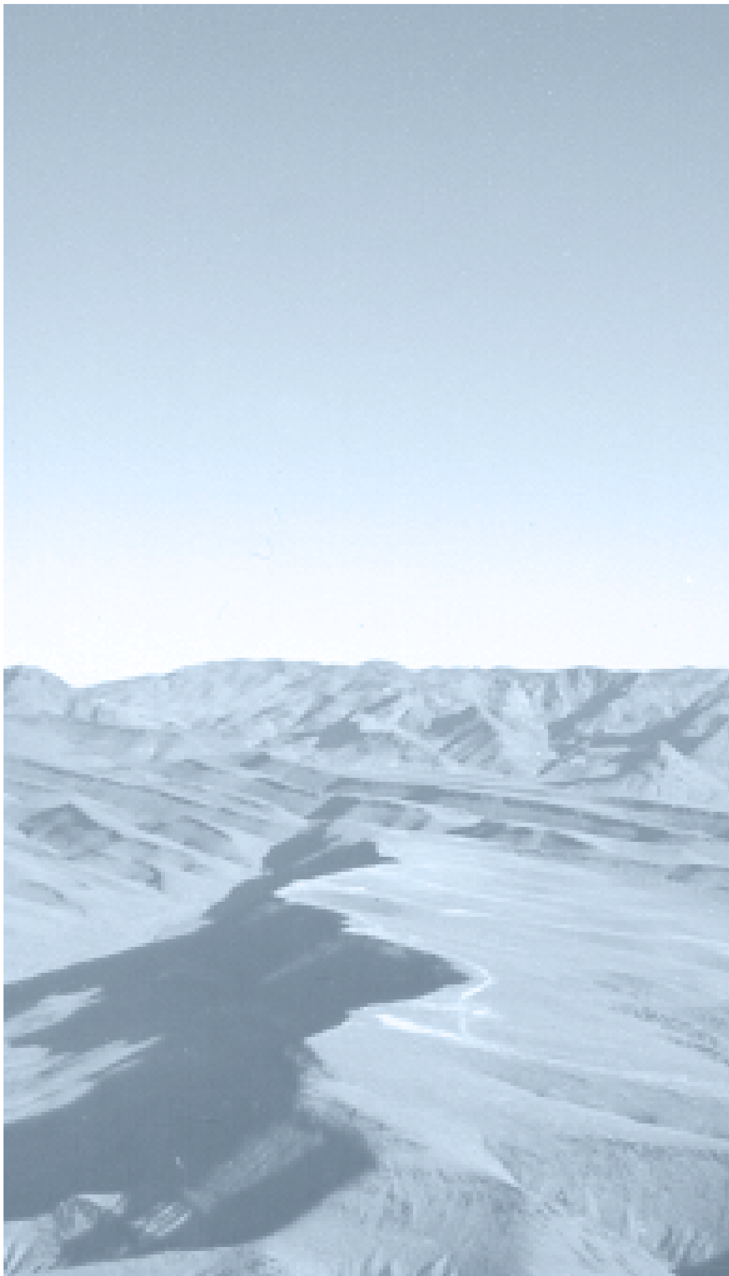
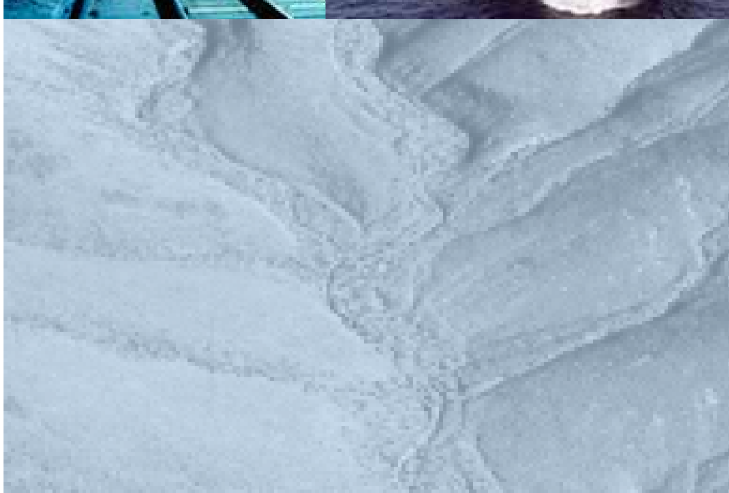
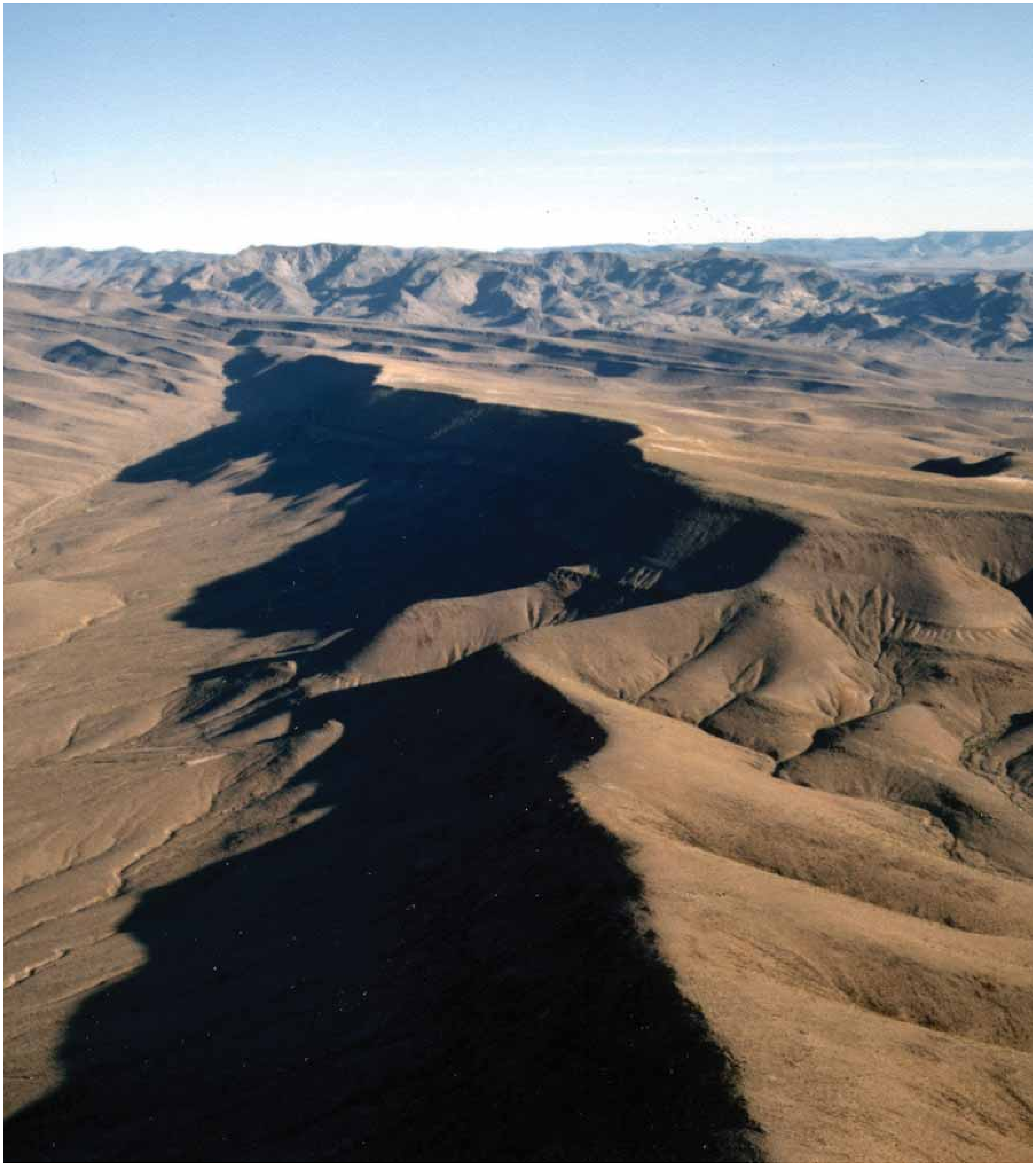


