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Total cost of ownership, payback, and consumer preference modeling of plug-in hybrid electric vehicles

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HIGHLIGHTS

- Review of plug in hybrid total cost of ownership modeling to date.
- Development and documentation of more comprehensive plug in hybrid total cost of ownership models.
- Discussion of sensitivity of payback period to modeling parameters and scope.
- Many plug in hybrid vehicles can be characterized by high net benefits, short payback period, and high consumer preference.

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ABSTRACT

Motor vehicles represent one of the widely owned assets in the US. A vehicle's ownership cost includes fixed expenses to purchase and own the vehicle and variable costs to use and operate the vehicle. Policymakers, analysts and consumers are interested in understanding the total ownership costs of various vehicle types and technologies so as to understand their relative consumer preference and valuation. Plug-in hybrid electric vehicles are an advanced technology vehicle that is presently in limited production, but whose relative cost of ownership is not well-defined. A few studies have attempted to calculate the costs and benefits of PHEVs but none consider the cost and benefits of PHEVs at a level of detail comparable to what has been performed for other vehicle technologies. In order to understand the costs and benefits of PHEVs purchase and use, this study constructs a comprehensive ownership cost model. The model is then used to analyze different PHEV designs within four vehicle classes. This study then performs a sensitivity analysis to understand the sensitivity of total ownership cost and payback period to model parameters and the modeled components of ownership costs. Results show that a more comprehensive PHEV ownership cost model has a lower net cost of ownership than studies to date, resulting in a shorter payback period and higher consumer preference.

1. Introduction

Plug-in hybrid electric vehicles (PHEVs) are hybrid electric vehicles which can draw and store energy from the electric grid. The benefits of plug-in hybrid vehicles are derived from their capability to displace petroleum energy for transportation with multi-source electrical energy. PHEVs are generally characterized by lower life-cycle petroleum consumption, lower fueling costs, lower criteria emissions, and lower carbon dioxide emissions than conventional vehicles [1], but at a higher manufacturing cost than conventional vehicles. Many automobile manufacturers have announced plans to develop and sell PHEVs in the US including: GM Chevrolet Volt in 2010, Fisker Karma PHEV in 2011, Toyota Prius PHEV in 2012, Ford C-Max Energi PHEV in 2012, Ford Fusion Energi PHEV in 2012, Mitsubishi Outlander PHEV in 2013, BYD F3DM in 2013, Honda Accord PHEV in 2014, Cadillac ELR in 2014, BMW i8 in 2014, Mitsubishi Px-MiEV PHEV in 2014 and Volvo V70 PHEV in 2014 [2].[1,2,3]

Despite their recent market introductions, the market potential, consumer acceptability, and economic efficiency of PHEVs are not well understood. A variety of studies have attempted to assess the market potential of PHEVs through tabulation of the fuel economy benefits and incremental costs of PHEVs [3–9]. These studies

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[1] Hybridcars, "A Comprehensive Guide to Plug-in Hybrids", http://www.hybridcars.com/plug-in-hybrid-cars, accessed 09/24/2012.
[2] EPA Fuel Economy, "New & Upcoming Plug-in Hybrids", http://www.fueleconomy.gov/feg/phevnews.shtml, accessed 09/24/2012.
[3] Plugincars, "Meet the Fleet", http://www.plugincars.com/cars, accessed 09/24/2012.

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have generally concluded that in order for the PHEVs to reach economic and marketplace viability, technology advancements must decrease the incremental cost of the vehicle over conventional vehicle costs, and regulation or macro-economic forces must increase the price of gasoline fuels to above roughly \$5.00 gallon^{-1} [6,9–11]. This consensus view of PHEV economics must be tempered by an understanding that these studies incorporate a wide range of scopes, vehicle usage models, ownership cost categories, and consumer preference models. Their analyses result in a wide variety of numerical valuations of PHEV economic efficiency, and these studies' assumptions and scopes have not been compared or synthesized.

The goal of the research effort documented in this paper is to more systematically synthesize a PHEV total cost of ownership (TCO) and consumer acceptability model so as to test this consensus view. This paper presents such a TCO model and compares it to the primary literature for PHEV techno-economic modeling so as to understand the effects of these studies' scope, methods and assumptions. A more comprehensive TCO model is shown to require significant increase in scope over previous models in literature. The TCO model proposed for this study includes models of various vehicle types, various PHEV types, vehicle purchase cost, loan cost, tax cost, insurance cost, annual registration cost, fuel cost, maintenance cost and salvage value. We then present the sensitivity of TCO and payback period to vehicle characteristics, economic assumptions and model scope. Survey data regarding consumer preference for PHEVs is then enrolled to understand the relationship between costs, benefits and consumers' willingness to pay for PHEVs. Finally, conclusions present a more comprehensive summary of the value, cost and market potential of PHEVs in the near-term.

2. Review of PHEV techno-economic studies

Four studies form the primary and most cited sources of information on the techno-economics of PHEVs (AEO [10] (85 Google Scholar citations); EPRI [3], EPRI [4] and EPRI [12] (19, 72, and 42 Google Scholar citations); Lemoine et al. [6] (75 Google Scholar citations); Simpson [9] (91 Google Scholar citations)). Other studies performing PHEV analysis cite these primary studies [8,13]. Model parameters and assumptions for these primary studies and this study are listed in Table 1.

Evaluation and synthesis of the results of these previous studies is complicated by differences between the scopes, assumptions and modeled components of each study. In order to design a more relevant, refined and comprehensive model of PHEV TCO and consumer acceptability, this study proposes to update the scope, vehicle usage assumptions, ownership costs and consumer preference models as shown in Table 1. For most categories, this TCO model is of larger scope than that of previous studies. For example, electricity and gasoline costs are projected rather than constant, this study uses a standardized utility factor (UF) [14] rather than outdated or low fidelity assumptions, and this study uses consumer preference surveys rather than simple cost-benefit analysis to represent the economic viability of the vehicles. In each category of classification shown in Table 1, this study aims to be more comprehensive, higher fidelity, and more defensible than previous studies.

3. Comprehensive TCO modeling methods

To determine the costs and benefits to consumers of a PHEV's purchase and use, we must construct a modeling environment that can connect individual PHEV's costs and benefits components. This study proposes a more comprehensive TCO model that includes all components of ownership costs as modeled in the literature and includes various other relevant ownership costs for PHEVs.

The baseline model is composed of sub-models where each model can be modified and adjusted individually and is described in detail in the sections following the discussion of TCO model scope.

3.1. Study scope

For this study, vehicles of similar fuel economy, functionality size, interior volumes and costs are grouped into vehicle fleets and vehicles classes following EPA vehicle classification methodology.[4] The four vehicle classes considered in our base model are Compact Car and Mid-Sized Car in the passenger car fleet, and mid-sized SUV and large SUV in the light truck fleet.

PHEVs can be designed to have different battery capacities, so as to satisfy consumers travel patterns and needs. Because each design will impose different costs and benefits to consumers, thirteen HEVs were designed and analyzed for each class of vehicles. The set of vehicles studied here includes grid-independent HEV0 (conventional hybrid electric vehicles) and grid-dependent PHEVs (of the PHEVx-type) with 5–60 miles of electric range [1].

HEV and PHEV incremental costs are derived by summing the costs of the Battery, Pack Hardware, Pack Tray, Pack Thermal, Traction Electric Motor, Traction Power Electronics, Traction Power Electronics Thermal, Charger, Charger Cable, Engine, Gasoline Storage Tank, Exhaust, Glider and Assembly Costs, Accessory Battery, and Transmission. The retail price equivalents (RPEs) reported here are derived from the EPRI PHEV studies as the averages of the "Base" and "ANL" methods at production levels of 100,000 units per year, inflated to 2010 currency [3,4]. Battery costs for modern lithium-ion (Li Ion) batteries are derived from [15] under the production scenario of 100,000 packs per year. The costs for each Li Ion battery are inflated to 2010 and added to the incremental component cost to represent the incremental cost of PHEV produced in 2010. The incremental RPE for every vehicle in this study is presented in Table 2, and Appendix A.[5]

3.2. Vehicle Usage

The distance driven in the first year of ownership for passenger cars and light-trucks is modeled as 12,000 mi (19,312 km) and 15,000 mi (24,140 km) respectively [18]. To account for decline in vehicle usage, yearly annual distance traveled declines at an annual rate that varies between 2.1% and 4.7% as in [19].

The gasoline fuel economy for CVs and HEVs is calculated using a utility factor (UF) weighted gasoline-only fuel economy method which assumes that the vehicle is charged on a daily basis. This method places no fuel economy cost on electricity since the petroleum content of marginal electricity is negligible. The method uses the SAE J2841 utility factor for urban and highway driving [14]. The gasoline fuel economy and electrical economy ratings were adjusted using EPA's labeling discount (10% for City and 22% for highway) to model real-world relevant fuel economy [20].

The energy consumptions for fully (FCTs) and partially charge tests (PCTs) are derived from previous work [3,4]. Eqs. (1) and (2) represent the calculated annual electricity consumption (E_a) and annual petroleum consumption (G_a) for each class and type of PHEV. Where VMT_a is the annual vehicle miles traveled:

[4] U.S. Environmental Protection Agency, "vehicle size classes", available at http://www.fueleconomy.gov/feg/info.shtml#sizeclasses.

[5] These incremental costs are comparable to other recent studies of PHEVs. For example, ANL calculates the incremental costs of a mid-sized PHEV 20 series vehicle (this study considers parallel vehicles) as \$4701 in 2015, and \$7347 in 2010 [16,17].

Table 1
Model parameters and assumption used in the primary PHEV TCO literature.

	Simpson, 2006 [9]	Lemoine et al., 2008 [6]	AEO, 2009 [10]	EPRI, 2004 [12]	Al-Alawi & Bradley, 2012 "baseline model"
Study scope					
Vehicle class	Mid-sized sedan	Compact Car, Full-sized SUV	Low drag, Mid-sized sedan	Mid-Sized Car, Full-sized SUV	Compact Car, Mid-Sized Car, Mid-sized SUV and Large SUV
PHEV type	HEV, PHEV2-60	HEV, PHEV20	HEV, PHEV5-60	EV, HEV, PHEV20	HEV, PHEV5-60
Battery type	Li-Ion	NiMH	Li-Ion	NiMH	Li-Ion
Economic year	2006 $	2008 $	2007 $	2003 $	2010 $
Vehicle usage assumptions					
Annual vehicle distance traveled model (Vehicle miles traveled, VMT)	15,000 mile year^{-1} (24,140 km year^{-1}), constant	11,000 mile year^{-1} (17,703 km year^{-1}), constant	14,000 mile year^{-1} (22,531 km year^{-1}), constant	117,000 and 150,000 mile (188,293 and 241,402 km) over lifetime	12,000 mile year^{-1} (19,312 km year^{-1}) for Cars 15,000 mile year^{-1} (24,140.16 km year^{-1}) for light trucks, with decline in vehicle usage with age
Vehicle life	15 years	12 years	6 years	10 years	5 and 13 years
Charging assumption	Full recharge each day	Full recharge each day	Full recharge each day	Full recharge each day	Full recharge each day
Utility factor, (UF) type	1995 NPTS-derived UF, with a 50% chance of starting the day charged	250 days year^{-1} fueled by electricity, the rest fueled by gasoline	None, 37% of VMT assumed fueled with electricity	26% of VMT assumed fueled with electricity (73% gasoline)	SAE J2841 UF [14]
Fuel economy method	Modified J1711, EPRI 2001	MWP weighted, EPRI 2002	105 mpg CD, 42 mpg CS modes, EPRI 2001	UF weighted	UF weighted gasoline consumption
Electricity consumption method	0.093 kW/h/mile for 100% of VMT	Unknown	37% of VMT	26% of VMT	UF weighted electricity consumption
EPA adjustment of fuel economy	Yes	None	None	Yes	Yes
Modeled components of ownership costs					
Gasoline cost model	$5.00 gallon^{-1} ($0.26 liter^{-1})	($0.53 liter^{-1}, $0.79 liter^{-1} and $1.06 liter^{-1}) $2.00 gallon^{-1}, $3.00 gallon^{-1} and $4.00 gallon^{-1}	$3.00 gallon^{-1}, $4.00 gallon^{-1}, $5.00 gallon^{-1} and $6.00 gallon^{-1} ($0.79 liter^{-1} $1.06 liter^{-1} $1.32 liter^{-1} $1.59 liter^{-1})	$1.75 gallon^{-1} ($0.46 liter^{-1})	Forecasted over vehicle life [21]
Electricity cost model	$0.09 kW h^{-1}	$0.05 kW h^{-1}, $0.10 kW h^{-1} $0.30 kW h^{-1}	$0.10 kW h^{-1}	$0.05 kW h^{-1} off peak	Forecasted over vehicle life [21]
Incremental cost model	EPRI, 2001	EPRI, 2001 corrected	Includes tax credit	EPRI, 2001; ANL	EPRI, 2001; Kalhammer et al., 2007 [3,15]
Vehicle salvage value model	None	None	None	Battery only	Entire vehicle has resale value
Maintenance cost model	None	None	None	Yes	Yes
Insurance cost model	None	None	None	None	Yes
Registration renewal cost	None	None	None	None	Yes
Loan model	None	None	None	None	Yes
Tax model	None	None	None	None	Yes
Discount rate	None	16%, corrects for vehicle depreciation and declining vehicle usage over 12 years, based on 6% interest rate	10%	8%	6%
Consumer preference model					
Metric of preference	Payback period-based	Payback period-based	Benefits-based	Benefits-based	Payback analysis, benefits analysis & consumers acceptability

Table 2
Incremental price of PHEVs over CVs base price in US $2010.

