United States Energy Association

Subsurface Synergies: Where Geothermal and CCUS Intersect

OVERVIEW

At first glance, geothermal energy and carbon capture, utilization, and storage (CCUS) may appear as distinct approaches — one harnessing the Earth's natural heat to generate firm, domestic power; the other capturing CO_2 from power generation and industrial activity (or in the case of Direct Air Capture, directly from the atmosphere). Yet, beneath the surface, both literally and figuratively, these technologies are intricately linked. Their integration offers a powerful opportunity to advance geothermal development, create American jobs, and leverage the oil and gas sector's unmatched expertise. From Texas to Utah, the United States is positioned to lead in this next chapter of energy production rooted in subsurface innovation.

FOUR KEY AREAS WHERE GEOTHERMAL AND CCCUS TECHNOLOGIES WORK TOGETHER TO DELIVER RESULTS

1. **Shared Subsurface and Engineering Expertise**
   - Geothermal and CCUS both depend on geological mapping, directional drilling, reservoir management, and real-time monitoring — all strengths of the U.S. oil and gas workforce. These overlapping skills make dual-use projects more efficient and cost-effective, while offering a natural path for redeploying skilled labor into next-generation energy roles.
2. **Geographic Co-location and Infrastructure Efficiency**
   - Sedimentary basins and depleted oil fields across the U.S. offer ideal conditions for both geothermal production and CO_2 storage. Co-locating these systems enables shared use of pipelines, wells, and monitoring systems — reducing capital costs and streamlining permitting.
3. **Geothermal as a Power Source for CCUS Operations**
   - Running carbon capture systems requires energy. Tapping geothermal heat or electricity ensures CCUS infrastructure operates reliably, especially in remote or off-grid industrial zones.
4. **CO_2 as a Working Fluid in Next-Generation Geothermal**
   - Using CO_2 itself as a heat-transfer medium in geothermal systems opens a frontier of innovation. CO_2 expands more than water when heated, boosting turbine output. It also eliminates the need for large volumes of water in arid regions and can be permanently stored after circulation — turning captured CO_2 into a driver of American energy security.

1) SHARED SUBSURFACE EXPERTISE

Both geothermal energy and CCUS are deeply dependent on subsurface geology — and both rely on technical capabilities that are common to the oil and gas industry. These include:

- Advanced geological mapping and seismic imaging
- Precision drilling technologies and techniques
- Reservoir engineering and pressure management
- Subsurface monitoring, modeling, and data analytics

This shared foundation enables powerful cross-sector synergies. For example, geothermal exploration data — such as temperature gradients, permeability, and porosity — can directly inform the suitability of nearby formations for CO_2 storage. Conversely, CO_2 injection tests can reveal heat potential and fluid pathways useful for geothermal development.

The same skillsets used in enhanced oil recovery (EOR), well decommissioning, or saline aquifer development can be rapidly adapted to support both technologies. Minimal retraining is needed to deploy existing American tools, talent, and infrastructure.

The Opportunity: U.S. companies with experience in subsurface operations are uniquely positioned to lead integrated geothermal-CCUS projects — powering communities while managing emissions, strengthening domestic energy security, and creating high-value jobs.

2) GEOGRAPHIC CO-LOCATION AND INFRASTRUCTURE SYNERGIES

Many regions rich in geothermal potential are naturally well-suited for CO_2 storage due to favorable subsurface geology and existing infrastructure. Key geological formations offering these dual opportunities include:

- **Sedimentary basins:** These large underground formations consist of porous rock layers, such as sandstone or limestone, overlain by impermeable caprock like shale. The porosity provides ample space to store CO_2 securely, while the caprock acts as a seal, preventing gas escape. Many of these basins also host geothermal reservoirs where naturally heated fluids circulate, making them prime candidates for integrated geothermal and carbon storage development.
- **Depleted oil and gas fields:** Fields that have been extensively produced often retain suitable pore space for CO_2 injection. Their geology is well-characterized from decades of exploration and production, reducing uncertainty and risk. Importantly, existing wells, pipelines, and surface facilities can be repurposed, significantly cutting development costs. Injecting CO_2 can also enhance oil recovery in some cases, providing an economic incentive to integrate CCUS with geothermal efforts nearby.
- **Volcanic formations, particularly basalt rock:** Basalts are rich in reactive minerals like calcium and magnesium, which chemically bind CO_2 through mineralization — converting it into stable carbonate rock within just a few years. This process, exemplified by Iceland's CarbFix project, accelerates permanent CO_2 storage and can be co-located with geothermal power plants exploiting the same volcanic heat sources.

