

Comparison of Value Retention of Plug-in Vehicles and Conventional Vehicles and Potential Contributing Factors

Y. Zhou¹, D. Santini¹, T. Stephens¹, J. Ward²

¹Argonne National Laboratory, 9700 S Cass Ave, Lemont, IL, USA, yzhou@anl.gov

²U.S. Department of Energy, 1000 Independence Ave., SW, Washington, DC 20585, USA

Summary

Plug-in Electric vehicle (PEVs) value retention rate (the ratio of resale value to the manufacturer's suggested retail price, MSRP) has been reported to be lower than that of their conventional and hybrid electric (HEV) counterparts by the National Automobile Dealers Association (NADA) and Kelley Blue Book (KBB). Based on a series of reports published by NADA, this study analyses the retention rates of selected PEV models and compares them with conventional and HEV models by vehicle size class taking into account federal and state incentives. A new metric for value retention, the adjusted retention rate, is calculated as the ratio of resale value to the purchase price minus incentives. The adjusted retention rates of plug in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) appear to be higher than those of comparable conventional internal combustion engine vehicles (ICEVs) for one to two years, but is slightly lower at three years. Factors that influence value retention are discussed, including BEV range and PHEV fuel economy in hybrid mode.

Key words: PHEV (plug in hybrid electric vehicle), BEV (battery electric vehicle). consumers, market

1. Introduction

In the U.S., the number of used-car transactions is approximately three times that for new cars [1]. On average, Americans purchase 13 cars during their lifetime, both new and used [2-4]. The Chevrolet Volt PHEV and Nissan LEAF BEV became available for sale in the U.S. in December 2010. Now, PHEVs and BEVs are available in diverse vehicle size classes ranging from two-seaters to compact sport utility vehicles (SUVs). In 2014, a total of 55,357 PHEV sold: 58% mid-size cars (e.g., Toyota Prius PHEV), 32% compacts (e.g., Chevrolet Volt), 8% subcompacts (e.g., BMW i3 range extended (REX) and i8) and 2% other car sizes [5]. Here, the U.S. Environmental Protection Agency (EPA) light duty vehicle size classification is used [6]. A total of 63,525 BEVs sold in 2014: 51% mid-size cars, mostly Nissan LEAF, 28% large cars, mainly Tesla Model S, 7% were subcompact (e.g., Chevrolet Spark, BMW i3), and 14% were other car sizes [5]. Major brands have announced plans to introduce more plug-in models in the coming years in various size classes with different electric ranges. However, it is unclear how PEVs hold their values due to the very early stage of the used PEV market, and limited information is available on demand and prices for these used vehicles. Numerous studies have reported the total cost of ownership or levelized cost of these new technologies for consumers, and compared these costs with those of conventional counterparts and HEVs [7-12]. The total cost of ownership (TCO) represents the cost of purchasing, operating, maintaining and selling (or disposing of) a vehicle over the ownership period, usually reported as a net present value or as a levelized cost per mile driven during the ownership period. Instead of reporting resale value as a revenue, depreciation of the vehicle is often reported. Studies vary

widely in what costs are included; many consider only capital and operation costs but not depreciation or the cost recovered when the vehicle is traded in or resold [7-9]. An increasing number of used PEVs are now returning to the market. Recently, NADA and KBB have reported that value retention rate, the ratio of the resale value to the MSRP, of some PEVs is less than that of comparable conventional vehicles [2-4, 13]. In the remainder of this paper, value retention rate is referred to as retention rate. In an analysis performed at the request of USA Today, KBB predicted low value retention for some plug-in cars after the first five years of ownership: about 28% of MSRP for Chevrolet Spark EV, 20% for Ford Focus EV, and 15% for Nissan LEAF [13]. NADA also reported lower retention rates for PEVs [4]. A trend appears to be emerging, specifically that PEVs tend to depreciate more quickly (or have lower resale values) than comparable conventional vehicles, however the number of pre-owned PEVs being sold is still limited so it is uncertain how significant this trend is or for how long it may continue. More fundamentally, reporting retention rate as the ratio of resale value to MSRP fails to consider transaction prices that can be well below MSRP, thanks to federal tax credits, automaker rebates, and state tax credits/rebates [14, 15].

Whether or not incentives are controlled for, vehicle depreciation depends on many factors, including vehicle age, mileage, condition, and other economic factors that have seasonal and long-term effects [1, 16]. While seasonal effects can be significant (especially for timing of vehicle transactions), longer-term effects (over several years) are of more interest here. When vehicles depreciate, however, the rate is not the same across brands, models, or drivetrain technologies. Regional policies such as annual fees and high occupancy vehicle lane access (that can influence consumer demand), and the zero emission vehicle mandate (that influences manufacturers' pricing strategies for new vehicles) also could affect resale values.

Previous studies have indicated that even non-vehicle factors that can affect resale values. Holweg and Kattuma [16] studied resale values of cars in the UK and identified several influential factors, including discounting of new cars, general economic and market conditions (as indicated by GDP growth, employment, etc.), supply and demand for used cars, which were influenced by automaker and dealer pricing, diversity of offerings, new model upgrades, variations in volumes of leased cars, make and model reputation, and public perception. Analyzing used passenger car auction prices in the UK from 1996 to 2004, they found that retention rates for three-year-old cars vary widely, ranging from 12% to 62%. Incentives on new cars did not appear to drive substitution between used and new cars, but did influence used cars prices. The effect was delayed, with an incentive (price decrease) of 10% on new cars immediately reducing prices of used cars about 1.5% and used car prices three years later an additional 6.5%. This suggests that not only incentives but other factors that decrease prices of new PEVs, such as lower-cost batteries and electric motors, can lead to lower used PEV prices, since as vehicle component costs to automakers come down with technological progress, the automakers can offer these vehicles at lower retail prices. Such cost reductions are more rapid for new technologies (such as electric motors and batteries), so faster price reductions are expected for PEVs than for conventional vehicles with mature technologies.

