Featured Research

Energy and Power: Engineering Sustainable Solutions From the Macro to the Micro Levels

There is no shortage of energy being devoted to finding new and sustainable energy solutions. Even amidst the current economic challenges, the U.S. government is supporting these efforts with nearly a 50% increase in funding for energy-related research that includes energy efficiency and renewable energy, "smart" grid and efficient electrical transmission, green cars, and basic scientific research.

Energy research requires a multidisciplinary approach that involves basic science, technology, materials, systems, business, policy, and even politics. "If you're going to tackle problems as big as energy, it takes people from multiple disciplines to actually make any impact," stated Stephen Forrest, U-M's VP for Research, and William Gould Dow Collegiate Professor in the EECS Department. "The University of Michigan is one of the few places in the world where we have enough breadth to take on a sizeable chunk of this humanity-wide problem."

Faculty in the division of electrical and computer engineering are tackling the problem from many angles. On a systems-wide level, they are investigating ways to transfer wind- and solar-produced electricity into the nation's electrical power grid, and managing the burden on the grid that comes with the increased use of electric vehicles. They are also improving the technology of electric vehicles in partnership with the auto industry, improving the efficiency of the largest single user of electric power – white lighting, and they are exploring new materials to make solar energy a practical reality. Related efforts with far-reaching human and societal applications include turning naturally-occurring vibrations and movement into electricity.

Power Systems and the Smart Grid

Electric cars hitting the road in greater numbers, as well as new energy sources in the form of solar and wind power, will impact the nation's grid infrastructure in novel ways. It is a systems integration problem, and the specialty of Ian Hiskens, Vennema Professor of Engineering.

"The success of electric-powered vehicles will depend on solid, innovative science and technology that is tied to policy and market considerations," said Hiskens, who is working with the Michigan Public Service Commission to explore the widespread use of Plug-in HEV's in Michigan.

Hiskens is also working with the Department of Energy to develop new techniques for assessing the impact of wind generation on the grid system, specifically on power system voltage control and transient stability. He will initially focus on the power system in Michigan's "thumb" area, ideal because of its peninsula-like geography that is perfect for windy environments.

The current grid system doesn't allow for simple use of these new energy sources. New technologies need to be developed that will allow the grid to operate in a manner resembling the Internet. For example, with the Internet, if one link is congested with information, control loops redirect packets of information around the congested link. This is not possible with today's power grid.

"Right now the grid is either on or off," explains Hiskens. "We need to be able to add controllability through power-electronic devices – and better utilize existing assets to make the existing grid a truly 'smart' grid."

Hybrid electric vehicle testbed for enhancing fuel economy and drive quality.

Electric and Hybrid Electric Vehicle Technology

Hybrid electric vehicles, or HEV's (i.e., vehicles with an internal combustion engine, an electric motor, and a battery), plug-in HEV's, and all-electric vehicles are no longer cars of the future. They are making real inroads in the marketplace, and are among the alternative and advanced vehicles supported by the U.S. Government.

One of the all-electric cars on the road, the Tesla Roadster, contains a control algorithm designed by Prof. Heath Hofmann. The algorithm, which is part of the digital controller, impacts the propulsion drive for the vehicle, ensuring efficient and robust performance under a variety of driving conditions. Prof. Hofmann's research is in the area of power electronics and electromechanical systems, with an emphasis on energy-related applications. He has also worked with Pentadyne Power Corporation to develop an energy-efficient flywheel energy storage system, writing a control algorithm for an electric motor generator that converts kinetic energy in the flywheel into electrical energy.

Jessy Grizzle, Jerry W. and Carol L. Levin Professor of Engineering, has been working with Ford Motor Company more than two decades, most recently turning his "control" expertise to hybrid electric vehicles. Working with graduate student Dan Opila, he has recently found a way to significantly increase mileage while retaining a pleasant driving experience.

Training students to work in the new auto industry is one of the goals behind the formation of Grizzle's Hybrid Electric Vehicle Design and Test Team. These students are designing and testing a HEV with both Ford and General Motors that uses compressed air as its primary power source. Jeffrey Koncsol from General Motors Company said, "The energy, enthusiasm, and diversity of abilities that the team members bring to this project is remarkable. U-M is producing engineering teams that are capable of the innovation and implementation of sustainable technologies required in today's world."

Solid-State Lighting

White lighting is responsible for 20% of all the electricity used in homes and buildings, and therefore key to defining the nation's dependence on fossil fuel. Small improvements in lighting efficiency stand to significantly reduce our demand for electricity, and hence our dependence on fossil fuels.

Prof. Forrest has been working on this issue for decades. He is currently exploring technology using organic thin films based light-emitting diodes (or OLEDs) that is more efficient than the best fluorescent lighting solutions. "We have the efficiency and the color and the lifetime," explained Forrest, "but we can't yet do it cheaply enough to compete with regular light bulbs. But that may change in just a few years." Forrest has been involved in several energy- and lighting-related companies to further research in this area.

Similarly, Prof. P.C. Ku and his group are investigating inorganic light-emitting diodes (LEDs) for solid-state lighting. Ku is working to achieve high efficiency in both the component and the overall system. "There is as much as a 20-40% efficiency loss when a high-efficiency LED is placed into a light bulb," explained Ku. "We can improve on that."

Graduate student Celia Cunningham (left) discusses organic solar cell fabrication with undergraduate student Christine Austin. They are working on a new method of incorporating carbon nanotubes in organic solar cells in a project funded by the National Science Foundation and private industry.

New Materials and Solar Cells

Several ECE faculty are members of a new five-year, $19.6M, Energy Frontier Research Center, called Solar Energy Conversion in Complex Materials, led by Prof. Peter Green in the Department of Materials Science and Engineering. This center has the goal of developing a new generation of inexpensive materials that will convert solar energy and heat into electricity much more efficiently than is currently possible. Sponsored by the Department of Energy, the center includes 25 faculty from no fewer than 5 different departments at U-M, with faculty from ECE playing a prominent role.

