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Electric Cars in California: Early Adopters' Total Cost of Ownership

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Executive Summary

This paper presents a unique approach to total cost of ownership (TCO) analysis for plug-in electric vehicles (PEVs) versus internal combustion engine vehicles. Unlike the TCO literature, which characterizes an average driver, this study estimates the actual costs incurred by early adopters of PEVs in California using multi-year survey responses.

The findings reveal that the higher the vehicle segment, the lower the annual mileage required to achieve cost parity, raising concerns about affordability and equity. Overall, this research sheds new light on the cost competitiveness of PEVs and has important implications for policymakers and consumers alike.

Keywords: Cost, passenger car, electric vehicle (EV), PHEV (plug in hybrid electric vehicle), ICE (internal combustion engine)

1 Introduction

Over the past decades, California has implemented numerous policies to reduce greenhouse gas emissions from the transportation sector, which is responsible for highest emissions. One of these regulations is a zero-emission vehicle adoption goal, which includes battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), collectively known as plug-in electric vehicles (PEVs). Although PEV sales have been increasing in California over the past decade, the current trend does not reflect early adopters' concerns, such as the higher purchase price of PEVs compared to internal combustion engine vehicles (ICEVs). To address the capital cost barrier, incentive programs have been implemented in the federal, state, and local levels.

The shift from conventional vehicles to alternative fuel vehicles (AFVs) is often analyzed through a comparative analysis of vehicle total cost of ownership (TCO). Typically, TCO studies make assumptions about an average driver and identify a future point where the ownership costs of vehicles with different powertrain types are equal [1], [2], [3], [4]. However, this paper takes a different approach by examining ownership cost parities of real early adopters. The Plug-in Hybrid and Electric Vehicle (PH&EV) Research Center at UC Davis conducted a multi-year online survey of new PEV owners in California from 2011 to 2020. By combining this data with external datasets, this study estimated the true TCO of the participants and their chosen PEV. This paper presents the change in TCO over time and driven miles, as well as identifying positive or negative TCO by assuming the alternative vehicle that could be otherwise purchased by the participants. Analyzing the costs of true adopters over the past decade raised a unique opportunity to evaluate the investment needed by early adopters to propel the PEV market to its current sales volume.

2 Literature Review

Research on the TCO of light-duty AVFs has been extensive and evolving over the past few years [5]. The main objective of TCO methodology is to identify the conditions under which cost parity can be achieved between comparable alternatives. TCO analysis is carried out on technology that is yet to be widely adopted and is aiming to predict future cost parity. Two main approaches are used for TCO studies: top-down (aggregated) and bottom-up (teardown) analysis. The top-down method focuses on a few representative vehicle models available in the market at the time of the study [2][6], [7], [8], [9]. The bottom-up approach requires rigorous assumptions regarding future technology developments, production volumes, and associated costs, which can lead to increased uncertainty in estimating current and future vehicle manufacturing and purchase costs [3], [4], [10], [11], [12].

Only two studies that estimated past TCO were found in the literature [13], [14]. The first study focused on California, Texas, the United Kingdom, and Japan from 1997 to 2015, while the second reviewed the Norwegian market between 1992 to 2019. The two studies took different approaches in their estimation of annual vehicle mile travelled (VMT). While Palmer et al. used a varied VMT across regions, Figenbaum instead assigned a fixed VMT value for the entire country, which increased every six years. While early studies considered average user characteristics, like the two above, recent studies considered household characteristics and heterogeneity in travel demand [15],[16],[17], and a series of three studies used car movement data from 64 vehicles in Sweden to better assess the shifting cost from ICEV to PEV [18], [19], [20]. This study utilized the PH&EV multi-year survey to provide TCO estimates for surveyed drivers, considering their home counties and driving attributes.

The TCO research exhibited a range of results, which varied based on market and user contexts and methodologies employed. Conflicting conclusions can be found in some cases, as demonstrated by two U.S. market studies that utilized the bottom-up approach [3],[11]. While Lutsey and Nicholas concluded that cost parity between a sedan BEV and a sedan ICEV could be achieved as early as 2024, Hamza et al. found that a cost parity by 2030 would require an exceptionally favorable set of assumptions.

3 Methodology

This section outlines the methodology used to estimate the individual TCO of PEV owners in California by combining comprehensive survey responses with online data sources. It describes the databases that were collected and explains how they were used to calculate ownership costs.

3.1 Online Survey

The PH&EV Research Center conducted a multi-year online survey targeting PEV owners in California who had purchased their vehicles within the previous five years of survey date. The survey was conducted in seven phases between April 2015 and November 2020 and collected information on vehicle details, finances, sociodemographic, and driving and charging behaviors [21]. This research considered the responses of 11,505 new PEV purchasers between 2011 and 2020, excluding leasers and second-hand buyers. These early adopters have unique socioeconomic characteristics, including high levels of education and income, that do not necessarily apply to the broader market [22].

3.2 TCO Evaluation Framework

The TCO evaluation framework used in this research includes capital costs, operating expenses, and resale value of the vehicle at the end of ownership with the unit of TCO results being dollar per mile driven.

