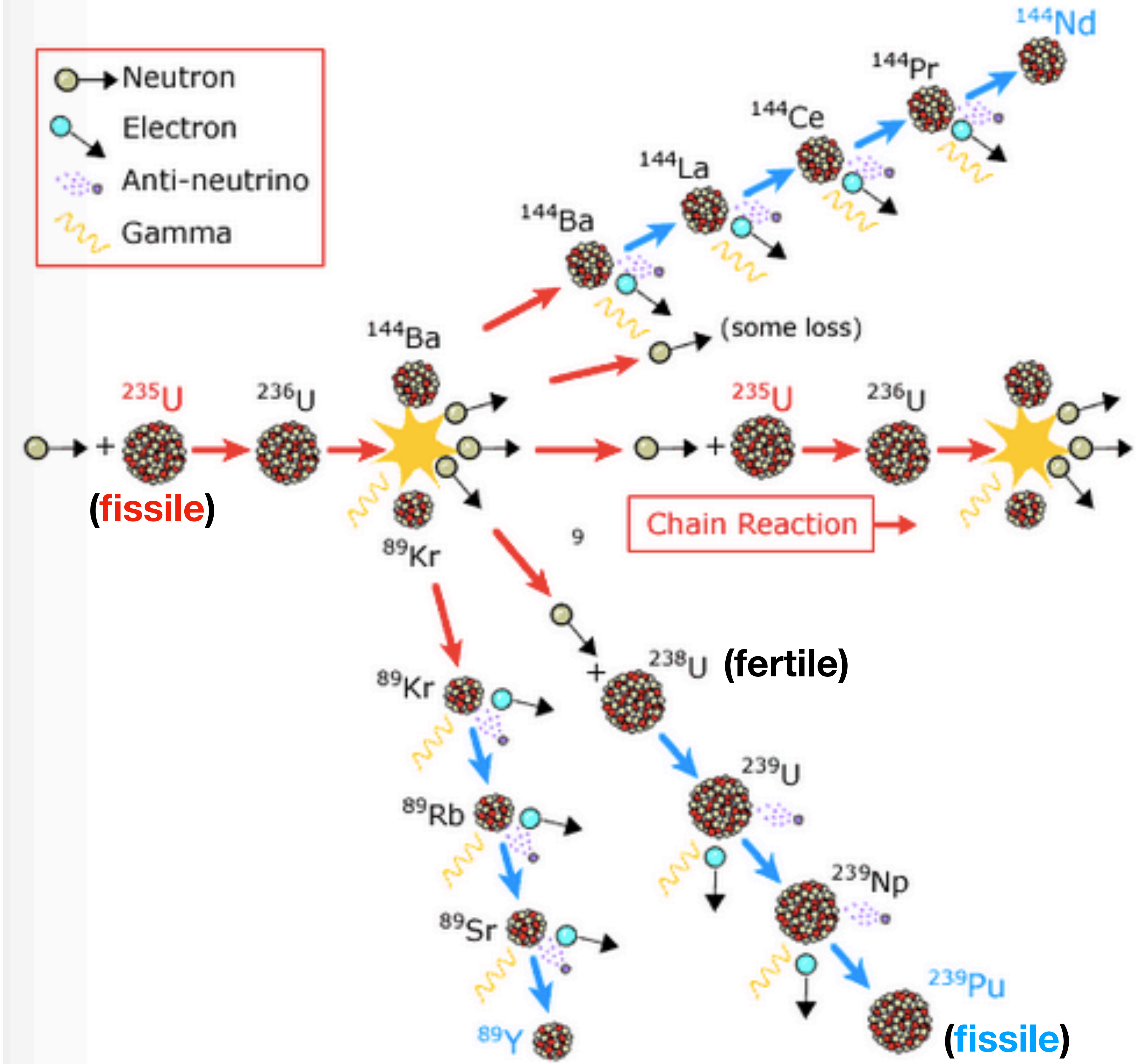
Rad “Waste”

