UCDAVIS

PLUG-IN HYBRID & ELECTRIC VEHICLE RESEARCH CENTER

of the Institute of Transportation Studies

Reoccurring and Indirect Incentives for Plug-in Electric Vehicles – A Review of the Evidence

September 2017

Scott Hardman

Plug-in Hybrid & Electric Vehicle Research Center

Institute of Transportation Studies ◦ University of California, Davis

1605 Tilia Street ◦ Davis, California 95616

PHONE (530) 752-6548 ◦ FAX (530) 752-6572

www.its.ucdavis.edu

Reoccurring and Indirect Incentives for Plug-in Electric Vehicles – A Review of the Evidence

Scott Hardman[*1]

[*]shardman@ucdavis.edu

[1]Plug-in Hybrid and Electric Vehicle Research Center, Institute of Transportation Studies, University of California, Davis

Abstract
More than 2 million plug-in electric vehicles (PEVs) have now been sold to consumers globally. The adoption of these vehicles is being promoted by policy makers due to them having high efficiencies and zero tailpipe emissions. This means they can contribute towards reducing harmful emissions and resource depletion. To encourage consumers to purchase the vehicles policy makers are utilising interventions that increase the convenience and lower the cost of owning a PEV. Governments are investing in PEV recharging infrastructure, allowing PEVs to use HOV, bus or transit lanes, providing parking incentives, giving PEVs toll fee waivers, allowing PEVs to pay lower annual road taxes, and are using disincentives such progressive vehicle fuel taxes. The aim of these interventions is to encourage more consumers to purchase PEVs. There are now numerous studies in the literature that investigate the impact of these incentives on PEV adoption. No study has reviewed these studies with the aim of reaching a conclusive understanding regarding the effectiveness of the incentives. This literature review therefore conducts a systematic review of the literature. The result of this is an understanding of which policy measures are and are not effective in promoting PEV adoption. These conclusions allow policy recommendations to be made which can help policy makers understand which incentives should be used and how.

1. Introduction

The introduction of plug-in electric vehicles (PEVs) which includes full battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) is important to help solve the issues of urban air pollution, global climate change, and fossil fuel resource depletion. Their successful market introduction may be dependent on governments providing incentives to consumers. These incentives are needed to convince consumers to purchase the vehicles rather than continuing to purchase internal combustion engine vehicles (ICEVs). Governments have introduced financial purchase incentives and reoccurring incentives in the hope that the market uptake of PEVs will increase. Financial purchase incentives include economic mechanisms such as rebates, income tax credits, purchase tax exemptions, and grants. The effectiveness of these on increasing PEV market uptake was explored in (Hardman et al., 2017). That previous review found that financial purchase incentives have led to increased adoption of PEVs. The review did not consider any other incentives although the authors did conclude that financial purchase incentives alone may not be sufficient to promote PEV sales and therefore they need to be paired with other incentives. That review did not outline what these other incentives could be nor did it explore the efficacy of any of these incentives. There is no study currently published within the literature that explores this subject. A 2016 review attempted to understand influential factors in the purchase of an electric vehicle (Liao et al., 2016). That review aimed to understand all different factors including purchase incentives. The authors investigated high occupancy vehicle (HOV) lane access, free parking and toll exemptions but were unable to state whether any of these incentives were effective. This current review adds to the literature by assimilating the results of all previous studies so that an in-depth understanding of how effective these incentives are in promoting PEV sales can gained. This results in a clear understanding of which reoccurring incentives are effective in increasing PEV sales and how these incentives should be used to have the most significant impact.

1.1. Introduction to Indirect Incentives

This paper considers the impact of several reoccurring incentives for PEVs. Included in this review are studies that consider the impact of PEV access to HOV, bus and transit lanes, the development of recharging infrastructure, parking incentives, toll fee waivers, annual road tax exemptions, and gasoline prices. The availability of these incentives differs between nations and even within nations. Table 1 shows a breakdown of which nations have these incentives currently in operation. The table shows whether the incentives are available across the entire nation or if they are available only in some regions. Each of these incentive types are described below.

	HOV, bus or transit lanes	State funded infrastructure	Parking Incentives	Toll or road charge exemptions	Annual road tax incentives	Progressive fuel tax
Canada	○	○				
China	○	●	○	○		
France	○	●			●	●
Germany	○	●	○	○	●	●
Japan		●	○	○		●
Netherlands	○	●	○		●	●
Norway	●	●	●	●	●	●
Portugal	○	●	○		●	●
Sweden		●			●	●
United Kingdom	○	●	○	○	●	●
United States	○	●	○	○		○
	●: Available nationwide ○: Available in some regions only					

Table 1: Breakdown of incentives available in the top markets for PEVs.

1.1.1. HOV, Bus or Transit Lane access

HOV lanes, bus lanes, and fast transit lanes are all lanes with restricted access. HOV lanes are only accessible to vehicles with 2 or more occupants. The rules restricting their access are sometimes only in operation during peak travel times. For example, in Northern California HOV lanes operate Monday-Friday 6am-10am and 3pm-7pm. Some HOV lanes are in operation 24 hours per day 7 days per week, such as the HOV lanes in Southern California (Caltrans, 2017). HOV lanes are sometimes called carpool lanes or 2+ lanes. Bus lanes are lanes that are usually only accessible to buses or coaches. In some cases taxis, motorcycles, or cyclists can access the lanes. Some nations have 'priority lanes' or 'fast transit lanes' these lanes are often restricted or require payment to use. HOV, bus, and transit lanes are common in many countries. Very few countries have introduced incentives that allow PEVs to use the lanes. Currently Canada, China, France, Germany, Netherlands, Norway, Portugal, the United Kingdom, and United States have these programs in operation for PEVs. Only in Norway is this incentive available nationwide with the other nations having this incentive available only in certain locations.

1.1.2. PEV Charging Infrastructure Availability

Electric vehicles are partially reliant on the development of recharging infrastructure so that they can travel distances beyond their range. In the early introduction of PEVs private companies may not be motivated to develop this infrastructure. This is due to low returns on investments which is associated with the low number of PEVs that would use the infrastructure. Many national and regional governments are developing public electric vehicle infrastructure to encourage PEV market growth, they are also funding the development of private and workplace charging infrastructure. Private companies have also funded the installation their own infrastructure and developed their own charging networks. In regions with more mature PEV markets private companies are operating networks of chargers which consumer pay to use. Some automotive OEMs have developed their own infrastructure networks for buyers of their BEVs to use. Some companies have also installed PEV charging at their office locations for employees to use. Most studies in the literature that investigate the importance of recharging infrastructure do not distinguish between private, public, OEM owned, and workplace charging. This means this review considers the importance of all types of infrastructure not just publically funded infrastructure. State funded infrastructure development is underway in Canada, China,

France, Germany, Japan, Netherlands, Norway, Portugal, United Kingdom, and United States.

1.1.3. Parking Incentives

Several nations have introduced incentives that enable PEVs to park at a reduced cost or for free. These incentives are most commonly applied in urban areas where parking is something that consumers already pay for. Free parking for BEVs has been widely introduced in Norway for public parking spaces. In most nations though this incentive differs on a regional basis. In the USA, some cities have introduced these incentives. In Sacramento California PEVs can park for free or receive a 50% discount in municipal garages. Parking incentives have been introduced in many cities in the US including Las Vegas, New York, Boston, Denver, and Salt Lake City amongst others. They are not available throughout the nation though. In London PEVs can park for free in several boroughs, this type of incentive does not exist across the United Kingdom, though there are plans to introduce this incentive in 5 more cities (Department for Environment and Rural Affairs and Department for Transport, 2016). In some regions in Germany PEVs can park for free once they have obtained a permit. Parking incentives are being used in China, Germany, Japan, Netherlands, Norway, Portugal, United Kingdom, and United States. This incentive is only being applied nationwide in Norway. Often free parking for PEVs is paired with PEV recharging so that consumers can charge their vehicle whilst parked.

1.1.4. Toll or Road Charge Exemptions

Toll charges are common in many nations. Toll charges are applied on roads or bridges that can be either publicly or privately owned. Drivers are required to pay a fee to access them. The money is intended to help fund the construction and maintenance of the road infrastructure. In some nations PEVs can access toll roads without paying a fee. In Norway PEVs do not pay toll fees on roads, bridges, and tunnels. They pay reduced tolls on ferries. In California drivers of PEVs can access high-occupancy toll lanes or express toll lanes for free. Congestion charge zones are like toll roads as drivers are required to pay a fee to drive in these areas. These are less common than toll roads though. Congestion charge zones mean that drivers must pay a fee when they drive anywhere within a certain area. In the United Kingdom, the central area of London is a congestion charge zone Monday-Friday 7am-6pm. During these times drivers, must pay a fee of £11.50 per day. Vehicles that have CO2 emissions lower than 75g/km do not pay the congestion charge fee. This means that all BEVs, most PHEVs and some HEVs do not pay the congestion charge. Similarly, in Milan older ICEVs pay a fee to access a central area of the city. New ICEVs, HEVs, and PEVs can access the zone for free. Both toll and congestion charge exemptions reduce the cost of driving to certain locations for drivers of vehicles that do not have to pay the fees. Studies in the literature that investigate these topics make distinctions between whether they investigate a toll exemption or a congestion charge exemption. Toll and road charge exemptions are being used in China, Germany, Japan, Norway, Sweden, United Kingdom, and United States.

