WHAT LIES BENEATH

Buried deep under an island in the Baltic, the world's first permanent nuclear-waste repository is nearing completion. If all goes according to plan, future generations may not know it's there.

BY ANDREW CURRY

PHOTOGRAPHS BY BERNHARD LUDEWIG

In Finland's nuclear-waste repository, 26 miles of storage tunnels will fan out into bedrock deep below the sea.

In 1980, a 29-year-old Finnish geologist named Timo Äikäs accepted a huge responsibility: He joined a team in charge of finding a way to permanently store his country's growing stockpile of nuclear waste. Doing so would require Äikäs and his colleagues to think far, far into the future. They would need to build something to last as long as the spent fuel from nuclear-power plants remains dangerous—between 100,000 and 1 million years. Considering that the pyramids are a mere 4,500 years old, this is an essentially unimaginable span.

When Äikäs began working on the project, repositories were already on the drawing boards in the United States, Sweden, Germany, and elsewhere. The Finns figured that other countries would do the early research and development, and Finland could copy their best ideas. Indeed, the plan Äikäs and his team settled on was borrowed from Sweden, which sits on the same slab of bedrock that Finland does.

Almost 40 years later, Finland is the only country in the world that has a permanent nuclear-waste repository under construction. The projects Äikäs had assumed would be completed long before Finland's have faltered on NIMBY politics. (Around the world, an estimated 250,000 tons of spent nuclear fuel are stored in temporary facilities that are showing their age, and accidents are surprisingly common; several have occurred at U.S. facilities in the past few years alone. Accidents risk exposing people and the environment to radiation, and cleanup costs can run into the billions of dollars.) "Our original strategy—to follow others—has failed," Äikäs says. Nevertheless, the facility he spent his career planning, known as Onkalo—which means "cave" or "hiding place" in Finnish—is on the verge of completion.

The facility's entrance is nestled in an evergreen forest on Olkiluoto, a sparsely inhabited island off Finland's western coast; three nearby nuclear reactors are just out of view, hidden by the surrounding trees. Beyond what looks like an oversize garage door, a tunnel descends nearly 1,500 feet into the bedrock. Eventually, 137 additional tunnels will fan out from the bottom. When the facility is up and running, spent fuel will be packed into 25-ton canisters made of cast iron wrapped in pure copper. The canisters will be stored in specially carved chambers sealed with bentonite clay (the active ingredient in kitty litter), which swells on contact with water.

Onkalo's design is deceptively simple. The near-seamless local bedrock, a type of rock called gneiss, is geologically stable and keeps water out. The bentonite clay will absorb any water that does seep in. The groundwater deep below the surface has a low oxygen content, which makes it less corrosive. And because copper is one of the most stable substances on Earth, geologists say it would take millions of years for groundwater to eat through the canisters. CONTINUED ON P. 57

