

Research Report – UCD-ITS-RR-14-36

Chrysler Plug-in Hybrid Electric Vehicle Project

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Executive Summary

In partnership with Chrysler LLC, Idaho National Laboratory (INL) and the city of San Francisco, the Plug-In Hybrid & Electric Vehicle Research Center at the University of California, Davis evaluated the use and consumer response to 28 of the RAM 1500 4X4 PHEV pickup trucks which were deployed in California. The demonstration project provided an opportunity to observe the deployment of Plug-in hybrid electric vehicle (PHEV) technology in fleets and focus on the context in which users responded to the technology. We accomplished this using multiple research instruments, which included surveys, driver logs, site visits, data analysis and in-depth interviews with every vehicle user. Our unique approach complements the large scale data gathering and analysis done by INL since we focus on individual users and explaining broader trends and behaviors. The following report will describe the findings from our in-depth consumer and market research efforts surrounding this advanced vehicle. In particular, we emphasize the following research highlights:

- Chrysler demonstrated PHEV technology in a full size truck platform and provided a large and distinct market segment (truck users) with access to electric and hybrid vehicle technology.
- Truck buyers may require more hands on experience than other segments in order to evaluate the functional aspects of the vehicle. As such, fleets might provide a good conduit to the consumer market for alternative fuel pickup trucks and vans.
- Experiences (good and bad) with a fleet vehicle can shape or influence the opinions of new car buying consumers around brand, model, technology and fuel type
- Pickup trucks, vans and SUVs are the most appropriate vehicle form for many municipal and corporate fleets. However, vehicle functionality is critical.
- PHEVs have features which appeal to fleets but it takes time, experience and appropriate instructional structure for them to recognize additional values beyond fuel savings.
- PHEV performance will vary depending on institutional factors, user behavior and operator training. Understanding best practices for PHEV deployment can ensure vehicles meet and surpass performance expectations.

Overall, the findings from this report emphasize the importance of piloting new and different technology among consumers. We find that fleets can provide a meaningful conduit for new car buying consumers to experience vehicles and technology in certain situations.

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1 Introduction

Beginning in 2009, Chrysler built 140 plug-in hybrid pickup trucks and placed them in fleets across the country to test the technology under real world driving in conditions representing a diversity of terrain, climate and travel demands. Fourteen of these demonstration vehicles were placed in San Francisco municipal fleets and fourteen in various fleets in Sacramento, California. The vehicles were deployed in a multitude of applications from August 2011 to September 2012. The full-size, blended-mode PHEV pickups, built on the Ram 1500 platform, were equipped with a 12.9 kW-hr Li-ion battery capable of being fully charged in 2-3 hours at 220V. The battery and motors operated in tandem with a 5.7L HEMI V8 400 HP engine. Chrysler specifications stated a fuel economy of 32 mpg in charge depleting mode with an all-electric equivalent range of 20 miles. The vehicles had regenerative braking, a multi-screen human-machine interface (HMI) display, and 6.6 kW of on-board auxiliary power available through several 120V and 220V receptacles (located in the truck bed and cabin). The truck was also reportedly capable of meeting the ATZEV emission standards which would make it eligible for High Occupancy Vehicle (HOV) exemption sticker in a California. In addition, three Chrysler Town and Country PHEV minivans equipped with the same technology were deployed in Sacramento for a much shorter period, approximately 3 months. UC Davis researchers analyzed the implementation and performance of all 31 demonstration vehicles, including user valuations.

In an effort to better understand consumer response to PHEV trucks and the issues which could affect PHEV benefits and fleet sales we present results from 13 months of this demonstration project. Both qualitative and quantitative data were collected and analyzed by UC Davis researchers. Between August 2011 through May 2013 researchers interviewed all 53 vehicle demonstration drivers and fleet operators at least once. These interviews provided insight into how the loaned PHEV fit the needs of the fleet and how it was valued by drivers and fleet managers. The interviews were guided by topics and interviewees were prompted with questions. However, the structure of the interviews was very informal and free-flowing in order to give the interviewees ample opportunity to

express their opinions. This interview technique proved extremely successful and brought up important issues critical to vehicle evaluation. A complete list of the interview topics is attached in the appendix A of this report. Although they are presented as questions, they served more as topic guides during the interviews.

Interviews were supplemented with an online survey to further explore issues that could impact PHEV sales and provide additional insight into the performance data.

In addition, 13 months of data was collected from the 28 PHEV pickups (plus 3 months from the minivans). This data included gasoline and electricity consumption, fuel economy, trip distances and duration, average trip speed, charge sustaining (CS)/charge depleting (CD) driving mode split, ambient temperature, auxiliary power usage, accessory power consumption, charging events (time, place and duration), continuous battery state-of-charge (SOC), distance travelled between charges, and GPS vehicle tracking. Data was collected from every vehicle at one-second intervals.

From these three primary data sources we provide an integrated analysis of the demonstration project. The results and analysis are discussed in the context of the following four themes:

- A recap of user's response to the RAM 1500 4x4 PHEV
- What fleets and fleet drivers value - strategies for marketing Alternative Fuel Vehicles (AFVs) to fleets
- RAM 1500 PHEV utilization
- The possible connection between fleets and private consumer markets

1.1 Background on the fleet market

Organizational fleets, consisting of vehicles used in work applications by companies and public entities, can play an important role in advancing the plug-in hybrid electric vehicle (PHEV) market. Public and private vehicle fleets represent approximately 21% of all light-duty cars and trucks operating in the US and account for even a larger share of all new vehicles sold each year (1). They are also driven disproportionately more, up to 2.5

times more for commercial fleets (FHWA & Energy Data Book and Bobbit). However, the PHEV fleet market has been slow to develop. In 2012 only 3.5% of all PHEVs sold in California were to commercial proprietors or public entities (2). If PHEVs are to capture a significant share of the fleet market, it is necessary to understand what PHEV performance characteristics are most valued by fleet managers and drivers, and how organizations can benefit from incorporating PHEVs into their fleet operations. Only then can successful marketing strategies be developed and the appropriate people and departments targeted within the organization. To date, messaging around AFV adoption in fleets has been focused on a messaging campaign of operational cost savings directed at fleet operators. There may be a potential to develop additional messaging and marketing strategies which move beyond this traditional pitch.

1.2 Demonstration Vehicle Fleet Applications

The demonstration vehicles were used in various applications for the primary purpose of transporting people and equipment. Many of the vehicles were assigned and used by only one person while others were shared, to varying degrees, among multiple drivers. All the drivers were volunteers who were comfortable driving large pickups (in fact many owned large pickups). Equipment and material transport was limited because a portion of the pickup bed was forfeited to accommodate vehicle instrumentation.

Dissimilarities in climate, road systems and traffic levels resulted in basic usage differences between San Francisco and Sacramento. San Francisco is a large, high-density metropolitan city, relatively small in area, with many steep hills, narrow streets with lots of traffic control signals, high traffic volumes, and severe peak-hour congestion. Consequently, travel by San Francisco fleets is best characterized by short distances with low speed, stop-and-go urban driving. The weather in San Francisco is very temperate year round, so vehicle heating and air conditioning demand was relatively low. There are a number of high-occupancy vehicle (HOV) lanes in the San Francisco area which could add value to any PHEV that is eligible for an HOV access sticker. Sacramento is flatter and more spread out with lots of high-speed freeway travel. Sacramento trips were generally longer and at higher speeds and best characterized as a combination of city and

highway driving. Sacramento is also generally much hotter in the summer which resulted in more air conditioning usage.

The fleet organizations participating in this project include the library, airport, police and sheriff departments, public utilities, port authority, human services, public works, real estate, parks department and others. Within each of these fleets, only one person is typically assigned to the demonstration vehicle, although the vehicle is often shared among 2-3 employees. Because San Francisco has a strict policy that prohibits city vehicles from being taken home at night, with exceptions for emergency responders, only one employee in our study drives the vehicle home at night on a regular basis. In addition, a few of the drivers use the pickup bed on a regular basis for equipment transport while others use it on occasion.

The 14 fleets all volunteered and were recruited largely by an open informal solicitation. A few of the volunteer fleets were identified as good candidates and invited to participate directly by the city fleet manager. Reasons for participation varied. Some wanted to try out a new technology others stated it was a good way to demonstrate leadership, still others thought a high-profile “clean, green vehicle” was a good acquisition for political reasons. However, the most common reason stated for wanting to participate was the opportunity to acquire a free vehicle in order to address vehicle shortfalls within the their respective fleets. The fact that the vehicle was new and “green” was a bonus.

