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Plug-In Electric Vehicles: A Case Study of Seven Markets

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Table of Contents

Figures and Tables

Abstract

At the current stage of plug-in electric vehicle (PEV) market development, sales rates vary dramatically across different countries and regions. For policy-makers and other stakeholders it is useful to understand the major social, economic, and policy drivers of vehicle adoption. This paper provides insights into the developing PEV markets in Norway, Netherlands, California, United States, France, Japan, and Germany. This is accomplished by applying a Technological Innovation System (TIS) approach that systematically identifies the role of different factors in promulgating new markets. Our comparison between markets shows that in all studied regions, sales of PEVs are supported through various types of government incentives, government resources, and other legitimation activities. However, regions with relatively strong PEV markets have a greater focus on market formation activities and relatively higher costs savings associated with operating an electric vehicle as compared to a conventional vehicle. To determine whether these factors are the primary determinants of PEV market shares, further research should be undertaken that also incorporates analysis related to the presence and government support for entrepreneurial activities related to electric vehicle innovation.

Introduction

The year 2008 marked what some have called the third wave of electric vehicle development, or “the age of mass production." Petroleum prices spiked over 140 dollars per barrel and Nissan and General Motors announced intentions to mass produce the Leaf and Volt, following the minor success of Tesla’s Roadster. From December 2010 to May 2014 total PEV registrations reached 500,000 units worldwide; meanwhile, the rate of sales continues to double every seven to eight months and new models are entering the market. Governments around the world are implementing electric vehicle initiatives and preparing the market with numerous national and regional incentives and supporting charging infrastructure. Despite this increased policy interest in encouraging PEV markets, market penetration rates vary dramatically from region to region. Therefore, the purpose of this paper is to understand the drivers of the PEV markets in various regions and develop related policy recommendations. Our research question is:

> *What are the factors that have contributed to supporting establishment and growth in PEV markets in different regions?*

The following is a comparison of seven markets and efforts; specifically, Norway, Netherlands, California, United States, Japan, France, and Germany. As shown in Figure 1, the market penetration rate of PEVs in the new vehicle market, in each region is markedly different. Each of these regions contains unique combination of cultural, political, and economic factors that are contributing to very different PEV markets. To describe the context for each PEV market, a Technological Innovation System (TIS) framework is used. In the following sections the TIS framework and methods applied are described; then an overview of the case study regions is provided, using TIS to frame the context for each market; and then markets are compared.

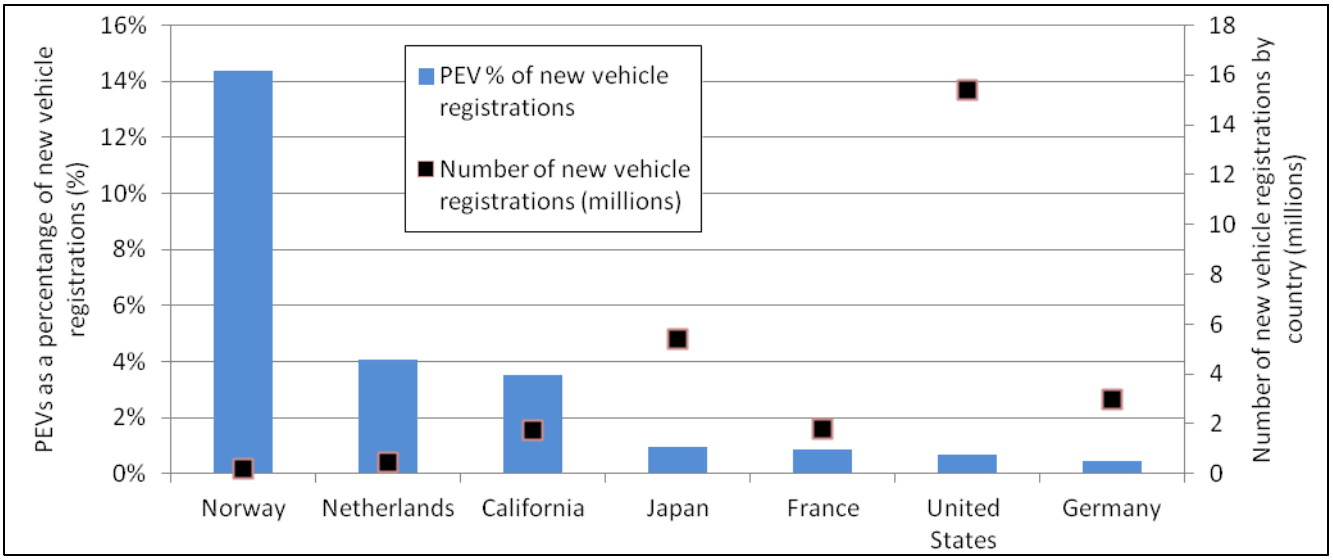

Figure 1: Market penetration rate of PEVs, by region (2014)[1]**. Sources: (1) (2) (3) (4)**

The analytical framework

Different innovation system (IS) approaches have been developed to research how systems affect the development, diffusion, and use of new innovations. Generally, these different IS approaches vary based on geographic or sectoral focus. In this research effort, we apply the Technological Innovation System (TIS) framework. TIS draws its research boundaries around a particular technology, in this case PEVs. We further delineate our research focus based on national and regional boundaries, specifically, Norway, Netherlands, California, UnitedStates, Japan, France, and Germany. A TIS is defined by the interactions between different structural components (actors, networks, and institutions) that drive the dynamics between several key "systems functions." Different sets of system functions have developed over time in TIS literature; this paper uses the framework described by Bergek (2008) (5)(6). These TIS functions include: knowledge development and diffusion; influence on the direction of search; entrepreneurial experimentation; market formation; legitimation; resource mobilization; and development of positive externalities (5). These functions and examples of indicators for each function are described in Table 1.

[1] PEV percentage of new vehicle registrations shown for January through September 2014 for all countries, with the exception of Japan and California, which are shown for January through June 2014. New vehicle registrations shown for 2013 in all countries.

Table 1: TIS system functions and indicators

	TIS functions	Description
F1	Knowledge development and diffusion	Relates to the generation of the knowledge base related to PEV technologies. Includes pilot and research programs and patent activities.
F2	Entrepreneurial experimentation	Relates to entrepreneurial activities supporting PEV development including testing new technologies and creating new applications and market opportunities. Includes research and development support.
F3	Influence on the direction of search	Relates to incentives or pressures for actors to direct their activities toward the PEV market. Includes Policy targets, standards, expectations, and promises related to technology development.
F4	Market formation	Relates to factors that drive markets to form new niches and grow into mass markets. Includes factors that increase consumer demand and market size such as providing or incentivizing charging infrastructure, vehicle purchase subsidies, tax exemption or reduction, feebate, company car tax waivers, and luxury tax waivers.
F5	Legitimation	Relates to the social acceptance of PEVs. Includes government efforts to support a new technology, such as establishing sales targets.
F6	Resource mobilization	Relates to the volume of resources available in different parts of the system, including for complimentary assets or technologies. Includes the amount of human and financial capital directed at subsidy programs or development of planning documents
F7	Development of positive externalities	Relates to complementary products, services and infrastructure that may support functions F1 through F6. Includes related business ventures and environmental benefits.

