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ARTICLE

Electric vehicle adoption: An analysis of best practice and pitfalls for policy making from experiences of Europe and the US

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Abstract

Accelerating the rate of electric vehicle (EV) adoption is an objective of many countries to mitigate and ameliorate negative externalities arising from the use of fossil fuels for personal motorised transportation including: greenhouse gas (GHG) emissions, air pollution and noise, as well as increasing energy security and reducing budget deficits. Within the dynamic field of EVs, this paper highlights strategic directions for policy makers to increase EV uptake. The paper critically reviews measures adopted by some industrialised countries to motivate consumer purchase of EVs rather than conventional internal combustion vehicles (ICVs). A key focus is the role of financial and soft incentives to encourage EV adoption. The analysis reveals that not all incentives are equally effective; an adequate recharger network appears to be a common concerning factor for EV adoption due to customer anxiety and vehicle limitations. Best practice strategies that could foster a faster transition to EV adoption include appropriate legislation, installation and maintenance of an adequate public recharger network, government procurement programs, and investment in information programs to accelerate the transition towards fossil free driving. The paper evidences how implementation of these strategies can affect overall adoption rates.

1 | INTRODUCTION

In 2010, the transport sector contributed 23% of total energy-related CO_2 emissions (UN Climate Summit, 2014), thus making it a driver of climate change as well as agent for responses towards its mitigation. Electric vehicles (EVs) have been identified as one relatively low cost solution to address climate change (Cox, 2014; Romm, 2014), due to the reduced emissions intensity of their energy source compared to gasoline and ongoing decarbonisation of electricity (CCA, 2015).

Focusing on two main types of EVs—fully (battery) electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV)—this paper aims to identify successful national and/or state level strategies and policies to incentivise individual car customers to buy an EV and to overcome perceived prejudices towards the technology. To this end, a critical literature review was conducted on actions taken in the most successful markets, particularly from Europe and the United States of America (US). A wide range of mainly English language materials were consulted, including peer reviewed journal articles, and government, NGO and car industry technical reports. Occasional use of news media was necessary to enable access to data otherwise not freely available to the public. Table S3 provides an overview of the sources used, and Table S2 is a compilation of EV market data used to identify those countries most successfully adopting EVs and to analyse factors affecting consumer decision making and government strategies seeking to encourage customers' purchase of EVs.

This paper reviews actions identified as helping to narrow the attitude-action gap towards buying an EV; it also discusses potential pitfalls of actions that are well intentioned, but if implemented poorly could reduce their effectiveness. A final section provides recommendations and notes some implications for countries yet to adopt relevant policies to encourage the transition towards EVs.

2 | FACTORS AFFECTING CONSUMER DECISION MAKING

The sum of individual motorists' decisions affect rates of EV uptake. This section discusses the main factors shown to affect car customers' purchasing decisions, including economic, environmental and social concerns, and those relating to EVs technical limitations.

2.1 | Consumer concerns about EVs

While many potential customers may be willing to change from ICVs to EVs, there are technical, financial, and institutional barriers to purchase (Dunstan, Usher, Ross, Christie, & Paevere, 2011). Customer perceptions about technological advantages and disadvantages, ownership cost, convenience, and environmental concerns are thought to be key, as discussed below and in Sections 2.1.1 and 2.1.2.

In 2011 when the very dynamic EV market had fewer and more technically limited vehicles, a consumer survey found relatively high interest in EVs, including in Australia, France, Germany, and United Kingdom (UK) (Deloitte, 2011). Yet such interest has not necessarily translated into higher rates of EV adoption (Figure 1 and Table S2). Results from prior research indicate consumers have numerous concerns including range, access to rechargers, charge time, price premium, vehicle purchase price, fuel price and fuel efficiency, brand and segment supply (Cluzel, Standen, Lane, & Anable, 2013; Deloitte, 2011; Figenbaum, Kolbenstvedt, & Elvebakk, 2014).

