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From Theory to Implementation: CO_2 Sequestration within Geothermal Reservoirs

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"We deserve clean energy"

Tunastahili nishati safi

INTRODUCTION

Anthropogenic carbon dioxide emissions remain a principal driver of global warming, prompting ambitious decarbonization commitments from the European Union and the Group of Seven (G7) nations, including the complete phase-out of unabated fossil fuels by 2050 (Isaka et al. 2019). While carbon capture and storage (CCS) is widely recognized as a pivotal mitigation strategy, its conventional applications emphasize deep geological sequestration without energy co-benefits (Ngata et al.2023).

This poster presents assessment of CO_2-based geothermal systems (Fig. 1) through global field-scale evidence from pilots, including projects in Turkey, Canada, New Zealand, Japan, and the United States. It provides standardized cross-case dataset including reservoir lithology, depth, temperature, brine chemistry, CO_2 injection mode, injectivity, scaling/corrosion observations, monitoring methods and a comparative evaluation of CO_2 versus conventional working fluids, The findings emphasize the potential of CO_2 reinjection to enhance reservoir productivity (Montague et al.2023).

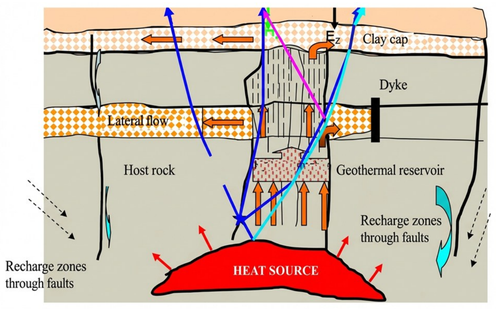


FIGURE 1. Conceptual diagram illustrating a geothermal reservoir beneath the Earth's surface

METHODS

- Reservoir lithology, depth, temperature
- Brine chemistry
- Injection mode & injectivity
- Scaling/corrosion observations
- Monitoring methods

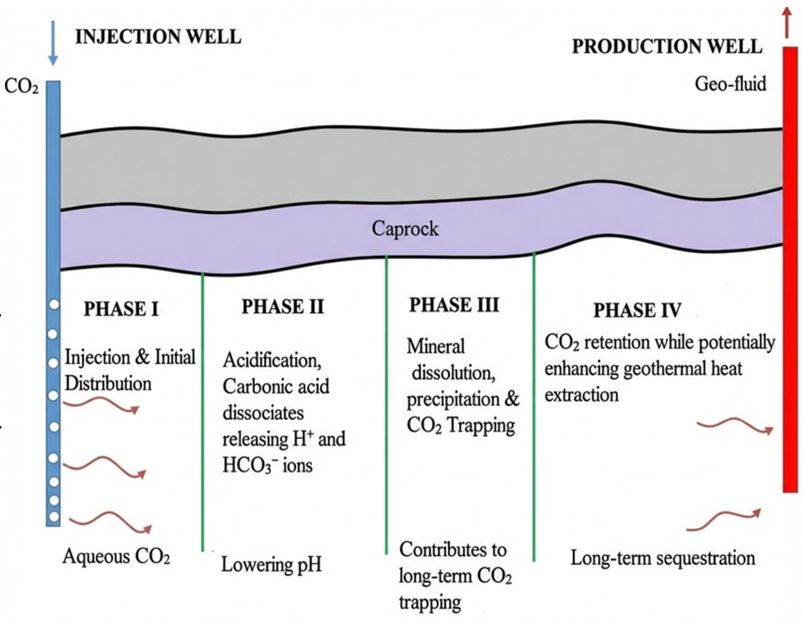


FIGURE 2. Systematic diagram showing phase changes during CO_2 injection into geothermal reservoir

RESULTS

Injected CO_2 in geothermal reservoirs dissolves into brine, forming carbonic acid and lowering the pH, which triggers mineral dissolution. The released cations then react with bicarbonate to form stable carbonates, effectively sequestering CO_2 within the geothermal reservoir. Additionally, secondary minerals may form, influencing reservoir properties. The predominant reactions are contingent upon the reservoir's mineralogy, temperature, pressure, and fluid chemistry. These processes render geothermal reservoirs, particularly basaltic ones, promising for CO_2 storage and utilization as depicted in Figure 2 and systematically elaborated upon in Figure 3.In Japan pioneering a novel geothermal power generation method that replaces reliance on natural hydrothermal fluids with supercritical carbon dioxide (CO_2) as the working fluid. The process involves injecting CO_2 into subsurface hot rock formations where it absorbs geothermal heat before being recirculated to the surface to drive turbines (Figure 4). This technique not only allows for power generation in reservoirs previously deemed unsuitable due to insufficient water content but also exploits the advantageous thermophysical properties of CO_2 at high temperatures and pressures, facilitating more efficient heat extraction.