Sources: (7) (6) (5)

In this paper, we focus primarily on the TIS system functions that have the greatest potential to provide an understanding of why vehicle markets in different regions have different levels of PEV market penetration. This paper is focused on the factors that are specifically contributing to regional variation in PEV sales. TIS functions F1-F3 tend to relate to developments in a specific technology; while F4-7 relate to the overall development of regional markets. F4-7 will be discussed in greater detail here, since they represent the functions that may account for the differences in market adoption. However, while F1-3 generally refer to events that could result in broader technology innovations that impact the overall global market, they sometimes can explain why a particular region initiated market support for PEVs. It is in that context that F1-3 will also be discussed; however, a full analysis of F 1-3 is reserved for future study.

A central tenant of IS literature is that by studying the activities occurring in each system function, market barriers or inducement mechanisms can be identified for the development, diffusion, and use of a new product (8). This premise is particularly appropriate given that our paper seeks to understand the dynamics that have led to different levels of market diffusion of PEVs across different markets.

TIS literature is primarily focused on studying technology transitions occurring in European countries, while studies related to North America, Japan, China and India are currently underrepresented (9). In addition to furthering our understanding of different PEV markets, this research contributes to TIS literature by expanding the applications of the framework to PEV markets in Europe, Asia, and the United States. A number of recent studies have attempted to explain the factors that are contributing to varied sales of PEVs across regions [e.g. (10) (11)]. This study expands on these works, by exploring the roles of different types of social, economic and political factors on vehicle markets using an established analytical framework.

Case Studies Comparison

In this section, PEV markets are compared across the seven case studies. Note that PEVs refers to both battery-electric (BEV) and plug-in hybrid electric vehicles (PHEV). In order to study PEV markets across different case studies, the TIS approach is used, since it incorporates a comprehensive perspective that takes into account a variety of cultural, economic, and political considerations. TIS is predicated on the idea that successful innovation systems arise when the different system functions are fulfilled. To understand the activities taking place in each function, data was collected from existing reports, newspapers, government publications, and advocacy organizations. Using the data collected and perspective provided by experts a narrative was formed for each case study using the framework provided by TIS.

A brief overview of the factors that are contributing to the PEV markets in each case study is provided. Different types of events are labeled according to the system function code as shown in Table 1. For example, in the following case studies, code “F1” will be listed after descriptions of events relating to the knowledge development and diffusion system function.

Norway

As of September 2014, Norway is the undisputed world leader in terms of the BEV market share of new vehicles sold. At the end of 2012, the total population of BEVs in

Norway numbered 9,565; in 2013 that number had more than doubled (19,678), and by the end of the third quarter in 2014 that number had climbed to 35,524 (12). The number of PHEVs registered in the country have been slowly rising as well and as of the third quarter in 2014, reached 2,014 vehicles (12). As of September 2014, PEVs represented 14.38% of new car sales; the vast majority of those vehicles were BEVs (13) (1). The country provides generous consumer purchase and in-use incentives for BEVs including: tax incentives, free electricity, free public charging, reduced company car tax, road toll exemptions, and use of bus lanes for BEVs (F4). These incentives have phased in since 1990 and recently were extended through 2018. Until recently, the government did not provide any incentives for PHEVs (14).

Norway's car market is relatively small in comparison to other countries; approximately 150,000 new vehicles are sold per year in a country with a population of five million (15) (16). Vehicle turnover is slow, mostly given the high import, VAT, and other taxes extracted on vehicles, which make it expensive to buy a new vehicle. Norway imports vehicles from Japan, Germany, Sweden, France and the United States.

Interestingly, 40% new car sales in Norway are "company cars" (17). Essentially, sales are among motivated individuals, a contrast to markets and incentive structures in other European nations, notably the Netherlands. This is a similar characteristic to the Californian market, where the PEV market primarily consists of individuals, instead of companies.

In addition to providing generous purchase incentives, much of Norway's success in supporting the BEV market can be attributed to committed activism and resolute policy over nearly two decades in this sector (F3, F5). In 1989, the environmental group, Bellona, imported Norway's first BEV as a showcase vehicle (F5). Early government efforts to support the Norwegian BEV market came in the form of government grants to Norwegian BEV and battery manufactures from officials who wanted to compete with Sweden's auto industry (F6). Additionally, government support has included symbolic support and consistent policy support. For example, in 1995 the Norwegian king and queen attended a highly publicized kickoff event in San Francisco for a BEV pilot program, to which PIVCO, a Norwegian BEV manufacturer had donated 40 vehicles (F5).

The government did try to support a Norwegian BEV manufacturing industry over a decade ago (F1, F2). Two BEV manufactures, PIVCO and Pure Mobility, were established in Norway in 1991. PIVCO focused on innovating lightweight BEV vehicle bodies. PIVCO's BEV, the City Bee, consisted of a thermoplastic body built on an aluminum frame. The company has undergone a number of ownership changes. In 1999, Ford purchased and rolled PIVCO in with its electric vehicle branch, Th!nk. Norwegian Th!nk operations were sold by Ford shortly thereafter to a series of different companies. Plagued with vehicle recalls and lawsuits by investors, in 2011 the re-named company, "Th!nk Global", declared bankruptcy and was subsequently purchased by the Russian company, Electric Mobility Solutions AS. Production of BEVs were scheduled to resume in 2012, but this has not yet occurred. Pure Mobility, formerly Ebil

Norge, was acquired in 1991 and production of the three-seat EV, known as the Buddy, was shifted from Denmark to Oslo, Norway. The company, funded exclusively through private investors, declared bankruptcy in 2011.

The environmental benefit from BEV use can be attributed to Norway's clean electricity grid (F7). Norway's electricity production consists of 96% renewable sources; most of which is hydropower. Also benefitting the BEV market is the high price of gas to consumers and a stable source of government income, in the form of oil exports. Unlike many oil producing countries, Norway does not subsidize gas prices and in fact, includes significant federal taxes..

