PLUG-IN ELECTRIC VEHICLES

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WHAT ROLE FOR WASHINGTON?

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CHAPTER FOUR

The CashBack Car

JON WELLINGHOFF

You're out for a Sunday afternoon drive, enjoying the open road and the feeling of freedom that comes with that great American institution, the automobile. As you pull back into your driveway, you notice that the fuel gauge is nearing empty, so you do what is necessary for your local distributor to fill it up at home. Yes, they now make deliveries. They deliver at a convenient time when the price of fuel is the lowest, and the delivery is made without interruption or intrusion. At the end of the month you open the statement for the fuel that you had delivered, and included with the statement is a check made out to you. Yes, they paid you to fuel your car. And they delivered at home. They also deliver at work, at the supermarket, at the mall, and even at your hotel while you are on vacation. In fact, delivery points are everywhere. And, better yet, it's automatic. No scheduling and no phone calls

Does that sound incredible? It's not. Automatic delivery of virtually free fuel for your car wherever you are is close at hand. The potential exists today, in current technology and infrastructure. That potential can be realized by shifting vehicles to electric power as the primary source of energy and enabling them to use that energy not only to move people from home to work and back but also to support and enhance the nation's electric grid.

The challenge is to make that capability commercially available to everyone. The first task is powering a car electrically. The second is using the car's electric system and battery to assist the electric grid to operate more efficiently. You will have a car for your transportation needs for the typical hour a day that you drive it; for the other twenty-three hours of the day, you'll have an electric storage, charging, and grid communication system to use to "refuel" the car and provide grid support services.[1] One task, providing you with transportation, will cost about $.04 per mile for fuel instead of the $.16 per mile for fuel for a gasoline-powered automobile.[2] That is equivalent to buying gas at about $1.00 per gallon. The second task pays you to charge the car by using it as a distributed energy resource to provide grid stabilization services, which will pay you back most, if not all, of the $.04 per mile cost to charge the car. But both tasks must be incorporated into the vehicle to realize the full value from electric-based transportation. The merging of the two functions will create the "CashBack" car.

Electrification of transportation is something that everyone seems to be talking about. From President Barack Obama, to prominent members of Congress, to respected statesmen such as George Schultz, former secretary of state, and James Woolsey, former director of the CIA, all are advocating moving from oil to electricity for our transportation needs.[3] Even the auto industry is recognizing this imperative. Rick Wagoner, CEO of General Motors, recently conceded, "The auto industry can no longer rely almost exclusively on oil to supply the world's automotive energy requirements."[4] Andy Grove, former CEO of Intel and another proponent of electric transportation, has concluded that we are at a "strategic inflection point" where "the drumbeat of electrical transportation is accelerating like nothing I've ever seen in my life. Electricity in transportation has to be done. It is urgent."[5]

Feeding the growing consensus is the fact that oil was recently priced well over $100 per barrel, driving gasoline to more than $4.00 per gallon. The first $60 to $80 fill-up is the kind of shock to the wallet that will propel anyone to contemplate alternatives. Even though prices for oil and gasoline have again fallen, that kind of volatility and uncertainty is one factor driving consumers to seek more stable transportation fuel sources. An electric-powered vehicle that could be "filled up" for less than $20 and then could "pay back" that fill-up the following week by providing services to the grid would get the attention of most consumers, despite its higher initial cost.[6]

Other compelling reasons to move rapidly from oil to electricity for our transportation needs include the potential to significantly reduce greenhouse gas emissions, reduce urban pollution, and improve national security. It is a myth (often repeated) that moving from gas-powered transportation to electric transportation does not reduce greenhouse gases, that it only moves the pollutants from the tailpipe to the smokestack.[7] But in fact, national studies from well-respected independent research institutions have concluded that changing the U.S. vehicle fleet to primarily electric drive could reduce greenhouse gas emissions by as much as 27 percent and reduce oil imports by as much as 52 percent.[8] That is because even coal plants are more efficient than the internal combustion gasoline engine and our total stock of power plants for generating electricity is becoming cleaner as we continue to add more renewable resources to the mix. In addition, any pollution that emanates from the stack of a generating plant is easier to control and clean than pollution from millions of tailpipes.

Finally, the need to reduce greenhouse gases is driving the need to incorporate more renewable energy into the total energy resource pool. One of the most abundantly available renewable resources in North America is wind. A recent U.S. Department of Energy study concluded that we could derive 20 percent of our total energy needs from wind power by 2030.[9] But because of the variability of wind, to integrate this clean energy resource into the electric grid requires a substantial increase in grid stabilization services. Those services can be supplied by the systems in electric vehicles when the vehicles are connected to the grid.

The Challenge of Electric-Based Transportation

So how do the economic and environmental benefits of using electric power in transportation become reality in the United States? Auto manufacturers and other entrepreneurs need to be encouraged through the appropriate government and regulatory agencies to aggressively move forward with the production and marketing of vehicles that use primarily electricity for drive power. They can take the form of a battery electric vehicle (BEV) or a plug-in hybrid electric vehicle (PHEV). A BEV is a car that is driven by an electric motor instead of an internal combustion engine. On-board batteries power the electric motor; the batteries are recharged through a plug much like the familiar small rechargeable batteries in power tools and other household appliances. Mrs. Henry Ford drove an electric car—no getting out and cranking.[10] The PHEV is a variant of the BEV in that in addition to the electric motor and batteries, it has an internal combustion engine (ICE) that can be used either to charge the batteries while the vehicle is under way (called a series PHEV) or to drive the vehicle directly as is currently done in a conventional gasoline-powered car (called a parallel PHEV).[11] The advantage to a PHEV is that it may have a longer range than a BEV and somewhat more flexibility due to its ability to run on gasoline (or diesel or other alternative fuel) in addition to electricity.

