ADVANTAGES OF PLUG-IN HYBRIDS

APRIL 10, 2009

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THE EMERGENCE OF PLUG-IN HYBRIDS

With a recent mandate that effectively requires major automakers to put at least 58,000 gas-electric vehicles on California roads by 2014, California has become a pioneer in new technology developments. After years of research and development the auto industry giants and startup companies are investing, researching and building prototype vehicles that can be fueled either with gas or electricity from a wall socket. General Motors and Toyota plan to launch PHEV versions by late 2010, while Honda and some smaller manufacturers are expected to follow.

"Plug-in hybrids are going to be the vehicle story of the next few years," said Joseph Romm, an energy policy expert with the Center for American Progress, a think tank in Washington, D.C. Plug-in hybrid electric vehicles (PHEV) have the potential to revolutionize the auto industry over the next decade. This is because PHEVs could provide a cost-effective, practical solution to improving automotive fuel-economy and emissions. In short, Plug-in hybrids are vehicles that are powered by an on-board engine and a battery/electric motor that can be charged by plugging into the electric grid. This gives PHEVs an extended 20-40 mile all-electric driving range vs. current hybrids plus the ability to drive long-distances like a regular car.

WHAT IS A PLUG-IN HYBRID?

A plug-in hybrid electric vehicle (PHEV) is a hybrid vehicle with batteries that can be recharged by connecting a plug to an electric power source. It shares the characteristics of both traditional hybrid electric vehicles, having an electric motor and a internal combustion engine, and of battery electric vehicles, also having a plug to connect to the electric grid. Most PHEVs on the road today are passenger cars, but there are also PHEV versions of commercial passenger vans, utility trucks, school buses, motorcycles, scooters, and military vehicles. They are sometimes called grid-connected hybrids, gas-optional hybrids, or GO-HEVs.

Plug-in hybrid electric vehicles combine the best of electric and hybrid drive technologies. They can be fully functional in either electric or hybrid mode and make even larger emissions reductions and fuel savings possible. Compared to conventional vehicles, PHEVs can reduce air pollution, dependence on petroleum, and greenhouse gas emissions that contribute to global warming. Plug-in hybrids use no fossil fuel during their all-electric range if their batteries are charged from nuclear or renewable energy sources. Other benefits include improved national energy security, fewer fill-ups at the filling station, the convenience of home recharging, opportunities to provide emergency backup power in the home, and vehicle to grid applications. The cost for electricity to power plug-in hybrids for all-electric operation has been estimated at less than one quarter of the cost of gasoline. And like the straight hybrid, the plug-in can burn liquid fuel to afford a long driving range with rapid refueling. What is more, these plug-in hybrids should not be much more complex, heavy or pricey than present hybrid models.

GOVERNMENT INITIATIVES

In March 19, 2009, President Barack Obama announced the launch of two major programs that will drive the development of the next generation of electric vehicles in the United States and support the growth of domestic jobs. In addition, these programs will also help meet the president's goal of putting one million plug-in hybrid vehicles on the road by 2015 (U.S. Department of Energy News). As part of the American Recovery and Reinvestment Act, the U.S.

Department of Energy announced the release of two competitive solicitations for up to $2 billion in federal funding for competitively awarded cost-shared agreements for manufacturing of advanced batteries and related drive components as well as up to $400 million for transportation electrification demonstration and deployment projects. Additionally, consumers and companies get massive tax breaks for buying plug-in hybrid cars and trucks in the economic bailout bill passed in Congress.

The American Recovery and Reinvestment Act of 2009, grants businesses up to $15,000 in tax credits for each plug-in hybrid vehicle they buy. Consumers could get up to $7,500 for buying smaller plug-ins such as the 2011 Chevrolet Volt. To meet the tax incentive's standards, a plug-in vehicle must have a battery with a minimum capacity of 4kWh, though an additional $200 of tax credit is added for every kilowatt-hour thereafter, which is how the Volt gets to the maximum $7,500 limit with its 16kWh battery. By contributing to the reduction of petroleum use and greenhouse gas emissions, these projects will advance the United States' economic recovery, national energy security, and environmental sustainability.

