Nano-Flex High Level Waste (HLW)

Spent Fuel Rods Recycling & Permanent Disposal

Dimitre Assenov, M.Sc.Eng

A Global Solution

US Patent 8,987,541 B2
WO 2013158196 A2
www.Nanoflex-hlw.com

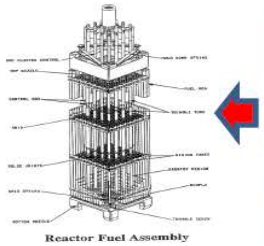
Nano Flex HLW / spent fuel rods recycling and permanent disposal

Dimitre Assenov, Nano Flex HLW, Bulgaria

Glass vitrification issues
Published in
- I Spectrum - August 2015, UK
- Waste Planning - October 2015, UK

Deep Geological Repository
Requires minimum 300 to 1,000 years
(Expected to be raised to 10,000 years minimum)
This requirement is unimaginable and from engineering perspective unsustainable

1600 kg

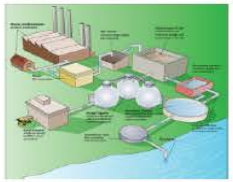


Dissolving

Liquid separation of U + Pu from TRU

liquid waste to be purified

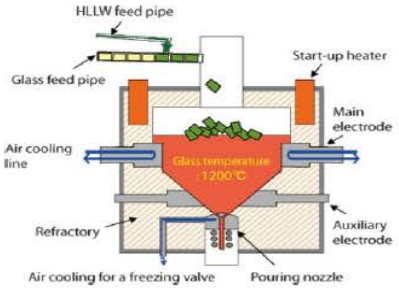
solid waste from filters



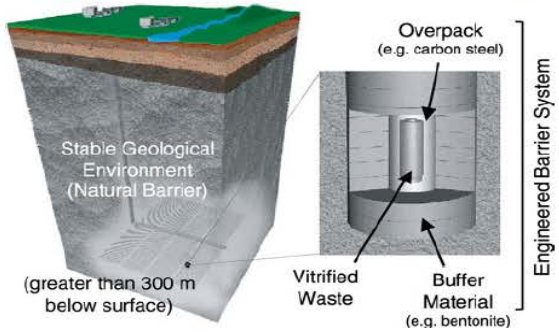
Waste Purification

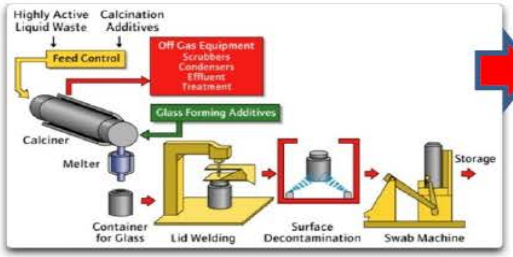
Concentration and Drying

32 - 35 kg isotopes (dry)

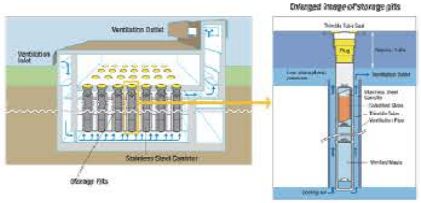


Existing Model



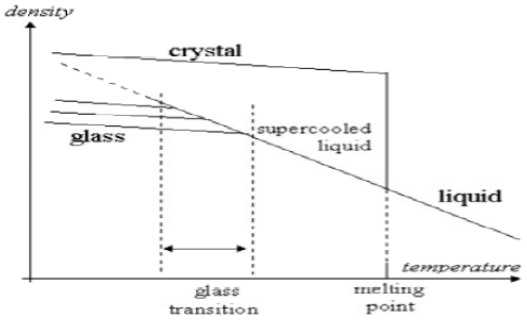


Temporary Storage for High-level Radioactive Waste (Vitrified Waste)

