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2026 DLA Energy Worldwide

Geothermal: Future Energy Born in Fire

April 21, 2026

U.S. DEPARTMENT of ENERGY BATTELLE

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Geothermal: Future Energy Born in Fire

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Geothermal energy can cover a wide range of topics. This session will identify the ones of most significance to the military, discuss the current state of the technologies involved, major issues facing implementation, and future potential in terms of energy production.

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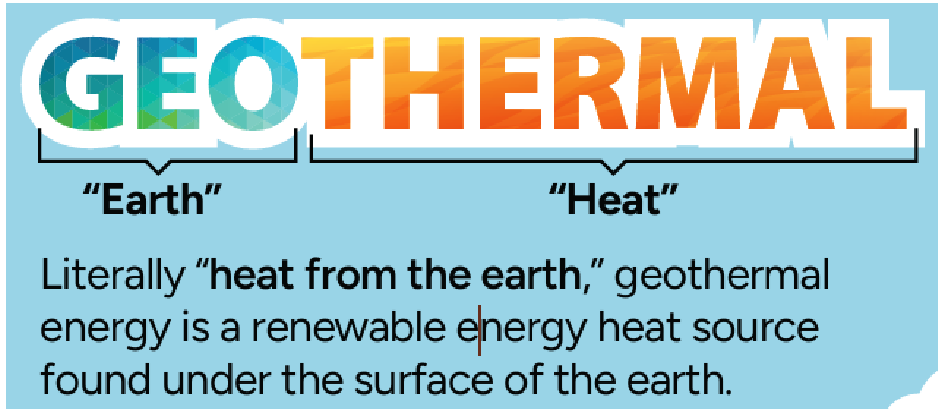
DOE’s 17 National Laboratories

What is Geothermal Energy



<u>Primordial Heat:</u> residual from the Earth's formation, trapped within the Earth's interior
→ ***Inexhaustible***

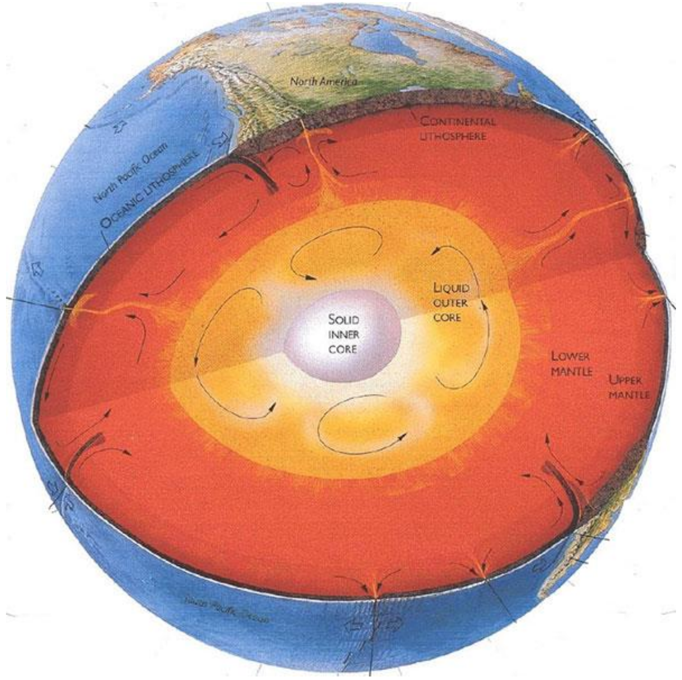
Radiogenic Heat: produced by the decay of naturally occurring radioactive isotope within the Earth's crust and mantle
→ ***Replenish Earth's heat supply continuously***

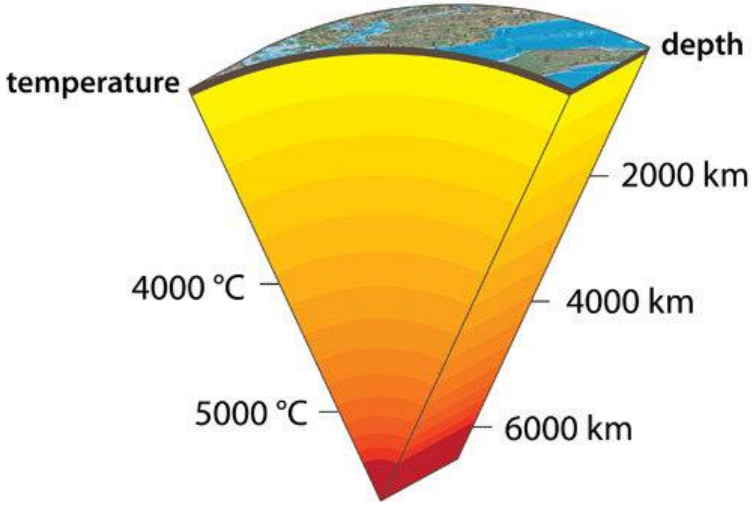
How does the heat get to the surface (or close)?

Convection: how heat is transferred through the movement of fluids
→ ***Magma or water movement due to tectonics***

Conduction: how heat moves through solid materials
→ ***Movement upward through rocks***

Volcanic Activity: movement of magma from the mantle driving volcanic eruptions, hot springs, geysers, steam vents
→ ***Often are indicators of geothermal energy potential***





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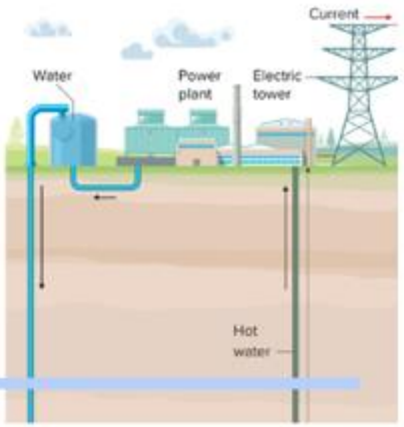
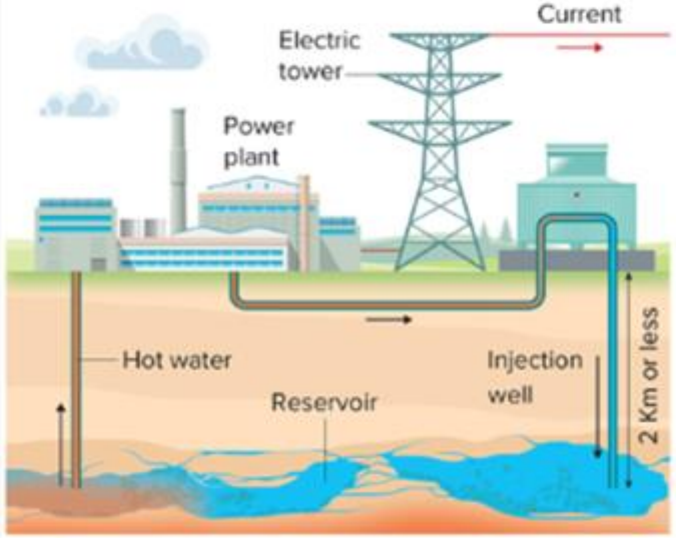
Power Production Technologies



Maturity — established — nascent — pilot — immature

TRADITIONAL GEOTHERMAL

Water naturally heats underground in volcanically active places. Power plants draw the hot water and/ or steam to the surface where it powers electricity-generating turbines. The used water is then returned.