Vehicle design	Compact Car incremental RPE	Mid-Sized Car incremental RPE	Mid-sized SUV incremental RPE	Large SUV incremental RPE
HEV0	$4,051	$3,882	$5,578	$5,636
PHEV5	$4,661	$4,341	$6,273	$6,100
PHEV10	$5,270	$4,799	$6,969	$6,563
PHEV15	$5,880	$5,258	$7,664	$7,026
PHEV20	$6,489	$5,716	$8,359	$7,489
PHEV25	$6,995	$6,226	$8,767	$8,078
PHEV30	$7,500	$6,736	$9,174	$8,668
PHEV35	$8,006	$7,245	$9,582	$9,257
PHEV40	$8,511	$7,755	$9,990	$9,846
PHEV45	$9,017	$8,265	$10,398	$10,435
PHEV50	$9,522	$8,775	$10,805	$11,024
PHEV55	$10,028	$9,285	$11,213	$11,613
PHEV60	$10,533	$9,795	$11,621	$12,202

$$E_a = VMT_a \cdot \left(0.55 \cdot \left(\frac{1}{0.9}\right) \cdot UF_U \cdot FCT_U + 0.45 \cdot \left(\frac{1}{0.78}\right) \cdot UF_H \cdot FCT_H\right) \quad (1)$$

$$G_a = VMT_a \cdot \left(0.55 \cdot \left(\frac{1}{0.9}\right) \cdot (1 - UF_U) \cdot PCT_U + 0.45 \cdot \left(\frac{1}{0.78}\right) \cdot (1 - UF_H) \cdot PCT_H\right) \quad (2)$$

3.3. Modeled components

In this study we have considered current and forecasted prices of both gasoline and electricity. Gasoline and Electricity prices for 2012–2024 years are based on EIA 2009 [21] estimates and adjusted to $2010. The salvage value of the vehicle represents its value on the used car market and is modeled as equal to the vehicle MSRP depreciated over the life of the vehicle at 13.8% per year, equivalent to the historical rate of depreciation of the 1st Generation Toyota Prius HEV,[6] and equivalent to the low-depreciation rate cases of Edmonds and Kelly Blue Book.[7,8]

3.3.1. Maintenance cost model

For each vehicle type we have constructed a maintenance schedule which includes periodic vehicle maintenance, 12 V battery replacement, and tire replacement [22].[9,10] The present value of the parts cost and labor cost of each maintenance operation is summed over the life of the vehicle to determine the vehicle lifetime maintenance costs.[11,12] For the CV and HEV, the maintenance costs and schedules were derived from the published costs and schedules for 2010 MY vehicles with similar functionality to the vehicles modeled in this analysis. The maintenance schedule for the CV and HEV is a function only of cumulative distance traveled. The maintenance schedule for the PHEV includes some vehicle maintenance that is a function of total distance traveled, and some engine maintenance that is a function of charge-sustaining distance traveled. Neither the HEV nor the PHEV has a scheduled battery replacement, and the battery is assumed to last the life of the vehicle [23–25].

The maintenance costs and schedules for each vehicle type are presented in detail in Appendix B.

3.3.2. Vehicle insurance cost model

Insurance costs vary by state, insurance company, insurance type and vehicle type. This model of insurance costs represents the cost of insurance premiums with liability, comprehensive and collision coverage as provided by major insurers where the personal information for the driver (age, marital status, credit history, driving record, and the garaging address of the vehicle) was not taken into consideration.[13] The insurance costs are modeled as a function of vehicle class and vehicle type. To model the insurance costs within a vehicle class, we surveyed vehicles of the same class that have the similar MSRP to the CV and the PHEV60. Insurance costs are modeled to vary linearly with vehicle retail price equivalent between these endpoints, defining the estimated insurance cost for the HEV and PHEV 5–55 technologies. For this particular study, the insurance costs were calculated for the location of Colorado, 80201, in 2010.[14] For this study, insurance costs are estimated to increase at 3.5% inflation per year over the life of the vehicle.

3.3.3. Registration renewal fees model

Registration renewal fees are generally assessed by US counties. This registration fee model is based on the fee schedule for vehicles registered in Larimer County, Colorado.[15] The registration renewal fee is the sum of an ownership tax based on the age and taxable value of the vehicle, and a license fee based on the weight of the vehicle. The registration renewal fee is paid yearly.

Ownership tax rates are a function of vehicle age. For vehicles in year 1 of ownership, ownership taxes are 2.1% of taxable value, 1.5% in year 2, 1.2% in year 3, 0.9% in year 4 and 0.45% in years 5 through 9. In year 10 and on, the ownership tax is $3 per year. The taxable value of a passenger vehicle is defined as 85% of MSRP.

The license fee schedule for the CV and HEV60 for each vehicle class is presented in Appendix B. The license fee for vehicles between these endpoints is modeled as a linear function of vehicle weight.[16]

3.3.4. Loan Model

Most of the vehicles in the US are purchased with an automobile loan. The Loan Model assumes that purchase cost is the sum of MSRP, sales tax and new vehicle registration. The purchaser provides a 10% down payment with the remainder of the purchase costs financed by a 48 month loan with 5% annual interest rate. A discount rate of 6% was used to represent all monthly payments in terms of 2010 dollars. A summary of vehicle costs and loan payments for all vehicles is presented in Appendix C.

4. Baseline results

4.1. PHEV TCO comparison among previous studies

The first result is a comparison of this study's baseline PHEV TCO model to the TCO as presented in the models that form the

[6] Prius depreciation data is available in Appendix D.
[7] Edmunds Inc., "Appraise your car," http://www.edmunds.com/appraisal/, accessed 09/25/2012.
[8] Kelley Blue Book., "Get your car value," http://www.kbb.com/car-values/, accessed 09/25/2012.
[9] Ford Motor Company, "Ford, Lincoln & Mercury Owner's Manuals, Videos and Guides," https://www.flmowner.com/servlet/ContentServer?pagename = Owner/Page/OwnerGuidePage, accessed 12/29/2011.
[10] Edmunds Inc., "Car Maintenance Guide," http://www.edmunds.com/maintenance/select.html, accessed 12/29/2011.
[11] Tire Rack, "Upgrade Garage," http://www.tirerack.com/ accessed 12/29/2011.
[12] Edmunds Inc., "True cost to own," http://www.edmunds.com/tco.html, accessed 12/29/2011.
[13] Ibid.
[14] Colorado is in the 33rd percentile of US states in terms of average insurance costs ($1,071 year^{-1}), whereas South Dakota has the lowest insurance costs ($759 year^{-1}) and Alaska has the highest ($1,901 year^{-1}) [26].
[15] Larimer County, Colorado Registration Fee & Estimate, http://www.co.larimer.co.us/motorv/estimate.htm.
[16] Colorado has the 5th highest registration fees (at $431.30 year^{-1} for a mid-sized car), whereas South Carolina has the lowest fees (at $12 year^{-1}) and Rhode Island has the highest (at $941.76 year^{-1}) [26].

primary literature. For comparison, we consider the characteristics of a PHEV20 design in the Mid-Sized Car class (except in the Lemoine et al. [6] where only the Compact Car is considered). The results of each study in terms of each component of TCO are presented in Fig. 1. All values are inflated to $2010.

These results show that discrepancies between studies are due to both differences in the scope of the model and in the assumptions related to each cost or benefit calculation. For example, each model concludes that PHEVs will cost more to purchase than CVs but the incremental costs of the PHEV20 varies among studies between $4600 and $9100. In addition, many of the components of TCO (e.g. maintenance costs, and salvage value) are not represented in all studies.

As an additional basis for comparison, Fig. 2 presents a comparison of this study's PHEV TCO model to the TCO models from primary literature with the modification that all parameters of the TCO models are identical. Each TCO model uses the harmonized values of vehicle lifetime, lifetime distance traveled, gasoline prices and electricity price. These parameters are chosen to be equal to the Al-Alawi & Bradley column of Table 1 so as to be representative of a present-day vehicle usage and cost scenario.

Even with this degree of scenario harmonization, there exists a great deal of discrepancy between the TCO of each model. These results show that only EPRI [12] and this model predict a TCO for the PHEV20 less than the TCO of the CV. Each study predicts that the purchase price of PHEVs is greater than that of CVs, but the assumptions regarding PHEV fuel consumption and the ratio of electrical to gasoline energy are a primary source of differences among these studies. For example, with the same vehicle type, lifetime, distance traveled, and fuel prices, the studies vary in their fuel costs predictions by 195%.

Overall, these results show that harmonizing these TCO studies requires harmonization of TCO modeling scope, and TCO model parameters.

4.2. PHEV payback period comparison among previous studies

Payback period is a common means for calculating the value of the investment in the purchase of a PHEV (or other fuel economy technology) [5,6]. In all of the studies surveyed, PHEVs have higher retail price equivalent compared to the CV due to their higher costs for the electric traction and battery system. Fig. 3 shows the cumulative TCO of a PHEV20 mid-sized passenger car and CV mid-sized passenger car for each study (except in Lemoine et al. [6]) which only considers the Compact Car). The TCO is calculated by replicating each study's assumptions and scope as defined in Table 1. Only Simpson [9], and this study's TCO model show a net TCO benefit to the PHEV20, compared to the CV. This study's TCO model shows a significantly different behavior than the other models because it includes the concept of net present value and the mechanism of monthly payments of an automobile loan. In this study's comprehensive baseline TCO model (as in the reality of financed automobile purchases) the consumer does not pay for the incremental costs of the PHEV in year 1. Rather, the comprehensive baseline TCO model accounts for the actual payments made by the vehicle purchaser.

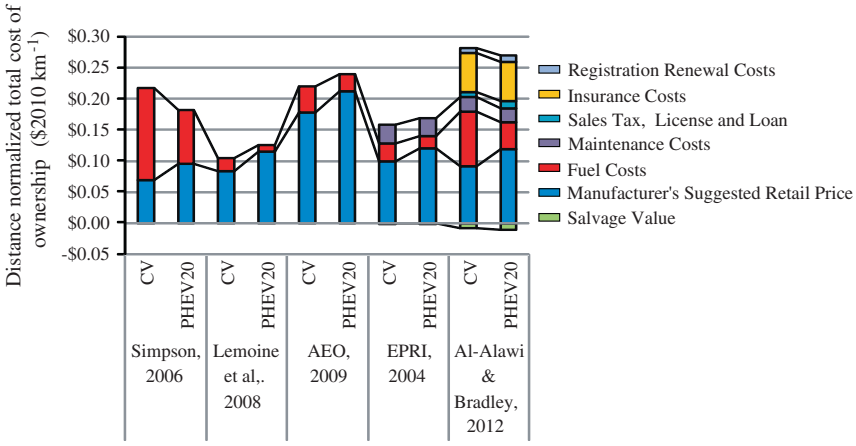

Fig. 1. Total cost in $2010 per kilometer using each study's parameters and TCO model.