Key concerns identified (Krupa et al., 2014; Mock & Yang, 2014) are vehicle price and aspects relating to recharging and vehicle range, with consumers tending to value purchase price more highly than future fuel prices (Allcott & Wozny, 2014). A US-based study (Carley et al., 2013) found that EV interest was largely affected by customer perceptions of multiple disadvantages associated with this type of vehicle, whereas for German consumers "perceived compatibility with daily life (was) the most important predictor for the willingness to purchase an EV" (Peters & Dütschke, 2014, p. 375). As Rezvani, Jansson, and Bodin (2015) have noted, mass acceptance of EVs will be largely reliant on customer perceptions. A Norwegian revealed choice survey showed that ICV owners were three times more worried than EV owners about vehicle range, access to charging stations, and time to recharge (Figenbaum & Kolbenstvedt, 2016). However, other research (Graham-Rowe et al., 2012; Hahnel, Ortmann, Korcaj, & Spada, 2014; Mairesse, Macharis, Lebeau, & Turcksin, 2012) indicates that positive attitude and purchase intention do not necessarily lead to sales, as discussed below.

2.1.1 | Vehicle price

In the rapidly changing world of EV technology, battery costs currently determine that EVs are more expensive to produce than ICVs, although battery prices are falling more rapidly than anticipated (Nykvist & Nilsson, 2015). A

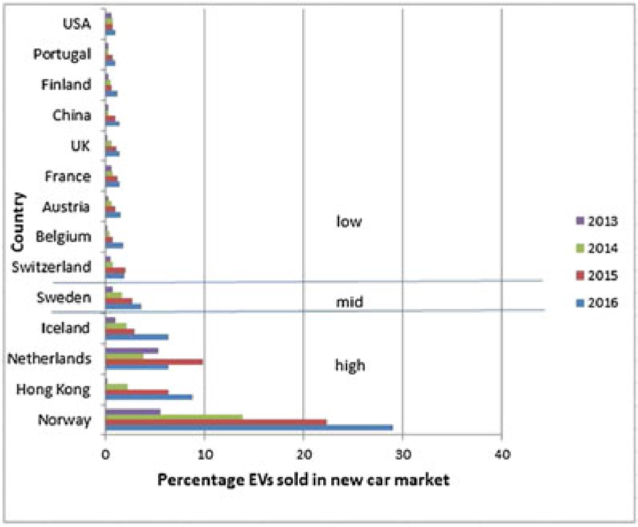

FIGURE 1 Uptake of EVs as percentage of new car registrations by market

UK study (Graham-Rowe et al., 2012) found vehicle purchase price and costs associated with using EVs influenced potential customers' attitudes to EVs; and for Germany, a survey conducted by Hahnel et al. (2014) found that for participants purchase price was more important than vehicle environmental attributes.

An issue for surveys investigating EV interest is that potential customer preferences can be expressed as *willingness to pay* for these more expensive cars, which may be different from *ability to pay* (Skerlos & Winebrake, 2010). For example, Krupa et al. (2014) found that even Americans most willing to buy a PHEV generally were reluctant to pay more than a few thousand dollars extra for it. The former aligns with the so-called *attitude-action gap* indicating people may have positive attitudes towards the environment but fail to carry out the action (Lane & Potter, 2007). After reviewing numerous theoretical frameworks, Kollmuss and Agyeman (2002) concluded that a definitive explanation is yet been found for this gap.

2.1.2 | Environmental concerns and other negative externalities

There is a wide range of negative externalities arising from burning fossil fuels as outlined in Table S1. Research indicates that EVs are less harmful than ICVs, including environmental and health impacts (Ke, Zhang, He, Wu, & Hao, 2017), though Hawkins, Singh, Majeau-Bettez, and Stromman (2012) point to some environmental concerns in the production phase of EVs. Prior research (Idaho National Laboratory, n.d.) evidences that BEVs, which use only mains electricity, can be a cost effective alternative to ICVs as they have fewer moving parts, require less maintenance, are more reliable, and are cheaper to drive per kilometre. Under on-road driving conditions, BEVs were found to be about four times more energy-efficient than petrol ICVs (California Energy Commission, 2016). Moreover, even if electricity is supplied from a poor grid mix (based on 2008 figures), life cycle analyses demonstrated that Renault's BEV *Fluence* produced fewer GHG emissions than petrol/diesel versions of the *Fluence* due to BEVs' overall efficiency and lower primary energy needs (Renault, 2011). With the exception of Iraq and South Africa, driving EVs results in lower emissions per kilometre of travel compared to ICVs (Broadbent, 2017). Jochem, Doll, and Fichtner (2016) found that EVs were advantageous compared to ICVs for reducing oil dependency and providing benefits to climate change, local air pollutants and noise, especially in congested inner cities, but other benefits were dependent on the local grid mix and recharging strategies of individual EV owners. EVs replaced 82% of ICV use in Norwegian multi-vehicle households (Haugneland, Bu, & Hauge, 2016) indicating the potential for EVs to reduce negative externalities from motoring.

