CO_2 Mineralization 101

Corey Myers

The Climate Center – Hybrid Carbon Dioxide Removal Strategies
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Q: Who am I to talk to you about CDR?

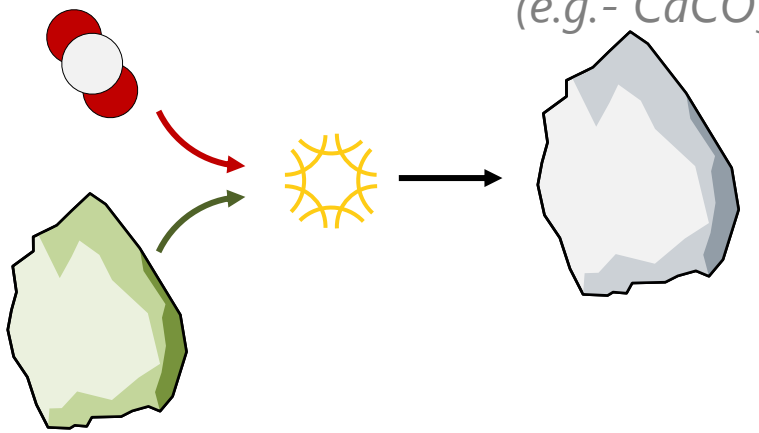
Dr. Corey Myers, Co-Founder & Chief Scientist

- Previously, **lead engineer at Lawrence Livermore National Laboratory** (LLNL) for CO_2 mineralization projects, including the KCAC Carbon Mineralization Field Test—the world's largest test of surface CO_2 mineralization technologies.
- LLNL project lead on a DOE-funded project to **set the protocols for Monitoring, Reporting, and Verification** (MRV) for CO_2 mineralization-based CDR processes.
- Sat on the **CDR Innovation Roadmap team for DOE** in the areas of CO_2 mineralization and marine CDR.
- **Expert witness for CA state government** when considering various CDR and carbon management options.
- **Led non-pipeline CO_2 transport modeling for DOE**.
- Previously, Assistant Professor in Mechanical Engineering at Waseda University in Tokyo, Japan.
- A pilot plant of his CO_2 removal process using desalination brines is **currently being operated at a Japan's national Carbon Recycling test center** (see: https://osakikamijima-carbon-recycling.nedo.go.jp).
- **Japan's national Enhanced Rock Weathering** test program (A-ERW) developed directly from his work and is led by his previous lab.

Q: What is CO_2 Mineralization?

