EVS27
Barcelona, Spain, November 17-20, 2013

Using dynamic scenario analyses to evaluate how market factors could shape San Diego California New Car buyer's interest in purchasing a Plug-in Electric Vehicle (PEV)

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Abstract

This analysis creates three temporally sequential hypothetical future time periods for a PEV market. In these scenarios, we present six factors which are likely to influence PEV ownership. These factors are the incremental cost of PEVs, the size of vehicles available for purchase, the vehicle manufacturers producing PEVs, vehicle turnover, the cost to install home charging infrastructure and the authority to install charging infrastructure at a primary residence. In each time period the characteristics of the vehicle and consumer market change to capture the dynamics of vehicle supply and new car buyers. Results from a mixed-method questionnaire of 470 San Diego California residents is matched with the hypothetical scenarios created for this analysis, which provides a baseline measure of how interest in PEVs might evolve over time for San Diego CA new car buyers. Incremental changes from the baseline conditions in each of the factors illustrate how different strategies such as: price reduction, larger vehicles offered for sale, introduction of new makes producing PEVs, and workplace charging infrastructure, might play a role in changing the pool of San Diego CA new car buyers who are interested in purchasing a PEV.

Keywords: list 3-5 keywords from the provided keyword list in 9,5pt italic, separated by commas

1 Introduction

Plug-in Electric Vehicles (PEVs) give consumers the option to use grid electricity as a transportation fuel. The substitution of electricity for gasoline is widely regarded as capable of providing societal and consumer benefits, the degree of which will fluctuate depending on consumer use patterns, energy costs, and the feedstock of the electricity grid (Davies and Kurani, 2013). In California, there exists consensus regarding the benefits or electric drive vehicles and there is a strong desire and initiative to accelerate the uptake of PEV purchases as a way to comply with federal and state laws related to the abatement of unhealthy criteria pollution and greenhouse gas emissions. While the sale of PEVs remain stronger than Hybrid Electric Vehicles (HEVs) at their market launch in 2002, policy makers, state and local agencies and automakers remain vigilant and are actively pursuing strategies to support the transition to PEVs. Understanding consumer preferences, expectations and the development of the market will aid in maintaining this transition.

Since the introduction in December 2010 of PEV models by original equipment manufacturers (OEMs) to the new car market, a total of 70,000 PEVs have been sold in the US, with a monthly high of 7,600 vehicles during November 2012 (Forbes, 2012). Within the context of the US new vehicle market, PEV sales for the month of November 2012 were a small fraction (0.6%) of the total 1.2 million passenger vehicles sold (Wall Street Journal, 2012). However, differences in purchase incentives, infrastructure deployment, customer experience, vehicle performance in cold climates and manufacturer marketing initiatives have produced an uneven geographic distribution of US PEV sales. For instance, California households are responsible for approximately 30% of all PEVs purchases. Given the smaller new vehicle market in California and the higher concentration of PEV sales, about 1.5% of all California new car sales in November 2012 were PEVs (California Center for Sustainable Energy, 2012).

1.1 A mixed-mode survey is used to evaluate San Diego CA new car buyer interest in PEVs

Within California, the marketing and infrastructure development efforts surrounding PEVs have been divided into five geographic regions of Sacramento, San Francisco/Bay Area, the Central Valley, Los Angeles, and San Diego. To explore the interest and expectations of consumers in one of these markets, Axsen et al. (2011) developed an in-depth, mixed-mode survey instrument which was deployed to households living in San Diego, California. The survey instrument included multiple parts which addressed respondent demographics, an estimate of the cost to install charging infrastructure at the respondent's primary residence, daily driving, charging opportunities, and a hypothetical vehicle design questionnaire in which respondents were given the option to "upgrade" a new vehicle that they were interested in purchasing to a hybrid, plug-in hybrid, or electric vehicle. The survey and the associated vehicle designs provide insight on consumers' interest in, and expectations for PEVs. The results showed that the majority of consumers (56%) are interested in a PEV if it's available to them in a body style, manufacturer, and drivetrain design configuration and price of their choosing.

