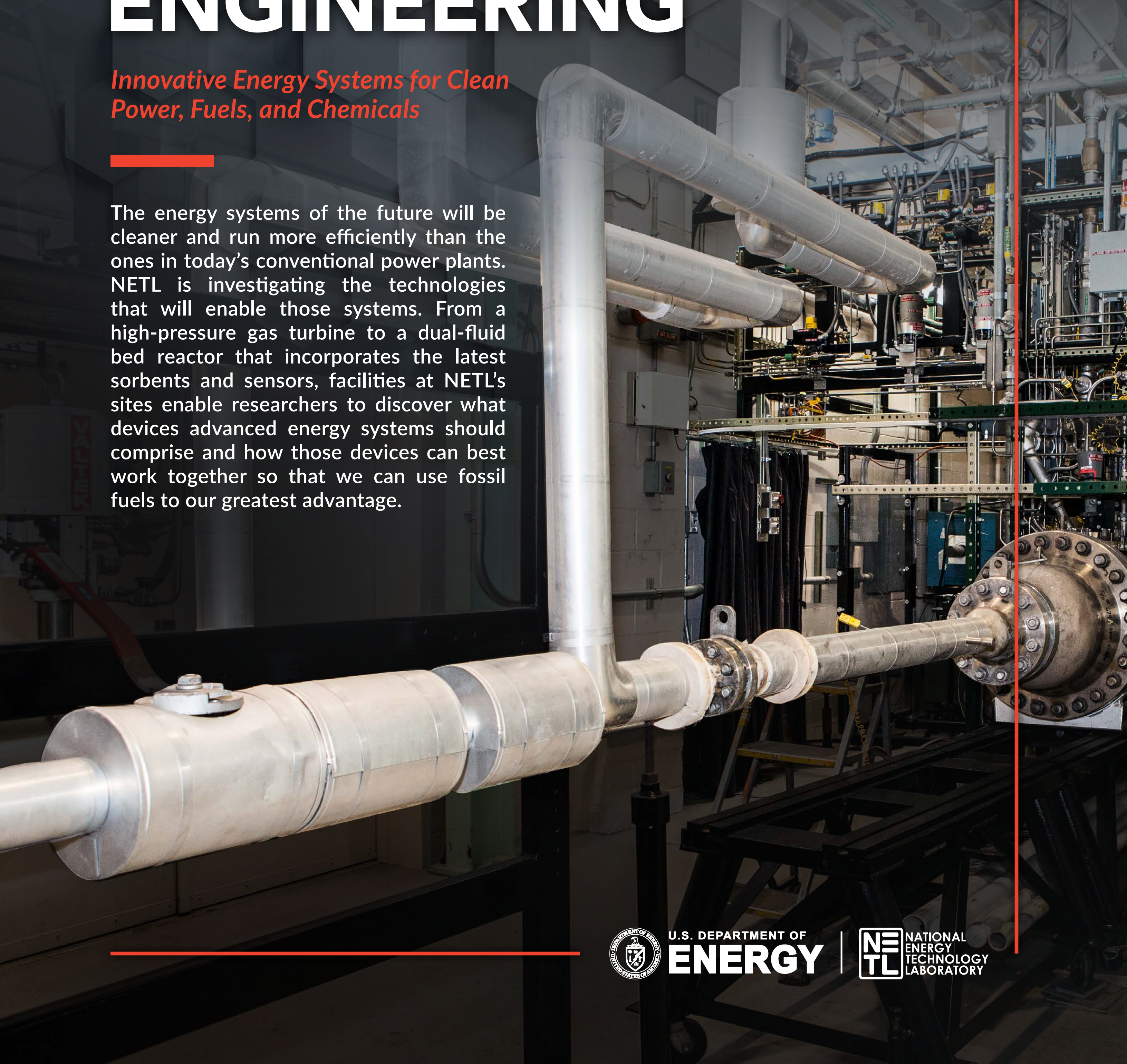
ENERGY CONVERSION ENGINEERING

Innovative Energy Systems for Clean Power, Fuels, and Chemicals

The energy systems of the future will be cleaner and run more efficiently than the ones in today's conventional power plants. NETL is investigating the technologies that will enable those systems. From a high-pressure gas turbine to a dual-fluid bed reactor that incorporates the latest sorbents and sensors, facilities at NETL's sites enable researchers to discover what devices advanced energy systems should comprise and how those devices can best work together so that we can use fossil fuels to our greatest advantage.



