CARBON DIOXIDE 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 gasses to fuels and chemicals.

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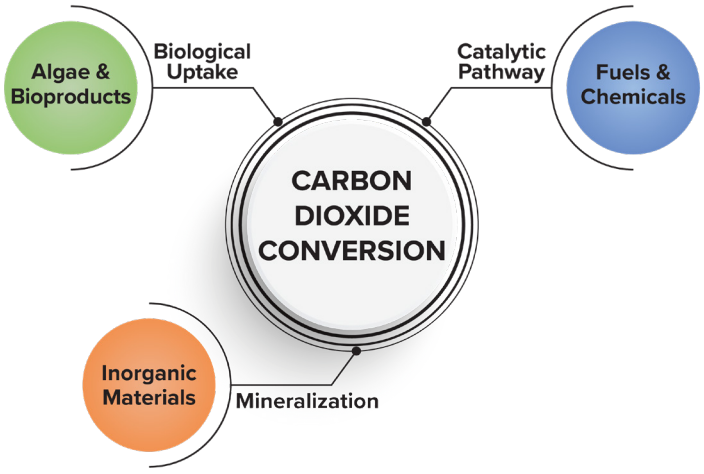
NATIONAL ENERGY TECHNOLOGY LABORATORY

PROGRAM OVERVIEW

The U.S. Department of Energy's (DOE) Carbon Dioxide Conversion Program's vision focuses on research, development and demonstration of a broad suite of technologies that convert CO_2 into environmentally responsible, equitable and economically valuable products, thus enabling low-carbon supply chains to meet the goal of a decarbonized economy by 2050. These products can provide revenue to the emitter that can offset the cost of capturing, treating, and transporting CO_2 — and to the user of the CO_2 — while also achieving a net reduction of CO_2 emitted into the atmosphere. Research and development (R&D) activities address the challenges and potential opportunities associated with converting CO_2 into beneficial products and integrating CO_2 conversion systems with existing carbon-emitting sources. The Carbon Dioxide Conversion Program seeks 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 in achieving net-zero greenhouse gas emissions in their most recent Strategic Vision publication.

PROGRAM OBJECTIVES

The Carbon Dioxide Conversion Program seeks to identify and develop new and improved materials, equipment, and processes that produce value-added goods and services using CO_2 as a feedstock. Pathways to generate products are diverse and can include biological uptake, catalytic conversion, and mineralization. Products can include fuels, chemicals, agricultural products, animal feed, building materials, and other goods and materials. Carbon dioxide 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 to the atmosphere. The development of technologies that lead to revenue-generating products can help support broader carbon dioxide emissions reduction strategies — such as CO_2 capture and storage (CCS) and hydrogen production — and lead to more sustainable power generation and industrial and agricultural practices.



Carbon dioxide conversion products and pathways are represented in the above model.

CARBON DIOXIDE CONVERSION PRODUCTS & PATHWAYS:

The Carbon Dioxide Conversion Program is focused on carbon dioxide biological uptake using algae, conversion into fuels and chemicals, and mineralization into inorganic materials:

BIOLOGICAL UPTAKE INTO ALGAE AND BIOPRODUCTS

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 Dioxide Conversion Program is working to develop economical adoption of biomass cultivation practices that consume CO_2 that would otherwise be emitted to the atmosphere. Current focus is on the cultivation of microalgae or blue-green algae (cyanobacteria) in outdoor ponds or photobioreactors. Ongoing R&D addresses CO_2 capture, conditioning, transport, and transfer to the algal medium in order to maximize CO_2 uptake and minimize the cost of CO_2 delivery.

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, waste carbon dioxide can be transformed into higher-value products such as synthetic fuels, chemicals, plastics, and solid carbon products like carbon fibers. 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

Carbon dioxide 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_2, especially for use in the built environment. R&D in this area seeks to react CO_2 with industrial alkaline sources, including wastes to manufacture valuable products and reduce CO_2 emissions from existing production processes. The Carbon Dioxide Conversion Program is pursuing R&D that increases process performance and optimizes CO_2 conversion rates, capacity, and energy use efficiencies while producing a product with equivalent or superior performance properties compared to current commercial products.

LIFE CYCLE ANALYSIS (LCA):

Life cycle analysis (LCA) assesses environmental and sustainability impacts (e.g., water, criteria pollutants, and greenhouse gases [GHGs] such as CO_2) 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 Dioxide Conversion Program uses LCA to determine if a project will result in lower life cycle GHG emissions in terms of carbon dioxide equivalents (CO_2e) 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_2 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 Dioxide 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 employed by NETL in its assessment of various aspects of energy systems, including energy conversion facilities, CO_2 transport, storage performance, and cost — with a QGESS for carbon dioxide conversion under development.

OPPORTUNITIES

NETL's Carbon Dioxide Conversion Program is working with universities, national laboratories, industries, and regional partners to advance technologies that meet the objectives of the program. The Carbon Dioxide Conversion Program is actively funding carbon dioxide 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 Dioxide Conversion Program website:

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

NETL is a U.S. Department of Energy national laboratory that drives innovation and delivers technological solutions for an environmentally sustainable and prosperous energy future. By leveraging its world-class talent and research facilities, NETL is ensuring affordable, abundant and reliable energy that drives a robust economy and national security, while developing technologies to manage carbon across the full life cycle, enabling environmental sustainability for all Americans.

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