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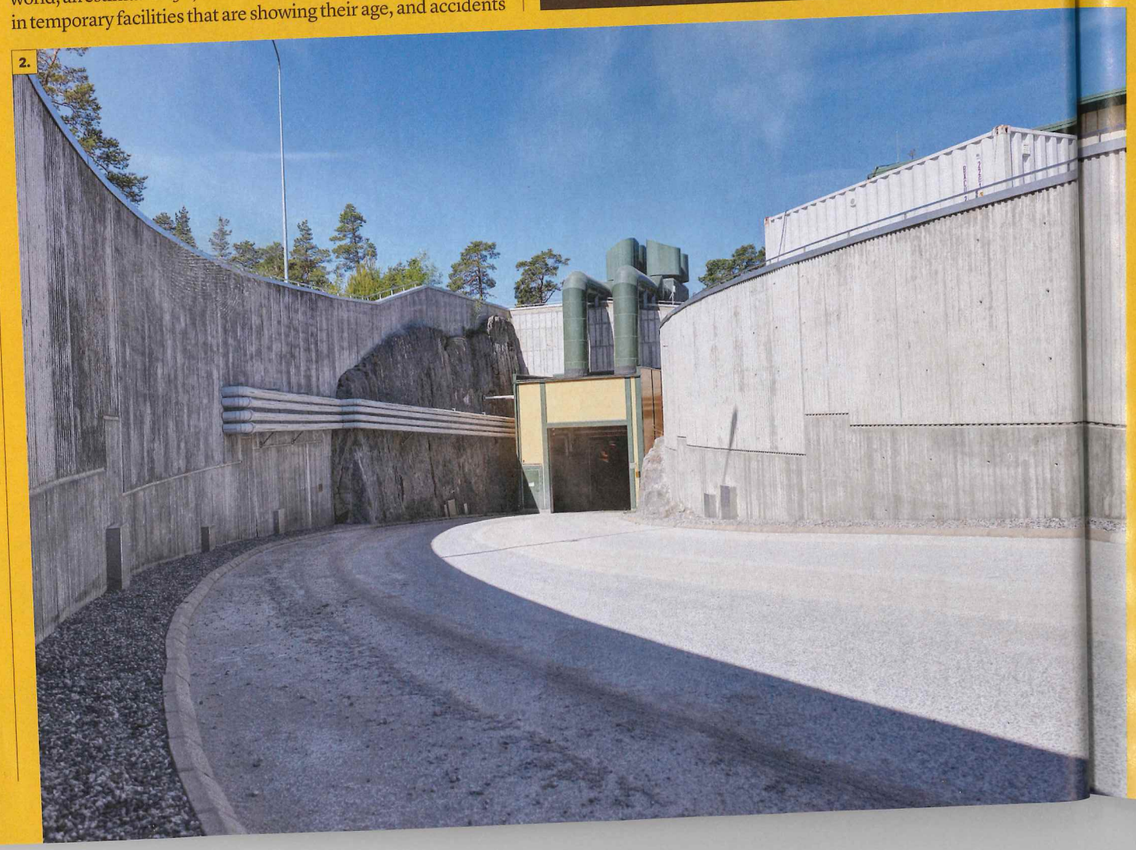

1. Spent nuclear-fuel rods will be encased in cast-iron canisters with a shell made of pure copper, which is extremely resistant to corrosion. The shell is almost two inches thick—equal to a little more than 32 stacked pennies.

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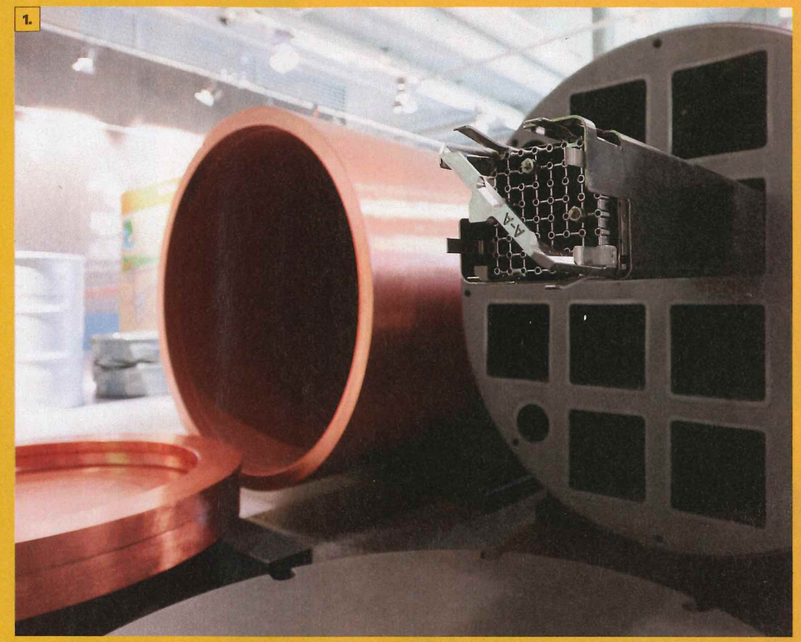

2. Beyond Onkalo's entrance, a tunnel extends nearly 1,500 feet below the surface. Planners expect to begin storing radioactive waste here by 2024. In the U.S., local opposition to a repository at Yucca Mountain, in Nevada—once expected to open in 2017—helped derail the project after billions had already been spent on an exploratory tunnel and geological surveys.

