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Incentivizing Adoption of Plug-in Electric Vehicles: A Review of Global Policies and Markets

Energy Systems Division

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The views expressed in the article do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

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NOTATION

ABBREVIATIONS AND ACRONYMS

AER	all-electric range
BEV	battery electric vehicle
CAFC	Corporate Average Fuel Consumption
CO_2	carbon dioxide
DCFC	direct current fast charging
DOE	U.S. Department of Energy
EC	European Commission
EPA	Environmental Protection Agency
EU	European Union
EVSE	electric vehicle supply equipment
FCV	fuel cell vehicle
GHG	greenhouse gas
HOT	high-occupancy toll
HOV	high-occupancy vehicle
ICCT	International Council on Clean Transportation
LDV	light-duty vehicle
MOU	memorandum of understanding
MPV	multi-purpose vehicle
MY	model year
NEV	new energy vehicle
NHTSA	National Highway Traffic Safety Administration
PEV	plug-in electric vehicle
PHEV	plug-in hybrid electric vehicle
OECD	Organization for Economic Cooperation and Development
RMB	Renminbi (Chinese currency)
SUV	sport-utility vehicle

UK	United Kingdom
VAT	value added tax
ZEV	zero emission vehicle
ZLEV	zero/low emission vehicle

UNITS OF MEASURE

g CO_2/km	grams of CO_2 per kilometer
g/km	grams per kilometer
g/mi	grams per mile
km	kilometers
kWh	kilowatt hours
L	liter
L/100 km	liter per 100 kilometer
lb	pound
mi	mile(s)
mpg	miles per gallon

ABSTRACT

This report summarizes current government policies that seek to increase deployment of light-duty, plug-in electric vehicles (PEVs) in the United States, Europe, and China. The paper also describes recent PEV market trends in these three regions. By comparing combinations of PEV policies and trends of PEV sales in different regions at national and subnational levels, the authors make several observations and draw general conclusions, using supporting examples for the findings. One finding, consistent with earlier studies, is that multiple, complementary PEV incentives and deployment policies are generally more effective in increasing adoption of PEVs within a given market than single policies. In most regions, financial incentives, especially point-of-sale incentives, are effective in increasing adoption, particularly when generous and combined with other supporting polices, such as increasing charging station availability, which contributes to ease of use. The authors also observed differences in policies and market trends between regions. In Europe, where taxes on vehicles are high, tax credits provide strong incentives for PEV adoption, whereas in several Chinese cities, where restrictions on vehicle registration or use are imposed, relaxation of restrictions on PEVs effectively promote PEV adoption. In addition, governments are replacing some policies based on technical specifications (e.g., battery capacity) with policies based on performance metrics (e.g., vehicle range and electricity consumption rate per distance).

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1 INTRODUCTION

Governments of different countries and regions have enacted a number of diverse policies to promote adoption of plug-in electric vehicles (PEVs). Industries, such as automakers and electric utilities, have also acted to promote PEV adoption by offering their own incentives. Motivations for promoting PEV adoption include reducing petroleum use/dependence, reducing greenhouse gas (GHG) and other air pollutant emissions, and promoting economic growth. The diversity of PEV policies and adoption trends in different countries offer a valuable opportunity to compare and contrast the policies and their results. This report focuses on government PEV policies for light-duty vehicles (LDVs), applicable to either battery electric vehicles (BEVs) or plug-in hybrid electric vehicles (PHEVs). The authors describe general categories of policies and incentives in Section 2 and summarize previous reviews of these policies in Section 3. Sections 4, 5 and 6 detail the policies and PEV market trends by region, and Section 7 compares policies and market trends in each major region. General conclusions are presented in Section 8.

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2 CATEGORIZATION AND BRIEF DESCRIPTION OF POLICIES

This section describes categories of incentives and policies that promote PEVs. Specific information about policies in each region are discussed in Section 4. Policies implemented in each category by region are listed in Section 6, Table 3 (Chinse cities), Appendix Table A-1 (U.S. states), and Appendix Table A-2 (European countries).

2.1 MONETARY VEHICLE PURCHASE INCENTIVES

Monetary vehicle purchase incentives are direct payments, discounts, rebates, or tax credits to new PEV purchasers. These can be paid to the consumer at the time of purchase, or may be applied as a discount to the PEV purchase price, or as a rebate (redeemable after the vehicle purchase). These incentives may or may not affect taxes such as sales taxes or fees indexed to the transaction price or assessed value.

Taxes and fees charged at the time of purchase or registration can be waived or reduced for PEVs to incentivize purchase. This policy can include reduced taxes on a PEV supplied by a company to employees. Another incentive is reduction of income tax in the form of a tax credit to PEV purchasers.

2.2 MONETARY VEHICLE USE/OWNERSHIP INCENTIVES

Vehicle use and ownership incentives reduce costs of owning and using PEVs and may take several forms. Vehicle ownership taxes or fees, including annual taxes, registration fees, or license plate fees may be reduced or waived. Some jurisdictions charge a registration fee for PEVs to cover reduced gasoline tax revenues. Other forms may include reduced or waived tolls on toll roads, or, in the case of company cars, reduced tax on a vehicle supplied by the company to employees.

2.3 MONETARY INFRASTRUCTURE INCENTIVES

Monetary incentives for PEV charging infrastructure include subsidies, rebates, or tax credits to defer purchase and installation costs of electric vehicle supply equipment (EVSE, also called charging stations). Government provision or subsidization of charging infrastructure (sometimes offered with dedicated parking for PEVs) helps address the issues of limited BEV range and inability to charge the vehicle at home.

Some jurisdictions offer free or discounted PEV charging, and this incentive is offered by some PEV manufacturers and electric utility companies. Other infrastructure incentives, such as creation of building codes to require pre-wiring of residential and parking structures for PEV charging are mostly local, and are not included in this discussion.

2.4 NON-MONETARY INCENTIVES

Non-monetary policies to promote PEV adoption include access policies that allow PEV drivers to use dedicated bus lanes, high-occupancy vehicle (HOV) lanes, and parking areas. PEV parking is often provided with charging infrastructure. In some local jurisdictions, PEVs are given access to low-emission zones.

Zero emission vehicle (ZEV) mandates target automakers by requiring that a certain fraction of their sales be ZEVs, as defined by regulation. (The ZEV program enacted in California and adopted by several other states is described in Section 4.2.) Other incentives focus on fuel economy or GHG emission standards and give preference to PEVs. Other methods offer relief from quotas or restrictions on vehicle purchase, registration, or daily use, such as relief from the lottery for license plates for PEV purchasers in some Chinese cities. A government incentive offers fleet procurement preferences for PEVs.

2.5 LOCAL INCENTIVES

This report discusses many subnational and municipal polices that promote PEVs; however, this list is not exhaustive.

2.6 SCOPE AND ORGANIZATION OF THE REPORT

In Sections 4, 5, and 6, respectively, the authors review national policies that promote PEVs and PEV market trends in the United States, European countries, and China. In each section, policies are described, and, although no cost/benefit analysis was conducted, observations are made on apparent market trends and possible inferences about the influence of policies. In Section 5, general observations are provided, including comparison of broad trends and types of policies in the three regions.

This report provides a comprehensive summary of PEV incentives in the United States, Europe, and China updated to the end of 2017. The policy types reviewed include regulation, credits to auto manufacturers, financial and non-financial incentives to consumers on vehicle purchase and ownership, and on EVSE purchase. This report also documents the PEV sales and market trends updated to 2017, showing cross-region comparisons of total sales volumes, number of public charging stations, market share, and PEV adoption per capita.

3 BRIEF SUMMARY OF LITERATURE AND OTHER RECENT VEHICLE POLICY REVIEWS

3.1 U.S. POLICY ANALYSIS

Zhou et al. (2016a) reviewed literature on the effectiveness of policies promoting PEV adoption in the United States. Their analysis compared findings from 18 studies of 30 incentives and government actions, including various policy measures that fall into several broad categories:

- Monetary incentives
- Access preferences for PEVs
- Infrastructure incentives
- Others, such as emission test exemptions, zero emission vehicle (ZEV) mandates, low-carbon fuel standards, and promotional activities by utilities

The majority of the studies reviewed found that nearly all these policies had a significant, positive effect on PEV adoption. At the city, state, and national levels, PEV policies were most effective when multiple incentives were offered simultaneously, that is, financial incentives with provision of charging infrastructure, and public promotion. The researchers compiled best practices from the studies reviewed, and concluded that:

- PEV adoption is greatest when multiple actions are taken in parallel.
- Policies that reduce the up-front cost of PEVs can promote early PEV market growth.
- Institutional support factors are important for market growth, such as outreach, standards, emission testing exemptions, low-carbon fuel policies, and PEV readiness grants.

Zhou et al. (2016a) also noted that challenges and barriers to PEV adoption remain, such as limited charging infrastructure and a limited offering of PEV models. Additionally, they reported on the diversity of findings of the studies reviewed, which were sometimes contradictory. For example, one study reviewed (Clinton 2014) found that granting PEV drivers access to HOV lanes had no significant influence on BEV adoption at a national scale, while another study (Narassimhan and Johnson 2014) concluded that HOV lane access was effective for promoting BEV adoption at the state level, and a third study (Tal and Nicholas 2014), based on surveys in California, reported that HOV access encouraged BEV and PHEV adoption. Several studies reported different conclusions about the relative effectiveness of tax credits and rebates on PEV adoption. Policy effectiveness apparently varies from region to region due to different mixes of policies as well as differences in market conditions. Importantly, analytical methods and data used differed between studies.

The researchers identified areas needing further investigation. Few of the studies differentiated between PHEVs and BEVs, but some of those that did indicated important differences. Few studies considered socio-economic factors, but these are likely to be important. For instance, financial incentives were found to be less influential for high-income purchasers. Further research is also needed on PEV incentives by electric utilities (and on potential benefits of PEV adoption to utilities), the ZEV program (as adopted in California and other states, discussed in Section 4.2), and the U.S. Department of Energy (DOE) PEV Readiness Grant Program. The study by Zhou et al. also suggested investigating impacts of reducing or eliminating incentives, such as the recent elimination of the tax credit for BEV purchase in the State of Georgia. They suggested that studies are rapidly becoming dated as the PEV market develops, and further research is needed to follow the influence of incentives and other factors as a wider range of consumers choose whether to adopt PEVs. Studies that are more recent and some not included in the review by Zhou et al. are discussed below.

A report by the National Research Council of the National Academies on overcoming barriers to electric-vehicle deployment reviewed electric vehicle technologies, barriers to PEV adoption, and policies to promote adoption (NRC 2015). The report noted that a key barrier to PEV adoption was limited all-electric range (AER), but concluded that general barriers include lack of adequate charging infrastructure, lack of awareness of PEVs, and high purchase price of PEVs. The report also recommended several actions that the Federal government could take to help overcome these barriers such as increasing public awareness of Federal tax credits and other incentives and continuing to sponsor research to lower PEV costs. The report recommended that local governments streamline permitting and building codes for new construction to support future charging installations, and engage with and encourage workplaces to provide charging stations. In particular, the report mentioned the need for amenable municipal-level zoning and permitting of charging installations. The report recommended that, for a limited time, both Federal and state governments not assess special roadway or registration surcharges on PEVs.

Vergis and Chen (2015) compared PHEV and BEV sales shares in 2013 in each U.S. state and used regression analysis to identify influential variables. Fitting separate models of BEV and PHEV sales share in 50 states to linear models of state averages of several different variables, they concluded that average winter temperature was the only variable common between the two models, but with opposite effects. Warmer winter temperatures were positively correlated with BEV share and negatively correlated with PHEV share. Vergis and Chen mentioned that a positive correlation between average temperature and BEV share made sense in that BEV range decreases at low temperatures; however, the negative correlation between PHEV share and temperature is harder to understand and warrants further research.

In their 2015 study, Vergis and Chen noted that BEV market share depended on the number of charging points per 1,000 population, whereas PHEV market share did not—reasonable, given the limited driving ranges of most BEVs. The positive correlation between BEV market share and average winter temperature may be due to decreased BEV range at low temperature, especially if electricity is used for cabin heating. Higher demand for four- or all-wheel drive in colder climates may have also contributed to this correlation. Vergis and Chen found that PHEV market share was correlated with different variables. They found a positive correlation between market share and the number of models available for PHEVs, which was not significant for BEVs; however, this finding may relate to the data selection method and the complexity of the relationship between model availability and sales. They noted that others analyzing similar data (Jin et al. 2014) did not report the absence of a significant correlation between BEV share and the presence of purchase incentives, but the observation may be an artifact of which incentives were included and how they were specified in the regression model.

Kwan et al. (2016) reviewed PEV market trends and policies to promote PEV adoption in six regions of the United States with higher-than-average PEV market share in 2015. They identified over 30 policy actions by state and local governments and by electric utilities. Generally, higher PEV adoption was seen in states with PEV incentives and that had adopted the ZEV program. Metropolitan regions that achieved higher PEV adoption rates than the regional average were generally those with more public charging infrastructure and higher availability of PEV models. They noted that PEV model availability is higher in states that have adopted the ZEV program. The also noted that local conditions and actions by cities and utilities can be important, and these varied between areas (and over time, in some cases).

Zhou et al. (2016b) compared PEV adoption trends in U.S. metropolitan areas and states based on 2014 vehicle registration data and examined correlations between PEV adoption and the policies and climate in these areas. They reported that PEV incentives and climate were correlated with PEV adoption, with different correlations for BEVs and PHEVs. PEV adoption was highest in three Pacific coast states (California, Oregon, and Washington) with moderate temperatures and more generous purchase incentives for BEVs than for PHEVs. They also found that California had a higher PHEV share of PEVs sold, which may be due in part to high sales of the Toyota Prius PHEV (80% of national registrations of Prius PHEVs were in California). They speculated that PHEVs were desirable for long-distance drivers who would benefit more from the HOV lane access granted for PEVs in California. This finding is consistent with earlier observations by Tal and Nicholas (2014), who surveyed PEV purchasers in California in 2013, and reported that 57% of those purchasing a Prius PHEV, 34% of those purchasing a Chevrolet Volt, and 28% of those purchasing a Nissan LEAF, responded with the claim that HOV lane access was their primary motivation for purchasing a PEV.

Santini et al. (2016) compared PEV adoption in 2014 and incentives and climates in the United States, Canada, and several European countries. They found higher PEV adoption in countries with more generous financial incentives for PEVs, and, in particular, they found higher BEV sales in countries with the most generous incentives for BEVs. However, support for public charging infrastructure also appeared to influence BEV adoption, while a colder climate was correlated with lower BEV adoption. Norway was an exception to the climate correlation, presumably due to the generous financial and other BEV incentives. As discussed in Section 5.2, Norway offers tax credits that can be valued at more than of 50% of a PEV’s retail price, plus other monetary and non-monetary incentives.

Slowik and Lutsey (2016) assessed near-term electric vehicle market trends and discussed how governments might best develop and continue to adapt their electric vehicle incentive programs to sustain market growth. Considering fuel prices and monetary incentives for PEVs in various countries, the study projected costs of conventional, petroleum-powered vehicles and PEVs to 2025, and compared projected ownership costs for the two types of vehicles. They concluded that electric vehicle range and cost improvements will greatly expand the electric vehicle market and reduce the need for incentives. Moreover, they recommended that policies shift incentives to target vehicles that are the most attractive to mainstream consumers. They also suggested that shifting to progressive tax exemption or polluter-pay systems (as in Norway), or a “feebate” program (such as the bonus-malus system in France) could provide a revenue source for financing electric vehicle incentives. As fiscal incentives are phased out, policy actions such as charging infrastructure improvements, consumer education, and fuel efficiency regulations will still be needed to promote electric vehicles.

Lutsey et al. (2016) analyzed the state of the electric vehicle market and actions that drive its development. Their report summarized 33 unique city, state, and utility electric vehicle promotion actions across the 50 most-populous U.S. metropolitan areas. They found that cities such as Portland, Oregon; Seattle, Washington; and several California cities with a greater number of PEV promotion policies had higher PEV market share. They also collected data from the 200 most populated metropolitan areas in the United States. They analyzed correlations between BEV and PHEV market share and model availability, state PEV monetary incentives, public and workplace charging per capita, HOV access, and the number of other local and state PEV promotion activities. Model availability, monetary incentives, and public charging were significantly correlated with both BEV and PHEV market shares in the 200 cities. Analysis of the 50-city data set showed that BEV market shares were correlated with BEV model availability, public and workplace charging, and HOV access, while PHEV market share was correlated with PHEV monetary incentives, workplace charging per capita, HOV access, and the number of other promotion activities. These results suggest that public charging availability is more influential on BEV adoption than PHEV adoption, and HOV access is more influential in larger cities, perhaps due to more severe congestion. The authors concluded comprehensive actions by diverse stakeholders are key to expanding the electric vehicle market. Incentives are helping to develop the early electric vehicle market. Financial consumer incentives drive electric vehicle uptake in California, Colorado, and Washington state markets.

Slowik and Lutsey (2017) also examined PEV adoption in the 50 most-populated metropolitan areas in the United States and in the 200 most populated metropolitan areas. They analyzed correlations between PEV market share and consumer PEV incentives, charging infrastructure, availability of PEV models, and various state and local PEV policies. They found correlations similar to those reported in their earlier study (Lutsey et al. 2016), but also some differences: for the 50-city data set, they found that PHEV share was significantly correlated with PHEV model availability, and, while PEV sales shares (BEV and PHEV shares combined) were correlated with state PHEV incentives, BEV and PHEV shares individually were not significantly correlated with state BEV or PHEV incentives. As market conditions change, the influence of incentives and other policies varies somewhat. However, the researchers still concluded that PEV market growth requires multiple, parallel actions by many parties and cited the comprehensive approach taken by the State of California, which has the ZEV program and complementary policies, including continued investment in charging infrastructure. They also noted that consumer incentives continue to be important to promoting the PEV market. They found that strong incentives were in place for most of the metropolitan areas with the highest PEV market shares. They also found that availability of public charging infrastructure is correlated with PEV market share, but such infrastructure is limited in many cities.

