ANS STEM ACADEMY | EDUCATOR TRAINING

What About the Waste? Managing the Nuclear Fuel Cycle

Thursday, January 26
6:00 – 7:00 pm EST

What about the waste? Managing the nuclear fuel cycle

Mary Lou Dunzik-Gougar, Ph.D.
Idaho State University
Idaho National Laboratory

ANS STEM Academy

EDUCATOR TRAINING

Questions about the nuclear fuel “cycle” and radioactive waste. . .

What is it?

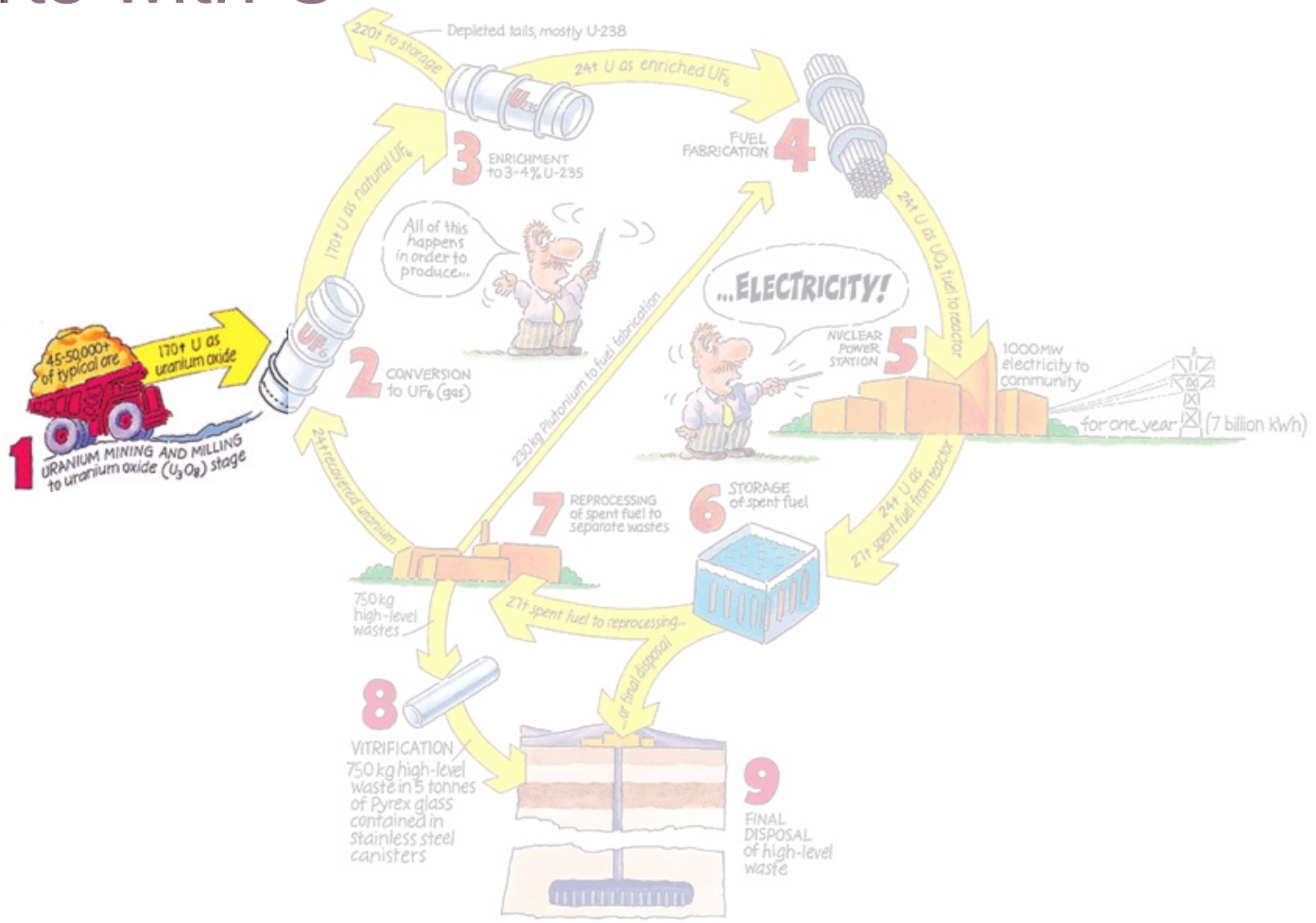
Where does it come from?

Can we handle it safely?

Radioactive waste

Where is it?

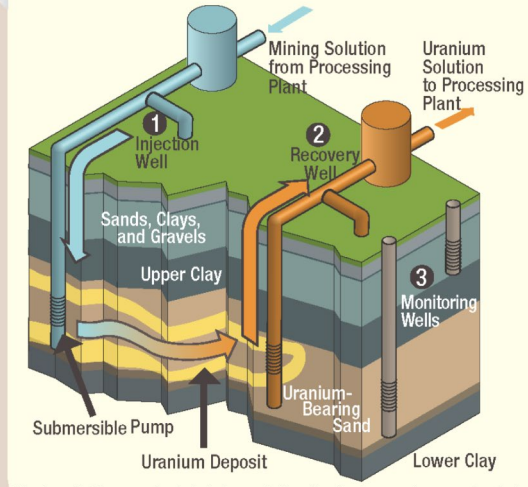
It starts with U



Uranium mining—open pit

Uranium mining—in situ

Figure 37. The In Situ Uranium Recovery Process

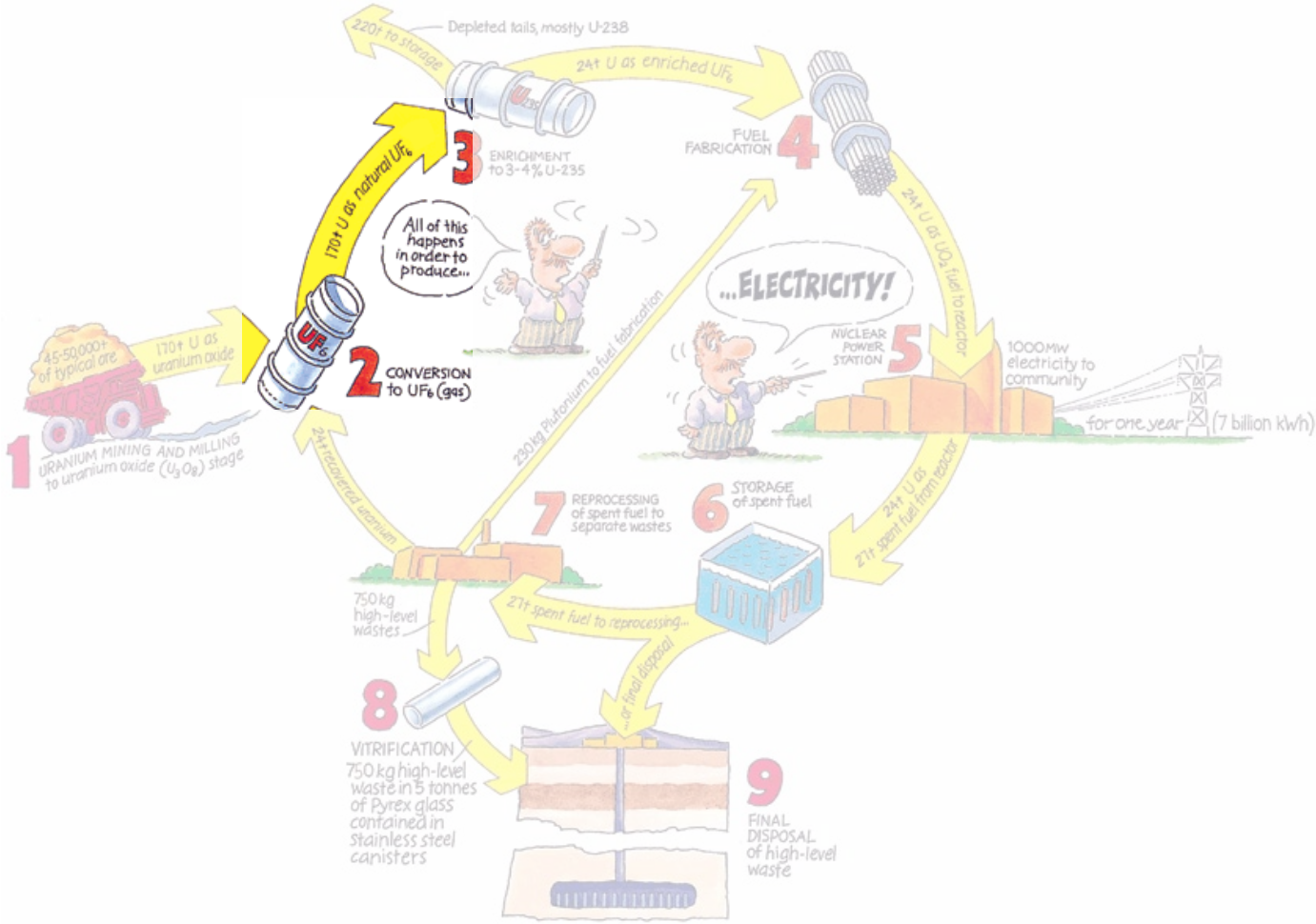


Injection wells (1) pump a chemical solution—typically groundwater mixed with sodium bicarbonate, hydrogen peroxide, and oxygen—into the layer of earth containing uranium ore. The solution dissolves the uranium from the deposit in the ground and is then pumped back to the surface through recovery wells (2) and sent to the processing plant to be processed into uranium yellowcake. Monitoring wells (3) are checked regularly to ensure that uranium and chemicals are not escaping from the drilling area.

Uranium milling

1. Ore is crushed
2. Uranium is separated
3. U_3O_8 “yellow cake” produced

Step 2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220t to storage
24t U as enriched UF6
170t U as natural UF6
3 ENRICHMENT to 3-4% U-235
FUEL FABRICATION 4
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...ELECTRICITY!
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1000MW electricity to community
for one year (7 billion kWh)
24t U as UO2 fuel to reactor
45-50,000t of typical ore
170t U as uranium oxide
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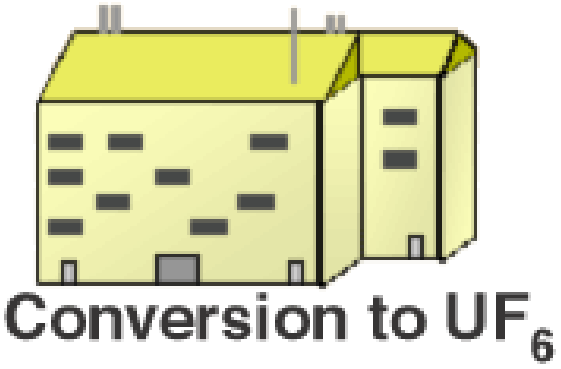
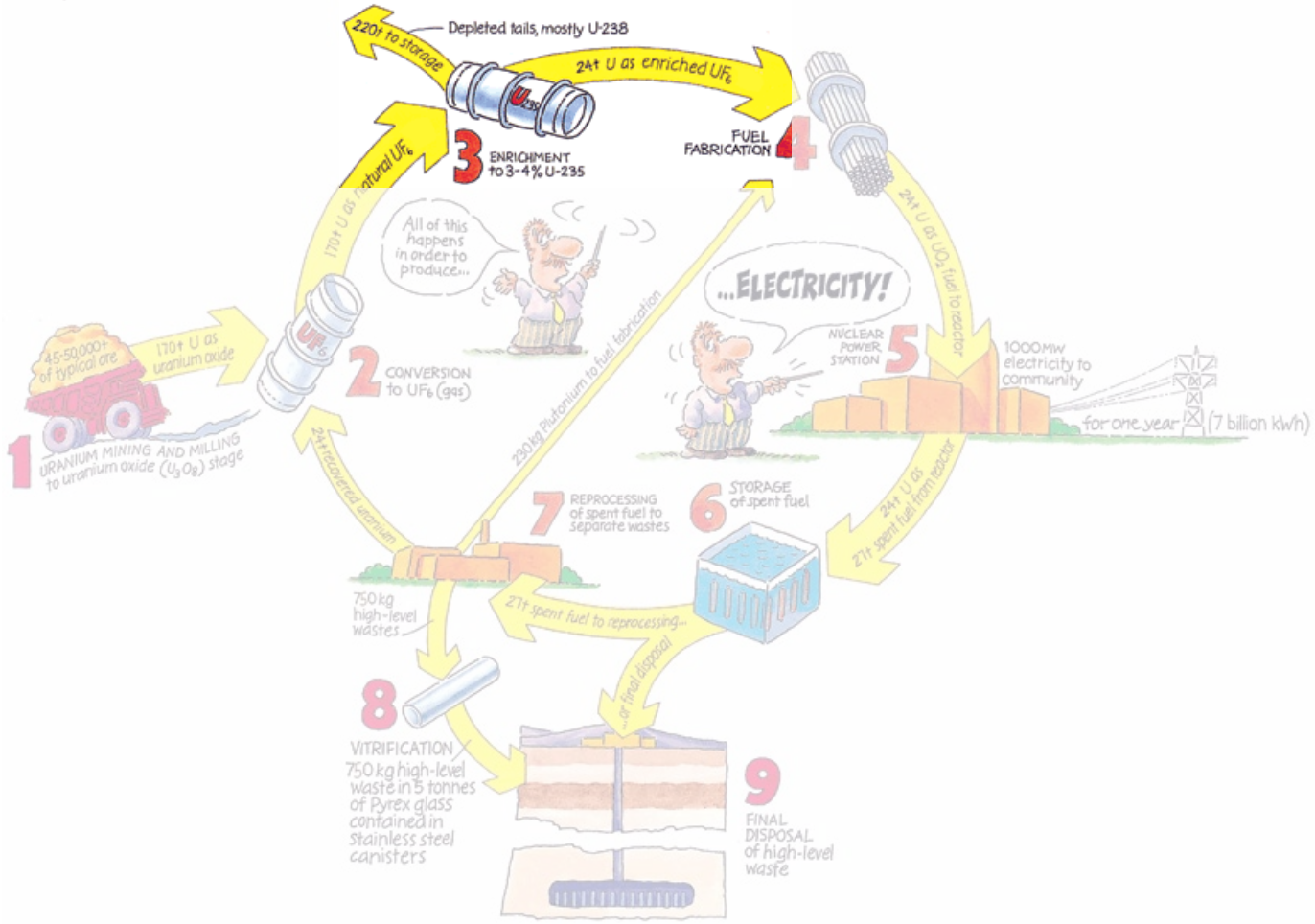
Uranium conversion (to UF_6 gas)

