EVS30 Symposium
Stuttgart, Germany, October 9 - 11, 2017

Early-Adoption Experience and Upcoming Challenges from the San Francisco Bay Area

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Summary

The San Francisco Bay Area has taken many early actions to promote adoption of plug-in electric vehicles (PEVs). Now with a 1.5% adoption rate, the early actions strategies need to be revisited and adjusted to ensure that they are appropriate for the next category of adopters of PEVs. Compounding this challenge is the rapid advancement of PEV technology. To ensure its investments continue to be effective, the Bay Area Air Quality Management District has reviewed its strategies to compile "lessons learned." These lessons and experience are now being applied to solving the challenges of adopting electric trucks and buses.

Keywords: Case-study, Incentive, Education, Policy, Mass market

1. Introduction

The San Francisco Bay Area is one of the United States' largest metropolitan areas, home to approximately 7.7 million people [1] and 5.7 million cars and trucks. This large fleet of vehicles makes transportation a major source of air pollution in the region, and tailpipe emissions from these vehicles account for more than 40% of the criteria air pollutants [2] and about 40% of the green-house gases (GHGs) in the region [3].

Figure 1: Map of the nine-county San Francisco Bay Area region

Major reductions in vehicular emissions are both critical and necessary to meet the region's air quality and climate protection goals. The Bay Area Air Quality Management District (District), the regional agency responsible for regulating stationary sources of air pollution in the Bay Area, views accelerating the adoption Plug-in Electric Vehicles (PEVs) as a viable and promising method of reducing tailpipe emissions and GHGs and thus has invested significant resources in support of rapid PEV adoption. These efforts, in combination with other initiatives being undertaken by PEV stakeholders, have led to the highest per-capita adoption rate (10.78 registered PEVs per 1,000 people) in the United States, with more than 83,000 PEVs (nearly 40% of the PEVs registered in California) on the road [4]. While the region has succeeded in initial PEV adoption, additional effort will be required to support the region's path to critical mass, or 100% zero emissions transportation.

Understanding the path to critical mass is helpful in mapping out the appropriate effort that is required to achieving mass adoption. PEVs drivers will fall into one of five categories: innovators, comprising of up to 2.5% of all potential adopters; early adopters, comprising of 13.5%; early majority, comprising of 34%; late majority, comprising of 34%; and laggards, comprising of 16% [5]. For each of these categories, the motivation to adopt PEVs will be different and needs to be understood.

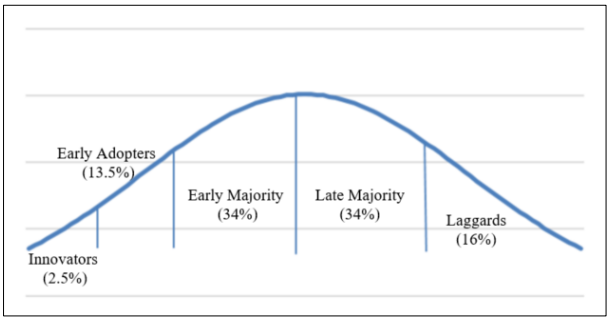

Figure 2: The five categories of PEV adopters [5]

Thus, as PEV uptake nears transition points, the strategies, policies, and incentives need to be reviewed and updated to ensure that they address the relevant barriers along the adoption curve. Past efforts to support PEV adoption have consisted of early technology demonstrations, planning efforts, and incentive programs designed to target the innovator category. Now, with 1.5% of the fleet comprising of PEVs, a robust regional public charging network, and the upcoming availability of new PEV models on the market, the District believes that the Bay Area's adopters of PEVs is in transition from innovators to early adopters, and that it is the opportune time to refocus its efforts to target these early adopters in order to facilitate the number of PEVs in the region, which is projected to grow past a quarter-million by 2025.

