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News From Argonne's Transportation Technology R&D Center

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VIEWPOINT

DOE Officials Visit Argonne's Transportation Facilities

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Argonne Expert Addresses Energy and Environmental Impacts of Fuel Ethanol

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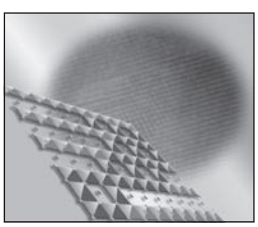

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Argonne's "Composite-Structure" Electrodes Promise to Enable the Switch to Lithium-Ion Batteries in Hybrids

Skyrocketing fuel prices have prompted automakers to begin adding fuel-saving hybrid-electric vehicles to their product lines, bringing lithium battery makers from around the globe to Argonne's door to learn about Argonne's newly patented manganese-based "composite-structure" electrode materials. The new materials would eliminate the need for lithium cobalt oxide electrodes, thus enabling rechargeable lithium-ion batteries that are much cheaper, safer, and more stable. ***Page 5***

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University of Waterloo Students Win First-Year Challenge X Competition

Students from the University of Waterloo took top honors at the first-year *Challenge X: Crossover to Sustainable Mobility* engineering competition, held June 5–8 at GM University in Auburn Hills, Michigan. General Motors, the U.S. Department of Energy, and Argonne sponsored the event, which challenged 17 universities from across North America to create a virtual advanced propulsion technology vehicle solution with the goal of improving on-road fuel economy and reducing emissions. ***Page 6***

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THE UNIVERSITY OF CHICAGO

DOE Officials Visit Argonne's Transportation Facilities

Secretary of Energy Samuel Bodman and Office of Science Director Ray Orbach visited Argonne's Advanced Powertrain Research Facility on May 6, 2005, after participating in a ceremony at the Laboratory's Center for Nanoscale Materials, which is currently under construction.

The centerpiece of Argonne's transportation research activities, the Advanced Powertrain Research Facility is the nation's premier hybrid vehicle test laboratory, where the latest equipment and state-of-the-art transportation technology come together for development.

Energy Secretary Samuel L. Bodman (right) tours the Advanced Powertrain Research Facility with Larry Johnson, director of Argonne's Transportation R&D Center. Johnson describes MATT HIL, Argonne's Mobile Automotive Technology Testbed Hardware-in-the-Loop.

Bob Larsen, Director of Argonne's Center for Transportation Research, noted that Secretary Bodman aims to establish a stronger link between basic and applied science. "That bodes well for our work," Larsen remarked. "We're devoting ourselves to technologies that benefit the nation."

During the visit, Bodman rode in a Ford Hybrid Escape while mechanical engineer Michael Duoba ran the truck on Argonne's four-wheel-drive dynamometer. Throughout the drive, details of the vehicle's hybrid operation could be observed in real time on a monitor as engine emissions and fuel economy data were collected.

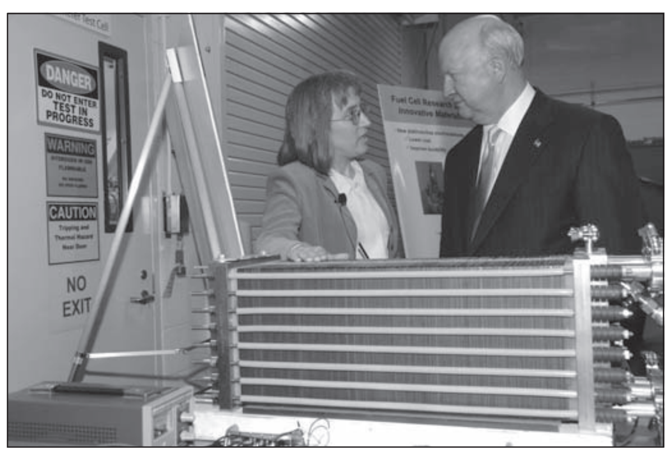
Bodman and Orbach were each presented with an Advanced Test Vehicle Driver's License by Transportation Technology R&D Center Director Larry Johnson.

While in the APRF test cell, the guests witnessed the following equipment at work:

- The nation's first hydrogen-capable four-wheel-drive dynamometer that can test diesel, gasoline, and electric vehicles up to 14,000 pounds;
- An extensive data acquisition system designed exclusively for testing fuel cell, hydrogen, hybrid electric, and electric vehicles; and
- One of the world's most precise emissions testing systems for gasoline, alternative fuels, and diesel-powered vehicles, with the capability to measure exhaust emissions from "super-ultra-low" emissions vehicles (SULEV).

