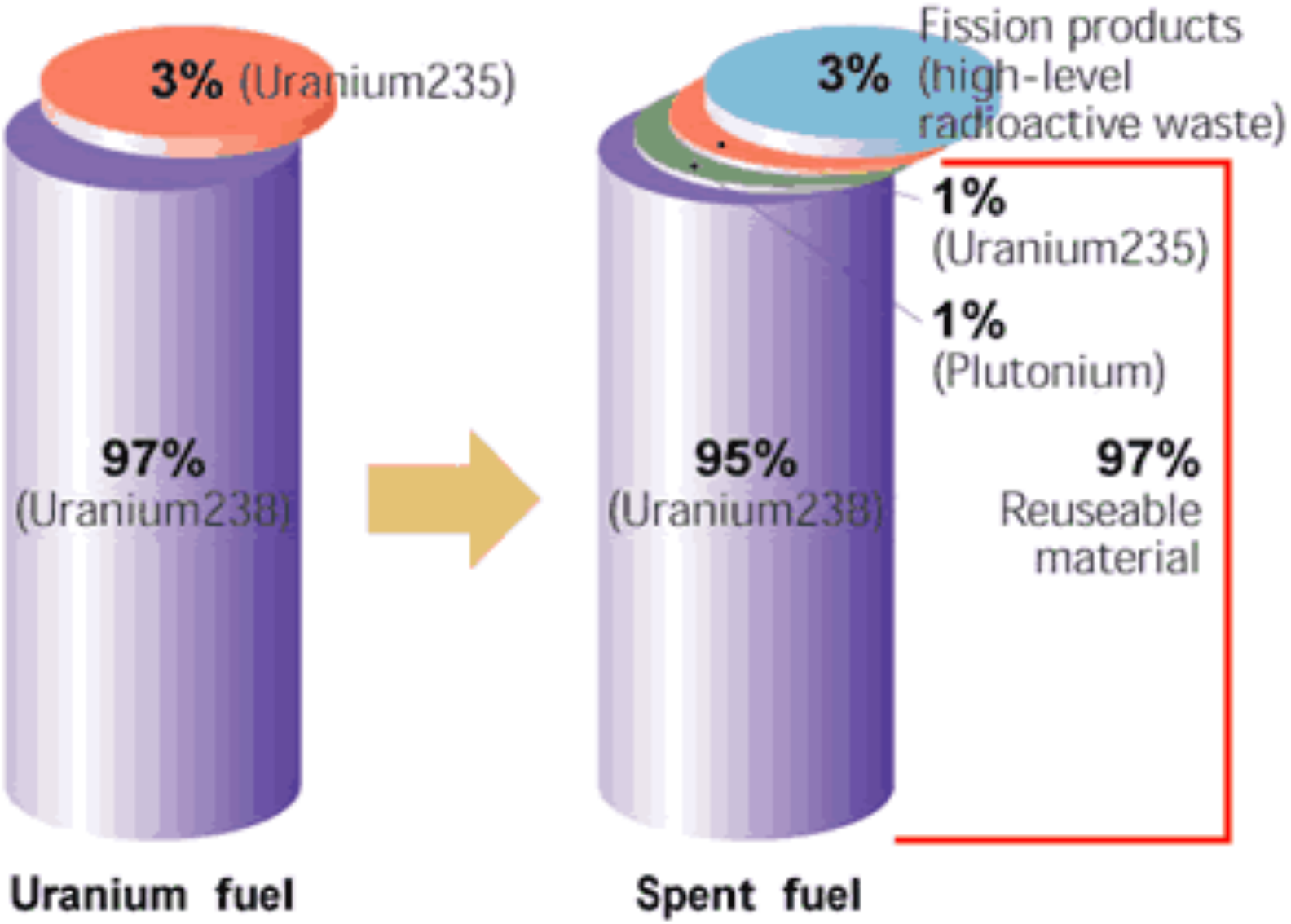
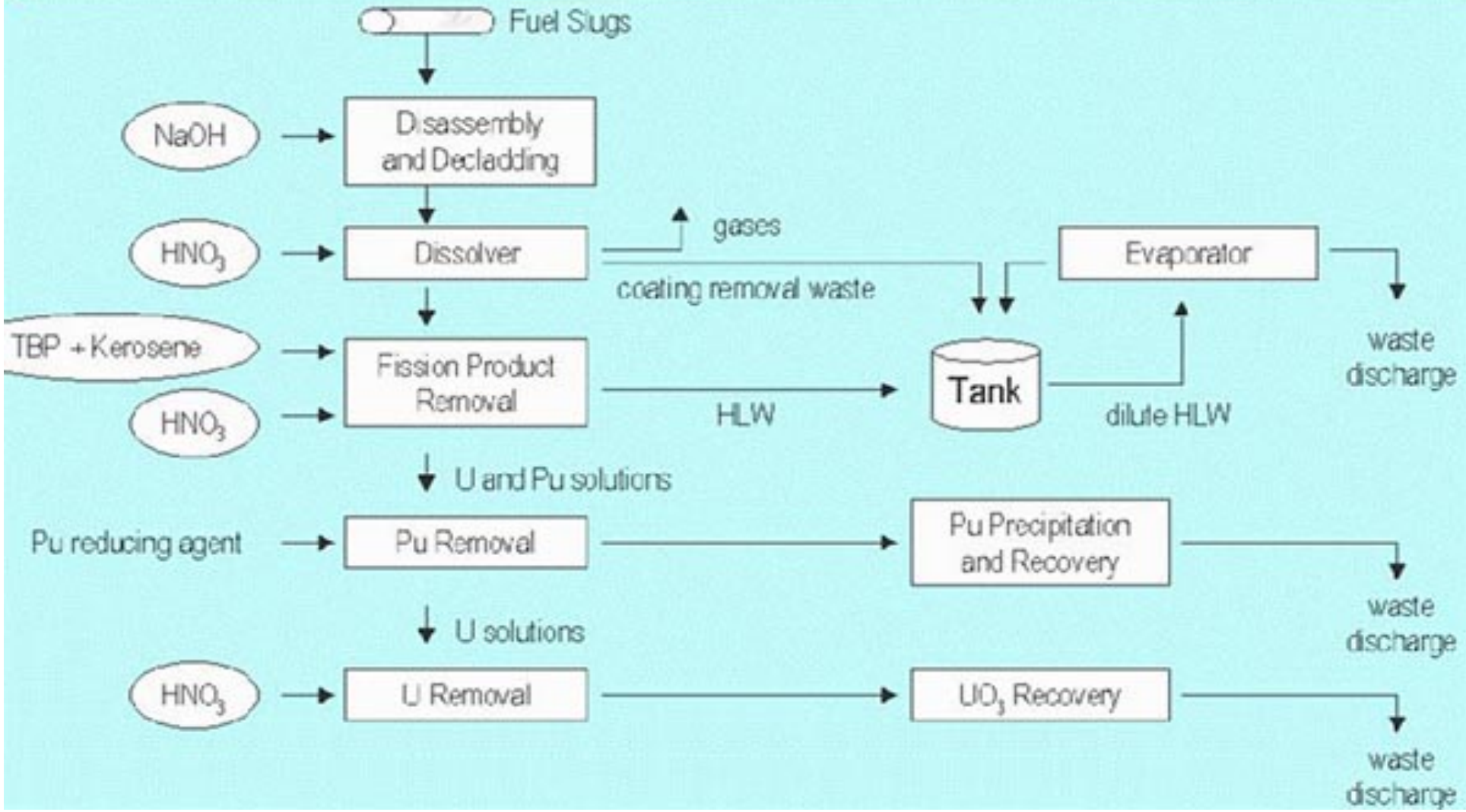
ROYAL INSTITUTE
OF TECHNOLOGY