About half the vehicles supplanted by the Chrysler demonstration vehicles were pickups (but smaller in size than the Ram 1500 that replaced it), the rest were sedans or vans. The titles and responsibilities of the drivers ranged considerably and included organizational managers, service personnel, maintenance crew workers, surveyors, emergency responders, library employees, and airport personnel. Because the users volunteered for participation, the Ram 1500 PHEV was generally put in applications that provided a reasonable fit for the job. In other words, travel and cargo transport demands could be met with the Ram 1500 and the assigned drivers were comfortable driving that type of vehicle.

1.2.1 Pre-Demonstration Attitudes and Experiences

The organizations and cities where the vehicles were placed were notable for their environmental efforts and accomplishments. For example, San Francisco has implemented a 100% green taxi program, operates the cleanest transit fleet in the nation (with over 1,000 alternative fuel vehicles), has launched a campaign to significantly reduce its fleet size, and is replacing all vehicles older than eleven years with cleaner alternatives. We found that our project participants were acutely aware of the city's green image and environmental stewardship, especially the fleet greening efforts. There was a supportive attitude among the participants who generally agreed with the city's efforts to "clean up" the fleet. Participants conveyed to us through interviews and survey responses they felt an obligation to support their organization's acts of social responsibility. The Ram 1500 users seem to put this demonstration program into a broader perspective and, consequently, seem less judgmental when problems arise.

Many of our subjects had at least some direct experience with compressed natural gas (CNG) vehicles. The consensus among our project participants is that the CNG vehicles were not appreciated by fleet operators or drivers. Many of the demonstration participants recalled negative experiences with using natural gas vehicles in the past citing long, frequent refueling and poor performance as the primary detractions. Overall, these experiences did not seem to shape preconceived notions regarding the PHEV demonstration vehicle. Instead, individual acceptance levels and willingness to drive the PHEV were more reflective of broader organizational commitments to finding the right green vehicle.

The trucks were delivered to the individual fleets with very little or sometimes no information or instruction. This became immediately evident in our interviews as participants expressed confusion about charging requirements, auxiliary power operation, display feedbacks and a host of other issues. In some cases the drivers were completely misinformed. For example, one driver thought the vehicle was all-electric (rather than a PHEV) and another was told to plug in only once a week - on Friday afternoon. When

possible, the research team offered basic information about the demonstration vehicles in effort to mitigate the problems created by misinformation and incorrect instructions. The users were appreciative of our efforts and, once properly informed, seemed more engaged in the process.

2 Themes identified from the user interviews

The RAM 1500 PHEV provided user's with a unique experience which required time to understand and fully value. Through using the vehicles in fleet applications users and fleets started to understand how the vehicle worked and could translate the benefits of the technology to their own circumstances. Here we explore each of the five themes which emerged from these user trials.

2.1 User response to the RAM 1500 4x4 PHEV

In general, vehicle performance far exceeded expectations. Nearly every driver was impressed with how the vehicle performed. Most impressive operational characteristics seemed to be the strong acceleration, quietness, and smooth transition between charge-sustaining (CS) and charged-depleting (CD) mode. Driver satisfaction was high for both those who previously drove large pickups on a regular basis (either their personal vehicle or work vehicle) and for those who had no prior experience with a pickup or large vehicle. Comfort and cabin amenities were also at the top of the list. However, the vehicles replaced by the Ram 1500s were usually very old, in poor state and unadorned. The inferior quality of the replaced vehicles undoubtedly enhanced the appeal of the demonstration vehicles. In fact, the creature comforts of the PHEVs – high-end media center, ergonomic controls, side storage boxes, automatic back window control, comfortable seats, spacious crew cab, generous interior storage, satellite radio, etc. – were very powerful in shaping opinions. The luxurious nature of the vehicle compared to their previous vehicle, seemed to overshadow the advanced technology aspects. When giving their initial impressions of the demonstration vehicle, few mentioned the PHEV

technology, it's potential to save fuel or reduce environmental impact. In contrast, everyone noted how plush and comfortable the vehicle felt. However, this was expected, as it takes time behind the wheel before users fully appreciate the value of new drivetrain features.

Some of the users were bothered about having to forfeit part of the pickup bed to the locked box; however, more often it was only a minor inconvenience. On occasion, drivers did have to make accommodations for the forgone bed space; usually this meant taking another vehicle or making an additional trip to transport items. Many of the drivers were curious and inquired about what was in the locked box. The bed cover presented no problem but was removed by some for convenience. Of the fleets, very few "needed" the extra passenger seating (crew cab) but many appreciated having it. When they did occasionally need the extra seating they were able to accommodate the passengers without making special provisions (such as taking two vehicles). The Ram 1500 met most travel needs and in many cases it was more vehicle than needed (a sedan or minivan would have met their needs and been more maneuverable and easier to park). On the other hand, nobody seemed bothered by driving a large truck (this would be expected given the self-selection process for participation). However, a few people noted that their co-workers declined the opportunity to drive the truck because its size was intimidating.

When assessing the Ram 1500 PHEV, drivers compared it to vehicles they were most familiar with and knew best. Consequently, personal vehicles and other work vehicles served as a reference for comparing the Ram 1500. In many cases this did not provide an equal reference for comparison. The exception was one participant who owned a Chrysler Ram 1500. He was extremely loyal to the brand and model. He had read about our research project long before the vehicles were deployed and was very excited to be chosen to drive one of the Ram 1500 PHEVs. His evaluation of the PHEV, compared to his personal Ram 1500, was very favorable. He did not notice any significant performance deficit and was impressed with his fuel economy improvement which he estimated at 22-23 mpg compared to the 11-12 mpg he was getting in his personal Ram 1500.

The HEMI engine plays an important role in the vehicle beyond its simple functionality. The HEMI engine is a very strong, positive symbol of Chrysler ingenuity, performance and quality. It was an important and surprising element of the demonstration vehicle for our participants. They were pleasantly surprised to find that the HEMI and electric motor were working in tandem. Before driving the demonstration vehicles, many of our participants considered a HEMI engine almost in opposition of an electric vehicle. In their minds, the fast and powerful HEMI engine provided direct contrast with their preconceptions of a relatively slow, sluggish electric vehicle. In fact, one participant reported a conversation with co-workers who had disparaging comments about plug-in hybrids. The participant defended the demonstration vehicle by pointing out the fact that “*it has a HEMI.*” Interviewees repeatedly expressed delight in driving a green vehicle without forfeiting power because “*the HEMI is there when you need it.*” The HEMI engine lent legitimacy to the top-end performance of the vehicle and users immediately recognized that there was no performance trade-off for driving a clean vehicle. Another way it was expressed was “*getting the HEMI without the guilt.*” Whether or not by design, linking the successful, iconic, widely-recognized HEMI engine with a largely unfamiliar technology seems to be a key marketing success within this audience.

Many of the drivers explained to us that they were unclear what was expected from them regarding the truck. They were given little or no information regarding the demonstration project or vehicle. They learned by doing. Some initially changed their driving behavior because they became more aware of how their driving could affect vehicle performance.

2.2 Marketing PHEVs to fleets – understanding user experiences and fleet priorities in the context of the organization

If PHEVs are to capture a more significant share of the fleet market, it is necessary to understand how vehicles are used in fleets, how fleets purchase those vehicles, and what PHEV performance characteristics are valued most by organizations that operate fleets. Only then can appropriate policies, pricing strategies, and marketing approaches be developed to support the incorporation of PHEVs into fleet applications. Here we report

the key values and considerations regarding fleet purchase and use of PHEVs as identified by the demonstration participants. Participants identified four main areas where PHEVs can provide value to their organization. These include:

- Reinforcing brand and image
- Improving driver experience and convenience
- Reducing fuel costs
- Meeting sustainability goals

However, our results show that these values are typically prioritized differently by personnel depending on their position and job function within the organization. CEOs, sustainability officers and marketing directors are typically the ones most concerned with image and sustainability goals; drivers want good driving characteristics and convenience; and fleet managers value fuel cost savings. While organizations participating in the demonstration project found significant value associated with the adoption and use of the PHEVs, fleet managers and vehicle users reported some key operational and procurement issues which could hinder the purchase and full utilization of PHEVs. We generalize user concerns into three categories:

- Lack of available task-appropriate vehicles
- Installation and use of chargers
- Restrictive vehicle purchase criteria

This work provided insights into some of the most important factors which will affect the rate at which PHEVs advance into the fleet sector. Results suggests the need to depart from conventional fleet vehicle marketing tactics in favor of adopting broader strategies that engage multiple actors within the organization (not just fleet managers). This important change is necessary to reveal the full value of PHEVs to an organization. Likewise, several individuals may need to be engaged to address the challenges that can accompany PHEV adoption which include company policies regarding vehicle purchase criteria, associated infrastructure placement, and limited PHEV model availability.