Resale values are driven by demand for used vehicles, which is affected by several factors as well. For example, income is an important influence on willingness to pay for quality [1] in both new and used vehicle markets. For PHEVs and BEVs, besides affordability, there are many other potential causes affecting demand and contributing to lower resale values. Possible causes could include limited home charging availability of potential used car buyers (i.e., the electric supply to the house might be insufficient for charging BEVs, in particular), lower proportion of garages and carports in older homes of used car buyers (which would be desirable for PHEVs/BEVs), and lower rates of use (VMT per year) used car buyers (lower vehicle value). Those are the barriers that can make used PHEV and BEV less financially attractive to buyers.

Given the heterogeneity in previous studies' approaches and conclusions regarding PEV resale value, and based on recently published NADA reports, 3-year retention rate estimates from KBB (as reported on the Kiplinger website, [17]) and TCO estimates provided in NADA User Guides by vehicle make and model, this study analyzes the depreciation rates of selected PEV models and compares them with conventional and HEV counterparts by EPA vehicle size class controlling for both federal and state incentives. Potential causes of depreciation are also discussed. However, this analysis is limited by the available three-year period data, and the number of models of PEVs in the resale market.

2. METHODS

2.1 Observations Based on NADA Vehicle Depreciation Reports

Retention rates are published in NADA reports for the best-selling trim level of three year-old light duty vehicles (2011-2014 model years), including conventional, hybrid, PHEV and BEV, and for averages by vehicle size class. Reported retention values are three-month averages of NADA's average trade-in value divided by a vehicle's typically-equipped MSRP. The MSRP does not include any incentives or rebates available at the time of purchase. We compared average adjusted retention rates of size classes, to examine how size may influence value retention rate of PEVs, since PEVs are offered in a wider range of models in smaller size classes. In addition, Kiplinger reported values for 3-yr and 5-yr retention rates (as the percentage of MSRP) for some models [17]. Note that Kiplinger no longer posts this data online. We selected the models which are also included in the NADA report.

In February 2014, NADA reported that subcompacts have the highest retention rate across all car sizes [2], 54.4% on average, for three-year-old cars. However, the fastest-depreciating subcompact car was the Smart ForTwo EV with a 45.4% reported retention rate after 3 years. Reported retention rates were lower for larger car size classes: 51.6% for compact cars, 47.4% for mid-size cars, and 44.8% for large cars, which supports the argument that affordability is a factor in car value retention over three years. However, this might not apply to the light truck segment. NADA published another report in March 2014, showing that large pick-ups have the best retention rate over three years, 62.5%, on average [3]. This suggests that hauling capabilities and other features of large pick-ups might influence resale values.

In April 2015, NADA and ALG published a report on retention rates of popular PHEV and BEV models [4] that gave estimates of one-, two- and three-year average retention rates (without considering federal or state incentives or rebates). This report also pointed out that low gasoline prices, ongoing gains in ICEV efficiency with more affordable prices erode demand for new and used PEVs, and made it even more difficult to justify a PEV purchase from an economic standpoint. Figure 1 summarizes the range of NADA-reported retention rates (for one- to three-year ownership) of selected PEV models (green bars) in comparison with conventional counterparts (blue bars) sold in the same time period [4]. Data in [4] indicates high resale values for models such as the Tesla Model S, Porsche Panamera S-E and Toyota RAV4 in comparison to other PEV models. Note that i-MiEV retention rate for two-year ownership was not reported. The RAV4 uses Tesla batteries and Tesla-developed powertrain [18]. Overall, mainstream PEV retention rates appear to be low according to NADA, at the end of first year, the Chevrolet Volt and Nissan LEAF held 56.1% and 43.5% of their original MSRP values, respectively, lower than those of the average of conventional segments of midsize cars. At the end of three-year ownership, NADA reported that the Volt retained about 31.3% of original value while the LEAF retained about 20.6%. While some PEVs are reported to have lower retention rates than conventional vehicles in the same size class segments, some retain value as well as or better than conventional vehicles, as discussed in the following section.

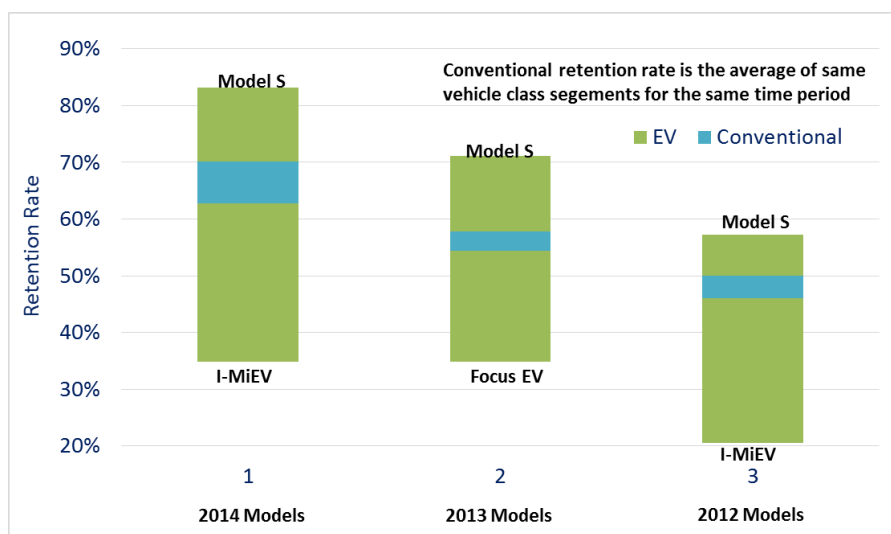


Figure 1: Ranges of NADA-reported retention rates of popular PEV models and of comparable conventional models (based on data from [4])

2.2 Extended Analysis

In order to compare the PEV retention rates reported by NADA and KBB with conventional vehicles sold in the same period, the TCO pricing information was downloaded from the NADA Guide website in 2013 [19] and from a Kiplinger website in 2015 [17], when yearly or 3 and 5 year data were available (these are no longer posted on-line). Selected comparable conventional and hybrid models for comparison include Malibu 4dr (2LT), Fusion 4dr SEL FWD, Accord 4dr SE, Sonata 4dr 2.4L SE, Mazda6 4dr I Touring Plus, Altima 4dr 2.5L CVT S, Camry 4dr 2.5L 4Cyl LE, Camry 4dr 2.5L 4Cyl XLE, Passat 2.5L SE 6-Spd AT, Fusion 4dr HEV FWD, Sonata 4dr 2.4L HEV, Camry 4dr HEV LE, and Camry 4dr HEV XLE.

