

The Nuclear Fuel Cycle

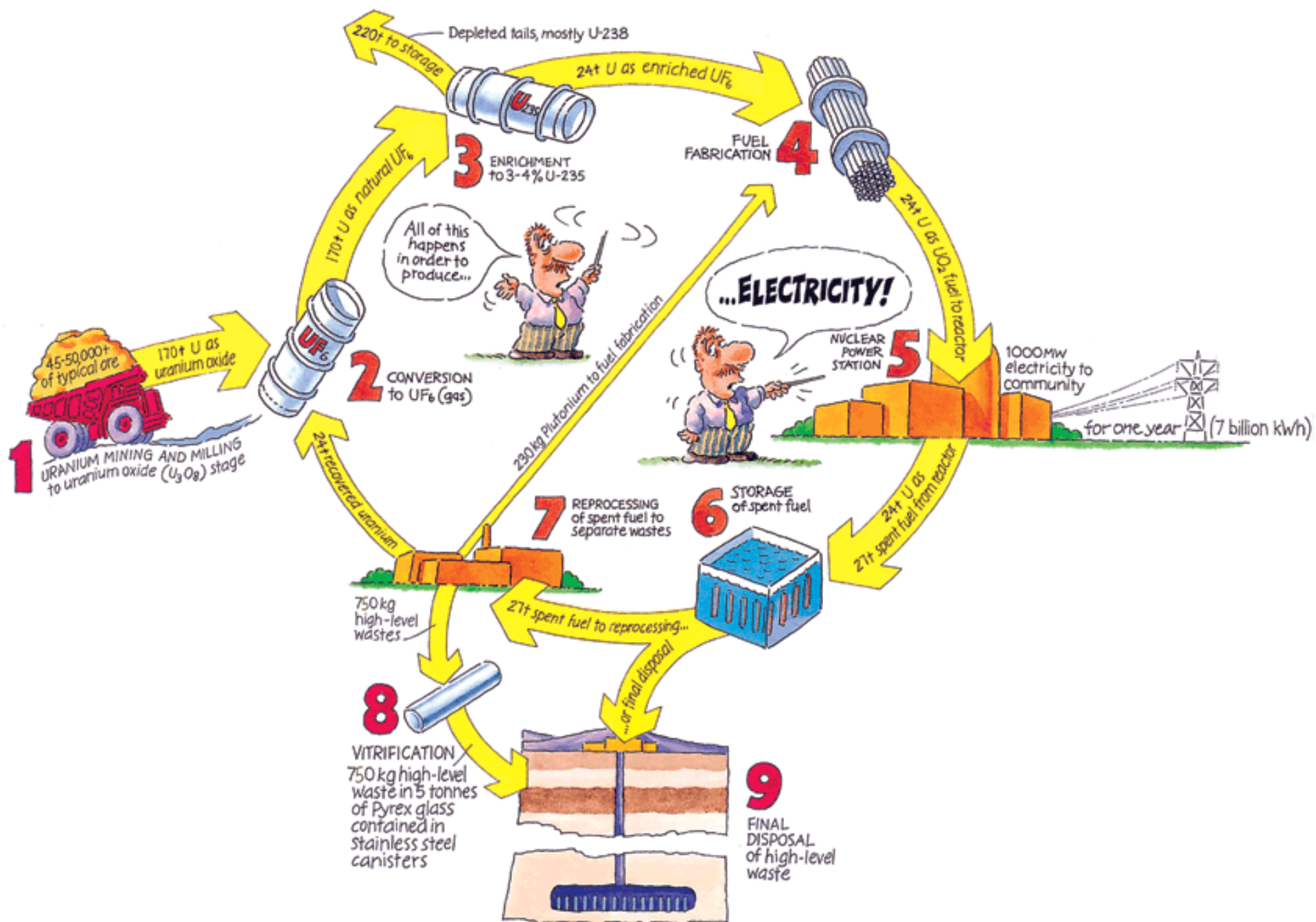
Mary Lou Dunzik-Gougar, Ph.D.