Despite widespread popular support for the production of BEVs and PHEVs, car manufacturers are moving very cautiously. Currently no PHEVs are in production for the mass market. Demonstration conversions of hybrid electric vehicles (HEVs) to PHEVs have been successfully tested, and commercial aftermarket converters have established conversion facilities to provide HEV owners with the opportunity to drive a PHEV.[12] The number of these conversions to date, including manufacturer demonstrations, is in excess of 150. There is limited production of BEVs (less than 1,000 units a year) by some small manufacturers; one major manufacturer is producing BEVs (on a limited basis) for lease only.[13] Although speculation continues in the auto industry, only two companies, China's BYD Auto and General Motors (GM), have announced commercial production of PHEVs for consumer purchase, in 2009 and 2011, respectively.[14] Toyota has announced limited production of PHEVs for fleet sales only in 2010.[15]

Admittedly, there are barriers to overcome and issues to understand before manufacturers accelerate production of such vehicles, including retooling existing production lines, improving battery reliability and cost, and integrating batteries with the electric grid. Of these, grid integration and interface is the issue that has been most ignored and misunderstood by auto manufacturers. Yet it is this unique aspect of the new variants that has the greatest potential to increase consumer acceptance and alleviate the single-biggest market barrier, the increased cost of vehicle production due to the high cost of the batteries required. The U.S. Department of Energy (DOE) in its 2007 R&D plan for PHEVs determined that "cost is the primary impediment" to producing PHEVs.[16] Yet in the same

R&D plan, DOE dismissed any immediate interest in developing vehicle-to-grid (V2G) capabilities for the PHEV that would enable it to interact with the grid as a distributed resource and to receive revenues to offset the incremental first costs. DOE concluded that "other aspects of PHEV-utility interface, such as vehicle-to-grid power flow, could have system-level benefits as well, but it requires more sophisticated communication and a more complex relationship between the customer and utility. It is not considered an enabler for vehicle technology in the short term."[17] This decision by DOE fails to consider the substantial synergies that would result from the use of a PHEV as both a means of transportation and as a distributed resource for the grid. The benefits for both uses would be substantial, but use as a grid resource would enable PHEVs to be effectively marketed for transportation by reducing the first cost to the consumer.

Many assume that the precursor to full production of PHEVs or BEVs by mainstream auto manufacturers is the hybrid electric vehicle (HEV) and that a PHEV is simply an incremental step up from the HEV. The Toyota Prius has been the most successful HEV to date.[18] Despite its success, auto manufacturers are discovering that the move from an HEV to a PHEV or BEV is not simply incremental; it is, in fact, disruptive.[19] Switching from gasoline to electricity for drive power would have profound disruptive impacts on how consumers and society view and use the device now commonly known as the "car." Those impacts would be a function of the interface of the PHEV or BEV system with the world's largest system, the U.S. electric grid. They would be the same impacts that could make the PHEV and BEV not only a superior transportation option for the nation from the perspective of the environment and oil security but also an affordable option that would enable rapid integration of large quantities of new, clean renewable resources such as wind power into the national grid.

The Grid

In order for auto manufacturers, government policymakers, and consumers to understand the full implications and potential benefits of a car that plugs into the electric grid, it is necessary to consider the grid's engineering, economic, and regulatory characteristics. From an engineering perspective, the grid must be operated as a large integrated system. It consists first and foremost of multiple, ever-changing loads that require power.

Loads range from the load from a cell phone charger, which may draw a few watts, to the load from an electric arc furnace in an aluminum smelter, which may draw tens of megawatts. Loads come on and off at all times of the day and night; the sum of all loads on a given system over a period of time is called a load duration curve. The loads are interconnected by a distribution system composed of local electric distribution wires and distribution transformers to regulate flows and reduce voltage to loads as required. Beyond the local distribution system are transmission lines that operate at higher voltages than the distribution system in order to transmit bulk power for longer distances at lower losses from neighboring electric systems and central generating plants (see figure 4-1).[20]

The generating side of the electric system is composed primarily of large coal-fired plants (about 50 percent), natural gas generators (about 20 percent), nuclear power plants (nearly 20 percent), and hydroelectric facilities (about 7 percent); facilities using oil and distributed renewable resources such as solar, wind, geothermal, and biomass energy make up the remainder.[21] The last category of resources typically is smaller than central station coal, gas, or nuclear plants, but facilities can range from 50 megawatt geothermal or biomass plants to 1 kilowatt (kW) solar photovoltaic systems on homes.

