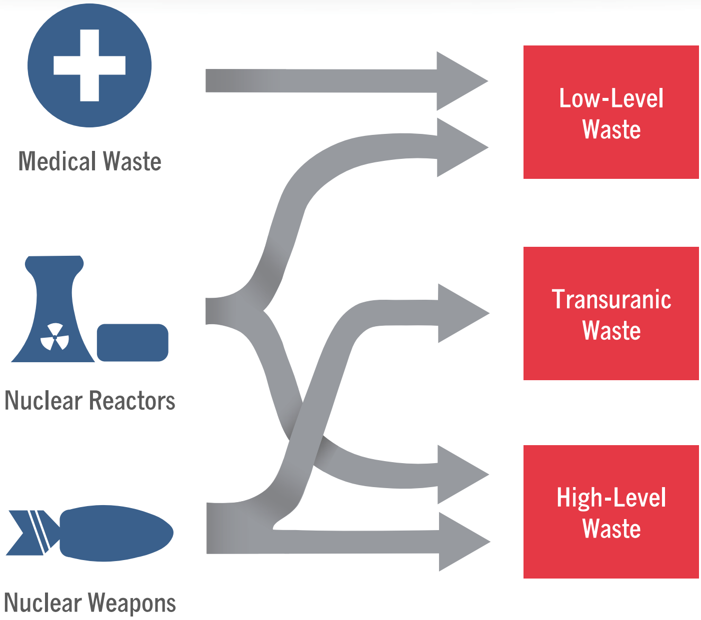
The Nuclear Waste Primer

September 2016

BIPARTISAN POLICY CENTER

What is **Nuclear Waste?**



Nuclear waste is the catch-all term for anything contaminated with radioactive material. Nuclear waste can be broadly divided into three categories:

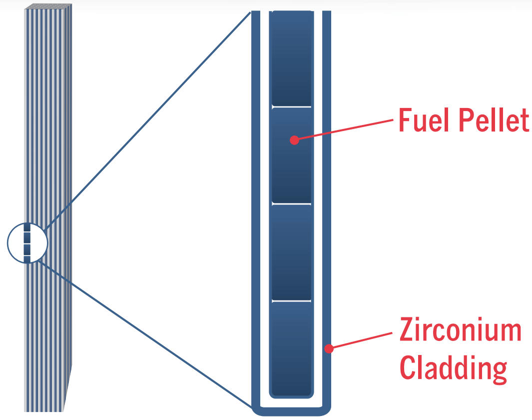
- Low-level waste (LLW), comprised of protective clothing, medical waste, and other lightly-contaminated items
- Transuranic waste (TRU), comprised of long-lived isotopes heavier than uranium
- High-level waste (HLW), comprised of spent nuclear fuel and other highly-radioactive materials

Low-level waste is relatively short-lived and easy to handle. Currently, four locations for LLW disposal exist in the United States. Two of them, Energy Solutions in Clive, Utah and Waste Control Specialists in Andrews, Texas, accept waste from any U.S. state.

Transuranic waste is often a byproduct of nuclear weapons production and contains long-lived radioactive elements heavier than uranium, like plutonium and americium. Currently, the U.S. stores TRU waste at the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico.

High-level waste includes spent nuclear fuel and the most radioactive materials produced by nuclear weapons production. Yucca Mountain is the currently designated high-level waste repository for the United States.

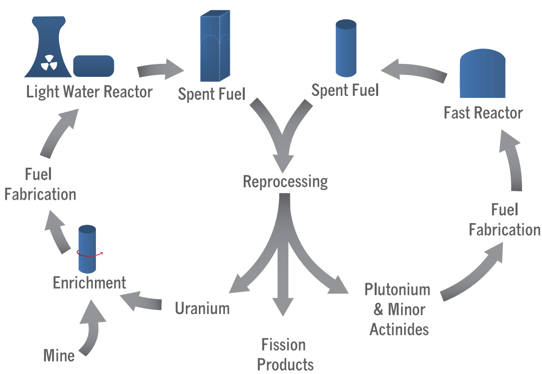
What is Spent Nuclear Fuel?



Spent nuclear fuel (SNF), alternatively referred to as used nuclear fuel, is the primary byproduct of nuclear reactors. In commercial power reactors in the U.S., fuel begins as uranium oxide clad in a thin layer of zirconium-aluminum cladding. After several years inside of the reactor, around five percent of the uranium has been converted in some way, ranging from short-lived and highly radioactive fission products to long-lived actinides like plutonium, americium, and neptunium.