Further, the Norwegian government has helped to support the installation of charging infrastructure throughout the country (F4). As of 2013, over 4,000 charging stations and 120 quick chargers had been installed. Additionally, the government had supported the development of a mobile application that provides consumers information on charger location and real-time availability.

Netherlands

Widespread support for the PEV market in the Netherlands began in 2009, when the government adopted the National Action Plan for Electric Driving (F3, F4, F6). This action plan included 89 million (USD) to support related pilot projects, charge points, research and development, and market support (18). PHEVs were first offered for sale in the Netherlands in 2011 (18). In 2012, total PEV registrations numbered 7,410 representing approximately 1% of new vehicle sales; this number soared to 42,017 as of September 2014, representing 4.07% of new vehicle sales (19) (1).

The government has committed to installations of 20,000 normal chargers and 100 quick chargers by 2015 (20).To that end, in 2013, the total number of charge points increased from 3,600 (2012) to 5,770; 400 of which have been supported through government incentives (F4) (20; 21) (22). Further, in 2013, the government announced that it had partnered with a Dutch startup company to install one EV charger every 31 miles by 2015 (F4, F7) (23).

The government provides PEV purchase incentives including a tax reduction that is equivalent to approximately 10-12% of the cost of the vehicle (F4) (20). This incentive has been available since 2006 and varies depending on the fuel economy of the vehicle. Leased PEVs and hybrid electric vehicles (HEVs) also qualify for incentives including annual tax waivers or reductions, depending on the type of vehicle. PHEVs represent the majority of PEV sales in the Netherlands and recently, due in part to changes in vehicle incentives, PHEV sales have been volatile. In December, 2013, PHEVs represented 24% of the market, at approximately 9,309 PHEVs sold (24). In January 2014, one month after the PHEV purchase incentives expired, only 581 PHEVs were sold (25). However, numbers stabilized shortly thereafter and in the month of April 2014, 1,900 units were sold. It appears that in the months leading into the dissolution of PHEV incentives purchases were high, fell shortly after the expiration of the PHEV incentives, and have since regained ground (see Figure 2) (1).

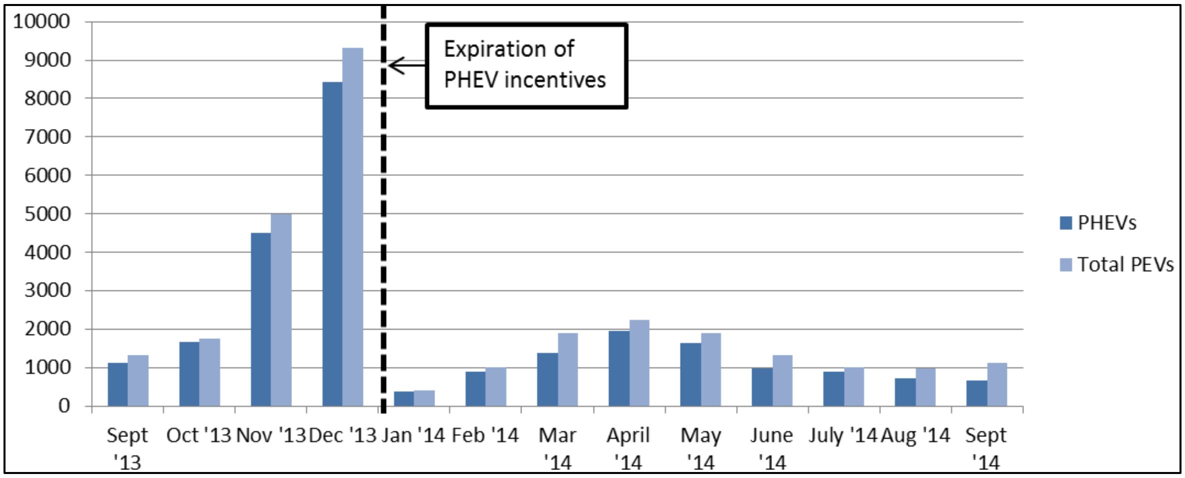

Figure 2: PHEV and PEV units sold, by month (Sept 2013- Sept 2014). Source: (1).

Local governments also support the PEV market. For example, the City of Amsterdam provides subsidies to businesses to install public charge points (F5) (26). In 2013, 100 quick chargers were located within the City (27).

Like Norway, the Netherlands does not have a significant vehicle industry; however, related Dutch businesses include manufacturers of related automotive components, charging infrastructure, bus, and vehicle assembly factories (F2, F7). Also, like Norway, Netherlands has a large region of affluent households, many of whom receive a car as a part of their work benefits (F7). Like Germany, the Dutch government works collaboratively with business interests in developing long-term electric vehicle visioning plans and facilitating deployment of vehicles by helping to resolve technical or infrastructure barriers (28).

California

California is the only non-country in this study, though with 35 million residents it is considerably larger than many countries. It also is perhaps the most auto dependent region in the world, with high auto ownership rates, few public transit opportunities, and low population densities. California has been an aggressive regulator of automobiles to reduce air pollution in its auto dependent cities.

California is a large auto market, about 12% of U.S. sales, with a more heavily Asian and European vehicle-oriented market, and fewer large pick-up and sport utility vehicles than other parts of the U.S. Once a manufacturing center, California does not have any traditional auto manufacturing left, although there are auto assembly, design and technology groups located in the State.

Zero-emission vehicle sales requirements set by California regulators, a few start-up electric vehicle companies, and the huge high technology industry in the State have created a unique innovation sector that has resulted in the development of several startup PEV and charger companies (F2, F3). The General Motors EV1 was originally developed as the Impact, by engineers at Hughes, working for GM in the 1980s. California is home to Tesla, as well as other PEV-related startups; enterprises that are arguably related to the State's technology sector and environmental policies.

California has a long history of environmental activism, efforts to make its energy sector efficient, less polluting, and in particular a long and successful history of regulating car emissions (F3, F5). As a result, two of its state agencies, the California Air Resources Board and the California Energy Commission are decades old institutions that have relatively powerful influence over vehicles and the energy sector. In addition to mandating sales of PEVs, the State also provides consumer purchase incentives up to $2,500 for different types of PEVs (F4). Additionally, in 2009, the State legislature authorized up to $120 million per year, over seven years to help support the development of PEV technologies including research, pilot and demonstration programs, publically available charging stations, and truck-stop electrification (F1, F2, F4). This commitment was renewed in 2013.

United States

In 2010, PEVs were introduced to the U.S. market in the form of the Chevy Volt and Nissan Leaf. Annual sales of PEVs has grown from 17,700 units sold in 2011 to 88,066 sold in 2014 (through September) (29). The total U.S. stock of PEVs is approximately 259,949 as of September 2014, out of approximately 603,932 globally (30). PEV sales by year as well as new PEV purchases as a percentage of new vehicles registered is shown in Figure 3.