Given that PEVs have only been prevalent for a decade, and with major technology developments are still occurring, estimating the residual value of long-owned PEVs would require a broader set of assumptions, which were preferably avoided. Therefore, the chosen ownership length was five years, although 2020 U.S. average vehicle ownership length being 8.4 years [23]. This decision is supported by the TCO literature, which frequently used an ownership length of five or six years.

The analysis focused on cost calculations between 2011 to 2024, with all cost components adjusted and capitalized to the year of purchase using annual interest rate. Although the inflation rates for the years 2011 to 2021 were known, the inflation rates for the years 2022 to 2024 were estimated as the rolling average of the previous five years. Figure 1 provides an overview of the TCO framework used in this research.

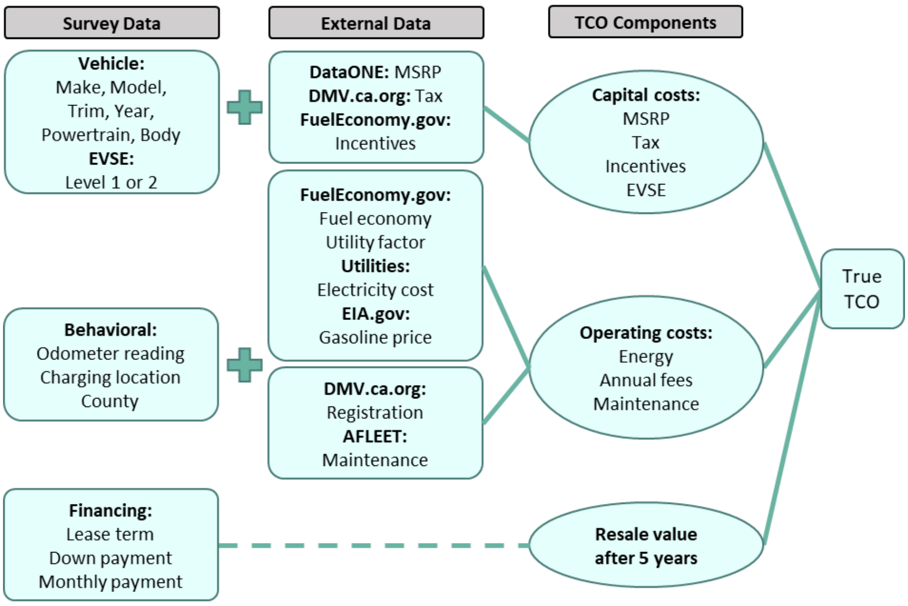

Figure 1: TCO framework

3.2.1 Capital Costs

The capital costs associated with owning a PEV include the vehicle purchase price, purchase tax, incentives, and the cost of purchasing and installing a home charger.

The purchase prices reported for a given PEV model varied possibly due to dealer markups, dealer discounts, and the purchasers' recollection. To establish a consistent vehicle manufacturer's suggested retail prices (MSRP) baseline, the DataONE database was used [24]. This database was merged with the PH&EV survey using specific attributes (make, model, model year, trim, powertrain, and body).

New vehicle purchase tax data for the years 2011 to 2020 was collected using the California DMV New Vehicle Registration Fee Calculator, with the tax varying by year and county [25]. For each county, a random zip code was chosen and vehicle purchase date was set to January 1st of each year. The household location, as reported by survey participants using a pin on a displayed map, was matched with the appropriate county.

The analysis considered federal and state incentives while excluding local incentives that often required purchasers to actively seek them out and meet certain eligibility criteria. By focusing on fixed-value incentives that apply to the general population, rather than on localized or temporary benefits, this approach allowed for more meaningful conclusions to be drawn. The past federal income tax credit, which varied from $2,500 to $7,500, was fully assigned to respondents with an annual income greater than $50,000. For those with lower annual incomes, the assigned credit amount was equal to the average federal tax obligation of a single and jointly filing for an income of $49,999 [25]. The California Clean Vehicle Rebate Project (CVRP) is a state incentive program that was modified over the years. It offered BEV buyers a rebate of $2,500 and $1,500 for PHEVs (with an addition of $2,000 for low-income households). This incentive was applied based on the year of purchase and the reported income.

Home charger costs varied depending on the charger type. In this analysis, no additional costs were associated with level 1 charger. For converted level 1, it was assumed that only an adapter was purchased at a cost of $100. For level 2, the assigned cost of the home charger was $1,836, which included $550 for equipment and $1,286 for installation [27]. The survey asked respondents to indicate their home charger type, with roughly half of them reporting the use of level 2 chargers.

3.2.2 Operating Costs

The main operating costs of vehicle ownership are energy expenditure, annual registration, and maintenance.

Energy expenditure is dependent on household driving and charging patterns. This study used the odometer value reported by survey respondents to ensure a representation of the heterogeneity of California drivers' behavior. With the vehicle age, a monthly average of VMT was calculated, and the five-year VMT was estimated for the analysis ownership length. The survey also collected information about respondents' charging behavior in the previous week. Using this data, Table *1* shows the summary statistics of each charging event per survey phase. This table allowed to granularly calculate charging costs. It was observed that the percentage of charging at home declined over time, while work charging increased.