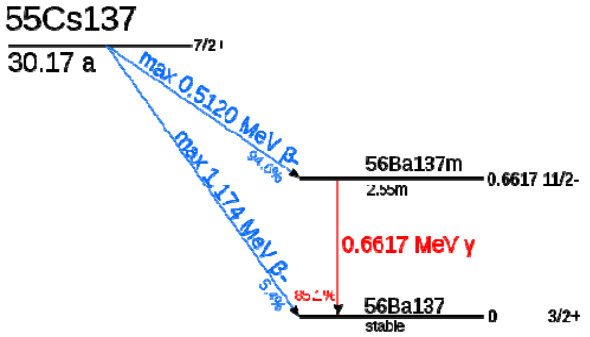


All existing modeling and experiments related to glass dissolution in water media

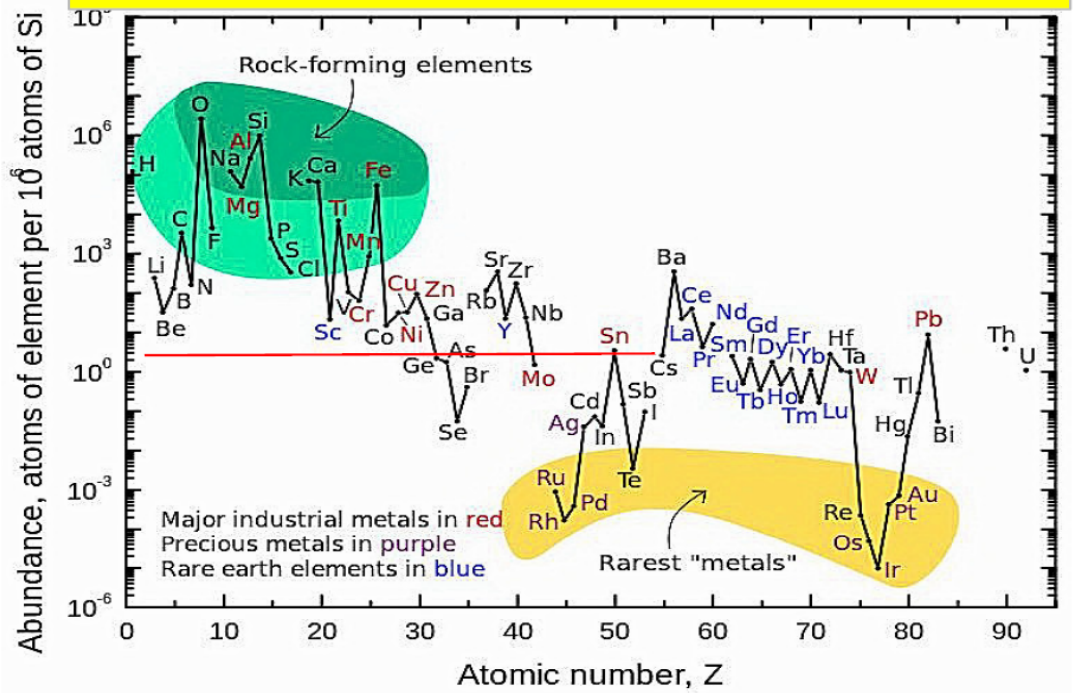
Such target modeling indicates that water is expected to be a considerable component in existing HLW geologic repository soluion

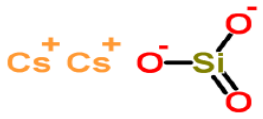


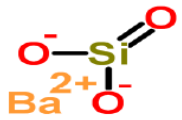
Density as a function of temperature in the phases of glassy materials



New Glass Vitrification Issues





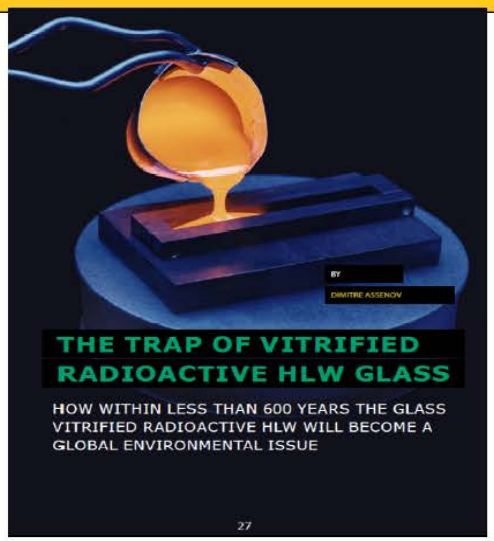


Cesium References:

Content in US Spent fuel - 23.11% (6 yr.)
Content in AREVA Spent Fuel -31.66% (NCE)
Content in US Sludge after recycling - 15.226 % (6 yr.)

