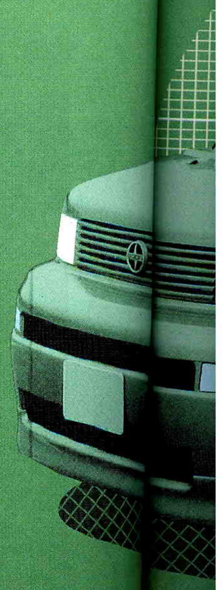
A NEW KIND OF CAR PAYMENT



Buried in the high hopes for electric cars is the very real possibility that they can make money by powering and regulating the grid.

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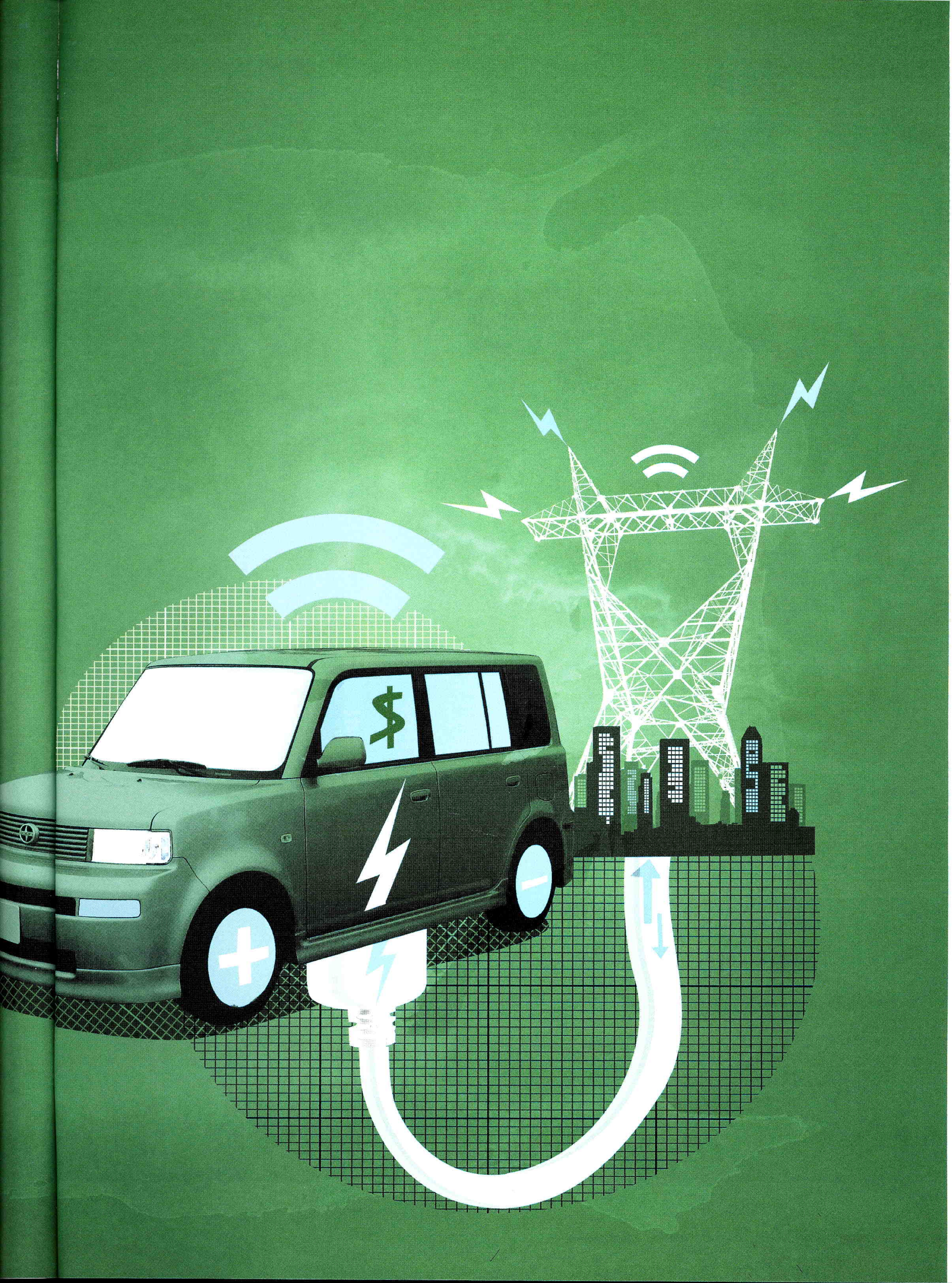


WILLETT KEMPTON IS AN ANTHROPOLOGIST. AND AN ELECTRICAL ENGINEER.

