

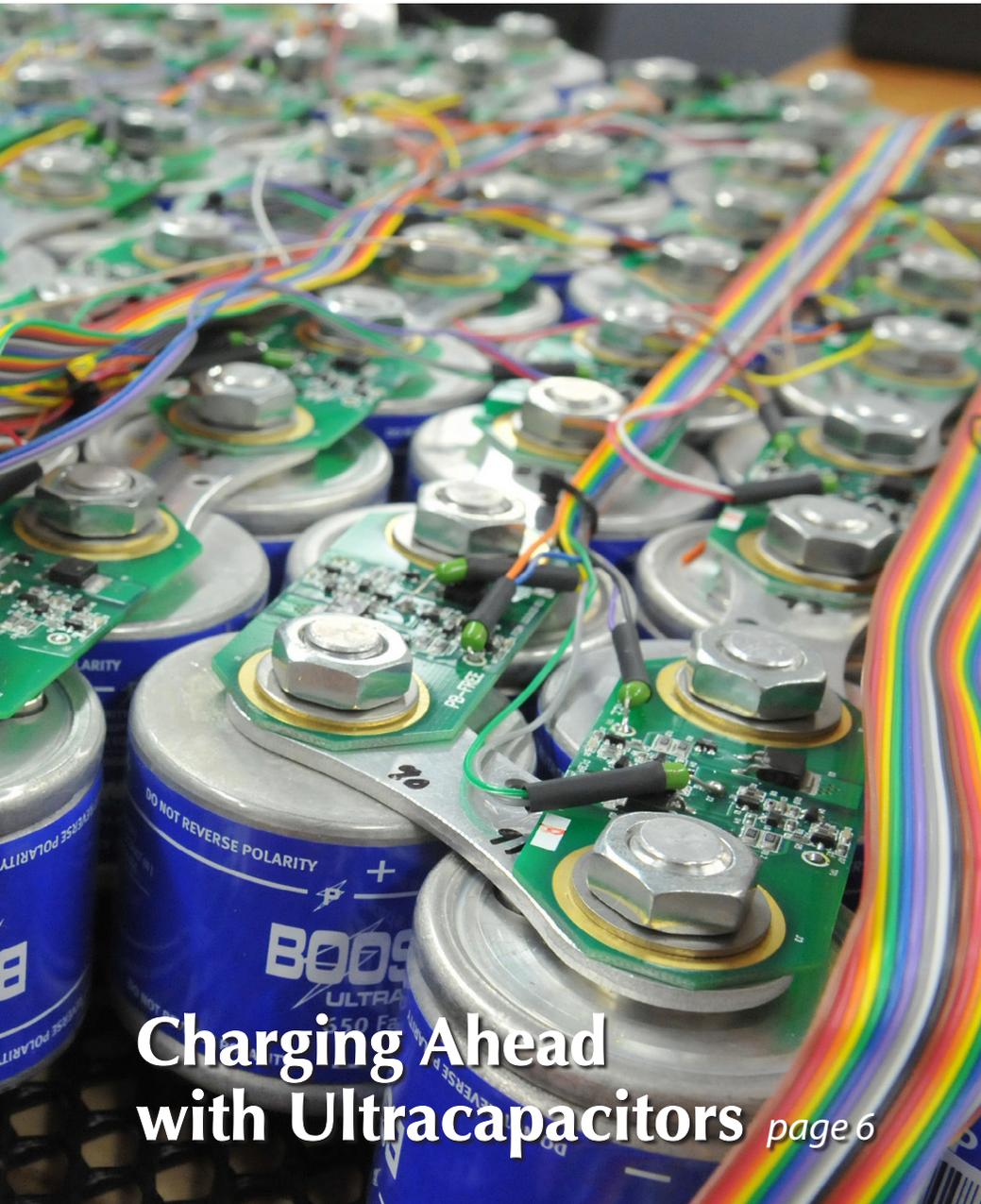
TransForum

News From Argonne's Transportation Technology R&D Center
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**Charging Ahead
with Ultracapacitors** *page 6*

Argonne Receives R&D 100 Award for Superhard and Slick Coating

Senior scientist Ali Erdemir and materials scientist Osman Eryilmaz of Argonne National Laboratory won a R&D 100 Award for their work on a superhard and slick coating (SSC).

In laboratory and engine tests, the SSC reduced friction by 80 percent when compared to uncoated steel. It eliminated virtually all wear under severe boundary lubricated sliding regimes.

The ingredients used to create the award-winning designer nanocomposite coating were predicted by a crystal-chemical model proposed by these Argonne researchers. Among the many possible materials, the model predicted that molybdenum and copper are the most promising candidates due to their very high combined ionic potentials. The other preferable combinations included molybdenum-silver, molybdenum-antimony, molybdenum-tin and molybdenum-mixed alloys of copper, silver, tin and antimony.



Ali Erdemir (left), student Guldem Kartal and Osman Eryilmaz load engine components into the deposition system used to coat samples with Argonne's SSC. Photo by Robert Erck.

SSCs Reduce Emissions and Improve Fuel Economy

SSCs can improve the performance and energy efficiency of all kinds of moving mechanical systems, including automotive engines and other components used in manufacturing. Friction, wear and lubrication strongly affect the energy efficiency, durability and environmental compatibility of such systems.

The SSC reduced friction by 80 percent when compared to uncoated steel.

Because SSCs reduce friction significantly, efficiency is improved, yielding higher fuel economy which lowers emissions.

“This new SSC, with its self-lubricating and low-friction characteristics, can help to increase the fuel economy of next-generation engines,” said Erdemir. “Superhard and slick coatings will help to reduce our dependence on imported oil and improve environmental quality.”