2. Early Demonstration and Planning Efforts

During the past twenty-five years, the District has awarded more than $500 million in grant funding to reduce emissions from motor vehicles (e.g., replace older, dirtier vehicles and equipment with cleaner alternatives, such as hybrid taxis, CNG buses, and higher tier off road equipment. The District also provided funding to demonstration and advanced technology projects, such as hydrogen transit buses, after-market conversion of hybrids to plug-in electric hybrids, and non-standard PEV charging stations (with pre-J1772 plugs). More recently, with the advancement of zero and near zero technologies, and with the introduction of standards and availability of OEM plug-in vehicles, District grant funding has been prioritized for projects that deploy full zero-emissions vehicles and equipment and supporting re-fueling infrastructure.

In 2010, the District's Board of Directors authorized an investment of $5 million dollars, which among other projects, was used to co-fund and participate in the United States Department of Energy (DoE) *The EV Project*, which resulted in ~1,400 Nissan LEAFs being adopted in the region by 2012. This early deployment of a "large" fleet of PEVs was instrumental in developing consumer confidence and visibility in these vehicles, and helping to seed the building of the charging station network in the region. With an increasing number of battery electric vehicles operating on Bay Area roads, site hosts were more willing to invest and install publicly available charging stations. Participants in *The EV Project* also provided valuable feedback on the behavior and motivations of innovators, and provided usage data that has helped the District and the region better prepare and plan for greater adoption of these vehicles.

To ensure that the region would be prepared for the influx of these new electric vehicles, the District, along with its partners in the Metropolitan Transportation Commission, and other interested stakeholders, developed the Bay Area *PEV Readiness Plan*. This region-wide plan, informed by surveys of potential and current owners of PEVs, such as the participants of *The EV Project*, identified barriers to adoption and strategies that the local governments in the region could take to mitigate these barriers. Additionally, the plan set a goal of 110,000 PEVs on Bay Area roads by 2020 and 247,000 by 2025.

Since adopting the *PEV Readiness Plan* in 2013, the District and local government agencies have been working to implement the strategies and actions identified in it, including convening quarterly meetings of an "*EV Council*" consisting of various public and private stakeholders to discuss challenges and solutions of adopting PEVs in the region, expanding the region's public network of charging stations, and proposing and adopting local ordinances and policies that support PEVs. In 2017, the District incorporated many aspects of the *PEV Readiness Plan* into its 2017 *Clean Air Plan*, and expanded the interim adoption goal of PEVs from 247,000 by 2025 to 90% of the entire Bay Area fleet by 2050.

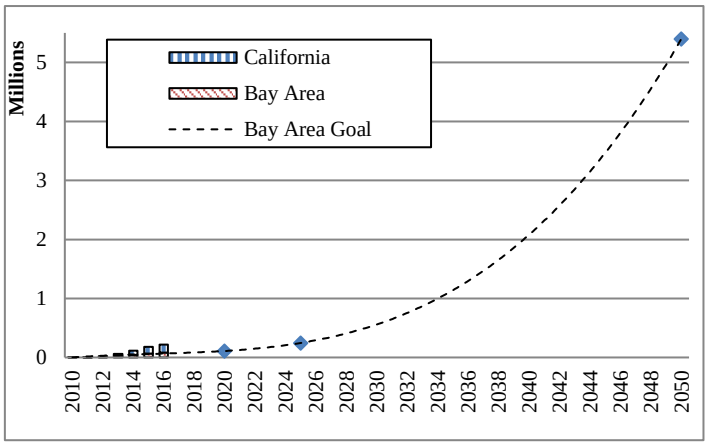

Figure 3: Bay Area PEV Adoption and Goals: 110,000 by 2020, 247,000 by 2025, and 90% of the fleet by 2050

3. Results

Over the past few years, the District along with its partners and other PEV stakeholders, have been working to implement the strategies identified in the *PEV Readiness Plan*. In terms of monetary incentives, the District has awarded more than $60 million to electrify mobile sources, both light and heavy duty, and on- and off-road. The table below shows the direct results of this investment.

