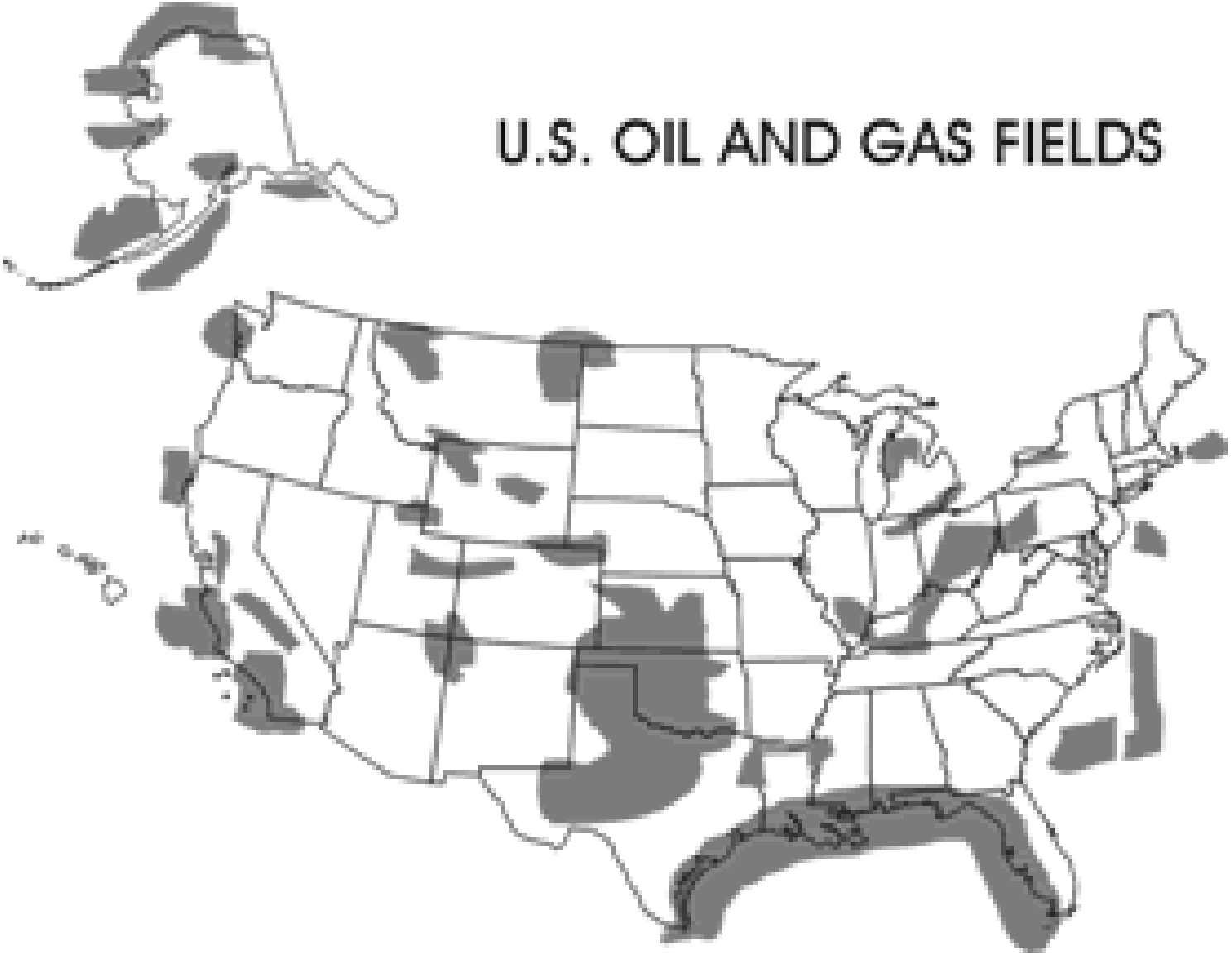


Crude petroleum from the ground must be refined by distillation.

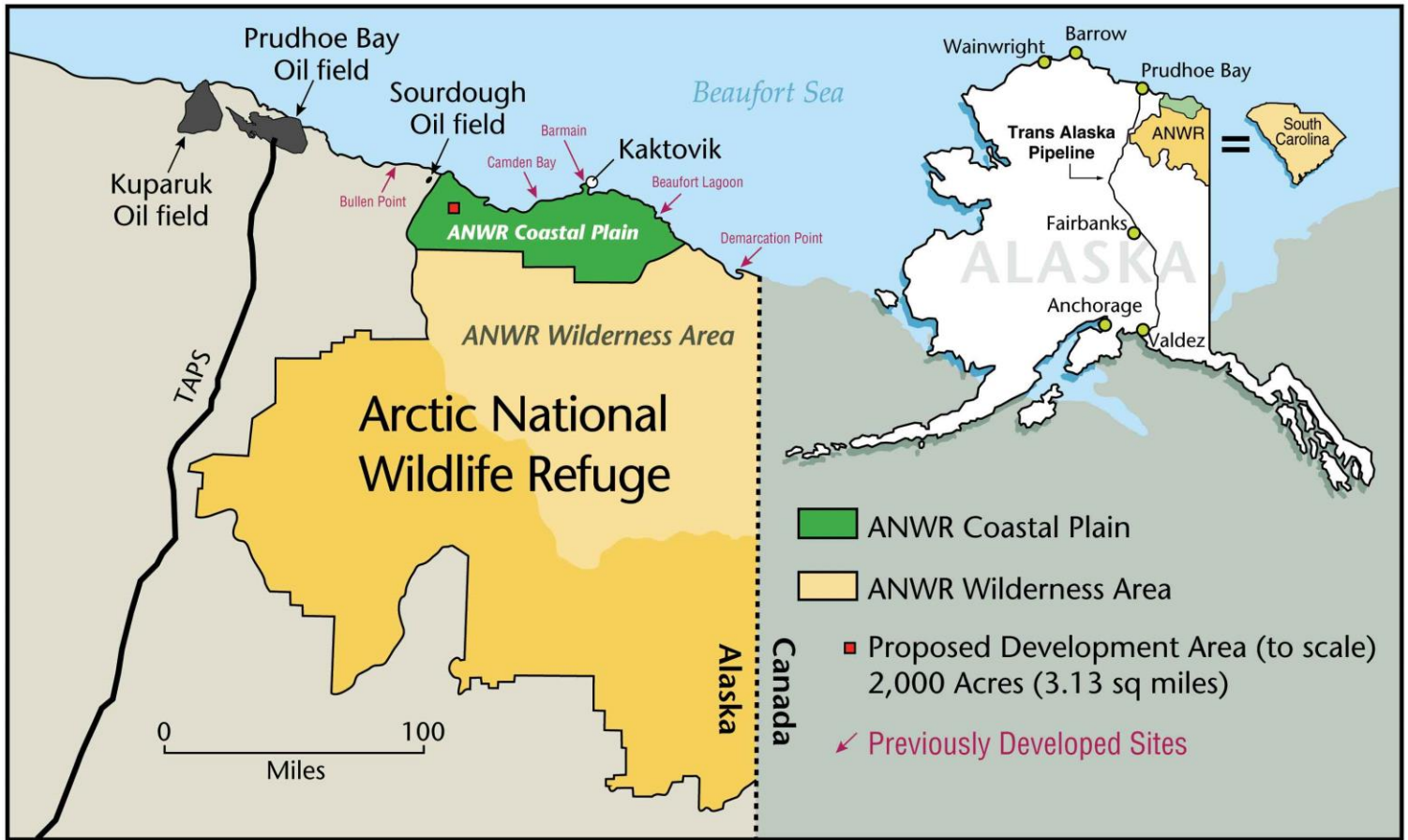




U.S. OIL AND GAS FIELDS



Over the past decade people have talked about potential drilling in the Arctic National Wildlife Refuge (ANWR) on Alaska's north shore. Caribou migrate to this coastal plain every spring for calving season because the ocean wind reduces the mosquito population, which would otherwise harm newborn caribou. As there is a considerable amount of oil drilling on either side of the coastal plain, the calving ground would be further reduced.



1973 OIL CRISIS

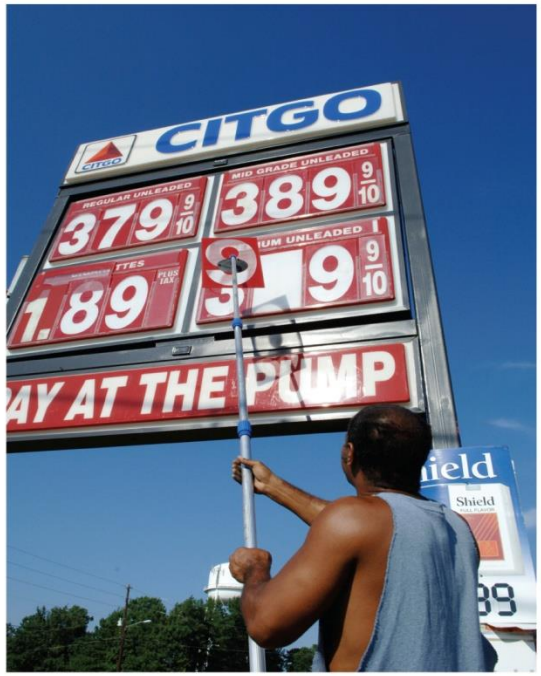
- In October 1973, Arab members of OPEC refused to sell oil (embargo) to nations that supported Israel in the Yom Kippur War against Egypt and Syria.
- They also raised the price of oil and cut production.
- The U.S. economy suffered since it was highly dependent on foreign oil.
- Oil prices quadrupled. Gas reached over $1 per gallon (was $0.29 per gallon before the embargo).

