

# **Plugging In: A Feasibility Study on Public Plug-In Vehicle Charging Infrastructure Investment**

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## **Abstract**

Radical changes to our transportation sector could have positive impacts on our economy, security, health, and natural environment. Of the available options to address fossil fuel dependency in the transportation sector, vehicle electrification stands as an exciting option with a number of appealing benefits. Plug-in vehicles can reduce operating costs, air pollutants and greenhouse gas emissions, as well as dependence on fossil fuels, but their successful penetration will depend greatly on the thorough build-out of both residential and public charging infrastructure.

Much has been made in the media and academic literature about the environmental benefits of vehicle electrification. Rather than focus on these “green” issues again, this project uses a spreadsheet-based investment model to examine the possibilities of the *profitable* deployment of public plug-in vehicle charging infrastructure by doing two things:

1. Determining ways that potential buyers can make profitable investment decisions based on their specific needs, and
2. Evaluating the market penetration of plug-in hybrid electric vehicles (PHEVs) that would be required for that investment to be profitable.

Our results indicate that public electric infrastructure build-out can be profitable for any stakeholder, depending on the assumptions made. Focusing in on retailer stakeholders, I reveal that profitability will be quite sensitive to retailer size. Larger retailers will likely be able to invest profitably in limited infrastructure right away, but retailers with smaller parking lots will want to wait for deeper plug-in penetration, or rely on sources of revenue from their installed infrastructure other than direct user fees.

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## List of Terms and Definitions

**Alternative Fuel Vehicle (AFV):** Alternative fuel vehicles may run on compressed natural gas (CNG), liquified natural gas (LNG), liquified petroleum gas (LPG), methanol, ethanol, or electricity. Vehicles running on other fuels that meet or exceed federal clean air standards may also be classified as AFVs.

**Charging Station:** Charging stations are any installed physical infrastructure that can charge electric vehicles. They may or may not include communications capabilities, and can be Level I at 120v, or Level II at 240v. Level III chargers require more extensive infrastructure, and carry additional impact implications for the electric power grid.

**Electric Vehicle (EV):** An electric vehicle is one that can only operate on battery-stored power; there is no internal combustion engine drive or hybrid mode possible (e.g., Tesla Roadster).

**Hybrid-Electric Vehicle (HEV):** A hybrid-electric vehicle is a conventional “hybrid” vehicle with no plug-in capability (e.g.,: Toyota Prius).

**Internal Combustion Engine (ICE):** Internal combustion engines are conventionally powered by gasoline or diesel fuel, but can also run on biofuels such as corn-based ethanol or biodiesel.

**Leadership in Energy and Environmental Design Certification (LEED):** LEED is a green building rating system developed by the U.S. Green Building Council to provide a suite of standards for environmentally sustainable construction and operation.

**Light-Duty Vehicle (LDV):** United States legislation defines LDVs as all vehicles of less than 8,500 lbs. gross vehicle weight. LDVs are sub-divided into passenger cars, light light-duty trucks, and heavy light-duty trucks.

**Neighborhood Electric Vehicle (NEV):** This U.S. Department of Transportation classification refers to speed-limited (or “low-speed”) and street-legal battery electric vehicles. These vehicles must have a gross weight of less than 3,000 lbs and a top speed of no greater than 25 miles per hour. Due to their low speeds, they are not subject to crash-test requirements.

**Plug-in Hybrid Electric Vehicle (PHEV):** A vehicle whose wheels are driven by either an electric motor with ICE (or fuel cell) backup to charge the battery (series design) or by either an electric motor or an ICE directly (parallel design) (e.g., Chevy Volt).

**Plug-in vehicle (PEV):** Any vehicle that uses an electrical charge as fuel, including PHEVs and EVs.

**Stakeholder:** Any party potentially interested in investing in electric-vehicle charging infrastructure.

**Vehicle-Miles Traveled (VMT):** A commonly used indication of how much motorists are using their cars. VMT is typically presented as the average number of miles traveled per registered vehicle.

## **Introduction: A Different Look at Charging Station Investment**

It has long been recognized that major changes to the transportation sector could have positive impacts on our economy, security, health, and natural environment. Of the four major sectors of energy usage in the United States: transportation, industry, residential/commercial, and electric power, dependence on fossil fuels is the greatest for transportation. Indeed, as of 2006, 98% of our transportation energy comes from crude oil and natural gas.<sup>1</sup> Of the available options to address fossil fuel dependency in the transportation sector, technology substitution in the form of vehicle electrification stands as an exciting option with a number of appealing benefits.

The reality of vehicle electrification has gained significant momentum as of late, thanks to its economic feasibility and implementation-ready status, and it even seems to be pulling away from other low-carbon transportation technologies, such as hydrogen fuel cells.<sup>2</sup> Electric vehicles can be new or converted conventional hybrid vehicles, and they run wholly or partially on electricity. They reduce operating costs, air pollutants and greenhouse gas emissions, and dependence on fossil fuels. In the future, these vehicles can help enable renewable energy generation and actually become cleaner as they age.<sup>3</sup>

Early models are already hitting roads in the U.S., including both factory-made and converted vehicles. Tens of thousands of factory-made plug-ins are expected to be available in the U.S. in the next few years. The success of plug-ins has been bolstered by timely investments of governments worldwide, which serves to spur technological research and progress even more.

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<sup>1</sup> EIA Annual Energy Review, 2007.

<sup>2</sup> Biello, 2009.

<sup>3</sup> “Federal Energy and Fleet Management,” 2009.

But even with all of this progress, the successful penetration of plug-in vehicles will depend greatly on the thorough build-out of both residential and public charging infrastructure.<sup>4</sup>

Much has been made in the media and academic literature about the **environmental** benefits of vehicle electrification. This project is designed to examine the possibilities of the **profitable deployment** of public plug-in vehicle charging infrastructure by doing two things:

1. Determining ways that potential buyers can make profitable investment decisions based on their specific needs, and
2. Evaluating the market penetration of plug-in hybrid electric vehicles (PHEVs) that would be required for that investment to be profitable.

This paper explores these possibilities using a spreadsheet-based model with a simple user-interface that takes key cost elements as well as potential revenue streams into consideration and presents relevant financial outputs to stakeholders. Users of this investment tool can enter unique stakeholder information; the tool will then map likely future cash flows. The results generated by this investment tool are the subject of the discussion and analysis in this paper.

Some investors are comfortable buying charging infrastructure simply because it is the “green” thing to do (for marketing benefits), or even just because infrastructure is required to support the penetration of plug-in vehicles. But for those stakeholders who need to understand the bottom line on infrastructure build-out, this report puts forward a business analysis and pathway to profitability for plug-in vehicle charging station investment. The day where carbon dioxide legislation allows clean-technologies to compete with fossil fuels may indeed be coming; but for

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<sup>4</sup> “Federal Energy and Fleet Management,” 2009.

the time being, investment opportunities in plug-in vehicles and infrastructure must be evaluated based on current policy and business conditions.

The results of the first section reveal that public electric infrastructure build-out can be profitable for any stakeholder, depending on assumptions made. When I explore the retailer stakeholder in more depth, a few factors stand out as particularly critical to successful investment. It will benefit stakeholders to investigate thoroughly hardware installation costs, as these vary greatly depending on the chosen installation site. Hardware choice is also critical, especially if the investor expects charging fee revenue to help offset high capital costs. Federal, state, and local incentives can help reduce the burden of high initial capital costs, and incentives may also serve to lower operating costs as well, such as providing discounted electricity rates.