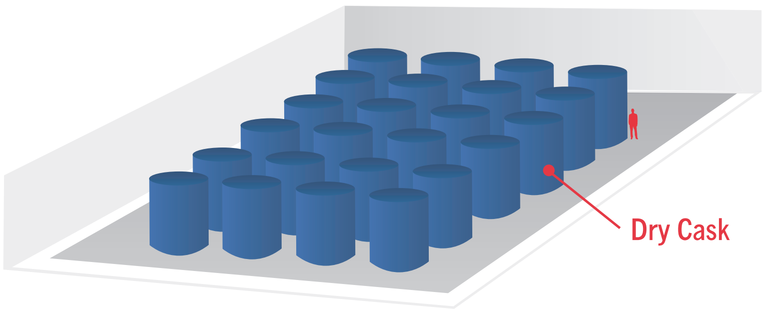
In an open fuel cycle, spent nuclear fuel is removed from the nuclear reactor, placed into interim storage to cool down over several decades as short-lived radioactive components decay, and permanently disposed of in a geologic repository.

Closed Fuel Cycle



In a closed fuel cycle, spent nuclear fuel is chemically processed in some way and the four major components of SNF (uranium, plutonium, fission products, minor actinides) are separated. In an ideal system, fission products would be mixed with glass and disposed of and the other components would be used to fabricate new fuel for a variety of reactor types.

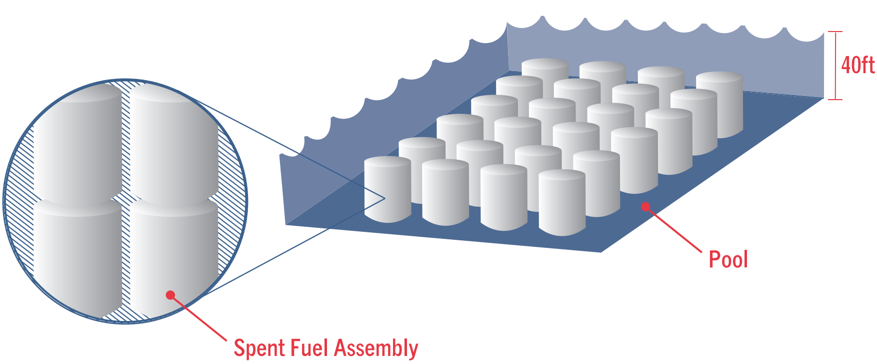
Interim **Storage**



After a spent fuel assembly is discharged from a nuclear reactor, radiation and heat from the decay of short-lived fission products are hazardous to workers. Consequently, freshly discharged fuel is stored in a temperature-controlled pool for several years.

As the spent fuel pool reaches capacity, the oldest (and coldest) fuel is transferred to dry cask storage. Dry casks are large steel and concrete containers which hold a dozen or more spent fuel assemblies. Dry casks are placed on a dedicated concrete pad near the reactor.

Several proposals for consolidated interim storage have been proposed. Dry casks from many reactor sites would be shipped to a central location for long-term storage as a national repository program progresses. A consolidated storage approach might favor "stranded" sites, locations at which spent fuel is the only remnant of a decommissioned reactor.



What are the design goals **of a Nuclear Waste Repository?**

The design of nuclear waste repositories has two major goals:

1. Isolate nuclear waste until its radioactivity has decayed away

2. Protect dangerous radioactive materials from theft

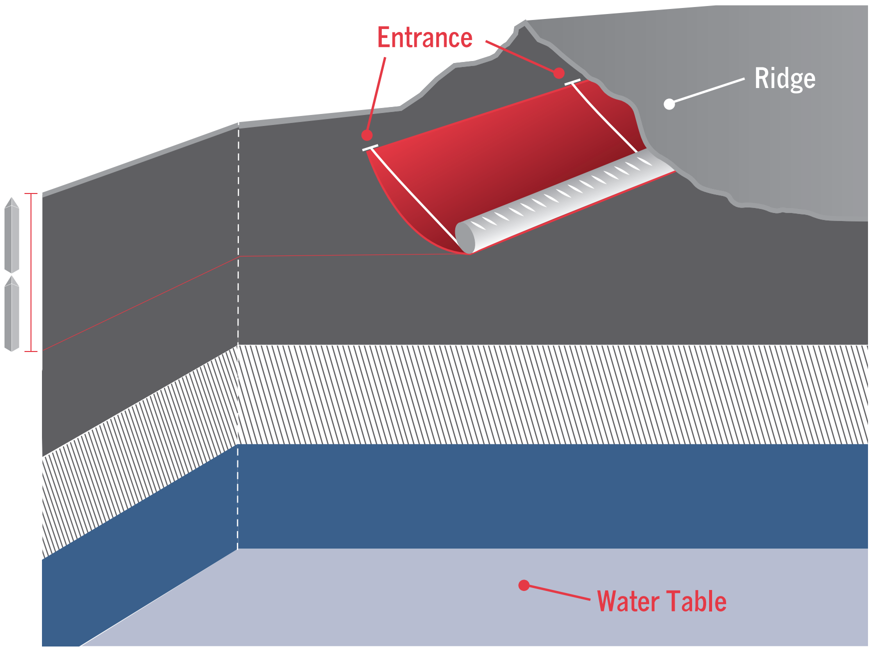
Repository designers employ two main strategies to accomplish these goals:

1. Engineered barriers, like corrosion-resistant canisters and clay seals

2. Natural barriers, like groundwater chemistry and impermeable rock

Ideally, a repository relies on both engineered and natural barriers with multiple redundancies.

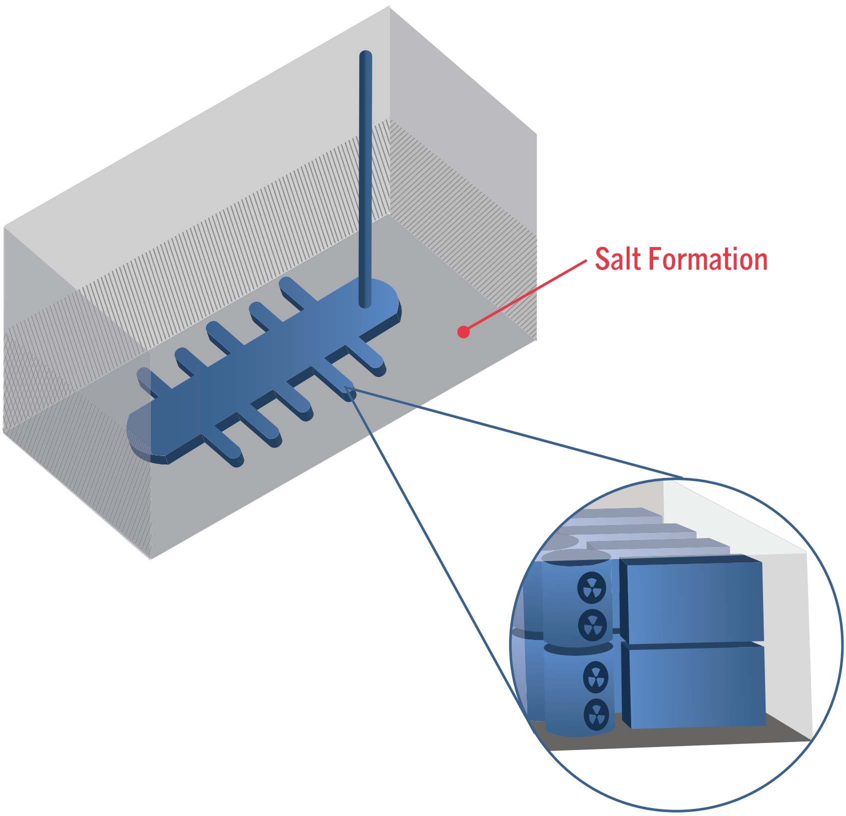
Volcanic **Tuff**



KEY:	1 Washington Monument = 555ft.