U.S. DEPARTMENT OF ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

1

HIGH PRESSURE, HIGH TEMPERATURE COMBUSTION

INVESTIGATING HIGH EFFICIENCY COMBUSTION TECHNOLOGIES

This unique resource within NETL provides the experimental capabilities and advanced diagnostics necessary to evaluate high-efficiency technologies for gas turbines and other advanced power cycles operating at high pressure and temperature conditions. Efficiency improvements through improved turbine cooling strategies and pressure gain combustion as well as novel supercritical CO_2 power cycles are being investigated in several unique high-pressure, high-temperature test rigs. Advanced optical diagnostic techniques are used to gather data at gas turbine relevant conditions to elucidate the underlying physics, develop empirical correlations and provide data for validating models. Researchers also use computational fluid dynamics simulations to gain insights into the complex thermal and chemical processes in these systems to help accelerate development and transition these technologies to the commercial sector.

2

KINETICS & CATALYSIS LAB

IN SITU KINETICS & MECHANISM DETERMINATION

Steady State Isotopic Transition Kinetic Analysis (SSITKA) is a valuable tool for obtaining in-situ mechanistic and kinetic data on various catalytic reactions. The isotopically labeled gas species, coupled with the rapid switching (step change) technique, are used to elucidate reaction mechanisms by analyzing the product stream as a function of the transient kinetic method with time. Fourier Transform Infrared (FTIR) Analysis examines the bond stretching of species on the catalyst surface under IR energy to identify surface reaction intermediates. Together these capabilities can be used to obtain detailed reaction mechanism and kinetic rate data for a given catalytic reaction.

Raman spectroscopy is a material characterization technique that detects vibrational and rotational bond modes to aid in the identification of molecular structure during catalytic reactions. As an in-situ technique it can evaluate changes to M-O bonds in a metal oxide as the crystal structure changes under reaction conditions and monitor the presence of adsorbed species up to 1500°C. This is also a useful technique for characterizing and quantifying different types of carbon (e.g. coal sample analysis).

3

HYBRID POWER SYSTEMS PERFORMANCE LAB

COUPLING ENERGY PRODUCTION & STORAGE SYSTEMS

This facility features the only hardware-based cyber-physical simulation of a hybrid advanced power system anywhere in the world. This one-of-a-kind facility is currently being used to develop control strategies for the reliable coupling of solid oxide fuel cell (SOFC) and gas turbine technologies. The gas turbine is physically represented in the system, while the SOFC stacks and ancillaries have been represented by a combination of hardware, which simulate flow dynamics through a SOFC stack, and software, which is used to characterize the electrochemistry for the SOFC and control the fuel fed into a combustor to generate the amount of physical heat provided to the facility. The cyber components can be readily swapped out using, for example, nuclear thermal energy generation, or concentrated solar power. A reformer or gasifier can be substituted as virtual components for the fuel processing. This system has proven to be valuable for improving the process flexibility such as thermal energy storage in the SOFC interconnects, novel load following control schemes, advanced dynamic multiagent controllers.

4

ELECTRO-OPTICS

ENABLING TRANSFORMATIONAL ENERGY CONVERSION TECHNOLOGIES THROUGH ADVANCED SENSORS

Sensors play a critical role in the operation of power plants, and with increased concern for high efficiency (low CO_2 generation), and robust operation given the increase in renewable generation on the grid, sensors have become an enabling technology for DOE's advanced power systems. NETL researchers apply electro-optical principles to develop and demonstrate sensors that are sensitive and rugged for measuring the high temperature and high-pressure conditions in these transformational technologies. NETL-developed sensors are used to measure critically needed flow data in chemical-looping combustion systems, characterize down-hole temperature and reactant environments in oil/gas wells, and distributed temperatures in hot process gas streams. Expertise resides in fiber-optic based sensors, and sensors based on flame ionization and emission analysis, Raman spectroscopy of gases and solid surfaces, laser-induced breakdown spectroscopy, and more.