Having environmental concerns does not assure EV purchase, regardless of vehicle affordability. A Belgian experiment by Mairesse et al. (2012) found a positive environmental attitude did not always result in EV sales; environmental attributes were outweighed by others such as cost and quality. Although range anxiety was a stronger concern, environmental concerns were demonstrated in Danish research (Jensen, Cherchi, & Mabit, 2013) to increase preferences for EVs both before and after driving an EV for three months. However, a German trial by Degirmenci and Breitner (2017) gave different results; surveying mainly young male German university students with limited EV experience found environmental performance of EVs was a stronger predictor of attitude and thus purchase intention than price or vehicle range. However, that these students may not have been intending to buy a car in the near future may have influenced their stated preferences. These results contradict Lane and Potter (2007) who found potential environmental benefits of EVs were insufficient to promote a change in consumer behaviour. Moreover, Axsen, TyreeHageman, and Lentz (2012) divided American participants with pro-environmental behaviours into three groups, depending on their interest in technology and lifestyle practices. One of their groups, the "low techs," were least open to change, less interested in technological solutions, and were the least interested in buying EVs, indicating that not all pro-environmentalists might be willing to buy an EV.

2.1.3 | Social conformity

Informational and social conformity appear highly significant mechanisms influencing individual EV over ICV decision making in a recent Danish experimental research (Cherchi, 2017). This is consistent with Norwegian data comparing EV and ICV owners (Figenbaum et al., 2014), ICV owners with EV owning friends were much more likely to consider buying an EV than ICV owners without such friends.

2.2 | Recharging infrastructure, interoperability, and harmonisation

Range anxiety and low availability of recharge stations can make consumers reluctant to buy BEVs (Egbue & Long, 2012; Harrison & Thiel, 2017; Struben & Sterman, 2008). Despite EV owners generally recharging cars overnight at home (Figenbaum & Kolbenstvedt, 2016; Morrissey, Weldon, & O'Mahony, 2016), prospective owners demand better infrastructure based on perceived need and fear of running out of charge (Deloitte, 2011). Extensive global research using a stated choice survey (Lieven, 2015) has indicated lack of a recharging network, especially on freeways, caused the strongest dissatisfaction for survey participants suggesting that convenient recharging is essential for attracting EV customers regardless of daily average distances travelled, whereas high purchase subsidies are desirable but not essential. Consistent with this finding, a more recent survey indicates that British drivers (mainly ICVs) are more concerned about availability of rechargers, including in their local area, and vehicle range than they are about vehicle cost (UK DfT, 2016).

Though perceivable as an expensive infrastructure investment by governments, recent modelling of investment in recharge station deployment showed it was three times more effective than subsidising EV purchase, due to indirect network effects on the demand and supply side of a market (Yu, Li, & Tong, 2016). In the UK, a network of rapid[1] chargers was deemed the most efficient way to complement overnight charging at home (Cluzel et al., 2013). The absence of adequate recharging networks can act as a market failure (Section 3.1) and may help explain low EV uptake in many countries. Financial support particularly for publicly accessible rechargers is commonplace in countries promoting the roll out of EVs (OECD, 2015).

Adequate country-wide distribution of recharge stations is important to ensure that motorists can readily travel long distances. Estonia was the first country to have nationwide coverage of fast chargers (Gerdes, 2013), with a recharge station located approximately every 50 km on all major roads and in towns with populations over 5,000 (ELMO, 2014). Regardless of improving battery capacity, which extends vehicle range, individuals' journey trajectories will always vary, meaning public rechargers—whether wireless conductive charging or plug-in—should be conveniently located to encourage the switch to EVs. The current frequency and distribution of gasoline stations, particularly on intercity routes, indicates that even with long range ICVs, there is a market for well-placed refuelling stations.