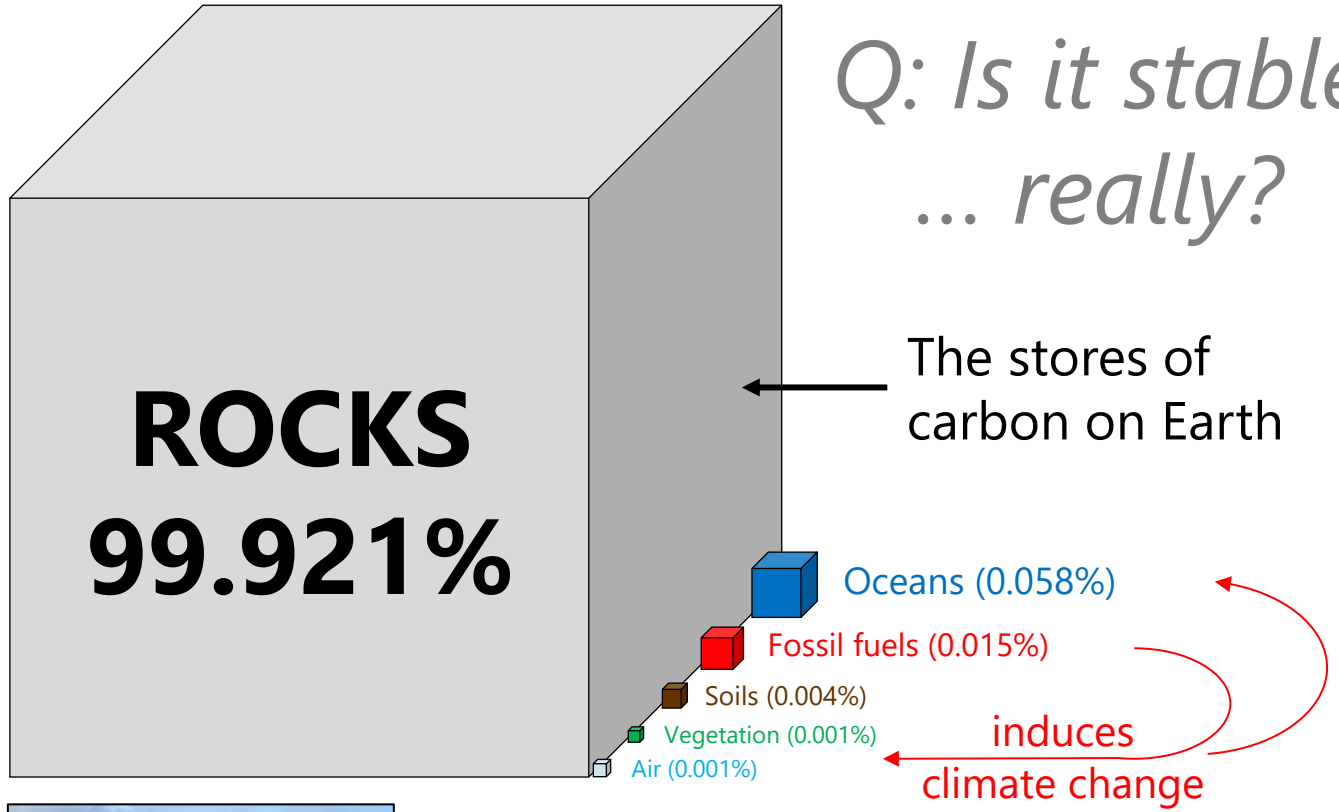
CO_2
(gas)

Mg-carbonate, or Ca-carbonate rock
(e.g.- $CaCO_3$)



Mg-, or Ca-bearing rock
(e.g.- CaO)

A: Converting gaseous CO_2 into a stable, solid mineral ("rock")



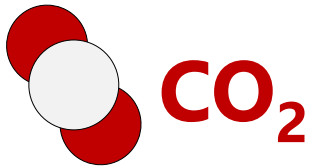
Q: Is it stable … really?

A: Yes!
You can find it all around you.

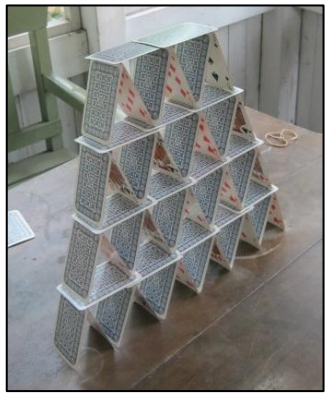
Q: Why does this happen?