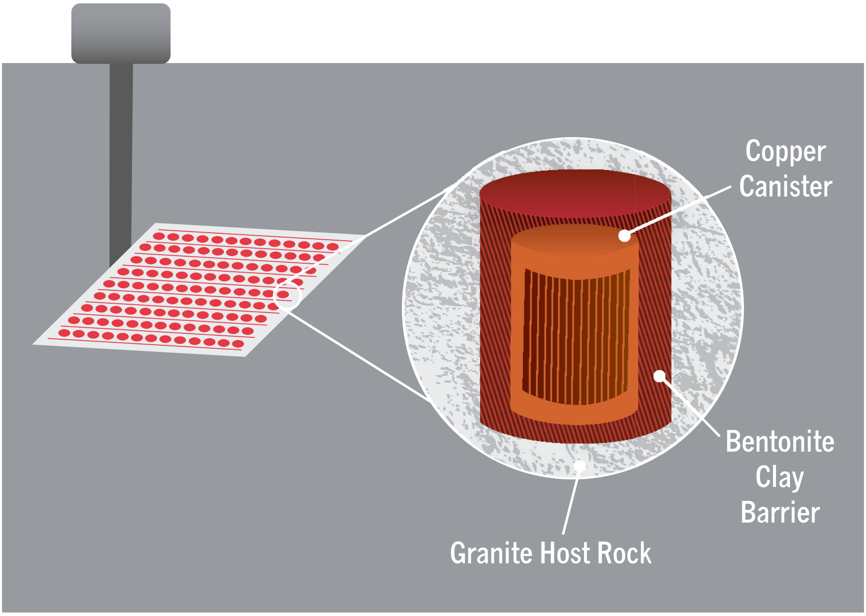
Volcanic tuff (also known as ignimbrite) is a rock formed from solidification of ash ejected from a volcano. In a repository in volcanic tuff, waste is stored in a tunnel bored into the tuff. Waste is ideally stored in an area with very little rainfall, protecting specially-designed canisters from corrosion. Owing to the lack of rain, the water table begins far below the waste and this isolation prevents the immediate escape of radioactive material from the site. The Yucca Mountain repository in Nevada is the major example of a high-level waste repository in volcanic tuff.

Salt



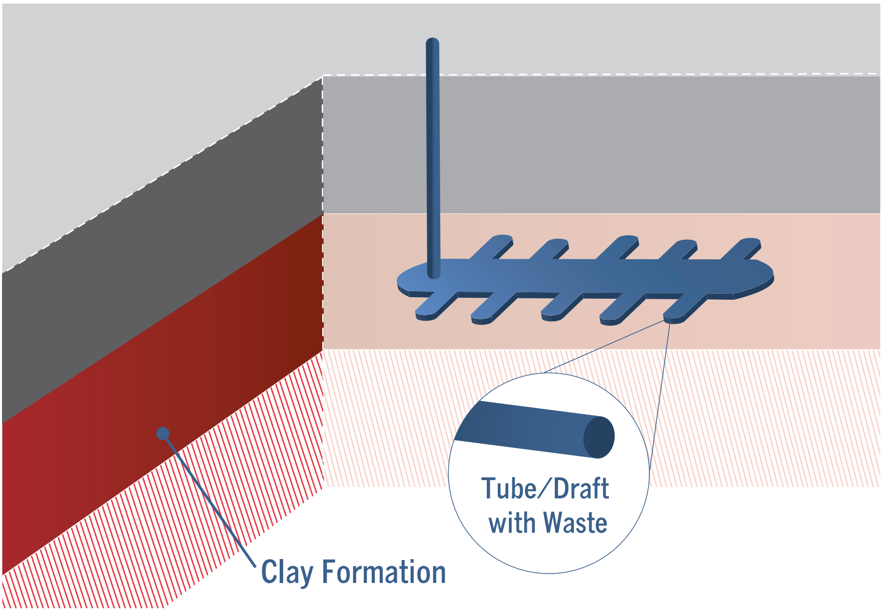
Repositories in salt use traditional mining techniques to tunnel into salt formations. Waste is emplaced in excavated caverns which will slowly entomb the waste over time. Salt formations have chemical conditions which limit the mobility of waste products, and the salt prevents most (if not all) water from reaching the waste. This method has been employed in the German HLW disposal program as well as the U.S. Waste Isolation Pilot Plant.

