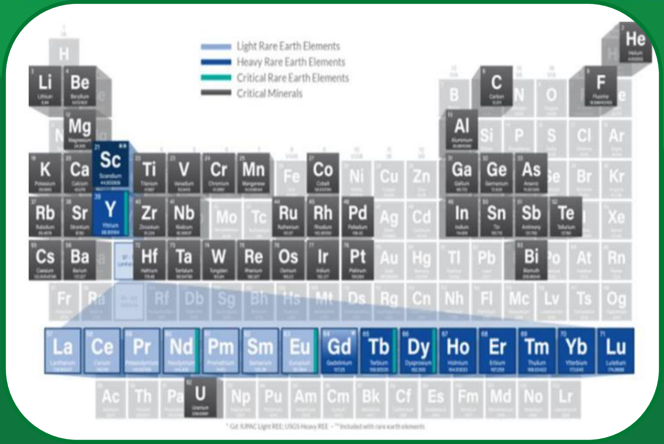
U.S. DEPARTMENT OF
ENERGY
Fossil Energy and
Carbon Management

Reactive Capture and Conversion (RCC) of CO_2

August 17, 2021

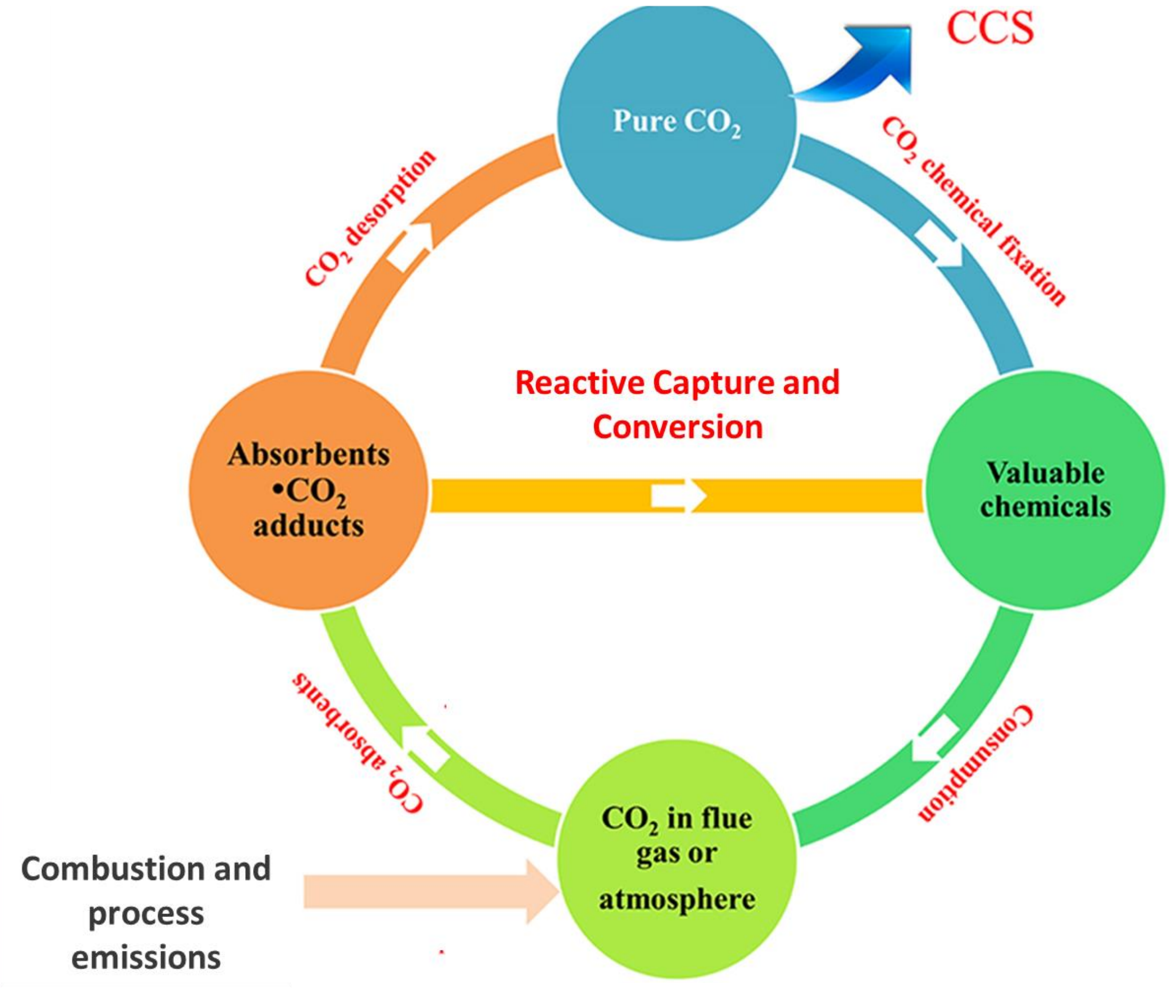


What is RCC?