The second section reveals that profitability is quite sensitive to retailer size. Specifically, infrastructure investors with small public parking lots may have to wait for deeper PHEV penetration in order to be profitable in their build-out. However, some large retailers could profitably build charging infrastructure early on, and likely be able to build several profitable charging stations before PHEV fleet penetration even reaches 1%.

The success of plug-in vehicles will depend on many interdependent factors, such as the strength of the economy, the price of gas, the continuation of federal and state subsidies, and the existence of public and residential charging infrastructure. Preparing for plug-in vehicles **now** carries a degree of risk; the cars may never come, or they may eventually lose out to competing technologies, such as hydrogen fuel cells or widespread use of biofuels. Building charging infrastructure now cannot guarantee the success of plug-ins. But it is my hope that information and preparation will both increase the chances of successful plug-in vehicle penetration, as well as the profitability of electric charging infrastructure as a business opportunity.

## **Background/Literature Review**

### ***Approaches to Reducing the Carbon Intensity of the Transportation Sector***

There are three distinct strategies for reducing CO<sub>2</sub> emissions in our transportation sector. These strategies have formed the bedrock of the Rocky Mountain Institute's three-decade long approach towards reducing the carbon footprint of transportation, and are worth briefly examining as a general approach to this problem.<sup>5</sup>

### **Reduced Vehicle Miles Traveled (VMT)**

A world in which no technological changes are made to our vehicles whatsoever can still be a cleaner world, if we just drive less. In order to convey a shifting focus on our “need” for energy, scientist and clean energy advocate Amory Lovins thirty years ago coined the now commonly-understood ideology of “soft energy paths,”<sup>6</sup> where rather than focusing on finding ways to secure more sources of energy for our lifestyles, Lovins suggested that we should instead recognize that energy is not an end in itself, but rather a means to an end. For example, rather than needing a car and gasoline, what we really need is transportation. Going even one level deeper, rather than needing transportation, what we really need are the benefits that convenient transportation provide for us, like accessing supplies, recreating, or being able to live miles away from our jobs, friends, and family. Thus, a large part of tackling the problem of CO<sub>2</sub> emissions is addressing the needs that require us to transport goods and people the way we do. Reducing VMT is therefore a multi-dimensional problem that has complicated implications on public policy, urban design, and American culture.

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<sup>5</sup> The Rocky Mountain Institute is an independent non-profit think tank that focuses on innovating and driving the efficient and restorative use of natural resources. <http://www.rmi.org/>

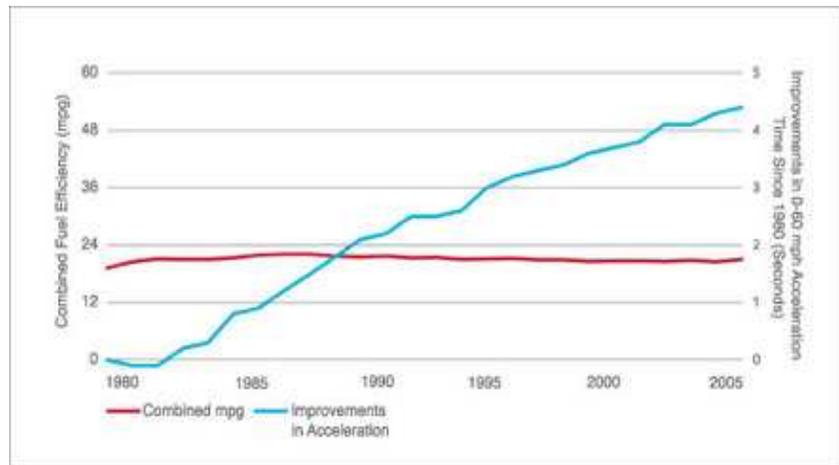
<sup>6</sup> Lovins, 1977.

## Vehicle Efficiency

Another emissions reducing strategy focuses on lowering the carbon intensity of the miles that we do drive, either reducing the fuel consumed per unit of transportation, or the carbon emissions emitted per unit of fuel consumed. In the automotive industry today, the focus of vehicle efficiency is improving the *platform fitness* of our vehicles, or the technologies that deal with aerodynamics and light-

weighting. Reducing the weight of our vehicles as well as the amount of their surface drag, increases their efficiency by improving their fuel

economy (mpg). Over the past 30 years, automotive engineers have been wildly successful in



**Figure 1:** Fuel efficiency and the performance of light-duty vehicles. Note the great improvements in vehicle acceleration have been made since 1980 while fuel economy improvements have been stagnant. (Graph is from Heavenrich, 2006.)

improving the platform fitness of our LDV fleet. However, most of the technological progress, or efficiency “dividend” has been used in making vehicles more powerful rather than more fuel efficient, due to market demands and relatively cheap fuel costs.

## Technology Substitution

The last strategy focuses on the complete replacement of the relevant technology in an automobile. In the application of cars, technology substitution specifically refers to the replacement of the internal combustion engine with an electric drive-train including electric motor and battery storage system (can be PHEV or pure EV). Battery-electric drive-trains offer the opportunity to eliminate or lower vehicle emissions by running on electricity produced from renewable sources of energy.

While reducing VMT and improving vehicle efficiency are essential strategies in reducing the carbon intensity of our transportation sector, neither one, alone or combined with the other, is capable of eliminating our dependency on fossil fuels. It is for this reason that technology substitution must be an integral part of the process. Of course, it is important to point out that the three above-mentioned strategies have synergistic effects when combined together. For example, improving the efficiency (particularly platform fitness) of vehicles lowers the cost of technology substitution (allows for smaller batteries), and technology substitution (drive-train electrification) automatically improves the energy efficiency of vehicles (due to electric motors being more energy efficient than ICEs).

***The Case for Public Infrastructure Investment: Aid in Our Transition to Plug-in Vehicles***

Basic research on driving habits indicates that most plug-in vehicle owners will do the bulk of their electric charging at home, perhaps overnight.<sup>7</sup> However, widespread public charging infrastructure (including that in workplace or retail parking spaces) will help facilitate the penetration of plug-in vehicles and help address consumer range anxiety.

Specifically, strategically well placed public infrastructure will:

1. Allow plug-in drivers to operate reduced range electric vehicles, which require smaller battery packs increasing the efficiency and lowering the overall cost of vehicles (longer-range plug-ins require heavier and more expensive batteries),<sup>8</sup>
2. Increase the visibility of plug-ins, making them more appealing to a general public that is concerned about finding a convenient place to charge once they commit to driving a plug-in vehicle,

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<sup>7</sup> “Driving the Solution: The Plug-In Hybrid Electric Vehicle,” 2005.

<sup>8</sup> Morrow, Karner & Francfort, 2008.

3. Support plug-in vehicle ownership for those who may not have a dedicated parking space or private garage at home, and
4. Facilitate the adoption of other electric power transportation technologies available now, including neighborhood electric vehicles (NEVs), bikes, motorcycles, and scooters.

### ***Building an Investment Modeling Tool to Generate Real Cash Flow Scenarios***

In order to evaluate how relevant stakeholders can make profitable investments in charging station infrastructure and what PHEV penetration is required for that to happen, I created a user-friendly investment tool into which investors can enter cost and benefit information, as well as baseline data for each unique stakeholder; the tool then maps likely future cash flows. The results generated by the investment tool drive the discussion and analysis in this paper. To a very real degree, interested stakeholders can use the tool to explore the results of various investment scenarios. For information on the assumptions behind of the investment tool, please see the Appendix.

