Connecting to the Future

"We were making the future … and hardly any of us troubled to think what future we were making. And here it is!"

— H.G. Wells

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PJM Interconnection

eBox - a University of Delaware research vehicle, a Toyota Scion converted into a specially modified PEV by A.C. Propulsion of San Dimas, CA.

Project Barbados is a 1 MW advanced lithium-ion energy storage system developed and operated by AES Energy Storage, an AES Corporation company. This demonstartion system is located at PJM.

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Sometimes the future arrives unannounced, but sometimes we have the opportunity to shape it. The plug-in electric vehicle (PEV) as a "one-in-every-garage" reality still lies in the future, but the vision of that day is edging close enough to realization that we have a genuine opportunity to shape and facilitate its arrival.

We've entered a new era.

- The need for upgrading our electricity grids and developing new sources of clean, reliable and sustainable energy has at last found its way onto Washington's agenda.
- The painfully dramatic spike that took the price of gasoline to over $4 per gallon in 2008—called by some the "psychological breaking point"—finally made independence from foreign oil a national goal.
- The importance of reducing carbon dioxide (CO_2) emissions to protect our global environment is attracting broad and serious consensus.
- And we've begun to confront the need for technological innovation and infrastructure development to revitalize our economy.

It is in this context that the energy and automotive industries are converging in what is being called a "transformational partnership," jointly seeking the birth of the PEV as a realistic option for where we go next.

The convergence of industries was highlighted at a benchmark executive summit co-sponsored by PJM Interconnection and the Electric Power Research Institute (EPRI) to draw attention to the progress being made in the development of PEVs. The summit, held January 26, 2009, at the Valley Forge headquarters of PJM, drew leaders of the energy and automotive industries, along with regulators, academics, researchers and representatives of technology companies.

PJM President and CEO Terry Boston convened the summit with a challenge to electric utilities, regional transmission organizations (RTOs), and independent system operators (ISOs) to join together to "step forward with innovation." He said, "We recognize that we need to explore new technologies and new solutions."

Boston pointed out that there's currently room on PJM's electric grid for 25 million PEVs to utilize off-peak charging. And, as technology advances, he explained, the energy stored in the batteries of aggregated groups of PEVs can be made available to flow back to the grid when needed for frequency control and load balancing. That's known as the V2G (vehicle-to-grid) concept, and it has the potential to produce revenue to PEV owners to offset their investment in their vehicles.

The adoption of PEVs promises to reduce carbon dioxide emissions by as much as 60 percent and cut significantly the nation's dependence on foreign oil. The impact on consumer cost speaks for itself: The estimated cost of charging a PEV at off-peak rates is the equivalent of buying gasoline at 60 cents per gallon.

Electric Vehicle – Equivalent Electric "Price Per Gallon"

Electric Fuel Economy in kWhs per Mile		0.25	0.30	0.35	0.40
Price of Electricity ($/kWh)	$0.05	$0.31	$0.38	$0.44	$0.50
	$0.06	$0.38	$0.45	$0.53	$0.60
	$0.07	$0.44	$0.53	$0.61	$0.70
	$0.08	$0.50	**$0.60**	$0.70	$0.80
	$0.09	$0.56	$0.68	$0.79	$0.90
	$0.10	$0.63	$0.75	$0.88	$1.00

Source: Duke Energy

Summit keynote speaker Jon Wellinghoff, acting chairman of the Federal Energy Regulatory Commission (FERC), said there's no doubt the integration of transportation and the electric system is coming. There are already 40 million electric vehicles in China, he noted, and, while

Keynote speaker Jon Wellinghoff, acting chairman of the Federal Energy Regulatory Commission (FERC)

most are scooters and motorcycles, that country is "moving aggressively" into electric cars. "There is definitely going to be a movement toward transportation electrification worldwide," Wellinghoff told summit attendees. "We need to get on the bandwagon."

One way to do that, he said, is to demonstrate to consumers the financial advantages of PEV ownership. Over a 10-year period, he declared, the net cost of owning a PEV that earns payments for providing energy and load frequency control back to the grid could "approach zero."

