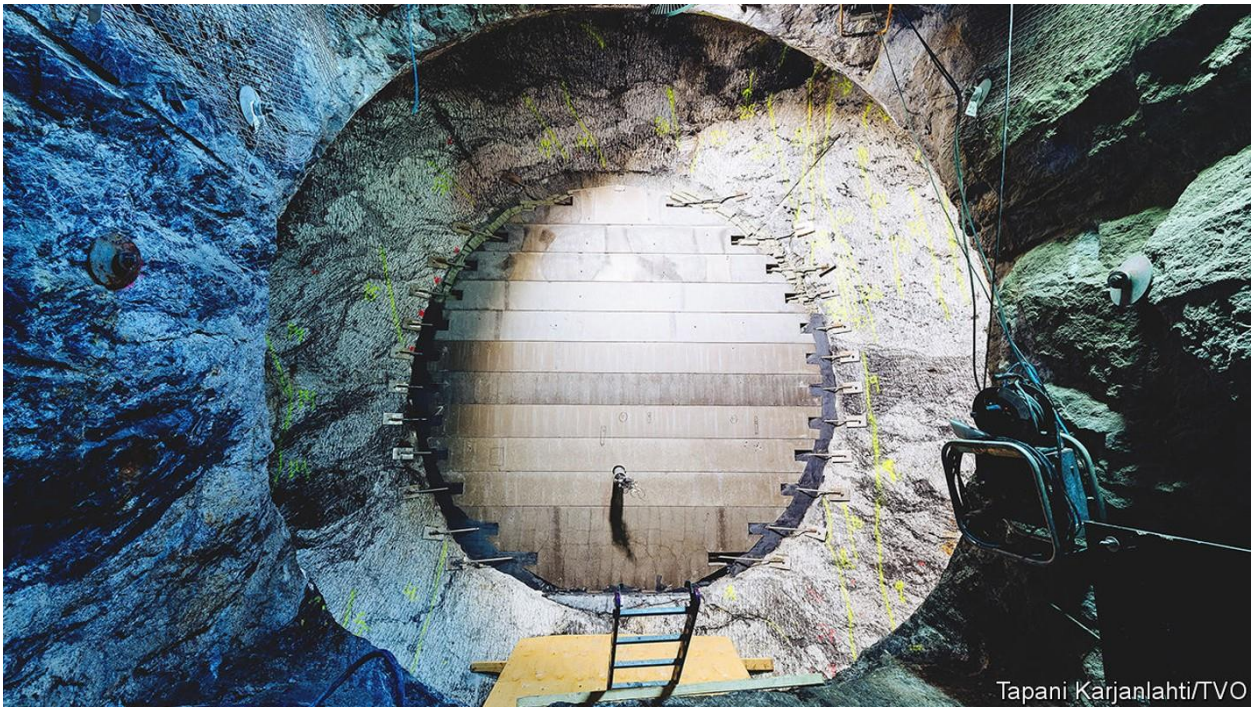
Science & technology | Nuclear waste

The first underground warren for disposing of spent nuclear fuel

Finland leads the way. Sweden and others may follow



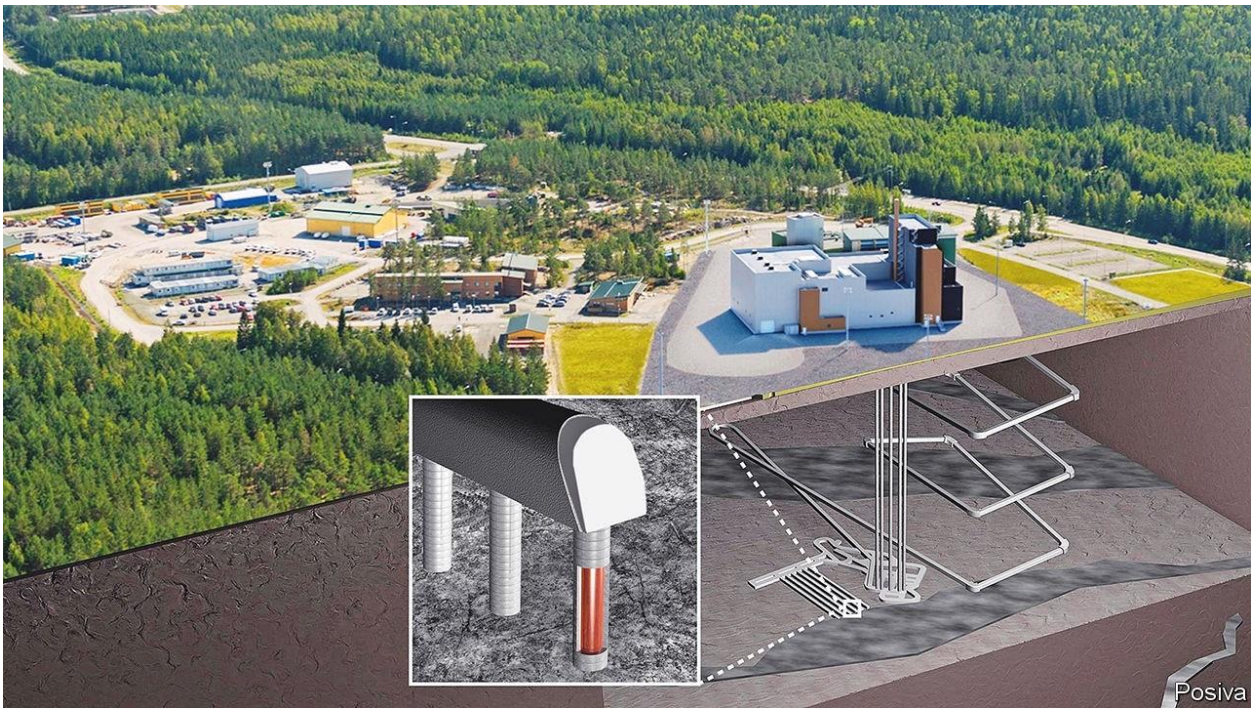
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Nearly half a kilometre underground, in the Precambrian bedrock of Olkiluoto, an island off the south-western coast of Finland, a rough-hewn gallery a few metres wide and similarly high runs dead-straight through the granite. Underfoot, the floor is a bit muddy, though mostly rocky. Overhead, steel meshing stops any fragments that might have been loosened by the drilling falling onto people's heads. Neither hard-hat-mounted torches nor the headlights of an electric van can reach far enough into the stygian darkness to pick out the gallery's end, some 350 metres away in the distance.

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Within a few years, this gallery, part of the Onkalo spent nuclear fuel repository, should be a resting place for batches of waste from Finland's two nuclear power stations to be sealed off permanently from the world. It was completed this month, the last of five almost identical tunnels that run parallel to each other, connected by a main access gallery (see diagram). If all goes well, a warren of roughly 100 more will be excavated as needed over

the coming century. As new galleries open, old ones will be backfilled with clay and sealed with concrete, entombing their radioactive contents.



Cold storage for hot waste

Deep geological disposal of this sort is widely held to be the safest way to deal with the more than 260,000 tonnes of spent nuclear fuel which has accumulated in 33 countries since the first nuclear-power plants began churning out electricity in the mid-1950s, and the still larger tonnage that may be generated in the future. Spent fuel is a high-level nuclear waste. That means it is both physically hot (because of the energy released by radioactive decay) and metaphorically so—producing radiation of such intensity that it will kill a human being in short order. Yet unlike the most radioactive substances of all, which necessarily have short half-lives, spent fuel will remain hot for hundreds of thousands of years—as long, in fact, as *Homo sapiens* has walked Earth—before its radioactivity returns to roughly the same level as that of the ore it came from.