Similarly, Searle et al. (2016) analyzed electric vehicle markets in 30 California cities in 2015 and concluded that comprehensive policy support is helping to support the electric vehicle market. The 30 cities in California with the highest electric vehicle uptake have implemented numerous, wide-ranging electric vehicle promotion programs involving parking, permitting, fleets, utilities, education, and workplace charging. More recently, Fowler et al. (2018) reviewed PEV market trends and policies relevant to adoption of PEVs (and ZEVs, in general). They reported that, in the first nine months of 2017, California BEV and PHEV sales were 41,455 and 35,287 , respectively. These figures represent a sales increase of 26% in BEVs and 32% in PHEVs over the same period of 2016. The percentage increase in California PEV sales was similar to the percentage increase in ZEV sales nationally. They suggested that barriers, such as PEV cost, range, selection of models available, and charging time, are lessening and will continue to do so as manufacturing costs come down and technology advances.

Zhou et al. (2017) analyzed new PEV registrations in 134 U.S. counties in 2014. They correlated sales of BEVs and PHEVs in three market segments (mass market, list price <$40,000; mid-market, list price of $40,000–60,000; and luxury/performance market, list price >$60,000) with county-level demographics, charging infrastructure availability, gasoline and electricity prices, seasonal temperatures (extreme summer and winter temperatures), and county and state incentives and other policies. They found that state-level incentives were important for both BEV and PHEV adoption, but more so for BEVs. HOV access was significantly correlated with PEV adoption, except for PHEVs in the luxury/performance market segment. Cold winter temperatures were negatively correlated with PHEV adoption for the mass and mid-market segments and BEV adoption for all market segments. High summer temperatures were also negatively correlated with PEV adoption, but less strongly, and only for mass and mid-market BEVs and mass market PHEVs. Level 2 public charging availability was positively correlated with PHEV mass market adoption, but not BEV adoption. Public direct current fast charging (DCFC) availability was not significantly correlated with BEV adoption. Availability of workplace charging was correlated with adoption of mass market PHEVs and mid-market BEVs. Income (county average) was positively correlated with PHEV and BEV adoption. The number of PEV models available in each county was positively correlated with BEV adoption, but not with PHEV adoption. These results indicate that the influence of PEV policies varies between different market segments, and numerous variables influence adoption.

Broadbent et al. (2017) reviewed PEV market trends, policy actions to promote PEV adoption, and other conditions relevant to PEV adoption in the United States and European Union (EU). They also discussed some of the barriers to consumer adoption of PEVs, including vehicle price, and, for BEVs, driving range and availability of convenient charging infrastructure. Comparing PEV market trends, government policy actions, and other factors in the United States and EU, they concluded that the main factors influencing the adoption of PEVs are likely to be purchase price, network of standardized charging infrastructure, and public information on PEVs. They suggested that policies addressing these factors would accelerate a transition to PEVs and mentioned that multiple actions are more effective than one alone, but the appropriate mix of such actions may differ between countries.

Lutsey (2017) considered United States and European fuel efficiency (or fuel economy) regulations and automotive CO_2 emission regulations, and specifically the provisions for PEVs in these regulations designed to incentivize automakers to produce more PEVs. These incentives include counting only tailpipe CO_2 emissions, and multipliers or "supercredits" for PEVs, which allow automakers to count PEVs for more than one vehicle when calculating fleet averages. He noted that tailpipe emission counting and multipliers reduce the costs to automakers of meeting CO_2 emission standards. However, Lutsey did not estimate the potential influence these regulatory provisions may have on the number or type of PEVs automakers might offer.

3.2 EUROPEAN POLICY ANALYSIS

The authors reviewed publications analyzing PEV adoption policies for Europe as a whole and European countries with significant levels of adoption. As European countries have a diverse set of policies and market conditions, these studies analyze how those factors impact PEV market trends.

Van der Steen et al. (2015) analyzed national, regional, and local PEV policies of seven European countries. They separated government actions into four categories (legal, financial, communication, and organization) and identified where in the PEV and EVSE value-chain (e.g., R&D, production, service, and customers) the policy focused. They found that most often PEV polices are from the national government, with a focus on financial benefits for consumers to purchase and operate a PEV. The authors suggested that vehicle and charging policies were often made in silos and that a more integrated strategy would improve effectiveness. They state that beyond the initial introduction of PEVs, governments need to focus on non-financial policies to cost-effectively stimulate the market.

Harrison et al. (2016) used an agent-based model to analyze PEV sales in the EU based on the interaction of three government regulations: CO_2 regulations on automotive manufacturers, PEV purchase subsidies for consumers, and infrastructure subsidies for the EVSE providers. The researchers found that CO_2 regulations are a crucial factor for the long-term success of PEVs. The PEV and infrastructure policies impact various EU countries differently depending on their GDP, GDP growth, vehicle stock, and vehicle stock growth. In general, PEV purchase subsidies are important for initial deployment of PEVs, but by themselves do not lead to significant long-term market share. Until PEV stock share reaches 5%, infrastructure subsidies are not as strong of a policy incentive for PEV sales, as early adopters are more likely to rely on home charging. However, for more widespread adoption, public infrastructure is beneficial. They found that public charging does influence PEV sales, but PEV sales are relatively insensitive to having more than one public charge point per five PEVs and less than one charge point per 25 PEVs. In addition, installing more than one public charge point per 10 PEVs is not cost-effective for increasing PEV sales.

Langbroek et al. (2016) performed a two-stage stated choice survey in Sweden that asked questions about respondents desire to purchase a PEV based on different policy incentives. The researchers found that although policy incentives, such as vehicle price, parking, and charging are effective in increasing PEV adoption, consumers with more PEV awareness are less sensitive to financial subsidies. In addition, these polices will become less efficient as the population's PEV awareness grows. They found that use-based policies (free parking, bus lane access) can be more cost-effective than direct financial subsidies. They suggest a strategy of advancing consumer's readiness to purchase PEVs and developing a package of less extensive policy incentives more targeted to this group.

Bjerkan et al (2016) surveyed 3,400 Norwegian BEV owners in 2014 to determine which incentives were most important for their purchase decision. They did not have data on infrastructure incentives and noted that about 75% of Norwegians live in detached or semi-detached houses, making it easier to charge at home. The survey showed that purchase tax and VAT exemptions were the most important incentives, with more than 80% of respondents saying they are critical. This finding is not surprising as Norway has the highest new car purchase taxes in the world, as described in Section 5.2, and includes a VAT of 25%, a registration tax of about 30%, and company car tax of 30%. About 50% of respondents said exemptions from tolls and reductions in license fees were critical. Many fewer respondents (~15–25%) highlighted the importance of free parking, bus lane access, or free ferry tickets.

Mersky et al (2016) performed a regression analysis to examine the effectiveness of incentives on BEV sales in Norway from 2011 to 2013 on a local level. They found that access to charging infrastructure, adjacency to a major, city and regional income to be the most significant factors when predicting BEV sales.

Ploetz et al. (2017) used regression analysis to examine the relationship between the direct and indirect incentives to PEV sales data from 2010 to 2016 of 30 European countries. They find that direct and indirect (nonmonetary) incentives, as well as higher income and diesel prices, have positive effects on PEV sales. They found increasing direct financial incentives by 1,000 euros ($1,200) increases PEV sales share by about 16% (relative increase of a given sales share). Indirect incentives seem to have a stronger impact than a direct 1,000 euro ($1,200) incentive. However, the study did not differentiate which indirect incentives are most effective, as they examined the number of indirect incentives available.

3.3 CHINESE POLICY ANALYSIS

The authors reviewed publications analyzing PEV adoption policies for selected provinces and cities in China, focusing on publications that reviewed policies in pilot cities that implemented national financial support policies for the promotion and application of PEVs. Those regions also have significant levels of PEV adoption.

Xing (2016) conducted PEV consumer surveys from July 2015 to February 2016 in Beijing and Shanghai, China, to explore the factors influencing PEV adoptions. Survey results revealed that supportive policies facilitate PEV adoptions heavily. About 52% respondents in

Beijing stated that they would not buy BEVs unless free license plates were offered for the vehicle.

The International Council on Clean Transportation (ICCT) published a report (in Chinese) in 2018 evaluating the effectiveness of city-level NEV policies in China (He 2018). This report concludes that the promotion of NEVs has been heavily focused on a few megacities and provincial capitals. Due to the strong preference for BEVs and BEV-focused policies by local governments in most of the cities (27 out of 30 cities studied), BEVs account for more than 80% of PEV sales in China. In only three cities, Shanghai, Shenzhen and Xi'an, are more PHEVs purchased than BEVs (which may have more to do with local government promotion of local industry then with local perceptions of the merits of PHEVs). Over 20 different types of financial and non-financial incentives have been implemented to promote NEV adoption.

Zhang and Qin (2018) summarize NEV policies launched by China's national, provincial, and municipal authorities from 2010 to 2016, and evaluate their successes and limitations. This study suggests that (1) the coordination mechanisms of central and local governments should be strengthened; and (2) future policies should focus on infrastructure construction, research and development, battery recycling, and private purchase regulations.

However, a nationwide investigation conducted by the Chinese government in early 2016 found 12 different companies had cheated to receive the subsidies. Over 8,000 NEVs sold between 2013 and 2015 were involved and about 80% of them were commercial vehicles. The main reason for the cheating is the subsidy amounts are too generous and apply to vehicles directly, regardless of the vehicle's level of technical sophistication. Some companies either illegally registered vehicles without producing them, or used smaller batteries in production. The scandal has caused Chinese government to reconstruct the NEV subsidy policies with tightened technical requirements and a phase-down of fiscal incentives (Cui 2017).

Li et al. (2016) summarize China PEV policies in seven categories: macroscopic, demonstration, subsidization, preferential tax, technical support, industry management, and infrastructure. They conducted a survey of 800 people, and, based on responses, they analyzed the consumers' evaluation of each policy type in terms of perceptions of importance and satisfaction. The results showed that consumers perceive macroscopic policies to be more important than industry management policies. Macroscopic policies are high-level plans and objectives issued by governments. For example, the State Council nominated the NEV industry as one of seven strategic emerging industries in 2010. Industry management policy refers to regulations aiming to manage NEV industry and the power battery industry, and to encourage enterprises with technical strength to invest in NEV technology research and development.

4 REGIONAL REVIEW: UNITED STATES PEV POLICIES AND MARKET TRENDS

To update and supplement findings of earlier studies of PEV policies and market trends in the United States, Federal and selected state PEV adoption policies are reviewed below. Included in the discussion are states with the highest PEV adoption (sales shares), that offer interesting contrasts in the BEV share of PEVs, or with differences in policies, climate, or other market factors.

4.1 UNITED STATES AS A WHOLE

The U.S. Federal government incentivizes PEV adoption through an income tax credit for consumers purchasing a qualified PEV.[1] A qualified PEV is one that draws propulsion energy from a battery with at least 5 kilowatt hours (kWh) of capacity. The amount of the credit is $2,500 plus $417 for each additional kilowatt-hour of battery capacity, not to exceed $7,500. The credit has a cap per company and phases out at reduced rates over one year beginning roughly three to six months after a vehicle manufacturer sells a cumulative total of 200,000 qualifying vehicles. As of February 2018, no automaker has reached that number of PEV sales in the United States; however, both GM and Tesla have sold more than 170,000 vehicles, as shown in Figure 1. PEV manufacturers that are PEV market leaders will lose this incentive first, but it remains to be seen how this will influence future sales of these manufacturers' PEVs, the models of PEVs they will offer in the future, and their marketing strategies.

1 Data in Section 4 are for light-duty passenger vehicles including cars, sport-utility vehicles (SUVs), vans, and pickup trucks, all considered LDVs.

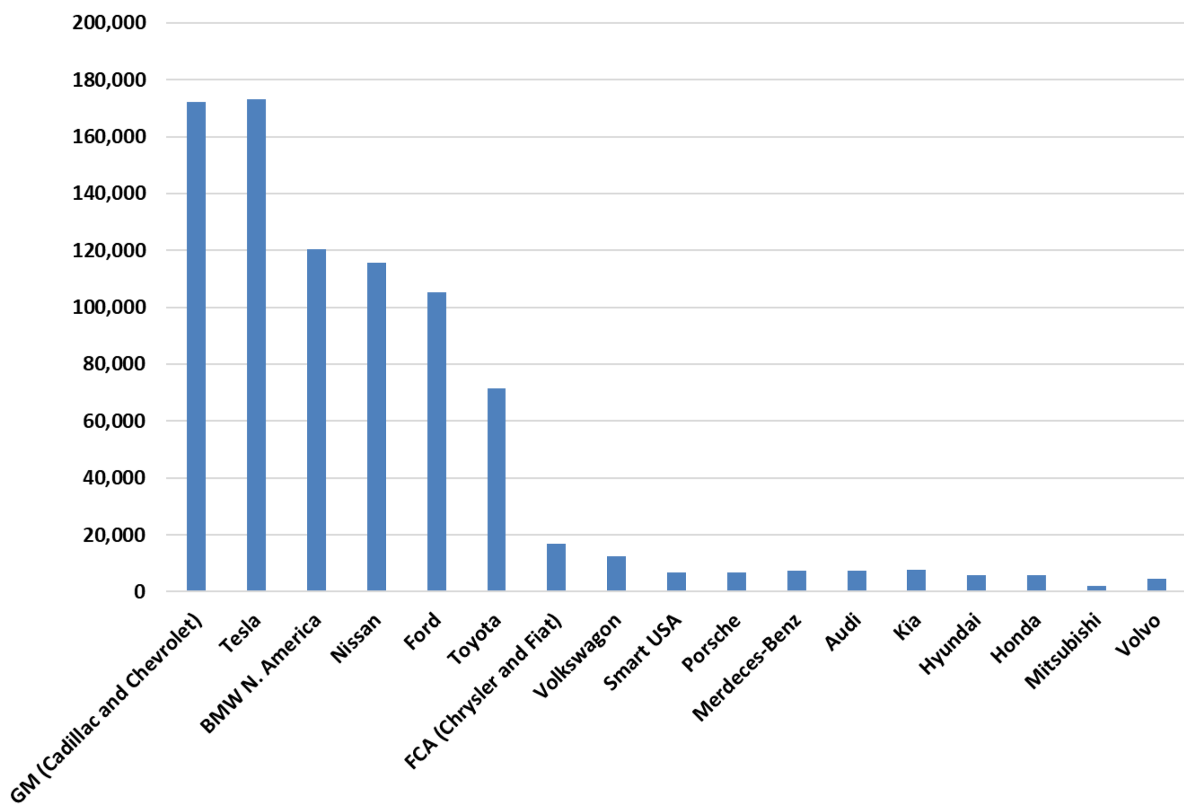

FIGURE 1 Cumulative PEV Sales by Automaker in the United States from 2010 through February 2018

Figure 2 shows the BEV and PHEV shares of new LDV sales in the United States in recent years.

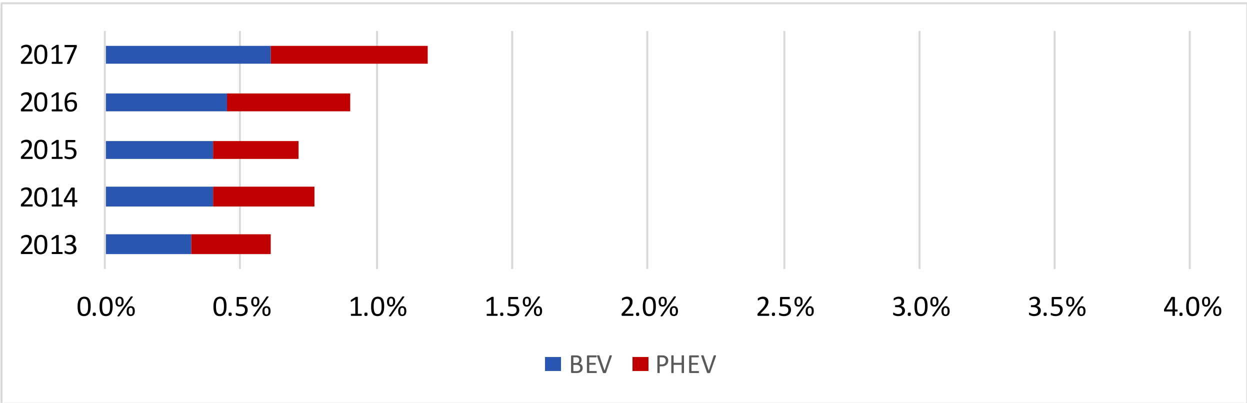

FIGURE 2 PEV Share of LDV Sales in the United States

Fuel economy standards and GHG emission standards in the United States grant automakers credits for alternative or dual-fueled vehicles (EPA and NHTSA 2010; EPA and NHTSA 2012). In particular, the GHG standard allows automakers to count BEVs and fuel cell vehicles (FCVs), as having zero GHG emissions, and PHEVs as having zero GHG emissions for miles driven electrically (assumed to be a given function of its electric range). However, there is a cap on the number of vehicles that automakers can count as having zero tailpipe GHG emissions. The cap is 300,000 total BEVs, PHEVs, and FCVs, except for automakers that sell more than 300,000 BEVs, PHEVs, and FCVs of model years (MYs) 2019 through 2021, in which case the cap is 600,000 vehicles. In addition, the GHG emission standard allows automakers to count each PEV produced as multiple vehicles when calculating the fleet-average emission level. Multipliers proposed for MYs 2017–2025 range from 2.0 for MY 2017 down to 1.0 for MY 2025 for BEVs and FCVs, and from 1.6 for MY 2017 to 1.0 for MY 2025 for PHEVs.

The market share of PEVs continues to grow, although market share of PHEVs appears to vary more from year to year than the market share of BEVs. Five states were selected to highlight those with high PEV market shares or factors that influence PEV adoption, such as recent changes in incentives or differences in climate, that influence PEV adoption. Statistics for selected states are presented in Table 1.

Figure 3 shows the number of PEVs registered at the end of 2017 per 1,000 people, in each state, and depicts how the adoption of PEVs varies widely between states.

