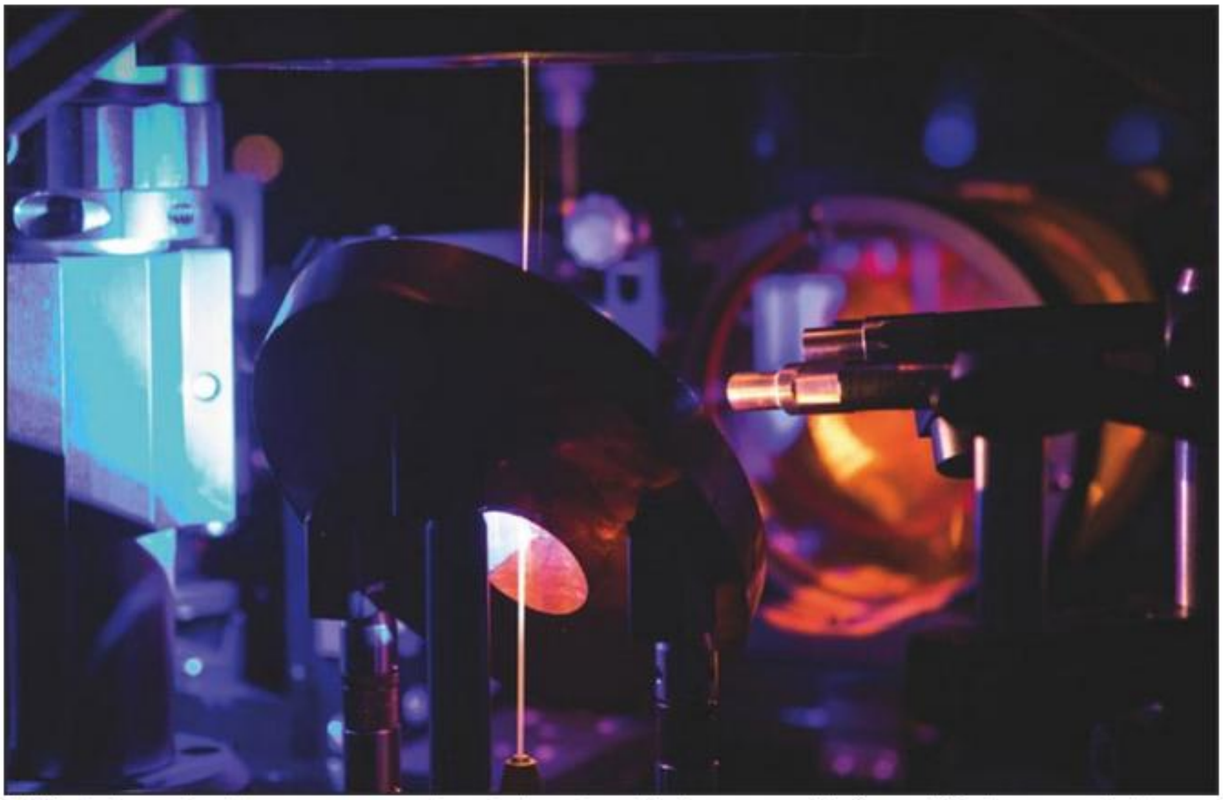
# Facility Focus: National Energy Technology Laboratory

The National Energy Technology Laboratory (NETL) is a U.S. Department of Energy (DOE) national laboratory — with sites in Anchorage, AK; Albany, OR; Morgantown, WV; and Pittsburgh, PA — that produces technological solutions to America's energy challenges. For more than 100 years, NETL — and its predecessor facilities — has advanced technology to provide clean, reliable, and affordable energy to the American people.



NETL tests and matures sensor and control systems that are operable in coal-fired power plants, that are capable of real-time measurements, and that improve overall plant efficiencies.

In 1999, NETL was designated as a DOE national laboratory with a mission to discover, integrate, and mature technology solutions to enhance the nation's energy foundation and protect the environment. As the only one of the DOE's 17 national labs that is both government-owned and -operated, NETL accelerates the development of technology solutions through strategic partnerships with academia, industry, and other research organizations.

