NATIONAL ENERGY TECHNOLOGY LABORATORY

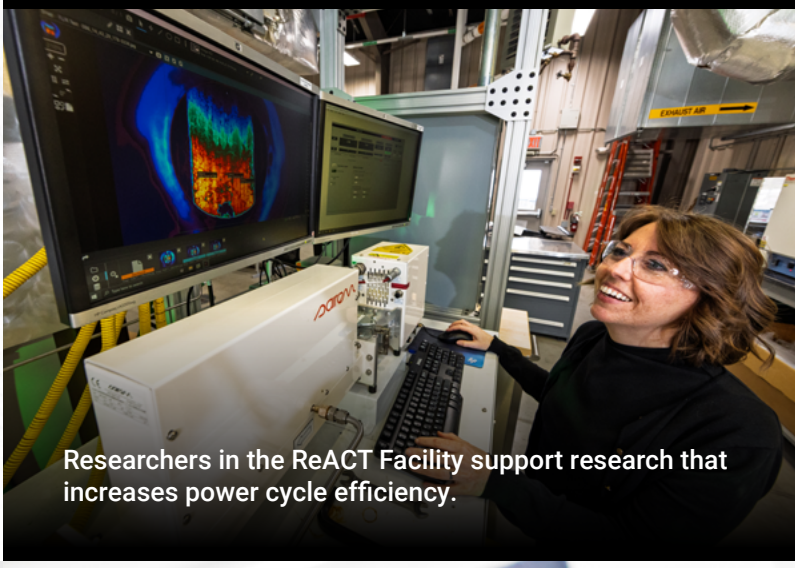
Carbon Engineering

NETL enables carbon engineering technologies to transform how fossil resources are used to support U.S. energy security, manufacturing competitiveness and supply chain resilience. Through innovations in materials science, chemistry and process engineering, NETL is creating new, high-value materials, fuels and chemicals from the nation's abundant coal, natural gas and carbon waste resources. These efforts enable the production of advanced products that strengthen domestic industries, enhance infrastructure and contribute to a stronger energy economy.

R&D Applications

- High-Value Carbon Products
- Critical Minerals and Rare Earth Element Recovery
- Coal-Based Additive Manufacturing
- Coal-Derived Construction and Infrastructure Materials
- Remediation and Waste Valorization
- Hydrogen and Chemicals via Coal Gasification
- Coal and Coal Waste Processing
- Microwave Chemistry for Ammonia Synthesis
- Carbon Dioxide Conversion

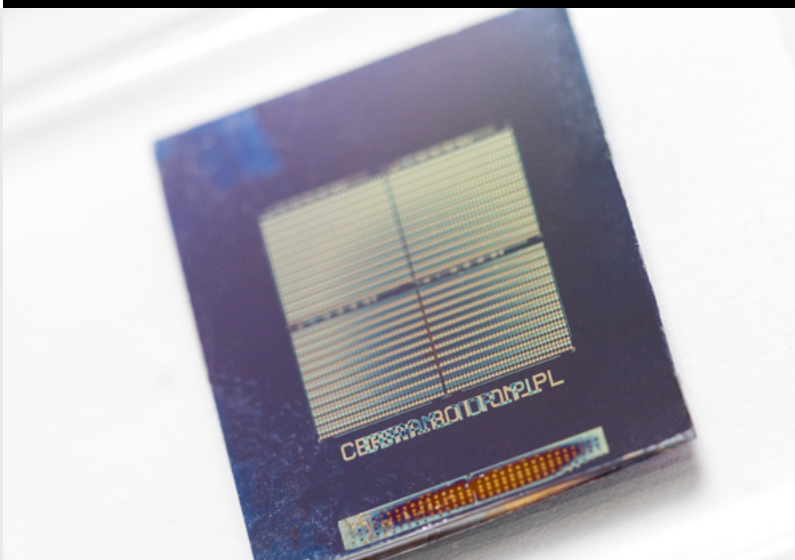
The Graphite Manufacturing Facility is creating valuable products from waste.



Researchers in the ReACT Facility support research that increases power cycle efficiency.