"The challenge is to be competitive with fossil fuels, and to do that the process needs to be efficient, cheap, and lightweight so it can be deployed anywhere, even as a coating on windows," stated Prof. Forrest. Forrest has an active research program to create high-efficiency solar cells using alternative and potentially very low cost materials that are either organic or "conventional" III-V thin-film nanostructures. Currently, most solar cells on the market are silicon based, and while silicon is relatively inexpensive per unit volume, it takes a large quantity to generate the electricity needed.

Prof. Jamie Phillips and his students are investigating the use of inorganic materials, in particular II-VI compound semiconductors such as zinc telluride (ZnTe), to improve the efficiency of the energy conversion process through the use of intermediate electronic states within the bandgap. The intermediate states may be introduced via nanostructures or intentional impurities, providing multiple absorption bands and theoretical conversion efficiencies for a single-junction cell comparable to more costly and complex triple-junction devices. Promising results demonstrating the intermediate band concept have been achieved using oxygen-doped ZnTe.

Prof. Ku is also investigating the use of the inorganic materials to improve the efficiency of solar cells, beginning with indium gallium nitride. He hopes to explain the fundamental science behind the inefficiency of most quantum dot solar cells so that this weakness can be overcome.

Prof. Ted Norris, Director of the Center for Ultrafast Optical Science, is helping define the fundamental aspects of newly engineered materials using ultrafast laser technology. He measures the response of charge to excitation by photons at the femtosecond time frame, exploring the most basic properties of these interactions. This work has the potential to significantly improve the ability of materials to harvest solar energy, and convert it efficiently to usable electrical power.

Prof. Zhoahui Zhong is working with Norris to improve our fundamental knowledge of nanomaterials, such as carbon nanotubes, to improve solar cell efficiency.

Energy Scavenging and Power Generation

Researchers are shrinking the size of microsystems to such a degree that powering them by batteries has become impractical. Energy-harvesting systems offer an alternative source of power for many emerging applications of miniature instruments used in health care, environmental monitoring, security, energy conservation and exploration, and a myriad of consumer electronic devices. The energy may be harvested from vibration, light, RF signals, and heat sources available in the immediate surroundings through piezoelectric, electromagnetic, or thermoelectric techniques.

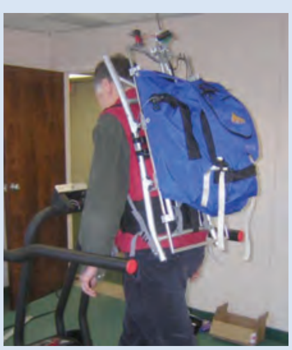
In one project, Khalil Najafi, Schlumberger Professor of Engineering and Chair of ECE, has designed an efficient energy scavenger for converting ambient low-frequency vibrations into electrical power. The goal is to allow networks of miniature environmental sensors distributed throughout an area to monitor the environment for long periods, powered only by naturally-occurring vibrations such as those on buildings, bridges, and other physical infrastructure.

Miniature power generator

Prof. Hofmann works on power electronic circuitry that interfaces with similar devices to extract the most power available from the system. He is investigating human-based energy harvesting by connecting an energy converter to a backpack equipped with springs, giving a Marine in the field, for example, virtually an endless supply of electricity.

Moving Forward in Energy and Power

Powering the way we live while sustaining a world that is clean and safe will require the ingenuity and expertise of countless engineers to create and refine new technology – as well as committed teamwork between researchers, industry, business, and political leaders. EECS faculty and students are making important and lasting contributions to this important goal.



Energy-producing backpacks have been marketed by Lightning Pack, LLC, based on technology developed by Heath Hofmann and Prof. Lawrence Rowe (U. Pennsylvania).

U-M Solar Car Team

No Michigan story about solar energy can be complete without mentioning the heroic efforts of the College of Engineering's primarily undergraduate student team, the Solar Car Team. Since this team has been building cars from scratch for the first American Solar Challenge in 1990, they have won 5 out of 9 races, and continue to incorporate new methods of solar technology in their cars. Recently, the team crossed the finish line to capture 3rd place for the fourth time in the World Solar Challenge, now part of the Global Green Challenge. EECS students always figure prominently in the makeup of the Solar Car team.

planet blue
UofM environmental & energy initiative

EECS has partnered with Planet Blue, whose mission is to reduce utility use and increase recycling within the U-M community. There is much at stake: the electricity used to power all of the PCs and monitors in the U.S. has a carbon equivalent of more than 41 million acres of pine forests, and most computers waste 50% of the power they consume. U-M is doing its part in stocking recyclable office supplies, making it easy to recycle, working with green-friendly vendors, and educating the community about how to conserve energy.

EECS Faculty Mentioned in the Article:

Stephen Forrest	Heath Hofmann	Ted Norris
Jessy Grizzle	P.C. Ku	Jamie Phillips
Ian Hiskens	Khalil Najafi	Zhaohui Zhong

Courses in Energy and Power Systems:

- Electric Machinery and Drives
- Grid Integration of Alternative Energy Sources
- Power System Analysis and Design
- Power Electronics
- Solid-State Lighting and Solar Cells
- Special Topics in Electric Power Systems Operation, Markets, Reliability, and Blackouts
- Electric Machinery and Drives

New courses in the area of transportation electrification being developed

Undergraduate concentration in energy being developed

Related Courses in Energy and Power Systems:

- Nanophotonics and Nanofabrication
- Semiconductor Optoelectronic Devices
- Semiconductor Lasers and LEDs
- Ultrafast Optics