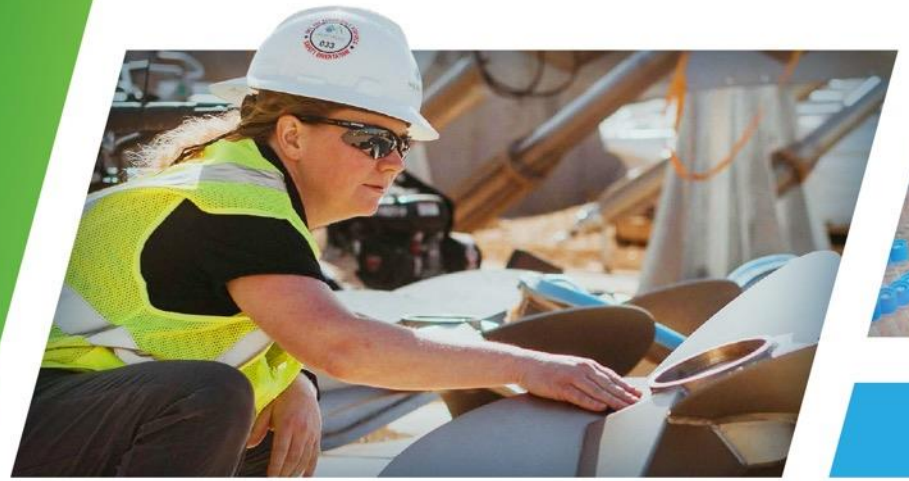
Montrose Carbon Capture Technology

MONTROSE ENVIRONMENTAL



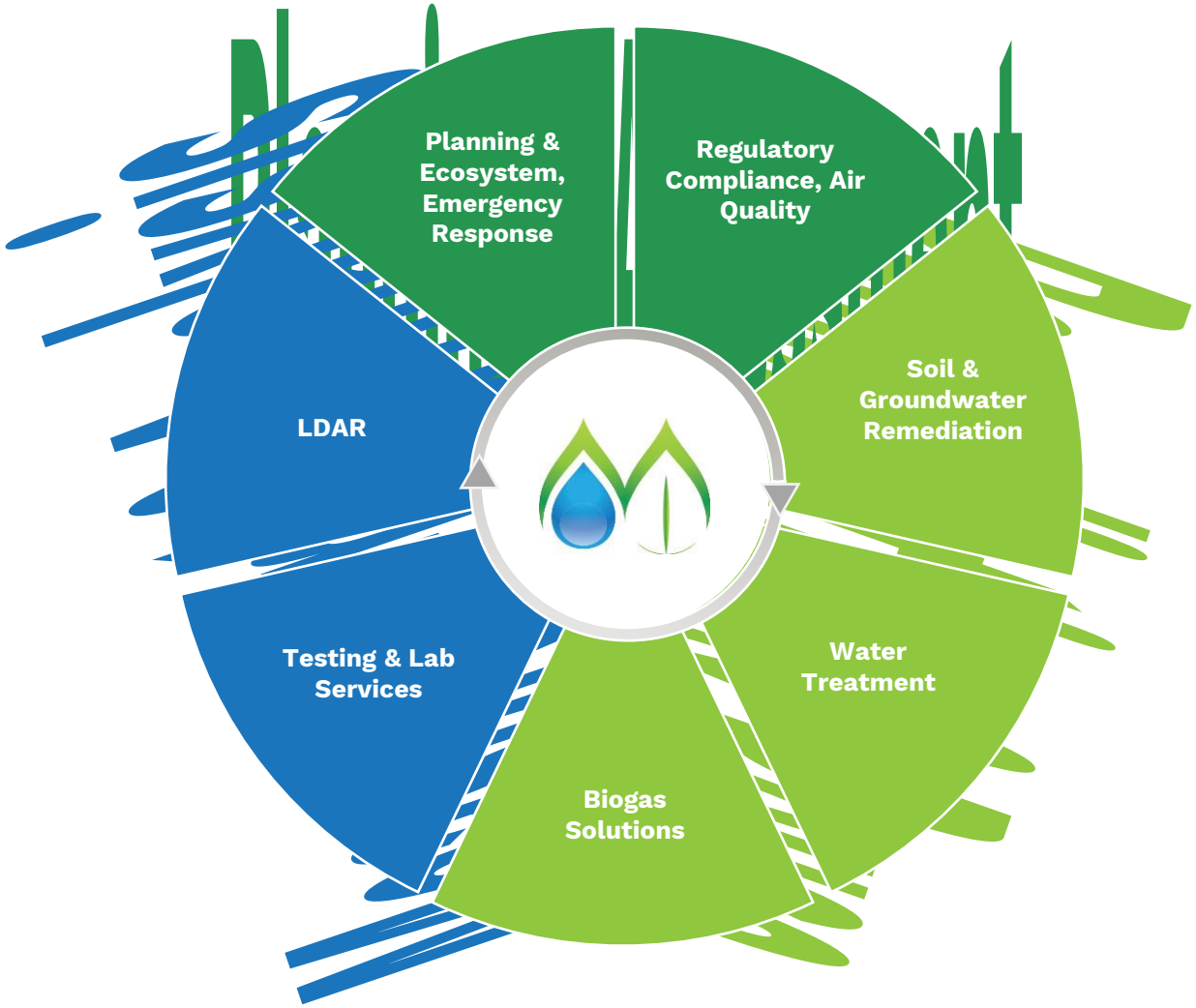
Outline

- Montrose – who we are
- Actionable Steps
- The Montrose Carbon Capture Process – how it was developed
- Process Benefits
- Block Flow Diagram
- Pilot and Next Steps …
- Discussion

Who We Are

Integrated Environmental Solutions

- Publicly traded (NYSE: MEG)
- Over 3,000 employees
- 90+ offices - US, Canada, Europe, and Australia
- Integrated services
- Dedicated R&D group - *innovation in environmental solutions*



Actionable Steps – Climate Change

Cut Emissions

- Electrify Transportation
