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# Understanding the impact of reoccurring and non-financial incentives on plug-in electric vehicle adoption – A review

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A B S T R A C T

The market introduction of plug-in electric vehicles (PEVs) is being partially driven by policy interventions. One type of intervention is reoccurring and non-financial incentives, these differ from financial purchase incentives which are a one-time financial incentive associated with the purchase of a PEV. Reoccurring and non-financial incentives include special lane access for PEVs (e.g. HOV/carpool lanes, bus lanes), parking incentives, charging infrastructure development, road toll fee waivers, and licensing incentives. They also include disincentives such as gasoline tax or annual vehicle taxes. The impact of these incentives differs between regions partially due to differences in traffic conditions, travel patterns, consumer preferences, and other local variations. Due to these differences, it is challenging to rank the importance of these incentives, however existing research shows that they all can have a positive impact on PEV adoption. Policymakers wishing to promote the introduction of PEVs will need to consider local travel patterns, the regulatory environment, and consumer preferences to determine the most viable policy interventions for their region.

## 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 partially dependent on policymakers providing incentives to consumers. Policymakers 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 impact of these on PEV market uptake was explored in Hardman et al. (2017). The review did not consider any other incentives although the authors acknowledge that financial purchase incentives alone may not be sufficient and could be paired with other incentives. Two previous literature reviews have investigated influential factors in the purchase of an electric vehicle including reoccurring and non-financial incentives (Coffman et al., 2017; Liao et al., 2016). Those papers were accepted for publication in mid 2016. Therefore, they do not include PEV adoption research published in the last two years. As this review will show much of this newer literature provides more conclusive evidence on the impact of non-financial and reoccurring incentives.

### 1.1. Introduction to reoccurring and non-financial incentives

Reoccurring and non-financial incentives are received by PEV buyers after they purchase their vehicle and often continue throughout the time of owning it. They differ from financial purchase incentives which are financial discount, tax credit, or rebate received only at the time of purchase. Reoccurring incentives are received repeatedly throughout owning a PEV, they can be financial in nature for example toll road fee waivers. Non-financial incentives may or may not be received repeatedly during vehicle ownership, and can include incentives that are not financial in nature, for example being able to drive a PEV in bus lanes. Infrastructure

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**Table 1**
The incentives considered in this study and an example of each.

| Incentive Type | Incentive | Example |
|---|---|---|
| Reoccurring or non-financial incentive | HOV, bus, or transit lane access | • PEVs in California can drive in HOV lanes with a single occupant.<br>• In Norway BEVs can drive in bus lanes. |
| | Free, discounted, or preferential parking | • In some London boroughs BEVs pay a substantially discounted parking fee.<br>• BEVs receive free or discounted fees in some public parking garages in California (e.g Sacramento). |
| | Infrastructure Development | • Workplaces offering charging for employees.<br>• Public charging in parking garages.<br>• Chargers on travel corridors. |
| | Toll or road charge waivers or discounts | • BEVs in Norway do not pay toll charges on roads, tunnels, or bridges.<br>• BEVs are exempt from the London congestion charge in the UK. |
| | Licencing Incentives | • In Shanghai BEVs do not need to enter the licence plate auction. |
| Disincentives | Gasoline prices | • In European Nations (e.g UK) 65% the price of gasoline is tax or fuel duty. |
| | Circulation tax or annual vehicle tax | • In Norway BEVs pay a reduced annual tax. |

development is also a way of encouraging consumers to purchase PEVs. Non-financial or reoccurring incentives may be funded by national, local, or regional government organisations; or by private companies (e.g. electric utilities). The incentives considered in this review include those that investigate the impact of PEV access to high occupancy vehicle (HOV), bus, and transit lanes; the development of recharging infrastructure; parking incentives; and toll, or road fee waivers. The review also covers studies that investigate disincentives, which are policy interventions that make ICEV ownership less attractive. These disincentives include annual or circulation tax exemptions and studies that include gasoline price in their analysis. Each of these policy interventions is described in brief below. Table 1 gives an overview these incentives and provides an example of each.

High occupancy vehicle (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, in some regions they are in operation 24 h per day/7 days per week. HOV lanes are sometimes called carpool lanes or 2+ lanes. Bus lanes are lanes that are usually only accessible to buses or coaches. Taxis, motorcycles, or cyclists can often access the lanes. Some nations have 'priority lanes' or 'fast transit lanes' these lanes are often restricted or require payment to use. Some regions have introduced incentives that allow PEVs unlimited access to these lanes.

Electric vehicles are partially reliant on the development of recharging infrastructure, though they can be recharged from standard electrical outlets. Infrastructure development is not a direct way of incentivising consumers to adopt a PEV. However, increasing the number of PEV charging stations may serve as an incentive to encourage consumers to adopt the vehicles. Policymakers, workplaces, utilities, and local agencies are facilitating the introduction of this infrastructure with the hope of increasing PEV market uptake. In some cases, charging is offered for free which adds an additional incentive for consumers.

Parking incentives include free or discounted parking in paid parking lots/garages. It can also include parking spaces reserved for PEVs or parking spaces in preferential locations. In many cases, PEV only parking spaces will also have electric vehicle charging.