In order to reflect the loss in value experienced by PEV owners, we defined an adjusted retained value metric, the ratio of the resale value to the MSRP minus the incentives.

$$\text{Adjusted value retention rate} = \text{resale value at age } i / (\text{MSRP} - \text{Incentives}); i = 1, 2 \text{ or } 3$$

Incentives decrease the purchase price or market value of an incentivized vehicle, but not the intrinsic value of the technology. More fundamentally, retention rates based on MSRP do not accurately reflect the impact of depreciation on PEV owners, since depreciation decreases the value of their investment, not the MSRP. This investment is the up-front cost of purchasing the vehicle, or more accurately the total present value of all costs and incentives associated with acquiring the vehicle (actual purchase price, taxes, fees, incentives, and financing charges, if the car was purchased). We did not obtain actual purchase prices or include fees, taxes, or finance charges, but used the MSRP minus the incentives, since these are the largest components of the total acquisition cost of a PEV. Therefore we suggest that the adjusted retention rate is a more objective metric for comparing value retention or depreciation of PEVs and conventional vehicles.

Incentives considered here include federal or state tax credits/rebates, or both, which vary by model [14, 20]. Illustrative state incentives were considered here: a \$2,500 rebate and \$5,000 tax credit, which were offered by California and Georgia, respectively, from 2012-2013. Fleet and government vehicle purchases were (and are) not eligible for such credits. Other incentives—non-monetary, or regional/temporal (such as automaker incentives)—were not considered. For ICEVs and HEVs, incentives were considered to be zero.

3. RESULTS AND DISCUSSIONS

We calculated the retention rates (with zero incentives) of the conventional and hybrid models listed above. Average values and ranges were calculated. Figures 2 and 3 compare the one- to three-year adjusted retention rates of popular PHEV and BEV models (calculated from values in [4]) with the average of these conventional and hybrid counterparts (taken from [20]). Two 3-yr retention rate values are shown for Volt from both NADA and KBB. Ranges are shown in the figure for the set of conventional ICEVs and HEVs considered. With up to \$7,500 federal incentives subtracted from MSRP, most of PEV models show similar one-year adjusted retention rate to the average of the ICEV and HEV models.

We also examined the difference between the average retention rates of ICEVs and the average adjusted retention rates of PHEVs and BEVs, over one to three years using two-tailed t-tests. Averages are shown in Table 1, with the p-values (the probability level at which the hypothesis that the averages are the same should be rejected) shown for PHEVs and BEVs. At one year, the average adjusted retention rate of PHEVs is significantly higher than that of ICEVs, but at three years, it is significantly lower. There is no statistically significant difference between the average adjusted retention rates of BEV and ICEVs. For the comparison between ICEVs and BEVs, we also tried excluding the Tesla Model S from the BEV group, because it seems to be an outlier. We found no significant difference between the average adjusted retention rates of ICEVs and BEVs with the Model S excluded.

Table 1: Comparison of Average Adjusted Value Retention Rates of PHEVs and ICEVs, and BEVs and ICEVs, with p-values shown in parentheses

	1 year	2 years	3 years
ICEVs	63.4%	55.9%	49.6%
PHEVs	71.5% (0.027)	50.3% (0.155)	39.9% (0.031)
BEVs	66.4% (0.494)	56.9% (0.851)	43.3% (0.409)
BEVs, no Tesla	63.7% (0.94)	52.9% (0.477)	38.6% (0.174)

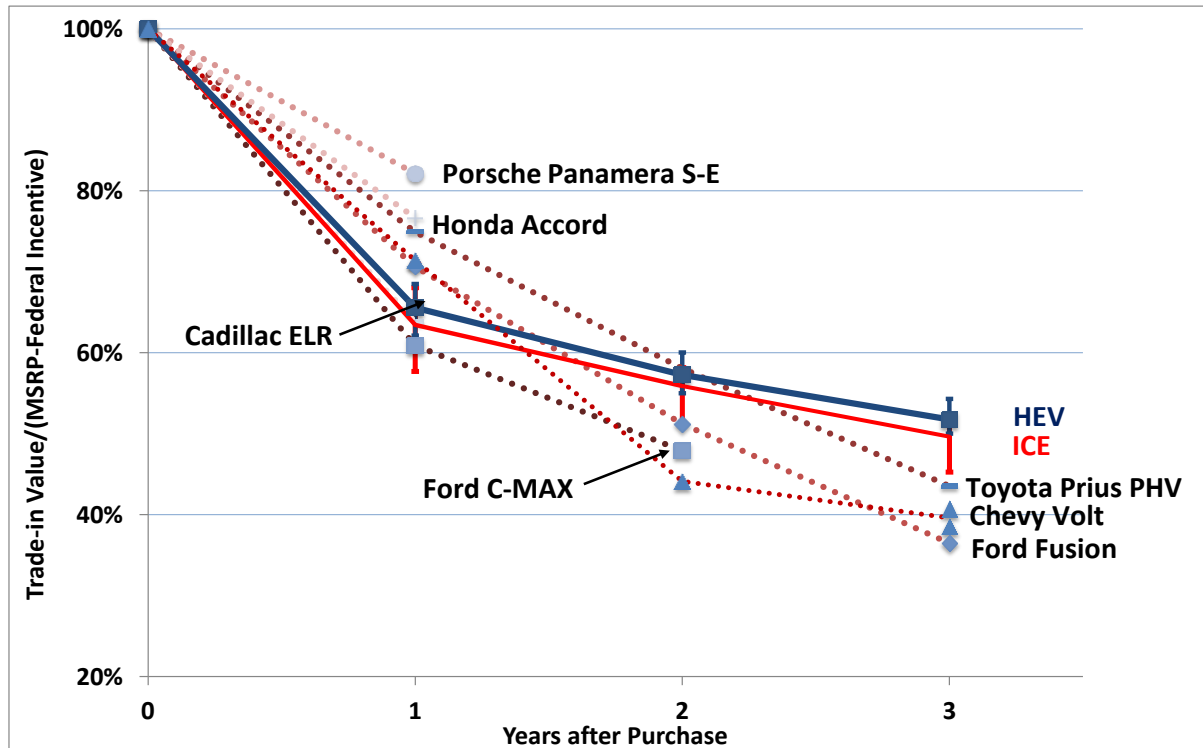


Figure 2: Adjusted retention rate comparison (federal incentives only): ICEV vs. HEV vs. PHEV (based on data from [4, 17])

