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Exploring the Role of Plug-In Hybrid Electric Vehicles in Electrifying Passenger Transportation

Scott Hardman, Patrick Plötz, Gil Tal, Jonn Axsen, Erik Figenbaum, Patrick Jochem, Sten Karlsson, Nazir Refa, Frances Sprei, Brett Williams, Jake Whitehead, & Bert Witkamp

Key Takeaways

1. Plug-in hybrid electric vehicles (PHEVs) have an important role in the electrification of passenger transportation. Long-range PHEVs not only are a transitional technology. They also are an enabling technology that can encourage more consumers to adopt electric vehicles.

2. The electric range of PHEVs has a significant impact on electric vehicle miles traveled. PHEVs with electric range of at least 60km (37 miles (EPA Range)) have a similar ability to electrify travel as short-range battery electric vehicles (BEVs).

3. Assuming the goal of policymakers is to increase electric vehicle miles traveled, policy support should correspond directly to electric driving range of both PHEVs and BEVs. Short-range PHEVs should receive less policy support; long-range PHEVs and BEVs should receive more policy support.

4. Consumer research in several countries shows that mainstream consumers tend to be more attracted to PHEVs than to BEVs, however many consumers are unaware of how a PHEV differs from a BEV. Consumers and car dealerships need to be educated about PHEVs, their benefits, and the importance of charging the vehicles.

Introduction

The role of battery electric vehicles (BEVs) in the transition to a future in which all vehicles are plug-in electric vehicles (PEVs) is clear. BEVs can contribute to reduced greenhouse gas and criteria pollutant emissions, and help reduce energy consumption. The role of plug-in hybrid electric vehicles (PHEVs) in the transition to PEVs is less clear and recently has been debated. This policy brief explores the role PHEVs can play in this transition.

PEVs include both BEVs and PHEVs. BEVs are driven only by a battery and electric motor. They are plugged in to charge, produce zero tailpipe emissions, and are more efficient than internal combustion engine vehicles. PHEVs are driven by a battery and electric motor combined with an internal combustion engine typically fueled by gasoline. The electric driving range of PHEVs is 10-50 miles (17-80 km), and once this range is depleted the vehicles are driven by the internal combustion engine. Some PHEVs, known as parallel hybrids, may also run in hybrid mode with the combustion engine starting when high power is required, even when the battery is fully charged. Most PHEV designs require the car to be plugged in to recharge the batteries, however, some can also be charged by the vehicle's combustion engine under certain conditions. PHEVs can produce zero tailpipe emissions when they are driven using electric propulsion, and can be more efficient than internal combustion engine vehicles.

PHEVs may offer greater flexibility for consumers to transition to an electric-drive vehicle

PHEVs can help overcome the barrier of consumers' real or perceived range anxiety. They may be a better fit for one-car households and households with more long-distance trips, and in cases where vehicles are used in unpredictable ways (such as for car rentals or in vehicle fleets). BEVs are better suited to two-car households, or households with mobility patterns that can be met with BEV range.

Large vehicle platforms (e.g. trucks and SUVs) and vehicles that require specific capabilities such as towing, may be easier and less costly to electrify as PHEVs than as BEVs. PHEVs require fewer batteries than BEVs, as a result, large-platform PHEVs may have less added weight and be more moderately priced than similarly sized BEVs. To date, most large-platform BEVs with long driving ranges are high-end or luxury vehicles, whereas some moderately priced large platform PHEVs are new entering the market.

Mainstream consumers often show more interest in PHEVs, however they lack an understanding of the vehicles

Consumers do not have to change their driving behavior with PHEVs the way they may have to with BEVs. This may be important for mainstream buyers, who often show more interest in PHEVs than BEVs [1–3]. PHEVs can introduce consumers to the idea of plugging in a vehicle, a practice that may encourage BEV adoption in the future. Still, with PHEVs, consumers retain the flexibility refueling with gasoline for longer distance travel.

However, PHEVs are the least-understood PEV on sale today. Studies in California and across the United States show low consumer awareness of PEVs in general, with PHEVs suffering from even lower awareness and understanding [2,4,5]. Consumers tend to confuse PHEVs with conventional hybrid vehicles or BEVs and lack an understanding of how the vehicles are refueled. Car dealerships may perpetuate consumer confusion because, in many cases, PHEVs are not charged at the dealer. As a result, consumers test drive PHEVs in engine-only mode, effectively experiencing these cars as they would conventional hybrids. This lack of understanding may create barriers to consumer adoption of PHEVs.