On this winter morning at the University of Delaware, both skill sets come in handy as he courts two Japanese businessmen. They've traveled here from Tokyo to see how much progress he's made toward a revolutionary idea: electric cars that will make several thousand dollars a year for their owners, and speed the switch to renewable energy sources.

Observing Japanese business etiquette, Kempton presents his business card to the senior visitor, Makoto Horiguchi, then the two exchange bows. He repeats the ceremony with Horiguchi's junior colleague and with their translator. Then Horiguchi steps to the front of the classroom to give a short talk describing the work that his employer, the industry-funded Japan Automobile Research Institute, does on electric vehicles. Kempton listens attentively and asks questions. Then he makes his pitch.

For 15 years, Kempton, who directs the University of Delaware's Center for Carbon-Free Power Integration, has pushed the idea that fleets of electric vehicles—rather than being another big draw on the electric grid—could provide valuable backup power on demand to utilities. This would reduce the need for costly new generating plants, and help ensure a reliable supply of electricity.

Utilities pay each other billions of dollars a year for such backup power through wholesale electricity markets, and Kempton believes that a hefty slice of that pie could be paid to electric-vehicle owners instead. Some industry analysts agree that the approach, known as "vehicle-to-grid," could take off; a

SPARK PLUG Willett Kempton stands next to the Scion xB that confirmed his faith in "vehicle-to-grid," in which fleets of electric cars will both contribute electricity to the national grid and help regulate it.


UNIVERSITY OF DELAWARE
Center for Carbon-fre
Power Integration

December 2010 report from the business research firm Global Data conservatively projected a global market for vehicle-to-grid that would pay $2.3 billion to electric vehicle owners by 2012—and $40 billion by 2020. Kempton and his colleagues have made some influential converts in policy circles, too. Marc Spitzer, a commissioner with the Federal Energy Regulatory Commission, has described the plan as "the salvation of the automotive industry in the United States."

Automakers, however, have been slow to warm to the idea, and the first crop of mass-market battery electric vehicles, including the Chevy Volt and the Nissan Leaf, can only plug and charge themselves. A small number of 2012-model electric vehicles from a few manufacturers, including the BMW Mini E, Daimler Smart E, and Detroit Electric e63, however, could provide power to the grid because they each contain a proprietary electric drivetrain built by AC Propulsion, a California-based maker of electric vehicle technology that has collaborated with Kempton.

But Kempton wants to take vehicle-to-grid to the mass market, and he pushed for years, unsuccessfully, to convince major automakers to ramp up their vehicle-to-grid work. Now, on this December morning, he has a chance to find a new ally.

For the next few minutes, as three graduate students on his team watch, Kempton presents results from his team's vehicle-to-grid demonstration project to his Japanese visitors. He gives them calculations that show that electric vehicles could provide plenty of valuable electricity to the grid without inconveniencing drivers. "These numbers are why we think the electric vehicle will become an important part of the electric system," Kempton explains. The Japanese duo does not seem convinced, and they ask polite but challenging questions. Kempton answers smoothly, and the visitors ask for a tour.

A few minutes later, Nat Pearre, a graduate student in Kempton's group, is showing off one of the university's five grid-enabled electric cars, a small, boxy Scion xB. Pearre pops the hood, the Japanese visitors crowd in for a look, and Horiguchi's colleague snaps some photos. There's no engine in the engine compartment—just an aluminum box containing the power electronics that control the car.

As Kempton could explain to his guests, after he plugged this car into a smart charging station at his house in late 2009, it began earning $300 a month. This Scion became the first car ever to earn cash for its owner while it sat parked.

