From new lighting particles to advanced fuel cells, Rensselaer breaks new ground toward an energy-efficient future—and trains the next generation of energy engineers.
The Center for Automation Technologies and Systems (CATS) recognizes the worldwide significance of energy in this century, so it’s working closely with industry to improve the quality, efficiency, and reliability of energy use in manufacturing through increased automation.

Industrial manufacturing requires huge amounts of energy. CATS has effectively partnered with many companies to obtain New York State Energy Research and Development Authority (NYSERDA) funding to improve energy efficiency. Among the successes in this partnership are improvement of the high-temperature process that forms titanium parts with Dynabil, and more efficient microwave heating for ceramic parts with Ceralink. Other highlights include a program to optimize bus engine heating with Brown Coach and energy-efficient automated pattern assembly for investment casting with MPI.

“We’ve sponsored research at CATS because we see a rigorous pursuit of valid technical information that has near-term use,” said Dana Levy, NYSERDA program manager for industrial research. “I was impressed when the RPI team achieved a Eureka! moment with the laboratory proof-of-principle confirmation of an effective wax welding technique on the MPI project. This discovery propelled the rapid development of a commercially viable product.”

Since 1988, CATS has contributed $118 million to New York’s economy. It generally works directly with industry to integrate automation technologies into manufacturing in ways that add value to business. There’s a great deal of fuel cell research happening at Rensselaer now (see related article on p. 6), and CATS is contributing valuable industrially driven efforts. The center partnered with fuel cell membrane manufacturer Celanese (later PEMEAS) to generate a successful proof-of-principle system, then developed the engineering specs and evaluated the automation vendor for a pilot facility in Germany. Rensselaer is helping to develop new plants for PEMEAS now, because demand outstripped the original facility’s ability to produce.

When fuel cells are manufactured today, the assembly is manually stacked, with flexible parts precisely aligned and tightly packed. Automation can increase throughput, reduce costs, and improve quality. In fact, CATS is holding a symposium on October 18 for component, equipment, and system manufacturers, users, NYSERDA, and the Departments of Energy and Defense. The goal is to present the needs, the state of the art, and Rensselaer’s research agenda. If everything gels, the Fuel Cell Stack Assembly Automation Consortium will arise, led by CATS’s program director in industrial automation, Ray Puffer.

The blackout that struck the East Coast a few summers ago inspired Rensselaer to create a consortium of power system operators from New York, the mid-Atlantic states, New England, and Canada, as well as Virginia Polytechnic Institute and the University of Wyoming. CATS is actively supporting the new Power System Research Consortium (PSRC), led by Associate Dean and Professor of Electrical, Computer, and Systems Engineering Joe Chow.

“Large swings in demand or voltage together with subsystem failure can shut the system down,” CATS Director John Wen explained. “The consortium will develop and implement systems that report potential trouble to the operators to decide how to address such situations.”

Wen sees great value in partnerships of industry, university, and government. “There needs to be a theoretical underpinning,” he said. “We don’t use a cookbook, so we’re in a position to see opportunities and have the freedom to act.”

Strength in Numbers
CATS uses industry partnerships to generate energy savings
In taking the position, Eisman was building on a major breakthrough. While extremely promising as an alternative energy generator—it produces heat and electricity with only water as a by-product—the fuel cell has run up against limitations of reliability, durability, and cost. Some of the issues relate to the fuel cell’s membrane and electrodes, which work together to produce the electricity that the fuel cell generates.

In response to the challenge, Brian Benicewicz (the director of Rensselaer’s Center for Polymer Synthesis) began to focus his research on polybenzimidazole (PBI) as a possible material for a less expensive, more effective fuel cell membrane. PBI has no melting point, will not ignite, and most importantly, does not require the complex water control systems that make fuel cells cumbersome and costly.

Benicewicz’s work inspired Eisman to join Rensselaer in September 2004. His first task was to learn about Rensselaer research. “I went knocking door to door to find out what people did around here,” he said. “All the time I was thinking, ‘Can we apply this research to fuel cells?’ In the end, I identified 10-15 faculty members who might have a contribution to make.”

With those faculty members on board, Eisman began to connect promising research, promising students, and funding sources interested in both. The results, to say the least, have been impressive.

Fuel Cell Research Gains Power

Buoyed by a new center, Rensselaer explores fundamental issues to make fuel cells viable

One major breakthrough in fuel cells had already taken place at Rensselaer. Could more follow?

Glenn Eisman is making sure it happens.

“I’m more of a strategic starter than a day-to-day operations person,” said the research professor of materials science and engineering. “Coming here and starting a center is more in line with my nature.”