After 603.4 years, the formed Barium Silicate requires an additional 30.452% volume.
This comprises 11.267% additional space in vitrified glass (63% glass 37% HLW).
Further transition to Barium Feldspar (known as solid dissolution) from initial composition of a tetrahedral lattice M(Al,Si)O2 to final form, which exists in nature Ba(Al2Si2)O8, will require much greater space.

The example is for only one isotope - Cesium. Similar processes for other isotopes would have a different time frames. The combined result of this natural process requires much greater space, compromising the integrity of the metal containers. This will be followed with formation of water condensation. Once this process starts, the final result will be an irreversible and uncontrollable environmental disaster with unknown consequences, undermining the current model of using deep geologic repositories.



Radioactive waste

The problems with vitrification

The common practice to deal with high-level radioactive waste through vitrification in heat-resistant glass is not as safe as we might think, warns ***Dimitre Assenov***. We should not ignore the perils at the expense of future generations

The main technology used for dealing with high-level radioactive waste (HLW) — vitrification in borosilicate glass (see box) — makes a number of critical assumptions. The first is that amorphous glass can sustain HLW with no significant degradation or release of radioactive materials over time. A key assumption for containment is based on the existence of ancient archeological glass artifacts, as well as computer models for borosilicate glass.

However, computer simulation itself is based on some incomplete or ungrounded assumptions. The limited laboratory tests for glass ageing — repeatedly heating and cooling the glass — ignores an important point that, unlike a crystalline matrix, the amorphous material very often sustains unexplained reversing to ageing results.

There is only one ongoing experiment to assess the ageing of amorphous glass for HLW vitrification, which is currently in its 16th year of testing in China.

Vitrification How it works

The glass vitrification process is based on forming borosilicate glass in an amorphous composition at a melting temperature of around 650°C. At this temperature, the glass matrix prevents evaporation of the selected radioisotopes, such as caesium. The next step is mixing the melted amorphous borosilicate glass with solidified HLW in proportions of around 63-67% glass and 33-37% solid HLW material.

The hot mix produced is poured into stainless steel containers and left to solidify. Once complete, the glass-encased HLW is placed into a stainless steel container that is encapsulated with a welded cap. The product may be stored in a deep geological repository, such as Carlsbad in New Mexico, US.

The process is based on the assumption that bedding the radioactive materials in multiple metal corrosion-resistant containers will keep the glass/HLW matrix stable until the decay levels have dropped below biohazard levels. The existing modelling assumes that minor volume expansion during the decay transition is not affected by major mineral geo-chemical transitions.

KBS-3: Swedish capsule for spent nuclear fuel

This paper raises concerns over key missing elements in the modelling process. The first ungrounded assumption is that the glass melting temperature is significantly higher than the radioisotopes' evaporation temperature. This threshold of glass transition will be narrowed significantly after applying pressure that was partially considered in the vitrification. The vitrified HLW generates heating and will remain at a temperature of 500 550°C for several hundred years.

The container volume is constant and, at some point, the pressure inside the stainless steel container will start to rise. As a result, the super-cooled liquid threshold will fall, bringing the solid glass into a semi-softening state. The combination of the rises in temperature and pressure of the amorphous glass matrix will first result in the formation of caesium silicate. The required oxygen atom will come initially from the caesium oxide in the HLW or silicon dioxide packets in the glass.

During this crystalline lattice formation, the newly formed caesium silicate will require additional space inside the amorphous glass matrix. As a result, the atoms re-arrange themselves in the much larger lattice compared with the amorphous one. As density increases, these new crystals put ever more pressure on the amorphous glass, until it breaks in order to release the internal stresses.