Table 1: Direct results of the District's investments from 2011 to 2016

Vehicles	**Infrastructure**	**Shore Power**	**Off-road Equipment**	**Rail (Caltrain)**
$17 M		$20M	$3M	$20M
1,561 Cars **172** Heavy Duty Trucks & Buses **99** Shared Autonomous Electric Vehicles	**1,041** Level 2 & **53** DC Fast Over **1,400** Residential Chargers	**14** Berths at the Port of Oakland	**81** Ground Support Equipment at SFO **121** Lawn & Garden Engines	Electrify engines and **51+** miles of track **75%** Electric by 2020, **100%** by 2040

Beyond incentives and outreach, the *PEV Readiness Plan* also calls for the formation of a forum for local governments, businesses, and other parties interested in electric vehicles to coordinate efforts, align policies, and share results and lessons learned. The District continues to convene this forum, the *EV Council*, which meets 3-4 times per year and engages on topics such as new plug-in vehicles being offered by OEMs, ordinances adopted by local agencies to require installation of charging infrastructure at workplaces and Multi-family Dwelling Units (MDU), and grant opportunities. By bringing the various government, private, and other stakeholders together, the forum provides a platform to share ideas, and facilitates innovation to solve barriers to electric vehicle adoption.

The District has also been working with local cities and counties to help them develop and implement their local climate action plans, which include measures for achieving greenhouse gas reductions. Many of these plans include measures to accelerate the adoption of PEVs, such as requiring electric vehicles in a municipality's own fleets, and identifying ordinances that can be adopted to require charging infrastructure be installed in all new construction projects.

These early efforts and investments have all contributed to the region's high rate of adoption of PEVs. As of December 2016, there more than 83,000 PEVs on Bay Area roads, representing 1.5% of the region's light duty fleet. From a global perspective, the Bay Area accounts for approximately 5% of the PEV market, and as a region, represents the eighth largest adopter in the world, behind France [6].

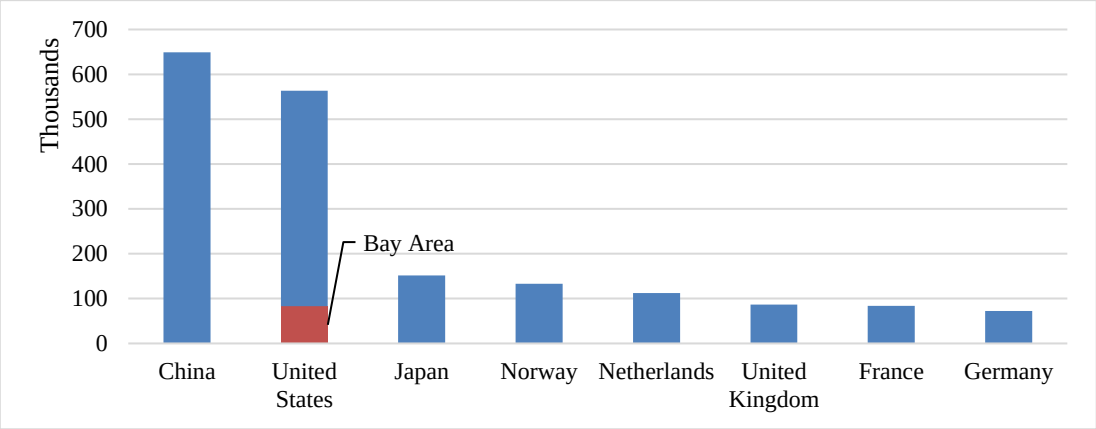

Figure 4: Global Electric Vehicle Stock, 2016

With PEVs comprising 1.5% of the Bay Area's fleet, the region has already made significant progress in reducing the region's petroleum usage, and therefore, GHG emissions. In 2016 alone, the light duty PEV stock displaced approximately 41 million gallons of petroleum usage, reducing tailpipe GHG emissions by approximately 340,000 metric tons [7]. Through continued investments and efforts, the District is confident that the region will achieve the 2020 and 2025 adoption goals set forth in the *PEV Readiness Plan*, which would reduce tailpipe GHG emissions by approximately 450,000 metric tons and 840,000 metric tons respectively. Achievement of the 2050 goal is key to reaching the State and District's long-term GHG reduction goal of 20% of 1990 levels.