Information about the location of EV recharge stations tends to be available via internet applications (e.g., Next Green Car, 2015a), though in some countries such information is not entirely reliable. For instance, Belgium (IEA 2016b, p. 153) fails to centralise information collection about recharger locations; hence, internet applications may be out of date or inaccurate and may discourage potential EV buyers. As well, fragmented recharge networks and missing standards and regulations amongst networks can inhibit larger market penetration (Brown, Pyke, & Steenhof, 2010; Steinhilber, Wells, & Thankappan, 2013). A case in point is the UK, with seven national and 10 regional members-only recharge networks, the actual number of rechargers available to any one driver at a reasonable cost is limited (Next Green Car, 2015a). As one BEV owner commented

> *"Having been a Leaf owner for 2-1/2 months, and having friends in the US who've had one for 4-1/2 years, I'm absolutely flabbergasted at the appalling mess of the UK public charging network in comparison to California. In the US you simply swipe your credit card. No messing around with pre-registering and pre-paying on multiple different networks. Charge points WORK [sic]" (Next Green Car, 2015b).*

The aforementioned factors preclude recharge networks being used to their full potential, limiting EV motorists' mobility including across borders. Improvements in interoperability, that is, the ability of a car's recharge technology system to communicate and operate with that of the recharge station and its billing system, are needed (Bakker, 2013). The State of California is a leading example of good practice in interoperability; through Executive Orders, it fosters zero emission vehicle uptake including recharger access (Governor E. G. Brown, 2012) and passed the *Interoperability Electric Vehicle Charging Stations Open Access Act* (California Senate, 2013) thus assisting a more streamlined roll out of EV charging stations and enhancing user friendliness. EVs can be recharged at any publicly accessible recharge station using a credit card to pay rather than requiring network membership. Additional legislation (California Assembly, 2014) allows the 40% of Californians who are tenants in multi-household housing complexes, as well as business tenants, to install a recharger in their building (Shahan, 2014). Legislation goes hand in hand with technological developments that enable electricity consumed by rechargers installed in multi-tenanted buildings to be billed separately (Simpson, 2015). The former has made Californian cities among the leading US cities adopting EVs (Lutsey, Searle, Chambliss, & Bandivadekar, 2015).

Initial steps towards interoperability, harmonisation, and standardisation of recharge fittings are underway (AVERE, 2013; European Commission, 2013), though it may take time as non-standard fittings are gradually replaced (Bakker & Jacob Trip, 2013).

3 | DRIVERS OF EV ADOPTION AND MARKET SUCCESS

3.1 | Innovation and technology transition

Transition from one technology to another innovation has been viewed simply as a six stage linear process from basic research to usage (Bijker, Hughes, & Pinch, 1987). However, it is more likely the process is multifactorial and complex (OECD, 2015). Literature relating to theories of innovation and transition shows it is unlikely that any one theory completely explains such transitions, indeed researchers have failed to find a consensus (Garcia & Calantone, 2002). However, two concepts, Diffusion of Innovations Theory (Rogers, 1983) and market failures (Bator, 1958), and government responses to various elements of these concepts, may reasonably explain why new products are not universally adopted despite their apparent benefits.

An analysis of policies and adoption measures shows that suitable policies, as discussed below, implemented well, could be seen as a necessary co-condition of market formation. Such measures could assist diffusion of innovations and address market failures that inhibit the adoption of innovative products such as BEVs and PHEVs. Market failures can include (a) incomplete markets from inadequate customer information; (b) failure to consider costs of negative externalities (see Table S1); and (c) lack of necessary co-conditions (Boundless, 2016).

Enabling conditions identified in markets that have most successfully encouraged EV uptake is discussed below. Other factors discussed include the impact of weak instruments on good policy, the role of awareness-raising, and the importance of Government procurement.

3.2 | Government actions influencing EV uptake

Governments can implement policies to encourage uptake of a new technology. Policy approaches can be statutory, market based, or information provision (Dovers & Hussey, 2013). Of these, market formation policies may contribute to higher shares of EV sales (Vergis, Turrentine, Fulton, & Fulton, 2014).