Team Members

The SSC was jointly developed with a team from Istanbul Technical University that included professors Mustafa Urgan and A. Fuat Cakir, associate professor Kursat Kazmanli and assistant professor Ozgul Keles.

Galleon International Co., Brighton, Mich. and Hauzer Technocoating, The Netherlands, are exploring market applications for the technology. The Galleon team includes Mark Dorbeck, David Parson and Frank Sykora. The Hauzer team includes Chief Executive Officer Thomas Krug, Process Engineering Manager Roel Tietema and Engineer Ruud Jacobs.

Funding for the SSC project was provided by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, Vehicle Technologies Program.

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Argonne to Explore Lithium-air Battery

Argonne National Laboratory will begin exploring lithium-air (Li-air) batteries that have the capacity to store up to five to 10 times the energy of lithium-ion (Li-ion) batteries, or almost as much energy as a tank of gasoline of the same size.

Researchers Khalil Amine and Michael Thackeray lead the team that will explore innovative and radically new concepts for dramatically advancing lithium-air batteries.

To develop the Li-air battery, Argonne will leverage its experience with Li-ion batteries, fuel cells and catalysts, its expert staff of scientists and engineers and its most advanced research facilities, including the Advanced Photon Source, the Center for Nanoscale Materials and some of the world's fastest supercomputers.

How Does a Lithium-air Battery Work?

A Li-air battery has a positive electrode made of lightweight porous carbon and a negative electrode made of lithium metal. To make electricity, oxygen from the air moves through the porous carbon electrode, where it reacts catalytically with lithium ions and electrons from the external circuit to form a solid lithium oxide.

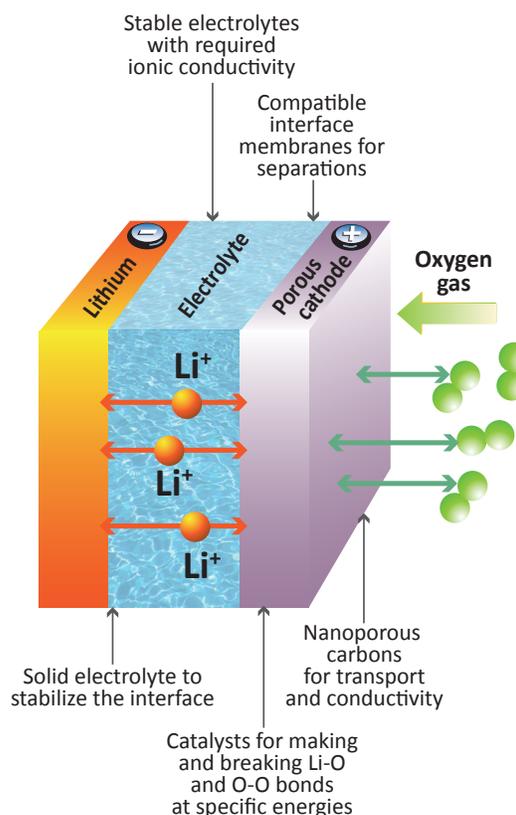
The solid lithium oxide gradually fills the pore spaces inside the carbon electrode as the battery discharges. When the battery is recharged, the lithium oxide decomposes again, releasing lithium ions and freeing up pore space in the carbon. Resulting oxygen is released back into the atmosphere.

Argonne's Team

Realization of a viable Li-air battery will require a technological breakthrough and it may take one to two decades before the product can be adopted in a commercial application.

"Research programs in lithium-air batteries are few and scattered at the moment," Amine said. "This is an opportunity to put together an interdisciplinary team of scientists and engineers from across the Lab to attack all problems and barriers of lithium-air in a concerted and collaborative way. We can take advantage of the expertise that Argonne has built in batteries, fuel cells, catalysts, modeling and the powerful characterization tools at the user facilities that we have on site."

The team members who will work with Amine and Thackeray are prominent Argonne scientists in materials and systems synthesis, characterization and computer modeling, and include Larry Curtiss, Mali Balasubramanian, Yugang



Li-air batteries hold the promise of increasing the energy density of Li-ion batteries by as much as five to 10 times.

Sun, Nenad Markovic, Di-Jia Liu, Yang Ren, Zonghai Chen, Zhengcheng Zhang, Lynn Trahey, Christopher Johnson and Jeffrey Greeley.

Argonne will also leverage existing relationships with start-up companies and other business partners who will be able to collaborate on commercializing the Li-air battery.

Funding for this project is provided through Argonne's Laboratory-Directed Research and Development Director's Grand Challenge program. The proposal, "Beyond Li-ion Battery Technology for Energy Storage," was submitted by Amine and Thackeray.

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Press release and video interviews: www.anl.gov/Media_Center/News/2009/batteries090915.html

Argonne's TTRDC Partners with India

With more than one billion people and one of the world's fastest growing economies, India is becoming a significant player in the global transportation industry. As India forges ahead in vehicle production and development, Argonne will be there to help the country incorporate energy-efficient transportation technologies.

On Aug. 27, 2009, Argonne entered into a Memorandum of Understanding (MOU) with National Automotive Testing and R&D Infrastructure Project (NATRIIP), India's counterpart to Argonne's Transportation Technology Research & Development Center (TTRDC). Eric Isaacs, director of Argonne, Larry Johnson, director of the TTRDC, and Raj Sekar, a senior mechanical engineer at Argonne, completed the MOU signing through a video conference call with NATRIIP officials.

"This MOU is important because it directly addresses a Department of Energy priority to engage India and China in energy technologies, especially transportation where imported petroleum is the source of energy," Sekar said.

"India's transportation industry is fast-growing and could become more energy-efficient by utilizing Argonne technologies and skill sets," Johnson added.