- Decarbonize the Grid

- Hockey stick growth
- Public transportation (busses, fleet infrastructure)

- Single largest source of carbon emissions (~40%)
- Learning rate besting Wright's law (2x production ~ 15% cost reduction)
- Battery storage, CH_4 leaks, heating/cooking

Focus on Efficiency

- Fix Food
- Address Heavy Industry

- Soil management (no-till, low-till)
- Rice (12% of global CH_4 emissions)
- Fertilizer application, beef consumption (if cows were a country: #3 GHG emissions), food waste

- Chemicals, refining, iron & steel, cement

Removal at Scale

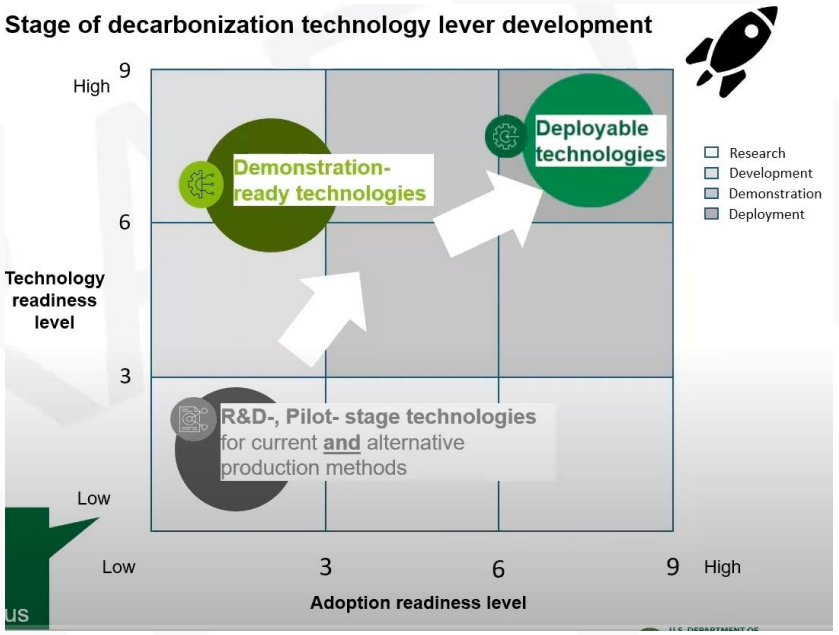
- Natural Systems
- Engineered Solutions

