Plug-in Electric Vehicle Projections: Scenarios and Impacts

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Technical Update, December 2015

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ABSTRACT

EPRI's Electric Transportation group maintains a plug-in electric vehicle (PEV) market adoption tool that estimates and projects the composition of the on-road vehicle fleet and calculates energy use, greenhouse gas emissions reduction, and other parameters that are important to utilities. The projection tool provides three default scenarios to estimate the market adoption of PEVs. The scenarios are not intended to be sales predictions, but they are valuable illustrations of possible future trajectories of the vehicle fleet and the associated impacts on utilities. This document provides a description of the methodologies used to develop the national and territory-level projections, an overview of the PEV fleet projection calculations and assumptions, and an explanation of the projection spreadsheet reports.

Keywords

Plug-in electric vehicles
Plug-in hybrid electric vehicles
Electric vehicles
Market penetration
Market adoption

EXECUTIVE SUMMARY

EPRI maintains a plug-in electric vehicle (PEV) market adoption tool that estimates and projects the composition of the on-road vehicle fleet and calculates energy use, greenhouse gas emissions reduction, and other parameters that are important to utilities. The tool provides three default scenarios to estimate the market adoption of PEVs.

The sales projections are highly speculative since a large number of unknown and unknowable factors are likely to affect the growth of the PEV market. The three scenarios are not intended to be sales predictions, but they are valuable to illustrate possible future trajectories of the vehicle fleet and the associated impacts on utilities. Projections are available for any region within the contiguous United States.

The national and localized PEV sales projections draw on the following data sources:

- Recent PEV registration data for 2010-2014, which EPRI has obtained at the county level
- A near-term national PEV sales estimate created by EPRI for 2015-2018
- A combination of external, publicly available forecasts.

These data sources were combined to create the three adoption scenarios. The resulting Low and High trajectories are intended for use as plausible bounding scenarios but they are not intended to capture the possible extremes in PEV market share. The Medium scenario may be considered a middle-ground estimate, but it is not intended to be used as a sales prediction.

The estimates of PEV sales for a particular territory are developed by adjusting the national scenarios on a county-by-county basis. Each national scenario is shifted up or down depending on the level of the local historical PEV sales relative to the national sales. As the projection advances farther into the future, the local effects diminish somewhat and the projections trend toward the overall national scenarios.

The PEV market adoption tool evaluates the impact of the introduction and market growth of new PEVs on the existing on-road vehicle fleet. The model uses a variety of data to simulate the evolution of the vehicle fleet over time. The software calculates the market penetration of different vehicle classes (categories of vehicle based on their typical usage patterns) and powertrain types (i.e., conventional vehicles and different kinds of PEVs) within the overall vehicle fleet. The tool generates projections of new vehicle sales, vehicle population, vehicle miles traveled (VMT), amount of electrified VMT, liquid fuel consumption (gasoline and diesel), electricity consumption, and greenhouse gas emissions. Internally to the model, each of these results is simulated separately by powertrain type, vehicle class, and age.

The territory-level projection results are presented using spreadsheet reports that contain information on new vehicle sales, fleet turnover, and various impacts of shifting vehicle energy consumption from liquid fuel to electricity.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1
PROJECTION SCENARIOS

Introduction

EPRI maintains a plug-in electric vehicle (PEV) market adoption tool that estimates and projects the composition of the on-road vehicle fleet[1] and calculates energy use, greenhouse gas emissions reduction, and other parameters that are important to utilities. The tool provides three default scenarios to estimate the market adoption of PEVs.

This report provides a description of the national and local projection scenarios for PEV market share, an overview of the PEV fleet projection calculations and assumptions, and an explanation of the projection output spreadsheet reports. This document serves as an update to the "Territory-level Sales Projections" chapter (Chapter 3) of EPRI report 3002003004, published in late 2014.

The sales projections are highly speculative since a large number of unknown and unknowable factors are likely to affect the growth of the PEV market. The three scenarios are not intended to be sales predictions, but they are valuable to illustrate possible future trajectories of the vehicle fleet and the associated impacts on utilities. Projections are available for any region within the contiguous United States.

This chapter describes the national and localized PEV sales projections, which draw on the following data sources:

- Recent PEV registration data for 2010-2014, which EPRI has obtained at the county level. EPRI report 3002003004 describes the registration data.
- A near-term national PEV sales estimate created by EPRI for 2015-2018
- A combination of external, publicly available forecasts.

Historic Sales and Near-term Projection

EPRI maintains a near-term projection of annual U.S. PEV sales that is based on a bottom-up estimate of PEV sales by vehicle model. The forecast for each vehicle model is guided by a number of factors including each model's own recent sales performance, the sales performance of similar vehicle models, availability, and, in increasingly rare cases, sales projections by the automakers. In spite of currently relatively low gasoline prices, which reduce the refueling cost benefits of PEVs, and relatively low or negative PEV sales growth in some parts of the United States, PEV sales are expected to continue to grow with about ten new light-duty PEV models scheduled to come on the market in the next three years. Table 1-1 shows the current near-term projection for the United States, which shows sales tripling between 2015 and 2018. It is

[1] The use of the term "fleet" in this report refers to the total population of new and existing vehicles currently in operation.