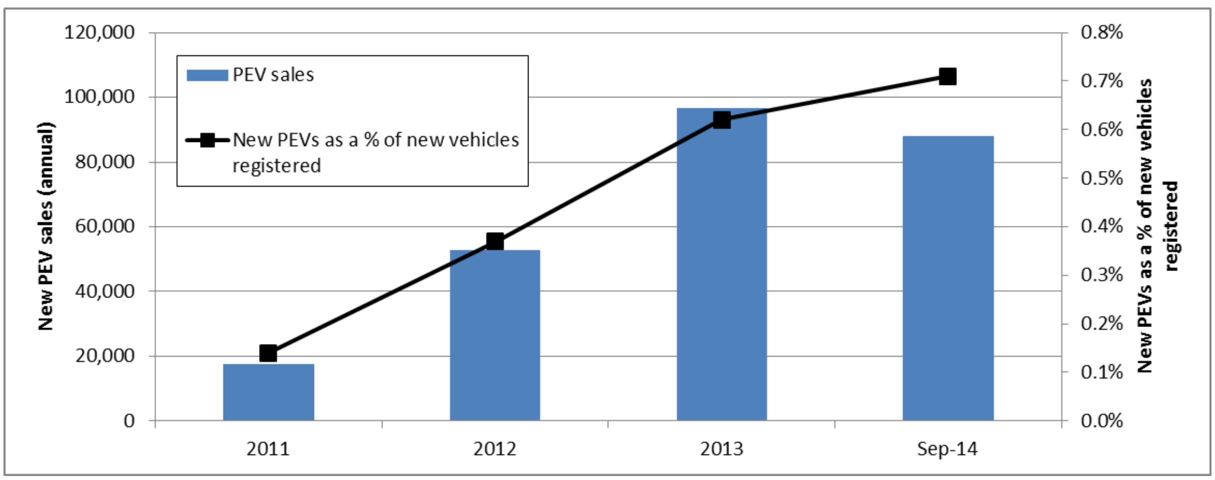

Figure 3: U.S. PEV sales by year. Source: (29).

Some notable regulations affect the U.S. PEV market including California regulations and National greenhouse gas emissions standards (F3). Federal law enables California to set mobile source emission standards that are independent from national standards. Other states may choose to adopt California's standards, or follow national standards; however, they may not set their own emission standards. In 1990, California implemented the Zero-Emission Vehicle program, which required that major vehicle manufacturers sell an increasing number of low-emission and zero-emission vehicles over time. Currently, nine states (Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont) have adopted California's zero-emission vehicle requirements. These states are referred to as Section 177 states and represent approximately 23 percent of the U.S vehicle market. Under the requirements of the ZEV program, PEV vehicle sales in California and the Section 177 states equate to 50,000 units for vehicle model year 2013.

These requirements increase every model year subsequent to 2013; in vehicle model year 2025 approximately 600,000 units must be sold. This represents about 15 percent of new vehicle sales in Section 177 States, or three to four percent of national vehicle sales.

Several Section 177 states have also adopted consumer purchase incentives (F4). For example, California offers up to a $2,500 rebate for purchase or lease of PEVs, as well as access to High Occupancy Vehicle (HOV) lanes. Rhode Island offers a state income tax credit up to $1,875 for purchase or lease of certain PEVs. Maryland offers a $400 tax credit as well as HOV lane access. Finally, New Jersey exempts certain PEV purchases from the state sales tax, offers HOV lane access, and reduced toll rates.

National standards for vehicle model years 2012-2025 require that passenger vehicles achieve, on average, a 54.5 miles per gallon fuel economy standard and 163 grams per mile of CO2e across the total vehicle fleet by model year 2025 (F3). Since 2009, the federal government has provided PEV consumers with tax credits up to $7,500 (F4).

Japan

In 2012, the Japanese BEV market represented 20% of the global market in sales, and the PHEV market represented about 12% of the global market (20). In 2013, 29,761 PEVs were sold with Nissan Leaf representing 49% of those sales and the Mitsubishi Outlander PHEV representing 36% (31). The market penetration rate of PEVs in 2013 was around .6% (11); in 2014, (as of June) that number increased to .94% (1).

Support for automakers involved in innovating and manufacturing PEVs and providing incentivizes to consumers for purchasing PEVs began in the 1970s, when the government developed a comprehensive plan to coordinate the efforts of government agencies, private entities, and local governments to support BEV development (F6) (32). Specifically, government funded research and development support for BEVs began in 1971 along with assisting in the creation of leasing programs (F2) (32). In 1993, the ECO-Station project began, with the goal of establishing 1,000 charging stations for PEVs (F4, F7). As of August 2013, Japan had over 1,700 quick chargers and 3,000 normal chargers installed in the country (33); many of these quick charges are located at Nissan dealerships (20).

The Japanese government has been phasing in PEV incentives since 1978 (F4). Since then, incentives have included subsidies, sales tax waivers and incentives, and leasing incentive programs. Early market support mechanisms included tax waivers and leasing incentive programs (34). The government itself also supported early markets through procurement programs that targeted PEV and low emission vehicles (F6) (32).

Japan was one of the early nations to commit to carbon reductions for climate policy; electrification of vehicles has been one of its strategies (F3). In 1973, Japan introduced the stringent ambient air quality standard for NO_X, as compared to the rest of the world. Under the Kyoto Protocol (1997), Japan committed to reduce its annual greenhouse gas (GHG) emissions to 6% below 1990 levels between 2008 and 2012. In 2009, as part of the Copenhagen Accord, Japan committed to GHG reduction of 25 percent below 1990 levels by 2020, including a 30 percent reduction of CO_2 from the use of fossil fuels below 1990 levels by 2030. In 2010, Japan increased its commitment to reduce GHG emissions 80 percent below 1990 levels by 2050. (35)

Japan currently imports almost all of its energy resources (F7). Until the tsunami in 2011, Japan was the third largest producer of nuclear energy in the world. Since the tsunami, the nuclear sector is under pressure and Japan has increased its imports of coal, oil and natural gas. Renewable energy sources, such as hydropower, only comprise six percent of Japan's energy consumption (36).

Japan is the home of Nissan, the world leader in BEV development, and the earliest car company to experiment with lithium ion batteries (F1, F2). Historically, it has been the leader in lithium ion battery manufacturing for consumer electronics. In 2009, Japan represented 57% of the global lithium-ion manufacture market share, with South Korea at 17% and China at 13% (37). Industrial policy in Japan has emphasized batteries as potential growth industry (F3). Recent government policy, "The Next Generation Automobile Strategy 2010," includes a target of installing two million chargers and 5,000 quick chargers in the country by the year 2020 (38) (20). As part of this policy, 356 million USD were earmarked for FY 2011-12 to support this charging infrastructure goal and to provide purchase incentives to PEV consumers (28).