- Forestation, ocean initiatives

- CCUS - DAC, point of capture, EOR, geological sequestration, utilization

Industrial Decarbonization

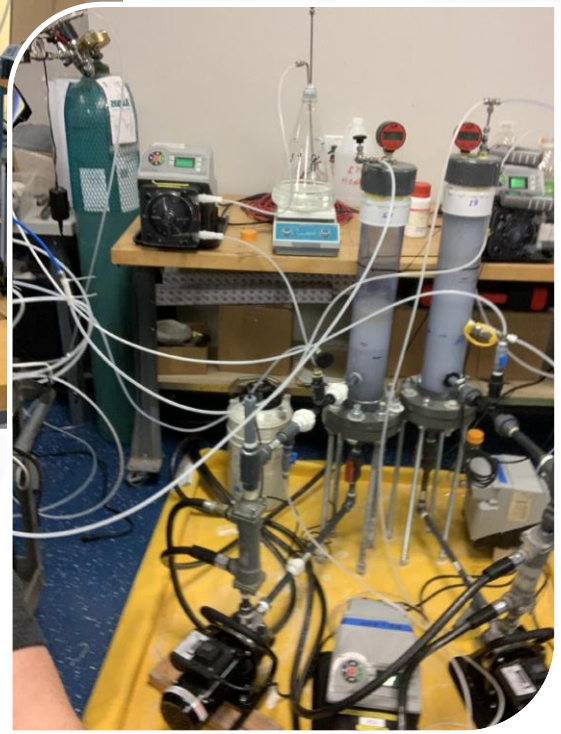
- The US is at risk of meeting net-zero targets; lagging behind
  - Note: Increasing federal support, customer expectation, shareholder pressure, and early private sector movers
- Least-cost-to-abate (DOE): energy efficiency, electrification, alt. fuels, and CCUS (greatest abatement potential in MMT)
- Potential capital deployment of $700B - $1.1T for decarbonization
  - Carbon Management (CCUS & CDR): ~$100B by 2030/ $600B by 2050
- For CCUS, 15MMT could be abated with net-positive impacts (considering 45Q/45V and utilization off-set)
- Market Acceptance – activating demand-side pull through
  - defined green premium shared across value chain
  - supplier assessments
  - voluntary or statutory requirements



US Department of Energy, 2023

The Montrose CCUS Process

- Started as a solid-phase CaO absorption/conversion process
- Shifted our focus to liquid-phase absorption
- Wanted to avoid toxic solvents, e.g., amines
- Lots of literature review and bench-scale testing performed at our R&D lab in NC
- Had to overcome the mass transfer challenges of a water-based solvent process
- Ultimately developed a process that very effectively and efficiently removes CO_2 from gas streams and converts it into useful product(s)
- Multiple patents filed



"Even with the highly reactive chemistry of NaOH absorption, the large volume of air that needs to interact with sodium hydroxide solution during the absorption step remains a major challenge."