The ventilation and water drainage systems of the deep geological repository are presumed to accommodate all external water condensation in the tunnel. It is the condensation and vapours inside the steel containers and large metal canisters that raises concerns. This water will react with metal silicates and turn them into complexes of calcium, sodium, potassium and barium alumina silicates.

At elevated temperature and pressure for significant hundreds of years, the amorphous borosilicate glass will undergo partial or complete transition into a complex crystalline lattice formation.

Caesium decays to stable barium within 30.17 years. This means that within 20 radioactive half lives almost the entire amount of caesium in the HLW will turn into stable barium. We must consider one specific mineral that occurs in nature as a by-product of the caesium decay – barium silicate to barium feldspar. In the HLW caesium appeared in the form of gas and oxide.

After completing the 20 half lives decay time (603.4 years), the formed barium silicate will require at least twice the volume of 20.45 per cent from the total HLW volume, or 11.27 per cent (63 per cent glass, 37 per cent HLW) additional volume from the total of the original glass vitrification matrix.

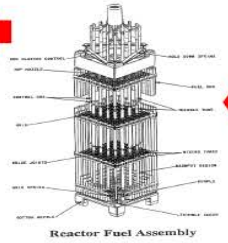
This raises concerns that most of the encapsulated steel containers will sustain significant volumetric changes such as cracks or ruptures, which will compromise the entire glass vitrification process. This will have disastrous consequences, because the entire geological repository will become highly contaminated and will be difficult to maintain and control. Additional problems will arise in preserving the engineering barrier for an extended geologic time, with unknown bio-hazard consequences.

This paper raises questions over the sustainability of HLW glass vitrification. The explained physical and geo-chemical processes are well known in disciplines such as geology, mineralogy and geochemistry. Simply assuming a good outcome after 1,000 or 10,000 years by using technically easy and cheep method for sequestering radioactive HLW will put our credibility and responsibility to the future generations in question. ■

Dimitre Assenov is the owner and operations engineer of Nano Flex HLW, Salt Lake County, Operations, Utah, US

Dismantling with Cryogenic Cooling

Gas Isotope Separation Volatization in Isolation


Reactor Fuel Assembly

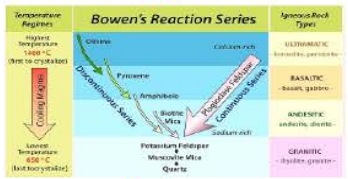
Liquid Separation of U + Pu from TRU in Vortex Apparatus

From 1 kg spent fuel remained 15g liquid Isotopes per liter Sludge

Fly Ash

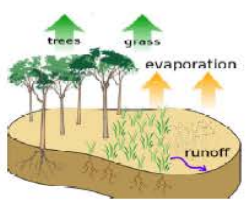
Liquid HLW mixing with Fly Ash (JMF)
Setting Time required to form


Fly Ash Melting Furnace



Crystallization &

Final Product



Top Soil and Vegetation

+

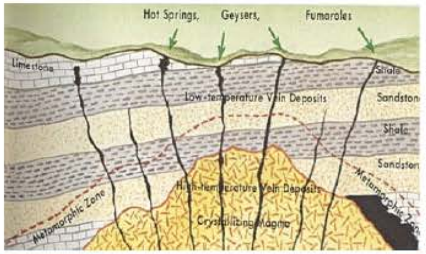
Engineering fill covered with clay/gravel Cap