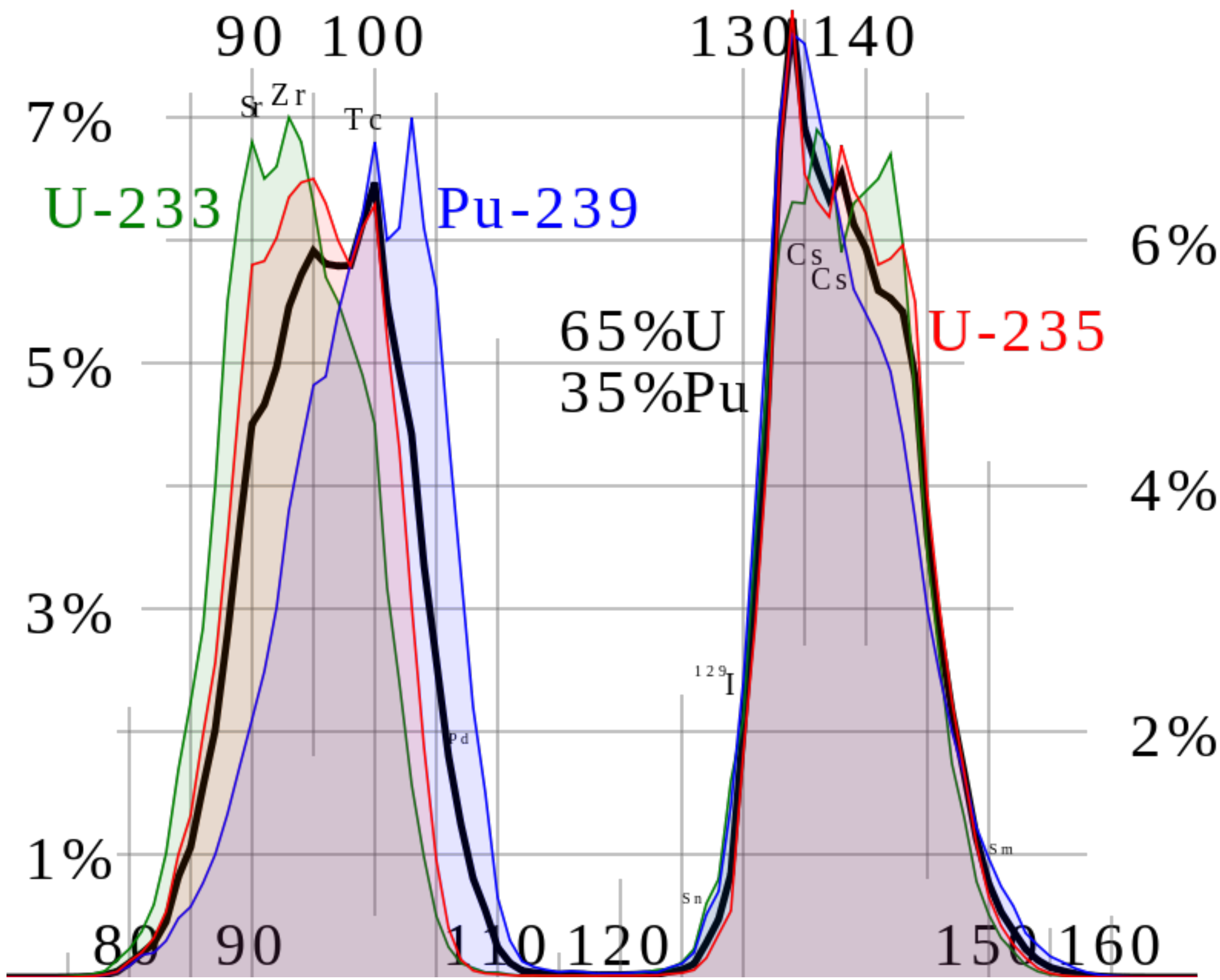
“Spent” fuel from a typical (old) reactor:

- What’s **in** it?
- What does it **do**?
- How **long** does it last?
- **Where** should we keep it?
- Is it **safe**?
- How much does it **cost** to maintain?

Transmutation tricks with Neutrons:



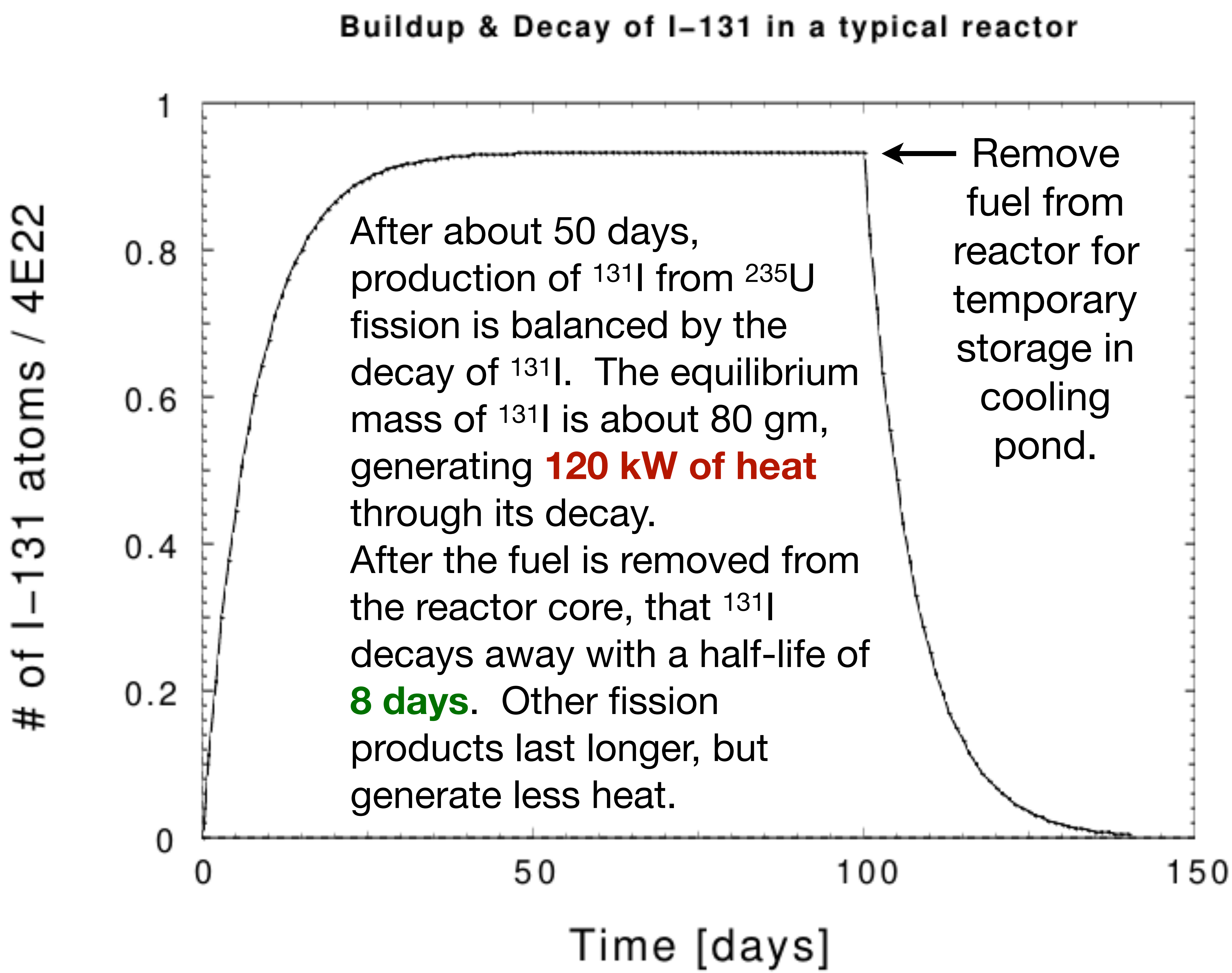
Fission Products



Health Concerns

Isotope	Radiation	Half-life	GI absorption	Notes
Strontium-90/yttrium-90	β	28 years	30%	
Caesium-137	β,γ	30 years	100%	
Promethium-147	β	2.6 years	0.01%	
Cerium-144	β,γ	285 days	0.01%	
Ruthenium-106/rhodium-106	β,γ	1.0 years	0.03%	
Zirconium-95	β,γ	65 days	0.01%	
Strontium-89	β	51 days	30%	
Ruthenium-103	β,γ	39.7 days	0.03%	
Niobium-95	β,γ	35 days	0.01%	
Cerium-141	β,γ	33 days	0.01%	
Barium-140/lanthanum-140	β,γ	12.8 days	5%	
Iodine-131	β,γ	8.05 days	100%	
Tritium	β	12.3 years	100%	[a]

^{131}I inventory



Short-Term Storage

Central Interim Storage Facility (CLAB), Sweden. Image: SKB

Decay of Fission Products

Wikipedia: "The radioactivity in the fission product mixture is [initially] mostly *short-lived* isotopes such as ^{131}I and ^{140}Ba; after about four months ^{141}Ce, $^{95}Zr/^{95}Nb$ and ^{89}Sr take the largest share, while after about two or three years the largest share is taken by $^{144}Ce/^{144}Pr$, $^{106}Ru/^{106}Rh$ and ^{147}Pm."