Table 1-1
Historical PEV Sales and Near-term Projection

	Historical Sales			Projected Sales				
	2009-2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Total**
Large Manufacturer								
Chevrolet Volt	31,458	23,094	18,805	16,000	20,000	30,000	40,000	**179,357**
Nissan Leaf	19,512	22,610	30,200	18,000	20,000	30,000	40,000	**180,322**
Ford Transit Connect	525	0	0	0	0	0	0	**525**
Mitsubishi i	668	1,029	196	150	500	500	500	**3,543**
Toyota Prius plug-in	12,750	12,088	13,264	4,000	4,000	15,000	20,000	**81,102**
BMW ActiveE	671	0	0	0	0	0	0	**671**
Ford Focus Electric	685	1,738	1,964	2,000	2,000	2,000	2,000	**12,387**
Ford C-Max Energi	2,374	7,154	8,433	8,000	10,000	12,000	15,000	**62,961**
Honda Fit EV	93	569	407	5	0	0	0	**1,074**
Toyota RAV4 EV	192	1,096	1,184	0	0	0	0	**2,472**
Scion iQ EV	0	60	30	0	0	0	0	**90**
Honda Accord PHEV	0	526	449	100	0	0	0	**1,075**
Ford Fusion Energi	0	6,089	11,550	10,000	12,000	15,000	25,000	**79,639**
Fiat 500e	0	405	1,503	4,000	4,000	5,000	5,000	**19,908**
Chevrolet Spark EV	0	539	1,145	3,500	4,000	5,000	5,000	**19,184**
Porsche Panamera S E-Hybrid	0	86	879	500	1,000	1,500	2,000	**5,965**
Cadillac ELR	0	6	1,310	1,600	1,500	2,500	4,000	**10,916**
BMW i3	0	0	6,092	10,000	15,000	20,000	30,000	**81,092**
BMW i8	0	0	555	1,500	2,000	3,000	4,000	**11,055**
Porsche Cayenne S E-Hybrid	0	0	112	1,000	1,000	1,500	2,000	**5,612**
Mercedes B-Class Electric Drive	0	0	774	2,500	3,000	4,000	5,000	**15,274**
Kia Soul EV	0	0	359	1,000	1,500	2,000	3,000	**7,859**
Volkswagen E-Golf	0	0	357	3,000	4,000	6,000	8,000	**21,357**
Audi A3 Sportback e-tron	0	0	0	200	2,000	3,000	4,000	**9,200**
Mercedes S500 Plug-In Hybrid	0	0	0	200	1,000	1,500	2,000	**4,700**
Volvo XC90 Twin Engine	0	0	0	500	1,000	1,500	2,000	**5,000**
BMW X5 xDrive 40e	0	0	0	500	1,000	1,500	2,000	**5,000**
Hyundai Sonata PHEV	0	0	0	1,000	6,000	8,000	12,000	**27,000**
Mitsubishi Outlander PHEV	0	0	0	0	2,500	5,000	7,500	**15,000**
Chevrolet Bolt	0	0	0	0	0	10,000	20,000	**30,000**
Audi e-tron crossover	0	0	0	0	0	0	500	**500**
Porsche "Pajun"	0	0	0	0	0	0	500	**500**
Unannounced EVs	0	0	0	0	0	2,500	10,000	**12,500**
Unannounced PHEVs	0	0	0	0	0	2,500	10,000	**12,500**
Small/Startup Manufacturer								
Tesla Roadster	2,140	0	0	0	0	0	0	**2,140**
Think City EV	350	0	0	0	0	0	0	**350**
Smart fortwo ED	777	923	2,594	2,000	2,500	2,500	2,500	**13,794**
Fisker/Elux Karma	1,500	100	0	0	100	500	500	**2,700**
Tesla Model S	2,620	18,650	16,550	25,000	30,000	36,000	30,000	**158,820**
Coda	100	50	0	0	0	0	0	**150**
VIA (both trucks and vans)	0	0	0	2,000	3,000	4,000	5,000	**14,000**
Tesla Model X	0	0	0	5,000	15,000	20,000	25,000	**65,000**
Tesla Model III	0	0	0	0	0	5,000	20,000	**25,000**
Total	76,415	96,812	118,712	123,255	169,600	258,500	364,000	**1,207,294**

important to note that not all regions will experience such rapid growth in the near-term. California and some other regions are expected to continue to lead PEV sales in the near future.

The bottom-up sales projection considers light-duty vehicles only and excludes motorcycles. There have been some sales of electric motorcycles and heavy-duty PEVs to date, and a number of prototype and demonstration vehicles are under development, but specific sales data are not currently available. However, the adoption tool can provide simplified projections of heavy-duty PEV sales, as described in the "Vehicle Classes" section below.

External Studies

The trajectories of EPRI's three market adoption scenarios are guided by a set of external, publicly available PEV projections. These external estimates are driven by a wide variety of assumptions and levels of forecast model sophistication, and span different timeframes. Figure 1-1 shows a selection of the most relevant external forecasts that were considered for evaluation. The trajectories are presented here as the PEV new-vehicle market share, or in other words, the amount of new PEV sales as a percentage of all light-duty vehicle sales. The trajectories illustrated in Figure 1-1 apply to light-duty on-road vehicles only.