Spent nuclear fuel –

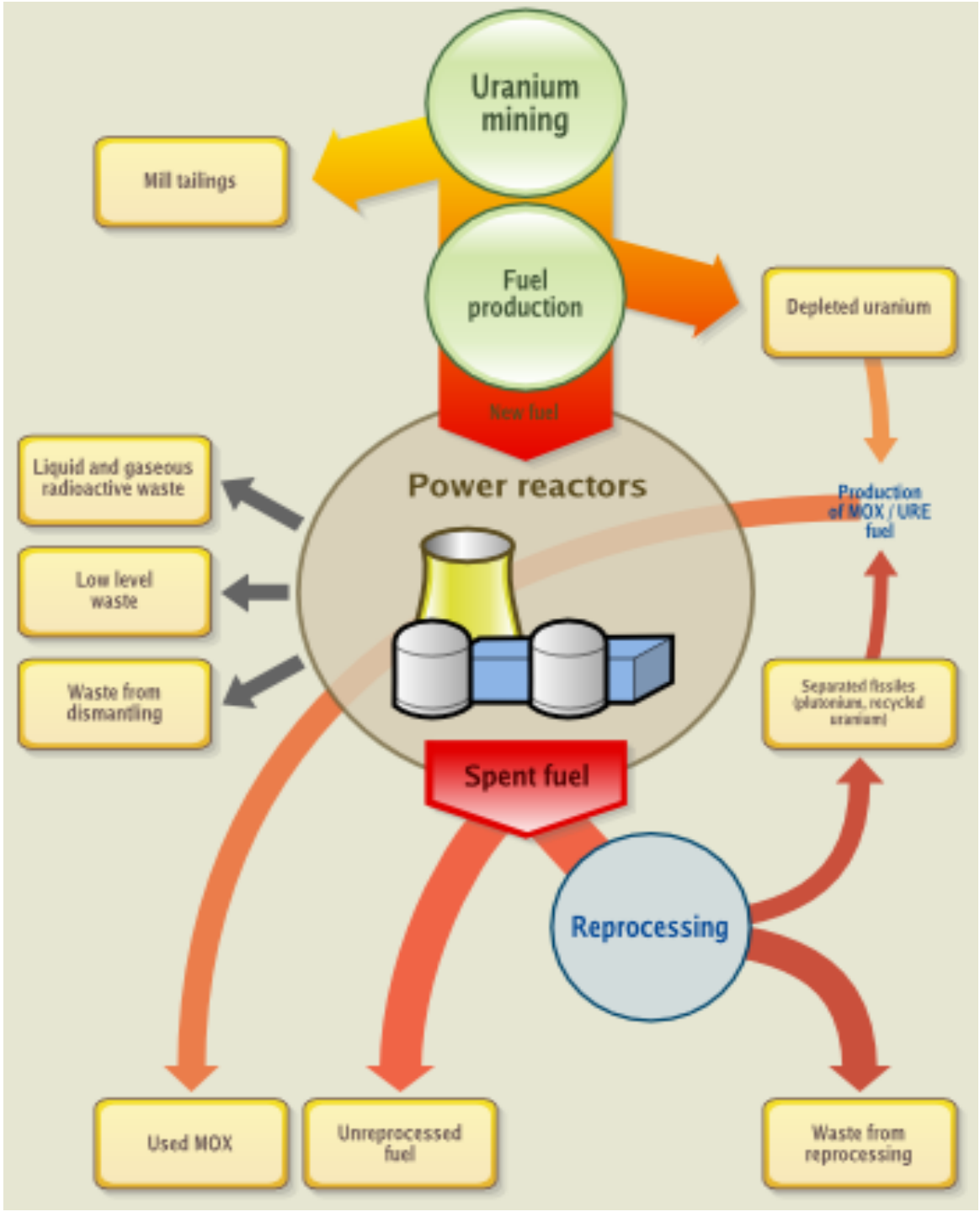
Handling the nuclear waste


3% (Uranium235)
97%
(Uranium238)
Uranium fuel
3%
Fission products
(high-level
radioactive waste)
1%
(Uranium235)
1%
(Plutonium)
95%
(Uranium238)
97%
Reuseable
material
Spent fuel

PUREX Reprocessing of Spent Fuel



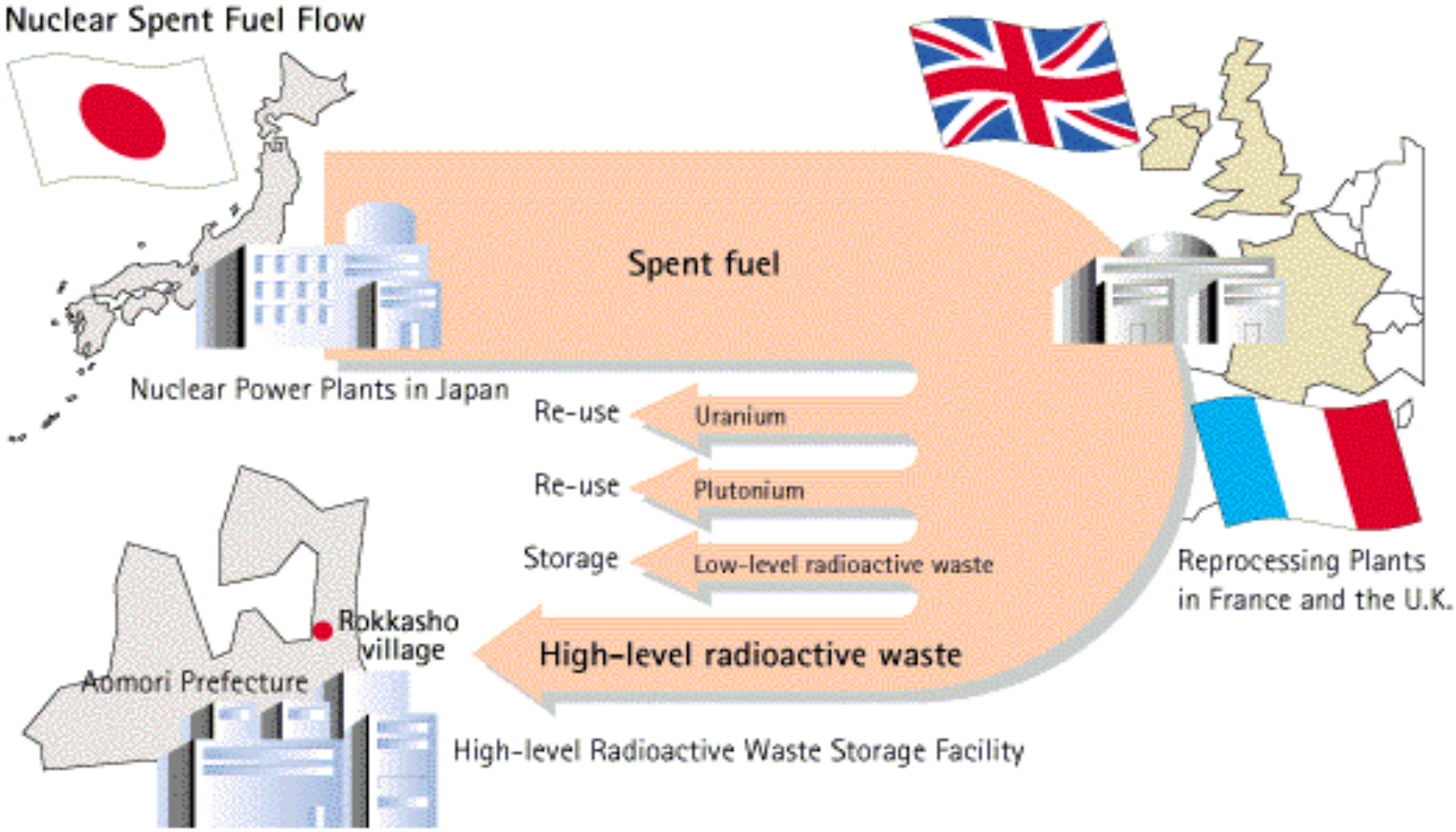
97 % recycled

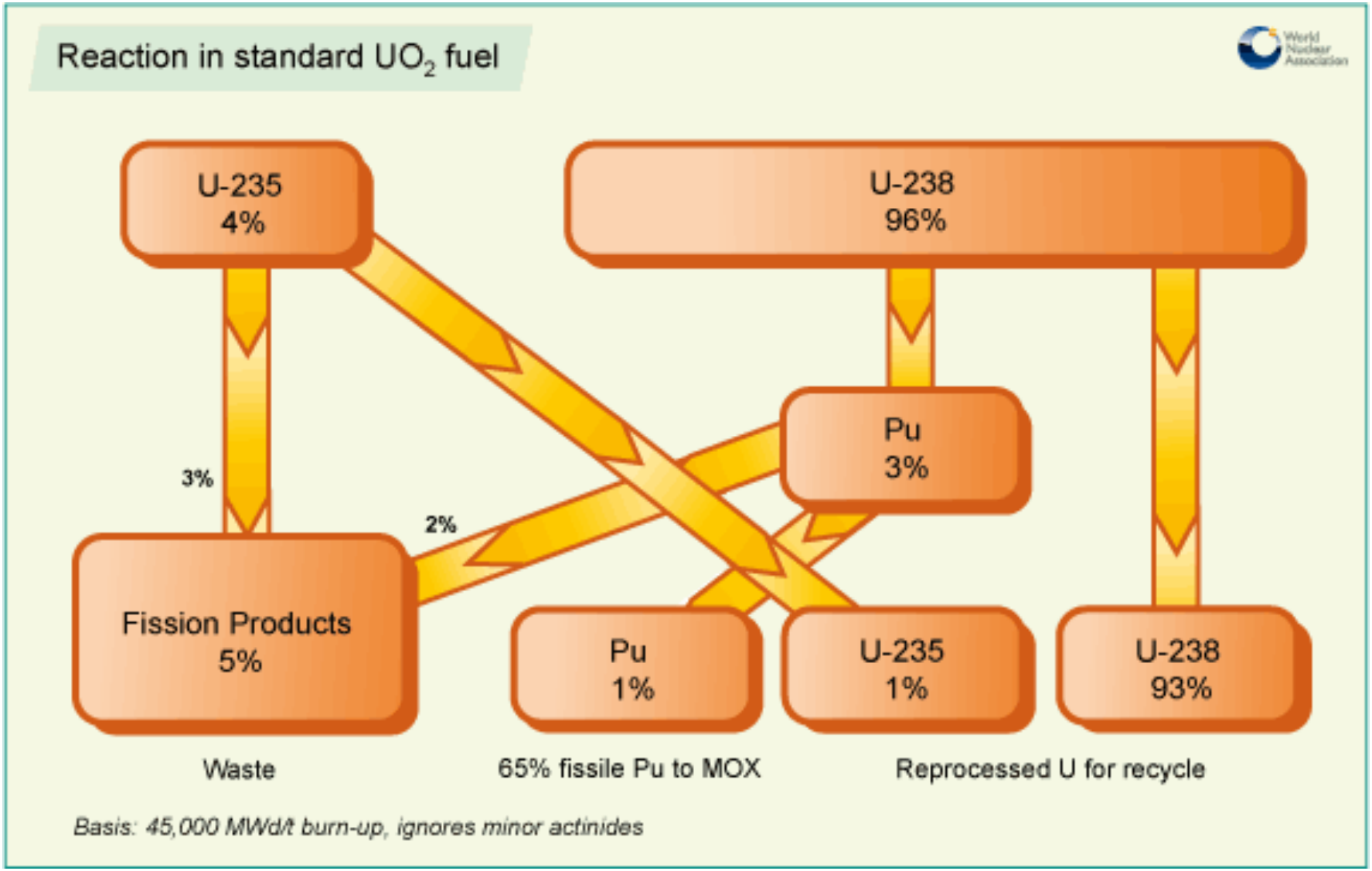

Uranium mining
Mil tailings
Fuel production
Depleted uranium
New fuel
Liquid and gaseous radioactive waste
Power reactors
Production of MOX / URE fuel
Low level waste
Waste from dismantling
Separated fissiles (plutonium, recycled uranium)
Spent fuel
Reprocessing
Used MOX
Unreprocessed fuel
Waste from reprocessing

