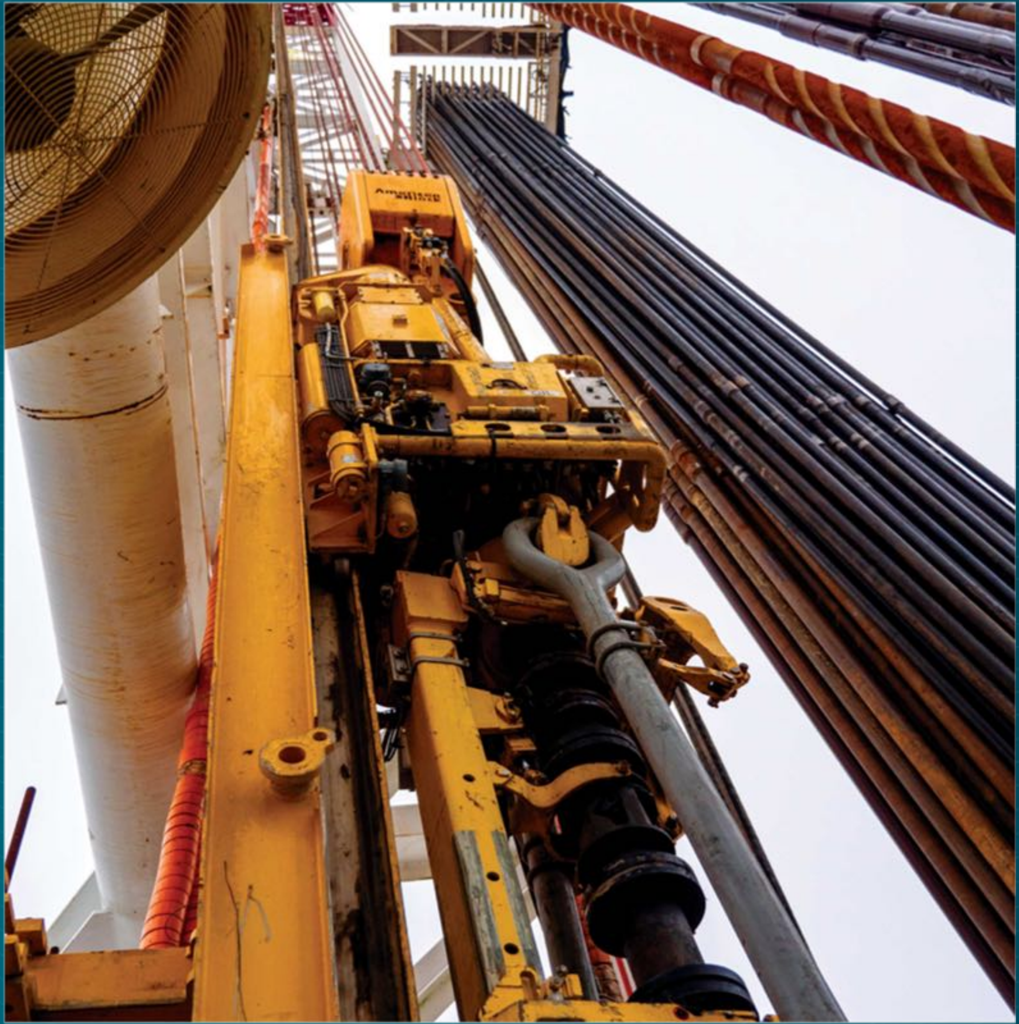
Disposal of Radioactive Waste from Advanced Reactors in Horizontal Boreholes