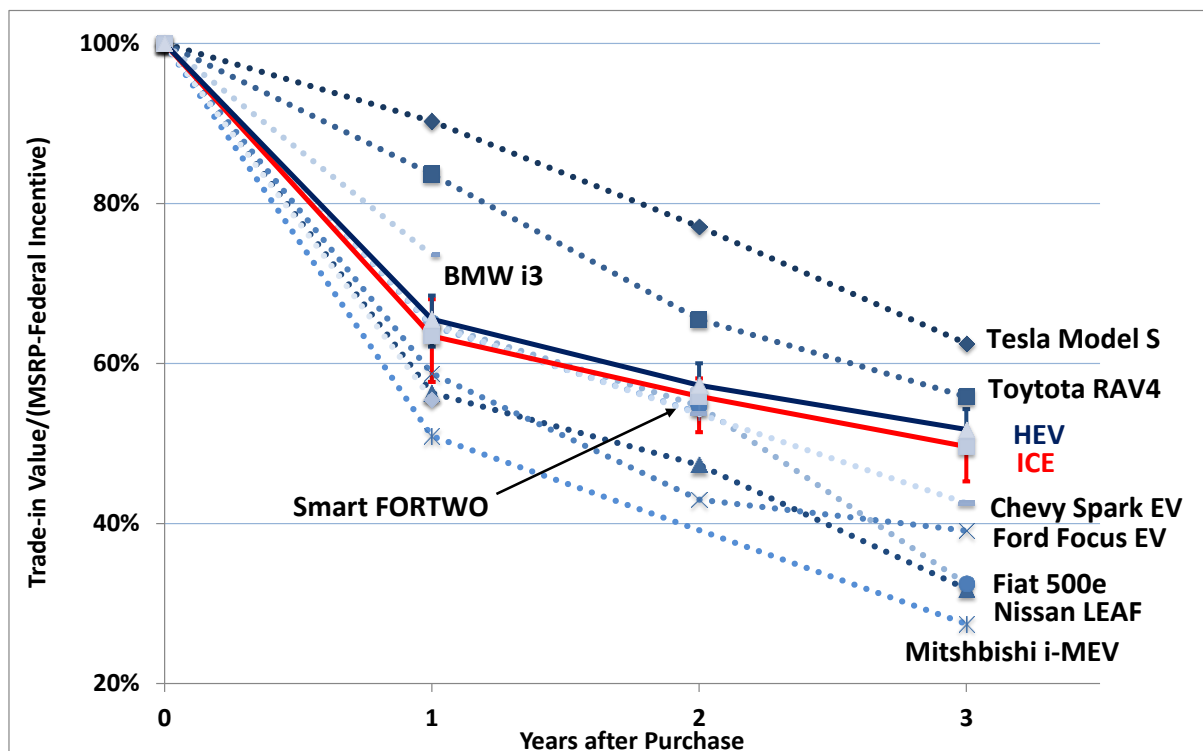


FIGURE 3 Adjusted retention rate comparison (federal incentives only): ICEV vs. HEV vs. BEVs (based on data from [4])

With both state and federal tax credits taken into account, the sales-weighted average adjusted value retention rates of both BEVs and PHEVs appear to be better than that of ICEVs at one year, and still

comparable at two-year ownership, as shown in Figure 4. BEVs appear to have better adjusted value retention rates even in two-year ownership and somewhat lower at three years.

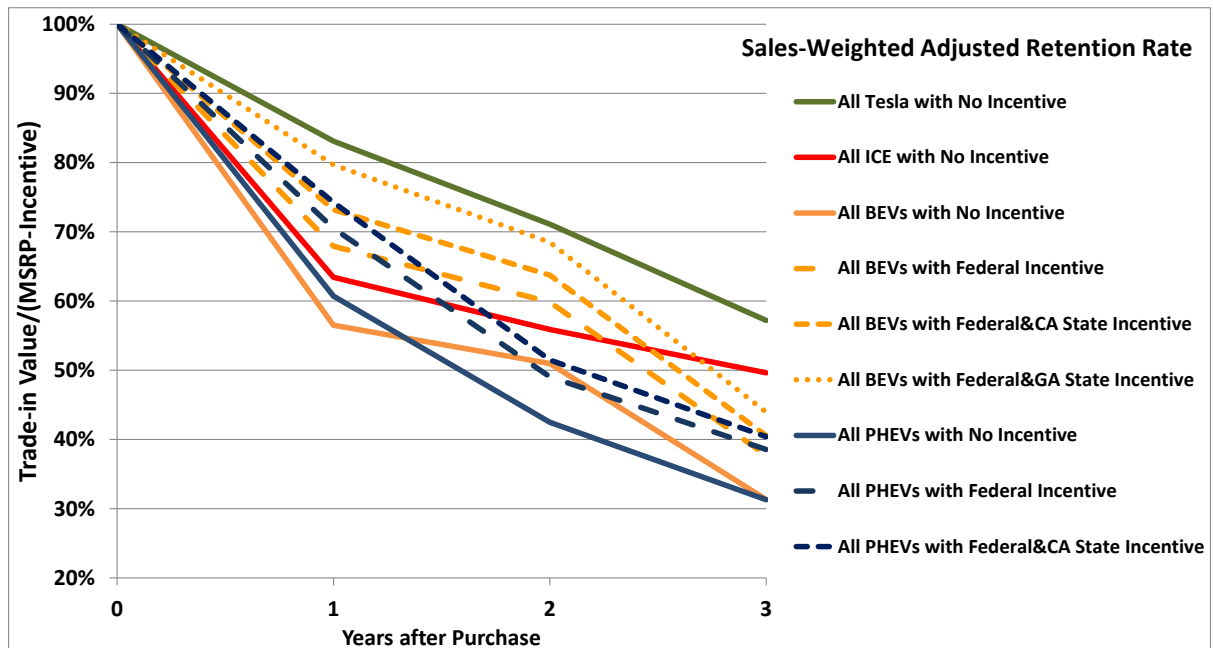


Figure 3: Sales-weighted average adjusted retention rates for PEVs, adjusting for both federal and state incentives, compared with average ICEV retention rates

3.1 What Might Contribute to Better PEV Retention Values

Both federal and state incentives may be discontinued at some point. For example, Illinois and Georgia have already terminated their PEV rebate/tax credit programs. As mentioned above, incentives for PEVs can lead to lower prices for used PEVs, but also help to grow the PEV market. Other factors, including vehicle characteristics and changes in fuel prices that influence the retention rates of PEVs relative to conventional vehicles are discussed below.