The National Repository at Yucca Mountain









The National Repository at Yucca Mountain: Solving a National Problem Now

On June 3, 2008, the U.S. Department of Energy (DOE) submitted an application to the U.S. Nuclear Regulatory Commission (NRC) for a license to construct a repository at Yucca Mountain. With this application, DOE's Office of Civilian Radioactive Waste Management moves forward in meeting its congressionally mandated directive to develop, build, and operate a deep-underground facility that will safely isolate spent nuclear fuel and high-level radioactive waste from people and the environment for hundreds of thousands of years.

The national repository at Yucca Mountain **will address a pressing national need** by safely securing and disposing of this waste in tunnels deep underground on federally controlled land in the Mojave Desert about 90 miles northwest of Las Vegas. Currently, the waste is stored at 121 temporary locations in 39 states across the nation. If licensed by the NRC, the national repository at Yucca Mountain will provide a permanent solution to disposing of the nation's nuclear waste rather than leaving it for future generations.

The Yucca Mountain license application presents the scientific information and engineering design work that demonstrate how the national repository **will protect people and the environment** for thousands of generations. Natural features of the mountain — including its geology, climate, distance above the water table, and isolation — make Yucca Mountain a suitable location for a repository. These features, combined with engineered barriers — including the solid nature of the waste, robust waste packages, and other features within the mountain — provide assurance that the nuclear materials will be safely isolated from the environment.

DOE's submittal of a license application to the NRC follows the process established by Congress in the Nuclear Waste Policy Act of 1982, as amended. The **NRC is the licensing agency responsible for reviewing** the application and determining whether to grant the DOE a license to proceed with construction of the repository.

The license application is the culmination of more than two decades of expert scientific research and engineering by more than 2,000 scientists and engineers, representing not only the DOE and its contractors but also eight national laboratories, the U.S. Geological Survey, and many colleges and universities.

The repository meets a pressing national need

What is spent nuclear fuel? The fuel used in nuclear reactors is made of solid enriched uranium pellets about the size of a pencil eraser (shown above). Hundreds of these pellets are sealed inside strong metal tubes (fuel rods) that are bundled together to form a nuclear fuel assembly.

Above-ground dry cask storage.

Spent nuclear fuel and high-level radioactive waste have been accumulating in the United States since the 1940s and 1950s, when nuclear materials were first used to produce electricity and to develop nuclear weapons. Currently, waste destined for Yucca Mountain is stored in temporary facilities at 121 sites in 39 states.

Spent nuclear fuel is generated by nuclear reactors and is being temporarily stored

Spent nuclear fuel is used fuel from commercial nuclear power plants, nuclear submarines and ships, and university and government research reactors. It is solid, in the form of uranium pellets.

Commercial nuclear power plants generate electricity through the controlled use of nuclear fission. In a nuclear reactor, uranium atoms in solid ceramic pellets inside sealed metal tubes (called fuel rods) are made to fission, or split. The heat released in this process is used to create steam, which drives a turbine to generate electricity