### ***This Report Offers a Path Forward for Stakeholders to Invest in Charging Stations***

I have worked with industry leaders to catalog the costs and benefits of installing charging infrastructure in public places. This project outlines the business case for charging stations, and evaluates strategic options for various stakeholders to use in pushing forward with infrastructure investments. Key stakeholders include:

- Parking garages and office parks where plug-in drivers park at work,
- Retail facilities where plug-in drivers spend time shopping,
- Municipalities and local governments which have an interest in serving the plug-in driving public, and,

- Electric utilities, which provide the needed power (and possibly charging stations) for vehicle electrification.

This report is not a black-and-white checklist; different stakeholders need different approaches, and different degrees of customer adoption of the technology. Rather, this document is a feasibility study of what makes financial sense, and what needs to happen for investment in charging stations to get off the ground. In the investment tool, as well as the main body of this document, I estimate the costs and potential revenues for each actor based on various assumptions (for more information on my assumptions, see the Appendix). Where I could not make estimates, I used sensitivity analyses to explore what investments—in terms of size and type—would break even or make a profit.

## Summary of Costs and Benefits of Charging Stations

### *Charging Station Build-out Costs*

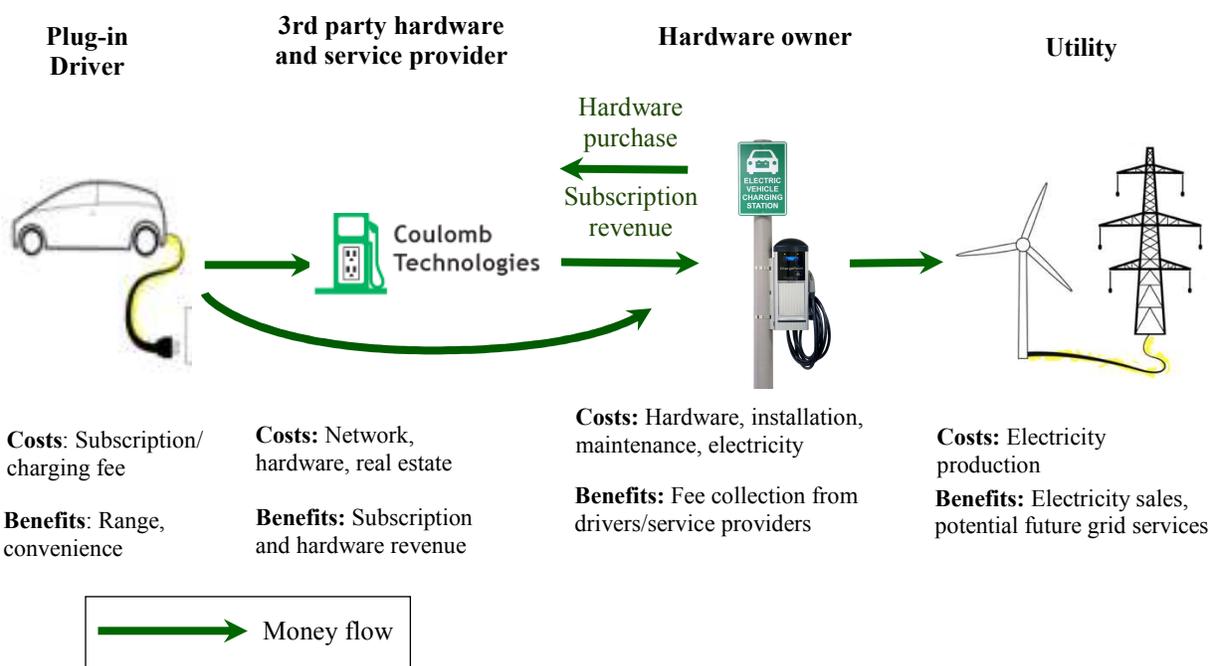
**Hardware Equipment:** Hardware options range from building a basic charging station with weatherproof cable and an electric meter to purchasing a network of pre-built charging stations that communicate with a central monitoring station that can remotely control charging services. The former scenario would offer limited capabilities, but also the lowest cost—as little as \$500 (including professional installation) per station, assuming that an appropriate electrical connection exists. Investors could also spend up to \$7,000 per charging station for models with the capability to monitor electricity usage remotely (smart metering), capture customer information, communicate information to a central monitoring station, and perhaps, most importantly, have the ability to generate revenue for the hardware owner. The hardware selection should be based on an investor’s specific situation, and investors should consider their communications, billing, security, and other needs. Research suggests that contracting with a third party and taking advantage of revenue raising will be more popular.

**Hardware Installation and Maintenance:** Charging station installation costs vary significantly depending on whether or not an appropriate electric connection is available, among other things.<sup>9</sup> Based on labor, construction, and permitting cost estimates from electricians, as well as estimates from hardware providers and charging station installers, the investment tool calculates installation costs according to the hardware chosen by the user. The cost of charging station installation also varies significantly by location. In some locations installation can even cost as much as or more than the original hardware. Interested investors need to consider seriously these uncertain installation costs when exploring the economics of investing in charging stations.

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<sup>9</sup> Electrical information is from a series of phone interviews conducted with Boulder, CO area electricians in June 2009.

**Electricity:** Interested investors can install chargers with different levels of charge, which has different implications on electricity costs. Level I chargers are assumed to deliver 120 volts at 15 amps, for a battery charge of 1.8 kW, while Level II chargers deliver a charge of 240 volts at 30 amps, for a battery charge of 7.2 kW.<sup>10</sup> The 2009 national average electricity price is 11.2



**Figure 2:** A visual explanation of the third-party charging hardware and services model, including direct monetary costs and benefits. Motorists pay a charging (or subscription) fee to the service provider (or possibly the hardware owner directly), who passes on the majority of these fees to the hardware owner to help offset equipment, installation, maintenance, and electricity costs. Hardware and service providers profit from hardware sales and subscription fees. Utilities' ability to profit from increased electricity sales depends on the degree to which their revenues and profits are decoupled.

cents/kWh. Some charging stations are likely to draw more electricity than others: plug-in drivers in parking garages and at charging stations in multi-unit residential complexes will likely charge for several uninterrupted hours, whereas drivers at, say, retail facilities may plug in for a much shorter time. Thus, depending on hardware choices and somewhat unpredictable consumer charging behavior, electricity costs for the hardware owners can vary considerably but, in

<sup>10</sup> Level I and II charging parameters vary depending on the hardware manufacturer. Level III chargers are even stronger, but have more electric grid impacts, and are not likely to be necessary for most charging applications. Electricity costs are from EIA. [www.eia.doe.gov/cneaf/electricity/epm/table5\\_3.html](http://www.eia.doe.gov/cneaf/electricity/epm/table5_3.html)

general, are less than hardware and installation costs. Please see Figure 2 for an explanation of how transactions between third-party service providers, owners of charging infrastructure, and plug-in driving consumers will be structured.

### ***Benefits of Building Charging Stations***

Some benefits of installing charging stations are transparent, or at least somewhat predictable, such as user charging fees (for some charging station models), government incentives, and the value of avoided carbon emissions. Other benefits are more difficult to conceptualize and calculate. The investment tool allows the user to enter values for some or all of these less tangible benefits so that the user can explore what these values would need to be in order for the chosen hardware to break even, or become profitable. Benefits of charging stations include:

**User Charging Fees:** Hardware owners may choose to charge plug-in drivers a charging fee.

However, interviews with stakeholders reveal that some hardware investors are more interested in offering charging services to plug-in drivers at no charge. Other hardware installers, through the use of more technologically advanced charging stations with built-in revenue generating functionality, would be able to draw a monthly income, the size of which would depend on how frequently plug-in drivers use their equipment. The investment tool assumes that the “do-it-yourself” charging hardware is not capable of revenue generation; however, the scenarios that utilize third-party hardware can include revenue generation capabilities if the hardware design accommodates it. Some stakeholders suggested billing customers for premium parking spots.