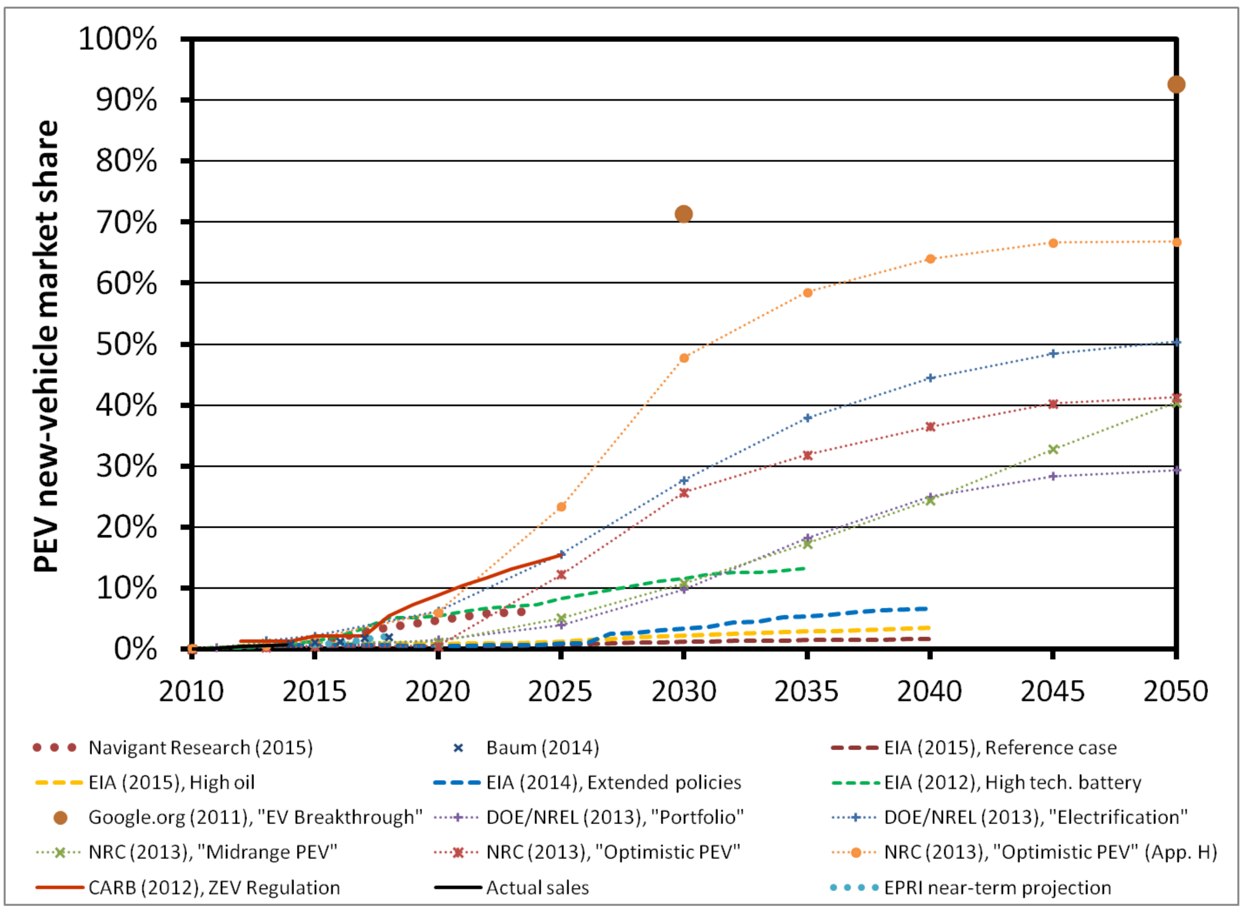

Figure 1-1
Selected external PEV projections

Determination of National Scenarios

Given the necessity of generating projections in order to estimate the potential impact of PEVs on utilities, EPRI has created a simplified methodology that provides three scenarios to estimate the market adoption of PEVs. The Low and High trajectories are intended to be used as plausible bounding scenarios. The Medium scenario may be considered a middle-ground estimate, but it is not intended to be used as a sales prediction.

In order to arrive at two bounding scenarios and a Medium scenario, the set of external scenarios shown on Figure 1-1 was further down-selected. Figure 1-2 illustrates the down-selected set of external scenarios along with three proxy scenarios, which were developed to guide the Low, Medium, and High scenarios.

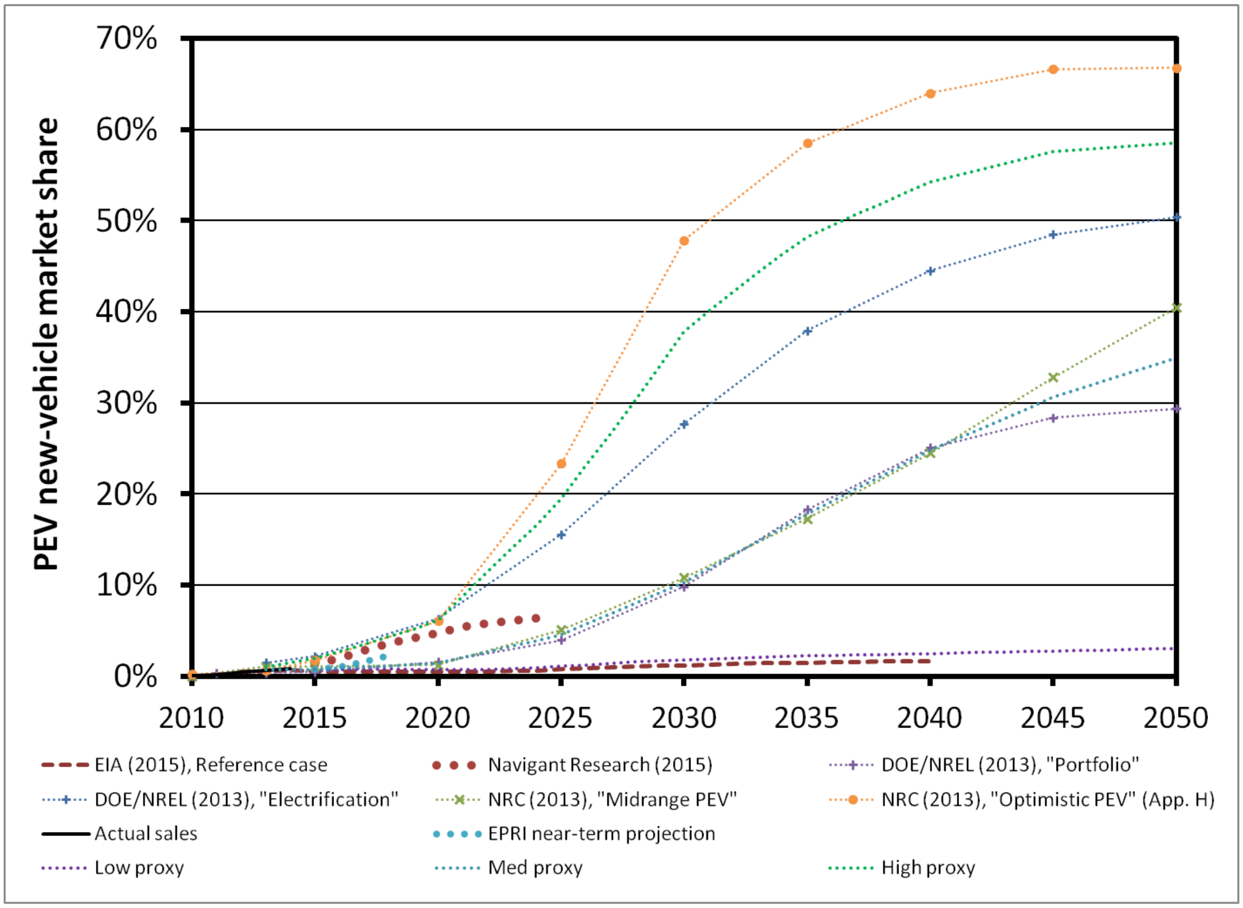

Figure 1-2
Down-selected external projections with proxy scenarios

The three proxy scenarios were developed as follows:

- The Reference case from the U.S. Energy Information Administration's (EIA) Annual Energy Outlook (AEO) 2015 (EIA, 2015) was selected as the fundamental component of the Low scenario. The AEO uses a vehicle choice model and assumptions that are generally unfavorable toward PEVs. In fact, the actual PEV market shares in 2013 and 2014 were about 25% higher than the AEO 2015 Reference case, and the 2015 sales are expected to be approximately 75% higher than the AEO-predicted sales. In light of this, the proxy Low scenario was set as the AEO Reference case multiplied by 1.5 (50% higher).
- The proxy for the Medium scenario was determined as a simple year-by-year numerical average of the "Midrange PEV" scenario from National Research Council's (NRC) *Transitions to Alternative Vehicles and Fuels* report (NRC, 2013) and the "Portfolio" scenario from the *Infrastructure Expansion* report published by the National Renewable Energy Laboratory (NREL) on behalf of the U.S. Department of Energy (DOE, 2013). These two external scenarios were chosen because of their moderate outlook for PEV adoption.
- The High scenario proxy is an average of two scenarios that utilize assumptions that are highly favorable toward PEV adoption: the "Optimistic PEV" case in Appendix H of NRC (2013) and the "Electrification" case of DOE/NREL (2013).