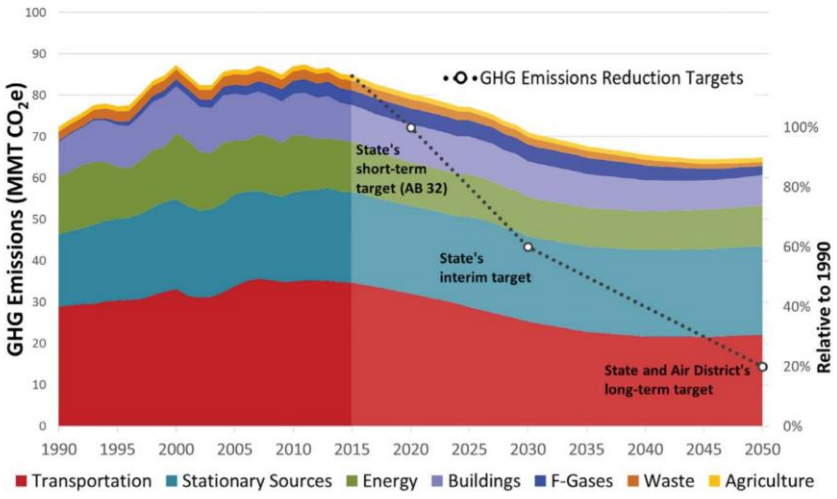

Figure 5: Projected Bay Area GHG Emissions by Sector

4. Lessons Learned from Early-Adoption Experience

4.1 Importance of Sustained Incentives

The importance of incentives that promote the purchase and use of PEVs cannot be overstated to driving adoption for the foreseeable future, as PEVs are not anticipated to reach cost-parity on a total cost of ownership basis until the mid-2020's [8]. During this "high incremental cost" phase, monetary incentives that can bring the higher up-front incremental cost to own a PEV closer to parity with the cost of acquiring a conventional vehicle and to encourage investments in public charging are needed to jump start the market and help seed the initial buildout of a charging network, which directly and indirectly in turn address many of the barriers to adoption. This positive feedback-loop is shown in the chart below (Figure 6) which shows the adoption rate of individual states on a PEV per capita basis that correlates closely with the number of PEV favorable incentives (both monetary and non-monetary) available in that State [9].

