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Geo-CARE LABORATORY

We CARE about the ground our infrastructure stands on

Integrating Geothermal Energy, Carbon Storage, and Critical-Mineral Recovery: A Multi-Benefit Subsurface Platform

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Read the full paper
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1 Three challenges, one subsurface

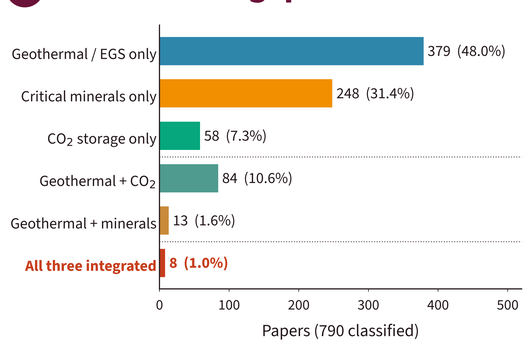
ENERGY **>7,700 GW**
EGS potential on US federal lands, only **0.12%** in use

CLIMATE **Gt-scale**
geological CO_2 storage needed by mid-century

MINERALS **85%**
of global rare-earth processing in one country (China)

Geothermal wells, CO_2 injection and lithium-rich brines use the **same rock, wells and surface plant**, yet they are developed separately.

2 The research gap

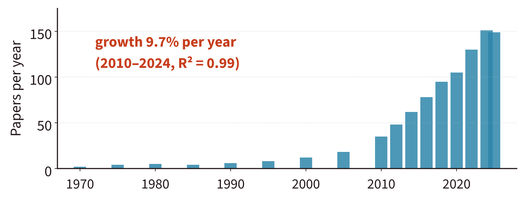


Systematic review of 1,008 records (1968–2026; 915 unique, 790 classified): 86.7% study one domain; **only 8 papers (1.0%) integrate all three**, even as the field grows quickly.

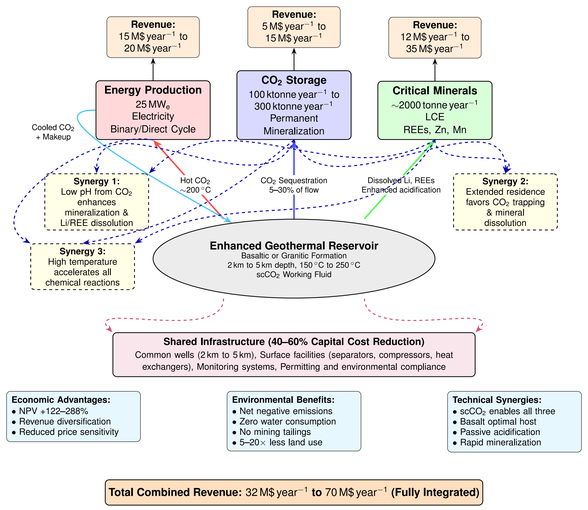
3 Objectives

1. Synthesise EGS, geological CO_2 storage and critical-mineral recovery to find **integration opportunities**.
2. Evaluate **supercritical CO_2** as working fluid: heat, fluid–rock reactions, mineral mobilisation.
3. Assess the **economics** of shared infrastructure and combined revenues.

THE FIELD IS GROWING FAST

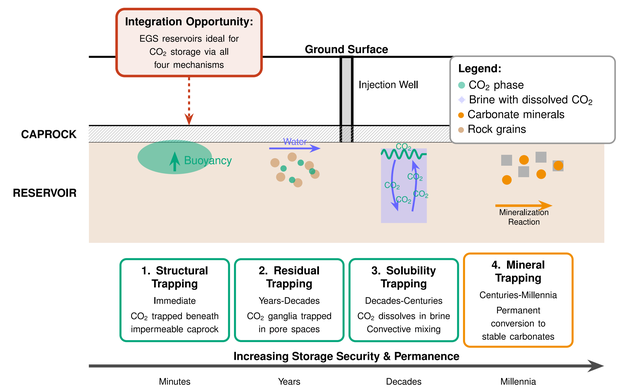


4 One platform, three products



Representative 25 MW_e facility: one reservoir, with $scCO_2$ as the working fluid, delivers electricity, permanent CO_2 storage and lithium / REE recovery through shared wells and surface plant.

5 Locking CO_2 away for good



>95%
of injected CO_2 mineralised within 2 years in basalt (CarbFix)

4.7 Mt
stored over 30 years by keeping 5% of a 100 kg/s flow (158,000 t/yr)

Basalt is the optimal host: fast mineralisation, >100 °C/km gradients and rare-earth enrichment.

