Guiding the way to a more sustainable energy future

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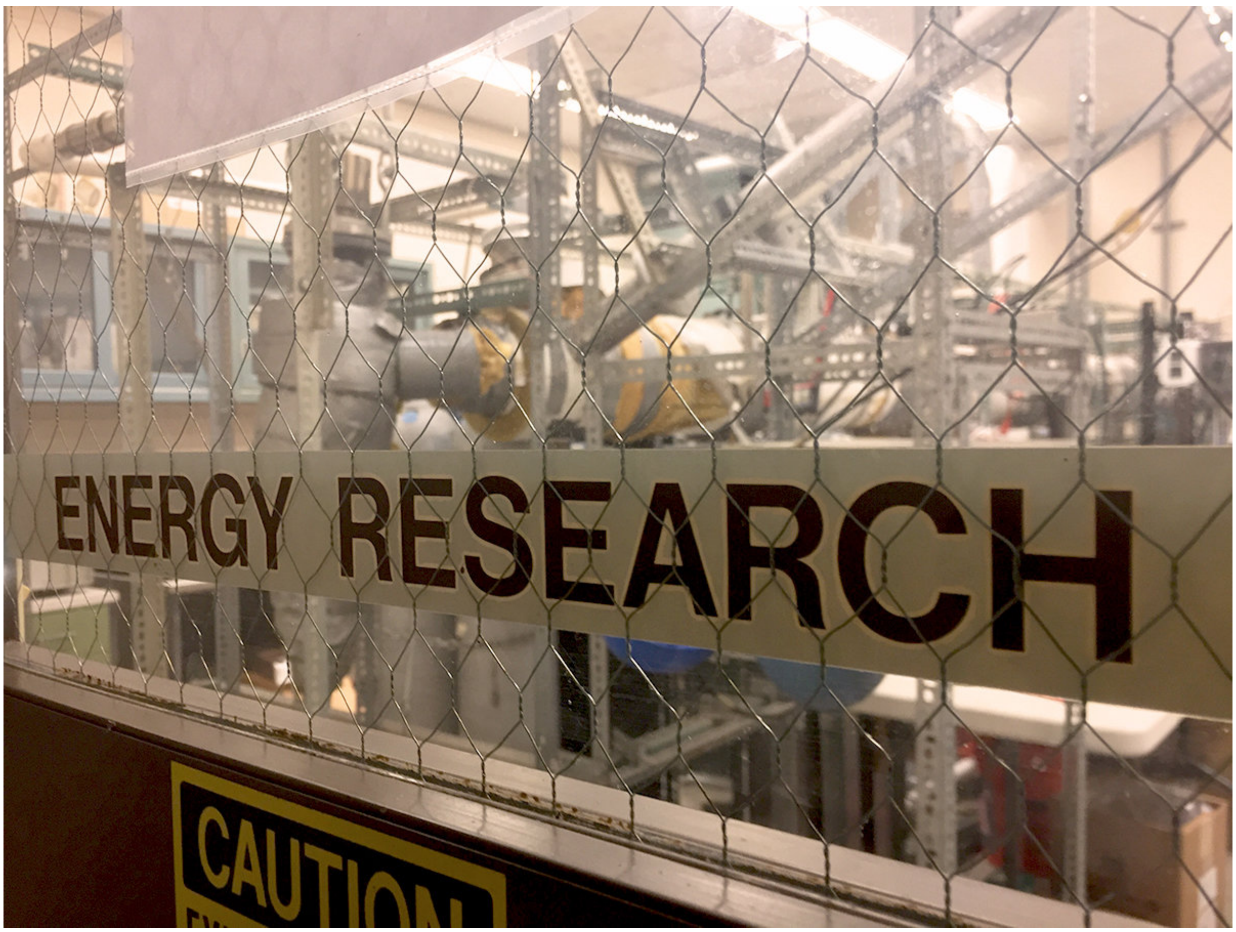

Lehigh University's Energy Research Center, which was recently awarded three projects with US and international funding, is positioned to help the energy industry meet the challenge of transforming fossil-fuel dependence. Credit: Lehigh University

The Intergovernmental Panel on Climate Change (IPCC) released an alarming report this October about what it would take to cap rising global temperatures at 1.5°C above pre-industrial levels. Hitting this target has motivated countries to start developing and executing plans for decarbonization of their power generation and energy matrix, as well as other options, such as removing CO_2 out of the atmosphere itself.