1.1.5. Annual Road Tax Incentives

In some nations vehicles are required to pay an annual road tax. This tax occurs every year the vehicle is registered to be driven on the road. Most tax regimes calculate the amount of tax based on a vehicles CO_2 emissions, vehicle class, and/or vehicle weight. In the United Kingdom] vehicles pay anywhere between £10-2,000 (Depending on CO2 emissions) for

their first year of registration and £140 each year after that (As of April 2017). In the United Kingdom BEVs are exempt from the first-year tax and any subsequent road taxes. In Norway vehicles pay an annual vehicle tax that is based on vehicle fuel type and weight. Petrol and diesel vehicles weighing less than 7500 kg pay between NOK2,820 (US$336) and NOK3,290 (US$393). BEVs pay a reduced rate of NOK455 (US$55) per year. Annual road tax incentives for PEVs are being used in France, Germany, Netherlands, Norway, Portugal, Sweden, and United Kingdom.

1.1.6. Other

Some governments, have utilised financial mechanisms to increase the price of gasoline. These mechanisms are usually referred to as fuel tax, fuel duty, or gas tax. Fuel taxes were introduced as a way of combating air pollution and climate change by encouraging consumers to purchase more fuel-efficient vehicles. Though this isn't technically an incentive for consumers to purchase a PEV it does disincentivise consumers from purchasing an ICEV in the hope they purchase more fuel-efficient vehicles. Therefore, it can be used as an intervention to encourage consumers to purchase PEVs. In many European nations fuel duty makes up a significant proportion of the price of vehicle fuel. In the Netherlands fuel duty and tax is 70% of the price of 1 litre of fuel. In the United Kingdom, it is around 65% the cost of 1 litre of fuel. In the United States, it is around 10-15% of the cost of a gallon of fuel. Studies in the literature do not only analyse the effectiveness of these fuel taxes. They analyse the impact of fuel prices on PEV sales. Therefore, the literature considers the impact of fuel price in general, not explicitly the impact of incentives. These studies therefore consider will therefore be impacted by increased in the cost of oil not just tax increases. These studies can still be used to inform policy makers as the data will show how trends in fuel price are related to PEV sales. For example, if high fuel prices are associated with PEV sales policy makers could use this information to future increase the cost of fuel by introducing high taxes with the goal of encouraging consumers to purchase PEVs.

Other incentives also include ones associated with obtaining a vehicle licence plate in China. In Shanghai consumers wanting to obtain a vehicle license plate, which is required to buy a vehicle, must bid for a licence in an auction. Typically, only 5% of consumers are successful in obtaining a licence at auctions. In Beijing consumers, must enter a lottery to obtain a license plant. Using this method only 0.15% of consumers are successful. Policy makers have made it easier for buyer of PEVs to obtain license plants in these regions. In Beijing buyers of BEVs receive a plate for free without needing to try and bid in an auction, therefore it is more convenient and requires no financial expenditure. In Shanghai consumers wanting to purchase a BEV or a PHEV receive a free licence plate without having the enter the lottery (Wang et al., 2017).

2. Literature Review

The existing literature analyses HOV lane access, but lane access, fast transit lane access, workplace PEV charging infrastructure, public PEV charging infrastructure, free parking, discounted parking, preferential parking, and toll and congestion charges. A number studies include analysis on the impact of gasoline prices on PEV markets. Table 2 shows a breakdown of the studies used in this review. The table shows the methods used in each study, which vehicles they consider, the region of analysis, and the incentives considered. 25 studies investigate the HOV, bus or rapid transit lanes, 19 study PEV infrastructure development, 15 parking incentives, 10 toll or road charge exemptions, 5 investigate annual

road tax reductions, 4 include gasoline cost in their analysis, and there are 2 studies that consider other incentives.

				Incentives Considered						
Authors	**Methods**	**Vehicle Type**	**Region**	**HOV, Bus or Rapid Transit Lane**	**State Funded Infrastructure**	**Parking Incentives**	**Toll or Road Charge Exemptions**	**Annual Road Tax incentives**	**Other**	**Conclusions**
Aasness, M. A., & Odeck, J. (2015)	Case Study	PEVs	Norway	✓		✓	✓			Toll exemptions, bus lane access and free parking have had a positive impact on PEV adoption. However revenue from toll and parking fees has dropped and bus lanes are more congestion
Adepetu, A., Keshav, S., & Arya, V. (2016)	Agent based model	PEVs	California		✓				✓	The presence of work based charging does lead to slightly increased rates of PEV adoption
Ajanovic, A., & Haas, R. (2016)	Statistical Analysis	PEVs	USA, Europe and China	✓	✓	✓				Free parking, bus lane access, availability of charging and zero emission zones are the most important factors in promoting PEVs
Bakker, S., & Jacob Trip, J. (2013)	Workshops with policy makers	BEVs	Europe	✓	✓	✓				Infrastructure development is the most important, free parking can be used as a temporary measure, bus lane access can also be used to increase BEV sales
Bjerkan, K. Y., Nørbech, T. E., & Nordtømme, M. E. (2016)	Questionnaire Survey	BEV	Norway	✓		✓	✓			Toll fee waivers followed by free parking and bus lane access are the most important factors in promoting PEVs
Bonges, H. A., & Lusk, A. C. (2016)	Case Studies	BEVs	USA		✓					Improving access to infrastructure will increase PEV rates of adoption
Clinton, B., Brown, A., Davidson, C., & Steinberg, D. (2015)	Statistical Analysis	BEVs	USA	✓						Results inconclusive due to limited variation in variables over the time of the study
Diamond, D. (2009)	Statistical Analysis	HEVs	USA	✓					✓	HOV lane access is the most significant in the state of Virginia. It is less significant in other states. HEV adoption is most related to income, gas price and vehicle miles travelled
Egbue, O., & Long, S. (2012)	Questionnaire Survey	BEVs	USA		✓					Developing infrastructure will reduce barriers to adoption. Education through social media and standard media channels will also help.
Figenbaum, E. (2016)	Multi-Layer Perspective	BEVs	Norway	✓			✓			Bus lane access and toll exemptions have been important in attracting buyers to BEVs
Figenbaum, E., & Kolbenstvedt, M. (2016)	Questionnaire Survey	PEVs	Norway	✓	✓	✓	✓	✓		Toll exemptions are the most important factor for adopters of PEVs, free parking is second, workplace charging is third. Bus lane access is the least important for adopters
Hackbarth, A., & Madlener, R. (2013)	Discrete Choice Analysis	AFVs	Germany	✓		✓		✓		Consumers are willing to pay an extra €1620-3280 for vehicles with free parking and bus lane access

Hardman, S., & Tal, G. (2016)	Interviews	BEVs	California	✓	✓	✓				High-end BEV buyers purchase for technological, environmental and performance motivations. HOV lane access, workplace charging and free parking are not motivational factors but they do increase likelihood of repeat purchases
Hoen, A., & Koetse, M. J. (2014)	Questionnaire Survey (Stated Choice Experiment)	FCVs and PEVs	Netherlands	✓		✓		✓		Free parking and bus lane access may stimulate AFV adoption. The findings are not statistically significant though. Bus lane access may be more important.
Javid, R. J., & Nejat, A. (2017)	Statistical Analysis	PEVs	California		✓				✓	Developing charging infrastructure and raising gas prices can help promote PEV sales
Krause, R. M., Carley, S. R., Lane, B. W., & Graham, J. D. (2013)	Questionnaire Survey	PEVs	USA	✓		✓				Awareness of incentives is too low for them to have an impact on consumer interest in PEVs
Kurani, K., Caperello, N., Tyreehageman, J., & Davies, J. (2014)	Workshops	PEVs	California	✓	✓	✓				Adopters value HOV lane access when they are located near to them. Free parking is valued if it is available. Free work and public charging is also valued by PEV owners.
Liao, F., Molin, E., & van Wee, B. (2016)	Literature Review	BEVs		✓		✓				No consensus within the literature on whether free parking or free charging is effective.
Lieven, T. (2015)	Questionnaire Survey (Stated Choice Experiment)	BEVs	Global	✓	✓	✓		✓		Some consumers value only financial incentives, some only charging infrastructure and some value all incentives that are available
Lutsey, N., Slowik, P., & Jin, L. (2016)	Statistical Analysis	PEVs	USA	✓	✓	✓				There is a statistically significant relationships between PEV market share and; vehicle model availability, consumer financial incentives, public charging infrastructure, workplace charging infrastructure, HOV lanes and the number of policies being used the region.
Mersky, A. C., Sprei, F., Samaras, C., & Qian, Z. (Sean). (2016)	Statistical Analysis	BEVs	Norway	✓	✓		✓			BEV infrastructure, being near to major cities and income are the most significant predictors of BEV market share.
Nicholas, M. a, & Tal, G. (2013)	Questionnaire Survey	BEVs	California		✓					Workplace charging can increase PEV sales. It can have negative effects if chargers become congested.
Nicholas, M. A., Tal, G., & Turrentine, T. S. (2016)	Questionnaire Survey & Vehicle Data Monitoring	PEVs	California		✓					Workplace charging can greatly increase eVMT for PHEVs.
Ozaki, R., & Sevastyanova, K. (2011)	Questionnaire Survey	HEVs	UK			✓	✓	✓		Free or priority parking and exemption from London Congestion Charge are effective incentives.
Percoco, M. (2014)	Statistical Analysis	AFVs	Italy				✓			Congestion charge increases the number of NGVs, HEVs and bi-fuel vehicles and reduces pre-euro 4 ICEV use