1.2 Expanded analysis of survey

However, a consumer's ability to purchase a PEV with similar characteristics as selected in their survey would likely be contingent upon a number of factors related to the timing of the household's next new car purchase, such as:

- Incremental price consumers would like to pay for a PEV
- Appropriate vehicle size and functional (or marketed) attributes of PEVs
- Makes and models of PEVs available for purchase
- The authority to install charging infrastructure at the primary residence
- The cost of installing charging infrastructure

To explore how these considerations might influence interest in PEVs over time from survey respondents, we build upon the results presented by Axsen et al. (2011) with further analysis and simulation. Here, we establish three scenarios for future periods of a California PEV market, 2010 to 2015, 2015 to 2020 and 2020 to 2025. Each of these periods represents successive automotive vehicle generations and are in-line with the standard vehicle product cycle of 5 years used in the automotive industry. The periods start in 2011, which is based on the US market launch of the first two OEM PEVs. In each time period we assume conditions relating to each of the five factors listed above. The grouping of these factors for each time period is referred to as our definition for attributes of the PEV market at a specific point in time.

The application of these definitions to the survey responses of 470 San Diego residents from Axsen et al. (2011) provides an estimate of the proportion of vehicle buyers in each period that fit the definition of possible PEV buyers, those who express interest in purchasing a PEV and having expectations for vehicles and lifestyles which fit the time period in which they expect to make a vehicle purchase. For additional scenario and what-if analysis, the analysis can change a single condition, while holding others constant, in order to provide feedback on how changes in assumptions may change interest in purchasing a PEV among survey respondents the most for each time period. The analysis will be helpful for policy makers and automotive analysts seeking to better understand the San Diego, California PEV market, consumer interest in PEVs and how some conditions influence the relative proportion of car buyers who can and want to purchase a PEV.

Lastly, these survey responses represent a snapshot which encompasses new car buyer's experience with and understanding of PEVs and relative prices of fuel at the time at which they filled out the survey. As the conditions of the market change due to policy, price, incentives, innovation or marketing strategies not explored in this survey and simulation, customer expectations, understanding and decisions will undoubtedly change. The work presented here should be interpreted in that light. Like all simulations it is limited by the imagination and creativity of the analyst.

2 Methods

This analysis creates three hypothetical time periods of a California PEV market. The time periods are successive and overlap with the 5 year product cycle or "vehicle generation" common in the automotive industry. We lay out requirements for PEV ownership in each period based on factors which express a series of vehicle and consumer characteristics that correspond to questions asked of respondents in Axsen et al. (2011). Survey respondents are categorized into a specific time period based on their own assessment of when they expect to purchase their next new vehicle. Later in the paper we evaluate how changing a single factor within each time period gives us the opportunity to observe how changes in the scenarios we present here could impact the proportion of San Diego California car buyers who are interested in purchasing a PEV.

2.1 Factors which could influence consumer interest in PEVs

By leveraging institutional knowledge from surveys and interviews of PEV owners (5, 6), PEV demonstration project participants (7, 8) and local alternative fuel experts and advocates (9) we develop three successive hypothetical time periods of the California PEV market. We then match each survey respondent to a time period based on the following criteria collected in the Axsen et al. (2011) survey based on when the respondent expects to purchase their next new vehicle.

2.1.1 **PEV incremental cost** represents the level of incremental cost at which the survey respondents upgraded their base vehicle to a PHEV or EV in the design game. The incremental cost of PEVs remains "high" for the first two time periods in this analysis. Appendix B summarizes the incremental purchase prices for the high and low cost scenarios from the Axsen et al. (2011) survey.

2.1.2 **Vehicle size** represents the size of the PEV which the household selected in their design game. In this analysis, vehicle size is divided into four possible classes: small sedans, large sedans, small SUVs / trucks and large SUVs / trucks. The size of

vehicles changes through time periods. Small SUVs and trucks are available for purchase in the second and third period. Survey respondents indicated if they would consider downsizing vehicles to reduce cost or to purchase a PEV.

2.1.3 **The vehicle manufacturers producing PEVs** in each time period is roughly based on the timing of the production guidelines set forth in the Zero Emission Vehicle (ZEV) mandate. The mandate requires manufacturers to meet sales target schedules for ZEVs according to the manufacturer's annual vehicle sales volume – large manufacturers are required to start to sell vehicles before intermediate manufacturers. A reference of large and intermediate manufacturers for the purposes of the ZEV mandate can be found in Appendix C.