- Impurities removed
- Uranium combined with fluorine



- UF_6 gas produced

Step 3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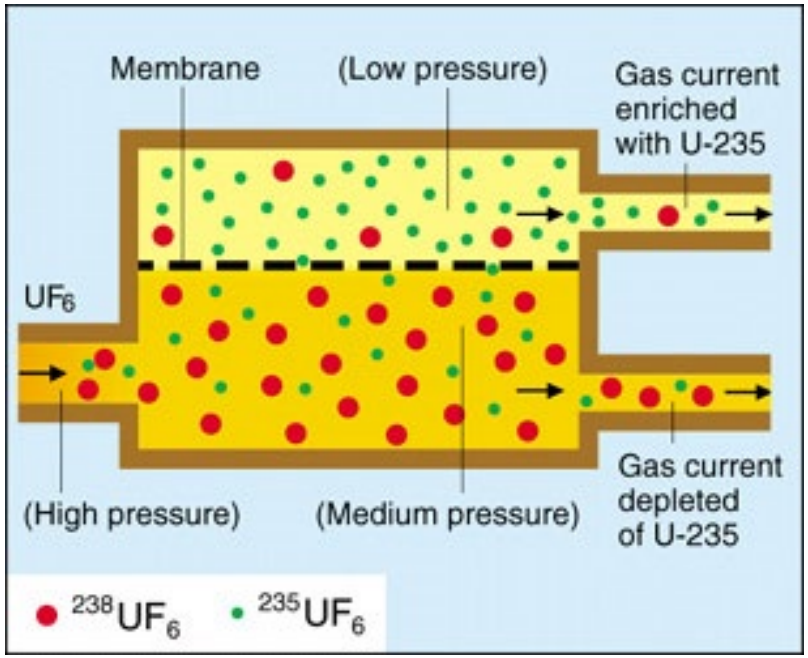
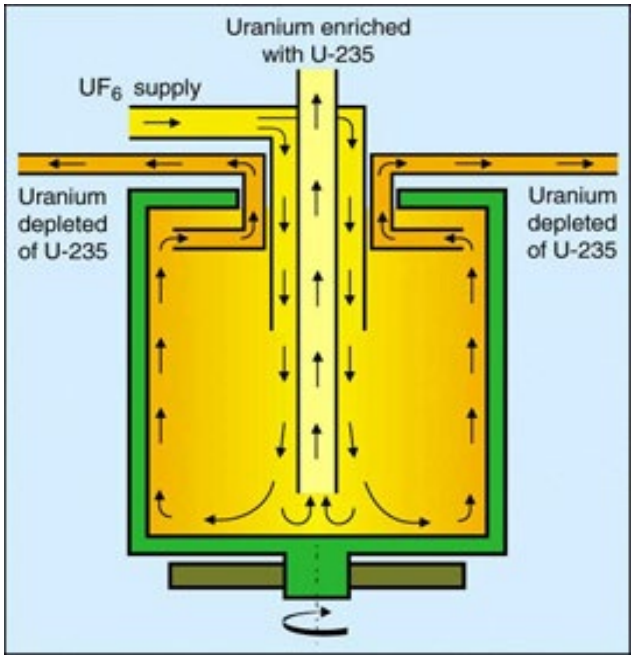
Uranium enrichment

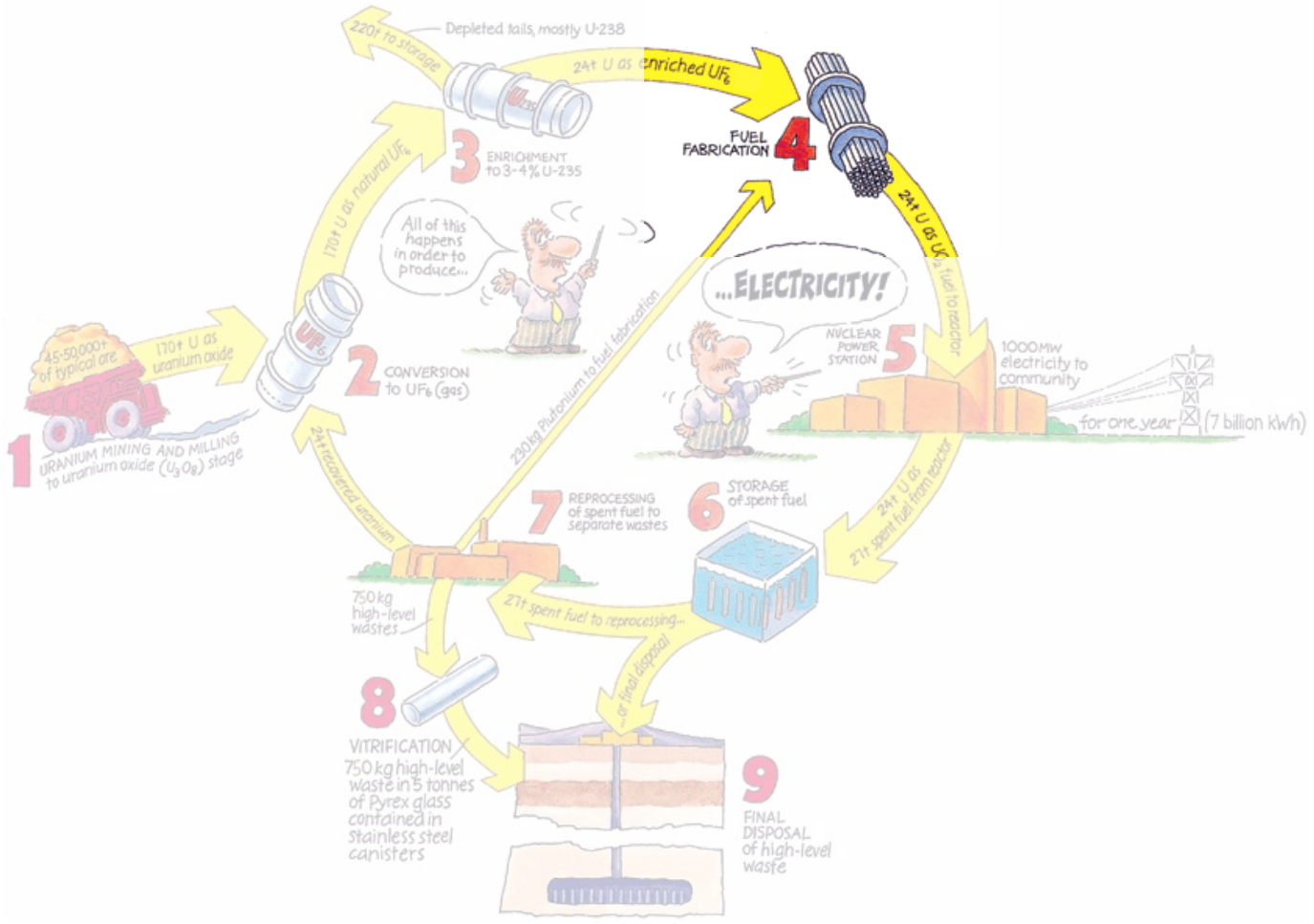
- Natural U is > 99% 238U and only ~ 0.7% 235U
- Separation of 235UF6 and 238UF6 based on (very small) mass