Plötz, P., Gnann, T., & Sprei, F. (2016)	Statistical Analysis	PEVs	USA and Europe		✓				✓	PEV adoption is correlated to income, gasoline price, the presence of in-direct incentives and the number of charging stations
Sangkapichai, M., & Saphores, J.-D. (2009)	Questionnaire Survey (Stated Choice Experiment)	HEVs	California	✓						Consumers are attracted to HEVs due to their beliefs related to energy, air pollution and health but also the ability to drive in HOV lanes
Shewmake, S., & Jarvis, L. (2014)	Statistical Analysis	HEVs	California	✓						HOV Lane access is highly valued. Used HEVs with HOV stickers are more valuable.
Tal, G., & Nicholas, M. A. (2014)	Questionnaire Survey	PEVs	California	✓						HOV lanes are valued by consumers who live in regions with HOV lanes and with higher levels of congestion.
Tal, Gil, Michael A. Nicholas, Thomas S. Turrentine (2016	Questionnaire Survey	PEVs	California	✓						PEVs with HOV lane stickers are purchase on average for US$1,400 more than if they do not have a sticker.
Tal., G. & Xing., Y. (2017)	Questionnaire Survey	PEVs	California	✓						Locality to HOV lanes is statistically related to PEV adoption rates
Tietge, U., Mock, P., Lutsey, N., & Campertrini, A. (2016)	Case Studies using statistical analysis	PEVs	Europe	✓	✓		✓			Financial incentives alone are not enough to encourage PEV adoption they should be paired with no-financial incentives for example HOV lane access and developing charging infrastructure
Wang, Y., Sperling, D., Tal, G., & Fang, H. (2017)	Short Communication	BEVs	China		✓				✓	Free vehicle licensing is the most important factor for adoption of BEVs. Exemption from road use restrictions and public charging infrastructure also have an impact.
Zhang, Y., Qian, Z. (Sean), Sprei, F., & Li, B. (2016)	Discrete Choice Model	BEVs	Norway	✓	✓		✓			Charging stations have greatest effect on BEV sales, toll waivers are also significant. Bus lane access is not desirable to potential BEV buyers as they perceive it as causing bus lane congestion
Zheng, J., Mehndiratta, S., Guo, J. Y., & Liu, Z. (2012)	Interviews with policy makers	PEVs	China	✓	✓	✓	✓			Road charging exemptions, priority/HOV lane access, free or discounted parking, infrastructure development

Table 2: Table showing the authors, methods uses, vehicles and regions of study along with the incentive types considered and a summary of the conclusions in each study.

2.1.HOV, Bus or Transit Lane Access

In total 25 studies analysed the impact that HOV, bus, or transit lane access has on PEV adoption. The first studies to investigate HOV lanes were in 2009 (Diamond, 2009; Sangkapichai and Saphores, 2009). These studies analysed the impact of HOV lanes on HEV sales. The study by (Diamond, 2009) used statistical analysis to investigate the impact of government incentives on HEV sales across the USA. They found statistically significant relationships between HEV sales and HOV lane access in the state of Virginia between 2001 and 2004. After 2004, when HOV lanes were introduced in a larger number of states they found that HEV sales were better correlated to vehicle miles travelled (VMT), household income and fuel cost. (Sangkapichai and Saphores, 2009) used a questionnaire survey in the form of a stated choice experiment to understand interest in HEVs. They found that interest in HEVs was related to energy use, air pollution, health, gas price increases, and HOV lanes. They discovered that people who live close to HOV lanes or who travel long distances are more attracted to HEVs.

From 2013 onward the literature began to assess the impact of HOV lane access on PHEV and BEV adoption. The clear majority of these studies investigated PEV sales in California or the USA. In total 17 studies investigated California or the USA. (Krause et al., 2013) used a questionnaire survey to understand the general populations awareness and knowledge of PEVs and some incentives available to them in the USA. They found that awareness of HOV lanes was very low, with only 2.8% of their 2302 respondents being aware of them. However, they found that if consumers were aware of HOV lane access 48% of them were more likely to consider purchasing a PEV. The authors were unable to find a statistically significant correlation between interest in PEVs and the presence of non-financial incentives. They state that this is due to low levels of awareness of the current incentive measures. Therefore, if consumers are made aware of HOV lane access levels of adoption would increase. Another study in the USA investigated the impact of HOV lane access on PEV sales in California (Tal and Nicholas, 2014). The study used a questionnaire survey to understand the behaviour of 3659 consumers who had purchased a PEV. The vehicles included in their study were Nissan Leaf BEVs, Chevrolet Bolt PHEVs, and Toyota Prius PHEVs. They found that for some buyers of PEVs the benefit of HOV lane access was so significant that it was the only factor in their decision to purchase a PEV. The study found differences in the impact of HOV lane access depending on the vehicle type and location of respondents. The authors found that HOV lane access was a greater influence on PEV buyer decisions in areas with more HOV lanes and greater levels of traffic congestion. The San Francisco Bay area and Los Angeles are heavily congested and have many HOV lanes. HOV lanes are an important factor for PEV buyers in those areas (Figure 1). In addition to regional differences the authors found differences between vehicle types. They found that HOV lane access was a more significant motivator for buyers of PHEVs with low driving ranges. Buyers of Toyota Plug-In Prius PHEVs with 11 miles of range were more motivated by HOV lanes than buyers of Chevy Volt PHEVs with 38 miles of range. The study suggests that HOV lane access should be limited to PHEVs with longer driving ranges. This is because HOV lanes could encourage consumers to purchase PHEVs with shorter electric ranges rather than ones with longer electric ranges. PHEV with longer electric ranges have greater environmental and energy related benefits (Nicholas et al., 2016). Another study by these authors on the same dataset found that many buyers of Toyota Plug-In Prius PHEVs did not plug-in their vehicles meaning that many of their vehicle miles driven were completed with

the use of their ICEV. Drivers of Chevy Volt PHEVs were found to plug-in their vehicles more frequently and achieved many more electric vehicles miles travelled (Tal et al., 2014).

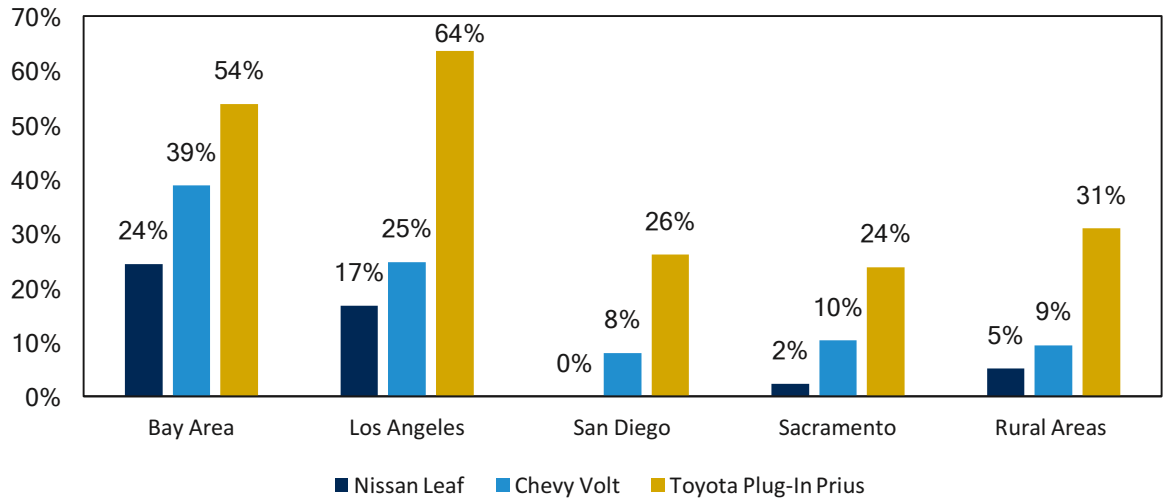

Figure 1: Percentage of respondents by location and vehicle type that state HOV access was a primary purchasing motivation (Tal and Nicholas, 2014).

A study conducted in California investigated used car markets for PEVs (Tal et al., 2017). The study analysed the transaction prices for used PEVs. This study identified differences in prices paid for PEVs with and without HOV lane stickers, which are required for PEVs to use HOV lanes. The study found that consumers were willing to pay more for a PEV that had a HOV lane sticker. The results revealed that PEVs with HOV lane stickers were sold for an average premium of US$1,400 over non-HOV lane sticker PEVs. This significant willingness to pay for a HOV lane sticker suggests that HOV lane access is significant factor in encouraging PEV sales. The results of this study also show that HOV lane access can not only encourage new PEV sales but it is also effective in encouraging used car buyers to purchase a PEV. A further study in California by (Tal and Xing, 2017) used a nested logit model to analyse data from the California travel survey and a PEV survey with 3881 respondents. In their analysis they found that distance to HOV lanes was correlated to PEV adoption. (Caperello et al., 2015) held workshops that involved both early adopters of PEVs and drivers of ICEVs in California. The workshops were designed so that PEV owners and ICEV owners could have an open dialogue with each other. This allowed the researchers to understand what questions ICEV owners had about PEVs but also what benefits of PEV ownership the PEV owners valued the most. They found that some PEV owners valued HOV lanes very highly. Some workshop participants stated that HOV lane access was the sole reason they purchased their vehicle. Some PEV owners only saw HOV lanes as a benefit of ownership and did not believe it motivated them to purchase their vehicle. The researchers observed differences in how PEV owners perceived HOV lanes based on where they live, agreeing with (Tal and Nicholas, 2014). (Caperello et al., 2015) found that PEV owners who lived in areas with traffic congestion, such as San Jose, valued HOV lanes more than people who lived in areas with less congestion.

(Lutsey et al., 2016) analysed PEV markets and policies in 50 U.S. cities. Using statistical analysis, they found that the relationship between HOV lanes and PEV sales was statistically significant. In-depth interviews with high-end BEV adopters conducted by (Hardman, 2016) found that for the buyers of Tesla BEVs HOV lane access was not a primary motivator. They found that only 1 participant in their study of 39 people stated that HOV lane access was a

reason for buying a high-end BEV. They found that 14 participants believe HOV lane access was a benefit of owning a high-end BEV. According to these results, HOV lane access was not a motivational factor in their decision to buy a BEV but it did increase the chances of these buyers purchasing another BEV in the future.