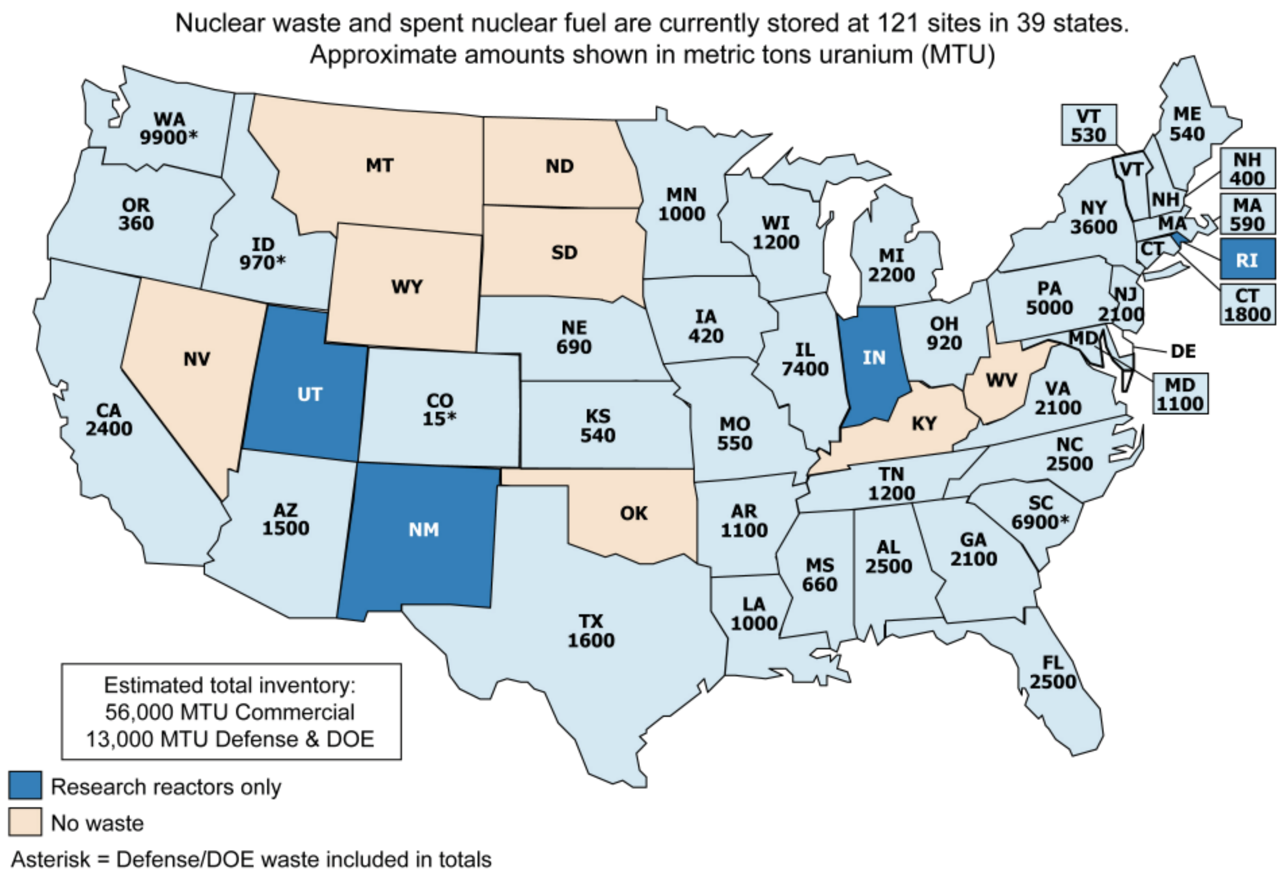
The uranium pellets are about the size of a pencil eraser. Hundreds of pellets are in each fuel rod, and fuel rods are bundled together in assemblies.

After a few years in a reactor, the uranium pellets in the fuel assembly are no longer efficient for producing electricity. At that point, the used or “spent” fuel assembly is removed from the reactor and placed in a pool of water. The water cools the spent fuel and also provides shielding from the associated radioactivity, which protects workers in the area.

If required, some spent fuel assemblies are later moved from a spent fuel pool to on-site dry-storage containers made of steel and/or concrete to shield radiation that is still being emitted. The containers are either placed upright on concrete pads, or stored horizontally in metal canisters in concrete bunkers. These containers are designed to store materials on a temporary basis, while waiting for the government to provide a permanent repository.

High-level radioactive waste is also being stored temporarily

High-level radioactive waste is highly radioactive material generated by the nation’s defense activities, including the development of nuclear weapons. Since the end of the Cold War, the United States has been working to close and clean up obsolete weapons plants and dispose



of nuclear weapons materials. This waste is being stored temporarily at government facilities, waiting for a permanent repository. It will be solidified before shipment to a repository.

Permanent disposal in an underground repository

Nuclear waste must be properly managed to minimize risk to the environment and to the health and safety of future generations.

For decades, experts throughout the world have studied many options for permanently disposing of spent nuclear fuel and high-level radioactive waste — including:

- Leaving the material at current storage sites
- Burying it in the ocean floor
- Putting it in polar ice sheets
- Sending it into outer space
- Placing it deep underground in a geologic repository

After analyzing these options, scientists determined that disposal in an underground repository was the best long-term solution for safely managing this waste.

As long as this waste remains in a solid form and is properly shielded, it will not harm people or contaminate the environment — and over time it will produce less and less radiation. The idea behind deep geologic disposal, therefore, is to keep the waste as isolated as possible, while its radiation diminishes.

Congress established the repository program as national policy

Recognizing the need for the permanent disposal of nuclear waste in a geological repository, Congress enacted the Nuclear Waste Policy Act in 1982. This law established U.S. policy for the permanent disposal of spent nuclear fuel and high-level radioactive waste by the federal government, and directed the Department of Energy to study potentially suitable sites for a geologic repository.

The repository is critical to America's energy security, environmental goals, and national security

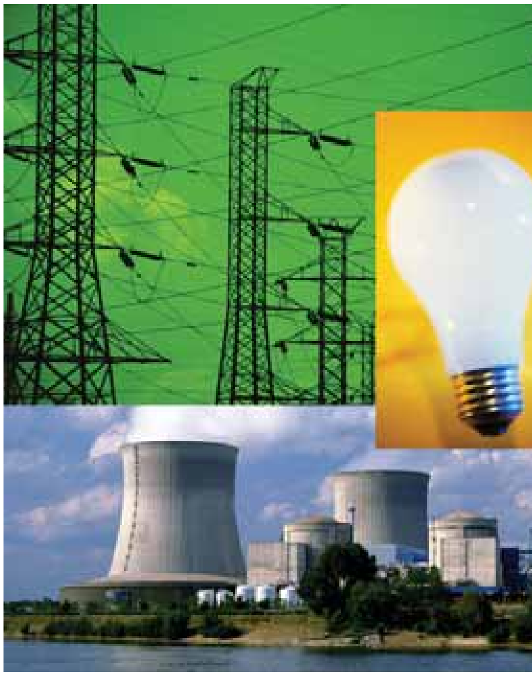
A repository is a vital part of America's energy, environmental, and security policies, and helps support important national interests such as environmental protection, energy independence, homeland security, and national security.