2.2.1 Reinforcing Brand and Image

Vehicle fleets are widely considered a necessary cost of doing business but PHEVs provide an interesting value proposition. They offer an opportunity to enhance public relations and reinforce company culture. Companies like to be seen doing the right thing, making a statement, setting an example, and distinguishing themselves from the competition. However, company branding is not typically a job performance metric for fleet managers who are pre-occupied with day-to-day tasks and the challenge of minimizing operating costs. Yet, many PHEV marketing efforts begin and end with the fleet manager. Aiming higher up the organizational chart and touting the image benefits of PHEVs may prove more effective. Previous research shows that high-level decision-makers value image benefits as much or more than economics when considering alternative fuel vehicle purchases (3). Many high-level personnel, often not associated with fleet duties, expressed an obligation to promote the organization's image and foster public relations. As two administrators put it:

“We’re part of a city wide plan to reduce our departmental emissions - and I think my job is to support the department and city”

“Doing what we can is important to show support for the mayor and city policies”

Drivers and fleet managers were also cognizant of the public relations benefits associated with driving clean vehicles. In fact, 83% of our survey respondents believe “PHEVs improve the image of their organization.” Drivers even took pride when interfacing with the public and sharing information about the PHEV. They proved to be good ambassadors of the technology and their agency. In fact, 80% of the survey respondents wanted more information to share with the public. However, at the fleet level budget constraints often drive purchase decisions. This created an “attitudes-behavior gap” (4) among many of the participating fleet managers.

Top level administrators are more likely to see the bigger picture and the value-added proposition that PHEVs offer. In general, they are less likely to be deterred by higher

upfront capital costs and more willing to accept longer PHEV payback periods in return for public relations benefits that continue to accrue to the company long after the financial return on investment is fully realized. PHEV vehicles are on the road everyday helping to market, not just a product, but the whole company or organization. Although the value of image promotion is not easily quantified, it does provide an important incentive for facilitating market development. Project participants were fully aware of the public relations opportunities a PHEV could provide:

“We did a lot of PR stuff with the truck... took some pictures and got it put in the government fleet magazine... We were a top green fleet last year...we are trying to be number one this year”

“The unofficial catchphrase of our department is ‘clean and green.’ If we clean our fleet I think that’s a good PR message to send”

Fleet PHEVs can also bolster corporate culture and signal a sense of social and environmental responsibility. Individuals recognize and consider corporate cultures when they look for employment opportunities. One survey found that 60% of full-time workers consider an employer’s impact on the environment *vital* when evaluating whether to work there (5). Conversely, businesses are proud of demonstrating environmental stewardship and welcome like-minded individuals. When employees feel their company is actively involved in environmental causes they also feel like they are a part of something significant which in turn can boost morale and efficiency. In a survey of 3000 U.S. businesses, 44% of human resource personnel stated that employee morale was the most valued outcome of their company’s environmental program (6). High-tech industry companies we interviewed tell us that investing in PHEVs conveys the right corporate culture which is important when recruiting and retaining highly-skilled labor in very competitive markets (7).

2.2.2 Improving Driver Experience and Operational Efficiency

Driving Characteristics

Drivers were overwhelmingly impressed with the demonstration PHEV performance.

However, the luxurious nature of the vehicle, especially compared to their normal work

vehicle, was very important when shaping initial impressions. Comforts and amenities like the high-end media unit, ergonomic adjustments, automatic back window, comfortable seats, cruise control and spacious crew cab were some of the most appreciated features. As one driver explained, in their normal work vehicles they are *“lucky to get FM [radio].”*

However, there were also inherent PHEV operational characteristics that were touted by nearly every driver. Almost all interviewees volunteered that they liked the quietness when operating in electric mode and the fact that there was no engine idling when stopped. Most were impressed with the power and acceleration noting that the truck had *“tons of power”* or could really *“get up and go.”* Drivers were surprised that a HEMI engine – an icon of power and high performance – was incorporated into a PHEV which many expected to be *“sluggish”* or *“like a golf cart.”* The HEMI engine seemed to lend instant credibility to the demonstration vehicle, as users felt like there was no performance trade-off for using a cleaner vehicle. As one participant put it, *“it’s an electric vehicle but the HEMI is there when you need it.”* In many cases, the HEMI engine helped sell the PHEV technology to the drivers.

Other driving characteristics commonly expressed include reduced vibration, more stability, less bed bounce, better weight distribution, improved handling, reduced road noise, and a smoother ride. Many mentioned the smooth transition between CS and CD modes. The one concern frequently mentioned was a slight but noticeable *“lag”* when accelerating from a complete stop, although most of the drivers said they *“got used to it.”* Finally, drivers told us of a positive feeling they got while driving the PHEV. As one interviewee put it: *“Talk about the things that make you happy... when I am in electric I am happy. It feels good to be in electric and not using the fuel.”*

On-board Auxiliary Power

One unique design aspect of the demonstration vehicle of particular interest to designers was the onboard auxiliary power (OAP) unit. The OAP unit consisted of two 110V duplex outlets (20 amp, standard NEMA) and a 220V outlet (30 amp) all located on a

power panel accessed through the side storage box on the passenger side of the vehicle. The OAP was capable of providing 6.6 kW continuous AC power. Overwhelmingly, drivers and fleet managers stated that the auxiliary power panel was a valuable feature for work purposes and an intriguing option for personal vehicles. Survey responses support these interview findings (Figure 1).

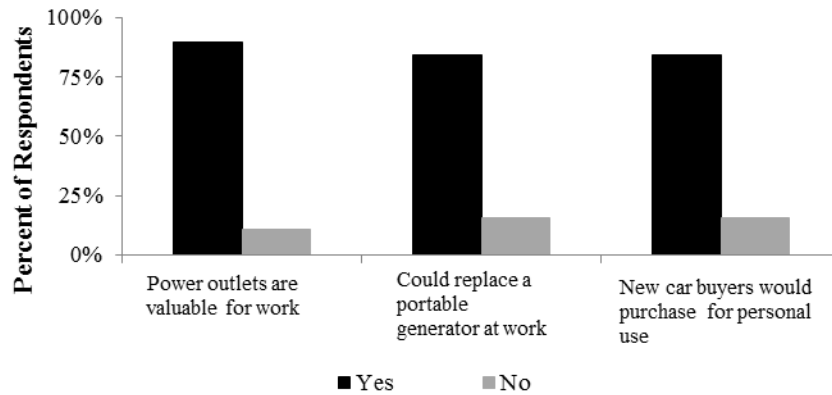


Figure 1: On-board Auxiliary Power Valuations by Survey Respondents

Onboard auxiliary power is an unfamiliar technology that fleets have difficulty understanding and evaluating. As with many unfamiliar, new and discontinuous innovations, there was considerable uncertainty when trying to predict the OAP’s future utility, even after having experienced it (8, 9, 10). As one fleet manager put it:

“Quite honestly, I don’t think we have actually thought about all the ways it could help us. If we really sat down to think about how we use a generator, I think we would find all kinds of ways it would be beneficial to us.”

This was further demonstrated when another project participant conveyed his excitement about a forthcoming opportunity to use the AOP but on the day of the event “forgot” the demonstration vehicle had auxiliary power available.

Convenience and time savings were cited as the main benefits by those who did use the OAP on a regularly basis. Users appreciated the freed up truck bed space or not having to

tow a trailer for generator transport. One participant who used the OAP unit on a regular basis detailed the convenience of it. She did not have to make a trip to the utility yard to pick up a generator and then solicit a fellow employee to help her load it into the truck and unload it at the site. The OAP unit allowed her to perform, single-handedly, what was otherwise a two-person task.

Participants also valued the OAP as emergency response equipment, even though usage would be very infrequent. Other stated benefits include the fact that loud, high-polluting generators could be replaced with clean, quiet energy while fostering good will with the public and allowing extended work hours in places with strict noise ordinances. However, it was also pointed out that an OAP takes the whole vehicle out of service, whereas a generator can simply be left at the job site. Such trade-offs need to be fully understood by prospective PHEV buyers in order to make an informed purchase decision.

Less Frequent Refueling

One PHEV fuel economy implication nearly every driver and manager stated was the benefit of fewer trips to the gasoline station. Drivers in San Francisco were especially appreciative because of the limited number of contracted fuel facilities throughout the city. Gasoline refueling often required an out-of-the-way trip during rush hour followed by a long wait to take a turn at the pump. Drivers and managers noted the convenience and time-savings resulting from fewer trips to the gasoline station.

This attribute could provide a significant economic benefit. In Manhattan, gasoline stations are so few and the lines so long, that FedEx pays employees overtime to refuel after work hours. These associated refueling costs are now even included in their return on investment (ROI) calculations, to the benefit of PHEVs (*II*).