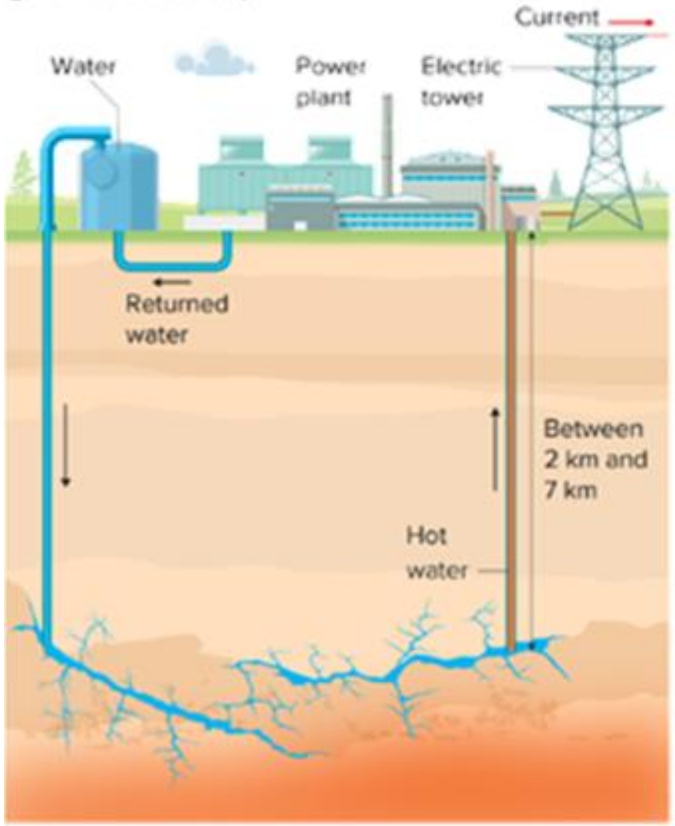


Ormat
Calpine
Cyrq

Fervo
AltaRock
Sage
UT-FORGE

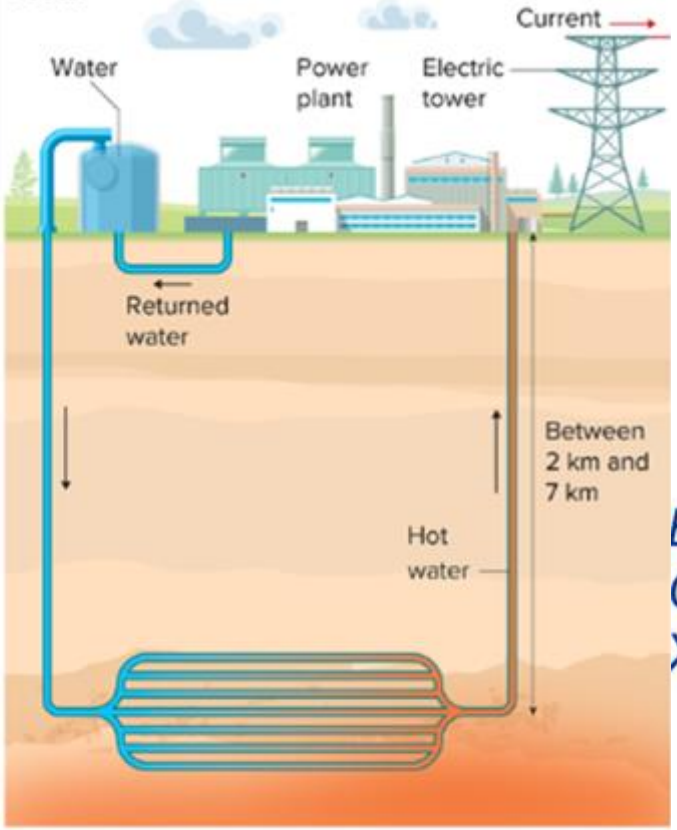
ENHANCED GEOTHERMAL - EGS

Geothermal energy can be extracted from non-volcanic places by pumping cool water through a system of man-made cracks in deep hot rock formations. Once heated, the water is used to generate electricity.



CLOSED-LOOP GEOTHERMAL - AGS

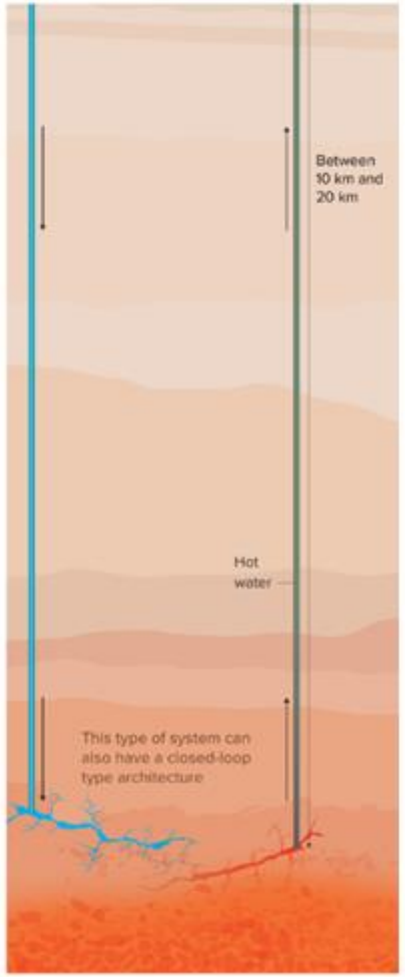
Rather than fracturing the rock to create an underground heat exchanger, closed-loop systems funnel cold water through a network of parallel boreholes deep in the ground, where the water heats.



Eavor
Greenfire
XGS

SUPER HOT ROCK GEOTHERMAL

Power plants could reap even more energy if they drilled to extreme depths where water reaches "supercritical" temperatures at which it carries much more energy than hot water or steam.



Quaise
Mazama
HERO
GeoX

Advantages and Challenges

Advantages:

- Resilient to disruptions
  - Below ground resource, onsite energy conversion, no supply chains
  - Grid independent – good for data centers, military bases, etc.
  - Domestic resource
- Small surface footprint – easier to site
- Potential to access everywhere if technical and economic barriers are overcome

Challenges

- **High initial cost**
- **Location-specific nature**
- **Economics**
- **Well system failure**
- **Permitting**

Current Projects and Partnerships

Summary

- Geothermal has significant potential to support the DOD mission space.
- Geothermal is a firm, reliable, scalable, 24/7 power resource.
- There are 4 type of geothermal power technologies.
  - Hydrothermal – mature, established
  - EGS – Nascent
  - AGS or Closed Loop – Pilot
  - Super Hot - Immature
- Geothermal power has high upfront costs and is location specific but has small footprint requirements compared to other technologies.
- Technology advancement should help decrease costs and increase feasible installation areas.