- Technology Assessment on DAC w/ chemicals, American Physical Society, 2011

Process Benefits

- Removes >99.9 % CO_2
- Sequesters the CO_2
- Compact footprint
- Overcomes historical mass transfer limitations (CO_2 → water)
- Flexibility; creates useful product(s); soda ash (Na_2CO_3) and/or sodium bicarbonate ($NaHCO_3$)
- Has a low parasitic load
  - **No toxic, amine-based solvents**
  - **No stripping of CO_2 from the solvent**
  - **No compression/refrigeration/pumping of recovered CO_2 required**
- Resistant to biofouling, acid gas removal benefits
- Net negative carbon intensity; avoiding the carbon intensity of the Solvay & Trona mining process

NaOH … a Net Negative C Footprint

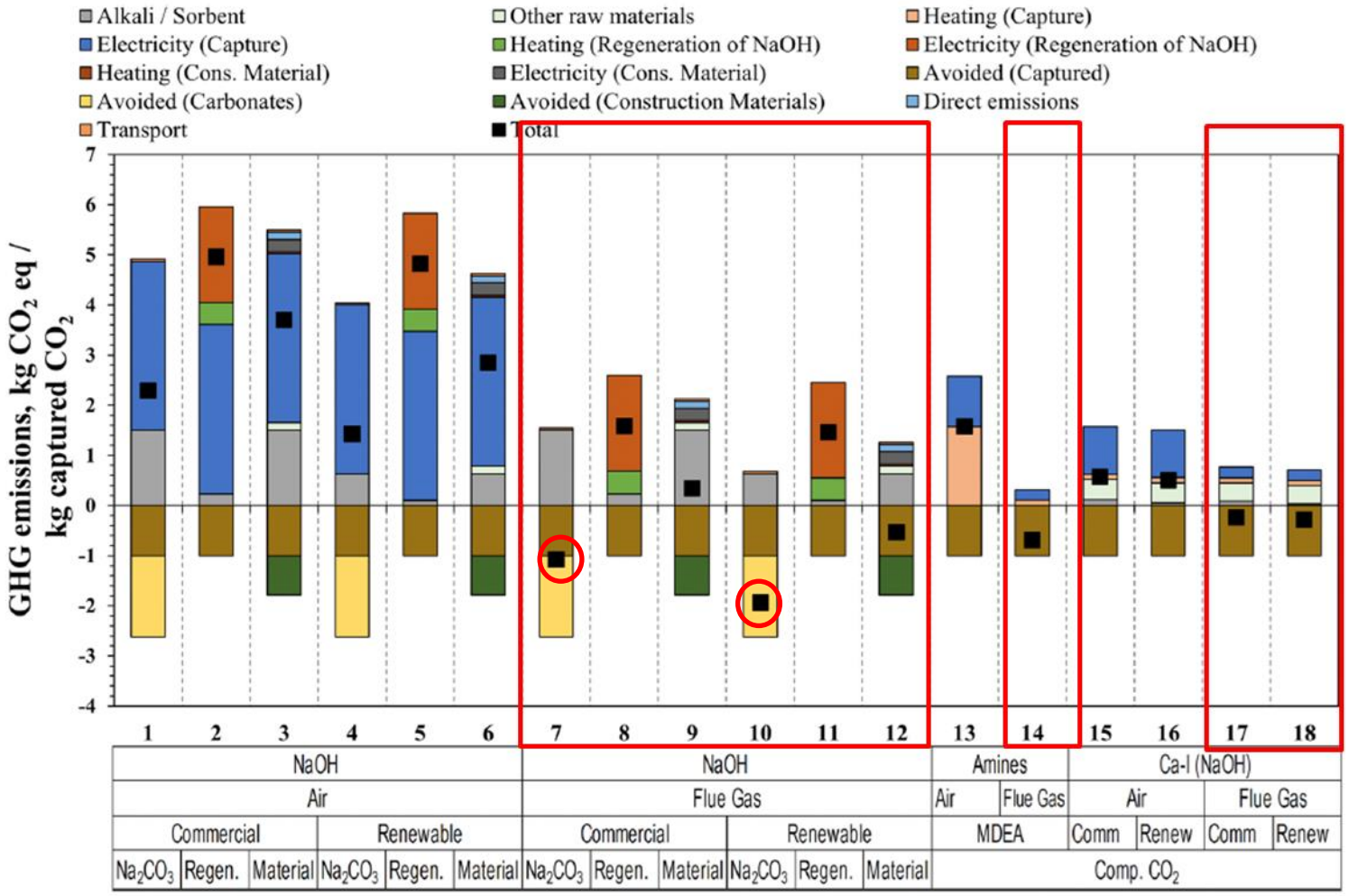
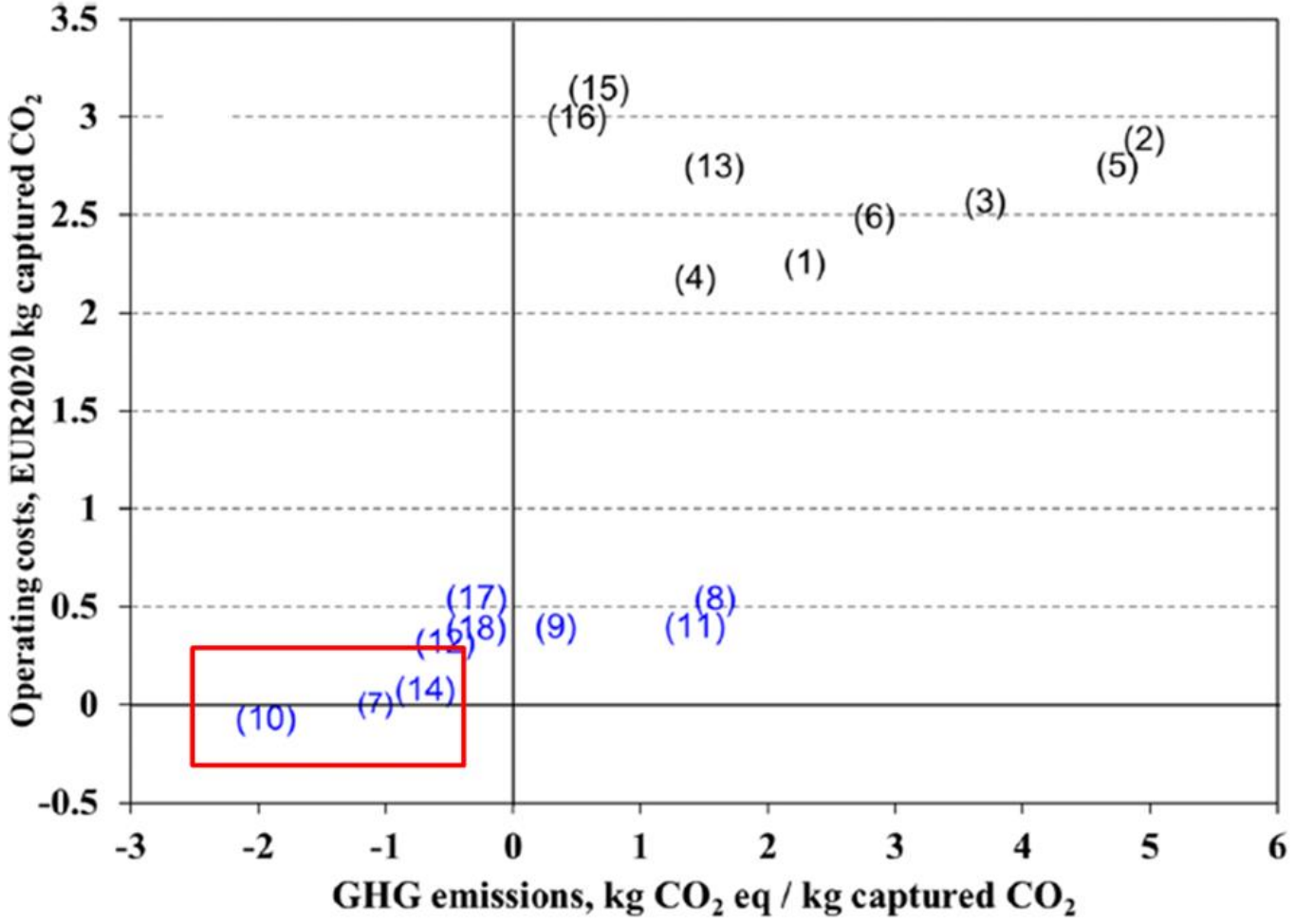


Fig. 3. Life cycle greenhouse gas emissions for the assessed scenarios.