Toll charges are applied on roads, bridges, tunnels, and boats that are 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 infrastructure. Some nations allow PEVs to drive on these roads without paying the toll fee or give a discount for PEVs. Road charge zones, for example the London Congestion Charge, apply to larger areas often the entire central area of a city. For vehicles to enter anywhere inside this zone they must pay a fee. Some congestion charge zones have fee exemptions for PEVs.

In some nations vehicles are required to pay an annual tax or circulation tax. This tax occurs every year the vehicle is registered to be driven on the road. These tax regimes calculate the amount of tax based on a vehicles $CO_2$ emissions or efficiency, vehicle class, and/or vehicle weight. In Norway for example vehicles pay an annual vehicle tax that is based on vehicle fuel type and weight. PEVs often pay a reduced fee due to their lower emissions, or in some cases are exempt from paying these fees.

The impact of gasoline price on PEV sales is also included in this study. Gasoline price increases are not always associated with tax increases or any policy intervention as gas price is also impacted by market forces. Some nations do have a progressive fuel tax, fuel duty, or gasoline tax. These taxes are often not introduced to encourage consumers to purchase PEVs, their introduction is as a measure to manage fuel consumption or emissions, or to raise tax revenue. This literature review includes studies that investigate the impact of fuel price on PEV sales, though the intended effect of fuel price increases is not always to promote PEV sales.

Finally, this review considers some incentives that are only used in limited locations. These 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. Consumers wanting to purchase a BEV or a PHEV receive a free licence plate without having the enter the lottery (Y. Wang et al., 2017).

## 2. Method

The aim of this study is understanding the impact of reoccurring and non-financial incentives on the purchase or use of PEVs. The scope of this review is studies that investigate the incentives outlined above, and investigate how they impact consumer purchase

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

| Authors | Methods | Vehicle Type | Region | Incentives considered | | | | | | Conclusions |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | HOV, Bus or Rapid Transit Lane | State Funded Infrastructure | Parking Incentives | Toll or Road Charge Exemptions | Annual Tax incentives | Licencing Incentives | |
| Aasness and Odeck (2015) | Case Study | PEVs | Norway | ✓ | | ✓ | ✓ | | | Toll exemptions, bus lane access, and free parking have had a positive impact on PEV adoption |
| Adepetu et al. (2016) | Agent based model | PEVs | California | | ✓ | | | | ✓ | The presence of work based charging leads to slightly increased rates of PEV adoption |
| Ajanovic and Haas (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 and Trip (2013) | Workshops with policy makers | BEVs | Europe | ✓ | ✓ | ✓ | | | | Infrastructure development is the most important measure in promoting BEV sales, free parking can be used as a temporary measure, bus lane access can also be used to promote BEVs |
| Bjerkan et al. (2016) | Questionnaire Survey | BEVs | Norway | ✓ | | ✓ | ✓ | | | Toll fee waivers, followed by free parking and bus lane access, are the most important incentives in promoting PEVs |
| Bonges and Lusk (2016) | Case Studies | BEVs | USA | | ✓ | | | | | Improving access to infrastructure will increase PEV rates of adoption |
| Caperello et al. (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 |
| Clinton et al. (2015) | Statistical Analysis | BEVs | USA | ✓ | | | | | | Results inconclusive due to limited variation in variables over the time of the study |
| Coffman et al. (2017) | Literature Review | PEVs | Global | ✓ | ✓ | | ✓ | ✓ | | There is a relationship between PEV sales and infrastructure though causality is not clear. Impact of HOV lanes is not well understood. Little evidence for toll fees. No literature on parking. Most studies on gas price are TCO type studies |
| Egbue and Long (2012) | Questionnaire Survey | BEVs | USA | | ✓ | | | | | Developing infrastructure will reduce barriers to adoption and increase BEV sales |
| Egnér and Trosvik (2018) | Statistical Analysis | PEVs | Sweden | | ✓ | ✓ | | | | Impact of parking incentives is positive and could be more cost effective than offering purchase subsidies. Increasing the number of charging points |

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**Table 2** (*continued*)

