Departments Focus on Environmental Research Challenges with Global Consequences

Chemical Engineering

When Dr. Paul Frymier talks about his research on energy and sustainability, his face lights up.

"I always tell students we're working on saving the planet," said Frymier, associate professor in the Department of Chemical Engineering (ChE).

Through an Environmental Protection Agency (EPA)-funded award competition, Frymier has the opportunity to learn more about a question that has been on his mind for 20 years—is there any way to produce energy sustainably? The Annual P3 (People, Prosperity and the Planet) Award competition was launched in 2004 as a response to challenges of the developed and developing world in moving toward sustainability. This national competition enables college students to research, develop and design scientific, technical and policy solutions to sustainability challenges. Drs. Robert "Pete" Counce and Barry Bruce are collaborating with Frymier on this project.

"What we proposed was a design study to determine if you could produce hydrogen sustainably using algae, how much land area would that consume, what would the price of the hydrogen be and how would that compare to the current price we pay for gasoline," said Frymier. "We want to address two big questions - can you generate more transportation energy in the form of hydrogen than the power required to operate the equipment needed to produce it; and, if so, what is the net energy recovered?"

Concerns about oil shortages also fuel his research.

"We are doing the most wasteful thing," said Frymier on the subject of petroleum. "It's like someone gave you diamonds and you crushed them up and used them for sandpaper. We're taking this valuable resource that took over millions of years to form and burning it to go back and forth from work every day. It's crazy! We're going to have to start thinking differently about how we make transportation fuels. We can't make them like we are now."

In addition to his EPA grant, Frymier received the Scholarly Activity and Research Incentive Funds (SARIF), a collection of small programs that provide specific support for faculty at UT. With this funding, Frymier continues his research looking at alternatives, using live algae for hydrogen production by taking cell parts out and embedding them in synthetic membranes, making what are essentially organic photovoltaic membranes.

Dr. Paul Frymier *(right)* and graduate assistant Mehrsa Raeiszadeh *(left)* are investigating production of hydrogen from algae, which may ultimately be used in hydrogen-powered vehicles.

"On one side of a synthetic membrane, you can split water into oxygen and protons and allow the protons to diffuse across the membrane," said Frymier. "In this process, four protons for each molecule of molecular oxygen can be recombined to make molecular hydrogen with a hydrogenase enzyme on the other side. At the risk of oversimplifying the whole cell work, we're basically making the algae upset so they burp hydrogen. With the membrane work, we hope to make the process more efficient by using only the parts of the algae we need."

Frymier was also recently chosen for the Joint Directed Research and Development Program (JDRD), a joint UT and Oak Ridge National Laboratory (ORNL) collaborative research venture that supports innovative new ideas, concepts or device development at the forefront of science and technology. With his collaborator, Dr. John Sanseverino, Frymier looks at different microbial cell types to make electricity or hydrogen from organic carbon-based fuels in microbial fuel cells.

"I hope the college can capture some of the resources expended at the national level and really gain the reputation for doing this kind of work," said Frymier about future research on energy in COE. "If global warming actually ends up being a serious problem, it ultimately may not be survivable, so I hope there is a moderate level of activity in the college until the problem is, at least in theory, solved."

Electrical and Computer Engineering

On the application side of hydrogen research is Dr. Leon Tolbert, associate professor in the Department of Electrical and Computer Engineering (ECE), whose research is focused in two areas: hybrid electric vehicles and distributed energy resources.

Dr. Leon Tolbert *(left)* and student Hui Zhang *(right)* are working with new silicon carbide materials to develop advanced power converter systems.

Funded by FreedomCAR, a U.S. Department of Energy (DOE) program focused on developing more energy efficient and environmentally friendly highway transportation technologies, Tolbert's research involves working on power electronics and electric machinery for the drive train in hybrid electric vehicles. Tolbert's main goal is to move to hydrogen-powered vehicles in order to reduce dependence on gasoline-powered vehicles, but his interim goal is to work on hybrid-electric vehicles using a conventional gasoline powered engine and combining it with electric motor and power electronics.

"As engineers, we always have to have an eye on economic issues," said Tolbert. "We need to bring the price down [on hybrid vehicles] so we're working on trying to make smaller, lighter, cheaper and more reliable power electronics for hybrid electric vehicles."

Tolbert also works on distributed energy resources, such as solar cells, wind power, fuel cells, microturbines and diesel generator sets, and their interface with the utility grid. Again, the question he seeks to answer is how to make these energy resources more economically competitive.

"Most alternative energy sources are still more expensive than conventional sources such as coal or nuclear, which can produce power at two to three cents per kilowatt hour, whereas solar power is roughly 15 cents per kilowatt hour and wind is down to about five cents," said Tolbert, who works with researchers at ORNL to design a cheaper power electronics interface that is able to work for several different energy sources.