A European study used workshops with policy makers in 7 regions to understand the importance of HOV or bus lanes. They found that policy makers believed HOV lane or bus lane access could be used to encourage consumers to purchase PEVs (Bakker and Jacob Trip, 2013). (Hackbarth and Madlener, 2013) used a discrete choice analysis to understand consumer preferences for alternative fuel vehicles (HEVs, PHEVs, Natural Gas Vehicles, Biofuel Vehicles, BEVs, and FCVs) in Germany. The study contained 711 respondents and included free access to bus lanes for AFVs in the choice model. The study found that consumers are willing to pay an additional €1620-3280 for a vehicle that can drive in bus lanes and can be parked for free. Another study conducted in Europe, this time the Netherlands conducted a choice experiment with private car buyers to understand preferences for AFVs (Hoen and Koetse, 2014). The study found that bus lane access could incentivise AFV adoption in urban areas. They authors were unable to confirm this at a high level of confidence due to the results of their statistical analysis not finding a statistically significant trend, although the authors state that there is a positive trend.

Norway has received interest from academics, perhaps due to there being significant progress in PEV market development in Norway and because BEVs can drive in bus lanes. (Zhang et al., 2016) conducted a discrete choice model on a sample of the private car buyers and business buyers in Norway. They investigated the impacts of car specifications and incentives on PEV sales. The study found interest in BEVs was correlated to technological development, toll fee waivers, and the number of PEV charging stations. They found that of these incentives access to charging infrastructure was the most significant factor. This study found that bus lane access was not an attractive feature in their sample. They found that potential PEV buyers believe bus lane access is an undesirable incentive. This is due to respondent's concerns that bus lanes could become congested with BEVs. Another study on the development of BEV markets in Norway used a mixed methods approach (Figenbaum, 2016). The study used multi-level perceptive theory, market data from 1990-2016, and data form a questionnaire survey. From this data, the authors found that bus lane access and toll exemptions can attract consumers who are unsure about BEVs to them. These consumers would ordinarily not purchase a BEV due to them being unsure about whether there are economic benefits due to the low running costs. Bus lane access and free parking therefore created a niche with consumers who value these two incentives. Bus lane access was effective due to it being a time saving benefit that can be utilised immediately by consumer. Bus lanes served an additional purpose, this was creating a 'display window' for BEVs. ICEV drivers would notice BEVs using bus lanes, this increases awareness of BEVs thus increasing sales. Another study in Norway conduced statistical analysis on disaggregated BEV sales in order to understand which variables are correlated to BEV market development (Mersky et al., 2016). This study found that the BEV market was correlated to access to charging infrastructure, locality to major cities, and income. In the study toll exemptions and bus lane access were not correlated the BEV market. This could be due to these two variables being correlated to the number of charging stations and locality to cities themselves. The authors state that future research is needed to help understand how bus lane access, toll exemptions, and free parking relate to BEV markets. (Tietge et al., 2016) investigated PEV market developments in Europe using case studies of 10 cities. The study found that PEV

markets were related to the presence of financial incentives and reoccurring incentives. They state that the most effective strategy to encourage PEV adoption is to undertake promotional activities consumer outreach, and introduce low emissions zones and HOV lanes. (Aasness and Odeck, 2015) reviewed data that was available at the time of undertaking their study to understand which incentives have been instrumental in encouraging PEV adoption. They found that toll fee waivers, bus lane access, free parking, and purchase tax exemptions have all induced consumers to purchase a PEV. They do note though that these incentives can also have negative effects. In the case of bus lanes they found that PEVs using these lanes could cause congestion and make transit journey times longer. (Figenbaum and Kolbenstvedt, 2016) used results from a questionnaire survey of 3111 BEV users, 2065 PHEV users, and 3080 ICEV users to gain insights into BEV and PHEV adoption. They found that transit lane access was the least important incentive for adopters, who valued free use of toll roads the most. Finally a study by (Bjerkan et al., 2016) surveyed consumers who own BEVs in Norway. They investigated how BEV adopters rank the importance of incentives in their purchase decision. They found that consumers rank purchase tax and vat exemptions the highest, these being a critical factor for over 80% of adopters. Access to bus lanes was found to be a critical factor for 21% of buyers. This factor although valued by a lower number of consumer is still an important incentive as is can convince buyers who are not motivated by financial reasons to purchase a BEV.

China has received little attention from researchers investigating PEV adoption and HOV or transit lanes. This review only identified one study by (Zheng et al., 2012). The authors conducted surveys with stakeholders in 10 cities in China. From these stakeholder surveys, they concluded that an effective non-monetary strategy to incentivise consumers to adopt PEVs was the use of what they refer to as ‘superior lanes’. They give HOV lanes as an example of a type of ‘superior lane’.

2.2.PEV Charging Infrastructure

This review identified 19 studies that investigate the impact of the availability of charging stations on PEV adoption. Most studies focus on the US and California. The earliest study that investigated the importance of PEV infrastructure was in 2012 (Egbue and Long, 2012). That study used a questionnaire survey to investigate ‘technology enthusiasts’ attitudes and perceptions towards BEVs. The study involved 481 people and observed several barriers to the adoption of PEVs. The most notable of which was the short range of BEVs. The authors found that the development of PEV recharging infrastructure could help to remove this barrier. They also state that increasing BEV driving ranges will contribute to improving consumer perceptions. A study by (Nicholas and Tal, 2013) investigated the impact of free workplace charging on PEV adoption in California. Using a questionnaire survey administered to PEV adopters they found that the provision of free workplace charging can encourage PEV sales. It can also cause problems and can lead to people being dissuaded from purchasing a PEV. If charging stations become congested consumers may be unwilling to purchase a PEV due to them observing this and perceiving it as a barrier to purchase of a PEV. The authors suggest strategies to mitigate charging station congestion. They state that workplace charging stations should be either many low-cost level 1 or level 2 chargers, or fewer DC fast chargers which PEV drivers can only use for a limited time. They suggest this could be done by making consumers pay for DC fast charging, this way they could only charge when they need to do so. They also suggest enforcing time limits on how long DC fast chargers can be used for before drivers need to move their cars to a new parking space. This would mitigate the issue of charge point congestion.

The workshops conducted by (Caperello et al., 2015), previously mentioned in section 2.1, also involved discussion of BEV charging infrastructure. The study found that free charging can be a benefit. Several PEV owners in their study mentioned free workplace charging and free public charging. The study found a low level of awareness of PEV charging infrastructure amongst ICEV drivers though. They highlight the need to increase education and awareness activities so that more consumers are aware of charging infrastructure. Another qualitative study (Hardman, 2016) found that high-end BEV adopters were not motivated to purchase their BEV due to the presence charging infrastructure. This is due to these vehicles having driving ranges of more than 200 miles per charge, meaning that public or workplace infrastructure is used less frequently. 9 out of 39 interviewees did believe that the use of free infrastructure was a benefit though, especially for long distance journeys.

(Lutsey et al., 2016) included public charging infrastructure as part of their analysis of PEV markets in 50 US cities. They found a statistically significant relationship between PEV market share and the presence of public and workplace charging infrastructure highlighting the need for both types of infrastructure. They also found relationships between vehicle availability, the number of policy actions, the presence of financial incentives, and HOV lane access as previously mentioned. A 2017 study analysed the California household travel survey using regression analysis (Javid and Nejat, 2017). The authors used this data along with assumptions relating to the demographic characteristics of early adopters to estimate PEV adoption in 58 counties across California. The study found that gas prices and charging stations per capita are related to PEV adoption. They suggest that transport planners should seek to increase gasoline prices and construct charging networks to promote PEV market development. Case studies conducted by (Bonges and Lusk, 2016) found that improving access to infrastructure will lead to increased PEV sales. They make recommendations on how to increase access by improving the design of PEV charging outlets and parking. They suggest that charging outlets should be accessible by 4 parking spaces rather than just 1 or 2.

Studies that investigate PEV uptake in Europe have also worked to understand the importance of PEV charging infrastructure. The Norwegian study by (Zhang et al., 2016) constructed a choice model to understand why some consumers were attracted to BEVs more than others. They found that a greater density of charging infrastructure would lead to more consumers being interested in purchasing a BEV. Another Norwegian study analysed regional PEV sales across Norway (Mersky et al., 2016). The authors found that market growth was correlated to PEV infrastructure. Another study in Norway used a questionnaire survey to understand several issues associated with BEV adoption. They found that access to workplace charging and public charging were important for around ¼ of their 3111 BEV respondents. A study by (Plötz et al., 2016) used regression analysis to understand PEV sales in the United States and Europe. They found that for Europe PEV sales were influenced by income, gas price, and the presence of incentives. For the United States, they found that gas price, incentives, and the number of charging stations per capita influenced BEV sales. They did not investigate the impact of charging stations for Europe. Another study in Europe did include infrastructure development as part of their analysis. The study conducted case studies of 10 regions in Germany, United Kingdom, France, Netherlands, and Norway. The study found that there was a correlation between PEV market share and the number of charging stations in the Regions. Workshops held by Bakker and Trip in Europe found that all policy makers recognised the importance of PEV infrastructure in encouraging PEV adoption (Bakker and Jacob Trip, 2013).

Two studies have analysed the importance of PEV recharging infrastructure in China. The first of these involved surveys with stakeholders in 10 Chinese cities (Zheng et al., 2012). The surveys asked stakeholders what was needed to progress the PEV market. The stakeholders stated that PEV charging infrastructure is needed along with financial incentives and other non-monetary incentives such as free or discounted parking. The second study that looked at China was a short commination by (Wang et al., 2017). This study explored reasons behind the market growth of PEVs in China. They found that in addition to other incentives recharging infrastructure could assist in the growth of PEV markets, though they found that it was not the most significant influencer. The most significant influencer was found to be free vehicle licensing, which is discussed in more detail in section 2.6.