# CORE COMPETENCIES

***Computational Science & Engineering (CES).*** NETL's CSE Directorate develops science-based simulation models, mathematical methods and algorithms, and software tools required to address the technical barriers to the development of next-generation technologies. CSE works with other NETL directorates to generate information and understanding beyond the reach of experiments alone. Through the integration of experimental information and computational sciences, scientists and engineers can simulate variations more efficiently while saving time, money, and materials.

The CSE Directorate is organized into three research areas: 1) Computational Materials models materials at the atomic, molecular, and microstructural scales, enabling understanding of materials behavior and providing insight into subsequent materials development opportunities. 2) Computational Device Engineering develops multiphase computational fluid dynamics models for predicting the performance of fossil energy devices such as combustion reactors, gasifiers, emissions capture, and carbon dioxide capture units. 3) Data Analytics develops and uses data science methods to gain scientific insight from complex, high-dimensional, high-volume datasets from experiments and simulations conducted in support of energy technology development and is beginning to use machine learning to advance energy technology development.

A NETL group produced a software portfolio of physics-based modeling codes (MFiX Suite) to guide the design, operation, and troubleshooting of multiphase flow devices, with an emphasis on fossil fuel technologies. NETL, Lawrence Berkley National Laboratory, and the University of Colorado Boulder are conducting a multi-year effort to enable NETL's open-source MFiX code to run on exascale computers.

Joule 2.0 is a 5.62 PFLOP (one quadrillion floating-point operations per second) supercomputer that enables the numerical simulation of complex physical phenomena and provides computational throughput to run high-fidelity modeling tools at various scales ranging from molecules to devices to entire power plants and natural fuel reservoirs.

Computational design combines theory, computational modeling, advanced optimization, experiments, and industrial input to simulate complex advanced energy processes. This research develops accurate and timely computational models of complex reacting flows and components relevant to advanced power systems.

***Energy Conversion Engineering.*** NETL has a long history of developing energy conversion systems for the production of power, fuels, and chemicals from coal, natural gas, and (more recently) integrated fossil fuel and renewable generation. Flexible power systems over a range of sizes will be needed to meet future energy demands as interests such as district heating and cooling, smaller grids, energy storage, and further integration with renewables emerge. NETL's new technologies enable low-carbon power production while optimizing environmental performance, water use, efficiency, and waste minimization.

***Geological and Environmental Systems (GES).*** GES is a focus area of NETL's Research & Innovation Center (RIC) that tackles the challenge of clean energy production from fossil energy sources by focusing on the behavior of natural systems at both the Earth's surface and subsurface, including prediction, control, and monitoring of fluid flow in porous and fractured media. Efforts include the long-term storage of $CO_2$, the environmentally sound production of the nation's conventional and unconventional fossil fuel resources, and the science needed to bring methane hydrates into the domestic natural gas resource base. SEQURE™, a tracer technology, uses non-toxic, chemically inert perfluorocarbon tracers to provide a verifiable way to fingerprint stored $CO_2$, thereby giving an early indicator if $CO_2$ is released from a storage reservoir.

***Materials Engineering and Manufacturing.*** NETL designs, develops, and deploys advanced materials for use in energy applications and extreme service environments. NETL utilizes a suite of computational and experimental methods for translating new material science concepts into practical technologies. This competency is responsible for the development and implementation of a number of commercial technologies:

- A corrosion-resistant refractory brick used in nearly all slagging gasifiers worldwide;
- A computational method to optimize heat-treatments of large-scale casting from complex heat-resistant alloys — an enabling technology for manufacturing Advanced Ultra-Super-Critical steam turbines;
- The BIAS class of regenerable, cross-linked, amine-silica sorbents that has been applied to removing pollutants ($CO_2$) for flue gas stream, removing contaminants (such as lead) from water, and extracting rare earth elements (REEs) from power plant and coal processing by-products;
- Alloy-based metal catalysts and electrochemical technologies that convert power plant waste streams such as $CO_2$ into valuable fuels and chemicals;
- Cathode infiltration technologies that increase the service lifetime of commercially available solid oxide fuel cell systems;
- A radiopaque alloy for medical coronary stents; and
- A multifunctional sorbent technology for contaminant removal in HVAC systems.

Functional materials development focuses on the design, synthesis, physical characterization, and performance testing of the nanomaterials, polymers, porous sorbents, ionic liquids, and electro-ceramics required for the next generation of carbon capture, gas separation, chemical looping, solid oxide fuel cell, chemical sensing, fuel processing, and carbon materials technologies. NETL also has capabilities for designing, developing, and prototyping magnetic alloys that improve the performance of power converters and the electrical grid.