US REACTIONS

- US implemented 55 m.p.h. speed limits to increase the gas mileage for automobiles.
- Began and implemented technology research on renewable energy: wood, wind, and solar
  - President Carter installed solar panels on the White House and allocated more funding to research than any other president to date.
- The government also wanted to develop more nuclear and coal power to reduce oil dependence
- We learned quickly how dependent we were on foreign fuel resources
- When the war ended, the embargos ceased. By the 1980s, oil prices dropped and renewable energy research all but stopped. Reagan promptly removed the solar panels from the White House.

CURRENT IMPACTS

- Because the politically volatile Middle East has the majority of oil reserves, crises are a constant concern for the U.S.



(b) Changing prices at the pump

POLICIES TO REDUCE RELIANCE ON FOREIGN OIL

- The U.S. government enacted policies to diversify its oil supply.
  - The U.S. is developing its own reserves.
  - Proposed drilling in ANWR, despite charges that drilling won't help much
  - It imports oil from several countries.
    - Canada is the #1 supplier of oil to the US
  - Resuming extraction at currently closed sites
  - Stockpiling oil
  - Research into renewable energy sources
  - Enacting conservation measures

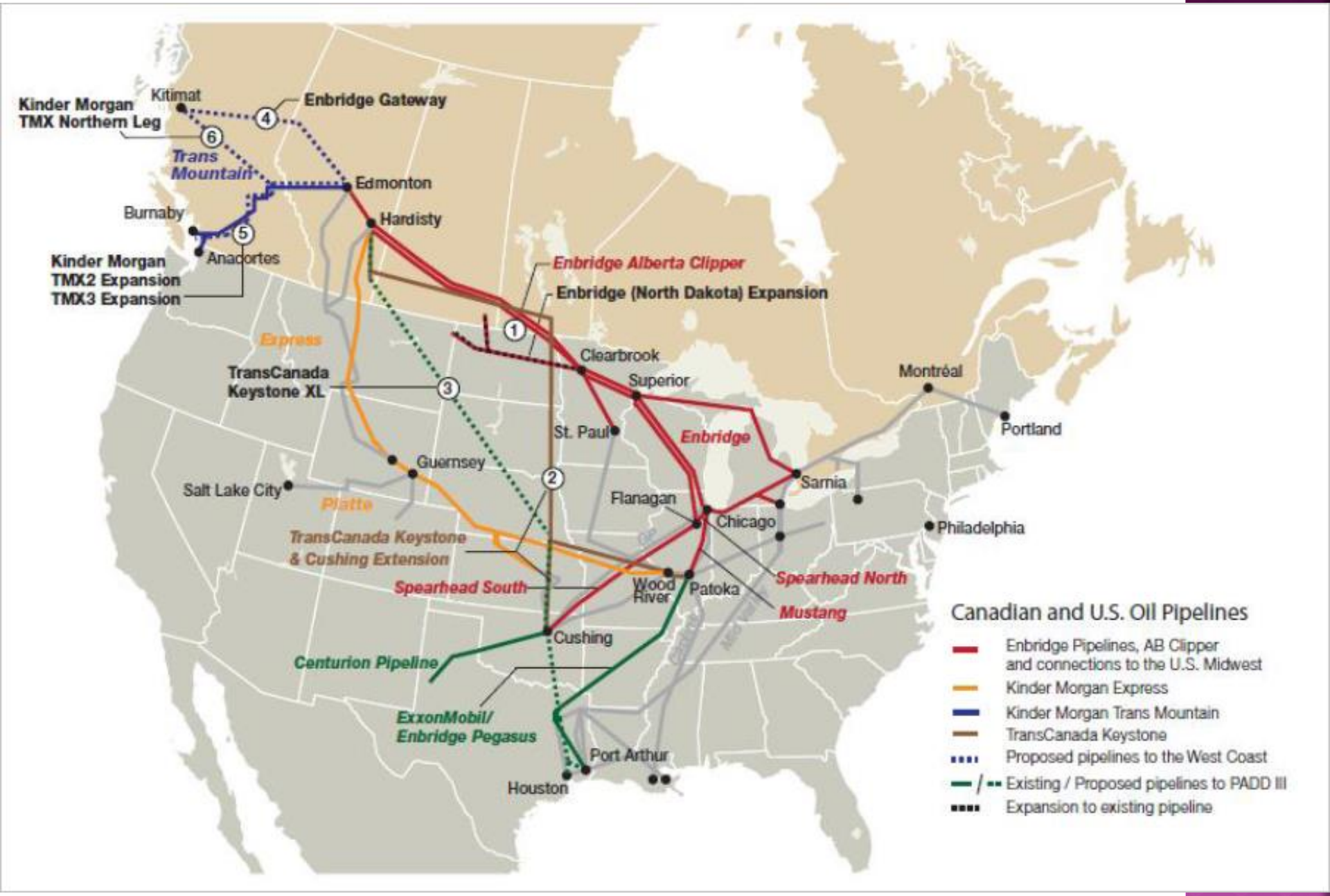
OIL/TAR SANDS

Primarily found in Canada and Venezuela.

Sand deposits with 1–20% **bitumen**, a thick form of petroleum rich in carbon, poor in hydrogen. In Canada, it is mined by removing boreal forest. Oil-rich soil is scraped up & the oil is extracted by heating the soil to 900 degrees with natural gas water from the Athabasca River. The leftover sludge and toxic materials are stored in slurry ponds (right) that are mistaken by birds for freshwater lakes.

PIPELINES THROUGH THE US AND CANADA

- After the bitumen is extracted from the tar sands, it is sent by pipeline to refineries in Canada and the US.
- After it is refined, the petroleum is sold in the US and Canada as well as other countries.


Kinder Morgan
TMX Northern Leg
Kitimat
Enbridge Gateway
4
6
Trans
Mountain
Edmonton
Burnaby
Hardisty
5
Kinder Morgan
TMX2 Expansion
TMX3 Expansion
Anacortes
Enbridge Alberta Clipper
Enbridge (North Dakota) Expansion
1
Express
TransCanada
Keystone XL
3
Clearbrook
Superior
Montréal
Portland
St. Paul
Enbridge
Guernsey
2
Salt Lake City
Platte
Flanagan
Sarnia
Chicago
Philadelphia
TransCanada Keystone
& Cushing Extension
Spearhead South
Wood
River
Patoka
Spearhead North
Mustang
Cushing
Centurion Pipeline
ExxonMobil/
Enbridge Pegasus
Port Arthur
Houston
Canadian and U.S. Oil Pipelines
Enbridge Pipelines, AB Clipper
and connections to the U.S. Midwest
Kinder Morgan Express
Kinder Morgan Trans Mountain
TransCanada Keystone
Proposed pipelines to the West Coast
Existing / Proposed pipelines to PADD III
Expansion to existing pipeline

Pipeline oil spills: Michigan, Minnesota, Utah, Montana, and many more.

NATURAL GAS

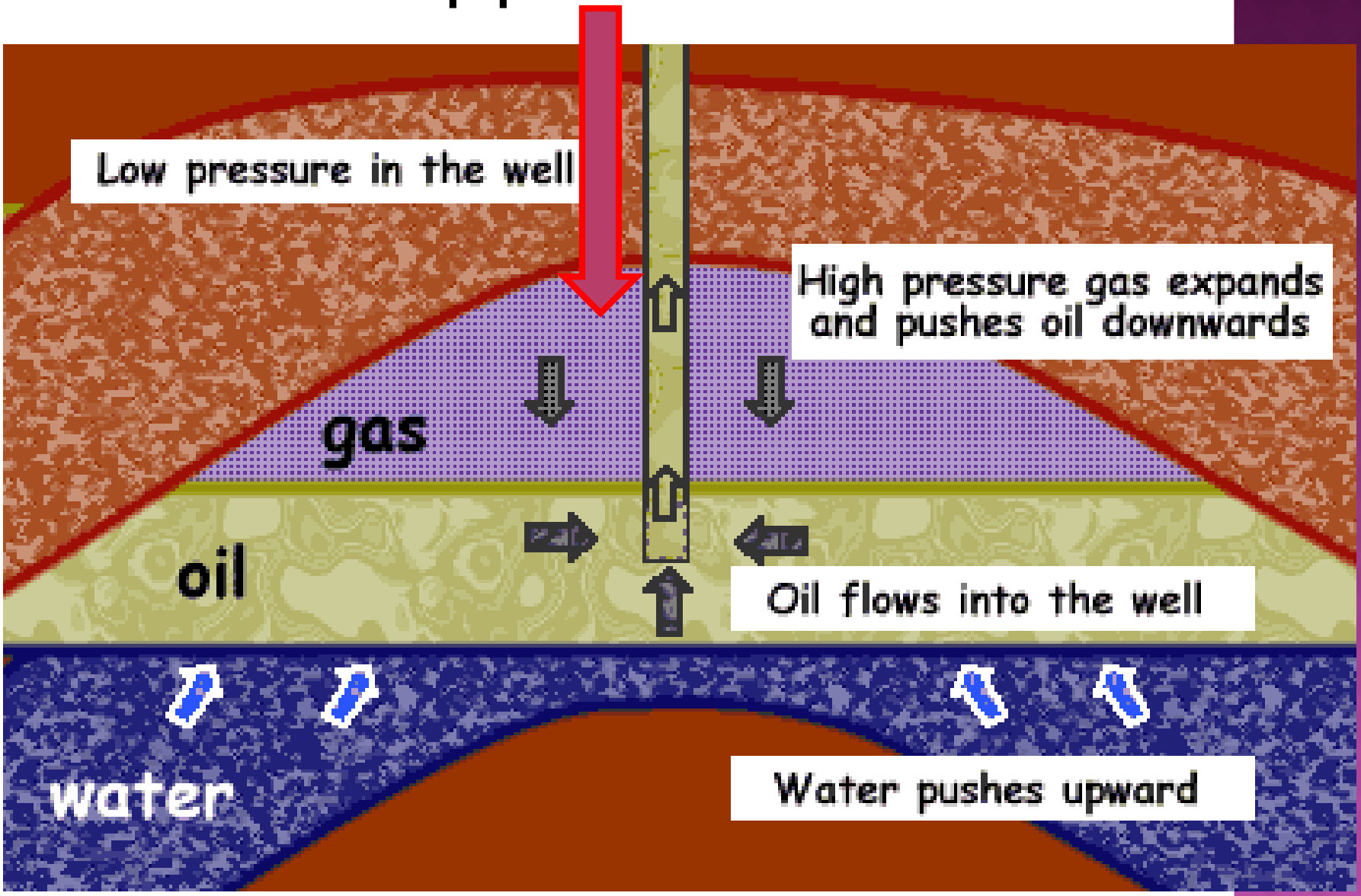
Pros

- Uses: primary source to produce electricity; heating for residential, industrial & commercial; automotive fuel
- Most refined. Contains least amount of carbon.
- Burns 50% cleaner than coal.
- Cleaner emissions than gasoline:
  - 70% less CO; 87% less NOx; 20% less CO_2

Cons

- Estimated 60 year world supply at current supply & consumption rate
- Infrastructure: difficult to transport because it is in a gaseous state. Can liquefy it for easier transport by storing it at -270 degrees.
- Controversial method of hydrofracking is used to extract natural gas from rock layers deep underground.