France

In 2009, France announced the goal of putting two million PEVs on the road by 2020 (39). At the same time, French automakers, including PeugeotCitroen (PSA) and Renault have pledged to produce over 70,000 PEVs for the French market by 2015; and French companies including the French electric company, have committed to purchasing 50,000 of those vehicles (39). Incentives for vehicle purchase are approximately 6,800 U.S. dollars per vehicle (39).

Local municipalities have committed to supporting installation of public charging infrastructure, and the French government estimates that one million publically available charge points will be installed by 2015 (39). Paris alone has put over 2000 electric vehicles and 4000 charge points on the streets under its “Autolib” program (40).

Germany

The German auto market is much bigger than Norway, and has an enormous vehicle sector and is export-oriented. Like Japan, the auto lobby is large, and actively engages in influencing government policy. Year-to-date sales of PEVs in 2014 (September) is at 9,270 vehicles, which represents about 0.46% of the new vehicle market.

In 2009, the government adopted the National Electromobility Development Plan (F6); the goal of which is to help facilitate Germany as the “world’s leading supplier and market for electric mobility by 2020.” The Plan includes recommendations for government support for battery, drive technologies, vehicle integration, lightweight materials, recycling, and information and communication technology research and development efforts, to develop showcase electric mobility regions. Showcase regions include Baden-Wurttemberg, Bavaria/Saxony, Berlin/Brandenburg, and Lower Saxony

(F5). Beginning in 2012, each region received central government funding to implement large-scale regional development of EV fleets and installation of a network of fast charging stations. Concurrently, Germany has been trying to clean up its energy sectors, which is heavily dependent on coal, with robust policy support for wind and solar and recently, following the Fukishima accident, drying up the nuclear sector, and looking at greater imports of natural gas (F7).

Comparing PEV systems across markets

For the purpose of comparing the PEV markets, each study region is explored in the context of the following TIS functions: market formation, legitimation, resource mobilization, and development of positive externalities.

Market Formation (F4)

Market formation is explored through the purchase and recurring vehicle incentives. Recurring incentives refers to annual reductions associated with vehicle costs, such as reductions in annual registration fees.

Purchase and recurring incentives

Direct purchase subsidies, annual registration fee reductions, and company car tax incentives are the most popular types of incentives offered across our case study regions. Income tax incentives are less popular, and are only offered in the Netherlands and the United States. The types and amounts of these subsidies vary from region to region and are often based on vehicle fuel, emissions or CO_2 rating.

Norway. Norway has been phasing in BEV incentives since 1990. Generally, the Norwegian tax system is structured to penalize heavy cars and only as of 2013 has that tax structure been modified to remove weight penalties from hybrids and PHEVs. BEVs are exempted from the VAT and the one-off registration fee. All non-BEVs are required to pay a one-off registration tax, which is based on the vehicle weight, engine rating, CO_2 emissions, and NO_x emissions. For context, a 2013 Volkswagen Golf weighing 1720 kg, emitting 113 g/km of CO_2, and 60 g/km of NO_x would be levied a one-off registration fee of 133,352 NOK (approximately $21,760 USD). The VAT on non-BEVs is 25% of the purchase price of the vehicle. Annual registration fees for BEVs are 405NOK ($66 USD), while other passenger vehicles are generally charged 2885 NOK/year ($470 USD). Like the Netherlands, individuals using an electric vehicle that is a company car, is exempt from the taxation that is normally applied under the company car benefit tax. These incentives are in place until 2018 or whenever the total number of PEVS in Norway hits 50,000 (41). As of September 2014, there were approximately 37,538 PEVs registered in Norway (15).

Table 2: Comparison of purchase and recurring vehicle taxes for individuals- Norway

	Conventional vehicles	PEVs
Purchase taxes	One-time registration fee (based on engine rating, weight, CO_2 and NO_x emissions)	BEVs. Exempt
	VAT (25% on purchase price)	BEVs. Exempt
Recurring taxes	Annual registration fee (Approximately 2885 NOK/year)	BEVs. 405NOK/Year
	Company car tax (based on the new price of the vehicle, 30% for the first 275,700 NOK; 20% for the excess)	BEVs. Exempt

Sources: (42) (43) (44)

Netherlands. In the Netherlands, vehicles being registered in the country for the first time are required to pay a one-time tax (BPM). This BPM is charged based on the vehicle's CO_2 emissions. An annual motor vehicle tax (MRB), or vehicle registration tax is also levied. Electric vehicles are exempt from both the BPM and MRB. Individuals with company cars, PEVs or otherwise, must treat the vehicle as additional income. Additional income is usually 20% of the vehicle's value, but is reduced for fuel efficient cars. BEV owners must pay 4% of the vehicle's value, while PHEV owners pay 7% (45). Leased cars are also charged an income tax tariff. Generally, that charge is 20% of the vehicle's value, while hybrids are 14%, and zero-emission vehicles are fully exempted. However, these company car taxes and related PEV incentives may not have a large impact on individuals. Businesses in the Netherlands often provide employees an allowance to offset the costs of the company car tax (46). Employees who use the car for private uses, in addition to company trips in excess of 500 kilometers per year, must add an additional amount to their income (47).

Table 3: Comparison of purchase and recurring vehicle taxes for individuals- Netherlands

	Conventional vehicles	PEVs
Purchase taxes	A one-off tax (BPM) based on the vehicle's CO2 emissions of the car	Exempt. Additionally certain HEVs are exempt.
	VAT- 19% of the vehicle's value (imported vehicles)	
Recurring taxes	Motor vehicle tax (MRB)- registration tax levied every three month, based on vehicle weight	Vehicles emitting 110 grams of CO_2/km using petrol and 95 grams CO_2/km using diesel are exempted until 2014. Vehicles emitting below 50 grams of CO_2/km are exempted until 2015.
	Company cars - additional income tax for individuals, calculated as a percentage of the cars value (usually 20%)	4%: BEVs 7%: HEVs, PHEVs

Sources: (48) (49)

California and the United States. Since 2008, California has been providing purchase rebates for new PEVs. Currently BEVs receive a $2,500 rebate; while PHEVs receive $1,500. Some neighborhood electric vehicles and zero emission motorcycles qualify for a $900 rebate. The United States provides a federal tax credit up to $7,500 for electric vehicles for vehicles acquired after December 31, 2009. This credit will be phased out once 200,000 vehicles have been sold for a given manufacturer. From 2005-10 a $3,400 federal tax credit for hybrid vehicles was available.