Fervo Energy 3.5 MW EGS Pilot in Nevada

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THE QUESTION IS NO LONGER CAN GEOTHERMAL WORK

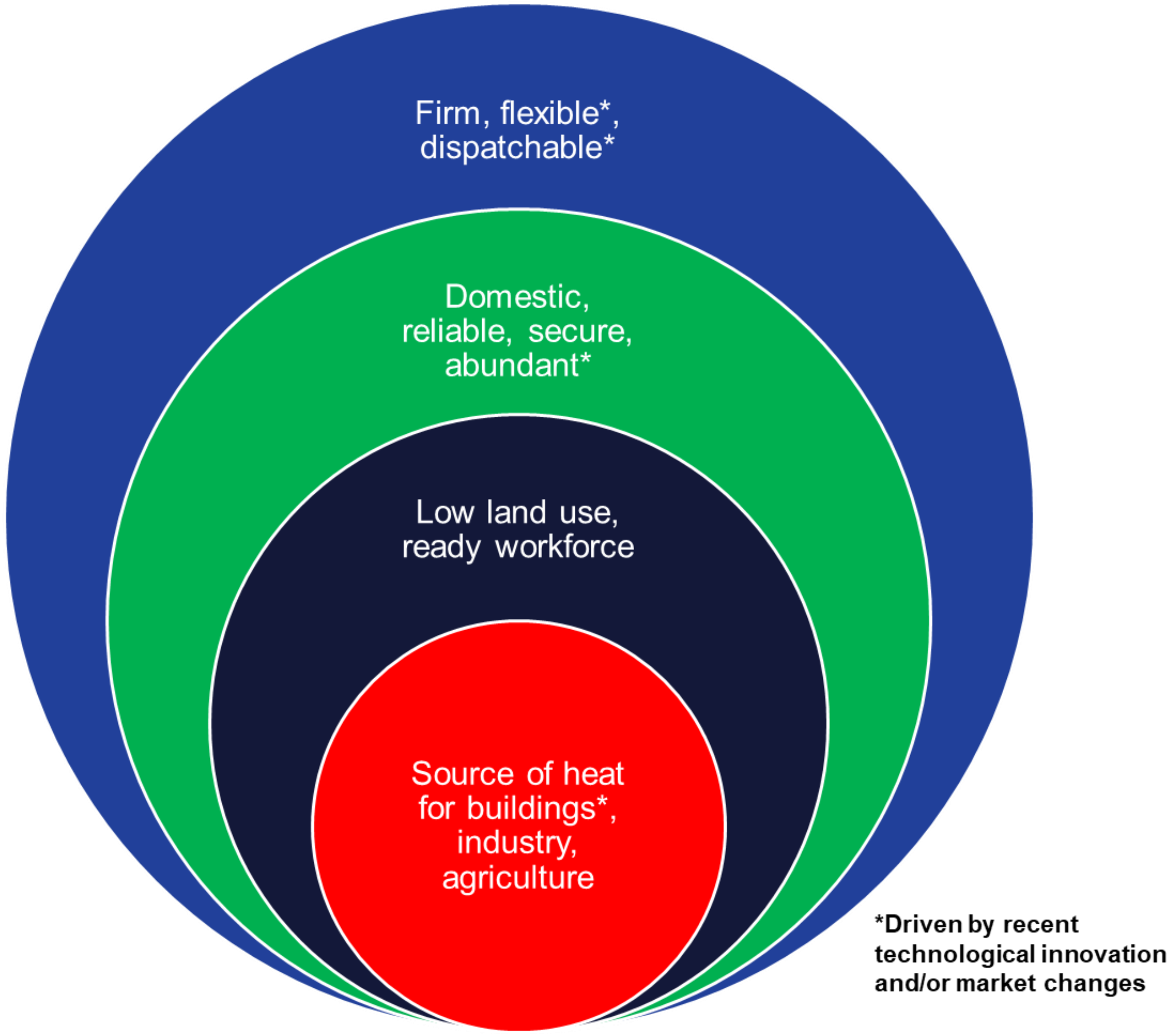
IT'S WHERE AND HOW WE DEPLOY IT EFFECTIVELY

High-Temperature Geothermal Technologies – Innovations and Outlook

Geothermal Technologies Barriers to Access

1. Barriers are changing:
    - Cost
    - Geographic Limitations
    - Risk
    - Nontechnical
        - Regulatory
        - Workforce
        - Awareness