Methane leak detection technology combines remote sensing and artificial intelligence capabilities in a system that can operate from an aerial platform — an approach that can more effectively help alleviate methane emissions from multiple operations in the natural gas industry.

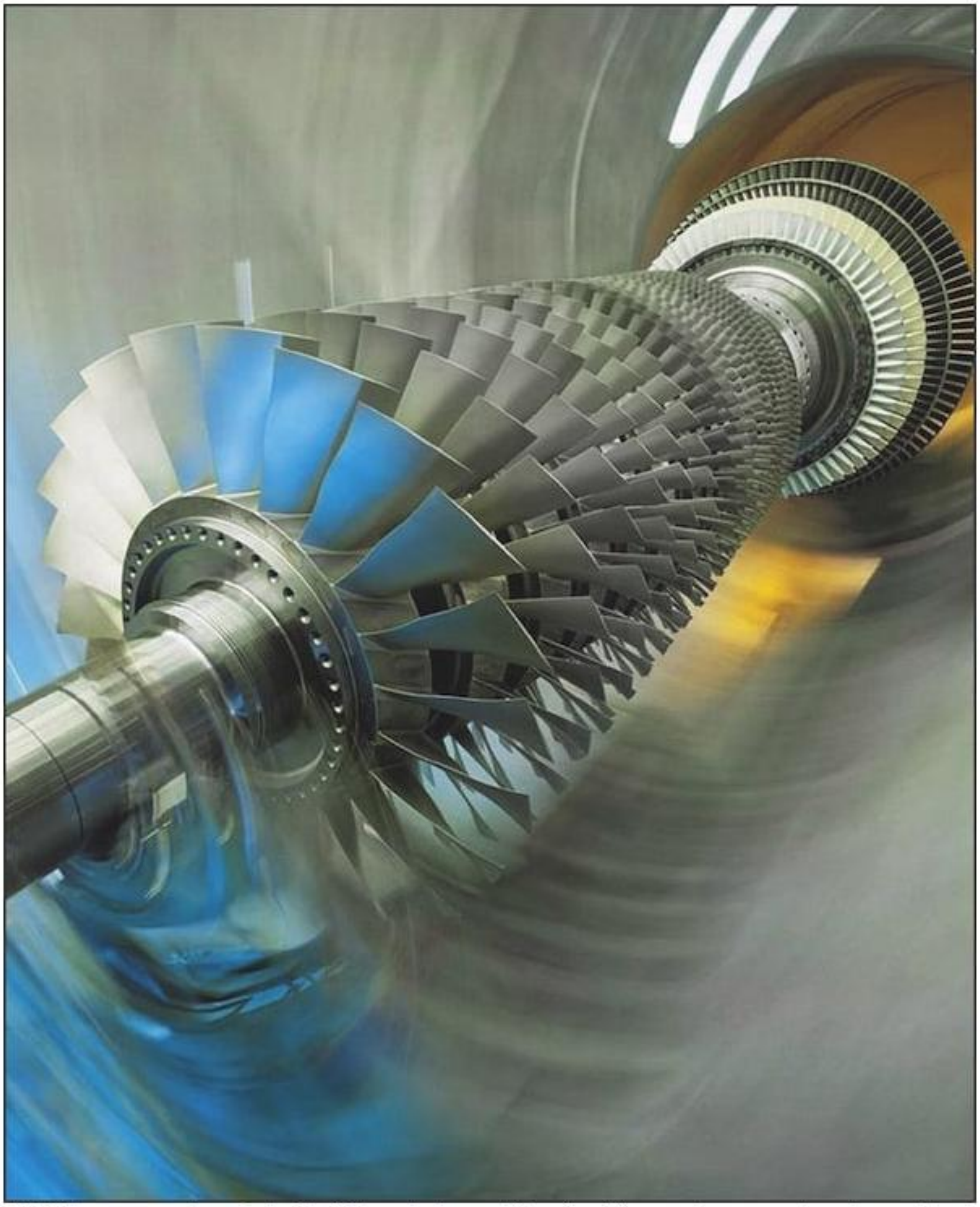
Structural materials are being developed for use in extreme environments associated with combustion, turbine, gasification, drilling, and other applications. Research focuses on developing cost-effective materials that can withstand a combination of mechanical stress, and corrosive and erosive environments for upwards of 100,000 hours of service life. This is accomplished through improving existing alloys, designing new materials, and reducing manufacturing cost. Research also investigates corrosion, wear, hot-corrosion, oxidation, creep, and fatigue resistance.