Most policies to incentivise EV uptake have been fiscal, though other policies such as direct subsidies, information programs, and regulatory changes were also promoted, especially those relating to recharger network provision (OECD, 2015). Such policies affect car buyers in diverse ways. Recent modelling (Harrison & Thiel, 2017) indicated that in Europe very high purchase subsidies could not lead to market success in the absence of policies to increase recharge infrastructure. They further found that to encourage transition away from fossil fuelled transportation, regulations with long-term fleet emissions targets for vehicle manufacturers were essential.

Incentives to EV purchasing play an important role in encouraging adoption. Modelling by Sierzchula, Bakker, Maat, and Van Wee (2014) showed rates of EV uptake in 30 countries positively correlated to financial incentives, charging infrastructure, and local vehicle production, with the number of charging stations per head of population assessed as most important. However, countries like the US evidence that EV deployment is not uniform, with uptake influenced by multiple factors, including vehicle purchasing subsidies, model availability, city-level awareness promotions, and good access to public electric charging stations (Lutsey et al., 2015). Examples of Government measures to promote EV adoption include (a) for European Union member countries, multiple directives including target setting for emissions reductions and use of renewable energy sources (European Parliament & the Council of the European Union, 2014); and (b) for the US, federal and state legislation, including incentives, for increasing the EV fleet (Reid & Spence, 2016).

Financial incentives appear crucial in market formation, though recent research suggests that EVs will only become more popular when price competitive with ICVs (Lévay, Drossinos, & Thiel, 2017). As previously indicated, EVs are more expensive than similar ICVs (Section 2.2). Thus, government incentives can encourage EV purchase and help overcome consumer resistance to high prices (Mock & Yang, 2014; OECD, 2015). However, the form of incentive is as important as its generosity; research showing tax waivers at time of purchase were more effective than delayed income tax credits, suggesting that immediacy and ease of application is important to consumers (Gallagher & Muehlegger, 2011). Diamond (2009) points out upfront payments are more effective, though such monetary incentives could act as subsidies for car dealers if these subsidies are factored into their pricing schedules.

Concurrent with strategies to encourage EV uptake, many countries set mandatory vehicle emissions reduction targets that have tightened over the years (European Commission Climate Action, 2016). It is notable that a number of important car manufacturers have been caught cheating on fuel economy tests (Farrell, 2016) while attempting to meet legislated targets for fuel efficiency standards. In Europe, car emissions are averaged across an entire brand (European Commission Climate Action, 2016) therefore producing more EVs could be an easier way for a brand to meet its emissions targets. One case in point was the decision by VW to expand its EV production in the wake of the company's emissions scandal (Cremer, 2016).

3.3 | Incentivising EV uptake

Many industrialised countries have implemented policies and strategies to incentivise individuals to buy EVs, however, some more successfully than others. Figure 1 shows rates of EV uptake in the leading markets; supporting data is presented in Table S2. Market uptake is a useful measure as it demonstrates EV acceptance regardless of population numbers, geographic area, and/or country wealth. The ranking is based on 2016 results and shows that EV uptake varies geographically and temporally.

Norway has been the most successful in encouraging uptake; EVs represented almost 30% of new cars sold in 2016 (Figure 1). BEV adoption in this country has had long standing political support with the implementation of a suite of measures, most importantly by making the cars cheaper and priced similarly to ICVs (Figenbaum, Assum, & Kolbenstvedt, 2015).

Denmark also evidences the importance of EVs not being too expensive compared to ICVs to encourage purchase. In 2015, Denmark ranked sixth with EVs comprising 2.39% of all new car sales. However, a policy decision to partially re-impose registration tax in 2016, with full tax by 2020, resulted in high EV sales in late 2015 as sales were brought forward, sales plummeting immediately to 0.63% for 2016 (Wenande, 2016) (Table S2).