Closed quarry / open pit mine

Permanent Geological Disposal

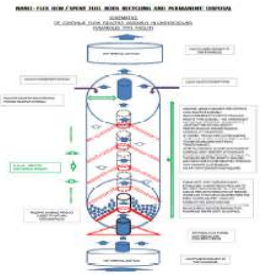
OR

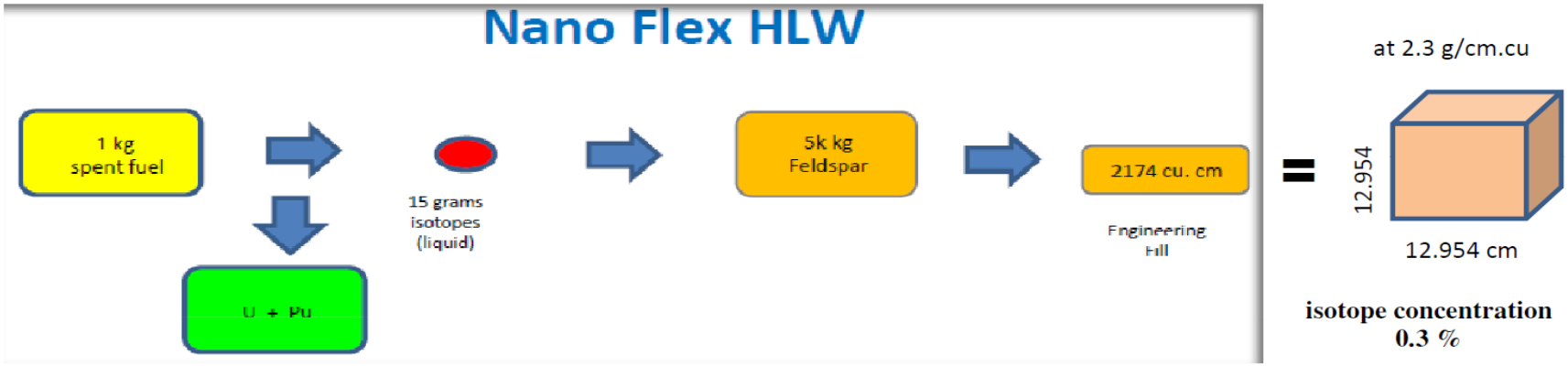
Dry Fumaroles Disposal



Permanent Geological Disposal

Nano Flex HLW





YES this is New type completely safe Geologic Disposal

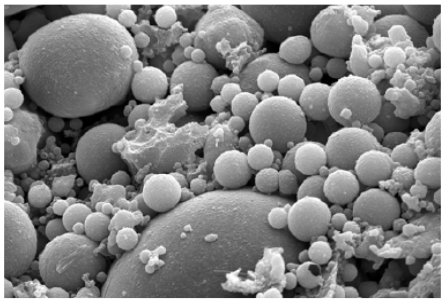
- NO additional produced waste to purify
- NO sky-shine radiation
- NO environmental footprint during commission, operation and decommission
- NO engineering barriers to maintain
- NO time required for maintenance of the disposal site (min 300 to 1000 years).
  Monitoring
  Proactive maintenance
- NO issues with exhumation, intrusion, proliferation or terrorist acts
- NO transport safety issues

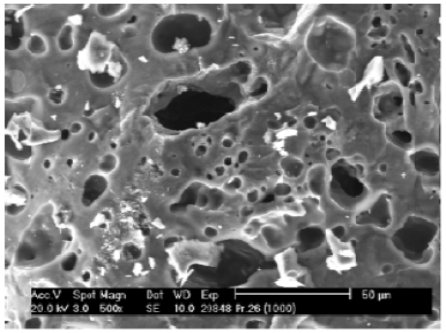
- Avoids liability transfer - most HLW storage companies are incorporatied as LLCs
- Detachable, mobile very low cost facility
- Product detectable very low radiation - less than 90cm in air; reduced to 0cm under the Cap
- One time cost of $160/kg for recycling and final disposal
- Applicable to all types and forms of radioactive HLW such as spent fuel, depleted uranium, medical and / or industrial HLW, nuclear incidents , nuclear detonation cleanups, mine tailings, Chemical or Reactive HLW, other industrial HLW wastes
-Avoids all issues associated with glass vitrification and existing geologic repository models

