CHANGING WHAT'S POSSIBLE

Reactive Carbon Capture Observations from ARPA-E 2022 Workshop

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2022 ARPA-E CO_2 Utilization/Reactive Carbon Capture Workshop

- Re-imagine the problem
  - Dramatically reduce cost and environmental footprint of C_1 and/or C_2 products
  - Leverage commercial downstream processes
  - Skip steps, and their related hardware and energy inputs
  - Leverage new materials/chemistry (ionic liquids, MOFs, homogeneous catalysts)
  - Maximize process intensification
  - https://arpa-e.energy.gov/events/reactive-carbon-capture-workshop

- Reactive Carbon Capture
  - Capture CO_2 and react it while in adsorbed/absorbed state
    - No intermediate CO_2 production, purification, compression
    - https://netl.doe.gov/projects/files/SummaryReportoftheReactiveCO2CaptureProcessIntegrationfortheNewCarbonEconomyWorkshop_08242021.pdf

- React CO_2 and separate the product(s), esp where CO_2 is hot and in reducing environment
  - Replace CO_2 capture with easier product separation (ie MeOH in water wash)

Options for RCC

- Inorganic RCC
  - Capture CO_2 with weak or strong base
    - Cement, pozzolanic ash, minerals
    - "Sequesters" the CO_2 as a mineral
    - Can operate over a wide range of temperatures (although rates vary)
    - Minimal concerns about impurities
  - Organic RCC
    - React CO and/or CO2 to make useful products
    - May be easier to separate products than CO2 (ie MeOH)
  - Biological
    - How Nature does it
    - Lanza Tech
    - ARPA-E ECOSYNBIO

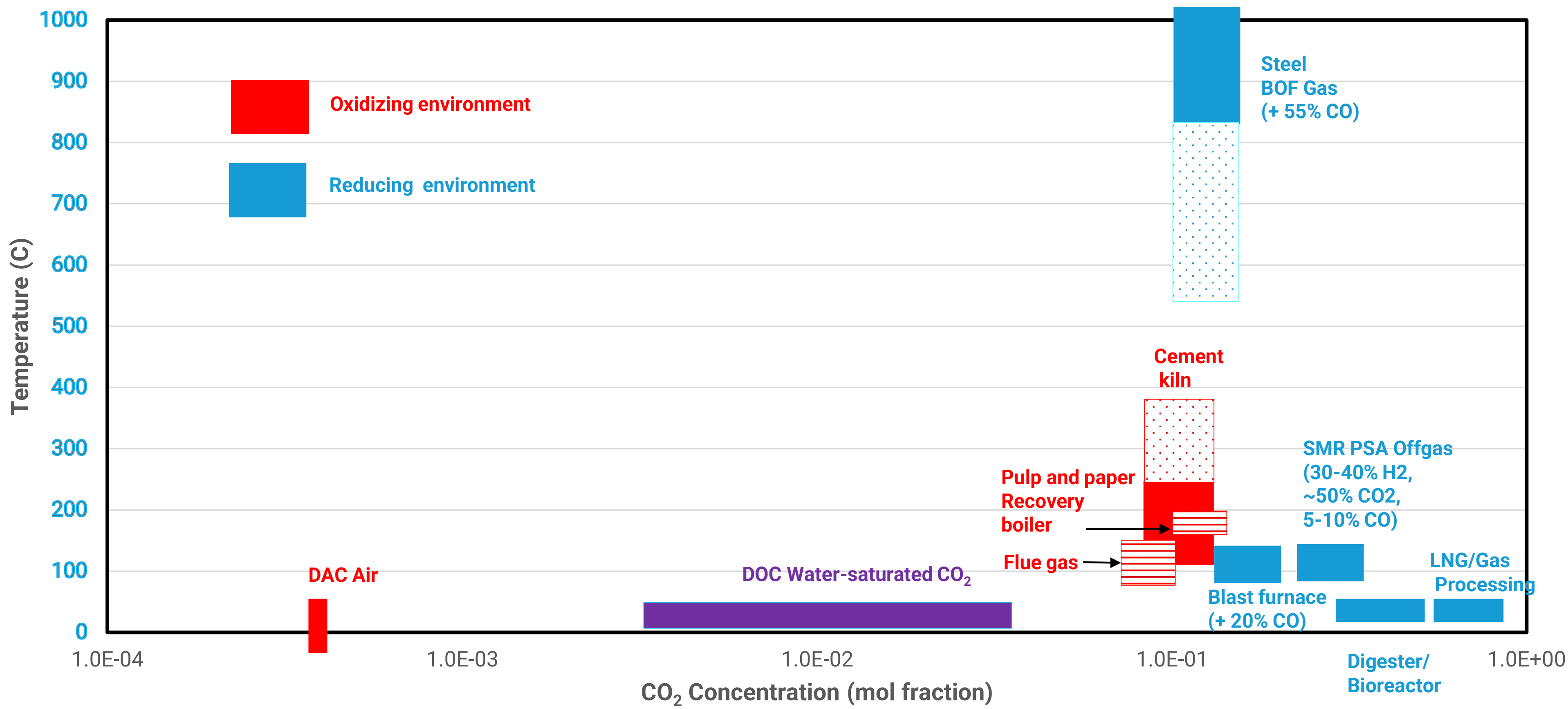
Organic and Biological RCC Challenges

- Carbon Capture (first step)
  - Prefer low temperature, high pressure, no competing species
  - "Goldilocks" affinity – less than a chemical bond, more than van der Waals forces
  - High selectivity for CO or CO_2 – esp. avoid O_2

- Reaction (second step)
  - Catalytic processes prefer high temperature, high pressure
  - Plasma processes prefer low pressure
  - No free oxygen to compete for reducing equivalents

- Biology already does this – what can we learn?

CO and CO_2 Sources/Attributes



System-Level Considerations

- "Contaminants"
  - O_2, possibly SOx and NOx from oxidizing environment (air and combustion point sources)
  - H_2S, NH_3, particulates from reducing environments
  - Possibly many from water-borne CO_2

- Temperature
  - Adsorption/absorption favors low temperature
  - Reaction favors high temperature
  - Not clear if there is a good middle ground
  - Cooling below 40 C is not easy or cheap

- Pressure drop to contact CO_2 from air or flue gas can be energy-intensive

- Liquids can be pumped, easy to change temperature

- Solids are hard to move, hard to change temperature. Adsorption system capturing CO_2 from oxidizing environments usually require multiple beds with interim purge steps

- Operating intermittently (to access off-peak electricity or accommodate variable flow CO_2 sources) can be difficult, lowers capital utilization, and increases costs