

## Overview of Hydrogen Energy Activities at Penn State

Penn State researchers are leading the way in developing hydrogen energy and fuel cell technologies. Their research on hydrogen production, storage, fuel cell technologies, and the demonstration of these technologies, will enhance the growth of a new hydrogen based economy in Pennsylvania and the USA. Penn State recently formed the **Hydrogen Energy (H<sub>2</sub>E) Center** to serve as a focal point for multi-investigator activities at Penn State in the various colleges, centers, and institutes on hydrogen production, storage and utilization systems. The H<sub>2</sub>E Center will:

- Facilitate the development of all types of hydrogen-based technologies
- Promote the use of hydrogen for sustainable energy production
- Develop coupled biological hydrogen production and fuel cell systems for complete conversion of biomass sources to energy
- Pioneer new hydrogen storage technologies
- Identify new uses of hydrogen for environmental remediation.

Over two years ago the COE Environmental Institute (EI) identified hydrogen energy research as an area of existing strength across many of the college's departments. Major centers of ongoing activities in different departments and institutes were identified, such as the Energy Institutes work in clean fuels. Other areas of focused activity included The Pennsylvania Transportation Institute (PTI) Hybrid Electric Vehicle (HEV) Laboratory that provides students hands-on experience in building HEVs. PTI's Graduate Automotive Technology Education (GATE) program studies advanced energy storage technologies for the development of clean, ultra fuel-efficient vehicles. The Electrochemical Engine Center (ECEC) conducts fundamental and applied research on fuel cells for electric propulsion, stationary power generation and portable electronics applications. With the creation of the H<sub>2</sub>E Center, currently under the direction of Professor Bruce Logan, these various group were able to come together to collectively tackle the larger technological issues associated with the development of a hydrogen economy.

Almost 40 Penn State faculty members are currently affiliated with the H<sub>2</sub>E Center. The following list summarizes examples of ongoing research activities at the University that form the multi-disciplinary backbone of Penn State's hydrogen energy program:

### Hydrogen Production Technologies

- **Biological production of hydrogen via fermentation processes**
  - Bruce Logan, Kappe Professor of Environmental Engineering
  - Mary Ann Bruns, Assistant Professor of Agronomy/Soil Microbial Ecology
- **Enhancing the production of hydrogen from fermentation routes through genetic engineering**
  - John Regan, Assistant Professor of Civil and Environmental Engineering
  - Mark Gultinan, Professor of Plant Molecular Biology
  - Bruce Logan, Kappe Professor of Environmental Engineering
- **Production of hydrogen from fossil fuels**
  - Robert J. Santoro, Distinguished Professor of Mechanical Engineering
- **Production of ultra-pure hydrogen through catalytic reforming**

- Chunshan Song, Associate Professor of Fuel Science
- **Water splitting using nano-structured catalysts**
  - Thomas Mallouk, Dupont Professor of Chemistry
- **Electrolysis in the area of charge transfer in the hydrogen electrode reaction and the oxygen electrode reaction at electro catalyst surfaces**
  - Digby D. Macdonald, Distinguished Professor of Materials Science and Engineering

### **Catalysts and Membranes**

- **Using combinatorial chemistry, and related high throughput methods, to find improved fuel cell catalysts**
  - Thomas Mallouk, Dupont Professor of Chemistry
- **New proton exchange membranes for fuel cells to improve proton conductivity, electro-osmotic drag water, thermal stability, and mechanical strength**
  - Harry Allcock, Evan Pugh Professor of Chemistry
  - Serguei Lvov, Associate Professor Energy & Geo-Environmental Engineering

### **Fuel Cell Structure and Operation**

- **Methanol fuel cell technologies and methods to increase fuel cell efficiency**
  - Chao-Yang Wang, Professor of Mechanical Engineering and Director, Electrochemical Engine Center (ECEC)
- **Improving fuel cells through the development of monitoring and new diagnostic tools**
  - Matthew Mench, Assistant Professor of Mechanical Engineering and Associate Director of ECEC
- **Producing electricity from wastewater using microbial fuel cells**
  - Bruce Logan, Kappe Professor of Environmental Engineering
  - Thomas Mallouk, Dupont Professor of Chemistry

### **Hydrogen Storage and Safety**

- **Hydrogen storage in carbon nanotubes**
  - Peter Eklund, Professor of Physics and Professor of Materials Science & Engineering
- **Novel, high yield fabrication process capable of generating in large quantities a multi-walled carbon nanotube based storage system**
  - Vijay Varadan, Distinguished Alumni Professor of the Department of Engineering Science and Mechanics
- **Development of new hydrogen monitors and sensors**
  - Mark Horn, Associate Professor, Engineering Science & Mechanics
  - Robert McGrath, Associate Vice President of Research
  - Vijay Varadan Distinguished Alumni Professor of the Department of Engineering Science and Mechanics

### **Demonstration of Technologies**

- **Development of a hydrogen fueling station in collaboration with Air Products and through a grant from the Department of Energy**
  - Bohdan T. Kulakowski, Professor of Mechanical Engineering

## **Education and Outreach**

- The Hydrogen Energy Center
  - Bruce Logan, Director H<sub>2</sub>E Center, and Kappe Professor of Environmental Engineering

Through the coordination provided by the H<sub>2</sub>E Center and the University's strong history of focusing on cutting edge energy-related research, Penn State will continue to be a leader in the research and development of technologies that will move us more rapidly towards a global hydrogen economy.