One final study to assess the importance of infrastructure conducted global analysis of the issue. (Lieven, 2015) used a choice based model to understand the most effective policy measures in 20 nations across 5 continents. The study involved 8147 respondents. Their analysis revealed that workplace, public, and freeway locations were all needed. They found that charging on freeways were 'must haves' and that the absence of these causes the highest level of dissatisfaction amongst potential PEV buyers. They found that utilisation of these charging stations will be low, but they help in alleviating PEV buyers concerns related to range anxiety. They used cluster analysis in their data and discovered three clusters depending on the incentives demanded by consumers. One of the clusters (22.6%) was buyers only sensitive to financial purchase incentives, the second was a cluster (35.5%) of buyers who demanded multiple incentives, and finally the largest cluster (41.9%) was made up of consumers who demanded freeway charging to be present if they were to purchase a PEV.

2.3.Parking Incentives

Within the literature 15 studies have assessed the impact of free, discounted, or preferential parking for PEVs. The first study to investigate the impact of parking incentives on AFV adoption was a 2011 study that looked at HEV adoption in the United Kingdom (Ozaki and Sevastyanova, 2011). The authors found that free or priority parking could be an effective incentive. It was especially prevalent for people living within the M25 London Orbital Motorway. This was due to free parking in the United Kingdom being mostly offered as an incentive in London and due to the high cost of parking in London. The authors suggest that free/priority parking schemes should be more extensive and expanded to other regions outside of London. They state that these schemes need to be publicised to be most effective. The stated choice experiment by (Hoen and Koetse, 2014) found that free parking is important in urban areas. The study by (Krause et al., 2013) found that in their sample of 2302 consumers 56% would be more likely to consider purchasing a PEV if free parking was available. However only 1.7% of consumers were aware that free parking was an incentive that was already available to them. The study found that free parking could be more effective than HOV lane access, which lead to 48% of consumers being more likely to consider a PEV. The discrete choice model study by (Hackbarth and Madlener, 2013) included free parking, bus lane access, and vehicle tax exemptions as part of their analysis. Consumers are willing to pay €1620-3280 for the combined benefits of free parking and bus lane access. They do not break this down into the individual incentives. (Mersky et al., 2016) also found that parking incentives may be important due to them finding that PEV sales were correlated to living close to major cities that have parking incentives. Three studies in Norway both found that free parking was an important measure that can be used to promote PEV sales (Aasness and Odeck, 2015; Bjerkan et al., 2016; Figenbaum and

Kolbenstvedt, 2016). A final study in Europe found that PEV parking incentives are an effective measure (Bakker and Jacob Trip, 2013). The stakeholders in that study believed that free parking could only be a temporary measure though. In the case of cities with high demand for parking stakeholders believed that ICEV drives could resent PEV drivers who could park for free. Stakeholders did not want to introduce too many parking spaces that were for PEVs only in case public support for PEVs fell. An additional consideration was the fall in revenue due to free PEV parking. This could create a budget deficit in some regions. Finally, one stakeholder believed that PEV parking should not be free as the goal of policy makers in their region was to reduce car use overall and to encourage the use of public transit.

Some buyers of PEVs in California have been found to value free or discounted parking (Caperello et al., 2015). This was dependent on location though. PEV owners in San Jose, California were found to be motivated to purchase a PEV because of free parking. However, participants noted that this incentive was due to expire in that region. PEV buyers in Sacramento, California also valued free parking. Preferential parking was valued for more reasons beyond the financial savings. PEV adopters indicated that it was beneficial not having to search for a parking space as there was usually an empty PEV space. (Hardman and Tal, 2016) found that free parking was only valued by a small number of consumers. This may have been due to that sample not sampling regions where free parking was currently available and because the goal of the study was not to investigate free parking. The study by (Ajanovic and Haas, 2016) on 14 urban areas in Europe, USA, and China found that free parking was one of the most important non-monetary measures along with bus lane or HOV lane access, charging infrastructure development, and congestion charge zones. The choice model by (Lieven, 2015) found that free parking was attractive for some consumers, though financial incentives, and freeway charging stations were more effective in promoting PEV sales. Finally the 2016 review by (Liao et al., 2016) was unable to find any evidence in the literature regarding free parking or its impact on PEV adoption, they therefore could not state whether it was or was not an effective policy measure.

2.4.Toll or Road Charge Exemptions

There are 10 studies that investigate the effectiveness of toll and road charge exemptions. These studies have considered Norway, United Kingdom, Italy, France, Netherlands, Germany, and China. 6 studies considered in the impact of toll waivers in Norway (Aasness and Odeck, 2015; Bjerkan et al., 2016; Figenbaum, 2016; Figenbaum and Kolbenstvedt, 2016; Mersky et al., 2016; Zhang et al., 2016). Statistical analysis of Norwegian BEV sales found that PEV sales are not related to toll exemptions (Mersky et al., 2016). The authors note that this may be due to cross correlations impacting their results. The discrete choice model conducted by (Zhang et al., 2016) found the presence of toll waivers can increase BEV sales. The study by (Figenbaum, 2016) containing data from consumers who have purchased a BEV found that toll exemptions were effective in attracting consumers to purchase a BEV. In the same way as bus lane access attracted consumers to PEVs toll exemptions did the same by allowing buyers of BEVs to receive immediate financial benefits, beyond fuel savings. Two further studies in Norway (Aasness and Odeck, 2015; Figenbaum and Kolbenstvedt, 2016) also found that toll fee waivers were effective in promoting BEV sales. The study by Figenbaum and Kolbenstvedt found that toll access was the most important reoccuring incentive. Finally (Bjerkan et al., 2016) found that exemption from road tolls was a critical factor for 49% of BEV buyers in Norway. This was less important than exemptions from purchase taxes, but more important than free parking and bus lane access. This

suggests that for some buyers the exemptions from road tolls are the most important reoccurring incentive. The authors suggest that exemptions from road tolls along with bus lane aces are the only incentives that convince some consumers to buy a PEV. These consumers are not motivated by the financial incentives applied at the point of purchase meaning these reoccurring incentives are critical in encouraging consumer who aren't financially motived to purchase a PEV.

The study of HEV adoption in the United Kingdom found that exempting HEVs from the London congestion charge had a significant effect on HEV adoption (Ozaki and Sevastyanova, 2011). It was especially true for consumers living close to London. (Percoco, 2014) investigated the impact of road charging in Milan. Road charging was introduced in Milan in 2008 in the centre of the city. At the time of the study alternative fuel vehicles (HEV, natural gas and biofuel vehicles) and ICEVs with emissions compliant with Euro 4 standards or above could access the road charge zones for free. ICEVs with emissions lower than Euro 4 standards must pay a fee of between €2-10 per day. In 2012 a part of the zone was suspended for a period of 50 days. The authors could record changes in traffic composition during the suspension and when the road charge zone was in full operation. The authors found that the road charge zone had a positive effect on the vehicle fleet, they found that drivers of ICEVs with lower than Euro 3 emissions switched to using bio-fuel, natural gas, or HEVs. (Tietge et al., 2016) found that there was a relationship between toll roads and PEV market share in Norway. In their conclusions, they state that financial purchase incentives are not sufficient on their own to drive PEV adoption. They indicate that non-financial measures are needed such as preferential access to road charge zones and toll waivers. Surveys with PEV stakeholders in China found that policy makers support the use of toll and road charge exemptions as measures to promote PEV adoption (Zheng et al., 2012).

2.5.Annual Road Tax Incentives

Fewer studies have analysed the importance of annual road tax exemptions or discounts for BEVs. Only 5 studies in this review considered this type of incentive. A possible reason for the lack of literature on this topic could be due this incentive only being available in few areas. The USA which much of the literature investigates does not have this incentive in place. The first study to consider the impact of annual road tax reductions was the study on HEV adoption in the United Kingdom by (Ozaki and Sevastyanova, 2011). The study found that reduced running costs, which in their study included reduced expenditure on gasoline and on road tax, was related to the adoption of HEV in the United Kingdom. The study found that perceived financial benefits were strongly affect the decision to purchase a HEV. (Hackbarth and Madlener, 2013) investigated the importance of annual road tax exemptions for AFVs in Germany. They found that the removal of this incentive would have a significant impact on AFV markets. Their analysis found that if annual road tax waivers were removed willingness to pay for AFVs would fall by €2330-4700. The study by (Hoen and Koetse, 2014) also found this to be the case. They found that in the Netherlands road tax exemptions are highly valued by consumers and their removal would have a negative impact on the market. They also state that although it is an effective measure it is expensive due to the lost revenue from PEVs. (Lieven, 2015) found that tax incentives are attractive for PEV buyers, they found that they are not a 'must have' but the presence of these incentives can encourage more consumers to adopt PEVs. Finally a study of Norwegian BEV buyers found that annual road tax discounts were an important reason for the purchase of a BEV (Figenbaum, 2016). This study found that road tax exemptions were a significant contributor to the purchase of a BEV for 49% of buyers. This was the second most important incentive

behind toll exemptions. This meant that in the case of Norway tax exemptions were more important than free parking, the presence of charging infrastructure, and bus lane access.