TABLE 1 Summary of PEV and Station Statistics for 2016 in Selected U.S. States

	California	Georgia	New York	Michigan	Washington
PEVs/1000 people	6.7	2.2	1.0	1.4	3.0
LDVs/1000 people	979.5	842.7	585.7	847.2	891.5
Total LDVs	30,559,571	8,739,824	11,622,376	8,427,684	6,546,912
Total PEVs	262,299	22,608	20,064	13,845	22,215
BEV market share	2.0%	0.3%	0.2%	0.3%	1.2%
PHEV market share	1.8%	0.2%	0.4%	0.5%	0.8%
Level 1 and 2 ports/1000 PEVs	16,412	2,059	1,843	897	3,029
DC ports/1000 PEVs	2,042	229	197	92	320

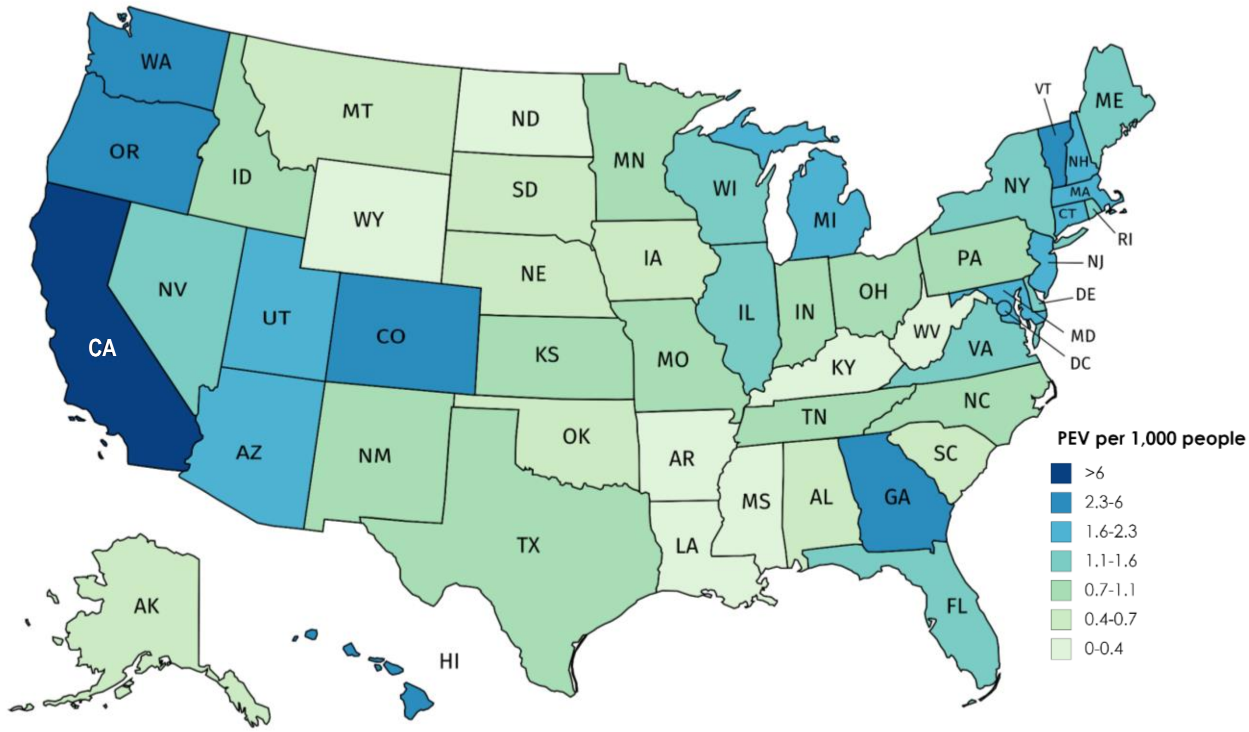

FIGURE 3 PEV Registration at the End of 2017 per 1,000 People in the United States
Note: Map was generated using mapchart.net.

4.2 CALIFORNIA

The State of California offers several PEV incentives. Under the California Clean Vehicle Rebate Program, California residents receive up to $2,500 for the purchase or lease of a new, eligible light-duty BEV and up to $1,500 for a new, eligible light-duty PHEV (CSE 2018). For vehicles purchased on or after March 29, 2016, an individual's eligibility for the rebate is based on gross annual income (no PEV rebate is available for those with a household income above a threshold).

PEVs (as well as compressed natural gas and FCVs) with a California Department of Motor Vehicles Clean Air Vehicle sticker may use HOV lanes regardless of the number of occupants in the vehicle (CARB 2018a).

The Zero Emissions Vehicles (ZEV) program established a requirement for ZEV credits for new, light-duty vehicles sold in California. The number of credits required each MY is a percentage of the volume of new vehicles sold by automakers in California. As of MY 2018, ZEVs are defined as vehicles that emit zero criteria pollutants, precursors, or greenhouse gases. The number of credits earned by a ZEV depends on its all-electric range, as measured in the Urban Dynamometer Driving Schedule (EPA 2018). The required percentage is 4.5% in MY 2018, increasing each year to 22% for MY 2025 and later.

Automakers may earn ZEV credits by selling "transitional ZEVs" (TZEVs), which are PHEVs and fuel cell vehicles meeting certain emissions and performance requirements. The number of credits automakers can earn from TZEVs is limited for automakers selling more than 60,000 passenger cars per year in California. There are flexibilities in the standard, such as buying, selling, and banking credits, and the requirement does not apply to automakers selling no more than 4,500 vehicles (CARB 2018b). Several other states, namely Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont, have established similar ZEV requirements (ZEV Task Force 2018). Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Vermont joined California in signing a memorandum of understanding (MOU) to support the deployment of ZEVs through involvement in a ZEV Program Implementation Task Force (NESCAUM 2013). In May 2014, the Task Force published a ZEV Action Plan identifying 11 priority actions to accomplish the goals of the MOU, including deploying at least 3.3 million ZEVs and adequate fueling infrastructure within the signatory states by 2025 (NESCAUM 2014). The ZEV Action plan was updated in 2016 (California 2016). Travel provisions in the ZEV program allow credits earned from the sale of ZEVs in one MOU state to be used in another MOU state, however, starting in MY2018, this provision applies only to FCVs.

The governor has announced a goal of 1.5 million PEVs on the road in California by 2025, as ordered in Executive Order B-16-2012 (California 2012).

As of December 2017, there were 3,764 Level 1 or 2 public charging stations with 12,636 charging ports, and 552 DCFC stations with 1,561 ports in California (U.S. DOE 2018). Although California has no incentives for private purchase of EVSEs, the California Capital Access Program and the Electric Vehicle Charging Station Financing Program provide loan guarantees to help finance the design, development, purchase, and installation of electric vehicle charging stations at small businesses in California (California 2018).

The market shares of PEVs in California are shown in Figure 4. Sales shares of both BEVs and PHEVs have doubled since 2013. Sales shares of PEVs in California are higher than in other U.S. states and have been increasing more rapidly.

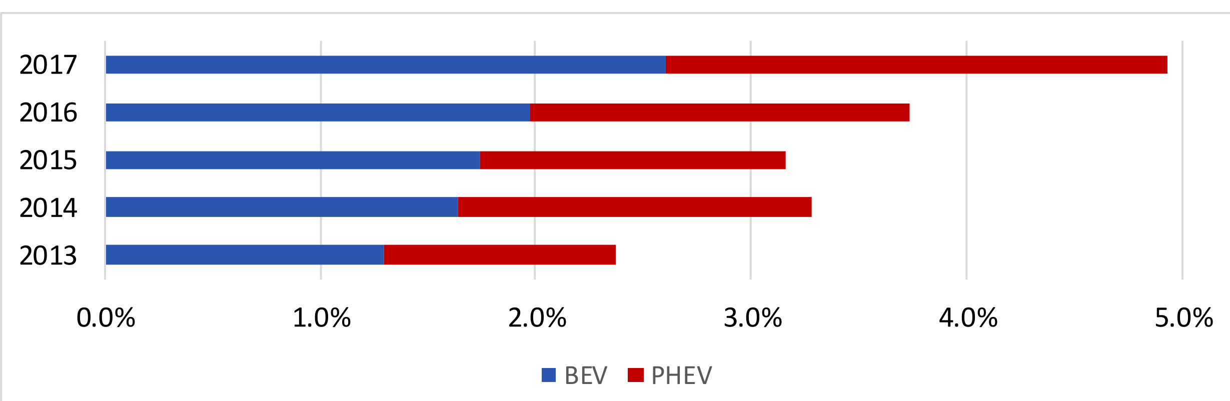

FIGURE 4 PEV Share of LDV Sales in California

4.3 GEORGIA

The State of Georgia offered a tax credit of 10% of the cost of PEVs up to $2,500, which expired in June 2015. This credit was available to BEVs only (or ZEVs operating on alternative-fuels only). Plug-in electric vehicles (as well as compressed natural gas and propane vehicles) are allowed to use HOV lanes and high occupancy toll (HOT) lanes without paying a toll, regardless of the number of passengers. Businesses that install publicly accessible EVSEs can claim an income tax credit for the purchase or lease of the EVSE for 10% of its cost up to $2,500. The State of Georgia charges an annual license fee of $200 for non-commercial PEVs and $300 for commercial PEVs to recoup some of the gasoline tax revenues lost.

As of December 2017, there were 583 Level 1 or 2 public charging stations with 1,548 charging ports, and 109 DCFC stations with 233 ports in Georgia (U.S. DOE 2018). The State of Georgia provides an income tax credit to eligible businesses for the purchase or lease of qualified EVSEs installed in the state and accessible to the public. The credit amounts to 10% of the cost of the EVSE, up to $2.500 (GeorgiaGov 2018).

As seen in Figure 5, annual BEV sales shares increased and were high while the tax credit was offered, but have dropped off since the credit ended. The sudden and dramatic decrease in BEV sales can be seen in the monthly sales shown in Figure 6. The drop-off has been attributed to the expiration of the tax credit (Tal and Brown 2017; Caputo 2016). There is a proposal for restoring the tax credit for BEVs, but at a lower level (Voelcker 2018).

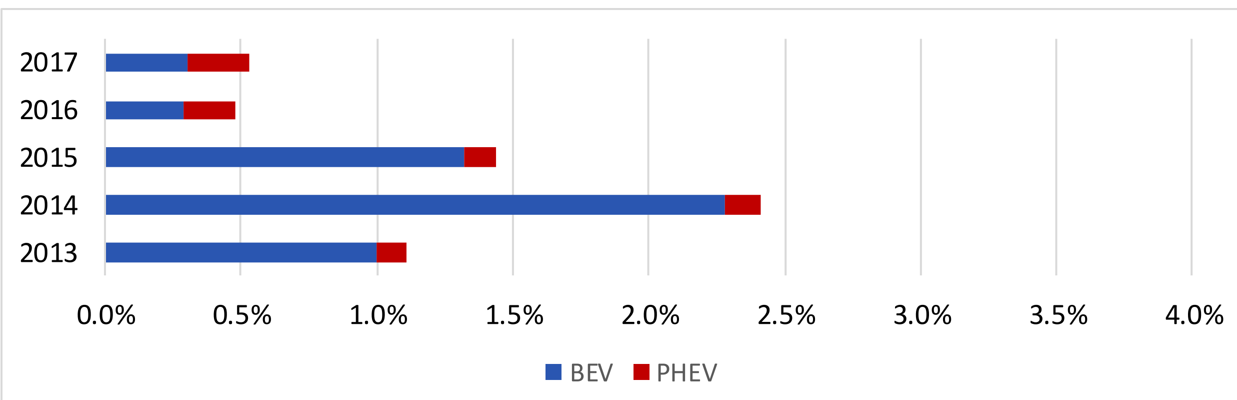

FIGURE 5 PEV Share of LDV Sales in Georgia

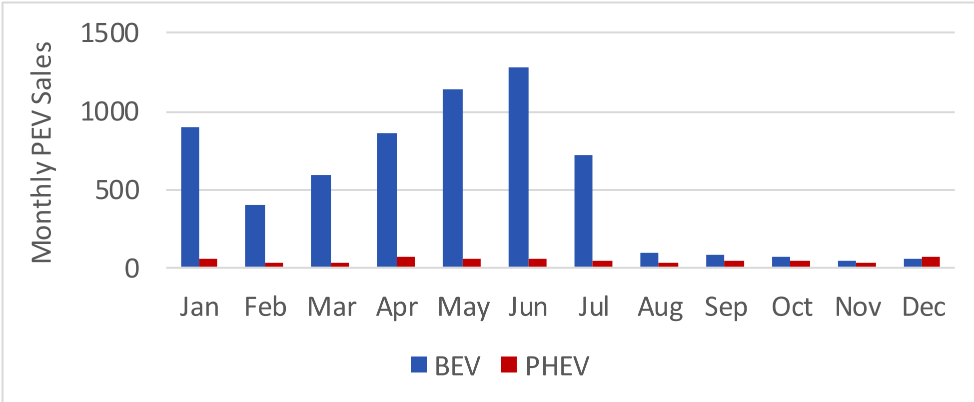

FIGURE 6 Monthly PEV Sales in Georgia in 2015

4.4 NEW YORK

The State of New York offers rebates of up to $2,000 for the purchase or lease of a new, eligible PEV (NYSERDA 2017). The state also offers an income tax credit for 50% of the cost of alternative fueling infrastructure, including electric vehicle supply equipment, for up to $5,000. PEVs are eligible for a discounted toll rate on Port Authority of New York and New Jersey off-peak hour crossings. In addition, eligible PEVs and hybrid electric vehicles may use the Long Island Expressway HOV lanes, regardless of the number of occupants in the vehicle. New York also exempts BEVs from state motor vehicle emissions inspections. As noted above, New York signed the ZEV MOU. The State of New York offers rebates to cities, towns, and counties for the purchase or lease of eligible ZEVs and for the installation of eligible ZEV fueling infrastructure. A municipality may receive up to $5,000 per ZEV with an electric range of 50 miles or greater and $2,500 per ZEV with an electric range of 10 to 50 miles. Municipalities may also receive up to $250,000 for EVSE installation. As of December 2017, there were 827 Level 1 or 2 public charging stations with 1,665 charging ports, and 59 DCFC stations with 195 ports in New York (U.S. DOE 2018).

Sales shares of PEVs in New York State are shown in Figure 7. While PEV shares are lower than in Georgia or California, the figure illustrates that PHEV shares are significantly higher than BEV shares. A higher PHEV share of PEV sales is consistent with the literature findings of a preference by consumers in cold climates for PHEVs, as discussed in Section 3.

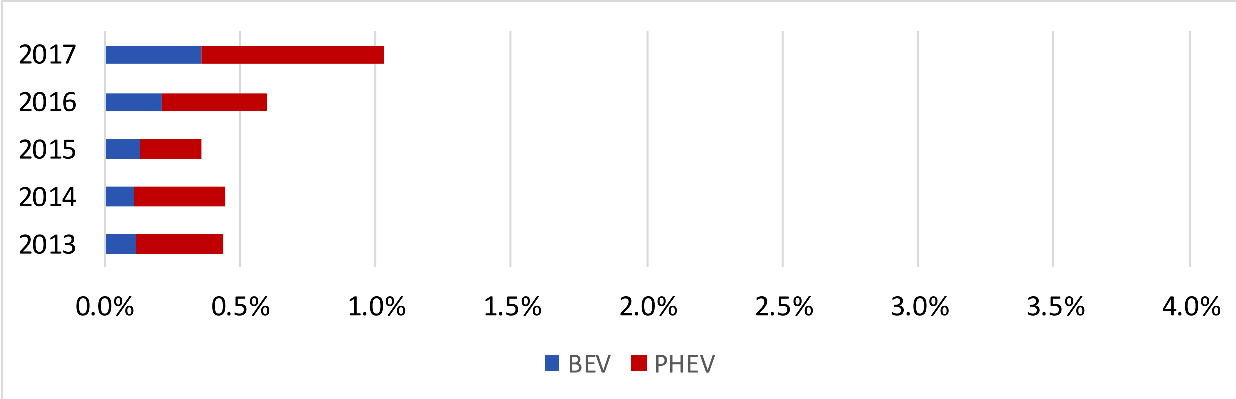

FIGURE 7 PEV Share of LDV Sales in New York

4.5 MICHIGAN

Michigan exempts PEVs from emissions inspection requirements. The State of Michigan charges an increased vehicle registration fee for PEVs. The increase is $30 for PHEVs and $100 for BEVs with a gross vehicle weight rating (GVWR) of 8,000 lb or less. As of December 2017, there were 325 Level 1 or 2 public charging stations with 857 charging ports, and 24 DCFC stations with 92 ports in Michigan (U.S. DOE 2018).

Figure 8 shows PEV sales shares and indicates that PHEV sales shares are much higher than BEV shares (similar to New York State).

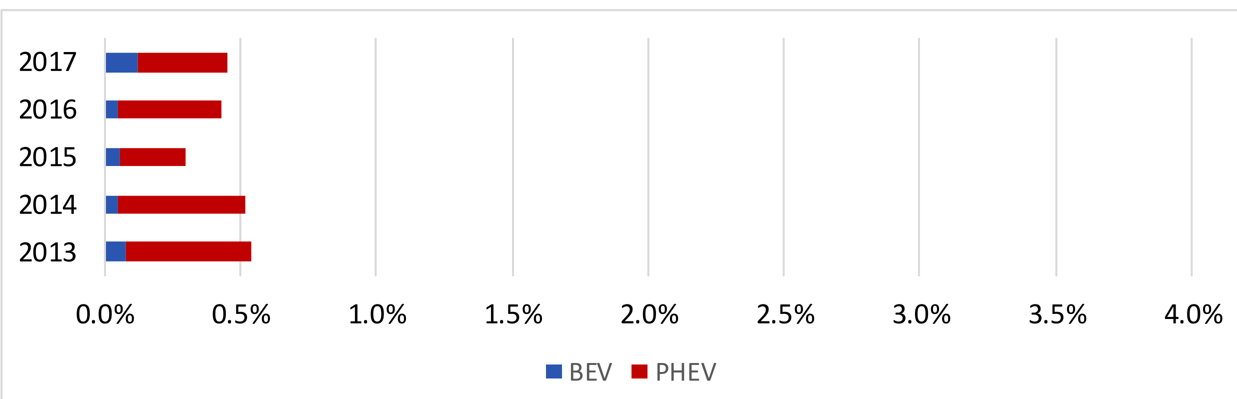

FIGURE 8 PEV Share of LDV Sales in Michigan

4.6 WASHINGTON STATE

In Washington State, new, qualifying PEVs are exempt from state motor vehicle sales tax and use taxes. PEVs must be capable of charging by an external power source and traveling at least 30 miles using only electricity. The PEV must have a base model price of $42,500 or less. The sales tax exemption applies to up to $32,000 of a vehicle's selling price or the total amount of lease payments made. PEV owners must pay an annual vehicle registration renewal fee of $150. These fees will contribute to the state's Electric Vehicle Infrastructure Bank to deploy charging stations. As of December 2017, there were 676 Level 1 or 2 public charging stations with 1,726 charging ports, and 77 DCFC stations with 206 ports in Washington State (U.S. DOE 2018).