High Occupancy Vehicle (HOV) Lane Access

Although the demonstration trucks did not have HOV stickers, some of our interviewees pointed out this potential convenience benefit (based on emission test results, the demonstration PHEVs would be eligible for an HOV sticker). HOV access not only

reduces travel time, it can also boost driver morale by mitigating traffic congestion experiences. One driver who anticipated this benefit exclaimed: *“As soon as I get stickers on the Focus EV, I will probably start driving that for my commute home, I get off just past where the carpool lane ends. It’s awesome!”*

HOV stickers can reduce work-related travel times and provide potential benefits to employees. Those allowed to drive work vehicles with HOV stickers home could benefit from reduced commute times and less commute-related stress. The assumption being that happier employees are more productive and reduced travel times mean they spend more time at work. This benefit is recognized by one high-tech company, Evernote, which subsidizes employee HOV compliant vehicles up to \$250 per month (12). As their CEO explained:

“The math works out. We have a lot of talented and highly paid people who waste time in traffic. So if we can save them a half hour a day, and many of them save more than that, then it very quickly adds up to more than what we pay per car every month.” (Phil Libbons, Evernote CEO).

Survey responses show the majority of demonstration participants felt that paying for the home electricity to charge a PHEV, in exchange for HOV lane access during their commute was a fair and acceptable trade off. However, those who already commuted in a work vehicle were less inclined to accept such a trade-off.

2.2.3 Reducing Fuel Cost

Beyond vehicle comfort, fuel economy was the factor most often cited by participants when evaluating vehicle performance. Participants often drew PHEV fuel economy comparisons to their normal work vehicle. However, fuel economy is a function of many variables including vehicle technology, driving cycles (e.g., stop-and-go vs. long freeway

trips), driving style (e.g., aggressive drivers vs. efficient drivers) and the fuel used (total electric miles vs. gasoline miles).

Driving data from the PHEVs suggest that the potential for fuel savings is substantial but can vary significantly. Although fuel cost is only one component of a vehicle's cost of ownership, it is very important to fleet operators. Gasoline prices are volatile which complicates budgeting. Fleet managers explained to us that more predictable fuel costs would help them project operating costs and stay within allocated budgets. Fuel expenditures were the only direct vehicle cost that could be measured by the participants in the demonstration. Although it is only one economic factor, it was important to fleet operators because it showed at least one potential cost benefit.

Figure 2 shows actual average fuel economies for each of the demonstration vehicles over a month period and compares it to the EPA ratings for a gasoline Ram 1500 of the same vintage (model year 2012). As can be seen, the PHEV demonstration vehicle significantly outperformed a gasoline Ram 1500 for both the San Francisco vehicles (more "city" driving demands) and the Sacramento vehicles (more "combined" city and highway driving). Using the EPA 2012 Ram 1500 "city" standard of 13 mpg as baseline for San Francisco and the EPA "combined" standard of 15 mpg for Sacramento, the estimated monthly gasoline savings for San Francisco and Sacramento are 133.7 gallons and 245.4 gallons, respectively. Fuel economy results from the demonstration should be viewed cautiously as representative of what is technologically possible because there was little or no incentive for fleet vehicle drivers to drive in an eco-friendly manner or to maximize charging. There was also no concerted effort to place the demonstration vehicles in applications where the full fuel economy benefits could be realized. To illustrate the importance of charging, we compared several weeks of CD fuel economy to several weeks of CS fuel economy when the vehicles were not charged, and therefore operated only in CS mode (4 vehicles did not experience long periods without charging). This comparison shows operation in the two modes over similar drive cycles (i.e., CS mode is not relegated to longer trips after the battery is discharged). The average fuel economy during these trial periods was 14.2 mpg (CS mode) versus 21 mpg (CD mode)

in San Francisco and 17.2 (CS mode) vs. 23.7 (CD mode) in Sacramento (Figure 3). On average the vehicles used 38% - 48% less fuel while operating in CD mode during the comparison periods.

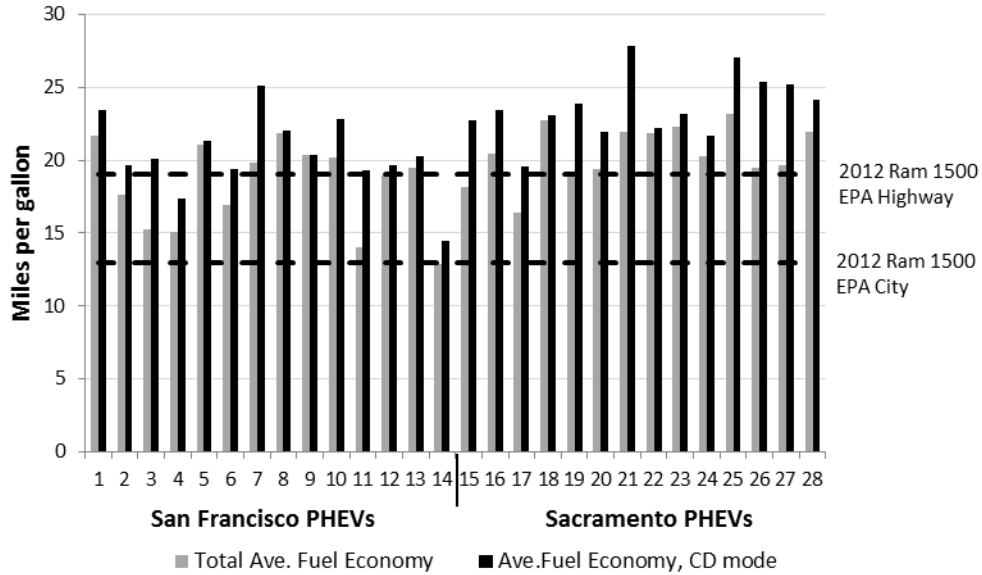


Figure 2: One Month of Fuel Economy Data

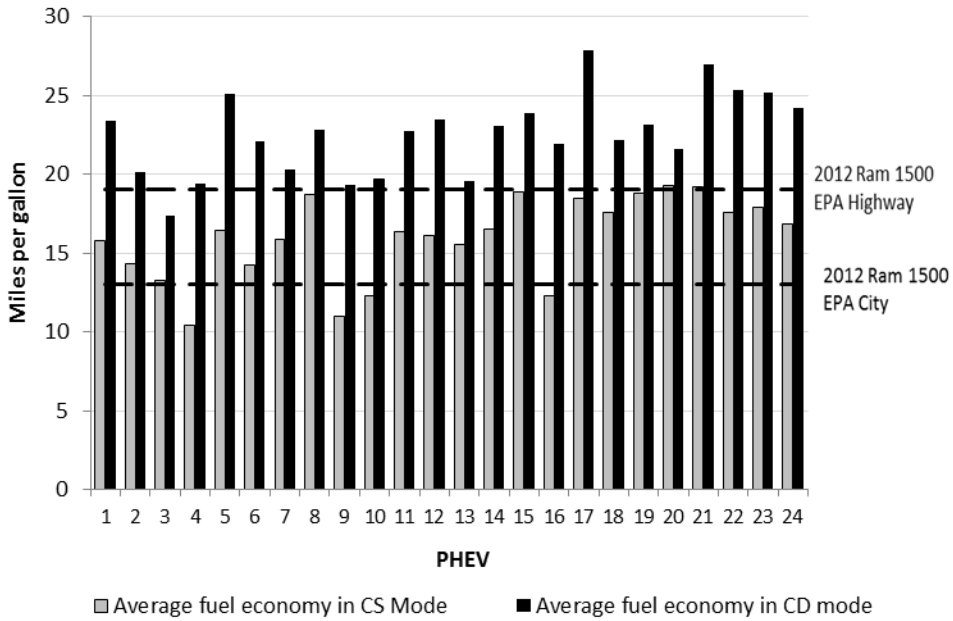


Figure 3: CS vs. CD Fuel Economy Over Similar Drive Cycles

2.2.4 Meeting Sustainability Goals

Decision-makers in various San Francisco departments discussed vehicle purchases in the context of the city's clean air vehicle replacement guidelines. Enforced by the department of the environment, the guidelines require all city vehicles (except for law enforcement and emergency response vehicles) to be "clean air" certified unless there is compelling justification. As one fleet manager explained:

"The city, in regards to going green, has taken a very hard line with what we can purchase. And if they know there is an alternative fuel vehicle available to purchase and you have asked for a standard fuel vehicle then you have to have an excellent justification as to why...we are not given a choice."

In addition to requiring the purchase of clean air vehicles each city department has to complete an annual climate action report detailing the sources and quantity of their greenhouse gas emissions. The report provides targets and specific strategies to mitigate greenhouse gas emissions. Enforcement of the clean air replacement vehicle mandate and obligations of meeting climate action plan goals are shaping the purchase behavior of San Francisco city fleets. They follow developments in clean air vehicles and technology to find the best vehicles to meet their needs. As one manager explained:

"Every year [when doing the budget] we talk about, are there electric vehicles available? Are there alternative fuel vehicles available that we can load up for our application?"