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

Step 4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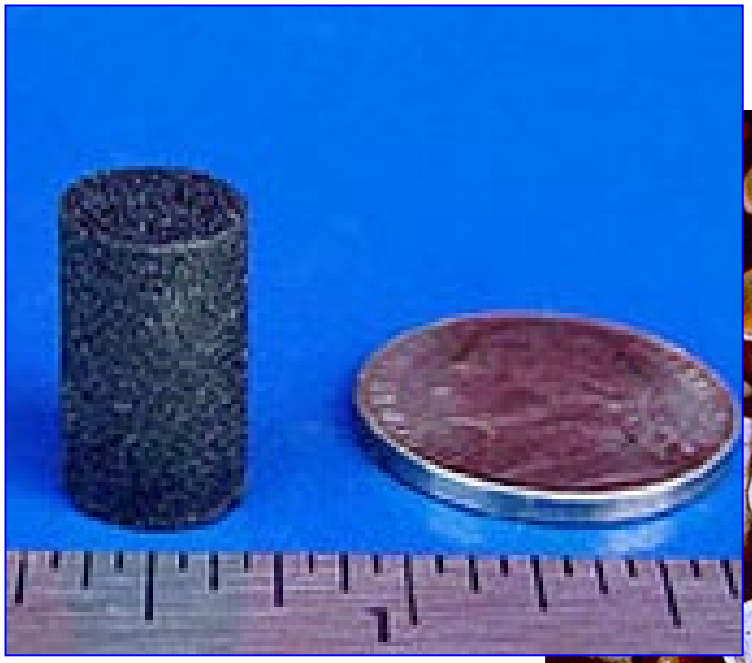
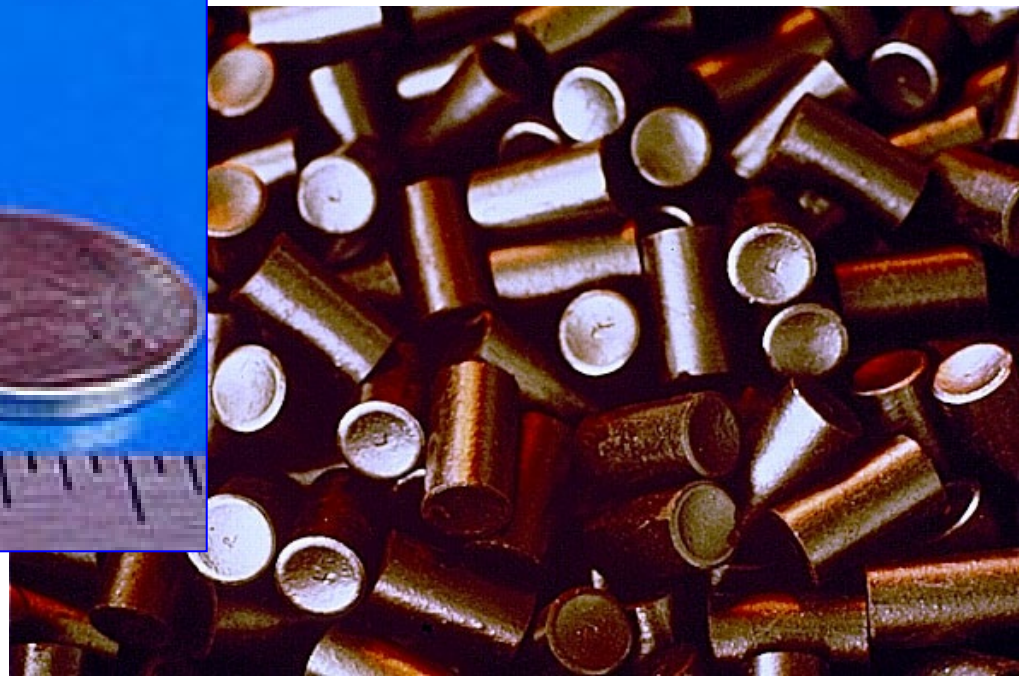
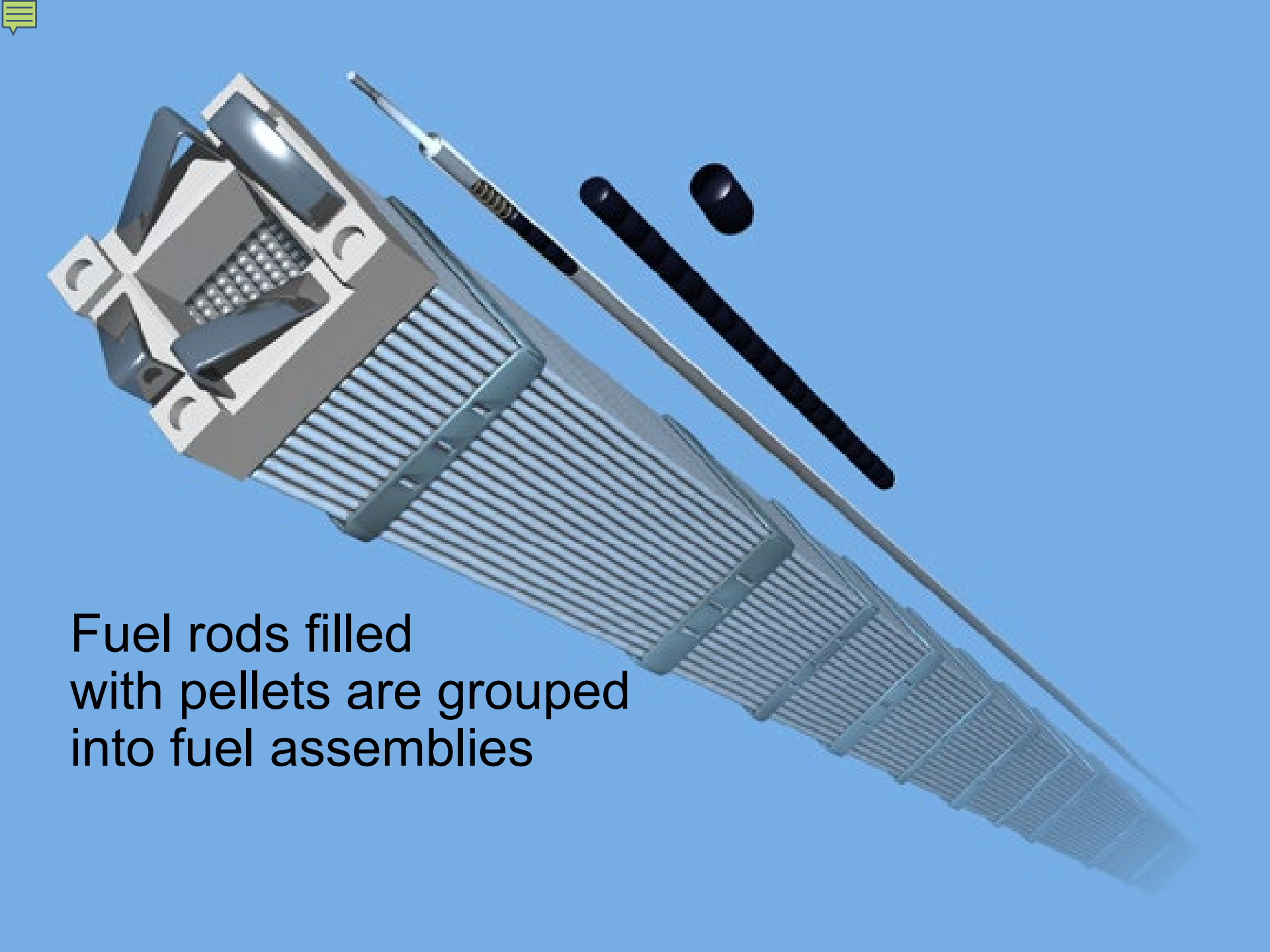
Fuel fabrication

Uranium Oxide Ceramic Fuel Pellets

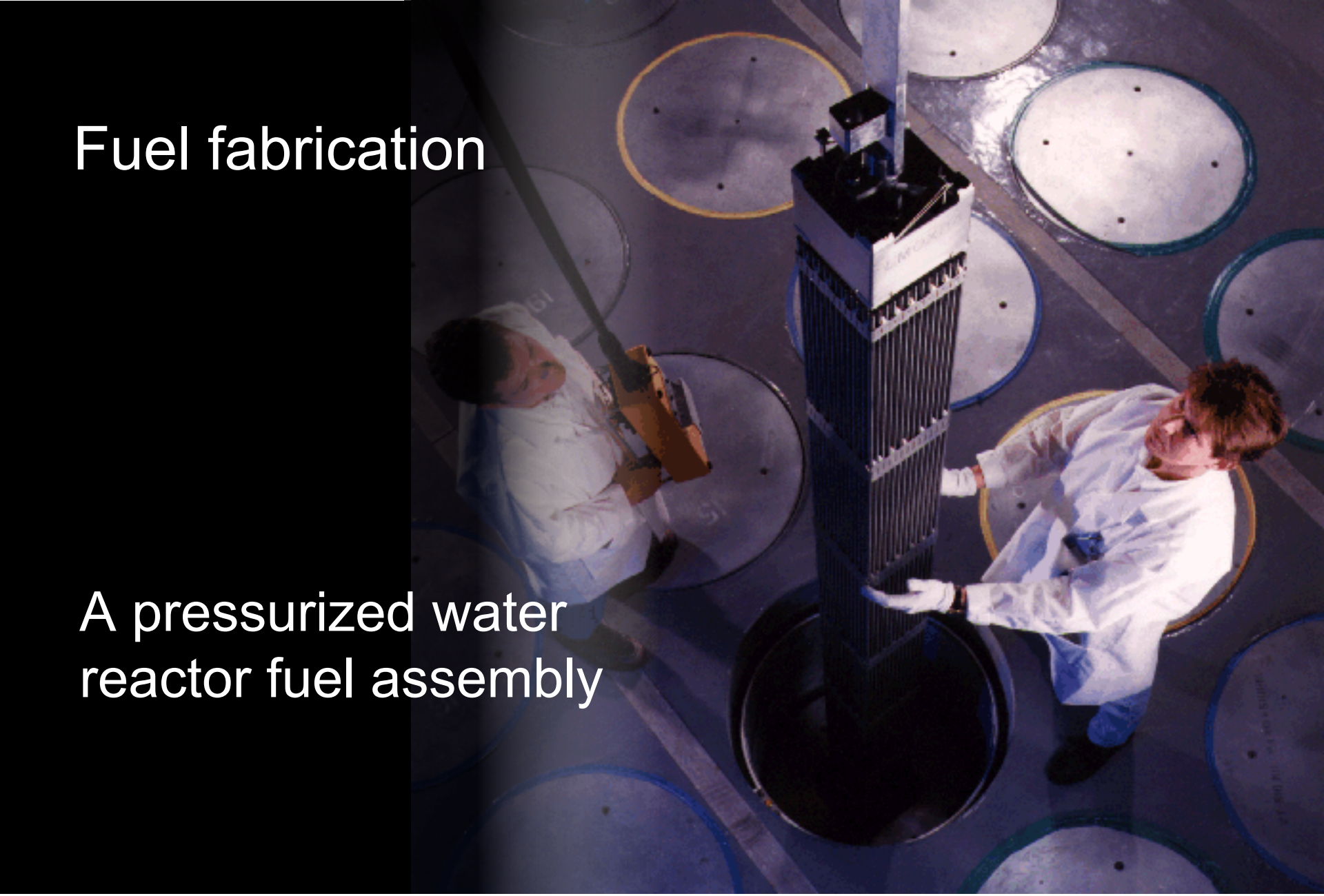






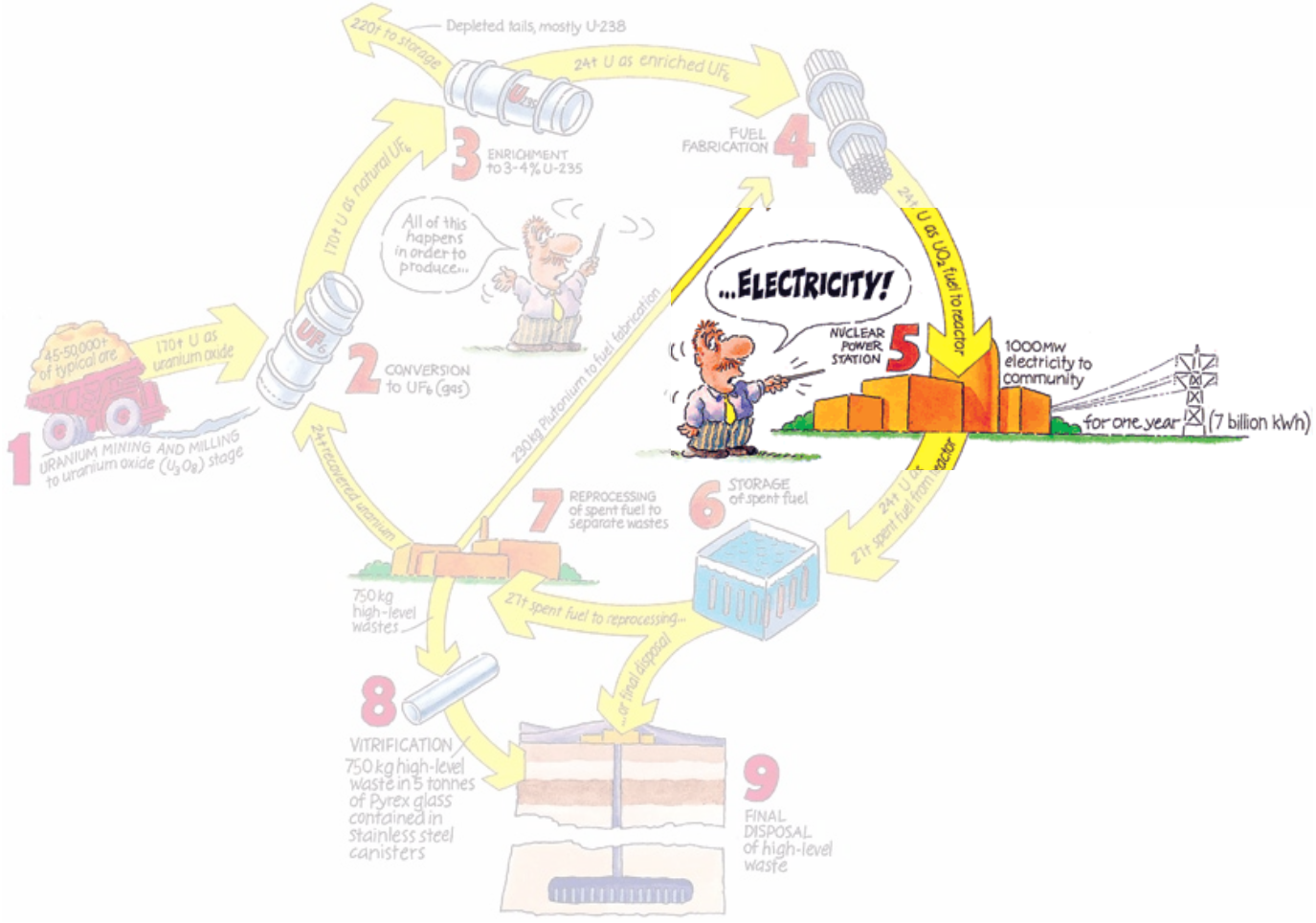
Fuel rods filled
with pellets are grouped
into fuel assemblies