2.6.Other

Several studies have included the impact of vehicle fuel price in their analysis. Several of these studies have found relationships between PEV sales and gasoline prices. The majority of these studies have focussed on the USA (Adepetu et al., 2016; Diamond, 2009; Javid and Nejat, 2017), one study investigated both the USA and Europe (Plötz et al., 2016). The first study in the USA considered the impact of gasoline prices on HEV adoption (Diamond, 2009). The authors found that the price of gas had the strongest effect on HEV market share. They state that a 10% increase in gas price could lead to a 72-95% increase in HEV market share. (Javid and Nejat, 2017) found that gas prices are also related to the size of the BEV market. Higher gas prices are significantly related to PEV market share. They suggest that transport planners could increase gas price in order to encourage PEV adoption. (Adepetu et al., 2016) did not find any evidence to suggest that gas prices were effective in promoting PEV sales. Though most research does indicate that increasing petroleum prices will lead to more consumers adopting HEVs, PHEVs, and BEVs.

The short communication by (Wang et al., 2017) found that one of the most effective incentives for PEV adoption in China was the ability to get a free license plate. In some regions in China there is a significant waiting list to get a license plate, which is required to purchase a vehicle. New car buyers must wait up to 20 months and pay on average US$12,434 for a license plate. Results from a survey in Shanghai show that 64% of PEV buyers state that the free license was the most important factor in their purchase decision. Free plates for PEVs mean that there is no wait time or financial expenditure. In addition to this some cities have rules dictating the days which vehicles can be driven. In Beijing PEVs are exempt from a rule that states vehicles can be only driven on the roads 1 working day per week. (Wang et al., 2017) state that these are effective in increasing PEV sales.

2.7.Summary

The review examined the findings of 35 studies that investigate indirect and reoccurring incentives for PEVs. 25 of these studies investigated HOV, bus or transit lane access, 19 infrastructure development, 15 parking incentives, 10 toll or road charge exemptions, 4 gasoline cost, and 5 annual road taxes. A breakdown of how many studies found these incentives to be effective in promoting PEV sales can be seen in Table 3. The table shows the number of studies that investigate each incentive type and how many of these concluded that the incentive was effective. The reasons why some studies did not find the incentives did not have an impact of PEV sales is also shown.

Of the 25 studies investigating the importance of HOV, bus or transit lanes 20 found that these lanes are effective in increasing PEV market shares. 5 studies were unable to state that HOV lanes were effective in increasing PEV market shares. (Mersky et al., 2016) were unable to detect relationships in PEV adoption and HOV lane access due to cross correlations in their dataset impacting their results. Bus lane access was found to be undesirable by (Zhang et al., 2016) due to respondents believing it would cause congestion in bus lanes. The literature review by (Liao et al., 2016) was unable to identify enough literature to fully understand the relationship between HOV lane access and PEV sales. The study by (Clinton et al., 2015) was unable to detect any trends between PEV sales and HOV lanes due to their being not enough variation in their dataset. Most studies find HOV lanes to be effective in promoting PEV sales. Studies using statistical analysis, stated choice

experiments, post purchase questionnaire surveys or interviews, and studies conducting case studies have all found that HOV, bus, or transit lane access for PEVs leads to increased sales of the vehicles (Ajanovic and Haas, 2016; Bakker and Jacob Trip, 2013; Caperello et al., 2015; Chorus et al., 2013; Diamond, 2009; Figenbaum, 2016; Hackbarth and Madlener, 2013; Hardman, 2016; Krause et al., 2013; Lieven, 2015; Lutsey et al., 2016; Nicholas et al., 2016; Sangkapichai and Saphores, 2009; Shewmake and Jarvis, 2014; Tal and Nicholas, 2014; Tal and Xing, 2017; Tietge et al., 2016; Zheng et al., 2012).

All 19 studies that explored the importance of charging infrastructure found that it was an important factor in increasing the market for PEVs. Studies that use statistical analysis, modelling, case studies, interviews and questionnaire surveys all came to this conclusion. Studies have found that charging infrastructure is an important factor in promoting PEV sales in USA (Adepetu et al., 2016; Bonges and Lusk, 2016; Caperello et al., 2015; Egbue and Long, 2012; Hardman and Tal, 2016; Javid and Nejat, 2017; Lutsey et al., 2016; Nicholas and Tal, 2013; Plötz et al., 2016), China (Wang et al., 2017; Zheng et al., 2012), Europe (Bakker, 2010; Mersky et al., 2016; Tietge et al., 2016; Zhang et al., 2016) and Globally (Lieven, 2015). Infrastructure development is needed at workplaces, public locations and on travel corridors. Some studies have found that consumers are not aware of charging infrastructure. Education and outreach campaigns should be used to promote the presence of charging infrastructure. This should increase PEV adoption rates.

There are 15 studies currently published that explore parking incentives. 13 of these find that free, discounted, or priority parking are effective in driving PEV adoption. The study by (Hardman and Tal, 2016) did not find parking to be an important motivational factor for high-end BEVs buyers perhaps due to the sample not including adopters of BEVs from regions where free parking was available. The review by (Liao et al., 2016) was unable to identify any literature that investigated parking incentives. The study by (Lutsey et al., 2016) included parking infrastructure in 'other incentives' so did not breakdown whether parking was correlated to market share. Their analysis did show that the presence of 'other incentives' were related to PEV market share suggesting that free parking may be a significant influence on purchase decisions. Most studies support the effectiveness of parking incentives. Studies from (Ajanovic and Haas, 2016; Bakker and Jacob Trip, 2013; Caperello et al., 2015; Hackbarth and Madlener, 2013; Hoen and Koetse, 2014; Krause et al., 2013; Lieven, 2015; Zheng et al., 2012) have found that parking incentives are an effective policy measure in promoting PEV use. Authors have noted that awareness of parking incentives is low which impacts their effectiveness. Therefore promotional activities are needed to increase awareness with the result being increased PEV sales (Caperello et al., 2015; Carley et al., 2013).

There are 10 studies currently published that investigate the impact of toll or road charges. Most studies investigating this topic concentrate on Norway. This literature has found that toll exemptions have contributed to the success of PEVs in Norway (Figenbaum, 2016; Figenbaum and Kolbenstvedt, 2016; Zhang et al., 2016). The rest of the world including the top PEV markets has received far less attention with just 1 study on China (Zheng et al., 2012), 1 on United Kingdom (Ozaki and Sevastyanova, 2011), 1 on Italy (Percoco, 2014), and 1 on Europe (Tietge et al., 2016). 9 out of 10 studies suggest that toll and road charge waivers are effective in increasing PEV adoption indicating that toll and road charge exemptions are effective.

Only 5 studies assessed the importance of annual tax exemptions or reductions (Figenbaum, 2016; Hackbarth and Madlener, 2013; Hoen and Koetse, 2014; Lieven, 2015). 4

of those studies found that they are an important consideration in the purchase of a PEV. One of these studies found that it was the most important incentive, with another finding that it was the second most important incentive (Figenbaum, 2016; Hackbarth and Madlener, 2013). This suggests that it is an incentive that can be used to promote PEV sales. To confidently state that tax incentives are effective in promoting PEV sales more research should be undertaken.

Incentives Investigated	Number of Studies	Studies finding incentive to be effective	Reasons behind studies not finding incentive to be effective
HOV/Bus/Rapid Transit Lane	25	20	• Not enough variation in dataset to detect any relationships (Clinton et al., 2015). • Consumers place a higher value on free use of toll roads (Figenbaum and Kolbenstvedt, 2016). • Literature review unable to find trends in literature (Liao et al., 2016). • Unable to detect relationship due to cross correlations in dataset (Mersky et al., 2016). • Potential buyers of PEVs concerned about bus lane congestion (Zhang et al., 2016).
Infrastructure Development	19	19	
Parking Incentives	15	13	• Consumers see this as a benefit but not a purchase motivation (Hardman and Tal, 2016). • Literature review unable to find trends in literature (Liao et al., 2016).
Toll/Road Charge Exemptions	10	9	• No statistically significant relationship indicating that toll fee waivers are effective. Though this could be due to neighbouring major cities containing those incentives impacting the results (Mersky et al., 2016).
Gasoline Cost	4	3	• No evidence to suggest that increasing gas prices results in increased PEV sales according to their model (Adepetu et al., 2016).
Annual Road Tax	5	5	
Other	2	2	

Table 3: Summary of the results of this literature review. The table shows the number of studies that investigate each incentive type and how many of these studies found that given incentive to be effective in increasing PEV sales. The final column shows the reasons some studies did not find each incentive to be effective.

3. Conclusion

This review has found that reoccurring incentives are effective in encouraging more consumers to adopt PEVs. These incentives should be paired with financial purchase incentives so that they have the most significant impact (Tietge et al., 2016). Introducing more reoccurring incentives will have a greater impact on PEV sales. The roll out of PEV recharging infrastructure is the most important factor in increasing PEV market shares. All studies that investigated the impact of infrastructure found that its development does lead to more PEV sales. This applies to studies that investigated public, private, and workplace charging. The relative importance of HOV, bus or transit lanes, parking incentives, toll and road charge incentives, annual road tax exemptions, and gasoline prices is difficult to rank. Studies investigating these incentives have generated different results relating to their importance. The study by (Bjerkan et al., 2016) found that in Norway toll fee waivers are the most important incentive for PEV buyers. However a study by (Mersky et al., 2016) found no relationship between PEV sales and toll fee waivers. This type of contradiction is common within the literature making it difficult to quantitatively rank the importance of these different incentive types. Each incentive type has emerged as the most important incentive in promoting PEVs sales in different studies. The reason for the differences between study's conclusions is due to the different methods used, the different regions studied, along with differing private motivations of the PEV consumers studied. HOV, bus and transit lane

access for PEVs is the most widely investigated incentive within the literature. Most studies found that HOV, bus and transit lane access for PEVs is effective. This is reliant upon consumers living near to or using these lanes. If consumers do not live near the lanes nor use them this incentive will not be effective. If they do live near to the lanes and use them this incentive can be influential in promoting PEV market growth. Parking incentives were found to be effective by most studies that analysed their impact. Parking incentives lead to consumers being more willing to adopt a BEV, but only in areas where this incentive is available. This incentive is most commonly applied in urban areas where parking is in high demand and costly. Toll and road charge exemptions have been investigated less than HOV lanes or parking incentives have. The literature finds that toll and road charge incentives are effective only in regions where these incentives are in place. Annual road tax exemptions have received the least amount of attention by academics. These incentives have been found to be effective in increasing sales of PEVs in locations where this incentive is applied.

