

## Thermo-Hydro-Mechanical-Chemical Coupling in Enhanced Geothermal Systems: Challenges and Opportunities

**Authors :** Esmael Makarian, Ayub Elyasi, Fatemeh Saberi, Olusegun Stanley Tomomewo

**Abstract :** Geothermal reservoirs (GTRs) have garnered global recognition as a sustainable energy source. The Thermo-Hydro-Mechanical-Chemical (THMC) integration coupling proves to be a practical and effective method for optimizing production in GTRs. The study outcomes demonstrate that THMC coupling serves as a versatile and valuable tool, offering in-depth insights into GTRs and enhancing their operational efficiency. This is achieved through temperature analysis and pressure changes and their impacts on mechanical properties, structural integrity, fracture aperture, permeability, and heat extraction efficiency. Moreover, THMC coupling facilitates potential benefits assessment and risks associated with different geothermal technologies, considering the complex thermal, hydraulic, mechanical, and chemical interactions within the reservoirs. However, THMC-coupling utilization in GTRs presents a multitude of challenges. These challenges include accurately modeling and predicting behavior due to the interconnected nature of processes, limited data availability leading to uncertainties, induced seismic events risks to nearby communities, scaling and mineral deposition reducing operational efficiency, and reservoirs' long-term sustainability. In addition, material degradation, environmental impacts, technical challenges in monitoring and control, accurate assessment of resource potential, and regulatory and social acceptance further complicate geothermal projects. Addressing these multifaceted challenges is crucial for successful geothermal energy resources sustainable utilization. This paper aims to illuminate the challenges and opportunities associated with THMC coupling in enhanced geothermal systems. Practical solutions and strategies for mitigating these challenges are discussed, emphasizing the need for interdisciplinary approaches, improved data collection and modeling techniques, and advanced monitoring and control systems. Overcoming these challenges is imperative for unlocking the full potential of geothermal energy making a substantial contribution to the global energy transition and sustainable development.

**Keywords :** geothermal reservoirs, THMC coupling, interdisciplinary approaches, challenges and opportunities, sustainable utilization

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