Southeast Section of Geological Society of America – 70th Annual Meeting

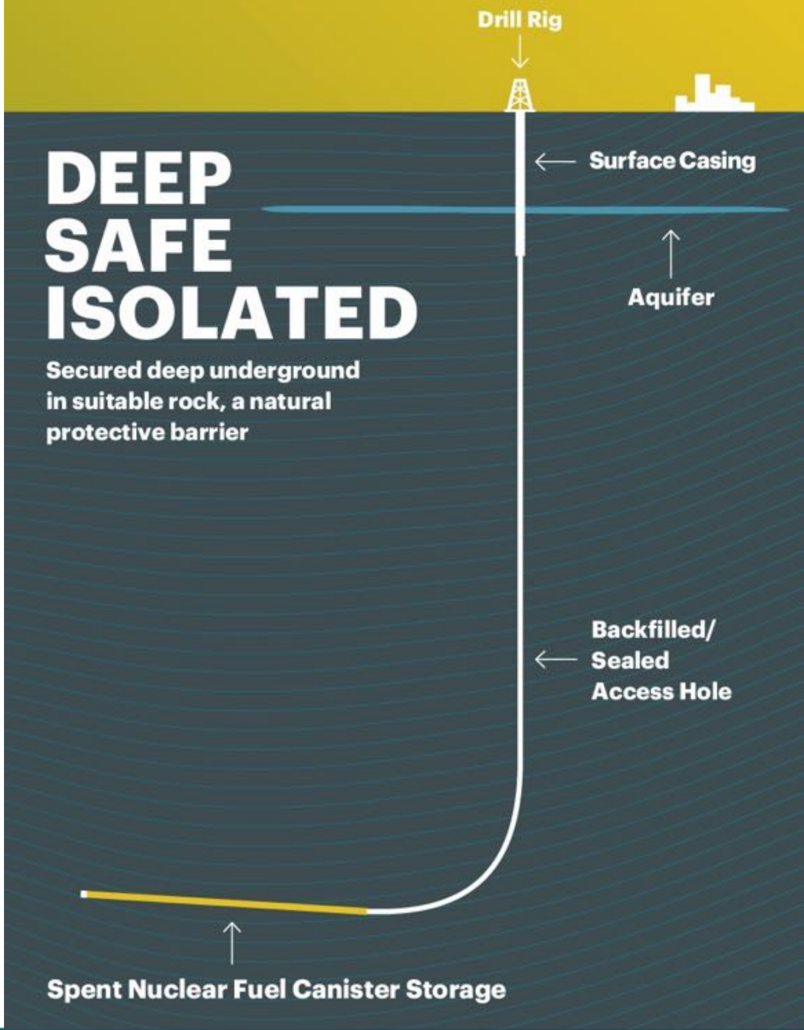
April 2021



Who We Are

Overview of Deep Isolation

- Deep Isolation offers safe, equitable and affordable disposal of nuclear waste
- Founded in US in 2016; Deep Isolation EMEA Limited launched in 2020, based in London.
- Our solution:
  - Places corrosion-resistant canisters containing spent fuel into borehole repositories deep underground (far deeper than feasible with a mined repository)
  - Uses directional drilling technology to drill into sedimentary, igneous or metamorphic host rocks that have remained isolated from the environment for millions of years
  - Leverages mature technologies that are widely used in industry and that we have integrated and enhanced with our own patented innovations



Developing an innovation ecosystem to tackle a global problem

1 Innovation

- 40+ inventions, with 38 US and international patents granted and in development:
  - Formation suitability
  - Repository Design
  - Canister Design
  - Handling, Emplacement, & Retrieval
  - Monitoring
- Most support all borehole architectures, some are specific to vertical or horizontal

2 Open and peer-reviewed science

3 World-class supply chain

Nuclear waste handling

DEEPISOLATION

Drilling

BECHTEL

NAC INTERNATIONAL

Schlumberger

4 Inter-disciplinary, cross-sector stakeholder engagement

universities
collaboration
NGOs
partners
communities
local government
civil society
green energy
citizens
municipalities
oil & gas
environment
research institutes
schools
nuclear
National Geological Surveys

5 Client collaboration

- Perhaps most importantly, we are now deeply engaged with potential clients and partners around the world – including many national radioactive waste management organizations
- Key focus of this engagement:
  - Waste inventory review
  - Geological suitability
  - Regulatory pathways
  - Local economic development impacts
  - Stakeholder engagement processes