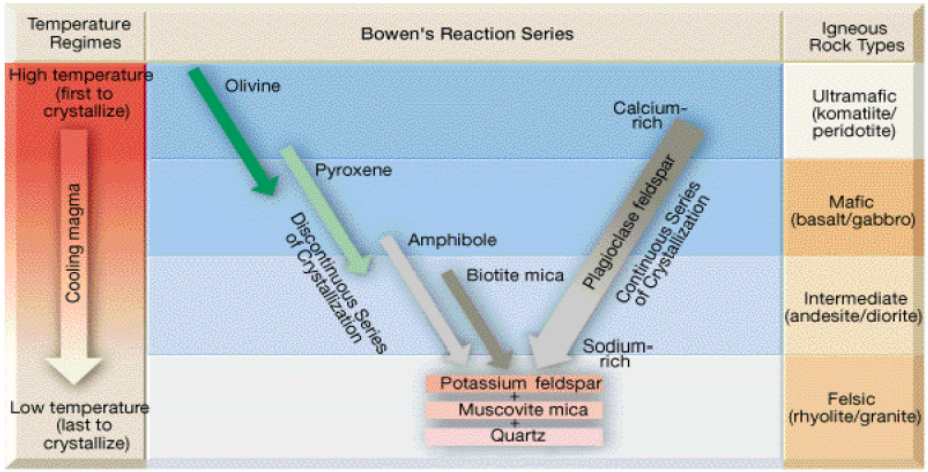
Nano Flex HLW is the first ever creation of an artificial geo polymer, mimicking feldspar, which comprises over 50 % of the Earth's crust and is a natural isotope carrier
Once Nano Flex HLW product is deposited, will follow without human interruption the natural mineral metamorphosis transition as was done for the pass 4,5 billion years .

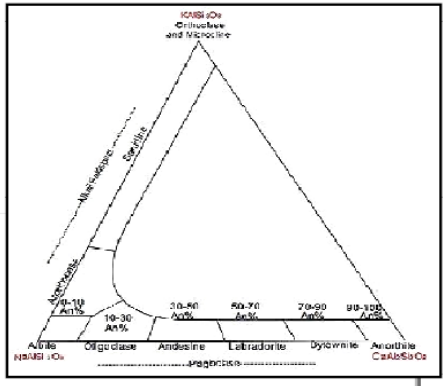
FLY ASH COMPOSITION

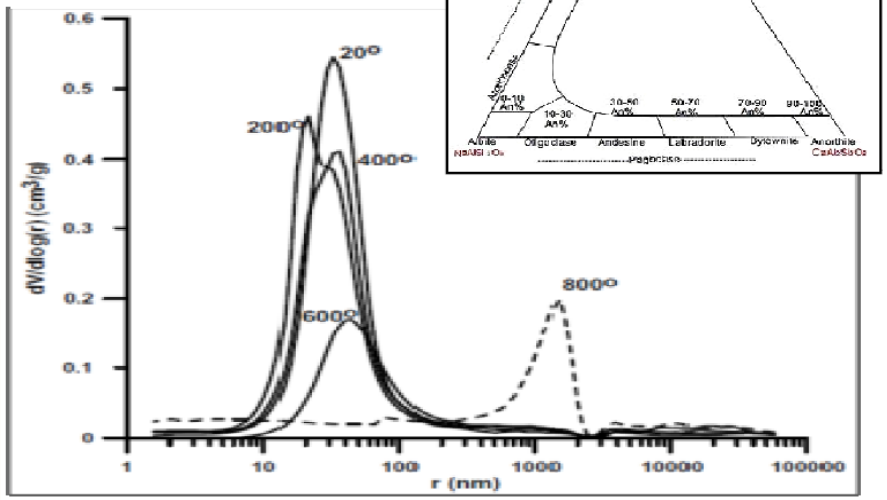
	BOYCE LA	MT. PLEASANT TX	MANSFIELD LA	TATUM TX
SiO2	37.77	55.61	58.52	48.7
Al2O3	19.13	19.87	20.61	16.6
SiO2/Al2O3	1.97	2.80	2.84	2.93
SiO2+Al2O3	56.90	75.48	79.13	65.3
CaO	22.45	12.93	5	18.72
Fe2O3	7.33	4.52	9.43	6.93
MgO	4.81	2.49	1.86	3.91
SO3	1.56	0.49	0.49	0.85
Moist. Content	0.12	0.02	0.14	0.12
LOI	0.17	0.22	0.05	0.49
Finess (% passing 325)	99.2	77.30	82.05	97.4