As seen in Figure 9, in Washington State, both BEV and PHEV sales shares are higher than the U.S. average.

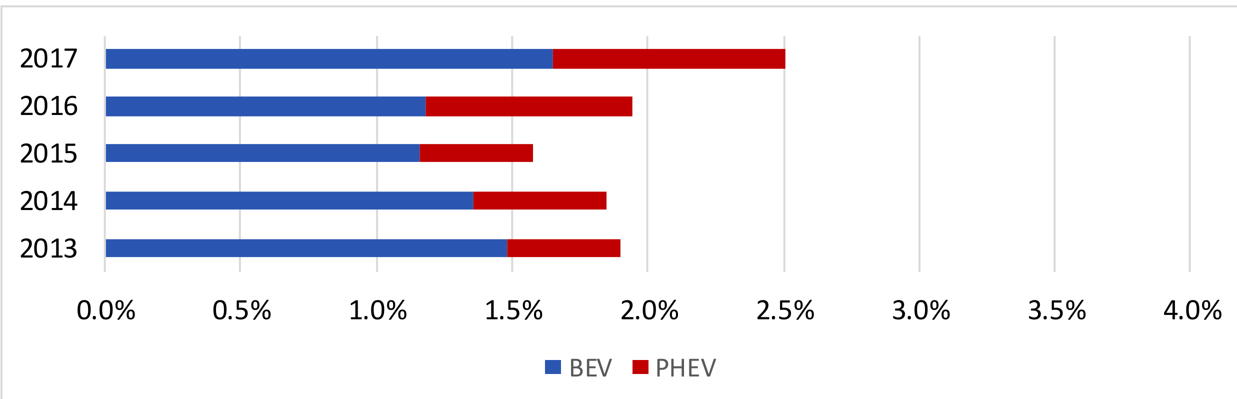

FIGURE 9 PEV Share of LDV Sales in Washington State

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5 REGIONAL REVIEW: EUROPEAN PEV POLICIES AND MARKET TRENDS

To update and supplement findings of earlier studies of PEV policies and market trends in Europe, national European PEV adoption policies are reviewed below. The authors discuss the PEV adoption of the three largest European car markets, as well as countries with significant PEV sales and sales shares to see how policies and other market factors have impacted adoption.

5.1 EUROPE AS A WHOLE

Europe is a diverse set of countries with varying levels of PEV adoption and policy support (see Table A-2 in the Appendix). As of 2017, European PEV per capita ownership was 1.4 PEVs owned per 1,000 people (IEA 2017; EAFO 2018). Europe has 114,000 AC and 17,700 DCFC charging ports[2], about 133 and 21 per 1,000 PEVs, respectively. Europe's annual passenger vehicle sales were about 16.3 million vehicles per year and vehicle ownership was 420 passenger cars per 1,000 people (Bekker 2018; EAFO 2018). In 2017, BEVs and PHEVs accounted for 0.8% and 0.9% of new vehicle sales in Europe, respectively, for a total of 1.7% for PEVs, as shown in Figure 10. Germany, France, and the United Kingdom have significant PEV sales (all were in the top 4 for Europe in 2017) as their new car market is large. However, the PEV market share was relatively low, ranging from 1.6% to 1.9%. In contrast, Norway led Europe both in PEV sales and market share (39.2%), while other countries that have recently had high sales and market share include the Netherlands (6.0% in 2016) and Sweden (5.3%). In the following sections, the PEV policies of these six countries will be examined.

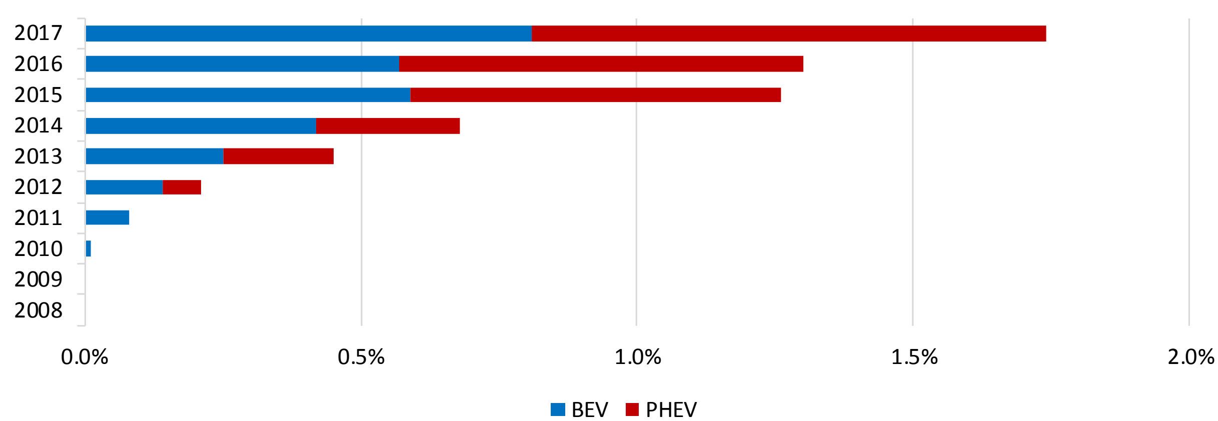

FIGURE 10 PEV Passenger Car[3] Market Share in the European Union

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2 Available European charging infrastructure data is for charging ports (or points); the number of charging stations is not available.

3 Data in Section 5 are for passenger vehicles. European M1 classification is for passenger vehicles with no more than nine seats (including the driver) and does not include pickup trucks or cargo vans.

The European Commission (EC) has been developing vehicle CO_2 tailpipe emission standards for its member states since the late 1990s. E-mobility, including PEVs and FCVs, plays an important role in EU CO_2 emission standards. In November 2017, the EC proposed new vehicle CO_2 emission standards for 2025 and 2030 with emissions 15% and 30% lower, respectively, than those of 2021. The proposal also contains a specific incentive mechanism to promote zero/low emission vehicles (ZLEVs) such as PEVs (EC 2017). The new proposal recognizes, partly from the Volkswagen diesel NO_x emission scandal, that the New European Driving Cycle, in place for more than 20 years, is not sufficient to address real-world driving in Europe. Therefore, it is being replaced with the Worldwide Harmonized Light Vehicle Testing Procedure.

From 2025 on, the specific CO_2 emissions target for a manufacturer will be calculated based on the share of ZLEVs in the manufacturer's fleet. For the calculation of that share, the ZLEV counts will be based on a weighting of the emissions of each vehicle. In particular, ZLEVs are defined as those with tailpipe CO_2 emissions of less than 50 g/km with BEVs considered as zero emission vehicles (because emissions from fuel/electricity production are not included in the regulation). The new proposal has voluntary targets of 15% sales of ZLEVs in 2025 and 30% in 2030. When the share by a manufacturer exceeds these targets, the manufacturer benefits from a higher CO_2 emissions target.

5.2 NORWAY

Norway is the world leader in PEV per capita ownership, with about 30 PEVs owned per 1,000 people in 2017 (IEA 2017; EAFO 2018). The country has 8,300 AC and 2,000 DCFC public charging ports, about 53 and 13 per 1,000 PEVs, respectively (EAFO 2018). Norway's annual passenger vehicle sales were about 159,000 vehicles per year, of which 42% were company vehicles (Bekker 2018; Tietge 2016). In 2017, BEVs and PHEVs accounted for 20.8% and 18.4% of new vehicle sales, respectively, for a PEV total of 39.2%, as shown in Figure 11 (EAFO 2018). Vehicle turnover has been historically slow owing to high taxes on new vehicles. The country has about 2.5 million passenger cars (420 per 1,000 people) and 133,000 PEVs today (EAFO 2018; IEA 2017).

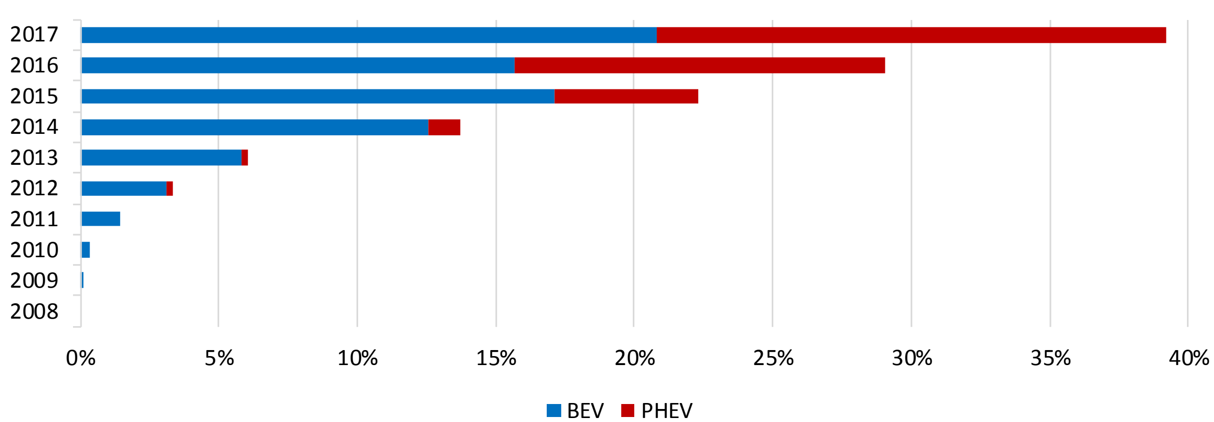

FIGURE 11 PEV Passenger Car Market Share in Norway

5.2.1 Financial Incentives

Norway has a long history, beginning in 1990, of enacting policies to incentivize PEV ownership. However, it was not until 2011 that PEVs became a meaningful portion of vehicles sold. With the introduction of the Nissan LEAF and Mitsubishi i-MiEV, the market share jumped from 0.3% in 2010 to 1.5% in 2011. While Norway does not have direct purchase incentives, they do have several tax benefits that significantly reduce the acquisition cost of PEVs. BEVs have had an exemption from the VAT on new vehicles, which, for conventional vehicles, hybrids, and PHEVs, adds 25% to the purchase price (IEA 2017). For a 30,000 euro ($36,100) BEV, the VAT tax reduction would be 7,500 euros ($9,000).

BEVs are also exempt from the one-time registration tax that can account for about 30% of the purchase price (Tietge 2016). For a 30,000 euro ($36,100) BEV, the registration tax exemption would be 10,000 euros ($12,000) (Tietge 2016). The registration tax is based on several factors: vehicle mass, engine power, CO_2 emissions, and NOx emissions. As of 2016, PHEV registration taxes can be reduced up to 10,000 euros ($12,000), as the electric powertrain is exempt from the mass and power calculations (IEA 2017). In addition, vehicles with low CO_2 emissions (below 100 g/km) have their tax reduced progressively, which benefits PHEVs and BEVs (Tietge 2016). In large part because of the introduction of the registration incentive, PHEV sales doubled from 2015 to 2016, with BEV sales declining slightly (Figure 11). However, sales of both BEVs and PHEVs increased in 2017.

Norway has a company car tax that is 30% of the first 30,000 euros ($36,100) of a vehicle's list price and 20% of the vehicle value exceeding that price. For BEVs, the calculation for this tax uses only 50% of the purchase price. For a 30,000 euro ($36,100) BEV, the discount would be 1,500 euros ($1,800). For a 30,000 euro ($36,100) BEV, the VAT, registration tax, and company car tax discounts can add up to about 19,000 euros ($22,900).

5.2.2 Infrastructure Incentives

Between 2009 and 2010, Norway's national government spent 6 million euros ($7.23 million) to subsidize the installation of about 1,800 public Schuko-point (similar to U.S. Level 2 voltage with a household plug) charging ports (Lorentzen 2017). Starting in 2015, Enova, a government enterprise, has supported the goal of locating a fast charging station every 50 km on the 7,500-km major road network. The plan requires that at least two 50 kW DC fast charging ports and two 22 kW AC points be installed at each location to reduce wait times. As of 2016, Enova has spent about 5 million euros ($6.02 million) on 230 fast charging stations, with a plan to finish the network by the end of 2017 (Deign 2016; Lorentzen 2017). The funding covers equipment and installation, but it does not cover operating costs.

In addition, regional governments have incentivized provision of additional public charging infrastructure. Oslo funded 700 public charging points between 2008 and 2014, and subsidized 60% of the cost of charging stations for non-public locations, like apartment buildings and shopping malls (Tietge 2016).

5.2.3 Other Financial Incentives

Norway has provided other financial incentives to support PEVs. BEVs have free access to the many toll roads, which typically cost several euros (ranging from 1 to 15) per toll (AutoPass 2017). This benefit was ranked the second most important incentive in a survey of Norwegian BEV owners. BEVs also have free access to ferries (Lorentzen 2017). From 1999 to 2015, BEVs were allowed free parking in public spaces. The current national BEV parking incentive does not require this concession, but rather lets individual local authorities decided whether to provide the benefit.

5.2.4 Non-financial Incentives

In 2005, Norway provided BEVs nationwide access to bus lanes. Similar to the free parking incentive, local authorities were granted the right in 2015 to determine bus lane access.

5.3 THE NETHERLANDS

PEV per capita ownership in the Netherlands was 7 per 1,000 people in 2017 (IEA 2017; EAFO 2018). The country has 32,100 AC and 760 DCFC public charging ports, about 269 and 6 per 1,000 PEVs, respectively (EAFO 2018). The Netherlands has one the largest public charging networks in the world on both an absolute and per PEV basis. The Netherlands' annual passenger vehicle sales are about 380,000 vehicles per year, and 54% of those are company vehicles (Bekker 2018; Tietge 2016). In 2017, BEVs and PHEVs accounted for 1.9% and 0.3% of new vehicle sales, respectively, for a PEV total of 2.2% as shown in Figure 12 (EAFO 2018). This number is down from the 2016 total of 6% (1.1% and 4.9%, respectively) and 2015 total of nearly 10% (0.7% and 9.2%, respectively).

In 2009, the Dutch government developed an action plan to increase PEV ownership, and set a goal of 200,000 PEVs by 2020 and 1 million PEVs by 2025. The country has about 8 million passenger cars (470 per 1,000 people) and 119,000 PEVs today (EAFO 2018; IEA 2017). As part of this plan, significant funding was earmarked—65 million euros ($78.3 million) for direct incentives and 500 million euros ($602 million) for economic stimulus for industry, regional government, and other organizations—to be spent between 2011 and 2015. More recently, the country announced plans to ban new gasoline and diesel car sales by 2030 (Lambert 2017).

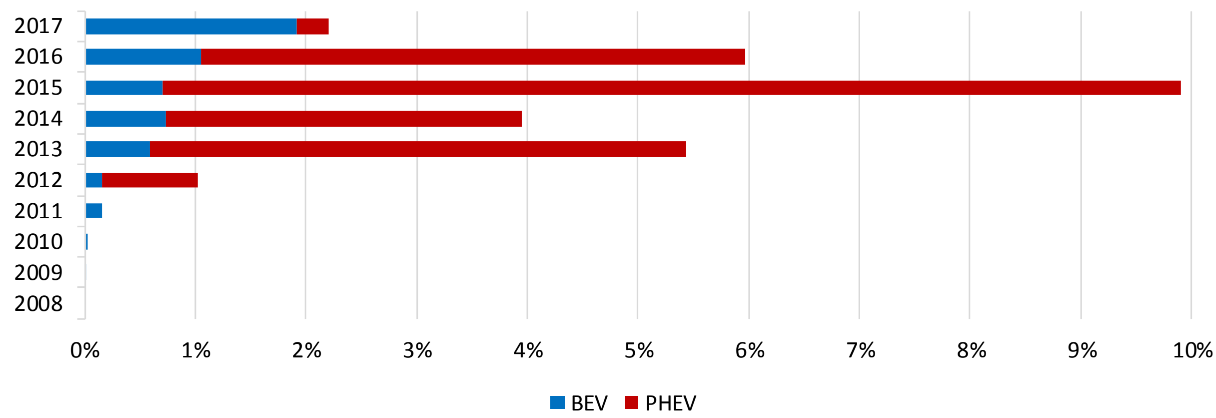

FIGURE 12 PEV Passenger Car Market Share in the Netherlands

5.3.1 Vehicle Purchase and Tax Incentives

With the action plan in place, PEV sales grew quickly, starting in 2012, with the introduction of the Opel Ampera and Toyota Prius PHV. In 2015, the Dutch government decided to focus primarily on BEVs, and in 2016 began to adjust PHEV taxes to match gasoline car taxes more closely. In anticipation of this alignment, sales of PHEVs spiked to 9% of new sales in 2015, dropped to 5% in 2016 as tax rates increased, and fell precipitously to 0.3% as the PHEV incentives disappeared. Figure 13 shows that PHEV sales spiked at the end of 2013, 2015, and 2016 in anticipation of changing incentives. In December 2016, sales of PHEVs were 10,500 units, and 2017 sales averaged 100 PHEVs per month.

