

UK Energy Research & Environmental Protection

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Research



Our state's energy needs are a priority for the University of Kentucky. And as we develop Kentucky's natural resources, protecting the environment is equally important.

UK's land-grant mission and the fact that Kentucky is a major fossil-fuel-producing state, have positioned the university as an international leader in energy research and energy-related environmental research.

This expertise accounts for about \$45 million in ongoing projects across a wide spectrum of research specialities in engineering, agriculture, arts & sciences, business &



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economics, and public health. Last fall, UK co-hosted Coal 2020 with Cinergy to highlight the role of university research in a discussion of our nation's energy future and issues concerning the vital role of our most abundant and economical fuel.

Energy production and environmental stewardship have tremendous implications for Kentucky's future. And UK researchers are doing their part.

Industry Benefits from Energy Research

Researching Energy for Three Decades

A major event for Kentucky energy policy was the establishment of the Center for Applied Energy Research during the 1970s' energy crisis. Since then, CAER has gained an international reputation for cutting-edge energy research that has led to important commercial applications. CAER was an early leader in synthetic fuels, and is known for its work on coal combustion to produce electricity (which accounts for 85 percent of coal use), control of air emissions from coal-fired power plants, technology to process minerals and advanced carbon-fiber composites for environmental cleanup, and the reuse of coal combustion by-products. Key energy companies from around the world use CAER's catalyst testing facilities, and hundreds of clients are served each year by CAER's problem-focused services.

Reducing Energy Costs for the Automotive Industry

Painting an automobile takes close to 50 percent of the energy consumption in the entire assembly process, and wasted paint due to overspray costs the industry \$1 billion each year. The Vortecone, invented jointly by Kozo Saito's mechanical engineering team at UK and Toyota engineers, captures small (sub-micron) particles of oversprayed paint using special vortex chambers. Toyota in-plant tests proved that the Vortecone is highly effective

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both in capturing paint particles and in reducing energy costs. This patented device is currently in use in seven Toyota assembly plants in Japan and the United States.

Energy Savings for the Aluminum Industry

Kentucky has the highest concentration and diversity of aluminum companies in the world, with 142 facilities and more than \$5 billion in shipments. A UK mechanical engineering research team, in conjunction with national laboratories at Albany, Oak Ridge and Argonne, and nine aluminum companies, is investigating energy efficiency in aluminum melting for Secat Inc., a Kentucky aluminum research and testing firm at the UK Coldstream Research Campus. Their goal is to reduce the amount of energy needed to melt aluminum, thereby reducing energy costs and producing less waste. Reverberatory furnaces, the principal means used for melting aluminum, operate at 30 percent thermal efficiency. Advancements in oxygen-air-fuel burners coupled with improved insulation, refractories, sensors and control systems have the potential to reduce fuel demands, improve production rates, and reduce greenhouse gas and nitrogen oxide emissions.

Energy Research in Eastern and Western Kentucky

Exploring Deep Natural Gas in Eastern Kentucky

The Rome Trough is a deep Cambrian sedimentary basin that produces natural gas from several fields in Eastern Kentucky. Since 1998, Kentucky Geological Survey researchers at UK, colleagues at state geological surveys in Ohio and West Virginia, and four energy companies have worked together to evaluate the natural gas potential in the Rome Trough. Analyses of Cambrian shales sampled in several wells in the Rome Trough found good hydrocarbon potential. This research has important implications for future exploration for deep natural gas in pre-Knox Cambrian rocks in the Rome Trough and Appalachian Basin.

Investigating Methane in Western Kentucky

Coalbed methane, previously considered a nuisance and hazard in some Kentucky coal mines, may become an important future energy resource. Geologists at KGS are investigating the potential for developing coalbed methane gas from seams in the Western Kentucky Coal Field, which extends across 19 counties. This coal field is estimated to have 36 billion tons of remaining coal, which may contain economically recoverable quantities of methane gas. This methane could be used as a fuel similar to natural gas. And the

potential demand for coalbed methane gas could be great: nearly all of the new electric plants proposed for Kentucky will be powered by natural gas. Methane is a clean fuel, and drilling and mining it causes little disturbance of the local environment.