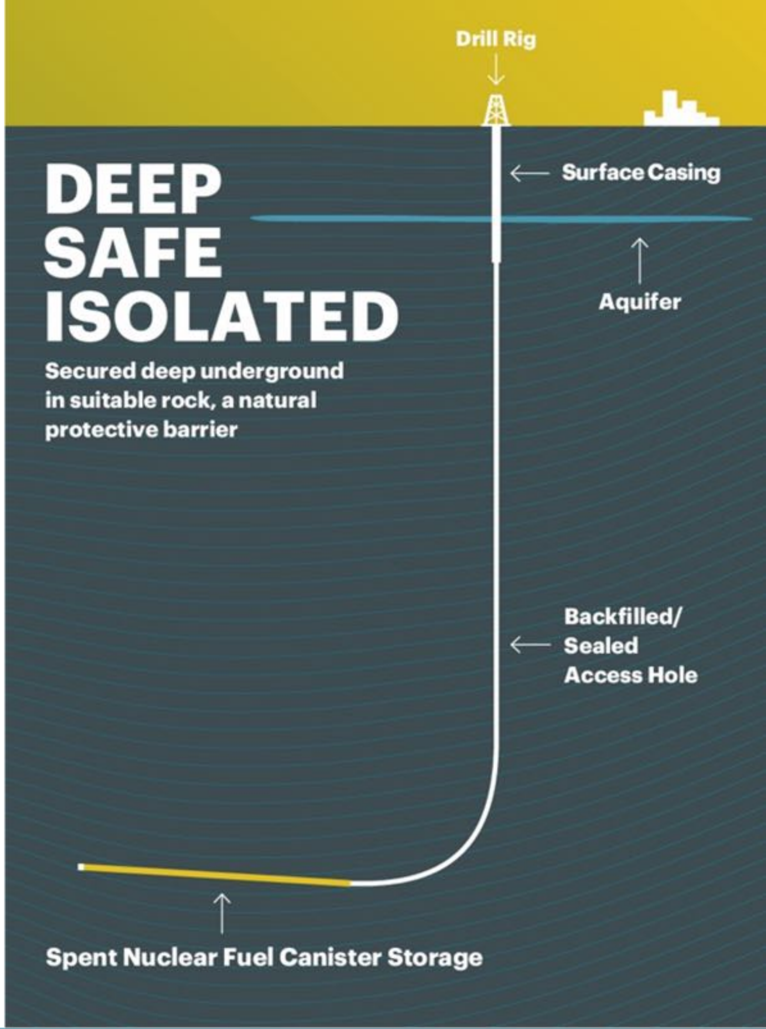
Stakeholder partnership and consent

- Planning and delivering a Deep Isolation borehole repository is a complex and multi-disciplinary process
- We bring together local and international experts, working closely with our client, to develop a bespoke **Deep Isolation Roadmap** informed by deep engagement with local stakeholders and communities

How It Works

The unique feature of our system is that we dispose of waste in a deep horizontal drillhole.

Secured thousands of feet deep in low permeability rock that has been isolated for millions of years

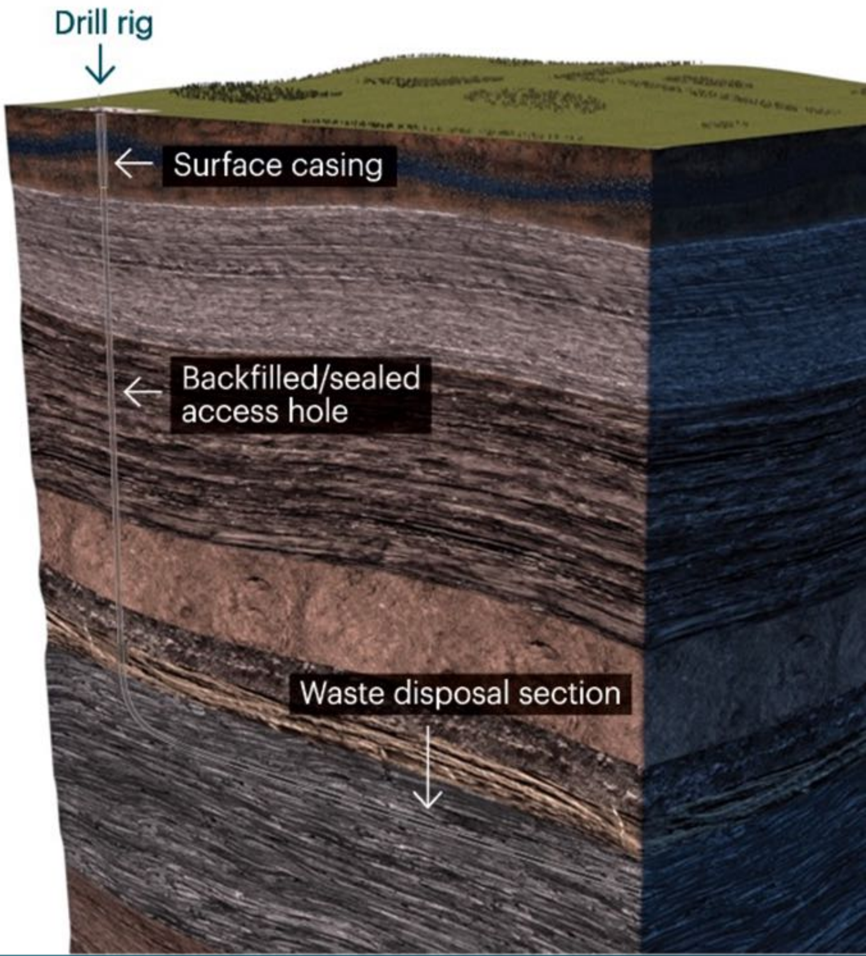


Deep Isolation Geologic Repository

- Thousands of feet below the surface and far below any aquifers
- Smaller diameter holes (e.g. 20cm to 76cm) reduce the of disturbed zone around borehole
- Horizontal disposal section allows waste canisters to be placed end-to-end rather than stacked