Less stable

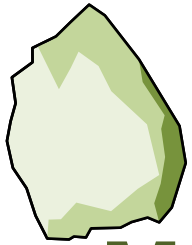
More stable



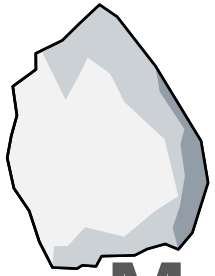
CO_2



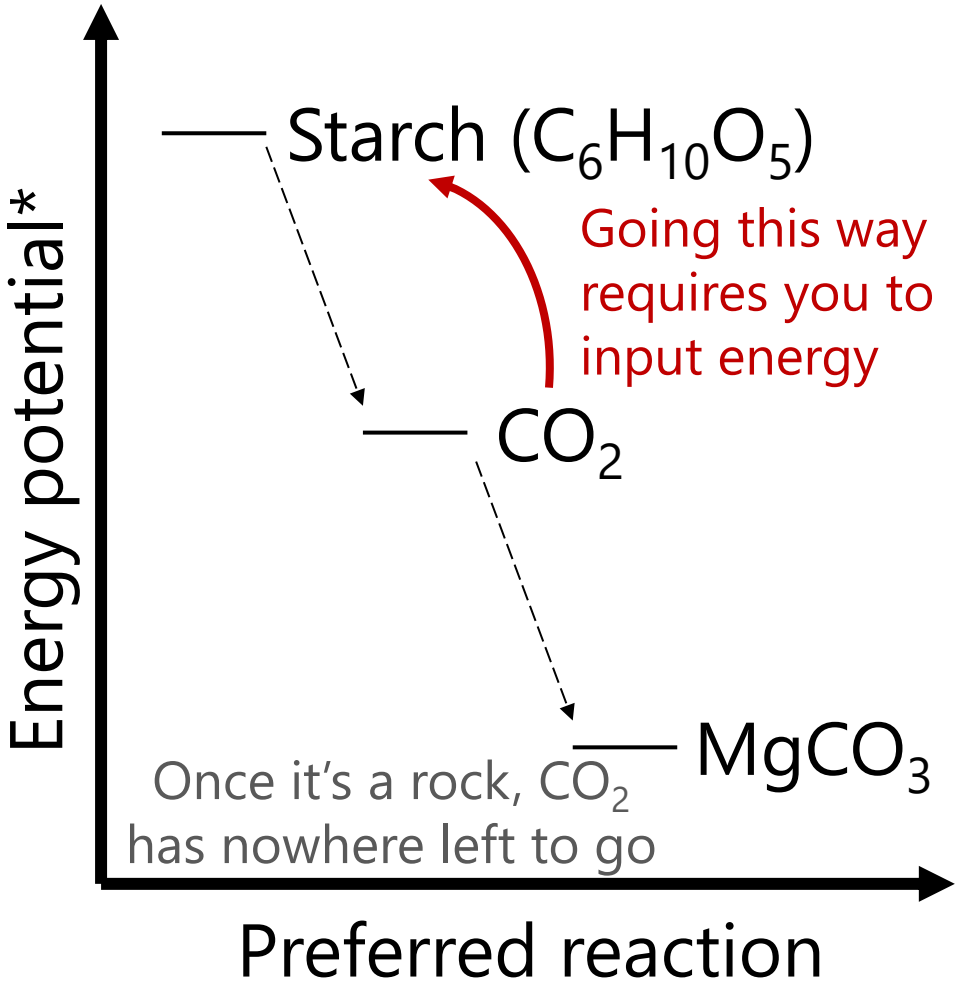
CO_2



MgO



$MgCO_3$



*more precisely, the change in the Gibbs Free Energy

Q: How do people do CO_2 mineralization?

Q: where do you get CO_2?

Q: what do you use to bind CO_2?

Q: where do you store the mineralized CO_2?

Flue gas → emissions reduction (not CDR)

Air → Wastes or byproducts → emissions reduction (not CDR)

Air → Rocks or the ocean → Below ground → "in-situ" CO_2 mineralization

Rocks or the ocean → Above ground → "ex-situ" CO_2 mineralization

Q: Is this like Enhanced Rock Weathering?

A: NO.

Enhanced rock weathering (or "ERW") disperses rocks into the environment where the **rocks dissolve** (like an alka-seltzer that takes centuries to dissolve). The slightly high pH solution *might* then remove CO_2 from the atmosphere. Contrast with CO_2 mineralization, which turns CO_2 into a rock.

Whether or not CO_2 removal occurs is modeled but **not directly measured in ERW** (because it is too difficult and expensive to measure). Contrast with ex-situ CO_2 mineralization, where the stored CO_2 can be held and directly measured.