For the entire system to work and not spin out of control and cause a blackout, the loads and generation to meet the loads must match exactly all the time—twenty-four hours a day, seven days a week. In the United States, there are three major segments of the grid: the Western Interconnect, from Colorado to California, Oregon, and Washington; the Eastern Interconnect, from Kansas to the East Coast from Maine to Florida, excluding Texas; and the Texas Interconnect, which is an independent system (see figure 4-2). Within each of those segments there are numerous control areas with separate control area operators who are responsible for keeping their area in balance by controlling loads and generation.[22]

To keep the grid functioning over the short term, grid operators typically have three concerns. The first is day-ahead scheduling, wherein the operator forecasts the expected loads on the grid for the next day and schedules the resources to meet those loads. The second concern is real time during the next day, when the grid operator must "follow" the load. That is, as the load ramps up or down over ten-minute to one-hour increments—usually in a relatively gradual incline or decline—new resources

FIGURE 4-1. U.S. Transmission Grid

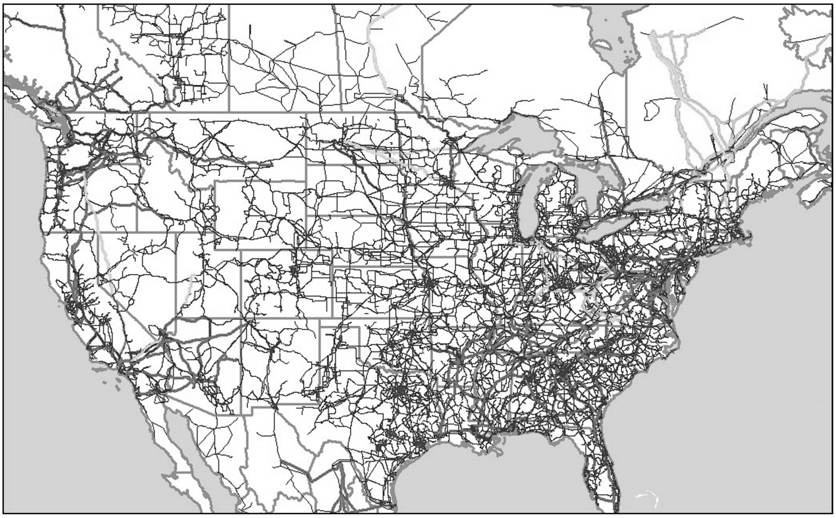
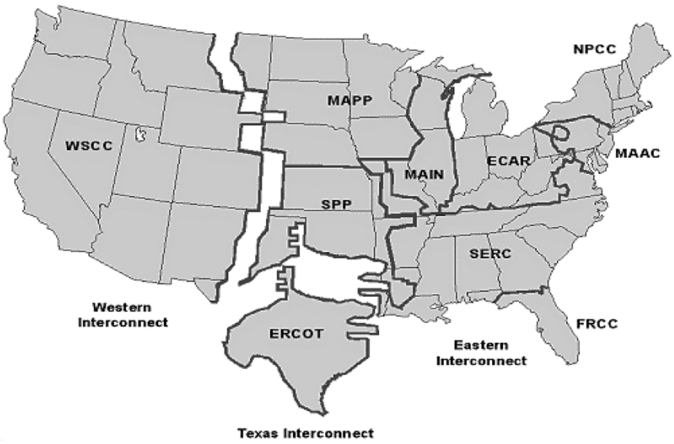


FIGURE 4-2. Major Segments of the U.S. Transmission Grid



must be called up to meet increasing loads or resources must to taken off the system to match declining loads. Variances over the day are the result of both human activity (such as employees arriving for work in the morning and leaving in the afternoon) and external events like the weather (such as hot summer afternoons that cause an increase in air conditioning loads and mild days that require neither heating nor air conditioning). Third, in order to keep the grid within its frequency tolerances, it is necessary to provide what are known as regulation services, through which rapid-response maneuverable resources deliver bursts of power on short time scales (seconds to minutes), allowing operators to maintain system balance and frequency. These services typically are provided by generators using automatic generation control (AGC), whereby grid operators communicate through Internet connections with the generators in real time to signal them to provide regulation services.

The first of these three operational parameters, day-ahead scheduling, is designed to deliver the power to operate the loads on the system—lights and air conditioners and everything else that runs on electricity. The other two—load following and regulation—do not deliver power per se, but they are necessary for the stable operation of the grid; they are called ancillary services. Historically, ancillary services have been provided by generating resources that have the capability to rapidly respond to the grid operator's communication signal within hours, minutes, or even seconds to keep the grid in balance. The type of generating resources capable of providing such services are rapid-response units like natural gas–fired combustion turbines, which can spin up and down quickly. This type of operation is not possible with a coal plant or a nuclear unit because they are too slow to respond.

Over the past several years it has been demonstrated that loads as well as generators can provide some types of ancillary services. The ideal ancillary service provider would respond virtually instantaneously to the communication signal of the grid operator, either adding or reducing power to the grid as required. A load can effectively perform the same function by turning on or off, if it can be signaled to do so by the grid operator. That has been demonstrated to be feasible for all loads—from the largest, such as an industrial electric furnace, to the smallest, such as a home dishwasher. In fact, Pacific Northwest National Laboratories (PNNL) conducted a test at 112 residential sites on the Olympic Peninsula in Washington, in which ordinary appliances like water heaters and dryers were retrofitted with electronic chips that could actually sense the frequency on the grid.[23] The appliances could thereby automatically determine whether ancillary regulation services were required; they then either shut off or turned on as required, but they did so within limited parameters set by resident participants. Thus, residents were not inconvenienced; their clothes got dried and their water was heated. But the grid was made more stable by the regulation services that the appliances provided. No grid operator intervention was required.