IN THE LATE 1960S, WITH MUSCLE CARS THE RAGE, Willett Kempton began overhauling engines. In high school, in McLean, Va., he'd drive his '65 Mustang to a local service station and spend hours watching a motorhead friend do repairs. Before long, Kempton was buying used Volkswagen Beetles and vans at police auctions for $100, taking them home, and rebuilding the engines from the ground up.

After three years of studying electrical engineering at the University of Virginia, Kempton took a year off "to get a change of pace," he says. He started an auto-repair business with a friend, which made no money, then got a job fixing engines at a busy Rockville, Md., shop run by a pair of German mechanics.

When he returned to school, Kempton changed his major to sociology and anthropology. "It seemed more useful to figure out why things were moving the way they were in society than to build a more accurate guided-missile electronic system," he recalls. By the 1980s, he'd earned a doctorate in anthropology. But he couldn't shake his affinity for the electrical and mechanical, so he studied people's attitudes about energy efficiency, presenting papers with titles like "Folk Theories of Home Heating Systems" and "Ethnography as a Tool for Interpreting Metered Energy Data."

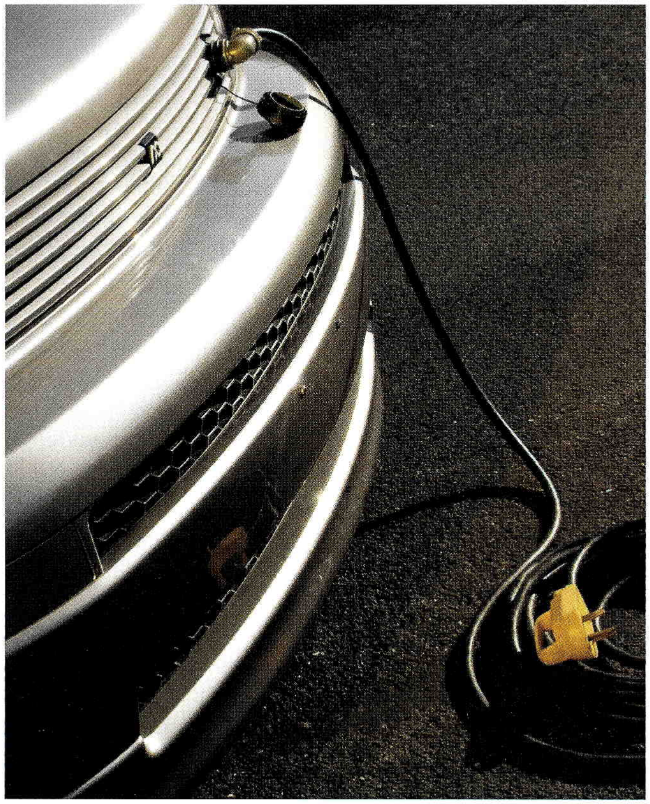
In the '90s, he began looking at the use of rooftop solar panels to power homes and businesses. In 1993, a graduate student named Steven Letendre joined Kempton's research group to study the value home solar panels would deliver to society if they were used widely. To get around the classic solar-home dilemma—the sun's power peaks at noon but people draw the most power after they arrive home from work—Kempton thought that each home would need a powerful battery to store this solar electricity. Then, while at a 1996 electric vehicle conference, an idea hit him: "Wait a minute," he recalls thinking. "We were looking at buying a battery, and there's already going to be one down in the garage."

At that point, California had mandated that 2 percent of all cars sold in the state in 1998—and 10 percent in 2003—would emit no tailpipe air pollutants. "The expectation was that there would be hundreds of thousands of electric vehicles" in California, Letendre recalls. Meanwhile, physicist Amory Lovins of the Rocky Mountain Institute had been promoting a "soft energy path" in which a distributed system involving solar panels, wind turbines, and conservation replaced a centralized system driven by large, fossil-fuel-consuming power plants.

"The ideas were percolating," Letendre says. "Lovins had talked about hydrogen cars in garages providing power. We looked at that and at the technology on the horizon," including electric cars.