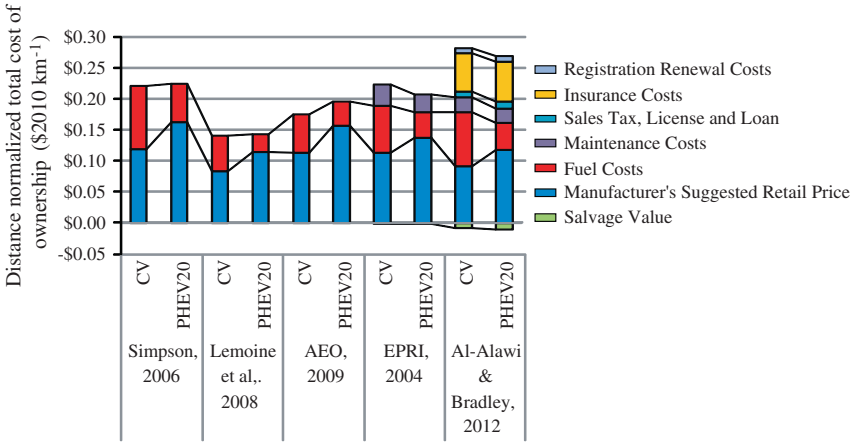

Fig. 2. Total cost in $2010 per kilometer using similar parameters as in base model.

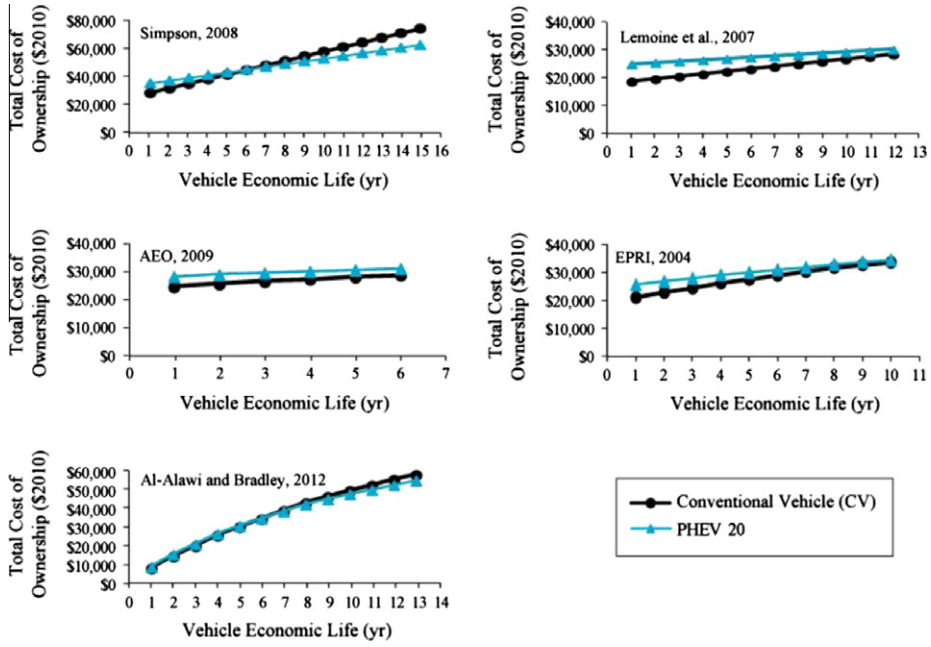

Fig. 3. TCO for the PHEV20 as calculated using each study's parameters and assumptions as presented in Table 1.

It is also evident from these graphs that the payback period published with each of these studies is very sensitive to assumptions implicit in each model. Slight changes to the slope (operating costs) or intercept (PHEV incremental costs) of any of these TCO curves can dramatically change the reported value of payback period.

Based on these analyses of previous studies, we can understand that there is little consensus on the TCO value or payback period of PHEVs relative to CVs. Previous studies and this work differ in scope, assumptions and results, making a synthesis of policy and economic recommendation difficult to achieve without a more detailed understanding of the scope and parameters of a comprehensive PHEV TCO model.

5. Analysis and discussion

To provide a more informative discussion of the TCO costs and benefits of PHEVs, this paper now analyzes the results of this study's baseline TCO model. These analyses include sensitivity analyses for the metric of payback period including (1) an investigation of the payback period of PHEVs across the breadth of PHEV designs, (2) a sensitivity analysis of the baseline comprehensive TCO model to discover which parameters are significantly important to PHEV payback period, and (3) a parametric study of the components of the baseline comprehensive TCO model to discover which components of the model are important to PHEV payback period. Finally, this paper considers the metrics of consumer market preference as an output of TCO modeling.

The results of these analyses allow for the rigorous defense of the included parameters, scope, and outputs of the proposed PHEV TCO model.

5.1. Payback period modeling and analysis

5.1.1. Sensitivity to PHEV type

As illustrated in Fig. 3, the baseline TCO model shows that the PHEV20 can have benefits to the consumer relative to a CV. To more completely understand the payback period of PHEVs under the assumptions of the baseline TCO model, we now calculate the payback period for a variety of vehicles. The analysis is performed using the model parameters and assumptions as listed in Table 1.

This payback analysis compares the TCO of PHEV 0–60 to CVs and of PHEV 5–60 to HEVs over the vehicles' lifetime. The TCO for each vehicle is evaluated during each year of its operation by summing its salvage value at that year, minus the cumulative total cost of operation (fuel, maintenance, insurance, registration renewal, down payment and loan payments with tax and new vehicle registration), minus the loan payments left if TCO is evaluated before the end of the loan period.

Fig. 4 shows the payback period of the PHEV 0–60 relative to a CV evaluated using the baseline comprehensive TCO model. The payback period of the PHEVs ranges from 7 to 10 years in the Mid-Sized Car class and from 3 to 5 years in the large SUV class. In general, these figures show a broad minimum in payback period for PHEVs with between 10 and 25 miles of all electric range (AER) due to the tradeoff between increasing incremental costs with increasing AER period and decreasing operating costs with increasing AER. Only for Compact Cars is the payback period longer than 9 years due to the PHEV's higher incremental costs and the high CV fuel economy. For a majority of PHEV designs and vehicle classes, PHEVs show a payback period of less than 6 years.

Fig. 4 also shows the payback period of the PHEV 5–60 relative to an HEV. These payback period curves show increasing payback period with increasing AER. The payback period for a PHEV compared to a HEV0 is 2–10 years in the Mid-Sized Car class, and is 3–7 years in the large SUV class. Only at very large values of all electric range (AER) might some PHEVs not achieve payback over the vehicle lifetime, relative to the HEV.

These results show that PHEVs are not only economically beneficial or only economically detrimental relative to conventional and hybridized vehicles. The payback period of these vehicles are dependent on the types of vehicle under comparison.

5.1.2. Sensitivity to modeling parameters

To quantify the sensitivity of a comprehensive TCO model to its input parameters, a sensitivity analysis is performed with sensitivity to 11 factors. The analysis is performed on the TCO model of the

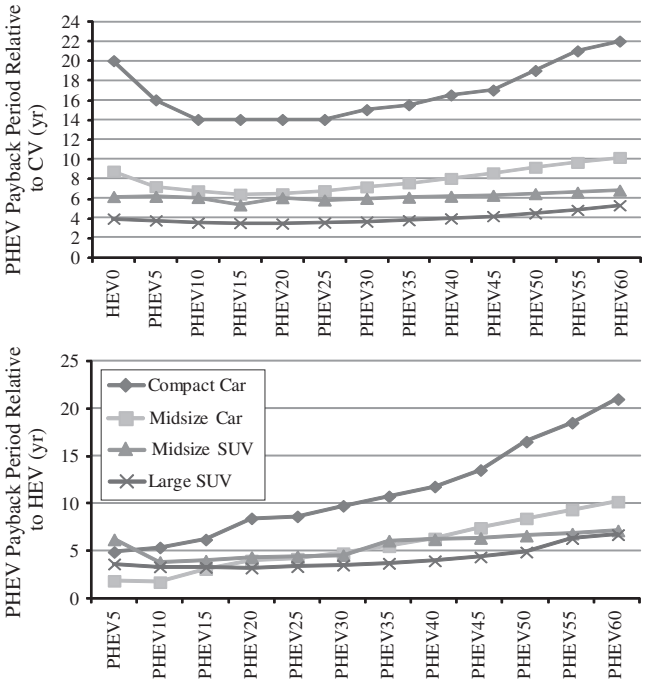

Fig. 4. Payback period of PHEV0-60 compared to CVs and HEVs.

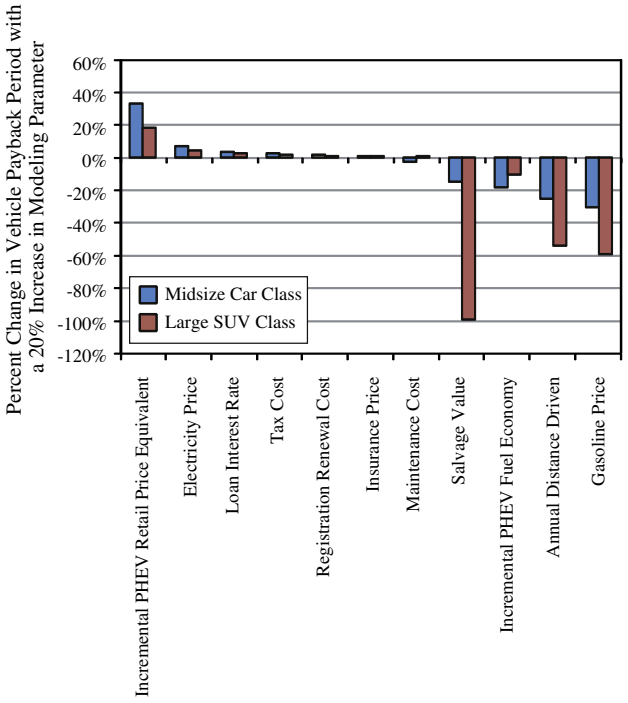

Fig. 5. Sensitivity of the PHEV20 economic payback period to TCO model parameters in the Mid-Sized Car and large SUV classes compared to CV.

PHEV20 in the Mid-Sized Car class and in the large SUV class. Each CV and PHEV20 TCO variable is varied from its baseline value to 120% of baseline. For example, in the Mid-Sized Car TCO model, the sensitivity of the model to annual registration renewal costs are assessed by evaluating the difference in payback period when annual registration renewal costs are increased by 20% or $303 per year. The resulting percent change in payback period is shown in Fig. 5 for the Mid-Sized Car PHEV20 and the large SUV PHEV20. For example, increasing the value of the incremental retail price equivalent by 20% results in a 33.4% increase in Mid-Sized Car PHEV20 payback period, and an 18.6% increase in the large SUV PHEV20 payback period.

We can use these results to understand that the most significant parameters to the TCO model are the parameters of annual distance traveled, fuel economy, gasoline prices, incremental costs, and salvage value. To reduce the uncertainty in the TCO model, the uncertainty regarding these parameters must be minimized. Uncertainty in the parameters of the TCO model which are less significant (i.e. insurance costs), will have less impact on uncertainty in the metric of payback period.

5.1.3. Sensitivity to model scope

Although the sensitivity analysis can help the designer of a TCO model to understand where reductions in parameter uncertainty can affect the uncertainty in the metric of payback period, it does not provide guidance regarding whether any particular portion of the model is necessary to differentiate PHEV TCO from CV TCO. In this section we will investigate the effects of the portions of PHEV TCO which have been considered insignificant in previous literature. This is performed by removing components of the TCO model from the baseline TCO model to see what effect each model component has on PHEV payback, relative to the CV.

Major TCO model components (including the effects of annual distance traveled, vehicle life, fuel cost, FE and incremental costs) are included in every TCO model surveyed in literature and are therefore considered indispensable components of a PHEV TCO model. Instead the comprehensive TCO model is run under the following eight conditions.

(1) Tax Model Removed.
(2) Registration Renewal Model Removed.
(3) Insurance Model Removed.
(4) Loan Model Removed.
(5) Baseline Model using all Model Components (Al-Alawi and Bradley, 2012).
(6) Maintenance Model Removed.
(7) Salvage Model Removed.
(8) Level 2 Electric Vehicle Support Equipment Costs Included (Level 2 EVSE are priced at $1500 as based on advertised costs from both Toyota and Ford) [24].

Fig. 6 shows that the payback period is indeed quite sensitive to the presence of many of these components of TCO. In the Mid-Sized Car class, inclusion of the Maintenance and Salvage Model are shown to decrease the modeled payback period by up to 3 years; inclusion of the tax, registration, insurance and loan are shown to increase the modeled payback period by up to 2 years.

5.1.4. Payback period discussion

Overall, these analyses of payback period can help TCO modeling studies to understand the most rigorous way to construct and interpret TCO modeling studies. A number of recommendations can be formed on the bases of these analyses.