3.1.2 Size and Range

The adjusted retention rates of several BEV models are compared with the average 3-year retention rate of conventional ICEVs in the same size class in Figure 4. The Tesla Model S and the Toyota RAV4 have higher three-year retention rates than the average of ICEVs in the same size segment. The subcompact BEV model BMW i3 has a high one-year adjusted value retention rate. BMW i3 has been introduced to the market for about two years, more data are needed to see how its two- or three-year retention rates will compare with that of ICEVs. The 2-seater FORTWO ED shows similar two-year retention rates as the RAV4, but there are no data for ICEVs in the same class to compare with (the 3-yr retention rate for the ICEV Fiat 300 is from KBB, whereas all other data shown in Figure 3 are from NADA). The high adjusted value retention rates of the BMW i3 REX suggests that with no daily refuelling need for 100-130 miles, even with an electric range penalty in bad weather conditions, it might prove to be a popular PEV model, in high demand as a used car. The i3 REX has a small engine which only comes on when the battery is depleted. According to R. L. Polk vehicle registration data, 57% of i3s sold in 2014 nationwide were the REX version which has about EPA rated 150 miles of gasoline and electricity combined range (registration statistics provided by National Renewable National Laboratory).

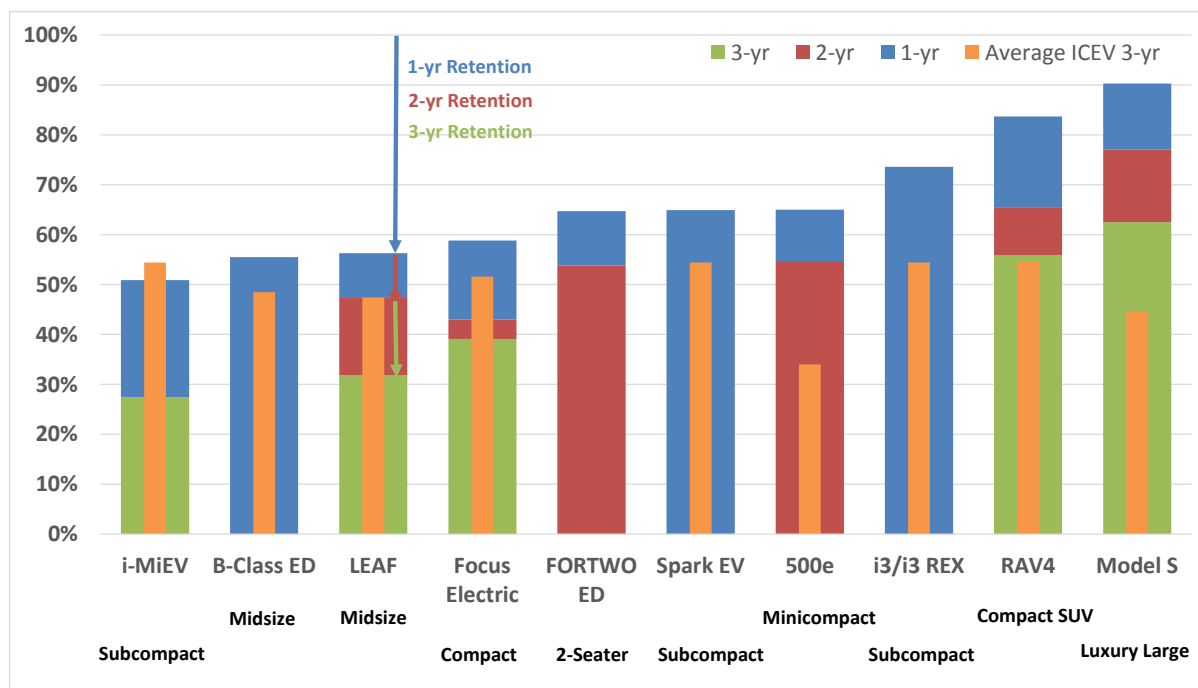


Figure 4: Adjusted BEV retention rates by model and EPA size class, with average ICEV retention rates

The Tesla Model S has the best one- to three- year retention rates, even better than comparable conventional models in either luxury large car or midsize car segments. The Model S has a much higher electric range (EPA-rated value of 208 or 265 miles) than mainstream BEVs (short range BEVs). Possibly, a large electric range helps the Tesla hold its value.

3.1.2 Fuel Economy

Long distance (highway) functionality of PHEVs on gasoline might also improve retention rates. Figure 5 shows the retention rate adjusted for federal incentives plotted against the difference in the highway fuel economy (MPG) of PHEVs in hybrid mode and that of HEVs and alternative gasoline vehicles in the same model line or size class that has the best MPG. For example, the Prius PHEV was compared with the Prius HEV and the Corolla, and the Ford Fusion PHEV was compared with the HEV and gasoline versions of the Fusion. With a fuel economy of 50 MPG fuel economy in hybrid mode, the Prius PHEV is 43% more efficient than the Corolla, and is 4% more efficient than the HEV version. The Volt has the lowest hybrid mode fuel economy of all PHEV models, even worse than its gasoline alternative, Cruze ECO. Likewise, the Ford Fusion PHEV has a lower fuel economy in hybrid mode than the hybrid Fusion. Higher highway fuel economy in hybrid mode is not well correlated with high adjusted retention rate, but the high fuel economy of the Prius PHEV may contribute to its retention rate.