Table 1: Average percentage of charging events per survey phase

Phase	Dates	Home	Work L1	Work L2	Work DC	Work Total	Public L1	Public L2	Public DC	Public Total
1+2	Apr '15 - Jul '16	81.5%	1.2%	5.3%	1.3%	7.8%	1.6%	3.6%	5.5%	10.7%
3	Aug '16 - Oct '16	77.5%	3.8%	10.3%	0.9%	15.0%	0.7%	3.0%	3.7%	7.5%
4	Jun '17 - Aug '18	76.1%	3.7%	10.8%	0.7%	15.2%	0.7%	4.6%	3.5%	8.7%
5	Oct '17 - Nov '17	74.5%	4.4%	12.9%	0.4%	17.7%	2.0%	4.7%	1.0%	7.8%
6	Aug '18 - Apr '19	73.5%	2.9%	12.6%	1.8%	17.3%	0.9%	4.6%	3.6%	9.1%
7	May '20 - Oct '20	73.8%	2.4%	12.4%	2.5%	17.3%	0.9%	3.8%	4.3%	8.9%

The utility factor (UF) measures the fraction of VMT that use the electric mode of a vehicle and is dependent on the battery's technical attributes and the driver behavior [28]. For BEVs, a UF of one was assumed, while for PHEVs, the values were obtained from the Office of Energy Efficiency & Renewable Energy (EERE) for each model and year [29]. Additionally, EERE fuel economy values were assigned based on vehicle model, year, and trim.

To obtain retail gasoline prices, the U.S. Energy Information Administration (EIA) datasets, which provided historical California average prices per grade and future projection, were used [30], [31]. To adjust for spatial differences, the prices were normalized per county using the ratio between the average county price and the average state price on a particular day (March 28, 2022) as a proxy for the entire analysis [32].

To determine the home electricity rate, survey data on the electric utility company and the rate program were incorporated. Respondents provided their local electric utility company and selected one of three plans (Flat Rate, Time of Use (TOU), and Electric Vehicle (EV)), and specified whether or not they used a timer to charge their vehicle. Historical rate schedules were collected from the top five reported utilities: Pacific Gas & Electric (PG&E) (43.1%), Southern California Edison (SCE) (27.3%), San Diego Gas & Electric (SDGE) (11.9%), Los Angeles Department of Water and Power (LADWP) (7.2%), and Sacramento Municipal Utility District (SMUD) (3.3%). Respondents served by other companies (7.2%) were assigned the average rate of the top five popular companies. Fixed minimum meter charge, low-income energy rates (CARE), and the California Climate Credit were excluded from the analysis. Future rates were predicted using the average growth rate of residential electricity rate per utility company between 2020 and 2025 [33].

To determine the residential rate for home vehicle charging, the following logic was applied:

- EV plan, timer charging → Average of off-peak rates from EV plans
- EV plan, no timer charging → Average of all peak rates from EV plans
- TOU plan, timer charging → Average of off-peak rates from TOU plans
- TOU plan, no timer charging → Average of all peak rates from TOU plans
- Flat Rate plan → Average of tier 2 rates from Flat Rate plans

Assuming that work (any level) and public level 1 charging events were free, the rate for public level 2 charging events was set as the average of EVgo's lowest advertised price for guests and basic members during off-peak and on-peak hours ($0.35/kWh as of March 2022). Similarly, the rate of public DC fast charging events was set at the guests and pass members rate in ElectrifyAmerica stations ($0.43/kWh as of March 2022). An annual factor was used to adjust for changes in electricity rates based on the average rate in California for each analysis year. Public charging costs were assumed to be zero in the analysis for certain Tesla models from specific years that were eligible for unlimited free Tesla Supercharging. Survey respondents were asked whether they had a rooftop photovoltaic (RPV) system and in cases where they did, the average 25% savings on electricity consumption, after accounting for installation and capital costs, were applied to their home charging expenses [34].

The annual registration fees were obtained for the years 2011 to 2022 using the California DMV New Vehicle Registration Fee Calculator [25]. The registration fee consists of state and county fees, with one fee based on the vehicle's MSRP. Future years (2023-2024) were assumed to have the same fees as in 2022. To estimate maintenance costs, the Argonne National Lab's Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool was used. Maintenance costs were estimated per driven mile, vehicle age, and vehicle body for the different powertrains [35].

3.2.3 Resale Value

To estimate the resale value of new vehicle types like PEVs, for which a secondary market has not been established yet, leased vehicle data from the PH&EV survey was utilized. The approach presented in this study subtracts the federal income tax credit from the MSRP, as this credit passes through to the next buyer, to avoid the deflated resale prices cited in the literature [36].

The survey included over 7,000 new leased vehicles covering around 250 models, with each vehicle having data on the down and monthly payments. The residual value after three years of ownership was obtained using a leasing calculator [37]. To estimate the residual value after five years, it was assumed that PEVs depreciate by 25% in the first year and at a constant rate every year thereafter. The constant depreciation rate for each year after the first can be easily calculated using the residual rate after three years. By using the first-year and constant depreciation rates, the resale value after five years was calculated for each vehicle. To simplify the analysis, the five-year residual values of the same vehicle group (powertrain, body, and class) were averaged and used for all analysis years. The resale value of hybrid electric vehicles (HEVs) and ICEVs was determined by referring to the top five popular vehicle models in California in 2021 [38]. Using Kelly Blue Book, the resale value was determined with the average of the private party and trade-in values of a five-year-old vehicle (2016-2020) in a "very good condition", with standard trim and equipment, and annual mileage of 12,000 miles in San Francisco (zip code 94115). Table 2 details the resale value for each group.