Environmental protection: A repository is important to America's environmental goals. Nuclear power is an alternative to power generated from fossil fuels, which emit carbon dioxide and other greenhouse gases. Nuclear power produces energy without producing greenhouse gases.

In addition, spent nuclear fuel and high-level radioactive waste is stored at former nuclear weapons production sites. The federal government cannot implement a comprehensive approach for the cleanup and decommissioning of these former weapons production sites without a facility for permanent disposal of this waste.

Energy independence: Nuclear power provides roughly 20 percent of our nation's electricity and is an essential part of our domestic energy supply. There are currently 104 operating reactors in the United States, and applications are pending for new reactors to supplement or replace the current fleet. A national repository is critical to ensuring the maintenance and potential growth of nuclear power.

Homeland security: Spent nuclear fuel and high-level radioactive waste are currently stored temporarily at 121 sites in 39 states, and millions of Americans live within 75 miles of one or more of these sites. The repository offers the benefit of consolidating the waste at one isolated, secure location. Geologic disposal will safeguard radioactive waste from deliberate acts of sabotage or terrorism.



National security: Many of the most strategically important vessels in the Navy's fleet, including submarines and aircraft carriers, are nuclear powered. They must be refueled periodically and the spent fuel removed. Providing a safe place to dispose of spent fuel from these warships will ensure the future operational capability of the nation's nuclear-powered fleet.

The U.S. Navy's aircraft carriers and submarines are powered by nuclear reactors, which produce waste that must be disposed of in a repository.

How the repository will protect people and the environment

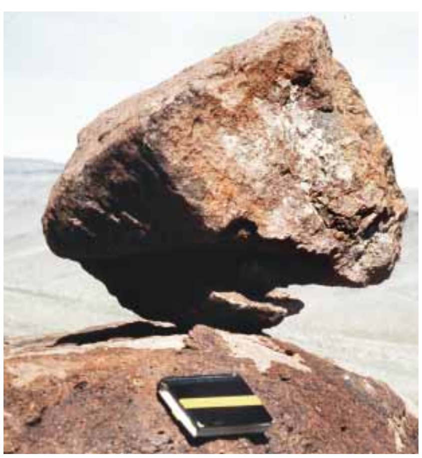
The Yucca Mountain site is located in a remote area of the Mojave desert in Nye County, Nevada, about 90 miles northwest of Las Vegas. The site is isolated from concentrations of human population and human activity. It is also on land controlled by the federal government and is in one of the driest regions in the United States.

The repository will combine Yucca Mountain's natural features — its remote location, dry climate, stable rock layers, and deep, isolated water table — with man-made engineered barriers such as tunnels deep underneath the mountain, the solid nature of the nuclear waste, and robust packaging to protect public health and safety.

The mountain's natural features act as barriers

Yucca Mountain is old (formed about 12 million years ago) and geologically stable. The rock at Yucca Mountain, called tuff, is composed of volcanic ash and flows that solidified by melting together (welded tuff) or compressing together (nonwelded tuff). Yucca Mountain consists of alternating layers of this tuff from an extinct volcano.

Precipitation as rain or snow at the mountain's surface currently averages about 7.5 inches per year, most of which either runs off, evaporates, or is used by the desert vegetation. Future regional climates could be somewhat cooler and wetter. But even if glaciers revisit North America, the annual average precipitation at Yucca Mountain is projected to be low, about 16 inches per year at the maximum.



This boulder on the crest of Yucca Mountain seems precariously poised for a tumble. Yet geologic evidence shows the rock has been immobile for thousands of years, even though the region has occasional earthquakes.

The mountain's water table lies far beneath the surface — on average, about 2,000 feet below the top of the mountain. This groundwater is part of the Death Valley hydrologic basin, which is geologically closed. The aquifer system under Yucca Mountain is separate from those under Pahrump, the closest major population center about 50 miles from Yucca Mountain. The aquifer system under Yucca Mountain is also separate from the aquifer system under Las Vegas and other more distant localities.

This feature ensures that even if radioactive particles were to escape at some time in the far distant future, they would be isolated from water supplies found outside the Death Valley basin.

The most important natural barriers Yucca Mountain offers for containing and isolating radioactive waste include:

- The surface soils and the natural physical shape and configuration of the mountain and its geologic environs — which limit the ability of water to infiltrate the surface

- Thick rock layers above the repository level — which limit the ability of water to enter the repository
- Rock layers below the repository — which limit the transport of radioactive particles that might escape from the repository
- Volcanic rocks and water-deposited gravel containing clay, silt, and sands below the water table — which further limit the movement of radioactive particles