Clean Fuels and the Hydrogen Economy

Producing Hydrogen—the Ultimate Clean Fuel

The ability to produce hydrogen in sufficient quantities will be a key factor for the success of a hydrogen-based economy. The question is, where will it come from? One of the more promising options for producing hydrogen is through the gasification of coal, natural gas or biomass. In each case, a catalytic reaction is needed to maximize the yield of hydrogen and generate an environmentally friendly, sulfur-free fuel. CAER researchers in the Clean Fuels and Chemicals Group have developed expertise in catalysis and continue to refine a unique catalytic process they are also using to “split” water, separating hydrogen and oxygen. The group is also investigating fuel-cell technology, including the materials to construct fuel cells and the purification of feed gases for use in fuel cells.

Using C1 Chemistry to Produce Clean Fuels and Hydrogen from Coal

UK is the lead university in the Consortium for Fossil Fuel Science, whose primary research focus is developing technology to produce ultra-clean transportation fuels from coal and natural gas—resources that are much more plentiful and domestically available than petroleum. Consortium researchers use C1 chemistry to convert feedstocks (synthesis gas produced by gasifying coal or reforming natural gas, methane—the principal component of natural gas—methanol, carbon dioxide, and carbon monoxide) into liquid transportation fuels such as gasoline, diesel fuel and jet fuel. CFFS is also focusing on the production of hydrogen from coal, new hydrogen storage technology, and the adverse health affects caused by fine airborne particulate matter, a byproduct of fossil-fuel combustion.

Protecting Kentucky's Environment

Working for Healthier Waterways

The Kentucky Water Resources Research Institute at UK is the state's leading authority in modeling the impacts of resource extraction on the state's waterways. One project establishes total maximum daily loads (TMDLs) for streams impacted by surface-mining operations. Protocols have been developed for determining TMDLs for pH (a measure of acidity and alkalinity), nutrients and pathogens. To date, KWRRI has completed 16 TMDLs for the Kentucky Division of Water.

Environmental Cleanup in Paducah

Researchers with the Kentucky Research Consortium for Energy and Environment at UK and the KWRRI are working with the DOE on environmental cleanup at the Paducah Gaseous Diffusion Plant. The plant produced low assay-enriched uranium for over 40 years for use as commercial nuclear reactor fuel until the enactment of the Energy Policy Act of 1992. Current cleanup work includes seismic hazard assessment, industrial battery applications for depleted uranium, new technologies for cleaning contaminated nickel stockpiles, and assessment of surface water, landfills, soils, and groundwater.

Reclaiming and Reforesting Surface Mined Lands

Vegetation, especially trees, helps reduce carbon dioxide levels in the atmosphere—rapidly growing trees sequester large quantities of carbon both above and below the earth's surface. UK researchers in forestry, biosystems & ag engineering, and mining are developing improved methods to plant and grow trees on thousands of acres of surface mined lands in Eastern and Western Kentucky. Successful reforestation will return economic and ecologic diversity to the impacted areas, and high-value hardwood forests can be a boon to the state's growing wood industry. In addition, the trees can be used for biomass material to produce renewable energy referred to as "green fuel." Researchers are also looking at a variety of associated issues such as soil compaction and watershed management, agricultural economics studies, and forest health initiatives that include wildlife restoration.

Carbon Sequestration: A Strategy to Address Global Warming

Hydrocarbon fuels (oil, natural gas and coal) are expected to be the primary energy sources in the United States for the next 50 years or more. Many scientists believe that increasing concentrations of carbon dioxide (CO₂) in the atmosphere, released when hydrocarbons are burned, are contributing to global climate change. One technology to "catch" CO₂, is carbon sequestration, a process in which CO₂ emitted in the atmosphere is captured and securely stored in subsurface reservoirs. Geologists at the Kentucky Geological Survey, along with colleagues at four other state geological surveys, have developed an integrated database, called the Midcontinent Interactive Digital Carbon Atlas and Relational Database, which can be used to estimate the amount of CO₂ emitted by a source (for example, electric power plants) and evaluate how close these sources are to reservoirs in five midcontinent states that can provide safe, secure, long-term storage.