2. Key benefits are increasingly valued
    - Firm
    - Reliable
    - Abundant

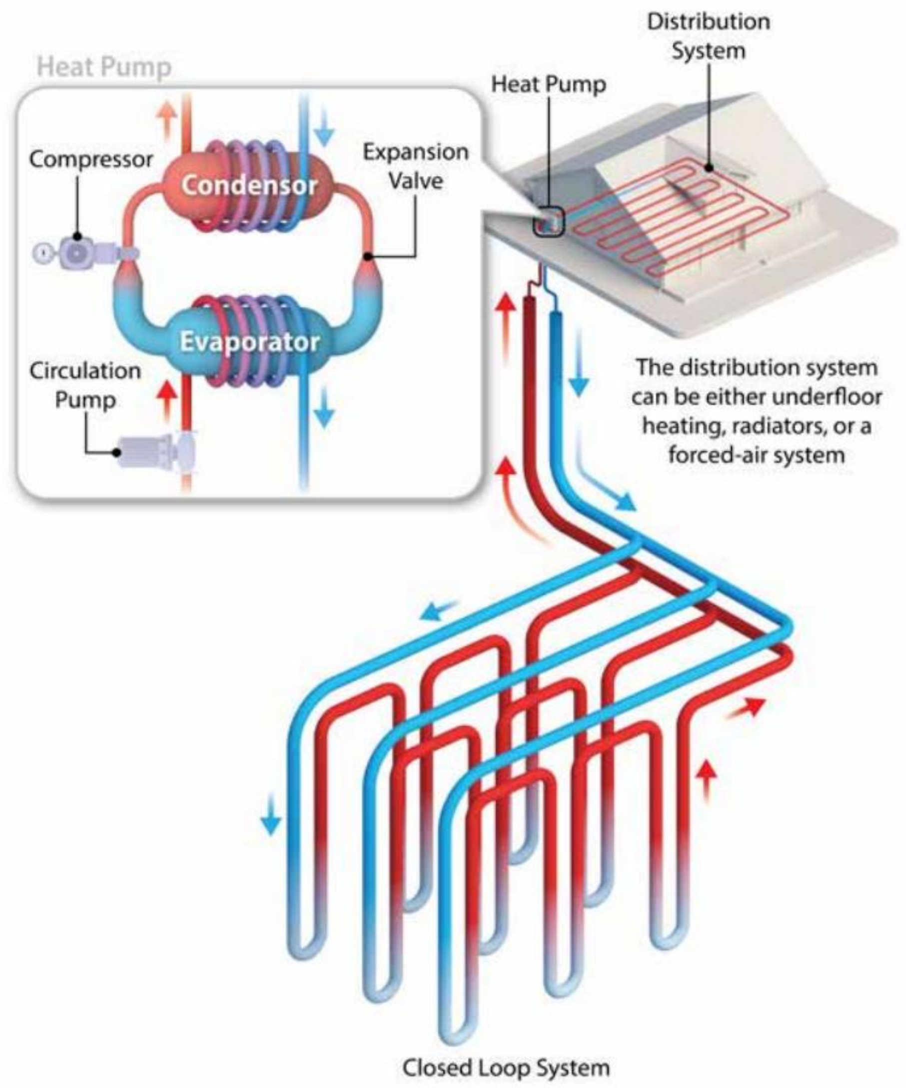


Forward-Looking Business Models

Behind-the-Meter Geothermal as a New Business Model	Growing Demand: Big Tech and Large Energy Users Turning to Geothermal
Startups are developing **dedicated, on-site geothermal power plants for data centers, military bases, and industrial users**. This model aligns generation directly with load, bypassing the traditional utility-scale grid-connected model, delivering localized, modular 5–25 MW systems that enhance **energy security and reliability** for mission-critical users. **Industry Example:** Greenfire Energy	Major technology companies are entering agreements to secure **hundreds of megawatts (MW)** of geothermal power. This reflects a shift toward **firm baseload energy** to support data-heavy operations like AI and cloud computing. **Industry Examples:** Google and Fervo Energy, **Nevada (115 MW)** Meta and Sage Geosystems **(150 MW)**

Low Temperature Geothermal Technologies

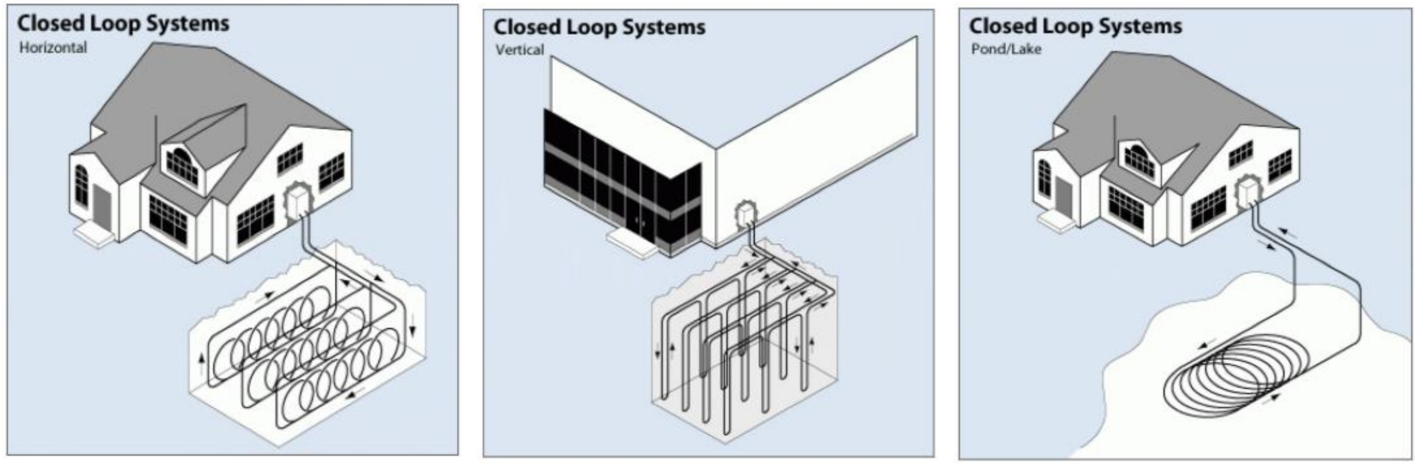
Geothermal Heat Pumps (GHPs)



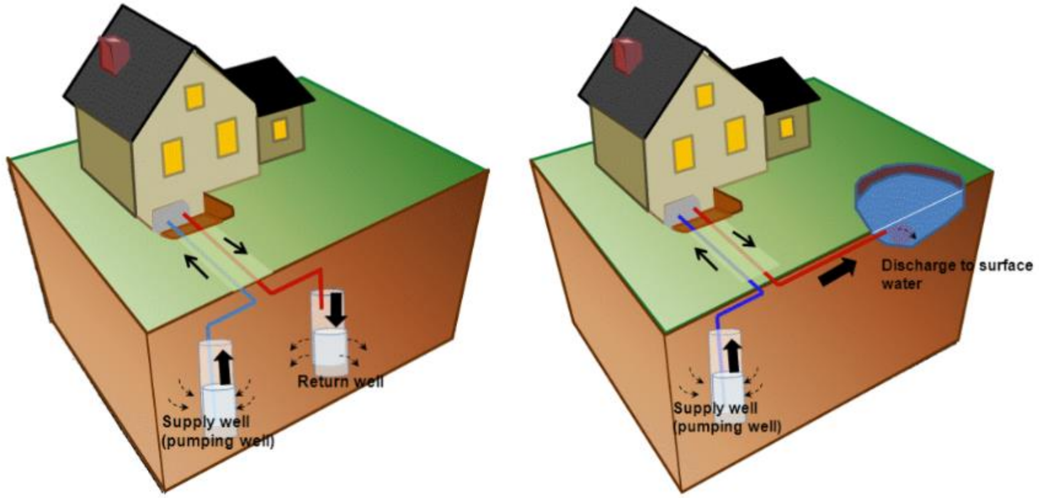
Geothermal heat pump schematic in heating mode. [Akindipe et al, 2026]

- **High efficiency** and **low energy consumption** of heating and cooling systems in residential and commercial buildings
- Many **configurations** and **integration opportunities** in individual buildings and/or with district energy systems
- Three main components: the **ground loop,** the **heat pump** and the **building distribution system**
- Can be tailored to suit a **variety of settings** and **site conditions**, making them **versatile** and **adaptable** to different environments

Types of Ground Loops



Closed loop systems (graphic from the [U.S. Department of Energy)](#)



Open loop systems (graphic from [The Ohio State University](#))