At the moment, the vast majority of spent fuel is kept underwater in cooling pools, often within or near the power plants that generated it. The rest is in dry store. Wet or dry, these facilities are all intended as temporary depots—way-stations on the path to permanent disposal while companies and governments wrestle with the headache of where to put the stuff permanently (or conveniently turn a blind eye to a problem which they hope will not become a crisis on their watch).

And so Finland stands, for now, as the only country to have built a complete deep geological storage facility. It is just down the road from Olkiluoto's nuclear-power plant, which generates 21% of the country's electricity. Operations are expected to begin in 2024 or

2025, according to Janne Mokka, chief executive of Posiva, the company behind Onkalo. Posiva applied for its operational licence in December 2021. A trial run is expected next year. Sweden is just a few years behind, with its own repository at Forsmark, directly across the water from Olkiluoto. Both use similar designs.

The basic principle of deep geological storage is to put a multiplicity of physical barriers and a great deal of stability between the waste and human beings. Spent fuel rods are first left to cool for a few decades before they are sealed into metallic capsules of a composition that depends on the repository's geochemistry. The idea is to use something which will not corrode—at least not faster than the radioactive material within it decays.

In both Onkalo and Forsmark the water pervading the granite's tiny fissures is free of dissolved oxygen. Copper, corrodible by oxygen but otherwise stable, can thus be used for containment. The cooled fuel rods are packed into cast-iron vessels sheathed in cylindrical copper capsules eight metres tall and 1.05 metres wide. Argon, an inert gas, is injected between the two metals and the copper welded shut by remotely operated machinery. The capsule is then cleaned and transported to a lift that lowers it 430 metres, to a place where the rocks are unperturbed by human activity, climate change or the kinds of fracturing that an ice age might impose.

All this happens inside a remotely operated assembly line on top of the lift shaft. Onkalo's encapsulation building was finished at the end of May and its rooms are now being kitted out with robots that will manipulate the waste.

When the capsules are at the bottom of the shaft, a fleet of remotely operated vehicles will ferry them through a network of underground tunnels to whichever gallery is in the process of being filled. Once there, each will be lowered into a hole in the floor that has been lined with bentonite, an absorbent clay commonly used in cat litter. This will help to keep the copper dry. Gaps that remain will be filled with further bentonite and the hole sealed off. In Onkalo, the floor of each 350-metre gallery can accommodate 30 evenly spaced capsules, together holding 65 tonnes of spent fuel. Once full, galleries will be backfilled with yet more bentonite before their entrances are sealed with a reinforced-concrete cap. *Et voilà*. Goodnight, sleep tight.

Nor will any unwitting adventurer easily blunder across the place in future to wake the sleeping horror lying beneath. In 100 years' time, Posiva will fill the whole site in, remove all traces of buildings from the surface and hand responsibility over to the Finnish government. The thinking is that leaving no trace or indication of what lies below is preferable to signposting the repository for the curious to investigate.

Eventually, the containers may corrode. How long that will take is debated. In 2007 Peter Szakalos, a chemist in Sweden, published a study suggesting copper canisters can do so even in oxygen-free water, and that this could cause them to crack within decades or centuries, not millennia. These findings caused some angst among regulators in Sweden and Finland. Nevertheless, in January of this year, Swedish authorities announced that their concerns had been allayed and construction at Formsark was given the go-ahead.

The current consensus is that corrosion rates, combined with the rates of processes which might bring any radioactive material towards the surface, are so slow that by the time anything does get there it will pose little risk to whatever life is around.

The technology needed to dispose of Finland's waste is thus now in place. But, crucially for Onkalo's success, the government has also, through decades of careful communication and negotiation, obtained popular buy-in for the project.

"It represents 50 years of building trust," says Mr Mokka. That trust-building started with the local power plant. On June 11th, at a summer fair in a town square in Rauma, 20km down the road from the repository, children tottered about holding balloons emblazoned with the logo of the local electricity company. Jenna, a young mother, described how she visited the plant on a school trip when she was a little older than her own child is now. Most people are fine with a nuclear facility just up the road, she says. It is an important employer, and the property taxes its operators pay help local finances. Of the final five sites that had appropriate geology to host Onkalo, two had local populations that were extremely pro-nuclear. Both were next to nuclear-power plants.