Medina-Martos, et.al., 2022

NaOH … the Lowest Opex



Legend

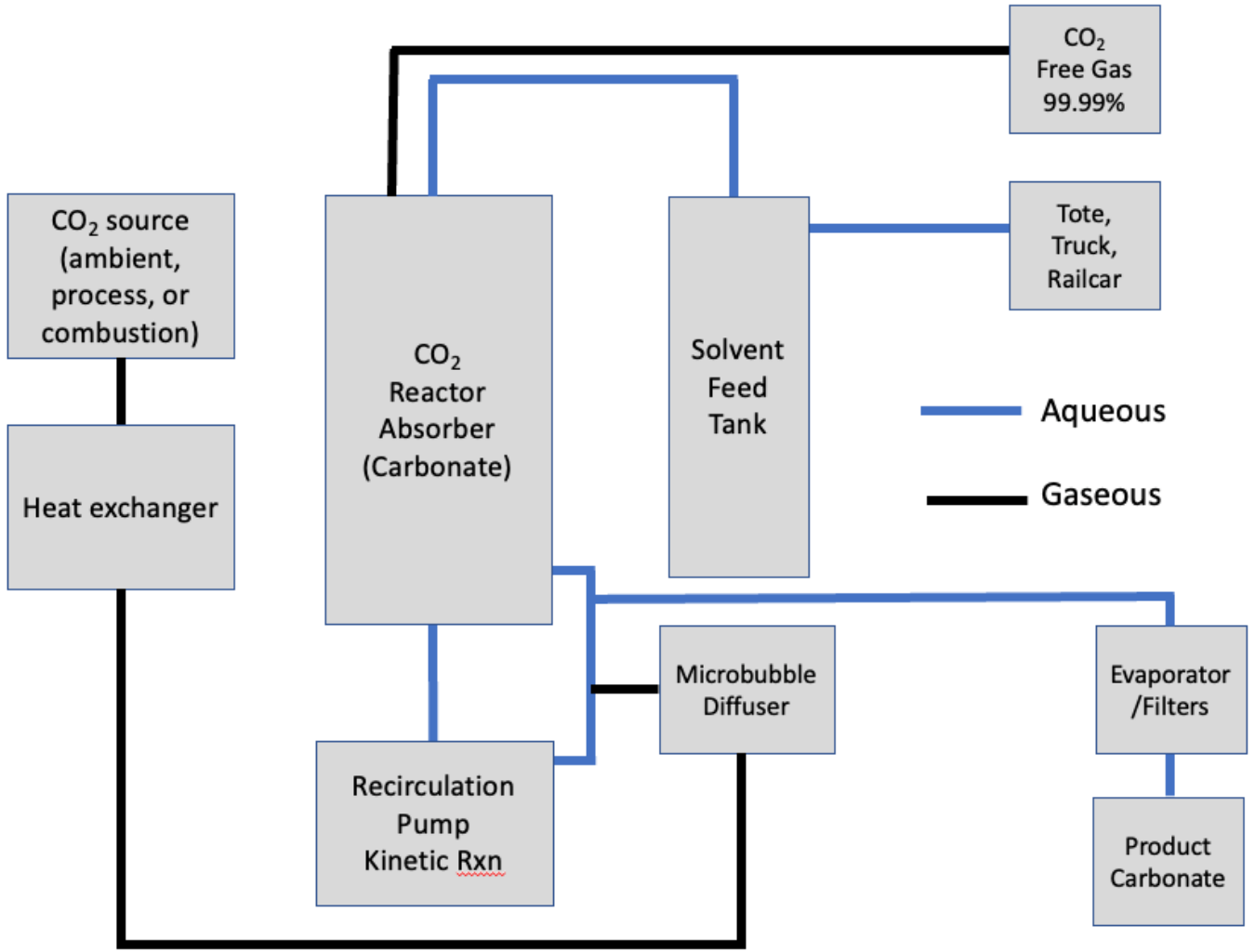
Blue, Flue gas-based process

Black, Air - based processes

1 NaOH – solid / Air/Comm NaOH / Na_2CO_3
2 NaOH – solid / Air/Comm NaOH / Elec Regen
3 NaOH – solid / Air/Comm NaOH / Material
4 NaOH – solid / Air/Re-NaOH / Na_2CO_3
5 NaOH – solid / Air/Re- NaOH / Elec Regen
6 NaOH – solid / Air/Re-NaOH / Material
7 NaOH – solid / Flue Gas /Comm NaOH / Na_2CO_3
8 NaOH – solid / Flue Gas /Comm NaOH / Elec Regen
9 NaOH – solid / Flue Gas /Comm NaOH / Material
10 NaOH – solid / Flue Gas /Re-NaOH / Na_2CO_3
11 NaOH – solid / Flue Gas /Re-NaOH / Elec Regen
12 NaOH – solid / Flue Gas /Re-NaOH / Material
13 Amines / Air
14 Amines / Flue gas
15 Ind Ca-loop (NaOH) /Air / Comm NaOH
16 Ind Ca-loop (NaOH) /Air / Re-NaOH