Idaho State University

Idaho National Laboratory

ANS Teachers' Workshop at WM 2014

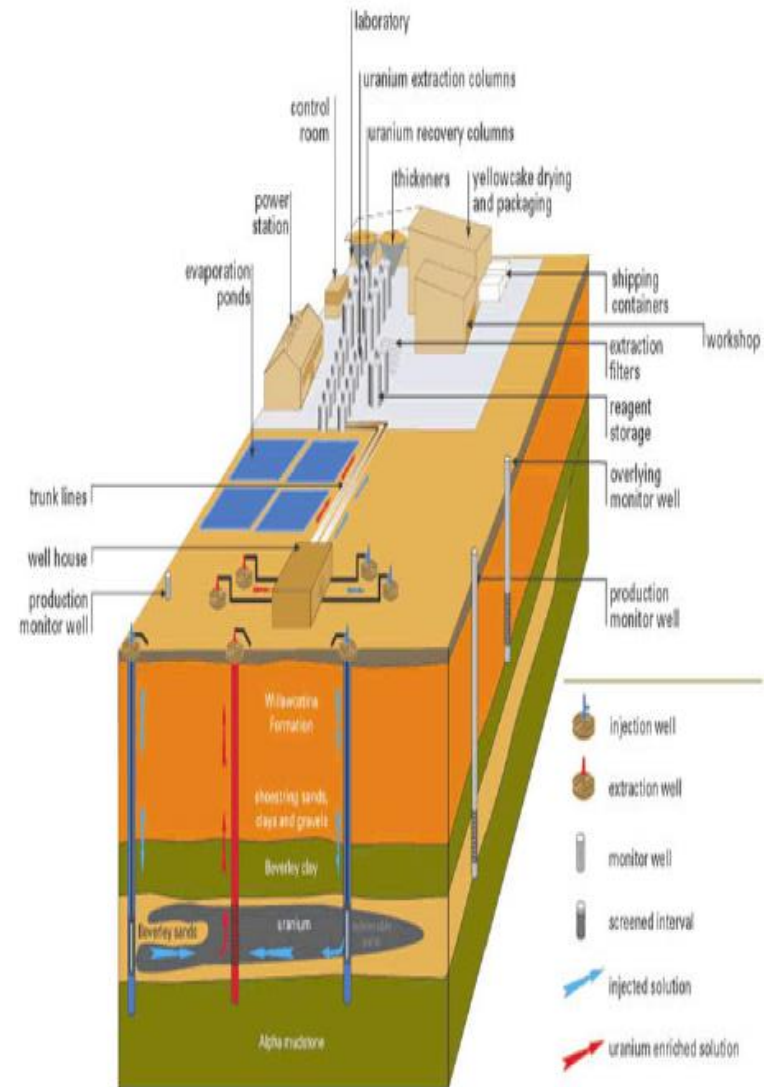
March 2014, Phoenix



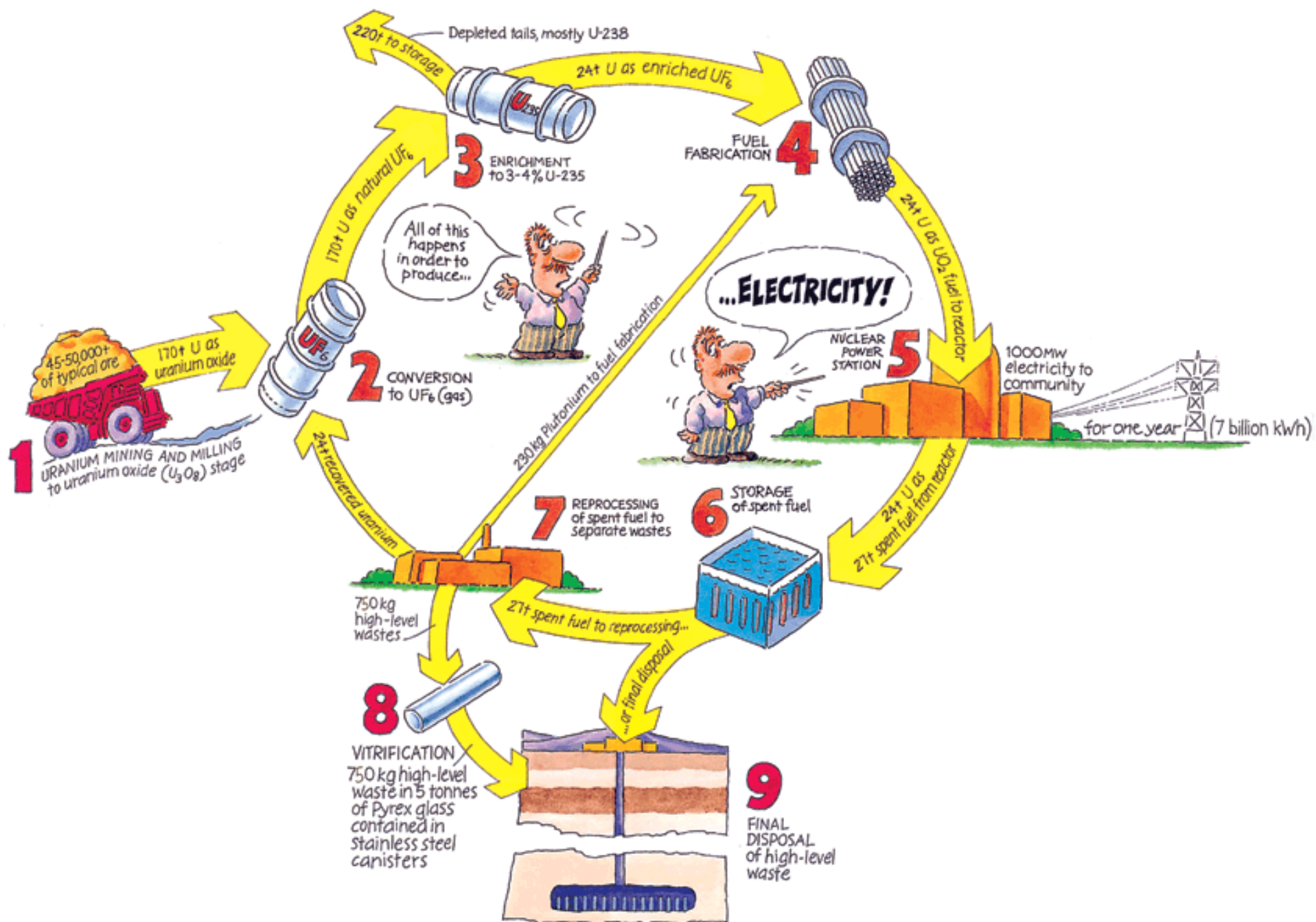
Uranium Mining

Open pit (strip) mining

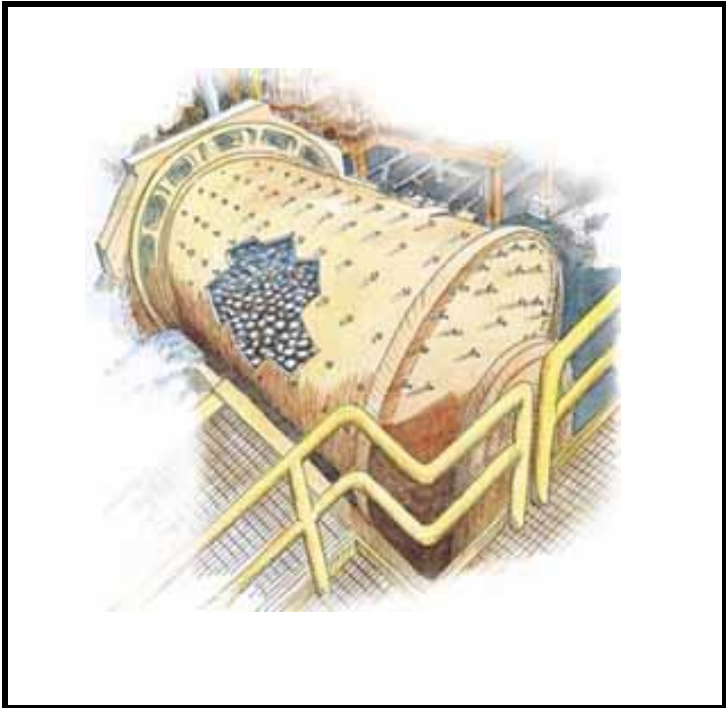
Underground mining



In situ leaching



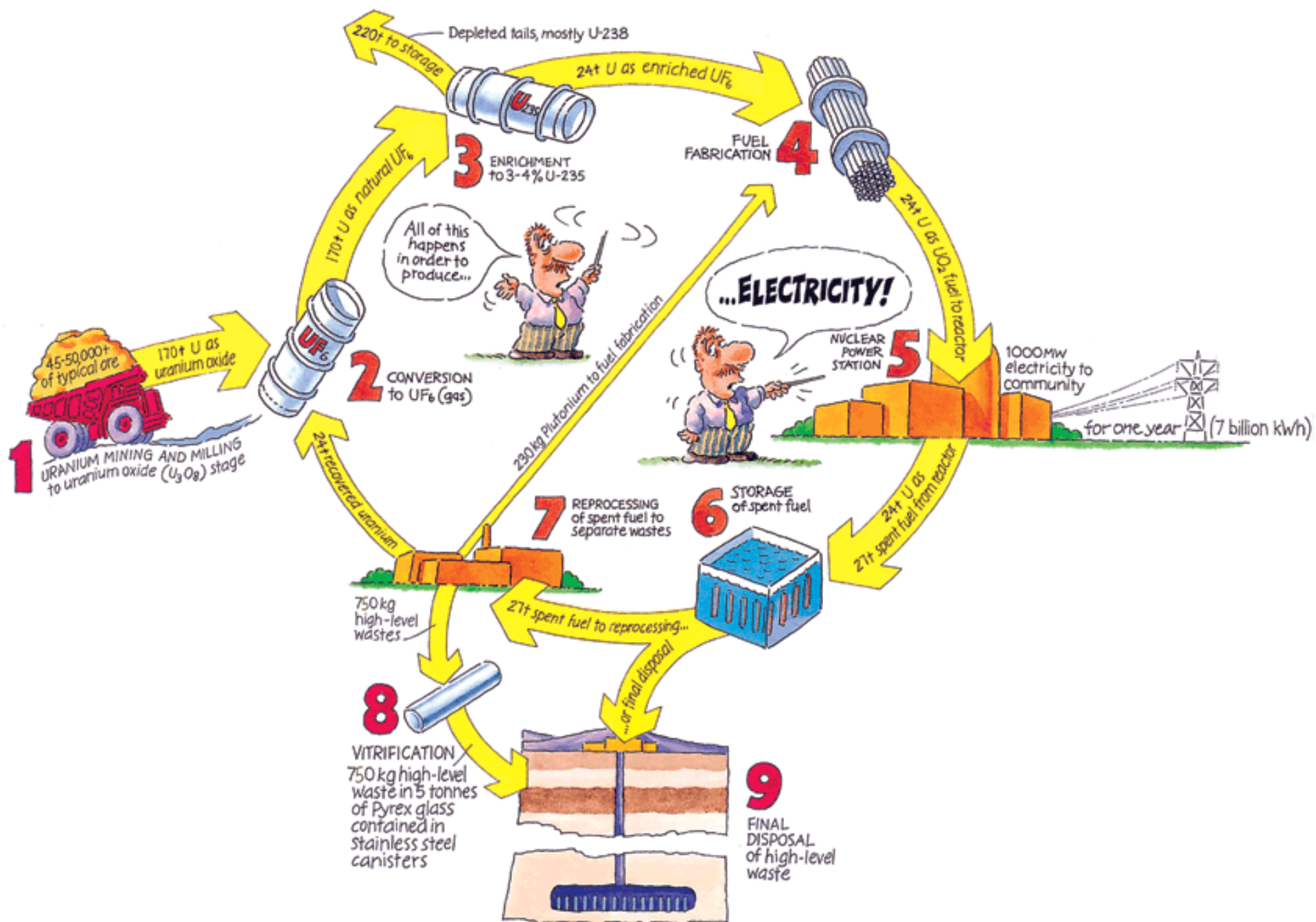
Uranium Milling



- Ore is crushed
- Uranium is separated



- U_3O_8 “yellow cake” produced

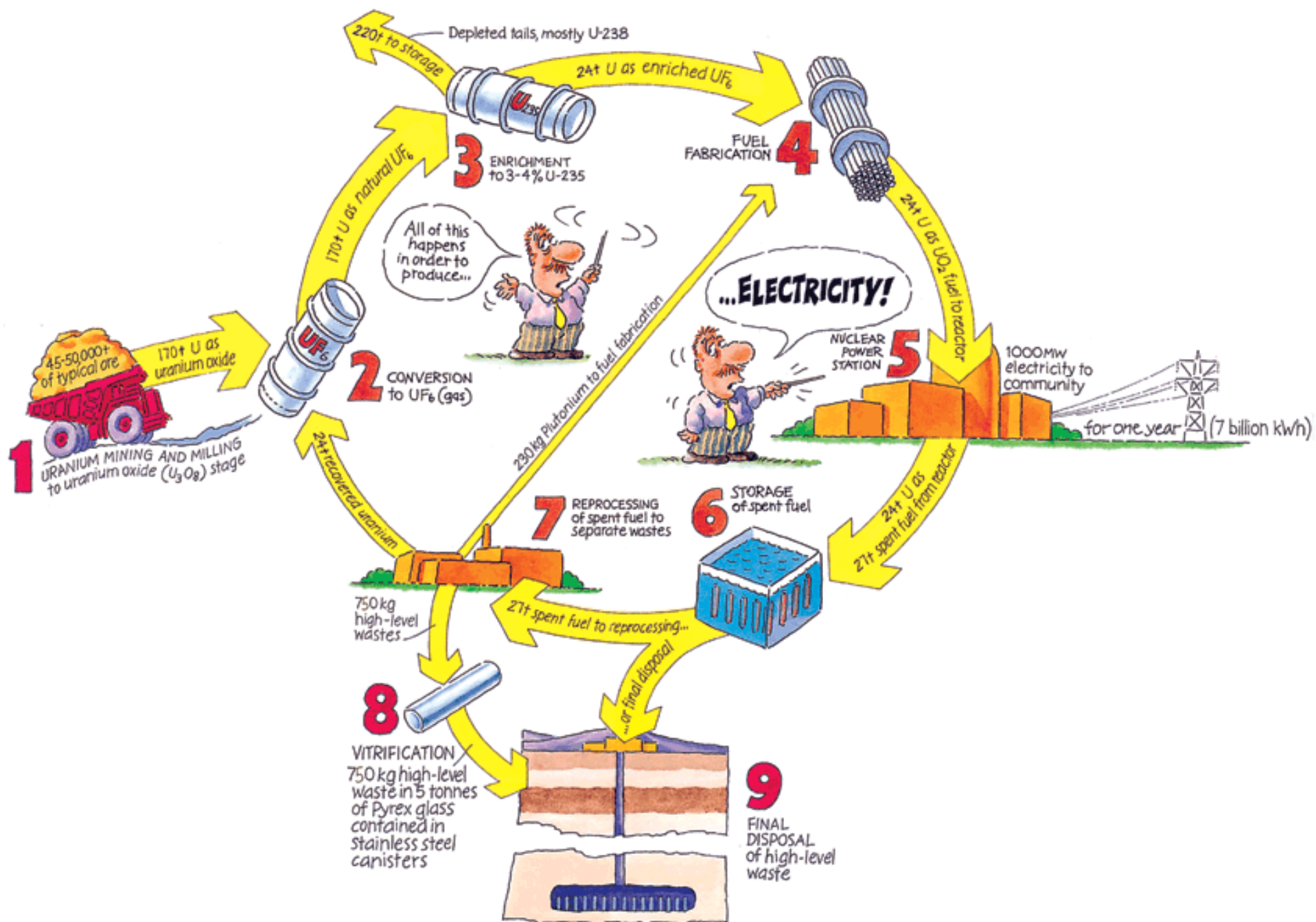


Uranium Conversion (to UF_6 gas)