Dr. Arshad Mansoor, vice president for power delivery and utilization sector at EPRI

"Electricity as a fuel gives us the opportunity to decarbonize," explained Dr. Arshad Mansoor, vice president for power delivery and utilization sector at EPRI. For example, even driving a plug-in hybrid electric car (PHEV) with only a 20-mile, all-electric range would save, on a per-vehicle basis, 300 gallons of gasoline per year and reduce carbon dioxide emissions by 38 percent.

Mansoor said the infrastructure necessary to achieve such a low-carbon future could take 20 to 40 years to evolve and requires success in four areas:

- Low-carbon energy generation encompassing renewable sources, nuclear, advanced coal technology, carbon capture and storage, distributed (small-scale) energy resources, grid-enabled PEVs and solar.
- "Smart" electricity grids that allow interactive two-way communication and energy flow and that operate with a common language and common standards.
- Local energy networks in which homes become mini energy centers equipped with smart appliances, photovoltaic panels, passive solar, ground-source heat pumps, thermal storage, and PEV charging stations.
- Widespread adoption of PEVs.

Currently, these four infrastructures are evolving independently. One of the missions of EPRI, said Mansoor, is to bring them together "so that they can be integrated and evolve as the electricity network of the future."

Summit participants had a chance to see, touch, and inspect PEV technology as it exists today. On display was the "eBox," a University of Delaware research vehicle, a Toyota Scion converted into a specially modified PEV by A.C. Propulsion of San Dimas, CA. The eBox can accelerate from zero to 60 mph in seven seconds, travel at a top speed of 95 mph, and run for 120 highway miles or 150 city miles on a two-hour charge at 240 volts or an overnight charge at 120 volts. The annual cost of driving the eBox 250 miles per week, using overnight (off-peak) charging, is estimated at $146.24. This compares to $2,427.36 for an equivalent gasoline-powered vehicle.

But the eBox has another feature with potentially important implications for the future. It's called V2G capability—vehicle-to-grid capability. When the vehicle is plugged in, it can respond to a real-time signal from PJM and discharge power from its batteries back to the grid. A group called the Mid-Atlantic Grid Interactive Car Consortium (MAGICC), of which PJM is a member, is evaluating the opportunities this presents.

Virtually from moment to moment, the power grid balances—"regulates"—the generation of electricity in relation to the demand for electricity. The grid operator's control computer sends a "regulation signal" to power generators every four seconds. The signal tells them the level at which they should send power to the grid to keep supply and demand in balance. If the balance tips, power may need to be rapidly boosted or reduced.

A large power plant can take minutes to respond if more power is needed—as long as 10 minutes for a coal-fired plant. One way to fill the gap is with stored energy, which can be released almost instantly. Enter the V2G concept. A battery unit that's plugged into the grid—either an aggregated group of PEVs collectively capable of one megawatt (MW) or a stationery aggregation of batteries capable of at least one MW of power generation—can respond within 50 milliseconds. (A power generating capacity of one MW is the minimum for participation in PJM's ancillary services market.) This kind of "regulation service" will become increasingly important as more wind and other variable power sources connect to the grid.

"PHEVs and stationery batteries have the potential to store energy from an intermittent source during times of low demand and discharge it at a later, higher demand time."

— Terry Boston, president and CEO of PJM Interconnection

In the case of PEVs, an aggregation capable of providing 1 MW would consist of about 800 to 1,000 vehicles, depending on the battery capacity of the vehicles. It's estimated most vehicles are stationery for an average of 22 hours per day. During that non-travel time, PEVs can be available to provide regulation service back to the grid. The premise is that an "aggregator" would sign up PEV owners and contract with the grid to provide the service. The aggregator, in turn, would share part of the revenue with the PEV owners, offsetting the cost of their vehicles.