First, the breadth of possible PHEV designs and PHEV usage conditions leads to a breadth of payback period results. The economic case for purchasing a PHEV depends on the PHEV type and vehicle class under consideration. Using the baseline model, PHEV payback period can vary from less than 2 years to more than 20 years. TCO modeling results for PHEVs must be qualified as representative of only a particular class of vehicle, PHEV type, or consumer. There are no generalizations available regarding PHEV payback results, or PHEV economic incentives. Instead, PHEV payback periods are shown to be particular to a vehicle type and scenario.

Second, the quantification of the sensitivity of PHEV payback period to the input parameters and to the modeling scope shows that the PHEV TCO model must be carefully constructed to develop

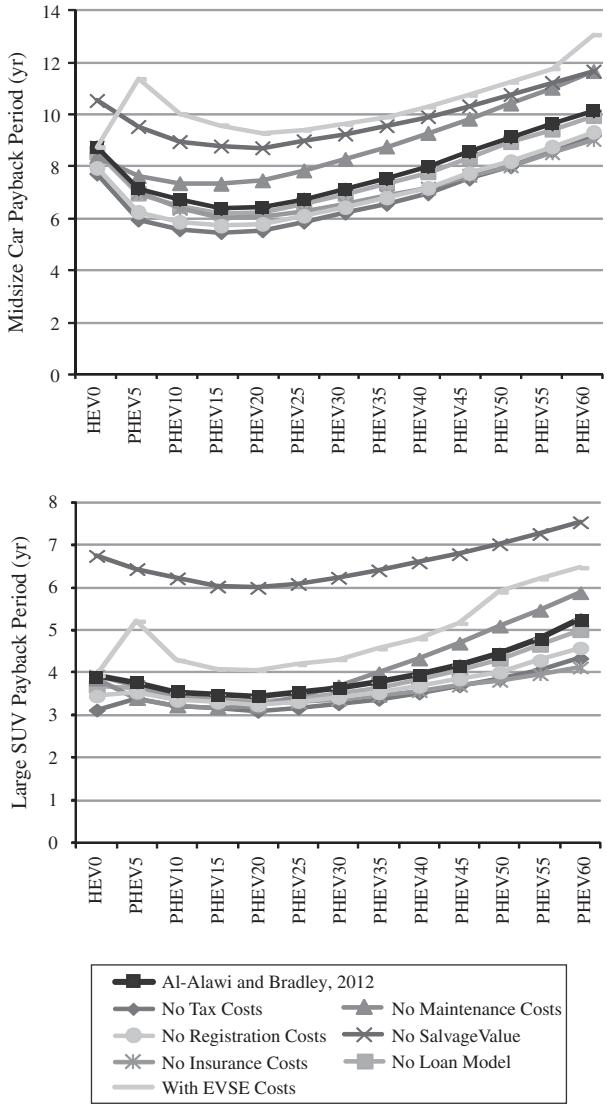

Fig. 6. Sensitivity of the PHEV20 economic payback period to TCO model scope in the Mid-Sized Car and large SUV classes compared to CV.

robust payback period estimations. Uncertainty in some key parameters of the TCO model can propagate into uncertainty in the payback period results. For example, uncertainty in the vehicle fuel economy is shown to be one of the primary drivers of payback period uncertainty, but the uncertainty in fuel economy simulation has been estimated at 10–12% [27,28], which corresponds to an uncertainty in the payback period of a Mid-Sized Car of 16–19%. Based on these types of results, cross-architecture payback period comparisons based on vehicle modeling should be presented with uncertainties on the order of approximately ±1 year in a 6 year payback period. The modeling and differentiation of vehicles by their payback period must consider the sensitivity of the metric of payback period in order to craft valid comparisons and conclusions.

Finally, these results show that the inclusion of the maintenance costs, and the salvage value of vehicles in the PHEV TCO model scope significantly decreases the PHEV payback period relative to ignoring their contribution to TCO. For instance, including the salvage value of the vehicle decreases payback period by more than 3 years for each vehicle studied here. These proper but previously discounted components of a comprehensive PHEV TCO model should be considered in future work on PHEV costs and benefits.

5.2. Surveyed market preference modeling and analysis

To this point, this study has quantified the costs and benefits of PHEV ownership to consumers, with the goal of understanding the sensitivity of payback periods to the parameter values and cost components of TCO. In the literature on vehicle TCO to date, there is a large philosophical interest in the metric of vehicle payback period, informed by the assumption that a rational PHEV consumer will insist on recouping his/her investment in the costs of PHEV components with equivalent or greater benefits [5,6,9]. Although economic rationality is an important indicator of the value of a product, very few consumers report performing NPV calculations to determine their preference for a particular vehicle type [29]. From the results of this TCO modeling exercise, we can test the economic "rationality" and price tolerance of consumers as measured through PHEV market preference surveys.

5.2.1. Consumer preference surveys

There are many factors that affect consumer's willingness to pay more for PHEVs, these have been studied both qualitatively and quantitatively. Qualitatively, consumers have been documented to display a preference for PHEVs because of their reduced fueling costs, reduced maintenance requirements, fewer trips to the gas station, the convenience of home refueling, lower CO_2 and GHG emissions, less petroleum use, less noise/vibration, improved acceleration, cabin preconditioning, the powering of 120 V appliances, better handling due to balanced weight distribution, and other benefits due to lower center of gravity [12]. Quantitatively, there have been a number of studies that survey consumers regarding their preference for PHEVs at certain price points, but none that present consumers with quantitative costs or benefits of the technology. Only a few studies characterize consumer preference for PHEVs under conditions of specific incremental costs and quantifiable benefits. For example, a 2006 survey by US Department of Energy claims that 42% of consumers are willing to pay an additional $2000 for a HEV with a fuel economy improvement of 40%, and 26% are willing to pay an additional $4000 for a PHEV20. [17] Curtin et al., found that 46% of consumers were willing to purchase a PHEV at a $2500 price increment with a 75% fuel economy improvement [30]. EPRI has surveyed consumer's willingness to pay for the purchase of PHEVs, but none of these results were not integrated with PHEV cost/benefit modeling [3,4].

5.2.2. Consumer preference for PHEVs

For this study, we would like to engage the new understanding of PHEV costs and benefits that comes from the development of the comprehensive TCO model so as to understand the relative rationality of PHEV consumers' willingness to pay. As an example dataset, we will enroll the EPRI [3,4] studies as they are the most complete dataset made available to the authors. That the dataset is somewhat dated is not important as it will serve merely as an exemplar of the type of results that are available from consumer preference surveys, and we will confine the discussion to the implications for synthesis of TCO modeling results.

These surveys recorded consumers' willingness to pay for each PHEV design (HEV0, PHEV20 and PHEV60) within each vehicle class (Compact Car, Mid-Sized Car, mid-sized SUV and large SUV) at two values of vehicle incremental cost [3,4].[18] We can use this data to calculate how consumers' preferences compare to

[17] Opinion Research Corporation International, "Would You Buy a Hybrid Vehicle?" #715238, 2006, available at http://www1.eere.energy.gov/vehiclesandfuels/facts/2006_fcvt_fotw431.html.

[18] Only survey data at a fuel cost of $3.00/gallon is used here, except the mid-sized cars where the survey was constructed assuming only a gasoline price of $1.69/gallon [3,4].

a strict total ownership cost versus total ownership benefit analysis. Ownership costs and benefits are calculated using a vehicle economic life of 5 years [31,32]. TCO for the base model is based on the default characteristics of the base model (as shown in Table 1), where TCO for EPRI's model is based on fuel and maintenance costs only. Each TCO model uses the harmonized values of vehicle lifetime, lifetime distance traveled, gasoline prices and electricity price. These parameters are chosen to be equal to the Al-Alawi & Bradley 2012 column of Table 1. The benefits are calculated relative to the CV within each model. All costs and benefits are represented in $2010.

Results are shown in Fig. 7. In each subplot of Fig. 7, the EPRI vehicles' costs and benefits are plotted along with lines of constant surveyed consumer preference as derived from EPRI's consumer preference data. As a general verification of the EPRI survey results, the consumer preference data from Curtin et al. is plotted in the Compact Car subplot as only Compact Car preferences were surveyed. These survey datasets describe how consumer's preferences change with changing costs and benefits. For example the EPRI survey data shown in Mid-Sized Car class of Fig. 7 illustrates that consumer preference generally increases with decreasing costs and increases with increasing benefits. Also, it shows consumer's sensitivity to incremental purchase price in that the slope of the line at 35% willingness to pay decreases at high incremental costs; in other words, the consumer is less willing to accept the same ratio of costs to benefits at higher incremental cost. The consumer preference data also shows that consumer preferences are not well-aligned with a rational model of economically-motivated consumers (represented by the dashed line at discounted incremental purchase cost = discounted incremental benefits).

These surveyed customer's willingness to pay as a function of the costs and benefits of PHEVs can then be compared to the costs and benefits of the suite of PHEVs whose TCO is modeled in this study. In Fig. 7, the costs of the PHEVs as modeled using the base TCO model are generally comparable to the costs presented in the surveys, and the benefits of the vehicles are generally larger than the benefits presented in the surveys.

5.2.3. Consumer preference discussion

This analysis leads to two primary discussion points. First, modeling consumer preference is generally more complicated than has been acknowledged in previous TCO models. Simple

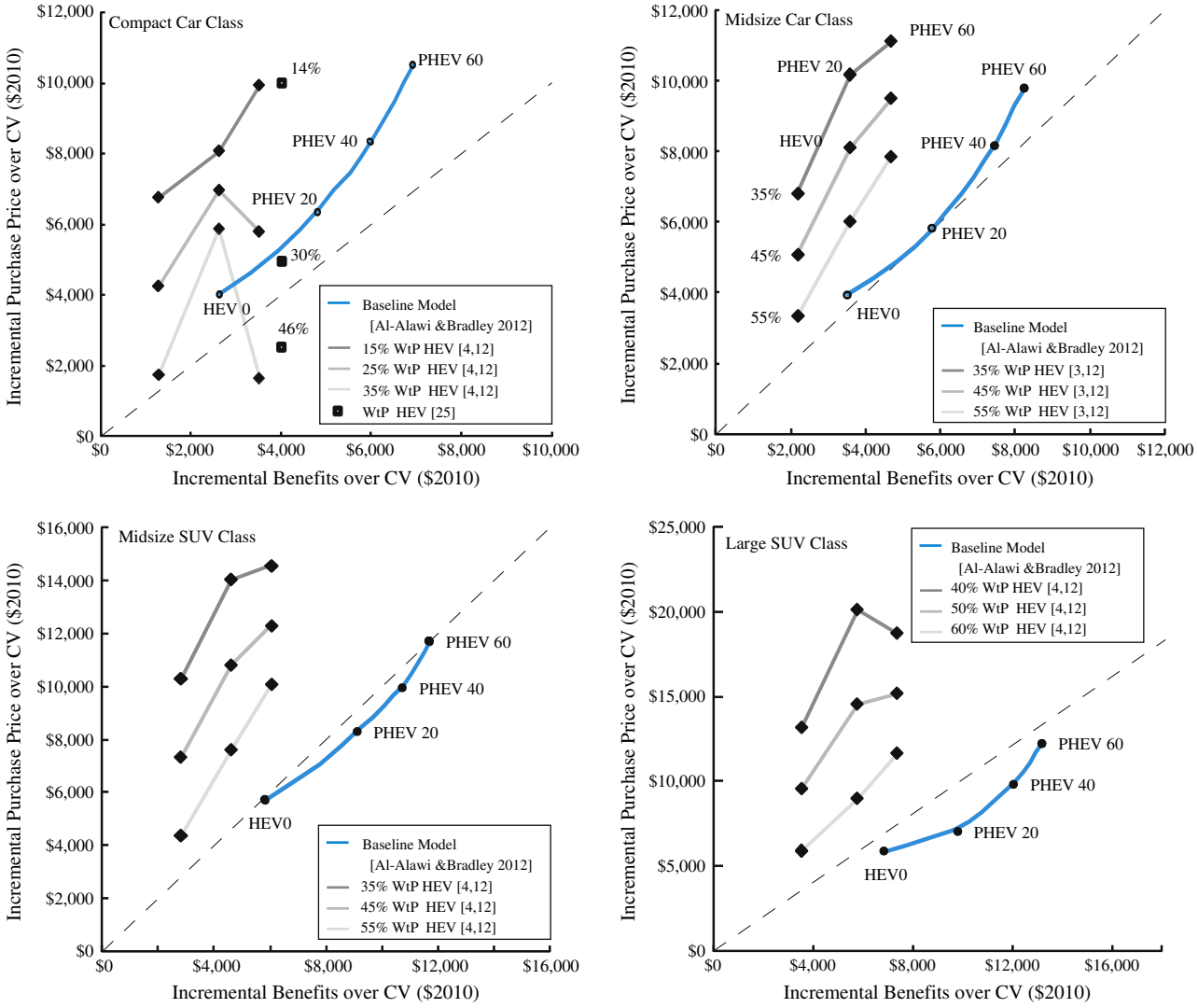

Fig. 7. Consumer's surveyed willingness to pay (WtP) for each vehicle class of PHEV0-60 plotted with the PHEV cost/benefit curve calculated using the baseline TCO model [3,4,12]. These curves can be compared to show that the modeled PHEVs display considerable consumer preference at presently available costs and benefits. These curves can be compared to the dashed line at incremental purchase cost equal to incremental benefits to show the qualitative differences between survey-based models and rational economic models of consumer behavior.

cost-benefit analysis cannot capture the richness of the consumer preference data that exists in the survey literature, and consideration of consumer preference can lead to an improved understanding of the design constraints that exist for incremental costs (and benefits) of PHEVs. Second, according to the comprehensive TCO modeling performed for this work, PHEVs of all types can exhibit substantial consumer preference. For example, in the Mid-Sized Car class, more than 55% of surveyed consumers are willing to pay the incremental costs of PHEVs with low AER. These types of results challenge the consensus view that PHEVs are not economically viable and are not capable of inciting consumer preference without significant component cost reductions and/or gasoline price increases.