***Systems Engineering and Analysis.*** The discovery, design, and operation of energy systems benefit from systematic decision-making techniques for the goals of maximizing profits, minimizing costs, addressing market and policy drivers, and meeting environmental and technical constraints. To accomplish this, NETL researchers develop and use advanced models coupled with optimization and uncertainty quantification to support decision-making. Integration of computational and applied research provides insights to new technology, identifies new energy concepts, and analyzes energy system interaction at plant, regional, national, and global scales.

## RESEARCH AREAS

***Coal Beneficiation***. The U.S. coal value chain can be extended by manufacturing carbon products directly from coal instead of using petrochemical or biomass feedstocks or by expanding markets for existing coal products. Coal beneficiation at NETL focuses on both enhancing the value of coal as a feedstock and developing new high-value products derived from coal. Coal can be used to manufacture high-value carbon products including carbon fiber, carbon additives for cements and structural composites, battery and electrode materials, carbon nanomaterials and composites, plastic composites, critical materials, coking process byproducts, and 3D printing materials.

***High-Performance Materials.*** The high-performance materials program drives to characterize, produce, and certify cost-effective alloys and high-performance materials suitable for extreme environments found in fossil-based power-generation systems. NETL supports and catalyzes a domestic materials supply chain that prepares materials for Advanced Ultra-Supercritical Steam Cycles (AUSC) and spinoff applications. The Crosscutting Materials program works to accelerate the development of improved steels, superalloys, and other advanced alloys to address challenges of both the existing fleet and future power systems. Materials of interest include those that enable components and equipment to perform in the high-temperature, high-pressure, corrosive environments of an advanced energy system with specific emphasis on durability, availability, and cost both within and across the areas of computational materials design, advanced structural materials, functional materials for process performance, and advanced manufacturing.



A NETL-managed project with Colorado-based Sporian Microsystems produced smart temperature sensors that can operate up to 1800 °C as well as pressure sensors that operate at temperatures up to 1600 °C for improved performance in monitoring gas turbines, combustion systems, and more.

***Modeling, Simulation, and Analysis.*** Simulation-based engineering focuses on developing and applying advanced computational tools at multiple scales: atomistic, device, process, grid, and market scales to accelerate development and deployment of fossil fuel technologies. Research provides the basis for the simulation of engineered devices and systems to better predict and optimize the performance of fossil fuel power-generating systems.

Computational design methods and concepts are required to significantly improve performance, reduce the costs of existing fossil energy power systems, and to enable the development of new system and capabilities such as advanced ultra-supercritical combustion and hydrogen turbines. This effort combines theory, computational modeling, advanced optimization, experiments, and industrial input to simulate complex advanced energy processes, resulting in virtual prototyping. This research develops accurate and timely computational models of complex reacting flows and components relevant to advanced power systems. Model development and refinement is achieved through in-house research and partnerships.

***Sensors and Controls.*** Sensors and controls research improves fossil energy power generation with sensors, distributed intelligent control systems, and increased security. Advanced sensors and controls provide insights into optimizing plant performance and increasing plant reliability and availability. NETL tests and matures sensor and control systems that are operable in coal-fired power plants, that are capable of real-time measurements, and that improve overall plant efficiencies. This research area explores advances within, and the integration of technologies across harsh-environment sensors, robotic inspection, controls, and cyber-physical systems.

Sensor research investigates a range of advanced manufacturing techniques to determine the feasibility of embedding sensors with condition-based monitoring algorithms and the capability of operating in extreme environments into turbine blades, piping, and tubing to predict component failure, anticipate maintenance needs, and reduce plant downtime. Sensors and controls lead to improved infrastructure while reducing operations and maintenance costs. Research is helping determine optimal sensor placement, allowing for characteristic readings such as temperature, pressure, fluid composition, and the state of materials. The information informs operators of plant health and performance in real time.

Robotic technology is used in the power sector to improve offline inspections. Robots, ranging from drones to crawlers, have transformed the inspection and repair of plant equipment. These advances help prevent unplanned power outages, enabling lower costs and more frequent inspections, and improving performance and reliability for a renewed energy infrastructure.