Fuel fabrication



A pressurized water reactor fuel assembly

Step 5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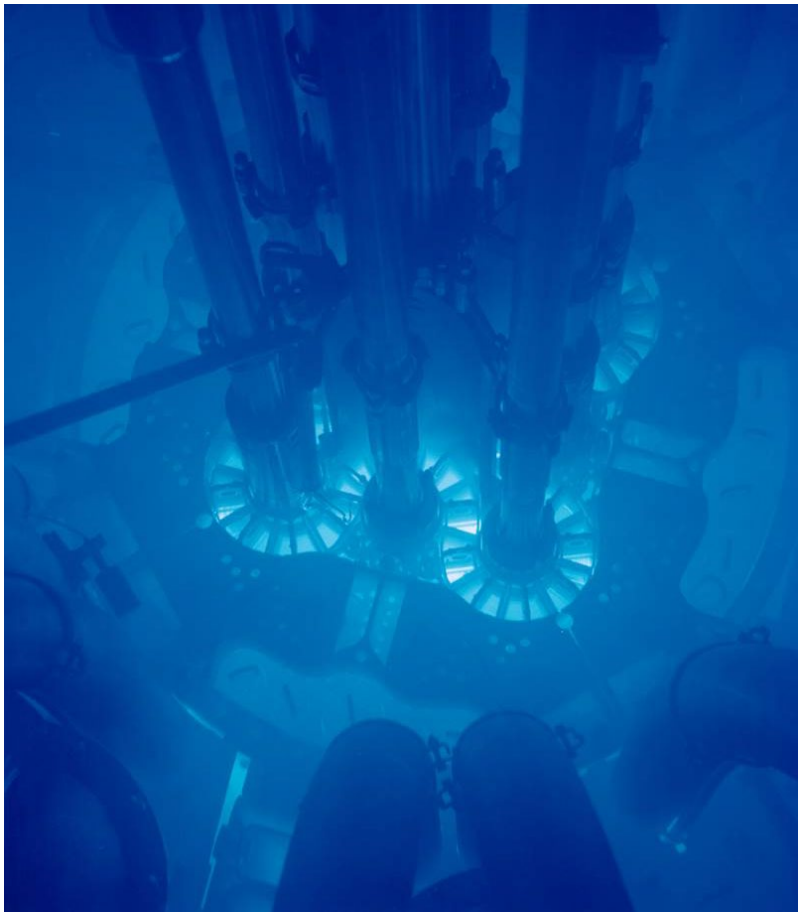
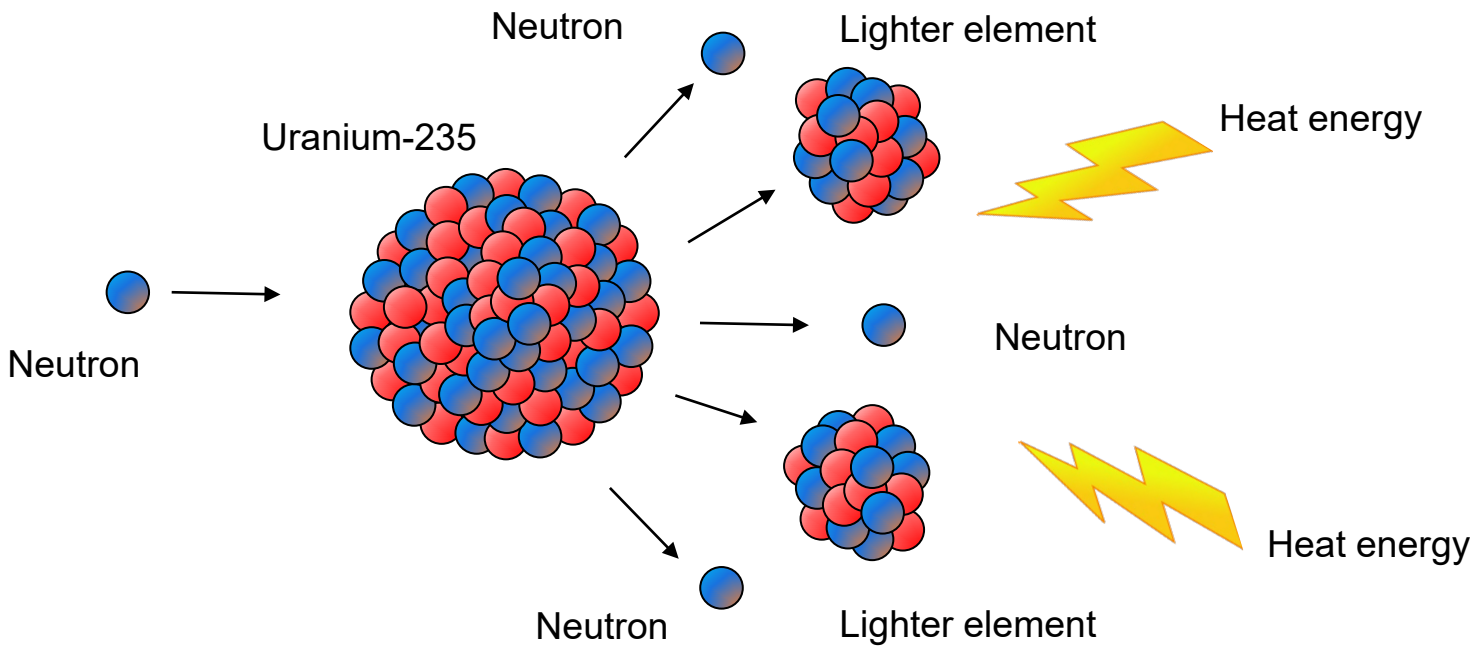
Inside the reactor



Cherenkov radiation glowing in the core of the INL Advanced Test Reactor.

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

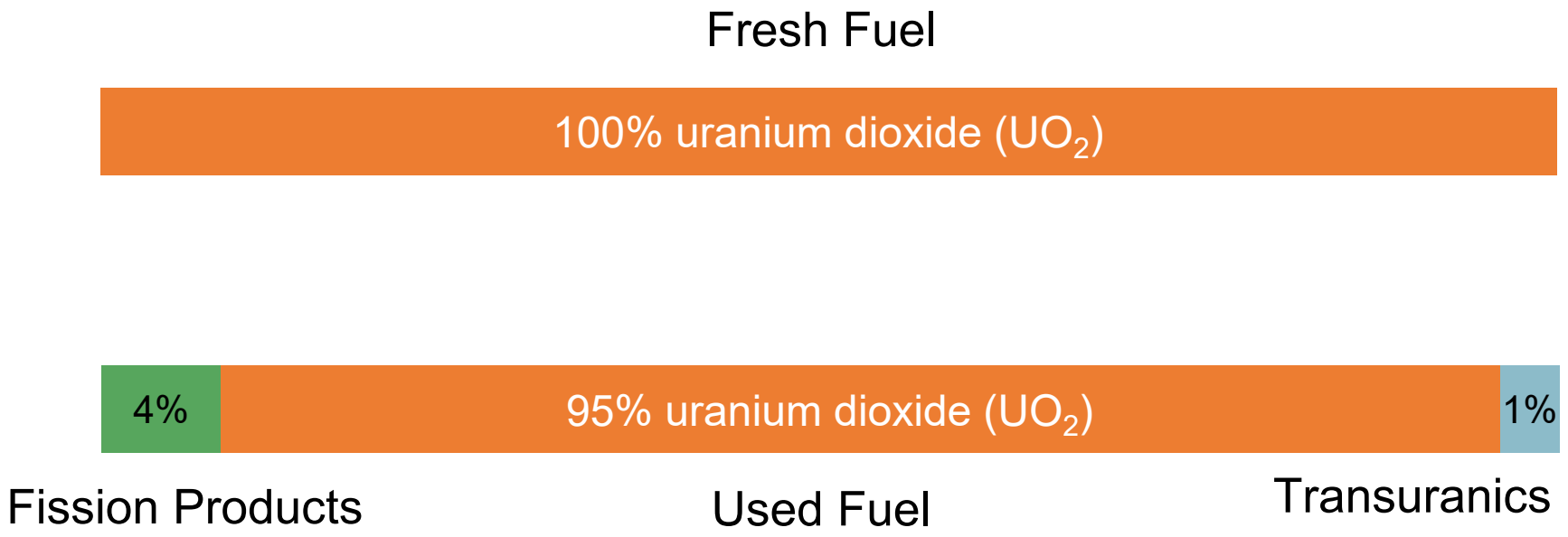


Neutrons may

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

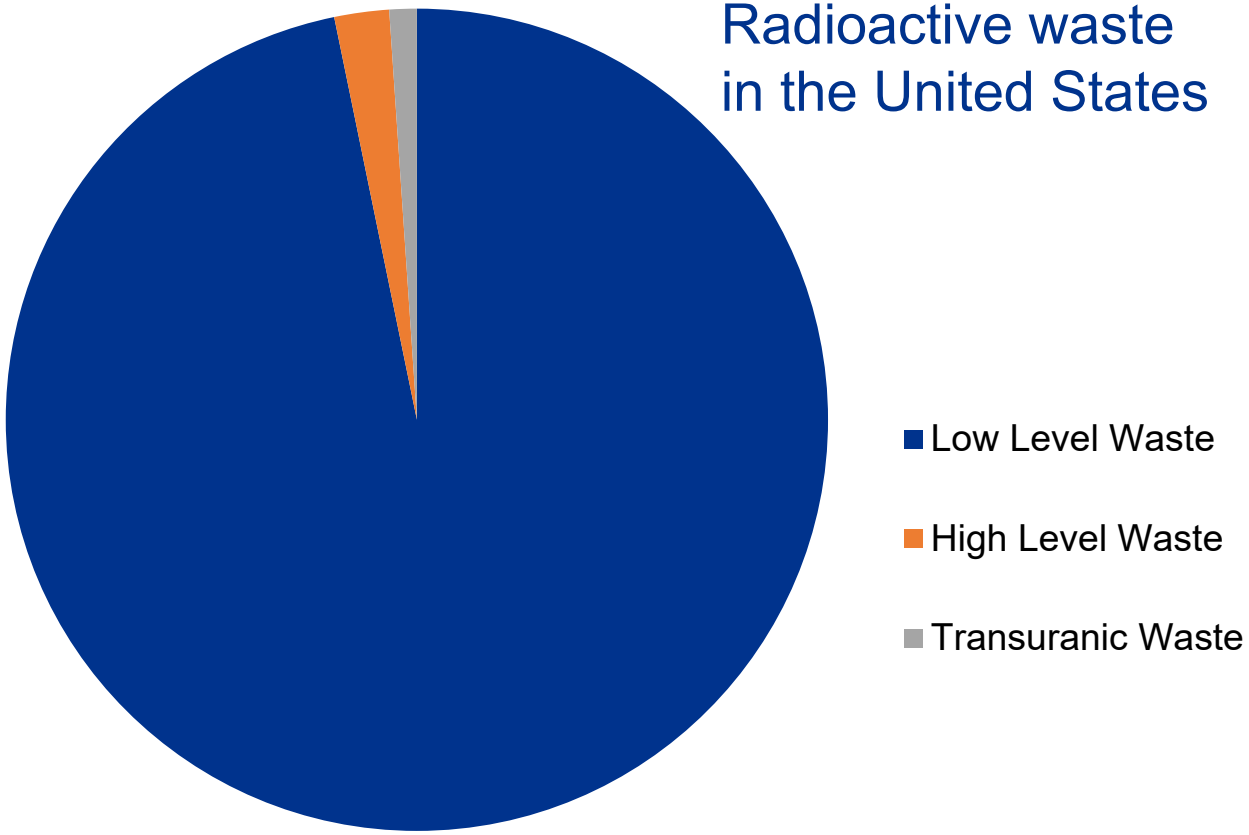
Fuel consumption in the reactor

- Fuel is in reactor for 4 – 6 years
- Uranium-235 consumed
- Fission products and transuranics produced



So, what and where is the waste?