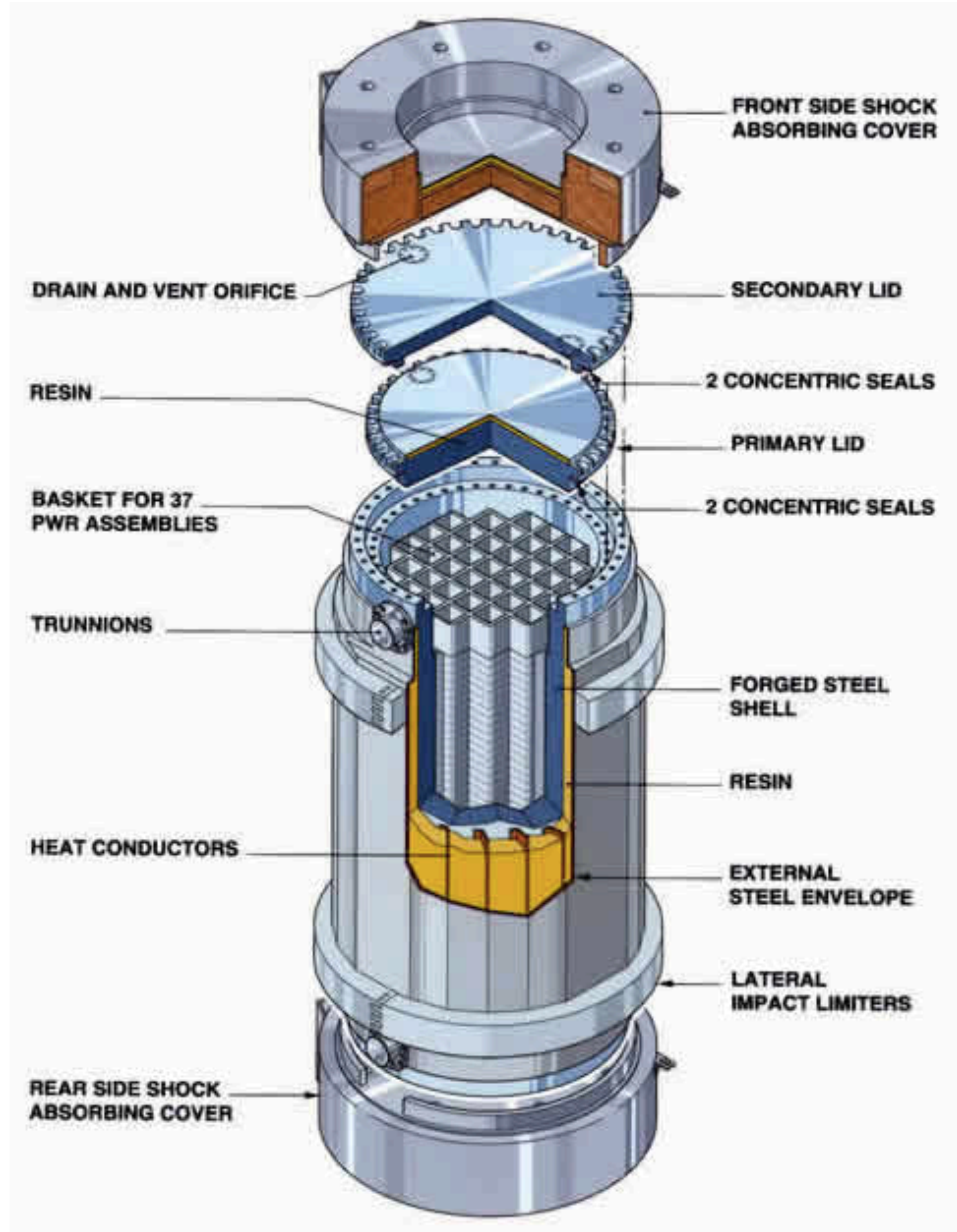
Medium-lived Daughters

Prop:	$t_{1/2}$	Yield	Q *	βγ *
Unit:	(a)	(%)	(keV)	
^{155}Eu	4.76	0.0803	252	βγ
^{85}Kr	10.76	0.2180	687	βγ
^{113m}Cd	14.1	0.0008	316	β
^{90}Sr	28.9	4.505	2826	β
^{137}Cs	30.23	6.337	1176	βγ
^{121m}Sn	43.9	0.00005	390	βγ
^{151}Sm	88.8	0.5314	77	β