Data from that demonstration verified that the appliances provided regulation services faster and more smoothly than a generator. In addition, the grid was made more efficient because regulation services that were usually provided by less efficient generating units were provided by a nonpolluting controlled load. And the generators that were operating were allowed to do so more efficiently, without having to ramp up and down constantly to match loads and keep the grid in balance. Thus generators could operate at their optimum efficiency and burn less fuel. Finally, consumers in the demonstration benefited in two ways. First, as just discussed, the grid was operated more efficiently, so overall electric costs were reduced for all electric customers on that grid. But second, the residents in the PNNL demonstration benefited directly and immediately in that they received direct payments for the grid regulation services that their appliances provided.

The use of loads to provide ancillary services has been so well established that several grid operators now pay controlled loads, generally called "demand response," or "DR," to provide services comparable to those of generators. In addition, to further the effort to make the grid more efficient, the Federal Energy Regulatory Commission (FERC) has found that the sale of ancillary services by demand response and other load resources should be permitted where appropriate on a basis comparable to service provided by generation resources.[24] Thus, under FERC rules, both generators and controlled loads have the opportunity to receive compensation for providing regulation services.

Electric Vehicles and the Grid

So what does the provision of regulation services to the grid have to do with PHEVs and BEVs? A 2006 research paper by two investigators from the National Renewable Energy Laboratory (NREL) and a university professor from Green Mountain College reviewed the potential for PHEVs or BEVs to provide regulation services to the grid and to be compensated for them.[25] That paper looked at two of the largest grid control areas in the country, PJM and ERCOT. PJM, the largest grid operator in the United States, encompasses an area from New Jersey to Illinois that serves more than 51 million people in thirteen states and the District of Columbia. It operates the grid independently under the jurisdiction of FERC.[26] ERCOT encompasses most of Texas, including the two largest load centers, around Houston and Dallas, and functions as an independent grid operator under the jurisdiction of the Texas Public Utilities Commission.

The paper investigated a number of issues related to electric-based transportation but focused on the economic viability of providing payments to a PHEV or BEV for supplying regulation services to the grid. The investigators chose regulation services for analysis because they are required twenty-four hours a day, every day of the year, and the PHEV or BEV would be available to provide such services 90 percent of the time—the amount of time the average vehicle is not being driven. Under FERC's mandatory reliability rules, grid operators are required to maintain regulation reserves approximately equal to 1.5 percent of the control area peak load for a given day. In addition, regulation services are the most valuable ancillary service provided. It is estimated that they constitute more than a $5 billion market in the United States, and they are growing as additional wind resources are added to the grid, thus requiring more regulation services.

The high value of regulation services relative to other ancillary grid services is demonstrated by the variance in the price of these services on the grid in relationship to other ancillary services, such as spinning reserve services. For example, in the New York Independent System Operator (NYISO), regulation services commanded prices from $50 to $70 per MWh during 2007–08 while spinning reserve services rarely exceeded $15 per MWh and usually averaged below $10 per MWh during the same period.

This magnitude of payments for regulation services for NYISO is consistent with that found by the researchers in the PJM and ERCOT study discussed above. The PJM and ERCOT average market prices for regulation services in 2005 (the year used in the study) ranged from $38 per MWh for ERCOT to $50 per MWh for PJM. The analysis then took the average market prices for regulation services and applied them to two hypothetical electric vehicles: one capable of plugging into a 120 volt, 20 amp standard electric circuit and providing 2 kW of reverse power flow and one capable of connecting to a 240 volt, 50 amp electric circuit (such as would be used for an electric dryer) and providing 10 kW of reverse power flow.

The results were astonishing. The owner of a PHEV or BEV providing 2 kW of power for regulation services could have received payments of approximately $500 for the year in ERCOT and $650 for the year in PJM, if we assume that grid services were provided 75 percent of the time in a given year. If the vehicle was capable of delivering 10 kW of regulation services, then the owner would receive a substantial increase in payments—approximately $2,500 for the year in ERCOT and $3,300 for the year for PJM. At 2007–08 NYISO compensation levels for regulation service, those payments could be 20 to 30 percent higher. One key parameter making that level of payment possible was that the vehicle could deliver both regulation-up and regulation-down services. That means that the charger in the vehicle was assumed to be capable of both taking power from the grid for charging and delivering power to it through discharge.

But in order to realize such payments for providing regulation services, several things are required. Primary among them is that the vehicle would have to be capable of receiving an automatic generation-control signal from the grid operator, just as a generator is, and responding to that signal within seconds to provide regulation services. The authors of the study admitted that that question had been analyzed "primarily from a theoretical perspective."[27] But concurrent with their theoretical analysis, other researchers were undertaking an effort to demonstrate in real time with a real electric vehicle its ability to deliver regulation services to the grid.

Real Time Demonstration of the CashBack Car

Willett Kempton leads a team of electric vehicle researchers at the University of Delaware. Over the past eleven years he has published numerous articles on the potential of electric vehicles, both PHEVs and BEVs, to provide support to the electric grid and to assist in integrating new wind sources into the grid.[28] In 2007 he formed a group called the Mid-Atlantic Grid Interactive Car consortium (MAGIC). MAGIC is composed of partners from the University of Delaware, PJM, the regional utility (PHI), an electric transportation propulsion system manufacturer (AC Propulsion), and a provider of demand response services to grid operators and utilities (Comverge). The objective of the consortium is to demonstrate at scale the delivery of grid support and support for the integration of additional wind resources into the grid by electric vehicles. Those vehicles would be equipped with the electronic control and communications devices necessary for them to receive signals from the grid operator and to respond by delivering grid support services.