Japan. Since 2001, the Japanese government has offered purchase incentives for consumers who purchase conventional and electric vehicles that are more efficient than Japanese emissions standards (50). These incentives have varied in amounts and structure, but for the most part have offered a reduction on the acquisition tax (VAT), which is levied on the purchase price of the vehicle. For example, early incentives included a 5% reduction on the VAT for vehicles that exceeded the fuel economy standards by 10% (50). Vehicles that exceeded the fuel economy standards by 20% were entitled to a 10% reduction on the VAT (50). These amounts have changed over the years. From 2012-15, PEVs and certain diesel and natural gas vehicles are exempt from the VAT tax. Additionally, these vehicles are exempt from an annual tonnage tax during the first year and are eligible for a 50% reduction the second year. Gasoline vehicles that exceed 2015 fuel efficiency standards and 2005 emission standards are eligible for a complete exemption to a 50% reduction in the VAT and tonnage tax.

In addition to this "eco-taxation" scheme, from 2011-13, the Japanese government allocated 300 billion yen toward subsidies of "eco-cars". Subsidies ranged from 1,000-10,000 yen ($10-$100 USD), with the specific amounts based on available funding.

Table 4: Comparison of purchase and recurring vehicle taxes for individuals- Japan

	Conventional vehicles	PEVs
Purchase taxes	VAT (5% assessed on purchase price) Exempted for vehicles purchased for less than 500,000 yen, and for vehicles meeting certain emissions criteria	Exempt
	Consumption tax (5% assessed on purchase price)	
Recurring taxes	Tonnage tax. Based on vehicle weight (generally 4,100 yen/ton/year; $40 USD/ton/year) Conventional vehicles meeting certain emission criteria are exempt.	Exempt from an annual tonnage tax during the first year and are eligible for a 50% reduction the second year

Sources: (51) (52)

France. In France, electric vehicles are also exempt from the company car tax and hybrids are exempt for the first two years after the initial sale (53). However unlike in the Netherlands, companies, not individuals are responsible for this tax. In addition to PEVs and HEVs, gasoline and diesel vehicles that emit less than 110 grams CO_2/km are also exempted from the company car tax.

Since 2007, the French government has been using a feebate system to provide a direct purchase subsidy to electric vehicle consumers. This system is funded by levying a €200 - €2,600 ($275-$3,600 USD) charge on vehicles with high emissions, and providing a purchase rebate to consumers of clean vehicles. The premiums allocated to clean vehicles varies depending on the CO_2 rating of the vehicle. For example, vehicles emitting 20g/km of CO_2 or less are given €7,000 ($9,600 USD), vehicles emitting 20-50 g/km of CO_2 are given €5,000 ($6,900 USD), 50-60 g/km of CO_2 €4,500 ($5,500 USD), and hybrids emitting 100g/km or less are given €4,000 (53) (54).

Table 5: Comparison of purchase and recurring vehicle taxes for individuals- France

	Conventional vehicles	PEVs
Purchase taxes	Bonus- malus fee (based on the vehicle's CO_2 rating). High emission vehicles may pay a malus ranging between €200 to €2,600	€7,000[2]= Maximum bonus for BEVs €4,000= Maximum bonus for HEVs
	VAT (19.6%)	
Recurring taxes	Registration tax, varies by region (applied with registering or re-registering a vehicles)	
	Annual registration fee (based on CO_2 rating and the first year the vehicle was registered).	

Sources: (53) (54)

Germany. Germany does not provide any direct purchase incentives for PEVs; however does provide several other incentives. Electric vehicles are exempt from the annual circulation tax for ten years from their first registration date. Further, similar to the Netherlands, company cars are treated as taxable income. Generally, consumers are responsible for one percent of the vehicle's list price for every month of vehicle use. However, drivers of an electric company car may deduct €500 ($690 USD) per unit of battery size from the list price, and offset up to €10,000 ($14,000 USD) (4).

Table 6: Comparison of purchase and recurring vehicle taxes for individuals- Germany

	Conventional vehicles	PEVs
Purchase taxes	VAT (19%)	
Recurring taxes	Annual circulation tax (based on engine size and CO_2 emissions)	Exempt
	Company car tax. 1% of the vehicle's list price, for every month of use	Individuals may deduct € 500 per unit of battery size from the list price, and offset up to € 10,000

[2] As of 2013.

The table below summarizes the types of PEV incentives that are available to consumers in each study region.

Table 7: Summary of incentives for individuals, by region

Region	Direct purchase subsidy[3]	Annual or recurring fee discount	Income tax incentive (including company and company car tax incentives)
Norway	X	X	X
Netherlands	X	X	X
California	X		
United States			X
Japan	X	X	
France	X	X	X
Germany		X	X

Legitimation (F5)

Several indicators are used in this paper track legitimation, or actions that help to increase social acceptance, of PEV technologies in each region. Those indicators include: regional or local efforts to support PEV markets or technology, the existence of a national (or statewide) plan to support integrated efforts to support PEV markets, and availability of EV charging station maps.

Vehicle and charging infrastructure targets

The governments in each study region have adopted PEV sales targets. Usually these goals are expressed in cumulative sales targets, with the exception of Japan, where the goal is expressed in terms of new vehicle sales.

Table 8: Vehicle and charging infrastructure targets, by region

Region	PEV goal	Goal year
Norway	50,000	2018
Netherlands	1 million	2025
California	1.5 million	2020
United States	1 million	2015
Japan	20%-50% PEV market share	2020
	50%-70%	2050
France	2 million	2020
Germany	1 million	2020

Only three of the studied regions have developed similar goals for charging infrastructure. The Netherlands adopted the goal of installing 20,000 chargers and 100

[3] Includes one-off registration fees.

quick chargers throughout the country by 2015; while Japan adopted the goal of adopting two million chargers and 5,000 quick chargers by 2020. In the United States, under the 2009 American Recovery and Reinvestment Act, the Department of Energy was charged with creating a Transportation Electrification Initiative. One goal of the initiative was to support deploying 22,000 charging station by December 2013.

Charging station maps and apps

Maps of charging stations are generally available in most of the countries included in this paper and many of the countries have provided government support to the development of online maps. Mobile applications containing this information are only available in the Netherlands, Norway, and the United States. In the Netherlands, there are at least eight online EV mapping services; only one is funded through the NL Agency, the government agency is responsible for issues related to sustainability, innovation and international business. Two private companies have developed mobile apps of charging stations, Oplaadpalen and E-tankstellen-finder.com.