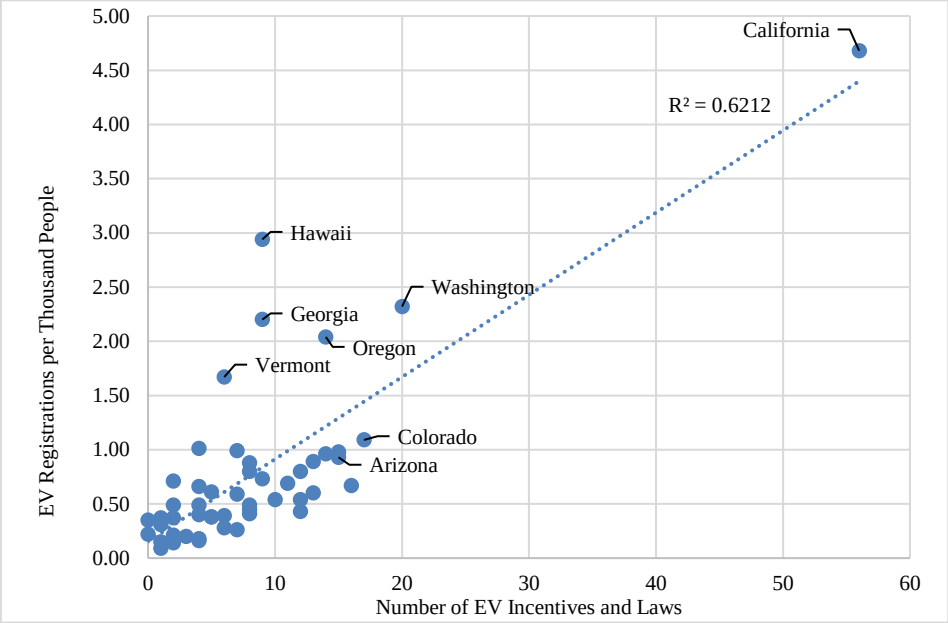

Figure 6: Effect of Incentives on PEV Registrations per Thousand People [8]

However, to be truly effective, these incentives must be sustained at least until the community achieves full adoption by Early Adopters. Removing incentives before this point (before these vehicles have reached cost parity) can adversely affect adoption rates. In the case of the State of Georgia, its removal of a $5,000 state tax incentive resulted in a significant decrease in new PEV sales and registrations. Outside of the United States, a similar situation unfolded in Denmark, where the elimination of a tax incentive also had adverse effects on PEV sales [10].

4.2 Promoting Workplace Charging

An example of a non-monetary incentives, such as increasing the availability of charging at workplaces, has also been instrumental in increasing the adoption of PEVs. The District's survey of innovators from 2011 – 2013 found that these pre-early adopters of PEVs predominantly followed a charge-at-home use case, where the majority of the charging occurs at the driver's home during the evening and night hours. This approach was both necessary and appropriate due to the lack of public charging infrastructure (and thus, the inability to charge away from home). However, as the public charging network has grown over the past five years, charging away from home has become a viable alternative. This removes a barrier to adoption for early adopters and those that will follow, who are unable to install a vehicle charging solution at their residences and those who may feel "range anxiety".

Charging at employment sites is key to supporting early adoption, since, aside from the home, vehicles are generally parked at places of employment the longest, and thus it makes sense to use that long dwell time to charge. A case study of 20 workplaces of various sizes throughout the Bay Area found that once charging stations are installed, employees are much more likely to consider switching to a PEV, and many have cited the availability of charging at work as an important factor in their decision [11].

In addition to providing access to drivers who otherwise don't have access to home charging, expanding access to workplace charging also helps alleviate a recent power utility challenge. Over the past decade, the cost to manufacture and install solar power dropped, leading California to augment power generation with significant quantities of both photovoltaic and thermal solar power. Thus, since 2012, the hourly amount of electricity generated from solar has increased from approximately 200 MW to nearly 10,000 MW [12].

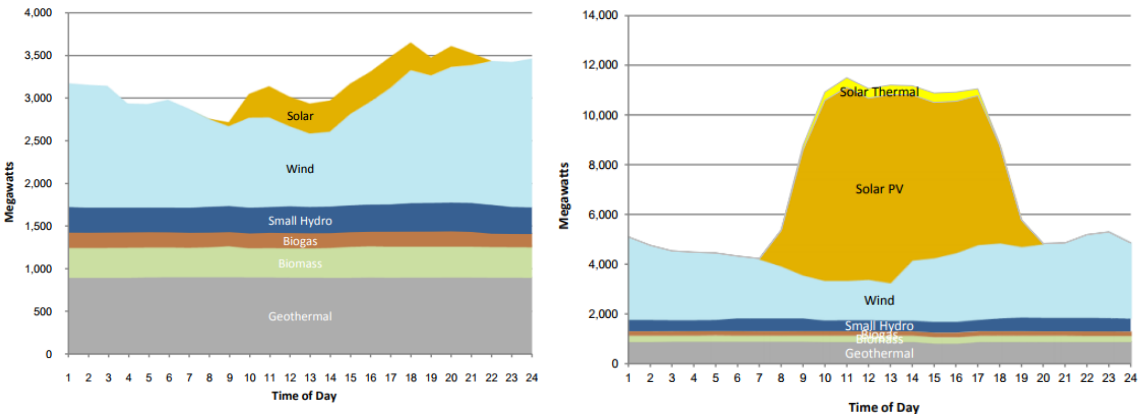

Figure 7: Power generation from renewable sources for a typical spring day in 2012 (left) and 2017 (right) [12].