- Impurities removed
- Uranium combined with fluorine
- UF_6 gas produced
 - Gaseous form facilitates enrichment

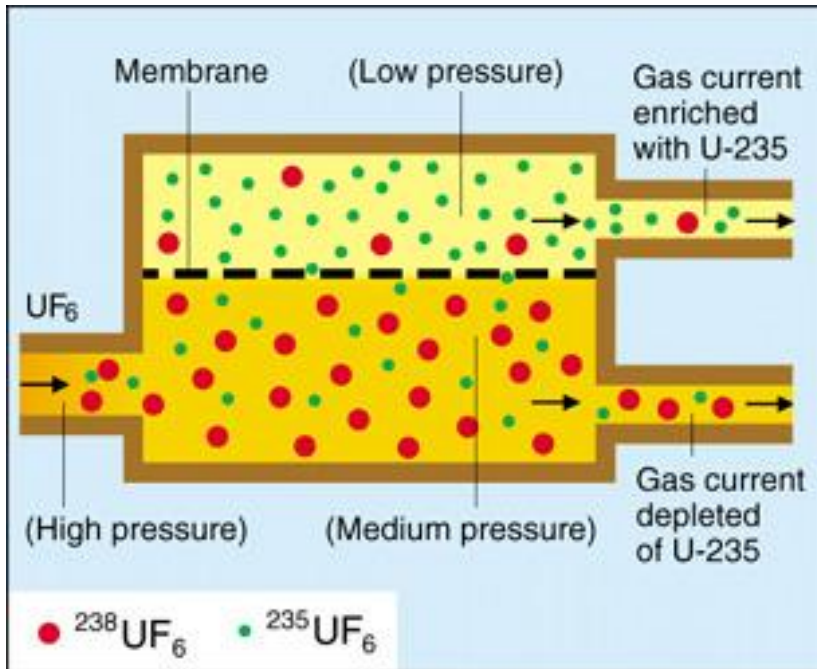


UF_6 containers

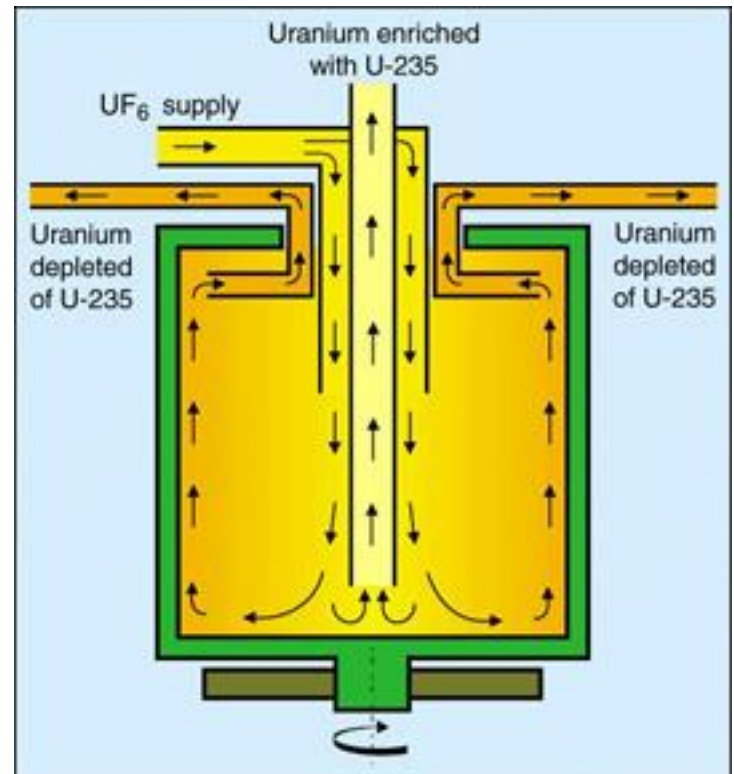


U Enrichment

- Natural U is $> 99\%$ ^{238}U and only $\sim 0.7\%$ ^{235}U
- Separation of $^{235}\text{UF}_6$ and $^{238}\text{UF}_6$ based on (very small) mass difference