Engineer Steve Ciatti exhibited some of Argonne's recent advances in understanding diesel combustion. Using sophisticated tools, including a visioscope, thermophoretic sampling, and transmission electron microscopy, Argonne scientists explore engine combustion to improve efficiency and reduce emissions. Ciatti demonstrated Argonne's ability to perform real-time imaging of a 1.9-L Mercedes diesel engine. Researchers can see soot as it forms and decomposes during combustion. Argonne researchers pioneered the use of x-ray beams to penetrate diesel engine fuel injector sprays to improve combustion. The Transportation Technology R&D Center is working to develop cleaner and more efficient diesels to cut down on fuel imports and to further clean exhaust from these engines. Diesels are popular for use in automobiles in other countries and in power construction equipment, semi-trucks, and trains.

Chemist Deborah Myers explained Argonne's role in developing new materials for fuel cells to Bodman and Orbach. Argonne researchers, including Myers, are working on many aspects of fuel cells to reduce costs and improve performance,



Secretary Bodman listens to chemist Deborah Myers explain Argonne's fuel-cell research in front of a 30-kW polymer electrolyte fuel-cell stack.

which will speed the development of fuel cells for stationary and transportation applications. Argonne is also working on low-cost catalysts to replace the expensive platinum currently used in polymer electrolyte fuel cells for automotive propulsion power. Argonne is developing polymer electrolyte membranes to operate at higher temperatures and under low-humidity conditions to reduce system cost, size, and complexity. The Laboratory is also developing a new design and fabrication process for solid oxide fuel cells that addresses the main issues facing the use of these cells (cost and durability), especially for portable applications. This novel design, dubbed "TuffCell," supports the cell on a rugged, inexpensive metal, rather than a brittle, expensive ceramic, and incorporates sealing of the fuel chamber into the single-cell fabrication process. The TuffCell design lowers the stack cost and improves the mechanical strength, thermal cyclability, and seal durability.

Funding of Argonne's transportation research and development work comes primarily from two programs in the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy: the FreedomCAR and Vehicle Technologies Program and the Hydrogen, Fuel Cells & Infrastructure Technologies Program.

Johnson described Argonne's transportation research program as the most varied in the national laboratory system, adding that "being in the Midwest, we are ideally located to work closely with the auto manufacturers, truck engine manufacturers, and the supplier industry."

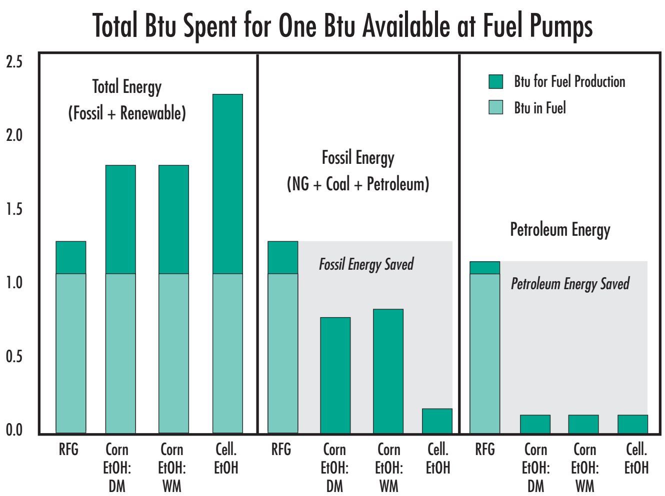
RESEARCH REVIEW

Argonne Expert Addresses Energy and Environmental Impacts of Fuel Ethanol

Although the United States used 3.4 billion gallons of fuel ethanol for blending with gasoline in transportation fuels in 2004 — virtually all of it produced from corn — the energy and environmental effects of using corn-based ethanol have nonetheless been questioned. A few researchers maintain that corn-based ethanol has a negative energy balance (which means that more fossil energy is required to produce ethanol than the amount of energy in the produced ethanol) and results in increased greenhouse gas (GHG) emissions relative to petroleum-based gasoline.