Table 2. Average resale value of five-year vehicle per powertrain, body, and class

	Passenger Car		Light Duty Truck	
	Standard	**Luxury**	**Standard**	**Luxury**
BEV	0.32	0.28	0.38	0.34
PHEV	0.29	0.29	0.31	0.31
HEV or ICEV	0.50	0.50	0.55	0.55

3.3 TCO Comparisons

The primary aim of this study was to find the share of California drivers who derived financial benefits from purchasing a new PEV as opposed to a combustion engine vehicle. To achieve this objective, specific PEV models were compared with selected ICEV or HEV comparable models in different vehicle segments. The comparison analysis was carried out for the year 2018, which saw the most extensive survey data collection. To ensure that the comparisons were as similar as possible, the trim level for each model was carefully selected based on its specifications.

Certain assumptions were made to address the research objective: that a new ICEV or HEV would have been purchased instead of the new PEV and that the substitute ICEV or HEV would have been driven similarly to the PEV in terms of annual VMT [39]. To differentiate users who derived a positive TCO from those who did not, the annual VMT at which parity was reached was employed.

4 Results

In this section, the estimated TCO of the survey sample is presented along with the findings of the comparison analysis. The TCO was illustrated over time, annual VMT, and by powertrain type. The comparisons provided insights into the number of survey participants who financially benefited from purchasing a PEV and the role of the federal income tax credit and the state incentive on this benefit.

4.1 Descriptive Statistics

The sociodemographic characteristics of the survey sample compromising of 11,505 early PEV adopters are presented as follows. The majority of participants identified themselves as male (65%), with the remaining identifying as female. Age-wise, the middle age groups of 30-39, 40-49, and 50-59 were equally represented, each accounting for 23% of the sample. Most participants were homeowners (85%) or lived in a detached house (82%). The annual income group of $100,000 to $200,000 was the most dominant, accounting for 47% of the sample. Over the years, more households with low- and medium-income (up to $200,000 per year) purchased PEVs, as expected with the increase in the number of models offered at a wider price range and the nature of market penetration. For PHEV owners, the general trend was an increasing percentage of participants who lived in apartments, whether owned or rented. The number of households with a single vehicle in their fleet (excluding motorcycles and motorhomes), which was a PEV only, increased from 4% in 2011 to 16% in 2019, indicating a positive trend in adoption and trust in this new technology.

4.2 TCO Overview

TCO was estimated for a five-year ownership period and is presented as the cost per mile driven in U.S. dollars, adjusted for the year of purchase. Figure 2 and Figure 3 show two major operating cost components: annual VMT and fuel cost segmented by powertrain type. The distribution of annual VMT between the two powertrain types was comparable, ranging from 4,100 miles to 27,700, with a median of 12,500 miles. That suggests that BEVs and PHEVs were driven similarly. The annual fuel expenditure distribution also exhibits a similar range, where the BEV distribution skewed towards the lower end due to the absence of gasoline expenditure.

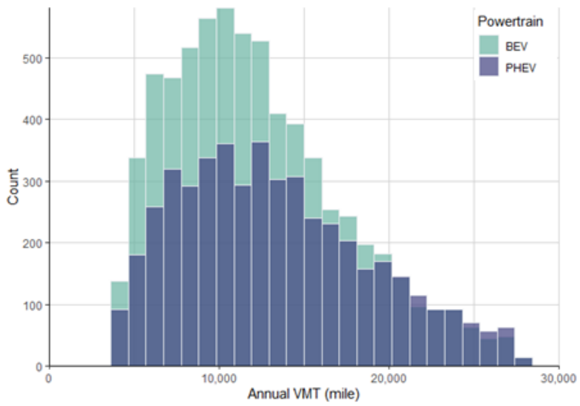

Figure 2. Annual VMT distribution

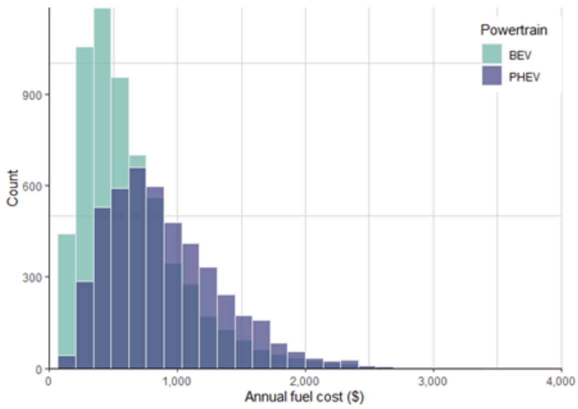

Figure 3. Annual fuel cost distribution

To track the TCO trend over time, the vehicle sample was split into standard and luxury auto manufacturers, as the MSRP plays a major role in the overall TCO. The standard manufacturers included Ford, Honda, Hyundai, Kia, Mitsubishi, Nissan, Smart, Subaru, Toyota, and Volkswagen, while the luxury manufacturers were Audi, BMW, Cadillac, Chrysler, Jaguar, Mercedes, Tesla, and Volvo (listed alphabetically). Figure 4 illustrates that the median BEV TCO per year of standard manufacturers fluctuated around $0.5/mile to $0.6/mile during the analysis term, while for PHEVs, it varied between $0.5/mile to $0.55/mile. The TCO of luxury BEVs decreases over time with the introduction of cheaper models under the same luxury brand. However, the luxury TCO remained higher than the standard TCO.