2.1.4 The timing of next new car purchase is the respondent's best guess as to when they plan to purchase their next new vehicle. The survey respondents' answer to this question determines the time period into which they are placed for this analysis.

2.1.5 **The cost of infrastructure installation** is an estimate of how much the respondent would have to pay to have a dedicated charging station installed for their PEV at their primary residence. In general, infrastructure installation ranged from \$0 to \$6000, excluding the cost of the charging station, and, obviously, the more difficult the installation process the higher the cost. Here, we separate infrastructure installation costs into three levels of difficulty. An installation which costs \$2000 or less is categorized as "standard", between \$2000 and \$4000 is regarded as "somewhat difficult", and between \$4000 and \$6000 is designated as "very difficult".

2.1.6 **The authority to install charging infrastructure** is the respondent's personal assessment of their ability to change characteristics of their primary residence without obtaining permission from any other person or entity (aside from permits). Home charging infrastructure will be crucial to enabling PEV purchases in all periods. However, the development of away-from-home charging networks (at work and regional fast charging stations) which could be available to those who cannot install charging infrastructure at their home, might serve to lessen the importance of a dedicated home charging station in some PEV purchasing decisions. We simulate the possible market effects of allowing this subset of new car buyers into the analysis.

2.2 How factors which affect consumer interest in PEVs might change over time

Three time periods are used in this analysis to simulate the evolution vehicle technology, market aspects and consumer demand over vehicle generations, which is the auto industry traditional innovation cycle. Table 1 summarizes the conditions present in each period and survey criteria used to evaluate respondent interest in purchasing a PEV across the three time periods.

Table 1: Overview of hypothetical market scenarios

	Period 1 (2010 to 2015)	Period 2 (2015 to 2020)	Period 3 (2020 to 2025)
Incremental cost of PEV compared to ICE	High incremental cost	High incremental cost	Low incremental cost
Vehicle sizes available as a PEV	Small cars Large cars	Small cars Large cars Small SUVs/Trucks	Small cars Large cars Small SUVs/Trucks
Vehicle makes with PEV models for sale	Large volume manufacturers as identified in the ZEV mandate	Large and intermediate volume manufacturers as identified in the ZEV mandate	All vehicle manufacturers
Timing of survey respondent's next new car purchase	Survey respondents who plan on purchasing their next new vehicle within 2 years	Survey respondents who plan on purchasing their next new vehicle within 2 to 5 years	Survey respondents who plan on purchasing their next new vehicle in more than 5 years
Infrastructure installation cost at Survey respondent's residence	Survey respondents with installations costing up to $2000	Survey respondents with installations costing up to $2000	Survey respondents with installations costing up to $4000
Survey respondent's authority to install charging infrastructure	Has the authority to install charging infrastructure at their primary residence	Has the authority to install charging infrastructure at their primary residence	Has the authority to install charging infrastructure at their primary residence

2.3 Strategies to change consumer interest in PEVs - Scenarios

In addition to the progression of innovation around PEVs and consumers illustrated in Table 1 there may be an opportunity to promote the adoption of PEVs through strategic programs or interventions. After assessing the interest of survey respondents in purchasing a PEV using the criteria in table 1, we create six alternate scenarios. We modify specific factors for each scenario and evaluate how the change modifies the proportion of survey respondents interested in purchasing a PEV.

- **Scenario 1 - Price** evaluates how changes in the incremental cost of PEVs from "High" to "low" might change the proportion of survey respondents interested in purchasing a PEV.

- **Scenario 2 – Manufacturers** evaluates how increasing the number of manufacturers producing PEVs might change the proportion of survey respondents interested in purchasing a PEV.

- **Scenario 3 – Home charging** evaluates how providing all PEV buyers with access to home charging might change the proportion of survey respondents interested in purchasing a PEV.