Natural Gas is piped out of oil wells

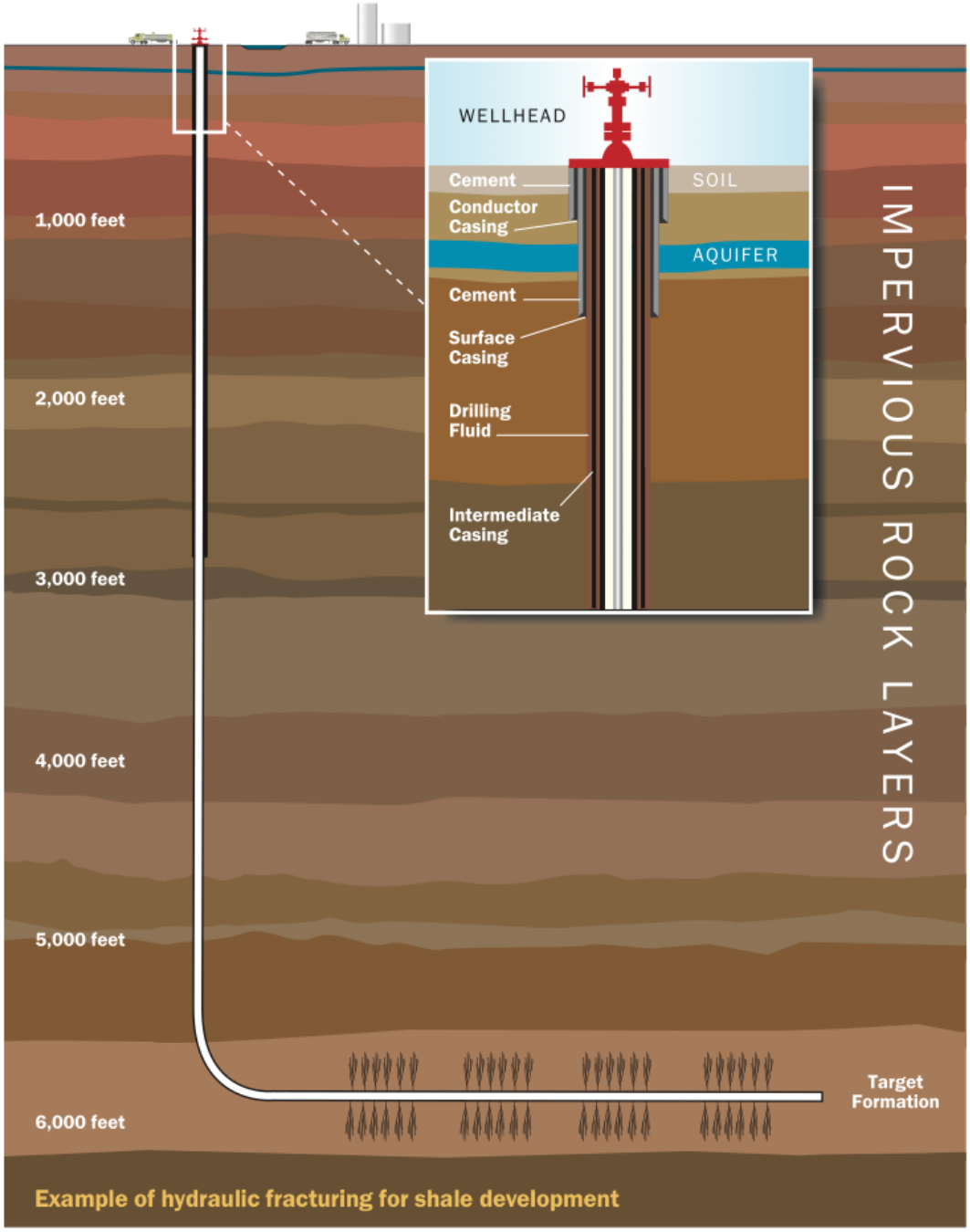


HYDROFRACKING (HYDRAULIC FRACTURING)

A mixture of water, sand, and chemicals are used to break apart rock strata containing oil and natural gas.

The fluid mixture can be reused, but eventually must be disposed in either underground containment basins or into surface waters.

Risks of groundwater contamination and release of VOC's (volatile organic compounds)



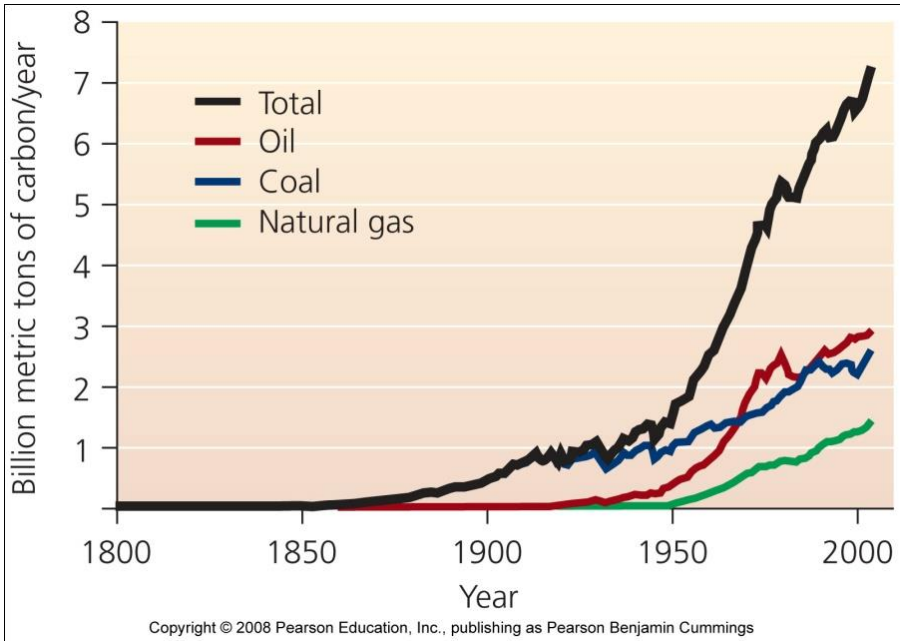
COAL BED METHANE (NATURAL GAS)

The primary component of natural gas is methane (CH_4). Coal reserves contain methane which can be extracted by removing water from the coal deposit to allow the methane gas to flow to the surface.

Wildlife habitat and antelope migration corridors are being reduced to allow increased methane extraction.

FOSSIL FUEL EMISSIONS POLLUTE THE AIR

- Releasing carbon dioxide through combustion is the greatest impact of fossil fuel use.
- Pollutants and hydrocarbons cause severe health problems.
- Clean coal technologies (i.e., scrubbers) can reduce sulfur, nitrogen, and ash emissions by 95%.