17 Ind Ca-loop (NaOH) /Flue Gas / Comm NaOH
18 Ind Ca-loop (NaOH) /Flue Gas / Re-NaOH

Medina-Martos, et.al., 2022

Single-Stage Reactor Process Flow Diagram*



$$2NaOH + CO_2 \leftrightharpoons Na_2CO_3 + H_2O$$

$$Na_2CO_3 + CO_2 + H_2O \leftrightharpoons 2NaHCO_3$$

*Patent pending

Off-take agreements & Carbonate uses (Na_2CO_3 or $NaHCO_3$)

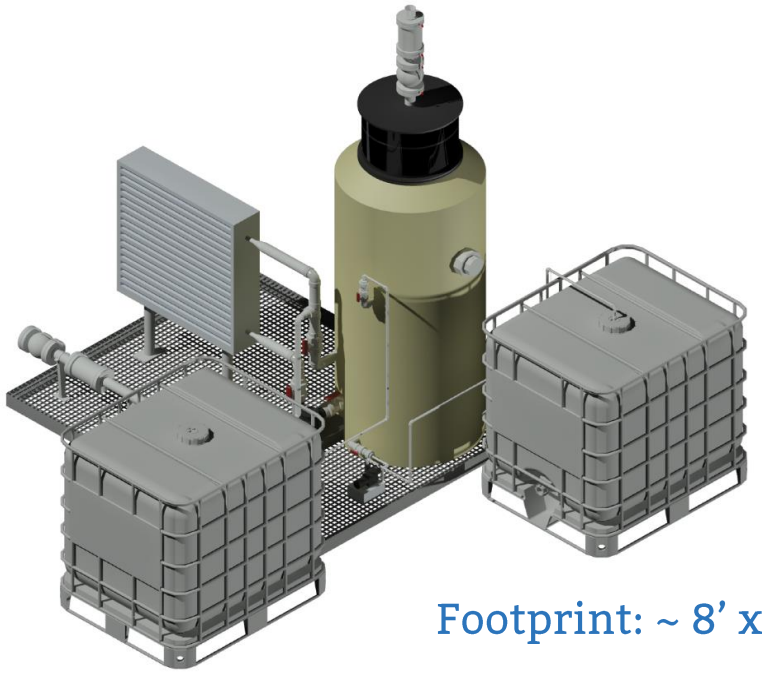
- Glass Manufacturing (soda ash- 64MT/yr.) – 58%+ used in glass industry – increasing in solar/automotive industries
- Chemical Industry (soda ash) – Precursor for fertilizer, detergents, pigments (phosphate, silicates, chromates)
- Animal Feed (bicarb – 4.6MT/yr.) – Nutritional ingredient; acid/base balance
- Food Industry (bicarb) – Baked goods industry; meat tendering agent; pH regulator – consumption expected to increase