**Customer Attraction & Retention:** Several large retailers have commented that the primary value of charging stations as they see them is the increased customer throughput that they could provide. Specifically, retailers such as Wal-Mart and Best Buy have expressed interest in forming relationships with customers that they are not currently reaching. While estimating how

many new customers charging stations would help attract is tricky, large retailers are well-prepared to calculate the corresponding value added to their businesses once the number of new customers has been established. Recent research suggests that 57 percent of consumers feel that it is important to purchase products with environmental benefits, even in a tough economy, and 51 percent are willing to pay more for them. More than 25 percent of consumers strongly agree that it is important to avoid purchases from companies that they disagree with.<sup>11</sup>

**Employee Attraction & Retention:** Office parking lot owners, and perhaps some retail facilities, can benefit from installing charging stations due to the services that they offer to current and potential employees. It is likely that plug-in owners would prefer to charge their vehicles more than once per day, making the workplace an obvious choice for daytime charging. Charging stations therefore offer real financial benefits to employers who can retain and perhaps attract employees who drive plug-ins (or would like to drive plug-ins). Even for employees who don't drive plug-ins, research suggests that almost 50 percent of Americans feel that it is at least "very important" that their employers are environmentally responsible.<sup>12</sup>

**Corporate Branding Opportunities:** My interviews indicate that stakeholders are not likely to pursue branding opportunities directly; rather, charging station investors are conscious of avoiding visible "greenwashing" efforts. Nonetheless, they are aware that their bottom line benefits from the public observing their investments in "green" technologies. And rightly so – charging station installation is something real that any retail facility with adjacent parking can pursue that will hasten the penetration of plug-in vehicles. While several retailers commented that good corporate public relations has benefits, those benefits are generally not specifically included in any kind of calculus that is required to approve of charging station investment.

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<sup>11</sup> BBMG Conscious Consumer Report, 2009.

<sup>12</sup> 2009 BBMG Conscious Consumer Report.

**Government Funding & Incentives**<sup>13</sup>: A federal tax credit offers up to 50 percent of infrastructure and installation costs, not to exceed \$50,000, for charging station equipment that goes into service after January 1, 2009. Furthermore, this credit is available *by site*, so that an interested investor can elect to take advantage of multiple \$50,000 credits. This credit, as written, expires on December 31, 2010. In addition to generous federal incentives, state incentives may apply, and several states have state-wide incentive programs that piggyback on federal incentives. Other states have city, county, and regional incentives.

**Fleet Cost Savings**: Big-box retailers and other companies that own parking lots could be interested in installing charging stations so they can charge their own plug-in fleets. This on-site charging capability will help these firms reduce fuel costs, which will in turn help offset the capital costs of acquiring plug-in vehicles. For a rough point of reference, estimates suggest that the cost of driving a gasoline-powered car are \$0.14/mile, while only \$0.03/mile for an EV.<sup>14</sup>

**Advertising & Customer Information Opportunities**: Some third-party hardware can capture and store customer information, while some can also offer electronic advertising opportunities for the hardware owner. Both of these capabilities offer potential value to stakeholders, particularly retailers, although how much value is difficult to quantify. Privacy concerns may limit the ability of charging station operators to capture plug-in vehicle user information, but it should still be a consideration.

**Contributions to LEED Certification**: According to LEED guidelines, charging station installation counts for one credit, called the LEED-NC Sustainable Sites Credit 4.3 for

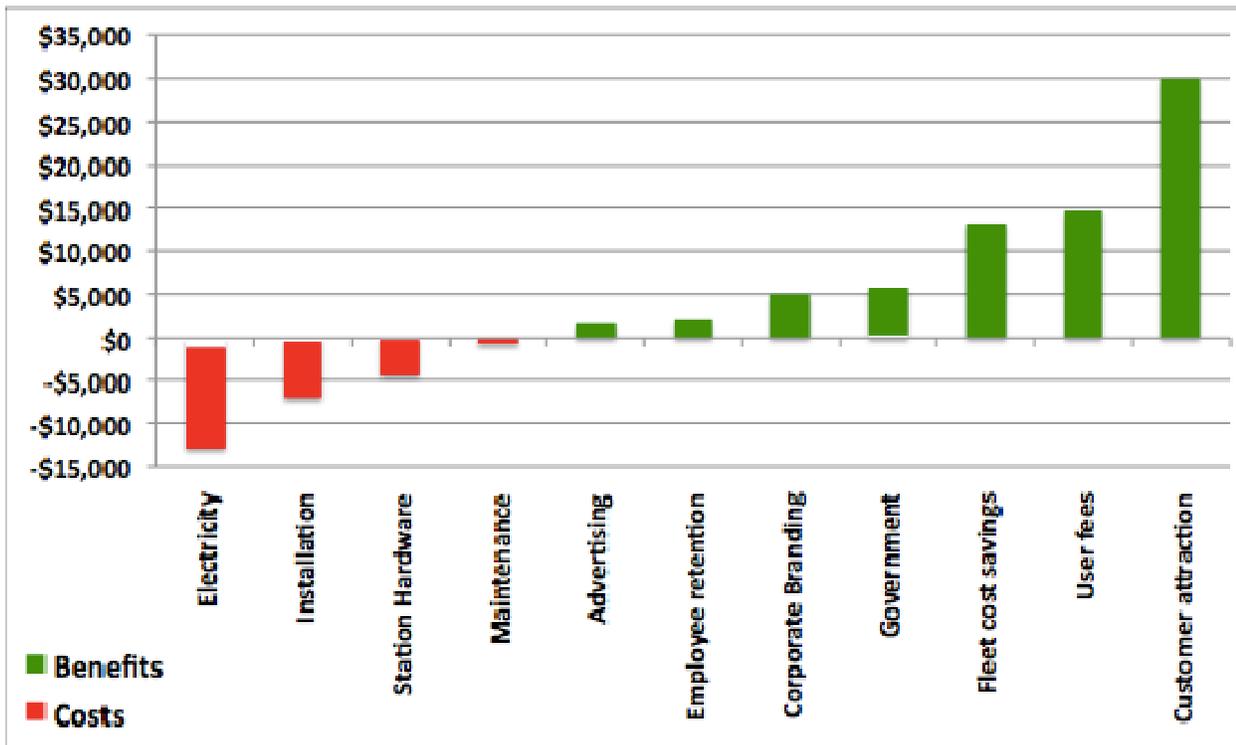
Alternative Transportation: Low Emission & Fuel-Efficient Vehicles. Research indicates that

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<sup>13</sup> While not really considered benefits of the stations themselves, state and federal incentives greatly increase the potential profitability of charging station investment, so they are included in the discussion about benefits.

<sup>14</sup> Assuming a gas price of \$2.50/gallon and electricity price of \$0.09/kWh. DOE estimate:  
[www1.eere.energy.gov/vehiclesandfuels/avta/light\\_duty/fsev/fsev\\_gas\\_elec2.html](http://www1.eere.energy.gov/vehiclesandfuels/avta/light_duty/fsev/fsev_gas_elec2.html)

facilities that invest in LEED certification profit from it.<sup>15</sup> However, quantifying how much a charging station contributes not only to LEED certification, but also to likely profit is, of course, challenging.