3. Geologists and engineers working for Posiva, the Finnish company responsible for building the facility, use chambers like this to measure groundwater seepage in the local bedrock and to gather other data.

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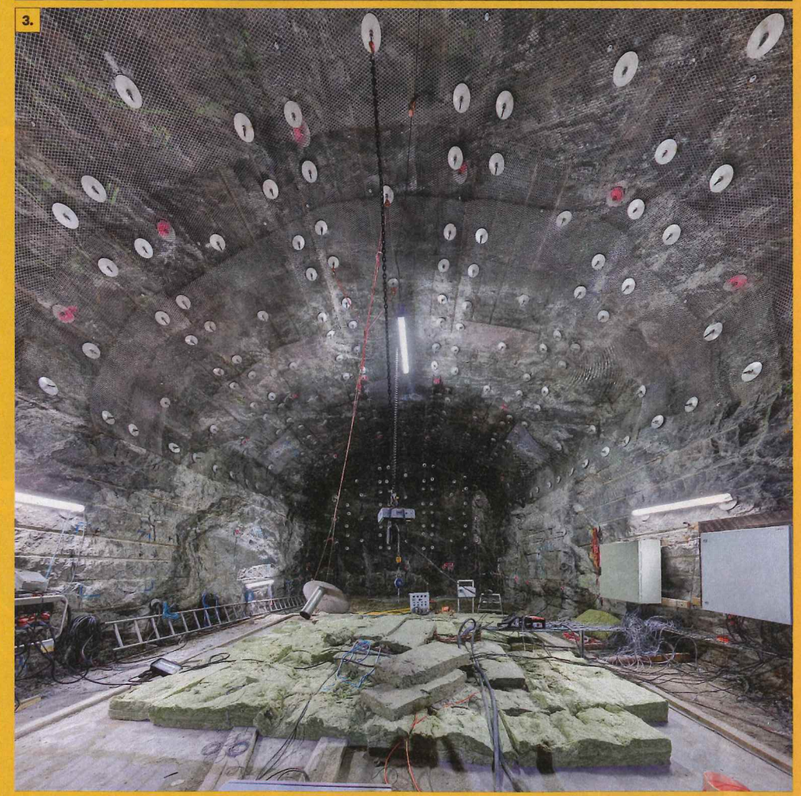
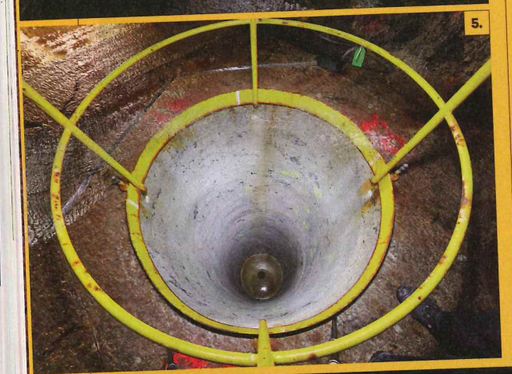
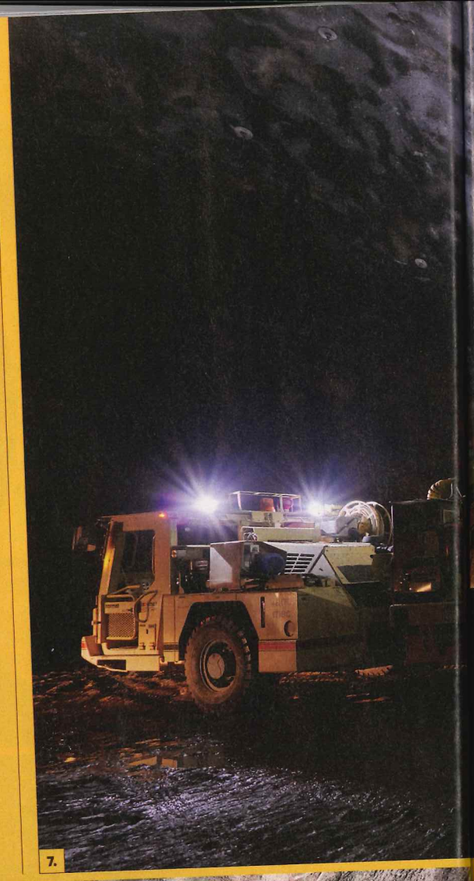