6. Conclusion

The objective of this study was to define the parameters and assumptions that constitute a comprehensive TCO model of PHEVs. In this study we have developed a comprehensive ownership cost model to calculate consumers' costs of purchase and use of CVs, HEVs and PHEVs. This model was compared to the most cited PHEV TCO models in literature to measure the effects of model assumptions and parameters on the total cost and benefit of each vehicle. PHEV TCO modeling scope, parameter values, and assumptions are found to be quite variable among studies, resulting in widely varying PHEV TCO results. For example, many of the common components of TCO (e.g. maintenance costs, title and registration renewal costs, and salvage value) are not represented in all studies, and payback period is shown to vary between <6 and >12 years.

To rigorously inform and defend the components and assumptions of the comprehensive TCO model, a sensitivity analysis was performed to determine which parameters and components of TCO are most influential. This analysis shows that TCO and payback period are sensitive to the value of parameters that have been extensively modeled in literature including incremental cost, gasoline prices, and annual driving distance. For example, a 20% increase in gasoline prices is shown to decrease the payback period of the mid-sized PHEV20 relative to a CV by 31%. This analysis also showed that TCO and payback period are sensitive to relatively understudied components of TCO modeling including salvage value, maintenance costs, and fuel economy. For instance, the inclusion of salvage value in the TCO model of the Large SUV PHEV decreases payback period by more than 4 years.

Finally, this study shows that the output of TCO modeling should be more than just a modeled PHEV payback period. Instead, the value of PHEVs can be presented in terms of total costs and total benefits or can be presented in terms of survey-based consumer preference.

Ideally, the technology improvements associated with high fuel economy vehicles are preferred by consumers at the same time as they enable improvements in consumer and economy-wide economic efficiencies. The type of consumer-centric TCO modeling that is presented in this study allows for consideration of the consumer's role as an enabler of any economic or environmental improvements that might result from the development of PHEVs. Only when consumers, researchers, and automakers are presented with the comprehensive costs and values of PHEVs can they consider the role that PHEVs can play in a more economically and environmentally sustainable personal transportation system.

Acknowledgements

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Appendix A

See Tables A1–A7.

Appendix B

See Tables B1–B16.

Appendix C

See Tables C1–C4.

Appendix D

See Fig. D1 and Table D1.

Table A1
EPRI 2001 incremental costs of HEV $2000.

	Incremental cost			Battery NiMH cost			Incremental cost of NiMH battery
	Base	ANL	Average	Base	ANL	Average	
Compact Car							
HEV0	$3,602	$2,490	$3,046	$1,200	$1,400	$1,300	$1,746
PHEV20	$6,062	$4,483	$5,273	$1,800	$2,600	$2,200	$3,073
PHEV60	$10,305	$8,077	$9,191	$4,100	$6,400	$5,250	$3,941
Mid-Sized Car							
HEV0	$4,058	$2,483	$3,271	$2,103	$1,606	$1,855	$1,416
PHEV20	$5,982	$4,081	$5,032	$3,117	$2,193	$2,655	$2,377
PHEV60	$10,269	$7,629	$8,949	$7,317	$4,634	$5,976	$2,974
Mid-sized SUV							
HEV0	$5,503	$3,960	$4,732	$1,900	$2,600	$2,250	$2,482
PHEV20	$8,505	$6,381	$7,443	$2,800	$4,100	$3,450	$3,993
PHEV60	$13,098	$10,109	$11,604	$6,200	$9,800	$8,000	$3,604
Full-sized SUV							
HEV0	$6,282	$4,482	$5,382	$2,500	$3,500	$3,000	$2,382
PHEV20	$8,542	$6,017	$7,280	$3,500	$5,300	$4,400	$2,880
PHEV60	$14,505	$11,006	$12,756	$7,100	$11,500	$9,300	$3,456

Table A2
Kalhammer et al. reported Li Ion battery and module costs and final incremental cost $2010.

	2006 data		2008 data, $f = 6.8\%$		2000 data	2010 $ data	2010 $ data
	Module cost ($/kWh)	Battery cost	Module cost ($/kWh)	Battery cost	(Inc cost – NiMH battery)		Cost with Li Ion battery
Compact Car							
HEV0	$535	$1,700	$571	$1,816	$1,746	$2,212	$4,051
PHEV20	$341	$2,400	$364	$2,563	$3,073	$3,892	$6,489
PHEV60	$256	$5,120	$273	$5,468	$3,941	$4,992	$10,533
Mid-Sized Car							
HEV0	$470	$1,930	$502	$2,061	$1,416	$1,794	$3,882
PHEV20	$315	$2,500	$336	$2,670	$2,377	$3,011	$5,716
PHEV60	$249	$5,570	$266	$5,949	$2,974	$3,767	$9,795
Mid-sized SUV							
HEV0	$390	$2,250	$417	$2,403	$2,482	$3,143	$5,578
PHEV20	$285	$3,050	$304	$3,257	$3,993	$5,058	$8,359
PHEV60	$235	$6,520	$251	$6,963	$3,604	$4,564	$11,621
Full-sized SUV							
HEV0	$338	$2,420	$361	$2,585	$2,382	$3,018	$5,636
PHEV20	$275	$3,550	$294	$3,791	$2,880	$3,647	$7,490
PHEV60	$224	$7,230	$239	$7,722	$3,456	$4,377	$12,202

Table A3
Fuel economy parameters and incremental costs (Compact Car).

PHEV	FCT (kWh mile^{-1})		PCT (mile gallon^{-1})		UF Petro FE Adj	UF		Inc Cost
Range	FCT_U	FCT_Hwy	PCT_U	PCT_Hwy	MPG	UF_U	UF_Hwy	
CV	0	0	31.6	49.3	32.2	0	0	0
0	0.235	0.237	48.50	50.50	42	0	0	$4,051
5	0.235	0.237	48.63	52.38	48	0.17	0.06	$4,661
10	0.235	0.236	48.75	54.25	56	0.32	0.12	$5,270
15	0.235	0.236	48.88	56.13	64	0.44	0.17	$5,880
20	0.235	0.235	49.00	58.00	74	0.54	0.23	$6,489
25	0.235	0.235	49.29	58.30	84	0.62	0.28	$6,995
30	0.235	0.234	49.58	58.60	95	0.69	0.32	$7,500
35	0.235	0.234	49.86	58.90	107	0.74	0.37	$8,006
40	0.235	0.233	50.15	59.20	119	0.79	0.41	$8,511
45	0.235	0.233	50.44	59.50	133	0.82	0.45	$9,017
50	0.235	0.232	50.73	59.80	148	0.85	0.48	$9,522
55	0.235	0.232	51.01	60.10	164	0.88	0.52	$10,028
60	0.235	0.231	51.30	60.40	181	0.9	0.55	$10,533

Table A4
Fuel economy parameters and incremental costs, (Mid-Sized Car).

PHEV	FCT (kWh mile^{-1})		PCT (mile gallon^{-1})		UF Petro FE Adj	UF		Inc cost
Range	FCT_U	FCT_Hwy	PCT_U	PCT_Hwy	MPG	UF_U	UF_Hwy	
CV	0	0	23.2	41.4	24.8	0	0	0
0	0.29	0.303	40.60	43.70	35	0	0	$3,831
5	0.29	0.302	40.68	44.55	41	0.17	0.06	$4,284
10	0.289	0.301	40.75	45.40	47	0.32	0.12	$4,736
15	0.288	0.299	40.83	46.25	53	0.44	0.17	$5,188
20	0.288	0.298	40.90	47.10	61	0.54	0.23	$5,641
25	0.287	0.297	41.09	47.43	69	0.62	0.28	$6,144
30	0.286	0.296	41.28	47.75	78	0.69	0.32	$6,647
35	0.286	0.295	41.46	48.08	88	0.74	0.37	$7,150
40	0.285	0.293	41.65	48.40	98	0.79	0.41	$7,653
45	0.284	0.292	41.84	48.73	109	0.82	0.45	$8,156
50	0.284	0.291	42.03	49.05	122	0.85	0.48	$8,659
55	0.283	0.29	42.21	49.38	135	0.88	0.52	$9,163
60	0.282	0.288	42.40	49.70	149	0.9	0.55	$9,666

Table A5
Fuel economy parameters and incremental costs (Mid-sized SUV).

PHEV	FCT (kWh mile^{-1})		PCT (mile gallon^{-1})		UF Petro FE Adj	UF		Inc cost
Range	FCT_U	FCT_Hwy	PCT_U	PCT_Hwy	MPG	UF_U	UF_Hwy	
CV	0	0	18.4	29.7	19	0	0	0
0	0.356	0.359	30.60	36.50	28	0	0	$5,505
5	0.354	0.357	31.05	36.85	32	0.17	0.06	$6,191
10	0.351	0.354	31.50	37.20	37	0.32	0.12	$6,877
15	0.349	0.352	31.95	37.55	43	0.44	0.17	$7,563
20	0.347	0.349	32.40	37.90	49	0.54	0.23	$8,249
25	0.345	0.347	32.54	38.01	55	0.62	0.28	$8,651
30	0.343	0.345	32.68	38.13	62	0.69	0.32	$9,053
35	0.341	0.342	32.81	38.24	70	0.74	0.37	$9,456
40	0.339	0.34	32.95	38.35	78	0.79	0.41	$9,858
45	0.337	0.337	33.09	38.46	86	0.82	0.45	$10,261
50	0.335	0.335	33.23	38.58	96	0.85	0.48	$10,663
55	0.333	0.332	33.36	38.69	106	0.88	0.52	$11,065
60	0.33	0.33	33.50	38.80	116	0.9	0.55	$11,468

Table A6
Fuel economy parameters and incremental costs (Large SUV).

PHEV	FCT (kWh mile^{-1})		PCT (mile gallon^{-1})		UF Petro FE Adj	UF		Inc cost
Range	FCT_U	FCT_Hwy	PCT_U	PCT_Hwy	MPG	UF_U	UF_Hwy	
CV	0	0	14.9	24.8	16	0	0	0
0	0.400	0.425	25.60	30.50	23	0	0	$5,636
5	0.401	0.422	26.10	30.93	27	0.17	0.06	$6,100
10	0.402	0.419	26.60	31.35	31	0.32	0.12	$6,563
15	0.403	0.416	27.10	31.78	36	0.44	0.17	$7,026
20	0.404	0.413	27.60	32.20	41	0.54	0.23	$7,489
25	0.405	0.410	27.71	32.26	47	0.62	0.28	$8,078
30	0.406	0.407	27.83	32.33	53	0.69	0.32	$8,668
35	0.408	0.404	27.94	32.39	59	0.74	0.37	$9,257
40	0.409	0.401	28.05	32.45	66	0.79	0.41	$9,846
45	0.410	0.398	28.16	32.51	73	0.82	0.45	$10,435
50	0.411	0.394	28.28	32.58	81	0.85	0.48	$11,024
55	0.412	0.391	28.39	32.64	89	0.88	0.52	$11,613
60	0.413	0.388	28.50	32.70	98	0.90	0.55	$12,202

Table A7
Vehicle miles traveled (VMT) and fuel prices in 2010 $.