Valuable national incentives offered in Norway included reduced vehicle price, and a more extensive range of soft incentives, such as deployment of recharge infrastructure, Norway having the highest number of rechargers per million population (Lutsey, 2015); free battery recharging; free parking in public car parks; exemption from road and public ferry tolls; and free BEV access to bus lanes (Bu, 2015). These incentives positively impacted BEV sales (Bjerkan, Nørbech, & Nordtømme, 2016) and were higher than offered by other European countries (Figenbaum et al., 2014, p. 54). While bus lane access and toll exemptions had lower impact than purchase incentives and adequate infrastructure (Mersky, Sprei, Samaras, & Qian, 2016), toll exemptions were the most cost effective of soft incentives offered (Fearnley, Pfaffenbichler, Figenbaum, & Jellinek, 2015). Active local government procurement policies were also positive (Figenbaum et al., 2015). Comparing Norway's relatively low uptake of PHEVs compared to BEVs (until 2016) (see Table S2) also points to the efficacy of Norway's incentives for BEVs. For many years, PHEVs did not attract the generous incentives given to BEVs, however in 2013 some financial incentives were offered (EV Norway, 2016) and this, with growing numbers of available PHEV models, could help explain the subsequent rising popularity of PHEVs there (European Commission, 2017).

In 2016, EVs made up almost 30% of the new car market, evidencing that EVs are now appealing to Norway's "early majority" as per Diffusion of Innovations Theory (Rogers, 1983), not just "innovators" and "early adopters".

Despite its importance, Figure 2 (IEA, 2016a, p. 16) evidences that the magnitude of a purchasing incentive is not the only factor encouraging EV buyers. Norway offered the highest financial benefit and was the most successful market. However, other countries in 2015 (including China, France, and US) offered the same or higher financial

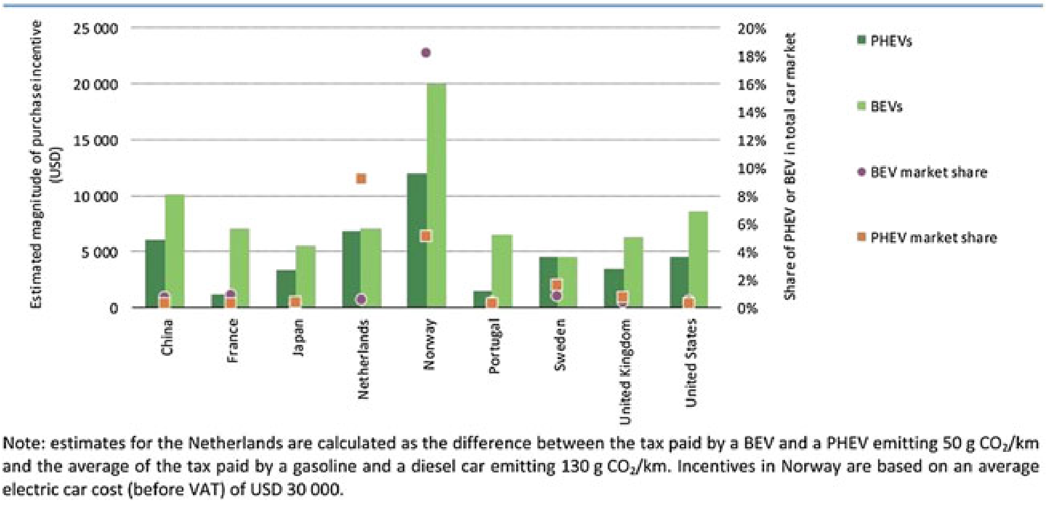

FIGURE 2 Purchase incentives and market shares for BEVs and PHEVs, 2015 (Source: IEA, 2016a, p. 16. © OECD/IEA (2016) *Global EV Outlook 2016 Beyond one million electric cars*, IEA Publishing. Licence: www.iea.org/t%26c)

incentives per vehicle than the second most successful country, The Netherlands, but lacked Dutch success in encouraging EV uptake.

3.4 | Effects of weak instruments on good policy: Case study of the UK

Despite the influence of financial policy instruments on EV market share (Section 3.2), Figure 1 shows EV uptake is still low; many more customers continue to buy ICVs. In the case of the UK, generous financial incentives have not necessarily encouraged EV purchase. Figure 2 and Table S2 show that in 2015, UK incentives were higher than Sweden's, but UK uptake (1.1%) was lower than in Sweden (2.5%).