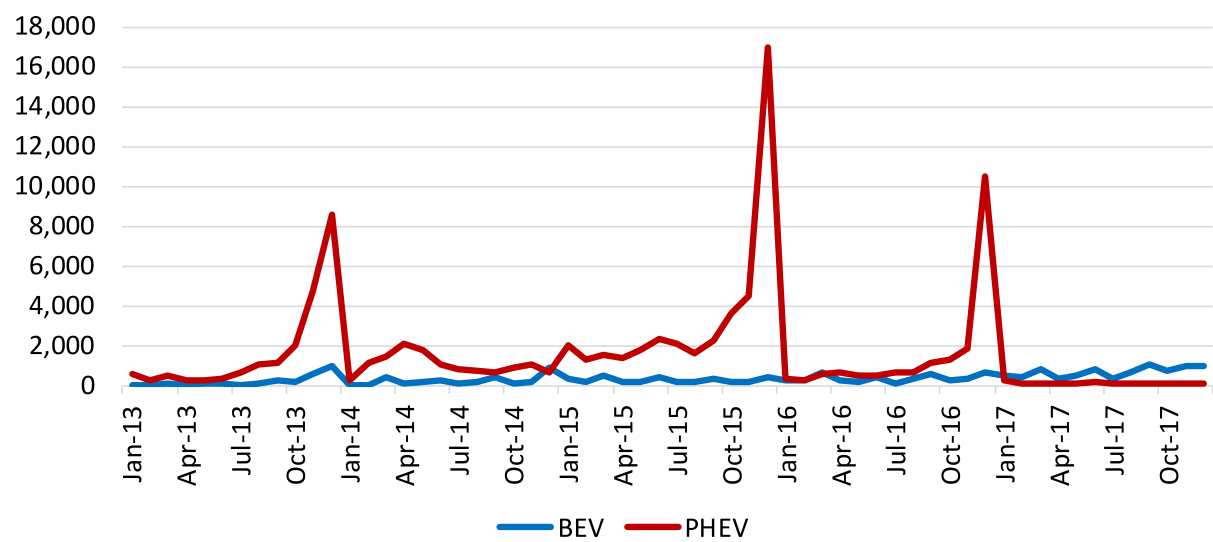

FIGURE 13 Monthly PEV Sales in the Netherlands from 2013 to 2017

While the Netherlands does not have direct purchase incentives, they do have a one-time registration tax benefit based on CO_2 emissions that reduces the acquisition cost of PEVs. BEVs are exempt from the CO_2 registration tax, which progressively increases as the emission rate increase. This tax can be tens of thousands of euros for vehicles with high emission rates. For example, a gasoline car emitting 150 g/mi pays 145 euro/g for a total of 21,750 euros ($26,200, Energielabel 2018).

In addition, the Netherlands has an annual ownership tax based on vehicle mass and powertrain type. Battery-electric vehicles are exempt from this tax, and until the end of 2015, vehicles with CO_2 rates below 50 g/km were exempt. Starting in 2016, the tax rate for vehicles with low CO_2 emission rates was set to half that of conventional vehicles, and the calculation was adjusted to account for the incremental weight of a hybrid's battery pack. For an average gasoline and diesel vehicle, the tax would be about 600 and 1,200 euros ($720 to $1,450), respectively (Tietge 2016).

The Netherlands has an income tax for private use of a company car that adds a percentage of the vehicle's list price, based on its CO_2 rate, to the individual's income when calculating annual taxes. For BEVs, the tax rate is 4% of the vehicle's list price. For PHEVs, the tax rate increased from 7% to 14% in 2015, to between 15% and 21% in 2016, and finally to 22% in 2017, matching the rate of gasoline vehicles (IEA 2017).

5.3.2 Infrastructure Incentives

The Netherlands became a leader in public charging infrastructure by developing public-private partnerships. For example, ElaadNL, a group of national and regional grid operators, generated 25 million euros ($30.1 million) in funding and installed 3,000 charging stations between 2010 and 2014 (Tietge 2016). In addition, the Green Deal public-private partnership has generated 33 million euros ($39.8 million) in funding, which is being spent between 2015 and 2018 to install chargers (Tietge 2016). The Green Deal includes a tax incentive for businesses that deploy chargers (IEA 2017). In addition, the Dutch government has the goal of installing 200 DCFC stations, located every 50 km along its major roadways. From this effort, the Dutch company Fastned has already built 60 DCFCs (IEA 2017).

5.4 SWEDEN

Sweden PEV per capita ownership was 5 PEVs per 1,000 people in 2017 (IEA 2017; EAFO 2018). The country has 2,400 AC and 2,400 DCFC public charging ports, about 48 per 1,000 PEVs for each type (EAFO 2018). Sweden is one of the few countries with equally large numbers of public AC and DCFC charging ports. Sweden's annual passenger vehicle sales were about 380,000 vehicles per year (Bekker 2018). In 2017, BEVs and PHEVs accounted for 1.1% and 4.2% of new vehicle sales, respectively, for a total of 5.3% for PEVs, as shown in Figure 14 (EAFO 2018). Plug-in hybrid sales continue to be strong in comparison to BEVs, even with Sweden's relatively large DCFC charging network and the reduction of incentives for PHEVs. The country has about 4.5 million passenger cars (460 per 1,000 people) and 49,000 PEVs today (EAFO 2018; IEA 2017).

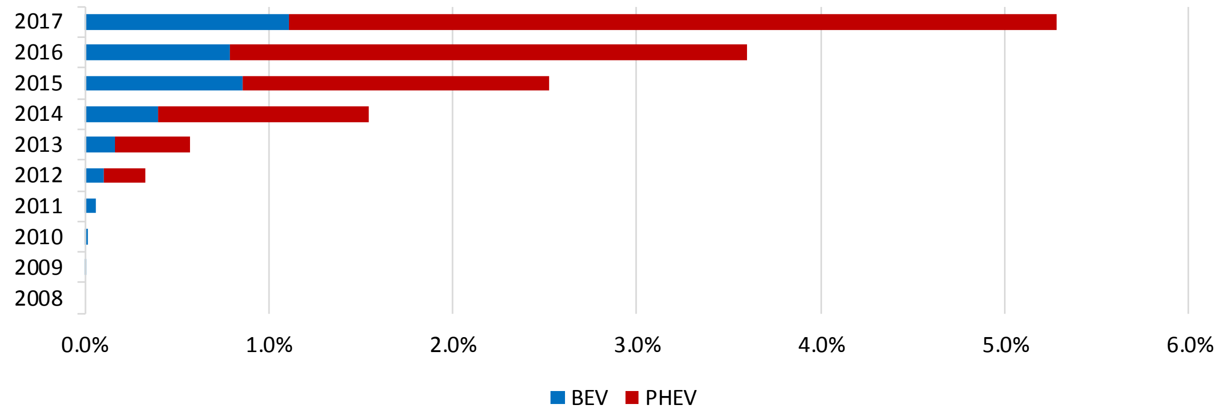

FIGURE 14 PEV Passenger Car Market Share in Sweden

5.4.1 Financial Incentives

In 2012, Sweden enacted their "Super Green Car Premium" purchase rebate program, which provides a 4,000 euro ($4,820) purchase incentive for vehicles with emissions lower than 50 g CO_2/km (IEA 2017). The funding appropriated for the program ran out in the middle of 2014, and each year from 2014 to 2016, the government retroactively funded the program (Tietge 2017). Beginning in 2016, PHEVs receive only half the incentive. For company cars, PEVs received a 5-year exemption from annual registration fees, ranging from 50 to 300 euros ($60 to $360) per year. From 2012 to 2016, Sweden reduced the income tax for private use of a company car (a benefit offered to employees that is considered taxable) to 40% of tax that would apply to a comparable conventional vehicle, with a maximum discount of 1,600 euros ($1,930), and in 2017, a maximum discount of 1,000 euros ($1,200) (IEA 2017).

The uncertain funding for the program helped increase the volatility in sales, as seen in Figure 15 as PEV buyers held off on purchasing vehicles until funding was restored (Tietge 2017). The Swedish PEV market favors PHEVs strongly, and even with their reduced incentives, their sales continue to be much higher than for BEVs.

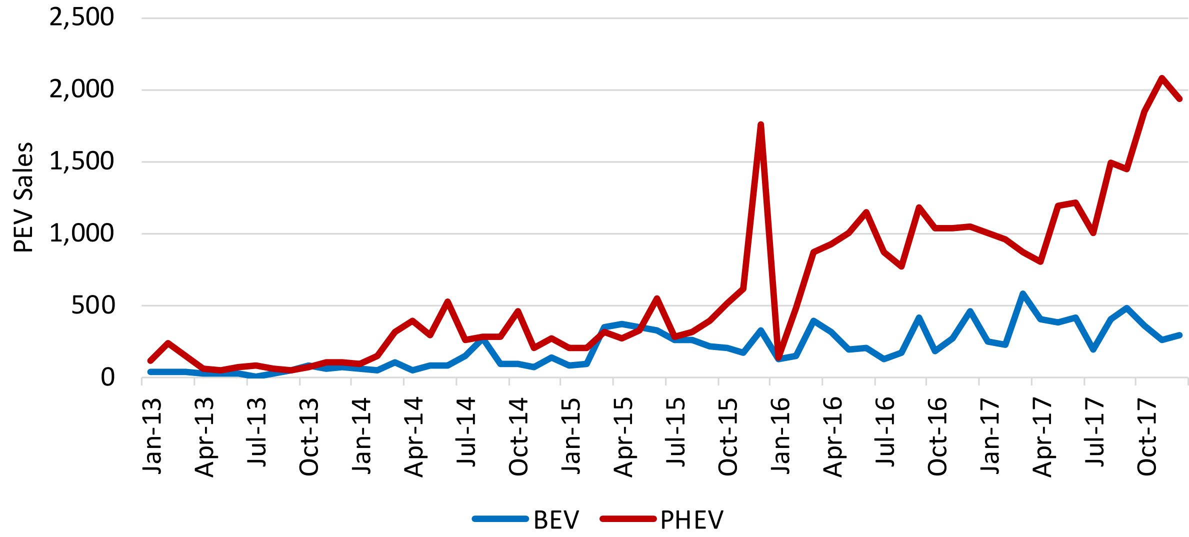

FIGURE 15 Monthly PEV Sales in Sweden from 2013 to 2017

Sweden announced it is replacing the "Super Green Car Premium" program with a new bonus-malus system, starting in July 2018, based on the vehicle's carbon emissions (g CO_2/km) certification level. For BEVs, the bonus is 6,000 euros ($7,230) and decreases linearly to 1,000 euros ($1,200) for vehicles at 60 g CO_2/km (IEA 2018). The funding for this program is expected to be more stable owing to the penalty on high emitting vehicles.

5.5 UNITED KINGDOM

The United Kingdom (UK) PEV per capita ownership was about 2 PEVs per 1,000 people in 2017 (IEA 2017; EAFO 2018). The country has 11,500 AC and 2,800 DCFC public charging ports, about 84 and 20 per 1,000 PEVs, respectively (EAFO 2018). The UK's annual passenger vehicle sales were about 2.5 million per year (Bekker 2018). In 2017, BEVs and PHEVs accounted for 0.5% and 1.4% of new vehicle sales, respectively, for a total of 1.9% for PEVs, as shown in Figure 16 (EAFO 2018). The country has about 28.5 million passenger cars (440 per 1,000 people) and 138,000 PEVs today (EAFO 2018; IEA 2017). The UK government recently announced plans to ban new gasoline and diesel car and van sales by 2040 (EC 2017).

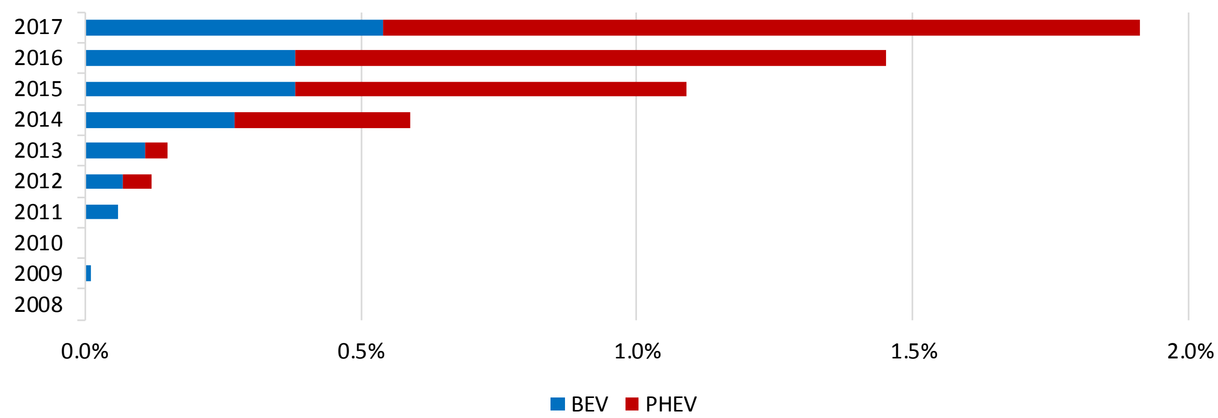

FIGURE 16 PEV Passenger Car Market Share in United Kingdom

5.5.1 Financial Incentives

Beginning in 2011, the UK enacted the Plug-in Car Grant, which provided a point of purchase discount up to 5,000 pounds (~5,700 euros or $6,900), depending on vehicle range, for PEVs with emissions lower than 75 g CO_2/km (Tietge 2016). The program initially covered 50,000 vehicles, but in 2015, the cap on the number of discounts was increased to cover an additional 80,000 vehicles from 2015 through 2020. The program now provides eligible BEVs up to 4,500 pounds (~5,000 euros or $6,000) and PHEVs up to 2,500 pounds (~2,800 euros or $3,400). The UK also exempts PEVs from the annual ownership tax that can be up to 600 euros, as well as company car taxes. Local incentives include PEV exemptions from London's congestion fee, an amount of nearly 3,000 pounds (~3,400 euros or $4,100) per year.

5.6 FRANCE

France PEV per capita ownership was about 2 PEVs per 1,000 people in 2017 (IEA 2017; EAFO 2018). The country has 14,400 AC and 1,900 DCFC public charging ports, about 117 and 15 per 1,000 PEVs, respectively (EAFO 2018). France's annual passenger vehicle sales were about 2.1 million vehicles per year (Bekker 2018). In 2017, BEVs and PHEVs accounted for 1.2% and 0.6% of new vehicle sales, respectively, for a total of 1.8% for PEVs, as shown in Figure 17 (EAFO 2018). BEV sales are strong in comparison to PHEVs.

The French government has set a goal of 2.4 million PEVs by 2023 (EC 2017). The country has about 32 million passenger cars (480 per 1,000 people) and 124,000 PEVs today (EAFO 2018; IEA 2017). The country recently announced plans to ban new gasoline and diesel car sales by 2040, while the city of Paris plans to ban the use of diesel cars by 2024 and petrol cars by 2030 (EC 2017).

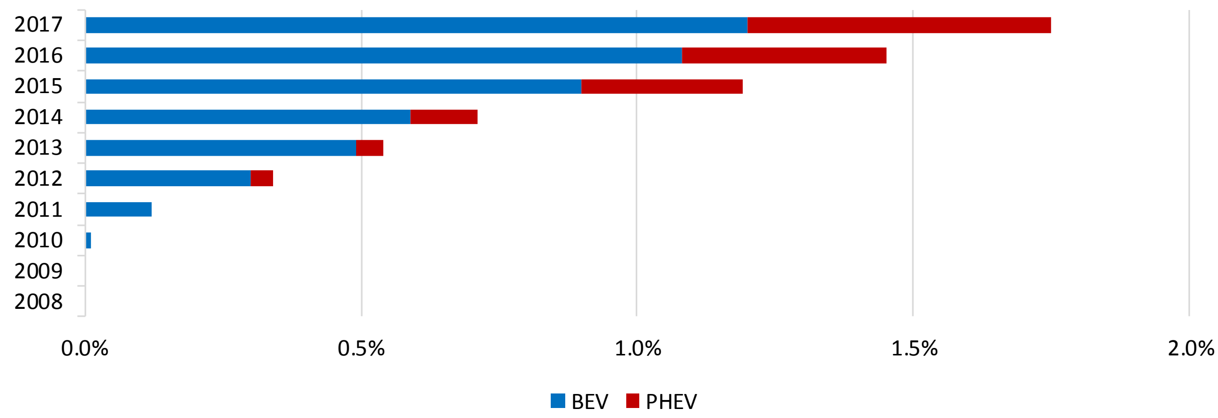

FIGURE 17 PEV Passenger Car Market Share in France

5.6.1 Financial Incentives

Beginning in 2008, France enacted a bonus-malus purchase rebate program based on the vehicle's carbon emissions (g CO_2/km). Initially the program provided 5,000 euros ($6,000) for PEVs and penalized high emitting vehicles by 2,600 euros ($3,130, Green Car Congress 2007). More recently, the program provided a bonus of 6,300 euros for BEVs, and an additional 4,000 euros ($4,820) for scrapping an 11-year-old diesel; and a bonus of 1,000 euros ($1,200) for PHEVs, and an additional 3,500 euros ($4,220) for diesel scrappage (IEA 2017). Starting in 2018, BEVs are eligible for a bonus of 6,000 euros ($7,230) and an additional 2,500 euros ($3,000) for scrappage of pre-2001 diesels or pre-1997 gasoline vehicles. PHEVs are no longer eligible for the 1,000 euro ($1,200) bonus (AVERE 2017). As seen in Figure 17, BEVs have had a larger market share than PHEVs, with the incentive structures likely playing a role in that outcome.

5.7 GERMANY

Germany PEV per capita ownership was 1.5 PEVs per 1,000 people in 2017 (IEA 2017; EAFO 2018). The country has 22,200 AC and 3,030 DCFC public charging ports, about 179 and 24 per 1,000 PEVs, respectively (EAFO 2018). Germany's annual passenger vehicle sales were about 3.4 million vehicles per year (Bekker 2018). In 2017, BEVs and PHEVs accounted for 0.7% and 0.9% of new vehicle sales, respectively, totaling 1.6% for PEVs, as shown in Figure 18 (EAFO 2018).

The German government has set the goal to become the lead market for electric vehicles and have 1 million PEVs on the road by 2020. The country has about 44 million passenger cars (540 per 1,000 people) and 124,000 PEVs today (EAFO 2018; IEA 2017). Recently, the German lead court ruled that German cities are allowed to put bans on driving diesel vehicles without federal legislation (Deutsche Welle 2018).