Reactive capture and conversion may comprise the integration of CO_2 separation and conversion in a method using fewer steps, one reactor, or simply process intensification (reduced unit operations) in the pathway from CO_2 in a mixed gas stream to a CO_2-derived product.

Great reference alert!

Joint lab (NREL, LLNL, LBNL, and NETL) workshop on RCC with proceedings webpage: https://www.nrel.gov/bioenergy/workshop-reactive-co2-capture-2020-proceedings.html and online published report: https://www.nrel.gov/docs/fy21osti/78466.pdf.



Value of RCC

Process Intensification

Increased Energy Efficiency

Reduced Capital Expenditure

Potentially Improved Transport and Storage Capabilities

Variable CO_2 sources

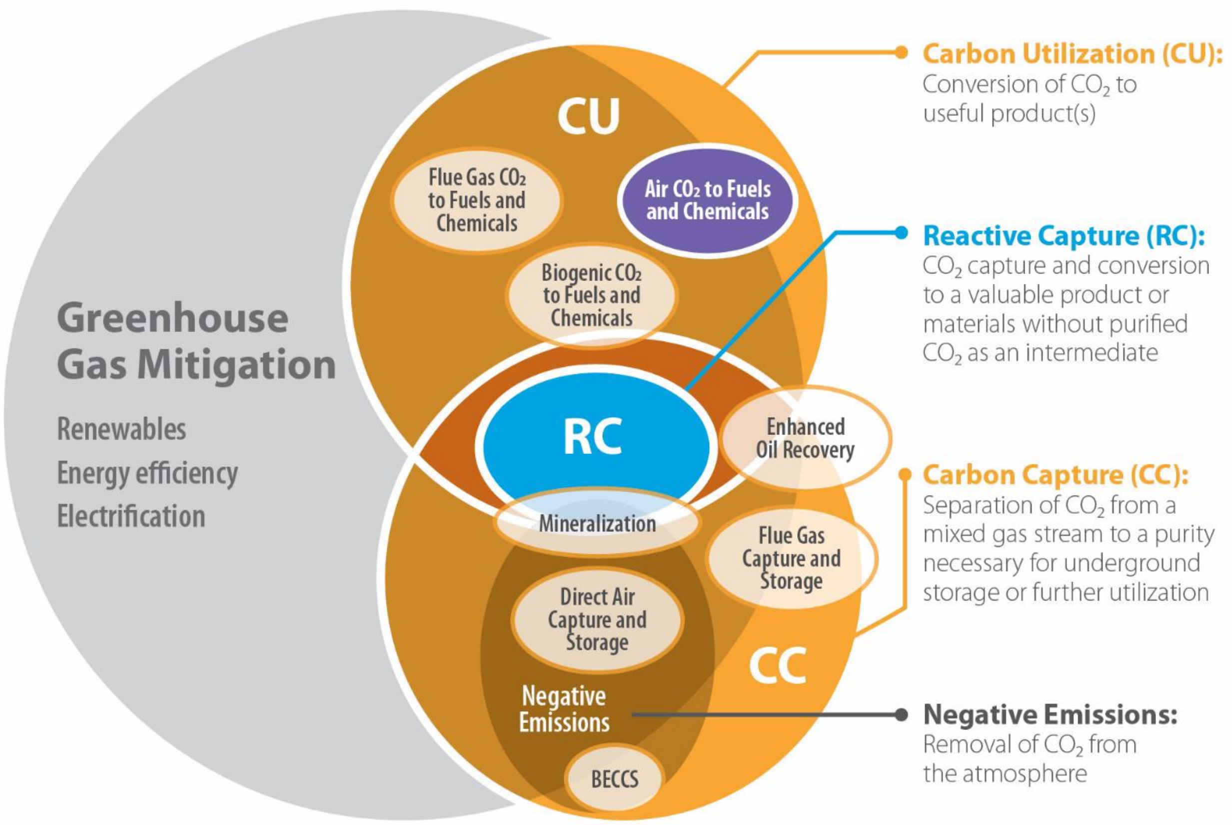


Figure 1. from Summary Report of the Reactive CO2 Capture: Process Integration for the New Carbon Economy Workshop, February 18–19, 2020

Challenges of RCC

(1) addressing the mismatch in existing rates
(2) developing approaches that are robust under intermittent operation;
(3) identifying locations with availability of CO_2, access to inexpensive, renewable electricity, and proximity to product markets.