| Authors | Methods | Vehicle Type | Region | Incentives considered | | | | | | Conclusions |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | HOV, Bus or Rapid Transit Lane | State Funded Infrastructure | Parking Incentives | Toll or Road Charge Exemptions | Annual Tax incentives | Licencing Incentives | |
| | | | | | | | | | | increases rates of adoption especially in urban areas |
| Figenbaum (2017) | Multi-Layer Perspective | BEVs | Norway | ✓ | | | ✓ | | | Bus lane access and toll exemptions have been important in attracting buyers to BEVs |
| Figenbaum and Kolbenstvedt (2016) | Questionnaire Survey | PEVs | Norway | ✓ | ✓ | ✓ | ✓ | ✓ | | The most important incentives for PEV buyers are toll exemptions, then free parking is, and finally workplace charging. Bus lane access is the least important incentive |
| Hackbarth and Madlener (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 and Tal (2016) | Interviews | BEVs | California | ✓ | ✓ | ✓ | | | | High-end BEV buyers are motivated for technological, environmental and performance motivations. HOV lane access, workplace charging and free parking are not motivational factors but may increase likelihood of repeat purchases |
| Hoen and Koetse (2014) | Questionnaire Survey (Stated Choice Experiment) | FCVs and PEVs | Netherlands | ✓ | | ✓ | | ✓ | | Free parking and bus lane access may stimulate adoption. The findings are not statistically significant though. Bus lane access may be the most important incentive |
| Huang and Qian (2018) | Questionnaire Survey (Stated Preference) | PEVs | China | ✓ | ✓ | | ✓ | | ✓ | Consumers are sensitive to vehicle purchase price, running costs, purchase incentives, and charging infrastructure availability. EV purchase intentions are not impacted by bus lane access, congestion charge exemptions, or licence lottery |
| Javid and Nejat (2017) | Statistical Analysis | PEVs | California | | ✓ | | | | ✓ | Developing charging infrastructure and raising gas prices can help increase PEV sales |
| Jenn et al. (2018) | Statistical Analysis | PEVs | USA | ✓ | ✓ | | | | | HOV lane access can increase PEV sales by around 50% (weighted by traffic density). HOV lane access can be particularly effective in states with high density of traffic and HOV lanes. Financial incentives and consumer awareness are also correlated with PEV sales |
| Kangur et al. (2017) | Questionnaire Survey (Stated Preference) | PEVs | Netherlands | | ✓ | | | ✓ | | |

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**Table 2** (*continued*)

| Authors | Methods | Vehicle Type | Region | Incentives considered | | | | | | Conclusions |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | HOV, Bus or Rapid Transit Lane | State Funded Infrastructure | Parking Incentives | Toll or Road Charge Exemptions | Annual Tax incentives | Licencing Incentives | |
| | | | | | | | | | | A combination of gasoline tax and fast charging networks leads to higher PEV sales |
| Krause et al. (2013) | Questionnaire Survey | PEVs | USA | ✓ | | ✓ | | | | Awareness of incentives is too low for them to have an impact on consumer interest in PEVs |
| Levinson and West (2017) | Modelling | PEVs | USA | | ✓ | | | | | DC fast chargers are more effective than level 2 chargers at encouraging PEV sales, though only if one DC fast is built for every 10 Level 2. Diminishing returns for BEV sales occur at 30,000 DC Fast chargers. No returns occur after 80,000 DC fast chargers |
| Liao et al. (2016) | Literature Review | BEVs | | ✓ | | ✓ | | | | No consensus within the literature on whether free parking or free charging is effective |
| Lieven (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 et al. (2016) | Statistical Analysis | PEVs | USA | ✓ | ✓ | ✓ | | | | There is a statistically significant relationship 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 et al. (2016) | Statistical Analysis | BEVs | Norway | ✓ | ✓ | | ✓ | | | BEV infrastructure, being near to major cities and income are the most significant predictors of BEV market share |
| Narassimhan and Johnson (2018) | Statistical Analysis | PEVs | USA | ✓ | ✓ | | | ✓ | | Regression model finds purchase incentives (rebates more than tax credit), charging infrastructure, and gasoline price are correlated with PEV sales. HOV lane access also correlated but not significant |
| Nicholas and Tal (2013) | Questionnaire Survey | BEVs | California | | ✓ | | | | | Free workplace charging can increase PEV sales, however It can have negative effects if chargers become congested |
| Plötz et al. (2016) | Statistical Analysis | PEVs | USA and Europe | | ✓ | | | | ✓ | PEV adoption is correlated to income, gasoline price, the presence of non- |

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**Table 2** (*continued*)

| Authors | Methods | Vehicle Type | Region | Incentives considered | | | | | | Conclusions |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | HOV, Bus or Rapid Transit Lane | State Funded Infrastructure | Parking Incentives | Toll or Road Charge Exemptions | Annual Tax incentives | Licencing Incentives | |
| | | | | | | | | | | financial incentives and the number of charging stations |
| Sheldon and DeShazo (2017) | Statistical Analysis | PEVs | California | ✓ | | | | | | 1/4 of PEV sales in California from 2010 to 2013 were a result of HOV lane access. Buyers in Sacramento and San Francisco are more sensitive to HOV lane access compared to those in LA and San Diego |
| Tal and Nicholas (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 et al. (2017) | Questionnaire Survey | PEVs | California | ✓ | | | | | | PEVs with HOV lane stickers are purchase on average for US$1400 more than if they do not have a sticker |
| Tal and Xing (2017) | Questionnaire Survey | PEVs | California | ✓ | | | | | | Locality to HOV lanes is statistically related to PEV adoption rates |
| Tietge et al. (2016) | Case Studies using statistical analysis | PEVs | Europe | ✓ | ✓ | | ✓ | | | Financial incentives alone are not enough to encourage PEV adoption they should be paired with non-financial incentives for example HOV lane access and developing charging infrastructure |
| N. Wang et al. (2017) | Questionnaire Survey (Stated Preference) | PEVs | China | ✓ | ✓ | ✓ | | | ✓ | Licence plate incentives and driving restrictions have the most significant positive effects on PEV adoption, followed by discounted/free charging, bus lane access, and reduced parking fees |
| S. Wang et al. (2017) | Questionnaire Survey (Stated Preference) | PEVs | China | ✓ | ✓ | ✓ | | | ✓ | "Convenience incentives" are correlated with intention to purchase PEVs. Financial purchase incentives and information provision are also correlated with purchase intentions, but are less important |
| Y. Wang et al. (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 |
| Wee et al. (2018) | 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 |
| Wolbertus et al. (2018) | Statistical Analysis | PEVs | USA | ✓ | ✓ | ✓ | | ✓ | | |