In France, Chargmap and Upplanding.nu provide online information regarding charging stations. These companies also provide charging location information in Norway and the Netherlands. The government funded mobile app in Norway is called Nobil.no; several other private companies offer mobile apps and online maps. No government funded charging maps or applications are available in Germany, although several private companies offer this service. In the United States and California, one private mobile application is available, Recargo- PlugShare, which is free. The United States Department of Energy funds the online Alternative Fueling Station Locator.

Table 9: Summary of charging station maps and applications, by region[4]

Region	Online charging maps	Charging map mobile applications	Government funded
Norway	X	X	X
Netherlands	X	X	X
California/ United States	X	X	X
France	X	X	
Germany	X		X

Support from local jurisdictions and states

Several countries in this study provided funding to local jurisdictions to help showcase electric vehicles, develop related infrastructure, and develop needed information and communication technologies (Japan, Germany). Cities in other countries developed their own goals and policies related to PEVs (Amsterdam) and others provide PEV purchase and infrastructure incentives (U.S. cities).

[4] No information available for Japan

Table 10: Support from local jurisdictions, by region [5]

Region	Local jurisdiction	Description
Norway	City of Oslo	Set its own goal of establishing 400 publically available charge points between 2008-11
Netherlands	City of Amsterdam	Provides subsidies to businesses for installation of public chargers
California	City of LA, San Joaquin Valley, Port of San Diego, Hermosa Beach, San Jose, Santa Monica, Los Angeles Airport	Provides incentives to residents including: $750 rebate for installing chargers; a purchase rebate for PEVs, streamlined permitting for installation of residential chargers, free parking, and free charging.
United States	California, Colorado, Delaware, D.C., Florida, Georgia, Illinois, Iowa, Louisiana, Maryland, Missouri, New Jersey, New York, North Carolina, Oklahoma, Oregon, Pennsylvania, Tennessee, Utah, Virginia, and Washington	Various states provide a range of PEV incentives including: purchase rebates, tax credits, high occupancy vehicle lane access, and reduced toll rates
Japan	11 model towns	The Japanese government-funded EV and PHEV Towns program helps local governments work to expand the use of PEVs.
Germany	Baden-Wurttemberg, Berlin/Brandenburg, Lower Saxony, and Bavaria/Saxony	Showcase regions received federal government funding

Resource mobilization (F6)

Resource mobilization refers to the volume of resources available in different parts of the system to support the TIS. Indicators can include the capital directed at subsidy programs, research and development, or government directed development of long-term planning documents.

[5] No information available for France.

Government PEV Plans

Each case study region has an adopted government plan that provides an integrated vision for the rollout of electric vehicles. These plans include elements such as establishing specific PEV market goals (Japan), plans and goals associated with the deployment of charging infrastructure (Japan, France, Germany), government purchase goals (France), establishing charging standards (France), second life considerations (France), and promoting battery research and development efforts (Germany, Netherlands, United States).

Germany's plan targets three main stages and timeframes: a research and development state (2014); a market roll-out and expansion phase consisting of vehicle and infrastructure policies (2017), and mobilizing a mass market (2020). The plan also funds four model regions, which will develop needed transportation infrastructure and information and communication tools needed to support EVs. Norway's plan is more broad. It is produced every four years and contains the Government's transportation policy goals and strategies. These goals related to multiple modes of transportation, including bicycling, walking, and rail transport.

Each government plan is shown in the table below.

Table 11: PEV planning documents, by region

Region	Plan- Name	Year adopted
Norway	National Transport Plan (2014-2023)	2013
Netherlands	National Action Plan for Electric Driving	2009
California	ZEV Action Plan: A roadmap toward 1.5 million zero-emission vehicles on California roadways by 2025	2013
	PEV Infrastructure Plan	(pending)
United States	EV Everywhere	2012
Japan	Next- Generation Vehicle Plan 2010	2010
France	14-Point Plan	2009
Germany	Integrated Energy and Climate Programme	2007
	National Development Plan for Electric Mobility	2009

Government resources for research and market support

The government in each of our case study jurisdiction provides resources for research and market support. Support ranges from battery research and development support, to infrastructure subsidies, to supporting pilot and demonstration programs.

Norway. The Research Council of Norway, a government agency, is responsible for funding PEV research and development projects. Transnova, a government program, supports charging stations, and demonstration and pilot projects at around €7.5 million/ year (since 2009). Government funding for clean energy programs is around €100 million/year. (55)

Netherlands. The Dutch government support battery research and development efforts. Federal funds are also spent on vehicle purchase incentives and on installation of vehicle charging infrastructure. In 2010, €10 million ($13 million USD) were allocated to the vehicle subsidy program and to support demonstration projects for BEVs and PHEVs. Since 2010, other government funded projects have included heavy-duty electric research and development projects along with battery, drivetrain, and engine research. (20)

California. Since 2009, California has been allocating approximately $120 million per year to PEV pilot and demonstration projects, infrastructure, and related research. Since the purchase rebate program began in 2009, approximately $88 million in rebates has been issued. (56)

United States. The United States expends resources on purchase incentives (federal tax credit), subsidizing the cost of commercial and individual installation of electric vehicle charging stations, and to support PEV research and development. In 2012, the $268 million was allocated toward battery, vehicle, and infrastructure research and development; $360 million as allocated for infrastructure demonstration projects. (20)

Japan. The Japanese government has focused its PEV spending on vehicle incentives, subsidizing electric vehicle charging infrastructure, and infrastructure research and development (20). In fiscal year 2011-12, the government allocated the equivalent of $356 million USD to support charging infrastructure and purchase incentives.

France. As of 2013, France has spent €450 million ($618 million USD) in rebates for PEVs; with the majority of those funds from the malus levied on inefficient vehicles. France has also provided €50 million ($68 million USD) in electric vehicle charging infrastructure subsidies and €140 million ($192 million USD) on vehicle research and development. (20)

Germany. Since Germany adopted its goal of one million electric vehicles by 2020, in 2009, the German government has launched several rounds of related funding efforts. From 2009-2011, the German government passed a stimulus package that included €500 million ($687 million USD) to support PEV research and development, along with supporting the PEV model regions. In addition to government funding, there are several government agencies that are focused on promoting EVs including: the Federal Ministry of Economics and Technology, the Federal Ministry of Transport, Building, and Urban Development, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, and the Federal Ministry of Education and Research. (57) (20)

Development of positive externalities (F7)

One of the positive externalities associated with PEV use is the relative per mile cost of operating a convention vehicle versus operating an electric vehicle. The figure shown below demonstrates the relative expense of operating a Volkswagen Golf[6] versus a

[6] Gasoline powered.