Other countries face more difficulties. France's deep-storage efforts, though well advanced, are plagued by demonstrations. America's Yucca Mountain project, in Nevada, is stalled by state-level opposition. But feelings could change over coming decades, and technological advances may make recycling spent fuel first before disposing of it—something France does already—a more attractive option. But regardless of whether nuclear power experiences a comeback, just solving the problem of that 260,000 tonnes of existing waste will surely require lots of digging.

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Policy Resolution 2022-09

Radioactive Materials Management

A. BACKGROUND

1. Western states have a vested interest in the safe management of radioactive materials, from mining and milling of uranium ore, to the production and use of radioactive materials for commercial and national defense purposes, to the transportation, storage and disposal of radioactive materials and waste. Large amounts of high-level radioactive waste have been, and will continue to be, transported through western states, both as a result of environmental cleanup of federal sites involved in the development and manufacture of nuclear weapons and for storage or disposal of spent nuclear fuel (SNF) used to generate electricity.

2. The Waste Isolation Pilot Plant (WIPP) located in New Mexico was constructed to serve as a permanent repository for defense-related transuranic (TRU) waste. On March 26, 1999, WIPP received its first truck shipment of TRU waste from the Los Alamos National Laboratory.

3. Since that date, the WIPP shipping campaign has demonstrated the safe transportation of TRU waste. More than 12,000 shipments of contact-handled (CH) waste and 719 shipments of remote-handled (RH) waste have been received at the WIPP facility. During that time, only a few minor incidents have occurred while shipments were en route. None of these incidents resulted in serious injury or a release of radioactive material into the environment.

4. More than 90 percent of the existing inventory of TRU waste is located at Department of Energy (DOE) facilities in western states. Tens of thousands of cubic meters of TRU waste – much of it mixed with hazardous chemical waste – await permanent disposal at WIPP.

5. The success of the WIPP TRU waste transportation campaign is directly attributable to a collaborative partnership and planning effort between DOE and the western states to develop and implement the WIPP Transportation Safety Program.

6. The 2006 National Academy of Sciences National Research Council report, "Going the Distance?: The Safe Transport of Spent Nuclear Fuel and High-Level Radioactive Waste in the United States," provides a comprehensive set of findings and recommendations that provide a sound basis for planning future SNF and high-level radioactive waste (HLW) shipping campaigns.

7. Currently, about 75,000 metric tons of commercial SNF is stored at or near nuclear power plant sites, research and test reactors, and independent spent fuel storage installations in 40 states. Historically, more than 80 percent of the SNF at operating and shut down reactor sites has been generated in the eastern portion of the United States.

8. The amount of SNF stored on-site at commercial nuclear reactors will continue to accumulate – increasing by about 2,000 metric tons per year and likely almost doubling to

about 140,000 metric tons before it can be moved off-site, because storage or disposal facilities may take decades to site, license, and develop before accepting waste.

9. Congress mandated that the federal government begin accepting spent fuel by January 30, 1998. However, it remains uncertain when an operating repository will be sited and licensed, let alone begin accepting waste.

10. High-level radioactive wastes that are the by-products of nuclear weapons production and spent nuclear fuel from the U.S. Navy's nuclear power activities will require permanent disposal. There are also quantities of weapons-capable plutonium and highly enriched uranium that the federal government has declared surplus to national security needs, which will likewise require disposal in a repository. Many of these wastes are being temporarily stored at locations in western states, including California, Idaho, New Mexico and Washington.