ADVANTAGES OF PLUG-IN HYBRIDS

The potential for PHEVs to displace fleet petroleum consumption derives from several factors.

1. **PHEV's match current driving habits and needs:** First, PHEVs are potentially well-matched to motorists' driving habits – in particular, the distribution of distances traveled each day. Based on prototypes from the last decade, PHEVs typically fall in the PHEV10-60mi range. According to data collected by the National Personal Transportation Survey (NPTS) in 1995, the majority of daily commuter mileages are relatively short, with 50% of days being less than 30 mi (48 km). Therefore, since most PHEV models are able to travel between 10mi and 60mi solely on their battery power, they are likely to displace the fuel consumption used for commuting, which, as data above shows, makes up the majority of vehicle use in the United States. This low-daily-mileage characteristic of current drivers is why **PHEVs have potential to displace a large fraction of *per-vehicle* petroleum consumption**. However, for PHEVs to displace *fleet* petroleum consumption, they must penetrate the market and extrapolate these savings to the fleet level (Simpson 2).

2. **The prior success of HEVs will help the market introduction for PHEVs:** A second factor that is encouraging for PHEVs is the success of HEVs in the market. Global hybrid vehicle production is currently several hundred thousand units per annum. Because of this, electric machines and high-power storage batteries are rapidly approaching maturity with major improvements in performance and cost having been achieved. Although HEV components are not optimized for PHEV applications, they do provide a platform from which HEV component suppliers can develop a range of PHEV components (Simpson 2).

3. **PHEVs are the perfect balance between electric and combustion power:** Finally, PHEVs are very marketable in that they combine the beneficial attributes of HEVs and battery electric vehicles (BEVs) while mitigating their disadvantages. HEVs achieve high fuel economy, but they are still designed for petroleum fuels and do not enable fuel substitution/flexibility. **PHEVs, however, are true fuel-flexible vehicles** that can run on petroleum or electrical energy. BEVs do not require any petroleum, but are constrained by battery technologies resulting in limited driving ranges, significant battery costs and lengthy recharging times.

PHEVs have a smaller battery which mitigates battery cost and recharging time while the onboard petroleum fuel tank provides driving range equivalent to conventional and hybrid vehicles. This combination of attributes is building a strong demand for PHEVs, as evidenced by the recently launched Plug-In Partners Campaign, a national grass-roots initiative to demonstrate to automakers that a market for flexible-fuel Plug-In Hybrid Electric Vehicles (PHEV) exists today (Simpson 2).

4. **Little collateral impact from PHEV use:** Minimal collateral impact is expected on other industries or on other parts of the resource food-chain with use of PHEVs. Unlike ethanol, which in its current form, impacts food supply or diesel/hydrogen/CNG fuel use, which could transfer carbon emissions up the supply chain to power plants, PHEV use seems to have no apparent negative collateral impact.

5. **No need for major new infrastructure:** PHEVs can be charged using electrical sockets at home (heavy duty plug may be needed) or commercial establishments, unlike diesel, ethanol or fuel cells, which require installation of a new distribution infrastructure. The only real infrastructure needed for successful implementation of PHEVs is development of "charging stations" at gas stations, parking lots and highway stops. Residences or charging stations could also be required to install a dedicated power consumption meter in the event that the government provides subsidies for PHEV use and overnight charging. According to the 2005 American Housing Survey, over 60% of occupied housing units had a garage or carport.

PHEVs have the potential to come to market, penetrate the fleet, and achieve meaningful petroleum displacement relatively quickly. Few competing technologies offer this potential combined rate and timing of reduction in fleet petroleum consumption (Simpson).

MARKET OPPORTUNITY; US HYBRID DEMAND

According to a report published by Morgan Stanley in March 2008, titled Autos & Auto-Related Plug-in Hybrids: The Next Automotive Revolution, the investment bank estimated a Base Case demand for hybrid vehicles in the US to grow from approximately 355K units in 2007 to 400K units in 2008, and then at a 18-20% CAGR between 2009 – 2012. Morgan Stanley believes hybrid vehicle sales will grow to almost 2 million units (or almost 10-12% of annual SAAR) by 2020. Following strong growth between 2004 -2007, the report suggests HEV growth rate will be moderate in 2008 and 2009 as consumers get accustomed to gasoline prices at $3/gallon.