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**Table 2** (*continued*)

| Authors | Methods | Vehicle Type | Region | Incentives considered | | | | | | Conclusions |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | HOV, Bus or Rapid Transit Lane | State Funded Infrastructure | Parking Incentives | Toll or Road Charge Exemptions | Annual Tax incentives | Licencing Incentives | |
| | | | | | | | | | | Whether free parking is related to PEV sales depends on parking provision and parking costs. Fuel and charging station variables are significantly related. HOV lane access does not appear to have a big effect on PEV purchase, though this could be due to the limited availability of HOV lanes |
| Zhang et al. (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 et al. (2012) | Interviews with policy makers | PEVs | China | ✓ | ✓ | ✓ | ✓ | | | Road charge exemptions, priority/ HOV lane access, free or discounted parking, infrastructure development and effective increasing PEV adoption |

decisions, or use patterns, of PEVs. The review does not consider whether consumers use these incentives, the cost effectiveness of them, impacts to congestion, how these incentives impact total cost of ownership of PEVs, or other issues associated with their implementation. This review also does not include other alternative fuel vehicles such as hybrid electric vehicles, natural gas vehicles, or any others.

The papers included in this review were identified using a literature search. Search terms were used to find papers based on the title of the study. These terms included the incentives themselves (e.g. HOV lanes, parking, infrastructure, etc.), and terms to identify studies that investigate these incentives and studies that focus on PEV sales, stated preference studies, and post purchase surveys. Once the studies were identified their titles were screened to ensure they were applicable to the topic in question, this process identified 62 relevant studies. These papers abstracts, and introductions were screened to further ensure they were relevant, this lead to 21 papers being omitted resulting in the 41 papers that are included in this study.

## 3. Literature review

Table 2 shows a breakdown of the studies reviewed. The table shows the methods used in each study, which vehicles they consider, the region of analysis, and the incentives considered. 30 studies investigate HOV, bus or rapid transit lanes, 28 studies PEV infrastructure development, 20 parking incentives, 10 toll or road charge exemptions, 4 investigate annual tax reductions, 7 include gasoline cost in their analysis, and there are 5 studies that consider licensing incentives. In the following sections, the findings of these papers on a topic by topic basis are presented, starting with HOV lanes, then infrastructure, parking incentives, toll or roach charge emptions, annual tax, gas costs, and finally licencing incentives.

### 3.1. HOV, bus or transit lane access

The literature search identified 30 studies that analysed the relationship between HOV, bus, or transit lane access and PEV adoption. Studies have mostly focused on investigating HOV lane access in the USA, specifically California; and bus lane access in Norway. This is perhaps due to California and Norway having numerous incentives for PEVs and high PEV market shares. Researchers have used statistical analysis, questionnaire surveys, qualitative methods, and interviews with stakeholders and policymakers to understand the impact of this intervention.

Studies analysing sales data have found a correlation between PEV adoption in the USA and California, and HOV lanes (Jenn et al., 2018; Lutsey et al., 2016; Narassimhan and Johnson, 2018; Sheldon and DeShazo, 2017). These studies suggest a 25% (Sheldon and DeShazo, 2017) to 50% (Jenn et al., 2018) increase in PEV sales are because of HOV lane access for PEVs. Some studies that analysed sales data were unable to find a significant correlation between bus or HOV lane access, and PEVs sales (Clinton et al., 2015; Mersky et al., 2016), though this may be due to issues of cross correlations in their data and not enough variation in the incentive throughout the time of analysis. A final study using sales data by Wee et al. (2018) was unable to determine whether HOV lane access for PEVs had a significant impact on PEV sales, they state this could be due to the limited availability of the lanes.

Qualitative research involving PEV adopters as research subjects found that HOV lane access can be important for PEV buyers living in congested regions (Caperello et al., 2014). Though for adopters of high-end BEVs (e.g. Tesla Model S) HOV lane access was not a reason for purchase (Hardman and Tal, 2016), these adopters were attracted to the vehicles for other reasons. Even for this group HOV lane access is an important benefit of owning the vehicles, which may increase the likelihood of repeat purchases.