Reoccurring incentives are not available ubiquitously to all consumers. This is due to their availability differing between regions. In some cases, the incentives are only available in a small number of urban areas. Therefore, they cannot be effective in encouraging all consumers to adopt PEVs, only consumers who have access to them. This is significantly different to how financial purchase incentives are applied, where the clear majority of consumers in each nation have access to the same incentives. Introducing reoccurring incentives that are available to all consumers will be more effective in promoting PEV sales. This is the case in Norway. Norway not only has the highest number of incentives but the incentives are available ubiquitously across the entire country. This has led to Norway having the highest PEV market share of any nation. Any incentive that increases the convenience and reduces the cost of owning a PEV in comparison to an ICEV will lead to more consumers adopting them. They should also be paired with policy measures that apply disincentives to ICEVs, such as gas tax (fuel duty). The most effective strategy will to be introduce as many incentives as possible so that as many different consumers are attracted to PEVs.

3.1. Policy Recommendations

Policy makers should look to introduce as many reoccurring incentives as possible to promote PEV sales. This will result in the larger increase in PEV market share compared to a strategy that introduces a small number of reoccurring incentives. Incentives should be introduced nationwide so that as many consumers as possible have access to them. This is compared to the current situation where incentives are sometimes available only in isolated areas. This literature review only considers the effectiveness of reoccurring incentives that have been investigated by academics. It may be possible that policy makers are considering the introduction of incentives that have not been investigated. Overall any reoccurring incentive that increases the convenience and lowers the cost of owning a PEV in comparison to an ICEV will be effective in promoting their adoption. For the incentives to be effective consumers need to be made aware of them and should be educated so that they understand the benefits of owning a PEV.

HOV, bus and transit lanes will be most effective when introduced in regions with high traffic congestion. The introduction of these is clearly reliant upon the presence of multi lane road networks or the presence of bus lanes. The use of car pool or HOV lanes may be preferential to allowing PEVs to drive in bus lanes due to the potential for negative impacts on bus travel times. Though it is unlikely for this to occur during early market introductions of PEVs. Some regions have existing networks of HOV or carpool lanes, it is possible that

rules dictating their access could be changed to allow PEVs to enter. Other regions have fewer HOV or car pool lanes and therefore these lanes would have to be introduced along with allowing PEVs to access them. This would be more challenging to implement but would be beneficial to PEVs. Some cities currently have zones where cars are unable to drive, with areas being restricted to certain vehicle types (e.g. delivery vehicles, taxis etc.) allowing PEVs access to these areas will have a similar impact on PEV sales as bus lane access has had. Bus lane access will only be a temporary measure that can be used to support the early market for PEVs. After PEVs have gained significant market shares bus lanes will become congested. Therefore, this incentive should be introduced with a phase out period in mind. This phase out could begin when PEVs have achieved a certain market share. A gradual phase out could be possible which gradually increases the number of vehicle occupants needed in a PEV for them to access the lanes. This has been used in Norway where BEVs were originally allowed to drive in bus lanes with 1 vehicle occupant, this has now changed to 2 vehicle occupants.

Currently most parking incentives are limited to heavily urbanised areas. Policy makers should continue to introduce incentives for parking in urban areas, but also introduce them in other areas. Parking incentives can also be introduced at transit stations, including bus and rail stations. They can be introduced at any locations where parking is costly or spaces are scarce (e.g. shopping malls). Incentives can include free or discounted parking rates or priority spaces for PEVs. Priority spaces can be spaces reserved only for PEVs and would usually be preferentially located. This could be close to the entrance of store, the entrance of a rail station, on the bottom floor of a multi-story car park, etc. Often parking spaces for PEVs also have charging stations located next to them to allow PEV drivers to recharge their vehicles whilst parked. Policy makers should consider the impact of reduced revenue because of PEVs being able to park for free. It is possible that this type of incentive will only be applicable in the early stage of PEV market introductions. When PEVs have a majority, market share the loss in revenue may have negative impacts. It is also possible to introduce parking surcharges for ICEVs as a method of encouraging consumers to adopt PEVs. This is being trailed in London where diesel ICEVs will pay 50% extra to park. This could allow free parking for PEVs to continue for longer due to surcharges supplementing the lost revenue from PEVs. Providing priority parking spaces for PEVs will not result in lost revenue and therefore may be a parking incentives with the most longevity.

Toll fee waivers can be introduced on any road infrastructure that have toll fees applied to them. Congestion charge zones are less widespread than tolls. Though they can be effective in reducing congestion and encouraging consumers to drive less polluting vehicles. Policy makers should consider introducing congestion charge zones in more locations to reduce congestion and increase PEV sales. This is something that is currently underway in the UK. The London congestion charge zone, which has operated since 2003, will be joined by 5 clean air zones across the UK, though it is currently not clear whether fees will apply to passenger vehicles or only commercial vehicles. Toll fee waivers for PEVs could result in lost revenue for road infrastructure and therefore policy makers should consider this impact before introducing such schemes. Congestion charge are new policy measures therefore exempting PEVs from congestion charge fees will not result in lost revenue as these areas represent a new source of revenue.

Exemptions or reductions from annual road taxes for PEVs will be effective in increasing their market shares. Exempting PEVs from these will be most effective when high CO_2 emitting ICEVs are heavily taxed meaning there is a significant economic benefit for

consumers. As with toll fee waivers and free or discounted parking policy makers must consider the impact on revenue because of this. A scheme where PEVs are exempt from annual road tax until they gain a foothold in the market may be most effective. In this way PEVs would pay a low rate after they have gained a foothold in the market and this rate would incrementally increase over time. An alternative system could involve introducing a progressively increasing tax for ICEVs which can be used to subsidise the lost revenue from PEVs paying no road tax. This would be a bonus malus style system.

Fuel duty or gas tax is applied to vehicle fuel in many regions. For it to be effective in pushing consumers towards PEVs it should be progressive, meaning that over time the level of tax increases thus increasing the cost of fuel for consumers. This type of incentive has been effective in pushing consumers towards more efficiency ICEVs and PEVs. Policy makers should look to introduce this type of policy measure. This type of measure however can be politically unfavourable due to consumer outcry regarding the price of vehicle fuel.

For all these incentives policy makers, should distinguish between BEVs, PHEVs with high electric ranges, and PHEVs with low electric ranges (<30 miles). BEVs and PHEVs are the most beneficial in terms of energy consumption and emissions and therefore should receive the most incentives. PHEVs with low electric ranges (<30 miles) should receive lower incentives that also should be phased out sooner. This is because they achieve less electric vehicle miles travelled than BEVs and long range PHEVs. Furthermore, drivers of PHEVs with shorter ranges plug-in their vehicles less often thus exacerbating the issue. Some drivers of short range PHEVs have been found to never plug in their vehicles (Tal et al., 2014).

Policy makers need to consider impacts on revenue that would result from parking incentives, toll fee waivers and annual road tax waivers. If alternative sources of revenue cannot be found these incentives will need to be phased out once PEVs have gained a stable foothold in the market. It may be possible to account for loss in revenue by enforcing higher tolls, parking fees or annual road tax on ICEVs.

Policy makers in some nations and regions need to consider interactions between PEV incentives, public transport systems, walking, and cycling. This has been previously mentioned by (Ajanovic and Haas, 2016; Bakker and Jacob Trip, 2013). Some nations, for example the United Kingdom, many other European nations, and China have higher public transport, walking, and cycling rates. In the United Kingdom 12% of journeys are taken on public transport, in London this figure is 38%. 22% of journeys are done via walking in the UK and 24% in London. Cycling is less frequent, but not insignificant with 2% of Journeys in the UK and London being done via bicycle. For comparison in the United States only 5% of journeys are on public transit, 5% by walking, and 1% by cycling. In regions with high modal shares for public transportation, cycling, and walking policy makers need to consider interventions that do not encourage PEV use over public transport, walking or cycling. Policy makers should seek to make PEV use cheaper and more convenient than ICEV use but not public transit use, walking or cycling. In these cases, policy makers should seek to introduce incentives that make it more convince and cheaper to access transit locations. This could be achieved by having parking and charging incentives at public transport hubs.

3.2.Future Research

All studies that investigate the importance of infrastructure for PEVs consider PEV with ranges of around 100 miles. There are now several PEVs on the market with ranges of more than 200 miles with more than 15 models expected before 2020. Consumers who purchase these BEVs may have different perceptions relating to the importance of infrastructure due to the differing ranges of their vehicles. They may also use their vehicles differently and

have different charging behaviours. Future studies should investigate the importance of recharging infrastructure for adopters of PEVs with around 200 miles of range. Some reoccurring incentives have received less attention in the literature. Research into the impact of congestion charge zones for example is limited. The studies that did investigate them found them to be influential in shifting vehicle use from ICEVs to PEVs or less polluting vehicles. More research is needed to properly understand their effectiveness. More research is also needed to understand the effectiveness of annual road tax reductions or exemptions for PEVs.