11. The Western Interstate Energy Board (WIEB) provides most Western Governors with the instruments and framework for cooperative state efforts to "enhance the economy of the West and contribute to the well-being of the region's people." WIEB's High-Level Radioactive Waste Committee, which consists of nuclear waste transportation experts from state energy, public safety, and environmental agencies, has been working with DOE since the 1980s to develop a safe and publicly acceptable system for transporting SNF and HLW under the Nuclear Waste Policy Act of 1982 (Pub. L. 97-425 as amended, 42 U.S.C. 10101 et seq.).

12. Given existing and proposed sites for disposal of radioactive waste in the United States, Western Governors are concerned that western states may be disproportionately affected by radioactive waste transportation, storage and disposal activities.

B. <u>GOVERNORS' POLICY STATEMENT</u>

1. Western Governors believe that the safe and event-free transport must be paramount in all federal policies regarding transportation of radioactive materials and SNF. This is true of all transportation modes, including truck and railway.

2. The Governors support existing federal radioactive waste transport safety requirements designed to protect public health and safety, including the Hazardous Materials Transportation Authorization Act.

3. Early coordination and effective communication with state, tribal and local governments are essential to the ultimate success of any nuclear waste transportation safety program.

4. The WIPP Transportation Safety Program Implementation Guide is an excellent model for transportation planning, and a similar guide should be used as a base document for DOE transportation programs including shipments of SNF, or HLW, to any storage and/or disposal facility.

5. If DOE decides to transport radioactive waste – such as SNF, HLW or TRU – by rail, federal agencies should work with states to design and implement such a transportation system. The rail industry should fully cooperate in this process and commit to implementing best

practices for such a transportation system. Congress should provide a firm legal basis for transportation system design and implementation.

6. The WIPP Transportation Safety Program is essential to the expeditious cleanup and disposal of TRU waste from the U.S. nuclear weapons complex and the operation of WIPP. Western Governors expect DOE to fulfill commitments made by the Secretary of Energy as set forth in Memorandums of Agreement with WGA signed in 1995, 2003 and 2009.

7. DOE must continue to comply with both the letter and spirit of all applicable requirements specified in the WIPP Land Withdrawal Act (Pub. L. 102-579, as amended by Pub. L. 104-201, 106 Stat. 4777 et seq.), especially regarding transportation safety, emergency preparedness and accident prevention. Further, the Governors support resumption of the economic assistance payments authorized in Section 15 of the Act.

8. The Governors also expect DOE to follow the safety standards, principles and procedures as contained in the WIPP Transportation Safety Program Implementation Guide, as amended, for the transport of all TRU waste, whether to WIPP or to an interim site for storage, characterization and/or repackaging.

9. DOE must continue to provide sufficient and timely in-kind, financial, technical, and other appropriate assistance to any state or Indian tribe through whose jurisdiction TRU waste will be transported for the purpose of planning, developing and implementing the WIPP Transportation Safety Program.

10. The Governors believe it is the responsibility of the generators of SNF and HLW and the federal government, not the states and tribes, to pay for all costs associated with assuring safe transportation, responding effectively to accidents and emergencies that may occur, and otherwise assuring public health and safety. This includes costs associated with route evaluations and inspecting and escorting shipments. In addition, funding allocations to states and tribes should be made on a needs-based rather than formula-based system.

11. In any radiological materials/waste shipping campaign, including SNF or HLW, no federal agency or other entity should have the authority to privatize or delegate to a contractor any key transportation responsibilities unless approved by the states. Such responsibilities include but are not limited to: interacting with states, tribes, and affected units of local government; selection of transportation modes, routes, and casks; preparation of an environmental impact statement that addresses transportation issues; preparation of transportation plans in concurrence with states and tribes; and decisions regarding the provision of technical assistance and funding to the states in preparation for shipments.

12. Trains transporting SNF and HLW should be inspected by fully qualified inspectors, using a consistent approach which has been developed cooperatively with the help of western states. To the extent practical, the inspection protocol should be commensurate with the Commercial Vehicle Safety Alliance Level VI inspection program, which has been successfully used by all highway shipments to WIPP.