Long-lived Daughters

Nuclide	$t_{1/2}$	Yield	Decay energy[a 1]	Decay mode
	(Ma)	(%)[a 2]	(keV)	
^{99}Tc	0.211	6.1385	294	β
^{126}Sn	0.230	0.1084	4050[a 3]	βγ
^{79}Se	0.327	0.0447	151	β
^{93}Zr	1.53	5.4575	91	βγ
^{135}Cs	2.3	6.9110[a 4]	269	β
^{107}Pd	6.5	1.2499	33	β
^{129}I	15.7	0.8410	194	βγ

Accessible Storage ("dry cask")



TN24 cask produced by Orano TN (formerly Areva TN)

Permanent Storage

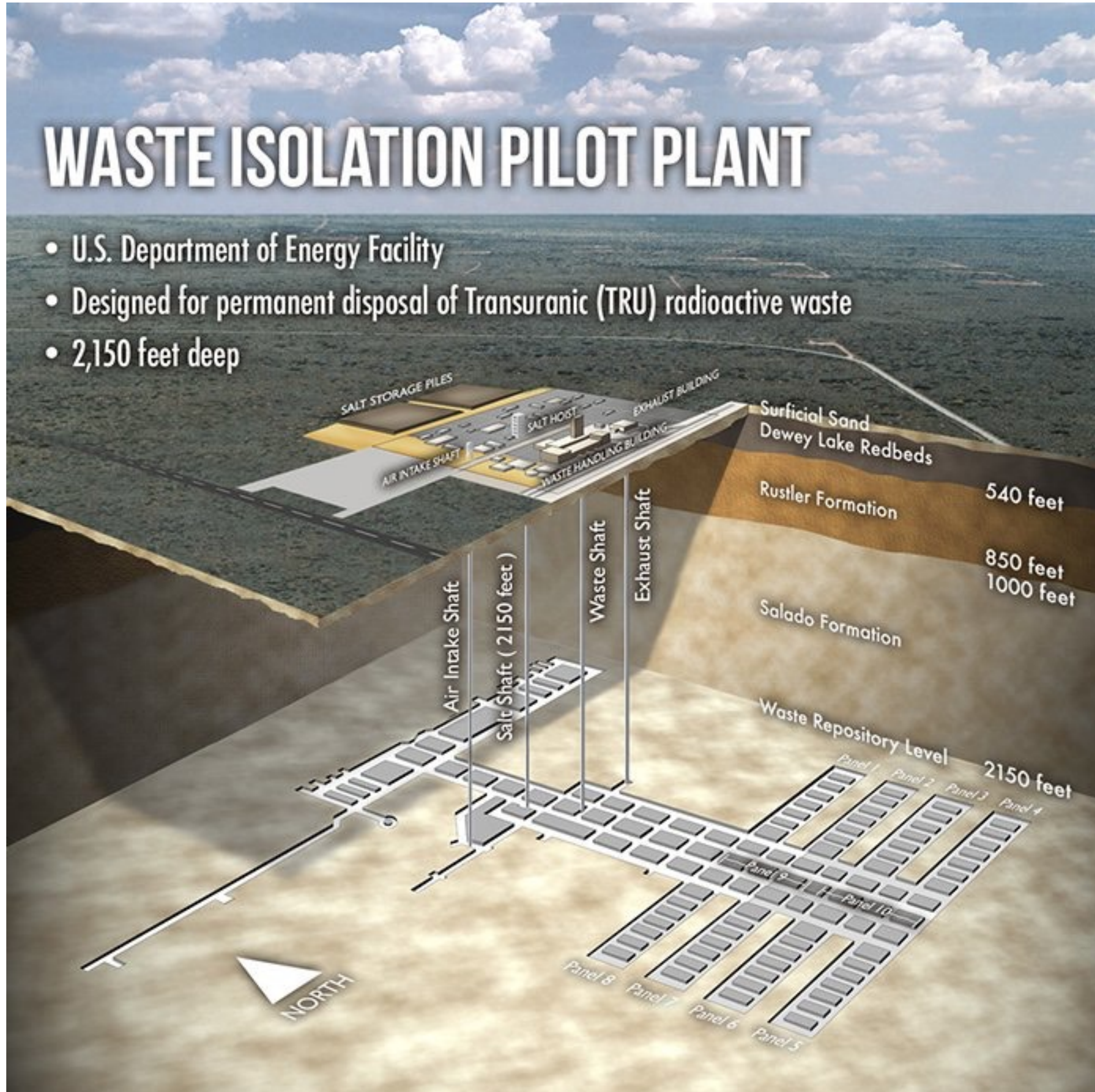
- WIPP
- Yucca Mtn
- France
- Sweden
- Finland