Controls research advances the accuracy of physics-based and data analytics-driven distributed intelligence systems for process control and automation. Cyber-physical approaches are used at NETL to explore interactions of power-generation subsystems as well as to improve control of plant components.

***Fuel Cells.*** Solid oxide fuel cells (SOFC) are electrochemical devices that convert chemical energy of a fuel and oxidant directly into electrical energy. Since SOFCs produce electricity through an electrochemical reaction and not through a combustion process, they are much more efficient and environmentally benign than conventional electric power generation processes. Their inherent characteristics make them uniquely suitable to address the environmental, climate change, and water concerns associated with fossil fuel based electric power generation.

Research is focused on the cell-related technologies critical to commercializing SOFC technology. The components of the SOFC — the anode, cathode, and electrolyte — are the primary research emphasis of this technology. Additional research projects include evaluation of contaminants, advanced materials, materials characterization, advanced manufacturing, and failure analysis. Other projects focus on interconnects and seals, identify and mitigate stack-related degradation, develop computational tools and models, and conduct laboratory- and bench-scale testing.

***Water Management.*** This focus addresses water needs and challenges through models and analyses that are essential in informing and deciding priority technology R&D initiatives. Research covers increasing water efficiency and reuse, treatment of alternative sources of water, and energy-water analysis.


Using an array of high-tech microscopy and x-ray diffraction capabilities, NETL researchers are discovering, developing, and commercializing technologies that allow the rearrangement of carbon dioxide ($CO_2$) molecules — processes that can help protect the environment by reducing $CO_2$ emissions.

## TECHNOLOGIES

NETL's Raman Gas Analyzer provides real-time control of turbine machinery based on fuel composition. A cooperative research and development agreement (CRADA) with Solar Turbines provided testing to help advance this technology toward commercialization. Its eventual implementation will enable more flexible operation of gas-fired power plants, creating clean, affordable power from domestic fuel sources.

Working in collaboration with partners at Carnegie Mellon University, NETL researchers have developed ionic liquids and polymers that provide a more efficient and economical process for $CO_2$ capture. An ionic liquid solvent for aluminum electroplating process electrodeposits aluminum using standard equipment available in most electroplating shops. The process replaces coatings based on heavy metals, such as cadmium and chromium, which are expensive and toxic.

Jointly developed by NETL and Boston Scientific Corporation, a platinum/chromium alloy is the first austenitic stainless steel formulation to be produced for the coronary stent industry. With a significant concentration of platinum with high radiopacity, the alloy enables high visibility with x-ray scanning. Better visibility means greater ease and precision in placement of the stent inside the patient's blood vessel. In addition, the greater yield strength of the alloy allowed the stent's designers to make a thinner, more flexible stent that is more easily threaded through the winding path of the artery without doing damage along the way.

NETL developed a cost-effective method to make high-quality graphene from domestic coal feedstocks. The method makes graphene directly from domestic coal with the co-production of rare earth elements and distilled crude oil liquid.

A system and method were developed for detecting corrosion in natural gas pipelines using an optical platform or a wireless platform. A fiber-optic sensor network is capable of monitoring internal corrosion in the pipelines by realizing precise, localized, multi-parameter measurements of condensed water properties. Wireless sensors can also be used and provide low-cost, distributed point measurements. The wireless sensors can be placed at an arbitrary number of locations to best acquire information about the system being monitored.

Sensors for use in early detection and quantification of corrosion degradation eliminate concerns over use in environments with intense pressures, temperatures, and corrosive potential. The new sensing methods offer safety advantages and compatibility with scalable semiconductor-based manufacturing techniques. Additionally, the sensor platforms are capable of wireless and distributed early corrosion detection.

Optical sensors integrated with advanced sensing materials were developed for high-temperature embedded gas sensing applications. Optical sensor materials address process monitoring in harsh environments and at temperatures approaching 1,000 °C.

## TECHNOLOGY TRANSFER

Technology transfer at NETL connects entrepreneurs, companies, universities, and others to move lab-developed technologies to commercialization. A number of current technologies are available for licensing.

*For inquiries regarding licensing of available technologies or other tech transfer questions, contact **techtransfer@netl.doe.gov**.*