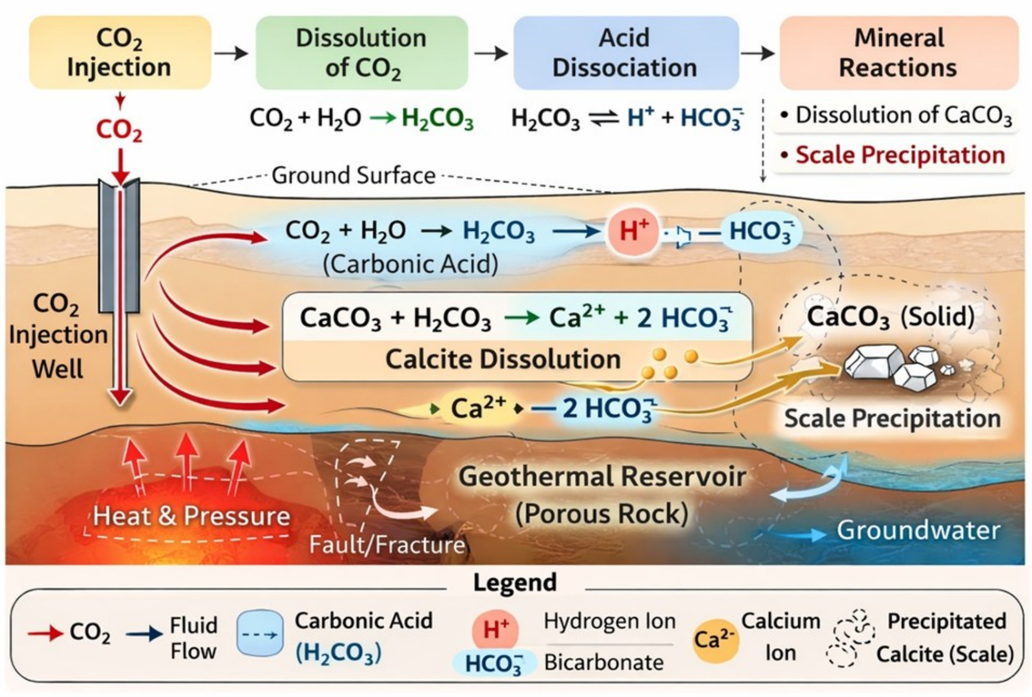


FIGURE 3. Systematic diagram for CO_2 injection into geothermal reservoir

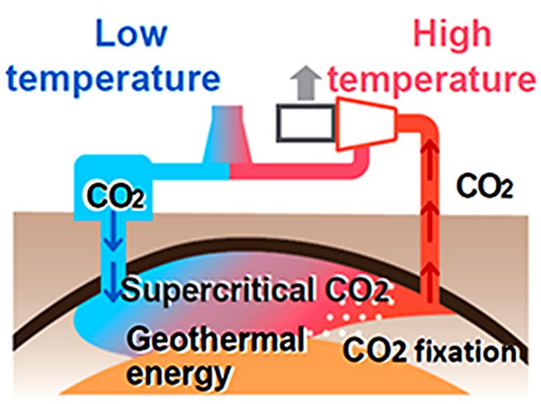


FIGURE 4. Diagram of the carbon recycling CO_2-based geothermal power generation system (Richter, 2021)

DISCUSSION

The discussions examined the technical feasibility, environmental benefits, and operational implications of CO_2 injection in geothermal systems. The CO_2 Plume Geothermal (CPG) approach demonstrates that supercritical CO_2 can function both as a heat extraction fluid and a permanent carbon storage medium. Compared to conventional water-based systems, CO_2 offers improved heat recovery, lower pressure losses, and enhanced sweep efficiency, while enabling long-term sequestration through dissolution and mineral trapping.

International pilot projects validate these findings. In Turkey's Kızıldere field, tracer tests and numerical modeling confirmed effective CO_2 dispersion and controlled reservoir behavior. In New Zealand, reinjection trials at Ngātamariki, Te Huka, and Ngawha show significant emissions reductions without compromising reservoir integrity. Reactive transport modeling indicates that dissolved CO_2 lowers pH, suppresses silica scaling, and in some cases improves injectivity. Full reinjection at Te Huka has demonstrated near-zero operational emissions.

Japan's CO_2-based geothermal innovation further expands application to hot dry rock systems. Despite promising results, challenges remain regarding long-term geochemical changes, permeability evolution, and economic sustainability, requiring continued research and monitoring.

CONCLUSION

From this study, it has been observed that anthropogenic CO_2 emissions remain a primary driver of climate change, prompting ambitious global decarbonization targets. Integrating CO_2 reinjection into geothermal reservoirs presents a transformative approach that simultaneously enhances renewable energy production and achieves long-term carbon storage. This study synthesizes field-scale evidence from global pilot projects, including Kızıldere (Turkey), Ngāwhā and NgāTamariki (New Zealand), Umurlu (Turkey), and the University of Alberta's CO_2 Plume Geothermal project, providing comprehensive insights into technical feasibility, operational performance, and environmental impacts. CO_2 reinjection offers multiple advantages over conventional water-based systems, including improved fluid mobility, enhanced heat transfer, and thermal efficiency, while mitigating silica scaling and promoting beneficial mineral dissolution. Pilot results demonstrate potential for substantial climate benefits, with emissions reductions equivalent to hundreds of thousands of vehicles annually.

Challenges remain in long-term reservoir management, scaling, chemical interactions, and site-specific geological variability. Addressing these requires integrated monitoring, advanced modeling, and adaptive management strategies. By scaling pilot initiatives and establishing supportive economic, regulatory, and technological frameworks, CO_2 reinjection in geothermal reservoirs can serve as a dual-purpose, sustainable solution that strengthens global decarbonization efforts while optimizing geothermal energy production.

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