Argonne has already partnered with China to work toward this priority. In 2004, the Lab entered into an MOU with the China Automotive Technology and Research Center (CATARC) to help foster the commercialization of energy-efficient vehicle technologies and clean transportation fuels in China. In June, Argonne continued its international outreach efforts by entering into another MOU with the Korea Automotive Technology Institute (KATECH).

This latest MOU with India will allow TTRDC and NATRIIP researchers to cooperate with information exchanges of publicly available research data and collaborative visits to each other's facilities.

"Staff interaction will be the main mode of collaboration," Sekar said. "Staff from NATRIIP labs will visit Argonne and work with our staff periodically. Our staff will assist NATRIIP in the areas of engine combustion of renewable fuels, batteries and hybridization."



Argonne Laboratory Director Eric Isaacs signs the MOU as TTRDC Director Larry Johnson (left) and senior mechanical engineer Raj Sekar look on. NATRIIP officials participated via video conference.

The partnership will focus on technical areas related to:

- ▶ Electric-drive vehicles (battery-powered electric vehicles, plug-in hybrid electric vehicles, hybrid-electric vehicles and fuel cell vehicles);
- ▶ Engine combustion and emissions technologies;
- ▶ Vehicle simulation models;
- ▶ Motor vehicle fuels;
- ▶ Mass transportation vehicles; and
- ▶ Instrumentation and test protocols.

Both organizations anticipate that the data and staff exchanges will result in mutual progress in automotive technologies in each country.

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EcoCAR Participants in Year Two of Competition

Year Two of EcoCAR: The NeXt Challenge began with a kick-off fall workshop and the delivery of vehicles donated by General Motors (GM) to the 17 participating North American university teams.

EcoCAR is a race to see which team's vehicle design will perform best in each phase of the competition. EcoCAR isn't focused on one technology or fuel; the competition provides an opportunity to evaluate unique, student-designed advanced powertrains and to learn about the advantages and trade-offs each technology has to offer. It is also a race to find alternatives to oil in order to supply the world's automotive energy requirements.

Fall Workshop

Student teams gathered in Boston for a fall workshop of training courses. EcoCAR teams learned real-world automotive engineering practices by using model-based design and graphical system design technologies, including software- and hardware-in-the-loop. Sessions offered hands-on training with software tools such as MATLAB and Simulink. EcoCAR sponsors The MathWorks, A123 Systems, dSPACE, National Instruments, Woodward, Freescale Semiconductor, AVL and GM provided additional training.

A123 and Lithium-ion Batteries

As a new challenge in the EcoCAR competition series, teams had to design and integrate advanced energy storage systems (ESS) into their vehicles. A123 Systems provided automotive-class, prismatic, Li-ion phosphate battery modules to 14 teams. To qualify for the modules, teams had to prepare sophisticated ESS design reports that outlined their battery pack designs and addressed issues such as thermal management, mounting schemes, pack wiring and high voltage safety.

A123 Systems' Energy Solutions Group, Hopkington, Mass., showed student participants the lithium-ion battery system's components and gave them a tour of the battery manufacturing facilities. In preparation for designing and building their own energy storage systems, students also learned assembly and safety critical practices and how to use software to communicate with their energy storage control systems.

Teams will integrate their battery packs into their competition vehicles—along with other powertrain components—throughout Year Two. By converting the competition vehicles to run on electricity, the teams are creating more energy-efficient engines that produce less exhaust emissions.

GM Donated Vehicles

Also as part of the second year of the competition, each of the 17 EcoCAR teams received a vehicle donated by GM. Teams will replace the vehicles' existing powertrains with drivetrains they designed during Year One of the competition. GM also presented \$10,000 in seed money and an additional \$25,000 in "blue dollars" to the teams. GM "blue dollars" are virtual dollars provided by GM that can be used to purchase vehicle components at half price.



Chris Fillyaw (left) of The MathWorks and John Kruckenberg of The Ohio State University check out engine data at the fall 2009 EcoCAR Challenge workshop in Boston.

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Charging Ahead: Taking PHEVs Farther on a Single Battery Charge

Every six months, we're reminded to change the batteries in our household appliances: smoke alarms, flashlights and radios. But what if you had to change the battery in your plug-in hybrid electric vehicle (PHEV) just as often?

Fortunately, researchers at Argonne may have found a way to exponentially increase the calendar and cycle lifetimes of lithium-ion batteries. Electric double-layer capacitors—typically referred to as ultracapacitors—have an energy density thousands of times greater than conventional capacitors and a power density hundreds of times greater than lithium-ion batteries.

“Ultracapacitors give an electric vehicle the initial boost it needs to get going.”

In an electric vehicle drivetrain, energy density provides sustained speed, while power density facilitates acceleration. “Energy density is what allows you to run a marathon; power density is what enables you to sprint,” said Ted Bohn, an automotive engineer in Argonne’s Center for Transportation Research.



Ultracapacitors will dramatically boost the power of lithium-ion batteries, enabling plug-in vehicles to travel much further on a single charge.

“Ultracapacitors aren’t of much use just by themselves,” he added, “but when you couple them with lithium batteries, they dramatically boost the performance of the entire vehicle.”

When an electric vehicle merely needs to maintain a particular speed, it requires little of the battery’s power density. However, when the car needs to accelerate from a standstill to a cruising velocity, today’s lithium-ion batteries must strain to provide the necessary “oomph.”

“Ultracapacitors give an electric vehicle the initial boost it needs to get going,” Bohn said.

A PHEV or pure electric vehicle needs a battery with sufficient power density to accelerate the vehicle quickly. A vehicle that uses an energy-dense battery that lacks sufficient power density will fail prematurely, possibly in a matter of months if driven aggressively. By using the same potentially lower cost energy-dense battery, in combination with ultracapacitors, the vehicle will have sufficient performance and the batteries should last 10 years or more.

