Low-Cost CO_2 Capture Using Enzyme Catalysis

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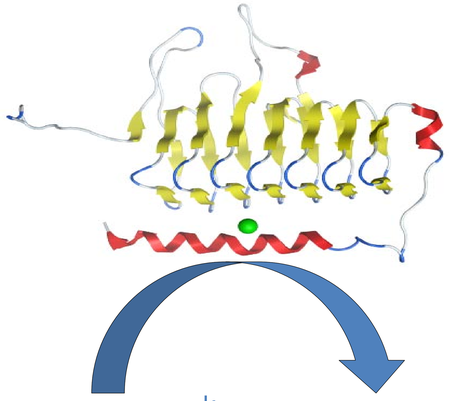
Limitations of Current Solvent Capture Technology

- High parasitic energy loss with MEA
- High heat of regeneration
- Predicted to nearly double cost of electricity from coal
- Solvents with lower energy loss tend to have very slow kinetics

	MEA	Accelerated-MDEA
Regeneration Energy	High due to formation of carbamates	Low due to bicarbonate formation; **30%+ lower total energy possible**
Corrosiveness	High; milli-inch / year = 136	Low to Moderate milli-inch / year = 68
Volatility	High; P_{amine}= 6.7kPa @373K	Low; P_{amine}= 0.3 kPa @373 K
Capture Rate	Excellent	Excellent
Commercially Attractive ?	No	**Yes**

Approach: Acceleration with Carbonic Anhydrase



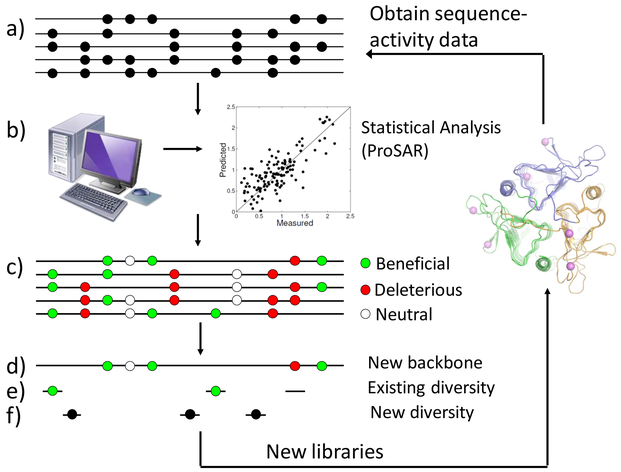
$$CO_2 + 2H_2O \xrightarrow{k_{CA}} HCO_3^- + H_3O^+$$

- Carbonic anhydrase (CA) accelerates an otherwise negligible reaction.
- CA turnover rate up to 1 million CO_2 molecules/s/s [1] .

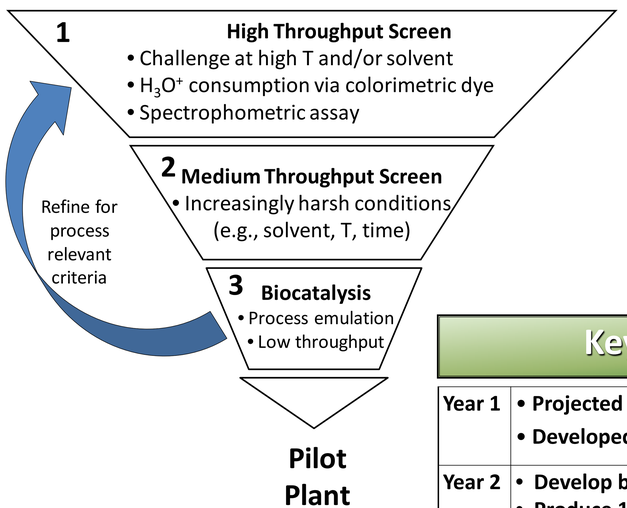
Directed Evolution to Create Stable CAs

Directed Evolution Strategy

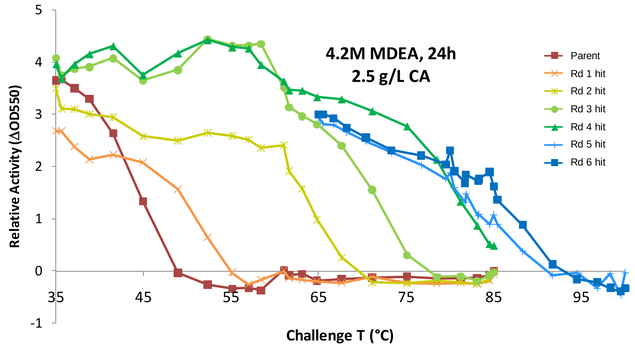
- Directed Evolution: tool to create an enzyme that is adapted to perform in harsh environments