Department managers, sustainability officers and others tasked with implementing these policies viewed the RAM PHEV as valuable because the PHEV technology, in a work truck format, could be a way to provide appropriate and flexible clean air vehicles for their staff. In fact, many fleet operators explained that one reason they elected to

participate in the demonstration project was to evaluate the PHEV technology to inform future purchase decisions.

The extent to which the PHEVs will likely be valued for sustainability reasons depends on the organization's commitment to sustainability, environmental stewardship, or petroleum reduction goals. In the US, there are several cities, counties and states which are implementing climate change mitigation measures. Thirty-two states and over 200 cities have climate action plans of varying requirements. For example, in California, local governments are required to develop climate action plans to meet greenhouse gas emission targets set in collaboration with the California Air Resources Board. These organizational goals are not unique to government fleets. Many companies have also been advancing sustainability programs and even specifically targeting vehicle fleet electrification.

The extent to which these organizational goals are pursued and linked to the organization's fleet will help determine the value of PHEVs. Such organizational goals can help promote PHEVs and influence fleet vehicle purchases, if the right decision-makers get involved.

2.2.5 Considerations Associated with Using PHEVs in Fleet Applications

The PHEV demonstration project provided participants with the opportunity to evaluate how a particular plug-in hybrid truck might function within their fleet. Participants also took the opportunity provided by the demonstration to assess conditions under which vehicle electrification might make sense. Interviews with project participants showed that, despite the benefits of PHEVs, certain issues must be addressed before PHEVs could be adopted on a large scale by their organizations. Even then, some fleet vehicle applications, such as law enforcement pursuit vehicles, may not be conducive to electrification based on drive cycles or vehicle performance requirements. We describe these considerations and conditions reported by our users in the context of three themes:

green vehicles must be task-appropriate; an appropriate charging network must be installed; and the fleet vehicle purchase process must not inhibit PHEV acquisitions.

PHEVs Must Be Appropriate for the Fleet Assignment

Fleet managers who participated in the demonstration consistently stressed the importance of purchasing “green vehicles” but also emphasized the fact that the vehicles had to meet the needs of their job functions. As one participant noted, “At the end of the day the job needs to get done...whether it’s electric or gasoline, it’s just got to happen.”

The fleet managers we interviewed as part of this demonstration described their placement of the RAM 1500 PHEV as part of a strategic decision-making process which was not representative of how they normally assign fleet vehicles to drivers. Our fleet managers reported trying to select trustworthy and appropriate drivers who had job functions which could be met by the RAM 1500 PHEV. The large vehicle size, limited bed space, and inability to modify the vehicle in any substantial way meant that some fleets were unable to use the vehicle within their normal “work truck” fleet. Fleet managers who had experience with compressed natural gas (CNG) vehicles in prior years described similar challenges they faced incorporating CNG conversion pickup trucks into their fleet.

The option of installing aftermarket components is also important to fleet managers. As one fleet manager put it “*any vehicle we purchase will have to be modified to accommodate tool boxes, ladders and enclosures.*” Fleet managers also noted the forfeiture of pickup bed space (because of the instrumentation box) was a problem. “*Because of that box in the back it’s not conducive to being a work truck.*” Another noted that “*a full-sized 8 ft. bed would go over better for those employees who really need a truck.*” Some of the drivers also noted that an easier-to-manuever vehicle would be more desirable for city driving.

While not all fleet vehicles need a lot of cargo or towing capacity, data on 2011 vehicle registrations indicates that SUVs, vans and pickup trucks account for approximately 70%

of government and commercial (excluding law enforcement) fleet vehicle purchases (*13*). Most of the PHEVs available today are much smaller light-duty cars. Therefore, the near-term PHEV fleet market may be limited by existing vehicle styles. However, careful planning could go a long way towards matching available PHEV models with a fleet's operating profile. In the longer timeframe, manufacturers have plans to increase the number and type of PHEV model offerings.

Vehicle-application compatibility issues can be mitigated through careful vehicle placement and driver selection. One solution is to assign the smaller PHEVs to supervisors or other staff who do not require the same cargo capacity or who have access to other substitute vehicles. However since supervisors and office staff typically drive less than most professional work crews, the financial incentives to switch from gasoline to an alternative low-cost fuel decreases proportionally.

It was also suggested that the PHEV battery size be a customizable option. Although an intriguing proposition, it's not clear that most fleet managers have the analytical resources to account for factors like vehicle load, driving behavior, charging frequency, and climate control when considering the optimal electric range.

Installing and Using a Charging Network

Most of the fleet managers tasked with incorporating the RAM 1500 PHEV into their fleet did not have prior experience with siting, installing or managing charging infrastructure. Proper placement, design, and use of the charging infrastructure are critical to maximizing electric driving and the benefits of PHEVs. Easy and convenient charging for all users increases the proportion of CD driving which reduces fuel costs and petroleum consumption while maximizing environmental benefits.

Problems with charging infrastructure placement were observed for some of the organizations who participated in the demonstration. Some charging stations were located behind locked gates, far away from where drivers normally parked their vehicle, or in tight spaces that made parking and charging difficult. Overall, 27% of the demonstration

survey respondents, if given the opportunity, would have moved their charging station to a different location.

As explained by those who drove the RAM PHEV home, appropriate charging infrastructure may extend beyond the corporate yard or office, depending on how vehicles are used. Providing employees who commute home with a PHEV the option to receive compensation for using their home electricity to charge a work PHEV, might help align their actions with the goals of the organization. Providing guidelines, public charger location information, and membership cards for away from home charging networks, while communicating the benefits of routine charging, may also help establish good charging practices beyond the workplace.

Most of the fleets had in-house capability to wire and install the single Level 2, J1772 charging station which came with the vehicle. Charging station installation was timely for most of the participants but a few reported it took longer, up to two months in some cases. Participants with the longest installation times had difficulty finding a secure location to install the charger, had permit delays, or tried to procure additional funding for installation. These challenges usually required cooperation or authorization from others both from within and outside the organization. Charger installation complications tend to escalate with the installation of multiple charging stations.

A potential problem revealed during the demonstration was the propensity for organizations to assign charger equipment and installation costs to the vehicles using them at the time of installation. This often resulted in all the costs being inaccurately apportioned to one vehicle which inflates the perceived PHEV cost. A more accurate accounting practice would be to amortize charger-related costs over all the vehicles that could use it during its functional life.

Finally, the fleets taking part in this demonstration project had almost no sense of the cost associated with charging the PHEV or how to separate electric vehicle charging from their total electricity bill. Billing users directly for electricity use, or budgeting PHEV

vehicle “fuel” costs may prove challenging for some who have no experience translating vehicle travel into electricity costs.

Restructuring Fleet Vehicle Purchase Criteria

A fleet manager’s job performance criteria often dictate that he/she select vehicles with the lowest purchase prices. This emphasis on upfront cost creates problems for fleet managers who want to purchase PHEVs. One fleet manager describing how his decisions must make economic sense said:

“I’m trying to migrate people to more fuel efficient vehicles but it’s always a challenge because a lot of them aren’t running a lot of miles. So, we look at the payback and it’s like 15 years sometimes... there is always an economic analysis [associated with] what we’re doing.”

One means of minimizing the risks associated with cost uncertainty is to lease PHEVs. Lease arrangements provide an excellent market development opportunity by helping fleets address the two largest unknown costs associated with a PHEV; resale value and maintenance costs. Some participants noted that they would be inclined to lease a PHEV but are unable to enter into lease agreements due to established purchase practices or company policies. PHEVs are well-suited for leasing since the Federal incentives (varying from \$2500 to \$7500 per vehicle) can be immediately deducted by the dealer and the savings passed down to the lessee.

Since PHEVs have been in the market for such a short time, the factors that affect the total cost of ownership (TCO) for PHEVs are not fully understood. There is little information about the residual value or resale value of PHEVs. Fleets that are unable to lease and those with mileage-based or time-based vehicle retirement policies face an additional TCO obstacle. Cost of ownership assessments must take into consideration not only the useable life of a PHEV but also the battery life.

2.2.6 Discussion

We identified four value propositions for plug-in electric vehicles deemed important by organizational representatives who had the opportunity to use a RAM 1500 PHEV for more than a year. These values vary in importance depending not only on the organization but, more importantly, on the responsibilities and job position of the evaluator. What is important for one employee may not even be a consideration for the individual tasked with purchasing fleet vehicles. We propose that effective PHEV fleet marketing campaigns target strategic coalitions within organizations, so that all the PHEV benefits are considered in the vehicle selection process.