Nuclide	$t_{1/2}$ (Ma)	Yield (%)[a 2]	Decay energy[a 1] (keV)	Decay mode
^{99}Tc	0.211	6.1385	294	β
^{126}Sn	0.230	0.1084	4050[a 3]	βγ
^{79}Se	0.327	0.0447	151	β
^{93}Zr	1.53	5.4575	91	βγ
^{135}Cs	2.3	6.9110[a 4]	269	β
^{107}Pd	6.5	1.2499	33	β
^{129}I	15.7	0.8410	194	βγ

Waste Isolation Pilot Plant (**WIPP**)

US DOE stores rad. waste (from nuclear weapons mfg.) 660 m underground in a salt basin near Carlsbad, NM

A breach in Feb 2014 released a small amount of radioactivity to the local environment. No one was harmed.



Yucca Mountain

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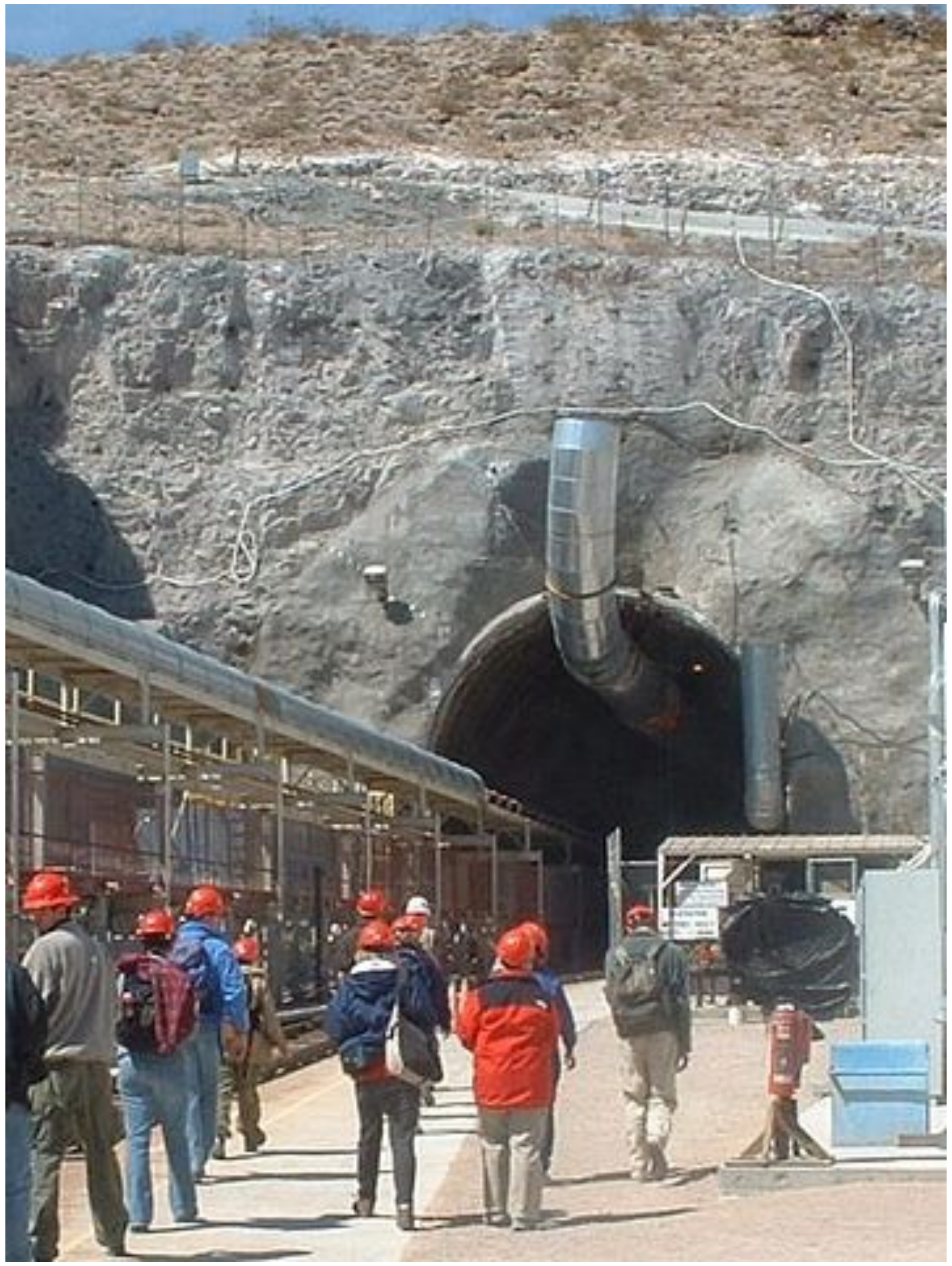