Computer Microelectronics from Coal

NETL is creating advanced microelectronic devices directly from coal, including memristors (memory devices) and field-effect transistors (current control devices). These coal-derived components are more energy-efficient and faster-performing than devices made with traditional semiconductor materials. NETL's ongoing research is expected to improve their performance by an additional 10% to 40% over the next several years.



Research Highlights

Fuel-Flexible Ammonia Synthesis Using Microwave Technology

NETL has developed an award-winning microwave-driven ammonia synthesis process that is more energy-efficient and fuel-flexible than traditional methods. By using microwave energy to selectively heat catalysts, this approach significantly reduces energy input and enables faster reaction rates. The process can utilize a variety of feedstocks—including coal, natural gas and diesel—and produces ammonia that can serve as fertilizer, a hydrogen carrier, liquid fuel or refrigerant. This breakthrough offers a lower-cost, scalable pathway for domestic ammonia production to support agriculture, transportation and energy applications.

High-Quality Graphite from Coal

Researchers have developed a technology that converts every rank and type of U.S. coal into high-quality graphite for use in steel and aluminum production, batteries, rocket nozzles and other advanced applications. This process reduces processing temperature, time and energy consumption by more than 40% compared to conventional industrial methods. In the near term, NETL expects to improve efficiency and reduce costs by an additional 30% to 60%, while advancing new methods for coal-to-graphite conversion.

Supercapacitor and Hybrid Battery-Supercapacitor Energy Storage Devices from Coal

Through the development of a coal-derived carbon electrode material, NETL research has improved the performance of supercapacitors and hybrid battery-supercapacitors by 30% to 80%. This technology converts domestic coal into a high-performance material optimized for energy storage applications. These devices are essential for backup and emergency power systems in hospitals, data centers, metropolitan transit systems and heavy equipment operations.

NETL Improves the Strength and Durability of Cement and Concrete with Coal-Derived Additives

NETL has developed a technology for making carbon additives from coal that can be utilized in cement and concrete formulations to improve the strength of these materials by 15% to 35%. The coal additives also cause a densification of the cement and concrete, which makes these materials more resistant to weather-induced degradation. NETL's research in this area aims to increase the amount of coal utilized in these cement and concrete formulations to further improve strength and durability.

Publications and Patents

- An, F., Wang, C., Pham, V. H., Borisevich, A., Qian, J., Yin, K., ... & Cao, Q. (2023). Ultrathin quasi-2D amorphous carbon dielectric prepared from solution precursor for nanoelectronics. Communications Engineering, 2, 93. https://doi.org/10.1038/s44172-023-00141-9.
- Fan, S. H. I., Gray, M. L., Matranga, C., & Ji, T. (2022). Production of Graphene-Structured Products from Coal Using Thermal Molten Salt Process. U.S. Patent No. 11,535,518. Washington, DC: U.S. Patent and Trademark Office.
- Gao, Y., Pham, V., Weidman, J., Kim, K., Spaulding, R., Wang, C., Matranga, C. (2024). High-performance cementitious composites containing nanostructured carbon additives made from charred coal fines. Scientific Reports, 14, 8912. https://doi.org/10.1038/s41598-024-59046-y.
- Pham, V., Wang, C. Gao, Y., Weidman, J., Kim, K., Matranga, C. (2024). Synthesis of Microscopic 3D Graphene for High-Performance Supercapacitors with Ultra-High Areal Capacitance, Small Methods, 8, 2301426. https://doi.org/10.1002/smtd.202301426.
- Wildfire, C., Abdelsayed, V., Shekhawat, D., Dagle, R. A., Davidson, S. D., & Hu, J. (2021). Microwave-assisted ammonia synthesis over Ru/MgO catalysts at ambient pressure. Catalysis Today, 365, 103-110. https://doi.org/10.1016/j.cattod.2020.06.013.

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 in Albany, Oregon; Morgantown, West Virginia; and Pittsburgh, Pennsylvania, NETL creates advanced energy technologies that support DOE's mission while fostering collaborations that will lead to a resilient and abundant energy future for the nation.