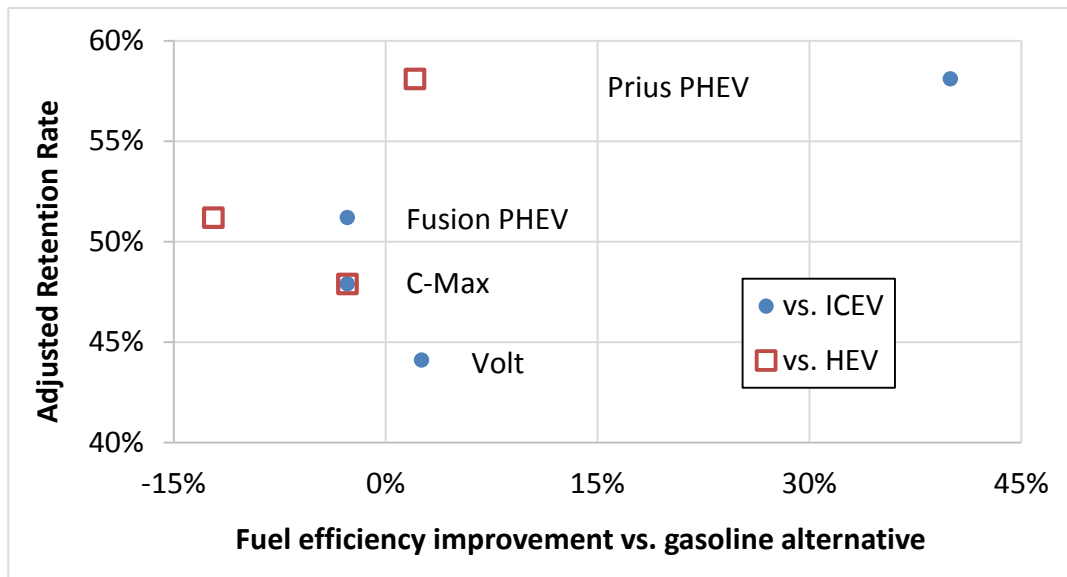


Figure 5: PHEV 2-yr adjusted retention rates plotted against difference in highway fuel economy from a comparable conventional vehicle (blue points) and comparable HEV (red squares)

3.1.3 HEV Retained Values

As shown in Figure 6, even with higher initial costs, HEVs retained value about as well as conventional gasoline vehicles in both standard and luxury markets perhaps due in part to their high fuel efficiency. However, the resale value and the fuel savings may not compensate for the high initial cost for some models within short period ownership time, especially at low gasoline prices. A recent survey sponsored by AutoMD.com indicates that 78% of drivers say that they plan on keeping their cars for 10 or more years after purchase [21]. Longer ownership may help consumers justify the extra up-front cost if they consider ownership costs over the vehicle ownership period.

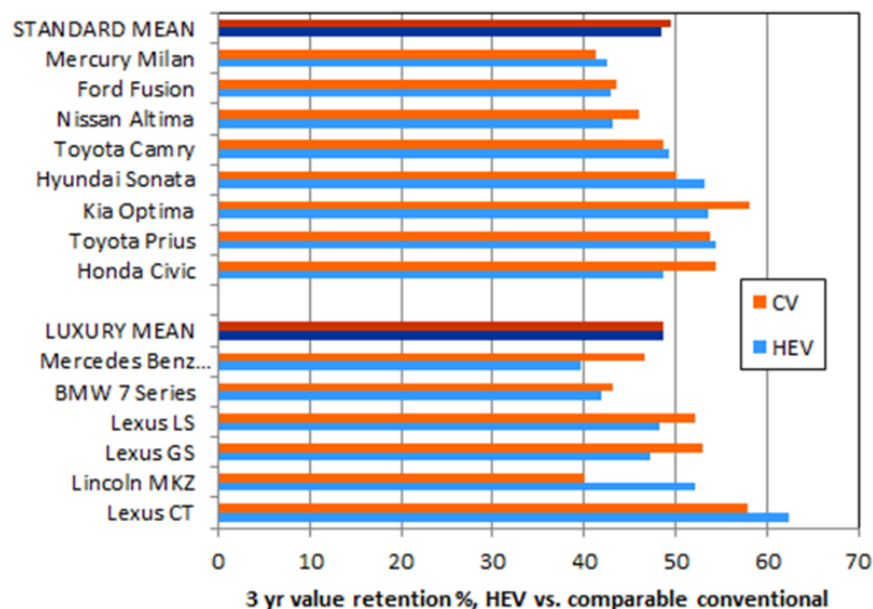


Figure 6: Three-year NADA reported retention rates: HEV vs. comparable conventional vehicles

Over three years, HEVs do not lose value as fast as PHEVs or BEVs with electric range less than 100 miles (mainstream BEVs). Possible reasons could be that battery replacement costs are less for HEVs, or that garages and carports are not needed for installing charging equipment for HEVs. HEV highway fuel efficiency is clearly better than that of conventional counterparts (not so for many PHEVs).

Gasoline Prices

In the U.S., the national average gasoline price in first six months of 2015 was about \$0.79 less than one year earlier [22], and more than \$1 lower than in previous years. Low fuel price, in combination with more efficient but less expensive conventional models made both new and used PEV less competitive on the basis of fuel savings. We compared the three-year NADA reported retention rates of the 2011 model year Volt and the 2011 model year LEAF with their 2012 counterparts. As seen from Figure 7, the drop in gasoline prices seems to have hurt the three-year retention rates for the Volt and the LEAF, more so for the LEAF.