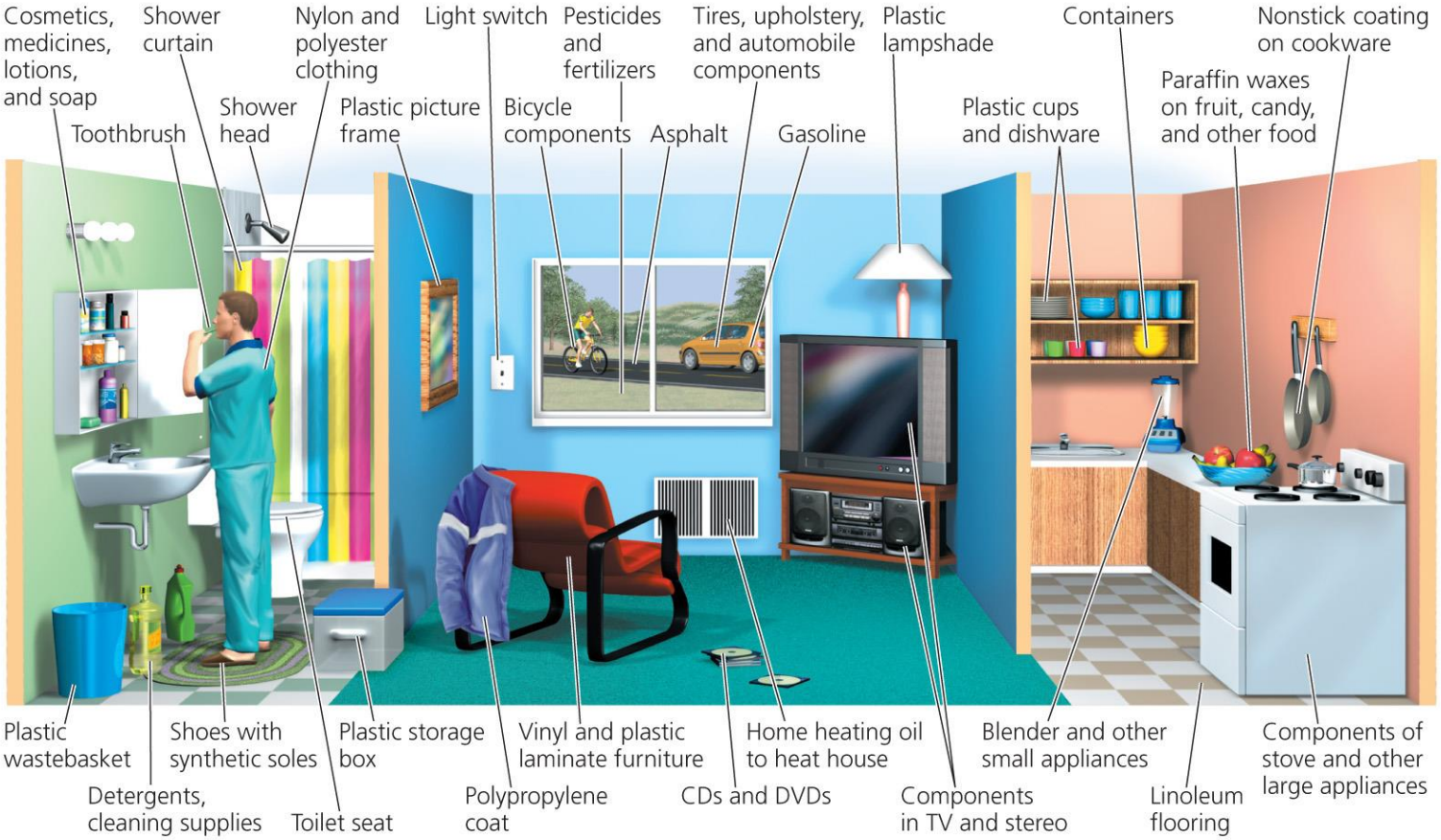


FOSSIL FUEL USE POLLUTES WATER

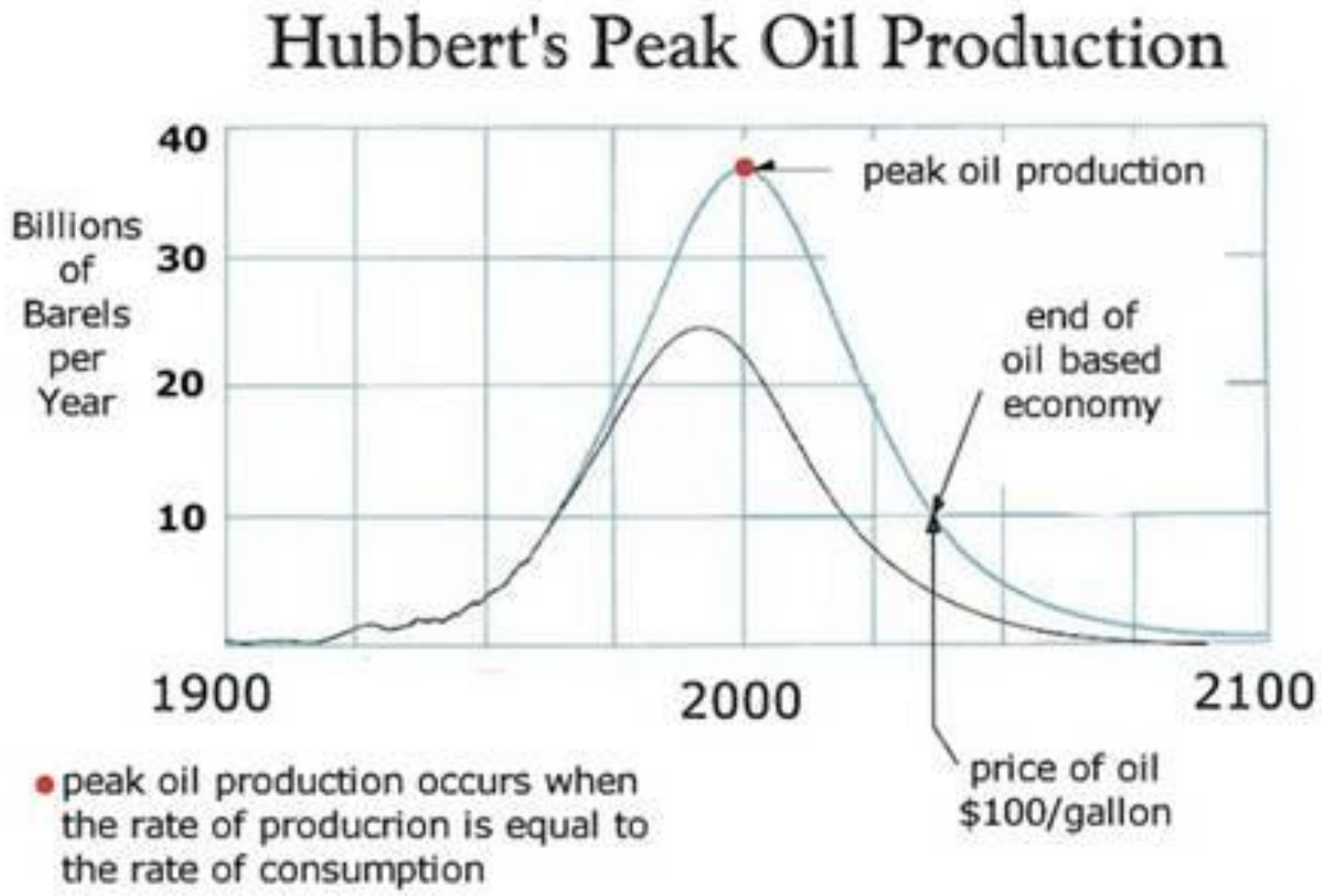
- Leaking underground storage tanks can pollute groundwater.
- Non-point source oil pollution ultimately ends up in oceans.
- Catastrophic tanker oil spills impact marine environments.
- Coal mining causes acid mine drainage and habitat destruction.
- Drilling requires new roads and infrastructure, which fragment habitats.

PETROLEUM PRODUCTS HAVE MANY USES

Oil is refined to create many products, so we should be concerned as we continue depleting it.



HUBBERT CURVE



NUCLEAR POWER

Pros:

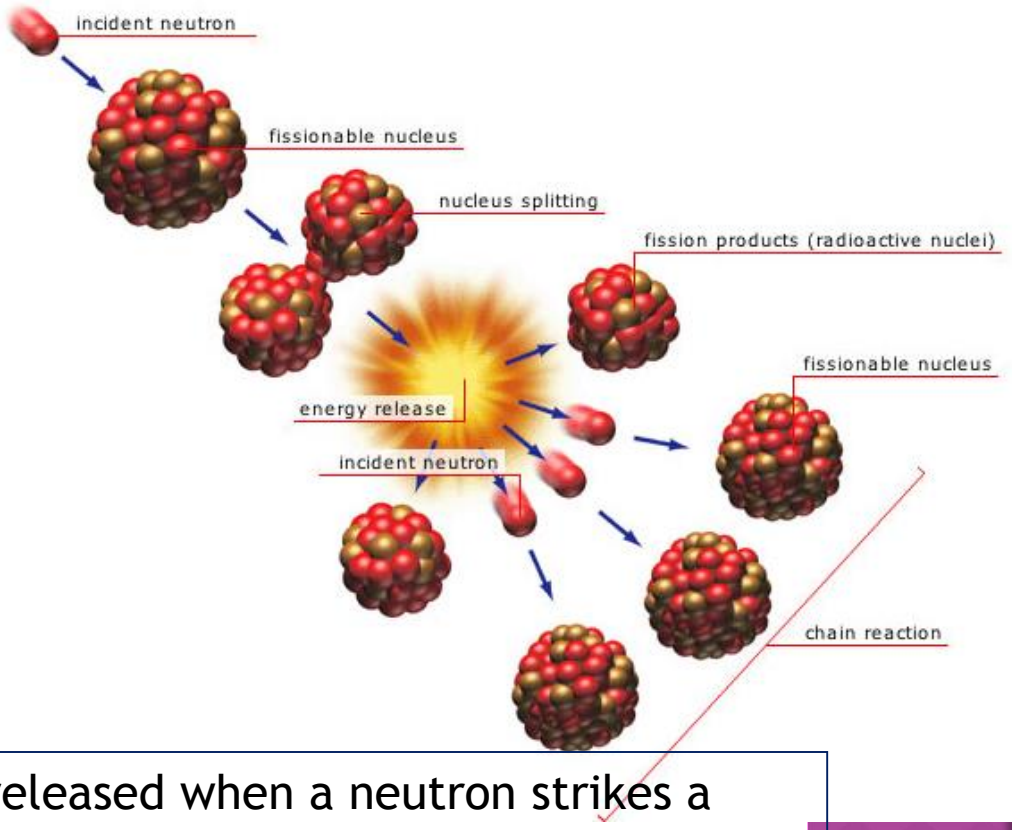
- Minimal air pollution: only water vapor
- Upfront costs are cheaper than renewable fuels
- Highly efficient: a lot of energy for each transformation.

Cons:

- Potential for nuclear accidents
- Uranium is a non-renewable resource
- Radioactivity half-life of plutonium is 24,000 years. We do not have a good plan for long-term storage of radioactive waste.
- There are environmental hazards along the whole process from mining uranium to disposing the waste.