One day, he and Kempton began crunching some numbers. A vehicle's power is usually calculated as horsepower for the driveshaft, but the two researchers converted those numbers into kilowatts available to the grid. The 146 million cars and SUVs and pickups that made up the United States' light vehicle fleet, they discovered, produced more than 10 times the power of all U.S. power plants combined. (Today's fleet produces seven times more.)

That automotive energy could be tapped for other purposes. Cars and other light vehicles are typically driven just one hour a day, so most of the time they sit idle. And electric



UNDER THE HOOD A vehicle-to-grid car shares most of the attributes of other electric cars—the plug to the battery (top left), or the electronics (top right). The critical addition: the extra electronics in the engine bay that become an active part of the electric grid.

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vehicle batteries have to store several times more energy than that hour of driving requires, to ensure the vehicle can make longer trips. "If we think about the vehicle fleet as an electric utility would think about its equipment, the vehicle fleet's power capacity is grossly under-utilized," the two reported in a 1997 paper.

Kempton and Letendre developed a plan, explained in the paper, showing how vehicle-to-grid would work. The car owner would enter information into a dash-mounted control panel, including when he needed to travel, and how far. A microprocessor in the control panel would calculate whether the car had power to spare. When the car was parked for long periods, the owner would plug it into a smart charging station that talked through power lines to the local utility, which could draw from, or charge, the battery as needed—so long as enough power remained to take the driver where he wanted.

Soon after the paper was published, Tom Gage, the CEO of AC Propulsion, the battery drivetrain maker, called Kempton to talk about experimenting with the idea.

Six months later, at the San Dimas, Calif., shop of AC Propulsion, Kempton and Letendre watched as Gage's team plugged in a prototype electric sports car they had built. They tapped a few commands into a laptop, the car started charging, and the dials in the shop's utility meter started spinning. Then they tapped some other commands. "The meter slowed down, stopped, and began to spin backwards," Letendre says.

ELECTRICITY IS FUNDAMENTALLY DIFFERENT from other commodities in that it's difficult to warehouse. Some electricity storage capacity exists, including stationary batteries, and there are ways to use electrical power to capture water or air to be released later to generate electricity when it's needed. Together these methods store only a few percent of the electricity produced in today's grid. For the most part, electricity must be produced when it's consumed, and supply must match demand. To ensure that happens, the nation's 10 regional organizations that run the grid operate several types of wholesale electricity markets.

Kempton and Letendre calculated the profits that vehicle-to-grid might generate in various wholesale electricity markets. They found it was too expensive to compete as a source of base-load power—the round-the-clock electricity available through large-scale coal-fired or nuclear plants.

The money looked more promising in the peak-power market, when utilities buy expensive bulk power from natural gas-fired "peaker" plants or hydroelectric dams for a few hours to meet demand at its height, such as on a hot summer afternoon when air conditioners are cooling full bore. Kempton and Letendre found that in this arena, the going rates were high enough that electric vehicle owners could earn \$300-\$500 per year simply by attaching their cars to the grid.

The economics were even better in little-known markets called the "spinning reserves," where power plants or hydroelectric dams ramp up quickly to produce extra electricity in a pinch (when, say, another plant on the grid stops working). Spinning reserves are called on about 20 times a year for an average of 10 minutes at a time.

But the economics looked best of all in the market for frequency regulation. Regulation fine-tunes the balance between supply and demand to make sure that the electricity in outlets has a frequency of exactly 60 hertz at all times. A frequency that's just slightly off can make clocks run too slow, make lights flicker, and raise havoc with electronics. To provide regulation, an electricity generator must adjust output up or down based on a hard-wired electronic signal that grid operators send out 400 times a day. Coal or gas power plants that typically provide this service can respond by quickly adjusting the spinning steam-driven engines that produce electricity to turn faster or slower. But it's often not quickly enough; adjusting turbine speed can take several minutes.

The advanced batteries in electric vehicles, on the other hand, can respond within seconds, as grid operators prefer.

"We looked at the value of peak shifting and get a dollar number of $300-$500 per year," Kempton recalls. "Then we looked at regulation, and holy cow, we can use the same car and it's worth $5,000 a year!" And the demand for regulation is high enough that millions of cars worldwide could participate.