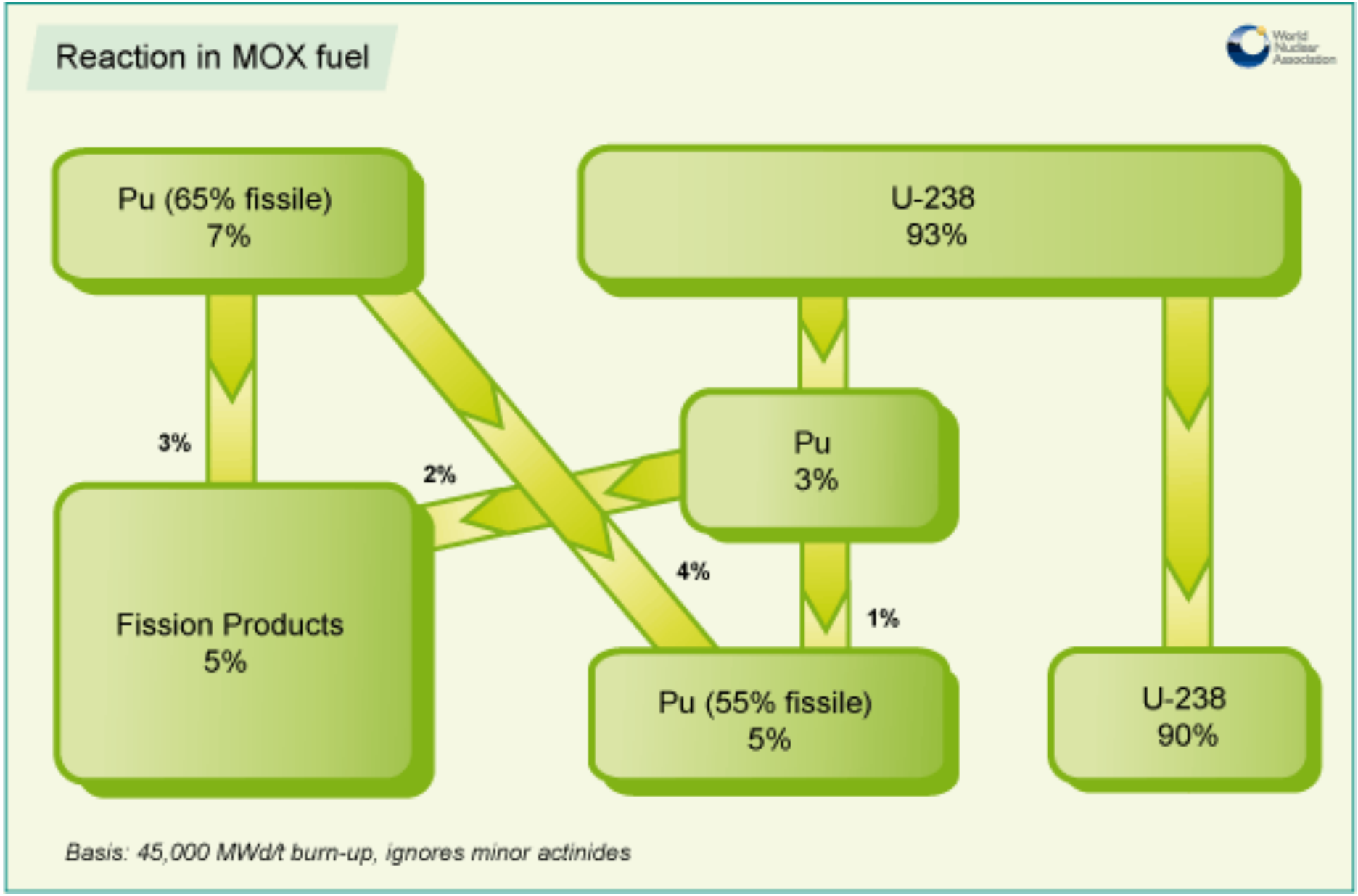
ROYAL INSTITUTE
OF TECHNOLOGY

MOX fuel (2 %) is manufactured from plutonium recovered from used reactor fuel. MOX fuel also burning weapons-grade plutonium (from military sources) to produce electricity.

World mixed oxide fuel fabrication capacities (t/yr)	2009	2015
France, Melox	195	195
Japan, Tokai	10	10
Japan, Rokkasho	0	130
Russia, Mayak, Ozersk	5	5
UK, Sellafield	40	40
Total	250	380


Nuclear Spent Fuel Flow
Spent fuel
Nuclear Power Plants in Japan
Re-use
Uranium
Re-use
Plutonium
Storage
Low-level radioactive waste
High-level radioactive waste
Reprocessing Plants
in France and the U.K.
Rokkasho
village
Aomori Prefecture
High-level Radioactive Waste Storage Facility


Reaction in standard UO_2 fuel
World Nuclear Association
U-235
4%
U-238
96%
Pu
3%
3%
2%
Fission Products
5%
Pu
1%
U-235
1%
U-238
93%
Waste
65% fissile Pu to MOX
Reprocessed U for recycle
Basis: 45,000 MWd/t burn-up, ignores minor actinides


Reaction in MOX fuel
World Nuclear Association
Pu (65% fissile)
7%
U-238
93%
3%
2%
Pu
3%
4%
1%
Fission Products
5%
Pu (55% fissile)
5%
U-238
90%
Basis: 45,000 MWd/t burn-up, ignores minor actinides

Belgium, Switzerland, Germany and France use MOX.

Japan are planning to.

ROYAL INSTITUTE
OF TECHNOLOGY

Vitrification: mixing the waste with borosilicate glass into stainless steel canisters. Each canister contains 150 litres of glass weighing 400 kilograms. Some 14% of the content is high-level waste derived from the reprocessing of about two tonnes of used fuel

Synroc

ROYAL INSTITUTE
OF TECHNOLOGY

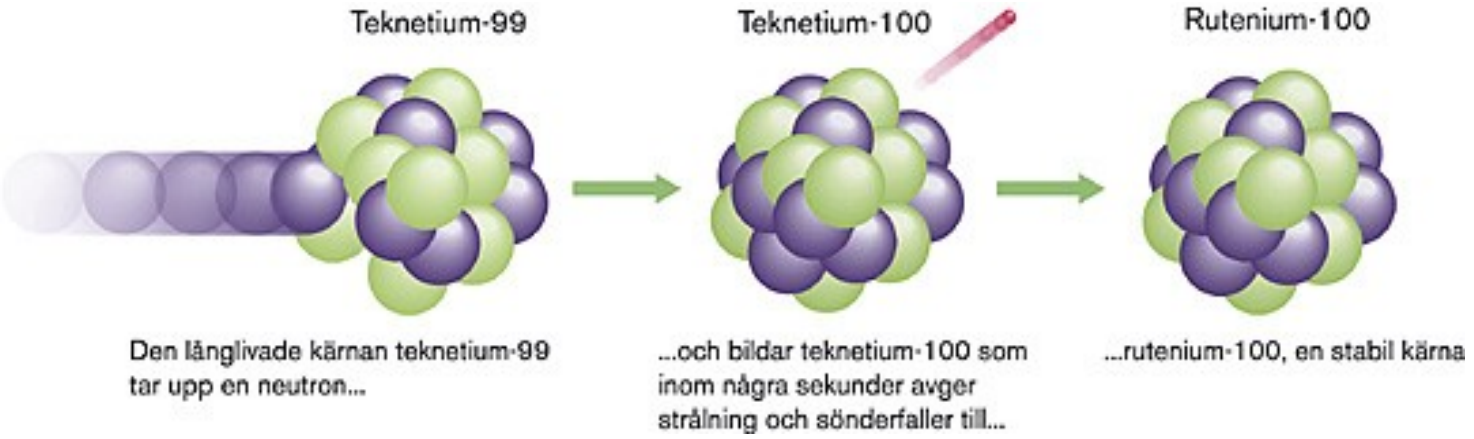
Synthetic rock incorporating radioactive waste in the crystal lattice, liquid waste from reprocessing.

Other applications have been developed related to the partitioning and transmutation of wastes.

This involves partitioning HLW into separate components, some of which can then be transmuted, or changed, into different forms which are less radioactive or shorter-lived (usually by neutron bombardment in a reactor or accelerator). Those which are not suitable for transmutation can then be immobilized in Synroc.

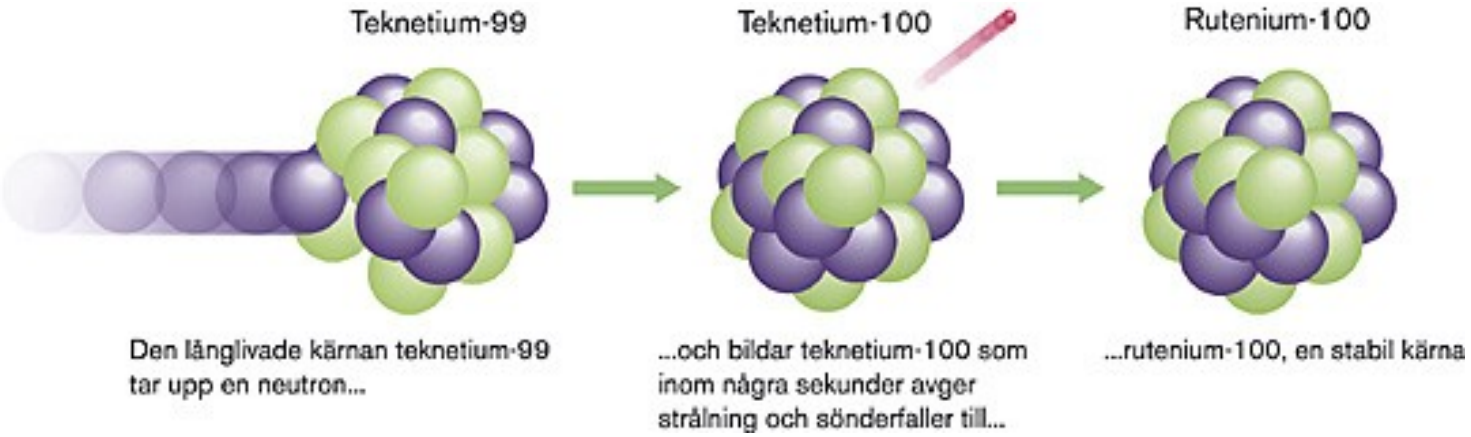
Transmutation of actinides in the nuclear waste

ROYAL INSTITUTE OF TECHNOLOGY

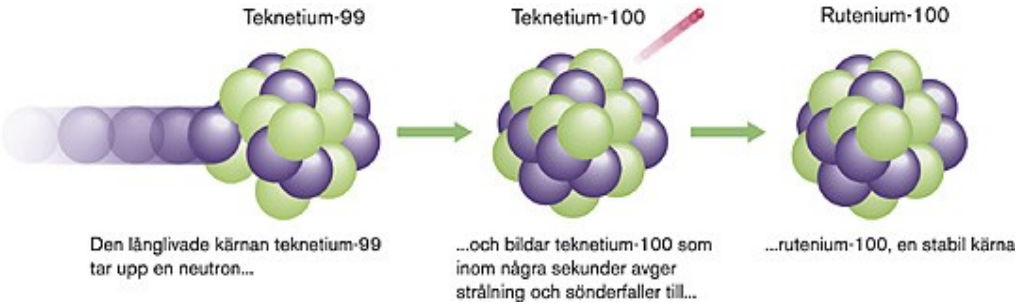


Needs separation in long-lived and short-lived actinides

ROYAL INSTITUTE OF TECHNOLOGY



Tranmutation of actinides such as Pu, Np, Am and Cm could decrease the problems around nuclear waste by reducing the part of long lived isotopes



ROYAL INSTITUTE OF TECHNOLOGY

At the time being the transmutation method is connected with large technical and economical uncertainties. The transmutation plants will probably be some large and complex that many countries have to join in. Since not all of the longer lived isotopes can be eliminated, there still will be a need of repositories of spent nuclear fuel.