Two years ago, Rensselaer officials asked Eisman to direct the new Center for Fuel Cell and Hydrogen Research—and they couldn’t have made a better choice. At the time of his hiring, Eisman was chief technology officer at Plug Power, a global leader in fuel cells, and had served as an industry leader himself. As a result, he knew many of the industry’s senior executives—giving him a distinct advantage in recruiting corporate partners, and granting the center instant name recognition.

Currently pursuing his Ph.D. through the IGERT program, Daryl Ludlow works on a National Institute for Standards and Technology (NIST) imaging project—offering the potential for real-time neutron imaging of water in PEM (proton exchange membrane) fuel cells.
Bold and Promising Research

Funding has come from across the spectrum of fuel cells: federal government, state agencies, and companies like Plug Power. All this support has led to a profusion of fuel cell research on campus.

On the federal side, the National Institute of Standards and Technology (NIST) has supported another potential breakthrough: the real-time neutron imaging of water in PEM (proton exchange membrane) fuel cells. “As the source of hydration for the membrane, water is the lifeblood and the Achilles heel of fuel cells,” Eisman explained. “The complexity and cost of water systems have made fuel cells slow to commercialize. With this research, we can actually see and characterize the flows inside fuel cells, allowing us to take steps to improve the effectiveness of water use.”

The Department of Energy (DOE), for its part, has awarded Benicewicz, Eisman, and other partners $900,000 to study high-temperature membranes—thus building on Benicewicz’s groundbreaking work. On another front, Eisman is attempting to develop “carbon-free” electrodes to overcome the stability issues that carbon introduces into the electrode structure.

The fuel cell activities on campus also include the Center for Future Energy Systems. Funded by the New York State Office of Science, Technology, and Academic Research (NYSTAR), the Center facilitates collaboration between the state and Rensselaer in fuel cell research. (See page 10 for a feature on this Center.)

Taken together, the research at Rensselaer addresses the issues behind nearly every aspect of the fuel cell. As Eisman said, “We have been initially received as the go-to center for this fundamental research.”

Creating Fuel Cell Engineers

This status is prompting another group to “go to” Rensselaer: promising students. To help attract them, Rensselaer has become the nation’s first university to receive an award from the National Science Foundation’s Integrative Graduate Education and Research Traineeship (IGERT) for fuel cell research.

IGERT’s goal—“to train Ph.D. scientists and engineers with the interdisciplinary background and the technical, professional, and personal skills needed to address the global questions of the future”—fits seamlessly with Rensselaer’s emphasis on cross-discipline thinking.

“Interdisciplinary research is difficult, but it has the potential for bigger breakthroughs, since these types of projects often work at the intersections of fields and disciplines,” said Michael Jensen, professor of mechanical engineering at Rensselaer, who heads up the institute’s IGERT program. “Our students are receiving interdisciplinary experience, and faculty from different disciplines are working together.”

Barely a year old, IGERT at Rensselaer has shown promising results. Already, six Ph.D. candidates from five different disciplines have served as IGERT trainees, with another group to come this year. And they have made an impact on research: Daryl Ludlow has worked with Jensen and Eisman on the NIST imaging project, while student Tequila Harris collaborates with Daniel Walczyk (associate professor of mechanical, aerospace, and nuclear engineering) to help a German firm develop a better method to cast membranes.

“Our relationship with IGERT certainly builds on our fuel cell research and establishes our reputation on a national level,” Jensen said. “Most importantly, it allows us to recruit excellent students like Daryl and Tequila.”

Eisman has seen a high level of excitement among students. “Even undergraduates are really keen on this,” he noted. “They’re knocking on my door and saying, ‘Can I work in your lab this summer?’”

Toward the Future of Fuel Cells

And what of the future? Eisman sees several possibilities for the center: an alliance with Rensselaer’s Lally School of Management and Technology to formulate policy, a biofuel cell project (one student has already begun exploring this), and more work in hydrogen. Even now, with support from the Department of Energy, Rensselaer hydrogen research is delving into separation and transport mechanisms via membrane technology. Eisman would like to expand this area.

Yet even as Rensselaer pursues fundamental research into fuel cells, its aims—like those of everyone in the industry—are inevitably practical. “Sponsors want practical solutions to current challenges,” Eisman said. “Our strength is to get deeply into the fundamental dynamics behind fuel cells and open up the science to the world. This is terribly important; in fact, the world’s future may depend on it.”
Rensselaer’s nuclear students get hands-on opportunities available at no other American University.

Top: Even first-year students can use the electron linear accelerator (LINAC) for undergraduate research.