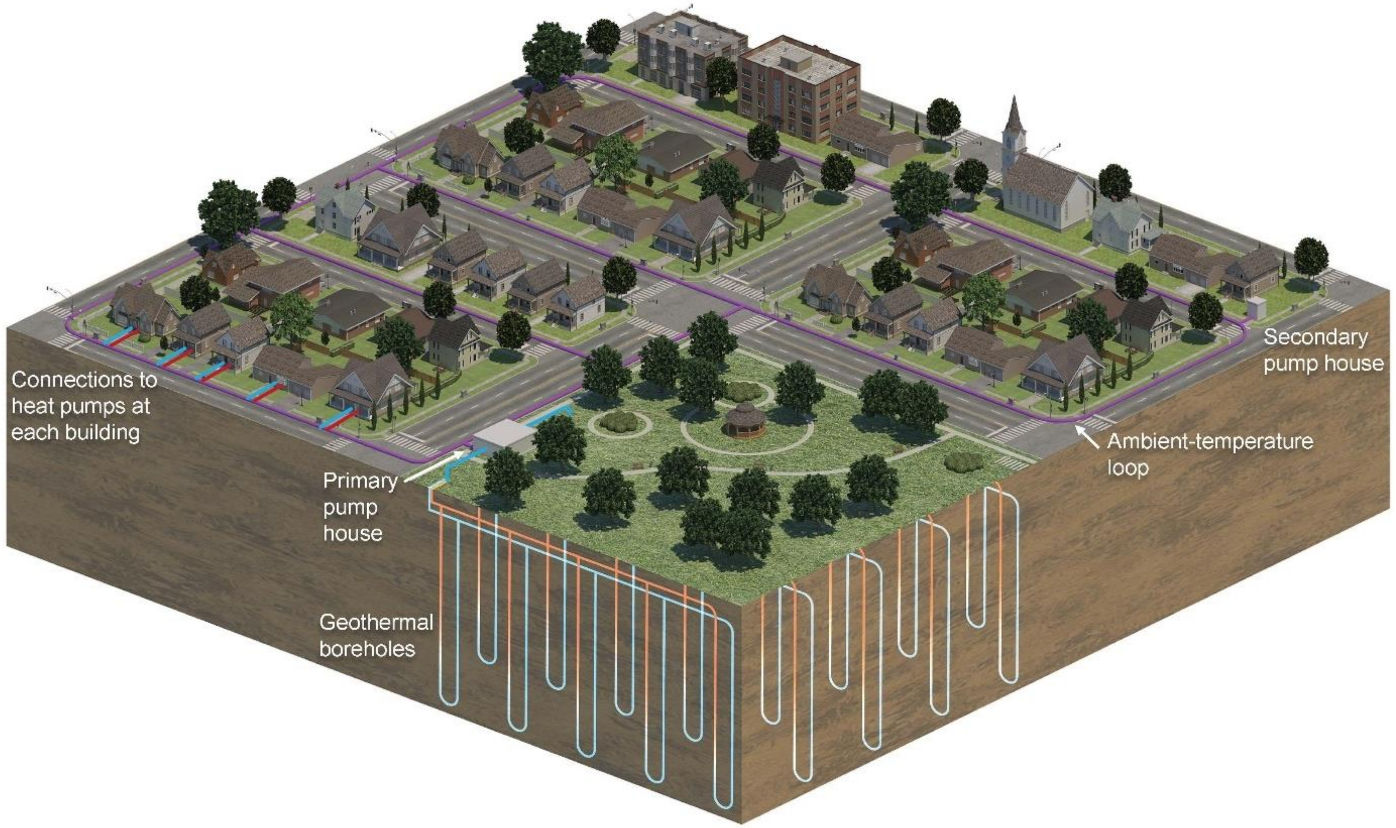
- **Closed-loop systems** are continuous loops of pipe that circulate a heat-transfer fluid (water or antifreeze solution) underground without ever taking in or discharging water
  - Horizontal loops: expected to require a larger footprint, may be cheaper to install vs. vertical systems
  - Vertical loops: Most common type. Generally suitable in all locations. Small lots, rocky terrains
  - Pond/lake loops: If a sufficiently large water body is available
- **Open-loop systems** uses groundwater or surface water directly as the heat-transfer medium

Can GHPs Work for My Site?

Ground Temperature Stable temperatures enable reliable heating in winter and efficient cooling in summer	**Thermal Conductivity of Soil/Rock** High thermal conductivity means better heat transfer: Granite, Limestone, Sandstone, <u>Moist</u> clays
Moisture Content Water conducts heat much better than air, so: Wet soils (clay, silt, saturated sands) perform very well	**Groundwater Flow** Moving water carries heat away from the loop. Ideal: steady groundwater flow (not too fast, not too stagnant)
Depth to Bedrock Shallow bedrock: reduces excavation costs for vertical installations but makes horizontal trenches harder	**Stability and Constructability** Loose fill, fractured rock, or karst conditions may complicate drilling
Availability of Land Subsurface conditions affect system choice. Horizontal loops need large open areas with diggable soil	**Environmental or Regulatory Constraints** Groundwater protection rules, restrictions on open-loop discharge

Geothermal District Heating and Cooling

- First, second, and third generation systems: Use 200°C–100°C resources to deliver heat directly to district networks (e.g., Boise, Idaho)
- Fourth and fifth generation systems: Use shallow, low-temp (<60°C) resources with heat pumps, and can also integrate waste heat from industrial, commercial, and municipal sources
- Near-ambient temperature loops are a defining feature of fifth generation (5G) also known as Thermal Energy Networks
- Heating/cooling costs for consumer lower than individual building geothermal heat pumps



Graphic by NLR

Thermal Energy Networks Examples

Colorado Mesa University, Grand Junction, Colorado

- **Installed Year:** 2008
- **System Type:** 5G, one-pipe loop, ambient temp
- **Thermal Source:** 471 boreholes, 91–152 m deep
- **Thermal Conversion:** heat pumps at users

Image from CMU

Eversource networked geothermal pilot Framingham, Massachusetts

- **Installed Year:** 2023
- **System Type:** 5G, one-pipe loop, ambient temp
- **Thermal Source:** 88 boreholes, 70–215 m deep
- **Thermal Conversion:** heat pumps at users

Image by NLR

Techno-Economic Considerations

Capital Costs

- Includes equipment (e.g., heat pumps, piping, heat exchanger) installation activities (drilling, trenching, grouting) and building retrofits
- Equipment prices vary regionally due to taxes, transportation, and supply-chain factors
- Installation costs can vary significantly by region due to differences in the cost and size of the borehole field (thermal conductivity plays a role)
- Overall costs also depend on the system's size, type, and efficiency rating
- System design and optimization are essential to maintaining economic feasibility
- See Table 52 (pg. 179) of REopt Web Tool User Manual for capital cost data resources

Image from Tetra Resources

Geothermal Heat Pump Economics

- GHP's main operational cost is electricity. Incumbent HVAC systems can be natural gas, heating oil, or electricity
- Economics of GHP systems will depend on how capital costs + operating costs to meet facility peak heating or cooling load compares with fuel/operational savings from incumbent HVAC system
- Installing a GHP system at a greenfield site or during a retrofit can be a good way to reduce or eliminate the capital cost penalty

Common Assumptions in Estimating GHP Economics

GHP Inputs	Units
Annual Existing Heating Fuel Cost	$/gal
Annual Heating System Consumption	Million British thermal units
Total Installed Cost for Heating Heat Pump	$/ton
Total Installed Cost for Cooling Heat Pump	$/ton
Borehole Depth	Ft.
Geothermal Heat Exchanger Cost	$/ft.
Space Heating Efficiency Thermal Factor	%
Space Heating Hot Water Temperature	°F or °C
Chilled Water Temperature	°F or °C
Ground Thermal Conductivity	Btu/hr.-ft.-°F
GHP Incremental Operations and Maintenance Cost Increase Over Existing HVAC System	$/ft.^{2}-year