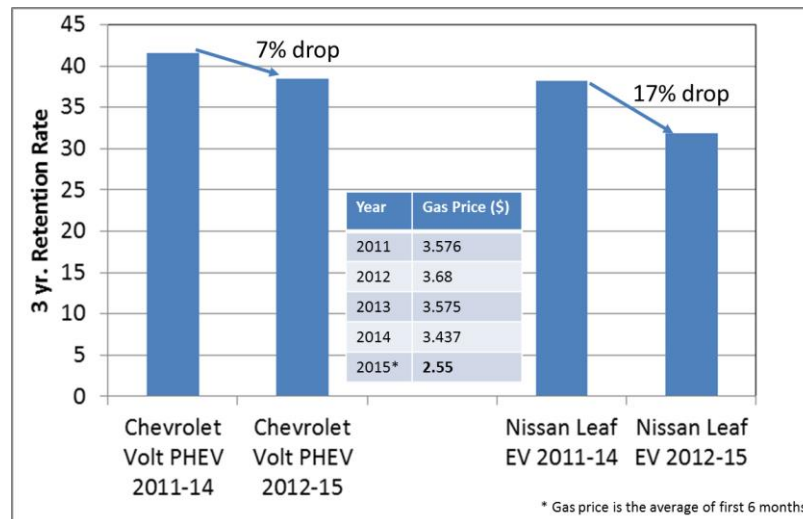


Figure 7: NADA-reported Volt and LEAF retention rates: 2011 model vs. 2012 model

However, fuel savings may not be a primary motivation for purchasing a PEV for many consumers, at least for new PEVs. In a 2014 survey of PEV drivers in California, motives for purchasing a PEV included environmental reasons, saving money, HOV lane access, or other reasons. The top motive given by LEAF owners was environment, the top reason given by Volt owners was saving money, and the top motive for Plug-in Prius owners was HOV lane access [23]. Motives of used PEV buyers may well differ from those of new PEV buyers, but no surveys of used PEV buyers are known to the authors.

Automaker Incentives

As stated above, automaker incentives for PEVs were not considered here, although automaker incentives have been generous at times for some PEV models. For the 2012 Volt, the first generation, Chevrolet provided up to \$7000 incentives during most months of 2012. With such amounts also subtracted from MSRP, the adjusted value retention rates of the Volt would appear even slightly better than that of average conventional counterparts in three-year ownership. On the other hand, if prices of new PEVs continue to decrease, with continued improvements in range and other attributes, prices of used PEVs may be suppressed as discussed above.

Automakers may be pricing some PEVs low in order to gain market share or in response to regulatory standards, including the EPA/NHTSA GHG and fuel economy standard or the Zero Emission Vehicle (ZEV) mandate of California and cooperating states [24, 25], however this is difficult to assess. Automakers' pricing strategies are driven by numerous and sometimes conflicting pressures and are difficult to gauge from publicly available information.

4. Conclusions

This study compares the retention rates of PHEVs and BEVs with comparable HEV and conventional models. A new metric for value retention, the adjusted value retention rate, defined as the ratio of resale value to the MSRP minus the value of incentive is suggested to be more relevant to consumer ownership costs than the commonly reported value retention rate, which is the ratio of resale or trade-in value to MSRP. When adjusted for both state and federal tax credits, the sales-weighted average adjusted value

retention rates of both BEVs and PHEVs are better than that of ICEVs at one year, and still comparable at two-year ownership. Adjusted retention rates for PHEVs at three years are somewhat lower, but data on three-year-old PEVs data are limited.

This study is limited by the available data, owing to the small number and types of PEVs in the resale market, which may not be representative of the PEV market as it develops. More data are needed to track how PEVs hold their values for longer ownership periods since an increasing number of vehicle owners keep their vehicles for more than five years. Most sources report ownership costs for only five years.

The Tesla Model S and the electric Toyota RAV4 have the best adjusted retention rates of all PEVs, even better than their conventional competitors in the same size segment. The long electric range (>200 miles) might contribute to the Tesla value retention.

Some small and low-cost electric cars appear to retain value fairly well, at least for one year. Higher fuel efficiency of PHEVs in hybrid mode might also improve retention values, but more quantitative analysis of the correlation between fuel economy and resale value are needed. HEVs do not lose value as fast as PHEVs or BEVs having a range less than 100 miles. Low gasoline prices seem to hurt the three-year value retention rates of the Volt and the LEAF.

As more PEV models become available in both new and used vehicle markets, their value retention and depreciation rates should be systematically studied to better understand the true ownership costs for consumers, especially with longer ownership periods (over five years). More importantly, as the PEV market expands, value retention may improve with higher efficiency, longer range, better performance and more charging infrastructure.

Acknowledgments

The authors would like to gratefully acknowledge the sponsorship of the Vehicle Technologies Office of the U.S. Department of Energy. This work was supported by the Vehicle Technology Office of the Office of Energy Efficiency and Renewable Energy of the United State Department of Energy. The submitted manuscript has been created by UChicago Argonne, LLC, Operator of Argonne National Laboratory (“Argonne”). Argonne, a U.S. Department of Energy Office of Science laboratory, is operated under Contract No. DE-AC02-06CH11357. The U.S. Government retains for itself, and others acting on its behalf, a paid-up nonexclusive, irrevocable worldwide license in said article to reproduce, prepare derivative works, distribute copies to the public, and perform publicly and display publicly, by or on behalf of the Government.

References

- [1] Gavazza, Alessandro, Alessandro Lizzeri, and Nikita Roketskiy. "A Quantitative Analysis of the Used-Car Market." *American Economic Review*, Vol. 104, No.11, 2014, pp. 3668-3700.
- [2] NADA Used Car Guide, NADA Retention Review: Passenger Cars. February 2014.
<http://www.nada.com/B2B/Portals/0/assets/NADA%20Perspective/2014/201402%20Perspective%20Retention.pdf>, accessed on 2016-03-11.
- [3] NADA Used Car Guide, NADA Retention Review: Light Truck and SUV. March 2014.
<http://www.nada.com/b2b/Portals/0/assets/NADA%20Perspective/2014/Perspective%20Truck%20SUV%20Retention%20April%202014.pdf>, accessed on 2016-03-11.
- [4] NADA Used Car Guide, Electric Vehicle Retention Report Card. April 2015.
http://img03.en25.com/Web/NADAUCG/%7B413f55a5-807f-4b2e-8310-48cd4aeb40da%7D_April_2015_NADA_Perspective.pdf, accessed on 2016-03-11.
- [5] Argonne, Light Duty Electric Drive Vehicles Monthly Sales Updates, Argonne National Laboratory, Argonne, IL.
http://www.transportation.anl.gov/technology_analysis/edrive_vehicle_monthly_sales.html, accessed 2015-07-25.
- [6] EPA Vehicle Size Class, [Fueleconomy.gov](http://www.fueleconomy.gov/feg/byclass/2014ClassList.shtml).
<http://www.fueleconomy.gov/feg/byclass/2014ClassList.shtml>, Accessed on 2016-03-11.
- [7] Ruth, M. Methodology for calculating cost per mile for current and future vehicle powertrain technologies, with projections to 2024, M. Ruth, National Renewable Energy Laboratory, NREL/CP-6A10-49231, January, 2011.
- [8] U.S. Department of Energy, Alternative Fuel Data Center, Vehicle cost calculator,
<http://www.afdc.energy.gov/calc/>, accessed on 2016-03-11.
- [9] Total cost of ownership model for current plug-in electric vehicles, Electric Power Research Institute, 2013, 3002001728.
- [10] Al-Alawi, B. M. and T. H. Bradley. Total cost of ownership, payback, and consumer preference modeling of plug-in hybrid electric vehicles. *Applied Energy*, Vol. 103, 2013, pp. 488-506.
- [11] Proepfe, B., M. Redelbach, D. Santini, H. E. Friedrich. Cost Analysis of Plug-In Hybrid Electric Vehicles including Maintenance & Repair Costs and Resale Values. *Electric Vehicle Symposium 26*, Los Angeles, USA, 2012.
- [12] Gilmore and Lave, Comparing resale prices and total cost of ownership of gasoline, hybrid and diesel passenger car and light trucks, *Transport Policy*, Vol 27, 2013, pp. 200-208.
- [13] USA Today, <http://www.usatoday.com/story/money/cars/2013/12/26/plug-in-cars-electric-cars-depreciation-resale-residual-value/4194373/>, accessed on 2016-03-11.
- [14] U.S. Department of Energy, Alternative Fuels Data Center, Federal and State Laws and Incentives, <http://www.afdc.energy.gov/laws>, accessed on 2016-03-11.
- [15] Jin, L., Searle, S., Lutsey, N. Evaluation of State-level U.S. Electric Vehicle Incentives, The International Council for Sustainable Transportation, October, 2014,
http://www.theicct.org/sites/default/files/publications/ICCT_state-EV-incentives_20141030.pdf, accessed on 2016-03-11.