ROYAL INSTITUTE
OF TECHNOLOGY

Cs-137
Sr-90 dominates up to 500 years

Cross sections low i.e. are not helped by transmutation

Pu the most important actinide in long time perspective, but can be used again in MOX-fuels for example

Am
Np
Cm

Principles employed in the in the management of radioactive wastes

ROYAL INSTITUTE
OF TECHNOLOGY

- Concentrate and contain
- Dilute and disperse
- Delay and decay

Waste produced in the nuclear industry

ROYAL INSTITUTE OF TECHNOLOGY

Low-level waste (LLW):

Intermediate-level waste (ILW):

High-level waste (HLW):

Countries choice of repositories

Sweden – Deep granitic bedrock repository

Finland – Deep granitic bedrock repository

Canada – In Sedimentary rocks, or crystalline bedrock

Belgium – Boom clay, enormous clay natural clay formations

China – So far reprocessing. Prospect of a deep granitic bedrock repository

France – So far reprocessing in Le Hague, but will probably get a deep bedrock repository

Germany – On hold, probably deep waste disposal in salt domes

India – Research on deep bedrock repositories

Japan – Reprocessing a lot of fuel but have decided on a deep bedrock repository

Korea – Envisaged deep geological repository

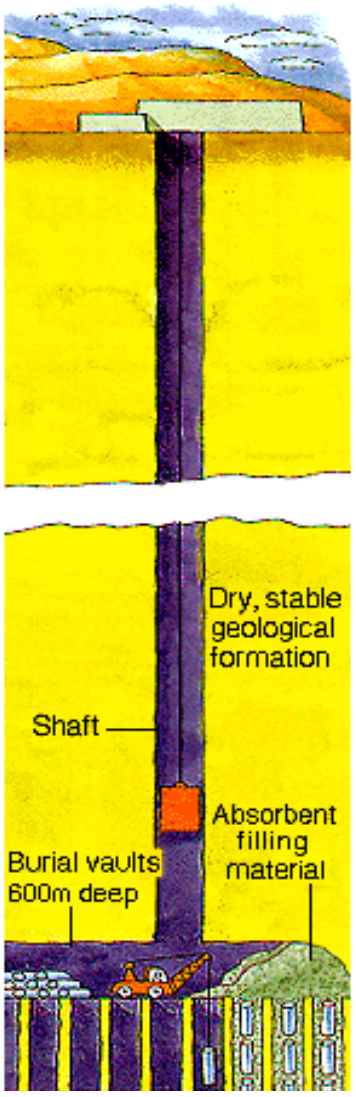
Russia – No waste repository is available, site selections is proceeding in granite in Kola peninsula

Spain – Have research ongoing on deep geological repositories, transmutation and salt domes

Switzerland – Reprocessing and have to decide what to do with waste. Have found sites in clay.

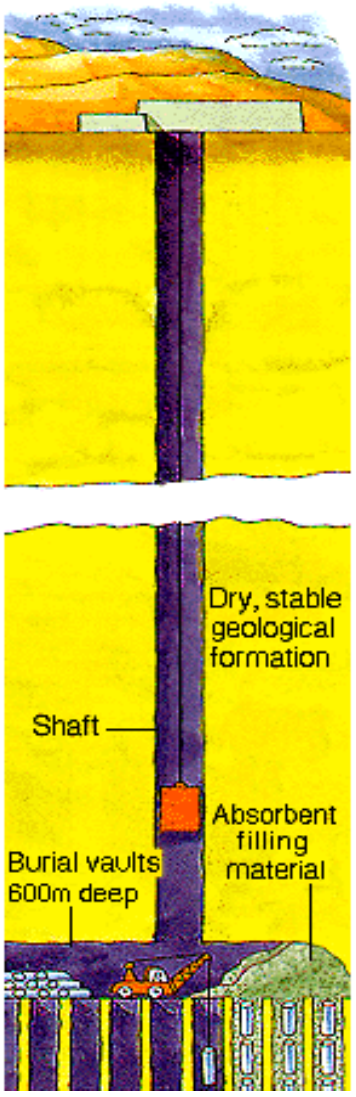
USA – ??