Cluzel et al. (2013) argued that subsidising EV purchase is not the most effective means of encouraging uptake; they concluded consumers value up-front costs and heavily discount running costs, with substantial subsidies needed to overcome customers' short payback periods, typically under four years. Swedish research (Langbroek, Franklin, & Susilo, 2016) found all incentives encouraged EV uptake to varying degrees, particularly for people already pre-disposed to EVs, but suggested expensive purchase price subsidies were not necessarily the most effective. Cluzel et al. (2013) contended that EV uptake could be enhanced via increased consumer awareness and other incentives such as better infrastructure. Regarding the latter, they argued the UK public recharge networks could have as few as 2,000 sites. However, at 21 March 2016, the UK had 10,508 rechargers in 3,856 locations, including 1,962 rapid rechargers (Next Green Car, 2015a) about the minimum requirement of rapid chargers predicated by Cluzel et al. (2013). Thus, factors beyond the number of rechargers (other than car price) influence the UK's poor rate of uptake, as compared to other advanced economies.

As a necessary market co-condition, an adequate recharger network would possess numerous charge locations that are well dispersed, adequately maintained, easily accessible, and well signposted. To achieve such a network to enhance EV acceptance, careful implementation of policy instruments would be necessary. The UK case shows that inadequate implementation of policies and strategies to increase the recharger network may have inadvertently contributed to the lower popularity of EVs in the UK, as compared to countries spending the same or less on financial incentives on a per car basis. Additional to recharger network problems already noted (Section 2.2), other difficulties could affect consumer attitudes. For example, London's Lord Mayor set an ambitious target of 25,000 recharge points in London by 2015, catering to the large number of households without off-street parking (Wiederer & Philip, 2010). However, in 2015, up to 40% of London's public rechargers were out of service at any one time, and nationally about 23% of rechargers were unable to be used (Sharman, 2015). Other network recharge-related deterrents to EV uptake identified by Sharman (2015) were (a) the risk of inactivity of the radio frequency identification (RFID) cards' mechanism to access the electricity once a car is plugged in and (b) the governance of recharger network maintenance, where British authorities failed to centralise and take responsibility for recharger maintenance, opting for an inadequate system of multiple actors and contracting out to private providers. EV owners' negative experiences with recharging networks is possibly a factor that could dissuade potential buyers from making the change; such positioning aligns with the contribution Diffusion of Innovations Theory makes to understanding successful EV uptake.

A closer analysis of UK market figures (Table S2) helps illustrate the point that factors other than financial incentives may be significant in EV adoption rates. While EV growth figures for 2016 look positive, inspection reveals growth was mainly due to increasing PHEV sales, while BEV growth virtually stagnated. These results add to the evidence that consumers are prepared to transition away from fossil fuelled transport if attractively priced models that meet consumer needs come onto the market. This scenario appears particularly true for PHEVs (which require manageable recharging behaviour change compared to BEVs) that may be perceived as more suitable in a country with an inadequate system of public recharging options. Recent research of Londoners by Bennett, Kottasz, and Shaw (2016) lends support to this argument; they recommended that to improve current customer messaging, promotional materials should emphasise information about battery improvements (including longevity), increased trip range, no need for recharging during most journeys plus the increasing availability of recharge points, with links to network maps, and trip planner phone “apps.”

Governments wishing to avoid pitfalls and maximise the benefits BEVs provide in mitigating negative externalities arising from fossil fuelled transportation might benefit from the salutary lessons of the British experience.

3.5 | Information dissemination

If Diffusion of Innovations Theory (Rogers, 1983) helps explain the mechanisms by which innovation is adopted in a society, then potential customers need information to aid the transition towards new technology. Education programs, field days, and the media play an important role in diffusion as customers need to be persuaded to make the change when innovative products such as EVs are not directly substitutable for the incumbent technology. The media was the most important source of information for Norwegian EV owners, followed by family and friends (Figenbaum et al., 2014). Supplying information to customers, such as available incentives and location of rechargers, helps address incomplete markets, one of the factors contributing to market failure (Section 3.1), and provides relevant information that spreads through communication channels thus assisting diffusion of innovations and improving adoption rates.

Being aware of EVs and their attributes is a necessary precondition for potential new customers. The accuracy of perceptions, many consumers being uninformed or misinformed, may influence decisions to buy (Krause, Carley, Lane, & Graham, 2013). Governments can assist with provision of information about EVs; Norway has had a sustained program for about 20 years to promote EVs and had time to build awareness (OECD, 2015 p. 55). Likewise, the US implemented a wide range of programs to encourage EV ownership, noteworthy is the EV Everywhere program (US DoE, 2012), an umbrella effort to promote and support the adoption of EVs, for example, US DoE (2016a), US DoE (2016b), Buell (2015). Similarly, educating both consumers and car dealers can help diffuse information into the market; for example, Plug in America has a pilot engagement program with “ride and drive” events (Cahill, 2016).