The Navigant Research (2015) projection was considered in the formulation of the scenarios but it appears to be quite optimistic initially and shows a growth rate that slows around 2024; therefore, it was not used directly.

Although the general intent behind the Low and High scenarios is to define bounding scenarios, these scenarios are not intended to capture the possible extremes in PEV market share, particularly over the long term (i.e., in 2050). For example, the AEO2015 Low Oil price scenario (not shown on Figure 1-2) foresees a PEV market that has only about 1.0% market share in 2050, which is roughly 40% lower than the AEO2015 Reference case that was used as the basis for the Low scenario. Furthermore, the Google.org "EV Breakthrough" trajectory (Google.org, 2011) presents a scenario that has a PEV market share of over 90% by 2050. While that is certainly a possible outcome and represents a useful scenario for evaluation, it was deemed to be excessively high for the purpose of illustrations to be used by utilities on a regular basis. Rather than representing extremes, the Low and High scenarios are intended to illustrate market conditions that are substantially (but not extremely) unfavorable and favorable, respectively, to PEVs.

Once the proxy scenarios were developed, each of them was realigned to emanate from the actual PEV sales rate in 2014 and the Medium scenario was aligned with the near-term projection through 2018. This realignment leads to the national Low, Medium, and High scenarios, which are illustrated by Figure 1-3.

Certain technologies and fundamental changes to the usage patterns of vehicles could substantially affect the rate of PEV adoption. The developing phenomena of autonomous self-driving cars and ride-sharing may transform the PEV market if these technologies and behaviors become widespread and are coupled with sufficient technological progress and cost reductions with batteries and power electronics. Autonomous vehicles and ride-sharing were not explicitly considered by the set of external scenarios that were evaluated for this study, but it is very possible that these factors, if successful, could lead to drastic changes in the light-duty vehicle market. Most likely there would be fewer vehicles in operation but on average those vehicles would have much higher utilization. In an environment where technological advancement, component costs, and fuel prices are such that PEVs have a favorable total cost of ownership, then greater per-vehicle utilization would further improve the benefits of PEVs and accelerate their adoption.

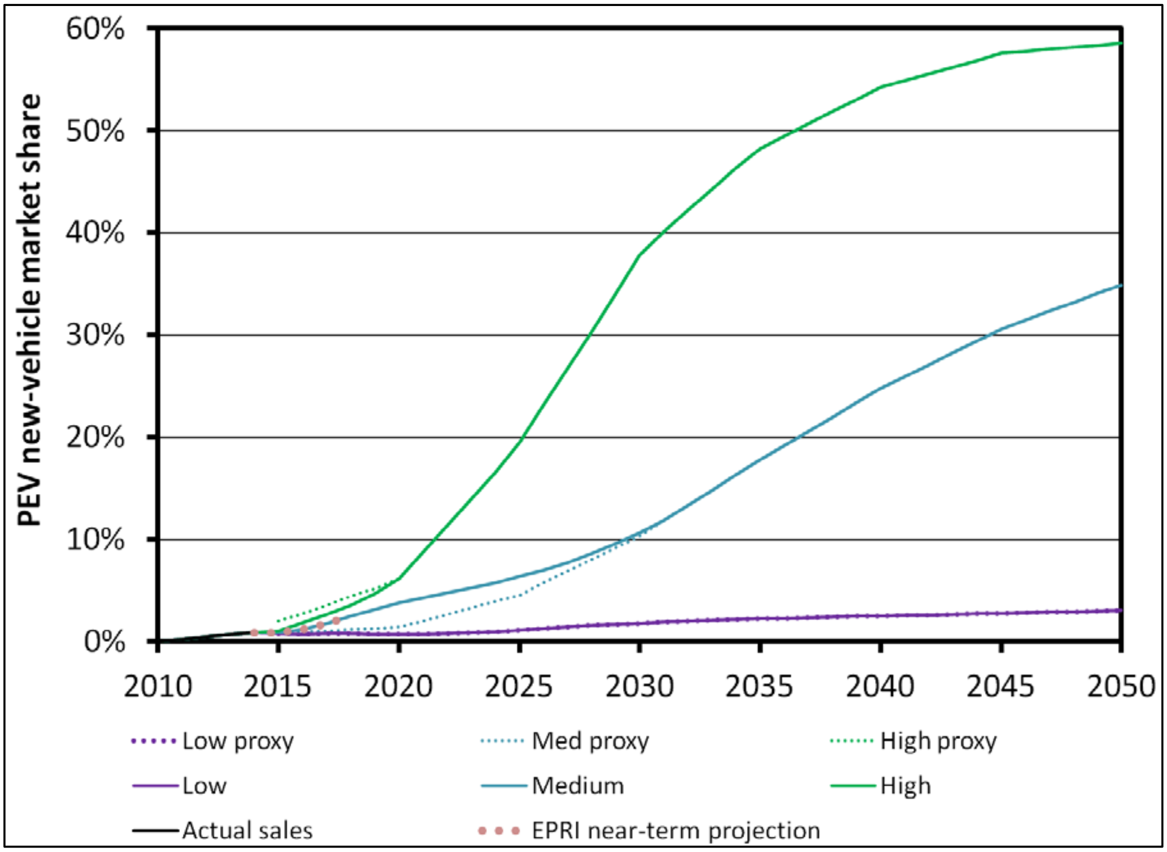

Figure 1-3
National projection scenarios

Vehicle Classes

In order to categorize the various classes of on-road vehicles, EPRI's vehicle sales projections adopt the 13 vehicle categories used by the United States Environmental Protection Agency's (EPA) Motor Vehicle Emission Simulator (MOVES) software (EPA, 2009). Table 1-2 lists these vehicle categories. The MOVES classifications group vehicles by their typical daily activity patterns rather than by the weight classes used in other classifications, such as "light duty vehicle" (LDV), "medium duty," and "heavy duty vehicle" (HDV). Despite this, most of the MOVES classes individually include either light-duty or heavy-duty vehicles, but two classes (Passenger Truck and Light Commercial Truck) include a mix of light-duty and heavy-duty. The naming of the MOVES category "Light Commercial Truck" is particularly misleading because although the majority of the category is light-duty, about 17% are "lighter" heavy-duty commercial trucks. The same applies to a lesser extent to the "Passenger Truck" category.