This added capacity could cause oversupply, when all anticipated power generation, including renewables, exceeds the real-time demand. If oversupply cannot be managed by the market, it can lead to over-generation, which requires manual intervention to maintain grid reliability. Shifting cars and trucks to electricity is a win-win strategy to combat this risk [13]. With California's adoption goal of 1.5 million PEVs by 2025, charging these vehicles during the daytime could provide a 9,000 MW load to combat the threat of over-generation.

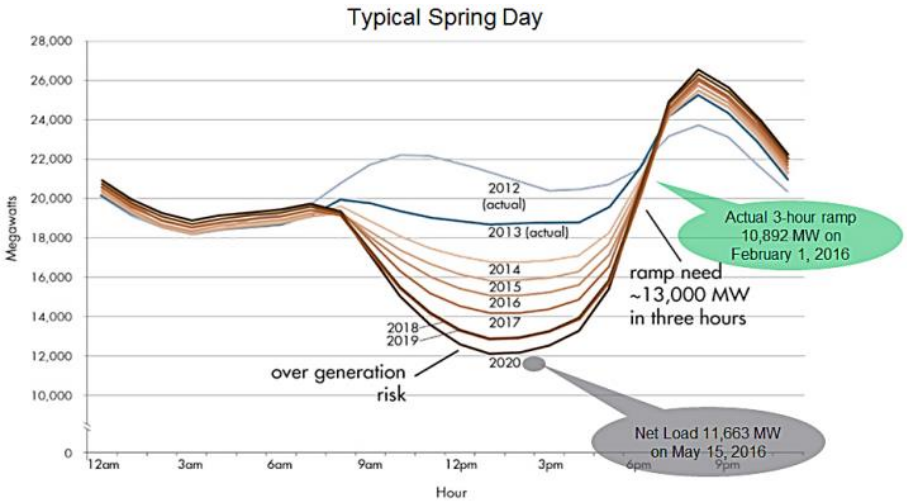

Figure 8: The duck curve for a typical spring day showing steep ramping needs and over-generation risk [13].

4.3 Promotions and Visibility

Surveys of new PEV adopters in the innovator category ranked word-of-mouth sources (e.g., friends, family, and colleagues, online discussion forums) as among the most important along with the manufacturer's website for how they obtained information about PEVs to help them in their purchasing decision. Sources that ranked least important include paid advertisements, government agencies, and new car salespersons [14].

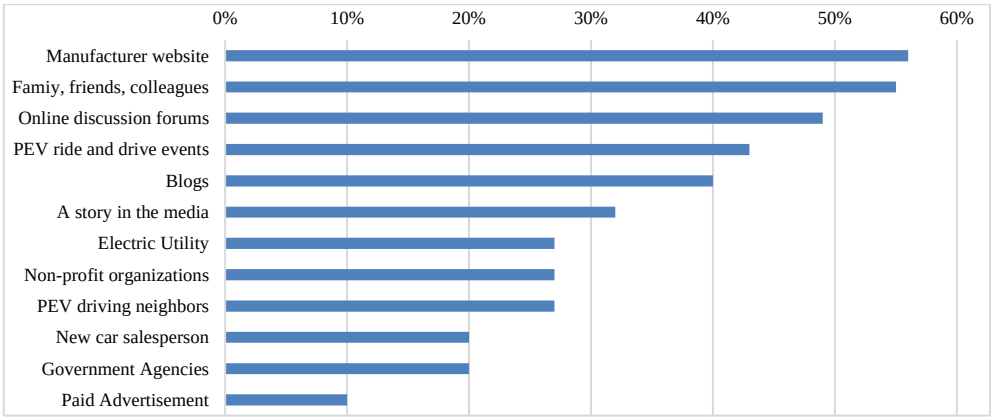

Figure 9: Survey results, percent of respondents that ranked informational source as extremely or very important