Federal Incentives for Geothermal Systems

- GHPs:
    - Eligible for a **30% investment tax credit (ITC)** through Section 48 of the U.S. Tax Code (until 2034)
    - **Eligibility for five-year modified accelerated cost recovery system (MACRS)**, but possibly eligible for 100% bonus depreciation
    - Exempt from **Foreign Entity of Concern compliance**
    - H.R.1 (One Big Beautiful Bill Act) exempted GHP systems from **limited use property doctrine**, potentially opening the door to third party finance business models (GHP Energy Sales Agreement?)
- Geothermal Power Generation:
    - Eligible for **30% ITC** through Section 48E of U.S. Tax Code ("Technology Neutral Credit") (until 2034)
    - Eligible for **five-year MACRS** accelerated depreciation and **100% bonus** depreciation

NLR Tools Across all Phases of Geothermal Development

GeoRePORT – Geothermal Resource Portfolio Optimization & Reporting Technique

SBT Tool

System Advisor Model

RAPID – Regulatory and Permitting Information Desktop Toolkit

dGeo

Job and Economic Development Impact (JEDI) Model

Prospecting, Data Collection & Access → **Resource Assessment & Reservoir Modeling** → **Techno-Economic Analysis** → **Policy & Permitting Analysis** → **Grid Modeling & Deployment Analysis** → **Demonstration & Deployment**

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GEOPHIRES

ReEDS

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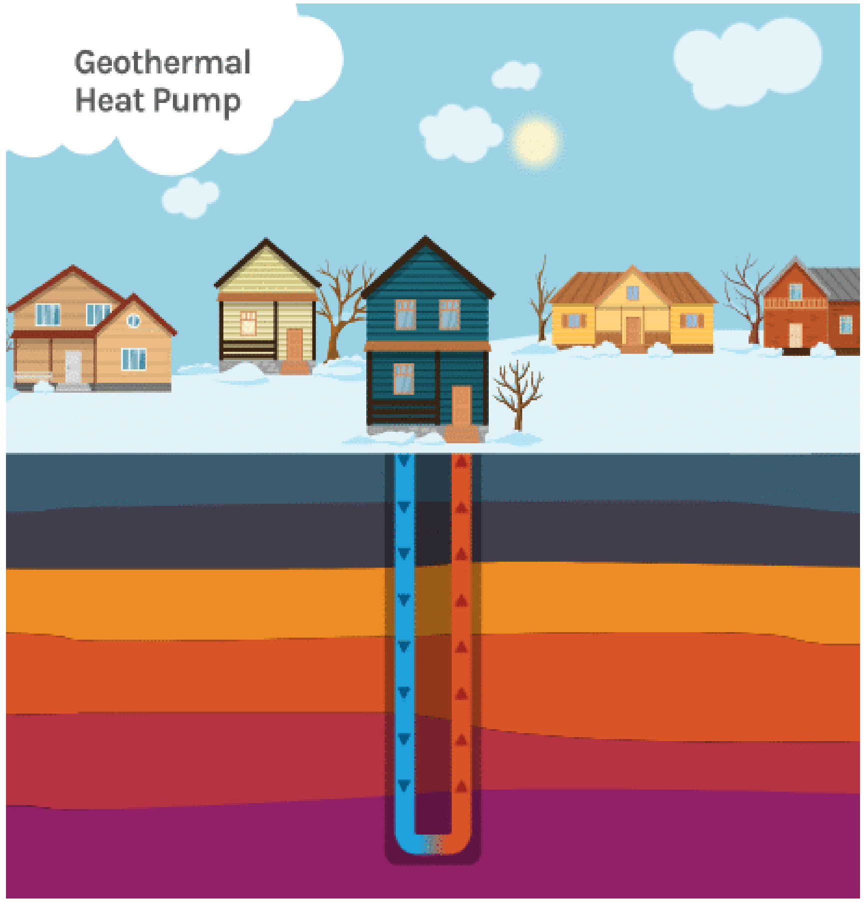
Geothermal Heat Pump Takeaways

Considerations

Subsurface and Geology, Heating and Cooling Loads Requirements, Loop Field Design and Sizing & Flexible Hybridization



Fully mature technology: Ready for immediate deployment. Proven reliability and performance.

High efficiency: Often 300–600% efficient because the system moves heat rather than generating it.

Lower operating costs: Reduced energy bills compared to traditional HVAC systems.

Reliable and quiet: No outdoor compressor; most equipment is indoors and long-lasting.

Stable performance: Not affected by outside air temperature swings. Works in almost all climates and building types

GHP systems can be tailored to suit a variety of settings and site conditions, making them versatile and adaptable to different environments.

Case Studies

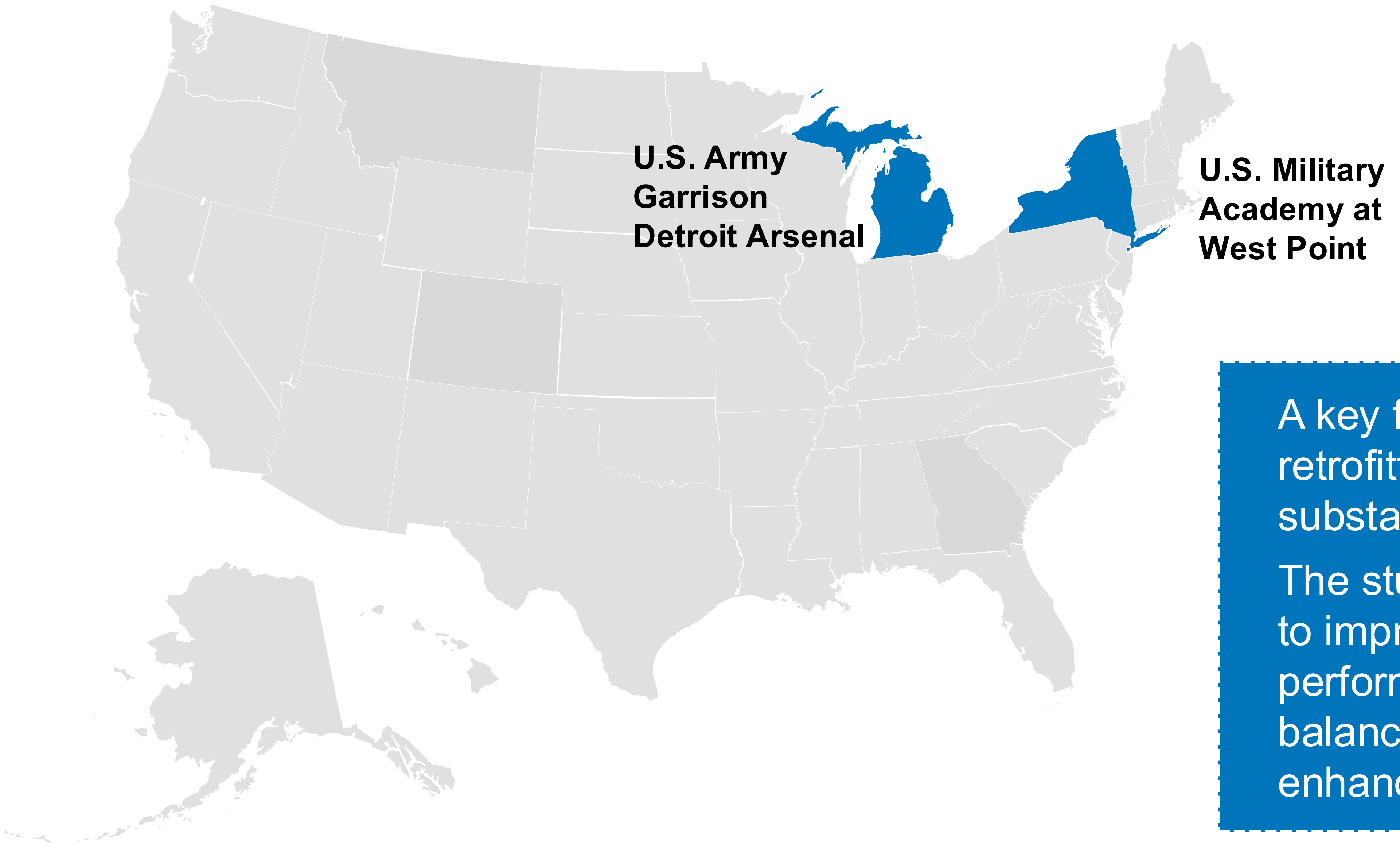
Expanding Geothermal Heating and Cooling at Federal Sites