- **Scenario 4 – Workplace as the primary charger** is an alternative to scenario 3. Here we evaluate how providing workplace charging for commuters, who cannot install charging infrastructure at home, might affect the number of people interested in purchasing a PEV. Of the 27% of the survey respondents who do not have authority to install a vehicle charger at their home, 80% commuted to a workplace.

- **Scenario 5 – Enhanced vehicle size (+1)** describes a scenario in which small SUVs and Trucks are made available for purchase in the first time period

- **Scenario 6 – Enhanced vehicle size (+2)** describes a scenario in which large SUVs and Trucks are made available for purchase in all time periods.

3 RESULTS

We used the hypothetical conditions for each time period shown in Table 1 and survey responses from Axsen 2010 to estimate the percent of respondents interested in purchasing a PEV. It is important to highlight the distinction between gauging consumer interest in purchasing a PEV and actual sales. Consumer interest shown here should not be directly translated to projections of number of vehicles sold. A host of other factors could shape the final purchase decision (many of which may **not** be predictable or are not included in this scenario analysis). Instead we focus on the relative changes in consumer interest given changes in the vehicle and consumer market over time and with hypothetical interventions. As always new innovations, marketing or pricing will alter consumer preferences and decisions.

3.1 Survey respondent interest in purchasing a PEV

As expected, the share of consumers who are interested in purchasing PEVs changes between time periods as the conditions which define the market become less restrictive.

Table 2 Survey respondent interest in purchasing a PEV by time period

Time period	First period 2010 to 2015	Second period 2015 to 2020	Third period 2020 to 2025
% of survey respondents interested in purchasing a PEV	Up to 10% of survey respondents	Up to 21% of survey respondents + unknown repeat buyers from first period	Up to 32% of new car buyers + unknown repeat buyers from first and second period

As noted in Table 2 the proportion of consumers interested in purchasing a PEV in the second and third time periods will be influenced by "repeat" buyers from the prior time period. There is very little publically available longitudinal data on the vehicle purchase habits of consumers. In general, there is a distribution of the timing between household planned new car purchases. Some households purchase vehicles frequently, at intervals of a year or two, while others may wait upwards of 15 years. So, in terms of actual number of new car purchases a portion of car buyers purchase new vehicles more frequently than others and, as such, are responsible for disproportionate share of new car purchases. While it is difficult to characterize these "repeat" buyers from our survey it has been observed from other measurements that up to 93% of PEV buyers have chosen to lease their vehicle. This would suggest that the number of "repeat" buyers in the second period has the potential to be significant.

Since the PEV market is so new, it is unclear if consumer loyalty to PEVs will make it more likely that a household will replace their current PEV with another one. Surveys of Chevrolet Volt owners report that 96% would definitely purchase another PHEV, and interviews with Nissan Leaf drivers suggest a majority of them have undergone lifestyle changes that indicate a strong desire for future PEV ownership. On the other hand, the loyalty of buyers of hybrid vehicles (which are "mass market") has been estimated to be on the order of 20 to 42 percent depending on the vehicle and the timing of the measurement. Lastly these measures apply to planned vehicle purchases. Unforeseen circumstances which result in the need for another vehicle or delay a purchase will change when the consumers represented in this this survey actually enter the new vehicle market again.

3.2 How changes in market factors alter the proportion of survey respondents interested in purchasing a PEV

The results in Table 2 provide a baseline for our analysis of San Diego California consumer interest in PEVs. Given our assumptions about market conditions, consumer informed PEV design preferences and purchase timing, we show what maximum proportion of survey respondents

might be interested in purchasing a PEV. However, as noted in section 2.3, we expect that changes in market conditions

will alter the proportion of survey respondents interested in purchasing a PEV. To characterize these possible effects the results of the six scenarios is reported here. In each of the scenarios only a single market factor is changed. In Table 3 we aggregate the results and show how each of the scenarios changes the proportion of survey respondents interested in purchasing a PEV. The results are presented as percentage point changes relative to the baseline scenarios in Table 1.