13. The Federal Railroad Administration Rail Safety Program and revised Safety Compliance Oversight Plan should be fully implemented along any route affected by prospective SNF/HLW shipments in any western state. Five years prior to the start of such shipments,

each affected western state should receive financial and technical support from DOE to ensure sufficient trained state rail safety inspectors.

14. Although DOE has the authority to self-regulate its shipments of SNF and HLW, the Governors believe DOE should adopt the U.S. Nuclear Regulatory Commission (NRC) physical protection requirements for all such shipments. NRC regulations establish a comprehensive physical protection system designed both to minimize the potential for theft, diversion, or radiological sabotage of such shipments, and to facilitate the location and recovery of such shipments that may have come under the control of unauthorized persons.

15. DOE should invoke provisions of its Standard Contract with nuclear utilities to prioritize shut-down nuclear reactors over operating reactors in terms of shipment priority. In addition, DOE should adopt a policy of shipping "oldest fuel first," so as to reduce the radiological risk during transportation.

16. No consolidated facility for nuclear waste, whether interim or permanent, or privately or federally owned and operated, shall be located within the geographic boundaries of a western state or U.S. territory without the written consent of the current Governor in whose state or territory the facility is to be located. Specifically, the federal government should develop a consent process for consolidated nuclear waste storage or disposal facilities, whether publicly or privately owned, that explicitly includes states in the siting and licensing process.

17. Any proposal to store or otherwise dispose of HLW and/or SNF must be viewed as being part of an integrated program that considers all aspects of necessary operation and intergovernmental considerations. Specifically, transportation and logistical considerations such as proximity to population centers or military installations should not be an afterthought to the planning or siting process.

18. The Governors support efforts by the federal government to examine alternative waste acceptance options, including but not limited to providing funds to utilities for expanded on-site storage and taking title to SNF at individual reactor sites. The search for alternatives must not detract from the imperative to develop a permanent solution to the management and disposition of SNF.

19. The Governors strongly encourage DOE and NRC to work cooperatively with the states in implementing a policy to ensure the safe management, transportation, storage, and disposal of SNF and HLW and to comply with any and all agreements negotiated and entered into by a state's Governor regarding these matters.

20. Commercial SNF should remain at reactor sites until:

    - One or more storage and/or disposal sites or reprocessing facilities are fully operational with appropriate permits and financial assurance as required by the state.

    - DOE and the nuclear utility companies have consulted with states along the waste transportation corridor and implemented a mutually acceptable transportation plan for shipping the SNF waste to interim storage facilities or permanent disposal sites.

- DOE and the nuclear utility companies have put into place adequate infrastructure capacity to handle, store and dispose of this waste.

- DOE, the U.S. Department of Transportation, and the nuclear utility companies have ensured and funded adequate state and local emergency and medical responder training and resources in case of an accident or terrorist attack while shipping this waste.

21. The creation of interim storage sites for SNF would be a direct result of the federal government's failure to begin accepting spent fuel on schedule. Therefore, the Governors maintain that it is the federal government's responsibility to ensure adequate preparation for shipments to these facilities, coordination with states, and provision of adequate federal funding, to reimburse the states for costs associated with shipments to any interim storage facility, whether publicly or privately owned and operated. The Governors consider it to be entirely appropriate to use the Nuclear Waste Fund to pay for these activities.

C. GOVERNORS' MANAGEMENT DIRECTIVE

1. The Governors direct WGA staff to work with Congressional committees of jurisdiction, the Executive Branch, and other entities, where appropriate, to achieve the objectives of this resolution.

2. Furthermore, the Governors direct WGA staff to consult with the Staff Advisory Council regarding its efforts to realize the objectives of this resolution and to keep the Governors apprised of its progress in this regard.

This resolution will expire in June 2025. Western Governors enact new policy resolutions and amend existing resolutions on a semiannual basis. Please consult http://www.westgov.org/resolutions for the most current copy of a resolution and a list of all current WGA policy resolutions.