3.6 | Other factors affecting EV market share

The importance of government procurement as an instrument to improve EV uptake should not be overlooked. Government procurement of EVs for its fleets is not only important in stimulating demand and relatively quickly creating a second hand market, but it also enables drivers to experience EVs without having to buy one, thus acting as a means to demonstrate ease of use and potential ownership benefits (Silvia & Krause, 2016). At the Sydney Global Forum on Sustainable Procurement, Yaker (2016, pers. comm.), a sustainable procurement officer for UN Environment, argued that government procurement officers should shift their thinking away from acquisition costs and total cost of ownership for their government department, to global costs for sustainable public procurement. As just one example, health costs from fossil fuelled transport (Xue et al., 2015) could be reduced by making the transition to EVs thus reducing costs not directly associated with car use by a particular government department but affecting whole of government spending.

The second hand market constitutes an important segment of the car market, for example, most Americans cannot afford to buy new cars (von Kaenel, 2016). So action, such as government procurement policy, that rapidly enlarges the second hand market is important. Another important attractant for different market segments is model availability (Cluzel et al., 2013).

It seems that offering a range of incentives helps drive EV car sales; theoretical modelling demonstrated that mixed incentives were the most effective in attracting customers (Silvia & Krause, 2016). In San Francisco, which offered numerous incentives, EVs represented almost 6% of new car sales in 2014 (Lutsey et al., 2015) compared to the US national average of 0.7% (Table S2). In addition to Californian legislative policy to facilitate EV adoption (Section 2.2), offering multiple incentives indicates that success is fostered by addressing the wide range of concerns that customers have and not just focusing on a small niche of the market.

4 | CONCLUSIONS AND POLICY IMPLICATIONS FOR COUNTRIES WITH LOW EV UPTAKE

Our analysis suggests that implementation of any single measure cannot guarantee customers will buy EVs. More likely, implementing multiple measures to appeal to the disparate motivations of individuals could engender a higher rate of uptake. As noted, (Section 3.4) pitfalls may beset governments that inadequately implement policy instruments. The full potential of investments associated with supporting increased EV adoption may not be realised if customer concerns are not kept in mind when acting.

Findings from this overview indicate the main factors affecting rates of EV uptake are likely to be

1. Purchase price: Affordability is extremely important for most consumers. As EV prices reduce and cheaper models come onto the market, government subsidies could be less important in the near term;
2. Roll out of an adequate public recharger network. A network should include (a) appropriate distribution, be well maintained, well signposted and easily accessible; such a network may be regarded as critical; and government support is evident in most successful countries; (b) legislation to ensure open access and payment by credit/debit card; (c) standardisation and harmonisation of recharge hardware; (d) legislation to ensure availability of rechargers in multi-tenant buildings and carparks; and (e) centralisation of data collection for recharge location and status;
3. Dissemination of accurate up to date information about EVs, raising consumer awareness, for example, field days; smart phone apps with recharge network maps;
4. Adoption of government procurement policies—increases second hand car market after a few years and increases diffusion of information via employee use of vehicles;
5. Implementation of a range of other soft incentives appropriate for particular market conditions, for example, free toll road access; access to HOV/bus lanes; free use of local car ferries; free electricity at public rechargers.

The previous sections show that a mix of well implemented government policies may help reduce purchasing impediments for EV customers by addressing market failures and assisting diffusion of innovations. However, the cost of supporting financial incentives to reduce EV purchase price may be too high for many countries/states in the short term. Thus, in places that have yet to adopt relevant policy to encourage EV uptake, adopting a suite of the above measures, especially the recharger network but excluding purchase price incentives, may be more effective in encouraging more people to buy EVs than one measure alone. As battery costs continue to fall, it may only be a few years before EV purchase prices are comparable with ICVs, widely regarded as important for EV uptake.

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ENDNOTES

[1] Cars may be recharged, depending on brand and model, using AC or DC electricity delivered at four possible rates (level 1, 2, fast or rapid).

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SUPPORTING INFORMATION

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