While summit participants heard about the potential of PEVs to contribute to regulation service, they actually saw a stationery battery unit called Project Barbados in action. Project Barbados is an advanced lithium-ion energy storage system owned and operated by AES Energy Storage, an AES Corporation company, and housed in a trailer at PJM headquarters. This experimental unit was the first of its kind certified by PJM to provide load-balancing regulation to the grid. A fast-responding, high-energy system capable of providing one MW for up to 15 minutes, the unit has since qualified for commercial operation and is now eligible to submit bids in PJM's ancillary services market. High efficiency energy storage systems, like Project Barbados, can lower the environmental footprint of critical ancillary services and contribute to the overall system stability.

It is from leading-edge experimental vehicles like the eBox that commercialization of PEVs is taking root and from which the necessary support technology and infrastructure is being identified, researched and developed. Nearly all of the major automotive companies, including BMW, Daimler, Dodge, Ford, General Motors, Mitsubishi, Nissan, Subaru, Toyota and Volkswagen, have electric cars at some stage of development.

Summit attendees received briefings on two projects, the General Motors Chevrolet Volt and the electric version of the Ford Escape. Both are on the road in test versions. The Volt is headed for production in 2010. Both are PHEVs (plug-in hybrid electric vehicles) rather than pure PEVs. They have gasoline-powered internal combustion engines that can supplement their

electric power or kick in when the electric charge runs out and the vehicle needs to keep going.

From the automotive side of the equation, the developmental focus is on batteries and charging infrastructure. Tony Posawatz, vehicle line director for General Motors, pointed out that GM's battery lab is now the largest in the world. Battery manufacturing technology is highly specialized and a critical element in the PEV development chain. Posawatz believes battery manufacturing will evolve into a "core business" but noted that at present not much of the capability is based in the United States.

Edward Kjaer, director of electric transportation for Southern California Edison, echoed Posawatz's concern even more strongly. He said the United States is competing with Europe and Asia in battery technology and manufacturing "and the United States is not leading." He warned, "This is all about energy security and the environment. Are we swapping our reliance on imported oil for reliance on imported batteries?"

To that point, GM has chosen LG Chem, a South Korean company, to produce the lithium-ion cells for the Chevrolet Volt's initial production batteries, which will consist of 200 to 300 cells packed in modules. The 400-pound battery units, which Posawatz said will be manufactured in Michigan, will produce a 40-mile driving range on a charge that will take three hours at 240 volts and six to eight hours at 120 volts. The battery unit is expected to have a 10-year, 150,000-mile service life.

"We have these forums to generate the imagination, to generate the questions, to start to generate the answers and to move forward with this technology."

— Edward Kjaer, director of electric transportation for Southern California Edison

"Electric propulsion is the propulsion of the future."

— Tony Posawatz, vehicle line director for General Motors

"It's all about the battery," reiterated Greg Frenette, chief PHEV engineer for Ford. "The risks and the costs are high." Ford is working on a plug-in version of its Escape, which, using a lithium-ion battery unit, will have a 20-mile, all-electric range at 40 mph and a "blended engine drive capacity" over 40 mph designed to deliver a fuel rating of 120 miles per gallon, city, and 70 miles per gallon, highway.

Charging is an equally crucial issue. Right now, there are 170,000 gas stations in the United States. A century ago, there were virtually none, which, in most of the country, is about where the charging infrastructure for PEVs is starting from. For PEVs to succeed, charging stations will need to proliferate. Homes will need to be made ready for convenient charging. Public charging stations at places of employment and public facilities such as parking garages will need to be thought through. Plugs, couplers and charging ports will need to be standardized.

On the utility side, the considerations are multi-faceted. Enabling PEVs to engage in multi-directional power flow will require investments, probably in the billions of dollars, to create an infrastructure of smart grids and smart metering. But an open question, according to Michael Ligett, director of market and energy services for North Carolina-based Progress Energy, is the basis on which such investments can be justified. It remains to be seen if a "defined business case" can be made, he said.

What's more, rates and methods of billing will need to be explored. "All of us have different rates and rules and incentives and policies," Ligett said. "The time-use rate is a very easy question with a thousand different answers." Should a PEV be treated like an electrical appliance? How will energy companies deal with a "mobile load"—users that cross service boundaries?