**Figure 3:** The large size ranges of various expected costs and benefits of installing one charging station and operating it for ten years. See the Appendix for more details on these estimated values.

**Value of Avoided Carbon Emissions:** There is uncertainty about when the U.S. Congress will adopt a carbon accounting system, and also how saved carbon will offer value—and to which parties. Nonetheless, the investment tool calculates carbon saved (in tons) and allows charging station hardware investors to include the revenue from the value of offset carbon emissions. Due to the aforementioned uncertainties, the default carbon price in the model is zero, but users may specify a price of their own. Interestingly, the future profitability of charging stations is not particularly sensitive to the price of carbon. Please see the Appendix for technical information concerning carbon accounting in the investment tool.

<sup>15</sup> Kats, 2003.

**Public Health Benefits:** Reductions of tailpipe criteria air pollutants due to vehicle electrification surely benefit everyone, regardless of who invests in charging infrastructure. But in my analysis, only municipalities/government stakeholders are able to quantitatively benefit from cleaner air, as the government is uniquely positioned to represent public interests and consider cleaner air as a possible benefit of their own infrastructure investments.

**Increased Energy Independence:** Vehicle electrification will likely prompt a greater reliance on domestic fuel sources (renewable or otherwise), and help to reduce oil imports, strengthen investment in domestic energy resources and jobs, lower national defense spending, and perhaps even mitigate national security risks. These benefits are, of course, difficult to quantify, and, in the investment tool, only municipalities/government stakeholders can reap them.

## Methodology

### *Part I: Analyzing Scenarios Using the Investment Tool*

Our investment tool helps forecast future cash flows of various user-selected charging infrastructure build-out scenarios. Model users can specify from pull-down menus or fill in values for the following variables:

- **Stakeholder status:** retailers, parking garages, office parks, utilities, homeowners associations, and municipalities.
- **Build-out scenario:** self build out or contract with third parties, such as Coulomb, Shorepower, eTec (Minit-Charger), Avcon, and Brusa.
- **Various measures affecting investment:** annual hardware maintenance cost, hourly charging fees, discount and inflation rates, federal and state incentives, price of offset carbon, charging time per user, number of Level I and II units to be built, and expected users per day per charging station.
- **Value of expected benefits:** customer attraction/retention, employee attraction/retention, corporate branding, fleet cost savings, advertising opportunities, LEED certification contributions, public health benefits, and increased energy independence.

While investment tool users can select their own inputs, this section of the report presents the results of one relatively conservative series of investment choices. Following the presentation and discussion of model outputs is a brief explanation for how these results can vary depending on stakeholders' choices.

#### Investment Tool Output from Representative Stakeholder: Retailers Business Case

Large retailers have much to gain from installing charging infrastructure. Of the benefits mentioned above, my research and interviews with retailers indicated that in addition to potential

charging fee revenues, retailers are especially interested in expanding their relationships to include more diverse customers. To the extent that vehicle chargers could increase a store's traffic, retailers might be willing to make infrastructure investments, and even strategically offer free charging to plug-in users as a strategic loss-leader. Retailers are also likely to benefit from the corporate branding opportunities of green investments and, perhaps, from cost savings due to their ability to charge electric fleet vehicles, as well as the charging stations' contribution towards LEED certification for buildings. For the purpose of this demonstration, the only revenue-positive factor considered is charging fee revenue. All other benefits are set to \$0 but can be included by users of the investment tool for sensitivity analysis.

Costs incurred by the retailers and entered into the investment tool include hardware purchase and installation costs for both Level I and II chargers, annual maintenance costs for each installed unit, and electricity costs for all installed units. The costs of all of the above increase annually by an inflation rate, and are discounted to the present 2009 using a discount rate.

In scenario presented here, I assume that this particular retailer chooses to build one Level I station in 2009 and one in 2010, followed by one Level II charger in 2011, and two Level II chargers in 2012. The model includes a 10 percent discount rate, a 3 percent rate of inflation, a 50 percent federal subsidy for hardware and installation, no additional state incentives, an average user charging time of one hour, and no price for offset carbon emissions (the model default). In addition, I assume the following number of expected users per day per charging station:

2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1	2	3	3	4	4	5	5	6	6

**Figure 4:** These numbers reflect a reasonable estimation. A more thorough forecast would require estimated ranges of future plug-in vehicle and charging station penetration, consumer subscription fees, average vehicle-miles traveled (VMT), as well as an evaluation of public vs. residential charging frequency. However, my research suggests that charging fee revenue may not be critical to stakeholders interested in investment.

The graphs in the following results section outline the net costs to a retailer of a feasible build-out and the ongoing operation of charging stations for ten years. The graphs map out the annual and cumulative cash flows of three building scenarios, discounted to US\$2009:

1. The retailer builds its own infrastructure at the lowest possible cost (orange)
  - Annual maintenance cost per unit is assumed to be \$25
  - Charging station users are not charged hourly charging fees
2. The retailer contracts with Coulomb Technologies to build the infrastructure (blue)
  - Annual maintenance cost per unit is assumed to be \$50
  - Hourly charging revenue for Level I chargers is assumed to be \$0.75
  - Hourly charging revenue for Level II chargers is assumed to be \$1.00
3. The retailer contracts with eTec Minit-Charger to build the infrastructure (green)<sup>16</sup>
  - Annual maintenance cost per unit is assumed to be \$50
  - Charging station users are not charged hourly charging fees

## ***Part II: EV Penetration Scenarios***

The modeling tool in Part I has explored the profitability of charging station investment for the relevant stakeholders, pending certain assumptions discussed above. In the demonstrated example of retailer stakeholders, we will see that charging station build-out can be profitable by

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<sup>16</sup> Model users have the option of choosing the same third-party manufacturer for both Scenarios 2 and 3 in order to test the sensitivity of changing projected charging revenue.

the end of the ten year investment period when the only revenue considered is hourly charging revenue when using 3<sup>rd</sup> party infrastructure with revenue generating capabilities. Indeed while investors in infrastructure will expect to benefit in many other ways, such as increased customer throughput or corporate branding, it is important to show that the investment in charging infrastructure can stand by itself as a profitable investment without including any of the difficult-to-define benefits discussed in the sections above.

However, the projection of charging revenue is difficult, and relies on a number of critical assumptions about consumer behavior and EV adoption. It is the purpose of the analysis in Part II to address the following questions: *Will enough retail customers charge at installed public charging infrastructure for the retailers to break even? If so, what does that breaking-even point suggest about the EV penetration that is required in the automobile market? Are different penetration levels required for different sized retailers to break even?*

#### Setting Up the Penetration Scenarios for the Retailer Stakeholder

In order to examine the needed EV penetration for a retailer stakeholder to make a successful investment, I must first set some boundaries and assumptions straight. For my analysis here:

- Retailers will expect to break even on their infrastructure investment in 5 years,
- Retailers contract with a 3<sup>rd</sup> party hardware manufacturer (Coulomb Technologies) to build one Level 1 charger in their parking lot,
- The only revenue source considered is hourly charging fees,<sup>17</sup>
- All other model options are set to their default values as explained above.

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<sup>17</sup> As mentioned above, interviews with retailers suggests that they are not counting on charge station revenue alone to make infrastructure investments profitable. However, due to the extremely difficult and possibly unreliable nature of estimating the sizes of these other benefits, it is the purpose of this analysis to attempt to prove that charging revenue alone is enough to allow stakeholders to at least break even.