"It's all about economics, and even though we want to take an environmental point of view on installing these things, they really need to be economically competitive," said Tolbert. "My research now is about applying what I know to areas I really think can help us conserve our natural resources and make the world a better place."

Students also benefit from Tolbert's research through integration into the classroom. Currently, Tolbert teaches a class on alternative energy sources, which he had previously taught as a special topics class.

"By teaching these classes, I'm able to bring the information back to the classrooms and expose lots of students to research in energy and sustainability," said Tolbert.

UT Driving the Development of Alternative Fuels and Hybrid Vehicles

Although alternative fuels may be a "hot topic" at the present moment, the UT College of Engineering has been involved in the development of hybrid vehicles for over 18 years.

Since 1989, UT student teams have scored several first-place wins or have placed in the top rankings of advanced vehicle technology design competitions, sponsored by the Department of Energy (DOE) and the U.S. auto industry. These unique, multi-year programs bring together the resources of industry, government and academia in a cooperative effort to address important environmental and energy-related automotive issues.

Dr. Jeff Hodgson, an emeritus professor in mechanical engineering at UT, initiated the COE's involvement in vehicle design programs and served as faculty advisor to the majority of the student teams until 2002.

The university has received nearly $3.3 million in contracts and resources as a result of participation in the alternative-fuel vehicle competitions.

Dr. David "Butch" Irick, Hodgson's successor, now serves as faculty advisor to the student team involved in the most recent competition, Challenge X. The competition, sponsored by General Motors, is now in its fourth year. The students are currently modifying a 2005 Chevrolet Equinox.

"Our goal for the final year of the Challenge X competition is to have a vehicle that is a 99 percent production-ready, biodiesel-electric hybrid. In the end, we want to have an environmentally friendly vehicle that is also acceptable to consumers; the type of automobile that you would buy off a showroom floor," said Irick.

Team Tennessee is composed of seniors in mechanical engineering (ME) and electrical and computer engineering (ECE). The ME students are primarily divided between students interested in machine design versus thermal sciences, while ECE majors are focusing on electronic controls. The group is lead by graduate students in mechanical engineering who have past industry and HEV competition experience.

The fourth year of the competition will primarily consist of testing, evaluation and improvements to make the vehicle appealing to consumers, Irick said.

Dr. Butch Irick (left) and members of the University of Tennessee student chapter of the Society for Automotive Engineers (SAE) continue to develop their biodiesel-electric hybrid vehicle as part of the multi-year Challenge X competition.

Irick is also the director of the COE's Graduate Automotive Technology Education program (GATE), established in 1999. The goal of the GATE program is to provide training to a future workforce of interdisciplinary automotive engineering professionals who have experience in developing and commercializing cost-effective, fuel-efficient vehicles.

In 2005, the program received a $625,000 grant from the DOE and the university to assist with updating and expansion of initiatives in the area of advanced hybrid vehicle propulsion and control systems.

Irick sees the future of automotive engineering research at UT as extremely promising.

"We have a very strong automotive engineering program with both research and teaching," Irick said. "The automotive industry projects that sales of hybrid vehicles will increase by 80 percent over the next few years. We are going to be educating engineers who can help meet the demand for those automobiles."

–Story by Kim Cowart

Environmental engineering graduate student Josh Cummins *(left)* and CEE Research Associate Professor Dr. Joshua Fu retrieve data from an air quality monitoring station in West Knoxville.

While research into energy sustainability and efficiency is important, impacts of energy production on the environment is equally crucial, according to researchers in the Department of Civil and Environmental Engineering (CEE).

"The Air Pollution Group has done quite a bit of modeling with respect to how different kinds of transportation and electricity production activities will impact future air quality here in the Tennessee Valley," said Dr. Gregory Reed, professor and head of CEE. "Our results show that we either have to achieve extraordinary high levels of pollution control at the source, or we have to change the source, in other words, stop using fossil fuels."

According to Reed, pollution from industry and transportation are the two kinds of energy use that needs to be addressed from an environmental point of view.

"However," said Reed, "other environmental issues exist. If you use coal, the whole business of mining and processing the coal come into play. If you produce electricity from nuclear, the question becomes what are you going to do with the waste. Every technology has its pluses and minuses. We look at how to minimize the minuses and maximize the pluses."

Sustainability is part of the civil engineering code of ethics and the only discipline code of ethics that says engineers should design things to be consistent with sustainable development, according to Reed.

"Civil engineers are ethically bound to look for sustainable options in everything we do," said Reed.

Researchers in the COE are working on the global energy problem at every level in order to contribute solutions to future generations.

"We should push the envelope," said Dr. Wayne Davis, associate dean of research and technology. "We don't know what the future will look like, and we should do a little bit of everything relevant to research in order to influence the future."

–Story by Amanda Womac