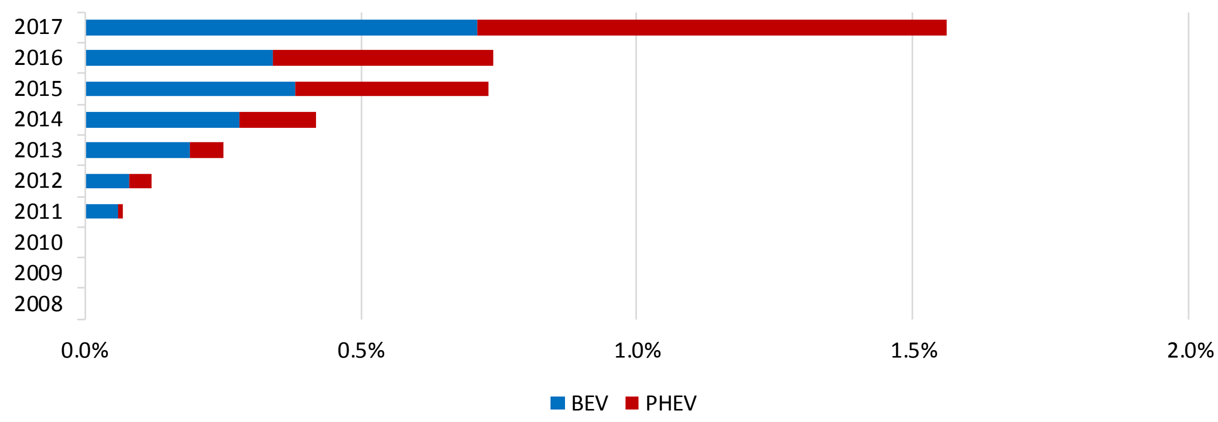

FIGURE 18 PEV Passenger Car Market Share in Germany

5.7.1 Financial Incentives

In May 2016, Germany launched a new program that offers purchase incentives of 4,000 euros ($4,820) for BEVs and 3,000 euros ($3,600) for PHEVs for vehicles with list prices less than 60,000 euros ($72,300) (Lambert 2016). The government and automakers set aside 600 million euros ($723 million) each for a total of 1.2 billion euros ($1.45 billion) of funding. The program ends by 2020 and funds a maximum of 400,000 cars. In 2017, both BEV and PHEV sales doubled, likely owing in part to this program.

5.7.2 Infrastructure Incentives

As part of the program, the German government will spend 300 million euros ($361 million) to build 15,000 charging points between 2017 and 2020. 100 million euros ($120 million) will be used for AC charging and 200 million euros ($241 million) will be used for DC charging infrastructure.

5.8 EUROPEAN SUMMARY STATISTICS

Table 2 provides summary statistics for Europe and the countries analyzed above, while Figure 19 shows the PEV registrations per 1,000 people for European countries in 2017.

TABLE 2 Summary of Selected European Country PEV and Station Statistics for 2017

	Europe	Norway	Netherlands	Sweden	UK	France	Germany
PEVs/1000 people	1.4	29.7	7.0	5.0	2.1	1.9	1.5
Cars/1000 people	420.0	480.0	470.0	460.0	440.0	480.0	540.0
Total cars	253,000,000	2,500,000	8,000,000	4,500,000	28,500,000	32,200,000	43,900,000
Total PEVs	858,000	158,000	119,000	49,000	138,000	124,000	124,000
Annual car sales	16,300,000	160,000	420,000	380,000	2,500,000	2,100,000	3,400,000
BEV market share	0.8%	20.8%	0.3%	1.1%	0.5%	1.2%	0.7%
PHEV market share	0.9%	18.4%	1.9%	4.2%	1.4%	0.6%	0.9%
AC charging ports/1000 PEVs	133	53	269	48	84	117	179
DC charging ports/1000 PEVs	21	13	6	48	20	15	24

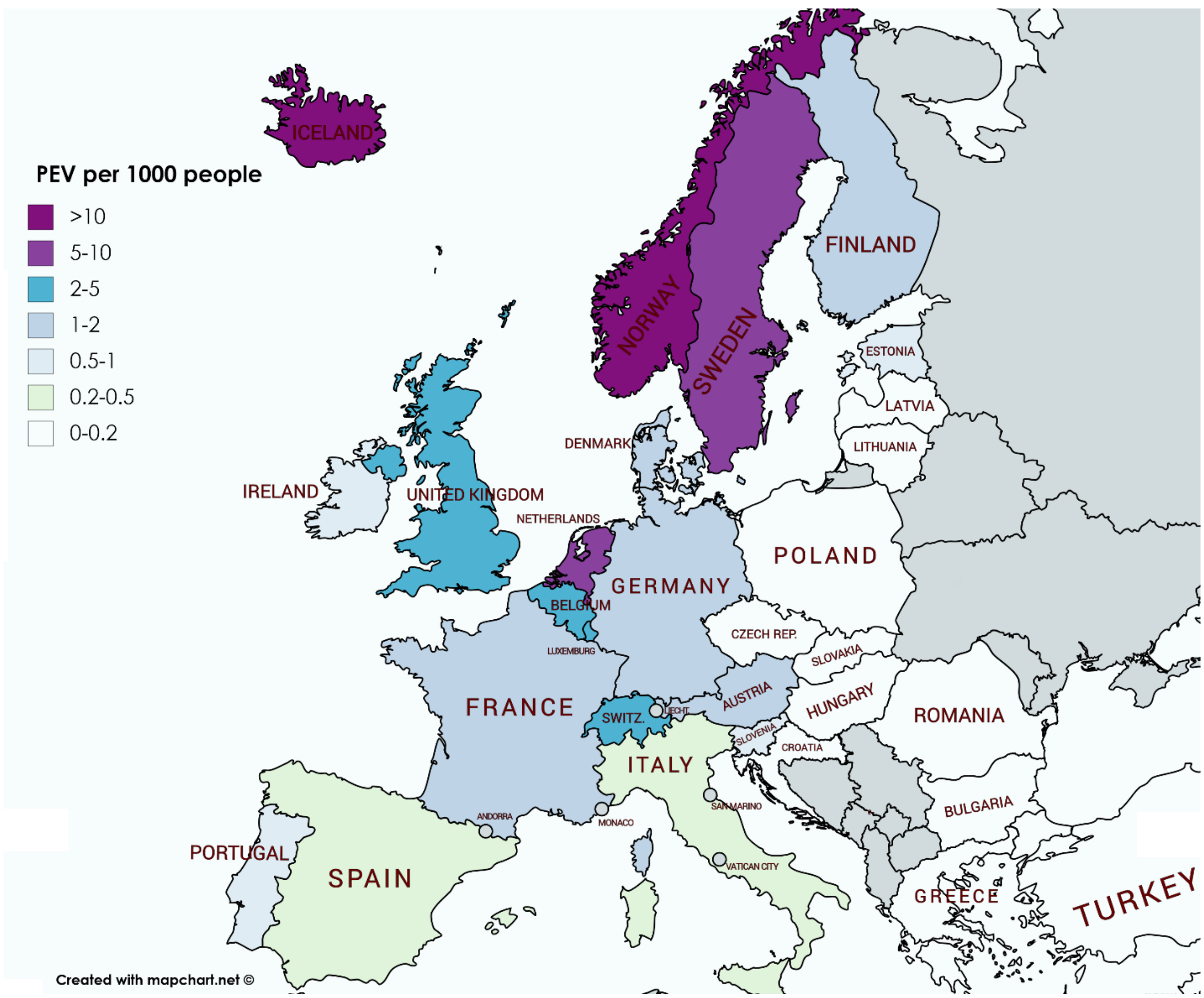

FIGURE 19 PEV Registration Per Capita in Europe in 2017
Note: Map was generated using mapchart.net.

6 REGIONAL REVIEW: CHINA PEV POLICIES AND MARKET TRENDS

To update and supplement findings of earlier studies of PEV policies and market trends in China, federal and selected state PEV adoption policies are reviewed below. Provinces or cities selected for discussion are those with the highest PEV adoption (sales shares) and offer diverse PEV incentives.

6.1 CHINA AS A WHOLE

Because of the significant increase in demand for imported petroleum for vehicle energy (Huo et al. 2012), combined with increased air pollution in major metropolitan areas, China is strongly motivated to accelerate the deployment of alternative vehicles—called new energy vehicles (NEVs), a category that includes both fuel cell vehicles and PEVs—with PEVs as a priority.

Adoption of PEVs has increased dramatically in the last few years. China became the biggest PEV market in the world in 2015, with 207,000 PHEV and BEV passenger cars sold. China kept the leading PEV market position in 2016, with about 320,000 PEVs sold (not including electric buses). In 2017, the number is about 550,000, representing a more than 60% annual increase.

Figure 20 shows the approximate number of PEVs per capita by province, based on data provided by Tsinghua University (Wang and Hao 2018). The numbers shown are the cumulative PEV sales for 2013 through 2017, divided by the population of each province as of December 2016. Despite the recent increase, the national average PEV ownership in China in 2017 is about 0.81 PEV per 1,000 people, which is lower than in the United States and Europe. Note that overall light-duty vehicle ownership in China (140 vehicles per 1,000 people in 2017) is much lower than that in the United States (780 per 1,000 people) and Europe (300–770 per 1,000 people). As of the end of 2017, China has installed more than 205,000 charging ports, with over 85% of them public. About 30% of the charging points are DCFC. In November 2015, China announced a plan to install 4.8 million charging ports by 2020.

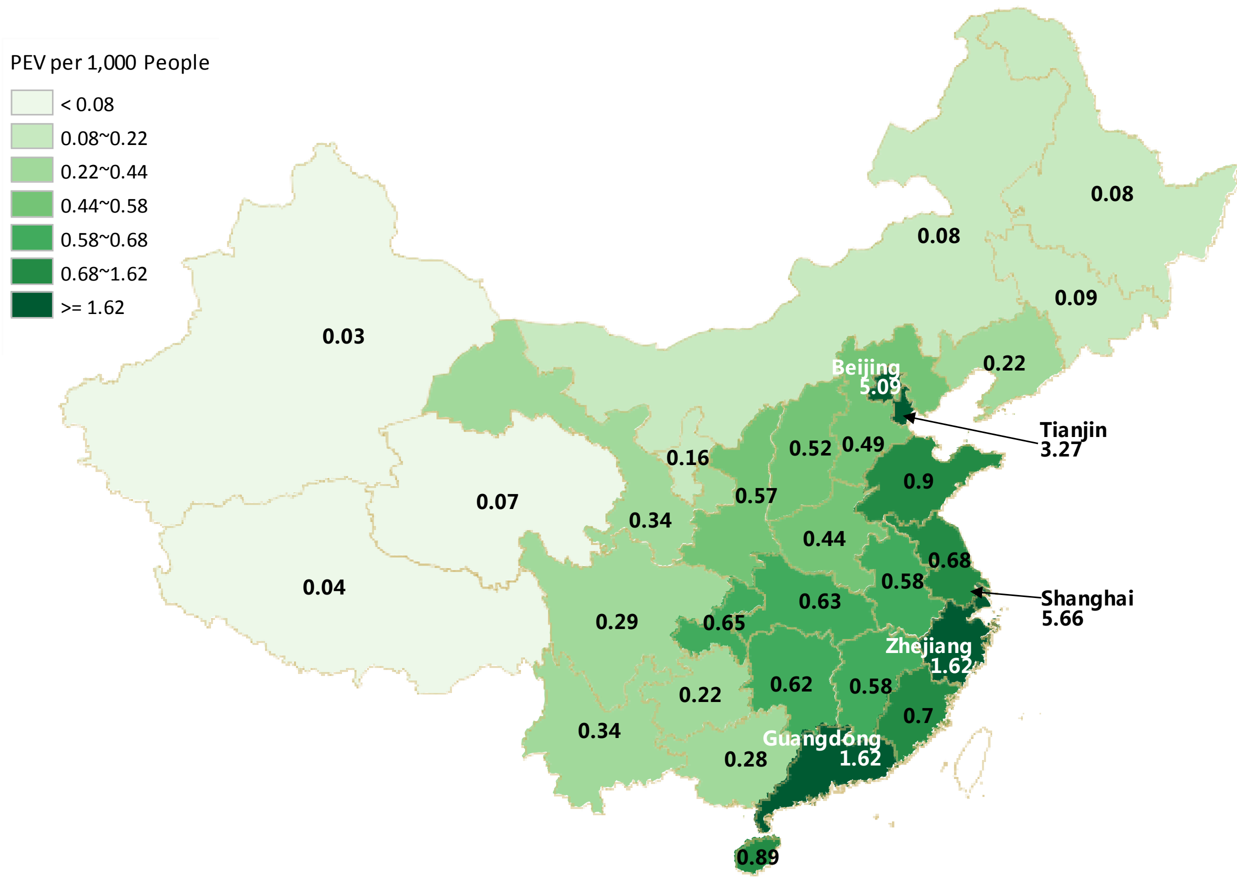

FIGURE 20 PEV Registration Per Capita in China by Province in 2017
Note: Data provided by H. Wang and X. Hao of Tsinghua University, Beijing, China. Registrations are estimated from cumulative PEV sales for 2013–2017, and population data are for December 2016.

China's first financial support policies for the promotion and application of NEVs started in 2009 in 13 pilot cities. Qualified vehicles, including PHEVs, BEVs, and FCVs, were required to have an electric range of at least 50 km for PHEVs and 100 km for BEVs. Phase 1 covered years 2009 to 2012 and based PEV purchase subsidies on battery capacity. The central government provided a purchase incentive of up to 50,000 RMB (about $7,800; 1 U.S. dollar equals about 6.4 RMB) per vehicle. Phase 2 covered years 2012 to 2015, shifted the subsidy basis to electric vehicle range, and decreased the maximum purchase incentive to 47,500 RMB ($7,400).

In April 2015, China central government issued a notice outlining Phase 3, covering years 2016 to 2020, of the financial support policies for the promotion and application of NEVs. This phase covers 88 metropolitan areas designated as NEV pilot cities and provides over 20 types of financial and non-financial incentives toward private NEV purchase/use and EVSE purchase/installation. The central government purchase incentive for NEVs was further decreased to 45,000 RMB ($7,050) per vehicle, but waives purchase taxes, registration fees, license fees, annual usage taxes, and import taxes.

On top of the central government incentives, many city and regional governments offer incentives. Table 3 summarizes the major types of regional incentives for 30 cities. These cities had the highest PEV sales in 2016, with 97% providing purchase incentives for PHEVs, BEVs, or both. As summarized in Section 2 of this report, many policy evaluations and consumer surveys show that incentives for vehicle ownership, such as exemptions from license limitations and travel restrictions are highly effective in promoting private PEV adoption.

Recent subsidy fraud has led to reforms for China's PEV market. On December 29, 2016, the Chinese government announced its decision to restructure the PEV subsidy policies, phasing down fiscal incentives, tightening technical requirements, and enhancing enforcement. The per-vehicle subsidy ramps down from the 2016 levels by 20% every two years, between 2017 and 2020, before the national fiscal incentive program ends in 2021. Also, subsidies will be graded to favor electric vehicles with advanced technologies, instead of a universal incentive system. Meanwhile, the government has taken measures to (1) verify proof of sale before releasing any subsidy, and perform regular or random checks to make sure vehicles are eligible; and (2) install onboard monitoring systems on all new PEVs for real-time monitoring of PEV use. Because 80% of vehicles involved in the subsidy scandal were commercial, new policy states that non-private PEVs will not receive any subsidies until mileage accumulates to 30,000 km.

In 2012, China started proactively promoting and implementing Corporate Average Fuel Consumption (CAFC) standards. The most recent target for fleet-wide fuel consumption is 5 L/100 km (47 mpg) by 2020. Moreover, China finalized its NEV program in September 2017. The NEV program is like California's ZEV program, with goals of promoting NEVs and providing additional compliance flexibility to the existing fuel consumption regulation. It applies only to passenger cars and formally took effect April 1, 2018, though the penalties are delayed until 2019. The rule establishes NEV credit targets of 10% of the conventional passenger vehicles manufactured or imported in 2019 and 12% in 2020. Each NEV generates some number of credits, depending on characteristics, such as electric range and whether it is a BEV or PHEV (Cui 2018).

A recent update to the rule added requirements on energy efficiency, battery energy density, and rated power of fuel cell systems (Cui 2018). The updated measure, "Notice on Adjusting and Improving the Policy of Financial Subsidies for Promoting and Applying New Energy Vehicles," was published on February 12, 2018 and will come into full effect June 11, 2018. Under the new policy, BEVs could receive a subsidy of at least 4,500 RMB ($700), but not more than 66,000 RMB ($10,300). The subsidy on battery capacity is limited to 1,200 RMB/kWh ($188/kWh). The battery life threshold requirement increases to 150 km (93 mi) from 100 km (62 mi) in 2017, and the battery system energy density requirement increases from 90 Wh/kg to 105 Wh/kg. Both battery energy density and efficiency (electricity consumption per 100 km) will affect the pure electric financial subsidy adjustment factor. The subsidy for PHEVs under the new policy decreases to 22,000 RMB ($3,450), which is only 8.3% less than the 2017 level, with enhanced technical requirements (MOF 2018).

TABLE 3 China City-level PEV Policy Summary

Cities	Purchase Subsidies	Tax Benefits	EVSE Benefits	Other Financial Benefits	Other Non-financial
Total	29	28	18	19	14
Percentage of Cities	97%	93%	60%	63%	47%
Beijing	X			X	X
Changsha	X	X		X	
Chengdu	X	X			X
Chongqing	X	X	X	X	
Guangzhou	X	X	X		X
Haikou	X	X	X		
Hangzhou	X	X	X		X
Hefei	X	X	X	X	X
Huzhou	X	X	X		
Kunming	X	X		X	
Lanzhou	X	X	X		X
Linbo	X	X	X		
Linyi	X	X	X	X	
Nanchang	X	X	X	X	X
Nanjing	X	X	X		
Nantong	X	X	X		
Qingdao	X	X		X	
Shanghai	X	X		X	X
Shenzhen	X	X	X	X	X
Shijiazhuang	X	X	X	X	X
Taiyuan	X	X	X	X	
Tianjin	X	X		X	X
Wuhan	X	X		X	X
Wuhu	X	X	X	X	X
Xi'an	X	X		X	X
Xiangtan	X	X		X	
Xiamen	X	X	X		
YiChun	X	X	X	X	
Zhenzhou				X	
Zhuzhou	X	X			

The final NEV market share achieved under the influence of the credit targets will therefore depend on the final fleet mix. Compliance includes meeting requirements for both CAFC and NEV credits. Regulations allow manufacturers to use surplus NEV credits to offset CAFC credit deficits, adding compliance flexibility to the existing fuel efficiency regulation for passenger cars but further incentivizing NEV production. Chinese regulators have indicated they intend to eliminate financial subsidies by 2020 as the fleet NEV credit system ramps up.