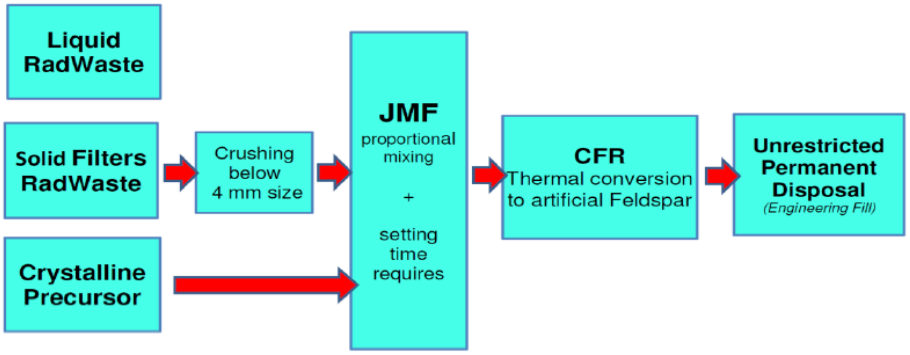








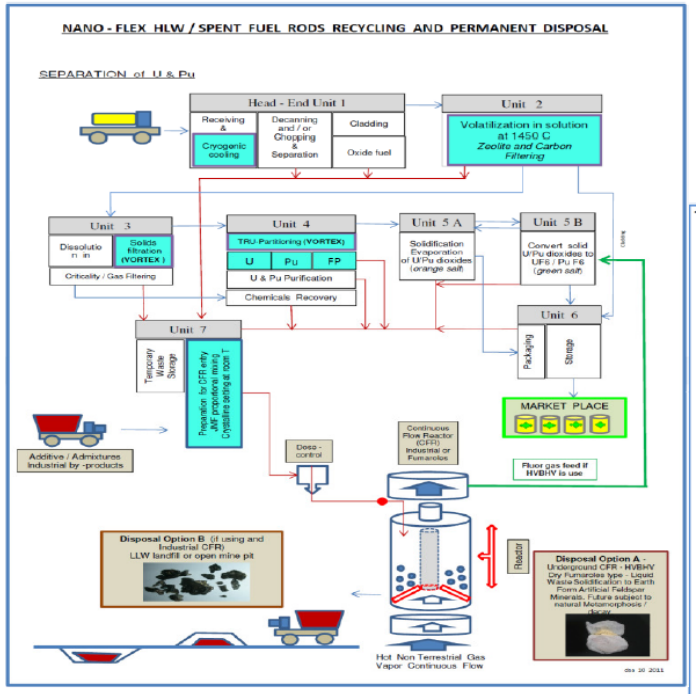
Feldspars are a well-understood Alumina-Silicate entity formed in accordance with Bowen's Reaction Series, which describes the order of crystallization of the common silicate minerals that form at specific temperatures as magma cools.

