

# CARBON CONVERSION PROGRAM



NETL's ReACT Laboratory's Variable Frequency Microwave Reactor (VFMWR) can be used for microwave-assisted catalysis reactions for the conversion of waste gases to fuels and chemicals.

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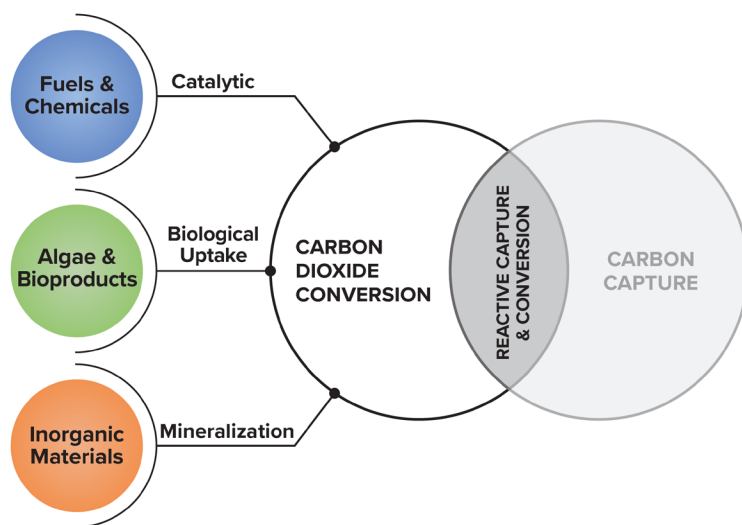
## PROGRAM OVERVIEW

The U.S. Department of Energy's (DOE) Carbon Conversion Program supports research, development and demonstration of a broad suite of technologies that convert carbon oxides, including  $\text{CO}_2$ , into environmentally responsible and economically valuable products. These products can provide a revenue stream to offset the cost associated with capturing, treating, transporting, storing and/or otherwise converting  $\text{CO}_2$ . Research and development (R&D) activities address the challenges and potential opportunities associated with converting  $\text{CO}_2$  into beneficial products and integrating  $\text{CO}_2$  conversion systems with existing carbon-emitting sources. The Carbon Conversion Program aims to develop technologies for both nearer-term and longer-term deployment. Learn more about DOE's Office of Fossil Energy and Carbon Management's role at <https://www.energy.gov/fecm/carbon-conversion>.



## PROGRAM OBJECTIVES

The Carbon Conversion Program seeks to identify and develop new and improved materials, equipment and processes that produce value-added goods and services using carbon oxides as a feedstock. Pathways to generate products are diverse and can include biological uptake, catalytic conversion and mineralization. Within each conversion pathway, the program is developing technologies to integrate the CO<sub>2</sub> capture and conversion steps into one continuous process, denoted as reactive capture and conversion, which eliminates redundancy and associated costs of the nonintegrated process. Products can include fuels, chemicals, agricultural products, animal feed, building materials and other goods and materials. CO<sub>2</sub> conversion is generally applicable to any flue gas stream generated by the combustion of carbon-based fuels, such as natural gas and biomass, as well as to several other carbon-rich waste gas streams that are currently vented. The development of technologies that lead to revenue-generating products can help support broader CO<sub>2</sub> capture and hydrogen production goals.



Major CO<sub>2</sub> conversion pathways and products.

## CARBON CONVERSION PRODUCTS AND PATHWAYS:

The Carbon Conversion Program is developing technologies to convert CO<sub>2</sub> into products through biological uptake using algae, catalytic conversion into fuels and chemicals, and mineralization into inorganic materials. These three major conversion pathways have the potential to employ a reactive capture and conversion methodology where the CO<sub>2</sub> capture and conversion steps are integrated into a streamlined process.

**BIOLOGICAL CONVERSION** — The biomass produced in algal systems can be processed and converted to chemicals, fish and animal feeds, human dietary supplements, soil amendments, and other specialty and fine products. The Carbon Conversion Program is working to develop economical adoption of biomass cultivation practices that consume CO<sub>2</sub>. Current focus is on the cultivation of microalgae or blue-green algae (cyanobacteria) in outdoor ponds or photobioreactors. Ongoing R&D addresses CO<sub>2</sub> capture, conditioning, transport and transfer to the algal medium to maximize CO<sub>2</sub> uptake and minimize the cost of CO<sub>2</sub> delivery. The Carbon Conversion Program also supports R&D of nonphotosynthetic biological conversion pathways, leveraging bacteria or archaea to convert carbon using energy sources other than solar photons.