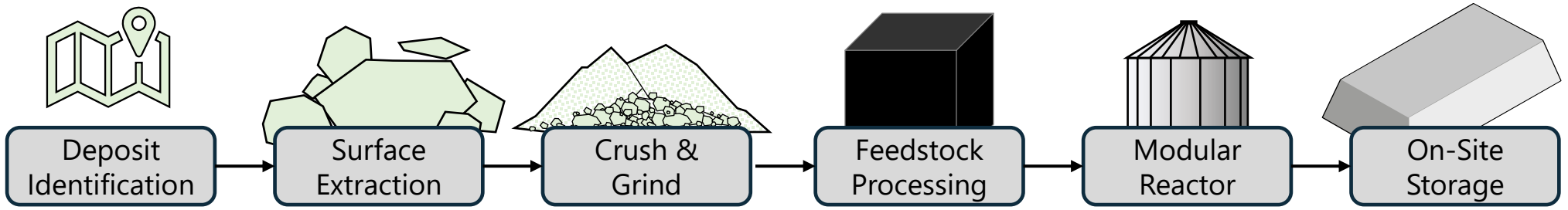
It is not known whether **by changing the base chemistry of an environment** ERW will positively or negatively impact the ecosystem. Contrast with Anvil's process, which does not release materials into the environment.

Q: How does Anvil do CO_2 mineralization?

(1) Mine and grind rocks

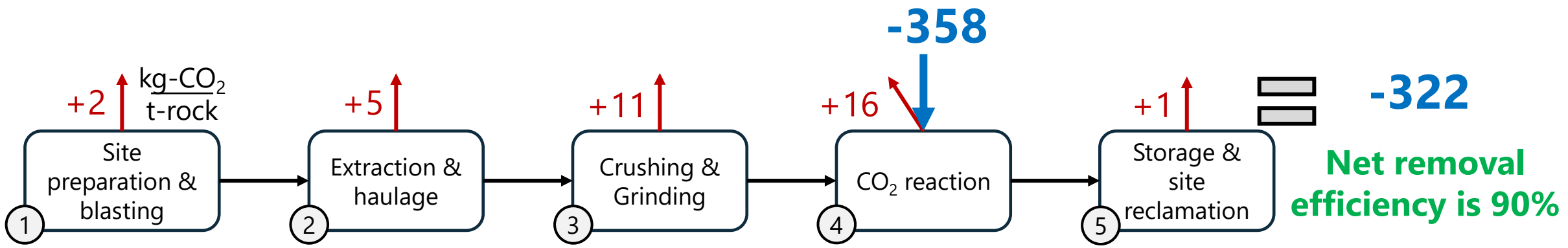
(2) Blow air through the rocks (CO_2 becomes a rock)

(3) Put the rocks back in the ground



NOTE! We don't use chemicals, high temperatures/pressures, concentrated CO_2, or biomass. Just, air, water, and rock.

Q: Are you removing CO_2 on net?







Emissions details:

1) primarily loss of ecosystem carbon (4 t-CO_2e/acre)[a,b,c] and explosives (1.5 t-CO_2e/t)[d]
2) primarily diesel fuel (well-to-wheel: 12.5 kg-CO_2e/gal)[e,f] used to operate heavy equipment
3) primarily electricity (Nevada: 494 g-CO_2e/kWh)[g] used to run comminution circuit
4) primarily electricity (Nevada: 494 g-CO_2e/kWh)[g] to operate reactor; no chemicals used
5) primarily diesel fuel (well-to-wheel: 12.5 kg-CO_2e/gal)[e,f] used to move rocks to lined/covered pit

Using electric trucks and behind-the-meter firmed, renewable energy would **increase the net CO_2 removal efficiency from ~90% to ~98%**

a) ORNL; b) Schlesinger; c) Koch et al; d) Flannery and Mares; e) GREET; f) EPA ; g) NETL