The expected trend of decreasing TCO per mile with an increase in annual VMT is demonstrated in Figure 5. For BEVs, drivers who travelled 4,100 miles a year had a TCO of $0.26/mile and $0.41/mile for standard and luxury classes, respectively. Those who drove over 27,000 miles annually, had a TCO of $1.65/mile and $4.83/mile for the two classes. Tesla Model 3 (any trims) was plotted separately, as its TCO fell between the standard and the luxury clusters.

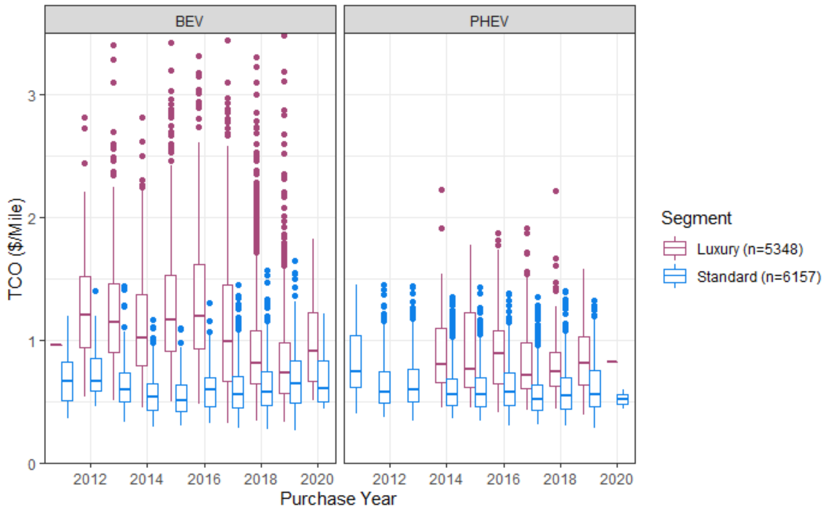

Figure 4. TCO per mile

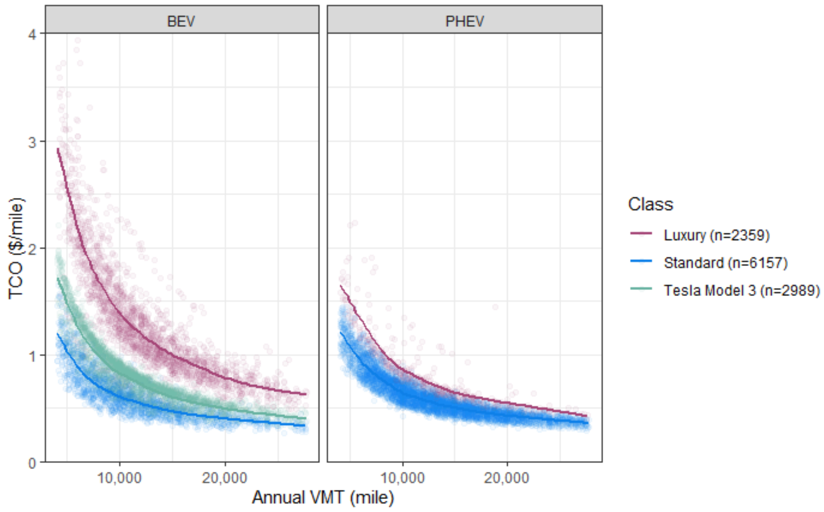

Figure 5. TCO versus Annual VMT

4.3 TCO Comparisons

The objective of the TCO comparison analysis was to assess whether California PEV drivers gained monetary benefits. The results are presented against annual VMT ranging from 4,000 to 28,000 miles, representing the lowest and highest annual mileage calculated from survey odometer records. The analysis focused on the year 2018, which received the highest number of responses. The TCO comparison analysis was conducted on four vehicle segments: near-luxury, mid-size, compact, and subcompact [39]. Comparative models with different powertrain were selected for each segment with careful consideration given to trim levels. The following vehicle models were included in the comparison analysis for each segment, with their MSRP indicated in brackets:

Near luxury
- BEV: Tesla Model 3 Long Range ($49,000)
- ICEV: BMW 330i xDrive ($43,450)

Mid-size
- PHEV: Ford Fusion Energi Platinum ($41,400)
- HEV: Ford Fusion Platinum ($37,370)
- ICEV: Ford Fusion Platinum ($36,990)

Compact (Nissan)
- BEV: Nissan LEAF SV ($32,490)
- ICEV: Nissan Sentra SV ($19,085)

Compact (Toyota)
- PHEV: Toyota Prius Prime Premium ($29,000)
- HEV: Toyota Prius Three ($26,735)

Subcompact (Chevrolet)

- BEV: Chevrolet Bolt LT ($36,620)
- ICEV: Chevrolet Spark 2LT ($17,475)

Compact (Chevrolet)

- PHEV: Chevrolet Volt LT ($33,220)
- ICEV: Chevrolet Cruze LT ($21,720)

Figure 6 to Figure 11 demonstrate that as the segment and cost of the vehicle increased, the required annual VMT to achieve a comparable TCO with a non-PEV vehicle decreased, leading to equity implications where households with higher affordability benefited the most by selecting a PEV over an ICEV or HEV. Moreover, in the analyzed period, incentives were more valuable in achieving TCO parity for lower segments.