Left: Changing the fuel pin configuration in the Institute’s low-power fission reactor.
Rensselaer Prepares Students for Growth in Nuclear Job Market

When the head of the Nuclear Energy Institute told Rensselaer students that the nation is “ripe for a renaissance of the nuclear power industry,” he was speaking at a national conference organized and run entirely by Rensselaer students belonging to the student chapter of the American Nuclear Society.

It was only appropriate, considering that Rensselaer’s nuclear engineering program will graduate more students this year (for the third year in a row) than any other university in the United States. The meeting gave students a chance to meet a commissioner of the Nuclear Regulatory Commission (NRC) and network with industry and government leaders. By the time they are ready for the job market, most of these students have not just a degree but contacts—and most get more than one offer.

Students at the Controls

There is a good reason for that. According to Retired Admiral Frank Bowman, who headed the Navy’s nuclear power program, American corporations and consortiums currently have 19 new nuclear power plants on the drawing board. At the same time, an aging workforce is driving tremendous demand for highly trained nuclear engineers.

With one of only nine undergraduate programs in the country, Rensselaer offers several programs and resources, both on and off campus, that uniquely equip students for the field. “We have a component in Malta Commons for naval personnel who are instructors at the nuclear Navy prototype facility,” explained Don Steiner, research professor in the department of mechanical, aerospace, and nuclear engineering (MANE).

“In the three years that students are stationed here,” they can earn a baccalaureate degree from Rensselaer—in nuclear engineering, engineering physics, or both,” added Michael Z. Podowski, academic director of the Malta Program. “Many will go on after their tour of duty to lucrative jobs in industry.”

The program also offers some exceptional hands-on opportunities that students can get at no other American university. At the Walthousen Lab, undergraduates run a functional, low-power fission reactor, which is set up and runs exactly like a commercial reactor. Unlike the reactors at other universities—which cost so much to run that the institutions have to sell time on them to large companies—this equipment is completely accessible, and safe, for students to use.

Rensselaer also owns an electron linear accelerator (LINAC), used to study the effects of different types of radiation on both organic and inorganic materials. Even first-year students can use the LINAC for undergraduate research; one junior undergrad received attribution on a paper in an international research journal as a result of his collaborative work.

According to Podowski, radiation-technology research using LINAC is one of the major departmental research thrusts in nuclear engineering; the others include advanced power reactor systems and biomedical applications of radiation.

Leading-Edge Research and Education

Of course, such unique facilities also attract an exceptional caliber of faculty. As director of the Center for Multiphase Research, Podowski heads a dynamic group of scientists and engineers dedicated to exploring and exploiting new developments in multiphase flow, with an eye to its transfer to industry.

Podowski is extremely optimistic about the recent resurgence of interest in nuclear power, citing a long-term Generation IV Reactor Initiative established by the Department of Energy (DOE), as well as the recent industrial action aimed at ordering new power reactors in the near future. He has received two DOE Generation IV grants and one NRC grant (totaling nearly $800,000) to develop advanced modeling and simulation capabilities for design and safety analysis of next-generation reactors. Anticipated future extensions of this program include very high-temperature gas-cooled reactors for hydrogen generation, and reactor physics and materials aspects of advanced reactors.

In the face of a strong nuclear marketplace, MANE continues to expand. The most recent department hire—Li (Emily) Liu, who comes to Rensselaer from MIT—has engaged in extensive research in both the NIST Center for Neutron Research and the Intense Pulsed Neutron Source of Argonne National Lab. Assuming the position of assistant professor, Liu said she was attracted to the program by its reputation, its people, and Rensselaer’s particle accelerator, which she will use to generate neutrons.

“The engineering program here is one of the best,” she noted. “Also, they didn’t have a specific person doing neutron scattering. So it’s a good fit for me and for them.”

With enthusiastic faculty, advanced research projects, and the sophisticated tools required to carry them out, it is hardly surprising that MANE produces exceptional nuclear engineers. As Steiner commented, “Their performance is quite extraordinary, year after year. Our faculty members are very proud of their students’ accomplishments. These young people inspire a great deal of confidence that the future of nuclear energy is in capable hands.”
Energy’s Future Happens Here
A new Rensselaer center explores the vanguard of a pressing global issue

Central lighting. Superconducting wires. Nanophosphors. For a place dedicated to conserving energy and to developing renewable energy resources, Rensselaer’s Center for Future Energy Systems is abuzz with it—in the form of ideas.

Lighting Gets Smarter
“The conventional wisdom is that improvements in lighting efficiency can only be incremental,” said Nag Patibandla, the center’s director. “But decades ago, researchers made the leap from incandescent to fluorescent. Where is the next logical step in the progression?”