Table 1-2
Vehicle classes

	Vehicle Class	PEV Adoption (Tool Default)	Likely PEV Adoption	Vehicle Class Description
LDV	Motorcycle		X	Motorcycle
LDV	Passenger Car	X	X	Passenger Car
Mixed	Passenger Truck	LDV only	X	Minivans, pickups, SUVs and other 2-axle / 4-tire trucks used primarily for personal transportation. This category is approximately 93% light-duty and 7% heavy-duty (on a vehicle-miles traveled basis).
Mixed	Light Commercial Truck	LDV only	X	Minivans, pickups, SUVs and other 2-axle / 4-tire trucks used primarily for commercial applications. This category is approximately 83% light-duty and 17% heavy-duty (on a vehicle-miles traveled basis).
HDV	Intercity Bus			Buses which are not transit buses or school buses, e.g. those used primarily by commercial carriers for city-to-city transport.
HDV	Transit Bus		X	Buses used for public transit
HDV	School Bus		X	School and church buses
HDV	Refuse Truck		X	Garbage and recycling trucks
HDV	Single Unit Short-haul Truck		X	Single-unit trucks with majority of operation within 200 miles of home base
HDV	Single Unit Long-haul Truck			Single-unit trucks with majority of operation outside of 200 miles of home base
HDV	Motor Home			Motor Home
HDV	Combination Short-haul Truck			Combination trucks with majority of operation within 200 miles of home base
HDV	Combination Long-haul Truck			Combination trucks with majority of operation outside of 200 miles of home base

By default, the PEV adoption tool outputs results for light-duty vehicles excluding motorcycles; this includes Passenger Cars and the majority of the Passenger Truck and Light Commercial Truck categories. The tool may be configured to generate results that include additional vehicle classes. Some other EPRI studies have assumed that most of the vehicle classes that travel less than 200 miles per day are assumed to be electrified, which includes the eight vehicle categories as indicated by the "Likely PEV Adoption" column of Table 1-2. Although it is possible that additional vehicle classes will also be electrified to some degree, it is likely that the energy-intensive operational requirements and limited market size of those other classes will present significant challenges.

The projection tool uses an approach that phases PEV sales into various vehicle classes over time. The allocation of PEV sales among vehicle classes initially follows the bottom-up projection through 2018. From 2015 to 2018 that projection assumes that the majority of sales will be in the Passenger Car class with sales of Passenger Trucks ramping up fairly quickly as several sport-utility PEVs come onto the market during 2014 to 2016. Then, PEV models are assumed to become available within the other vehicle categories following a linear ramp-up in market share over the period of 2016 to 2025. By 2025 it is assumed that the PEV market share is equal across all vehicle classes within the subset of classes that experience PEV adoption.

Allocation of PEV Subtypes

The projection tool considers a number of different electric vehicle types. A Battery Electric Vehicle (BEV) relies solely on an on-board battery for stored energy, and once the battery has been depleted, a BEV cannot drive further until the battery is recharged. A Plug-in Hybrid Electric Vehicle (PHEV) utilizes both grid electricity and another fuel (typically gasoline or diesel) as energy sources; a PHEV can continue operating with a depleted battery, but in general it is beneficial to recharge the battery as frequently as possible.[2] BEVs and PHEVs taken together are designated PEVs, and both PEV types draw electricity from the grid.

The PEV sales within each vehicle class are categorized into sub-types according to all-electric range (AER), the distance an individual vehicle can travel on electricity after a full recharge. For "blended" PHEVs (such as the first-generation Prius Plug-in, which relies on the engine under certain conditions while in electric mode), this is the distance that an equivalent non-blended PHEV could drive on electric power. This report and the results reports identify the AER of PHEVs and BEVs by appending the AER in miles to the 'PHEV' or 'BEV' descriptor. For example, a PHEV 20 is a plug-in hybrid with 20 miles of electric range. The PEV projections consider PHEV 10, PHEV 20, and PHEV 40 configurations and a single BEV type with that has a 100 mile range. (BEVs with various driving ranges are lumped into a single BEV category.) A PHEV 10 is similar to a first-generation Plug-in Prius, a PHEV 20 is similar to a Ford Fusion Energi or Ford C-MAX Energi, and a PHEV 40 is similar to a first-generation Chevrolet Volt.

Figure 1-4 shows how the new PEV sales are distributed across the various PEV types over time. The allocation is based on actual data through 2014 and then follows the vehicle types assumed by the bottom-up projection through 2018. The distribution then shifts in the future toward vehicles with greater AERs, based on the assumption that as battery costs decrease the PEV market will favor vehicles with greater electric range. By 2030, the allocation of new PEV sales is 20% PHEV 20, 25% PHEV 40, and 55% BEV 100. On a national basis, this distribution of PEV types applies equally to all vehicle categories that contain PEV sales. Locally, the distribution may vary as explained below.

Hybrid-electric vehicles (HEV) are sometimes designated as "electrified" vehicles, but HEVs do not recharge from the grid and instead rely on regenerative braking and generation provided by the engine to charge the battery. Due to increased regulatory and consumer pressure to improve fuel economy, automakers are including increasing levels of hybrid-electric technologies into conventional vehicles, such that the line between HEVs and conventional vehicles is becoming increasingly blurred. Although the projection tool currently categorizes HEVs as a separate vehicle type, the development team intends to remove the distinction between conventional vehicles and the various degrees of hybridized vehicles.

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[2] The PHEV categories used in this study include so-called "extended-range electric vehicles."