The goal of this analysis is to arrive at a “required EV penetration” estimate for a selection of retailer types. The types chosen for this analysis, from largest to smallest, will be a Wal-Mart Supercenter, a Best Buy store, a McDonalds restaurant, and a Starbucks coffee shop. A number of inputs must first be calculated, the steps for which are as follows:

1. Using the investment tool, a simple solver function allows for the binding of all constraints except for the Users-Per-Day variable. For each stakeholder, I can execute model runs such that an estimate of Users-Per-Day is outputted for each year into the future, from one to ten (Ex: more charge station users per day are required to break even in less time).
2. At the end of the analysis, once an implied PHEV penetration figure is calculated, I will need some way to decide if it is a reasonable number. For comparison’s sake, I shall calculate a proxy PHEV fleet penetration figure by examining the penetration of HEVs over the last decade. To do this, I will use HEV sales data, compiled by the National Renewable Energy Laboratory (NREL), as well as registered LDV fleet data for the entire U.S., compiled by the Research and Innovative Technology Administration's Bureau of Transportation Statistics.
3. In order to calculate the required EV penetration for my four chosen retailers, I compile the above mentioned data into a programmed calculator interface that makes the following assumptions:
  - A Wal-Mart Supercenter has 800 parking spots, a Best Buy has 500, a McDonalds has 50, and a Starbucks has 30;
  - Each of these retailers is open for 16 hours a day and has a parking space utilization of 50% for all open hours;

- Shoppers average 60 minutes per visit at Wal-Mart, 45 at Best Buy, 30 at McDonalds, and 15 at Starbucks;
- 50% of PHEV owning shoppers at all retailers will decide to use the provided charging infrastructure while parking; and
- PHEV penetration rates among shoppers at all of these retailers is the same as the national penetration rate.

# Results

## Part I: All Stakeholders Can Be Profitable

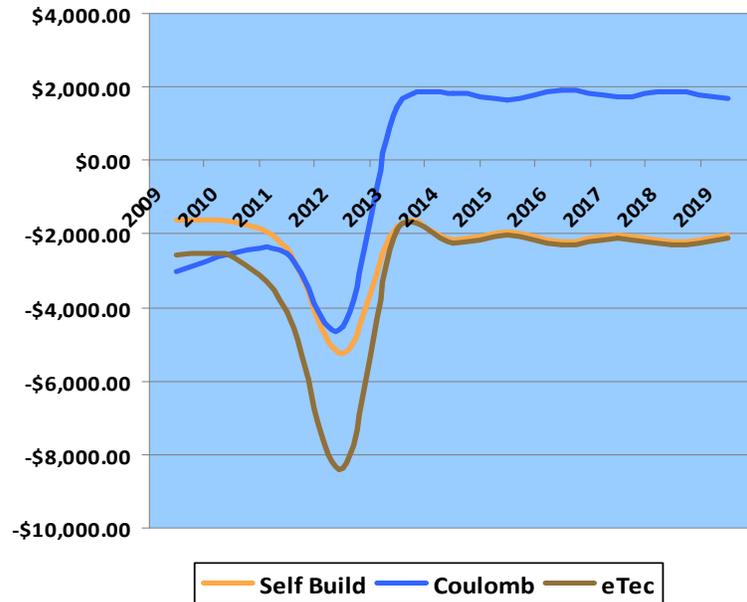
As seen in Figure 5, annual net revenues for Scenarios 1 and 3 remain negative for the duration, whereas annual revenues become positive by 2013 for Scenario 2. In Figure 6, we see that

Scenario 2 breaks even and

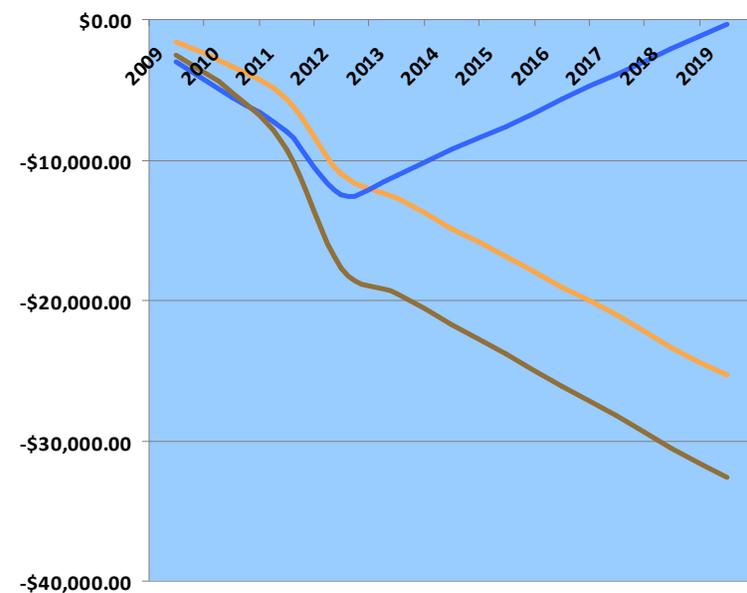
becomes cash positive by the end of the ten-year period.

Scenarios 1 and 3, which have no hourly charging revenue stream, never become cash positive.

**Figure 5:** Annual cash flow, in US\$2009, over ten years for retailers building and operating charging stations.



**Figure 6:** Cumulative cash flow, in US\$2009, over ten years for retailers building and operating charging stations.



### Sensitivity of User-Defined Benefits

Consideration of unquantified benefits (customer attraction, employee attraction, corporate branding, fleet cost savings, etc.) will be necessary for this retailer to decide if it should install

charging stations. For example, by year ten in Scenario 1, the retailer would need to assume that the value of these above-mentioned benefits of their infrastructure build-out will be \$25,000 in order for the project to at least break even by the end of the ten-year period. Once stakeholders are in a position to estimate these unquantified benefits, this investment tool will let them to determine if a particular investment strategy will become cash positive, and when it will become cash positive.

Although several retailers said that charging plug-in driving customers a fee was not a priority, other stakeholders may be more receptive to charging fees. And as Figures 5 and 6 demonstrate, hourly charging fees of just \$1 per hour (or less) can make an enormous difference in future cash flow, especially as expected charging station use increases with greater plug-in vehicle penetration. The results of this investment tool run seem to illustrate the benefit of having simple and effective revenue-generating capabilities built-in to charging infrastructure. However, even without this revenue, the other benefits mentioned in this report would need only to generate \$25,000 cumulatively by the end of the ten-year period in Scenario 1, or just under \$33,000 for Scenario 3, for the investments to break even.

### Analysis of Other Stakeholders

The results of the investment tool run described above apply only to a retailer. While the results don't differ drastically for the other stakeholders (parking garages, office parks, utilities, homeowners associations, municipalities, etc.), it is important to note some of the factors that change the perspectives of each of these other groups.<sup>18</sup>

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<sup>18</sup> The investment tool can be downloaded and used to run any desired scenarios. You can find the tool at: <http://projectgetready.com/resources/plugging-in-a-stakeholder-investment-guide-for-public-electric-vehicle-charging-infrastructure>

**Parking Garages:** Parking garages are in the business of making money from customers parking their cars, so they are likely to be interested in charging infrastructure with built-in revenue-generating capacity. They may also be more likely to position charging stations strategically in order to charge higher fees for premium parking spaces. According to interviews with electricians, parking garages may have lower infrastructure installation costs for stations because garages are often already wired for daytime electricity use. In addition, garages' physical infrastructure (walls, low ceilings, etc.) facilitate the easy installation of equipment and may preclude the need for expensive items such as charging station pedestals or wiring.