The multitude of organizational complexities that affect PHEV purchase decisions calls for a broader, more robust, PHEV marketing strategy. These strategies should take into account the various organizational decision structures that influence fleet acquisitions **(13)**. Whereas vehicle purchase decisions are routine, PHEV purchases will likely require a more strategic approach involving several individuals. It should not be pursued through normal channels. Tax breaks and subsidies, infrastructure installation, a fleet's ability to accommodate PHEVs, sustainability goals, corporate culture and image, and feedback from fleet networks are a few considerations that can complicate the purchase decision. Typically, no single person in the organization has full knowledge of all these factors.

The decision itself can take many paths. It may be a team collaboration that requires bargaining or compromise, a linear process that relies on an "idea champion" to move it up the chain of command, or a decision sent down from the top of the organization. Decision interrupts and vetoes anywhere in the decision process can undermine a chain of "yes" votes. Even top-down PHEV purchase directives can fail if the decision is not properly implemented. In some cases, the fleet manager may simply need a nod from upper management to feel comfortable enough to break with the convention of purchasing the least expensive option.

Our results also highlight a number of issues that must be addressed to ensure successful adoption of PHEVs into fleets. Again, some of these - like charger installation - require input and action from employees who are not normally involved in the vehicle purchase process. Engaging these employees is imperative and requires planning before the purchase. The rate at which PHEVs enter the fleet market depends on getting the right message to the right people within each organization and correctly matching products with customer needs.

2.3 RAM 1500 4x4 PHEV utilization – Expectations electric vehicle miles travelled for PHEVs

The flexibility of using multiple fuel sources (electricity and gasoline) provides an interesting compromise for organizational fleets. Organizations can benefit from the purchase and use of a vehicle with an electric drivetrain while using gasoline in place of electricity when charging is not convenient or practical. But how do we anticipate and measure the performance of Plug-in Hybrid and Electric Vehicles (PHEVs) in fleet applications given differences in travel behavior of users, access to charging infrastructure, organizational policy and individual driver motivation? All of these differences between users make a true assessment of fleet user's performance with a PHEV difficult. Previous academic studies and services by consulting groups state that PHEVs used in fleet applications assume PHEVs will be charged once per driving day. This assumption about PHEV charging by fleet users is untested and, as is the case for private consumers, may not be true. In reality, other factors may influence the driving and charging behavior of fleet operators using PHEVs especially, since fleet operators do not pay for fuel or purchase the vehicles themselves and as such have little financial incentive to plug-in. Although users do not have to plug-in, the environmental, sustainability and economic benefits of PHEVs are predominantly linked to this behavior. The demonstration project provided an opportunity to collect real world data on fleet driver use patterns with a prototype PHEV. We test the once-per-day charging assumption for users of these demonstration PHEVs by comparing each user's actual CD driving distance with their simulated potential base on a once a day charging assumption and

vehicle simulation model. The results show an unexpectedly large variation in CD driving performance among fleet users – some users exceed their expected CD driving by up to 36% while others fall short by 75%. These results suggest a more complex use case for PHEVs in fleets than a once per driving day charging assumption implies.

We integrate multiple data sources and undertake simulations to produce a rich assessment of vehicle use patterns and the context for that use. The following describes our data collection and simulation methodologies in the context of the three parts of this analysis, calculating the observed CD driving, simulating the expected CD driving and the CD ratio calculation. Where appropriate the assumptions which have been made are noted and their possible influence on findings is assessed.

2.3.1 Observed CD Driving

The observed driving and charging data for each of the 28 prototype RAM 1500 PHEVs was collected using on board data collection units provided by Chrysler LLC. Here we describe in greater detail the data collection, validation and processing needed to calculate CD driving for individual vehicle users.

Real world PHEV use data collection and validation was conducted in partnership with Chrysler LLC and Idaho National Laboratory. Each of the 28 RAM 1500 PHEVs was equipped with data loggers which recorded vehicle use and charging data for over 70 signal values at 1 second intervals. The signal values included vehicle speed, DC energy use, throttle position, engine RPM, gasoline use, AC energy, power use from climate control systems, charging voltage and current, and state of charge, to name a few. The vehicle data was wirelessly transmitted to Chrysler, who then uploaded the data to UC Davis and Idaho National Laboratory servers. INL and UC Davis undertook independent testing of a RAM 1500 PHEV to assess the accuracy of the signal values recorded by on board vehicle loggers. Data post processing was completed by UC Davis researchers to assign and summarize vehicle use data into consecutive trip segments. For the purposes of this project we define a trip as a full cycle of the vehicle's ignition (from an ON to an

OFF state lasting more than 5 seconds). The results from the data processing of the observed data were validated with Idaho National Laboratory to ensure accuracy and consistency of analysis methods for both institutions. A driving period for each PHEV demonstration participant is established based on best available project data, which included screening of GPS coordinates, in-vehicle driver logs, and survey data from each driver. The start date for each participant occurs after their charging station or charging solution was installed. Only a subset of drivers, those who acted as a primary driver of the demonstration PHEV were used for this analysis, so enough travel and charging data from each user could be compared.

2.3.2 Potential CD Driving

The expected CD driving is an estimate of the CD driving each demonstration participant likely would have completed, assuming they started every driving day with a fully charged battery. These models are developed specifically for the RAM 1500 PHEV, using actual trip level summary data for charge depleting driving. Each of the four models represents an operating condition with a unique electrical energy consumption rate for the RAM 1500 PHEV. In the following text we discuss each of these models in further detail. While the models go into as much detail as possible based on the available data, these models do not account for several measures which are likely to impact the electrical energy consumption of a PHEV, such as climate conditions matched to road conditions (wind speed and direction), driving terrain (altitude gain or loss) and the amount of energy recuperated from regenerative braking. Understanding these data will increase the accuracy of energy predictions. These energy use models are combined with actual driving data and an assumption of charging behavior to predict the electrical energy consumption of every trip.

The vehicle idling model predicts the energy consumption for trips where the vehicle distance traveled is 0 and climate control is not activated during any part of the trip (7.5% of all trips). Under these circumstances we expect that the electrical energy consumption in CD mode is associated predominantly with the parasitic loads of operating the

vehicle's battery management system (BMS) and the power available from the traction battery. For the RAM 1500 PHEV the power available from the traction battery decreases with the state of charge (SOC). The energy used from the BMS depends on the duration of the trip and the energy intensity of BMS operation. Since we do not have data on the vehicle's specific BMS energy use (only total energy use) we approximate BMS status through a series of conditions which approximate when BMS energy use should be high - during the first trip of the day (before any battery conditioning), temperatures below 63 degrees Fahrenheit, and trips over 45 seconds (time from ignition for BMS to engage). The model is detailed in Equation 1. The linear model described by Equation 1 returns an adjusted R Squared of 0.7629 from 1400 observations. While a higher adjusted R Squared is always desired, this model represents a small portion of trips which are typically low energy. As such, the magnitude of any error is relatively small based on absolute values. Additional information regarding the actual energy use from the BMS would likely help increase the adjusted R squared for this use scenario.

Equation 1

$$y = (x_1 * 0.0236) + (x_2 * 0.000294) + (x_3 * 0.1502)$$

Where y is the predicted energy use (kWh)

Where X₁ is equal to trip duration in minutes

Where X₂ is equal to beginning state of charge in %

Where X₃ is equal to BMS high energy state on

Vehicle idling w/ Air Conditioning (A/C) on predicts the energy consumption for trips where the vehicle distance traveled is 0 and the A/C was in operation (9% of all trips). Under these conditions, we expect that the energy consumption of the vehicle is associated predominantly with the parasitic loads of operating the vehicles BMS, running the A/C (the system is fully electric and metered) and the power available from the traction battery represented by the SOC. While the activity of the BMS still remains unknown in this model we expect that A/C use among drivers is a good approximation for BMS energy use since both systems are likely tied together for increased efficiency.

Furthermore, batteries typically perform best within temperature ranges of x and x , which, are likely to overlap with comfortable cabin temperatures for occupants. The linear model described in Equation 2 returns an adjusted R Squared of 0.9249 from a sample size of 1500 observations.

Equation 2

$$y = (x_1 * 0.0185) + (x_2 * 0.000572) + (a_1 * 1.4324)$$

Where y is the predicted energy use (kWh)

Where X_1 is equal to trip duration

Where X_2 is equal to beginning state of charge in %

Where a_1 is equal to the energy used by the climate system (kWh)

The high speed model predicts the energy consumption for trips where the distance traveled is greater than 0 and the average speed of a trip is more than 20 miles per hour (25.5% of trips). For this use case the energy consumption from the traction battery is limited by the DC to DC converter which delivers power from the battery to the Hybrid drive system. Because of the maximum power consumption from the traction battery is limited, in this high power use state, the total electrical energy consumption for the vehicle is predominantly a function of vehicle trip characteristics (driving time, average speed and distance), beginning battery SOC, and the energy used to power the A/C. The linear model described in Equation 3 returns an adjusted R squared of 0.944 from a sample size of 2300 observations. Other factors not recognized here which could affect the electrical energy consumption of the PHEV are likely to include climate conditions (wind speed and direction), terrain (altitude gain or loss) and amount of energy recuperated from regenerative braking.