The consequences of society's response to this threat, needless to say, are dire.

"There's no question that the current proposition of fossil fuels as the world's primary energy sources needs to be transformed," says Dr. Carlos Romero of Lehigh University's Energy Research Center (ERC), "but doing so is a massive global undertaking that will not happen overnight. As an example, currently, the US gets about 70 percent of its total energy from coal, oil, and natural gas. How we go about making the transition, and understanding the ramifications of decisions made along the way, is crucial."

"Until renewables are fully established," continues Romero, who is also affiliated with Lehigh's new Institute for Cyber Physical Infrastructure and Energy (I-CPIE), "the world's energy and power demand will still need to be met. It is imperative that we continue to develop innovative ways of managing traditional power plants as reliably, cleanly, and efficiently as possible, while at the same developing cost-effective alternative energy sources."

Romero has conducted research on behalf of the ERC for nearly 25 years and served as its director for the past five. Since 1972, the ERC has provided research and engineering support to the power generation industry, supporting collaboration among Lehigh researchers and energy-focused federal, state, and local agencies, businesses, technology developers and suppliers, as well as associated academic and research communities in the United States and abroad.

According to Dr. Richard Sause, I-CPIE director and the Joseph T. Stuart Professor of Structural Engineering at Lehigh, the ERC is positioned to help the energy industry meet the challenge of transforming the fossil-fuel dependence.

"Supporting the development of new technologies and approaches in this space is central to our Institute's mission," says Sause. "Yet, the reality is that the adoption of such innovation on a global, industrial-strength scale will not happen overnight. The ERC boasts nearly five decades of deep engagement in the electric power generation industry, serving a valuable role in Lehigh's work in this field and acting as a conduit of crucial knowledge and insight. The ERC will continue to have a significant impact, now and in the future, as we transition from fossil fuels."

Sause points to research by the ERC and a group of faculty working on ultra-high temperature thermal energy storage as an example of collaboration within I-CPIE. This research will help conventional fossil-fired assets to operate more efficiently in a new dispatch environment, he says, while contributing to the establishment of solar power as a reliable source of renewable energy.

Romero believes that three recently announced ERC projects—two supported by the US Department of Energy (DOE), the other by the World Bank and Mexico's National Council for Science and Technology and its Secretary of Energy—attest to the significance of the ERC's ongoing work.

Smarter carbon capture

In a three-year, $2.3 million project supported by the government of Mexico and the World Bank, Lehigh will partner with the Mexican

Institute for Electricity and Clean Energies (INEEL, for its acronym in Spanish) to study the use of a renewable energy source—solar thermal energy—to improve the performance of CO_2 capture systems installed in natural gas combined cycle (NGCC) power plants. Mexico has a large number of NGCC's for power generation. Although NGCC power plants have a lower carbon intensity than coal plants, a portion of these plants will require CO_2 capture technologies to ful?ll Mexico's greenhouse gas (GHG) emission targets set by the Climate Change Act. The country has committed to reducing its greenhouse emissions by 50 percent below 2000 levels by 2050.

This project is part of large $90 million inter-institutional consortium designed to advance carbon capture, utilization, and storage (CCUS) in Mexico. According to the International Energy Agency, CCUS can potentially contribute to the mitigation of about 12 percent of the cumulative greenhouse emissions needed to reach the global goal of 1.5°C cap temperature by 2050. The consortium includes international participants from the research community, academia, and industry and will support the development of a group of projects, including a carbon capture pilot plant project and a CO_2-enhanced oil recovery project.