Studies using questionnaire surveys have either used stated preference methods or post purchase surveys. Stated preference studies have found that HOV lane access for PEVs can increase purchase intentions in the USA (Krause et al., 2013), Germany (Hackbarth and Madlener, 2013), the Netherlands (Hoen and Koetse, 2014), and China (N. Wang et al., 2017; S. Wang et al., 2017). Though for the incentive to have an impact on consumer purchase decisions they first need to be aware of the inventive (Krause et al., 2013). Two stated preference studies in Norway were unable to conclude that bus lane access was an effective policy intervention in promoting PEV sales, this was because respondents were concerned about PEVs causing congestion in bus lanes (Aasness and Odeck, 2015; Zhang et al., 2016). A study in China also found that HOV lanes would not increase purchase intentions of PEVs (Huang and Qian, 2018), though their sample size was small (n = 348). The results of post purchase surveys are less contentious. Studies in the USA (Tal et al., 2017; Tal and Nicholas, 2014; Tal and Xing, 2017), and Norway (Bjerkan et al., 2016; Figenbaum and Kolbenstvedt, 2016) have found that HOV or bus lane access was important for PEV adopters, though the most importance incentive was financial purchase incentives.

Two studies interviewed policymakers and stakeholders in Germany (Bakker and Trip, 2013) and China (Zheng et al., 2012). Both studies found that policymakers believed the intervention could be an effective incentive to promote PEV sales. Finally diffusion study by Figenbaum used multilevel perspective theory to understand the PEV market in Norway, the author describes the benefit of bus lane access as a time saving benefits and that it also serves to advertise the vehicles to other drivers who see PEVs driving in bus lanes (Figenbaum, 2017).

Of the 30 studies on HOV or bus lanes 23 concluded that they have some impact on PEV sales. The ones that did not find any correlation include stated preference studies and studies using statistical analysis methods. All post purchase studies found that PEV buyers report HOV lane access and bus lane access as having some impact on their decision to buy a PEV.

### 3.2. PEV charging infrastructure

PEV charging infrastructure has been investigated from several perspectives, including how PEV adopters use the infrastructure,

impacts on electricity grids, emissions impacts, and other topics. This paper only includes studies that investigate the impact of PEV charging infrastructure on consumers purchase decision. 28 studies investigated infrastructure and PEV adoption.

Studies using statistical analysis in the USA (Adepetu et al., 2016; Ajanovic and Haas, 2016; Javid and Nejat, 2017; Lutsey et al., 2016; Narassimhan and Johnson, 2018; Plötz et al., 2016; Wee et al., 2018), Sweden (Egnér and Trosvik, 2018a), Norway (Mersky et al., 2016), and China (Ajanovic and Haas, 2016) have all found a relationship between PEV sales, and the number of charging stations or the presence of workplace, public, or home location infrastructure. Determining whether infrastructure development has a causal relationship with PEV sales is difficult. Often infrastructure is developed in regions that have an existing PEV market. Without high resolution data this makes it difficult to detect whether PEV sales increased because of infrastructure development, or whether they are both increasing in conjunction with each other.

Determining causality can be easier with surveys and interviews, though these rely on self-reported data. One study using interviews found that the presence of public infrastructure did not motivate buyers of these vehicles, as they mostly charged from home, workplace charging was an important benefit of owning a BEV for some interviewees though (Hardman and Tal, 2016). Stated preference studies have found that developing PEV infrastructure can alleviate buyer concerns about PEV range and increase their likelihood of purchasing a PEV (Egbue and Long, 2012; Huang and Qian, 2018; S. Wang et al., 2017; Zhang et al., 2016). Lieven (2015) surveyed consumers in 20 counties, using cluster analysis they identified three types of consumers based on their preferences for incentives. The first cluster valued only financial incentives, the second only charging infrastructure, and the third all incentives (including infrastructure). The second cluster was 42% of their sample. Using a vehicle choice model Levinson and West (2017) found that increasing the number of level 2 and DC fast chargers can increase PEV sales, though DC fast chargers were more effective in increasing sales. Deployment of DC fast chargers was also found to increase PEV sales in the Netherlands (Kangur et al., 2017). Using a discrete choice model N. Wang et al. (2017) found that in China discounted or free charging can lead to increased rates of PEV adoption. Researchers have also surveyed consumers who have purchased a PEV. These studies found that the provision of free workplace charging can encourage PEV sales in California (Nicholas and Tal, 2013) and in Norway (Figenbaum and Kolbenstvedt, 2016), though in Norway it was the third most influential intervention (after toll exemptions and free parking).

In workshops with policymakers in Europe all policymakers recognised the importance of infrastructure in encouraging PEV adoption (Bakker and Trip, 2013). A study in 10 Chinese cities also found that stakeholders believed infrastructure was needed, in addition to purchase incentives (Zheng et al., 2012), agreeing with (Y. Wang et al., 2017) who also highlight the need for infrastructure but state that it is not the most important consideration.

Of the 28 studies reviewed in this paper 28 concluded that the development of infrastructure is somehow related to PEVs sales, though it is difficult to determine causality, something that was also highlighted by Coffman et al. (2017). This is especially true as PEV markets are still relatively immature and concentrated in a few locations where infrastructure development is also occurring. Stated preference and post purchase surveys have also found that infrastructure is important in the decision to purchase a PEV, this may suggest that developing infrastructure can increase PEV market growth.

### 3.3. Parking incentives

Within the literature 20 studies have assessed the impact of free, discounted, or preferential parking for PEVs using statistical analysis, questionnaire surveys, interviews, and workshops. This research has been conducted in the USA, often in California; in Europe, often in Norway or Sweden; and in China.