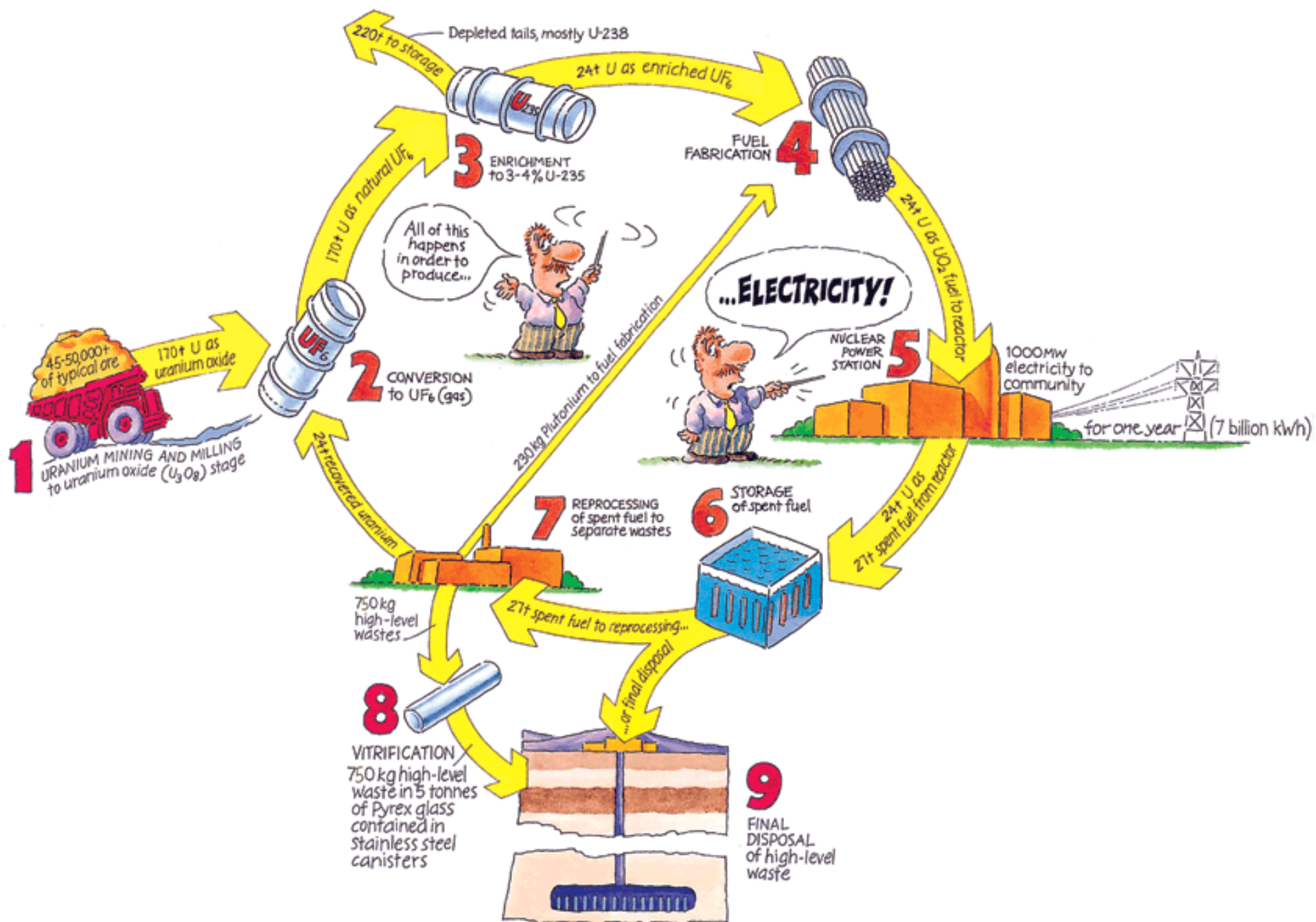


Diffusion



Centrifugation

- UF_6 enriched from 0.7% ^{235}U to $3\%-5\%$ ^{235}U

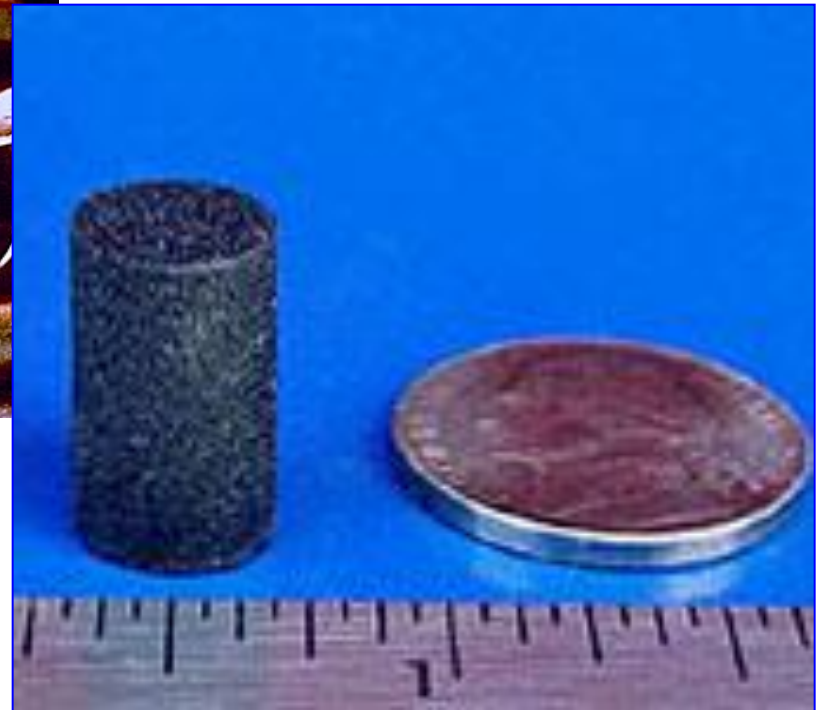


Fuel Fabrication

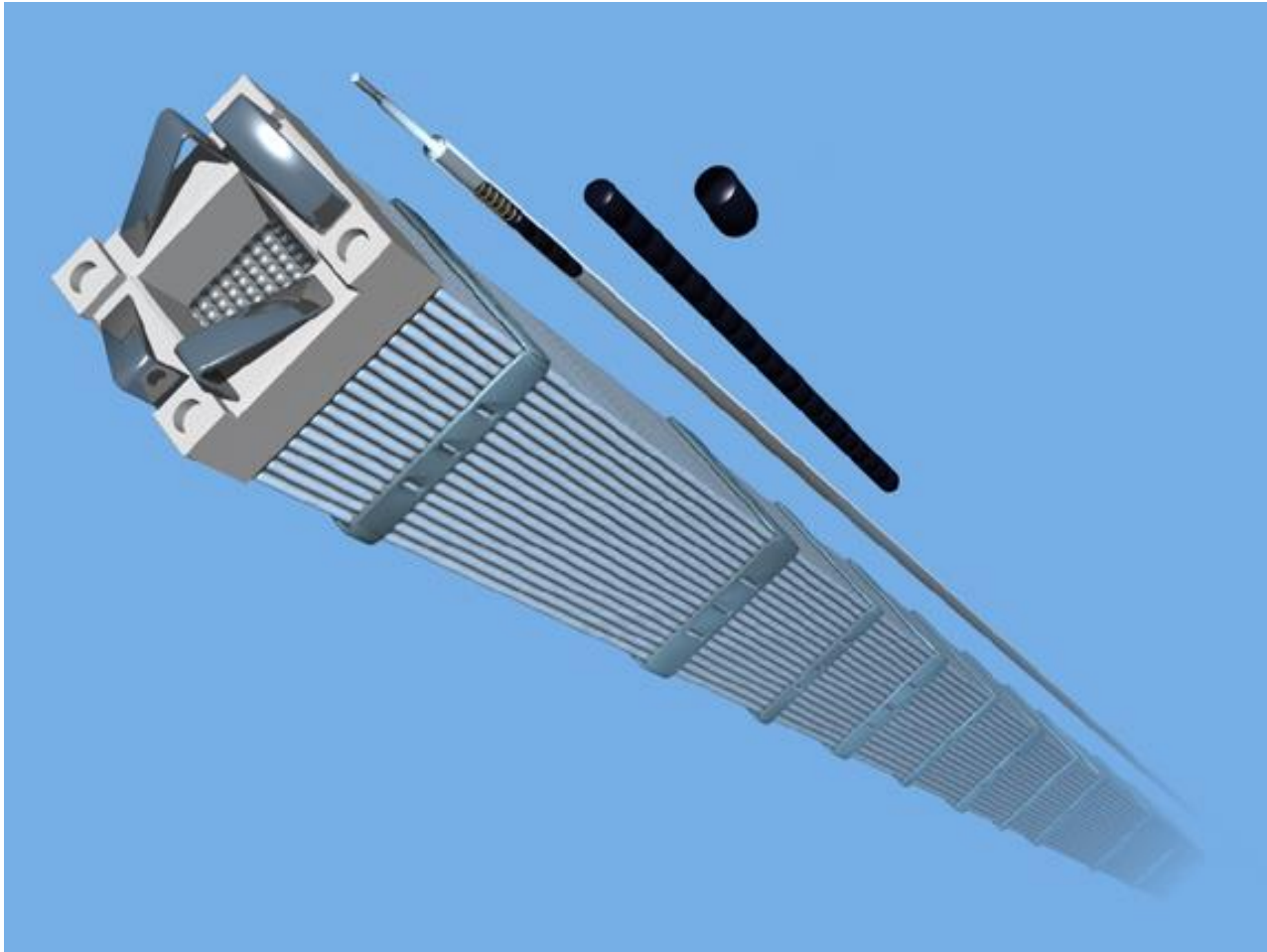
Enriched UF_6 gas converted to uranium oxide (UO_2) solid



Uranium Oxide Ceramic Fuel Pellets



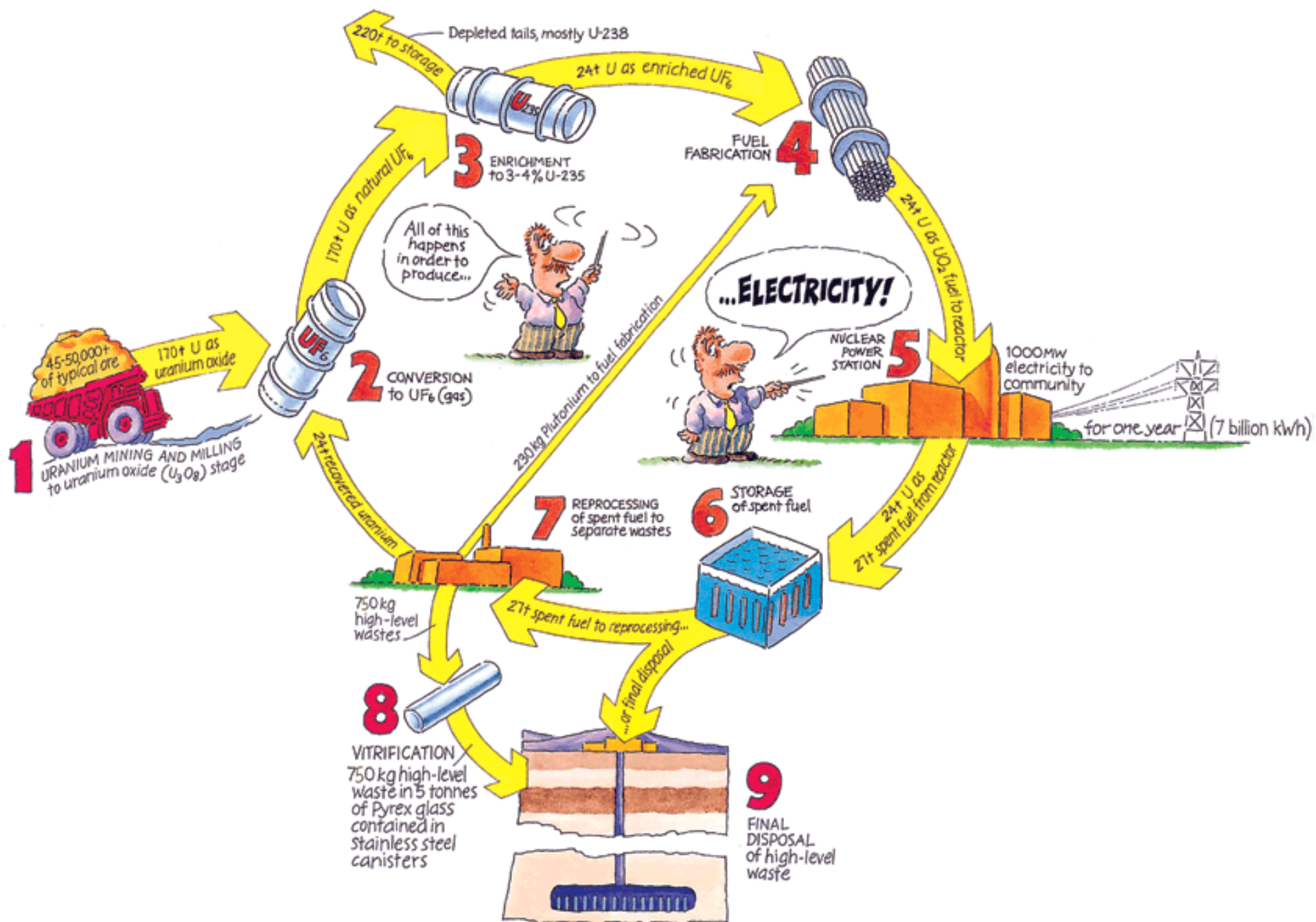
Fuel rods filled with **ceramic pellets** are grouped into **fuel assemblies**