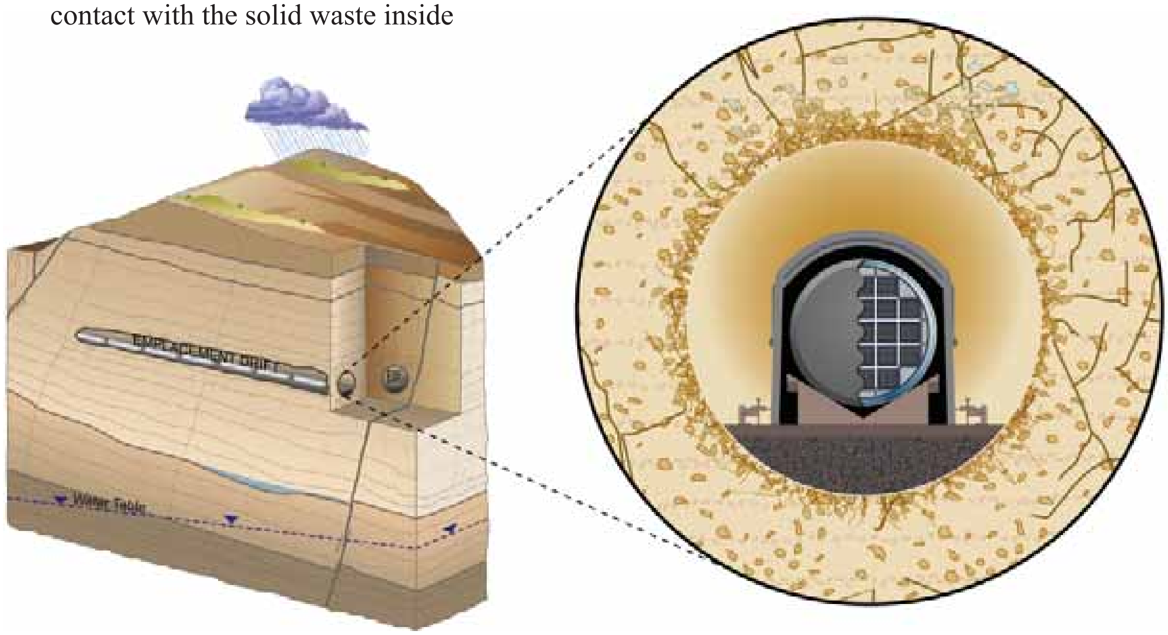
With very little water available to start with, the Yucca Mountain repository's natural features significantly limit the amount of moisture that can infiltrate below its surface. At most locations within the mountain, it would take thousands of years for the small amounts of water that can infiltrate the surface to actually reach the level of the repository. In fact, collectively, the features of the mountain reduce the amount of water available to reach the nuclear waste by up to 99 percent.

Yucca Mountain's natural features, including thick layers of unsaturated rock, contribute to its ability to safely house a repository.

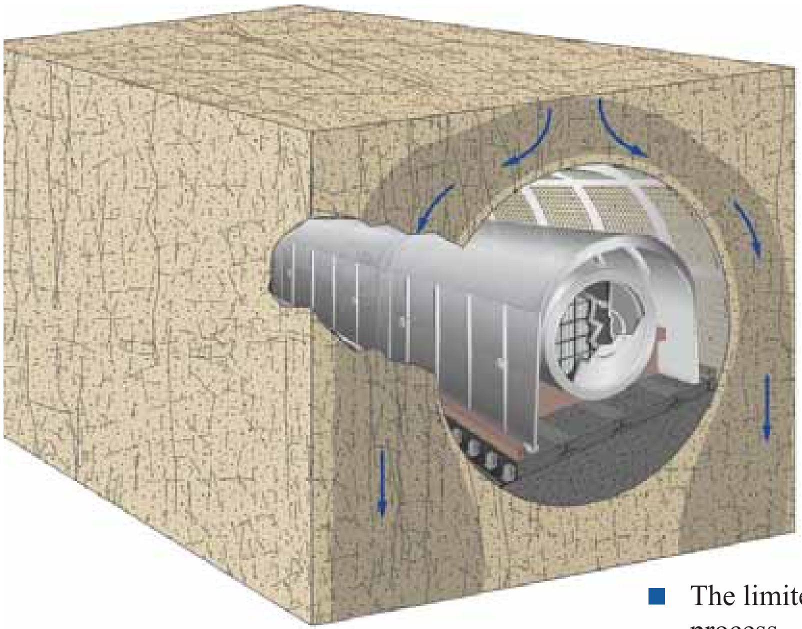
Engineered barriers enhance protection

By itself, the mountain would provide a high degree of waste isolation. To enhance the mountain's natural barriers, however, scientists and engineers have devised what is known as the engineered barrier system:

- The repository "emplacement" tunnels — which would be built approximately 1,000 feet below the surface of Yucca Mountain
- Titanium drip shields — which limit the ability of falling rocks or the small amount of water that could move through the natural features and enter the emplacement tunnels to contact the waste packages
- Double-shelled, corrosion-resistant waste packages — which prevent water that might get below the drip shields from coming into contact with the solid waste inside



Yucca Mountain's natural features limit the amount of water that would ever reach the nuclear waste packages.



The engineered barrier system adds even more protection to the waste packages.

- Solid nature of all the waste — which limits the rate at which radioactive particles can be dissolved, picked up, and moved by any water that might contact the waste
- Inverts (waste package support structures partly surrounded with crushed volcanic rock) — which further capture or slow the release of radioactive particles to the natural barriers below the repository level

Key barriers work together

The robust waste packages are expected to resist corrosion in the environment inside Yucca Mountain for hundreds of thousands of years due to the combination of these natural and engineered features:

- The limited amount of water available to trigger the corrosion process
- The natural tendency of water to move around large openings or excavations in rock; in this case, the tunnels in which the waste will be emplaced
- The relatively benign chemical environment expected inside the mountain
- The corrosion-resistant shells of the waste packages
- The corrosion-resistant drip shields above the waste packages

When designing systems intended to last longer than recorded human history, scientists and engineers must consider the possibility that one or more barriers, natural or engineered, may not perform as expected. Thus, the Yucca Mountain repository's ability to isolate its contents does not depend on any single barrier, natural or man-made.

Predicting how the repository will perform in the future

Projecting what will happen to a complex, first-of-a-kind system over hundreds of thousands of years is a daunting task. That's one reason why scientists have spent nearly 30 years conducting experiments on Yucca Mountain and designing the key engineering features that will keep nuclear waste safely isolated.

With enough data, the right mathematical equations, and powerful computer technology, scientists and engineers can simulate expected behaviors of complex systems. They can test theories about things that are impossible to experiment on directly; thus, they can make predictions about outcomes over time. This is accomplished through computer modeling.