**CATALYTIC CONVERSION INTO FUELS AND CHEMICALS** — Catalytic conversion pathways can include thermochemical, electrochemical, photochemical, plasma-assisted and microbially mediated approaches. Many approaches require catalysts or integrated processes to lower the energy needed to drive these systems. Via this pathway, CO<sub>2</sub> can be transformed into higher-value products such as synthetic fuels, chemicals, plastics and solid carbon products. Currently, the manufacture of value-added chemicals, polymers and other products often involves complex, multiple chemical synthesis steps; however, other novel approaches are being explored, including multifunctional nanocatalysis, biological catalysis, and process-intensified conversion systems.

**MINERALIZATION INTO INORGANIC MATERIALS** — CO<sub>2</sub> mineralizes with alkaline reactants to produce inorganic materials, such as cements, aggregates, bicarbonates and associated inorganic chemicals. Carbonate materials may be an effective long-term storage option for CO<sub>2</sub>, especially for use in the built environment. R&D in this area seeks to react CO<sub>2</sub> with industrial alkaline sources, including wastes to manufacture valuable products and utilize CO<sub>2</sub> from existing production processes. The Carbon Conversion Program is pursuing R&D that increases process performance and optimizes CO<sub>2</sub> conversion rates, capacity and energy use efficiencies while producing a product with equivalent or superior performance properties compared to current commercial products.

**REACTIVE CAPTURE AND CONVERSION METHODOLOGY** — In contrast to the three above carbon conversion pathways, reactive capture and conversion is a methodology of integrating the conventionally separate CO<sub>2</sub> capture and conversion steps into a single, streamlined process. The reactive capture and conversion approach, which can be used in any of the three major pathways, is actively being developed.



## LIFE CYCLE ANALYSIS (LCA):

Life cycle analysis (LCA) assesses impacts (e.g., water, criteria pollutants) associated with all the stages of a product's life, from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal.

The Carbon Conversion Program uses LCA to determine if a project will result in lower life cycle emissions in terms of carbon dioxide equivalents (CO<sub>2</sub>e) than the current state-of-the-art options on the market, and combines this knowledge with economic and market performance data, technical risk evaluations, and other criteria to evaluate project merit. The most attractive CO<sub>2</sub> conversion options aim to both displace the carbon in an existing product and improve the overall carbon efficiency of the manufacturing process.

NETL has developed a Carbon Conversion Life Cycle Analysis Guidance Toolkit document that provides guidance on what to include in an LCA, along with helpful information on completing an LCA. Also to assist researchers in evaluating the performance and economic aspects of their research, NETL develops Quality Guidelines for Energy System Studies (QGESS) documents that present the methodology NETL employs in its assessment of various aspects of energy systems, including energy conversion facilities, CO<sub>2</sub> transport, storage performance and cost – with a QGESS for CO<sub>2</sub> conversion under development.

## OPPORTUNITIES

NETL's Carbon Conversion Program is working with universities, national laboratories, industries and regional partners to advance technologies that meet the program's objectives. The Carbon Conversion Program is actively funding CO<sub>2</sub> conversion projects and continues to seek further collaborations and partnerships. Additional information about the program and funding opportunities can be found on NETL's Carbon Conversion Program website:

<https://netl.doe.gov/carbon-management/carbon-conversion>



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NETL is a DOE national laboratory dedicated to advancing the nation's energy future by creating innovative solutions that strengthen the security, affordability and reliability of energy systems and natural resources. With laboratories and computational capabilities at research facilities in Albany, Oregon; Morgantown, West Virginia; and Pittsburgh, Pennsylvania, NETL addresses energy challenges through implementing DOE programs across the nation and advancing energy technologies related to fossil fuels. By fostering collaborations and conducting world-class research, NETL strives to strengthen national energy security through energy technology development.

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