- [16] Holweg, M. and P. A. Kattuma. The Incentive Whiplash: Sales Discounts and the Dynamics of Residual Value in the Automotive Industry. (unpublished), <http://www.eea-esem.com/files/papers/EEA-ESEM/2006/2414/IncentiveWhiplash.pdf>, accessed on 2016-03-11.
- [17] Kiplinger: Find the Best New Car for You. <http://www.kiplinger.com/tool/cars/T011-S001-2012-new-car-rankings-compare-costs-performance-da/results.php>, accessed on 2015-02-17.
- [18] John Voelcker, 2012, 2014 Tesla Model X Vs. 2012 Toyota RAV4 EV: Electric SUV Showdown http://www.greencarreports.com/news/1078247_2014-tesla-model-x-vs-2012-toyota-rav4-ev-electric-suv-showdown, accessed on 2016-03-14.
- [19] NADA Guide, New Car Pricing and Used Car Values. <http://www.nadaguides.com/Cars>, accessed on 2016-03-11.
- [20] U.S. Internal Revenue Service (IRS). Plug-In Electric Drive Vehicle Credit (IRC 30D). [http://www.irs.gov/Businesses/Plug-In-ElectricVehicle-Credit-\(IRC-30-and-IRC-30D\)](http://www.irs.gov/Businesses/Plug-In-ElectricVehicle-Credit-(IRC-30-and-IRC-30D)), accessed on 2015-08-01.
- [21] Tuttle, B. Driver Consensus: It's Silly to Upgrade Cars Every Couple of Years, Time Magazine, July, 27, 2012, <http://business.time.com/2012/07/27/driver-consensus-its-silly-to-upgrade-cars-every-couple-of-years/>, accessed on 2016-03-11.
- [22] Energy Information Agency, Weekly Retail Gasoline and Diesel Prices, http://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_m.htm, Accessed on 2016-03-11.
- [23] Center for Sustainable Energy, February 2014 Survey Report, February 2014, <https://energycenter.org/clean-vehicle-rebate-project/vehicle-owner-survey/feb-2014-survey>, accessed on 2016-03-12.
- [24] U.S. Environmental Protection Agency, National Highway Traffic Safety Administration Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule, Federal Register / Vol. 75, No. 88, 25314-26728,
- [25] California Environmental Protection Agency Air Resources Board Zero Emission Vehicle (ZEV) Program <http://www.arb.ca.gov/msprog/zevprog/zevprog.htm>, accessed on 2016-03-12.

Authors

Yan Zhou is a transportation systems analyst at Argonne National Laboratory. At Argonne, she has been developing Long-Term Energy and GHG Emission Macroeconomic Accounting Tools which are widely used by government agencies, research institutes and consulting companies to project energy demand and analyse greenhouse gas emissions of different transportation sectors and evaluate the impact of adoption of renewable fuel and advanced vehicle technologies in these sectors. In addition, she has been collecting international sales data of advanced vehicle technologies and providing market trend and niche analysis for the Department of Energy's Vehicle Technology Office. She received her master and Ph.D. degree in Transportation Engineering from Clemson University, South Carolina.



Danilo J. Santini, a senior economist at Argonne National Laboratory, obtained his Ph.D in Urban Systems Engineering and Policy Analysis from Northwestern University in 1976. From 1992-2008 Dr. Santini was a section leader within Argonne's Center for Transportation Research. He has served on the Alternative Fuels Committee of the National Research Council's Transportation Research Board since 1989, was chair from 1996-2002; is now

Emeritus. From 2001-2014 he was one of the Department of Energy's technical representatives for the U.S. to the International Energy Agency Implementing Agreement on Electric and Hybrid Vehicles. In 2010 he was awarded the Society of Automotive Engineers' Barry McNutt prize for Excellence in Automotive Policy Analysis for work on Plug-in Hybrid Electric Vehicles.



Thomas Stephens is a Transportation Systems Analyst at Argonne National Laboratory, where his work focuses on assessing energy use and emissions from advanced-technology vehicles as well as their potential costs and market potential. He has Ph.D. in Chemical Engineering from the University of Massachusetts. In 2015 he received the DOE Vehicle Technologies Distinguished Achievement Award for economic, market, and integrated vehicle technology analysis.



Jacob Ward serves as the Program Manager for Analysis in the Vehicle Technologies Office of the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy. His work includes vehicle and energy efficiency market analysis, technology forecasting, macroeconomic benefit estimation, and the public dissemination of vehicle technology information.