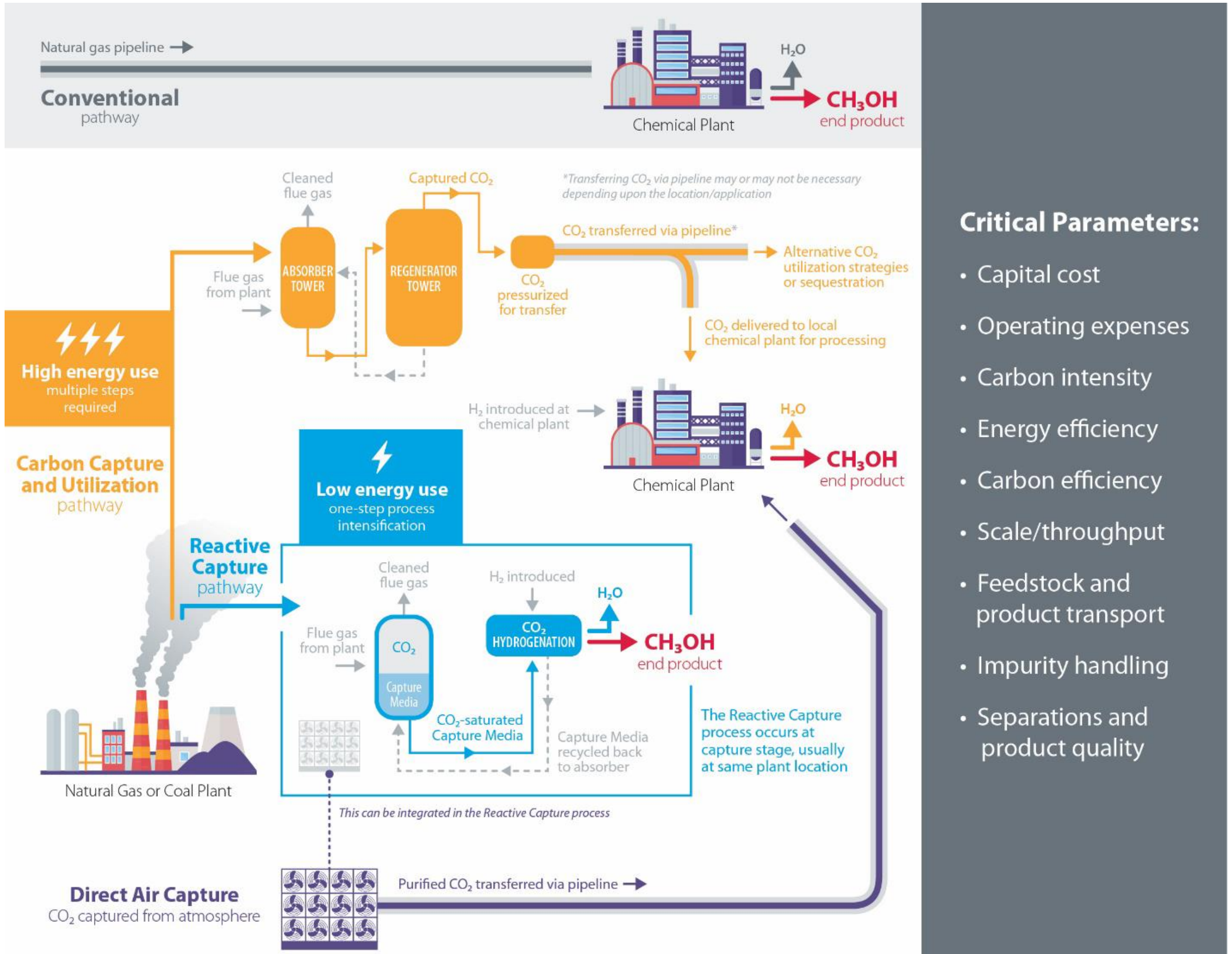
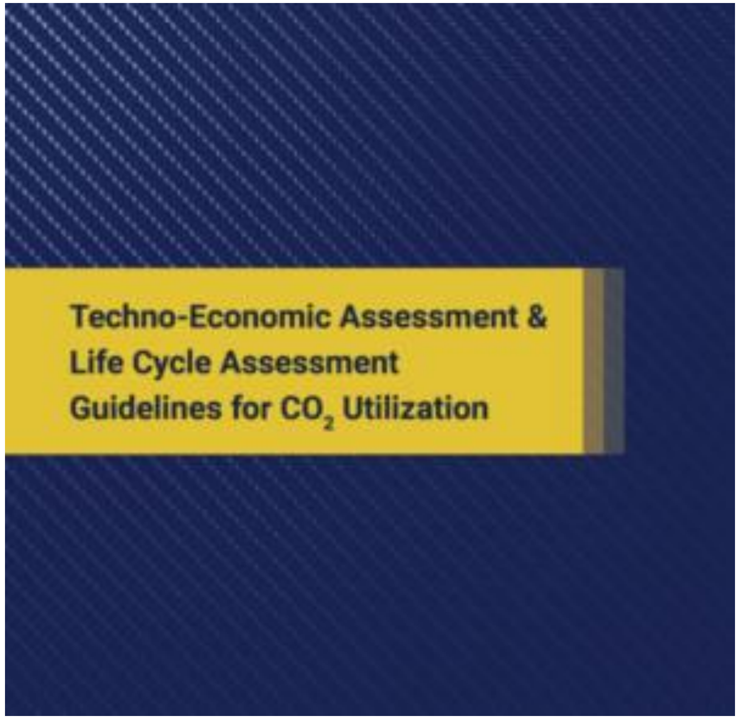