In 2001, Kempton and his colleagues included these calculations in a report published by the University of Delaware and the University of California, Davis, for the project's sponsors, the California Air Resources Board and the Los Angeles Department of Water and Power. They were greeted with enthusiasm—and skepticism. "The electric industry said, 'Yes, this is incredible. Yes, we'll pay for it,'" Kempton says. "But the car industry said, 'Not with our batteries you don't.'"

So Kempton and chemical engineer Jasna Tomic kept plugging away on what Kempton knew would convince the industry: the numbers. The results, reported in 2005, confirmed that vehicle-to-grid—especially in the spinning reserves and frequency regulation market—was economically competitive for battery electric vehicles, hybrids, and fuel cell vehicles.

Technical analysts started to come around, slowly. The industry "shifted from saying Kempton's a nut, to saying that vehicle-to-grid is a cool idea that's 20 years away, so we don't have to think about it right now," Kempton says.

At the Philadelphia headquarters of PJM Interconnection, one of 10 independent system operators (or regional transmission organizations) that operate the electrical grid for a particular region, Ken Huber, the company's manager of advanced technology, passes muster at two security checkpoints. He leads us down a flight of stairs and knocks on a heavy steel door. A man lets us in, and we peer down from a balcony at a two-story room, covered floor to ceiling with electronic displays, including brightly colored maps, charts, graphs, and tables. This is PJM's control room, where workers ensure reliable electricity for a good chunk of the eastern United States.

The control room workers were monitoring power plants, hydroelectric dams, high-voltage transmission lines, and substations, all to help PJM ensure that electricity supply and demand are balanced every second of the day. "I think that's the toughest job we've got," Huber tells me.

As more and more wind and solar plants are introduced into the grid, balancing supply and demand gets more complicated, since wind and sun don't necessarily produce electricity when it's needed. In PJM's territory today, wind supplies 3 percent of PJM's typical load, but an equal amount is under construction. And if half the wind farms already proposed come to fruition, wind could supply up to one-fourth of the region's power by the 2020s, Huber says. "If we want a future with very high penetration of renewables, we need to have the ability to control the flow of energy they create," says Chris Shelton, president of AES Energy Storage.

Two large-scale ways to store electricity exist today. The most widely used method involves pumping water uphill into a reservoir and releasing it to drive turbines when electricity is needed. One utility, based in Alabama, stores energy by compressing air into a huge underground cavern, then releasing the pressure to drive an electricity-producing turbine. Both of these methods, which require a very specific natural infrastructure, can replace a downed generator for hours or days at a time. But they can't produce energy quickly enough to provide spinning reserves or frequency regulation.

Batteries can.

Which is why Huber, who directs a team that searches for technological fixes to grid-operator problems, partnered with Kempton in 2005 to test vehicle-to-grid.

Huber, Kempton, and several companies cobbled together the Mid-Atlantic Grid-Interactive Car Consortium, or MAGICC. Kempton's longtime research partner AC Propulsion kicked in that converted 2007 Scion; a smart grid company provided software that enabled the car to communicate with the grid; and Kempton's team developed the hardware at Kempton's house—now coined the "University of Delaware secret laboratory."

On Oct. 18, 2007, Kempton, Huber, and half a dozen colleagues gathered at the secret laboratory. Kempton plugged in the Scion; a computer at PJM sent a message down the line signaling a need for frequency regulation; and the car responded by delivering power to the grid.

The operators of the frequency regulation market aren't much interested in dealing with minor players, like one Scion, so to enable the car owner (the University of Delaware in this instance) to earn money for providing regulation, MAGICC piggybacked the 15 kilowatts delivered by the Scion xB onto a 1-megawatt bank of advanced batteries at AES Energy Storage. Down the road, companies like AES Energy Storage will pool the electricity from cars all over town, allowing ordinary car owners to earn money in wholesale electricity markets like PJM's.