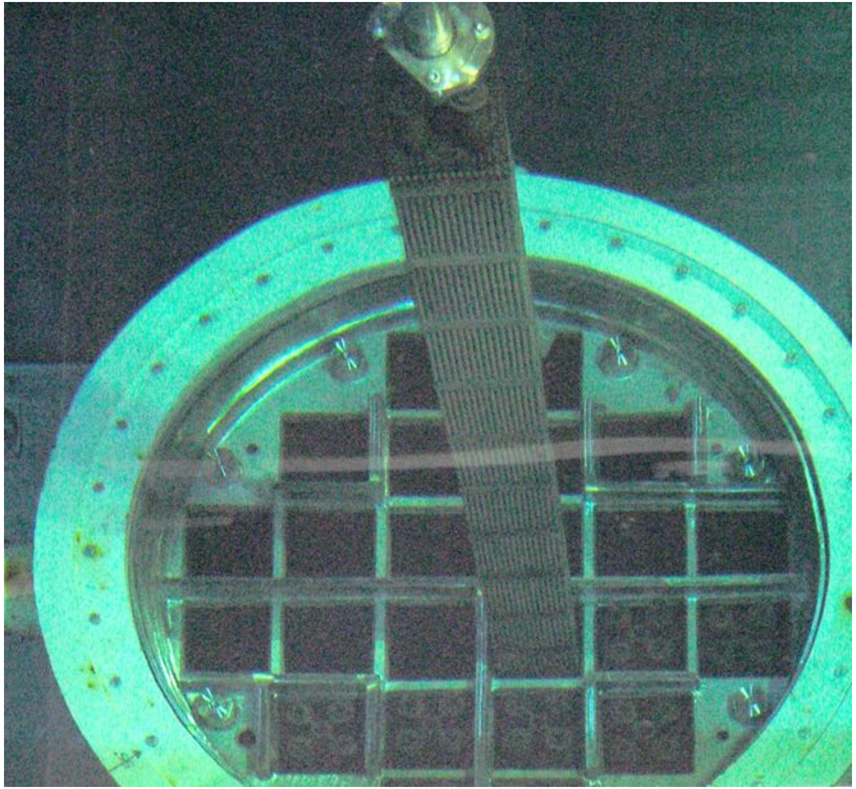
Engineered Barriers

- Reducing environment at depth significantly slows corrosion
- Corrosion resistant canisters provide an important barrier that will survive for tens of thousands of years
- Engineered seal plugs the drillhole to block potential pathway



Waste Handling

- Decades of experience in the nuclear industry with designing, engineering, licensing, operating and maintaining used nuclear fuel management systems for storage and transport.
- Similar methods will be used to move fuel from storage pools to Deep Isolation disposal canisters.



Canister and wireline & tractor

Technology test and demonstration on 16 January 2019

We tested and retrieved prototype disposal canister sized for caesium/strontium capsules