A recent proposal by the Department for Agriculture and Rural Affairs and the Department for Transport (Department for Environment and Rural Affairs and Department for Transport, 2016) in the UK includes some incentives that have not been considered in the literature to date. One incentive would allow PEVs to move off from traffic lights before ICEVs. Another would allow PEVs to drive both ways down streets that are currently 1-way streets. These incentives do appear that they will increase the convenience of owing a PEV and therefore should be effective measures, though empirical research should be undertaken to ensure that this is the case. Some incentives, for example toll exemptions, will not be able to last indefinitely due to impacts of revenue. The removal of incentives too early in the market introduction of PEVs will have a negative impact on the market. PEVs should be able to gain a stable foothold on the market prior to incentive removal. Innovation theory suggests that new product market growth can be self-sustaining when they achieve around a 20% market share. Will this be the case for PEVs and at this point the market will no longer be reliant upon incentives? This question has significant implications and needs to be greater understood.

4. Acknowledgements

The authors would like to thank ClimateWorks Foundation for providing the funding that made this research possible.

5. References

Aasness, M.A., Odeck, J., 2015. The increase of electric vehicle usage in Norway incentives and adverse effects. Eur. Transp. Res. Rev. 7. doi:10.1007/s12544-015-0182-4

Adepetu, A., Keshav, S., Arya, V., 2016. An agent-based electric vehicle ecosystem model: San Francisco case study. Transp. Policy 46, 109–122. doi:10.1016/j.tranpol.2015.11.012

Ajanovic, A., Haas, R., 2016. Dissemination of electric vehicles in urban areas: Major factors for success. Energy 115, 1451–1458. doi:10.1016/j.energy.2016.05.040

Bakker, S., 2010. The car industry and the blow-out of the hydrogen hype. Energy Policy 38, 6540–6544. doi:10.1016/j.enpol.2010.07.019

Bakker, S., Jacob Trip, J., 2013. Policy options to support the adoption of electric vehicles in the urban environment. Transp. Res. Part D Transp. Environ. 25, 18–23. doi:10.1016/j.trd.2013.07.005

Bjerkan, K.Y., Nørbech, T.E., Nordtømme, M.E., 2016. Incentives for promoting Battery Electric Vehicle (BEV) adoption in Norway. Transp. Res. Part D Transp. Environ. 43, 169–180. doi:10.1016/j.trd.2015.12.002

Bonges, H.A., Lusk, A.C., 2016. Addressing electric vehicle (EV) sales and range anxiety through parking layout, policy and regulation. Transp. Res. Part A Policy Pract. 83, 63–73. doi:10.1016/j.tra.2015.09.011

Caltrans, 2017. High Occupancy Vehicle Systems [WWW Document]. URL http://www.dot.ca.gov/trafficops/tm/hov.html

Caperello, N., Tyreehageman, J., Davies, J., 2015. I am not an environmental wacko! Getting from early plug-in vehicle owners to potential later buyers. Transp. Res. Board 2015 Annu. Meet.

Carley, S., Krause, R.M., Lane, B.W., Graham, J.D., 2013. Intent to purchase a plug-in electric vehicle: A survey of early impressions in large US cites. Transp. Res. Part D Transp. Environ. 18, 39–45. doi:10.1016/j.trd.2012.09.007

Chorus, C.G., Koetse, M.J., Hoen, A., 2013. Consumer preferences for alternative fuel vehicles: Comparing a utility maximization and a regret minimization model. Energy Policy 61, 901–908. doi:10.1016/j.enpol.2013.06.064

Clinton, B., Brown, A., Davidson, C., Steinberg, D., 2015. Impact of Direct Financial Incentives in the Emerging Battery Electric Vehicle Market: A Preliminary Analysis.

Department for Environment and Rural Affairs, Department for Transport, 2016. Draft Clean Air Zone Framework.

Diamond, D., 2009. The impact of government incentives for hybrid-electric vehicles: Evidence from US states. Energy Policy 37, 972–983. doi:10.1016/j.enpol.2008.09.094

Egbue, O., Long, S., 2012. Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions. Energy Policy 48, 717–729. doi:10.1016/j.enpol.2012.06.009

Figenbaum, E., 2016. Perspectives on Norway's supercharged electric vehicle policy. Environ. Innov. Soc. Transitions. doi:http://dx.doi.org/10.1016/j.eist.2016.11.002

Figenbaum, E., Kolbenstvedt, M., 2016. Learning from Norwegian Battery Electric and Plug-in Hybrid Vehicle Users.

Hackbarth, A., Madlener, R., 2013. Consumer preferences for alternative fuel vehicles: A discrete choice analysis. Transp. Res. Part D Transp. Environ. 25, 5–17. doi:10.1016/j.trd.2013.07.002

Hardman, S., 2016. Consumer Adoption of Fuel Cell Vehicles: Lessons from Historical Innovations and Early Adopters of Battery Electric Vehicles. University of Birmingham.

Hardman, S., Chandan, A., Tal, G., Turrentine, T., 2017. The Effectiveness of Financial Purchase Incentives for Battery Electric Vehicles - A Review of the Evidence (Article Under Review). Renew. Sustain. Energy Rev.

Hardman, S., Tal, G., 2016. Exploring the decision to adopt a high-end battery electric vehicle: The role of financial and non-financial motivations. Transp. Res. Rec. J. Transp. Res. Board 16–1783.

Hoen, A., Koetse, M.J., 2014. A choice experiment on alternative fuel vehicle preferences of private car owners in the Netherlands. Transp. Res. Part A Policy Pract. 61, 199–215. doi:10.1016/j.tra.2014.01.008

Javid, R.J., Nejat, A., 2017. A comprehensive model of regional electric vehicle adoption and penetration. Transp. Policy 54, 30–42. doi:10.1016/j.tranpol.2016.11.003

Krause, R.M., Carley, S.R., Lane, B.W., Graham, J.D., 2013. Perception and reality: Public knowledge of plug-in electric vehicles in 21 U.S. cities. Energy Policy 63, 433–440. doi:10.1016/j.enpol.2013.09.018

Liao, F., Molin, E., van Wee, B., 2016. Consumer preferences for electric vehicles: a literature review. Transp. Rev. 1647, 1–24. doi:10.1080/01441647.2016.1230794

Lieven, T., 2015. Policy measures to promote electric mobility - A global perspective. Transp. Res. Part A Policy Pract. 82, 78–93. doi:10.1016/j.tra.2015.09.008

Lutsey, N., Slowik, P., Jin, L., 2016. Sustaining Electric Vehicle Market Growth in U.S. Cities.

Mersky, A.C., Sprei, F., Samaras, C., Qian, Z. (Sean), 2016. Effectiveness of incentives on electric vehicle adoption in Norway. Transp. Res. Part D Transp. Environ. 46, 56–68. doi:10.1016/j.trd.2016.03.011

Nicholas, M.A., Tal, G., Turrentine, T.S., 2016. Advanced Plug-in Electric Vehicle Travel and Charging Behavior Interim Report Advanced Plug in Electric Vehicle Travel and Charging Behavior Interim Report. Inst. Transp. Stud.

Nicholas, M. a, Tal, G., 2013. Charging for Charging : The Paradox of Free Charging and Its Detrimental Effect on the Use of Electric Vehicles.

Ozaki, R., Sevastyanova, K., 2011. Going hybrid: An analysis of consumer purchase motivations. Energy Policy 39, 2217–2227. doi:10.1016/j.enpol.2010.04.024

Percoco, M., 2014. The effect of road pricing on traffic composition: Evidence from a natural experiment in Milan, Italy. Transp. Policy 31, 55–60. doi:10.1016/j.tranpol.2013.12.001

Plötz, P., Gnann, T., Sprei, F., 2016. Can policy measures foster plug-in electric vehicle market diffusion ? EVS29.

Sangkapichai, M., Saphores, J.-D., 2009. Why are Californians interested in hybrid cars? J. Environ. Plan. Manag. 52, 79–96. doi:10.1080/09640560802504670

Shewmake, S., Jarvis, L., 2014. Hybrid cars and HOV lanes. Transp. Res. Part A Policy Pract. 67, 304–319. doi:10.1016/j.tra.2014.07.004

Tal, G., Nicholas, M.A., 2014. Exploring the Impact of High Occupancy Vehicle (HOV) Lane Access on Plug-in Vehicle Sales and Usage in California.

Tal, G., Nicholas, M.A., Davies, J., Woodjack, J., 2014. Charging Behavior Impacts of Electric Vehicle Miles Traveled- Who Is Not Plugging in? J. Transp. Res. Board 10.3141/24.

Tal, G., Nicholas, M.A., Turrentine, T.S., Turrentine, T., 2017. First Look at the Plug-in Vehicle Secondary Market. Inst. Transp. Stud.

Tal, G., Xing, Y., 2017. MODELING THE CHOICE OF PLUG-IN ELECTRIC VEHICLES IN CALIFORNIA: A NESTED LOGIT APPROACH, in: Transportation Research Board 2017 Annual Meeting.

Tietge, U., Mock, P., Lutsey, N., Campertrini, A., 2016. Comparison of Leading Electric Vehicle Policy and Deployment in Europe.

Wang, Y., Sperling, D., Tal, G., Fang, H., 2017. China's electric car surge. Energy Policy 102, 486–490. doi:10.1016/j.enpol.2016.12.034

Zhang, Y., Qian, Z. (Sean), Sprei, F., Li, B., 2016. The impact of car specifications, prices and incentives for battery electric vehicles in Norway: Choices of heterogeneous consumers. Transp. Res. Part C Emerg. Technol. 69, 386–401. doi:10.1016/j.trc.2016.06.014

Zheng, J., Mehndiratta, S., Guo, J.Y., Liu, Z., 2012. Strategic policies and demonstration program of electric vehicle in China. Transp. Policy 19, 17–25. doi:10.1016/j.tranpol.2011.07.006