Studies using statistical analysis in the USA (Lutsey et al., 2016; Wee et al., 2018); the USA, Europe, and China (Ajanovic and Haas, 2016); Sweden (Egnér and Trosvik, 2018b); and Norway (Aasness and Odeck, 2015; Mersky et al., 2016) found that free parking is correlated with PEV sales, especially in urban areas. Stated preference studies in Germany (Hackbarth and Madlener, 2013), the Netherlands (Hoen and Koetse, 2014; Wolbertus et al., 2018), the USA (Krause et al., 2013), China (N. Wang et al., 2017; S. Wang et al., 2017), and globally (Lieven, 2015) found free parking was important for some potential buyers. These studies find that offering free or discounted parking, or a dedicated parking space can increase intent to purchase a PEV, these studies found that this incentive is more important in urban areas. Lieven (2015) found that, though valuable, purchase incentives and infrastructure development were more important for potential PEV adopters. Krause et al. (2013) found that whilst free parking can increase purchase intentions, only 1.7% of adopters were aware of the free parking already offered in regions that they live suggesting its actual impact on sales was low.

The authors of this literature review identified two studies that surveyed PEV adopters and asked them about the importance of free parking in their purchase decision. Both of these studies were conducted in Norway and found that free parking was the second most important reoccurring incentive, after toll road access (Bjerkan et al., 2016; Figenbaum and Kolbenstvedt, 2016).

Workshops in Europe found that policymakers believed free parking could promote PEV sales though it would only be a temporary measure. In the case of cities with high demand for parking stakeholders believed that ICEV drives could resent PEV drivers and there could be a fall in revenue from parking, this could create a budget deficit in some regions (Bakker and Trip, 2013).

Two studies found no evidence to suggest parking incentives could increase PEV sales, the first used interviews and did not focus on the topic (Hardman and Tal, 2016) and the second was a literature review (Liao et al., 2016). The review was unable to find any evidence in the literature regarding free parking or its impact on PEV adoption, perhaps due to them omitting studies included in this review paper and the review not benefiting from subsequent research. This research finds a positive relationship between PEV sales and parking incentive. Therefore, it appears that free parking for PEVs does impact PEV sales, though more so in urban areas.

### 3.4. Toll or road charge exemptions

Toll or road charge exemptions have been studied less than the other incentives considered, this is perhaps due to them being used less frequently. There are 10 studies that investigate the effectiveness of toll and road charge exemptions. These studies have considered Norway, France, Netherlands, and China. Most of these studies (6 in total) considered in the impact of toll waivers in Norway. The first of these analysed disaggregated sales data but was unable to find a relationship between PEV sales and toll exemptions, however this may have been due to the toll exemption variable being correlated with the level of urbanisation (Mersky et al., 2016). Stated preference surveys found that toll exemptions increased the likelihood of consumers purchasing a PEV (Zhang et al., 2016), and surveys of PEV buyers have found that they report this as being an important incentive in their purchase decision (Bjerkan et al., 2016; Figenbaum and Kolbenstvedt, 2016). These surveys of PEV buyers found that toll fee waivers were the most important reoccurring incentive for PEV adopters in Norway. Case studies have also identified toll fee waivers as important policies in promoting PEV sales in Norway (Aasness and Odeck, 2015; Figenbaum, 2017). A stated preference study in China was unable to determine a relationship between toll fee waivers and purchase intentions of PEVs (Huang and Qian, 2018).

Toll or road charge fee waivers have not been as well researched as some of the other interventions considered in this review. However, 7 of the 10 studies identified found a relationship between the two. The three studies that did not find a relationship were an older literature review, a study on PEV sales with potential collinearity issues, and a stated preference survey.

### 3.5. Annual/circulation tax incentives

Only 5 studies in this review considered the impact that annual or circulation taxes have in promoting PEV sales. These policies may not have explicitly been introduced to promote PEVs, but they can have an impact of PEV sales. Three studies used stated preference methods to investigate the impact of these incentive. (Hackbarth and Madlener, 2013) investigated the importance of annual tax exemptions for AFVs, which included BEVs and PHEVs. They found that the removal of this incentive would have a significant negative impact on AFV markets, and consumers willingness to pay for AFVs would fall by €2330–4700. (Hoen and Koetse, 2014) found that in the Netherlands road tax exemptions are highly valued by consumers and their removal would have a negative impact on the market. (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 tax discounts were an important reason for the purchase of a BEV (Figenbaum, 2017). This study found that tax exemptions were a significant contributor to the purchase of a BEV for 49% of buyers.

### 3.6. Gasoline prices

Several studies have investigated the impact of vehicle fuel price in their analysis, again the price of gasoline often isn't dictated by policy nor are increases in its price intended to increase PEV sales, however studies have observed a relationship between the two. Four of these studies have focussed on the USA (Adepetu et al., 2016; Javid and Nejat, 2017; Narassimhan and Johnson, 2018; Wee et al., 2018), one study investigated both the USA and Europe (Plötz et al., 2016), and another focused on the Netherlands (Kangur et al., 2017). Most studies found that higher gas prices are significantly related to PEV market share. Suggesting that if policymakers did increase gas price the impact on PEV sales could be positive. 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 PHEVs and BEVs.