LIFE-CYCLE CARBON INTENSITY (g CO_2e/kWh)

Integrated platform	**−800 to −1,600**
Conventional water EGS	**+15 to +50**
Natural-gas combined cycle	**+400 to +490**

6 Supercritical CO_2: a dual-purpose fluid

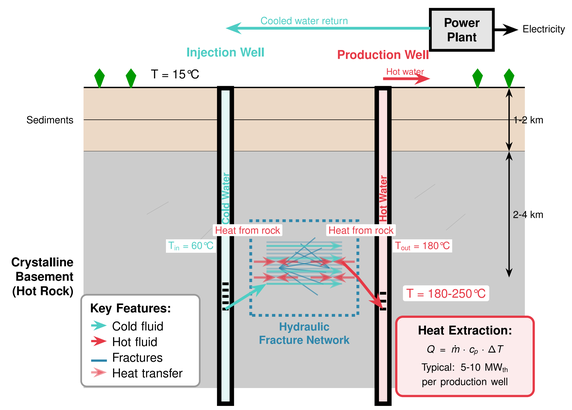
At 200 °C, 25 MPa	$scCO_2$	Water
Viscosity (mPa·s)	**0.04–0.05**	0.13–0.15
Density (kg/m³)	**280–400**	860–880
Specific heat (kJ/kg·K)	**1.5–2.5**	4.2
Pumping	**thermosiphon**	production pumps
Parasitic power	**5–10%**	10–20%

+25–40%
thermal power vs water in tight reservoirs (<10 mD)

2–10×
faster mineral dissolution through controlled acidification (pH 4–6)

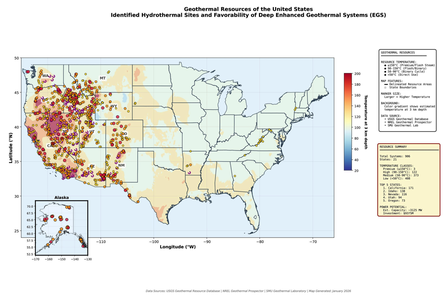
Trade-offs: long-term heat-extraction efficiency is comparable (30–50% vs 35–55%), and carbonic acid demands corrosion-resistant materials.

7 How an EGS extracts heat



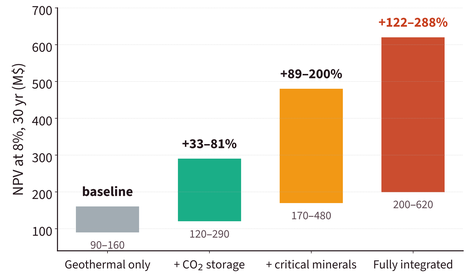
Fluid is circulated through a stimulated fracture network in hot, low-permeability rock at 2–4 km (180–250 °C) and returns to a surface power plant.

8 Where the heat is



US hydrothermal sites and temperature at 3 km depth. Markers by quality, from ≥150 °C (flash steam) to <50 °C (direct use); data: USGS, NREL, SMU.

9 Integration pays



$15–20M	$5–15M	$10–30M	$2–5M
electricity	carbon credits	lithium	rare earths

Annual revenue, fully integrated 25 MW_e **$32–70M**

Shared infrastructure cuts capital cost by **40–60%** versus three separate projects. Lithium revenue assumes brines with 50–300 mg/L.

10 Conclusions

- Integration can make geothermal resources viable that are **marginal for power alone**.
- **Basalt** is the optimal host: rapid mineralisation, high heat flow, REE potential.
- Geothermal Li and REE could supply **10–30% of projected 2040 demand**.
- Demonstrations by 2028–2030, GW scale by 2040; delays push this back 5–10 years.

MANAGING INDUCED SEISMICITY

Basel (M3.4) and Pohang (M5.4) were shut down after induced earthquakes. Proposed traffic light protocol:

Green	M < 1.0, ΔP < 0.5 MPa	normal operation, continuous monitoring
Yellow	M 1.0–2.0, ΔP 0.5–1.0 MPa	cut injection 30–50%, notify regulator
Red	M ≥ 2.0 or felt	stop injection, independent review

CRITICAL RESEARCH NEEDS

THMC modelling
coupled thermal-hydraulic-mechanical-chemical

Field pilots
at commercial scale

Materials
CO_2-resistant casing and cement

Monitoring
integrated MRV, seismicity control

Policy
multi-use permitting; $500–1,000M R&D for deployment by 2035–2040

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