The natural alignment between geothermal and CCUS resources creates practical opportunities for more efficient development:

- **Joint project development:** Co-locating geothermal energy production and CO_2 storage on the same site allows for integrated subsurface operations, reducing exploration risk and maximizing reservoir utilization.
- **Shared infrastructure:** Surface assets such as injection wells, monitoring systems, and site access roads can support both geothermal and CCUS activities, lowering upfront capital and long-term operational costs.
- **Efficient permitting and regulation:** Coordinated site planning and land use may simplify regulatory pathways, accelerate permitting, and reduce delays associated with overlapping jurisdictions or surface disruption.

Regions with a strong fossil energy legacy and geothermal resources — and the workforce, data, and infrastructure that come with it — are especially well-positioned to capitalize on these synergies. This approach minimizes duplication, leverages prior investments, and opens new commercial pathways for American companies.

ICELAND'S CARBFIX: TURNING CO_2 INTO STONE

Iceland's CarbFix project captures CO_2 emissions by dissolving the gas in water and injecting this solution into porous basaltic rock formations beneath the surface. Thanks to the reactive minerals in basalt, the injected CO_2 mineralizes rapidly turning into stable carbonate rock within about two years. This innovative approach offers permanent and leak-proof carbon storage, leveraging Iceland's volcanic geology and geothermal industry, and serves as a promising model for carbon sequestration in other basalt-rich regions worldwide.

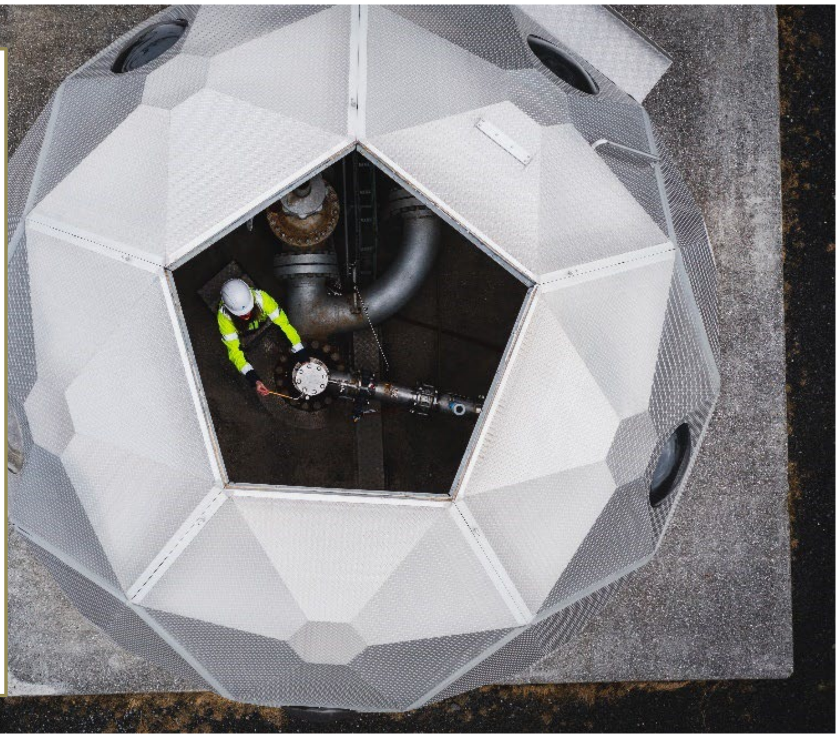

Image 1: Reuters: Carbfix's geodesic dome, where piped CO_2 is mixed with water and injected into the basalt rock below.

This method is now being replicated under the EU-funded GECO Project, which is testing similar methods in Italy, Turkey, and Germany.

Meanwhile, in the U.S., co-location opportunities exist in:

- **Salton Sea (California)** — High geothermal gradient and lithium-rich brines
- **Utah's FORGE site** — A national testbed for enhanced geothermal systems (EGS)
- **Texas Gulf Coast** — A prime candidate for both saline aquifer CO_2 storage and geothermal heat

3) GEOTHERMAL AS A RELIABLE ENERGY SOURCE FOR CCUS OPERATIONS

Running a CCUS system — particularly CO_2 capture, compression, and injection — requires a steady energy supply. Geothermal offers a locally sourced, baseload energy option that can support these demands with high reliability and minimal logistical complexity.

Geothermal can provide:

- Continuous, dispatchable electricity to power CO_2 capture and compression equipment
- High-temperature heat for industrial processes such as cement, steel, or chemical production
- On-site energy supply for running CO_2 transport and injection systems, even in off-grid or remote locations

In Munich, Germany, a geothermal district heating system is being evaluated as an energy source for CO_2 capture from local waste-to-energy plants. In Pohang, South Korea, the government is piloting geothermal heating for steel mills — one of the most emissions-intensive sectors — with plans to integrate CCUS.