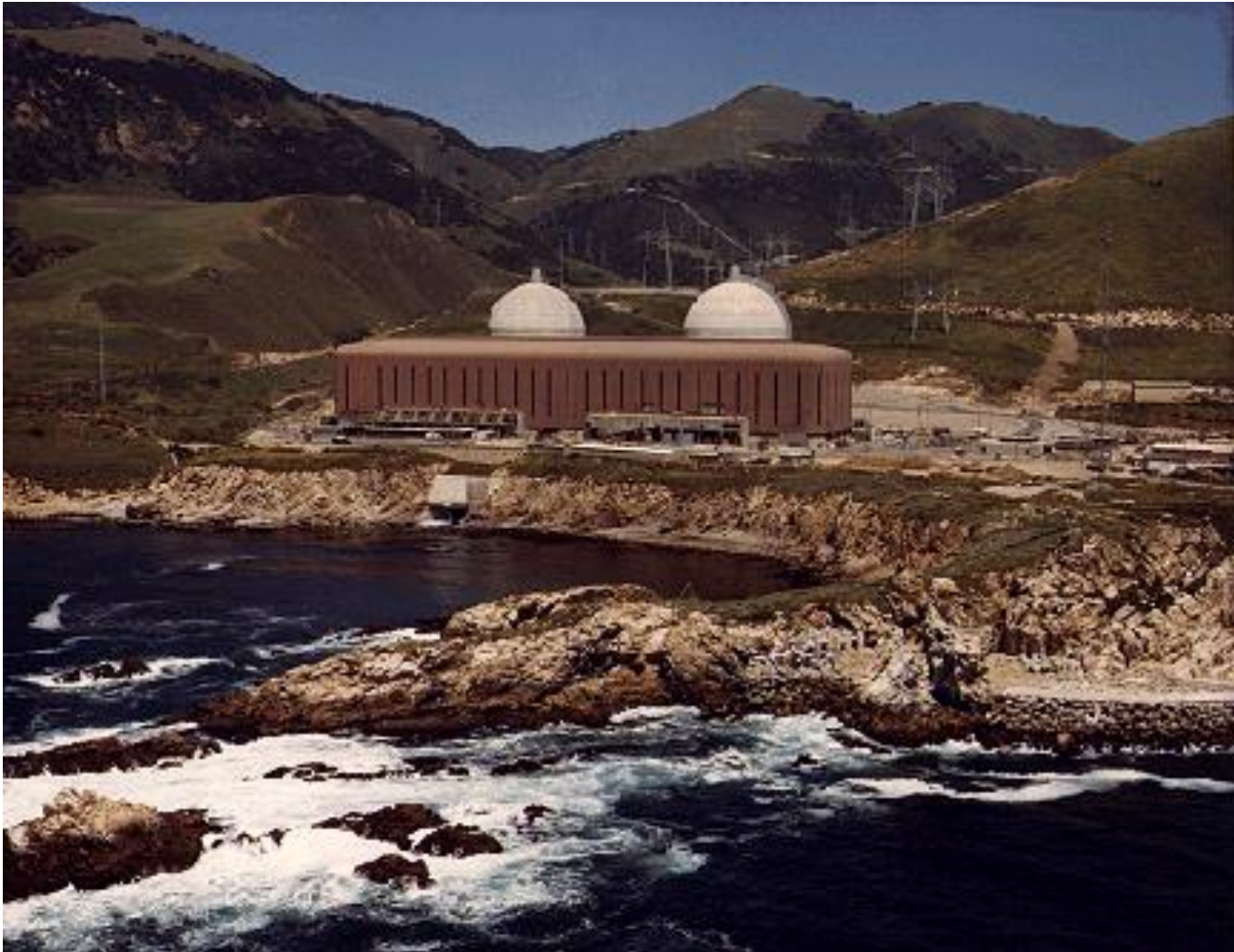
Fuel Fabrication



A pressurized water reactor fuel assembly



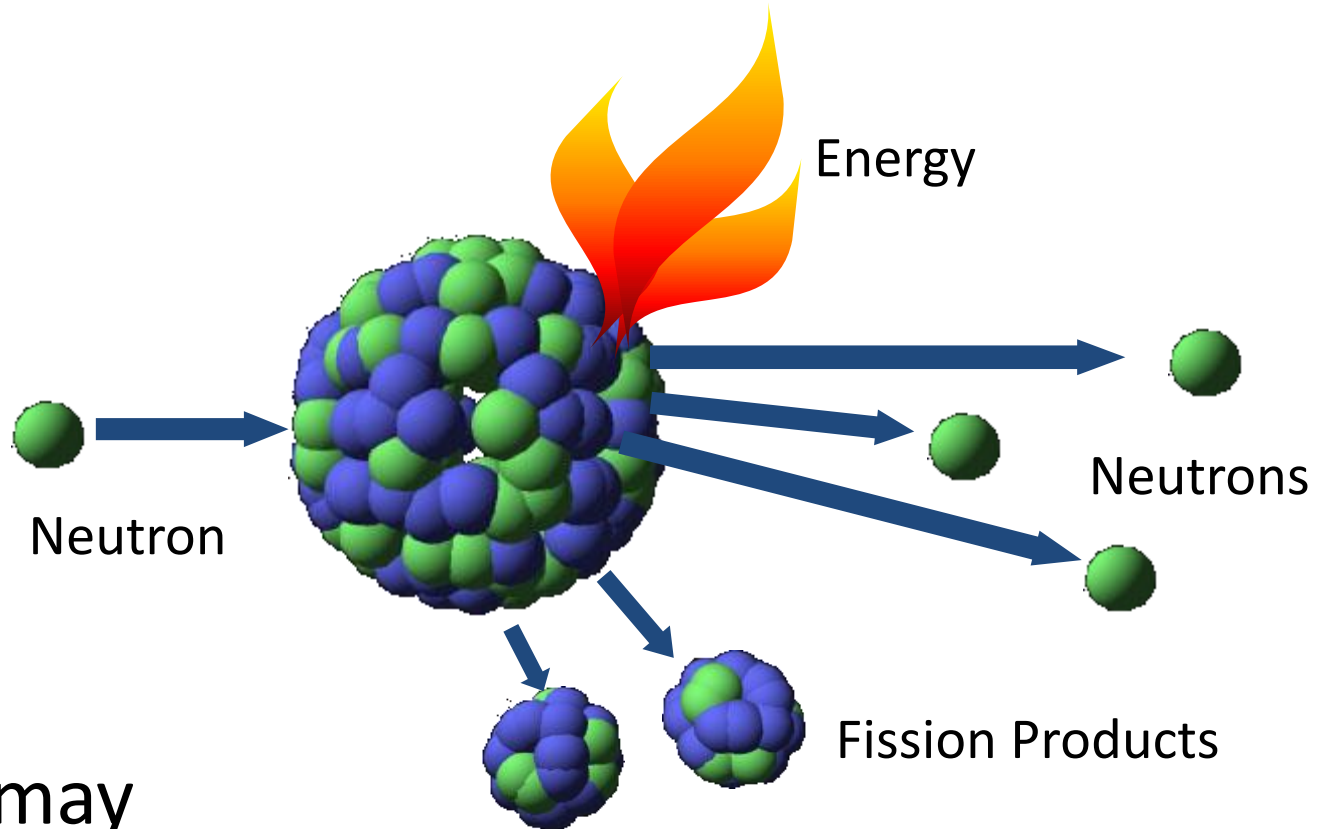
Reactors



Diablo Canyon nuclear power plant in the U.S.



In the reactor, ^{235}U fissions to produce . . .

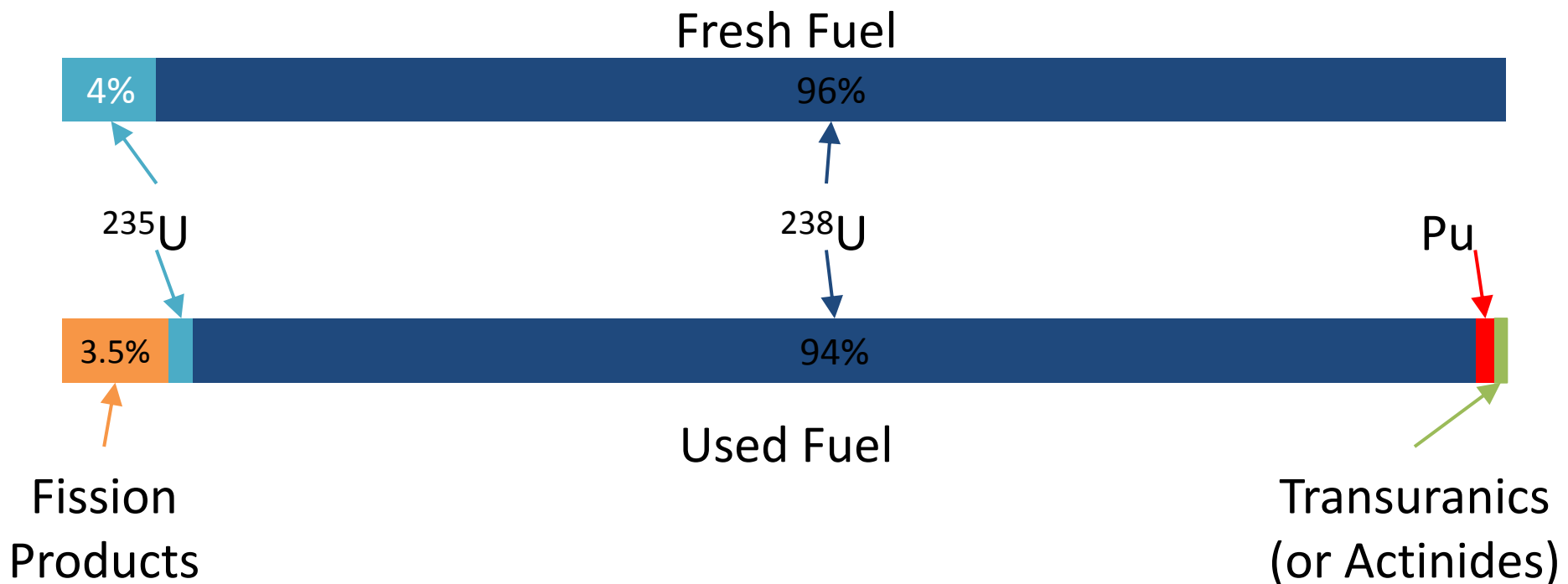


Neutrons may

- Cause new fissions to occur
- Be absorbed to form unstable, radioactive nuclide