**Office Parks:** Office parks/employers will likely be interested in installing charging stations in order to offer a service to current employees, or in an attempt to appeal to future employees. They are also in a position to benefit from corporate branding and savings associated with lowered fleet costs, should they decide to operate electric vehicles. In addition, these investors may be interested in the contribution to LEED certification that charging stations offer. Also, unlike the situation with parking garages or retail facilities, employees will likely plug in for several uninterrupted hours while they work. This would decrease user turnover and increase drivers' time of use, perhaps allowing for more predictable revenue forecasts should employers elect to charge a user-fee.

**Utilities:** Interviews with utilities reveal that, for the most part, they are not currently interested in investing in public charging infrastructure, despite a desire to be a part of—and, to a degree, control—developments in this industry. Utilities that are not subject to decoupling requirements will already benefit from the additional sales of electricity that vehicle electrification will most certainly spur. Perhaps a more developed electric-vehicle market in the future will encourage utilities to make infrastructure investments themselves. In an interview with an American

hardware provider, I learned that European utilities are already contracting to purchase charging hardware directly from manufacturers for installation in public places.

**Home Owners Associations:** Research suggests that there are 247 million cars on the road in the U.S. but only 53 million garages.<sup>19</sup> Multi-family housing units thus stand as an intuitive place for charging infrastructure to stimulate plug-in vehicle penetration. As with the case of office parks, plug-in drivers are likely to charge for long periods, perhaps overnight. This long charging time may allow homeowners' associations (HOAs) to invest in cheaper Level I infrastructure, as fast charges may not be required. However, given that not all residents would benefit from electric charging stations, it remains unclear whether or not HOAs would levy assessments on residents to build infrastructure. Research in the Boulder, Colo. area suggests that developers building environmentally progressive multi-family communities could invest in charging stations in order to appeal to environmentally conscious residents.

**Municipalities/Government:** Much of the charging station infrastructure that has already been installed in the U.S. in recent years has been built by city and county governments. Some charging stations have been designated for free charging, while other infrastructure—such as the Coulomb Technology stations being built by Sonoma County, California—will use Coulomb's service network and charge users service fees. Municipalities differ from other stakeholders in that they are not usually in a position to benefit financially from user charging fees. However, this does not seem to have inhibited their interest in public charging station installation.

### ***Part II: Profitability Not Likely For All Stakeholders Yet***

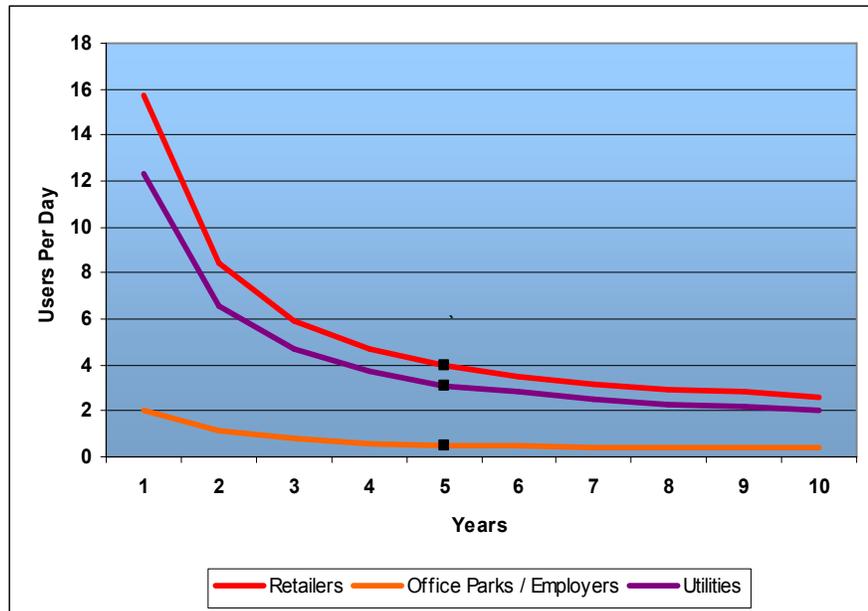
I have discussed earlier how each stakeholder interested in charging station deployment has different costs and opportunities for revenue. Thus, each stakeholder must expect a slightly

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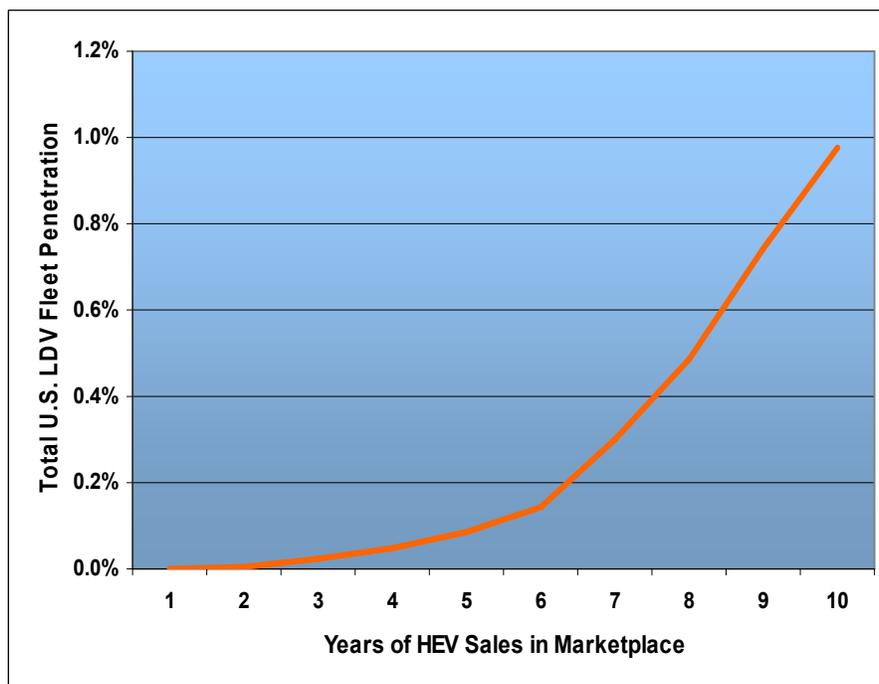
<sup>19</sup> Presentation by Richard Lowenthal of Coulomb Technologies. University of Colorado, May 6, 2009.

different intensity of customer adoption should they desire to break even on their investment within a five year period. Please see Figure 7.

The next step for this analysis was to calculate and evaluate an HEV fleet penetration number that could be reasonably compared with the determined required PHEV penetration figures. NREL publishes HEV sales data that goes



**Figure 7:** Retailers will require four users per day for each of their Level 1 charging stations to break even on their investment. Due to other revenue opportunities and longer charge times, other stakeholders will require fewer.



back to 1999 with the introduction of the Honda Insight. The Toyota Prius followed in 2000, and 17 other models as well from 2002-2008.<sup>20</sup> By 2005, HEV sales numbered

**Figure 8:** HEV penetration in the U.S. LDV fleet has been steadily rising since HEV introduction in 1999. By 2008, year 10 of HEV sales, total fleet penetration reached 1%.

<sup>20</sup> <http://www.nrel.gov/vehiclesandfuels/hev/hevs.html>

209,711, which represented 1.2% of the total new LDV sales in the United States, and by 2008, 352,274 HEVs were sold, making up 2.1% of new cars sold. By 2008, the 10<sup>th</sup> year of HEV sales in the U.S., HEVs made up roughly 1% of the total registered U.S. LDV fleet.<sup>21</sup> Please see Figure 8.