Since 1997, researchers in the Center for Transportation Research (CTR) at Argonne have been studying the energy and GHG emission impacts of fuel ethanol as part of their overall efforts to evaluate the well-to-wheels energy and emission effects of various advanced vehicle technologies and transportation fuels. They use the Greenhouse gases, Regulated Emissions and Energy use in Transportation (GREET) model, developed by CTR researcher Michael Wang. This peer-reviewed model employs the most current and accurate data to conduct life-cycle analysis for more than 100 vehicle-fuel pathways (see http://greet.anl.gov).

The results of Argonne's ethanol analysis — like those of many other recently completed ethanol studies — reveal that corn-based ethanol achieves energy and GHG emission-reduction benefits relative to gasoline. In fact, Wang and his colleagues concluded that corn ethanol requires 26% less fossil energy because it contains "free" solar energy that ends up in the corn. The fuel's energy and environmental benefits accrue primarily because of (1) improved productivity by U.S. corn farmers in the past 30 years, (2) reduced energy use in ethanol plants over the past 15 years, and (3) appropriate treatment of ethanol's co-products in the analysis.



The energy benefits of fuel ethanol result from reduced fossil energy and petroleum use during production and the absence of fossil and petroleum in the final product.

Wang, who is a leading worldwide expert in this field, presented the overall results of his research at the Ethanol Energy Open Forum, sponsored by the National Corn Growers Association, at the National Press Club in Washington, D.C., on August 23, 2005.

> "In summary, bioethanol may play an important role in replacing petroleum use and reducing greenhouse gas emissions by motor vehicles,"
>
> *Michael Wang*

Conclusions from Wang's presentation include the following:

- Energy balance value alone is not meaningful in evaluating the benefit of ethanol or any other energy product. For proper evaluation, a product's energy use must be compared with that of the product it replaces.
- Compared to gasoline, any type of fuel ethanol helps substantially reduce fossil energy and petroleum use.
- Ethanol produced from corn can achieve moderate reductions in GHG emissions.
- Ethanol produced from "cellulosic" plants such as grass and weeds offers even greater energy and GHG emission-reduction benefits than does corn-based ethanol. In fact, cellulosic-biomass-based ethanol reduces fossil energy use by 90%. GREET also showed that cellulosic ethanol offers an 85% reduction in GHG emissions on a per gallon basis.

The consensus of analyses by Wang and many researchers supports the premise that corn ethanol can supply some of our motor fuel needs now, and cellulosic ethanol can provide a greater portion in the future. Currently, 88 ethanol plants operate in the United States, with 16 more being built. Approximately 50 to 70 new plants are anticipated to open by 2012, according to industry observers.

The growth in ethanol use is being aided by energy legislation recently adopted in the United States that will require fuel ethanol use of 7.5 billion gallons annually by 2012. The legislation contains provisions to encourage production of cellulosic ethanol. Argonne's fuel ethanol analyses have been supported by the U.S. Department of Energy's Office of Planning, Budget, and Analysis (PBA) and Biomass Program, which are both part of the Office of Energy Efficency and Renewable Energy.

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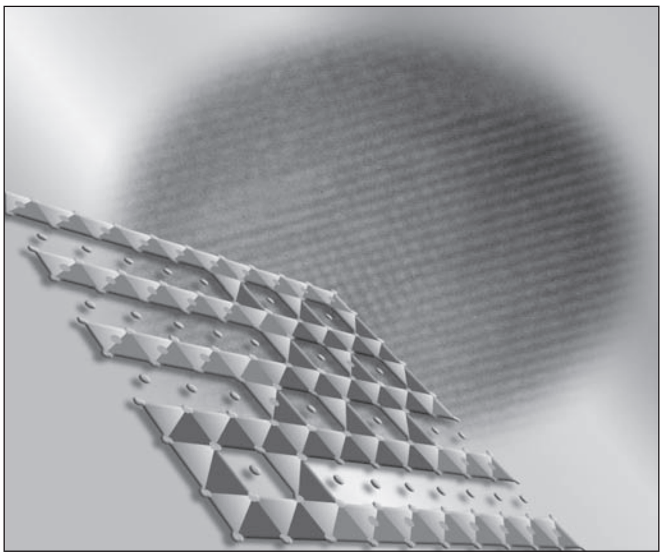
Argonne's 'Composite-Structure' Electrodes Promise to Enable the Switch to Lithium-Ion Batteries in Hybrids

Skyrocketing fuel prices have prompted automakers to begin adding fuel-saving hybrid-electric vehicles (HEVs) to their product lines, thereby creating a burgeoning demand for the nickel-metal-hydride (NiMH) batteries these vehicles require. This, in turn, has prompted battery makers to look into ways of replacing the NiMH batteries with lithium-ion batteries. The reason is that "lithium-ion batteries would allow them to put more energy into the same size package for less money," says Gary Henriksen, manager of the Chemical Engineering Division's Battery Department at Argonne.