The **Federal Geothermal Partnership (FedGeo)**, led by U.S. Department of Energy's Hydrocarbons and Geothermal Energy Office (formerly GTO), aims to help federal facilities adopt **low-temperature geothermal technologies** like GHPs and hybrid systems.

The initiative provides a **technical assistance pathway** for federal organizations to **analyze, design, and deploy** geothermal heating and cooling solutions to lower energy costs.

Drilling rig in U.S. Army Garrison Detroit Arsenal.
Image from the U.S Army Newsroom

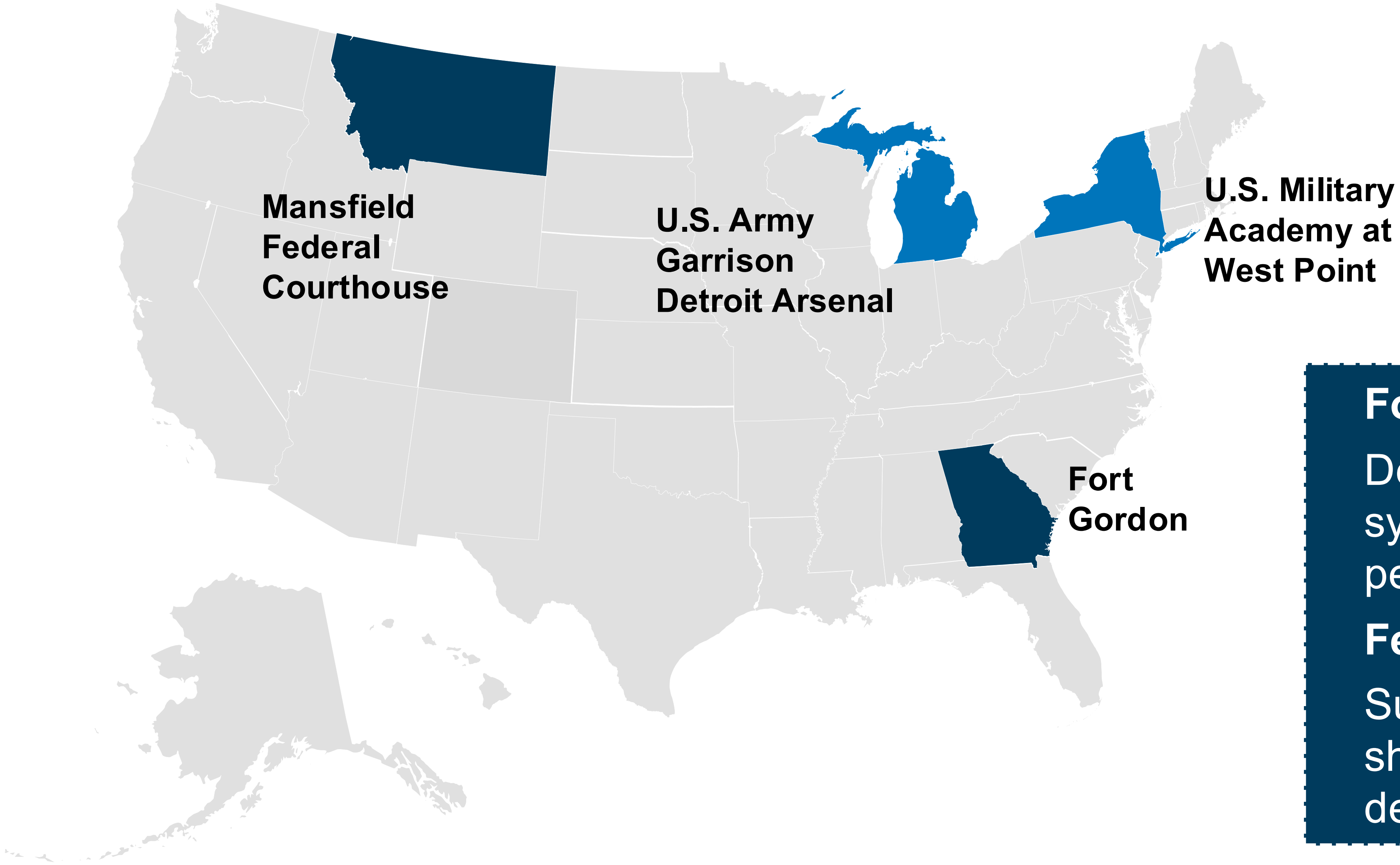
FedGeo Initial Facilities



A key finding of the studies is that retrofitting HVAC systems with GHPs could substantially reduce energy expenses.

The studies also offered recommendations to improve economic viability and performance, such as thermal load balancing and building envelope enhancements.

FedGeo Additional Facilities



Fort Gordon – Georgia

Developing system models of the GHP systems and supporting system performance troubleshooting

Federal Courthouse – Montana

Subsurface exploration of a nearby mine shaft, assessing geothermal development feasibility

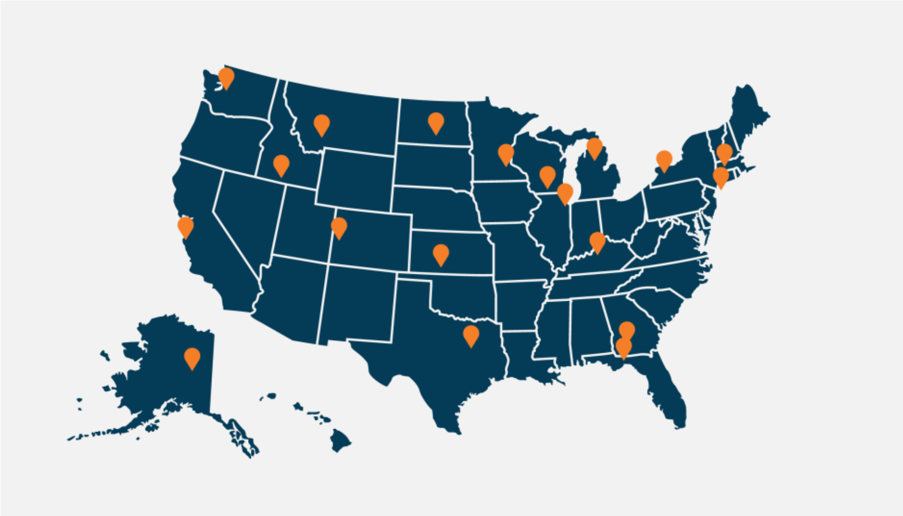
Department of Energy – Geothermal Heat Pump Case Studies