The Nuclear Regulatory Commission requires the DOE to use a computer model to project how the Yucca Mountain repository will perform over time, under normal conditions as well as during postulated events including earthquakes, volcanic activity, climate change, and accidental disturbance by people in the future.

This computer model is called the total system performance assessment, or TSPA. Using huge amounts of data, massive computing power, and advanced mathematics, the TSPA calculates how well and how long the repository will isolate the nuclear materials while their radiation levels decay over hundreds of thousands of years.

The TSPA model calculates the potential radiation dose that a hypothetical person living at the repository boundary (about 11 miles from the repository) could receive over the next 10,000 to 1 million years. The dose calculations consider the conditions expected to happen, which include minor earthquakes and climate change. They also consider unlikely events, such as major earthquakes and volcanoes.

The results of the TSPA model show that the repository can be expected to protect the public's health and safety. For the first 10,000 years after closure of the repository, for all the scenarios added together, the mean annual radiation dose would be significantly less than one additional millirem per year. At its highest, the potential maximum dose to that hypothetical person would still be slightly less than one additional millirem per year — approximately 720,000 years in the future.

Adding confidence: natural and man-made analogues

The mathematical models in the TSPA show how the repository most likely would respond to changing climatic and geologic conditions over a vast expanse of time.

There is also real-world evidence that reinforces the validity of the computer modeling.

The world offers many examples of natural and man-made structures that embody the kind of protective systems that a repository would use. Called "analogues," these examples offer direct, real-world analogies for some of the long-term processes that would occur in a repository.

Multiple analogues studied by DOE scientists — including early human cave paintings, insides of pyramids, and ancient uranium deposits — suggest that a Yucca Mountain repository would naturally keep the waste dry and isolated over several hundred thousand years, while most of the radioactivity decays away. The analogues help add confidence in the results of the computerized models of the TSPA.

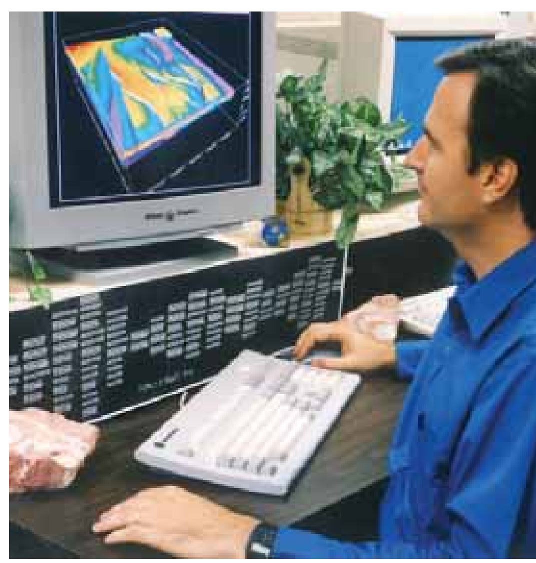
What is a "millirem?"

A millirem is a measurement of radiation dose absorbed by the human body. The average American receives 360 millirem per year from all radiation sources, both natural and man-made. In some areas of the United States this number is much higher.

Natural radiation comes from rocks and soils, radon gas coming up from the Earth's crust, cosmic rays from outer space, food, and many other sources.

Man-made doses come from medical and dental procedures, color television sets, computer monitors, and similar sources.

- A typical chest X-ray gives the patient about 10 millirem of radiation.
- Watching television for three hours per day for a year gives the typical viewer about 1 millirem.
- Smoking 1.5 packs of cigarettes a day gives the smoker an annual additional radiation dose of 1,300 millirem.



Scientists use both natural and man-made analogues to increase their confidence.

Safely operating the national repository

In the "canister within a canister" approach, three containers are nested inside one another to safely shield the radioactive waste.

Canister within a canister

Before it is ready for emplacement underground in the repository, spent nuclear fuel will be placed into transportation, aging, and disposal (TAD) canisters at nuclear power plants. In this "canister within a canister" approach, TAD canisters containing spent nuclear fuel will always be inside something else — be it a transportation cask, a shielded transfer machine, a waste package, or some other shielded device.

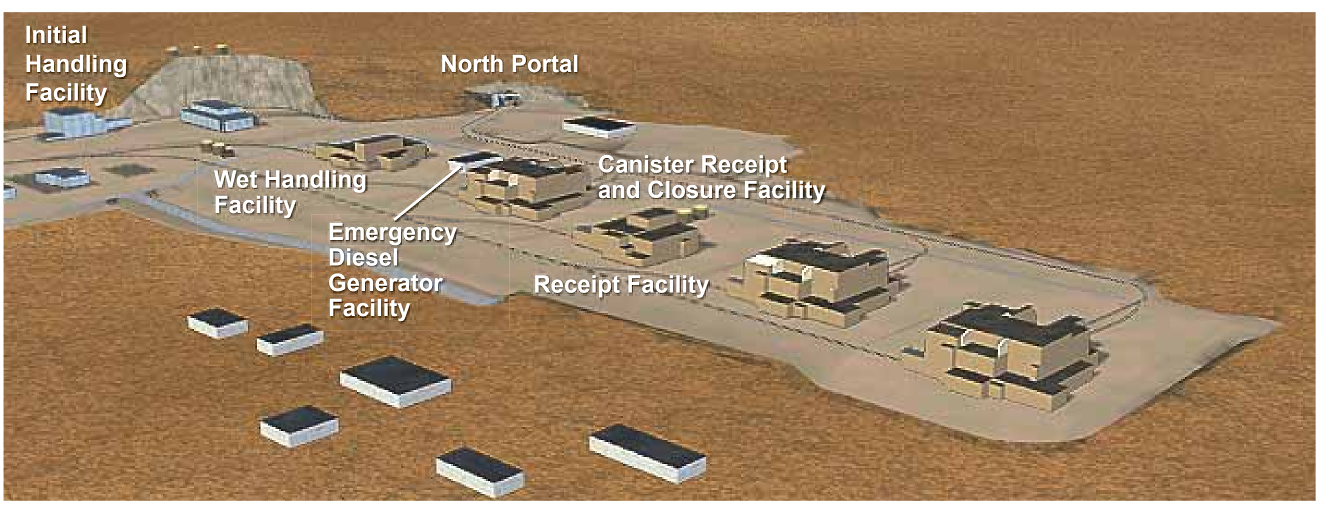
TAD canisters will be loaded and sealed at the power plant and, under normal conditions, will never be re-opened. Spent nuclear fuel has been stored and moved in similar canisters for decades.