The Tesla Model 3 Long Range, a popular near-luxury model owned by 17% of respondents, achieved TCO parity with the BMW 330i xDrive after just 10,100 annual miles, as seen from Figure 6. The survey also revealed that 62% (1,246 participants) of Tesla owners drove more than 10,100 miles per year. Without incentives, comparable TCO was achieved after driving over 26,000 miles annually.

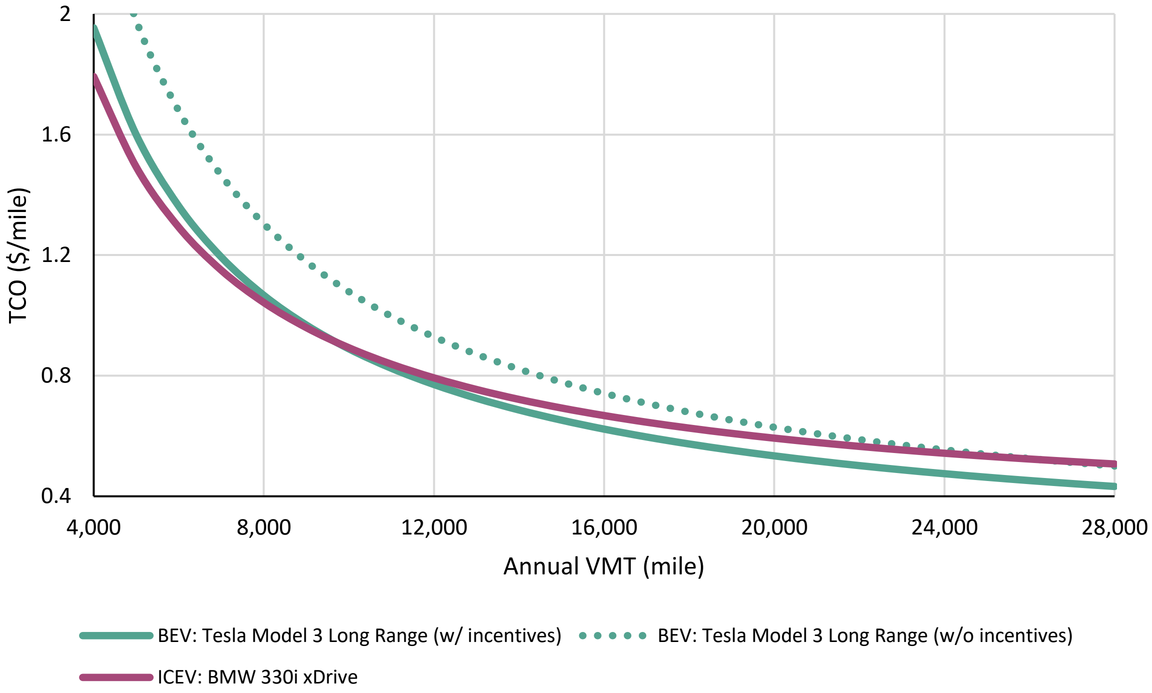

Figure 6. TCO comparison, near-luxury segment

For the mid-size segment, Figure 7 shows that the Ford Fusion Energi Platinum PHEV reached TCO parity with the Ford Fusion Platinum ICEV just under 16,000 annual miles with incentives and a little above 20,000 miles without incentives. However, a TCO equivalency was not reached between the HEV and PHEV models of the Fusion, within the given mileage range.

The compact segment had several popular vehicles, and Figure 8 shows the TCO comparison for Nissan. The SV trim of the LEAF reached comparable TCO with the Sentra after 14,600 miles with incentives, despite having an MSRP that is $13,405 higher. The VMT equality point for this comparable pair was equivalent to a daily commute of 36.5 miles (assuming 200 workdays/year). The survey revealed that 28% (40 participants) of the LEAF SV owners benefited financially by purchasing this model over a similar ICEV.

The Toyota and Chevrolet PHEVs required high annual mileage to achieve TCO parity; however, 10% of the owners benefited financially by their choice (21 participants for Toyota and 48 for Chevrolet). The Toyota comparison included the Prius Prime Premium PHEV and Prius Three HEV, which had similar fuel efficiency when using the combustion driving mode. Despite a minimal MSRP difference of $2,265, these models achieved TCO parity after 21,000 annual miles with incentives, according to Figure 9. The Chevrolet Volt LT PHEV and the Cruze LT ICEV had a much higher MSRP difference of $11,500. However, they achieved TCO parity at a similar mileage of 22,000 miles due to the lower fuel efficiency of the Cruze compared to the Volt, as Figure 10 illustrates.