5

COLD-FLOW REACTOR DEVELOPMENT LAB

MULTIPHASE FLOW REACTOR ENGINEERING

NETL's cold-flow reactor development lab houses a collection of cold-flow (room temperature) atmospheric pressure multiphase flow reactors (moving, fluid, spouting, circulating, rotating, and vortexing beds) and state-of-the-art diagnostic equipment used to validate engineering and computational models of energy systems, including their complex fluid dynamics; investigate changes in hydrodynamic behavior; and assess the performance of multiphase flow reactors. Insights such as these support the scale-up, optimization, and commercialization of multiphase flow reactors, particularly as they apply to combustion, gasification, and the biofuels and oil-refining industries. Fossil fuel conversion and energy storage concepts can be evaluated using a suite of experimental bench-scale test facilities, reacting and non-reacting. The performance and durability of solid reactants, as well as, catalyst materials can be assessed using ASTM attrition test methods, high temperature fluidized bed reactors, spouting bed reactors, and a 50 kWth circulating dual reactor test facility. In addition to advancing the state-of the- art in fossil fuel conversion and energy storage technologies, these capabilities also provide a basis for validating multiphase CFD simulations and other process intensification simulation initiatives.

6

MAGNETOHYDRODYNAMICS (MHD) LAB

ELECTROPHYSICS

Electro-physics technology with its focus on transport and interaction of ionic particles has not seen broad consideration within fossil energy systems. Depending on the application need, either power extraction or flow pumping can occur using certain magnetohydrodynamic (MHD) methods. Current NETL research focus is on enhancing power generation when using charged atoms in a hot, high-velocity, oxy-coal flame, where thermal energy of combustion is converted into electricity using a magnetic field (in place of a turbine and generator). Researchers are predicting the performance of these advanced concepts and accelerating their development.

7

REACT FACILITY

A STATE-OF-THE-ART REACTION ENGINEERING LAB

The Reaction Analysis and Chemical Transformation (ReACT) laboratory (>6000 sq ft) is a state-of-the-art reaction engineering facility providing reactors and process-scale equipment for NETL researchers and its collaborators. New chemical processes can be tested at a wide range of pressures, temperatures, and feed compositions which are not typically available in more conventional reactor laboratories. The facility, both modular and flexible, is designed to accommodate NETL's, and DOE's, changing needs and demands to accomplish its mission.

8

VARIABLE FREQUENCY MICROWAVE REACTOR (VFMWR) FACILITY

MICROWAVE SCIENCE EXPLORATION FOR FUEL CONVERSION

The Variable Frequency Microwave Reactor (VFMWR) facility is a one-of-a-kind system that does not exist in any of the known research laboratories around the world. While most typical microwave reactors operate at a fixed 2.45 GHz, the VFMWR has been designed with the ability to vary the frequency from 2 to 8 GHz, giving researchers the ability to design and conduct experiments across a wide range of frequencies.

9

HIGH TEMPERATURE ELECTROCHEMICAL TEST FACILITIES

SOLID OXIDE FUEL CELL R&D

A family of high temperature electrochemical test facilities at NETL is allowing researchers to develop new materials for fuel cell systems to achieve improved lifetime and performance. From small stack test capability to single button cell testing to materials characterization capability, researchers evaluate novel approaches to cell configuration and material structure, and find solutions to improved cell and stack performance.

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ENERGY CONVERSION ENGINEERING

- High Pressure, High Temperature Combustion – *Morgantown*
- Kinetics & Catalysis Lab – *Morgantown*
- Hybrid Power Systems Performance Lab – *Morgantown*
- Electro-Optics – *Pittsburgh*
- Cold-Flow Reactor Development Lab – *Morgantown*
- Magnetohydrodynamics (MHD) Lab – *Albany*
- ReACT Facility – *Morgantown*
- Variable Frequency Microwave Reactor (VFMWR) Facility – *Morgantown*
- High Temperature Electrochemical Test Facilities – *Morgantown*

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Program staff are also located in Houston, TX and Anchorage, AK

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