Lehigh's team for this project includes Romero, Dr. Hugo Caram, Dr. Sudhakar Neti, Dr. Joshua Charles, Dr. Xingchao Wang, and graduate students.

"One of the most promising technologies for capturing carbon dioxide from fossil-fired power plants is the use of chemical solvents or amines to capture the CO_2 in a solution," Romero says. "However, it is not practical to try to sequester the entire CO_2-laden stream. The CO_2 must be extracted back out, and optimally the solvent can be regenerated for future use."

According to Caram, a professor of chemical engineering, the process of this extraction of CO_2 from amine requires an astonishing amount of heat—one that would lead to a large reduction in the plant's cycle efficiency and total power output.

"The heat used to extract captured CO_2 from the amine normally would be 'bled' from the steam used to turn the plant's turbines," explains Neti, a professor emeritus of mechanical engineering and mechanics. "We're proposing to use solar thermal energy, instead of essentially wasting a portion of the steam energy intended for power generation. Our primary goals in the project are to screen the most suited solar technology for this application, design the solar field and coupling it with the CO_2 plant, and understand how solar energy's inherent variability impacts the process of CO_2 capture."

A cleaner 'power cycle'

In another new project closer to home, ERC researchers, including Dr. Alp Oztekin, Zheng Yao, Romero, and graduate students, are working with colleagues from Western Kentucky University, with support from the DOE Office of Fossil Energy, to analyze the impact of "cycling" on different power plants' wastewater treatment processes, including physical-chemical and biological technologies.

Titled "Coal-Fired Power Plant Configuration and Operation Impact on Plant Effluent Contaminant and Conditions," this $400,000 effort analyzes the impact upon the wastewater treatment process when coal-fired power plants engage in cycling operations.

With the advent of competition from renewable energy sources—which has introduced a demand for flexible power generation—power plant operators have been forced to cycle aging units that were originally designed to be operated at base-load conditions.

The team will collaborate with power plants in Virginia, Illinois, and North Dakota to obtain operating data and material samples to characterize the impact of cycling operation on the wastewater treatment trains. DOE is particularly interested in the emissions of mercury, arsenic, selenium, bromide, and nitrates/nitrites in the discharge effluent.

"Every time a power plant is cycled from maximum to minimum load, all of its components go through unavoidably large stresses, which cause issues that shorten plant life," says Oztekin, a professor of mechanical engineering. "Since these units weren't designed to cycle, this study is to determine the impact of this cycling on the performance efficiency and the economics of the wastewater treatment process."

This kind of analysis is vital, says Yao, because it would help assess how the final emissions of target toxic elements respond to cycling operation and the cost associated with it.

'Cleaning' coal more efficiently

A third recently announced project, also related to reducing coal contaminants, is a partnership effort funded through the DOE Small Business Innovation Research (SBIR) program, which enables small businesses to meet federal research and development needs.

ERC researchers will participate in a million-dollar Phase II project with Advanced Cooling Technologies, Inc. (ACT), of Lancaster, Pa. The company is pursuing coal-cleaning technology and has developed a unique spouted bed reactor that increases performance of thermal desorption of mercury, sulfur, and rare earth elements (REEs). ERC researchers include Romero, Yao, and graduate students.

In Phase 1, ACT's spouted bed design demonstrated a reduction of 65 percent of mercury and 28 percent of sulfur content in bituminous coal, which doubled the removal efficiency compared with standard conical spouted bed. In Phase II, Lehigh will perform experimental research and the analytics of the toxic metals and REEs, and will provide support on the kinetics of the desorption process. ACT will fabricate a scaled-up pilot scale reactor designed to remove contaminants from coal via an automated/continuous process, as well as to investigate the economics of applying the technology.

"There's an opportunity through this innovation to allow coal-fired power plants to utilize coal with higher mercury content while realizing cost savings over existing post-combustion mercury capture systems," says Romero. "The technology could also be extended to other waste sources, such as municipal solid waste (MSW) and cement."

Provided by Lehigh University

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