Finally, in the subcompact segment, Figure 11 shows the highest MSRP difference of $19,145 between the Chevrolet Bolt LT BEV and Chevrolet Spark 2LT ICEV. As a result, TCO comparison was achieved only if driving over 27,000 miles per year.

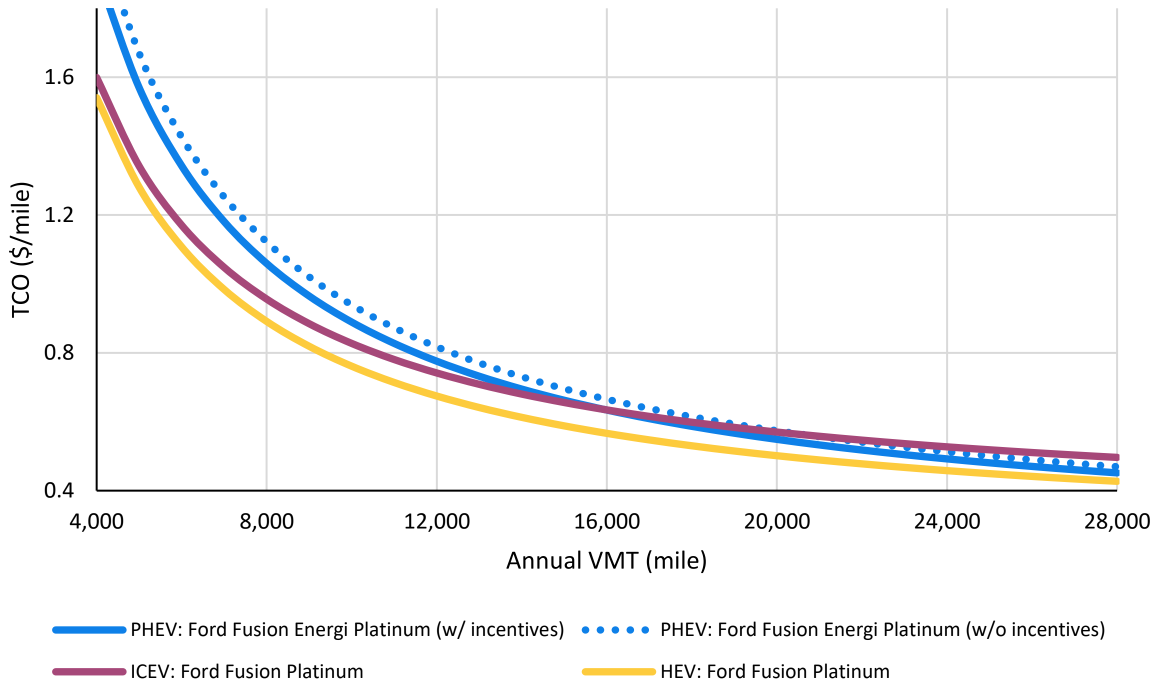

Figure 7. TCO comparison, mid-size segment

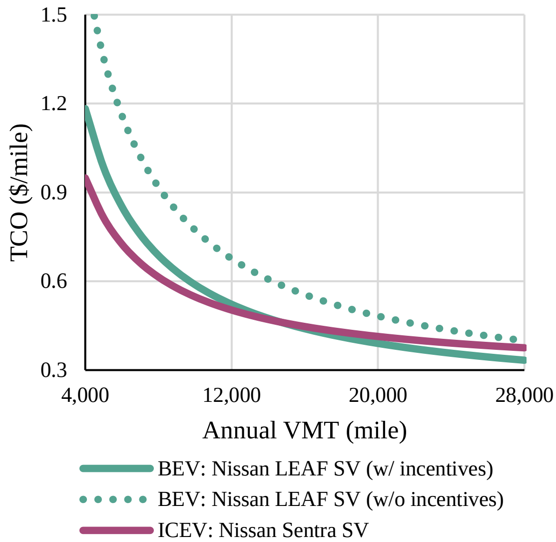

Figure 8. TCO comparison, compact segment (Nissan)

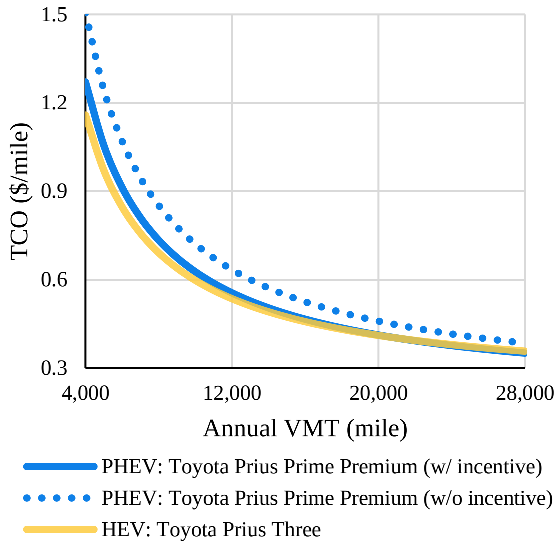

Figure 9. TCO comparison, compact segment (Toyota)