The Department of Energy estimates about 90 percent of spent nuclear fuel shipments will arrive at the repository in TAD canisters within shielded transportation casks. The rest will be placed into TAD canisters at the repository before being placed underground.

The repository's surface facilities

On the surface, outside the main tunnel entrance at Yucca Mountain, a complex of buildings will house the facilities needed to prepare the radioactive materials for disposal. Those activities will include, among other things:

- Receiving the material
- Placing it in special metal containers (waste packages) for emplacement in the mountain

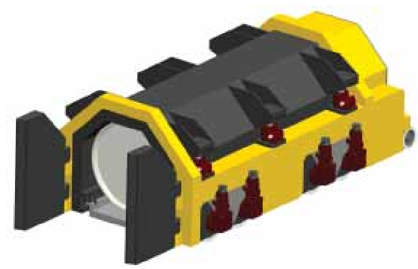


This artist's three-dimensional conception shows the complex of reinforced concrete and steel buildings planned for the surface of Yucca Mountain.

- Welding those waste packages closed
- Checking them for leak tightness
- Loading them in special transporters for movement underground

Some of these buildings will be the size of a sports arena — 400 feet long and several stories high. Buildings in which nuclear materials are processed will be designed to withstand major earthquakes, tornadoes, and acts of sabotage.

The design is flexible and modular, which will allow the DOE to begin receiving the material while still improving the system based on advances in safety, science, and engineering.



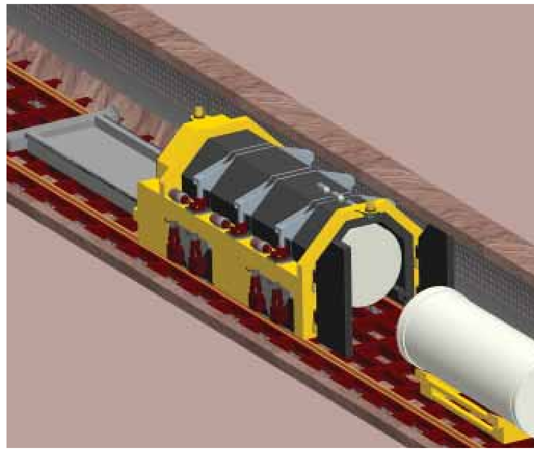
An electric transporter called a Transport and Emplacement Vehicle (TEV) will move into the waste handling facility to transport the waste package to the emplacement tunnels.

The underground facility

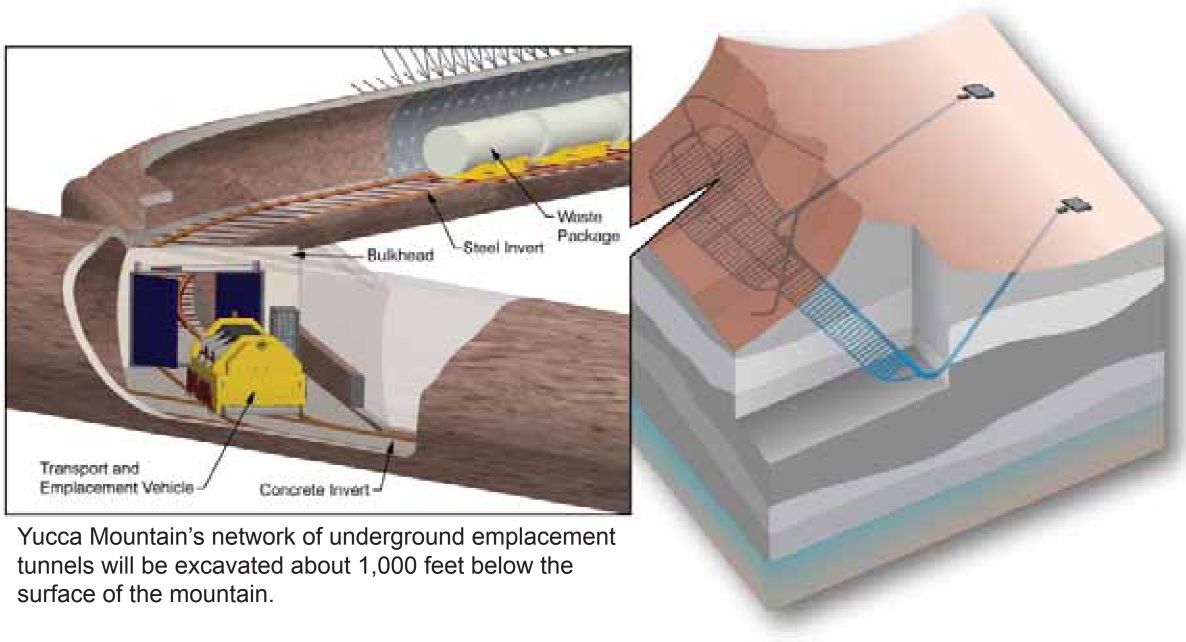
Forty-two miles of 18-foot diameter emplacement tunnels are planned, each about 250 feet apart from the next parallel tunnel. They will be lined with perforated stainless steel plates to prevent rock from falling on the tunnels' contents.

The tunnels will be excavated in phases. This will allow emplacement operations to begin while construction continues via a separate access tunnel.

The NRC requires that the waste packages be fully retrievable for at least 50 years after the start of waste emplacement. Future generations may decide that the used nuclear fuel is economically worth retrieving, or that additional safety monitoring is needed. Therefore, the DOE has designed the repository so that it could be kept open for more than 100 years.