Waste disposal



Alternatives that are not any longer present

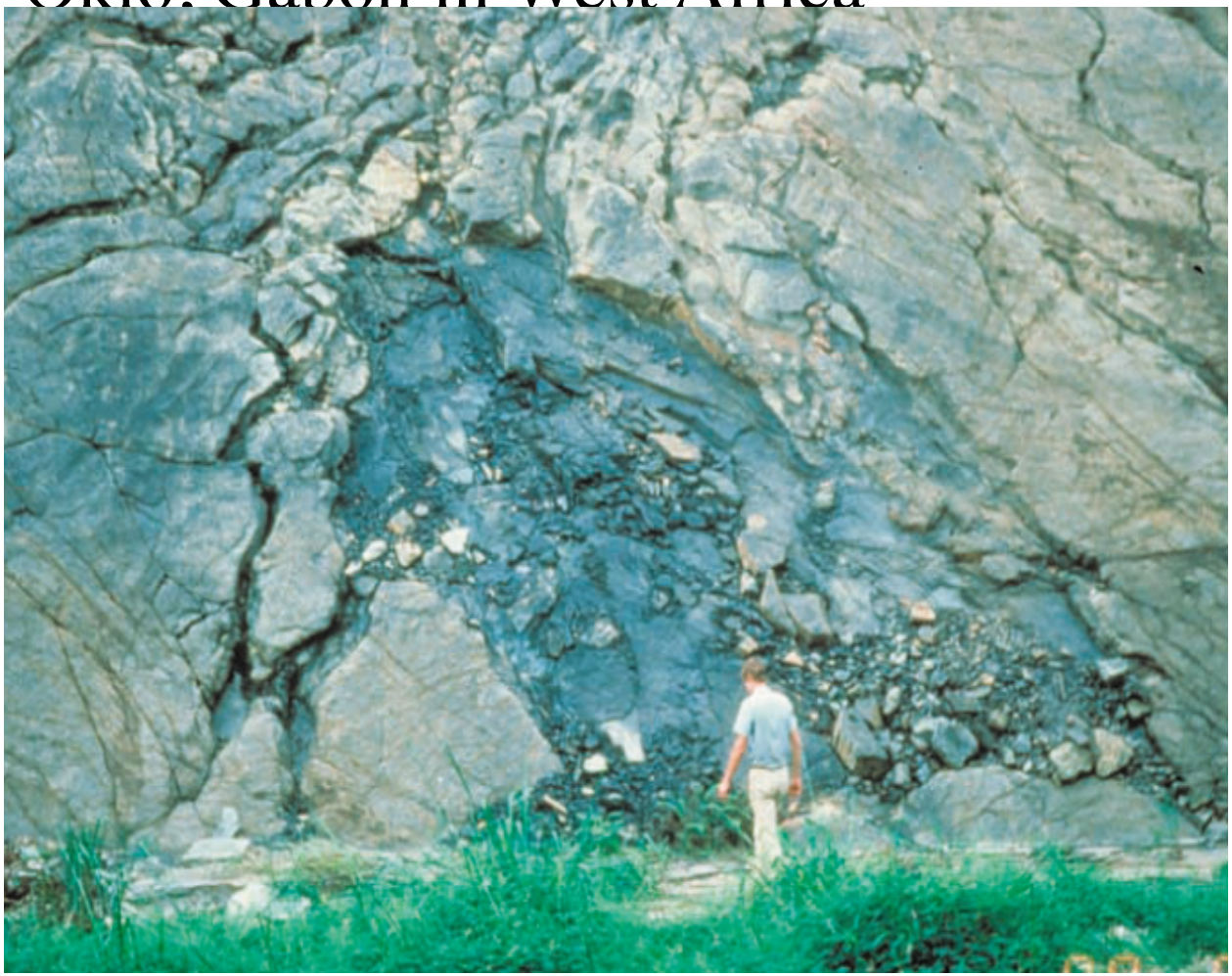
Waste disposal



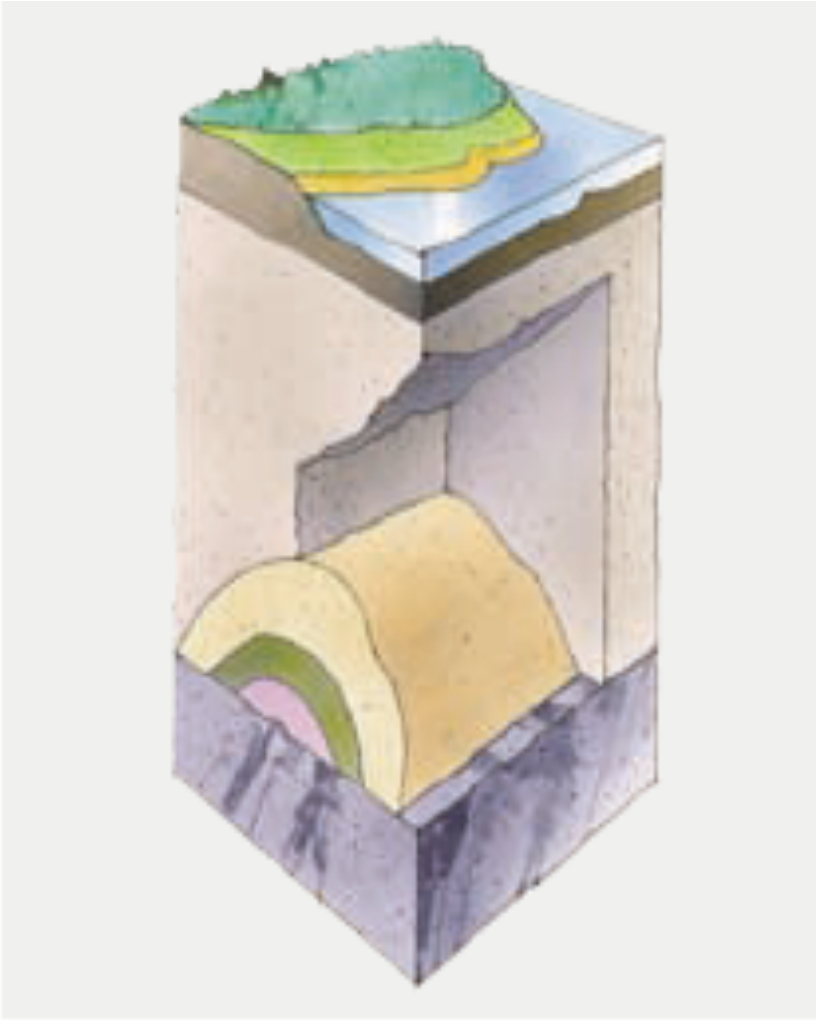
Deep geological disposal: Basic Idea

Granite, clay, salt

Example from nature indicating that final disposal of high-level waste undergroundis safe: Oklo, Gabon in West Africa

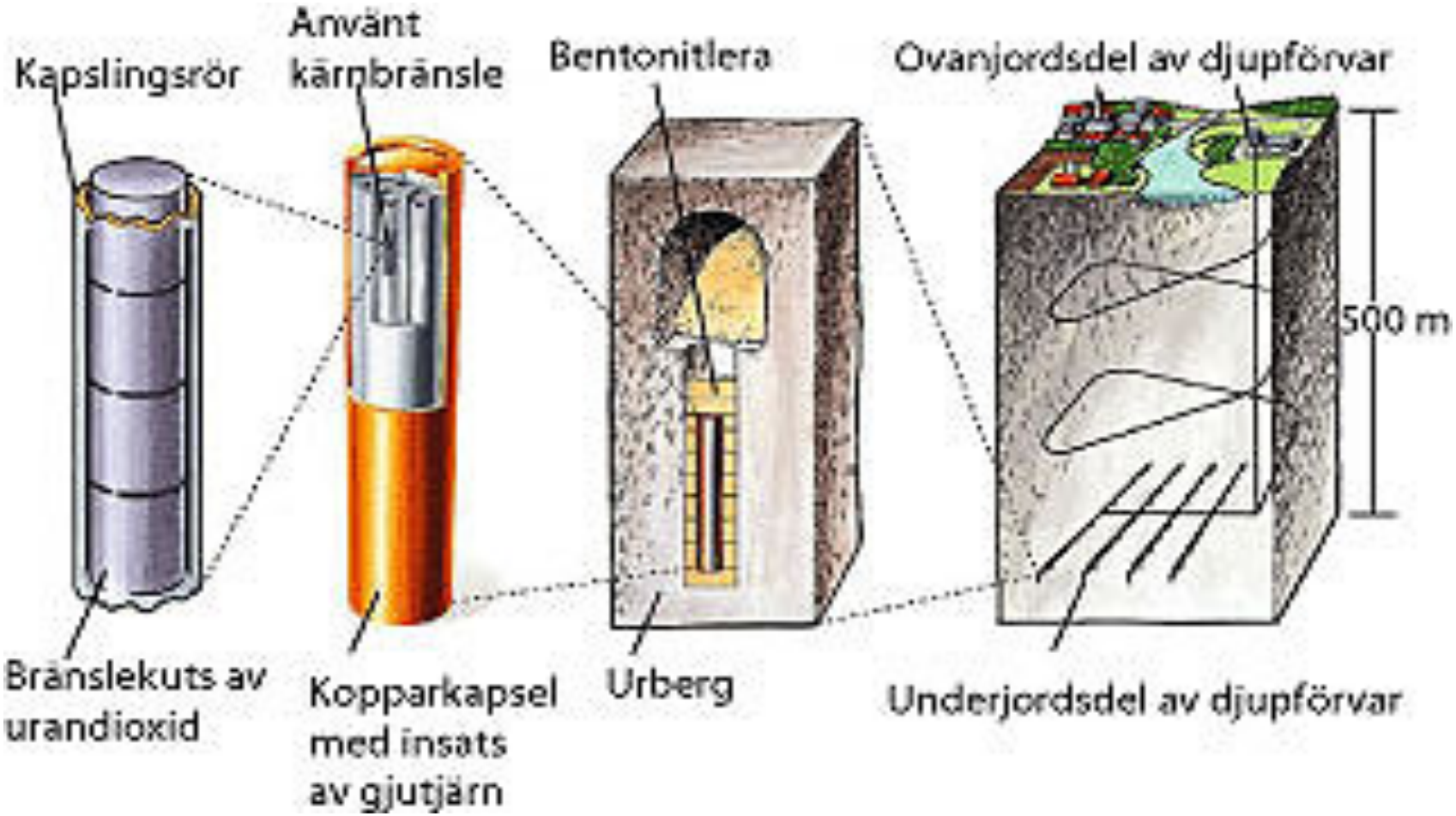


Cigar Lake:

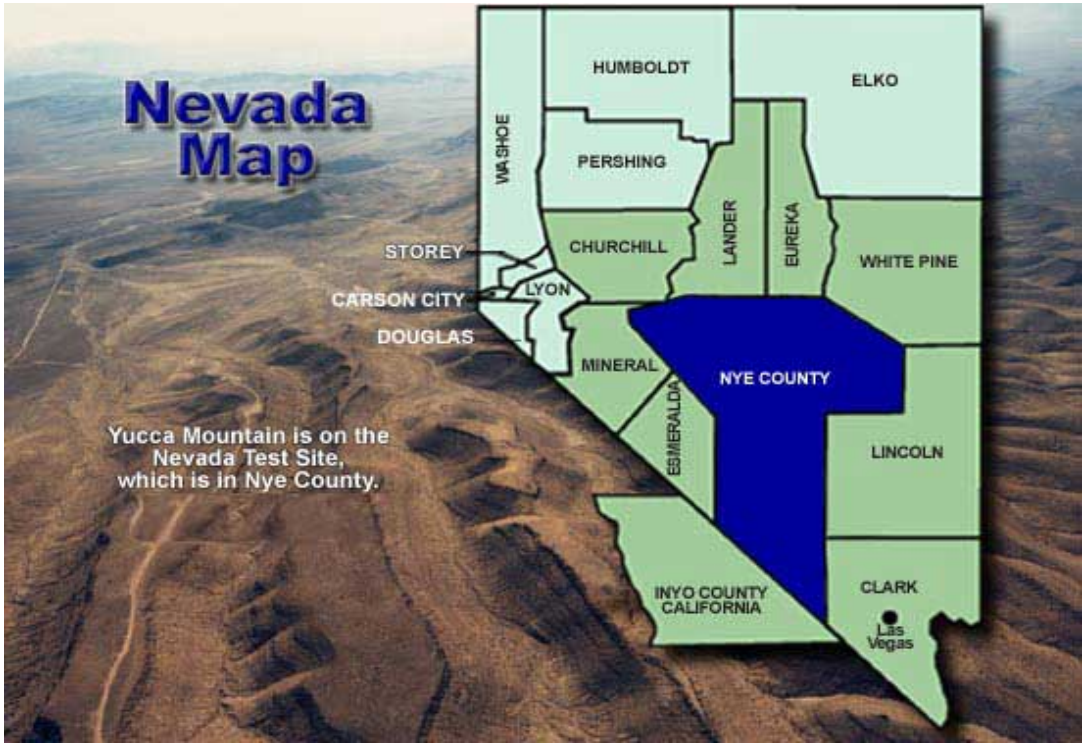


Uranfyndigheten i Cigar Lake liknar ett djupförvar. Runt malmkroppen finns ett tjockt lager lera.