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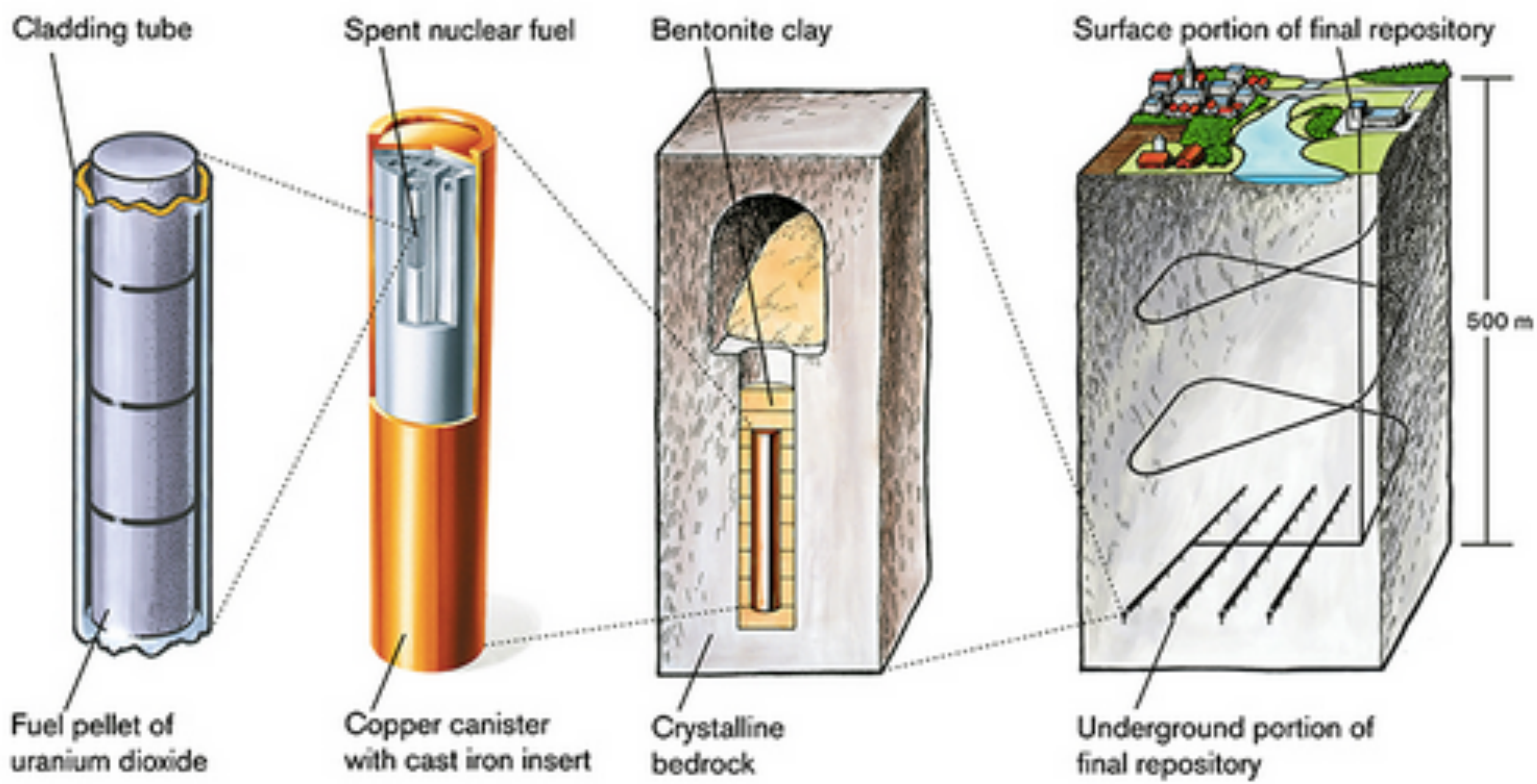
$US 9 billion project (73% funded by tax on nuclear power) cancelled in 2009 due to opposition by Nevada residents (site is 130 km from Las Vegas).