Nissan Leaf. In each country, the per mile cost of fuel for the Volkswagen Golf is higher than the electricity costs associated with operating the Nissan Leaf. In Norway, the country with the highest PEV uptake rates, operating a Volkswagen Golf costs approximately an additional $.40/ mile extra, as compared to a Nissan Leaf. However, it appears that more that the relative operating costs are affecting market penetration rates. For example, of our case study regions, California has the third highest market penetration rate of PEVs, but the lowest operating cost differential between operating a conventional vehicle versus a battery-electric vehicle.

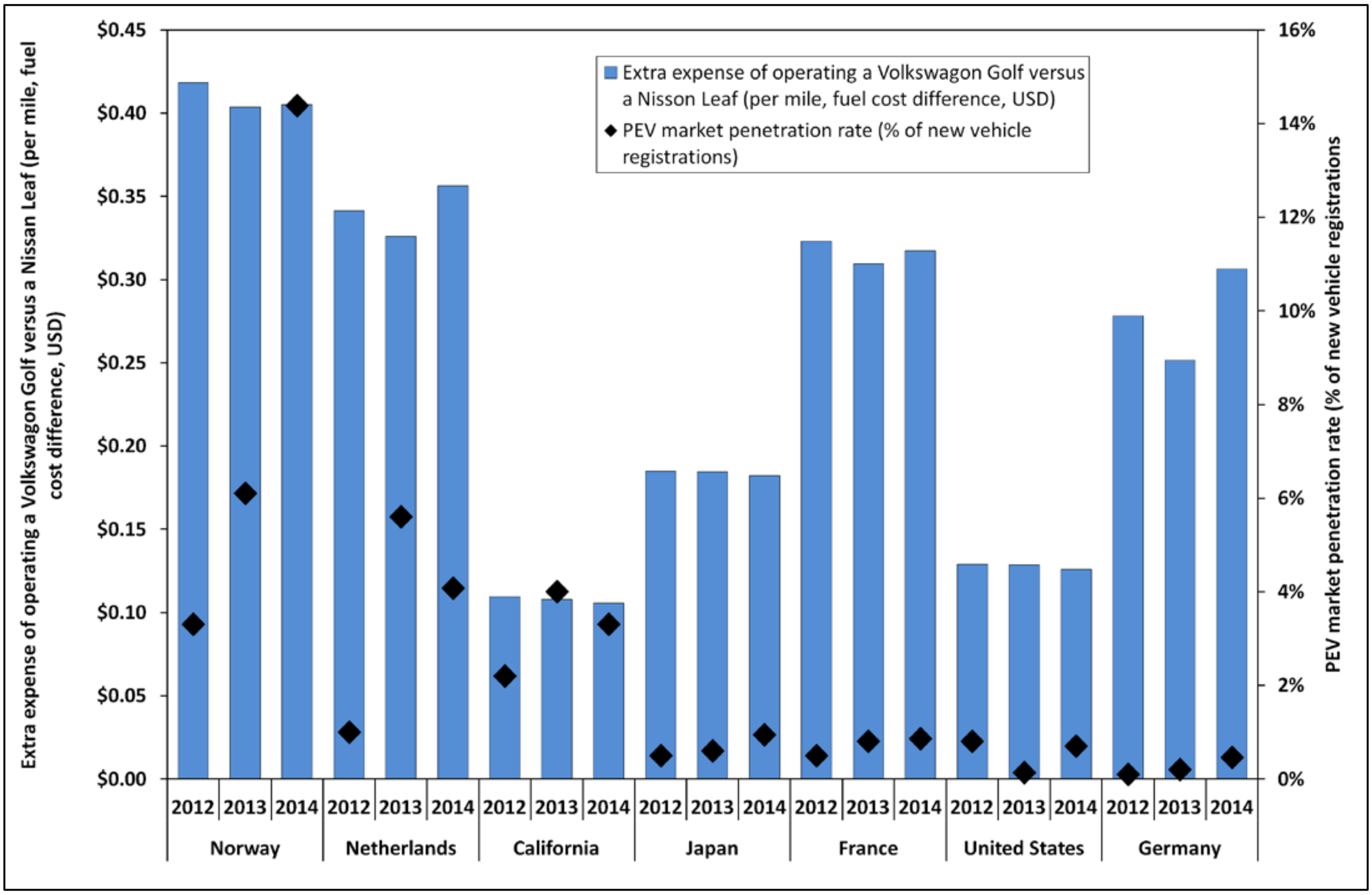

Figure 4: Per mile operating costs of a gasoline versus a BEV, as compared to PEV market penetration rates

Country TIS Rankings

While there is no simple way to combine all the preceding information into a quantified comparison of countries, in order to establish a broad understanding of the important factors contributing to EV sales (and the importance of being strong in several areas) we ranked each country's performance within each TIS category, based on the information described in previous sections. Data was corrected for factors such as population so that countries could be more readily compared. Some countries scored very closely within certain TIS factors, therefore, within some categories, some countries are scored the same (see Table 12).

Table 12: Rankings of case study regions across studied TIS factors

Region	PEV market share ranking	Market Formation (F4)	Legitimation (F5)	Resource mobilization (F6)	Positive externalities (F7)
Norway	1	2	3	5	1
Netherlands	2	1	2	7	2
California	3	3	3	3	7
Japan	4	6	3	4	5
France	5	5	1	2	3
United States	6	4	2	6	6
Germany	7	3	3	1	4

As noted, Norway and the Netherlands have the highest rates of PEV market share, as compared to the rest of our case studies. They were the top two ranked countries in the Market Formation and Positive Externalities TIS category. The United States and Germany have the lowest PEV market share, as compared to the rest of our case studies. Germany was ranked the highest in the Resources Mobilization category, which apparently was not enough to ensure a high PEV market share. The United States was ranked low in the resource mobilization and positive externalities categories, which perhaps helps to explain its market share.

These rankings are not intended to suggest statistical significance, but they do suggest correlations that are worthy of further investigation in trying to better understand why some countries have higher PEV market shares than others.

Conclusions

Based on the information collected in this study, it appears that Market Formation, Legitimation and Positive Externalities may be contributing to higher shares of PEV market shares. However, this analysis is preliminary. To determine whether these TIS factors are the primary determinants of PEV market shares, further research should be undertaken that also incorporates the TIS factors that relate to technology development; specifically, knowledge development and diffusion (F1), entrepreneurial experimentation (F2), and influence on the direction of search (F3), should be studied in greater detail. It may be that the market activities that support PEV innovations may also be impacting regional variations in consumer acceptance. Additional investigations and on-going data collection will help to strengthen our understanding of the importance of various TIS factors and strategies.

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