### 3.7. Licencing incentives

In their short communication Y. Wang et al. (2017) indicate that one of the most important incentives for PEV adoption in China was the ability to get a free license plate. In some regions, there is a significant waiting list to get a license plate for new vehicle buyers. 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. Two stated preference studies in China found a significant relationship between vehicle licensing incentives and the intent to purchase a PEV (N. Wang et al., 2017; S. Wang et al., 2017), a third study was unable to find a significant relationship (Huang and Qian, 2018).

## 4. Summary

This review examined the findings of 41 studies that investigate non-financial and reoccurring incentives for PEVs. Of the 30 studies investigating the importance of HOV, bus or transit lanes 23 found that these lanes have a positive impact on PEV adoption. All studies that explored the importance of charging infrastructure found that it was an important factor in growing the PEV market. 18 of the 20 studies that explore parking incentives found them to be an effective measure for encouraging consumers to purchase PEVs. 10 studies investigate the impact of toll or road charges, 7 studies found that toll fee waivers have a relationship with PEV sales. 7 papers investigated the impact of gasoline price on PEV sales of which 5 found a relationship. All 4 studies on the importance of

**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 the given incentive to be effective in increasing PEV sales. The final column shows the reasons some studies did not find the incentive to be effective.

| 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 | 30 | 23 | • Not enough variation in dataset to detect any relationships (Clinton et al., 2015).<br>• Literature review unable to find clear trends in literature (Liao et al., 2016).<br>• Literature review unable to find clear trends in literature (Coffman et al., 2017).<br>• Unable to detect relationship due to cross correlations in dataset (Mersky et al., 2016).<br>• Potential buyers of PEVs concerned about bus lane congestion (Zhang et al., 2016).<br>• Stated preference study that finds bus lane access doesn't impact purchase intentions, the study has a small sample size (n = 248) (Huang and Qian, 2018).<br>• Analysis of sales data in USA finds no relationship between PEV sales and HOV lanes access, though this could be due to the limited availability of the lanes (Wee et al., 2018). |
| Infrastructure Development | 28 | 28 | |
| Parking Incentives | 20 | 18 | • Consumers see this as a benefit but not a purchase motivation (Hardman and Tal, 2016).<br>• Literature review unable to find trends in literature (Liao et al., 2016). |
| Toll/Road Charge Exemptions | 10 | 7 | • 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).<br>• Literature review unable to find clear trends in literature (Coffman et al., 2017).<br>• Stated preference study that toll fee waivers do not impact purchase intentions, the study has a small sample size (n = 248) (Huang and Qian, 2018). |
| Gasoline Cost | 7 | 5 | • No evidence to suggest that increasing gas prices results in increased PEV sales according to their model (Adepetu et al., 2016).<br>• Literature review unable to find clear trends in literature (Coffman et al., 2017). |
| Annual Tax | 4 | 4 | |
| Licencing Incentives | 5 | 5 | |

annual tax exemptions or reductions found a relationship with these incentives and PEV sales. Finally, 5 studies investigated the impact of vehicle licensing incentives in China, these studies found that the ability to register a PEV more easily than a conventional vehicle was a strong incentive. Table 3 outlines the reasons why some studies on special lane access, parking incentives, toll or road fee waivers, or gasoline prices were unable to detect any relationships between these and PEV adoption. The reasons are often methodological in nature, including a lack of variation in the data, issues with collinearity, or small sample sizes. Some previous literature reviews were unable to conclude whether incentives impact PEV sales due to these reviews being published before more recent studies published in 2016, 2017, & 2018.

Most studies on incentives find that they can have a positive impact on PEV adoption. These incentives make PEV ownership easier, cheaper, and more convenient for buyers. HOV lane access can reduce travel times for buyers. Infrastructure gives buyers easier access to charging making it more convenient to own a PEV, though caution is needed in determining causality with PEV sales and infrastructure as it is not clear whether PEV increase as a result of developing more infrastructure or vice versa. Parking incentives allow PEV drivers to save money or give them better access to parking spaces. Toll fee waivers reduce the cost of driving a vehicle. Progressive gasoline tax or annual tax creates an environment where the low running costs of PEVs are even greater and finally vehicle licensing incentive such as those in China make it easier and cheaper to purchase a new vehicle.

## 5. Conclusion and discussion

Various reoccurring and non-financial incentives currently exist that promote the adoption of PEVs, either as an intervention designed to promote PEVs or policy not specifically designed to promote PEVs (e.g. Gasoline tax). It was hoped that by reviewing the literature on these incentives this review could rank the importance of them by those that have the largest impact on PEV sales. However, the impact of these incentives differs between regions, within regions, and based on the data and methods used by researchers, which makes it difficult to rank these incentives. Based on currently published research it appears that all of these incentives have a positive impact on PEV sales. The impact of HOV or bus lane access on PEV sales may depend on the level of congestion in the region they are deployed. In more congested regions the ability for PEVs to drive in special lanes and bypass densely trafficked roads will be more incentivising to potential PEV adopters. Evidence on these lanes is so far limited to California and Norway. Research needs to consider whether these incentives will be effective in other regions, though it would seem likely that they