KBS-3 model in Sweden



Yucca mountain



Principles employed in the in the management of radioactive waste

ROYAL INSTITUTE OF TECHNOLOGY

- Concentrate and contain
- Dilute and disperse
- Delay and decay

Nuclear waste produced

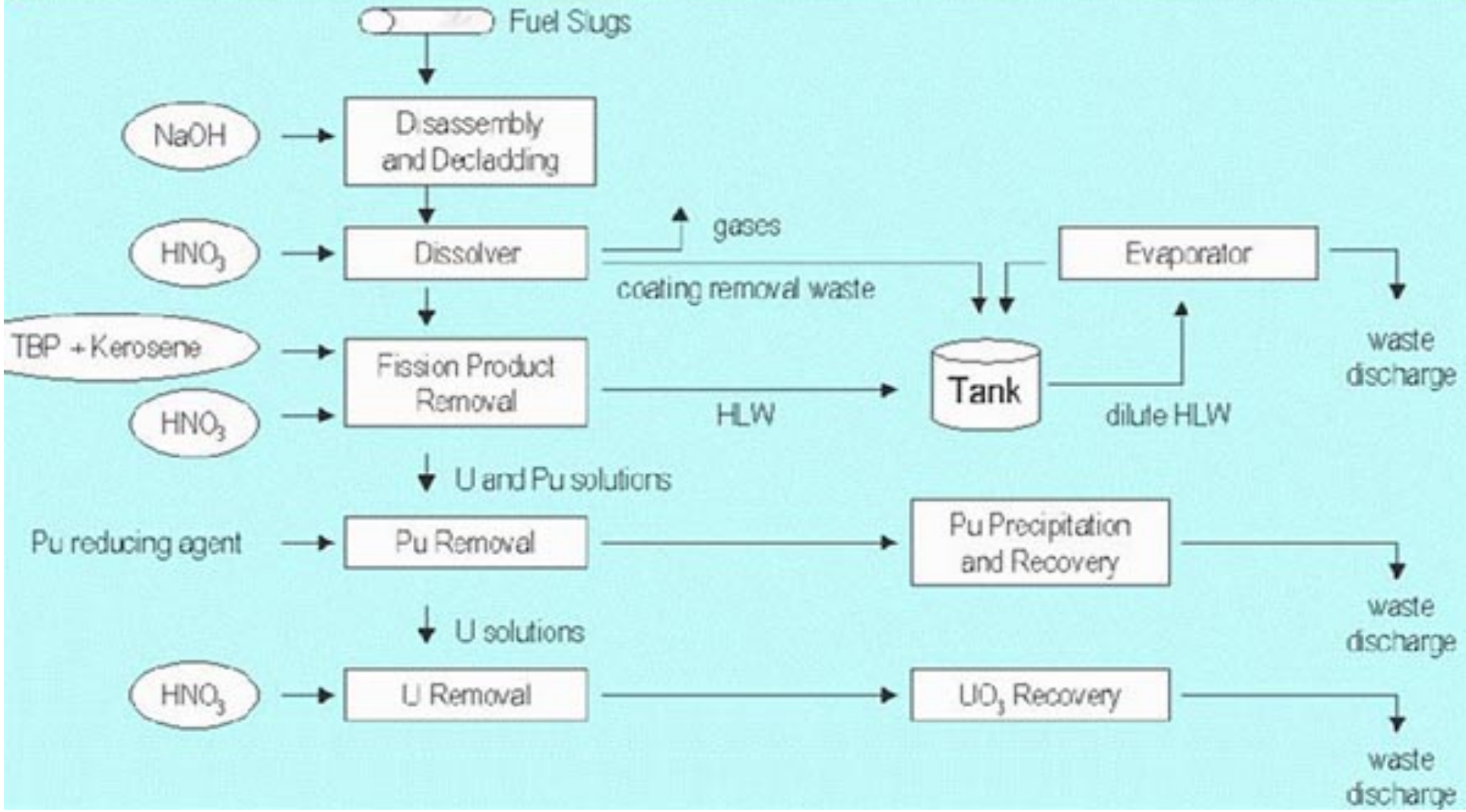
ROYAL INSTITUTE
OF TECHNOLOGY

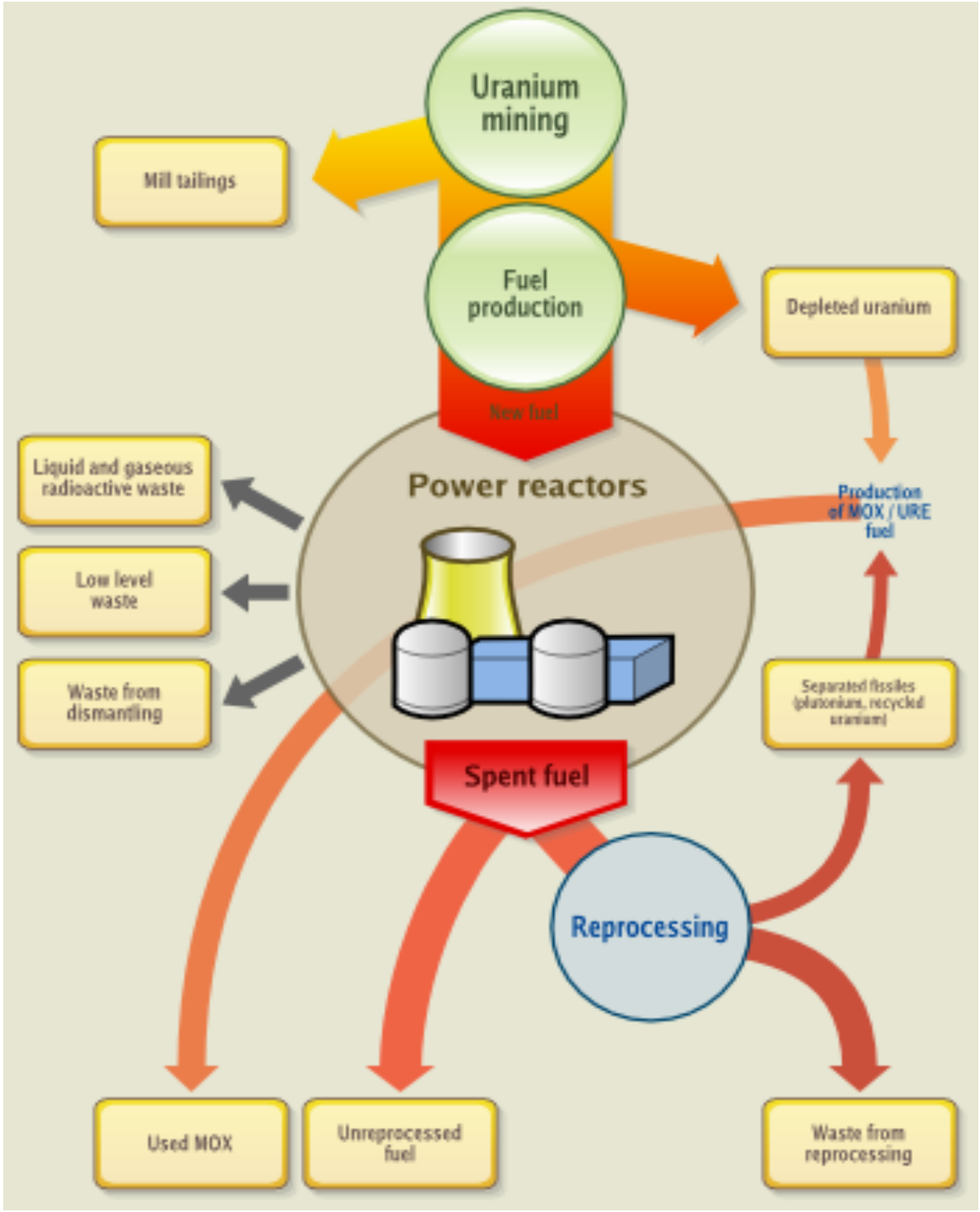
Low-level waste (LLW):

Intermediate-level waste (ILW):

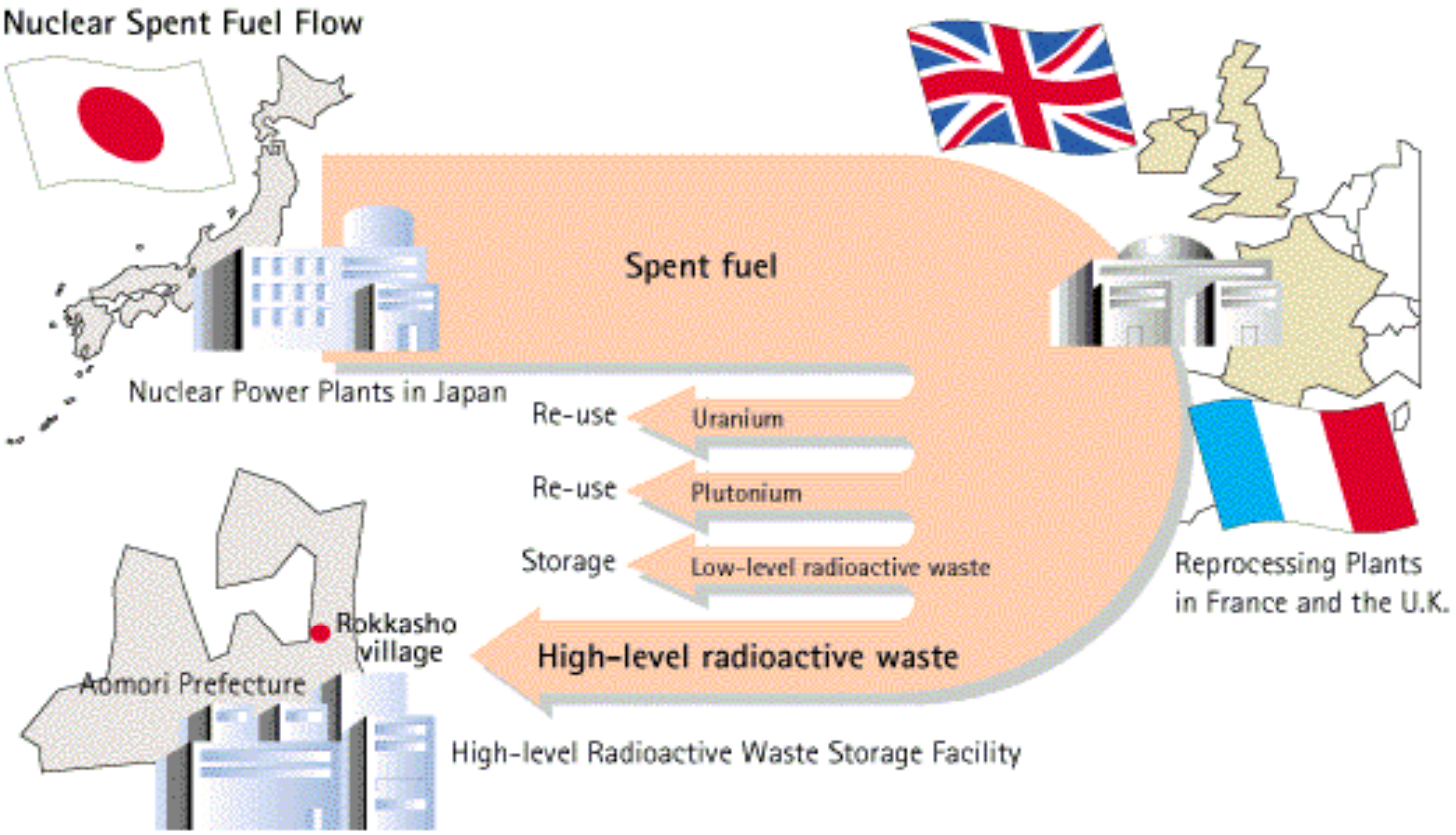
High-level waste (HLW):