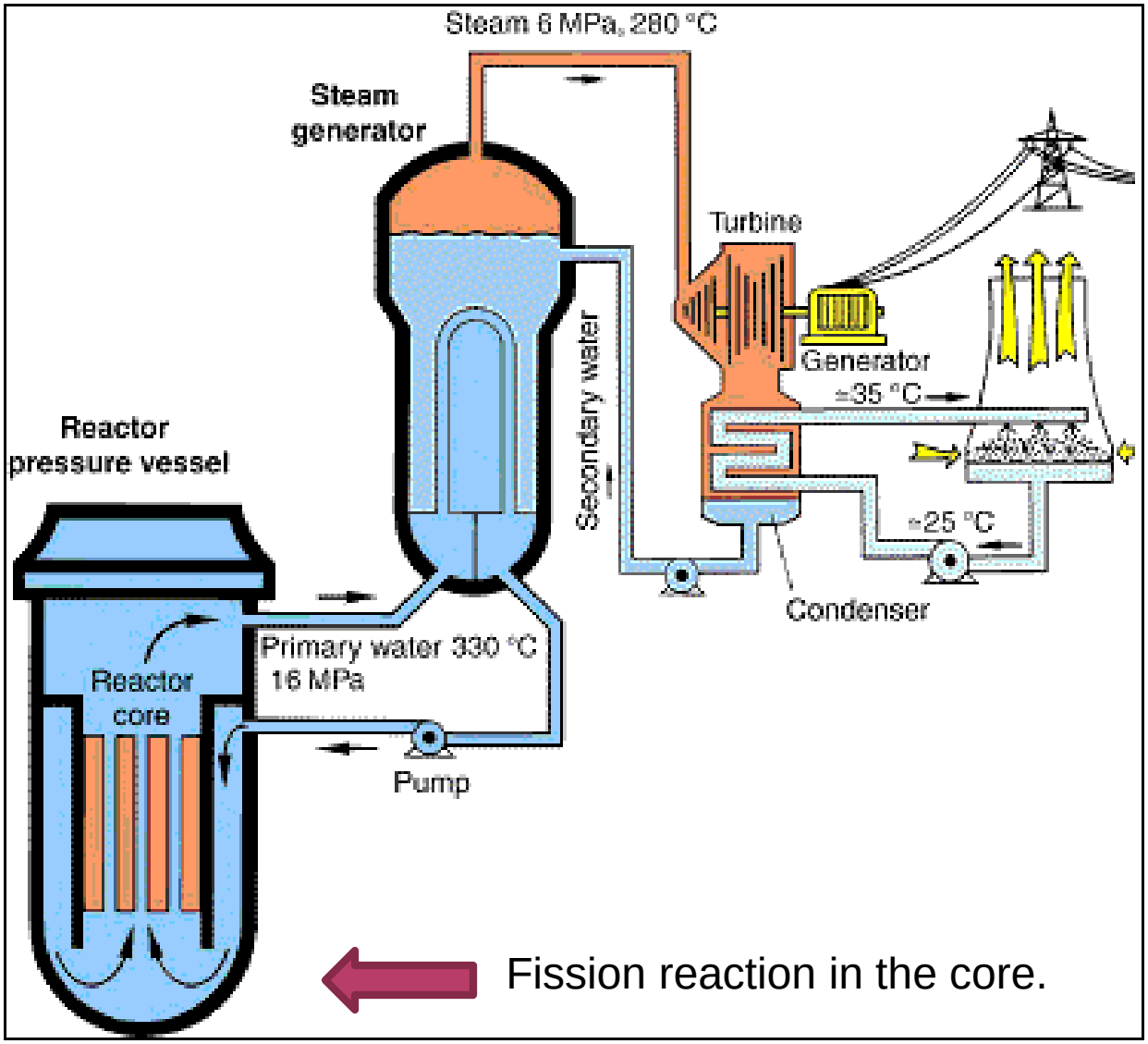
HOW A NUCLEAR POWER PLANT WORKS

- Water is heated and converted to steam, which then turns a turbine and operates a generator (similar to a coal power plant).
- NUCLEAR **FISSION** is used to create heat (instead of combustion).



Heat is released when a neutron strikes a **uranium 235** atom and splits it apart. A chain reaction ensues whereby the atom releases more neutrons that strike more U^{235} atoms. Plutonium isotopes, Barium and Krypton are some of the radioactive by-products.

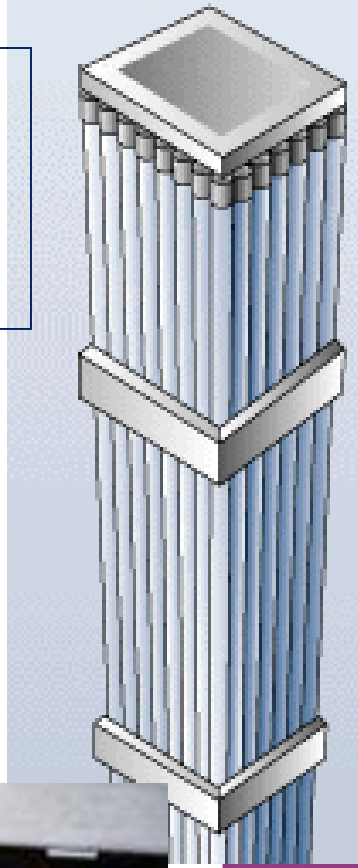
NUCLEAR POWER PLANT



Uranium pellets

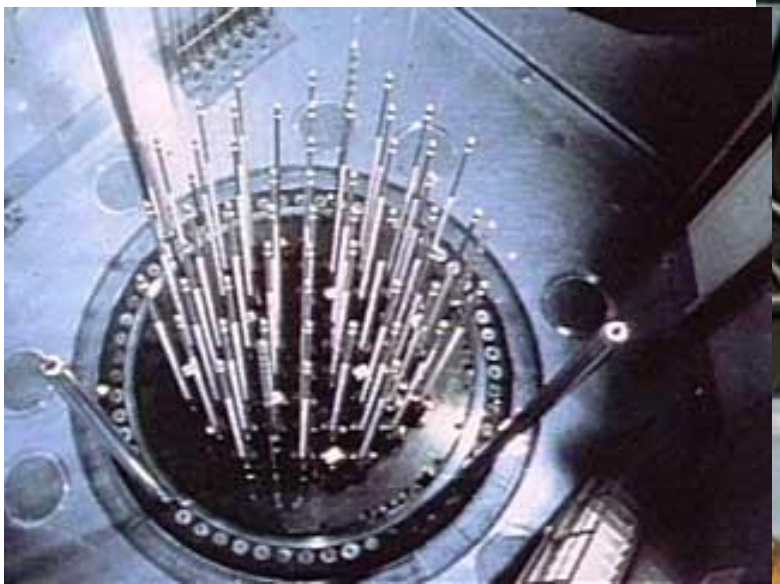
Fuel Rods filled with pellets.

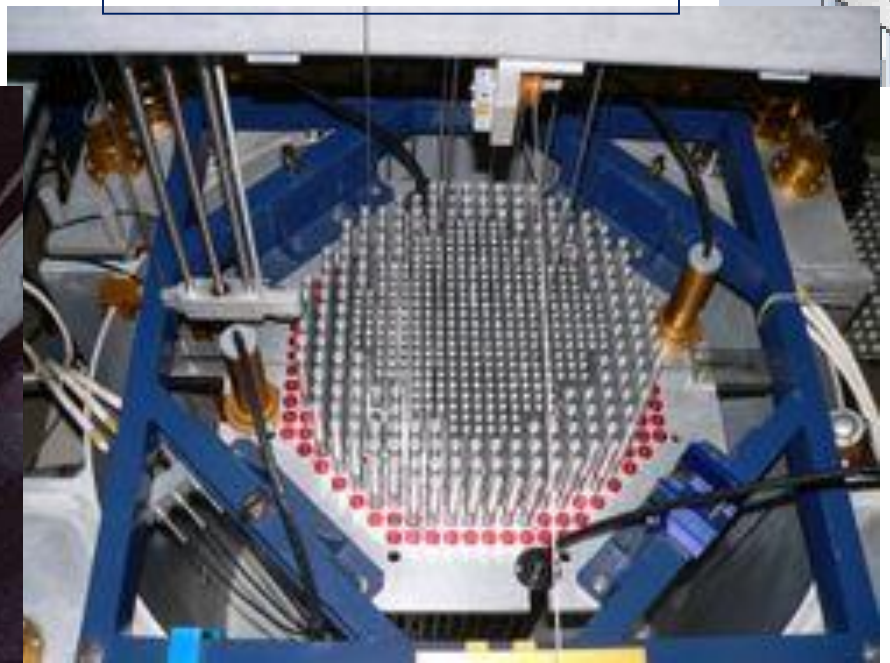
Rods last @ 3-4 years.



Control rods are inserted between the fuel rods. They absorb neutrons which slows the chain reaction to keep it under control.

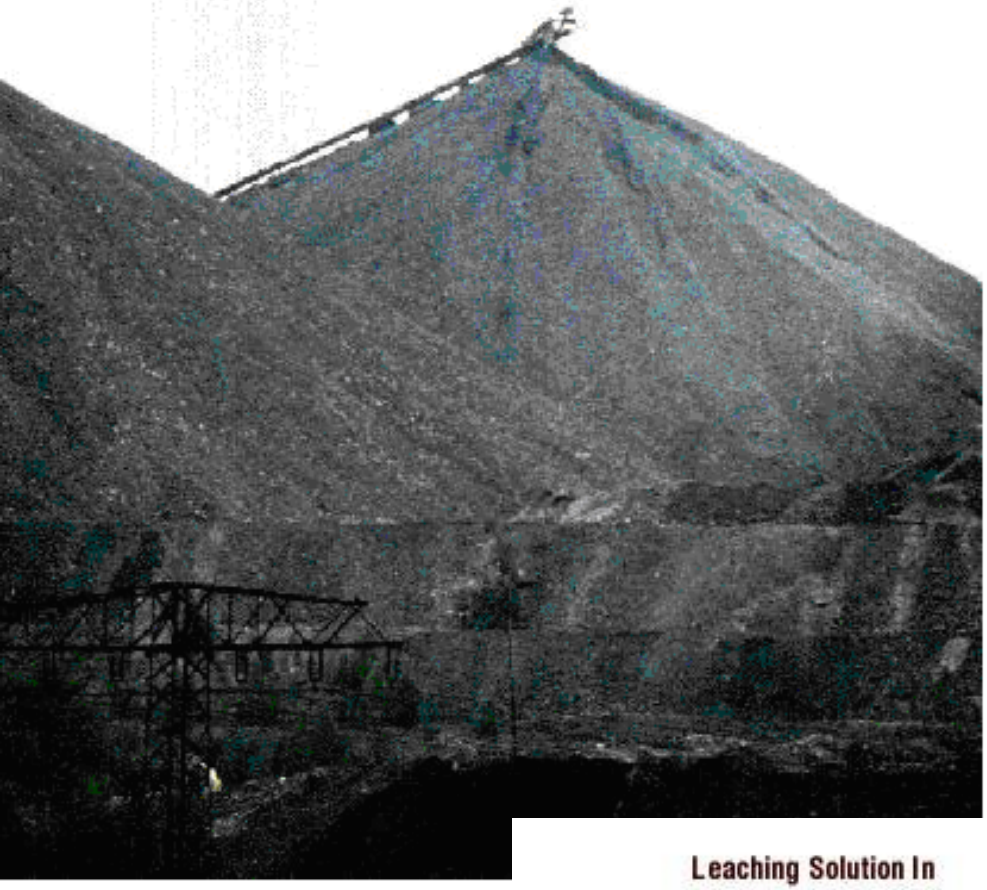
Top ends of fuel rods in the reactor.