Today’s hybrid cars recharge their batteries by transforming kinetic energy from the wheels into potential electrical energy as the driver brakes. Conventional lithium-ion batteries, however, absorb this energy slowly and inefficiently. By contrast, ultracapacitors, because of their immense internal surface area, sort of soaking up reclaimed energy like a sponge.

“By integrating the entire system,” Bohn said, “we can drive down the cost. When we can put these various electronic elements together, we’ll transform an \$8,000 battery into a \$4,000 all-electric drivetrain system.”

Funding for this project was provided by the U.S. Department of Energy’s Vehicle Technologies Program under Lee Slezak.

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New Molecule Could Help Make Batteries Safer, Less Expensive

Safety, life and cost are three of the major barriers to making commercially-viable lithium-ion batteries for plug-in hybrid electric vehicles (PHEVs) and electric vehicles. But with only a small change in Li-ion chemistry, Argonne researchers Khalil Amine and Zonghai Chen may have found a formula that will lead to improvements in all three areas.

The scientists are testing a new molecule based on boron and fluorine as an additive in the electrolyte of Li-ion batteries. By adding a small amount of this substance to battery cells, they have found they can keep individual cells in the battery from reaching an unsafe voltage level.

PHEV batteries typically consist of 200 to 400 cells. A common safety issue occurs when an individual cell is overcharged. When the voltage increases above an acceptable level, the cell chemistry becomes unstable and gives off heat, initiating a thermal runaway condition in the cell. This, in turn, can lead to a chain reaction in adjoining cells, which presents the potential for a battery fire.

Amine said the new molecule helps combat this problem by picking up electrons and keeping the cell charge from increasing if the cell reaches an unsafe voltage level.

This research would also help reduce manufacturing costs since the overcharging issue is currently regulated by expensive electronic controls in each cell that cause the cell to shut down when voltage is too high.

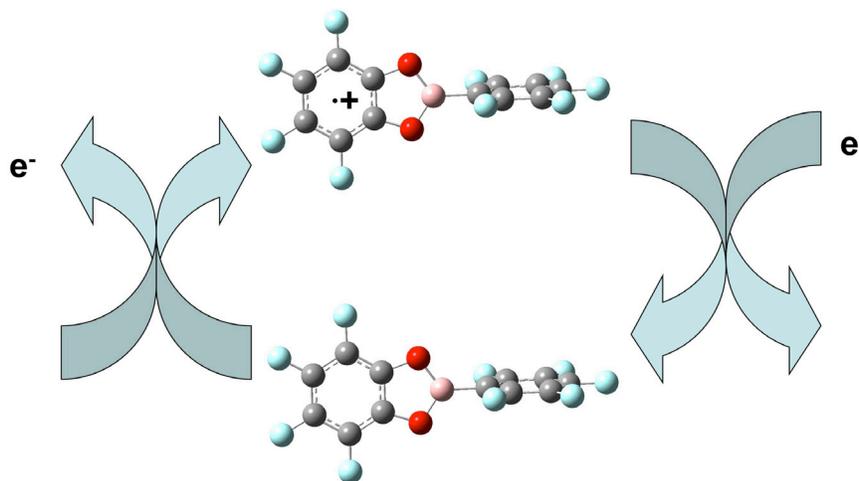
According to Amine, the new molecule promises to be more reliable than electronic controls and other molecule-based approaches. Other kinds of molecules that have been tested may only work for one overcharge cycle, but the Argonne-developed molecule can be used for 500 or more overcharge cycles.

Though the material only makes up two to three percent of the electrolyte by weight, it costs about \$1,000 per kilogram. Amine believes the cost can be driven down to about \$100 per kilogram if it were made in larger batches. EnerDel, Inc., is currently collaborating with Argonne to commercialize this important technology.

Amine said the chemistry change could lead to batteries that cost \$100 to \$200 less than current projections.

Funding for this project is being provided by the U.S. Department of Energy's Vehicle Technologies Program under the direction of David Howell.

Charge Transfer Mechanism for Li-ion Battery Overcharge Protection



When the battery is overcharged, the redox shuttle (bottom molecule) will be oxidized by losing an electron to the positive electrode. The radical cation formed (top molecule) will then diffuse back to the negative electrode, causing the cation to obtain an electron and be reduced. The net reaction is to shuttle electrons from the positive electrode to the negative electrode without causing chemical damage to the battery.

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A Great Debate: Fuel Consumption versus Fuel Economy

What is the difference between *fuel consumption* and *fuel economy*? In Europe, consumers look at vehicle fuel consumption as liters/100km, or fuel used per a set distance. In the United States, consumers look at fuel economy in miles/gallon (mpg), or distance per fuel.

Lately, some advanced technology vehicle makers are making claims of extremely high fuel economy (instead of 30 mpg, up to 230 mpg). The key to understanding this is mathematical: is the reduction of fuel consumed for fuel over distance versus distance over fuel linear?

In the case of liters/km, as fuel used goes to zero, fuel consumption goes to zero (a very good thing). In the case of miles/gallon, as fuel consumed goes to zero for fixed miles driven, mpg goes to infinity (which is impossible or illogical). This reciprocal relationship is also misleading when representing gallons of fuel consumed per year as a function of mpg.

The plots at left show the diminishing returns of increased fuel economy. For example, the difference between 15 mpg versus 20 mpg is (800 gal/year vs 600 gal/year=200 gallons), compared to 50 mpg versus 55 mpg (240 gal/year vs 218 gal/year= 22 gallons). Both comparisons enlist only a 5 mpg difference, but due to a non-linear change, there is a 178 gallons-per-year difference in improvement (200 gallons-22 gallons=178 gallons).

Pop Quiz

To what level would the fuel economy of a **50 mpg** vehicle need to be improved to match increasing a **13 mpg** vehicle to **18 mpg**, to save the same amount of fuel per year (15,000 miles)?