High-resolution transmission electron micrograph (TEM) (in background) and schematic illustration of a composite "layered-spinel" lithium-manganese-oxide electrode structure.

Despite their promise, current lithium-ion batteries are plagued by several problems of their own, including safety issues, rising cost, and limited calendar life. As it happens, all three of these problems stem largely from the current reliance on lithium cobalt oxide as an electrode material. The effort to address these problems has brought lithium battery makers from around the globe to Argonne's door, to learn about Argonne's newly patented manganese-based "composite-structure" family of electrode materials. The new materials, which can be tailored to various applications, would eliminate the need for lithium cobalt oxide electrodes, thus enabling rechargeable lithium-ion batteries that are much cheaper, safer, and more stable. Also, some versions of these new materials could significantly increase the energy capacity of current lithium batteries. This new family of cathode materials is already starting to replace conventional materials in lithium batteries for consumer electronics applications.

"The composite structures of the high-capacity manganese-rich electrodes have a Li_2MnO_3 layered component that is structurally integrated with either a layered $LiMO_2$ component or a spinel LiM_2O_4 component — the 'M' in either case is typically Mn or Ni," explains Michael Thackeray, a senior scientist and the group leader responsible for materials development in the Battery Department. The strategy being adopted is to use the layered component predominantly to provide increased energy capacity and the spinel component to provide high power. "We are trying to integrate these two types of structures to achieve the best of both worlds," Thackeray adds.

What constitutes the best of both worlds will depend on the type of hybrid being targeted. The HEVs that have already been commercialized vary in their degree of hybridization; that is, Toyota's Prius and Honda's Insight require more onboard energy storage than the so-called "mild" hybrids, such as Honda's Civic. However, they all use rechargeable batteries primarily for leveling the load on the internal combustion engine (ICE) and for capturing energy associated with regenerative braking.

If fuel prices continue to rise, automakers may be led to consider introducing "plug-in" hybrids, which possess sufficient battery power and energy to provide a limited range capability while operating only on battery power, without the ICE. For longer-range trips, the ICE would be used in combination with the battery, much like the conventional HEV. Batteries in this type of HEV could be recharged from the electric power grid while the vehicles aren't in use, particularly during off-peak periods at night when energy demand is low. This would allow various types of electrical power generation, rather than gasoline, to be used as the "fuel" for the vehicles during local commutes. This type of HEV requires a battery not only with more power but also with considerably more energy. This is where ANL's high-capacity cathode materials come in; they would provide maximum benefit in terms of allowing a greater range capability on battery power.

The design and selection of electrode and electrolyte materials that will continue to improve the performance of state-of-the-art HEVs will challenge Argonne's lithium battery researchers in the years to come.

Argonne's battery research is funded by the U.S. Department of Energy's Office of Basic Energy Sciences and FreedomCAR and Vehicle Technologies Program.

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University of Waterloo Students Win First-Year Challenge X Competition

Students from the University of Waterloo, located in Ontario, Canada, took top honors at the first-year *Challenge X: Crossover to Sustainable Mobility* engineering competition, held June 5–8 at GM University in Auburn Hills, Michigan. General Motors (GM), the U.S. Department of Energy (DOE), and Argonne sponsored the event, which challenged 17 universities from across North America to create a virtual advanced propulsion technology vehicle solution with the goal of improving on-road fuel economy and reducing emissions.

The Waterloo team designed a series fuel cell hybrid that uses a Hydrogenics polymer electrolyte membrane (PEM) fuel-cell engine with a COBASYS 288-volt nickel-metal-hydride (NiMH) battery and a Ballard 54-kilowatt electric drive.

The second-place advanced propulsion technology solution, designed by students at the University of Akron, is a through-the-road parallel hybrid with a 1.9-liter Volkswagen turbo direct-injection (TDI) engine that runs on biodiesel fuel, a DSG transmission, and a Ballard 65/45-kilowatt drive motor. The Ohio State University team was awarded third place overall for their design, a through-the-road parallel biodiesel hybrid that uses an EV-1 electric drivetrain, a Panasonic NiMH battery, and a 1.9-liter Fiat 110-kilowatt compression-ignition, direct-injection (CIDI) engine with an integrated starter/alternator and an automatic transmission.