Borehole total length was 823 metres – 670m vertical and 153m horizontal

Local community members participated in the public demonstration

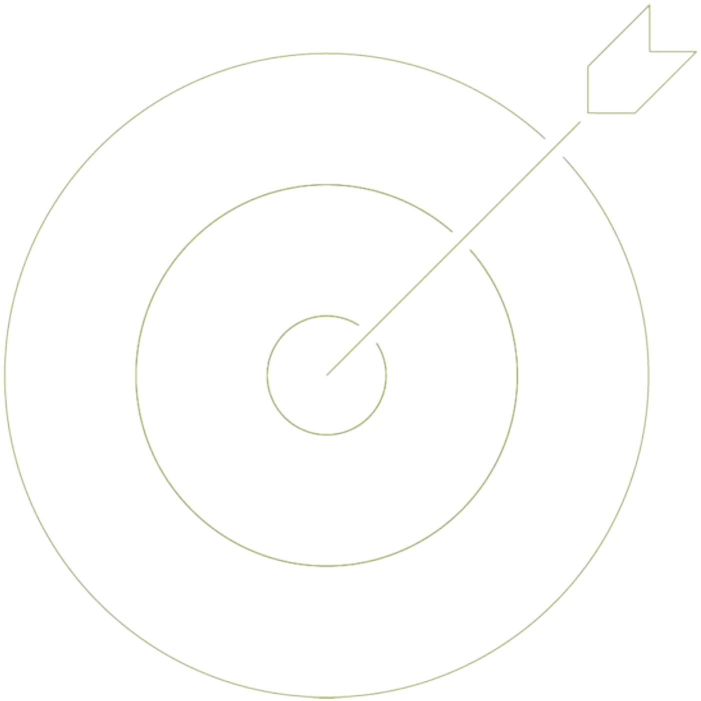
Potential Benefits of Our Solution

We minimize or eliminate transportation because waste can be disposed at or near existing nuclear reactor sites.

Spent fuel is compact: one drillhole can store 200 to 400 tonnes.

As few as 10 boreholes are needed per nuclear reactor to accommodate 60 years of spent nuclear fuel.

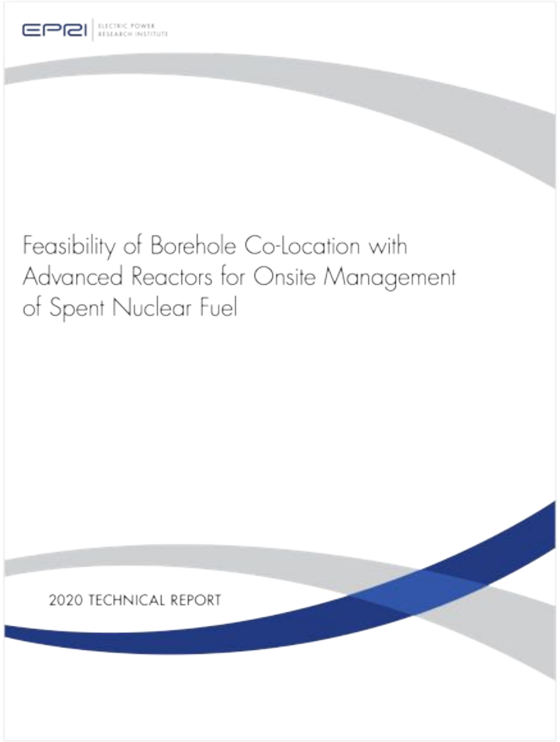
Costs are about half of a traditional mined repository.



Key Finding from Report

Topics

1) Introduction and Background
2) Study Scenarios and Assumptions
3) Regulatory Considerations
4) Physical Site Characteristics
5) Spent Nuclear Fuel, Waste, and Package Specifications
6) Concept of Operations
7) Safety Assessment
8) Public Acceptance
9) Strategic Partnerships for Borehole Disposal
10) Risk Management
11) Notional Schedule and Budget
12) Key Findings and Next Steps



PURPOSE OF REPORT

”For future deployment of advanced reactors (ARs), having an answer to the “What about the waste?” question is widely considered a fundamental building block for establishing and maintaining public confidence and support.”

“…commercially deployable deep horizontal borehole technology could offer utilities and other AR owner-operators a viable and beneficial alternative path for managing the backend fuel cycle.”

“…the issues and gaps that emerge from this review can inform actionable recommendations and next steps with respect to planning, design, siting, licensing, deployment, and operation.”

RESULT

“This preliminary evaluation, focused primarily on the U.S. context, indicates that onsite integration of deep borehole disposal technology with the deployment and operation of ARs may offer some unique and valuable options for a future owner-operator.”

No technical showstoppers.

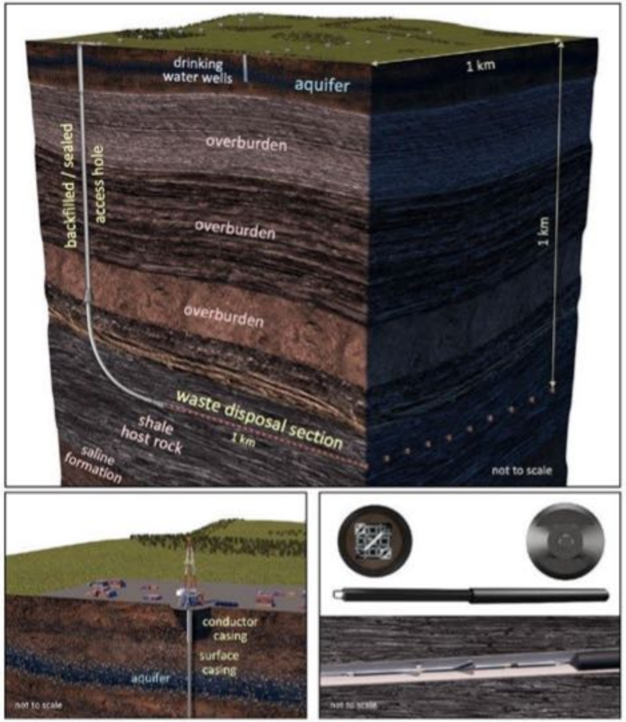
No technical showstoppers are identified based on a generic site and AR technology agnostic evaluation.

