

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.

NETL

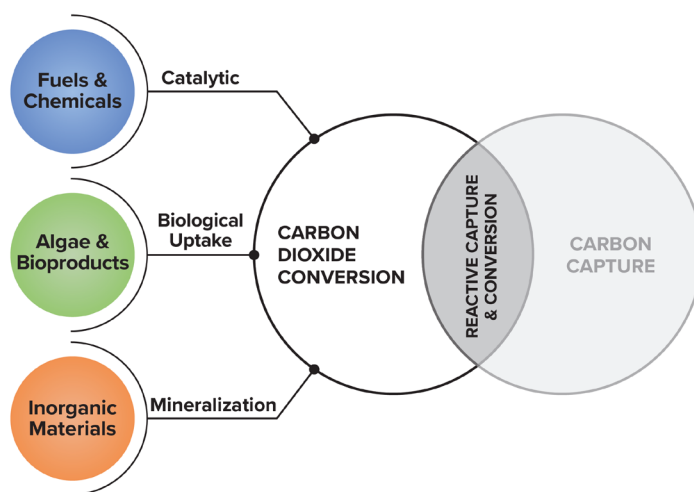
NATIONAL ENERGY TECHNOLOGY LABORATORY

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 converts carbon oxides, including CO₂, 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 a revenue stream to offset the cost associated with capturing, treating, transporting, storing and/or otherwise converting CO₂ while also achieving a net reduction of CO₂ emitted into the atmosphere. Research and development (R&D) activities address the challenges and potential opportunities associated with converting CO₂ into beneficial products and integrating CO₂ 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 in achieving net-zero greenhouse gas emissions in their most recent [Strategic Vision](#) publication.

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 recently began developing technologies to integrate the CO₂ capture and conversion steps into one continuous process, denoted as reactive capture and conversion, which eliminates redundancy and associated costs of the non-integrated process. Products can include fuels, chemicals, agricultural products, animal feed, building materials and other goods and materials. CO₂ 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 CO₂ emissions reduction strategies – such as CO₂ capture and clean hydrogen production – and lead to more sustainable power generation and industrial and agricultural practices.



Major CO₂ conversion pathways and products.

CARBON CONVERSION PRODUCTS & PATHWAYS:

The Carbon Conversion Program is developing technologies to convert CO₂ 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 CO₂ 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 CO₂ 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 CO₂ capture, conditioning, transport and transfer to the algal medium to maximize CO₂ uptake and minimize the cost of CO₂ delivery. The Carbon Conversion Program also supports R&D of non-photosynthetic 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, waste CO₂ 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 CO₂, especially for use in the built environment. R&D in this area seeks to react CO₂ with industrial alkaline sources, including wastes to manufacture valuable products and reduce CO₂ emissions from existing production processes. The Carbon Conversion Program is pursuing R&D that increases process performance and optimizes CO₂ conversion rates, capacity and energy use efficiencies while producing a product with equivalent or superior performance properties compared to current commercial products.

REACTIVE CAPTURE & CONVERSION METHODOLOGY

In contrast to the three above carbon conversion pathways, reactive capture and conversion is a methodology of integrating the conventionally separate CO₂ 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 environmental and sustainability impacts (e.g., water, criteria pollutants, and greenhouse gases [GHGs] such as CO₂) 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 GHG emissions in terms of carbon dioxide equivalents (CO₂e) 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 CO₂ 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 employed by NETL in its assessment of various aspects of energy systems, including energy conversion facilities, CO₂ transport, storage performance and cost – with a QGESS for CO₂ 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 CO₂ 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>

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.



Contacts

Joseph Stoffa

Technology Manager

Joseph.Stoffa@netl.doe.gov

Emily Connor

DOE HQ Program Manager

Emily.Connor@hq.doe.gov