GEOMICROBIOLOGY RESEARCH

R&D 203, July 2025

NATIONAL ENERGY TECHNOLOGY LABORATORY

INTRODUCTION

NETL continues our research in geomicrobiology to characterize microbial communities and relevant microbial processes in energy systems, energy storage systems and energy waste systems.

Microbial processes affect reservoir properties such as porosity, permeability, pH and interstitial fluid chemistry. Characterization of dominant microbial communities and respective microbial processes will help researchers optimize existing infrastructure, carbon and hydrogen storage, critical material recovery and waste management. Microbial processes also offer a likely option for alternative energy or novel waste management technology with less energy costs and reduced environmental impacts.

COMPETENCY

Researchers rely on metagenomics — the study of genetic material obtained from environmental samples — to further understand how geomicrobiology impacts energy environments. However, critical metagenomic characterization of various environments related to energy and energy waste are not yet available. To determine the role microbiology will play in advancing energy technology, relevant samples must first undergo thorough microbial characterization.

Access to environmental samples related to energy production such as hydrogen storage reservoirs, oil and gas fields, carbon storage reservoirs, fluid impoundments, coalbed reservoirs, and waste streams is key to successful metagenomic analysis. Traditionally, these types of samples have been difficult to obtain. However, because NETL is the only U.S. DOE national laboratory devoted to fossil energy and carbon management research, it has forged connections within the energy industry that can facilitate acquisition of relevant samples.

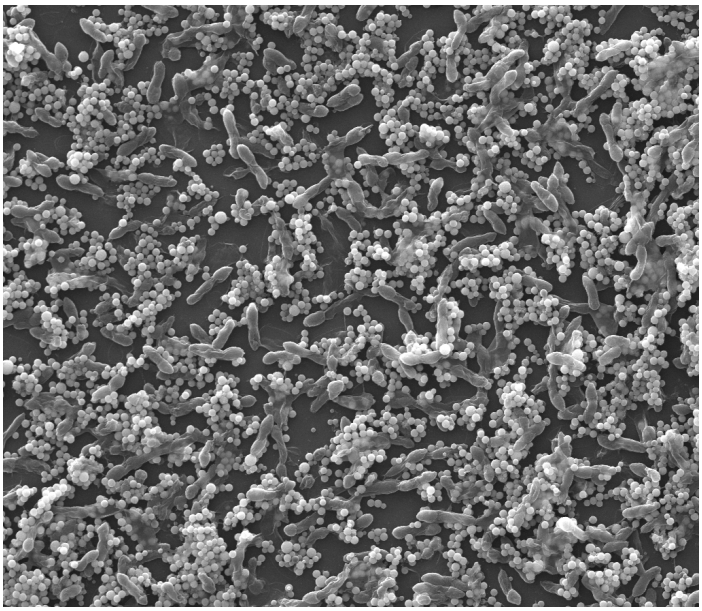
NETL key capabilities also ensure success in the characterization of microbial communities and their biological processes. These capabilities include:

- Anaerobic reactors and high-pressure, high-temperature reactor vessels to simulate subsurface conditions.
- Capabilities to cultivate microbial communities in strict anaerobic environments.
- 16S rRNA gene sequencing methods to investigate abundant microorganisms of various energy environments.
- Long- and short-chain sequencing capabilities to determine the functional potential of microbial communities in energy environments.
- Fluid Chemistry Laboratory and Material Characterization Laboratory to measure inorganic and organic constituents in formation fluids and solids.
- Bioinformatic capabilities that allow processing and detailed analysis of sequencing data.
- Quantative polymerase chain reaction (qPCR) with droplet digital polymerase chain reaction (ddPCR) to evaluate approximate microbial population in energy environments.

RESEARCH PROJECTS

NETL has amassed a wealth of knowledge and operates with unique expertise in various energy processes and geomicrobiology. By combining and refining these tools, the Laboratory can fill knowledge gaps in the complex biogeochemical systems common in environments related to energy, energy storage and energy waste. A better understanding of geomicrobiology will facilitate new technologies in a variety of energy fields. Ongoing research includes characterizing the microbial community in environments, such as:

- Future hydrogen storage reservoirs.
- Biological CO_2 utilization systems.
- Critical mineral sources.
- Power plant waste effluent.
- Future carbon storage reservoirs and CO_2 leakage analogues.
- Produced water and impoundment fluids in unconventional resource environments.
- Acid mine drainage (AMD) systems.



NETL has imaged microorganisms from coal fired power plant effluent capable of producing elemental nanospheres.