Scenario	First Period 2011 to 2015	Second Period 2015 to 2020	Third Period 2020 to 2025
Scenario 1 Decreasing incremental price (from high to low)	Up to 16% of new car buyers **(+60%)**	Up to 27% of new car buyers + repeat buyers from first period **(+28%)**	NA
Scenario 2 Increasing the number of manufacturers producing PEV	Up to 15% of new car buyers **(+50%)**	Up to 24% of new car buyers + repeat buyers from first period **(+14%)**	NA
Scenario 3 Ubiquitous home charging	Up to 14.5% of new car buyers **(+40%)**	Up to 27% of new car buyers + repeat buyers from first period **(+28%)**	Up to 38% of new car buyers + repeat buyers from first and second periods **(+19%)**
Scenario 4 Workplace as the primary charger (commuters only)	Up to 14% of new car buyers **(+39.5%)**	Up to 24.5% of new car buyers + repeat buyers from first period **(+16%)**	Up to 35% of new car buyers + repeat buyers from first and second periods **(+9%)**
Scenario 5 Enhanced vehicle size (+1)	Up to 12% of new car buyers **(+20%)**	NA	NA
Scenario 6 Enhanced vehicle size (+2)	Up to 18% of new car buyers **(+80%)**	Up to 30% of new car buyers + repeat buyers from first period **(+42%)**	Up to 46% of new car buyers + repeat buyers from first and second periods **(+44%)**

- For the first time period making Large SUVs and Trucks available for purchase results in an 80 percent increase in the number of consumers interested in PEVs. This constitutes the single largest impact on the number of consumers interested in purchasing a PEV.

- A decrease in incremental prices of small and large sized sedans is also shown to increases the proportion of survery respondents interested in purchasing a PEV in the first time period by 60 percentage points. In the second time period, adjusting purchase price has equal weight to the other initiatives.

- In terms of improving access to charging infrastructure for those consumers who do not have the authority to install one at their primary home, a "workplace based" charging network (assuming it is judged as an acceptable alternative to home charging by the consumer) may provide almost as much benefit as the enhanced access to home charging infrastructure scenario in the first period and increases the number of consumers interested in a PEV by 40% in the first period.

4 Discussion

Substantial work remains for further investigation of the market drivers, tactics, and features which

help build consumer interest and actually lead to additional PEV purchases. The results of the scenario analysis presented here provide a first step, but do not encompass all the possible strategies. Moreover, they are tailored to San Diego, California, and the results are based on a general population survey which represents a snapshot in time of the quickly evolving consumer market. As we look to new car buyer behaviour, it is certain that their expectations and understandings will change over time with the progression of technology, education, innovation, fuel prices and with developments in society and culture – the latter of which may ultimately prove a stronger force than any of the factors which have been measured in the scenarios currently under consideration in this analysis.

Within their scope, however, the results presented in this analysis provide interesting and meaningful findings for evaluating the interest in PEVs among San Diego new car buyers at a certain point in time. The scenarios examined here clearly demonstrate that, as market conditions change so could the number of consumers interested in purchasing a PEV. Elements such as: the size of vehicles available for sale; the expected timing of the consumers' next new car purchase; the incremental price of PEVs; the available choice manufacturers who produce PEVs; and access to home charging could all play a role in shaping consumer interest in PEVs. Although localized and far from comprehensive in scope, the analysis done here is a first step towards understanding how changes in some market dynamics may alter consumer interest in PEVs, which may, in turn, lead to a potential increase in future PEV demand/sales . Specifically, we show that making PEVs available in large SUV and Truck body styles could increase the number of consumers interested in a PEV more than a simple decrease in price (although, price is also a very important factor). Other strategies, such as providing workplace charging to those interested in purchasing a PEV, but who do not the authority to install charging infrastructure at home, could also increase the pool of interested PEV buyers. However, it remains unclear in this specific case to what extent such an arrangement would meet the needs and expectations of those buyers. However, the results discussed here regarding workplace charging access do not address or capture the other three likely benefits from a workplace charging network, which will include increasing the electric miles traveled for some PEVs, enabling long commutes by EVs, and promoting awareness of PEVs within a workplace community.

Lastly, as a general point, it is important to emphasize the dynamic nature of consumer experience. As we look to help grow consumer interest in PEVs and sales (through strategies discussed in scenarios here and many others not mentioned here) it will be important to measure the relative impacts and adapt strategies and tactics based on continuing research.

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