On October 23, 2007, Kempton drove from his research lab at the University of Delaware to FERC in Washington. He made the trip at my behest in a converted Toyota Scion in order to demonstrate the provision of regulation services by an electric vehicle. The vehicle had been converted to an eBox BEV by the MAGIC consortium partner AC Propulsion.[29] The converted Scion eBox has a range of more than 120 miles and will go from 0 to 60 mph in less than seven seconds. It has a 20 kW charger. Most important, an automatic generation-control system module was installed in the vehicle, enabling it to communicate in real time to the grid operator at PJM. The car was brought to FERC and connected to a 240 volt outlet through a standard mechanical electric meter, and the meter started to move as the charger drew power from the grid to charge the car.

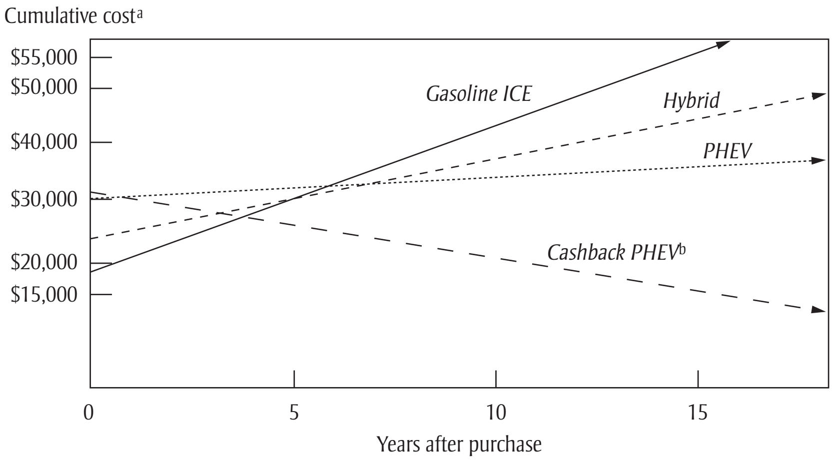
As part of the demonstration, the senior engineer from PJM, Kevin Komara, brought his laptop computer and connected through a wireless Internet connection to his grid control center at PJM headquarters in Pennsylvania. He then accessed the PJM regulation control screen, where he was able to see the generation resources that were available to PJM to provide regulation services. Among those resources was an 35 kWh Scion eBox ready to be dispatched, just like any other regulation service generator. With a few strokes on the keyboard, Komara called on the eBox to provide regulation-up service (to stop charging and provide power to the grid), and instantaneously the meter stopped and then reversed, pushing power back into the grid. Kevin signaled again, and the meter reversed again, in the charging direction, now providing regulation-down services. This demonstration established—in real time, with a real vehicle—that it is possible to charge a PHEV or BEV and at the same time get paid to do so by providing electric services to the grid. And what is astounding is the fact that at the same time that this demand resource is providing regulation services, the grid is operating more efficiently because a nonpolluting passive load is being controlled and dispatched instead of a polluting active generator. That allows generators that would otherwise be rapidly ramping up and down to operate instead at optimum levels, thus reducing fuel use and producing fewer emissions while lowering overall grid system costs. Questions by auto manufacturers and battery manufacturers regarding the process focus on the effect on battery life. But provision of regulation services by controlling the charging of a PHEV or BEV likely will not significantly affect the battery life in any material way because there is no deep cycling of the battery during the regulation control cycle. And as discussed below, a one-way regulation charging scheme for the provision of regulation service also could be implemented that would have no effect on battery life.

The next step for the MAGIC consortium is to conduct a demonstration at a scale of 300 to 500 vehicles to provide regulation services to the PJM grid.[30] A demonstration of that size would more closely match PJM's minimum requirements for providing compensation for regulation services. The consortium is actively seeking sponsors to conduct the demonstration at scale. Once at-scale regulation services are proven, the economic benefits of providing such a service becomes real for auto manufacturers and prospective purchasers of PHEVs and BEVs. At that point, the remaining barriers to the rollout of the CashBack car would lie primarily in issues of economics, logistics, and regulatory requirements and communications protocols.

Economics

The economics and marketability of a CashBack car to consumers would depend on its sales price and associated benefits and the incentives that consumers receive for purchasing it. With gas prices at \$4.00 per gallon, the cost increment barrier of approximately \$4,000 to \$6,000 between an internal combustion engine, gasoline-powered car and an HEV seems to be falling.[31] But while the ability to purchase fuel at a gasoline equivalent price of \$1.00 per gallon for a PHEV may now be more attractive, the expected price differential of the PHEV would appear to still be a barrier to widespread consumer acceptance. Figure 4-3 analyzes the economics of owning various types of cars in today's environment. The figure shows the initial cost for the car and the lifecycle cost of fuel (excluding maintenance, depreciation, insurance, and discount rate factors), assuming that

FIGURE 4-3. Economics of Ownership of Various Types of Cars Today



a. $4.00/gallon; $0.084/kWh (off-peak rate); maintenance costs not included, no discount rate applied.
b. Payments to CBH owners for regulation services. Assume $1,500/year.

gasoline is $4.00 per gallon and electricity is $.08 per kWh. The internal combustion engine vehicle selected was a Chevrolet Cobalt, which had a manufacturer's suggested retail price (MSRP) of $18,000.[32] Estimated EPA mileage was 24 miles per gallon. Average yearly mileage driven for all vehicles analyzed was estimated at 15,000 miles per year. You can see that in less than ten years, the owner of this vehicle would pay more for gasoline than the original purchase price of the car.