Surveys of these PEV consumers found that 43% consider ride-and-drive events an extremely or very important information source [14]. Informed by these results, the District's sister agency, the MTC, conducted an 18 month PEV promotional outreach campaign. This outreach campaign, *Experience Electric*, consisted of marketing through traditional, digital, and social media, as well as various "ride-and-drive" events that provided over 5,000 test drives of battery electric and plug-in hybrid vehicles. The campaign was envisioned to provide an opportunity for the public to experience the benefits of, and change perceptions of, PEVs. Between April 2014 and May 2016, 27 ride-and-drive events were held throughout the region, targeting the innovator group, such as tech-savvy homeowners and urban car-sharers. In addition to the test drives, *Experience Electric* also invited local PEV owners to volunteer to display their PEV at campaign events. These "EV Ambassadors" were more than glad to share their personal story about life as a PEV driver and owner, providing a peer-to-peer education component to the campaign. To track the results of the events and marketing activities, pre- and post-test drive surveys of participants of these events were conducted, which showed that test drives were a very effective tool in changing negative consumer perceptions of electric vehicles. Post-test drive surveys also showed that many of people who participated in the test drive were somewhat or much more likely to purchase an electric vehicle [15].

Similarly, the results of *The EV Project's* deployment of Nissan LEAFs on Bay Area roads demonstrated the importance of "visibility" projects in sparking interest and changing perception of these vehicles. Since then, local incentives for PEVs have focused on providing funding to expand the region's publicly available charging network, and to deploy vehicles in "visibility" situations, such as city and county fleets, taxi fleets, and in car-sharing fleets. In addition to directly deploying PEVs, these visibility projects have the co-benefit of providing an opportunity for wider audience to test and experience PEVs, who may have not otherwise considered or known about these vehicles.

4.4 Accounting for Changing Priorities and New Barriers to Adoption

As the market transitions from innovators to early adopters and to mass adopters, planning efforts and incentive programs must also be revisited at the transitions to ensure that they continue to be relevant and are effective at addressing the changing barriers to adoption for each group.

Steps will also need to be taken to ensure both monetary and non-monetary incentives are sustainable. In the Bay Area, two of the primary non-monetary incentives for PEV drivers are access to High Occupancy Vehicle (HOV) lanes, and free charging and/or parking. With an uptake of 1.5% of the fleet, both of these non-

monetary incentives are becoming unsustainable: HOV lanes along Bay Area are becoming as congested as the non-priority lanes of travel, due in part of the high number of PEVs now using those lanes. Free charging is becoming a major cost burden for site owners, and many have decided to end this "perk." And, access to charging, while significantly expanded, is insufficient to meet the current, let alone future, demand.

As the consumers of PEVs move from the innovators to early adopters and beyond, the priorities and barriers can change. Understanding the changing motivations and priorities of these groups will be necessary to keep incentives responsive to their audience's needs. In general, the majority and latter adopters tend to be more cost-conscious, and surveys of the innovator group has already shown a shifting of priorities to cost savings and other non-monetary benefits [14].