Morgan Stanley believes PHEVs will gain gradual acceptance with consumers and capture an increasingly larger share of HEV sales and total sales between 2010 and 2012. The report notes that we should see PHEV sales of a few thousand units upon launch in 2010, growing to 100K units in 2012 and 250K units in 2015. PHEV penetration will be driven by regular hybrids adding on plug-in capability. As PHEV penetration increases, we see HEV growth moderating.

PHEVs ADVANTAGES IN ENERGY & FUEL CONSUMPTION

Fuel Consumption: Plug-in hybrid electric vehicles (PHEV) can contribute significantly to transportation system efficiency by introducing vehicles that, within a limited range, can operate entirely in an electric mode and be powered by the electricity grid. Conventional Hybrid Electric Vehicles (HEVs) are already starting to create great benefits to US energy including consumption and security. Based on EPA data, the most energy efficient existing hybrids cut gasoline consumption by around 40 percent compared with similar conventional cars. But PHEVs typically replace half of the remaining gasoline consumption with electricity (IEEE Spectrum, July 2005). Thus, according to a report by the Institute of Electrical and Electronics Engineers (IEEE), PHEVs could reduce the consumption of liquid fuels by at least 70 percent compared with conventional cars.

Energy Savings: In addition to reducing gasoline consumption they have the potential to also reduce total energy expenses for the owner and the electric power industry. Existing commercial hybrid vehicles have proven to be successful components of the transportation system in the US and abroad. Plug-In Hybrid Electric Vehicles use grid-supplied electricity from diverse domestic energy sources such as renewables, coal and nuclear, and reduce the nation's demand for imported Petroleum (IEEE).

Fuel Flexibility: PHEVs can also make it easier to achieve the goal of fuel flexibility and alternative liquid fuels. Fuel flexibility is easier to incorporate in hybrid vehicles than in conventional vehicles as recent concept cars illustrate. After plug-in hybrid electric vehicles substantially reduce our nation's liquid fuel requirement in cars, it will become far easier for alternative liquid fuels to supply the remaining liquid fuel demand (IEEE).

In summary, conventional hybrids can cut fuel bills 15 to 50 percent compared to regular cars. Plug-in hybrids have the potential to cut gasoline consumption by at least 50 percent and more, in some cases. In addition to reducing gasoline consumption, plug-in hybrids also have the potential to reduce total energy expenses for the owner. If properly designed, these cars can provide extra security, in that they will remain viable should a disruption of the gasoline supply system occur (IEEE).

PHEVs ADVANTAGES OVER HYDROGEN FUEL CELLS

PHEVs would be better at utilizing zero-carbon electricity than hydrogen fuel cell vehicles because the overall hydrogen fueling process is inherently costly and inefficient. Any effective hydrogen economy would require an infrastructure that could use zero-carbon power to electrolyze water into hydrogen either at a local filling station or small regional plants to prevent loss through diffusion, and pump it at high pressure into the car—all for the purpose of converting the hydrogen back to electricity in a fuel cell to drive an electric motor. The entire process of electrolysis, transportation, pumping, and fuel-cell conversion would leave only about 20 to 25 percent of the original zero-carbon electricity to drive the motor. In a plug-in hybrid, the process of electricity transmission, charging an onboard battery and discharging that battery would leave 75 to 80 percent of the original electricity to drive the motor. Thus, according to an

article published by the Scientific American, a plug-in should be able to travel three to four times farther on a kilowatt-hour of renewable electricity than a hydrogen fuel cell vehicle could (Scientific American).