Greater flexibility and optionality

Greater flexibility and optionality emerge from scenarios in which onsite disposal options are available, including mitigation of business risk by decoupling reactor operations from external backend fuel cycle issues.

Retrievability offers unique benefits

The horizontal variant of borehole technology evaluated in this study offers unique benefits for applications where waste package retrievability is a priority, such as for interim, fully-reversible storage prior to closure for permanent disposal.



Potential regulatory path is available in US

10 CFR Part 60 represents a barrier for near-term implementation of deep borehole disposal in the United States; a potential path exists through 10 CFR Part 72

Retrievable storage in borehole systems would be pursued with the option for permanent disposal under a new regulation with the benefit of information gained from monitoring and inspection over the period of retrievable interim storage.

Support is foundational

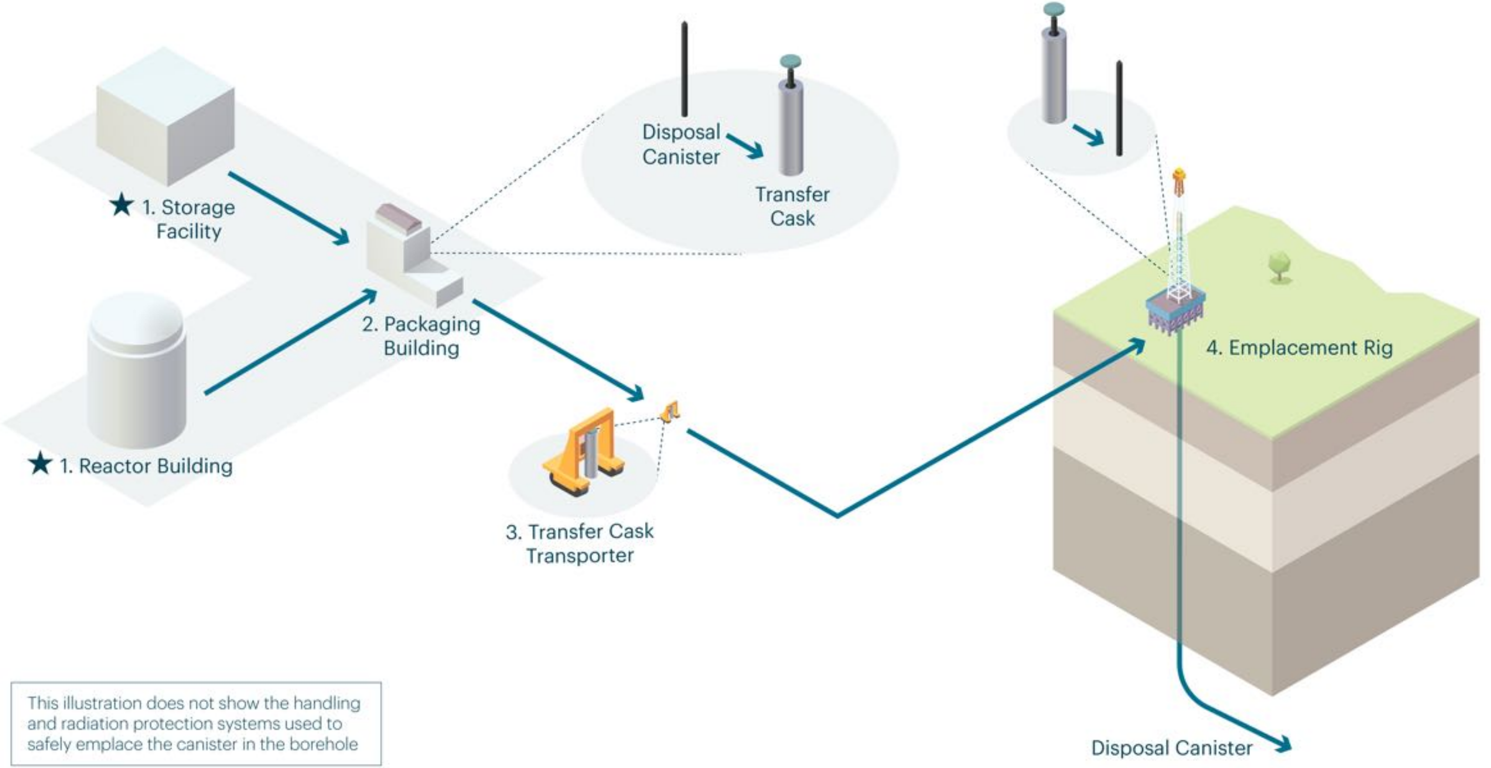
Establishing and maintaining support from the public, regulators, and other stakeholders is foundational.