Measures of PHEV Performance

The term, electric vehicle miles traveled (eVMT), refers to miles driven using electric power over a given period of time. The more general term, VMT, is a measure of overall miles driven over a period of time. Another common measure of performance is reflected in the term utility factor (UF), which is the percentage of travel that is electrified. This brief focuses on eVMT (sometimes referred to as electric vehicle kilometers travelled (eVKT)) as performance metrics for PHEVs; it does not consider the associated emissions of PHEVs or BEVs. PHEV and BEV emissions will depend on: the source of electricity used to charge the vehicles, which can differ considerably between regions and the time of day of charging; how much they are driven in electric mode; and the efficiency of the PHEV in both electric and gasoline mode. However evidence from California shows that long range PHEVs such as the Chevrolet Volt achieve similar greenhouse emissions per mile as long range BEVs such as the Tesla Model S [6].

Long-range PHEVs can electrify as many miles as short-range BEVs

The eVMT of PHEVs is positively correlated with the electric range of the vehicles: longer range vehicles have the potential to achieve more electric miles [7,8]. Empirical evidence from PHEVs finds that in the real world longer electric range results in more eVMT [9,10]. Long-range PHEVs (e.g. Chevrolet Volt with 37 miles (60 km) of range) can drive 75% of all miles using electricity [9,11]. Figure 1 shows the relationship between PHEV electric range and eVKT.

Short-range PHEVs generate fewer electric miles

Short-range PHEVs have lower eVMT potential. PHEVs with 15-31 miles (25km-50km) of range can potentially electrify 30%-55% of per-vehicle VMT [9,12], however, empirical data has found their performance can be lower. A California study found that PHEVs with 12 miles (20 km) of range achieved eVMT of 15%, and PHEVs with 20 miles (32km) of range achieved eVMT of 25% [11]. The lower than expected eVMT is due to these drivers plugging in their PHEVs less frequently and some drivers never plugging in their vehicles; with 15%-30% of these PHEV owners never plugging in.

Drivers of these short-range PHEVs are less motivated to plug in for several reasons. First, recharging the vehicles may not necessarily improve the way the vehicle drives. Second, they do not experience a significant benefit from charging (i.e. fewer electric miles gained). Third, consumers may have other motivations for purchasing these vehicles (e.g. to access HOV lanes, or due to other incentives).

Long-range PHEVs can electrify as much household travel as short-range BEVs

PHEVs achieve lower per-vehicle eVMT when compared to BEVs, because BEVs will always achieve

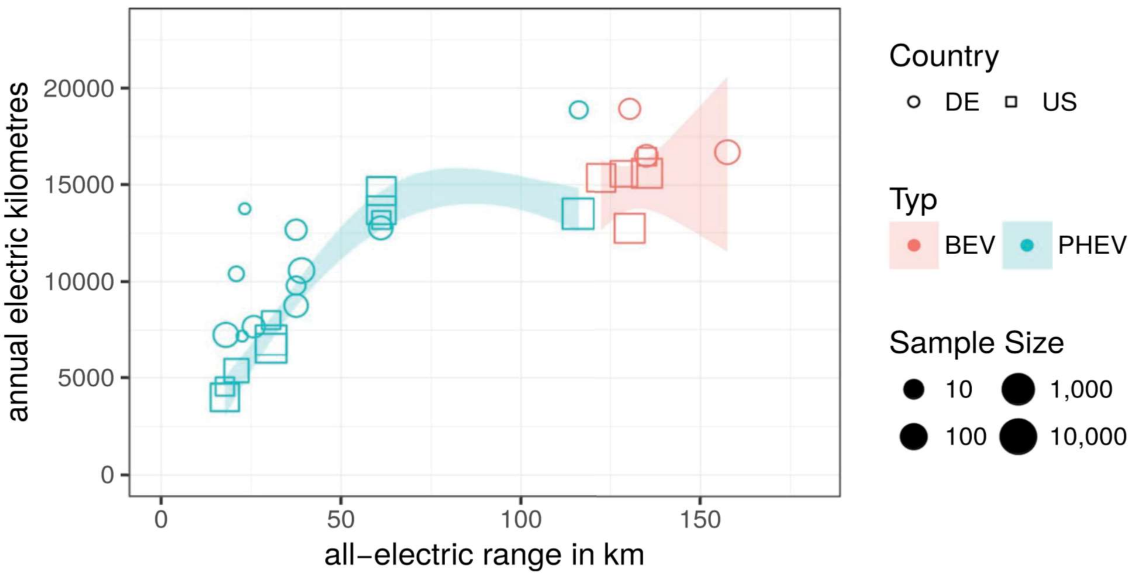

Figure 1: Annual electric kilometers achieved for PHEVs with different all-electric range in USA (US) and Germany (DE) [15]. Range figures for US models are EPA range and for German models 75% of the NEDC range, which is a more accurate estimate of real world range.