Image 2: ThinkGeoEnergy, Drilling rig on site at HKW Süd, Munich

4) CO_2 AS A WORKING FLUID IN NEXT-GENERATION GEOTHERMAL

Emerging research suggests that supercritical CO_2 — carbon dioxide in a state between gas and liquid — could serve as a highly effective alternative to water in geothermal systems. This innovative approach, known as **CO_2-Plume Geothermal (CPG)**, offers the potential to transform how we produce energy while simultaneously storing carbon underground.

Why CO_2?

- **Higher energy yields:** CO_2 expands more than water when heated, which increases the pressure driving turbines and improves overall efficiency — particularly in high-temperature geothermal reservoirs.
- **Water conservation:** In arid or drought-prone regions, using CO_2 instead of water dramatically reduces the strain on local water supplies.
- **Permanent storage:** After completing its cycle through the geothermal system, the CO_2 can be reinjected into the subsurface, where it remains permanently trapped — offering simultaneous power production and carbon sequestration.

This dual-use approach — turning CO_2 from a waste product into a working fluid — offers a compelling model for next-generation energy systems. A leading figure in this field is Professor Martin Saar, Director of the Geothermal Energy and Geofluids Group at ETH Zurich. Prof. Dr. Saar and his team have been at the forefront of developing and modeling CO_2-based geothermal systems, demonstrating how CPG can harness deep geological formations for both sustainable energy production and long-term CO_2 storage.

Their research shows that CPG systems can be deployed in sedimentary basins and former oil and gas fields — areas already well understood by industry — allowing for faster commercialization. Saar's team has also contributed to numerical modeling tools that simulate fluid flow, heat transfer, and chemical reactions in CPG systems, helping de-risk pilot projects around the world.