- Reselling capabilities and distribution
- Warehouse storage, trucking, rail networks
- Worldwide distribution

> If you have a 10-year offtake contract then excellent--that's a bankable stream. But **right now it's not quite at the level we need.**
> *-DAC investor*

U.S. DEPARTMENT OF ENERGY

Pilot System Layout



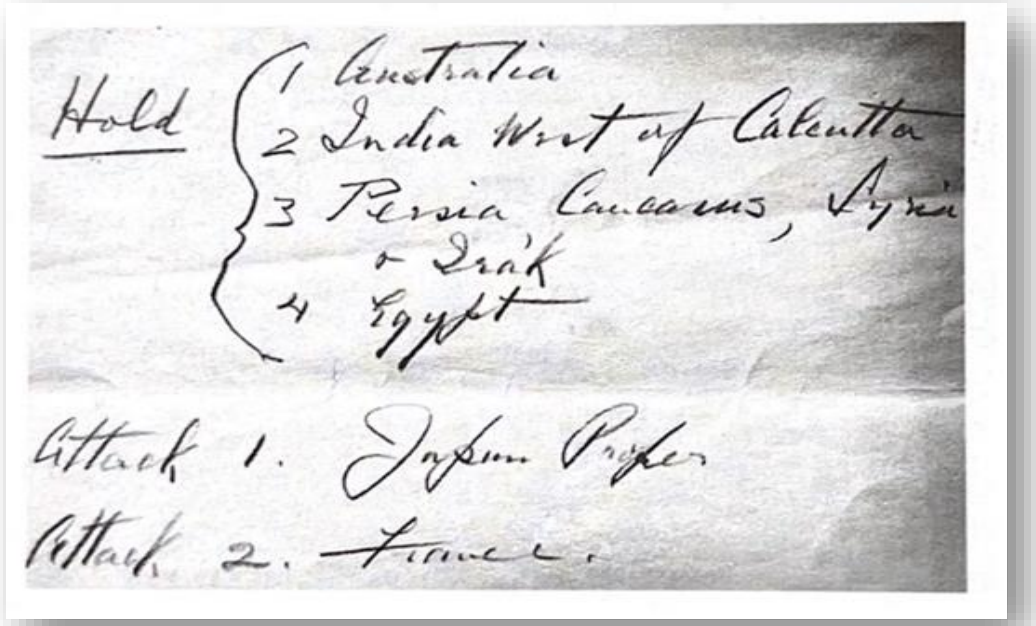
Footprint: ~ 8’ x 16’

- Early adopter – Glass Manufacturing Facility
  - Reducing direct emissions by 50% by 2025 (scope 1, 2)
  - Circular economy
  - Supply side security – 130,000 MT of soda ash/year
  - Limited multi-party agreements (emitters, transportation, processing, storage, tax equity brokers, etc).

- Exceptional mass transfer of gaseous CO_2 into a water-based solvent = substantial differentiator
- Primary inputs/outputs = CO_2 and NaOH & clean air and soda ash
- IRA 45Q tax credits and direct pay subsidies: Direct pay option avoids having to generate tax liability
  - $60/ton CO_2 (for the use of carbon emissions)
  - Industrial facilities threshold – 12,500 tons/yr.
- Agnostic to class VI permits, greater storage and transportation capacity
- Future carbon tax legislation benefits
- Corporate ESG goals

Next Steps / Discussion

- Execute on Pilot
- Data collection
  - LCA steps for 45Q, process optimization (efficiency, $)
- Increasing ESG focus vs early days
  - Marketing piece w/ white paper follow-up
- Early adopters in glass manufacturing, solar, lithium carbonate processing, concrete/cement sectors)



Doerr, 2021

https://montrose-env.com/content/carbon-capture-sequestration-conversion/