6.2 REVIEW OF PEV MARKET TRENDS

In 2014, China's PEV market experienced dramatic increases in both production volume and market penetration compared to 2013. In years prior to 2013, almost all PEVs sold were BEVs. From 2013 to 2017, BEVs accounted for almost 70% of PEVs sold annually in China because most of the cities provided more subsidies toward the purchase and use of BEVs. This trend continued in 2017 with BEVs representing almost 80% of PEVs sold. Figure 21 shows annual PEV production and market shares of passenger vehicles.[4]

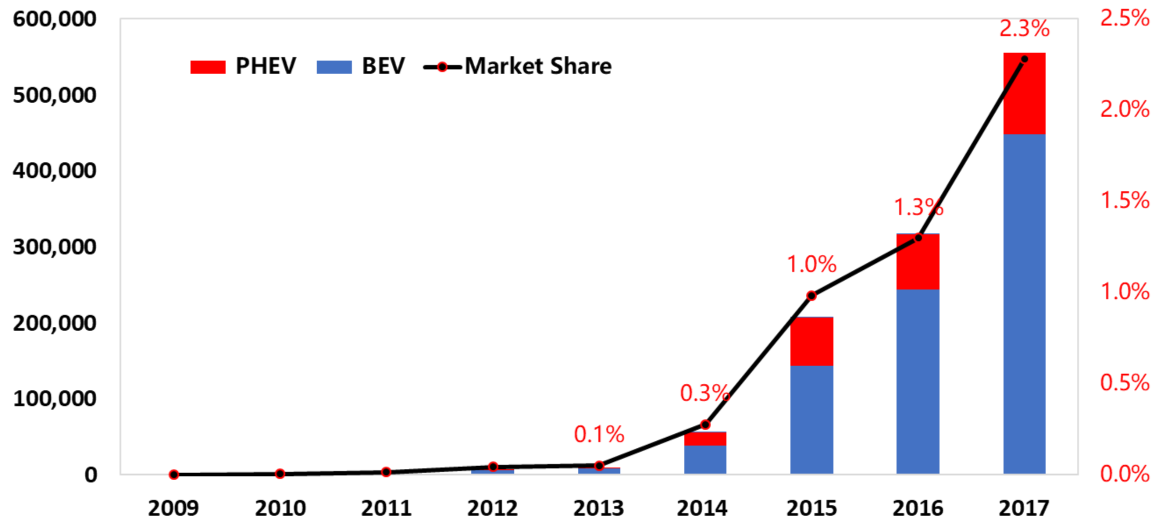

FIGURE 21 Annual PEV Production and Market Share of Passenger Vehicles in China
Note: Data provided by Tsinghua University, Beijing, China

6.3 REGIONAL OBSERVATIONS

The development of the NEV markets in China's different cities (mainly first tier cities) and regions varies largely because policies and PEV model/type availability differ, as shown in Table 3. For example, incentives and promotions are more generous in some regions than others. A consumer survey about NEVs in six cities in China in 2017 (Xing 2017) showed significant differences among NEV users in different cities in terms of the type of vehicle adopted. Beijing, Wuhan, and Shijiazhuang adopted primarily domestic BEVs, while Shanghai and Chengdu focused heavily on PHEVs, likely a result of municipal protectionism. For example, the application process for models made by non-local producers to become permitted in the NEV subsidy catalogue issued by local governments is more complex than for models made by local automakers. Moreover, local governments prefer to choose local PEV models for public vehicles

4 Passenger vehicles in China include cars, SUVs, multi-purpose vehicles (MPVs), and minibuses or vans with fewer than nine seats. Vehicles are classified into six sizes according to vehicle wheel base and length: A00, A0, A, B, C, and D.

such as buses and taxis. After 2016, the local NEV subsidy catalogues were replaced by the national unified subsidy catalogue in order to abolish local protectionism.

Among the 31 provinces and cities across the country, six sold more than 10,000 PEVs in 2016, accounting for 75.4% of the national total. Three provinces sold more than 20,000 PEVs in 2016, Beijing, Shanghai, and Guangdong, accounting for 55.9% of the national total. Table 4 summarizes the major PEV incentives in several PEV leading markets (cities).

TABLE 4 PEV Incentives in Selected Cities in China

Cities	Subsidies	Tax Benefits	EVSE Incentives	Other Financial Benefits	Other Non-financial Benefits
Shanghai	• BEV 23,000 • PHEV 30,000 • Group Purchase Discount	Vehicle use tax waived	EVSE Installation	• Discounted electricity rate • Taxi fleet subsidy • Battery recycle subsidy • EV R&D subsidy	No limitation on license registration
Shenzhen	• BEV 34,000 • PHEV 34,000	Vehicle use tax waived	EVSE Installation	• Discounted electricity rate • Waived first time charging fee • Taxi fleet subsidy • Battery recycle subsidy • Free/ discounted parking	No limitation on license registration
Guangzhou	• BEV 34,000 • PHEV 34,000	Vehicle use tax waived	EVSE Installation	–	No limitation on license registration
Beijing	• BEV 32,000	Vehicle use tax waived	–	• Discounted electricity rate • Taxi fleet subsidy • EV R&D subsidy	No driving restriction

6.4 SHANGHAI

Shanghai has the highest PEV market share of all Chinese cities, with over 10% of total new passenger vehicle sold, because of its high vehicle purchase subsidies, diverse model availability, and attractive non-financial incentives. From 2011 to 2017, over 160,000 PEVs were sold in Shanghai, and about 73% of these were PHEVs. Two factors influenced these numbers: (1) The locally owned automaker, SAIC, produces mainly PHEVs—over 67% of the PHEVs sold in Shanghai were manufactured by SAIC; and (2) Shanghai incentivizes for PHEVs are higher than BEVs, as shown in Table 4. Shanghai provides about 23,000 RMB ($3,600) for BEVs and 30,000 RMB ($4,700) for PHEVs in purchase subsidies toward private purchase. The city also waives vehicle annual use tax and offers discounted electricity rates for PEV owners. PEV owners can obtain a vehicle license plate without the regular auction process required for conventional vehicle purchase. Shanghai set a monthly ceiling of approximately 8,000 on the number of new vehicle license plates to limit the number of vehicles in the notoriously gridlocked city (Hao et al. 2011). The Shanghai municipal authority released a certain number of license plates every month for auction with an average selling price of 85,000 RMB ($13,300) in

2016 (Zhou 2016c). The total benefits provided to private PEV owners are worth about 165,000 RMB ($25,800) for each PHEV purchase, and about 105,000 RMB ($16,400) for a BEV purchase, according to ICCT's most recent (2017) investigation (He 2018). The city also provides extensive subsidies and support to charging infrastructure installation, vehicle charging, taxi fleet, battery recycling, and PEV R&D.

6.5 BEIJING

Beijing, in contrast, provides a subsidy of about 32,000 RMB ($5,000) for a BEV purchase, but none for a PHEV. Because of this policy, almost 99% of PEVs sold in Beijing are BEVs. Similar to Shanghai, Beijing limits the number of car license plates issued by official decree and the competition for license plates in Beijing is fierce. In the June 2016 lottery, there were 2.7 million applicants and only about one in 725 were granted a license plate, making the system one of the most selective in the country (Guo 2016). Beijing has no driving restrictions for PEVs, another significant non-financial incentive. The objective of Beijing's driving restriction is to manage transportation demand and aims to reduce traffic by restricting automobile travel, based upon the last digits of the vehicle license number, on certain days during certain periods. Besides these two very effective promotion policies, Beijing also waives the annual use tax for PEVs and provides a discounted electricity rate to PEV owners. The total benefits provided to BEV owners are worth more than 160,000 RMB ($25,000) (He 2018).

6.6 GUANDONG

Guangzhou and Shenzhen are both in Guandong province and both cities offer the same subsidies for private purchases of PHEVs and BEVs, about 34,000 RMB ($5,300). The cities neither charge a PEV vehicle use tax, nor limit PEV registrations. Shenzhen allocates 100,000 new vehicle plates annually, thus limiting city vehicle purchases, and distributes half the plates through lottery and the other half by auction. In December 2017, the average auction price reached 95,103 RMB ($14,900), the highest since the city began requiring prospective buyers to acquire car plates by lottery or auction in late 2014, according to China Daily (Qiu 2017). Shenzhen also offers a discounted electricity rate to PEV owners and waives their first-time charging fee. In 2016, PHEVs accounted for almost 6% of Shenzhen's new passenger vehicle sales, while BEVs accounted for over 4%. BEV and PHEV market shares in Guangzhou were about 4% and 2% in 2016, respectively. Note that, unlike Shanghai, slightly more PHEVs than BEVs were sold in Guangdong from 2011 to 2017. Out of a total 140,000 PEVs sold in this period, about 58% were PHEVs. This balance might reflect the fact that local automaker, BYD, produces both PHEV and BEV models.

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7 GENERAL COMPARISON

China became the biggest PEV market in the world in 2015, and maintained the lead position over the last two years, as shown in Figure 22. About 80% of PEVs sold in China are BEVs due to the largely BEV-focused policies. However, in Chinese cities that offer almost the same incentives for BEVs and PHEVs, PHEV sales dominate. Shanghai exemplifies this scenario, with a much higher PHEV share of PEVs than Beijing, which incentivizes BEVs much more than PHEVs. The focus of local automakers, whether on PHEV or BEV models, also plays a factor in Shanghai, Guangdong, and Beijing.

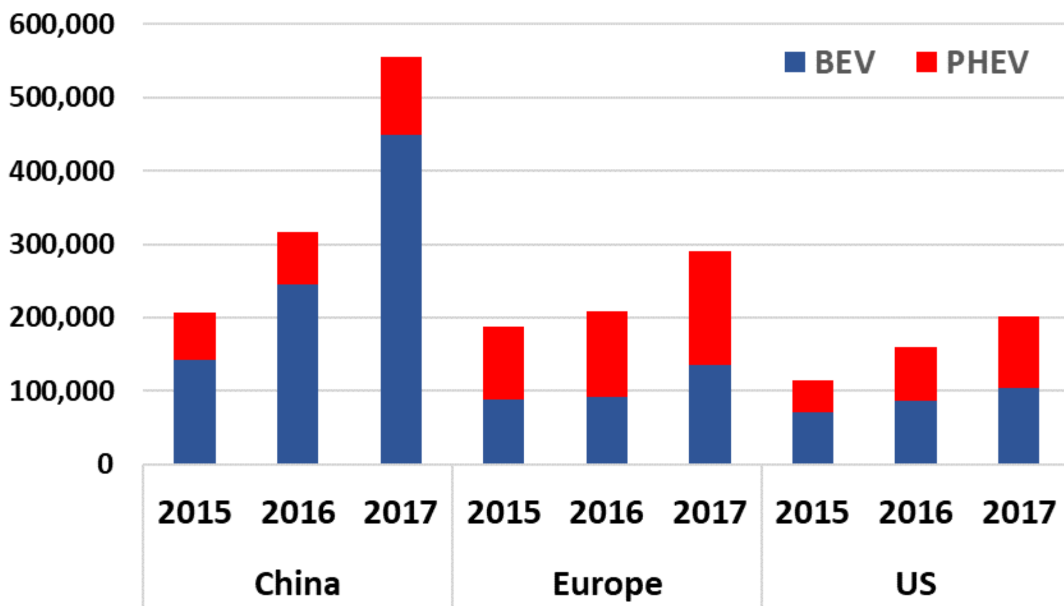

FIGURE 22 PEV Sales by Type and Region, 2015, 2016, and 2017

In Europe, a similar trend is seen—France and (until recently) Norway incentivize BEVs much more than PHEVs, and BEVs outsell PHEVs. In other European countries, PHEVs outsell BEVs because market factors, such as the number and diversity of PEV models offered and consumer preferences, play an important role in PEV sales. As seen in Figure 23, BEV sales growth from 2015 to 2017 largely came from sales of four models: the Tesla Model X and Hyundai Ioniq Electric (both introduced in 2016), and the growing sales of the Renault Zoe and BWM i3 (EAFO 2018). However, PEV sales owe their growth between 2015 and 2017 to a larger number of models. European car manufacturers have produced a wider variety of PHEVs, in different sizes and vehicle classes, than BEVs. Strong growth in PHEV sales accompanied the introduction of new PHEV models in Europe, as shown in Figure 24.

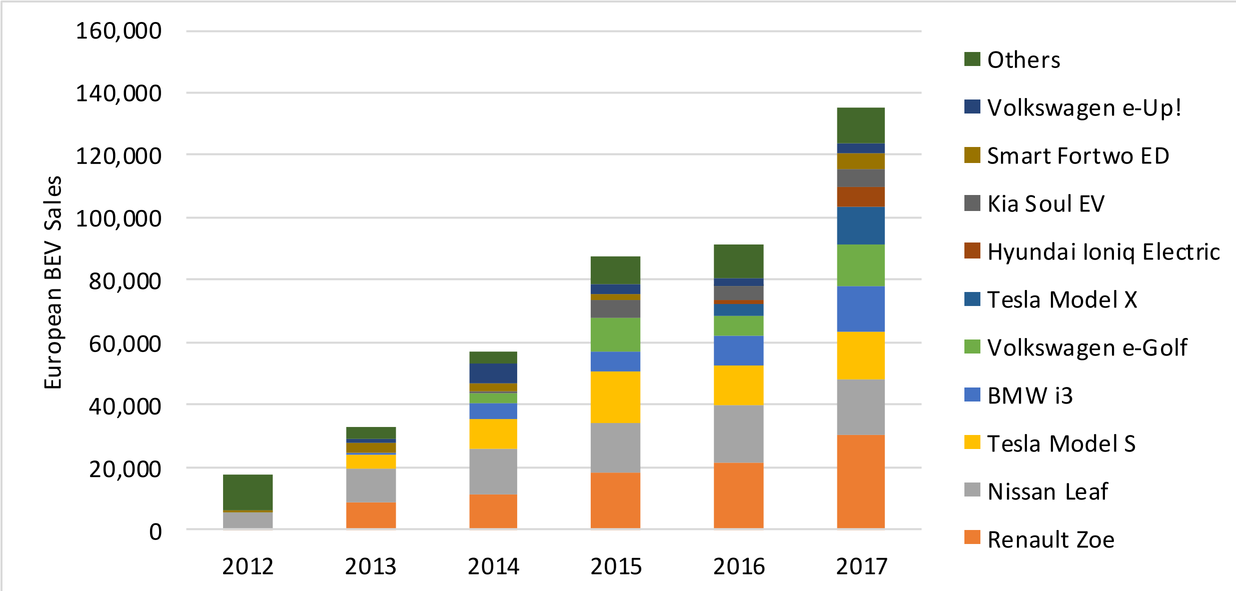

FIGURE 23 BEV Sales by Model in Europe from 2012 to 2017

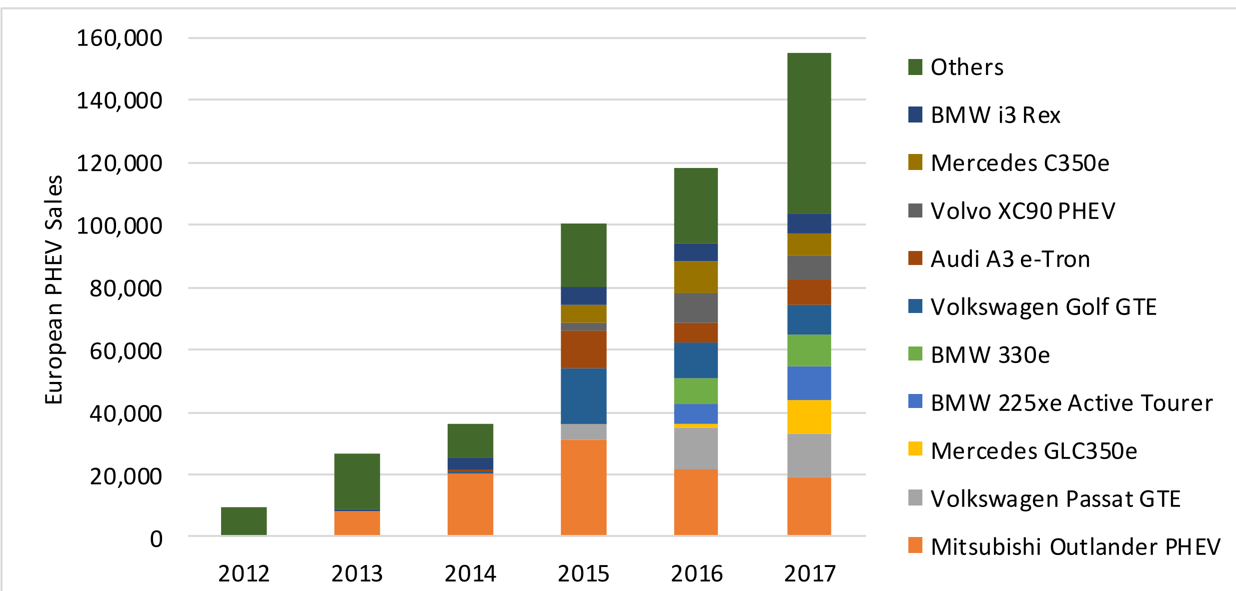

FIGURE 24 PHEV Sales by Model in Europe from 2012 to 2017

In the United States, the increase in PEV sales between 2016 and 2017 was due in part to sales of the Chevrolet Bolt BEV and Toyota Prius Prime PHEV. In 2017, Chevrolet introduced the new Bolt with a range of over 200 miles and a lower purchase price than earlier, comparable BEVs; and Toyota reintroduced a new Prius PHEV with an electric range of 25 miles. While the Bolt and Prius Prime outsold eight other new PEV models introduced in 2017, all eight contributed to the growth in total BEV (Figure 25) and PHEV (Figure 26) sales that year. As discussed above, federal and state policies, including monetary and non-monetary incentives, like special access and build-out of public charging infrastructure, also influence sales, especially in states that offer multiple, complementary incentives.