AS WITH SO MANY ELECTRIC CAR PROJECTS, IT IS A LONG ROAD FROM DEMONSTRATION PROJECT TO COMMERCIALLY VIABLE ENTERPRISE. For vehicle-to-grid to work on a large scale, utilities would have to manage huge amounts of data, says Mark Griffith, of the engineering firm Black & Veatch. Millions of smart charging stations would be needed at homes, shopping centers, and other public charging stations; and hundreds of small transactions would have to be monitored at each station. Difficult, but doable, Griffith says; phone companies manage equally huge volumes of data in billing for calls and texts. And the electric power industry is "intrinsically complicated," he adds.

There are also business challenges, says Ray Boeman, director of energy partnerships at Oak Ridge National Laboratory's National Transportation Research Center. The price of electric vehicles must come down, which means battery makers need to get better at making cheaper advanced batteries that are still reliable, safe, and long-lasting.

And making consumers confident that the program is safe could be a hurdle. Electric car owners may worry that using the car for vehicle-to-grid could, for example, damage their car's expensive battery or void its warranty, says Venkat Srinivasan, acting head of electrochemistry at Lawrence Berkeley National Laboratory and This Week in Batteries blogger.

But steps have been taken: Kempton lobbied successfully, without opposition, to change Delaware's net metering law to include vehicle-to-grid, and to require utilities to pay the same rate to customers when meters run backward as the customer pays to draw electricity. So far, Delaware is the only one of the 43 states with net metering laws that include vehicle-to-grid.

Kempton's University of Delaware team recently patented his team's "vehicle smart link," a 2.5-inch square circuit board that monitors the owner's driving habits and decides how much electricity the battery can hold or discharge. They've developed software that keeps tabs on each car in a fleet and helps pool their electricity, which allows the fleet to act as a virtual power plant or virtual storage facility. And they've built a smart charging station that not only charges the car, but also keeps tabs on it to ensure the owner gets an accurate bill—or a check.

To Kempton's delight, Autoport, a company in Wilmington, Del., that modifies cars, vans, and trucks, licensed the vehicle smart link last year. The company has overhauled several of the cars in the University of Delaware fleet, and with AC Propulsion, were chosen by the U.S. Postal Service for a trial run of vehicle-to-grid on the postal service's ubiquitous mail-delivery vehicles. (In 2007, Kempton and Tomic determined that a standard commercial fleet of a couple hundred vehicles could generate low-six-figure profits to the regulation market.) Autoport is doing a trial run with electric delivery vans for a large urban cable television company.

And Kempton has made strides overseas. Last year, he and tech industry veterans Gregory Poilasne and Emir Kiamilev founded Nuvve Corporation, which opened a facility in Horsens, Denmark, this year to bring vehicle-to-grid hardware and software to market. Nuvve is launching a pilot program in which 30 electric cars will provide regulation services to the Danish grid operator Energinet.dk. Poilsane claims that Nuvve will be able to pay electric or hybrid car owners up to $10,000 for the use of their car battery's extra energy over the lifetime of the car, enough to make electric vehicles more attractive to customers.

The world market for regulation services is $6 billion—$1.5 billion in the United States and $4.5 billion overseas—so Nuvve has plenty of room to grow, Poilasne says. Vehicle-to-grid aggregators such as Nuvve could also provide virtual storage directly to wind farms, which would enable the wind company to deliver a steadier flow of electricity. They could also store electricity from solar panels or utility-scale solar plants, as Kempton envisioned years ago.

Meanwhile, back at the University of Delaware, Kempton's engineers and social scientists are honing the hardware, software, and know-how to bring Kempton's idea to the world. The Japanese researchers and I pile into the Scion xB, and Pearre accelerates across campus, fast as a sports car but noiselessly. We talk for a while—which model electric cars will be out soon, which cities are building networks of charging stations. The researchers plan another visit to Kempton's lab. Both in the U.S. and across the Pacific, it seems, electric cars are here. The fleet has left the charging station.

If vehicle-to-grid catches on as well, tomorrow's electric vehicles would be more than simply transportation, they'd be resources for all of us. If so, it would help achieve Kempton's dream "to have most of the light vehicles in the industrialized world be powered primarily by electricity; to have that electricity use integrated with the electrical grid, to do that with 100 percent renewable power, and not have the lights flicker." It could happen yet. ❡