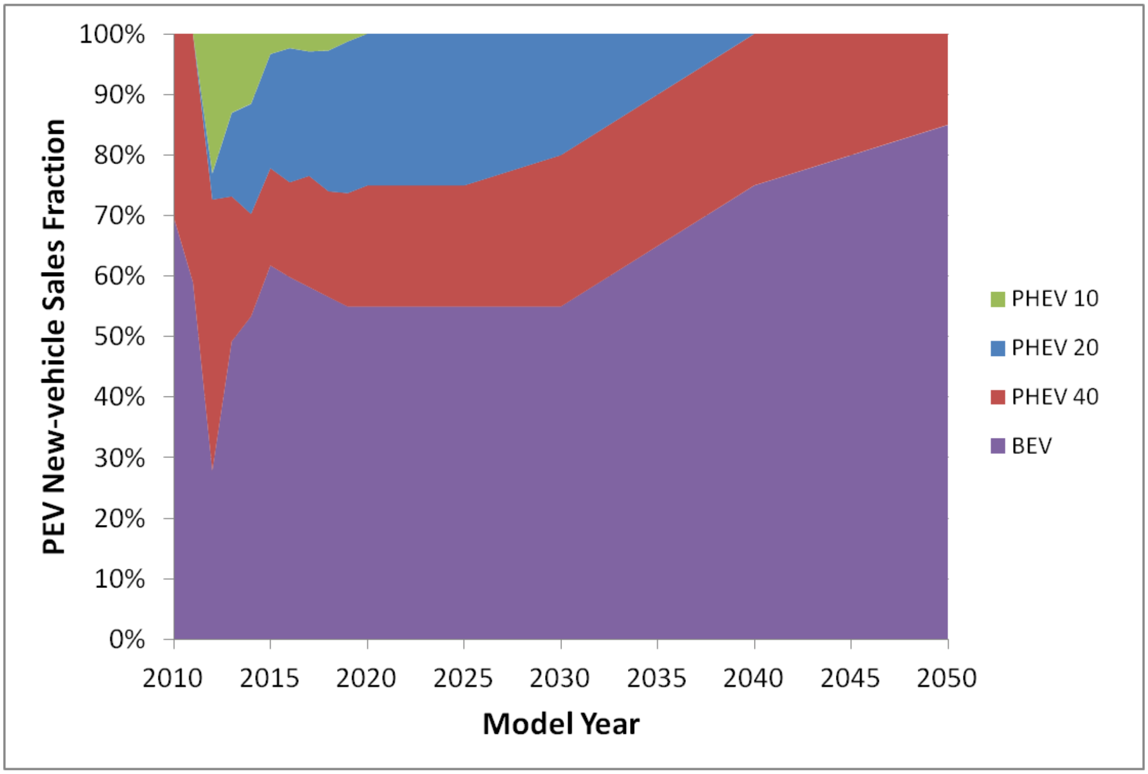

Figure 1-4
Allocation of PEV Types

Localized PEV Projections

This subsection discusses the procedures used to localize the national projections to a specific territory or region. Starting with the national projections, the PEV market shares for a particular territory are adjusted on a county-by-county basis. The projections are initially tied to the trajectory of the local sales using actual county-level PEV sales data for 2010 through 2014. Beyond 2014, the national scenario is shifted up or down depending on the level of the local historical PEV sales relative to the national sales. Specifically, the local sales bias is based on the local PEV market share in 2013 and 2014. As the projection advances farther into the future, the local effects diminish somewhat and the projections trend toward the overall national scenarios. This assumes that PEV technology becomes increasingly mainstream and that the geographic distribution of PEVs becomes relatively homogenous. However, in regions where the local PEV sales rate in 2013 and 2014 are significantly different than the national sales rate, that difference continues to impact the localized estimate over the long term (through 2050).

The local distribution of PEV sales by vehicle class follows the same assumptions used for the national projections, which are explained in the "Vehicle Classes" section. Furthermore, the distribution of sales among the various PEV subtypes (BEV, PHEV40, etc.) follows the same methodology used to localize overall PEV sales. The share of each subtype starting in 2015 is based on the share within the local region of that type in 2013 and 2014. As the simulation progresses, the PEV mix trends toward the national-average allocation.

The geographic distribution of PEV sales for the Medium scenario was tuned so that sales within California meet California's zero-emissions vehicle (ZEV) regulation through the year 2025

(California Air Resources Board, 2011). Since actual PEV sales in California through 2014 (and 2015, based on available data to date) have exceeded the ZEV requirement, the resulting PEV market share trajectory also exceeds the mandated levels through 2024 (and meets the requirement in 2025). The so-called "Section 177 states" that have adopted the California ZEV requirement are not required to fully meet the standard until 2018. The PEV sales in these states to date (for 2010 through 2014) vary greatly, and in some cases are below the national average sales rate. The analysis of sales in the Section 177 states is ongoing, and the projections for these states have not been constrained to meet the ZEV mandate. Therefore, at the present time the projection results for the Medium scenario in certain Section 177 states may not meet the ZEV requirement, particularly if the PEV sales in the state were not sufficiently above the national average in 2013 and 2014.

2
FLEET CALCULATIONS

PEV Market Adoption Tool

The PEV market adoption tool evaluates the impact of the introduction and market growth of new PEVs on the existing on-road vehicle fleet. The model uses data and assumptions for vehicle miles traveled (VMT), vehicle survivability and retirement, new vehicle market shares, and vehicle performance to simulate the evolution of the vehicle fleet over time. The software calculates the market penetration of different vehicle classes and powertrain types within the overall on-road vehicle fleet and generates projections of new vehicle sales, vehicle population, VMT, amount of electrified VMT, liquid fuel consumption (gasoline and diesel), electricity consumption, and greenhouse gas emissions. Internally to the model, each of these results is simulated separately by powertrain type, vehicle class, and age.

Fleet Turnover

The scenarios presented in Chapter 1 represent the market shares for new vehicles. It is important to consider the effects of fleet turnover to understand the impacts on the overall vehicle market. A vehicle fleet turnover model is used to project the evolution of each vehicle class within the fleet and track how new vehicle powertrain types impact the fleet over time. The turnover model implemented by the PEV adoption tool uses the vehicle population and VMT growth calculation formulas described in the MOVES 2009 Software Design and Reference Manual (EPA, 2009).

Figure 2-1 provides an overview of the turnover model. The model tracks vehicle cohorts over time so that vehicles "age" as the calculation progresses. This cohort tracking accounts for changes in vehicle usage and performance as the market evolves. The turnover model uses the projection scenarios for new-vehicle market share along with other necessary parameters to determine the vehicle population and VMT, categorized separately by vehicle class, powertrain type, and model year. The parameters required by the model include the initial vehicle population by vehicle category, vehicle age, and type; vehicle population growth over time; changes in VMT over time, both at the fleet level and per-vehicle level; vehicle survival rates (i.e., the inverse of what portion of the existing fleet is retired each year); and other data.