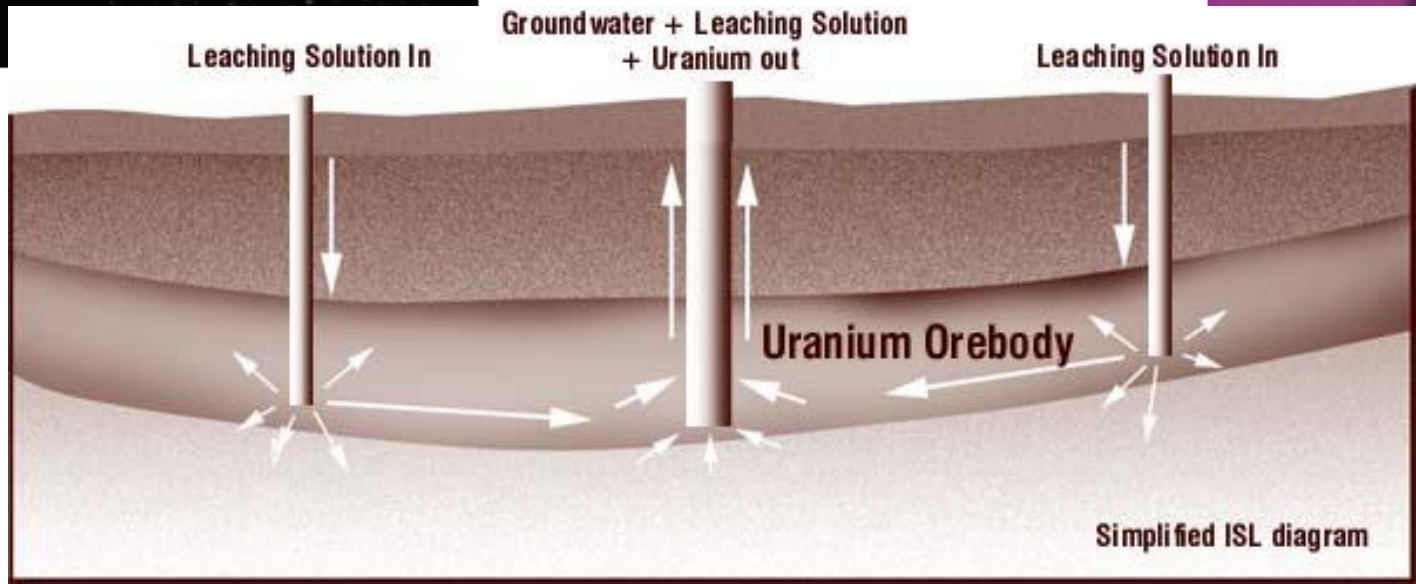


BY-PRODUCTS OF NUCLEAR ENERGY

- Mining Waste
  - Every 1,000 tons of Uranium result in 100,000 tons of radioactive tailings (mine waste) and 3.5 million liters of liquid waste.
- Electricity Production Waste
  - Spent fuel rods contain plutonium 238 waste that is more radioactive than the uranium prior to energy production.
  - Plutonium waste has a half life of 24,000 years
  - Some countries reuse some of the waste to make more electricity.

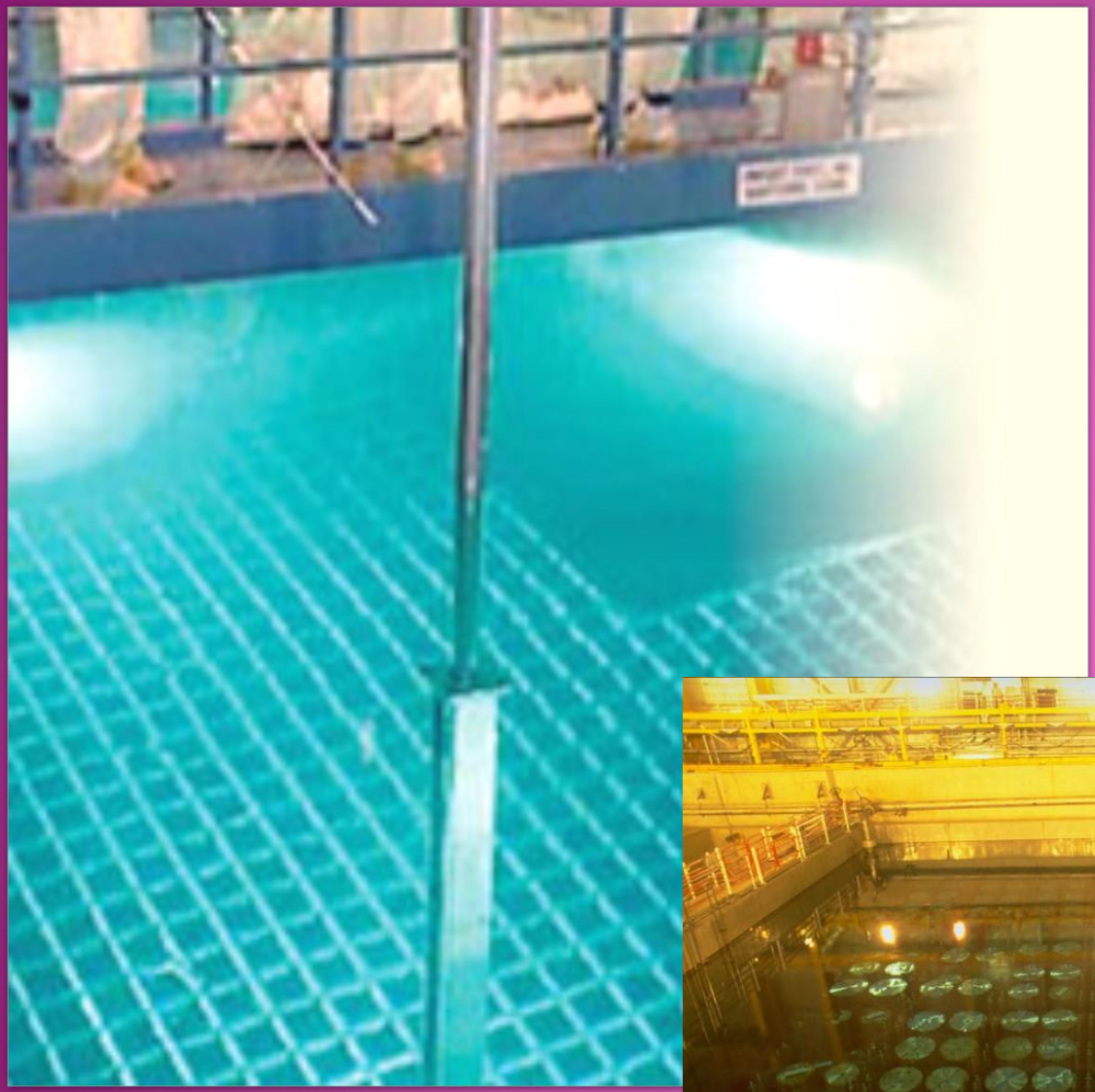


Extracting Uranium



HALF-LIFE

- The half-life is the time it takes for ½ of the potential radioactivity to be released.
- Plutonium has the longest half-life, which is 24,110 years.
- After 24,110 years, the fuel rod will be one-half as radioactive. After another 24,110 years, it will be 25% (half of the half) as radioactive. After a third half-life, it will be 12.5% as radioactive….