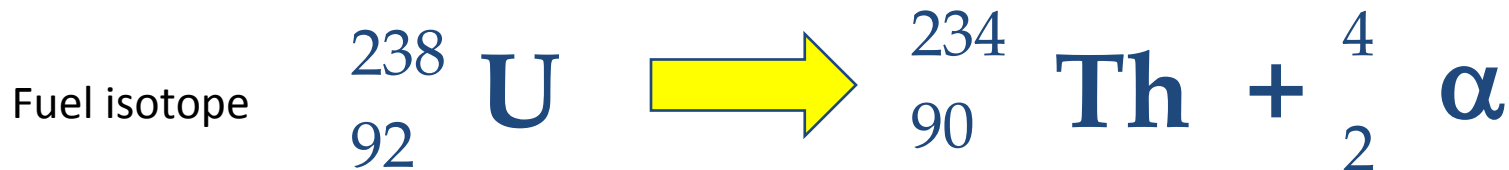
Fuel Consumption in the Reactor

- Fuel is in reactor for 4 – 6 years
- U consumed, fission products and transuranics (mostly Pu) produced



Radioactive Decay Equations

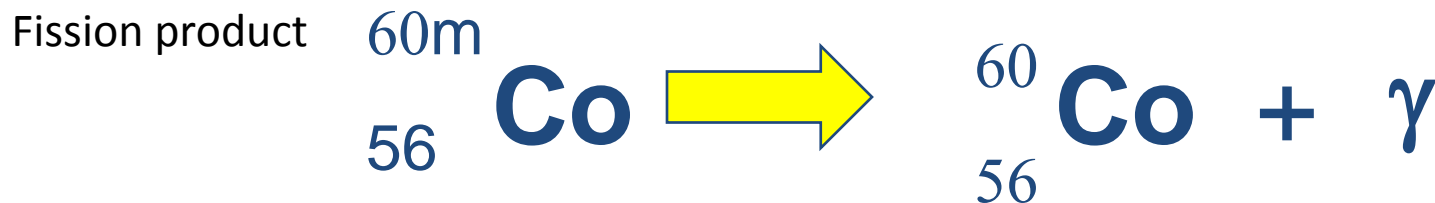
Alpha Decay



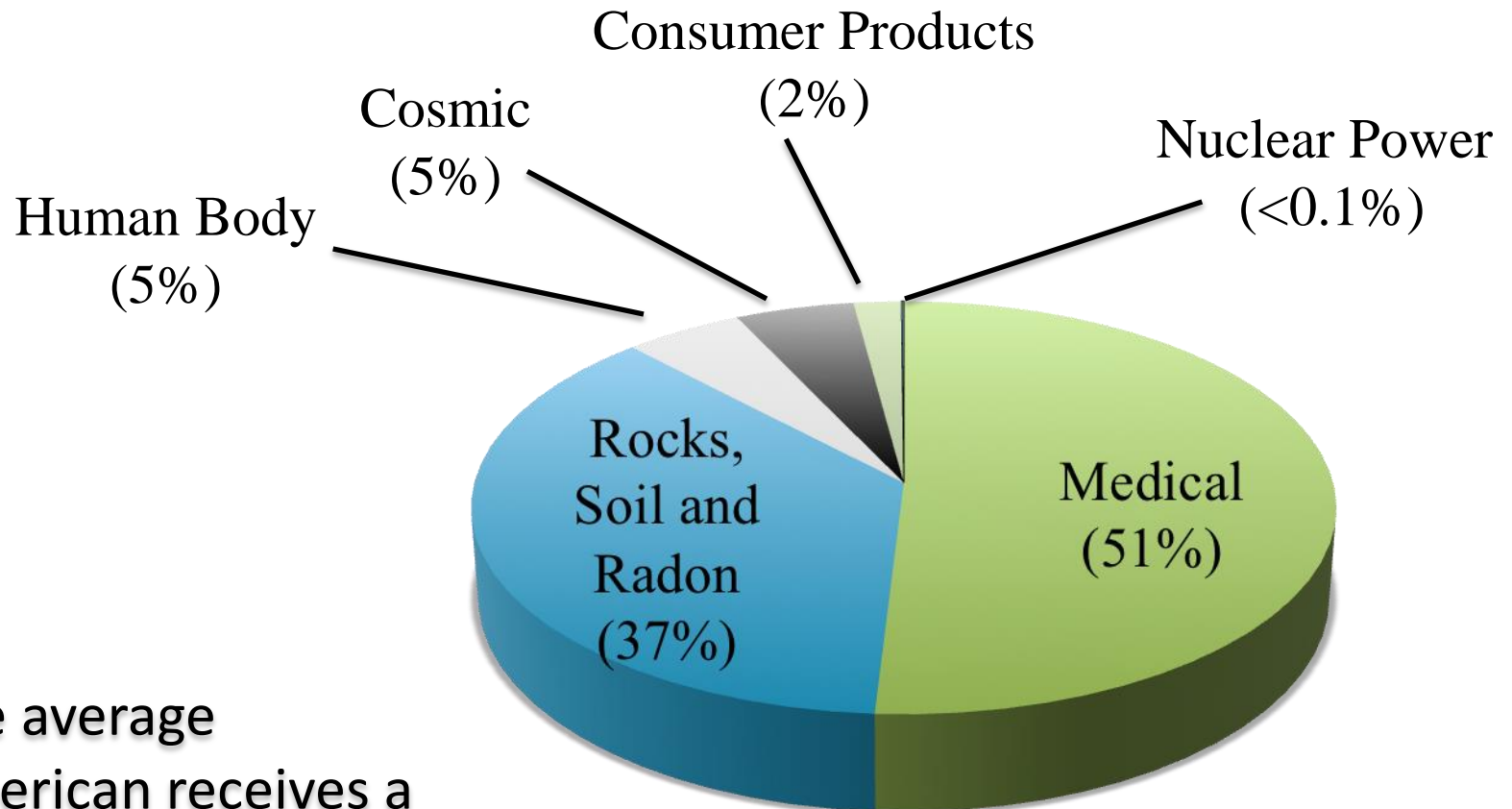
Beta Decay



Gamma Decay



Sources of radiation



The average American receives a radiation dose of 620 millirem per year.

Units of Dose and Exposure

- **Roentgen (R)** - unit of exposure - ionization of air by x or gamma rays
- **RAD (Radiation Absorbed Dose)** - energy deposited in material (Gray (Gy) is international unit)
- **rem** - (Roentgen Equivalent Man)
 - unit of dose equivalent
 - Sievert (Sv) is international unit

Units of Radioactivity

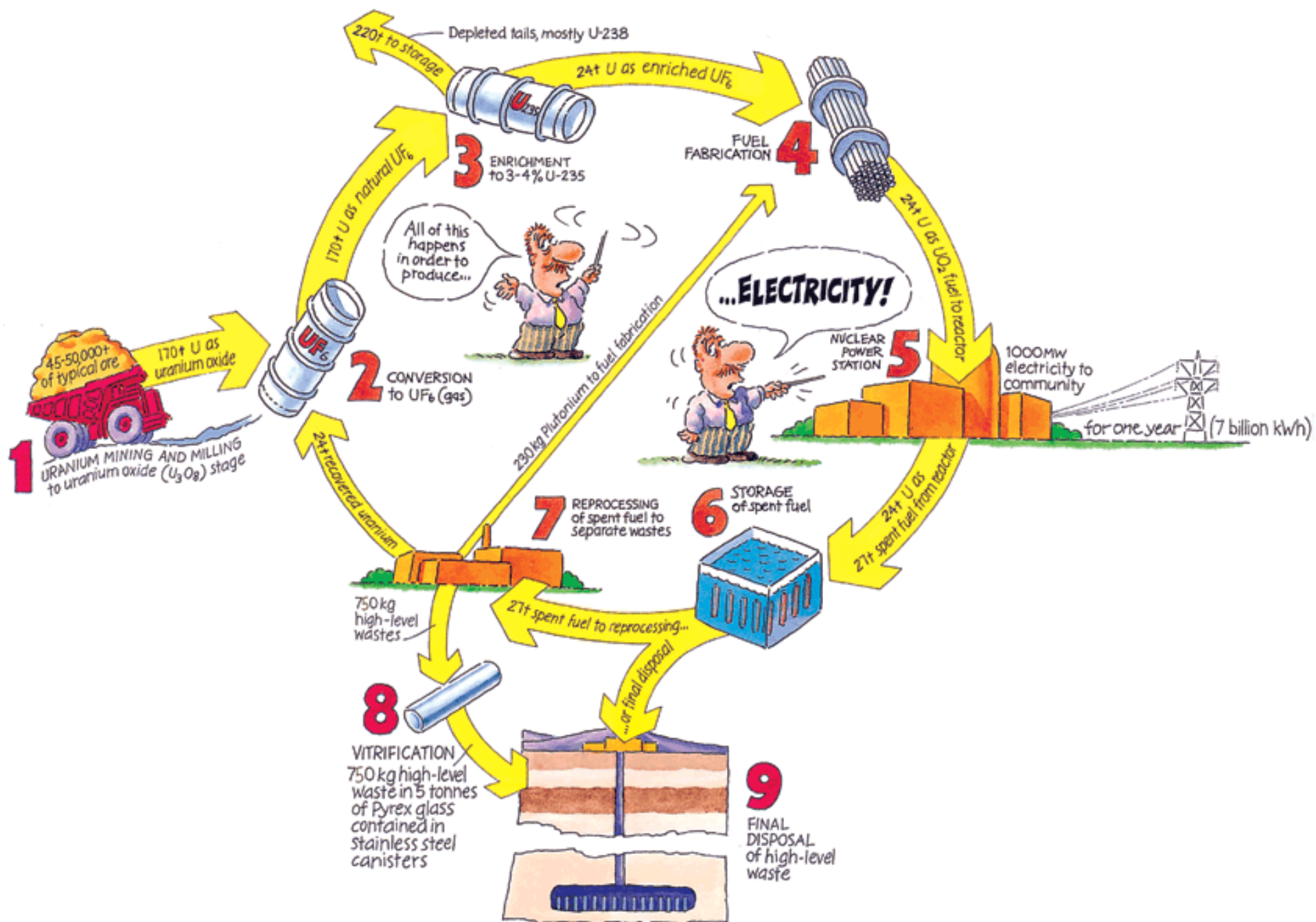
Activity - a rate; the number of emissions (of radiation) per unit time.