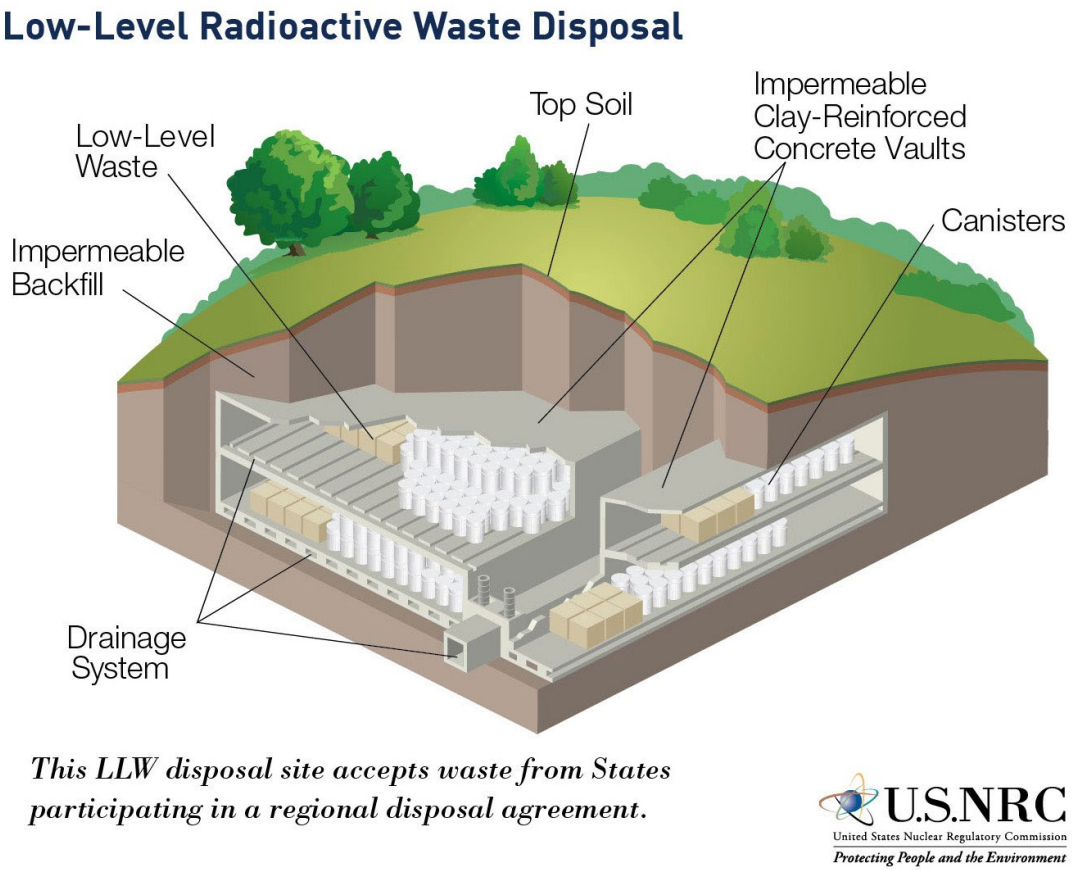
Types of radioactive waste



Low-level waste

- Largest quantity from nuclear power
- Also from medical facilities, industry, research institutions, monitoring labs

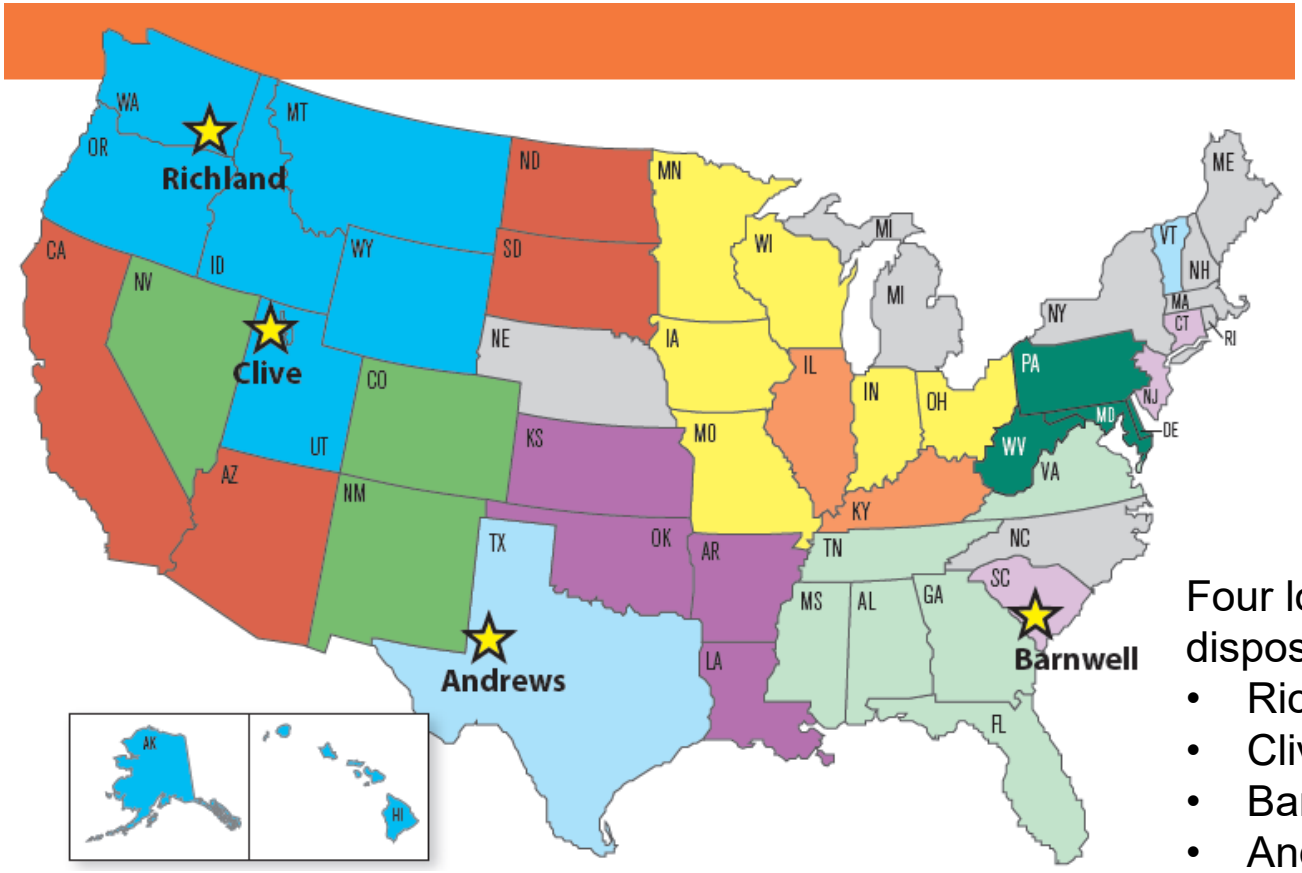
Low-level waste disposal



This LLW disposal site accepts waste from States participating in a regional disposal agreement.

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

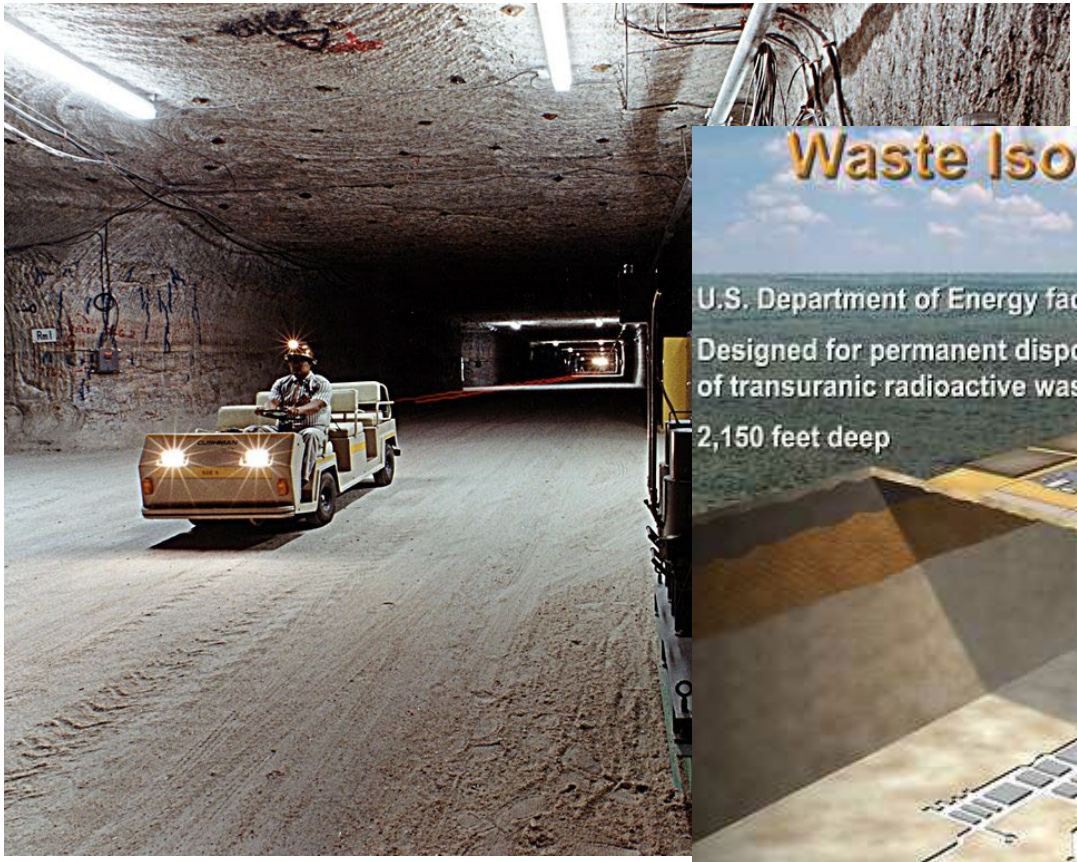
Low-level waste disposal sites

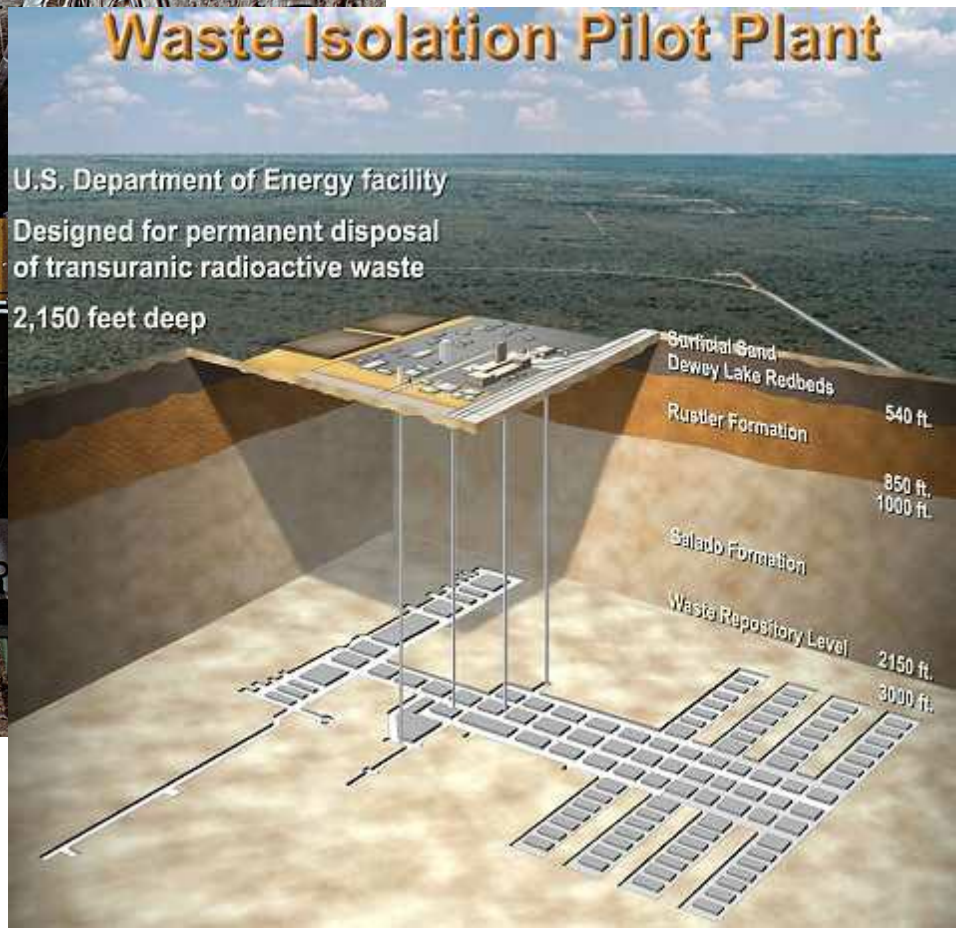


Four low-level waste disposal facilities:

- Richland, WA
- Clive, UT
- Barnwell, SC
- Andrews, TX

Transuranic waste




Waste Isolation Pilot Plant
U.S. Department of Energy facility
Designed for permanent disposal
of transuranic radioactive waste
2,150 feet deep
Surficial Sand
Dewey Lake Redbeds
Rustler Formation
540 ft.
850 ft.
1000 ft.
Salado Formation
Waste Repository Level
2150 ft.
3000 ft.