PUREX Reprocessing of Spent Fuel

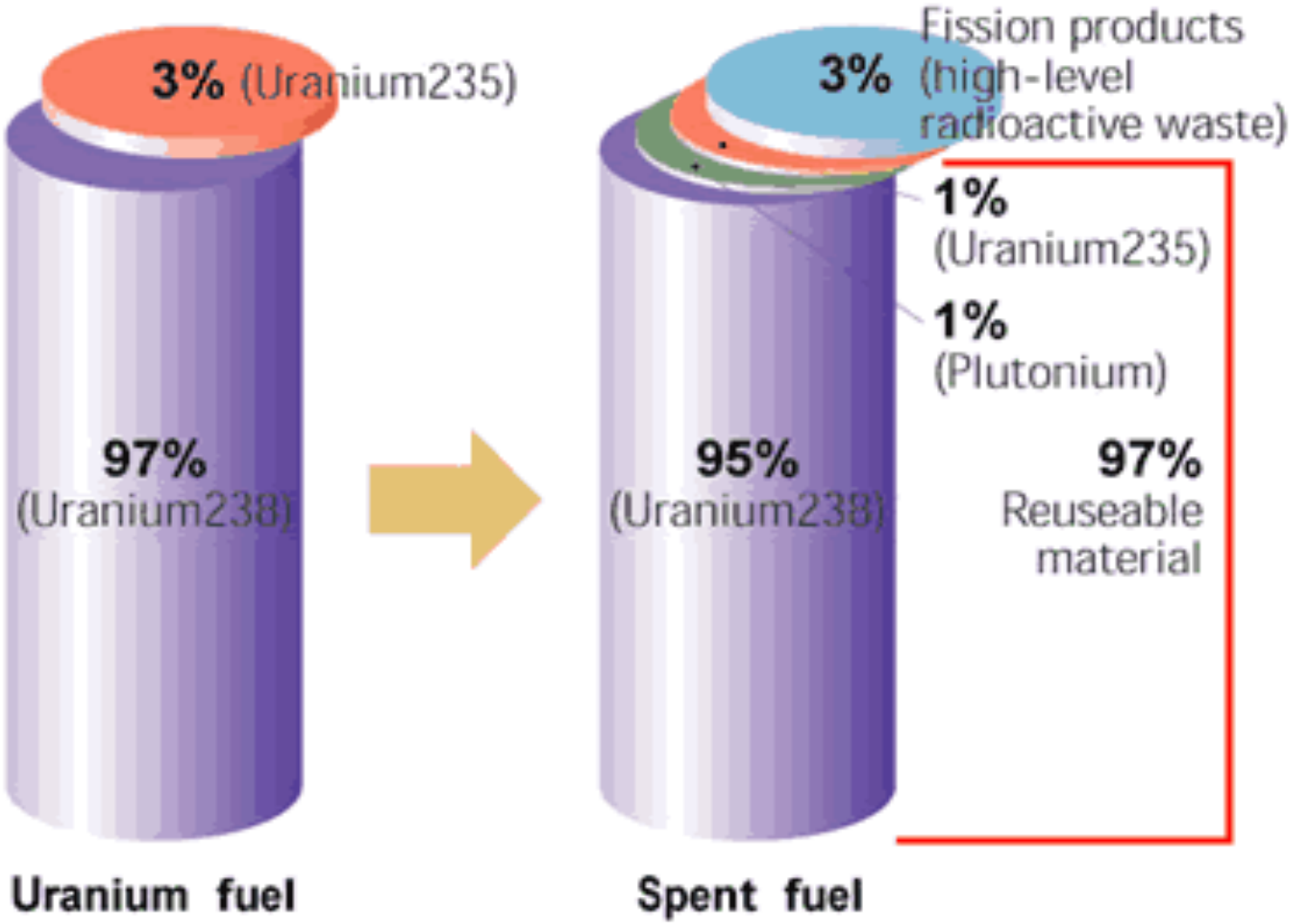



Uranium mining
Mil tailings
Fuel production
Depleted uranium
New fuel
Liquid and gaseous radioactive waste
Power reactors
Production of MOX / URE fuel
Low level waste
Waste from dismantling
Separated fissiles (plutonium, recycled uranium)
Spent fuel
Reprocessing
Used MOX
Unreprocessed fuel
Waste from reprocessing

Transportation of Nuclear Materials



ROYAL INSTITUTE
OF TECHNOLOGY



Countries choice of repositories

Sweden – Deep granitic bedrock repository

Finland – Deep granitic bedrock repository

Canada – In sedimentary rocks, or crystalline bedrock

Belgium – Boom clay, enormous clay natural clay formations

China – So far reprocessing. Prospect of a deep granitic bedrock repository

France – So far reprocessing, but will probably get a deep granitiv bedrock repository

Germany – On hold, probably deep waste disposal in salt domes

India – Research on deep bedrock repositories

Japan – Reprocessing but have decided on a deep bedrock repository

Korea – Envisaged deep geological repository

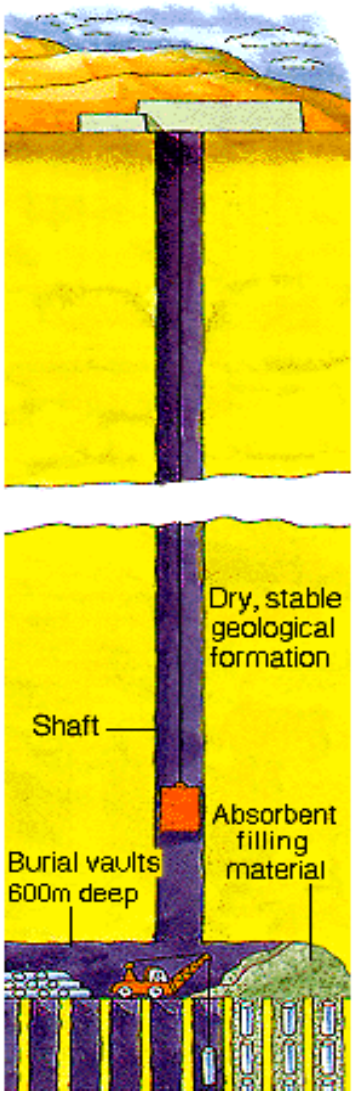
Russia – No waste repository is available, site selections is proceeding in granite in Kola peninsula

Spain – Have research ongoing on deep geological repositories, transmutation and salt domes

Switzerland –Clay formations.

USA – ?

Waste disposal

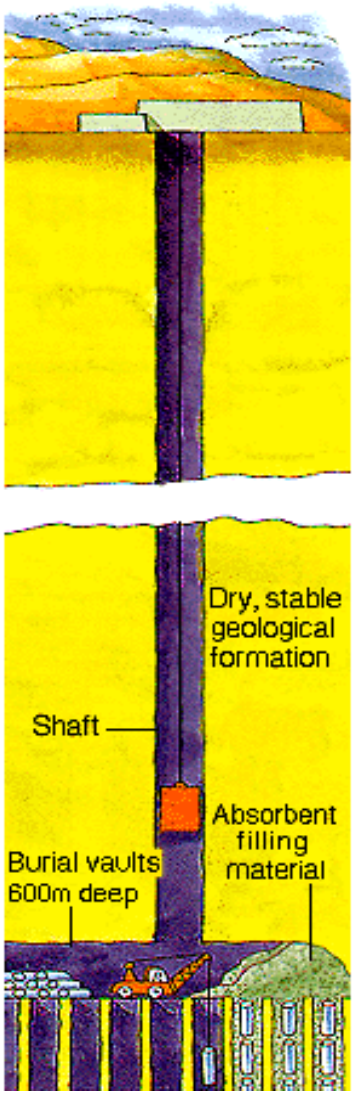


Most favorable: Deep geological disposal

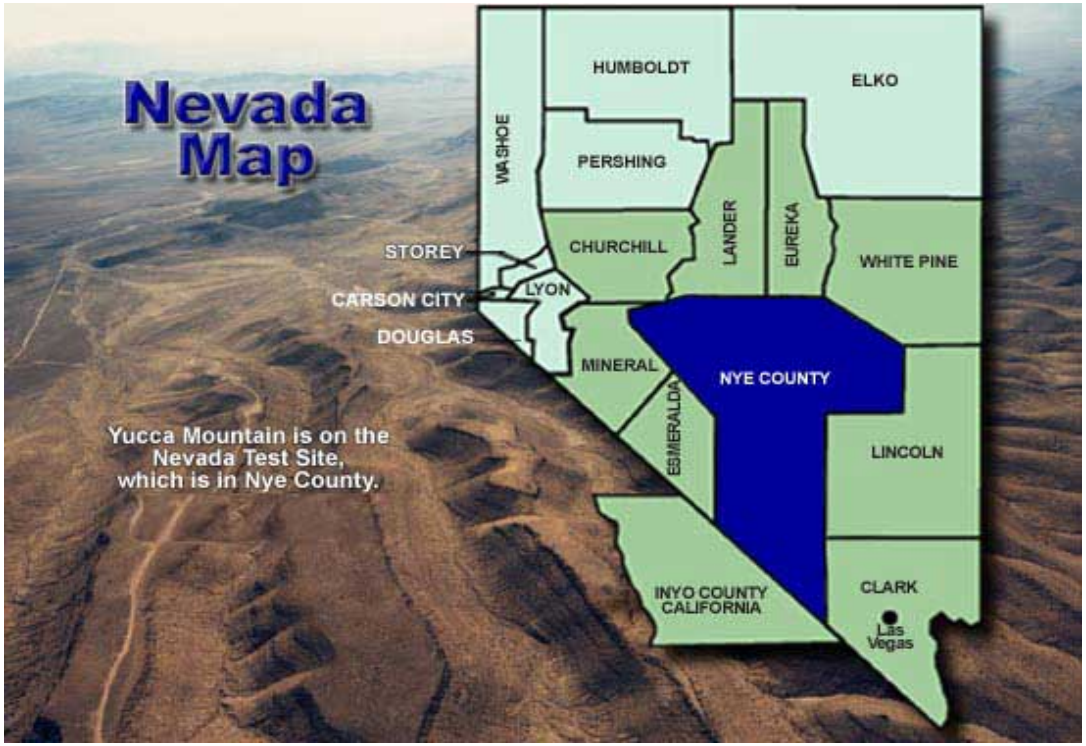
Alternatives:

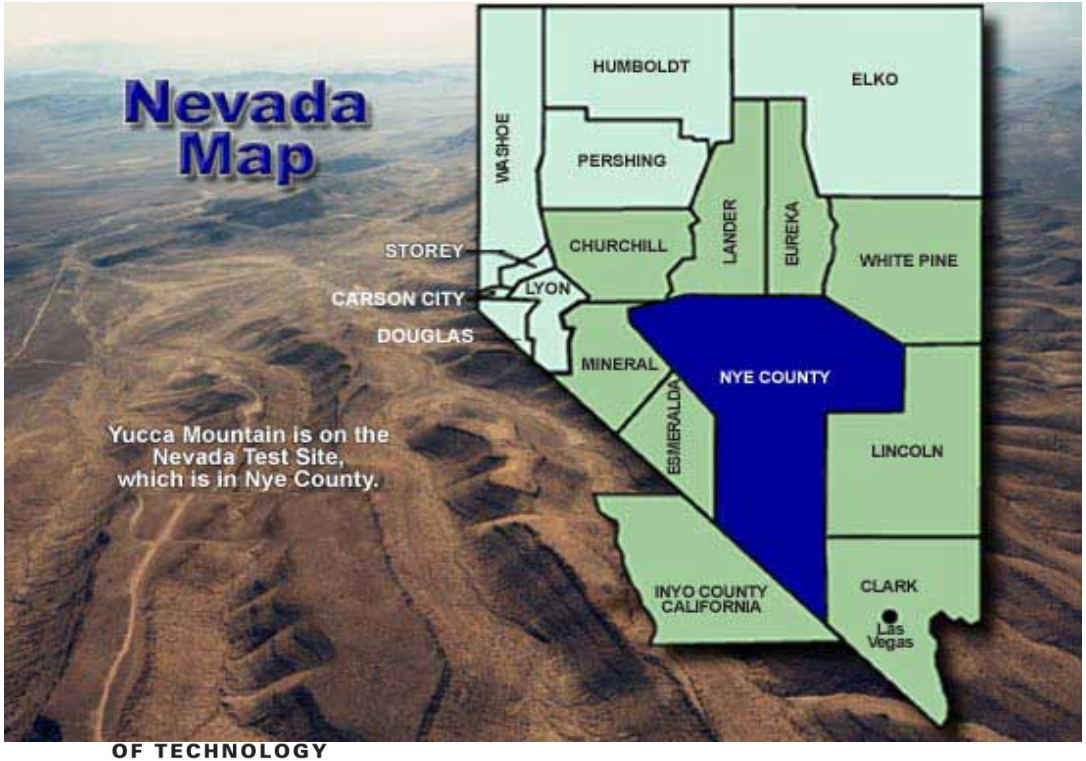
Waste disposal

Deep geological disposal: Basic Idea



Yucca Mountain

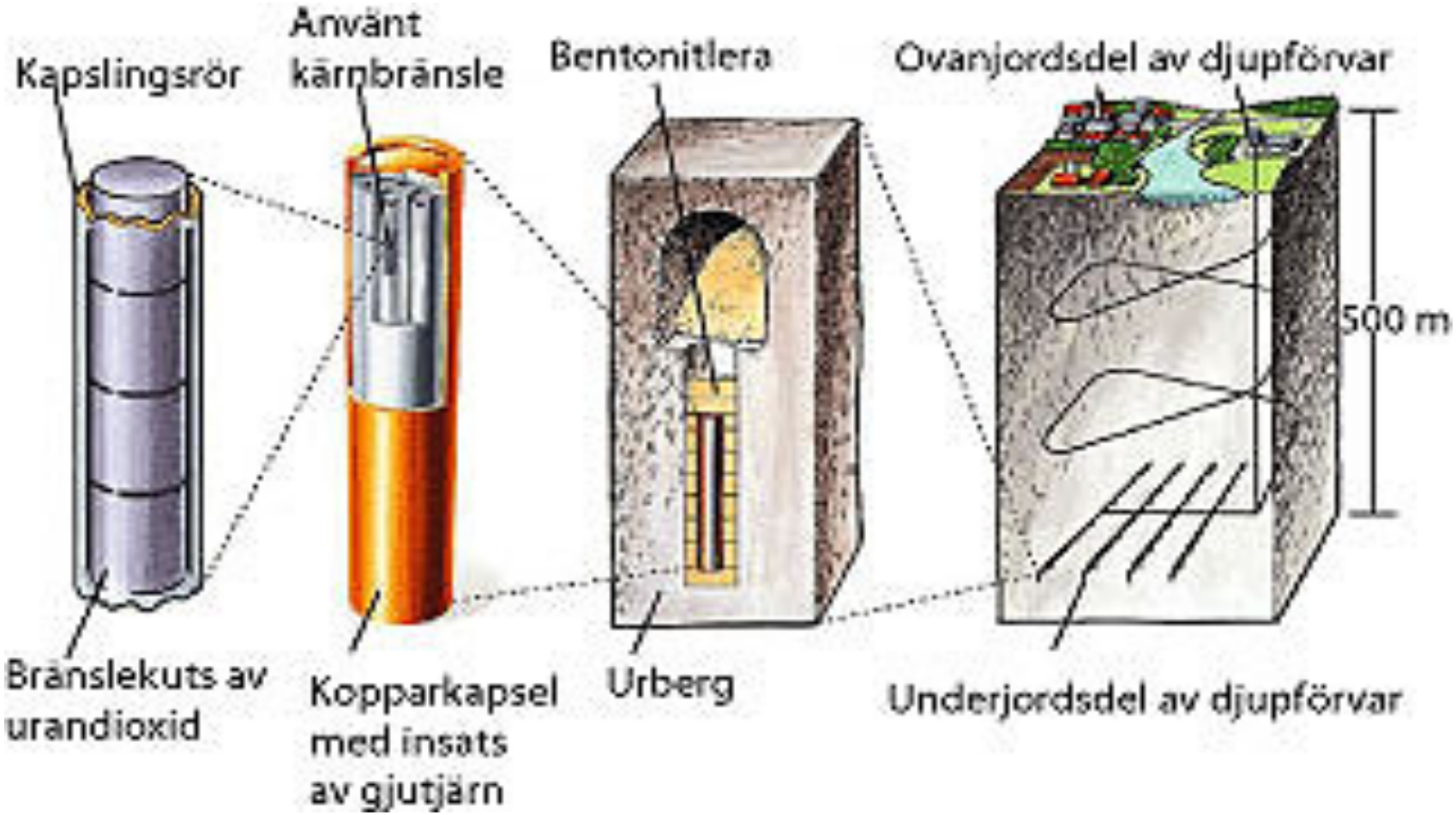




OF TECHNOLOGY

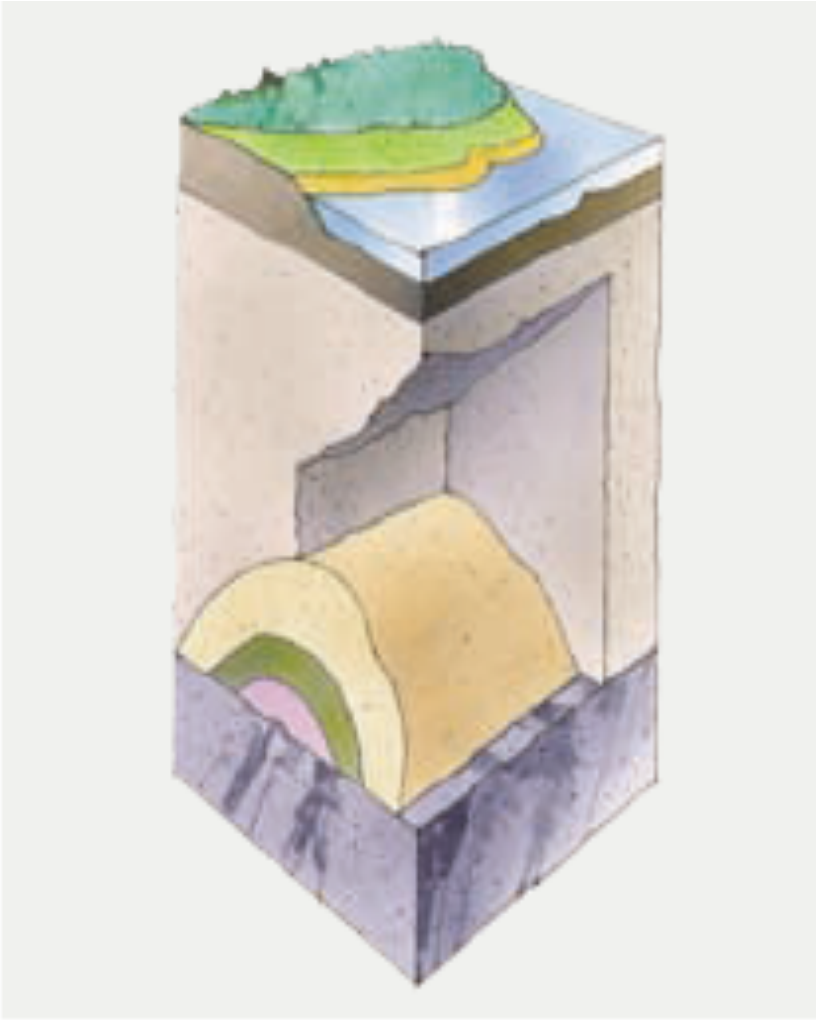
Resistance to water
Minimal rate of water infiltrating the mountain
Cl-36 (isotope from bomb testing in Pacific in the 1950s in a tunnel below the ridge. The only way to get there is by seeping rainwater

KBS-3 model in Sweden



Natural Analogue Oklo, Gabon in West Africa

Natural Analogue Cigar Lake



Uranfyndigheten i Cigar Lake liknar ett djupförvar. Runt malmkroppen finns ett tjockt lager lera.