The answer, according to Rensselaer researchers, is solid-state lighting—the use of light-emitting diodes (LEDs) that could be four times as efficient as compact fluorescents. In this research, the Center works closely with Rensselaer’s Future Chips Constellation, which recently received a $1.8 million grant from the U.S. Department of Energy (DOE) to improve the power and efficiency of green and deep green LEDs.

Those two colors represent the field’s current state of the art. DOE’s ultimate goal, however, is to create a white LED by 2025. “Right now we create white light by mixing colored LEDs,” Patibandla said. “But actually developing a white LED would greatly improve light quality and energy efficiency.”

Toward that end, the center is sponsoring research from the nano arena. Because LED technology relies on quantum-sized phosphor particles—and different particles produce different wavelengths—a research team is working to create particles that will generate white light.

The center-sponsored LED research could lead to all kinds of applications: in-wall lighting turned on by a simple touch, central remote controls for lighting (analogous to central air and central heating), advanced sensors, timers, and more.

How important is lighting to the total energy picture? “Twenty-five percent of the total energy use in the United States is used in lighting,” Patibandla said. “So any leaps forward in efficiency here would make a significant impact.”

Nag Patibandla, Research Professor and Director, Center for Future Energy Systems
Bandgaps Get Broader

Most people think of solar energy as energy-efficient. But how do you convert the sun’s rays effectively to electric current? Behind that question lies a specific problem that the center is actively investigating.

“In simple terms, only a small fraction of all the photons from sunlight will have the proper energy to generate electrons for electric current,” Patibandla explained. “The challenge, then, is to put as many of those photons to work as possible.”

Therein lies the problem with current materials, which have narrow bandgaps (the difference between the valence band and conduction band of energy values). The narrower the bandgap, the fewer the appropriate photons that the material can capture.

To overcome this problem, the center works with Rensselaer researchers who are striving to create higher-bandgap materials for microelectronic and nanoelectronic applications. “These same materials can use a much broader spectrum of the sun’s energy to generate electricity at much higher efficiencies than today’s photovoltaic materials,” Patibandla said. “When optimized, they will provide a sufficient number of free electrons to run solar-powered applications with acceptable levels of reliability.”

Distributing Generation

In tried-and-true electricity generation, where nearly all electricity is generated at a central plant, the voltage differential between plant and users carries the current forth. But what happens when generation is more broadly distributed?

Center researchers are working to understand the dynamics of current flow in that new landscape—and how to ensure reliable supply.

“Let’s say an industrial customer introduces a fault into the grid,” Patibandla said. “A photovoltaic or fuel cell system in a nearby building could interpret that as a power outage and shut itself off. We want distributed generation to work so that when all these devices are connected to the grid, that grid works at its current level of reliability or better.”

Finding the answer will soon be critical. Several alternative technologies lend themselves to generating energy closer to the user: think fuel cells and solar panels. The more that users themselves become generators, the more they will need a grid that adapts with them.

Toward Wires Without Resistance

What if someone created a wire with almost no resistance?

The answer would gladden the heart of large urban utilities. By using such wires to replace copper cables of the same size, they could increase transmission capacity by a factor of three to five. That, in turn, would enable them to keep up with today’s skyrocketing demand—without squeezing more cables into their tightly packed underground networks.

The center’s research into high-temperature superconductivity (HTS) aims at making just such a wire out of ceramic. The major challenge is that wires of this type are exceptionally difficult to manufacture; as part of resolving this challenge, the center’s research is currently focused on second generation, yttrium-based HTS materials. (A first-generation, bismuth-based HTS cable is currently being installed as part of a demonstration project in Albany, New York.) Patibandla and colleagues are also excited about the HTS cables’ potential bi-directionality—the ability to use the grid in either direction as a real long-term prospect. This property will become essential in a clean and renewable distributed-generation landscape.

…and Beyond

To say that the Center for Future Energy Systems is just getting started is true on several levels. Even beyond the current research, Patibandla is exploring relationships with industry and universities to explore a range of areas, from the use of carbon nanotubes for hydrogen storage to the conversion of corn stalks into biofuels.

“Anywhere we can contribute to the future of energy, we will seek to make that contribution,” Patibandla said. “Already we have brought together many institutions to create interesting synergies. The more synergies we create, the more potential solutions to benefit our world.”

Left: Rensselaer’s Future Chips Constellation received $1.8 million from the U.S. Department of Energy (DOE) to improve green and deep green LEDs. DOE’s ultimate goal: a white LED by 2025.

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