

The Next Big Thing:

Why Electric Vehicles Are Here to Stay

Introduction

In 1977, the Department of Defense connected three computer networks in the world's first demonstration of "inter-networking." Today, more than 30 years later, 1.5 billion people around the world rely on the connectivity of the Internet.¹ Like the World Wide Web, the modern passenger electric vehicle (EV) made a modest debut. In 1989, General Motors unveiled its Impact EV, later marketed as the EV-1 in test cities. Twenty years later, as the auto industry gears up to reinvent the car in electric form and billions of dollars are allocated for EV investment, some consumers are still asking the practical questions: Why EVs, and why now?

Politically, EVs have never been more attractive, packing a bipartisan punch to address both energy dependence and climate change. The U.S. spends nearly half a billion dollars a day on foreign oil just for transportation, and internal combustion engine (ICE) vehicles are the leading source of greenhouse gas emissions.² In response to these concerns and in light of recent advancements in lithium battery technology, the federal government has committed billions of dollars to the development and manufacture of EVs, with the added objective of supporting the domestic automotive industry.

While policymakers and automakers alike promote EVs, the 130 million-strong U.S. voting, driving, and taxpaying population still requires that their needs for convenience, speed and price are met. In order to capture the hearts and minds of Americans and to achieve broad adoption, EVs must be practical, accessible, and affordable. In addition to the car and battery pack, EV "refueling" infrastructure is an enabler of the real evolution from internal combustion engine (ICE) vehicles to clean electric vehicles.

Industry Momentum

The U.S. imports more than six million barrels of oil a day for transportation alone, and the transportation sector is also the leading source of carbon dioxide, nitrous oxide and volatile organic compounds in the U.S.³ Policy makers have taken notice. National security and environmental impact concerns have created unprecedented interest among the electorate and legislative representatives to pursue alternatives to petroleum-burning ICE vehicles. The answer is evident to legislators, research institutions, and automakers alike. Where hydrogen fuel cell technology proved impractical, zero emission Battery Electric Vehicles (BEVs) and near-zero

emission Plug-in Hybrid Electric Vehicles (PHEVs) are regarded by a large and growing number of people as the practical long-term solution to clean transportation.

Consumer Demand

In order to meet the demands of the mass market, EVs need to meet the performance, affordability, and convenience requirements of the average American driver. Recent advancements have put EVs on the map as the primary alternative technology to rival the ICE standard. Improved battery energy density and charge acceptance have narrowed the price, performance and convenience gap between EVs and ICE vehicles. Lithium-ion batteries, which have become the standard for today's high performance battery packs, have twice the energy density of the nickel-metal hydride batteries commonly found in today's hybrids, such as the Toyota Prius.⁴ Vehicle range has increased to 250 miles in some models and is expected to increase in the future with further improvements in vehicle and battery efficiency. In terms of performance, EVs are far more responsive than torque-limited internal combustion vehicles, with acceleration that rivals high-end sport cars and speeds of up to 125 miles per hour in some models.

Given recent technological innovations, industry cooperation, and tax incentives, EVs are moving toward becoming more price competitive with ICE vehicles. Ford and Magna, for example, are joining forces to produce the Ford Focus EV, a zero-emission BEV slated for 2011 delivery with a sticker price of less than \$15,000 after tax rebates.⁵ Moreover, the total cost of ownership of an EV is very attractive. Electric "fuel" costs far less than regular gas, with a price per mile of around two to four cents versus eight to ten cents for gas, depending on local prices and rates. EV maintenance is also relatively hassle-free; EVs don't require oil changes, filters, spark plugs or new brakes. And the automotive industry is working together to continue to innovate with the appreciation that industry cooperation spreads risk, encourages scale economies, and creates a win-win environment for all stakeholders in challenging economic times.

Charging Infrastructure: The Critical Enabler

Just as ICE vehicles need gasoline or diesel fuel, EVs need electricity – and charging infrastructure is the key to the practical, widespread roll out of electric vehicles. To consumers, radical changes in behavior to accommodate EVs are unattractive. To be adopted successfully, new technologies must offer compelling benefits, and cannot require major behavioral changes. In the case of EVs, consumers will demand fast "refueling" in minutes and not hours, ubiquitous charging stations that are available when and where the driver runs low on charge, universal charging standards, and simple and secure payment methods at the point of sale. In order to succeed, the EV and EV charging infrastructure package needs to meet or exceed customer

expectations on these dimensions. Even at lower pilot volumes, early EV drivers should enjoy a favorable experience in order to communicate their satisfaction to a larger market. Whether there are 5,000 or 50 million EV drivers on the road, the EV approach scheme must win on practicality, accessibility, and affordability.

Make it Practical:

Home Charge Every Night, Fast Charge When You Need It

Hybrids were initially praised because they required no change to driver behavior – a hybrid driver turns on the ignition, drives normally, and stops for fuel when the gas gauge runs low. But a hybrid vehicle consumes an estimated average of 300 gallons of gas per year and is responsible for an estimated three tons of CO₂ emissions. PHEVs can consume 100 gallons less than hybrids, and BEVs consume no gas at all and emit no greenhouse gasses.⁶ Moreover, the EV's primary charging method will be the at-home slow charge over a few hours when the driver is having dinner, spending time with family, and sleeping. This "Level 2" charging method operates at 220 volts, recharges an EV in two to six hours and can also be implemented in a public setting, such as at the mall or at work. The average American driver commutes 30 miles per day,⁷ and employing at-home and opportunistic charging can mean infrequent public refueling even on a 100-mile range EV. The quality of life improvement resulting from eliminating many of one's weekly, biweekly, or even monthly trips to the gas station is a staggering benefit of EV driving that is rarely recognized.