Calendar year	Vehicle life	VMT, Passenger car	VMT, Light truck	Electricity ($ kWh^{-1})	Gasoline ($ gallon^{-1})
2012	1	12,000	15,000	$0.11	$2.84
2013	2	11,754	14,739	$0.11	$3.00
2014	3	11,484	14,437	$0.11	$3.16
2015	4	11,192	14,097	$0.10	$3.32
2016	5	10,881	13,724	$0.10	$3.44
2017	6	10,551	13,321	$0.09	$3.57
2018	7	10,206	12,893	$0.09	$3.66
2019	8	9,848	12,444	$0.09	$3.74
2020	9	9,479	11,978	$0.08	$3.81
2021	10	9,101	11,499	$0.08	$3.83
2022	11	8,716	11,011	$0.08	$3.86
2023	12	8,327	10,518	$0.07	$3.88
2024	13	7,936	10,024	$0.12	$3.88

Table B1
Salvage value (Compact Car).

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
1	$12,707	$16,236	$16,767	$17,298	$17,829	$18,360	$18,800	$19,240	$19,681	$20,121	$20,561	$21,002	$21,442	$21,882
2	$10,442	$13,343	$13,779	$14,215	$14,652	$15,088	$15,450	$15,812	$16,173	$16,535	$16,897	$17,259	$17,621	$17,983
3	$8,581	$10,965	$11,323	$11,682	$12,041	$12,399	$12,696	$12,994	$13,291	$13,589	$13,886	$14,183	$14,481	$14,778
4	$7,052	$9,011	$9,306	$9,600	$9,895	$10,189	$10,434	$10,678	$10,923	$11,167	$11,411	$11,656	$11,900	$12,144
5	$5,795	$7,405	$7,647	$7,889	$8,131	$8,374	$8,574	$8,775	$8,976	$9,177	$9,378	$9,579	$9,779	$9,980
6	$4,763	$6,085	$6,284	$6,483	$6,682	$6,881	$7,046	$7,211	$7,376	$7,541	$7,707	$7,872	$8,037	$8,202

(*continued on next page*)

Table B1 (*continued*)

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
7	$3,914	$5,001	$5,164	$5,328	$5,492	$5,655	$5,791	$5,926	$6,062	$6,198	$6,333	$6,469	$6,604	$6,740
8	$3,216	$4,110	$4,244	$4,378	$4,513	$4,647	$4,759	$4,870	$4,982	$5,093	$5,205	$5,316	$5,427	$5,539
9	$2,643	$3,377	$3,488	$3,598	$3,709	$3,819	$3,911	$4,002	$4,094	$4,185	$4,277	$4,369	$4,460	$4,552
10	$2,172	$2,775	$2,866	$2,957	$3,048	$3,138	$3,214	$3,289	$3,364	$3,440	$3,515	$3,590	$3,665	$3,741
11	$1,785	$2,281	$2,355	$2,430	$2,505	$2,579	$2,641	$2,703	$2,765	$2,827	$2,888	$2,950	$3,012	$3,074
12	$1,467	$1,874	$1,936	$1,997	$2,058	$2,120	$2,170	$2,221	$2,272	$2,323	$2,374	$2,425	$2,475	$2,526
13	$1,206	$1,540	$1,591	$1,641	$1,691	$1,742	$1,784	$1,825	$1,867	$1,909	$1,951	$1,992	$2,034	$2,076

Table B2
Salvage value (Mid-Sized Car).

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
1	$16,876	$20,258	$20,657	$21,057	$21,456	$21,855	$22,299	$22,743	$23,187	$23,632	$24,076	$24,520	$24,964	$25,408
2	$13,869	$16,648	$16,976	$17,304	$17,632	$17,960	$18,325	$18,690	$19,055	$19,420	$19,785	$20,150	$20,515	$20,880
3	$11,397	$13,681	$13,951	$14,220	$14,490	$14,760	$15,060	$15,360	$15,659	$15,959	$16,259	$16,559	$16,859	$17,159
4	$9,366	$11,243	$11,465	$11,686	$11,908	$12,129	$12,376	$12,622	$12,869	$13,115	$13,362	$13,608	$13,855	$14,101
5	$7,697	$9,239	$9,421	$9,604	$9,786	$9,968	$10,170	$10,373	$10,575	$10,778	$10,981	$11,183	$11,386	$11,588
6	$6,325	$7,593	$7,742	$7,892	$8,042	$8,191	$8,358	$8,524	$8,691	$8,857	$9,024	$9,190	$9,357	$9,523
7	$5,198	$6,240	$6,363	$6,486	$6,609	$6,732	$6,868	$7,005	$7,142	$7,279	$7,416	$7,552	$7,689	$7,826
8	$4,272	$5,128	$5,229	$5,330	$5,431	$5,532	$5,644	$5,757	$5,869	$5,982	$6,094	$6,207	$6,319	$6,431
9	$3,510	$4,214	$4,297	$4,380	$4,463	$4,546	$4,639	$4,731	$4,823	$4,916	$5,008	$5,100	$5,193	$5,285
10	$2,885	$3,463	$3,531	$3,599	$3,668	$3,736	$3,812	$3,888	$3,964	$4,040	$4,116	$4,192	$4,267	$4,343
11	$2,371	$2,846	$2,902	$2,958	$3,014	$3,070	$3,133	$3,195	$3,257	$3,320	$3,382	$3,445	$3,507	$3,569
12	$1,948	$2,339	$2,385	$2,431	$2,477	$2,523	$2,574	$2,626	$2,677	$2,728	$2,779	$2,831	$2,882	$2,933
13	$1,601	$1,922	$1,960	$1,998	$2,036	$2,073	$2,116	$2,158	$2,200	$2,242	$2,284	$2,326	$2,368	$2,411

Table B3
Salvage value (Mid-sized SUV).

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
1	$23,860	$28,719	$29,325	$29,930	$30,536	$31,141	$31,497	$31,852	$32,207	$32,562	$32,917	$33,273	$33,628	$33,983
2	$19,608	$23,601	$24,099	$24,597	$25,094	$25,592	$25,884	$26,176	$26,467	$26,759	$27,051	$27,343	$27,635	$27,927
3	$16,114	$19,395	$19,804	$20,213	$20,622	$21,031	$21,271	$21,511	$21,751	$21,991	$22,230	$22,470	$22,710	$22,950
4	$13,242	$15,939	$16,275	$16,611	$16,947	$17,283	$17,480	$17,677	$17,875	$18,072	$18,269	$18,466	$18,663	$18,860
5	$10,882	$13,099	$13,375	$13,651	$13,927	$14,203	$14,365	$14,527	$14,689	$14,851	$15,013	$15,175	$15,337	$15,499
6	$8,943	$10,764	$10,991	$11,218	$11,445	$11,672	$11,805	$11,938	$12,071	$12,205	$12,338	$12,471	$12,604	$12,737
7	$7,349	$8,846	$9,032	$9,219	$9,405	$9,592	$9,701	$9,811	$9,920	$10,030	$10,139	$10,248	$10,358	$10,467
8	$6,040	$7,270	$7,423	$7,576	$7,729	$7,883	$7,973	$8,062	$8,152	$8,242	$8,332	$8,422	$8,512	$8,602
9	$4,963	$5,974	$6,100	$6,226	$6,352	$6,478	$6,552	$6,626	$6,700	$6,773	$6,847	$6,921	$6,995	$7,069
10	$4,079	$4,909	$5,013	$5,116	$5,220	$5,323	$5,384	$5,445	$5,506	$5,566	$5,627	$5,688	$5,748	$5,809
11	$3,352	$4,035	$4,120	$4,205	$4,290	$4,375	$4,425	$4,475	$4,524	$4,574	$4,624	$4,674	$4,724	$4,774
12	$2,755	$3,316	$3,385	$3,455	$3,525	$3,595	$3,636	$3,677	$3,718	$3,759	$3,800	$3,841	$3,882	$3,923
13	$2,264	$2,725	$2,782	$2,840	$2,897	$2,954	$2,988	$3,022	$3,056	$3,089	$3,123	$3,157	$3,190	$3,224

Table B4
Salvage value (Large SUV).

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
1	$23,522	$28,432	$28,836	$29,239	$29,643	$30,047	$30,560	$31,073	$31,586	$32,099	$32,612	$33,125	$33,638	$34,151
2	$19,331	$23,365	$23,697	$24,029	$24,360	$24,692	$25,114	$25,535	$25,957	$26,379	$26,800	$27,222	$27,644	$28,065
3	$15,886	$19,201	$19,474	$19,747	$20,019	$20,292	$20,638	$20,985	$21,331	$21,678	$22,024	$22,371	$22,717	$23,064
4	$13,055	$15,780	$16,004	$16,228	$16,452	$16,675	$16,960	$17,245	$17,530	$17,815	$18,099	$18,384	$18,669	$18,954
5	$10,728	$12,968	$13,152	$13,336	$13,520	$13,704	$13,938	$14,172	$14,406	$14,640	$14,874	$15,108	$15,342	$15,576
6	$8,816	$10,657	$10,808	$10,959	$11,110	$11,262	$11,454	$11,646	$11,839	$12,031	$12,223	$12,416	$12,608	$12,800
7	$7,245	$8,758	$8,882	$9,006	$9,130	$9,255	$9,413	$9,571	$9,729	$9,887	$10,045	$10,203	$10,361	$10,519
8	$5,954	$7,197	$7,299	$7,401	$7,503	$7,605	$7,735	$7,865	$7,995	$8,125	$8,255	$8,385	$8,515	$8,644
9	$4,893	$5,914	$5,998	$6,082	$6,166	$6,250	$6,357	$6,464	$6,570	$6,677	$6,784	$6,890	$6,997	$7,104
10	$4,021	$4,860	$4,929	$4,998	$5,067	$5,136	$5,224	$5,312	$5,399	$5,487	$5,575	$5,663	$5,750	$5,838
11	$3,304	$3,994	$4,051	$4,108	$4,164	$4,221	$4,293	$4,365	$4,437	$4,509	$4,581	$4,653	$4,726	$4,798
12	$2,716	$3,282	$3,329	$3,376	$3,422	$3,469	$3,528	$3,587	$3,646	$3,706	$3,765	$3,824	$3,883	$3,943
13	$2,232	$2,697	$2,736	$2,774	$2,812	$2,851	$2,899	$2,948	$2,997	$3,045	$3,094	$3,143	$3,191	$3,240

Table B5
Maintenance costs (Compact Car).

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
1	$141	$141	$129	$129	$99	$99	$99	$99	$99	$69	$69	$69	$69	$69
2	$226	$226	$204	$117	$204	$173	$173	$173	$173	$173	$173	$173	$173	$173
3	$343	$381	$325	$314	$233	$261	$235	$235	$235	$233	$233	$233	$233	$206
4	$793	$793	$771	$834	$834	$747	$747	$747	$722	$749	$749	$722	$722	$747
5	$162	$162	$155	$78	$78	$137	$161	$78	$78	$78	$55	$81	$81	$55
6	$328	$360	$169	$242	$194	$191	$169	$225	$169	$169	$169	$169	$147	$171
7	$169	$169	$289	$289	$175	$131	$129	$129	$182	$109	$129	$109	$129	$129
8	$367	$367	$557	$535	$535	$578	$537	$535	$535	$584	$584	$535	$535	$515
9	$383	$410	$244	$163	$285	$142	$182	$144	$142	$142	$124	$189	$124	$142
10	$180	$180	$166	$109	$109	$225	$109	$147	$110	$109	$109	$91	$153	$91
11	$79	$79	$72	$55	$57	$55	$165	$55	$39	$39	$39	$55	$39	$39
12	$410	$433	$289	$391	$336	$336	$336	$320	$370	$337	$336	$320	$336	$375
13	$70	$70	$193	$210	$178	$180	$178	$276	$178	$210	$180	$178	$164	$164

Table B6
Maintenance costs (Mid-Sized Car).