Figure 2 from Summary Report of the Reactive CO2 Capture: Process Integration for the New Carbon Economy Workshop, February 18–19, 2020

Evaluation of RCC

Tools we have now



What we need:

- Benchmarking
- Reporting
- Testing Facilities
- Systems-level understanding of risks & benefits
- Knowledge sharing across disciplines

RCC FECM Lab Call

Lab call objectives focused on the analysis and R&D of RCC technologies to address, but not limited to, the following:

(1) Developing RCC technologies that work to match carbon capture and utilization rates and magnitudes
(2) RCC systems must not compromise the capture material during the conversion process (i.e., the capture material must be recyclable)
(3) Dual functional materials composed of a sorbent and a catalytically active component. Calcium oxide (CaO), for example, may serve as the adsorbent and a metal species catalyzes the conversion of adsorbed CO_2.

Timelines	**issued March Selections May**
Number of Applications Received	**15 application**
Estimated Federal Funding	**$15MM**
Award Size	**$3MM- 3 to 5 awards**
Period of Performance	**Up to 36 months**

Integrated Capture and Conversion of CO2 into Materials: Pathways for Producing CO2-Negative Building Composites

Pacific Northwest National Lab PNNL

Demonstrate viability of solvent-based processes to catalytically upgrade lignin and lignite with carboxylic acids to enable their use as composite fillers. Manufacture CO2-negative composite materials that meet or exceed international building code (IBC) requirements. . Confirm viability of a new large-volume market for CO2-negative building materials.

PI: Dr. David Heldebrant PNNL

Team: PNNL

Objectives

- Expand PNNL's Integrated Capture and Conversion of CO2 to Materials (IC3M) platform to building materials (platform currently funded via TCF with Capture & Use program)
- The system will leverage enhanced reactivity of CO2 chemically captured in our CO2-Binding Organic Liquid (CO2BOLs) carbon capture solvents to perform the first direct carboxylation of the aromatic rings (substituted phenols) in lignin and lignite.

Relevance and Outcomes/Impact

- The IC3M platform as a decarbonization approach enabled by expansion of CO2-containing lignin or lignite (CO2LIG) composites (assuming 1-5 wt.% CO2 incorporation, with lignin/lignite serving as 40-80 wt.% filler) could provide the world's second largest CO2 sink next to enhanced oil recovery, capable of sequestering up to 61,000 M tonnes of captured CO2 per year in the US alone.