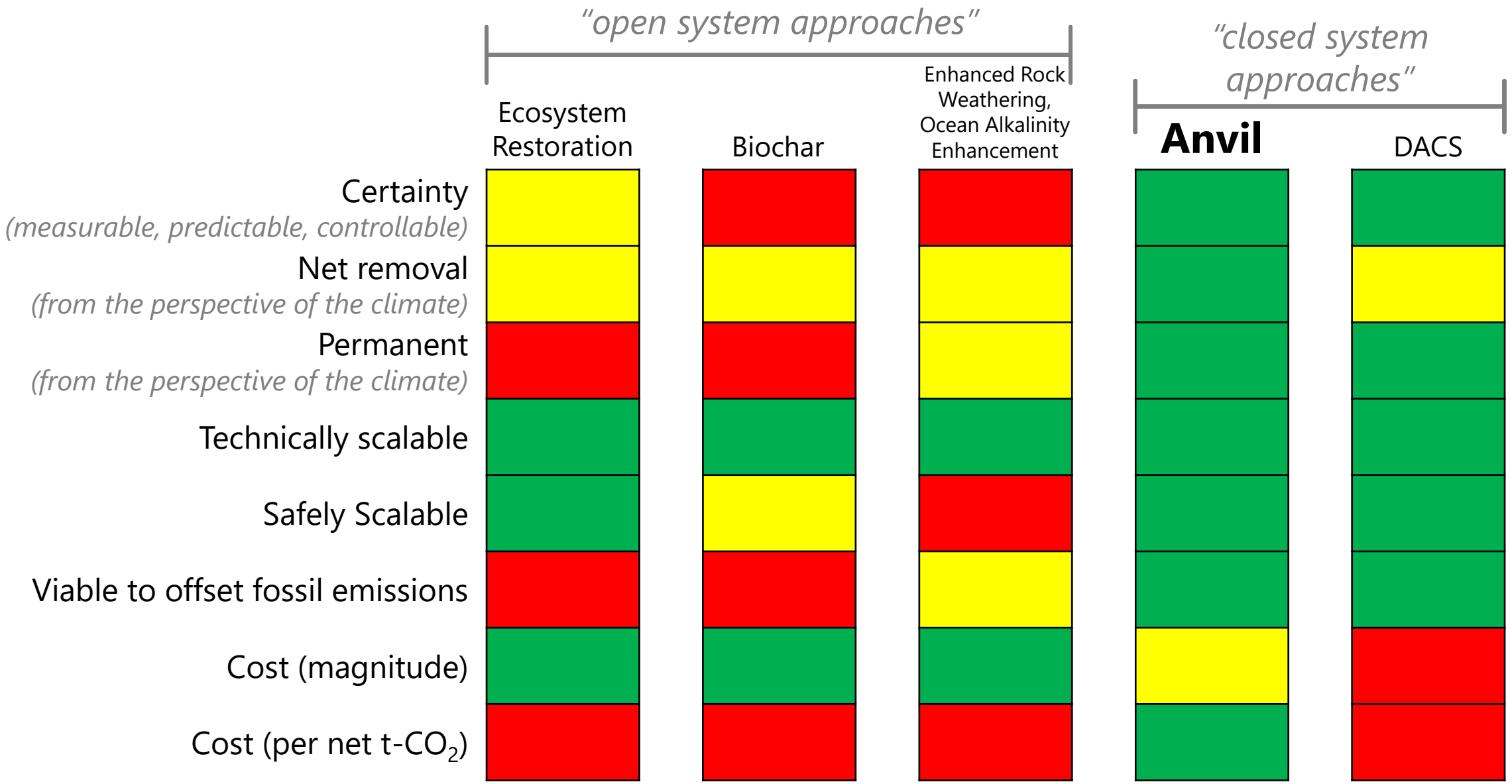
Q: What are the benefits?

Net removal of CO_2 that is measurable and permanent.