Equation 3

$$y = (x_1 * 0.005) + (x_2 * 0.0224) + (a_1 * 0.3438) + (d_1 * 0.09945) + (S_1 * -0.01762)$$

Where y is the predicted energy use (kWh)

Where X_1 is equal to trip duration

Where X_2 is equal to beginning state of charge in %

Where a_1 is equal to the energy used by the climate system (kWh)

Where d_1 is equal to the distance traveled

Where S_1 is equal to the average trip speed

The low speed model predicts the energy consumption for the remaining trips (58% of all trips), which are where the distance traveled is greater than 0 and the average speed is less than 20 miles per hour. In this operating state the energy output from the traction battery does not approach the maximum allowed by the DC to DC converter and, as such, the electrical energy consumption is more variable than in the high speed model.

Equation four summarized below returns an adjusted R squared of 0.8515 from a sample size of 9800 observations

Equation 4

$$y = (x_1 * 0.01824) + (x_2 * 0.00322) + (a_1 * 0.5042) \\ + (d_1 * 0.1223) \\ + (S_1 * -0.00496) + (S_2 * 0.02165) + (T_1 * 0.02165)$$

Where y is the predicted energy use (kWh)

Where X_1 is equal to trip duration

Where X_2 is equal to beginning state of charge in %

Where a_1 is equal to the energy used by the climate system (kWh)

Where d_1 is equal to the distance traveled

Where S_1 is equal to the average trip speed

Where S_2 is equal to the number of stops made

Where T_1 is equal to the first trip of each driving day

2.3.3 Ratio_{CD} Calculation

The Ratio_{CD} is a normalized measure of each driver's CD driving performance. For each of the Ram 1500 PHEV drivers we divide a user's actual CD driving distance by their

potential CD driving distance (which is estimated using the linear regression models). The Ratio_{CD} is particularly helpful in evaluating use across a fleet, since it controls for differences in use patterns between drivers. As such, each user is only judged against how well they met expectations based on their own baseline and driving behavior. A Ratio_{CD} above 100% indicates that the vehicle users drove more miles in CD mode than was expected while a result below 100% indicates that the user drove less miles in CD mode than expected.

Equation 5

$$\text{Actual CD driving to potential CD driving ratio} = \frac{\text{Observed CD driving distance}}{\text{Potential (simulated) CD driving distance}}$$

2.3.4 Results

The results of the simulation and analysis are summarized below in Figure 4. Each of the participants is represented by a single black circle and plotted according to their average driving distance (miles per week) and Ratio_{CD} measure calculated using Equation 5. Figure 1 highlights the range in user's performance with and use of the RAM PHEV based on the arbitrary baseline of a single charging event per day. Using this baseline, users drove between 75% less and 36% more CD miles than expected, however, 75% of the sample did not meet their estimated CD driving potential. The results of the simulation and analysis for this small sample of drivers suggest there is a significant difference between some fleet drivers' observed CD driving performance and the suggested outcome which is widely assumed by PEV advocates, analysts or policy makers.

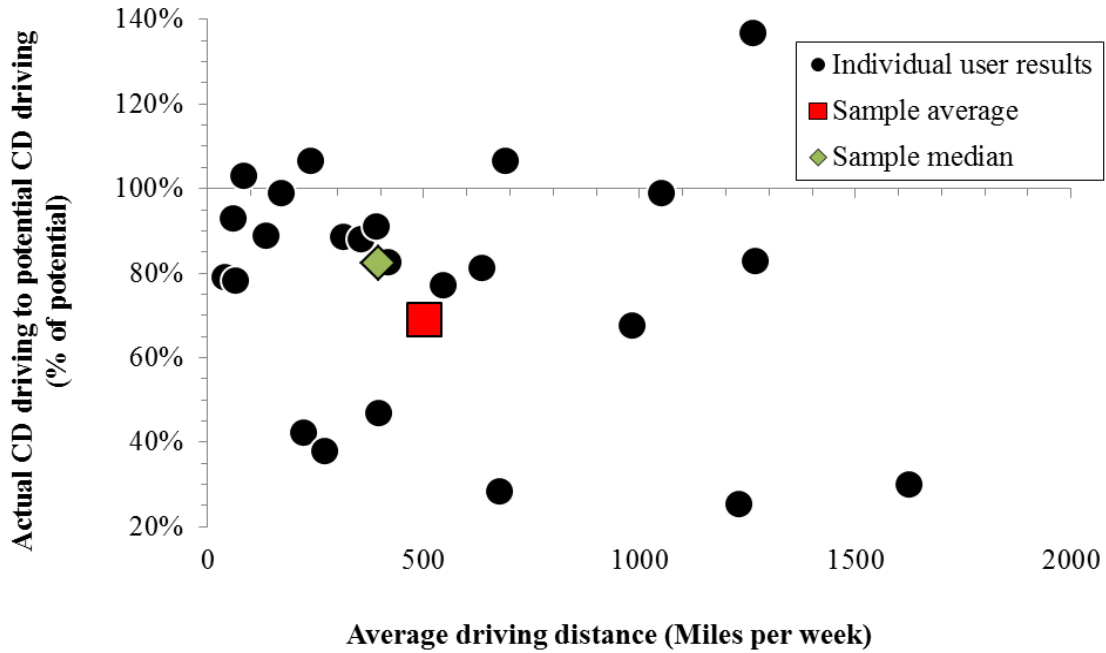


Figure 4: Summary of actual CD driving to potential CD driving ratio

2.3.5 Discussion

The extent to which PHEVs displace gasoline will depend on how much driving is completed in CD mode. To this end the results from Figure 1 provide an interesting, albeit limited, data point to which we can observe some Fleet operator’s use of a PHEV-conversion for an extended period of time. While the ranking methods used in this analysis and the results are useful they do not provide the context necessary to understanding the set of behaviors or circumstances which led to the level of performance observed, if the once a day charging baseline is actually an appropriate measure, if user’s could do better, or what kinds of management or motivational strategies would lead to improvements in an individual’s CD driving ratio.

2.4 The connection between fleet and consumer markets

The workplace provides a potential opportunity for introducing employees to new technologies. A couple of Ram 1500 PHEV drivers in our study provided good examples

of workplace influence. One employee bought a Ram 1500 after driving one for a previous job. He liked the vehicle so much that he purchased one for his personal use. Another individual conveyed to us how he spent \$1000 to get the same premium yard maintenance equipment he used at work because it worked so well. His budget for these items was originally approximately \$200.

Nearly every employee owns a car and every fleet vehicle operator is a vehicle buyer in their personal life. In previous studies, UCD research found that the workplace makes an excellent showroom for new technologies because it's a place where individuals gather and exchange opinions and ideas (14). Furthermore, co-workers are for the most part considered a trusted, reliable source of information. More importantly, fleet vehicles can provide an opportunity for employees to experience the different technologies for extended periods. In our interviews with fleet vehicle drivers, we discovered that experiences with work vehicles can influence individuals' perceptions of brands, technology and even vehicle purchase decisions. Thus, the benefits of having AFVs in a company fleet extend far beyond economics and public image boosting. Having AFVs in a business or government fleet allows employees, clients and associates to see and learn about the vehicle. The vehicle is on display and users become ambassadors for that technology. Other employees may inquire about a vehicle or charging station they walk past every day. AFV drivers interact, sometimes every day, with the public and often the discussions are initiated by passing individuals curious about the technology. A simple response from an AFV driver can be sufficient impetus for the passing individual seek more information about the technology. For those fortunate enough to drive one in the course of their daily duties, employees can learn a lot about AFVs. Time behind the wheel on a regular basis, and even refueling the vehicle, helps to dispel misconceptions and increase knowledge of AFVs. It helps the driver to better understand and visualize how such a vehicle might work in his/her private life. In addition, they take their AFV experience beyond work and into their personal network by talking about it with family, friends, neighbors, teammates, fellow church members, etc. However, it should be noted that it is crucial for the success of AFVs that fleets build positive experiences. To achieve this, operator instruction, vehicle reliability and infrastructure must be handled

appropriately. Given the functional requirements of trucks it seems even more important for truck buyers to experience an AFV truck before purchasing one. To this end, fleets may actually provide a good opportunity to target private consumers, allowing them to test the technology before making an investment of their own.