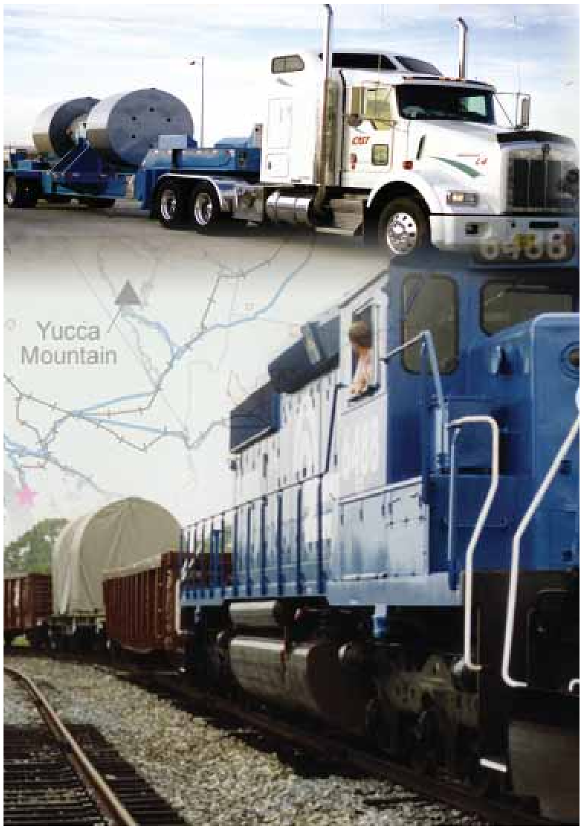


This cutaway of an emplacement tunnel shows the TEV placing a waste package in its designated spot.



Yucca Mountain's network of underground emplacement tunnels will be excavated about 1,000 feet below the surface of the mountain.

Transporting the waste safely



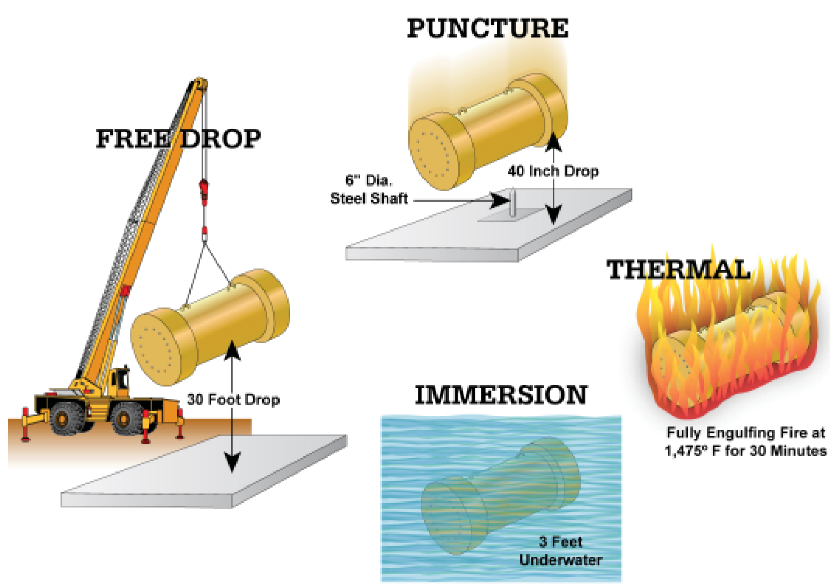
The United States has an exemplary history of safe transportation of nuclear materials.

Since the early 1960s, the U.S. has safely conducted more than 3,000 shipments of spent nuclear fuel, traveling more than 1.7 million miles, without any harmful release of radioactive material.

For all shipments of this waste to the repository, the DOE would use extremely durable and massive transportation casks whose designs are certified by the NRC. To be certified, casks must be designed to withstand severe accidents without releasing their radioactive contents.

Rail has been selected as the preferred mode of transportation because it is well suited to move larger casks — reducing the overall number of shipments. Public and state officials have also expressed a preference for rail.

The DOE is committed to developing and operating a safe and secure transportation system for Yucca Mountain and will meet or exceed U.S. Department of Transportation and NRC standards. The agency is working with state, local, tribal, federal, and industry stakeholders to develop the transportation system and routes.



To be certified by the Nuclear Regulatory Commission, every type of transportation cask must be able to withstand all of the tests shown above.

A legal-weight truck carries a cask containing spent nuclear fuel. Drivers are specially trained and certified, must be accompanied by at least one escort, must report in with the DOE every two hours, and are continuously monitored and tracked by satellite.

Next steps involve a new phase for the repository program

The Yucca Mountain license application, more than 8,600 pages in length, integrates the results of more than two decades of scientific and engineering work at Yucca Mountain.

The submittal of the application starts a new phase of the United States' effort to address this national problem — a phase laid out by Congress and governed by strict rules. The NRC is the licensing agency that reviews the application and makes a decision whether to grant DOE a license to proceed with construction of the repository.

This phase includes an initial "docketing" review of the information contained in the application. If the NRC staff determines that the license application is acceptable for docketing, the NRC then begins the licensing process. This process, open to the public, is conducted over a three-year period, with the potential for one additional year.

In parallel with the NRC staff review process, there are licensing hearings presided over by an NRC Atomic Safety and Licensing Board. If the licensing board approves NRC granting the construction authorization, and the Commission upholds that decision, DOE would be granted authorization to build the repository.

The NRC will grant a construction authorization only if it concludes that the repository would meet all applicable requirements and that the health and safety of workers and the public would be protected.

The submittal of the license application to the NRC is a major milestone for DOE. If licensed by the Nuclear Regulatory Commission, the repository will meet pressing national needs — including environmental cleanup and increased energy production with a secure, clean, domestic energy source.

The repository will also satisfy our obligation to dispose of these wastes now, rather than leaving them as an unwelcome legacy for future generations.

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

DOE/YMP-0621
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1551 Hillshire Drive
Las Vegas, NV 89134
1-800-225-6972
http://www.ocrwm.doe.gov