dps - disintegrations per second

Bequerel = 1 dps

Curie = 37,000,000,000 dps

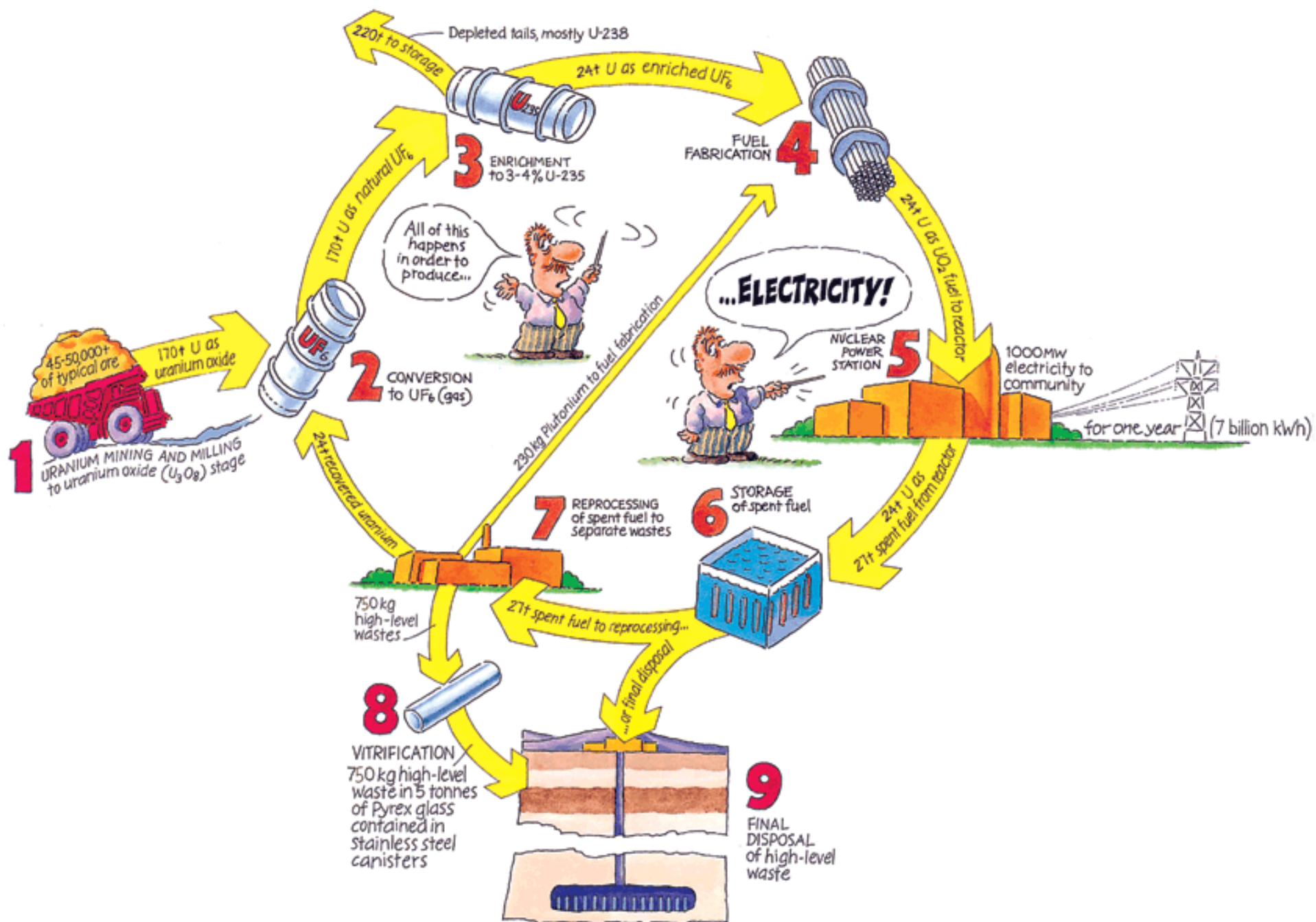
Picocurie = 0.037 dps or 2.2 dpm



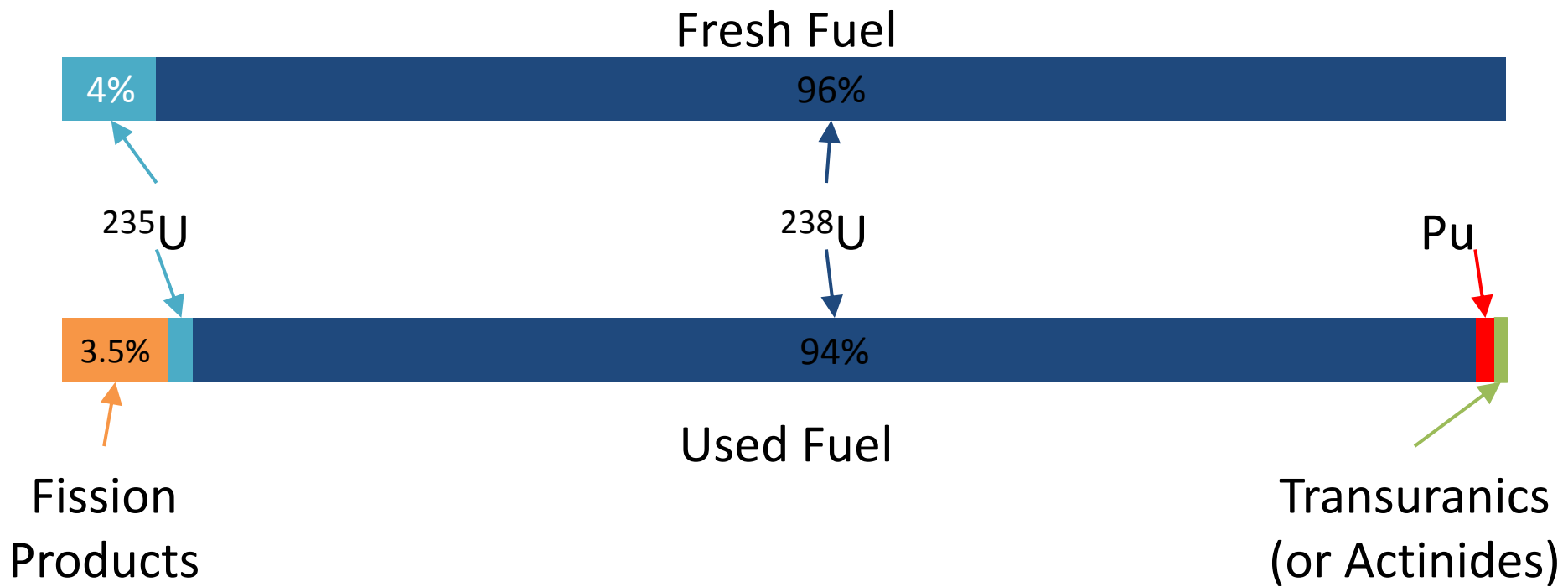


- Used fuel first stored in pool at least 5 years
 - Cooling and shielding
- Older fuel can move to dry casks
 - Air cools
 - Steel and concrete shields