Waste Recycling and Reclaiming Ash Pond Land

Approximately two-thirds of the waste ash generated by U.S. coal-burning power plants is dumped into ash ponds. UK's Center for Applied Energy Research is continuing to work with state and regional utilities to recover ash from ponds and put it to use as products such as filler for construction and for lightweight resins, re-usable high-carbon fuel, lightweight aggregates, and high-grade pozzolan, a composite material used to form a strong, slow-hardening cement. Reclaiming ash pond land is increasingly critical as the availability of landfill space continues to diminish and energy demand continues to rise.

Improving Coal Preparation and Miner's Health

Mining Engineering Develops New Technology Critical to Kentucky's Coal Industry

Researchers from UK's mining engineering department are currently pursuing opportunities to develop new technology in two areas that are critical to the long-term health of the coal industry in Kentucky: automated methods to recover coal from abundant thin seams (many of the thicker reserves have been depleted), and improved methods of handling coal slurry to minimize the need for impoundments and to guarantee their integrity when they are necessary.

UK is currently leading nine major advanced coal-preparation projects involving industrial partners such as Peabody Energy, Arch Coal, Consol Energy, Massey Energy, James River Coal, and Carbontronics Fuel Management.

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Producing Premium Fuel from Coal Waste & Sawdust

Mining engineering and Center for Applied Energy Research scientists are utilizing fine coal waste and waste from the timber industry as biomass to create a premium fuel for utilities (energy value of more than 13,000 Btu/lb). The fuel is in the form of a briquette, which is easy to handle and transport to the end user.

Improving Coal Plant Equipment

The Advanced Surface Enhancement Project involves using infrared and laser-based technologies to create a molecularly smooth hardened surface that will decrease the wear and corrosion rate of coal-preparation plant equipment, and may decrease plant maintenance by 20 percent. This project and the Premium Fuels Project mentioned above are funded by the USDOE Mining Industry of the Future Program.

Reducing Methane Concentrations for Miners

Due to advances in remotely controlled equipment, longer cuts are possible in underground coal mines. However, extended cuts can present problems for the ventilation system. A recent project by mining engineers at UK resulted in improved ventilation for miners by reducing methane concentrations to safe levels at the face of underground mines where extended cuts are made. The research involved a computational fluid dynamics computer model as well as physical modeling.

Renewable Energy

Converting Kentucky's Abundant Renewable Resources into Fuels and Chemicals

Kentucky has abundant renewable biomass resources (plant matter or other biological material) such as agricultural residues and forestry wastes. Turning this biomass into biofuels offers the potential for our country's reduced dependence on imported crude oil and new income for

Kentucky farms. UK's Biosystems & Agricultural Engineering scientists are doing research to collect, characterize, pretreat, convert, and store Kentucky's biomass resources, such as corn stover—the residue remaining after harvest. They are also leading an outreach effort to promote the use of ethanol and biodiesel as alternative fuels; both use our renewable resources and are environmentally friendly.

Producing Biofuels for Diesel Engines

Research in the College of Engineering is also looking at biomass and new methods for direct conversion into liquid transportation fuels, specifically biodiesel fuels. This fuel can be used as an additive to reduce vehicle emissions (typically by 20 percent) or in its pure form as a renewable alternative fuel for diesel engines.

Positioning Kentucky to Compete in Tomorrow's Economy

Using Coal to Produce High-Value Carbon Materials

Carbon materials researchers at the Center for Applied Energy Research are developing technologies for converting coal to high-value carbon materials and specialty chemicals such as carbon fibers, binders, pitches, and activated carbon. Such advanced carbon materials have environmental and composite-materials applications. Various engineering materials can benefit from the addition of relatively small quantities of special carbon components to provide superior properties like strength, and thermal and electrical conductivity. Carbon nanotubes are a specific category of advanced carbon materials, and CAER has developed a unique, continuous process to produce multi-walled carbon nanotubes. There is significant interest from the defense and electronic industries in these products, which could be produced in Kentucky and provide economic growth opportunities.

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