CO_2 -PLUME GEOTHERMAL (CPG) SYSTEMS

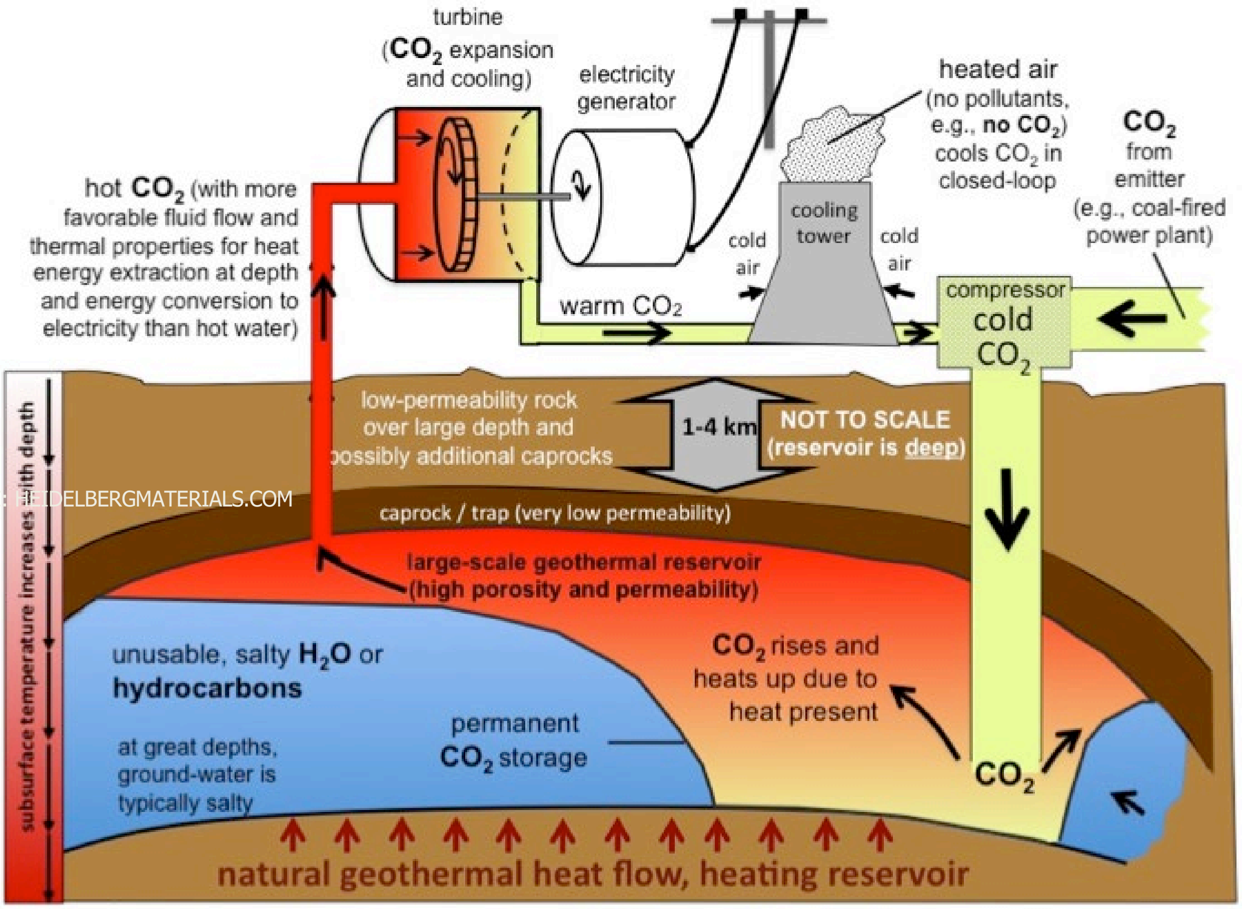

Image 3: ETH Zurich, Geothermal Energy and Geofluids

ONGOING RESEARCH AND DEMONSTRATION PROJECTS

The U.S. Department of Energy (DOE), through its Geothermal Technologies Office, has supported several early-stage CO_2 Plume Geothermal (CPG) pilot projects to explore new uses of U.S. sedimentary basins. These projects aim to validate CPG's technical viability, cost profile, and ability to scale in regions where traditional hydrothermal systems are not present.

The National Renewable Energy Laboratory (NREL) has identified CPG as a promising approach for tapping into vast geothermal potential in non-conventional settings — including areas with low permeability, limited water availability, or where oil and gas infrastructure already exists.

CPG systems use injected CO_2 as the working fluid to extract heat from deep geological formations. This approach offers engineering advantages, such as:

- Enhanced heat transfer efficiency due to CO_2's thermophysical properties
- Potential reuse of existing oilfield wells and infrastructure
- Dual-use opportunities in regions already mapped and drilled for hydrocarbon production

These innovations reflect a broader opportunity to repurpose legacy energy assets and subsurface data for future geothermal development — with minimal new surface disturbance and strong alignment with American subsurface expertise.

LOOKING AHEAD: BUILDING A DUAL-USE SUBSURFACE FUTURE

Aligning geothermal energy and CCUS opens the door to a highly efficient, technically compatible subsurface strategy for the United States. Key opportunities include:

- Shared R&D investments and industry-government partnerships
- Streamlined permitting through integrated planning and co-location
- Cross-sector workforce development, including retraining oil and gas professionals for dual geothermal–CCUS roles
- Targeted deployment in regions with existing infrastructure, geological data, and operational experience

The oil and gas sector is especially well-positioned to lead. With deep expertise in subsurface systems, a skilled labor base, and existing capital assets, these companies can expand into dual-use geothermal and CCUS operations — optimizing known resources and extending the commercial life of their investments.

In short, geothermal and CCUS are more valuable together than alone. Their convergence represents a strategic opportunity to extract more utility from America's subsurface — generating long-term economic value while keeping traditional energy regions engaged in future-facing industries.

SOURCE LIST

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https://www.carbfix.com

GECO Project (Geothermal Emission Control)
https://www.geco-h2020.eu

Equinor – Northern Lights CO_2 Storage Project
https://www.equinor.com/energy/northern-lights

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U.S. Department of Energy – Geothermal Technologies Office (GTO)
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National Renewable Energy Laboratory (NREL) – CO_2-Plume Geothermal Brief
https://www.nrel.gov/docs/fy20osti/76131.pdf

ETH Zurich – Geothermal Energy and Geofluids Group (Martin Saar)
https://geg.ethz.ch

GreenFire Energy – CO_2-Based Geothermal Systems
https://www.greenfireenergy.com

European Commission – Innovation Fund
https://climate.ec.europa.eu/eu-action/funding-climate-action/innovation-fund_en

European Commission – Net Zero Industry Act
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NREL – Geothermal Research Program Overview
https://www.nrel.gov/geothermal

IMAGE SOURCE LIST

Image 1
Reuters / Kelly, J. (2023, October 30). *Aerial view of Hellisheiði geothermal power station near Reykjavik, Iceland* [Image]. In Slavin, T. *How Iceland's CarbFix is harnessing the power of turning CO_2 into stone*. Reuters. https://www.reuters.com/sustainability/climate-energy/how-icelands-carbfix-is-harnessing-power-turning-co2-into-stone-2023-10-30/

Image 2
SWM (Stadtwerke München). (2020, April 18). *Drilling rig on site at HKW Süd, Munich, Germany* [Image]. In *Geothermal heat to also fuel district cooling network in Munich, Germany*. ThinkGeoEnergy. https://www.thinkgeoenergy.com/geothermal-heat-to-also-fuel-district-cooling-network-in-munich-germany/

Image 3
Saar, M. O., et al. (n.d.). *Figure 1. Schematic of the CO_2-Plume Geothermal (CPG) technology* [Image]. In *Project CO_2 Plume*. ETH Zurich, Geothermal Energy and Geofluids. https://geg.ethz.ch/project-co2-plume/