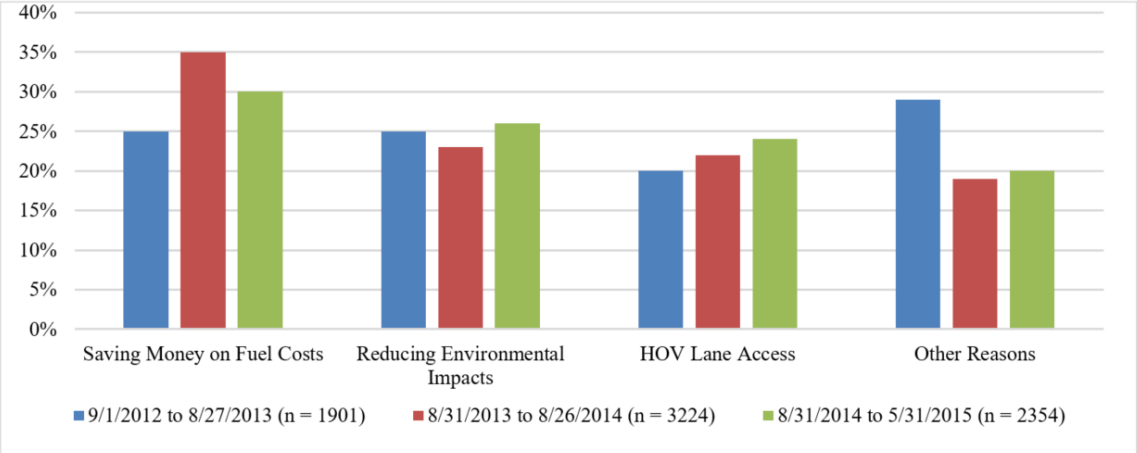

Figure 10: Survey results reporting the most important reasons for purchasing a PEV, separated by response date

5. Future Efforts

Adoption of zero-emission vehicles across the entire transportation sector will be one of the key aspects to achieving the State's GHG emission reduction targets of 1990 levels by 2020 and 80% below 1990 levels by 2050. Going forward, the District is working to refine its efforts to move past early adoption and expedite adoption of zero-emission technologies into other mobile source equipment categories.

Specifically, the District has allocated $27 million in incentive funding through 2018 to shift multiple mobile source sectors to zero emission. Drawing from the lessons learned, the District is designing its incentive programs to be sustained for multiple years and to fund projects that will increase the visibility of PEVs in the region. In addition, the District is working to secure funding for early, large-scale demonstration projects of electric heavy-duty trucks and buses. Based on the Bay Area's experience with *The EV Project*, the District believes that these large demonstration projects will be key factor to build user acceptance and confidence in this new technology.

Recognizing that the use-case for PEVs are shifting with the upcoming introduction of multiple long range (200+ miles) battery electric vehicles, the District is re-doubling its efforts to expand the public charging network. Future efforts will include a focus on installing new Ultra-fast (150+ kW) Direct Current Fast Chargers in "plazas" along major highway corridors, which will operate in a similar fashion to gasoline refueling stations. The District envisions that such plazas will be necessary to support the longer trip use-cases for these 200+ mile range PEVs, and to build user acceptance of these new vehicles among the mass-adopters, who have a higher expectation that PEV operate and refuel in a similar fashion to comparable gasoline vehicles.

The combination of these new ultra-fast charging plazas along with a continued focus on increasing the availability of workplace charging will be a key component in helping address a major barrier to PEV adoption for residents of multi-family dwelling units, such as apartment complexes and condos. While 30%

of the Bay Area population resides within these complexes, PEV uptake among this group has lagged behind due to both the lack of dedicated parking and the challenge of installing charging infrastructure in a shared parking structure. The presence of ultra-fast charging plazas and workplace charging presents a viable alternative to home charging, helping to ease the uncertainty of where to charge for those that do not have access to home charging.

As the region transitions through the various adoption phases for passenger PEVs and the early-adoption of heavy-duty electric trucks and buses, it will face a new set of unique challenges, such as ensuring the regional charging network and electrical grid is robust enough to handle and balance the exponentially increasing demand, building consumer acceptance and confidence in electrifying the heavy-duty sector, safely integrating autonomous technology in PEVs and shifting charging behaviors to align with renewable power generation. The experience and lessons learned from the early-adoption of passenger PEVs will be invaluable in developing solutions to these new challenges.

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Mr. Mak holds a Bachelor of Science in Chemical Engineering from the University of California, Davis.