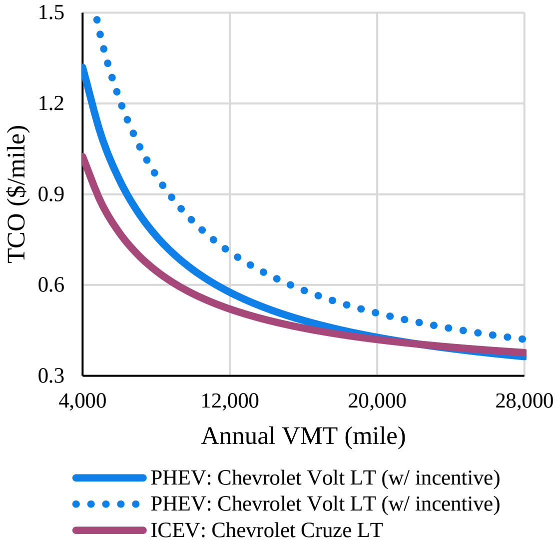

Figure 10. TCO comparison, compact segment (Chevrolet)

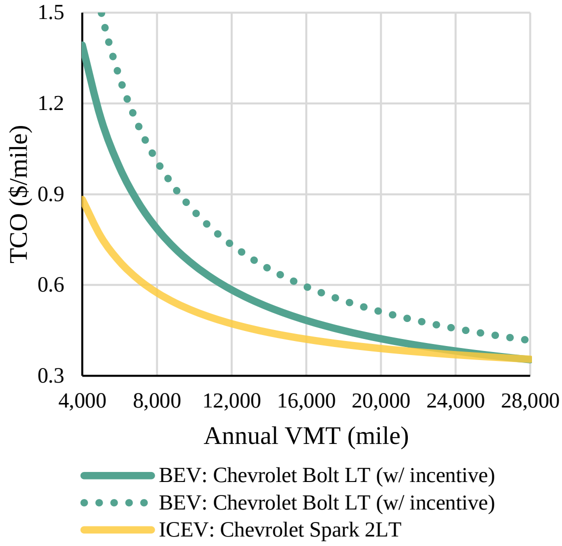

Figure 11. TCO comparison, subcompact segment

5 Discussion and Conclusions

This study estimated the ownership cost of PEV early adopters in California using the PH&EV survey, with participants purchased their vehicle between 2011 and 2020. Assuming an ownership length of five years, the TCO estimation included capital and operational costs, as well as resale value. This study distinguishes itself from existing literature by using actual driver data instead of average driving behavior.

The results show that PEV TCO ranged from $0.26/mile to $4.83/mile. The TCO comparisons were between different drivetrain technologies vehicle models purchased in 2018. A corresponding ownership cost for a BEV and an ICEV in the mid-luxury segment was reached for drivers who drove 10,100 miles a year and received the federal income tax credit. Similarly, for the compact segment, a BEV must be driven over 14,600 miles annually to financially benefit from the purchase. Overall, the results indicated that some PEV owners made a financially sound purchase in 2018. Based on TCO estimations presented in this study, 62% of Tesla Model 3 Long Range owners and 28% of Nissan LEAF SV owners reached cost parity. Without governmental subsidies, other studies predicted a cost parity only after 2024 or even 2030 for the average driver [3], [10]. The role of PEV incentives is emphasized by the notable difference in parity finding of 6 to 12 years. Moreover, cost parity was not reached for most selected models with the lack of incentives.

According to the results, the mid-luxury segment reached parity with the lowest annual driven miles among the compared segments. However, purchasing a mid-luxury vehicle is associated with a lifestyle choice rather than a mobility need. Thus, future incentive programs should support the purchase of a BEV rather than the purchase of a mid-luxury vehicle to drive equity. This finding reinforces the recent changes in the structure of the CVRP and the federal tax credit for clean vehicles, which set MSRP and income caps.

The early adopters of both luxury and standard PEV models established a fundamental second-hand market, which offers opportunities for drivers with stricter budgets. Incentivizing all PEV models without MSRP caps during the analysis period was essential in reaching the current state of the PEV market. These incentives were passed on to the next owner through reduced second-hand prices, benefitting the mass market.

Although this study used data from real vehicle owners, several assumptions were necessary to estimate their TCO, such as the ownership length and UF for PHEVs. Therefore, the TCO represented an estimate of true costs. Future research could involve clustering sociodemographic attributes to discover which market segments financially benefit from purchasing a new PEV and by how much. Additionally, the survey asked participants about their previous vehicle and whether the new PEV replaced it, which could help estimate changes in TCO and provide new insight to the "willingness to pay" literature that currently focuses on stated preferences and lacks revealed preferences [40].

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Koralle holds two Master's degrees from the University of California, Davis in Civil Engineering and Transportation Technology and Policy. During her studies, her research work at the Plug-in Hybrid & Electric Vehicle Research Center revolved around Total Cost of Ownership (TCO).
After extensive experience serving the Davis Chapter of Women Transportation Seminar (WTS), Koralle now is an active member of Women of Electric Vehicles (WEV) – Sacramento. Through her involvement, she empowers women to pursue rewarding careers in the transportation industry.