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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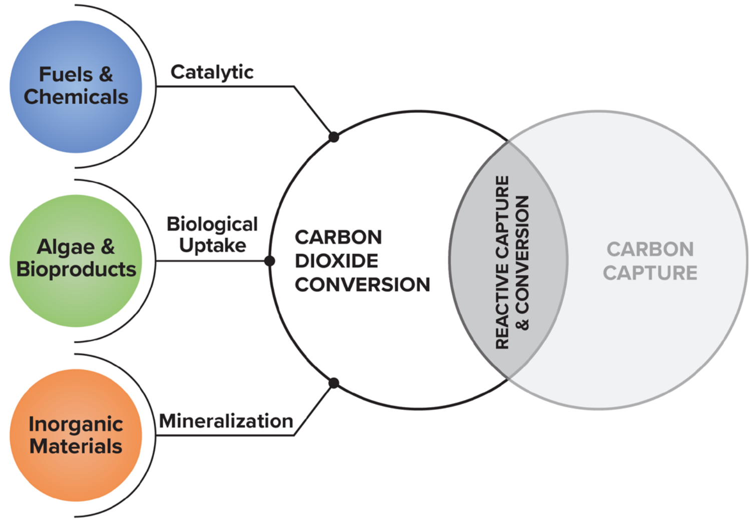
NATIONAL ENERGY TECHNOLOGY LABORATORY

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 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 a revenue stream to offset the cost associated with capturing, treating, transporting, storing and/or otherwise converting 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 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 CO_2 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. CO_2 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 CO_2 emissions reduction strategies — such as CO_2 capture and clean hydrogen production — and lead to more sustainable power generation and industrial and agricultural practices.



Major CO_2 conversion pathways and products.

CARBON CONVERSION PRODUCTS & PATHWAYS:

The Carbon Conversion Program is developing technologies to convert CO_2 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_2 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_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 to maximize CO_2 uptake and minimize the cost of CO_2 delivery. The Carbon Conversion Program also supports R&D of non-photosynthetic biological conversion pathways, leveraging bacteria or archea 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 CO_2 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 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.

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 CO_2 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 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 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 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 CO_2 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_2 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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