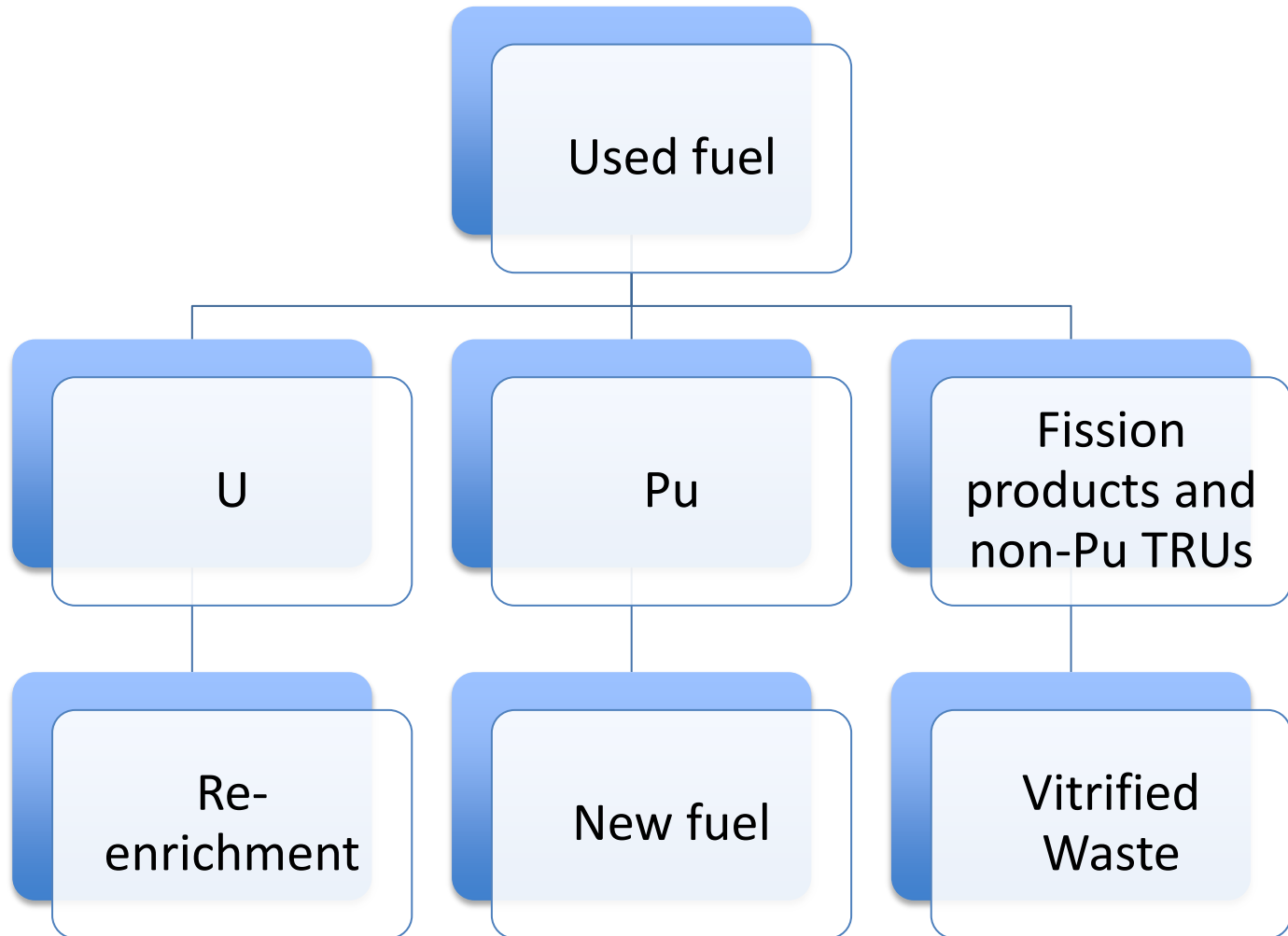


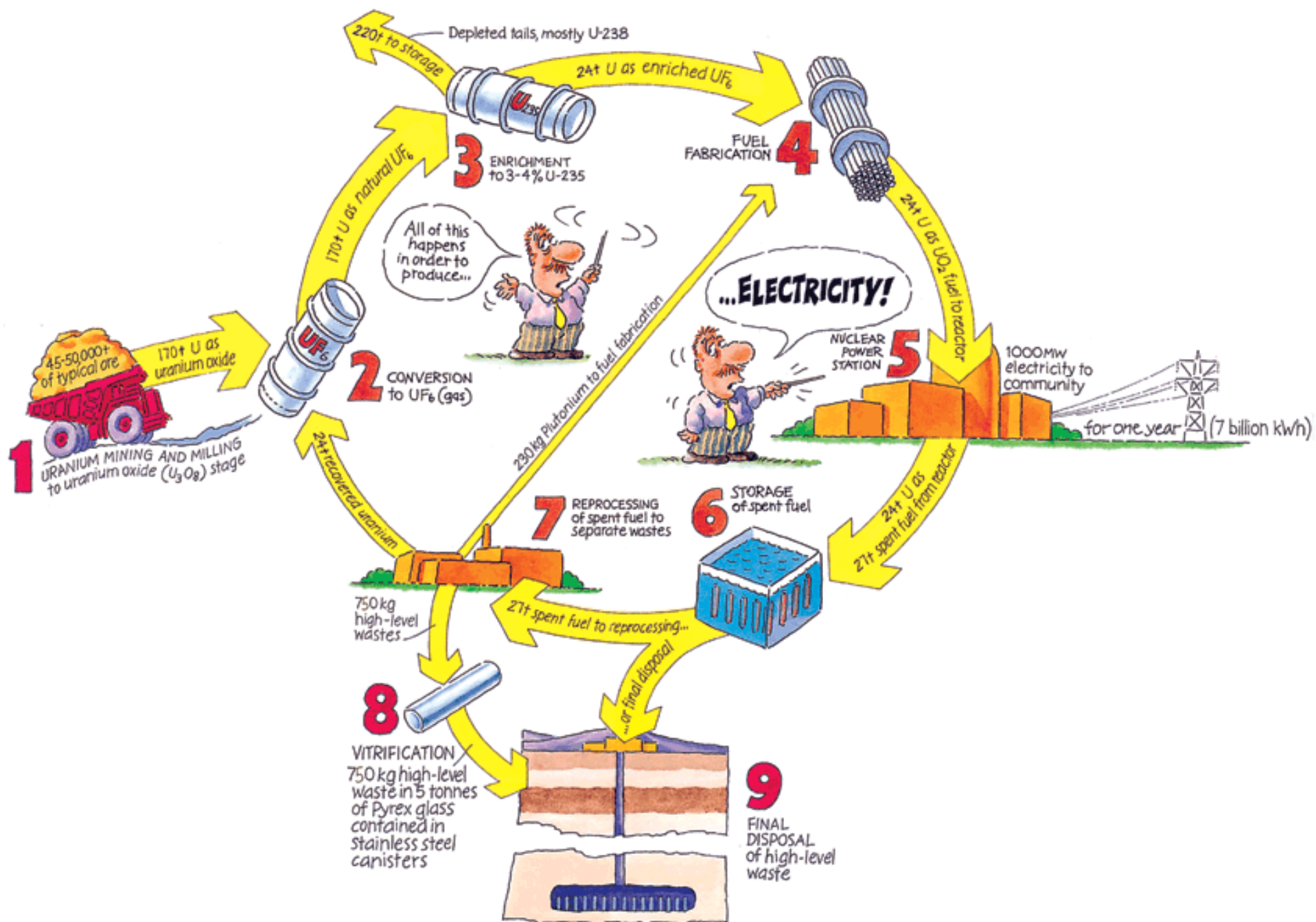


Fuel cycle/reprocessing



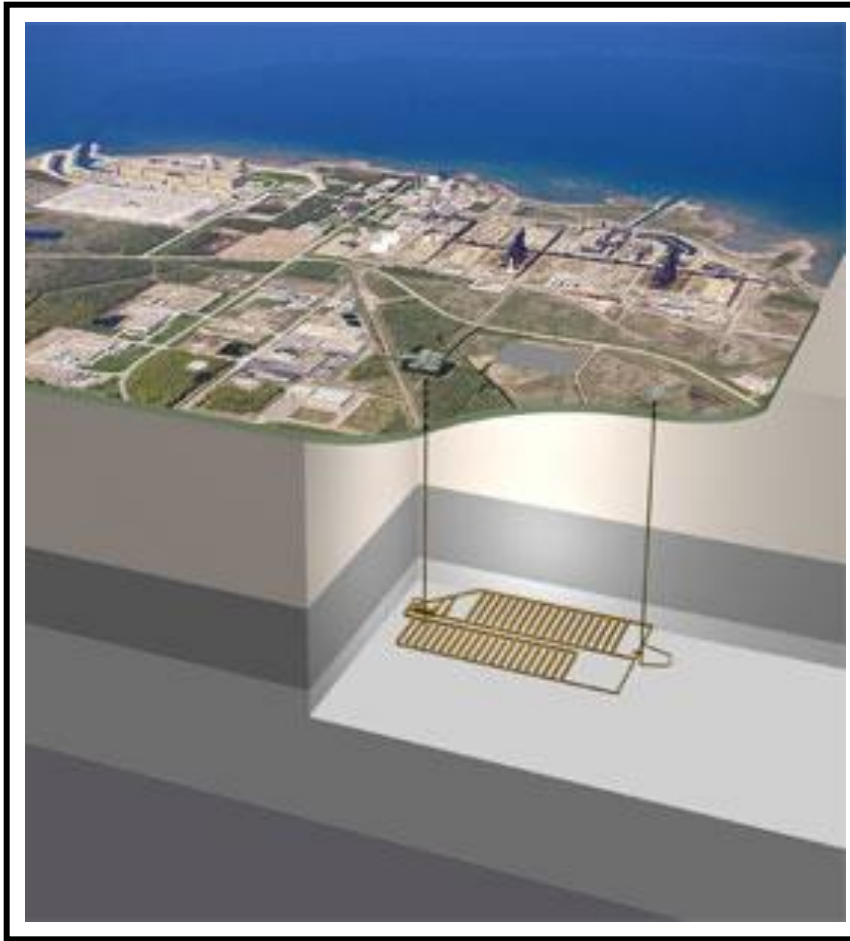
Fuel recycle/reprocessing





Geologic Repository

- The choice of countries worldwide
- U.S. has studied Yucca Mt., Nevada as potential location



The End . . .