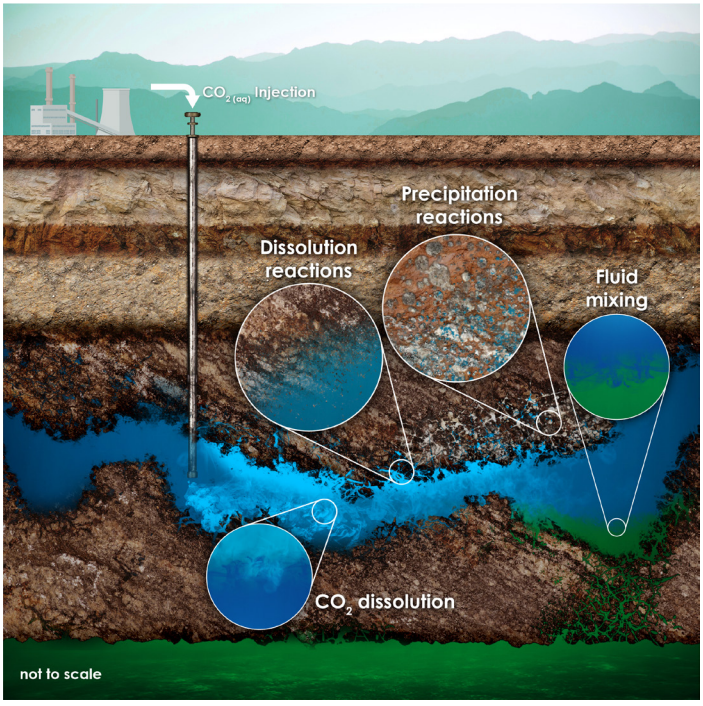
ACCOMPLISHMENTS

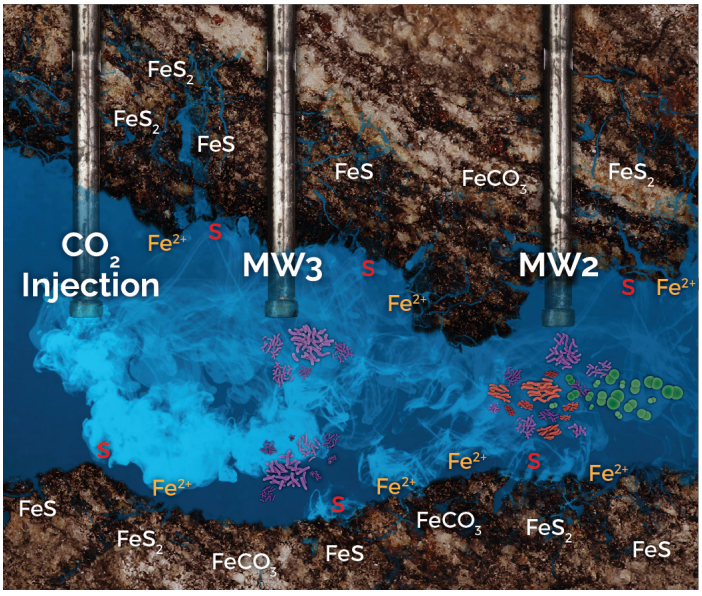
NETL is leveraging connections within the energy industry with its competency in metagenomics and geochemistry to create an unparalleled biogeochemical characterization of energy environments. The following represent recent accomplishments:

- 16S rRNA sequencing, metagenomic sequencing and quantitative PCR were used on carbon storage environments to demonstrate selection of microorganisms that are capable of utilizing CO_2.
- 16S rRNA sequencing on samples from over 300 unconventional production wells demonstrated microbial DNA signals fluid migration and reservoir reaction, increasing risk of microbially driven corrosion events.
- Metagenomes from various subsurface energy environments have been evaluated for key carbon degradation pathways, carbon fixation pathways and nutrient cycling pathways.
- Draft genomes with over 99% completion have been reconstructed from deep subsurface energy environments. These draft genomes allow a detailed look at key metabolic pathways of abundant subsurface microorganisms.
- Pan-genomic and pan-metagenomic analysis demonstrate core functional pathways and unique functional pathways among various energy environments. Results suggest functional similarity among communities within the same basin/reservoir compared to geographically separated systems with analogous conditions.
- Enrichment of coalbed microbial communities has been demonstrated to biocatalyze upgrading CO_2 waste products and AMD waste solids into higher-value material for potential market resale. This may provide a revenue stream for CO_2 capture and waste management.

Geomicrobiology research at NETL is ongoing. The Laboratory anticipates further evolution of the characterization of microbial communities and biological processes, resulting in more effective use of existing infrastructure, safer storage of CO_2 and more efficient management of waste.

This ultimately helps ensure the energy security of our nation for future generations. Learn more about NETL's Geomicrobiology team at edx.netl.doe.gov/geomicrobiology





NETL has investigated the complex fluid mixing patterns, reactive chemistry and altered microbiology in carbon storage environments for over 10` years.

NETL is a U.S. Department of Energy (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.

Contacts

Djuna Gulliver
Principal Investigator
Research Engineer
Djuna.Gulliver@netl.doe.gov

Brian Strazisar
Supervisor, Geochemistry Team
Geological & Environmental Systems Directorate
Brian.Strazisar@netl.doe.gov

Research Partners

Leidos Research Support Team (LRST) | Carnegie Mellon University | Oak Ridge Institute for Science and Education (ORISE) | University of Pittsburgh | West Virginia University