Hint

A 5 mpg improvement from 13 to 18 mpg is 38 percent, right? Thus, 38 percent better than 50 mpg is $1.38 \times 50 = 69$ mpg, right?

For 15,000 miles of annual driving,

- ▶ A 13-mpg vehicle uses **1154** gallons, and
- ▶ A 18-mpg vehicle uses **833** gallons, or **321** gallons less.
- ▶ A 50-mpg vehicle uses 300 gallons.

So what fuel economy improvement for a 50-mpg vehicle would yield a fuel savings of 321 gallons?

Trick Question

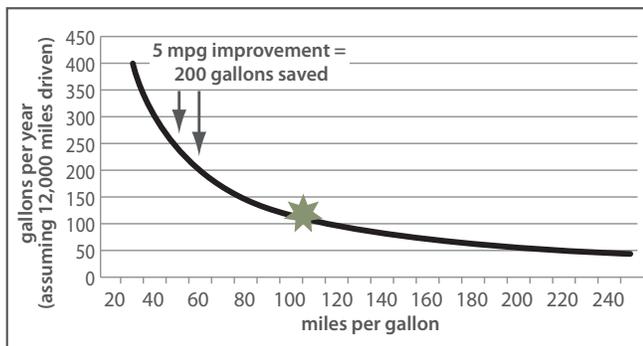
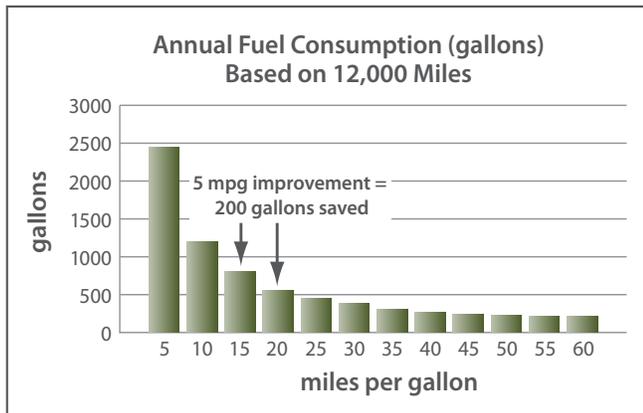
There is **no improvement above 50 mpg** that can achieve the same annual fuel savings as improving 5 mpg on a 13-mpg vehicle. In other words, the vehicle would need to save more fuel than the total used at 50 mpg.

By comparison, a 13 mpg to 17 mpg improvement (31 percent) saves 272 gallons. For a 50-mpg vehicle to achieve a 272 gallon fuel savings, it would need to have an annual fuel consumption of 28 gallons (300-272), therefore the fuel economy would need to be **535 mpg** (15,000/28), or **1,000 percent better**.

Bottom Line

Improving fuel economy (miles per gallon) does not result in a linear decrease in fuel consumption (gallons per distance driven).

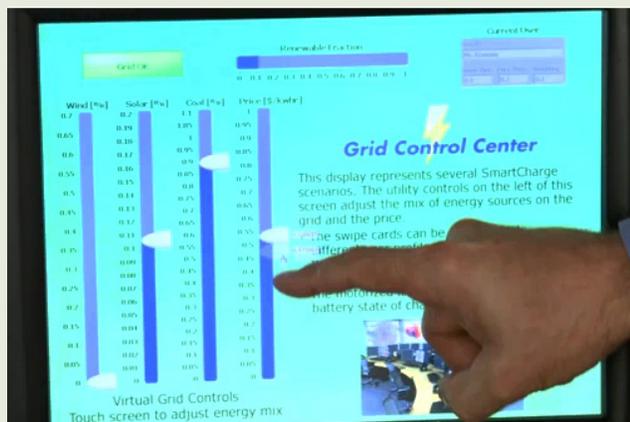
Fuel economy is misleading. Fuel consumption is a more useful representation (that is, gallons/mile, or liters/100km).



Some Comparisons of Electricity versus Liquid Fuel Net Emissions, or “How Green is Your Grid?”

The carbon impact of the millions of electric vehicles that may soon hit the road will depend on the electric grids that supply them.

The odds are that your batteries won't be recharged with solar or wind energy. In most places, grid power will come from the burning of fossil fuels, which generate their own emissions.



The smart grid interactive model demonstrates how consumers may one day choose their vehicles' energy source. See more on YouTube at www.youtube.com/watch?v=hkf_tA-A11g.

So the question really is: “If you power a vehicle with electricity from the grid rather than with fuel from the tank, **is that better or worse for the environment**, particularly with respect to greenhouse gases like carbon dioxide?”

How do you compare a PHEV (plug-in hybrid electric vehicle) that can recharge from wall current against a conventional gasoline car that consumes, say, 9.4 liters per 100 kilometers (25 miles per gallon)? In this case, using grid power to drive electrically emits fewer greenhouse gases per kilometer—under any circumstances.

But if you compare the plug-in with an ultra-economical European diesel or a conventional hybrid-electric like Toyota Motor Corp.'s Prius—either of which burns just 4 to 5 L/100 km—the picture is more complicated: the plug-in emits fewer greenhouse gases in some circumstances, but more in others.

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Smart Grid on the Web:

www.transportation.anl.gov/smart_grid/index.html

ARPA-E Awards \$6 Million to Two Argonne Projects

As part of the Department of Energy's (DOE's) Advanced Research Projects Agency-Energy (ARPA-E) funding, Argonne National Laboratory will be part of a new \$4 million collaborative project that seeks to lower the cost, extend the all-electric-range and speed the adoption of plug-in hybrids and electric vehicles.

In this case, lowering the cost of plug-ins and electric vehicles means lowering the cost of high-energy density lithium-ion batteries. To further this effort, ARPA-E is providing funding for a joint effort between Argonne and Envia Systems.