The base source of the initial VMT data is EPA's National Mobile Inventory Model (NMIM)[3] database, version NCD20101201, that provides the VMT by vehicle class and by county for calendar year 2008 (version NCD20101201). Vehicle population data was developed for 2008 using EPA MOVES (2010a version)[4] and NMIM data. The county-level VMT and vehicle population was forecasted using the MOVES model and is aligned with the projections in AEO 2011. The resulting forecasts of VMT and vehicle population represent the totals for all vehicle

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[3] U.S. Environmental Protection Agency, Assessment and Standards Division, Office of Transportation and Air Quality. http://www.epa.gov/otaq/nmim.htm

[4] U.S. Environmental Protection Agency, Motor Vehicle Emission Simulator model, version 2010a. http://www.epa.gov/otaq/models/moves/moves-archive.htm

types, including PEVs, HEVs, and conventional vehicles. The vehicle survival rates and other data required by the turnover model are sourced from MOVES 2010a.

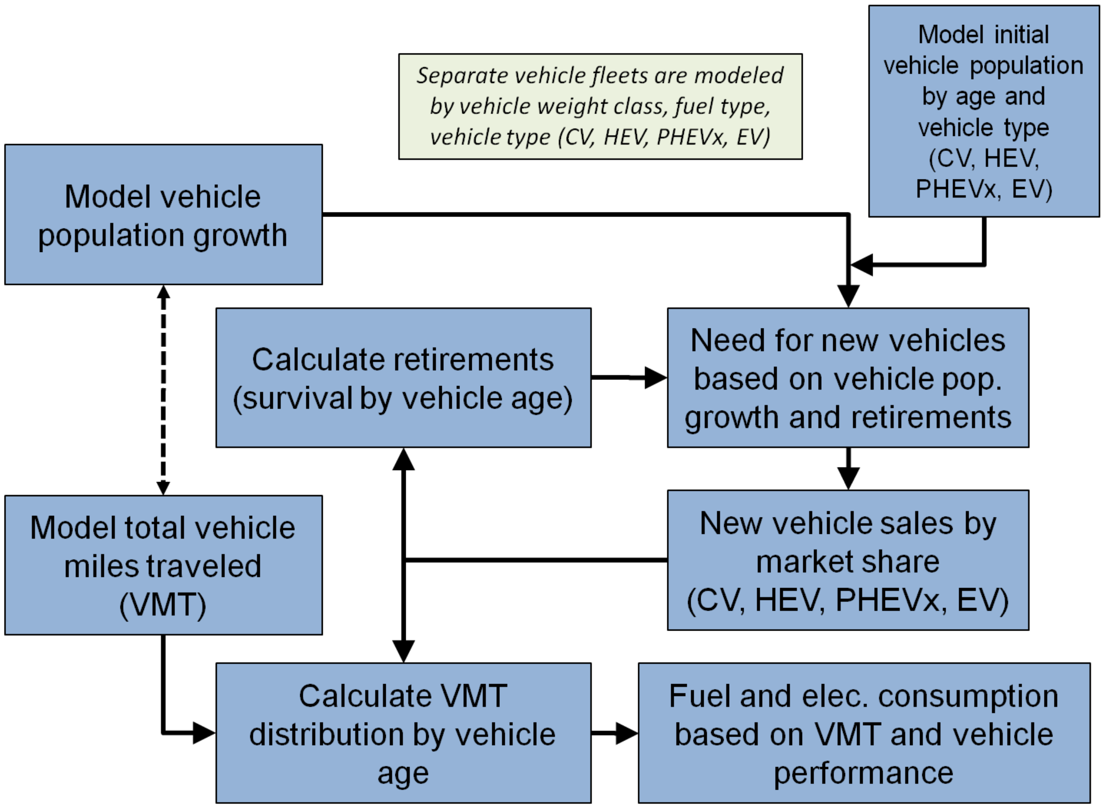

Figure 2-1
Schematic of the vehicle turnover model

Energy Consumption Calculations

The consumption of liquid fuel and electricity is determined for each vehicle class and powertrain type using assumptions of vehicle energy use per mile. The consumption data is then totaled to determine the overall impact. The calculations assume that internal combustion engines (used in all vehicle types except BEV) consume either gasoline or diesel; alternative fuels such as biofuels, natural gas or hydrogen are not explicitly considered.

The conventional and hybrid vehicle types consume only gasoline or diesel; these vehicles do not use grid electricity. The calculations assume that PHEVs operate in one of two distinct modes, either as battery-electric vehicles (during which time no gasoline/diesel is consumed) or as charge-sustaining hybrid-electric vehicles (when the amount of electricity consumed is effectively zero). "Blended" PHEV operation, where the battery charge depletes while the engine is also operating, is not considered. The portion of PHEV operation in each mode is determined by the utility factor, which is described in a separate section below. BEVs primarily use electricity only, but the calculations assume that some portion of a BEV's annual mileage is substituted with a longer-range vehicle that consumes gasoline or diesel, as explained below.

Gasoline and Diesel Consumption

The fuel economy of light-duty vehicles follows the assumptions in the Annual Energy Outlook (AEO) 2013[5] through 2025, after which it is assumed that the fuel economy continues to improve at 0.5% per year. The calculations assume that PHEVs that travel beyond their all-electric range have the same fuel economy as an HEV in the same vehicle class.

The fuel economy assumptions for heavy-duty conventional vehicles follow the default values in the EPA MOVES software for model year 2010, and then track the rates of improvement projected by AEO2013 for medium-duty vehicles. For heavy-duty HEVs (and PHEVs operating beyond their all-electric range), the fuel economy ratings are based on the corresponding conventional vehicle in the same vehicle category and adjusted using estimates available from the National Academy of Sciences (National Research Council, 2010).

Electricity Consumption

The PEV energy economy assumptions are based on AEO2013 projections for various light-duty vehicle types through 2025, with continued improvement at 0.5% per year beyond 2025. For simplicity, PEV types (BEVs and PHEVs with different electric ranges) are assumed to have the same electricity consumption per mile. However, diesel-fueled PHEVs are assumed to have slightly higher electricity consumption than gasoline PHEVs when operating as electric vehicles, based on an assumption that a diesel hybrid powertrain would typically weigh more than a gasoline powertrain.

The electricity consumption of heavy-duty PEVs is based on the HEV fuel economy, in miles per gallon (mpg), for the corresponding vehicle category multiplied by an appropriate energy efficiency ratio.[6] The resulting "mpge" (miles per gallon equivalent) quantities were then converted to equivalent measures of electricity consumption.