Crystalline **Rock**



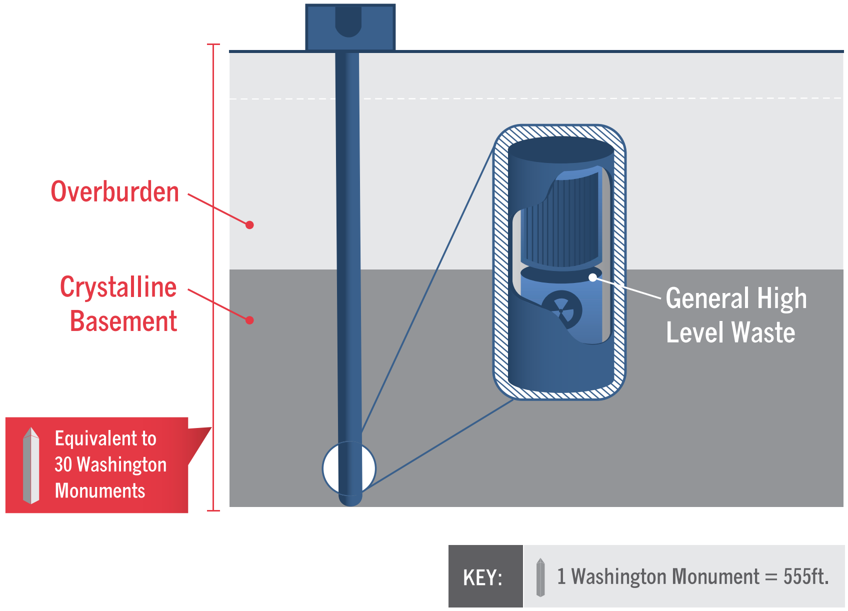
Crystalline rock refers to many different types of rock which form directly from cooling magma at or below the Earth's surface including granite and basalt. Granite nuclear waste disposal has slow rates of groundwater flow and water chemistry which immobilizes many components of spent nuclear fuel. In the Swedish method of waste disposal in granite (known as KBS-3), the natural properties of granite, copper disposal canisters, and a bentonite clay barrier serve to trap waste until it the radioactivity has decayed away. In addition to Sweden, crystalline rock repositories have been proposed in Finland and Canada.

*Clay/***Shale**



Disposal in clay, shale, or argillite are three similar disposal methods which emplace waste in rock formations which contain clay minerals. Radioactive ions in water can stick ("sorb") to the surface of clay minerals, slowing or stopping their escape from the host rock formation. Clay minerals also swell in the presence of water, resulting in rock formations which are very impermeable to flow. This method has been pursued by France, Belgium, and Switzerland, although the common occurrence of shale formations for radioactive waste disposal make this option available to almost all nuclear countries.

Deep **Boreholes**



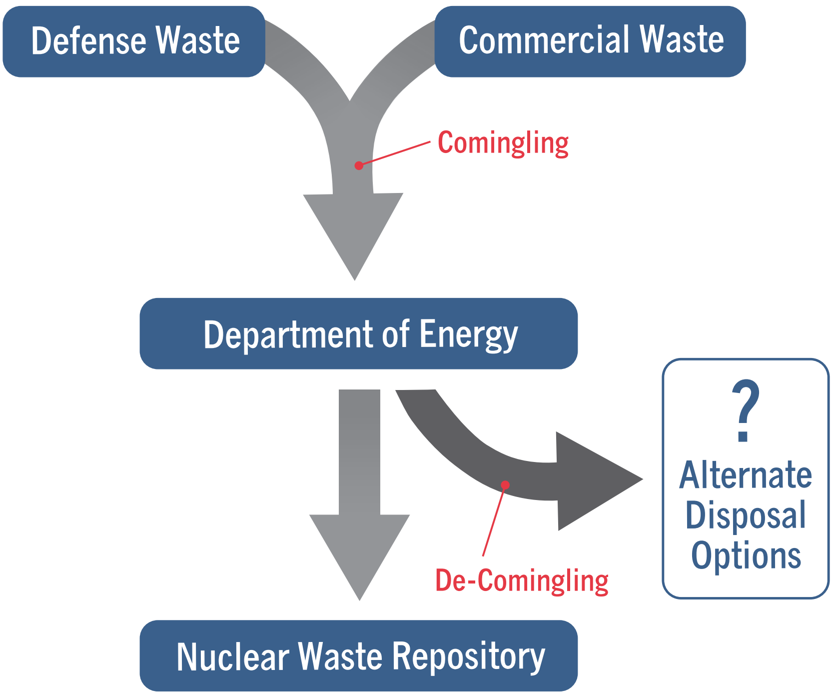
Deep borehole disposal, also known as very deep hole disposal, aims to dispose of nuclear waste in deep basement rock much deeper than alternative repository designs. A single deep borehole is a three mile-long shaft, similar to an oil or natural gas well, with 220 to 330 tons of nuclear waste entombed in the bottom 1.25 miles of the borehole. Deep boreholes are drilled by a complex rig system rather than mined or excavated like other repository designs are, meaning that humans cannot travel down to disposal depths for inspection or handling purposes.