PHEVs ADVANTAGES TO THE US ELECTRIC GRID

Although critics have warned that the PHEVS could put too much pressure on an already strained electrical grid, experts are now arguing that rather than being a strain on the grid, plug-in hybrids may actually help prevent brownouts, cut the cost of electricity, and increase the use of renewable energy (Bullis). Plug-in hybrids, like today's hybrid cars, can run on either an electric motor or an internal combustion engine. But plug-in hybrids have much larger battery packs and can be recharged by being plugged into the wall, making it possible to rely much more on the electric motor.

The concern is that plug-ins are not a good way to reduce gasoline consumption, because if they become popular, and millions of car owners recharged their cars at three in the afternoon on a hot day, it would crash the grid. But plug-in hybrids could actually help stabilize the grid if owners charged their cars at times of low demand, and if the vehicles could return excess energy to the grid when it's needed--say while parked in the company lot at work during peak demand.

Since utilities have built enough power plants to provide electricity when people are operating their air conditioners at full blast, they have excess generating capacity during off-peak hours. As a result, according to an upcoming report from the Pacific Northwestern National Laboratory (PNNL), a Department of Energy lab, there is enough excess generating capacity during the night and morning to allow more than 80 percent of today's vehicles to make the average daily commute solely using this electricity. If plug-in-hybrid or all-electric-car owners charge their vehicles at these times, the power needed for about 180 million cars could be provided simply by running these plants at full capacity (Bullis).

This could be a boon to utilities, because they'd be able to sell more power without the added cost of building more plants. Ideally, this will translate into lower electricity prices, says Robert Pratt, a scientist at PNNL. It might also help utilities justify the added capital costs of building cleaner coal-burning plants, because they'll be able to recover their investment faster by "selling more electricity with the same set of iron, steel, and concrete," Pratt says.

Such a system could be further optimized by using smart chargers and other electronics. This system would include a charger that runs on a timer, charging cars only during off-peak hours. Researchers at PNNL are taking this a step further with smart chargers that use the Internet to gather information about electricity demand. Utilities could then temporarily turn off chargers in thousands of homes or businesses to keep the grid from crashing after a spike in demand.

The next step would be to add smart meters that would track electricity use in real time and allow utilities to charge more for power used during times of peak demand, and less at off-peak hours. Coupled with such a system, the PNNL smart charger could ensure that the plug-in batteries are charged only when the electricity is at its cheapest, saving consumers money.

The Vehicle-to-grid System: What many experts are excited about now is a concept called "vehicle-to-grid," often abbreviated V2G. In such a system, plug-in hybrids, rather than being merely an extra burden to the grid, become a much needed way for grid managers to balance the amount of energy generated at any given time to match the amount of energy being consumed. Millions of cars, each with several kilowatt hours of storage capacity, would act as an enormous buffer, taking on charge when the system temporarily generates too much power, and giving it back when there are short peaks in demand. In a V2G system, the batteries of millions of plug-ins would be used as a buffer to even out supply and demand and to help keep the grid stable, says Karl Lewis, chief operating officer of GridPoint, a startup based in Washington, D.C., that has developed technology that could help make such a system work. In this kind of system, each vehicle would have its own IP address so that wherever it is plugged in, the cost of the energy it uses to recharge would be billed to the owner. With the right equipment, the car could also return energy to the grid, giving the owner credit. Mock-ups of such systems have already been tested by the National Renewable Energy Laboratory (NREL), in Golden, CO, and by a company called AC Propulsion, based in San Dimas, CA (Bullis).

A GLIMPSE INTO THE FUTURE

If current trends in fuel costs and concerns about climate change continue, a broad market transition is expected around the year 2020, when hybrids are likely to become an option for most models. Relatively soon thereafter, we believe plug-in hybrids will probably become the dominant alternative-fuel vehicle, with the speed of that progress determined primarily by oil price rises and government policy on climate change and energy security. Whenever the world's transportation system finally moves to replace oil as its main power source, the most plausible car design would be a flexible-fuel, plug-in hybrid vehicle running on a combination of zero-carbon electricity and a biofuel blend. If the performance of batteries were to improve substantially at some point, drivers might then gradually switch to all-electric cars. It makes sense for us to adopt this highly practical personal transportation technology as expeditiously as possible (ScientificAmerican).

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