The next vehicle analyzed was a Toyota Prius HEV with an MSRP of $24,000, or a $6,000 premium over the Chevy Cobalt. Estimated mileage was 42 miles per gallon. Given the higher gas mileage of the Prius, it would overcome its cost premium and become less expensive to operate than the Cobalt in approximately five years. The next vehicle on the chart is the PHEV. This PHEV cannot provide grid regulation services and does not incorporate the automatic generation-control communication module necessary for such services. It was estimated to have a cost premium of $12,000 over the Cobalt, or an MSRP of $30,000, the price initially estimated by GM for its PHEV Volt to be available in 2010.[33] More recent estimates by GM have revised the price to be the range of $40,000 to

$45,000.[34] The analysis in figure 4-3 shows that even at the $30,000 price point and a fuel cost advantage equivalent to $1.00-per-gallon gasoline, this PHEV with no CashBack services overtakes its cost premium over the ICE vehicle only in the sixth year and does not overcomes its cost premium over the Prius until at least the seventh year of ownership.

The CashBack PHEV analyzed last in the figure was identical to the PHEV except that it could provide regulation services. It would at least have a 240 volt connection and could have a charger with two-way power flow capability. As can be seen from the PJM and ERCOT study discussed previously and the estimates of future levels of compensation for regulation services, the $1,500 yearly compensation estimate for the provision of regulation services may be conservative. On the other hand, if the charger is 120 volts and is capable only of one-way power flow (to charge the battery), the compensation level may be overestimated. The incremental premium for the controller hardware, software, and communications module to make the PHEV capable of providing grid-compatible regulation services is estimated at $200. That is really no more sophisticated than the electronics that will be in the new Apple iPhone 3G. As figure 4-3 shows, adding payments for regulation services, the CashBack car will better the cost premium over the ICE vehicle in a little over three years; that is within the financing period for many vehicles. That means that if the grid regulation payments could be bundled with the original purchase price of the vehicle, it may be possible to structure payments for the CashBack car that are less than those of an ICE vehicle.

Logistics

Auto manufacturers are very uncertain of the benefits of incorporating vehicle-to-grid CashBack characteristics into the PHEVs that they plan to manufacture in the near future. The manufacturers, primarily GM, are on an accelerated schedule to have a PHEV on the market by 2010, and stopping to consider, design, and implement the incorporation of vehicle-to-grid technology into the first round of PHEVs could delay that schedule. Recent discussions were conducted between representatives of FERC and the automotive industry at a board meeting of the Electric Drive Transportation Association to describe the benefits of the CashBack car for the auto manufacturer representatives present.[35] During the discussions several things became apparent. First, auto manufacturers are still largely uninformed about the ability of demand resources, including properly equipped PHEVs, to provide services to the grid and receive payments for those services. Second, once informed of the progress in this area, they are interested and enthusiastic about the prospect of such benefits to assist in marketing the vehicles. Third, manufacturers do not have the scheduling flexibility to fully incorporate 240 volt, two-way power flow charger technology with vehicle-to-grid communication-and-control modules into the first round of PHEVs that they manufacture and market.

Despite that limitation there was discussion at the meeting of the possibility of a "CashBack Lite" solution for the first round of PHEV vehicles that would entail incorporating only one-way control (on/off only) capability, similar to that demonstrated by the PNNL residential appliance test in Washington state. This simplified control strategy would allow the grid operator to switch the charger off or on to provide regulation services for the grid. Because the flow of power would be only one way, the level of payment would be reduced, but there also would be no effect on battery life.[36] Discussions revealed that that was possible because the currently contemplated communication-and-control technology to be incorporated into the first PHEV production run will provide for off-peak charging and can easily be adapted to the CashBack Lite scheme.

From a logistics perspective, it would be useful next to schedule a series of meetings between key auto manufacturers and selected large grid operators to determine the common interfaces necessary to initiate regulation services from this first group of PHEVs. It is contemplated that the services would be provided by an aggregator, who would bundle scale-size groups of vehicles to bid for regulation services in the grid operators' regulation markets. The MAGIC consortium could assist in developing the business plan for such aggregated services. Regulatory issues also need to be considered and potential changes in tariffs and regulations evaluated. FERC representatives are working with the ISO/RTO Council (IRC), the Electric Power Research Institute (EPRI), automotive industry representatives, and others to schedule meetings to discuss those issues. FERC and the IRC met in November 2008 to initiate discussions on PHEV and BEV grid integration issues. As a result, an IRC working group will be formed to develop policies and procedures for the provision of fast-response regulation services by PHEVs and BEVs to ISO/RTO grid operators, including necessary communication protocols and economic settlement procedures. Meetings with EPRI and other electric and automotive industry representatives are scheduled for January 2009 at PJM headquarters.

Policy Implications and Conclusions

Moving to an electric-based transportation system has many benefits for this country and for the world. Those benefits multiply significantly when the move incorporates the synergies of both electric fuel for transportation and electric storage and systems for grid support and enhancement. The CashBack car can be driven more efficiently at less cost with less pollution and less dependence on foreign oil. But it also can provide for more efficient operation of the grid while helping to incorporate more clean wind energy into the grid.