100% eVMT. However, PHEVs can electrify as many -- or more -- miles of a household's VMT because they can electrify most miles for short journeys and some miles for longer journeys. One study found that PHEVs electrify 45% of household VMT and BEVs electrify 43% of household VMT [11]. Short-range BEVs electrify all miles on short journeys, but are not frequently used for longer journeys. Because BEV owners often have access to other vehicles in their household, they use an internal combustion car for long-distance driving, thus reducing the proportion of miles the household would travel electrically [13].

Company, business, and fleet vehicles face challenges in ensuring drivers recharge their PHEVs

Some nations, notably the Netherlands and the UK, currently have or at one time had strong incentives for PEV company cars. Company cars are vehicles provided to employees for the employee to use for business and personal travel, the vehicles are considered part of employee compensation and are therefore part of their tax liability. Drivers of these vehicles have been encouraged to choose PHEVs due to substantial tax incentives. Often company car drivers also have a fuel card -- meaning they do not pay for their own gasoline. They do, however, pay for electricity on their household utility bill if they plug in their vehicle to charge at home. Empirical evidence from the Netherlands has found that company car drivers are less likely to plug in their PHEVs [14]. Drivers who own PHEVs with 40km (25 miles) of range achieved 25% eVMT on average (compared to 50% eVMT for non-company car drivers). Subsequent research by Plötz has also observed this trend [15]. For these drivers, there is no financial benefit to recharging their PHEV, which severly reduces eVMT. Situations such as these should be avoided.

Summary

PHEVs play a role in the electrification of passenger transportation. Long-range PHEVs not only are a transitional technology, but also are an enabling technology, i.e. a technology that can encourage more consumers to adopt electric vehicles. PHEVs may appeal to consumers who are unlikely to purchase a BEV due to their specific vehicle needs or their perceptions of BEVs, or because theirs is a single-car household for whom BEVs are not a good fit. PHEVs also may facilitate the electrification of difficult-to-electrify platforms.

Policy support for PHEVs (and BEVs) should be based on the vehicles' ability to electrify VMT. Short-range PHEVs should receive less policy support than long-range PHEVs. Automakers and policymakers should seek to introduce PHEVs with at least 60km (37 miles) and ideally more than 50 miles (80km) of electric range. Purchase incentives, reoccurring and non-financial incentives, and regulatory mechanisms (e.g. ZEV regulations) should be tied to electric driving range of PEVs (both PHEVs and BEVs), as is common practice in some nations, such as China.

Policymakers should also develop charging infrastructure with increasing eVMT of PHEVs in mind. In addition to home charging, workplace charging has been found to have a positive impact on PHEVs' ability to travel using electric propulsion [16]. Slower, lower-power chargers can be adequate to charge PHEVs due to the vehicles' smaller batteries. In regions where 120 V is the standard domestic voltage, Level 1 (120 V) chargers are often sufficient, though Level 2 (240 V) will achieve faster charging times. In regions where 230 V is the standard, single-phase (230 V, 16-32 A) chargers will be sufficient.

More needs to be done to increase knowledge and awareness of PHEVs (and BEVs) to help grow the market. Education and awareness for both PHEVs and BEVs is discussed in [17].

Future Research

It is currently not well understood how well long-range BEVs perform in terms of eVMT in the household context. Long-range BEVs may be able to electrify more miles than both short-range BEVs and long-range PHEVs. If this is the case, then structuring incentives around the driving range of PHEVs and BEVs will ensure that the vehicles with the highest eVMT potential receive the most favorable incentives.

Definitions

- Short-range PHEVs: PHEVs with range of 12-20 miles.
- Long-range PHEVs: PHEVs with range of 37 miles or more.
- Short-range BEVs: BEVs with around 100 miles of range.
- Long-range BEVs: BEVs with 200 miles of range or more.

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Contact Information

Scott Hardman, University of California Davis, USA, shardman@ucdavis.edu

Patrick Plötz, Fraunhofer Institute for Systems and Innovation Research, Germany, patrick.ploetz@isi.fraunhofer.de

Gil Tal, University of California Davis, USA, gtal@ucdavis.edu

Jonn Axsen, Simon Fraser University, Canada, jonn_axsen@sfu.ca

Erik Figenbaum, TOI (Institute of Transport Economics), Norway, Erik.Figenbaum@toi.no

Patrick Jochem, Karlsruhe Institute of Technology, Germany, patrick.jochem@kit.edu

Sten Karlsson, Chalmers University of Technology, Sweden, sten.karlsson@chalmers.se

Nazir Rafa, Elaadnl, Netherlands, Nazir.Refa@elaad.nl

Frances Sprei, Chalmers University of Technology, Sweden, fsprei@chalmers.se

Brett Williams, Center for Sustainable Energy, USA, brett.williams@energycenter.org

Jake Whitehead, University of Queensland, Australia, j.whitehead@uq.edu.au

Bert Witkamp, EAFO, Belgium, bert.witkamp@eafo.eu

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