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
1	$183	$183	$168	$168	$121	$102	$102	$102	$102	$73	$73	$73	$73	$73
2	$330	$330	$264	$126	$264	$234	$234	$234	$234	$217	$217	$199	$199	$199
3	$298	$336	$323	$340	$210	$255	$213	$213	$213	$210	$210	$226	$226	$184
4	$1,317	$1,317	$1,302	$1,368	$1,368	$1,262	$1,262	$1,262	$1,222	$1,265	$1,265	$1,222	$1,222	$1,262
5	$203	$203	$194	$96	$96	$158	$196	$96	$96	$96	$58	$98	$98	$58
6	$298	$330	$176	$270	$214	$212	$176	$235	$176	$176	$176	$176	$141	$179
7	$603	$603	$657	$657	$575	$525	$523	$523	$578	$489	$523	$489	$523	$523
8	$753	$782	$722	$688	$688	$737	$690	$688	$688	$740	$740	$688	$688	$656
9	$57	$57	$192	$85	$173	$53	$99	$55	$53	$53	$23	$102	$23	$53
10	$197	$197	$188	$114	$114	$199	$114	$158	$116	$114	$114	$86	$161	$86
11	$102	$102	$94	$67	$69	$67	$147	$67	$41	$41	$41	$67	$41	$41
12	$480	$502	$319	$461	$394	$394	$394	$369	$433	$396	$394	$369	$394	$436
13	$45	$45	$462	$475	$438	$440	$438	$510	$438	$475	$440	$438	$415	$415

Table B7
Maintenance costs (Mid-sized SUV).

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
1	$336	$336	$267	$267	$267	$222	$222	$222	$222	$222	$222	$177	$177	$177
2	$379	$420	$338	$295	$295	$295	$295	$250	$250	$250	$250	$250	$250	$250
3	$664	$664	$1,290	$1,290	$1,290	$1,228	$1,188	$1,231	$1,191	$1,191	$1,191	$1,188	$1,188	$1,188
4	$890	$890	$323	$224	$187	$282	$282	$187	$187	$187	$187	$189	$189	$149
5	$371	$405	$353	$339	$248	$210	$210	$265	$300	$210	$175	$210	$210	$212
6	$679	$679	$1,112	$1,214	$1,164	$1,166	$1,114	$1,112	$1,078	$1,130	$1,078	$1,078	$1,045	$1,078
7	$679	$710	$228	$196	$290	$163	$212	$165	$163	$163	$211	$211	$163	$163
8	$273	$273	$223	$178	$180	$268	$148	$194	$150	$148	$148	$118	$194	$118
9	$598	$625	$578	$547	$504	$504	$617	$504	$548	$506	$504	$504	$476	$547
10	$103	$103	$478	$520	$519	$480	$452	$532	$452	$493	$453	$452	$452	$425
11	$550	$550	$225	$151	$124	$124	$126	$124	$200	$124	$163	$126	$124	$124
12	$382	$405	$321	$391	$358	$332	$295	$295	$295	$272	$272	$272	$272	$295
13	$408	$408	$400	$378	$378	$378	$378	$379	$378	$445	$378	$412	$379	$355

Table B8
Maintenance costs (Large SUV).

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
1	$374	$374	$318	$318	$318	$275	$275	$276	$276	$276	$276	$232	$232	$232
2	$465	$505	$388	$347	$347	$347	$347	$299	$299	$299	$299	$300	$300	$300
3	$617	$617	$1,355	$1,355	$1,355	$1,265	$1,227	$1,271	$1,232	$1,232	$1,232	$1,227	$1,227	$1,227
4	$995	$995	$442	$267	$231	$352	$352	$231	$231	$231	$231	$236	$236	$194
5	$494	$528	$467	$451	$291	$252	$252	$332	$366	$252	$218	$252	$252	$257
6	$670	$670	$1,176	$1,347	$1,294	$1,299	$1,181	$1,176	$1,143	$1,219	$1,143	$1,143	$1,111	$1,143
7	$751	$781	$262	$231	$388	$196	$307	$201	$196	$196	$267	$267	$196	$196

(*continued on next page*)

Table B8 (*continued*)

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
8	$351	$351	$279	$212	$216	$364	$183	$288	$187	$183	$183	$154	$250	$154
9	$665	$692	$680	$613	$550	$550	$720	$550	$649	$554	$550	$550	$522	$613
10	$101	$101	$488	$581	$547	$491	$462	$597	$462	$555	$466	$462	$462	$436
11	$576	$576	$305	$181	$154	$154	$157	$154	$281	$154	$242	$157	$154	$154
12	$468	$490	$339	$456	$422	$366	$312	$312	$312	$289	$289	$289	$289	$312
13	$406	$406	$439	$417	$417	$417	$417	$420	$417	$531	$417	$496	$420	$396

Table B9
Annual insurance costs (Compact Car).

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
1	$1,093	$1,093	$1,104	$1,114	$1,125	$1,135	$1,146	$1,156	$1,167	$1,177	$1,188	$1,198	$1,209	$1,219
2	$1,067	$1,067	$1,077	$1,088	$1,098	$1,108	$1,118	$1,129	$1,139	$1,149	$1,159	$1,170	$1,180	$1,190
3	$1,042	$1,042	$1,052	$1,062	$1,072	$1,082	$1,092	$1,102	$1,112	$1,122	$1,132	$1,142	$1,152	$1,162
4	$1,017	$1,017	$1,027	$1,037	$1,047	$1,057	$1,066	$1,076	$1,086	$1,096	$1,105	$1,115	$1,125	$1,135
5	$993	$993	$1,003	$1,013	$1,022	$1,032	$1,041	$1,051	$1,060	$1,070	$1,079	$1,089	$1,098	$1,108
6	$970	$970	$979	$989	$998	$1,007	$1,017	$1,026	$1,035	$1,045	$1,054	$1,063	$1,073	$1,082
7	$947	$947	$956	$965	$974	$984	$993	$1,002	$1,011	$1,020	$1,029	$1,038	$1,047	$1,056
8	$925	$925	$934	$943	$951	$960	$969	$978	$987	$996	$1,005	$1,014	$1,023	$1,031
9	$903	$903	$912	$920	$929	$938	$946	$955	$964	$972	$981	$990	$998	$1,007
10	$882	$882	$890	$899	$907	$916	$924	$933	$941	$949	$958	$966	$975	$983
11	$861	$861	$869	$877	$886	$894	$902	$911	$919	$927	$935	$944	$952	$960
12	$841	$841	$849	$857	$865	$873	$881	$889	$897	$905	$913	$921	$929	$938
13	$821	$821	$829	$837	$844	$852	$860	$868	$876	$884	$892	$900	$908	$915

Table B10
Annual insurance costs (Mid-Sized Car).

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
1	$1,159	$1,159	$1,167	$1,175	$1,183	$1,191	$1,199	$1,207	$1,214	$1,222	$1,230	$1,238	$1,246	$1,254
2	$1,132	$1,132	$1,139	$1,147	$1,155	$1,163	$1,170	$1,178	$1,186	$1,194	$1,201	$1,209	$1,217	$1,224
3	$1,105	$1,105	$1,113	$1,120	$1,128	$1,135	$1,143	$1,150	$1,158	$1,165	$1,173	$1,180	$1,188	$1,196
4	$1,079	$1,079	$1,086	$1,094	$1,101	$1,108	$1,116	$1,123	$1,131	$1,138	$1,145	$1,153	$1,160	$1,167
5	$1,053	$1,053	$1,061	$1,068	$1,075	$1,082	$1,089	$1,097	$1,104	$1,111	$1,118	$1,125	$1,133	$1,140
6	$1,029	$1,029	$1,036	$1,043	$1,050	$1,057	$1,064	$1,071	$1,078	$1,085	$1,092	$1,099	$1,106	$1,113
7	$1,004	$1,004	$1,011	$1,018	$1,025	$1,032	$1,039	$1,046	$1,052	$1,059	$1,066	$1,073	$1,080	$1,087
8	$981	$981	$987	$994	$1,001	$1,007	$1,014	$1,021	$1,028	$1,034	$1,041	$1,048	$1,054	$1,061
9	$958	$958	$964	$971	$977	$984	$990	$997	$1,003	$1,010	$1,016	$1,023	$1,029	$1,036
10	$935	$935	$941	$948	$954	$961	$967	$973	$980	$986	$992	$999	$1,005	$1,012
11	$913	$913	$919	$925	$932	$938	$944	$950	$957	$963	$969	$975	$982	$988
12	$891	$891	$897	$904	$910	$916	$922	$928	$934	$940	$946	$952	$958	$964
13	$870	$870	$876	$882	$888	$894	$900	$906	$912	$918	$924	$930	$936	$942

Table B11
Annual insurance costs (Mid-sized SUV).

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
1	$1,050	$1,050	$1,068	$1,087	$1,105	$1,123	$1,142	$1,160	$1,178	$1,197	$1,215	$1,233	$1,252	$1,270
2	$1,025	$1,025	$1,043	$1,061	$1,079	$1,097	$1,115	$1,133	$1,151	$1,168	$1,186	$1,204	$1,222	$1,240
3	$1,001	$1,001	$1,019	$1,036	$1,053	$1,071	$1,088	$1,106	$1,123	$1,141	$1,158	$1,176	$1,193	$1,211
4	$977	$977	$995	$1,012	$1,029	$1,046	$1,063	$1,080	$1,097	$1,114	$1,131	$1,148	$1,165	$1,182
5	$954	$954	$971	$988	$1,004	$1,021	$1,038	$1,054	$1,071	$1,088	$1,104	$1,121	$1,138	$1,154
6	$932	$932	$948	$964	$981	$997	$1,013	$1,030	$1,046	$1,062	$1,078	$1,095	$1,111	$1,127
7	$910	$910	$926	$942	$958	$973	$989	$1,005	$1,021	$1,037	$1,053	$1,069	$1,085	$1,101
8	$888	$888	$904	$919	$935	$950	$966	$982	$997	$1,013	$1,028	$1,044	$1,059	$1,075
9	$867	$867	$883	$898	$913	$928	$943	$958	$974	$989	$1,004	$1,019	$1,034	$1,049
10	$847	$847	$862	$877	$891	$906	$921	$936	$951	$965	$980	$995	$1,010	$1,025
11	$827	$827	$841	$856	$870	$885	$899	$914	$928	$943	$957	$971	$986	$1,000
12	$808	$808	$822	$836	$850	$864	$878	$892	$906	$920	$934	$949	$963	$977
13	$789	$789	$802	$816	$830	$844	$857	$871	$885	$899	$912	$926	$940	$954

Table B12
Annual insurance costs (Large SUV).

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
1	$1,089	$1,089	$1,111	$1,133	$1,156	$1,178	$1,200	$1,222	$1,244	$1,266	$1,289	$1,311	$1,333	$1,355
2	$1,063	$1,063	$1,085	$1,107	$1,128	$1,150	$1,172	$1,193	$1,215	$1,236	$1,258	$1,280	$1,301	$1,323
3	$1,038	$1,038	$1,059	$1,081	$1,102	$1,123	$1,144	$1,165	$1,186	$1,207	$1,228	$1,250	$1,271	$1,292
4	$1,014	$1,014	$1,034	$1,055	$1,076	$1,096	$1,117	$1,138	$1,158	$1,179	$1,199	$1,220	$1,241	$1,261
5	$990	$990	$1,010	$1,030	$1,050	$1,070	$1,091	$1,111	$1,131	$1,151	$1,171	$1,191	$1,211	$1,232
6	$966	$966	$986	$1,006	$1,026	$1,045	$1,065	$1,085	$1,104	$1,124	$1,144	$1,163	$1,183	$1,203
7	$944	$944	$963	$982	$1,001	$1,021	$1,040	$1,059	$1,078	$1,097	$1,117	$1,136	$1,155	$1,174
8	$921	$921	$940	$959	$978	$996	$1,015	$1,034	$1,053	$1,071	$1,090	$1,109	$1,128	$1,147
9	$900	$900	$918	$936	$955	$973	$991	$1,010	$1,028	$1,046	$1,065	$1,083	$1,101	$1,119
10	$878	$878	$896	$914	$932	$950	$968	$986	$1,004	$1,022	$1,039	$1,057	$1,075	$1,093
11	$858	$858	$875	$893	$910	$928	$945	$963	$980	$997	$1,015	$1,032	$1,050	$1,067
12	$838	$838	$855	$872	$889	$906	$923	$940	$957	$974	$991	$1,008	$1,025	$1,042
13	$818	$818	$834	$851	$868	$884	$901	$918	$934	$951	$968	$984	$1,001	$1,018

Table B13
Registration renewal costs (Compact Car).