“Developing the advanced technologies that reduce U.S. dependence on imported oil is critical to the future prosperity of our country. Challenge X shows that the cooperation of industry, government, and academia is an excellent approach to developing more energy-efficient and ‘greener’ automotive technologies,” said Ed Wall, Program Manager for the FreedomCAR and Vehicle Technologies Office of DOE’s Office of Energy Efficiency and Renewable Energy.

“You are working on the same challenges that our GM engineers continually work on every day — high-efficiency, high-performance vehicles that consume less fuel and produce fewer emissions from the well to the wheel,” Larry Burns, Vice President of GM’s Research and Development and Planning, told the students. “This hands-on learning will provide you an unparalleled experience that will enable you to embark on a career in engineering with a competitive advantage.”

All 17 teams met the minimum Challenge X goals during the first year of the competition, and each team received the keys to a 2005 Chevrolet Equinox on June 9.

The three-year program follows GM’s Global Vehicle Development Process. Year 1 focused on vehicle simulation and modeling and subsystem development and testing, introducing the students to the engineering tradeoffs that occur in the early stages of vehicle design. In Years 2 and 3, students will integrate their advanced powertrains and subsystems into the Chevrolet Equinox, a compact sport-utility vehicle (SUV) that already provides competitive fuel economy. Competitions will be held at the end of the 2006 and 2007 academic years to showcase the teams’ learning and vehicle development from year to year.

“The impressive applied technologies that I have seen have come from students’ creativity and design,” said Steve Gurski, lead technical coordinator of the Challenge X program at Argonne. “In the past,” Gurski said, “students had one year to make significant improvements on the vehicles once the competition was over. What we expect to see in three years of refinement are some fantastic vehicles.”

For more information about Challenge X, go to www.challengex.org or contact

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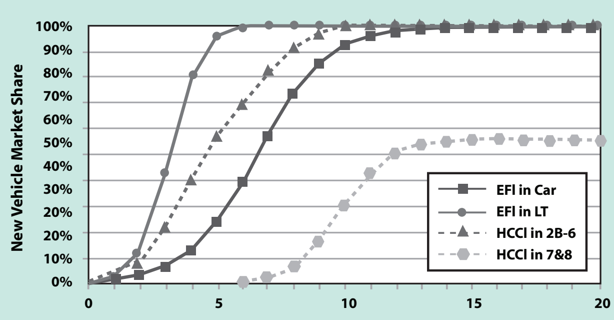
Correction

A chart included in the Spring 2005 issue of TransForum in the article entitled “Argonne is Part of a Team Selected to Develop Advanced Combustion Technology for Vehicles” contained an error. The labels “EFI in Car,” “EFI in LT,” and “HCCI in Class 2B-6” were interchanged. The corrected chart is provided below. We regret the error.



Prior analogous technology (electronic fuel injection) and illustrative projected HCCI introduction paths (estimated year of introduction in the ITEC engine manufacturing plant is 2010 — “year 1”)

Dileep Singh and **Jules Routbort,** both of Argonne's Energy Technology Division, along with researchers at The Ohio State University, received a 2005 R&D 100 award, given annually by *R&D Magazine* to the 100 most significant technical products of the year. They have developed a compact sensor to monitor combustion processes in coal-fired power plants, petrochemical plants, blast furnaces, glass processing equipment, and even internal combustion engines. Because the sensor can withstand high temperatures (up to 1,600°C), it can monitor in real time, providing performance information that is important to manufacturers seeking to increase energy savings and efficiency. The new oxygen sensor technology allows for very small sensors — smaller than a dime — because no external air source or plumbing is required, and it provides unsurpassed oxygen-sensing accuracy for a cost that is approximately one-twentieth that of conventional oxygen sensors. The oxygen sensor development was sponsored by DOE's Office of Energy Efficiency and Renewable Energy, FreedomCar and Vehicle Technologies Program.

The bion® microstimulator — a miniature, rechargeable, implantable neurostimulator trademarked and manufactured by Advanced Bionics Corporation — also received a 2005 R&D 100 Award. Argonne's researchers on the project, **Khalil Amine, Bookeun Oh, Ilias Belharouak, Qingzheng Wang,** and **Donald Vissers** of the Chemical Engineering Division, were primarily involved in developing the battery chemistry and materials for the bion®. The key to the battery's success is an advanced lithium-ion chemistry that provides a calendar life significantly greater than that of commercially available lithium batteries. The battery technology was developed under Argonne's hybrid electric vehicle battery development program, funded by DOE's FreedomCAR and Vehicle Technologies Program.