Both the states and the federal government are considering incentives or requirements for lower-emissions vehicles such as PHEVs. For example, California's zero-emissions vehicle program mandates that nearly 60,000 plug-in cars be sold in the state between 2012 and 2014. Connecticut, Massachusetts, Maine, Maryland, New Jersey, New Mexico, Oregon, Rhode Island, and Vermont have adopted similar requirements, and other states will follow. At the federal level, several bills have been introduced to provide tax credits for PHEVs and BEVs.[37] Yet none of those initiatives directly addresses the desirability of ensuring that any PHEVs or BEVs produced include CashBack capabilities.

In *Freedom from Oil*, policy analyst David Sandalow made a number of solid policy recommendations for the next president regarding PHEVs.[38] They include the following:

—Buying 30,000 PHEVs for federal fleets at an $8,000 premium and agreeing that half the vehicles purchased by the federal government thereafter will be PHEVs

—Issuing consumer tax credits of $8,000 for the first million PHEVs and $4,000 for the second million

—Replacing CAFE standards with Fuel Reduction and Energy Efficiency (FREEdom) standards

—Creating a Federal Battery Guarantee Corporation to help manufacturers provide ten-year battery warranties for the first million cars.

The book ends with a proposed speech by the president-elect to the nation calling for "new ways of doing business that create jobs, cut pollution, and make us stronger" and "proposing a grand bargain with American automakers. If you invest in advanced technologies, we'll invest in you."

As demonstrated by the economic analysis in figure 4-3, all of that is needed. This chapter demonstrates, however, that any such incentive programs, state or federal, should also require all new PHEVs or BEVs to incorporate vehicle-to-grid CashBack capability into their electronic architecture if they are to receive the incentives. By insisting on this standard for the vehicles, the nation will gain substantial benefits at relatively little cost.

Notes

1. From home to work, the average commute is 26.4 minutes. Bureau of Transportation Statistics (BTS) Omnibus Household Survey, *OmniStats* 3, no. 4 (October 2003) (www.bts.gov/publications/omnistats/volume_03_issue_04/).

2. Assume a mid-sized sedan averaging 21 miles per gallon, gasoline at $4.00 per gallon, and electric rates of $.10 per kilowatt-hour. Note that the fuel cost difference of $.12 per mile is enough to allow you to afford an additional $150 per month in car payments. Gasoline prices have dropped by more than $2.00 a gallon recently, but most analysts concede that the drop is likely to be a short-lived phenomenon. But even with gasoline at $2.00 a gallon, electric transportation is more economical.

3. The California Cars Initiative (www.calcars.org/endorsements.htm).

4. "As Oil Prices Rise, Carmakers Look to Electric Future," *NewsHour with Jim Lehrer*, June 25, 2008 (www.pbs.org/newshour/bb/transportation/jan-june08/electric cars_06-25.html).

5. Ken Thomas, "Ex-Intel Head Pushes Electric Cars," *Chicago Tribune*, June 27, 2008 (www.chicagotribune.com/news/chi-ap-grove-plug-ins,0,1749993.story).

6. Assume electricity at $1.00 per gallon equivalent ($.08 to $.10 per kilowatt-hour) for the equivalent of fifteen to twenty gallons of drive power.

7. David Sandalow thoroughly debunks this myth in his recent book, *Freedom from Oil: How the Next President Can End the United States' Oil Addiction* (New York: McGraw-Hill, 2007), pp. 64–65.

8. Scott Kintner-Myer, Warwick Pratt, and Elliot Schiedner, *Impacts Assessment of Plug-In Hybrid Electric Vehicles on Electric Utilities and Regional U.S. Power Grids* (Pacific Northwest National Laboratory, January 2007). Also see Electric Power Research Institute and Natural Resources Defense Council, *Environmental Assessment of Plug-In Hybrid Electric Vehicles* (July 2007).

9. U.S. Department of Energy, *20 Percent Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electric Supply*, prepublication version, May 2008.

10. Henry Ford Estate, "Inside Henry Ford's Garage–1914 Detroit Electric" (www.henryfordestate.org/claracar.htm).

11. It is possible to have a combined serial/parallel PHEV that can both charge the batteries through the internal combustion engine and drive the car's wheels.

12. Currently there are at least eight conversion companies in Europe and North America. One company, Hymotion (www.hymotion.com) of Ontario, Canada, retrofits the Toyota Prius, as do many of the other converters. Hymotion was recently acquired by battery maker A123Systems (www.a123systems.com) of Hopkinton, Massachusetts. Crash-tested Prius conversions can now be ordered for $9,950 plus $400 delivery (with a $1,000 deposit) from Hymotion distributors at several cites.

13. Tesla Motors is the most well-known entrant in the BEV sphere in the United States, producing a $100,000-plus battery-powered sports car built on a Lotus frame. The chairman of Tesla, Elon Musk, stated at the roll out of Tesla's first commercial production car on February 1, 2008, "I want to be very clear; we are going to put thousands of vehicles out there." See the Tesla Motors website (www.teslamotors.com). BMW is producing a BEV version of its popular Mini Cooper. But first-year production is limited to 500 vehicles, for lease only. See EV World, "Mini E: AC Propulsion Inside" (www.evworld.com/EVWORLD_TV.CFM?storyid=1595).

14. "Plug-in hybrid," *Wikipedia*, November 14, 2008 (http://en.wikipedia.org/w/index.php?title=Plug-in_hybrid&oldid=251735441). A comprehensive listing of each auto manufacturer's current position on producing PHEVs or BEVs can be found on the CalCars site (www.calcars.org/carmakers.html).