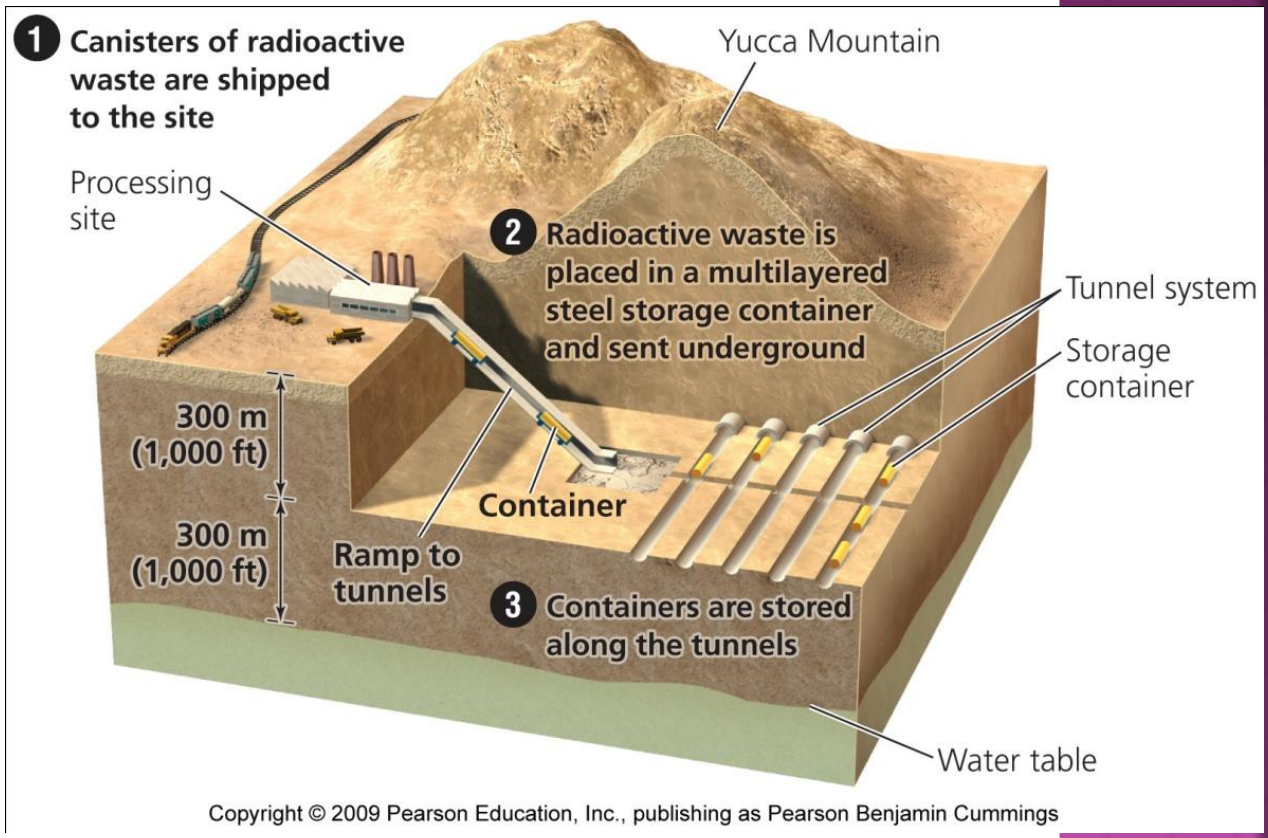


The US currently has no long-term storage plan for the waste products. They are stored on site in underground cement-lined casks.

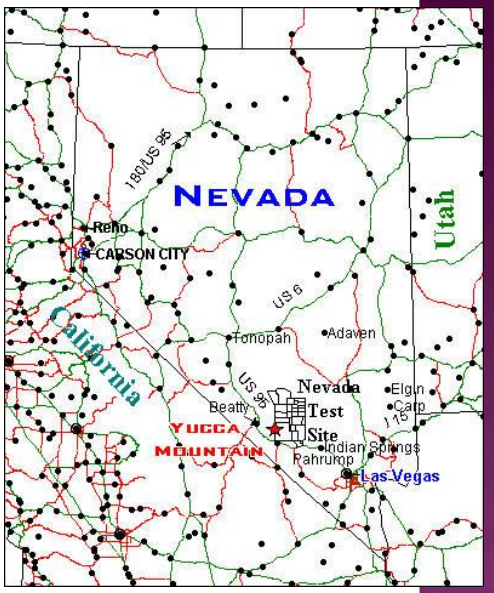
WASTE STORAGE AT YUCCA MOUNTAIN, NEVADA

Nuclear waste managers want to send all waste to a central repository that can be heavily guarded

With final approval, Yucca Mountain will begin receiving wastes by 2017.



WHY YUCCA MOUNTAIN?



- It is remote and unpopulated.
- It has minimal risk of earthquakes.
- Its dry climate minimizes groundwater contamination.
- The water table is deep underground, on top of an isolated aquifer.
- Its location on federal land can be protected from sabotage.
- However, nuclear waste will need to be transported from 120 current storage areas, nuclear plants, and military installations.

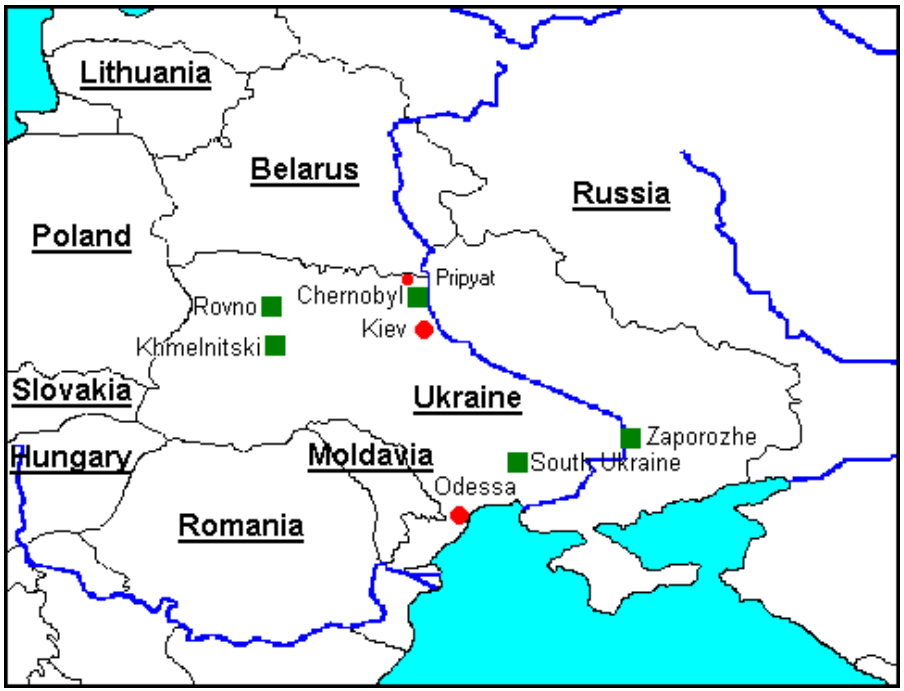
NUCLEAR POWER HAS CLEAN EMISSIONS

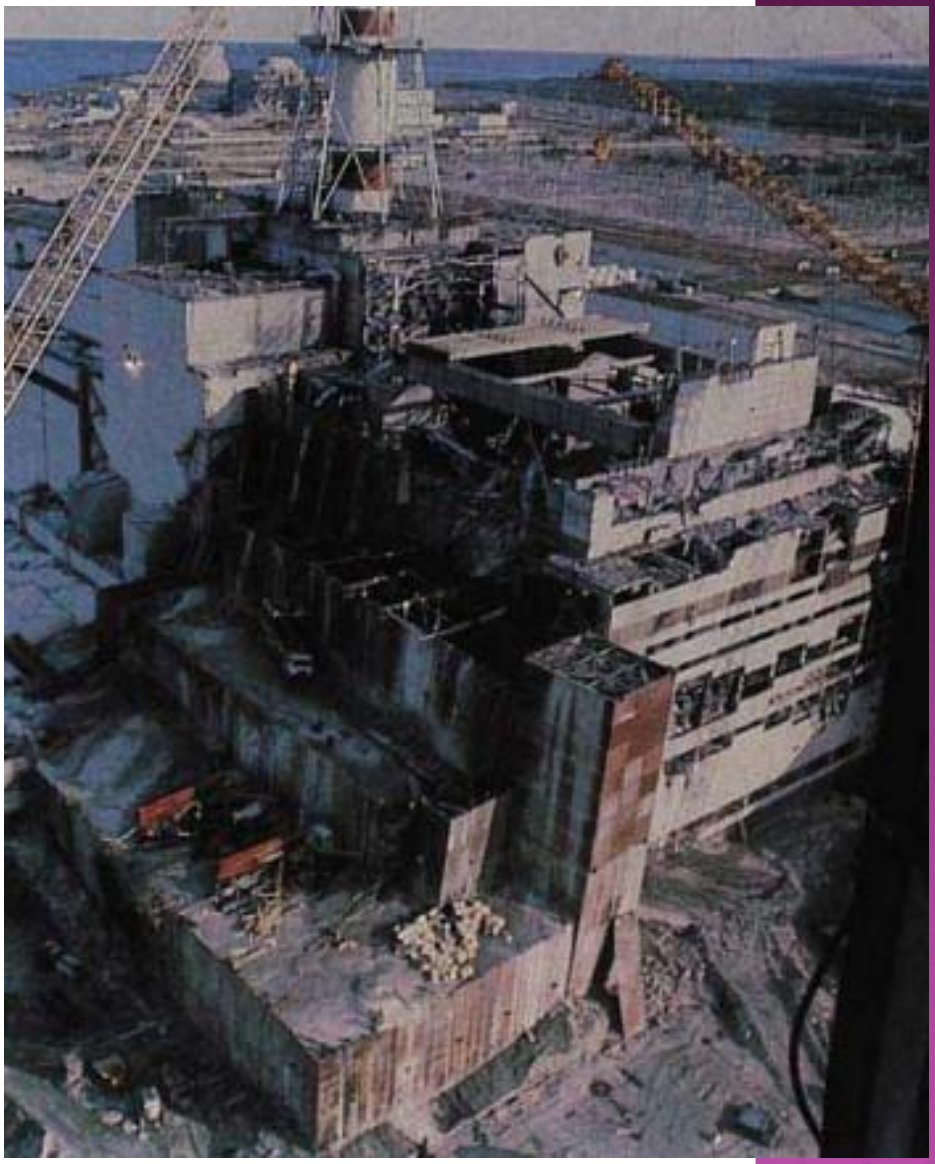
- Nuclear power prevents 600 million metric tons of carbon emissions each year.
  - Equivalent to 8% of global greenhouse gas emissions
  - Poses far fewer chronic health risks than fossil fuels
- Nuclear power plants cause less landscape damage, generate less solid wastes, and are safer for workers than coal-fired plants.
- Drawbacks of nuclear power:
  - Nuclear waste is radioactive.
  - If an accident occurs, or the plant is sabotaged, the consequences can potentially be catastrophic.
- Today, the world has 439 operating nuclear plants in 31 nations.