High-level “waste”

Dry cask storage

Waste packaging

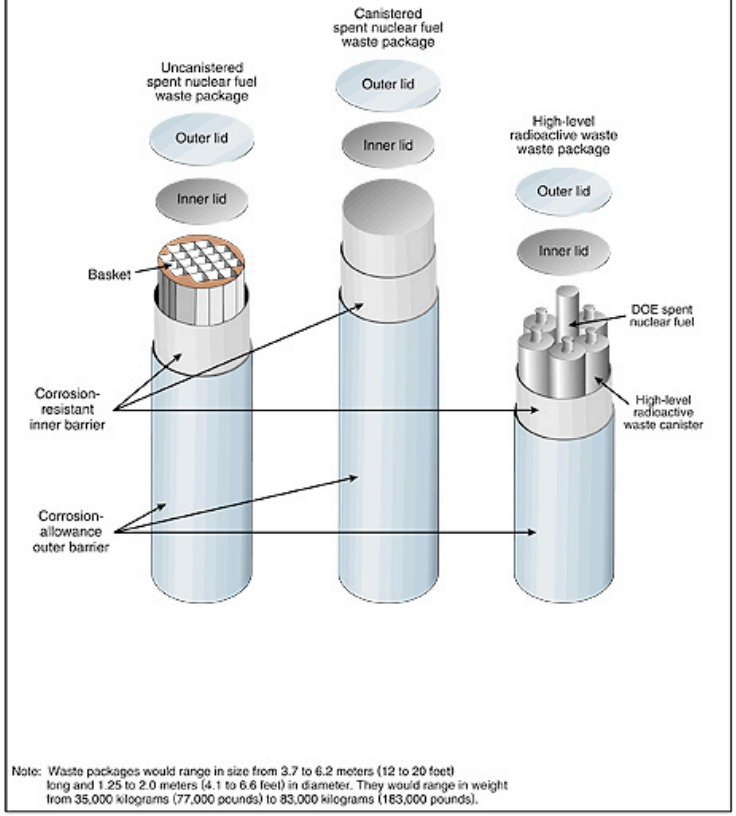
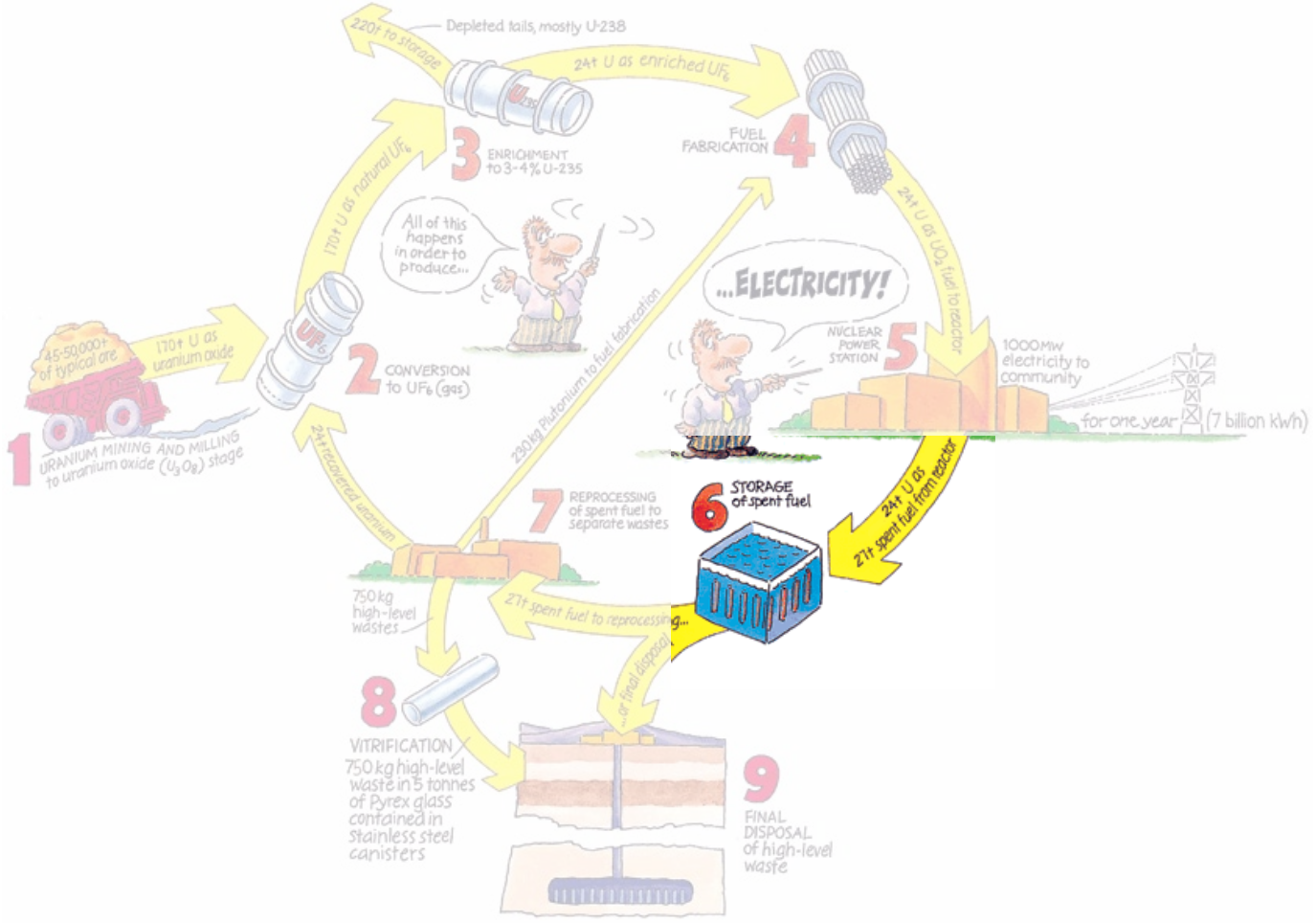


Figure S-5. Potential waste package designs for spent nuclear fuel and high-level radioactive waste.

Step 6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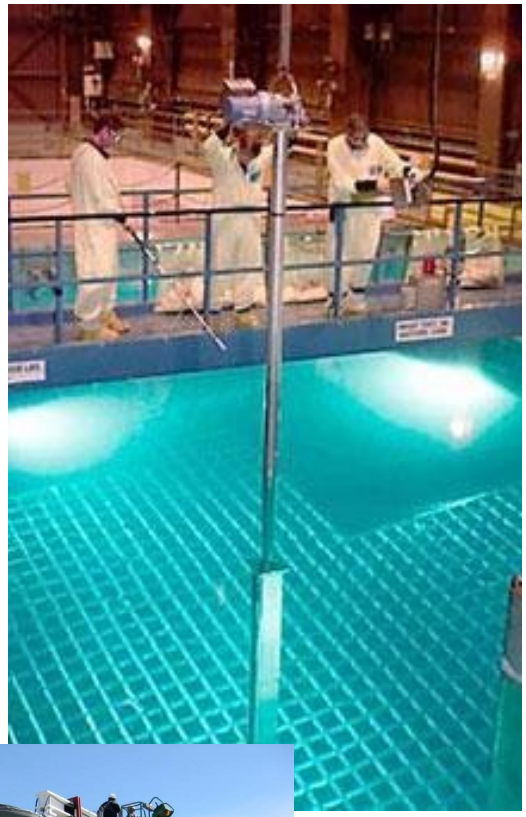
Used nuclear fuel storage