When the driver forgets to charge, plans for a long road trip, or is otherwise unable to get to her home charger, she will need to refuel quickly at a convenient location en route to her destination. Fast charging technology makes it possible to recharge an EV in approximately 10 minutes, which eliminates drivers' "range anxiety" – the effect on the driver of perceived limited range and potential of being stranded in an EV. Fast or "Level 3" charging operates at a higher voltage than Level 2 over a three-phase connection from a fixed charging kiosk in a public setting like a gas station. Fast charging provides a convenient charging experience akin to that of refueling an ICE vehicle at a gas pump – at a much lower price per mile.

Make It Accessible:

An Open and Distributed Network of Fast Charging Stations

Research has shown that vehicle adoption rates are inextricably linked to the accessibility of refueling infrastructure. Some studies have found that the number of alternative refueling stations should equal 10 to 30 percent of the total number of gas stations. That is, for every three to ten gas stations, there should be, at a minimum, one alternative refueling station.⁸ In the Washington D.C. Metropolitan Statistical Area (MSA), that would mean roughly 150 to 400 fast charge

stations; in the Los Angeles MSA 250 to 750 stations; and in the New York MSA 450 to 1300 stations.⁹

The ideal charging stations will be universal, designed to charge any battery type of any size. These stations will also exist as single kiosks distributed throughout the city. The universal kiosk model of fast charge “refueling” stations make their build-out costs far lower and proliferation much more affordable than central battery rooms with battery handling equipment, an assortment of EV batteries, and specially-designed EVs that require removable battery compartments. Universal fast charging has been proven in commercial markets for nearly 10 years, where industrial EV drivers have increasingly eliminated battery changing rooms in favor of distributed fast chargers.

Accessibility also means free access to an open charging infrastructure network. A network that relies on a closed, contract-based subscription model works against widespread EV adoption by imposing added inconvenience on the driver. From a legislative perspective, an open network is the optimal solution for American constituents who may be, in good faith, supporting charging infrastructure funding with their tax dollars in the name of job creation and the benefit of the driving public at large. The ideal charging infrastructure solution is open and accessible nationwide to anyone who needs a charge, whenever they might need it.

Make It Affordable: Lower Infrastructure Costs and Encourage Proliferation

Level 2 and Level 3 charging systems can be acquired and installed for less than an estimated \$2,000 to \$4,200 and \$110,000 to \$160,000 respectively, depending on local labor rates and requirements. In comparison, gas stations cost about \$2 million each to build, and the cost for a national build out of fuel cell infrastructure is estimated in the hundreds of billions.¹⁰ Battery changing stations employing automated battery swapping systems, and excess battery inventory may also cost an order of magnitude more than a single fast charging station due to higher real estate, labor and risk management costs.

In a strong show of support, the Department of Energy will be disbursing up to \$700 million toward EVs and EV charging infrastructure as part of the American Recovery and Reinvestment Act – and it’s a great start. In order to support EV rollout in 20 key metropolitan markets and the corridors that connect them, the U.S. may be able to build out Level 2 and Level 3 charging infrastructure for an estimated incremental investment of \$3 to \$5 billion by 2015, which is remarkably affordable compared to other alternative fuel infrastructure models.

The Future

While legislative support, technical innovations, lower costs, and major automaker launch announcements pique consumer interest in EVs, it's the practicality, accessibility, and affordability of available EV charging infrastructure that will convert interest into reality. As legislators, automakers, utilities, municipalities, and other stakeholders work together to promote EVs, this conversion is beginning to happen. And like the Internet, a modest beginning has the potential to become a revolution in transportation.

¹ World Internet Usage Stats, 2009

² Energy Information Agency:

http://tonto.eia.doe.gov/dnav/pet/pet_move_impcus_a2_nus_epc0_im0_mbbldpd_a.htm

http://www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications/oil_market_basics/demand_text.htm

6 billion barrels at \$70 per barrel.

³ Energy Information Agency

http://tonto.eia.doe.gov/dnav/pet/pet_move_impcus_a2_nus_epc0_im0_mbbldpd_a.htm

See also U.S. Environmental Protection Agency, Emission Facts: Greenhouse Gas Emissions from a Typical Passenger Vehicle

<http://www.epa.gov/otaq/climate/420f05004.htm#step4>

⁴ Forbes Oct. 2008: http://www.forbes.com/forbes/2008/1124/034_2.html

⁵ Ford Planning New Electric Hybrid and Plug-in Vehicles in Next 4 Years; Partners Help Speed Vehicles to Market. Jan. 11, 2009. <http://www.ford.com/about-ford/news-announcements/press-releases/press-releases-detail/pr-ford-planning-new-electric-hybrid-29683>

⁶ Estimates, based on conservative American VMT (2008, DOE Vehicle Technologies Program), reasonable mpg estimates, and CO₂/gallon calculations as per Environmental Protection Agency (EPA420-F-05-001, Feb 2005). Excludes CO₂ emissions at origin, i.e. refinery or grid.

⁷ Emission Facts: Greenhouse Gas Emissions from a Typical Passenger Vehicle, EPA420-F-05-004, 2005

⁸ Nicholas, Michael A. and Joan M. Ogden (2007) Detailed Analysis of Urban Station Siting for California Hydrogen Highway Network. Transportation Research Record 2006 (1983), 129 – 139

⁹ One Gas Station for Every 2,500 Residents: US Census: http://www.census.gov/Press-Release/www/releases/archives/facts_for_features_special_editions/011092.html

¹⁰ Lawrence Livermore National Laboratory