NUCLEAR POWER POSES SMALL RISKS OF LARGE ACCIDENTS

- The possibility of catastrophic accidents spawns public anxiety.
- **Three Mile Island** (1979): the most serious accident in the U.S.
  - **Meltdown**: melting of uranium fuel rods, releasing radiation, as coolant water drained from the reactor vessel, and increased temperatures
  - It proceeded through ½ of one reactor core.
  - Radiation remained trapped in the containment building.
  - The cleanup cost billions of dollars.
- Three Mile Island is regarded as a near-miss: the emergency could have been far worse.

CHERNOBYL NUCLEAR ACCIDENT 1986





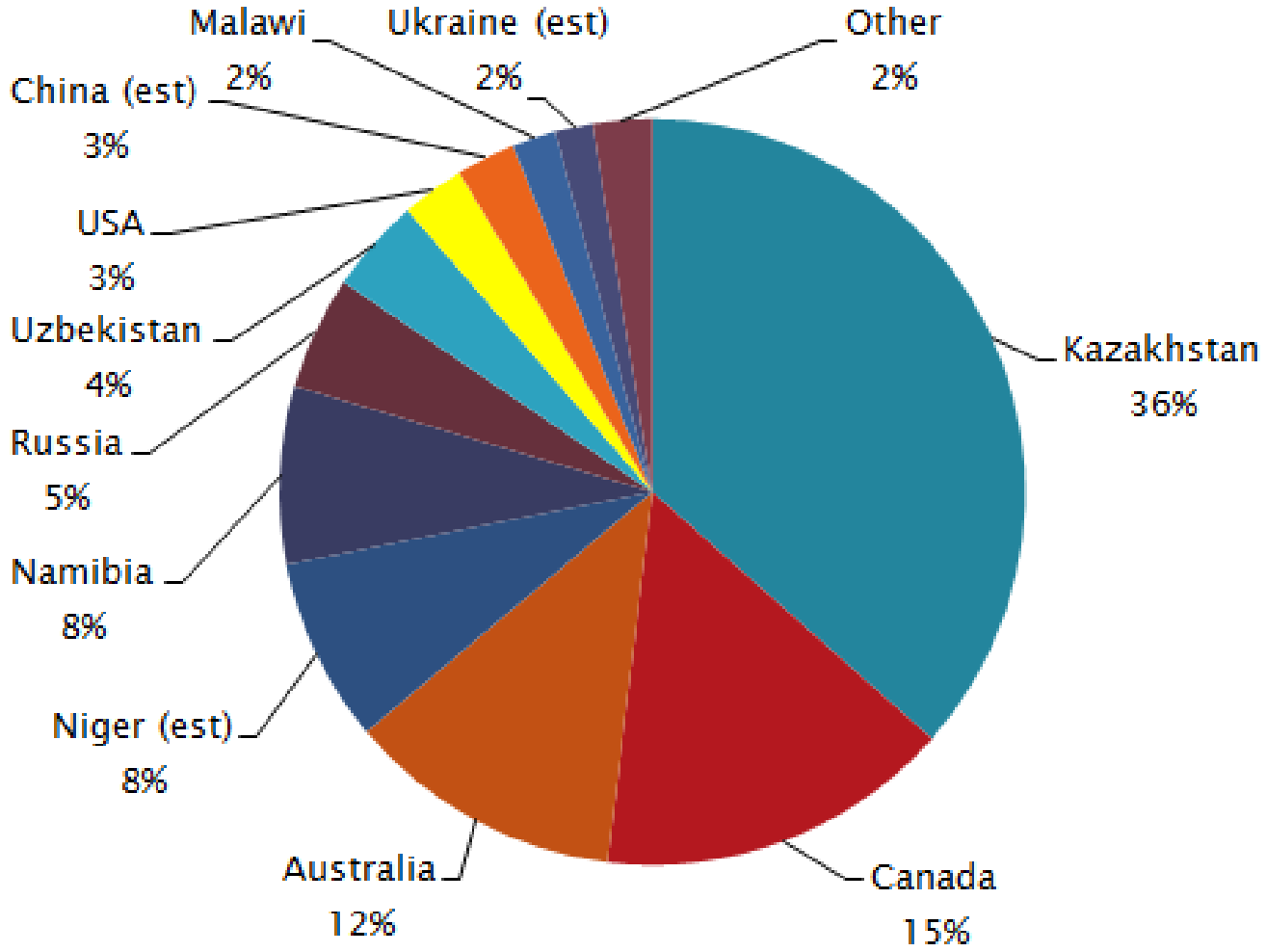
Equipment failure and human error caused the 1986 meltdown in the former Soviet Union.
It brought to light many concerns about nuclear power. It also brought about many new regulations to avoid similar problems in the future.

Fukushima Dai-ichi

A magnitude 9 earthquake 130 km off the coast of Japan triggered the shutdown of several nuclear reactors.

US NUCLEAR POWER PLANTS

As of 2019: 58 commercially operating nuclear power plants in US



World Uranium Mining Production 2012

Uranium Mine: Moab Utah

ENERGY CONSERVATION

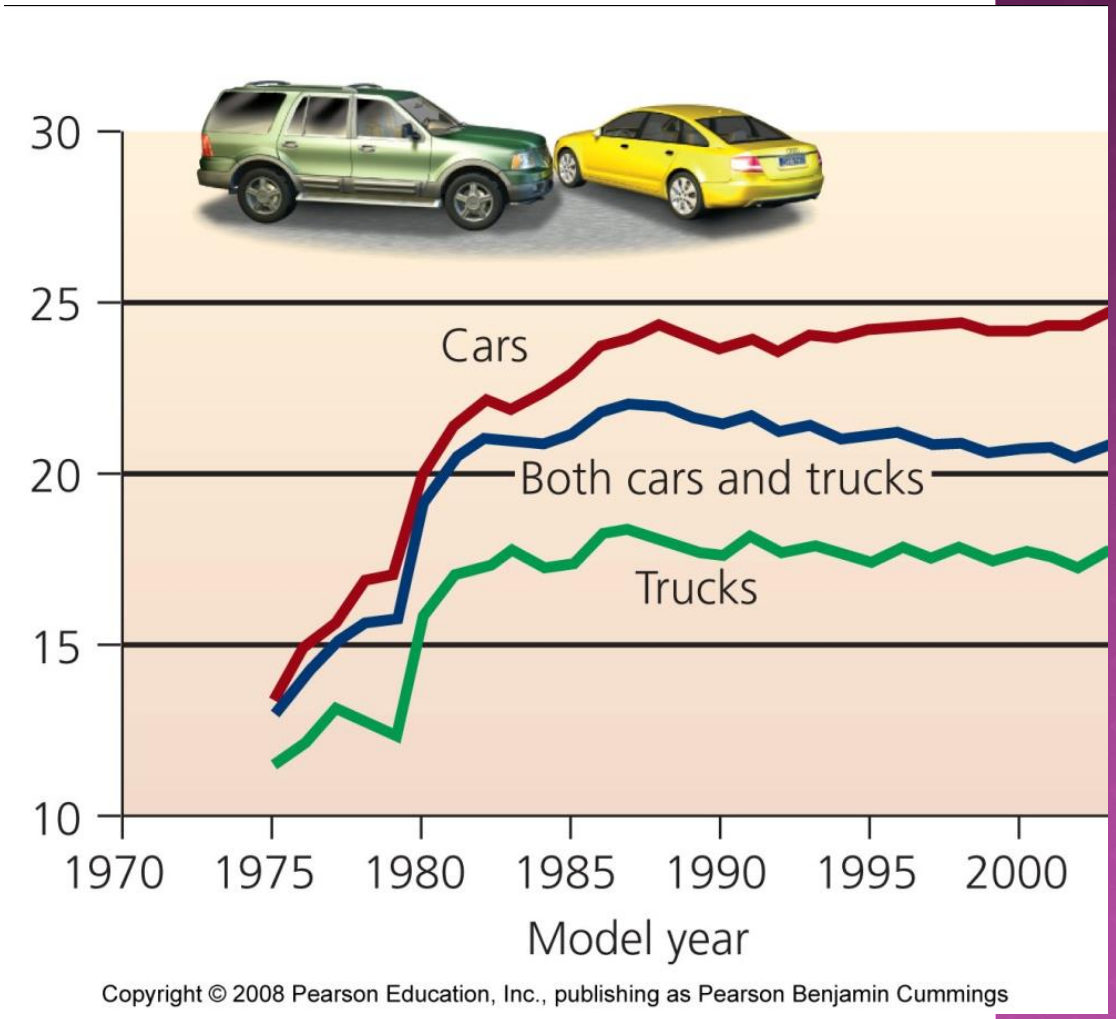
- **Energy conservation**: the practice of reducing energy use to:
  - Extend the life of our nonrenewable energy supplies
  - Be less wasteful
  - Reduce our environmental impact

ENERGY EFFICIENCY

- **Cogeneration**: excess heat produced during electrical generation is used to heat buildings and produce other types of power
- Improvements in home design reduce energy required to heat and cool them.
- Appliances have been reengineered to increase energy efficiency.
- Consumers need to vote with their wallets by buying energy-efficient products.
- Individuals can choose to reduce energy consumption.
  - Driving less, turning off lights, turning down thermostats, buying efficient machines
- Society can make more efficient devices.
  - Fuel efficient cars, electric or hybrid vehicles

FUEL EFFICIENCY STANDARDS

Finally, in 2007, Congress passed legislation to raise average fuel efficiency to 35 mpg by 2020, but this is still far lower than in other developed nations.



Conservation and Renewable Energy is Needed

- Effective energy conservation could save 6 million barrels of oil a day.
- Conserving energy is better than finding a new reserve.
  - It decreases environmental impacts while extending our access to fossil fuels.
- However, regardless of how much we conserve, we will still need energy. . .
- Next, we will focus on sources of renewable energy!

HALF-LIFE CALCULATIONS