Even home charging is "not a slam dunk," Ligett said. Seventy-four percent of the customers his company has surveyed so far have a 120-volt plug within 20 feet of where they park at home. But a 15- to 20-amp dedicated circuit is recommended, and fewer than five percent have such access.

"Consumers don't like confusion. The value proposition has to be crystal clear."

— Britta Gross, manager of vehicle infrastructure at General Motors

While the challenges are considerable, there was agreement among conference presenters that, given the right tools, incentives, collaboration and rules, the challenges can be met. Citing the PJM model as an example, Wellinghoff predicted that "to the extent we have robust wholesale markets that allow for competition in ancillary services, that's going to foster these types of [PEV-related regulation] technologies. I suspect this is ultimately going to become a best practice in the most of the RTOs and ISOs across the country." He said he thought this could "happen naturally" rather than from federal regulation of the industry.

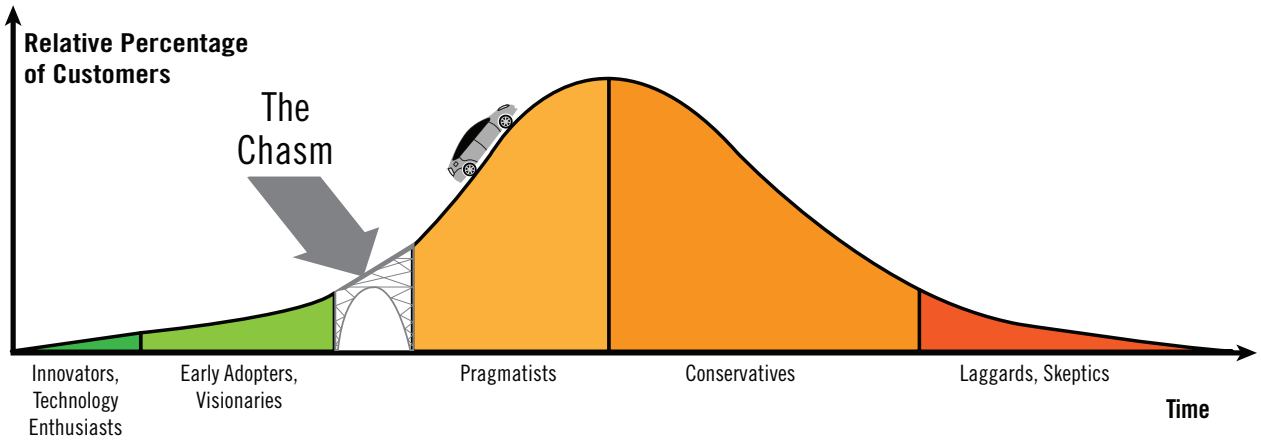
Britta Gross, manager of vehicle infrastructure at General Motors, said the auto industry and EPRI are collaborating and more than 40 utilities are on board with the effort. Mark Duvall, director of electric transportation and energy storage at EPRI, said EPRI's Infrastructure Working Council is studying the impacts PEV charging and service regulation could have on power generation, transmission and distribution and is exploring standards with a number of professional organizations, among them the Institute of Electrical and Electronics Engineers, the International Electrotechnical Commission and the Society of Automotive Engineers.

Gross said the newness of the concept makes it a tough sell to the public—no one wants to be first, and the value proposition for PEVs has to be made crystal clear. "Public education is everything in selling these vehicles," she said.

Dr. Ake Almgren, a member of the PJM Board, invoked the analogy of "crossing the chasm" from Geoffrey A. Moore's book, "Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers." The chasm is the gap between the relatively few early adopters of PEVs and the point at which a much larger group of pragmatic members of the public becomes willing to accept and buy the new technology.

"Based on his decade long experiences of plug-in hybrid vehicles and related technologies, Dr. Almgren predicted, "The scene is set for crossing the chasm in the next 5 to 10 years."

Dr. Ake Almgren is a member of the PJM Board.



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