will be effective if the right conditions exist. All studies on infrastructure found that it has an impact on sales. There will be regional differences in the importance of infrastructure, something which is explored in more detail in another literature review (Hardman et al., 2018). Infrastructure needs depend on travel patterns, and whether vehicle owners can charge their vehicles at home, amongst other factors. In regions with less home charging access, more public and workplace charging may be needed. Parking incentives also have a positive impact on PEV sales. These incentives may be most effective in regions where parking is costly or scarce, which may mean this incentive is mostly applicable in urban areas. Toll and road charge exemptions are clearly only an option in regions with these fees, however these fee waivers provide a valuable incentive to drivers that use those roads. Their effects may not spread nationwide, as toll roads do not typically cover whole counties. Increases in gasoline prices may have an impact on PEVs sales, since the market introduction of PEVs began in around 2010 there hasn't been a consistent increase in gasoline prices, which makes understanding the correlation between gas price and PEV sales challenging to investigate. Further to this in many regions increasing gas prices is politically unfavourable or infeasible, making it a difficult intervention to introduce. Lower annual taxes also appear to encourage PEV adoption, the impact of this is likely greater in regions that have higher annual taxes. The final incentive considered in this study was vehicle licensing incentives, such as those operating in China. The ability to obtain a licence for a PEV far easier and at a lower cost than a conventional vehicle appears to have a substantial impact on encouraging consumers to purchase a PEV.

This study did not focus on all topics relevant to PEV market entry. It did not consider consumers purchase motivations, attitudes toward PEVs, financial purchase incentives, or consumer education and outreach, all of which are important considerations in the market introduction of PEVs. This reviews contribution is a detailed look at the literature on reoccurring and financial incentives, it is hoped that by providing this the paper can inform the debate on the role of these incentives in the market introduction of PEVs.

### 5.1. Policy implications

This review shows how several different types of incentives can promote PEV sales. In Norway PEVs benefit from free parking, toll fee waivers, bus lane access, well developed infrastructure, and do not pay annual tax. PEVs also receive financial purchase incentives, gas price is high in Norway, and Norway benefits from an electric vehicle association. The policy environment in Norway is perfect for PEVs and it is not surprising that the PEV market share was 40% in 2017. The situation in Norway is insightful but may not be applicable to all regions as policymakers may not have the budget or regulatory power to introduce all of the interventions in place there. The challenge for policymakers is in determining which interventions are right for their region, where they will first need to understand which incentives they could feasibly introduced and which of these incentives will be effective in promoting PEVs.

Regarding the effectiveness of incentives, it is not possible to rank the importance of the incentives due a lack of consensus in the literature across regions. It can be possible to rank the importance of incentives in specific markets, e.g. in California or in Norway, but differences between regions mean making broad statements on the importance of incentives in comparison with one another is not possible. This variation is likely due to difference in local conditions, including the incentives used and how they are deployed, travel behaviour, traffic conditions, different consumers motivations, amongst other factors. Policymakers may need to conduct analysis on their own region to understand which incentives will be most effective or identify regions with similar characteristics as their own to understand the impact of incentives there.

Policymakers may also want to consider the different types of PEVs that will be incentivised. If the goal of policymakers is to increase the number of electric vehicle miles travelled, BEVs and PHEVs with longer driving ranges may be more suitable than PHEVs with short driving ranges (i.e. less then 30 miles of electric range). BEVs and PHEVs with longer driving ranges can achieve more electric miles than short range PHEVs which can lead to lower greenhouse gas and criteria emissions (Nicholas et al., 2017; Plötz et al., 2017; Tal et al., 2014).

### 5.2. Future research agenda

Most studies currently published consider the impact of incentives on BEVs with around 100 miles of range. The future BEV market may be dominated with BEVs with more than 200 miles of range (e.g. Tesla Model 3, Chevrolet Bolt, Hyundai Kona Electric). The importance of incentives and the effectiveness of different incentives may be different for these vehicles, especially for infrastructure. Future studies should consider longer range BEVs in their analysis.

Some reoccurring incentives have received less attention in the literature. Research into the impact of congestion charge zones and BEVs does not exist, the only studies currently published investigated hybrid electric vehicles (Ozaki and Sevastyanova, 2011; Percoco, 2014). More research is also needed to understand the effectiveness of annual tax reductions or exemptions for PEVs, and what impact gasoline prices, and vehicle licensing incentives (like those in China) can have on PEV sales.

Some incentives will not be in operation indefinitely for several reasons. Toll exemptions or free parking may need to be phased due to impacts on revenue. HOV lane and bus lane access for PEVs may become unfeasible due to congested HOV or bus lanes. It is currently not well understood how long these incentives will be needed for, or what the impact of removing them would be. Research should investigate how the importance of these is changing overtime and what impact removing these incentives could have on the PEV market. This may allow policymakers and researchers to work together and develop strategies for the phase out of incentives while minimising negative impacts on the PEV market. Developing interventions that promote PEV adoption and have clear time horizons may help ensure the smooth market introduction of PEVs.

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