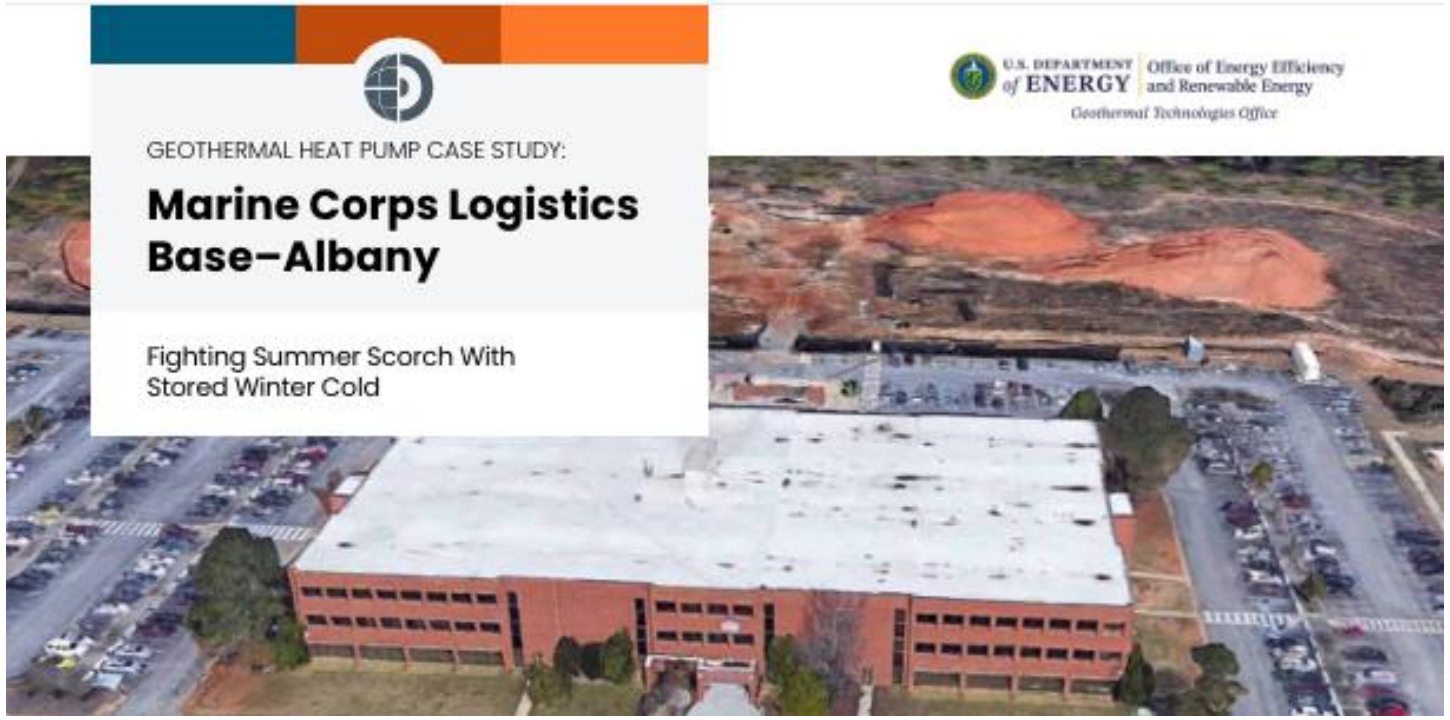
19 detailed case studies of GHP installations in multiple climate zones with varying system types, sizes, and end uses

Real-life stories behind installed GHP systems and highlight the benefits of geothermal heating and cooling in a variety of application scenarios

LEARN MORE

bit.ly/3U3W3MK





Size

- Five modular, six-pipe, heat recovery, 85-ton, water-to-water, geothermal heat pumps
- Two adiabatic dry coolers
- 306 boreholes, each drilled 210 feet deep
- Heats/cools three-story, 168,000 square feet building

Unique Features

- The building's borehole thermal energy storage system is a specialized geothermal closed-loop heat exchanger designed to efficiently store cold in the subsurface.
- Reduced water consumption by 4.2 million gallons/year compared to on-site cooling tower

Cooling

In the building's mechanical room, five modular heat recovery geothermal heat pumps replaced two centrifugal chillers and two condensing boilers.

Once **Georgia's cooling season** begins, the GHPs withdraw the cool previously stored underground to efficiently keep personnel comfortable during hot summers.

Energy Use

47.5% reduction over a 12-month period compared to conventional HVAC

Energy Savings

Reduced electricity bill by 30%

Cost Savings

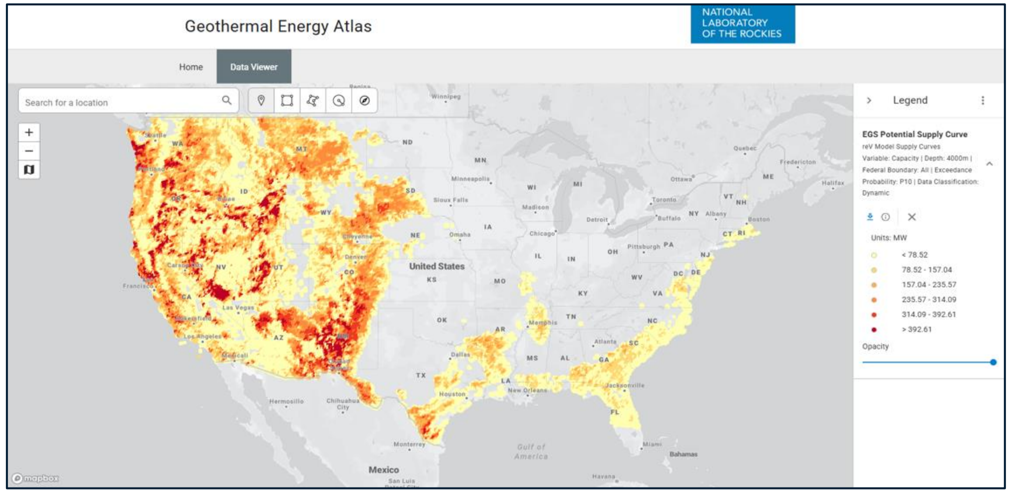
$5.1 million system installation cost with simple payback in 11–13 years

Funding Sources

U.S. Department of Defense Environmental Security Technology Certification Program and U.S. Department of Energy

Geothermal Resources

GEOTHERMAL ENERGY ATLAS



10 YEARS GDR

DOWNLOADS OVER TIME (CUMULATIVE) BY FY

From 120 to 10,129,059

Thank you!

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