According to the ARPA-E project description, "Envia Systems (Hayward, Calif.), in collaboration with Argonne National Laboratory, will develop high-energy density, low cost next-generation Li-ion batteries using novel nanosilicon-carbon composite anodes and high capacity manganese rich-layered composite cathodes discovered at Argonne National Laboratory. These batteries, if successfully developed, could triple the energy density of existing electric vehicle batteries (target: 400 watt hours per kilogram) and rapidly hasten adoption of low cost plug-in hybrids and electric vehicles."

Argonne also received \$2.2 million for a joint research project with the Naperville, Ill.-based Nalco Company to develop an electrochemical process to improve carbon dioxide capture from coal flue gas.

ARPA-E's mission is to develop nimble, creative and inventive approaches to transform the global energy landscape while advancing America's technology leadership.

ARPA-E was originally established under the America Competes Act of 2007. In April 2009, President Obama announced \$400 million in initial funding for ARPA-E through the American Recovery and Reinvestment Act.



Argonne's Through-the-Road plug-in hybrid electric vehicle

In this first round of funding selections, a total of 37 energy research projects were awarded \$151 million. A second set of ARPA-E funding opportunities will be announced later this year.

In announcing the selections, Secretary of Energy Steven Chu said: "After World War II, America was the unrivaled leader in basic and applied sciences. It was this leadership that led to enormous technological advances. ARPA-E is a crucial part of the new effort by the U.S. to spur the next industrial revolution in clean energy technologies, creating thousands of new jobs and helping cut carbon pollution."

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Green Racing: Fueling Change in the Auto Industry

The American Le Mans Series' (ALMS) Green Challenge is a hotbed for innovation. With the goal of racing the fastest while leaving the smallest environmental footprint, ALMS is the only race series so far to adopt green racing principles established by the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA) and the Society of Automotive Engineers (SAE) International. In so doing, ALMS is spurring car manufacturers worldwide to experiment with new, green technologies and demonstrate their effectiveness on the race track.

On September 26, 2009, green racing celebrated its first anniversary at the 2009 Petit Le Mans endurance race held at Road Atlanta in Braselton, Ga. The wide variety of alternative fuels, including the introduction of biobutanol to the race, was one of the highlights of the milestone event.

Biobutanol Debuts

Butanol made its first-ever appearance in the race, as Dyson Racing ran its Lola-Mazda on a blend of biobutanol, ethanol and gasoline. The car did not race for points because of the fuel's experimental nature, but it was considered a successful test run. The butanol in the fuel, which was developed by Dyson sponsor BP and engine supplier Mazda, came from sugar cane. In the future, the fuel will be produced from a variety of cellulosic sources.

The team has high hopes that biobutanol will be an accepted fuel for the 2010 ALMS season because of its advantages over ethanol. Biobutanol has more energy, burns similarly to gasoline and can be blended with gasoline in higher concentrations while achieving the same oxygen levels mandated for road fuel (thus displacing more petroleum than conventional E10 gasoline). Its high octane and increased knock resistance also makes it a very good fuel for engines that are turbocharged, an increasingly common technology for street vehicles.



The Audi R15 TDI took home the Michelin Green X Challenge Prototype Green Racing victory at Petit Le Mans for its superior combination of fuel efficiency and performance in the Prototype class.

E85 Gains Ground

E85, a high-octane renewable fuel consisting of 85 percent ethanol and 15 percent gasoline, is gaining increased acceptance as a clean, powerful race fuel. A late switch from E10 to E85 gave the Flying Lizard Motorsports Porsche team the edge they needed to win the Michelin Green X Challenge Grand Touring award, defeating their archrivals, the factory Corvette team, that has been running on E85 since 2008. This change may foreshadow all the factory-supported Porsche cars switching to E85 for the 2010 season. Porsche found that using E85 gave them a noticeable power boost while reducing their greenhouse gas emissions significantly. Given the intense competition in the GT class, other teams such as BMW are thought to be developing E85 engines for 2010.

Ultra Low Sulfur Diesel with GTL Shows Power Potential

The fastest cars in the field, the Prototype class, all used a special ultra low sulfur diesel fuel provided by Shell (made in part from natural gas). Dominating the competition were the factory Peugeot 908HDI-FAPs, taking first and second place. The Audi team was also part of the winner's circle, finishing third overall with their GTL (natural gas to liquid) ultra low sulfur diesel-fueled Audi R15 TDI, and winning the race's Michelin Green X Challenge Prototype Green Racing award. They were able to win the Prototype award by using significantly less fuel than their Peugeot competitors while nearly matching their speed in the rain-shortened race.

This season, the Green Challenge race has become a regular feature of the ALMS. The Green Racing Challenge Award is based on a green score which takes into account the car's energy efficiency, petroleum consumption and greenhouse gases emissions. To fairly compare the wide variety of vehicle types and technologies, scores are adjusted by the number of laps completed and the speed of the vehicles.

The race and protocols were developed by DOE, EPA and SAE International. Argonne National Laboratory provided the formulae and technical support to determine the "green winner." Tire giant Michelin has joined this program by establishing the "Michelin Green X Challenge," a complementary companion award that goes to the teams in the Prototype and GT classes that win each Green Challenge race. Sponsorship for this project is being provided by the U.S. Department of Energy's Vehicle Technologies Program.

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Six Myths about Plug-in Hybrid Electric Vehicles

Plug-in hybrid electric vehicles (PHEVs) hold great promise as the key to weaning America from its dependence on imported oil, which represents nearly two-thirds of all the petroleum burned in the United States today.

The U.S. Department of Energy's Argonne National Laboratory has taken a lead role in developing and testing plug-in hybrid technologies. At the Lab's Center for Transportation Research (CTR), principal mechanical engineer Forrest Jehlik and his colleagues work to bring these cars to market quickly and cheaply. Here, Jehlik dispels some commonly held myths about plug-in hybrids.