Further evaluation needed

Further evaluation and demonstration of deep borehole technologies could yield a valuable enabling option for the commercialization of advanced nuclear power plants.

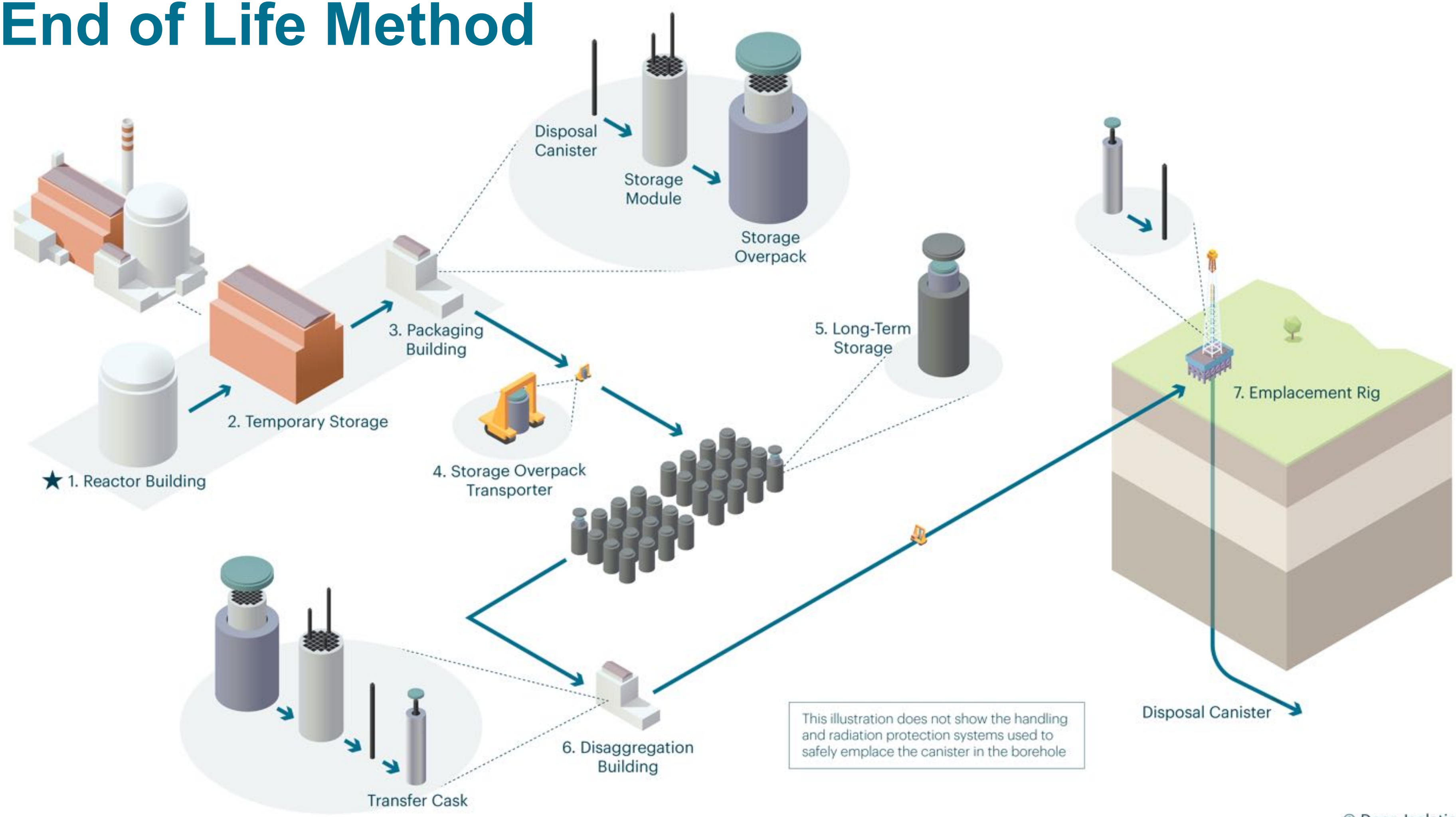
Cost Assumptions and Estimates

Ongoing Disposal Method



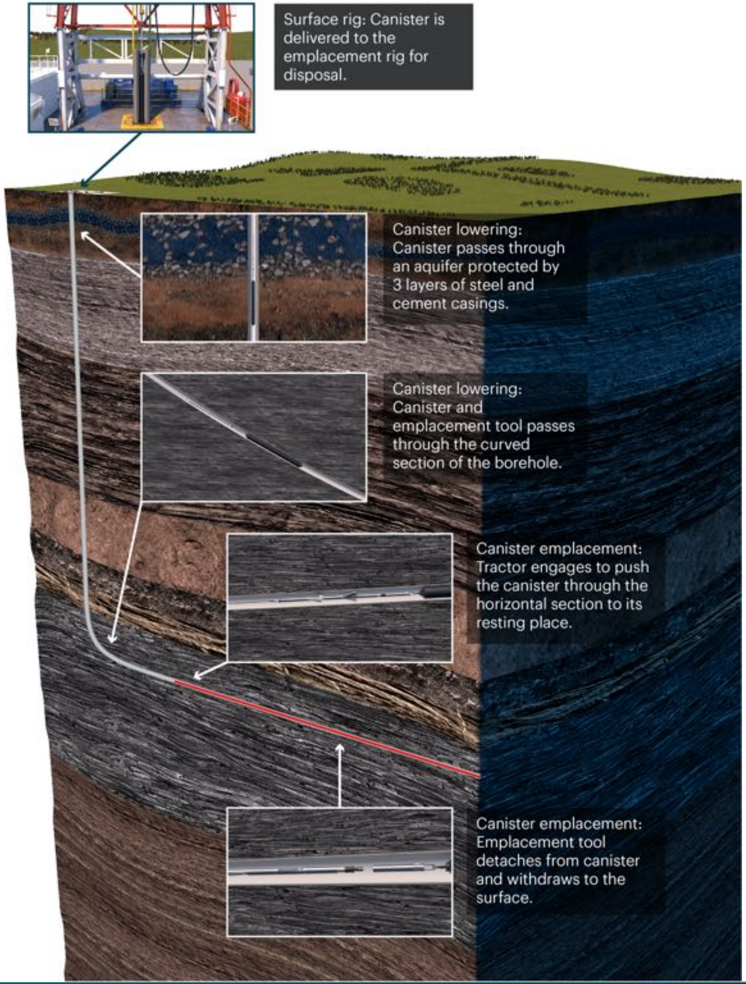
This illustration does not show the handling and radiation protection systems used to safely emplace the canister in the borehole

End of Life Method



Operational assumptions

Assumption area	Description of assumption
Repository	1 km deep and 1.5 km long in sedimentary rock with 44cm diameter borehole. Holds 210 disposal canisters, so 10 boreholes are needed.
Fuel	Size and characteristics of PWR fuel. SNF is produced ratably over 20-years resulting in 2,100 assemblies with 1,000 MTHM.
Storage	Storage pad and MPC costs were $130M and storage after shutdown was $192M based on US average of $20,682/MTHM.
Method	Ongoing requires additional mobilization for drilling rig, but no storage costs. End of Life requires storage, but no mobilization.



Estimated Disposal Costs by Scenario

	End of Plant Life Borehole Disposal	Ongoing Borehole Disposal	Mined Repository	Two Unit Plant	
				Ongoing Borehole Disposal	Mined Repository
	Millions of USD				
Base disposal	$469	$469	$1,240	$724	$2,480
Mobilization and Demobilization	—	$9	—	$17	—
Storage During AR Operation	$130	—	$130	—	$260
Storage After AR Shutdown	—	—	$192	—	$192
Total costs	**$599**	**$478**	**$1,562**	**$741**	**$2,932**
Savings Relative to Mined Repository	$963	$1,085	—	$2,192	—
Savings Relative to Mined Repository (%)	62%	69%	—	75%	—

Thank you!

Deep Isolation, Inc.

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