Used fuel first stored in pool at least 5 years

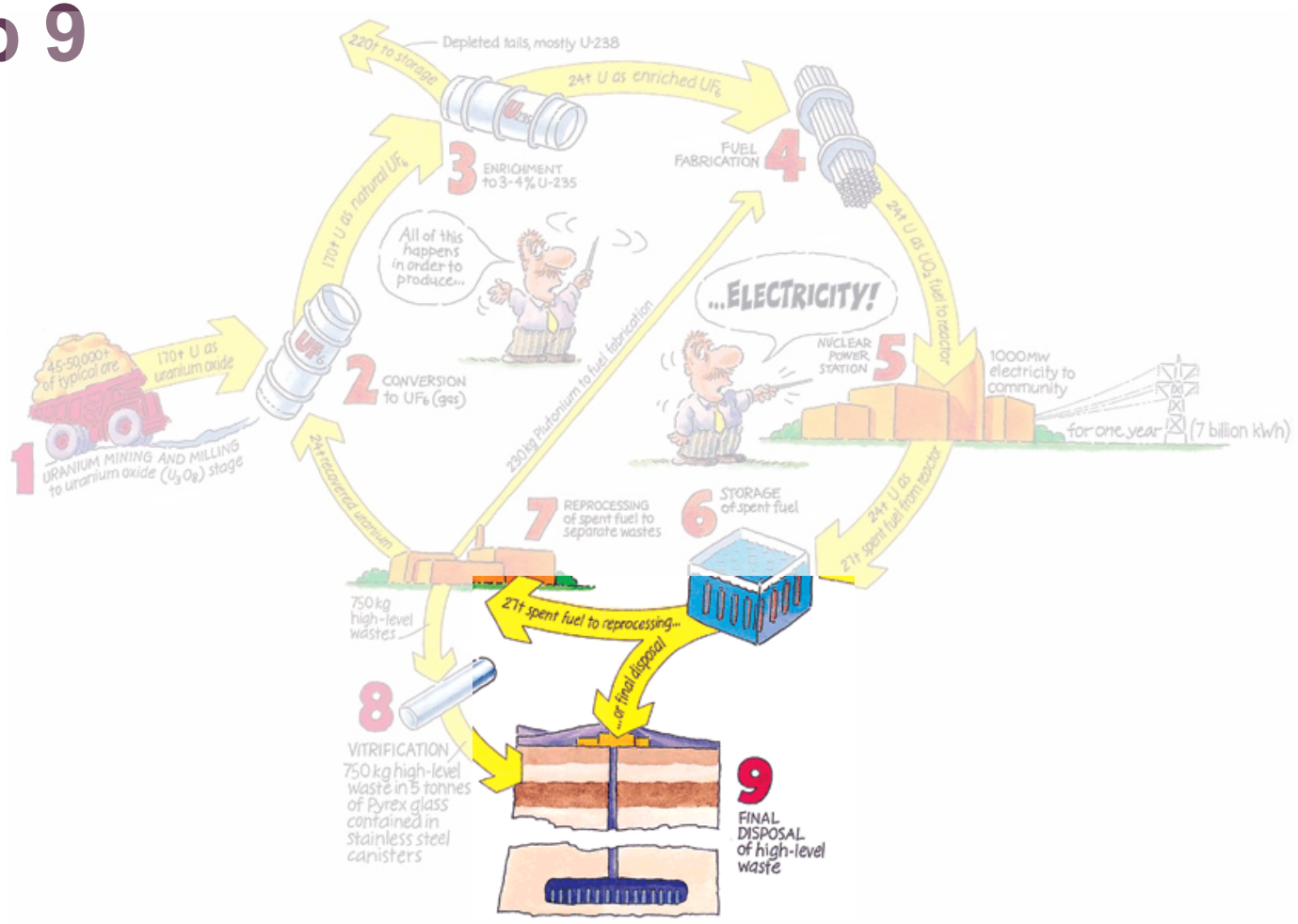
- Cooling and shielding

Older fuel can move to dry casks

- Air cools
- Steel and concrete shields



Step 9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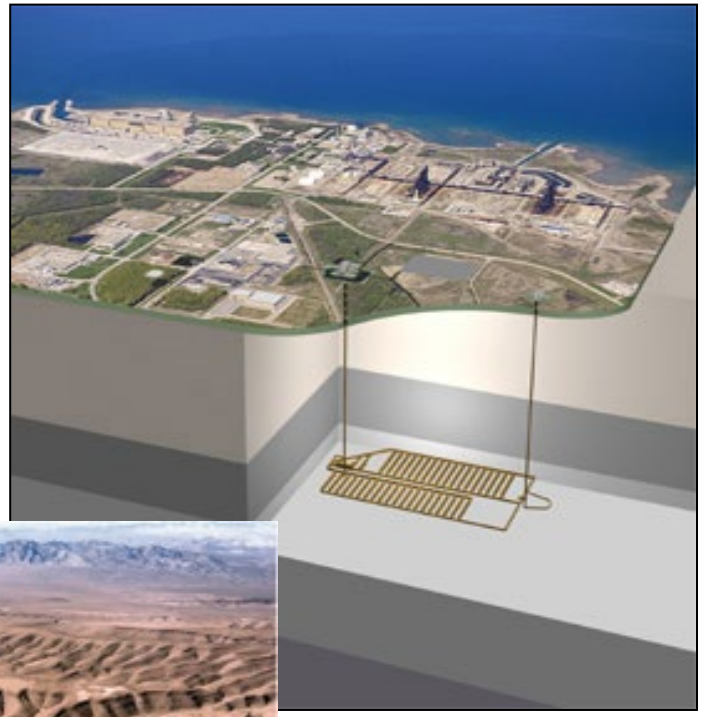
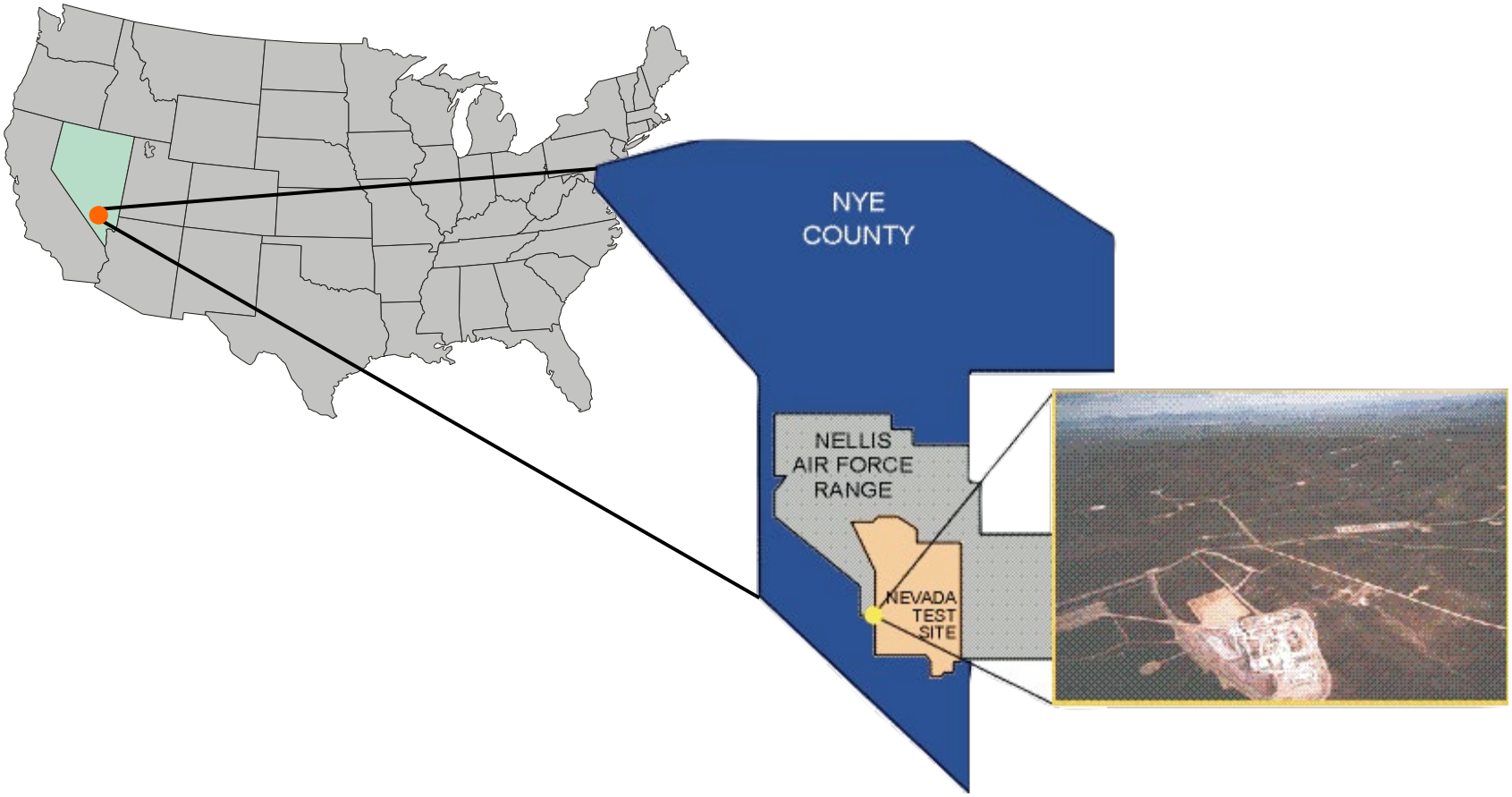
Geologic repository

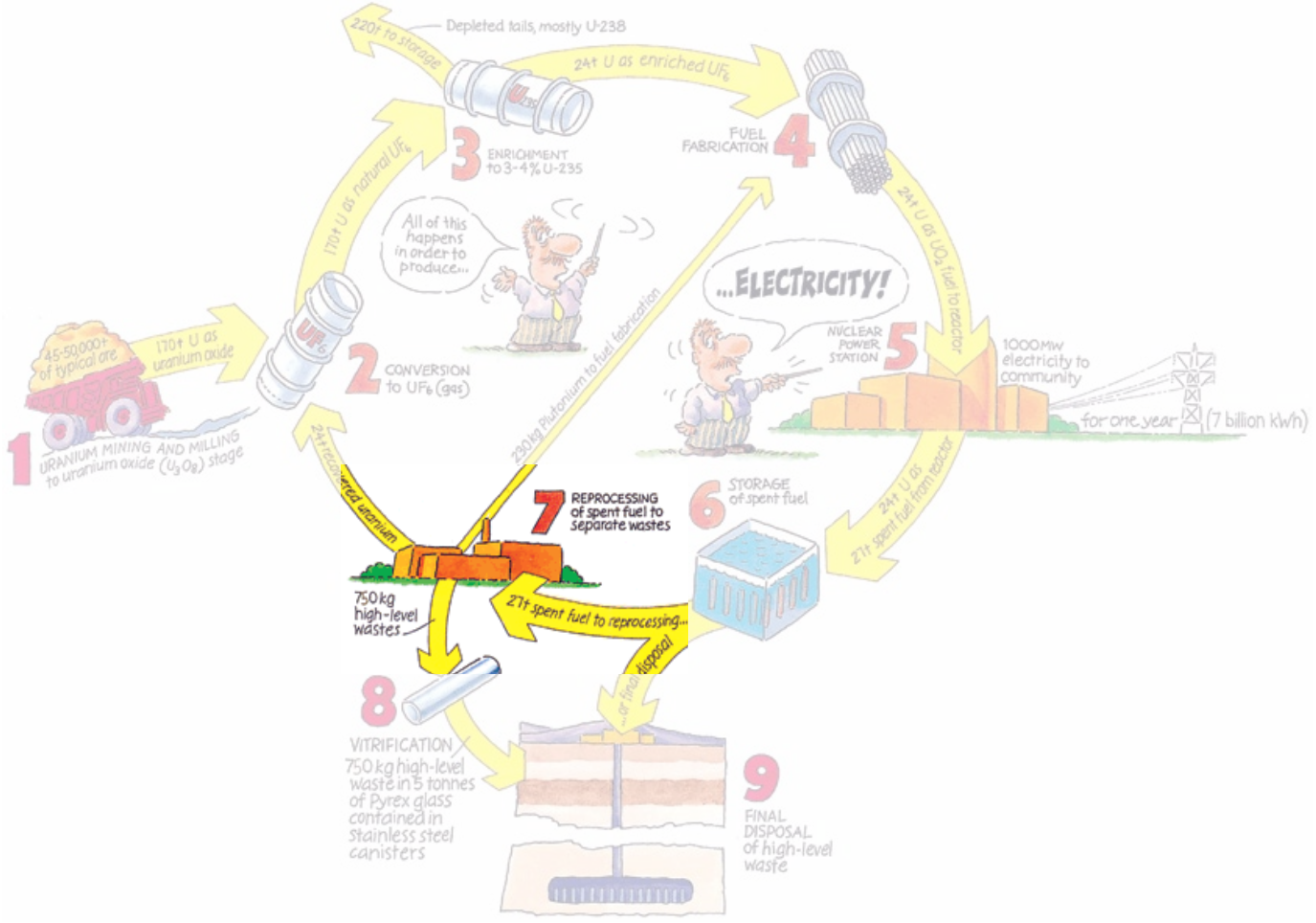
- The choice of countries worldwide
- U.S. has studied Yucca Mt., Nevada as potential location