Integrating CO2-Selective Polymer Layers and Electrocatalytic Conversion

National Energy Technology Lab NETL

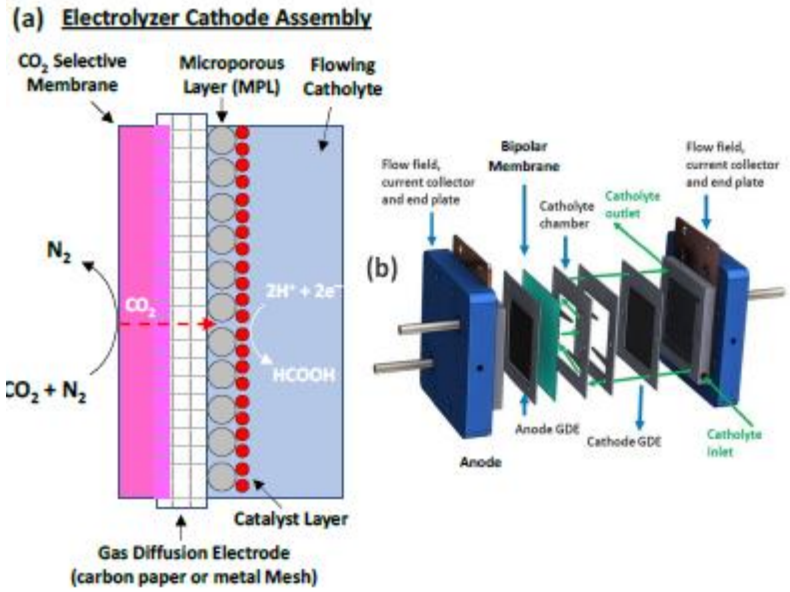
Develop a RCC technology that combines CO2-selective polymer membranes and electrochemical conversion. CO2 will be extracted from dilute streams representative of flue gas compositions and electrochemically upgraded in electrolyzer reactors into formic acid.

PI: Dr. Doug Kauffman NETL

Team: NETL, NREL

Objectives

- The project will leverage ongoing efforts in CO2 separation, electrocatalyst development, electrolyzer optimization, and LCA/TEA.



Relevance and Outcomes/Impact

- The resulting technology will enable scalable "all-in-one" electrochemical capture and conversion technology capable of off-setting the carbon footprint of fossil-based (or any CO2 emitting) chemical manufacturing

Porous Catalytic Polymers for Simultaneous CO2 Capture and Conversion to Value-added Chemicals

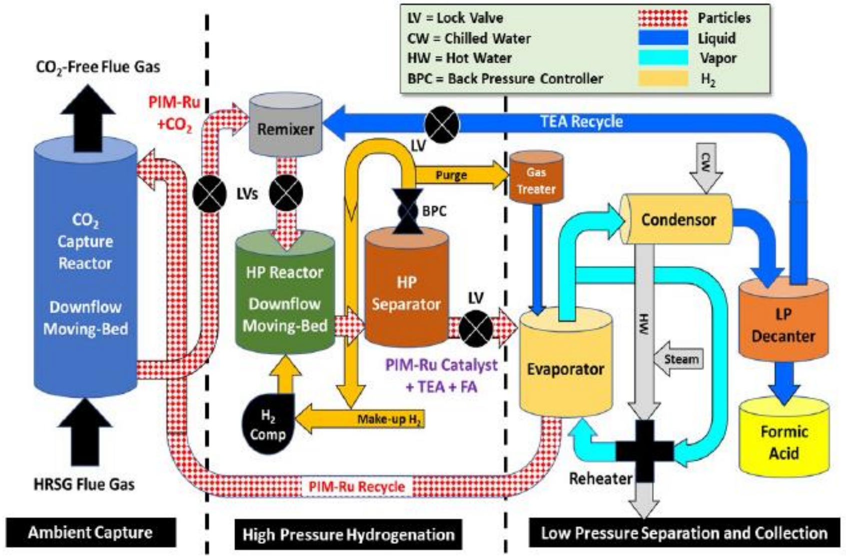
Oak Ridge National Lab ORNL

Advance the technology readiness level (TRL) from 2 to 4, of a dual functional porous catalytic polymer material that captures (adsorbs) and catalytically converts CO2 to a value-added, easily transportable liquid product (formic acid), and (2) assess the techno-economic feasibility of the polymer for RCC in a natural gas combined cycle application to produce formic acid.