As opposed to engineered barriers like corrosion-resistant canisters or drip shields, deep boreholes rely on geologic features to safely isolate waste, such as:

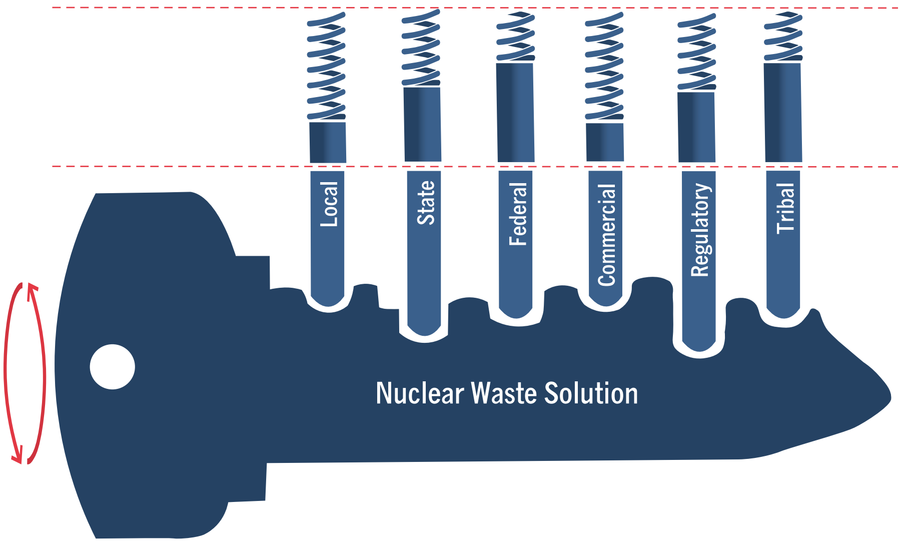
- Extreme depth
- Favorable chemistry
- Slow groundwater flow

These barriers have been (and likely will be) stable over many millions of years, which is ideal for a repository which could have million-year containment guidelines.

Defense Waste **Comingling**



The repository siting program established by the Nuclear Waste Policy Act of 1982 aimed to store both commercial and defense-related waste in the same repository. Known as "comingling," this combination of commercial SNF, submarine reactor fuel, high-level waste, and other products of nuclear weapons production placed unique constraints on the design of the Yucca Mountain repository. In recent years, many scientists and policymakers have proposed "de-comingling" strategies, ranging from deep borehole disposal of a small number of cesium and strontium capsules to an entirely separate repository for defense wastes.



The key to consent-based siting is a solution which balances the distinct needs of local communities, states, the federal government, and regulatory agencies.

In a consent-based siting strategy, the Department of Energy (or a successor nuclear waste management agency) partners with all stakeholders, especially potential host communities, to site a nuclear waste repository. Such a process would ideally be fully transparent to local and state oversight.

Glossary

What is **Radioactive Decay?**

Radioactive decay is the process by which unstable atoms break down into more stable ones by releasing energy and particles. Depending on the material, the decay process can take less than a day, decades, hundreds of years, or many thousands of years. The "half-life" of a material is the time necessary for half of a material to decay into something else. In this way, material with a long half-life takes a long time to decay away, but consequently releases less intense radiation.

The ingestion or inhalation of radioactive materials, usually through the contamination of food or water, bypasses the body's natural barriers to radiation. As a result, the long-term safety of radioactive materials involves isolating them from sources of drinking water, through which a future person could ingest harmful materials.

LLW: Low-Level waste, comprised of protective clothing, medical waste, and other lightly-contaminated items. (1)

TRU: Transuranic waste, comprised of long-lived isotopes heavier than uranium. (1)

Glossary

HLW: High-level waste, comprised of spent nuclear fuel and other highly-radioactive materials. (1, 7)

Granite: Type of crystalline rock which forms directly from cooling magma, at or below the Earth's surface. (8)

Tuff: Rock formed from solidicication of ash ejected from a volcano. Also known as ignimbrite. (6)

Spent fuel: Primary byproduct of nuclear reactors. (2, 3, 11)

Actinide: Fifteen radioactive metallic elements commonly found in nuclear waste. (2)

Half-life: The time necessary for half of a material to decay into something else. (4)

Notes

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