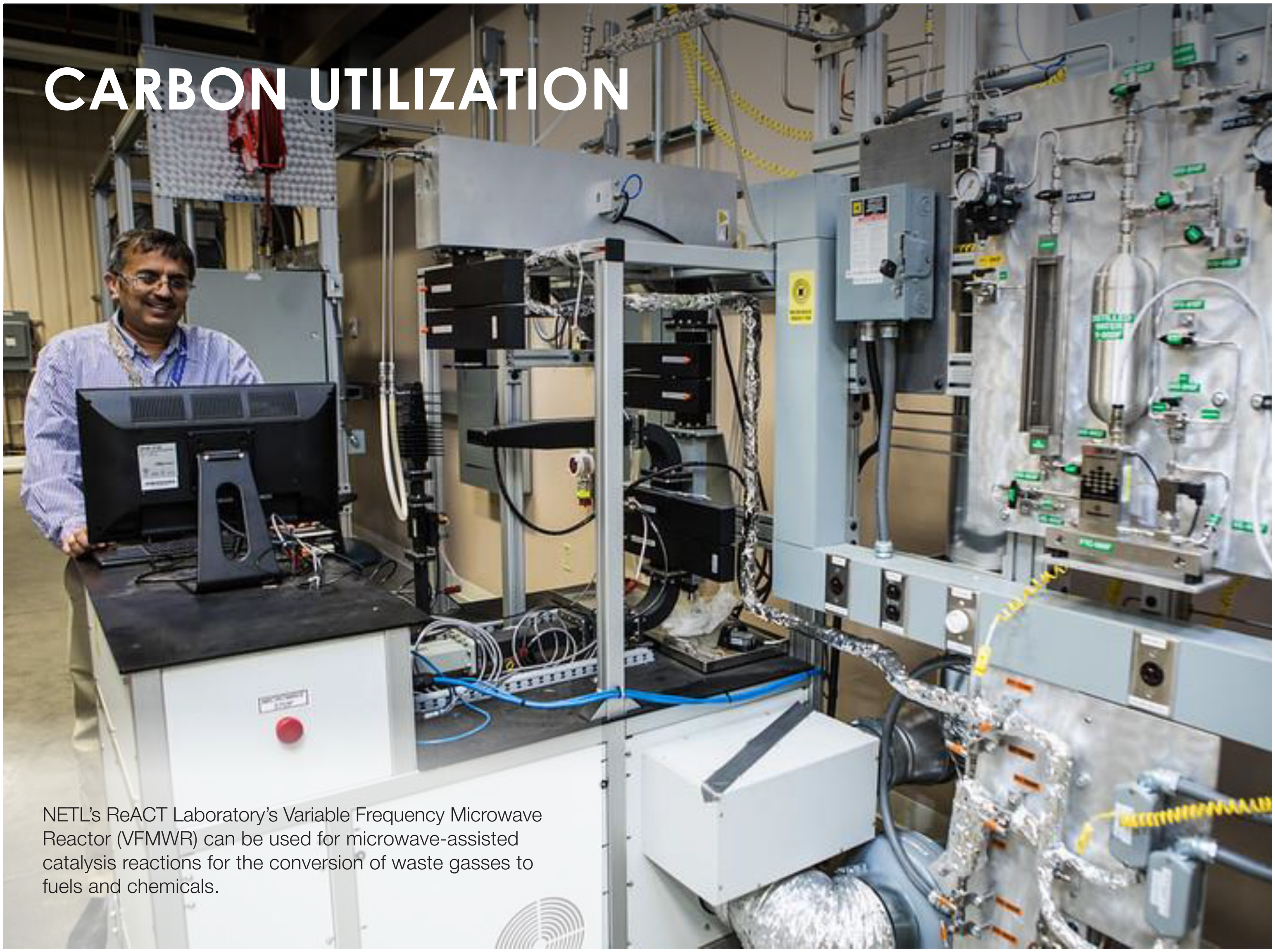
CARBON UTILIZATION



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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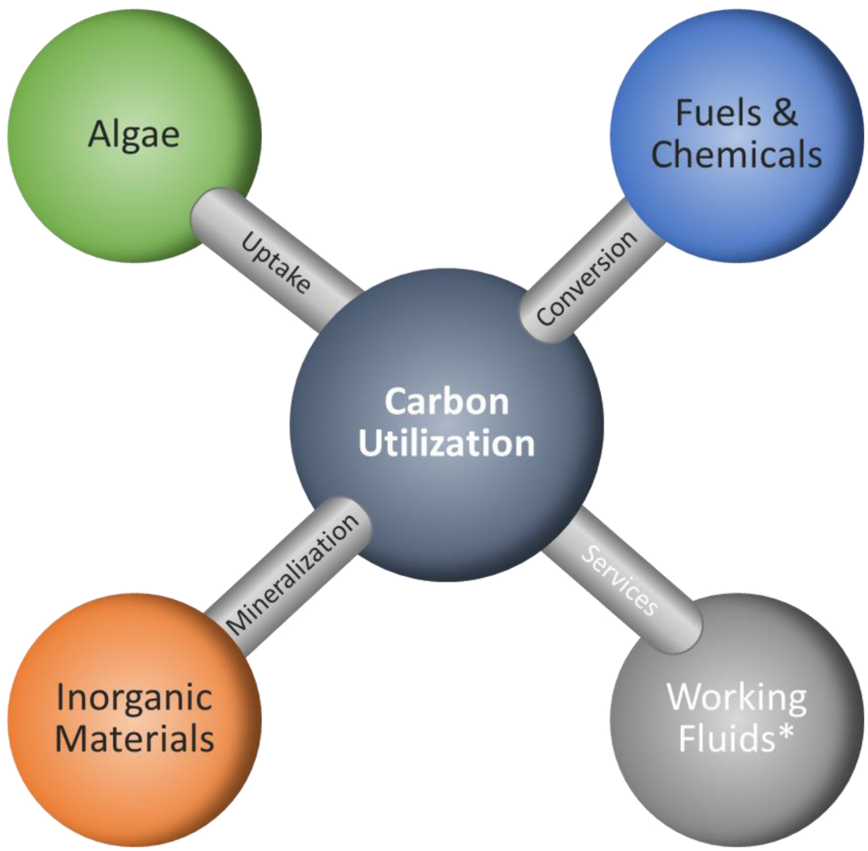
NATIONAL ENERGY TECHNOLOGY LABORATORY

PROGRAM OVERVIEW

The U.S. Department of Energy's (DOE) Carbon Utilization Program aims to develop technologies that transform carbon dioxide (CO_2) and carbon monoxide (CO) into value-added products in an efficient, economical, and environmentally responsible manner. 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 to 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 utilization systems with existing carbon-emitting sources. The Carbon Utilization Program seeks to develop technologies for both nearer-term and longer-term deployment.

PROGRAM OBJECTIVES

The Carbon Utilization Program seeks to identify and develop new and improved materials, equipment, and processes that produce value-added goods and services using CO_2 or CO as a feedstock. Pathways to generate products are diverse and can include carbon uptake to grow algae, chemical and biological conversion, and mineralization. Products produced can include fuels, chemicals, agricultural products, animal feed, building materials, and other goods and services. Carbon utilization is generally applicable to any flue gas stream generated by the combustion of carbon-based fuels, such as coal, natural gas, and biomass, as well as 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 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 utilization products and pathways are represented in the above model. *Working Fluids such as enhanced oil recovery (EOR) are a focus of other NETL programs.

CARBON UTILIZATION PRODUCTS & PATHWAYS:

The Carbon Utilization Program is focused on carbon uptake using algae, conversion into fuels and chemicals, and mineralization into inorganic materials.

CARBON UPTAKE USING ALGAE

The biomass produced in algal systems can be processed and converted to fuels, chemicals, fish and animal feeds, human dietary supplements, soil amendments, and other specialty and fine products. The Carbon Utilization 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.

CONVERSION INTO FUELS AND CHEMICALS