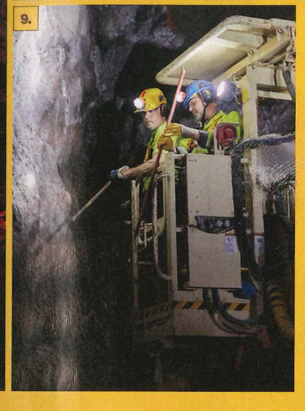


4-5. Canisters full of nuclear waste will be welded shut and then lowered into storage shafts as deep as 26 feet. The shafts will then be filled with bentonite clay, a substance that absorbs water.

6. A drill used to place blasting charges. The geologist Ismo Aaltonen likens the underground construction work to mining, with one important difference: Workers will still be active underground a century or more from now.

7. As the repository is filled, operators will use remote-controlled machinery to backfill the tunnels and seal them off. One day, the entire facility may be covered by the surrounding forest and—perhaps—forgotten forever.





8. Engineers use 3-D scanners to measure the tunnels after drilling and blasting.

9. For safety, the tunnel roofs are covered in spray concrete and loose rocks are pried from the walls after blasting.

By then, the radioactive isotopes inside will have degraded to a form that no longer poses a threat to the environment.

Planners have also devoted lots of thought to the question of how to warn our distant descendants, "Don't dig here!" That's because if humans still inhabit the Earth in 100,000 years, they probably won't be able to read our writing. After all, just 10,000 years ago humans were roaming the planet in small groups of hunter-gatherers and using stone tools; we're baffled by Stonehenge, which is only 5,000 years old. One hundred millennia from now, the human race might be totally unrecognizable.

A short-lived academic subfield called nuclear semiotics arose in the 1980s to answer the warning-sign question. It yielded proposals ranging from fields of jagged, menacing stone spikes to cats genetically engineered to change color when exposed to radiation. The idea was that if you were digging and saw cats changing color, you'd be freaked out enough to stop. (The cat plan called for seeding global religions and folklore with the belief that fur fluctuations are a bad omen.)

The Finns have taken a simpler—and much more Finnish—tack: At least for now, they've decided against putting any kind of warning sign on the site at all. "If we mark it, we'd most likely invite people to look and see what's down there," Äikäs says. Instead, they've designed Onkalo to be as inconspicuous as possible.

Äikäs says he purposely chose a location where the boring bedrock wouldn't interest future prospectors looking for metal, ore, or oil deposits. As the tunnels are packed full, they will be backfilled with absorbent clay blocks. Sometime in the early 2100s, the repository will reach capacity. Once that happens, it should require no oversight or management, no guards or electricity. One day, it will likely be covered by the surrounding forest. A few hundred years from now, Onkalo may be all but forgotten.

The Finns avoided the NIMBY problems that have stalled other projects by garnering consensus from the outset. Nearby communities were granted veto rights during the planning process. Äikäs and his team at Posiva, the company in charge of building the facility, spent years organizing town halls, giving tours of mine shafts, and patiently answering questions about the potential risks of a direct meteor strike or future ice age.

Äikäs retired in 2014. Today, Ismo Aaltonen, another young Finnish geologist, is shepherding Onkalo through the final phases of construction and preparation. Aaltonen's colleagues are already planning final practice runs of the disposal procedure, with real canisters and components but no spent fuel, for 2022.

If the practice runs go well, Aaltonen expects to start filling the tunnels with radioactive waste by 2024. It'll be up to his successors, or rather their successors, to complete the task a century or more from now. "I hope I'm not retired when we start disposal," he says. "But I'm sure I'll be dead when we're finished."

Andrew Curry is a journalist based in Berlin.