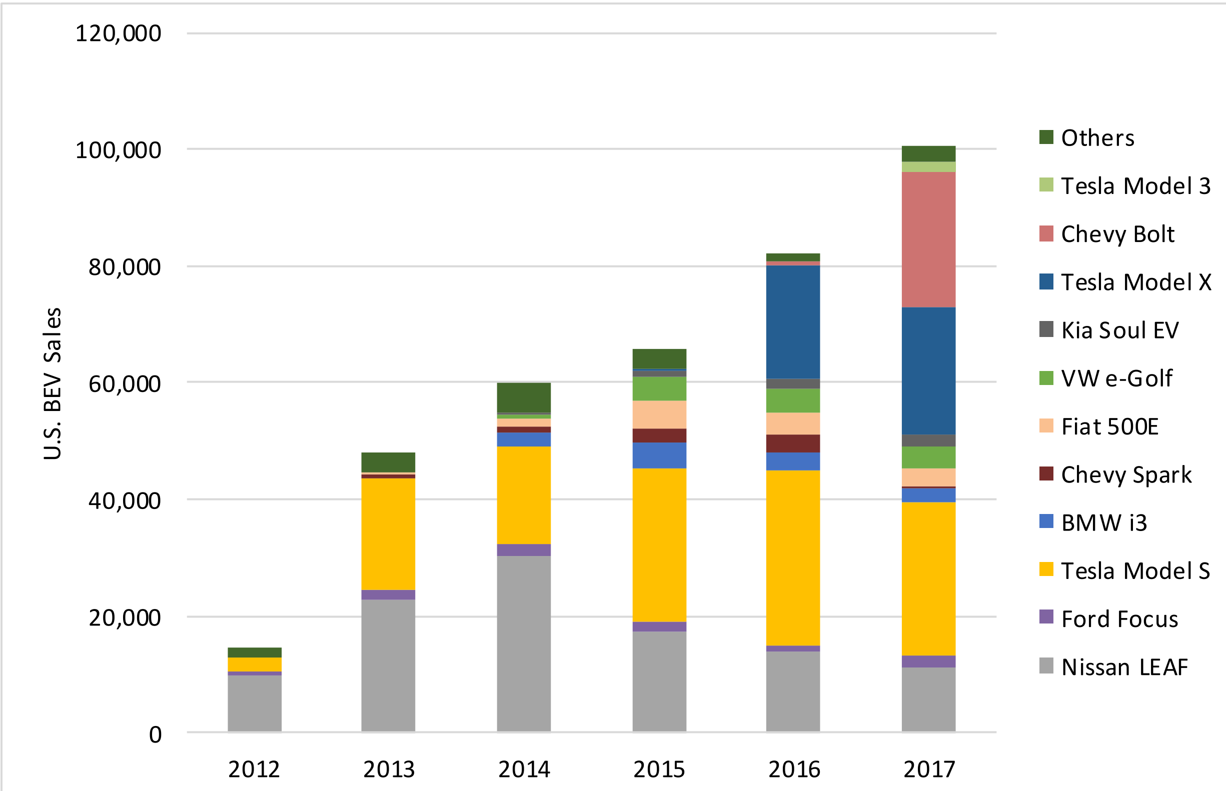

FIGURE 25 BEV Sales by Model in the United States from 2012 to 2017

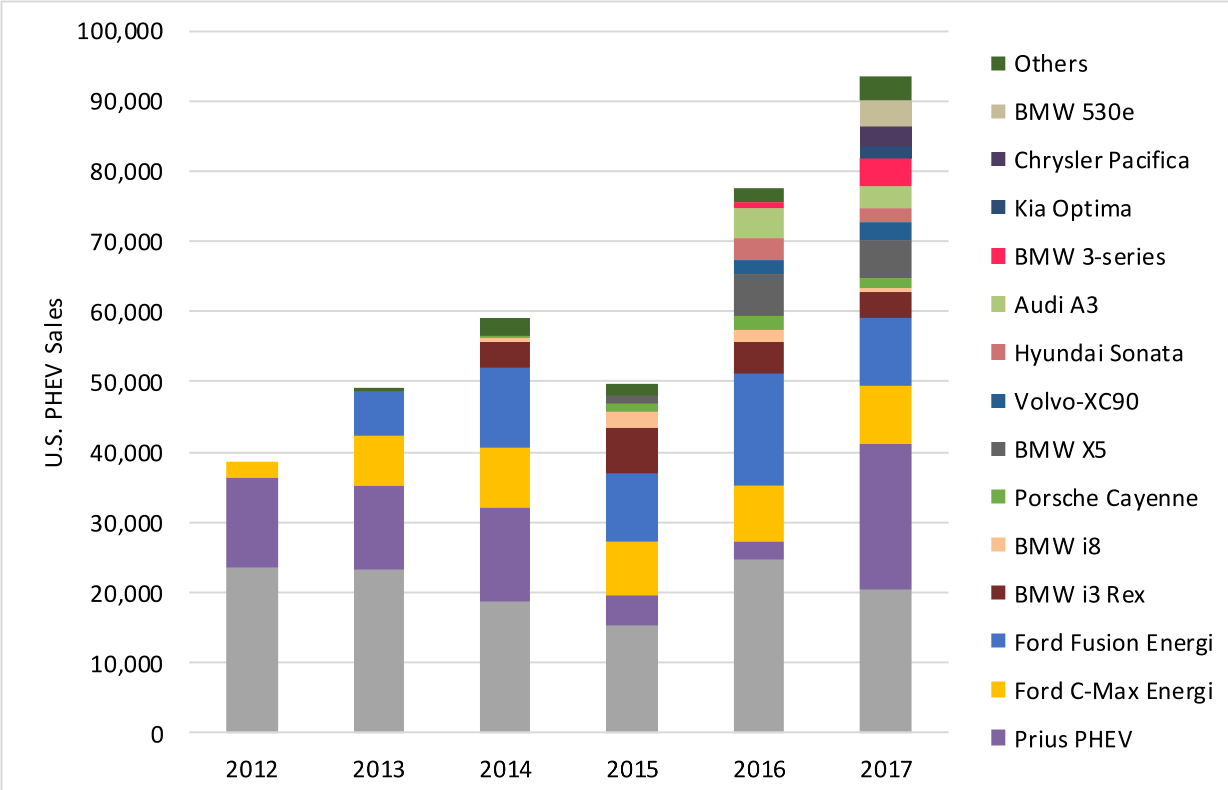

FIGURE 26 PHEV Sales by Model in United States from 2012 to 2017

PEV market share of all new passenger vehicles sold in China reached 2.3% in 2017—higher than in Europe (on average) or the United States—as shown in Table 5. However, the number of PEVs registered per capita in China, about 0.81 per 1,000 people in 2017, is lower than in Europe or the United States. Note that light-duty passenger vehicle stock per 1,000 people in China was only 1/5 that of the United States in 2017. Shanghai and Beijing have the highest PEV market share and registration per capita in China.

TABLE 5 PEV Market Share and Registration per Capita in 2017

		Market Share	PEV Registration/ Capita (000)
Region/Country	China	2.3%	0.81
	Europe	1.7%	1.5
	United States	1.2%	2.3
Country (City)	Beijing (China)	10% *	5.1
	Shanghai (China)	10% *	5.7
	Norway (Europe)	39.2%	37.6
	Netherlands (Europe)	2.2%	7.2
	California (United States)	4.9%	9.0
	Washington (United States)	2.5%	3.9

* Numbers are estimated.

Currently, China's national subsidy catalogue lists about 370 BEV models and 60 PEV models. However, there are only minor differences between these models, because with only a change to the battery or motor, the catalogue treats a vehicle as a new model. The catalogue does not show the general model name, which makes identifying and tracking PEV models sold in China over time difficult. Some observations can be made, however. PHEVs manufactured by BYD and ROEWE dominate the PHEV sales in China. The top-selling PEVs in each province are produced by local automakers. For example, the bestselling models—EC180/EC150 by BAIC (Beijing), BYD e6 (Guangzhou), and Geely Emgrand EV (Zhejiang)—were all made locally in those provinces and account for approximately 10–14% of the total BEV sales in the province. As described earlier, municipal protectionism, promoting locally made models, was strong before 2016.

PEV adoption has increased most dramatically in regions where it is incentivized with multiple strong policies, such as Beijing, Shanghai, and Shenzhen in China; California in the United States; and Norway in Europe. General differences between these high-PEV adoption regions should be noted.

- In Beijing, Shanghai, and Shenzhen, strong policies restrict vehicle use or ownership. Incentives relieving PEV purchasers from these restrictions provide very strong motivation for PEV purchase.

- In Europe, VAT and registration fees greatly increase vehicle acquisition costs, and countries that offer relief from these fees provide a strong motivation for purchase, especially when combined with multiple, complementary incentives. For example, Norway offers BEV purchasers public charging, relief from parking fees, and use of bus lanes.

- In California, tax credits for PEV purchase combined with a number of other incentives including HOV lane access and public charging are effective.

Other factors also influence PEV adoption, such as high fuel prices in Europe and China, a high fraction of homes with garages or carports with electricity in California, and consumer preferences. Consumers who adopt PEVs tend to prefer PHEVs over BEVs in several regions. PHEV share tends to be higher than BEV share, unless BEV incentives are much more generous than those for PHEVs. PEV sales have been growing in many regions, and not only because of policy influences: increased driving range, decreased purchase price, and increased diversity of PEV model offerings all contribute to PEV sales growth.

Hall (2017) provides an update of policies and status of markets for the 20 cities that lead the transition to electric drive with the highest PEV sales and sales share among all other cities, worldwide. This study further indicates that strong regulatory and fiscal policies have driven the early electric vehicle market worldwide. The markets with the highest electric vehicle uptake—China, Europe, Japan, and the United States—are in regions with a combination of vehicle efficiency regulations, strong consumer incentives, and direct electric vehicle requirements. The U.S. markets especially are supported by the California ZEV program. China has consistently applied strong fiscal incentives and has now adopted its New Energy Vehicle (NEV) quota scheme. Many nations across Europe have spurred the market with some of the most generous incentives, and the EU has some of the more stringent CO_2 standards.

8 CONCLUSIONS

By comparing the different combinations of PEV policies in different regions around the world and comparing the PEV sales trends, the authors make several observations and draw general conclusions, with supporting examples.

Multiple, complementary incentives and policies in place simultaneously are more effective than single policies. This conclusion was reached by multiple groups analyzing PEV policies in a number of regions. Although detailed findings of studies often differ from or even contradict each other, many studies find significant synergistic interactions between policies such as financial incentives (tax credits or rebates), provision of public charging stations, or special access to HOV lanes or parking for PEV drivers. Regional market conditions, like the number and diversity of PEV models offered, also influence sales trends.

Financial incentives appear to be generally effective if sufficiently generous or if combined with other policies. In Norway, significant financial incentives as well as complementary polices have led to high PEV sales share. In contrast, discontinuation of financial incentives in Georgia in the United States and the Netherlands led to a sudden, sharp drop in PEV sales. In Sweden, although financial incentives are similar to those in other countries, PEV market share has grown more quickly, and factors other than financial were likely important. For example, the Swedish government has long been considered a leader in sustainable development and Sweden's population is generally very aware of environmental issues (EC 2005; OECD 2014).

Generally, point-of-sale incentives are more effective than rebates or tax credits where funding is in question. The effect of financial incentives in Europe was estimated by Ploetz et al. (2017), who found that increasing incentives by 1,000 euros ($1,200) increases PEV sales share by about 16% (relative increase of a given sales share); however, indirect incentives are potentially more important than a 1,000 euro ($1,200) incentive increase.

Provision of public charging infrastructure also appears to be influential, but the influence depends on regional or local conditions. In the United States, for example, roughly 60% of housing units have a garage or carport (AHS 2015), and the vast majority of these have access to electricity to charge a PEV while parked, a feature less common in many European countries and Chinese cities. The Netherlands and Sweden have deployed significant AC charging and DC charging (respectively) infrastructures, in combination with other incentives, and both countries have strong sales of PHEVs. However, Kansas City, Missouri, has made significant provision of public charging with few other supporting policies, and has not experienced high PEV sales.

Non-monetary incentives can create very substantial impacts on adoption. Restrictions on vehicle registration and usage, such as those in several Chinese cities, can result in strong incentives when exceptions are granted solely to PEV purchasers. While proposed far into the future, bans on gasoline or diesel vehicle usage could be expected to have similarly large impacts in France and the UK.

A trend to move from monetary incentives to non-monetary incentives is appearing in some regions. Several regions have specifically incentivized BEVs over PHEVs, and in many countries, PHEVs outsell BEVs if similar incentives are offered for both. The Netherlands and Sweden, where PHEVs have outsold BEVs by a wide margin, and France, where the PHEV share of PEVs is small but growing rapidly, have recently reduced incentives for PHEVs. The preference for PHEVs over BEVs could be an artifact of limited-range models dominating BEV availability (until recently), or it could presage greater sales of PHEVs, as availability and models increase. However, incentives have played a key role in determining which have sold to date.

Outcomes of any specific policy can be hard to foresee, and frequently depend on other policies in place and on general market and economic conditions. Policies in different regions often have multiple goals, and while PEV adoption may support these goals, it is a means, not an end. Countries and states have enacted policies to promote PEV adoption for a variety of reasons including reducing air pollutants and GHG emissions, reducing petroleum use/dependence, or promoting economic growth. How PEV adoption helps achieve these goals depends on many factors: the type of vehicles PEVs are replacing, the source of electricity, how PEVs are used, if PHEVs are driven on electricity, the dependence of a region on imported or domestic petroleum, and if domestic automakers are developing PEVs.

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APPENDIX

Table A-1 lists types of Plug-in Electric Vehicle (PEV) policies by state in the United States. Purchase incentives include rebates, subsidies, and tax credits granted to PEV purchasers. Electric vehicle supply equipment (EVSE) incentives include rebates, subsidies, or tax credit for purchase or installation of EVSE and for provision of public charging infrastructure. Other financial benefits include reduced electricity rates for PEV charging, and reduced or waived fees for registration and vehicle emissions testing. Other incentives include PEV parking preference and high-occupancy vehicle (HOV) access.

TABLE A-1 U.S. State-level PEV Policy Summary and Market Share

State	Purchase Incentives	Tax Benefits	EVSE Benefits	Other Financial Benefits	Other Benefits	2016 PEV Market Share	2017 PEV Market Share
Alabama				X		0.17%	0.20%
Alaska						0.40%	0.37%
Arizona		X		X	X	0.66%	0.89%
Arkansas	X				X	0.10%	0.16%
California	X			X	X	3.74%	4.93%
Colorado		X			X	1.07%	1.57%
Connecticut	X			X	X	0.88%	1.39%
Delaware	X			X	X	0.68%	0.86%
District of Columbia		X		X	X	1.22%	1.87%
Florida	X				X	0.48%	0.52%
Georgia			X	X	X	0.50%	0.53%
Hawaii				X		1.43%	2.32%
Idaho	X				X	0.39%	0.41%
Illinois	X			X	X	0.42%	0.62%
Indiana				X		0.29%	0.41%
Iowa	X		X		X	0.22%	0.36%
Kansas						0.39%	0.49%
Kentucky						0.19%	1.34%
Louisiana			X			0.13%	0.15%
Maine						0.50%	0.80%
Maryland	X		X	X	X	0.69%	1.05%
Massachusetts	X				X	0.84%	1.35%
Michigan	X		X	X		0.43%	0.45%
Minnesota	X			X	X	0.46%	0.60%
Mississippi						0.07%	0.12%
Missouri					X	0.32%	0.42%
Montana			X			0.17%	0.28%
Nebraska				X	X	0.25%	0.33%
Nevada				X		0.69%	0.79%
New Hampshire						0.55%	0.89%

TABLE A-1 (Cont.)

State	Purchase Incentives	Tax Benefits	EVSE Benefits	Other Financial Benefits	Other Benefits	2016 PEV Market Share	2017 PEV Market Share
New Jersey	X		X		X	0.69%	0.91%
New Mexico			X			0.30%	0.47%
New York	X			X	X	0.60%	1.03%
North Carolina				X	X	0.29%	0.49%
North Dakota						0.12%	0.12%
Ohio					X	0.28%	0.31%
Oklahoma					X	0.03%	0.10%
Oregon			X	X	X	2.10%	2.36%
Pennsylvania	X		X	X		0.48%	0.55%
Rhode Island	X		X		X	0.60%	0.92%
South Carolina			X	X	X	0.22%	0.27%
South Dakota						0.12%	0.22%
Tennessee						0.33%	0.33%
Texas	X			X	X	0.31%	0.39%
Utah	X		X	X	X	0.94%	0.94%
Vermont	X					1.31%	2.13%
Virginia	X			X		0.57%	0.81%
Washington			X		X	1.94%	2.51%
West Virginia						0.09%	0.15%
Wisconsin			X		X	0.76%	0.60%
Wyoming	X					0.21%	0.68%

Table A-2 lists types of PEV policies by country in Europe. Purchase subsidies include rebates and subsidies granted to PEV purchasers. Tax benefits include reduced or waived registration tax, ownership tax, company tax, and value added tax (VAT) benefits. EVSE incentives include rebates, subsidies, or tax credits for purchase or installation of EVSE, and for provision of public charging infrastructure. Other financial benefits include exemption from luxury or import taxes. Other incentives include free parking, free tollways, and use of bus lanes for PEVs.

TABLE A-2 European Country-level PEV Policy Summary and Market Share

Country	Purchase Subsidies	Tax Benefits	EVSE Benefits	Other Financial Benefits	Other Benefits	2016 PEV Market Share	2017 PEV Market Share
Austria	X	X			X	1.5%	2.1%
Belgium	X	X				1.7%	2.7%
Bulgaria						0.1%	0.2%
Croatia		X				0.2%	0.1%
Cyprus		X				0.3%	0.8%
Czech Republic		X				0.1%	0.2%
Denmark	X	X	X		X	0.6%	0.4%
Estonia						0.3%	0.2%
Finland		X				1.2%	2.6%
France	X	X			X	1.5%	1.8%
Germany	X	X		X	X	0.7%	1.6%
Greece		X		X		0.1%	0.2%
Hungary		X			X	0.3%	1.0%
Iceland		X	X		X	6.3%	14.1%
Ireland	X	X	X		X	0.5%	0.7%
Italy	X	X	X			0.2%	0.2%
Latvia		X			X	0.3%	0.6%
Liechtenstein	X					0.0%	0.0%
Lithuania		X			X	0.4%	0.3%
Luxembourg	X	X				0.6%	1.9%
Malta	X	X	X		X	0.1%	0.4%
Netherlands		X				6.0%	2.2%
Norway		X	X	X	X	29.0%	39.2%
Poland						0.1%	0.2%
Portugal	X	X			X	0.9%	1.9%
Romania	X	X	X			0.2%	0.4%
Slovakia	X	X			X	0.1%	0.4%
Slovenia	X	X				0.4%	0.7%
Spain	X	X	X	X	X	0.3%	0.6%
Sweden	X	X				3.6%	5.3%
Switzerland		X		X		1.7%	2.6%
Turkey		X				0.0%	0.0%
United Kingdom	X	X	X		X	1.5%	1.9%
Total	**17**	**29**	**9**	**5**	**15**		
Percentage of Countries	**52%**	**88%**	**27%**	**15%**	**45%**		

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