Potential Profitability is Extremely Sensitive to Retailer Size

The above described assumptions can be entered into a simple calculator where I reverse engineer the required PHEV penetration that is required for each retailer to break even on their charging station investment. The results are as follows:

Type of Retailer:	Wal-Mart Supercenter	Best Buy	McDonalds	Starbucks
Number of parking spots:	800	500	50	30
Parking lot utilization:	50%	50%	50%	50%
Length of shopping (min.)	60	45	30	15
Number of cars per day	6400	5333	800	960
EV drivers willing to charge:	50%	50%	50%	50%
EVs needed to break even:	8	8	8	8
Hour factor adjustment	8.0	11	16	32
<b>Implied PHEV penetration:</b>	<b>0.1%</b>	<b>0.2%</b>	<b>2.0%</b>	<b>3.3%</b>
<b>HEV Penetration in Year 5</b>	0.1%	0.1%	0.1%	0.1%
<b>HEV Penetration in Year 10</b>	1.0%	1.0%	1.0%	1.0%

**Figure 9:** Larger retailers require a much smaller PHEV penetration in order to recoup their investment in building one charger. For smaller retailers, they require much deeper vehicle penetration. As a benchmark, I have shown actual HEV market penetrations in years 5 and 10 since their introduction to the marketplace (2003 & 2008).

As demonstrated above, super-large retailers with hundreds of parking spaces should be expected, in a five year period, to barely recoup their investment in building one PHEV charging station, relying only on hourly charging revenue collected from the 3<sup>rd</sup> party services provider (Coulomb). Smaller retailers, such as fast-food restaurants and coffee shops will need to wait for much deeper PHEV penetration before they can safely invest profitably, or rely on some of the other revenue streams discussed in detail above. Mid-sized big-box retailers, such as Best Buy in

<sup>21</sup> [http://www.bts.gov/publications/national\\_transportation\\_statistics/html/table\\_01\\_11.html](http://www.bts.gov/publications/national_transportation_statistics/html/table_01_11.html)

this example, are right on the edge of not quite being able to recoup their investment in charging infrastructure in five years, but easily being able to by ten years.

It further complicates the investment in charging infrastructure that it may be against the best interests of small retailers to possibly slow down their customer turnover by installing charging infrastructure. Larger retailers like Best Buy or Wal-Mart would likely benefit from the opportunity of keeping customers shopping for as long as they are willing to stay. But fast food restaurants and coffee shops may decide against large-scale investment in charging infrastructure if it is determined that such investment is likely to increase the length of each customer visit beyond desirable limits.

## **Concluding Thoughts**

Our investment tool shows that charging station build-out can be profitable for any stakeholder, but a few factors are particularly critical to successful investment. Stakeholders should thoroughly investigate hardware installation costs, as these can vary greatly depending on the site. Hardware choice is also critical, especially if charging revenues are required to offset initial capital costs. Federal, state, and local incentives can help reduce the burden of high initial capital costs, and may also lower operating costs as well, such as providing discounted electricity rates.

The most crucial unknown variable that will impact investment is simply the penetration of electric vehicles in the next decade. Automotive companies are introducing PHEV models into the U.S. market in 2010–2011, but these are mostly pre-production launches. The success of these vehicles will depend on the strength of the economy, the price of gasoline, the continuation of federal and state subsidies, and the existence of public and residential charging infrastructure.

Our analysis shows that the success of retailer stakeholders investing in public infrastructure will depend greatly on the depth of PHEV penetration. If PHEV penetration depth is similar to the success of HEV over their first 10 years, larger retailers will be able to invest profitably in infrastructure right away. Smaller retailers will likely need to wait for deeper penetration, or depend on sources of revenue from their installed infrastructure other than direct user fees.

Preparing for electric vehicles now carries a degree of risk – plug-ins may never come, or they might eventually lose out to competing technologies. More likely, our transition away from fossil fuels will depend on *many* technology alternatives being successful. Building charging infrastructure now will not necessarily guarantee the success of plug-ins. But more information and preparation will both increase the likelihood of plug-in vehicle penetration, and also the profitability of plug-in charging infrastructure when that penetration does occur.

## **Appendix: Assumptions for Investment Tool Runs**

- Level I chargers run at 120V and 15A for a total charge of 1.8 kW, while level II chargers are 240V and 30A for a total charge of 7.2 kW. Level III chargers are not included in the model as options for stakeholder investment.
- Electricity price forecasts are from the EIA's Annual Energy Outlook 2009. Emissions data to calculate offset carbon (equivalent) emissions from PHEV use are from Argonne's GREET model. The investment tool assumes that all PHEV use is PHEV-40, or PHEVs with a 40 mile all-electric range.
- All installed infrastructure is assumed to remain functional over the course of the 10 year period forecasted in the model. It is likely that charge equipment would become technologically obsolete before its product lifetime ran out.
- All costs in the model, such as installation, hardware, and maintenance are increased annually by a measure of inflation, which is set at a default value of 3%. All future revenue streams are discounted to 2009 using a discount rate that is set at a default of 10%. Both inflation and discount rates are variable by the model user.
- Offset carbon emissions are measured by comparing tailpipe emissions of plug-in and conventional vehicles. As of now, the model does not include the added GHG emissions associated with increased electricity production required to power the plug-ins.
- The model is set up to assume that charging infrastructure built in the year 2009 will only come online by the year 2010. Specifically, Level I and II chargers built out in 2009 in the model do not accumulate benefits for the builders, nor incur electricity costs, until 2010. From 2010 on, any stations built in a particular year are assumed to be installed and operational instantly on January 1 of that year.
- Some charging hardware has the capability to charge more than 1 car. Some of these will require additional hardware purchases in order to do this. This factor will only affect the model runs when a non-zero hourly charging fee is selected. My model assumes, perhaps conservatively, that all hardware chargers only charge one vehicle at a time. Please check with the menu of hardware options below to see which hardware options have the capability of charging more than one vehicle simultaneously, and what additional equipment is required to do this. For these hardware options, my model may underestimate revenue generation.
- Coulomb Technologies' infrastructure requires that at least one unit at each location be a "gateway" unit that is in charge of cellular communication with a service center. These units cost about \$1000 more than a standard non-Gateway model. The investment tool assumes that the cost of Coulomb charge stations includes a portion of this additional capital cost.
- Federal incentives in support of charge station hardware and installation is set at 50% in the model. Additional state incentives, where available, are assumed to piggyback directly on top of this 50% federal incentive.
- Avcon does not currently offer a Level I charger, while Shorepower does not currently offer a Level II charger. Thus users should be aware when using the investment tool that no Level I chargers should be built-out when using Avcon products, or Level II chargers when using Shorepower products.

- Estimated costs and benefits from Figure 3 are as follows:
  - Electricity cost range is the cost of running a Level 1 station for 1 hour per day (minimum) ranging to the cost of running a Level 2 station at 8 hours per day.
  - Installation, station hardware, and maintenance costs come from interviews with hardware providers, as well as publicly available cost data.
  - Advertising benefits are assumed to be equivalent to running one small advertisement in a local paper.
  - Employee retention benefits are estimated as the value of one employee taking a job for one dollar less per hour.
  - Corporate branding benefits are assumed to equal 1% of a \$500,000 budget.
  - Government incentives are calculated by taking 50% of a high priced charging station combined with standard installation costs.
  - Fleet cost savings are assumed to be the value of one car using no gas for ten years where gas is \$3 per gallon.
  - User fees assumes that hardware owners charge \$0.50 per hour for charging.
  - Customer attraction is assumed to be the value of five extra customers per day, each of whom buys an \$8 item at a 20% profit margin for the seller.

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