15. Irv Miller, "Plug-in Hybrid Fleet Coming, Toyota Chief Says," *Toyota Open Road Blog*, January 13, 2008 (http://blog.toyota.com/2008/01/plug-in-hybrid.html).

16. U.S. Department of Energy, *Plug-in Hybrid Electric Vehicle R&D Plan*, external draft, February 2007, p. 3 (www1.eere.energy.gov/vehiclesandfuels/pdfs/program/phev_rd_plan_02-28-07.pdf).

17. Ibid., p. 32.

18. The HEV has a gasoline-driven engine plus an electric motor that runs in parallel (or for very short periods in series) for added mileage and performance. Its extra batteries, which run the electric motor, are charged by the gasoline engine and are not recharged from the grid. Toyota says cumulative worldwide sales of the Prius hit 1,028,000 in April 2008. See http://blog.wired.com/cars/2008/05/prius-sales-top.html.

19. *Disruptive technology* is a term describing a technological innovation, product, or service that uses a "disruptive" strategy, rather than a "revolutionary" or "sustaining" strategy, to overturn the existing dominant technologies or status quo products in a market. "Disruptive Technology," *Wikipedia* (http://en. wikipedia. org/w/index.php? title=Disruptive_technology&oldid=25211 7278). See also Graeme Pietersz, "Disruptive Technology," Moneyterms Guides (http://moneyterms.co.uk/disruptive-technology/).

20. Transmission efficiency is improved by increasing the voltage using a step-up transformer, which reduces the current in the conductors while keeping the power transmitted nearly equal to the power input. The reduced current flowing through the conductor reduces the losses in the conductor since the losses are proportional to the

square of the current. Thus halving the current makes the transmission loss one-quarter of the original value. See "Electric Power Transmission," *Wikipedia,* November 16, 2008 (http://en.wikipedia.org/w/index.php?title=Electric_power_transmission&oldid= 252240357). See also Edward Oros and Bob Cocco, "Determine the Efficiency of Your Transmission Line" (www.qsl.net/w4sat/lineeff.htm).

21. Energy Information Administration, "Electricity InfoCard 2006," November 2007 (www.eia.doe.gov/bookshelf/brochures/electricityinfocard/elecinfocard2006/elecinfocard.html).

22. There are approximately 150 control area operators in the United States and seven major independent control areas; see note 26 below.

23. "Department of Energy Putting Power in the Hands of Consumers through Technology," Pacific Northwest National Laboratory, January 9, 2008 (www.pnl.gov/topstory.asp?id=285).

24. For a complete discussion of FERC's consideration of demand response to provide ancillary services in wholesale electric markets see Jon Wellinghoff and David Morenoff, "Recognizing the Importance of Demand Response: The Second Half of the Wholesale Electric Market Equation," *Energy Law Journal* 28, no. 2 (2007): 389–419.

25. Steven Letendre, Paul Denholm, and Peter Lilienthal, "Electric and Hybrid Cars, New Load or New Resource?" *Public Utilities Fortnightly*, December 2006, p. 28.

26. There are six independent grid operators in the United States under the control and jurisdiction of FERC: PJM (grid operator for the Mid-Atlantic states), Mid-West Independent System Operator (MISO), California ISO (CAISO), New York ISO (NYISO), New England ISO (ISO-NE), and Southwest Power Pool (SPP). The Texas grid is independently operated by the Electric Reliability Council of Texas (ERCOT). In other regions of the county, the interstate grid is also under the jurisdiction of FERC, but the grid is operated by the owners of the transmission system or in some instances by other federal, state, or municipal agencies.

27. Letendre, Denholm, and Lilienthal, "Electric and Hybrid Cars, New Load or New Resource?" p. 30.

28. See "V2G: Vehicle to Grid Power," Center for Carbon-Free Power Integration, University of Delaware, April 2007 (www.udel.edu/V2G/).

29. See "About the eBox," AC Propulsion (www.acpropulsion.com/ebox/).

30. Willett Kempton, "Vehicle to Grid Power," briefing for the Federal Regulatory Commission, October 23, 2007 (www.ferc.gov/news/media-alerts/2007/2007-3/10-22-07-v2g.pdf).

31. Eoin O'Carroll, "Hybrid Availability Plunges as Demand Rises," *Christian Science Monitor Bright Green Blog*, June 11, 2008 (http://features.csmonitor.com/environment/2008/06/11/hybrid-availability-plunges-as-demand-rises).

32. Manufacturer's suggested retail prices and EPA mileages were obtained from *Consumer Reports*. Models and prices may vary.

33. Ralph Hanson, "GM Expects Volt to Cost Less Than $30,000," *Motor Authority*, May 24, 2008 (www.motorauthority.com/news/concept-cars/gm-expects-volt-to-cost-less-than-30000).

34. "Volt Could Spark GM Bailout," *Newser*, July 2, 2008 (www.newser.com/story/31427.html).

35. I made a presentation summarizing the material in this chapter and had discussions regarding the material with the board of directors of the Electric Drive Transportation Association in Washington, D.C., on June 18, 2008.

36. Regulation service payments for one-way power flow would be one-quarter the level of payments for two-way power flow.

37. See “Legislation, Tax Credits, Funding, and Other News,” Electric Drive Transportation Association (www.electricdrive.org/index.php?tg=articles&topics= 127&new=0&newc=0).

38. Sandalow, *Freedom from Oil.*