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
1	$326	$397	$408	$419	$430	$441	$450	$459	$468	$476	$485	$494	$503	$512
2	$238	$286	$294	$301	$308	$316	$322	$328	$334	$340	$346	$352	$358	$364
3	$192	$228	$234	$240	$245	$251	$255	$260	$264	$269	$273	$278	$283	$287
4	$150	$176	$180	$184	$188	$192	$195	$198	$202	$205	$208	$211	$215	$218
5	$98	$110	$112	$114	$116	$118	$120	$121	$123	$124	$126	$127	$129	$130
6	$93	$104	$106	$108	$110	$111	$113	$114	$116	$117	$119	$120	$122	$123
7	$87	$98	$100	$102	$103	$105	$106	$108	$109	$111	$112	$113	$115	$116
8	$83	$93	$94	$96	$97	$99	$100	$102	$103	$104	$106	$107	$108	$110
9	$78	$88	$89	$90	$92	$93	$95	$96	$97	$98	$100	$101	$102	$103
10	$43	$43	$43	$43	$43	$43	$43	$43	$43	$43	$43	$43	$43	$43
11	$40	$40	$40	$40	$40	$40	$40	$40	$41	$41	$41	$41	$41	$41
12	$38	$38	$38	$38	$38	$38	$38	$38	$38	$38	$38	$38	$38	$38
13	$36	$36	$36	$36	$36	$36	$36	$36	$36	$36	$36	$36	$36	$36

Table B14
Registration renewal costs (Mid-Sized Car).

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
1	$413	$481	$489	$497	$505	$513	$522	$531	$540	$549	$558	$567	$576	$585
2	$297	$343	$349	$354	$360	$365	$371	$377	$383	$389	$396	$402	$408	$414
3	$237	$272	$276	$280	$284	$288	$293	$298	$302	$307	$311	$316	$320	$325
4	$183	$207	$210	$213	$216	$219	$222	$226	$229	$232	$235	$239	$242	$245
5	$114	$126	$127	$129	$130	$132	$133	$135	$136	$138	$139	$141	$142	$144
6	$108	$119	$120	$121	$123	$124	$126	$127	$129	$130	$131	$133	$134	$136
7	$102	$112	$113	$115	$116	$117	$118	$120	$121	$123	$124	$125	$127	$128
8	$96	$106	$107	$108	$109	$110	$112	$113	$114	$116	$117	$118	$120	$121
9	$91	$100	$101	$102	$103	$104	$105	$107	$108	$109	$110	$112	$113	$114
10	$44	$44	$44	$44	$44	$44	$44	$44	$44	$44	$44	$44	$44	$44
11	$41	$41	$42	$42	$42	$42	$42	$42	$42	$42	$42	$42	$42	$42
12	$39	$39	$39	$39	$39	$39	$39	$39	$39	$39	$39	$39	$39	$39
13	$37	$37	$37	$37	$37	$37	$37	$37	$37	$37	$37	$37	$37	$37

Table B15
Registration renewal costs (Mid-sized SUV).

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
1	$560	$659	$672	$685	$699	$712	$720	$728	$736	$745	$753	$761	$769	$777
2	$398	$465	$474	$483	$493	$502	$508	$513	$519	$525	$531	$537	$542	$548
3	$314	$365	$372	$379	$386	$393	$398	$402	$407	$412	$416	$421	$425	$430
4	$238	$275	$280	$285	$290	$296	$299	$302	$306	$309	$313	$316	$320	$323
5	$143	$160	$163	$166	$169	$172	$174	$176	$178	$180	$182	$184	$186	$188
6	$135	$151	$154	$157	$160	$162	$164	$166	$168	$170	$172	$174	$175	$177
7	$127	$143	$145	$148	$150	$153	$155	$157	$158	$160	$162	$164	$166	$167

(*continued on next page*)

Table B15 (*continued*)

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
8	$120	$135	$137	$140	$142	$144	$146	$148	$149	$151	$153	$154	$156	$158
9	$113	$127	$129	$132	$134	$136	$138	$139	$141	$143	$144	$146	$147	$149
10	$47	$48	$49	$49	$50	$50	$51	$52	$52	$53	$53	$54	$55	$55
11	$45	$45	$46	$46	$47	$48	$48	$49	$49	$50	$50	$51	$51	$52
12	$42	$43	$43	$44	$44	$45	$45	$46	$46	$47	$47	$48	$49	$49
13	$40	$40	$41	$41	$42	$42	$43	$43	$44	$44	$45	$45	$46	$46

Table B16
Registration renewal costs (Large SUV).

Vehicle life	PHEV													
	CV	0	5	10	15	20	25	30	35	40	45	50	55	60
1	$568	$668	$676	$684	$693	$701	$712	$722	$733	$744	$754	$765	$775	$786
2	$408	$475	$481	$486	$492	$498	$505	$512	$519	$527	$534	$541	$548	$555
3	$324	$375	$379	$384	$388	$392	$398	$403	$409	$414	$420	$425	$431	$436
4	$249	$285	$288	$291	$294	$297	$301	$305	$309	$313	$317	$321	$325	$329
5	$154	$171	$173	$174	$176	$177	$179	$181	$183	$185	$187	$189	$191	$193
6	$145	$161	$163	$164	$166	$167	$169	$171	$173	$175	$176	$178	$180	$182
7	$137	$152	$154	$155	$156	$158	$160	$161	$163	$165	$166	$168	$170	$172
8	$129	$144	$145	$146	$148	$149	$151	$152	$154	$155	$157	$159	$160	$162
9	$122	$135	$137	$138	$139	$140	$142	$144	$145	$147	$148	$150	$151	$153
10	$57	$57	$57	$57	$57	$57	$57	$57	$58	$58	$58	$58	$58	$58
11	$53	$53	$54	$54	$54	$54	$54	$54	$54	$54	$55	$55	$55	$55
12	$50	$50	$51	$51	$51	$51	$51	$51	$51	$51	$52	$52	$52	$52
13	$47	$48	$48	$48	$48	$48	$48	$48	$48	$48	$49	$49	$49	$49

Table C1
Payments for Compact Car, 2010 $ (sales tax and registration payments are included in the loan).

Vehicle type	MSRP	Down payment	Monthly payment	Sales tax	Title and registration	Loan
CV	$14,587	$1,459	$330	$977	$248	$14,354
HEV0	$18,639	$1,864	$422	$1,249	$317	$18,340
PHEV5	$19,248	$1,925	$436	$1,290	$327	$18,940
PHEV10	$19,858	$1,986	$450	$1,330	$338	$19,540
PHEV15	$20,467	$2,047	$464	$1,371	$348	$20,140
PHEV20	$21,076	$2,108	$478	$1,412	$358	$20,739
PHEV25	$21,582	$2,158	$489	$1,446	$367	$21,237
PHEV30	$22,087	$2,209	$500	$1,480	$375	$21,734
PHEV35	$22,593	$2,259	$512	$1,514	$384	$22,231
PHEV40	$23,098	$2,310	$523	$1,548	$393	$22,729
PHEV45	$23,604	$2,360	$535	$1,581	$401	$23,226
PHEV50	$24,109	$2,411	$546	$1,615	$410	$23,724
PHEV55	$24,615	$2,461	$558	$1,649	$418	$24,221
PHEV60	$25,120	$2,512	$569	$1,683	$427	$24,718

Table C2
Payments for Mid-Sized Car, 2010 $ (sales tax and registration payments are included in the loan).

Vehicle type	MSRP	Down payment	Monthly payment	Sales tax	Title and registration	Loan
CV	$19,373	$1,937	$439	$1,298	$329	$19,063
HEV0	$23,256	$2,326	$527	$1,558	$395	$22,884
PHEV5	$23,714	$2,371	$537	$1,589	$403	$23,335
PHEV10	$24,172	$2,417	$548	$1,620	$411	$23,786
PHEV15	$24,631	$2,463	$558	$1,650	$419	$24,237
PHEV20	$25,089	$2,509	$568	$1,681	$427	$24,688
PHEV25	$25,599	$2,560	$580	$1,715	$435	$25,189
PHEV30	$26,109	$2,611	$592	$1,749	$444	$25,691
PHEV35	$26,619	$2,662	$603	$1,783	$453	$26,193
PHEV40	$27,129	$2,713	$615	$1,818	$461	$26,694
PHEV45	$27,638	$2,764	$626	$1,852	$470	$27,196
PHEV50	$28,148	$2,815	$638	$1,886	$479	$27,698
PHEV55	$28,658	$2,866	$649	$1,920	$487	$28,200
PHEV60	$29,168	$2,917	$661	$1,954	$496	$28,701

Table C3
Payments for Mid-sized SUV, 2010 $ (sales tax and registration payments are included in the loan).

Vehicle type	MSRP	Down payment	Monthly payment	Sales tax	Title and registration	Loan
CV	$27,391	$2,739	$621	$1,835	$466	$26,953
HEV0	$32,969	$3,297	$747	$2,209	$560	$32,442
PHEV5	$33,664	$3,366	$763	$2,256	$572	$33,126
PHEV10	$34,359	$3,436	$778	$2,302	$584	$33,810
PHEV15	$35,055	$3,505	$794	$2,349	$596	$34,494
PHEV20	$35,750	$3,575	$810	$2,395	$608	$35,178
PHEV25	$36,157	$3,616	$819	$2,423	$615	$35,579
PHEV30	$36,565	$3,657	$828	$2,450	$622	$35,980
PHEV35	$36,973	$3,697	$838	$2,477	$629	$36,381
PHEV40	$37,381	$3,738	$847	$2,505	$635	$36,783
PHEV45	$37,788	$3,779	$856	$2,532	$642	$37,184
PHEV50	$38,196	$3,820	$865	$2,559	$649	$37,585
PHEV55	$38,604	$3,860	$875	$2,586	$656	$37,986
PHEV60	$39,012	$3,901	$884	$2,614	$663	$38,387

Table C4
Payments for Large SUV, 2010 $ (sales tax and registration payments are included in the loan).

Vehicle type	MSRP	Down payment	Monthly payment	Sales tax	Title and registration	Loan
CV	$27,003	$2,700	$612	$1,809	$459	$26,571
HEV0	$32,640	$3,264	$739	$2,187	$555	$32,117
PHEV5	$33,103	$3,310	$750	$2,218	$563	$32,573
PHEV10	$33,566	$3,357	$760	$2,249	$571	$33,029
PHEV15	$34,029	$3,403	$771	$2,280	$578	$33,485
PHEV20	$34,493	$3,449	$781	$2,311	$586	$33,941
PHEV25	$35,082	$3,508	$795	$2,350	$596	$34,520
PHEV30	$35,671	$3,567	$808	$2,390	$606	$35,100
PHEV35	$36,260	$3,626	$822	$2,429	$616	$35,680
PHEV40	$36,849	$3,685	$835	$2,469	$626	$36,259
PHEV45	$37,438	$3,744	$848	$2,508	$636	$36,839
PHEV50	$38,027	$3,803	$862	$2,548	$646	$37,418
PHEV55	$38,616	$3,862	$875	$2,587	$656	$37,998
PHEV60	$39,205	$3,921	$888	$2,627	$666	$38,578

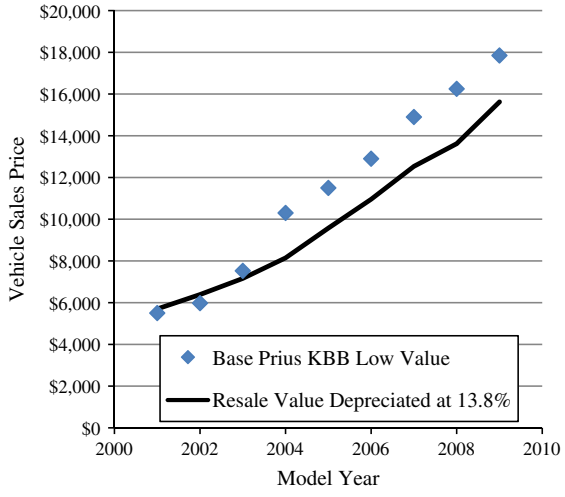

Fig. D1. Comparison of modeled and actual Prius depreciation showing that 13.8% depreciation models Generation 1 Prius (MY 2001–2003). Generation 2 Prius shows a higher resale value and therefore a lower depreciation rate.

Table D1
Comparison of modeled and actual Prius depreciation (MSN Autos, 2002 Toyota Prius Prices, http://autos.msn.com/research/vip/default.aspx?ICID=FAC&make=Toyota&model=Prius#used.)

Prius model year	Base Prius KBB low value	Base Prius MSRP in $2012	Resale value depreciated at 13.8%
2009 Gen 2	$17,850	$24,392	$15,623
2008 Gen 2	$16,250	$24,672	$13,622
2007 Gen 2	$14,900	$26,337	$12,534
2006 Gen 2	$12,900	$26,706	$10,956
2005 Gen 2	$11,500	$27,068	$9,572
2004 Gen 2	$10,300	$26,725	$8,146
2003 Gen 1	$7,525	$27,251	$7,161
2002 Gen 1	$5,975	$28,205	$6,388
2001 Gen 1	$5,500	$29,192	$5,700

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