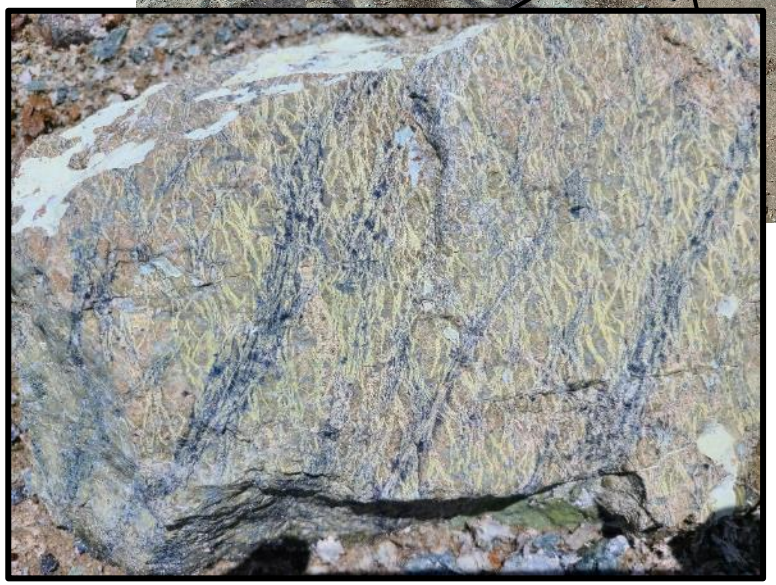
Our process gives you CO_2 removal that is:

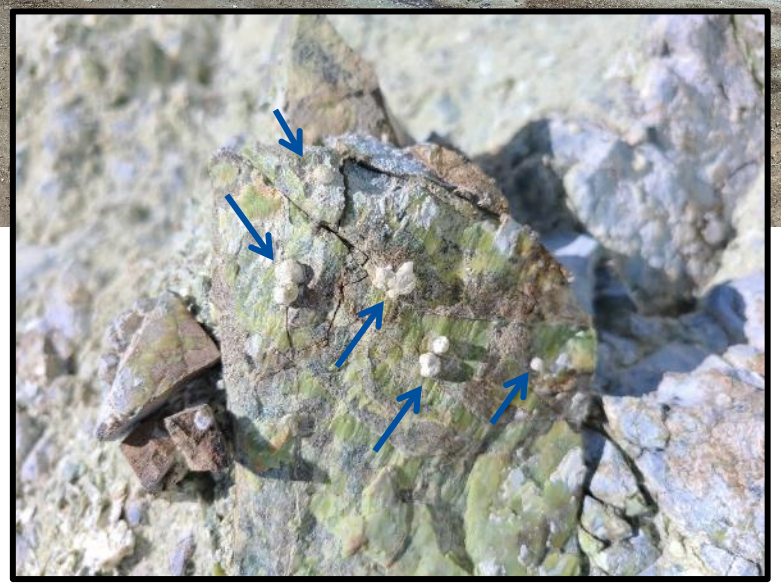
- **high removal efficiency today** (not dependent on renewables & electrification)
- **certain** (as certain as the emissions being offset)
- **auditable** (you can hold the CO_2 in your hand)
- **permanent** (thermodynamically stable over geologic time)
- **low energy** (~1/10th of direct air capture and storage)
- **a good neighbor** (no watershed impact, no truck traffic, no pipelines)
- **land sparing** (everything stays at the mine site, energy footprint << DAC)
- **low cost** (e.g., comparable to Municipal Solid Waste treatment/disposal costs)

Q: How does Anvil compare to other CDR?



Q: What's California's Potential?