Myth #1: A significant number of plug-in hybrids are currently for sale.

Although several major auto manufacturers—including General Motors, Toyota, Ford, Volkswagen, and Volvo—

have plug-in vehicles currently in the development pipeline, the first wave of these cars is still at least a year away from officially hitting the market, Jehlik said. The first plug-in hybrid for sale will likely be the Chevrolet Volt, which General Motors claims can travel up to 40 miles on a single charge. The Toyota Prius and other hybrids currently on the roads are not plug-ins—their batteries are charged by kinetic energy transferred from the brakes and wheels.



Forrest Jehlik, principal mechanical engineer, dispels PHEV myths.

Myth #2: Researchers can measure the fuel economy for a plug-in hybrid just as easily as they can for gasoline-powered cars.

Establishing fuel economy standards—how many miles a plug-in hybrid vehicle can travel per gallon of gasoline burned—is a complicated question. The answer, Jehlik said, depends entirely on the driving and charging habits of the vehicle's owner. If a particular plug-in hybrid gets 40 miles on a single charge, then a driver who has a 15-mile commute each way to work and does 10 miles of additional driving each day before charging the battery overnight would, theoretically, use no gasoline at all. If the same driver had a five-mile-longer commute, she'd probably burn just over a gallon of gasoline per week, despite driving 250 miles.

Myth #3: Prices for plug-in hybrid vehicles are currently so high because manufacturers are trying to make a killing on them.

"The truth of the matter is that the components required to build a viable plug-in hybrid are still quite expensive," Jehlik said. In many cases, the battery for a plug-in vehicle by itself costs nearly \$10,000. Because the price of petroleum remains relatively low, consumers may not yet be willing to invest the extra money in a plug-in vehicle—even with sizable government rebates.

Myth #4: The batteries in plug-in hybrid vehicles are unreliable, possibly unsafe and require frequent replacement.

Most plug-in hybrids currently under development use lithium-ion batteries in their battery packs. Although complex chemical processes produce energy within the battery, vehicle system engineers have built in advanced control systems to prevent fires or other safety issues. "Researchers have devoted just as much time and effort to developing inner-pack safety systems as they have to the batteries themselves," Jehlik said. "Consumers don't need to worry about battery malfunction."



MATT – Argonne’s wheeled Mobile Advanced Technology Testbed is outfitted with scalable motor components, extensive instrumentation and a rapid prototyping control system to allow testing of plug-in hybrid electric vehicle systems.

Jehlik and his colleagues in the CTR have also tested the current generation of lithium-ion batteries in what are known as “life cycle vehicle tests,” which take the car through its paces for more than 150,000 miles. Even at the end of the car’s life, the vast majority of batteries still function quite well, Jehlik said. “When these cars become available for sale, the batteries are going to last as long as any part of them will,” he said.

Myth #5: Scientists have identified lithium-ion batteries as the only battery technology that could work in plug-in hybrid cars.

Although lithium-ion technology came to replace nickel-metal hydride (NiMH) batteries as the preeminent focus of electric vehicle development efforts, scientists at Argonne and around the world are currently investigating several different approaches for energy storage that could help to bring down the cost of plug-in hybrids. “Manufacturers are looking at these possible solutions not as silver bullets but as silver shotgun pellets,” Jehlik said. “The organizations that hedge their bets among a number of different technologies will likely be the ones that bring vehicles to market the earliest and the most successfully.”

Myth #6: America’s electric grid can’t handle the increased load caused by the charging of millions of electric vehicles.

According to Jehlik, the nation’s current electric grid has the capacity to accommodate the imminent rollout of plug-in hybrids onto the country’s roads. “If everyone were somehow able to buy a plug-in hybrid tomorrow, that would probably present a problem as far as the supply of electricity is concerned,” Jehlik said, “but given the pace that they are likely to enter the market, we won’t face a system-wide failure.”

However, Jehlik noted that the country’s electric infrastructure would need to change eventually—not only to keep up with added demand, but to ensure the smarter transmission, distribution and consumption of electricity.

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In the News

September 2009 – **Bassam Jody** talked about recycling automobiles in *The Environment Report* (www.environmentreport.org/story.php?story_id=4640). In a related video, Jody and **Jeff Spangenberg** explained the research taking place and the goals of Argonne’s Recycling Pilot Plant. www.youtube.com/watch?v=r3YOf9xtfXk

September 2009 – **Ted Bohn** discussed how ultracapacitors are one key to making electric vehicles more economical in the *Daily Journal of Commerce Oregon*. www.djcoregon.com/news/2009/09/18/electric-vehicles-surge-forward/

September 2009 – **Four of Argonne’s programs** aimed at making renewable energy practical, and enabling carmakers to build better, cheaper electric cars were featured in “Your Tax Dollars At Work: Argonne Lab’s Better Batteries, Greener Fuels” at *GreenCarReports.com*. www.greencarreports.com/blog/1035177_your-tax-at-work-argonne-labs-better-batteries-greener-fuels#

September 2009 – Details of the report, “National Labs Developing Methodology for Estimating Real World Fuel and Electricity Consumption of Plug-in Hybrids Based on Dynamometer Data,” by researchers from the U.S. Department of Energy’s National Renewable Energy Laboratory, Idaho National Laboratory and **Argonne National Laboratory** were featured online at *Green Car Congress*. After examining data on the only plug-in hybrid electric vehicles (PHEVs) available in large numbers, the new adjustment method shows promise for reasonably predicting PHEV average fuel and electricity use, despite differences in design. www.greencarcongress.com/2009/09/nrel-phev-20090929.html#more