Utility Factor

PHEVs can travel beyond their all-electric range through the use of an on-board range-extending engine. This means that over the vehicle's lifetime, some portion of the vehicle's travel will be provided by grid-sourced electricity and the remaining will be provided by another fuel. The majority of present-day PHEVs use gasoline engines, but the projections assume that some future PHEVs will incorporate diesel engines.

"Utility factor" is a term that describes the fraction of PEV operation that uses grid electricity as the energy source. Utility factors vary with each individual vehicle based on its usage pattern and are affected by opportunities to charge the vehicle. In general, PHEVs that are driven very long distances between recharging events will have a low utility factor, while PHEVs that perform many short trips will have a very high utility factor. Since BEVs have longer "refueling" (charging) times than many other vehicle types, there will be certain long trips when a BEV driver will choose to use a substitute vehicle over other travel options. In most cases the alternate

[5] AEO2013, Table 59.

[6] Heavy-duty PEVs are not considered by AEO2013, so electricity consumption estimates were not available from that source.

vehicle will be a vehicle type that uses a fuel other than electricity, so the concept of utility factor may be extended to BEVs as well.

Table 2-1 shows the utility factor assumptions, which are based on the methodology described in EPRI report 1021848. The utility factors were determined assuming that charging is available only at the driver's home and that the charge rate is 3.3 kW, both of which are likely to be conservative assumptions over the long term. While the evaluation of BEV utility factors is more complex than for PHEVs, the projections use a simplifying assumption that the BEV utility factor is equal to that of a PHEV that has 80 miles of all-electric range. This simple but conservative estimate assumes that long trips that cannot be completed with the BEV are instead driven using a substitute hybrid vehicle.

Table 2-1
PEV Utility Factor Assumptions

	Utility Factors			
Annual VMT (mi)	**PHEV10**	**PHEV20**	**PHEV40**	**BEV**
10,000	34%	53%	72%	85%
16,000	28%	46%	67%	84%

The derivation of utility factors was based on driving pattern data and assumptions regarding charging availability for personal, non-commercial vehicles. Due to the limited availability of driving pattern data for commercial vehicles and a wide range of potential applications (and thus recharging patterns) of larger PEVs, utility factors for heavy-duty PEVs have not been evaluated in detail. For simplicity, the same utility factor assumptions are applied to all vehicle classes.

Fuel Savings and CO_2 Reduction

PEVs are intended to displace the consumption of liquid fuels in favor of electricity. The PEV adoption tool calculates the reduction in liquid fuel consumption as the difference in the fuel consumed between the scenarios with PEVs and a base case without PEVs. The vehicle fleet in the base case includes conventional and hybrid vehicles. By default, the PEV adoption tool assumes that PEV sales displace HEV sales. This leads to a conservative estimate of liquid fuel savings, because HEVs are more efficient than traditional conventional vehicles.

The amount of greenhouse gas (GHG) reduction includes the avoided emissions of reduced gasoline and diesel consumption and accounts for additional emissions due to the electricity consumption of PEVs. The greenhouse gas intensities (emissions per unit of fuel or electricity) of liquid fuels are sourced from the California Low Carbon Fuel Standard, Tables 1 and 2 (California Air Resources Board, 2011). The GHG intensities of electricity are sourced from the 2007 EPRI-NRDC study (EPRI report 1015325).

3
PROJECTION SPREADSHEET REPORTS

The territory-level projection reports contain information on new vehicle sales, fleet turnover, and various impacts of shifting vehicle energy consumption from liquid fuel to electricity. The following subsections describe the various tabs contained in the report spreadsheet file.

The reports provide results for the combined set of vehicle classes that were considered for the particular model run. The default vehicle classes considered are indicated on the "Tool Default" column of Table 1-2.

Territory

"Territory" shows the counties included in the projection, including the fraction of each county considered, allowing the assumed service area to be validated.

New-vehicle market share

This tab shows the numerical PEV new vehicle market share for each scenario. This is the amount of new PEV sales as a percentage of the total new vehicle sales, shown as a weighted average over the vehicle classes considered for the particular model run. This data includes the fraction of the market allocated to different vehicle types, including PHEV 10, PHEV 20, PHEV 40, and EV. These vehicle types are modeled separately since they have different energy usage characteristics.

New-vehicle market

This chart shows the PEV new-vehicle market share data for each scenario.

Fleet penetration

This graph illustrates the "fleet penetration," which is the rate at which PEVs flow into the overall fleet, i.e. the quantity of PEVs as a fraction of the total vehicle fleet including existing vehicles of all ages. Since the total fleet contains the vehicles already in service in addition to the new vehicles, the fleet penetration percentages are smaller and lag behind the new-vehicle market shares.

New sales[7]

This chart shows new PEV sales in terms of the absolute number of vehicles. This is the PEV new-vehicle market share multiplied by the total assumed sales within the region, for the specific set of vehicle classes considered.

[7] Prior to December 2015, the "New sales" tab was labeled "New fleet."

Fleet size[8]

This chart shows the total PEV fleet size within the region. The fleet size is calculated using the vehicle turnover model and represents the number of PEVs in service in a particular year. It includes additions due to new vehicle sales and subtractions due to retirement or scrappage (based on historical rates for all vehicles).

Electric consumption, Fuel saved, GHG reduction[9]

These charts show the electricity consumption of PEVs, the fuel saved relative to the trajectory of the base-case fleet without PEVs, and greenhouse gas emission reductions due to this fuel switching. The "Fuel saved" chart presents the reduction in terms of gasoline-equivalent gallons of avoided gasoline and diesel consumption. The "GHG reduction" chart presents the results as CO_2e, i.e., the greenhouse gas reduction presented as a CO_2-equivalent quantity. The GHG intensity data is included in the spreadsheet on the "CO2" tab.

PEV load profile, Fleet load profile

These charts were present in earlier versions of the results files. These charts show estimated charging load profiles of the PEV fleet in terms of per-PEV load and total fleet load. The load estimates are based on a limited set of assumed scenarios in order to show sample daily profiles, but in general a wide variety of potential PEV load shapes is possible depending on local conditions and the presence of load management programs. Before using these load shapes, please consult with Electric Transportation staff to discuss the appropriateness of the load shape for a particular territory and purpose.

Other tabs

The other tabs contain the numerical data used in the charts described above.

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[8] Prior to December 2015, the "Fleet size" tab was labeled "Cumulative fleet."

[9] Prior to October 2014, the "Electric cons." tab was labeled "Electric load" and the "Fuel saved" tab was labeled "Gasoline saved." Prior to December 2015, the "GHG reduction" tab was labeled "CO2 reduction."

4
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