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 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. 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 coal and industrial alkaline wastes to manufacture valuable products and reduce CO_2 emissions from existing production processes. The Carbon Utilization 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 Utilization 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 utilization 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 Utilization Life Cycle Analysis Guidance 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 utilization under development.

TECHNO-ECONOMIC ANALYSIS (TEA):

Techno-economic analysis (TEA) assesses the economic impacts associated with the technology being developed. The Carbon Utilization Program is utilizing TEA in conjunction with LCA to identify and evaluate emerging CO_2 utilization strategies, establish minimum performance benchmarks, and evaluate the techno-economic feasibility, carbon life cycle, and potential market penetration of emerging technologies. NETL efforts include conducting bench-scale research that provides data for techno-economic feasibility studies and potential market penetration of developing technologies.

Since CO_2 is thermodynamically stable, any efforts to convert it to another molecule will be energy-intensive. The Carbon Utilization Program uses TEA to quantify the cost implications of overcoming this thermodynamic limitation and offer insight into how researchers could focus their efforts to reduce this cost through R&D. The key to this effort is the development of rigorous, transparent analytical approaches that can be used by internal and external stakeholders to compare the feasibility and merit of potential CO_2 utilization concepts.

OPPORTUNITIES

NETL's Carbon Utilization Program is working with universities, national laboratories, industries, and regional partners to advance technologies that meet the objectives of the program. The Carbon Uilization Program is actively funding carbon utilization projects and continues to seek further collaborations and partnerships. Additional information about the program and funding opportunities can be found on NETL's Carbon Utilization Program website: https://netl.doe.gov/coal/carbon-utilization

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