Argonne's Materials Science Division Director **George Crabtree** testified before the House Subcommittees on Energy and Research on July 20, sharing his thoughts on the research needed to usher in a hydrogen economy to reduce the nation's dependence on foreign energy sources. Crabtree met with 13th District U.S. Rep. Judy Biggert, who chairs the Science Subcommittee on Energy, and other members of the committees to discuss the revolutionary breakthroughs that are needed to overcome the challenges we face in establishing a hydrogen economy: production of hydrogen by splitting water renewably, storage of hydrogen at high density with fast release times, and improved catalysts and membranes for fuel cells. Argonne and other national laboratories are seeking solutions to all of these issues, with funding support from DOE's Energy Efficiency and Renewable Energy; Nuclear Energy, Science and Technology; Fossil Energy, and Science Offices.

Steve Plotkin, of Argonne's Center for Transportation Research, received the Barry D. McNutt Award for Excellence in Automotive Policy Analysis from the Society of Automotive Engineers (SAE) at the SAE International 2005 Government/Industry Meeting held May 9–11 in Washington, D.C. This award recognizes an individual or team of individuals for an outstanding contribution to the development of efficient and effective federal policies for the automotive sector. The award recognizes Plotkin's recent work on advanced automotive technology, greenhouse gas reduction strategies, and automotive fuel economy policy. Said Plotkin, "This award means a great deal to me. Barry [McNutt] was a superb analyst, a passionate believer in getting things right, and a wonderful friend and colleague [and] so receiving an award honoring his memory is a great privilege. And getting an award from my peers is worth much more to me than a raise or a promotion — it feels like an affirmation of my career."

Michael Thackeray, of Argonne's Chemical Engineering Division, will receive the 2005 Research Award from the Battery Division of the Electrochemical Society during the Battery Division Luncheon and Business Meeting in October. The award was established in 1958 to recognize outstanding contributions to the science and technology of primary and secondary cells and batteries and fuel cells. Thackeray's research has focused on the structural and electrochemical characterization of silver-iodide-based solid electrolytes; the design of several transition-metal oxides, particularly manganese oxides for rechargeable lithium battery applications; and a new class of intermetallic negative electrodes that operate by reversible lithium insertion/metal displacement reactions. He has more than 160 research publications and holds 24 patents, some of which have led to the international commercialization of battery materials. Earlier this year, Thackeray was recognized on the commemorative wall at Africa's first internationally accredited science park — The Innovation Hub, South Africa — for contributions as a South African to world science and technology.

Marianne Mintz and **Michael Wang,** of Argonne's Center for Transportation Research, along with other team members, received the 2005 DOE Hydrogen Program Award for Excellence in R&D in May. The team of scientists and engineers was recognized for advancing the analysis capabilities of hydrogen production and distribution. Their efforts resulted in an H2A model that provides a clear and transparent methodology, enabling DOE to evaluate various technology options for producing and delivering hydrogen and make decisions in an unbiased manner. "It is especially gratifying to be recognized for our work — not just because of the usefulness of the tool that has been developed but also because the project gave us the opportunity to work with a diverse and dedicated group of professionals," notes Mintz. "The group includes members of the H2A team who shared this award with us, the industrial collaborators who provided their time and expertise, and our DOE sponsors."

Industrial technology development is an important way for the national laboratories to transfer the benefits of publicly funded research to industry to help strengthen the nation's technology base. The stories highlighted in this issue of *TransForum* represent some of the ways Argonne works with the transportation industry to improve processes, create products and markets, and lead the way to cost-effective transportation solutions, which in turn lead to a healthier economic future.

By working with Argonne through various types of cost-sharing arrangements, companies can jump-start their efforts to develop the next generation of transportation technologies without shouldering the often-prohibitive cost of initial R&D alone. Argonne has participated in dozens of these partnerships and has even been involved in helping to launch start-up companies based on the products and technologies developed here.

If working with world-class scientists and engineers, having access to state-of-the-art user facilities and resources, and leveraging your company's own capabilities sound like good business opportunities to you, please contact our Office of Technology Transfer and see how we can put our resources to work for you.

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