PI: Dr. Michelle Kidder ORNL

Team: ORNL, NETL

Objectives



Relevance and Outcomes/Impact

- Our aim is to provide a co-designed optimization of material and process conditions for the from of natural gas supply from power plants having the largest share of 39% of 2019 total 4,100 TWh U.S. electricity generation, resulting in a total ~1,600 metric tonnes of annual CO2 emissions.

Lawrence Livermore National Lab LLNL

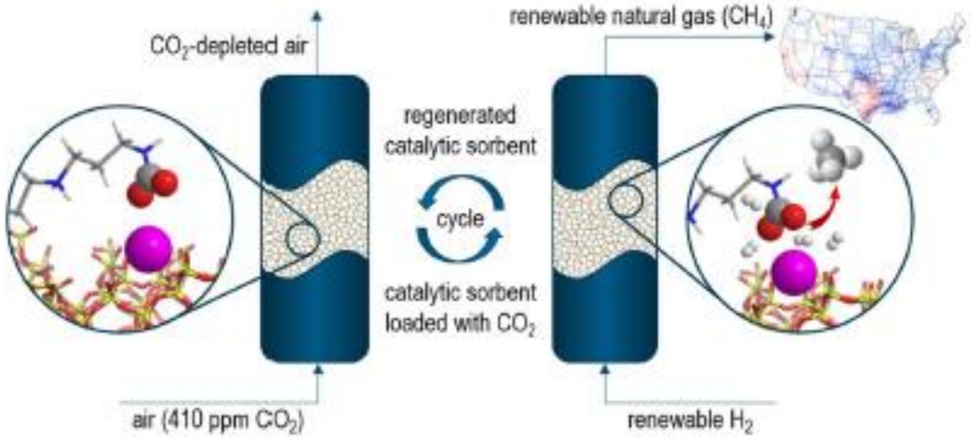
Develop a RCC technology of dual-functional materials capable of capturing CO2 directly from the air and converting it into renewable natural gas (RNG) using renewable hydrogen. Sourcing carbon from the air allows production of climate-neutral fuel

PI: Dr. Simon Pang LLNL

Team: NREL

Objectives

- Develop highly selective and oxidatively stable amines to capture CO2 directly from the air
- Atomically dispersed metal catalysts enable low-temperature CO2 methanation



Relevance and Outcomes/Impact

- The resulting technology addresses an urgent and growing need for natural gas grid decarbonization and utility-scale seasonal energy storage.

A Pressure-Swing Process for Reactive CO2 Capture and Conversion to Methanol through Precise Control of Co-Located Active Sites in Dual Functional Materials

National Renewable Energy Lab NREL

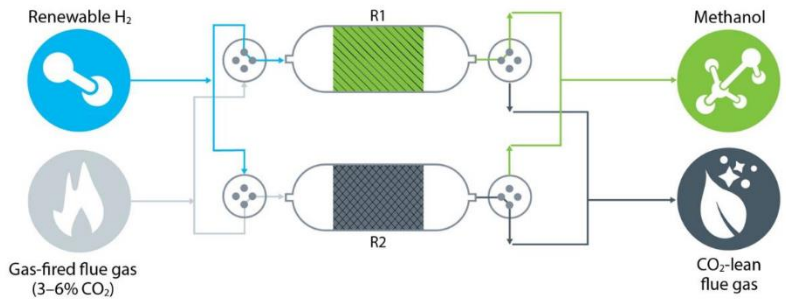
Development of dual-functional materials (DFMs) and the accompanying pressure-swing process for the reactive capture and conversion (RCC) of CO2 to methanol, a vital product in the chemical market and a versatile precursor to fuels.

PI: Dr. Daniel Ruddy NREL

Team: University of Colorado Boulder, Forge Nano

Objectives

- design DFMs to employ catalysts that enable the production of more valuable products
- operate at more mild conditions (e.g., ≤ 100 °C, ≤ 10 atm) that favor lower capital and operating expenses and offer compatibility with a dynamic energy grid to provide favorable process economics.



Relevance and Outcomes/Impact

- The RCC of CO2 to directly into methanol. The higher value that methanol holds over methane as the target product is highlighted through a comparison of pre-pandemic prices (i.e., monthly average of 2019 prices) on an energy-equivalence basis for methanol at \$20.61/MMBTU versus natural gas at just \$2.57/MMBTU.

Questions?

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