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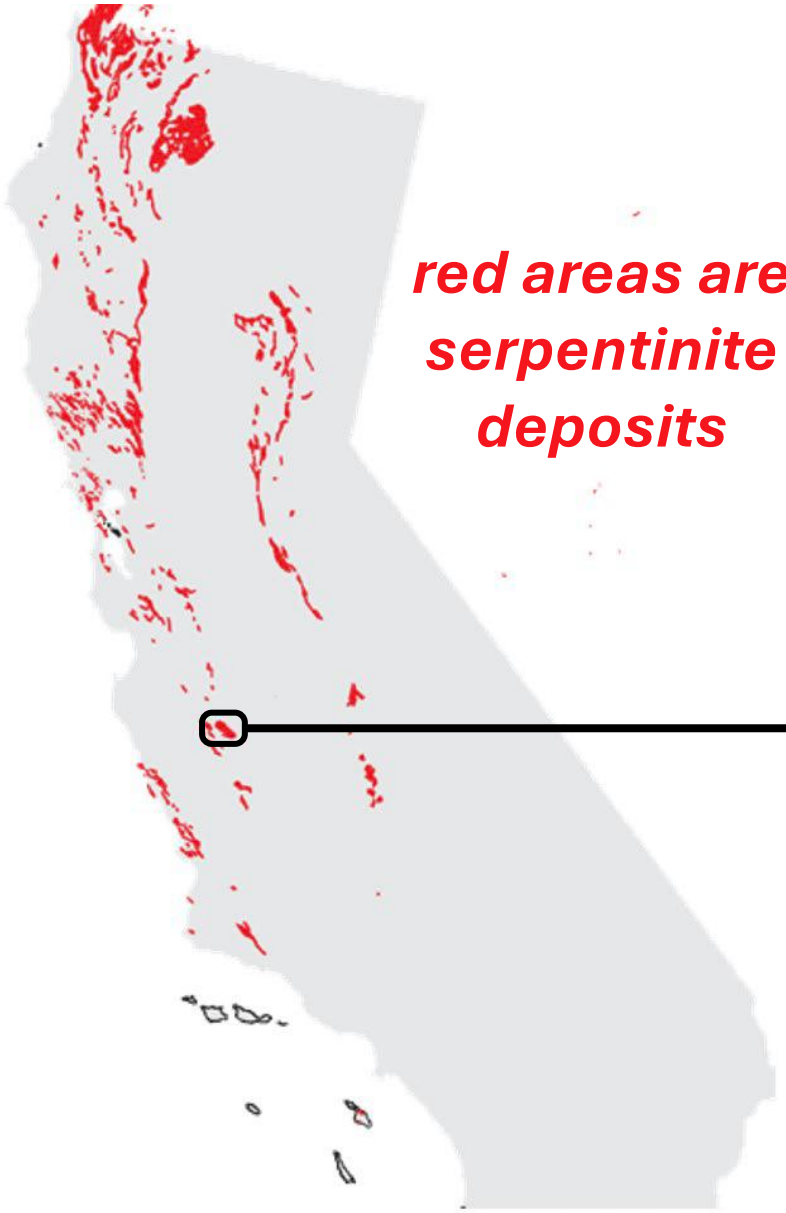
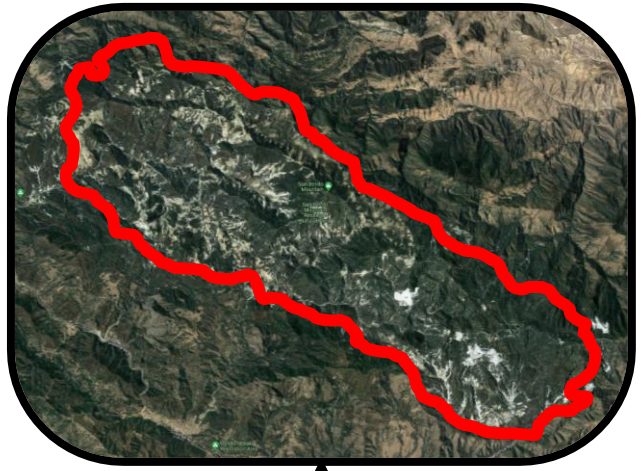


red areas are serpentinite deposits



New Idria Deposit:
~142 km^2 (~2% of CA resource)
→ ~50–100 Gt-CO_2 removal potential via Anvil's process

Anvil has been working with Lawrence Livermore National Laboratory via a Strategic Partnership Project to develop the New Idria deposit for CDR in California.

Anvil Capture Systems

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