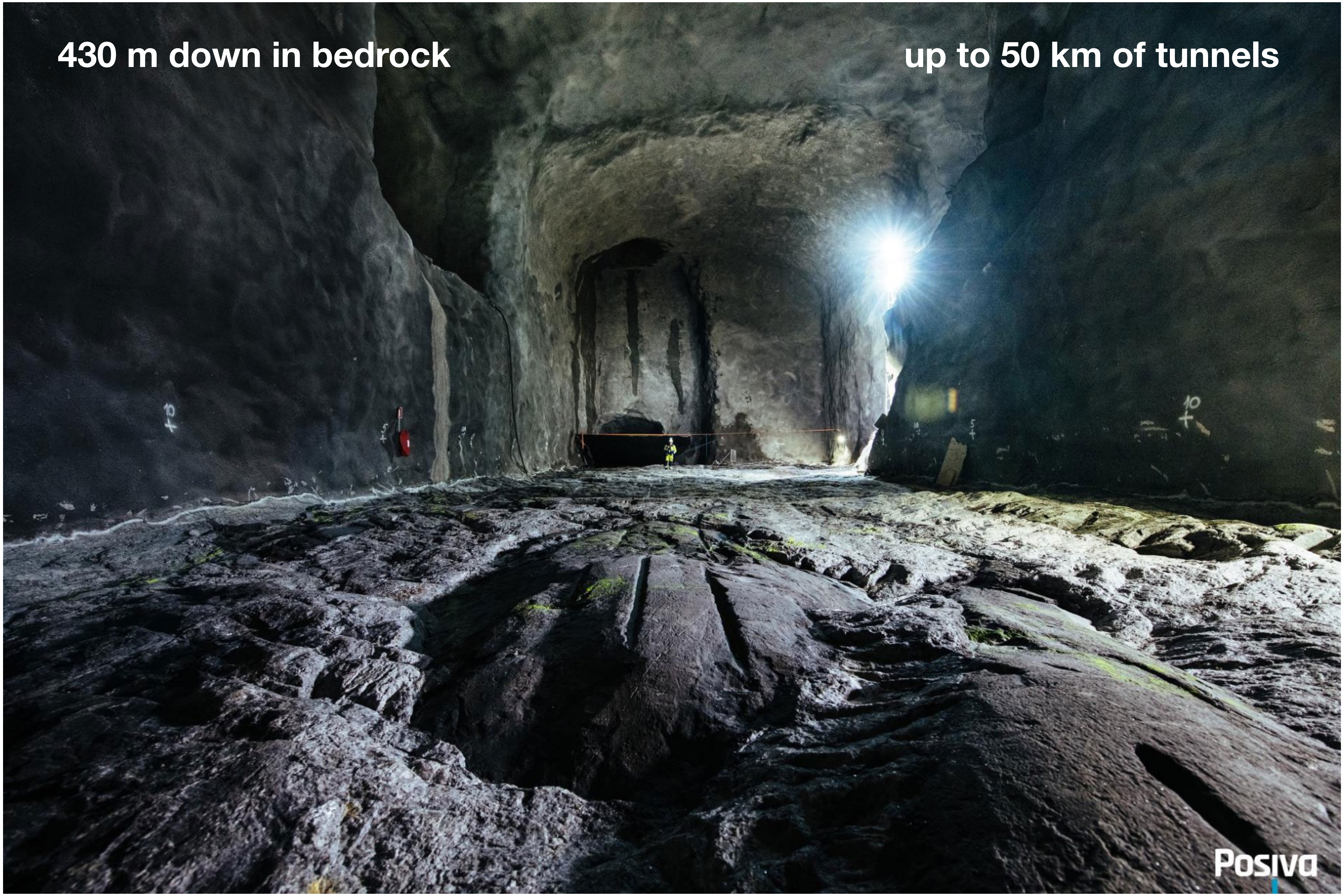
Orano La Hague (France)

SKB: Forsmark, Sweden

KBS-3 method is based on three protective barriers: copper canisters, Bentonite clay and the Swedish bedrock.



Finland: Olkiluoto Island



Canada: ***still thinking about it*.**

The Canadian Shield offers some of the world's most stable deep bedrock — but ***why bury something so valuable***?

Especially when we can use it as ***fuel***
in a **M**olten **S**alt **R**eactor!

MSR
Molten Salt Reactor