All of the drivers had, at least periodically, interactions with the public about the PHEV during the course of conducting business. Most were proud of the vehicle and anxious and willing to engage the public about it. The most popular question was “*are those available for purchase?*” Drivers tell us stories about how people waited for them in parking lots to inquire about the vehicle. Unfortunately, the drivers were very limited in what they told people because their knowledge was limited. Some of the interviewees lamented how they wish they could convey more to the public. They were proud to drive the trucks (even if they did not understand the full benefits) and enjoyed being “*ambassadors*” of the technology and the city. Some of the interviewees mentioned that they would like to have an informational handout that better explained the vehicle or provide a website where the public could go to get more information. Ideas in this regard included handing people a card with an internet information link or putting a Quick Response QR code or website URL on the truck. Drivers told us the public comments were always positive and encouraging. Many wanted more information. One Chrysler dealer the saw the Ram PHEV even asked if how he could get the vehicle in stock. In lieu of providing detailed information about the vehicles and specifications, the drivers more often described the demonstration program and gave a very short, simple description of the technology (“*it’s a vehicle that runs on electricity and gasoline*”). In some cases we suspect misinformation was conveyed to the public. In fact, during the interviews, the drivers often asked us about the technology and benefits of the PHEVs including how exactly it worked, where the battery was stored, what does regenerative braking do, and what environmental benefits were expected.

3 Discussion

The demonstration project provided an opportunity for fleets to test a plug-in hybrid pickup truck for an extended period of time. Over the course of the 13 month project UC Davis researchers interviewed and surveyed every driver and provided detailed data analysis on an individual user basis. This report highlights the findings of this research which are summarized below:

- Chrysler demonstrated PHEV technology in a full size truck platform and provided a large and distinct market segment (truck users) with access to electric and hybrid vehicle technology.
- Truck buyers may require more hands on experience than other segments in order to evaluate the functional aspects of. As such, fleets might provide a good conduit to the consumer market for alternative fuel pickup trucks and vans.
- Experiences (good and bad) with a fleet vehicle can shape or influence the opinions of new car buying consumers.
- Pickup trucks, vans and SUVs are the most appropriate vehicle form for municipal and corporate fleets. However, vehicle functionality is critical.
- PHEVs have features which appeal to fleets but it takes time, experience and appropriate instructional structure for them to recognize values beyond fuel savings.
- PHEV performance will vary depending on institutional factors, user behavior and operator training. Understanding best practices for PHEV deployment can ensure vehicles meet and surpass performance expectations.

Although the market for PEVs continues to expand, recent surveys and interviews with new car buying consumers has identified the lack of awareness as one of the primary barriers to PEV adoption and further market development. Before consumers can purchase these novel and engaging products they need to gain experience and understand the technology so they can appropriately value the new and different features and benefits which these vehicles provide. We have found that fleets can provide this experience to new car buying consumers, however, care must be taken to build positive, and worthwhile experiences for consumers. This could include extended driving periods

where employees can take PEVs home for a weekend, providing resources to explain PEVs to employees, encouraging ride and drive events, providing workplace charging for fleet and employee vehicles, and providing appropriate training and resources to ensure employees have a good experience with PEVs.

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5 APPENDIX A: Interview Topics for RAM 1500 4x4 demonstration participants

Background

What is your position within the organization?

Job responsibilities and duties

How do you use the vehicle during the course of your job? How much do you drive it?

What vehicle were you using before the RAM PHEV?

Any experience with AFVs?

Why did your agency opt into the demonstration? How, and by whom, was that decision made?

How and when did you get involved in the process?

Do you know why you were asked to drive the RAM?

What do you hope to gain or learn from the demonstration? Any goals?

What instructions, if any, were you given?

Will vehicle duty change over 3 yr. period?

What is your personal vehicle? When did you last purchase?

User Experience

Any problems so far? Pleasant surprises?

What instructions/ briefing/training were you given if any?

Tell us about the vehicle. First impressions. What do you like - not like?

Have your opinions/evaluation changed over time? How?

How does the vehicle perform respective of your needs?

Do you use the pickup bed? Sideboxes? Is there enough capacity (with and without the box)?

Would you consider purchasing or leasing this type of vehicle (a PHEV or all electric)?

What were your expectations before driving the vehicle?

Will the vehicle be kept overnight at a private residence at all?

Can you tell when the engine is on? How?

Inquiries/Curiosity from Others

Have you been asked questions about the PHEV? How did you answer them? Who asked?

How often do you get inquiries? What questions are asked? (how many ask if it is available for purchase?)

How do you answer them? How does it make you feel? Do you feel like an ambassador for the technology or company?
Have you ever tried something at work and purchase in your personal life?

Fueling/Charging Behavior

When and where do you plug-in?
Why do you choose to plug-in?
Is plugging in frequently preferred to going to a gasoline station more often?
Do you know what electricity costs are?
Where and how do you refuel? How is payment handled?
Have you noticed a difference in how often you refuel with gasoline/diesel?

HMI Usage

Do you look at the feedback display while driving?
If so, what information, specifically, do you look at?
What do the displays tell you?
Do you like the feedback displays or would you change the design or feedback information?
Do you modify your driving style because of the gauges?
Do you have fuel economy gauges in your personal vehicle? Do you use it?
Can you tell when the engine is off?
What is your fuel consumption? Does that matter to you?
How can you tell what the battery SOC is?

Personal beliefs about energy and the environment

Usually deduced from answers to other questions...

Belief in climate change
Seriousness of air pollution problem
Foreign oil concerns

Using the workplace as a gateway to the personal market
Have they been asked questions about the PHEV? How did they answer them? Who asked? How often do they get asked questions? What questions are asked? How do you answer them?
Have you ever tried something at work and purchase in your personal life?

Power Panel Usage

Do you know how to use the power panel?
Do you use a generator while performing your job? How about at home?
What do you usually use a generator for? How often do you use one?

Does anyone currently use a genset for auxiliary power?
Any foreseeable use for the onboard auxiliary power?
How do you value onboard power for work? For personal vehicle?
What did you use before it was available?
Did you use a portable generator? If so, trailer or pickup bed transport?

Fleet Manager Questions

Fleet Purchase Behavior

What are your duties with regard to the vehicle fleet operation?
Are you involved with day-to-day fleet operations? Vehicle purchase decisions?
Have you noticed any operating cost differences (fuel cost, maintenance requirements, etc.)?
What is the composition of your fleet? (i.e., type, age and number of passenger vehicles, medium & heavy-duty vehicles, equipment units, etc.)
What types of vehicles are typically purchased?
How are vehicle purchase decisions usually made?
What is the size of the fleet?
What is the replacement cycle?
What is your vehicle replacement policy?
Who makes vehicle selection decisions? What are the criteria?
Do they know vehicle costs? How much is the TCO?
What types of alternative fueled vehicles have they purchased in the past?
Why? Were incentives used?
How does the RAM / PHEVs compare if fuel type is different (ie: CNG vs. PHEV)
How are trucks in your fleet generally used? Yearly mileage? Regular use? 24 hour shifts?
What do you hope to gain or learn from the demonstration? Any goals?
What are motivations for adopting AFVs?
Do you want the public to know if you purchased an AFV? Should the car have a sticker?
Is public image important?
Would you consider purchasing or leasing this type of vehicle (a PHEV or all electric)?

Charging Infrastructure Installation

What was the infrastructure installation process like?
How much did it cost?

How long did it take?
How was the charging location determined?
What was the installation process (e.g., RFP, permits, contractor) and how long did it take?
What was the total installation cost? ?
Does anyone take the vehicle home? Who pays for electricity?
Will 220V charging be supplemented with 120V charging?
Can we see the charger location? (Coordinates noted)

Experience with AFVs

What have you learned so far?
For what reason or under what circumstances would you consider an PHEV?
Expected duty cycle for RAM PHEV?
Who will be using the RAM over the course of the demonstration?
Why was it assigned to them?
Will the assignment change?
Has downtime been problematic?
What do you want to learn from the demonstration?
Noticeable fuel cost savings?
Any department specific caveats affecting potential PHEV purchase?
Size limitations? Budget? What vehicle platform do you need?

Potential for PHEVs in Your Fleet

Would you feel comfortable investing in PHEVs?
Did the demonstration help? What else would you like to know?
How many of this type of vehicle could you use? Could realistically purchase?
How do you value the onboard power? Have you considered cost savings associated with foregone generators? Environmental benefits or credits, etc.?

Organizational Leadership Questions

Who is responsible for purchasing vehicles?
What policies are in place for influencing AFV purchase?
Is there a preference for AFV technology?
What role does public image play, if any?
Does the city have any goals regarding CO2 reductions, fuel savings, or air quality?

Do you have any other questions or comments for us?

6 APPENDIX B: Web Survey for Demonstration Participants