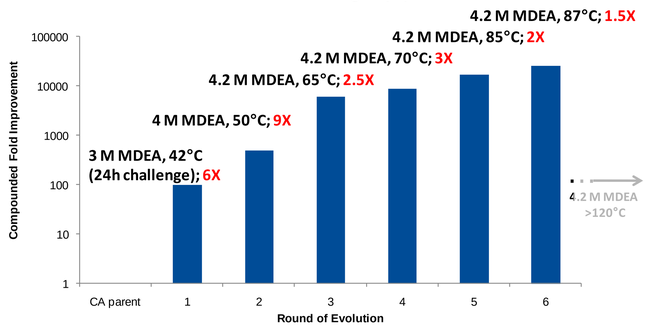


CA screening: tiered approach

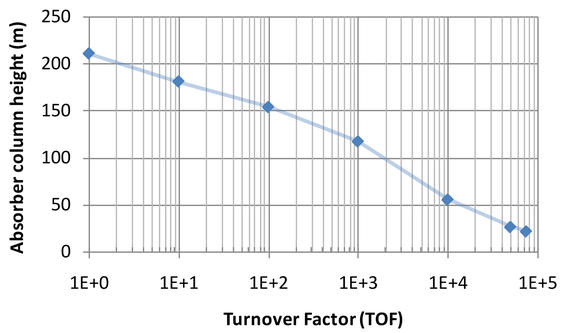


CA Results to Date





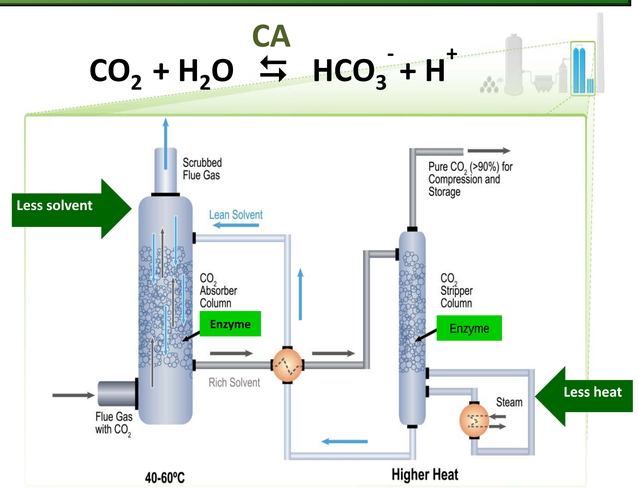
- Challenge temperatures increased up to 87 C after 6 rounds of evolution.



Enzyme Accelerated Process

- CA is a platform for any basic aqueous solution to accelerate the capture of CO_2 as HCO^-_3 .
- Process shifts toward bicarbonate formation, reducing overall heat of regeneration in the scrubber.
- Natural CAs tested not stable to T≥125°C in solvents (10-50 wt% base).
- Evolved enzyme on trajectory towards surviving desorber process conditions.

$$CO_2 + H_2O \overset{CA}{\leftrightarrows} HCO_3^- + H^+$$



Key Milestones and Deliverables

Year 1	• Projected COE exceeded Year-1 milestone • Developed biocatalyst stability exceeded (4X) Year-1 performance target
Year 2	• Develop biocatalyst with > 3 months stability • Produce 100 kg enzyme for pilot plant runs • Projected COE < 35% based on catalyst performance

Acknowledgement

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1. Khalifah, R.; Silverman, D. N., Carbonic Anhydrase Kinetics and Molecular Function, The Carbonic Anhydrase In Plenum Press: New York, 1991; pp 49-64.

Acronyms COE: Cost of electricity, MDEA: N-methyldiethanolamine, MEA: monoethanolamine, ProSAR: Protein structure activity relationship.

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