100 miles northwest of Las Vegas



Step 7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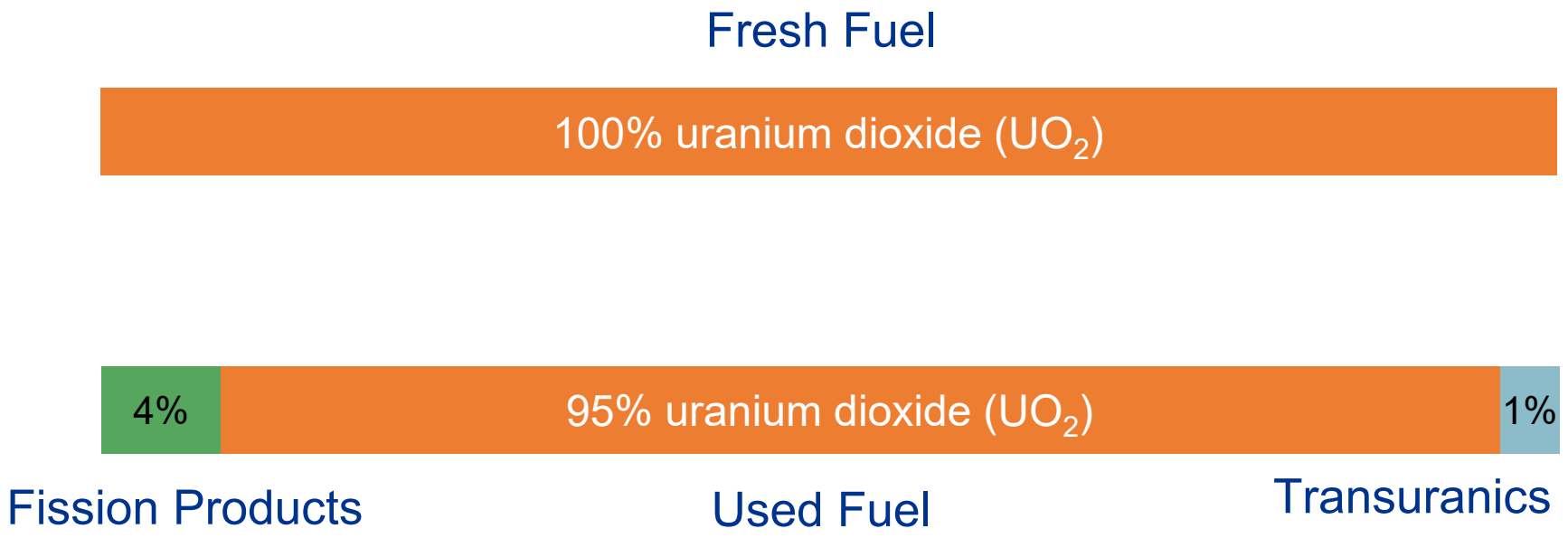
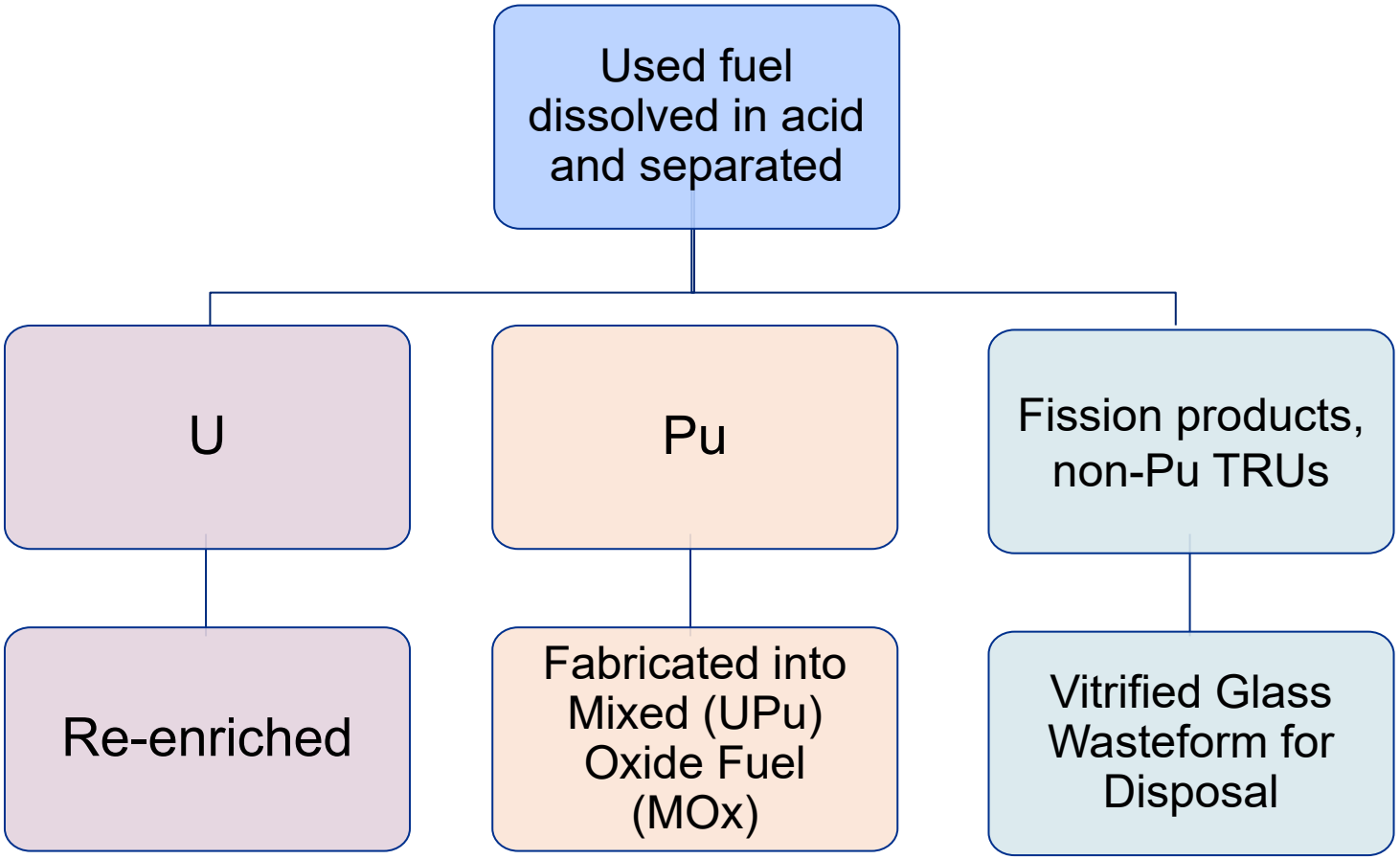
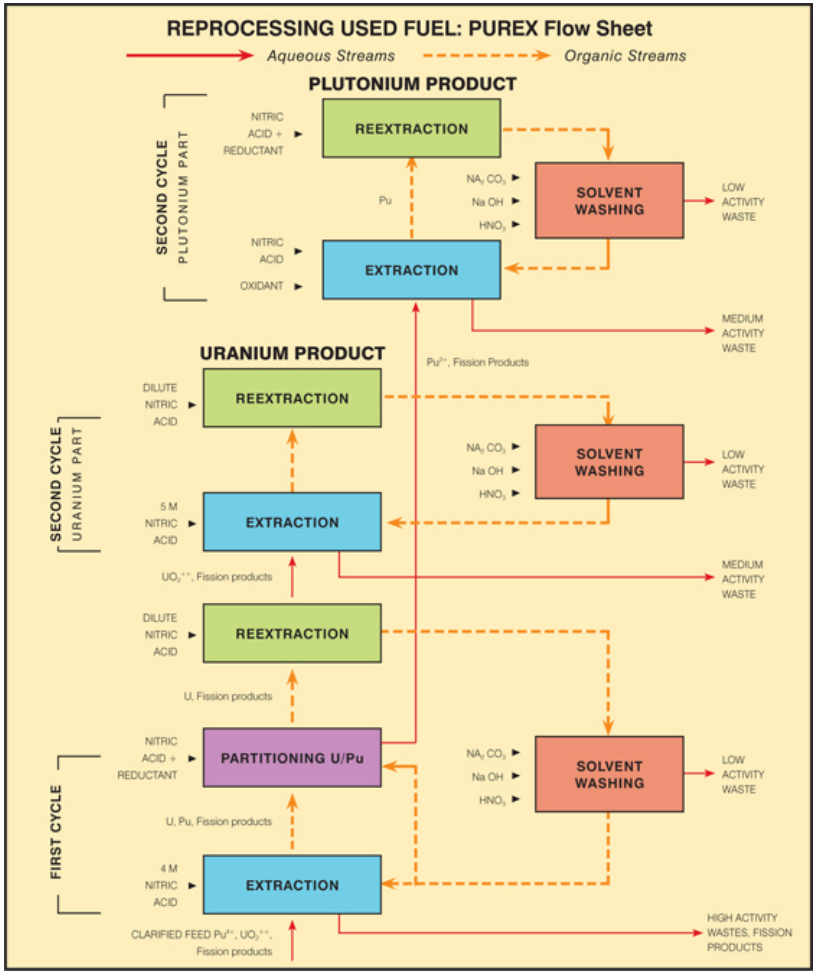
Fuel consumption in the reactor



Fuel recycling/reprocessing



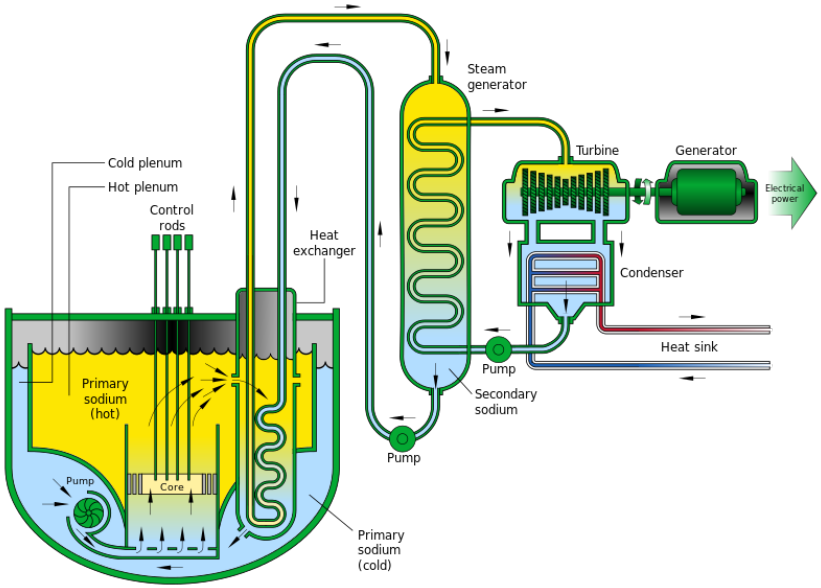
Reprocessing



World Nuclear Association

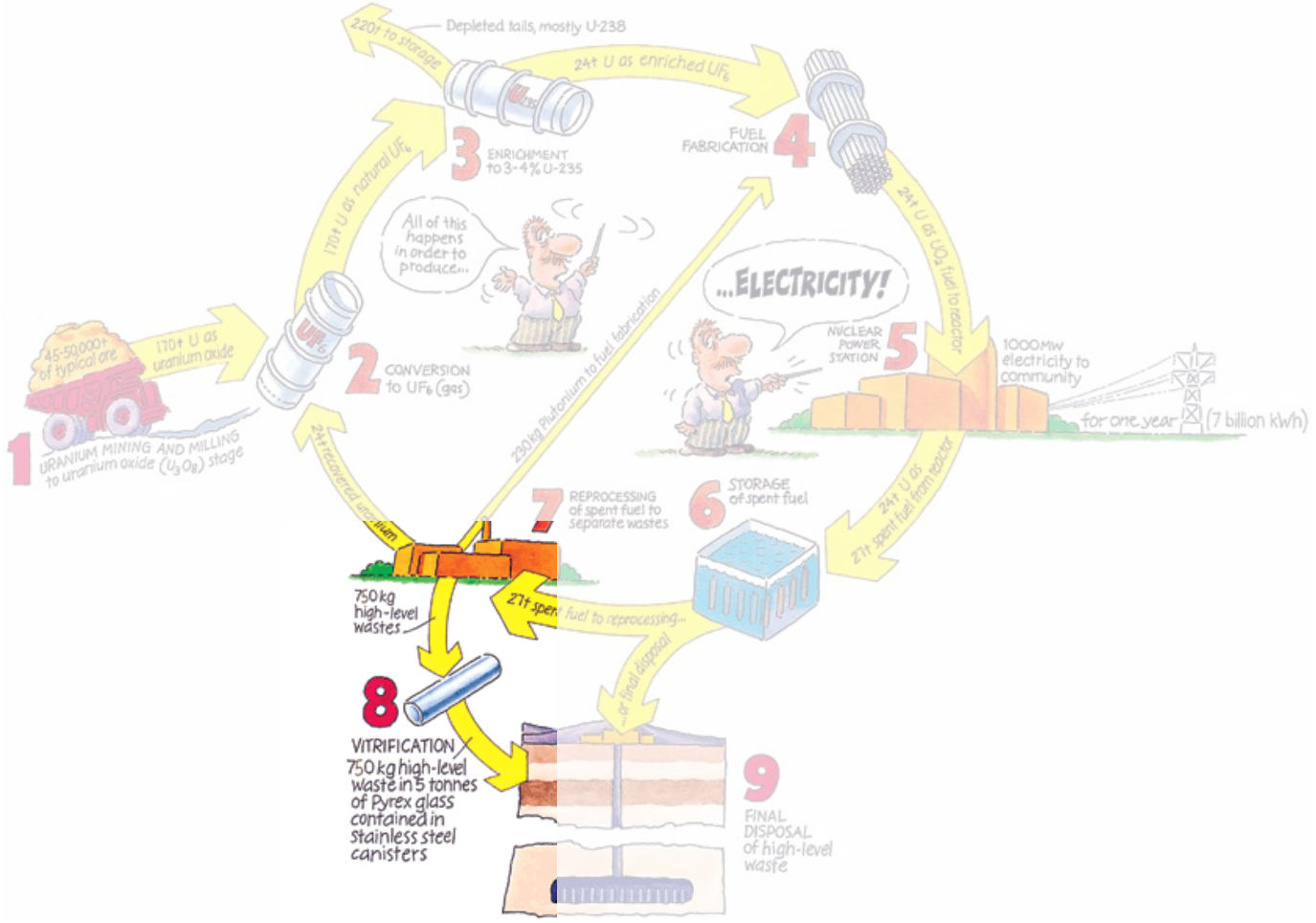
Research

Electroplated uranium
from pyroprocessing



Sodium cooled fast reactor

Step 8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Recycling nuclear fuel

- Continuously recycling fuel can reduce spent fuel waste volume by over 95%
- Reduces isolation time from 1000s of years to 100s
- Remaining waste is placed in robust containers designed for safety and shielding

Why not here in the U.S.?

Big picture about spent fuel as waste

Nuclear is the cleanest type of reliable power production, producing the least waste

Spent fuel is very safely managed

For a 1000 MWe plant, annual waste production is…

Wind (0.32 cp)
36,000 tons used turbine blades (assuming other components recycled)

Coal (0.57 cp)
62,500 tons SO_2
1050 tons fly ash

Nuclear (0.93 cp)
20 tons SNF
175 tons DU
500 m^3 LLW

Solar (0.23 cp)
10,700 tons used panels
Leach Cd

Questions?