October 2009 – **George Crabtree** (Argonne) and John Sarrao (Los Alamos National Laboratory) described what makes a technology sustainable and outline the materials science challenges standing in the way of clean, long-lasting energy in “The Road to Sustainability” online at *PhysicsWorld*. www.physicsworld.com/cws/article/print/40527

October 2009 – *FleetOwner* examined the innovations highlighted in the **EcoCAR Challenge**, a student race that prepares future engineers to design and build more fuel-efficient vehicles. blog.fleetowner.com/trucks_at_work/2009/10/07/letting-innovation-loose/

October 2009 – **Don Hillebrand** described Argonne’s use of nanomaterials and ultracapacitors to ration the energy drain of lithium-ion batteries and make them more efficient in “Car Tech Trends for 2010 and Beyond” online at **MSN.autos**. editorial.autos.msn.com/article.aspx?cp-documentid=1094624

November 2009 – **May Wu** talked about the amount of water needed to grow and process corn ethanol and cellulosic biofuels in “Green Energy: Another Biofuels Drawback: The Demand for Irrigation,” online at *ScienceMag.org*. www.sciencemag.org/cgi/content/full/326/5952/516

November 2009 – **Ira Bloom** and **Glenn Keller** explained Argonne’s work on cutting-edge cathode lithium-ion batteries, plug-in hybrid electric vehicles, electric power as a renewable fuel, and testing of electric vehicles in “New Battery Technology at Argonne National Labs,” a video on *Clean Skies News*. www.cleanskies.com/videos/new-battery-technology-argonne-nat-labs



Glenn Keller speaks to Clean Skies News.

November 2009 – In “Why Do We Power Our Cars With Gas?” *NBC Chicago* interviewed Argonne’s **Mike Duoba** and **Thomas Wallner** about plug-in hybrid electric vehicles and the omnivorous engine. www.nbcchicago.com/around-town/cars/Why_Do_We_Power_Our_Cars_With_Gas_Chicago.html

November 2009 – **Gary Henriksen** was quoted on Argonne’s work to expedite the commercialization of better, longer-life lithium-ion batteries for hybrid electric vehicles, plug-in vehicles and other electric vehicles in “Argonne gets \$8.8 million for battery research” in the *Daily Herald*. www.dailyherald.com/story/?id=337909

November 2009 – **Gary Henriksen** talked about three battery research facilities that will be built at Argonne with stimulus funds from the U.S. Department of Energy in “Argonne gets \$8.8M boost for battery research,” an article in the *SouthTownStar*. www.southtownstar.com/news/1899052,112309argonne.article

January 2010 – **Dan Santini** was named one of the “Top 15 Connected Car Influencers” by Earth2Tech, a blog dedicated to clean technologies. www.earth2tech.com/2010/01/25/earth2techs-top-15-connected-car-influencers/

FASTRAX



May Wu

May Wu attended the Life Cycle Assessment conference in Boston on Sept. 29-Oct. 2, 2009. She chaired the biofuel session, covering recent biofuel studies emphasizing the estimates of direct and indirect land use changes related to greenhouse gas emissions. Wu also presented Argonne's water analysis research in a poster titled "Water is Key to Sustainability of Energy Production." The analysis covers water use in the

production of corn ethanol, cellulosic fuels, petroleum gasoline from conventional and oil sands as well as electricity generation from various sources. **Marianne Mintz, Michael Wang, Salil Arora** and **Jui-kun Peng** co-authored the poster.

Ted Bohn participated in the SAE J2293 Standards committee Electric Vehicle Supply Equipment (EVSE) Collaboration Day and design review on Sept. 28, 2009. Each of the EVSE manufacturers presented their vision of features and functions that they want to see included in the various EVSE related standards. Bohn was a reviewer and commented on the Smart Grid/Smart Charging work at Argonne National Laboratory.

Ted Bohn was an invited speaker at the John Deere Corporate Tech Center in Moline, Ill. on Sept. 16-17, 2009. He spoke on "Hybrid Drive Systems, Electric Machines State of the Art With Review of PHEV Fuel Economy Complications" and "SAE, ISO, IEC, IEEE and other Standards Development; Electrical Safety Practices and Smart Grid Communications."

Dan Santini, Anant Vyas and **Larry Johnson** were recognized with the TRB 2010 Barry D. McNutt Award for Best Paper for their Transportation Research Board 2009 Annual Meeting paper "Plug-In Hybrid Electric Vehicles' Potential for Petroleum Use Reduction: Issues Involved in Developing Reliable Estimates."

Dan Santini was honored with the SAE 2010 Barry D. McNutt Award for Excellence in Automotive Policy Analysis in recognition of his outstanding contributions to the development of improved federal automotive policy.

Linda Gaines discussed how "Idling Reduction Makes \$ense" at three separate venues: the Clean Cities Workshop, held in Washington, D.C. in September 2009; the October 2009 Federal Energy Management Program's Webcast; and the Central Indiana Clean Cities Meeting in November 2009. Gaines also presented "Lithium-ion Batteries: Material Demand and Recycling," at Argonne's Partnership Meeting in October 2009. Gaines talked about "Sleep Cheap: How to Minimize Overnight Costs with Idling Reduction Equipment" at the Commercial Vehicle Engineering Congress and Exposition in Rosemont, Ill., also in October.

Henning Lohse-Busch and **Michael Kern** were honored with Argonne Pacesetter Awards in October 2009. Argonne presents Pacesetter Awards for extraordinary effort in meeting or exceeding difficult deadlines or demands of a technical, administrative or sponsor-related nature; and for innovations, discoveries, program development and cost-cutting suggestions.



Mike Kern and Henning Lohse-Busch (center front) receive Pacesetter Awards while Ann Schlenker (left), Ed Daniels, Dave Shimcoski and Glenn Keller look on.

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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