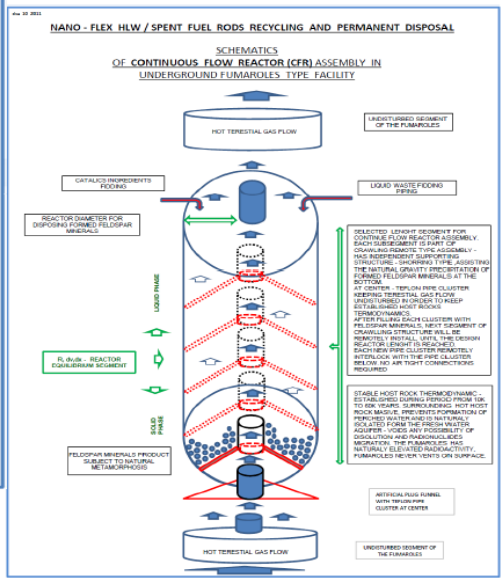


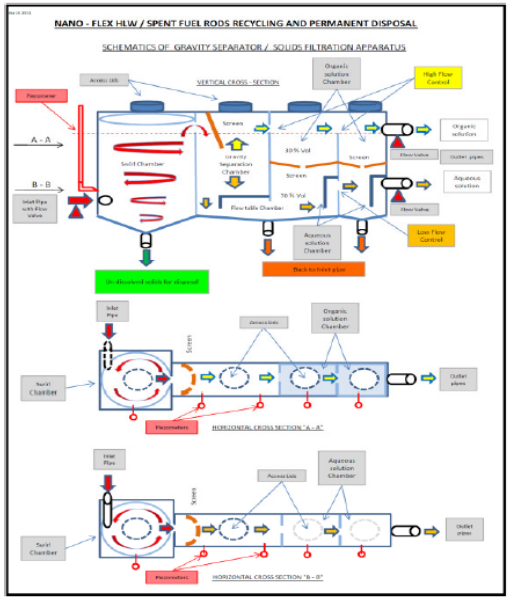
Pellet formation is an easily deployed and cost effective technology. The melted matrix is dropped over a quickly rotating hedgehog cylinder, ejecting droplets with almost perfect spherical geometry promoting quick air-cooling crystallization (prevent s growth of large crystals) and surface coating with Crystalline Silicon Dioxide. The droplets land in a shallow, hot water basin where a bottom elevator quickly moves them into a silo for final air-cooling.

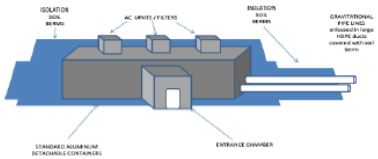
This process completely washes the pellets, depositing the remaining dust in water. This mixture is later used for the initial mixing with fly ash. This avoids any production of additional waste and purification.

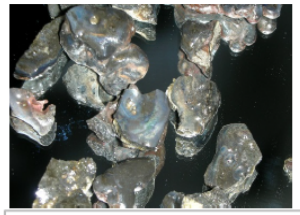
At decommision, all equipment, including the front-end production modules, are dissolved, mixed with fly ash, and converted to artificial feldspar, avoiding a contamination footprint.

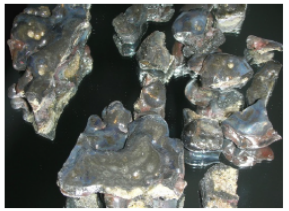












IGD-TP FORUM PROPOSAL TO CONSIDER RESEARCH & DEVELOPEMENT PILOT PROGRAM FACILITY

A PRACTICAL AND LOW COST APPROACH TO DEMOSNTRATE THE ADVANTAGES OF THIS UNIQUE RECYCLING AND PERMANENT GEOLOGICAL DISPOSAL TECHNOLOGY

Economics

HLW	Current	N. FLEX
1. Spent Fuel Recycling	$1400/kg	$160/kg
2. Glass Vitrification	$560/kg	0
3. Stainless Steel Container	EU $160K	0
4. Titanium Cask	$250K - $5M	0
5 Disposal cost	$550/kg	0
6. Transportation cost	Yes	No
7. Safeguarding - recycling	Yes	No
8. Safeguarding - storage	Yes	No
9. Recycling facility cost	> $2B	$5M-$20M
10. Decommissioning cost	Yes	0
11. Purification facility cost	> $ 1.2B	0
12. Glass Vitrify. facility cost	> $240M	0
13. Interim storage cost	$18B	0
14. Interim storage decommission	Yes	0
15. Deep Geologic storage cost	> 28B	0
16. Geologic storage maint. 1000y	Y	0
17 Geologic storage safeguard 1Ky	Y	0
18. Miscellaneous cost	Y	0
19. Incidents cost	Y	0
20. Remediation cost after 1000 y	Y	0
21. Production/ recovery cost	Y	0
22. Other cost as go	Y	0

Other Advantages & Benefits

	HLW-GV/DGR	N.FLEX HLW
1. Proliferation / exhumation	Yes	No
2. Intrusion / Terrorism	Yes	No
3. Glass Vitrification	Yes	No
4. Geologic Disposal w/t maintenance	Yes	No
5. Steel encapsulating containers	Yes	No
6. Titanium Casks	Yes	No
7. Transportation cask	Yes	No
8. Recycling facility	Yes	Yes
9. Purification facility	Yes	No
10. Interim storage	Yes	No
11.Remote handling	Yes	No
12. Licensing for recycling	Yes	Yes

Questions

Thank you!