Edison Electric Institute

Power by Association℠

Transportation Electrification

Utility Fleets Leading the Charge

June 2014

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1. Executive Summary

Electrification Is Our Biggest Opportunity

Against the backdrop of slowing growth in the electric power industry, bringing electricity to the transportation sector is a huge, albeit long-term opportunity for load growth. According to the U.S. Energy Information Administration (EIA), the transportation sector is the second largest consumer of energy in the U.S. (behind electric power generation), and yet 93% of the energy consumed in transportation today comes from petroleum. Electrifying the transportation sector is a proactive, positive strategy: it enables significant economic and environmental benefits and new opportunities for consumer engagement.

Participating in Our Own Success

Despite the significant opportunity to power the transportation sector with electricity, we are not yet leading by example. An analysis of utility fleets by Utilimarc shows only about 1.7% of the vehicles purchased by electric utilities in the last five years were equipped with plug-in technology.

Convergence of Public Policies

Public policies at the federal, state, and local levels are increasingly pushing in the same direction. Automakers are investing in electrification as a compliance strategy for federal fuel economy standards as well as state air quality regulations. Leading the charge on electrification will help the electric utility industry control its own destiny and meet future regulations on its terms.

Technology Is Available and Becoming More Mainstream

In the passenger car market, plug-in technology is available at scale: approximately 200,000 Plug-in Electric Vehicles (PEVs) are on the road today. They are being adopted roughly three times as fast as hybrid vehicles during their first three years on the market. The market is evolving quickly as more automakers, also known as Original Equipment Manufacturers (OEMs), embrace the technology. Zero PEV models were available three years ago, and more than 16 models are available today.

A similar transformation is occurring in the truck market. Grid-connected vehicles are available today, including Plug-in Hybrid Electric Vehicle (PHEV) technology in pickups and electric Power Take-Off (ePTO) technology in service trucks. Plug-in technologies will continue to penetrate new sectors of the market as costs are driven down with improved technology and higher volume. For example, U.S. Department of Energy data show that battery costs fell by roughly 50% in the last four years alone.

Utilities collectively represent a major market driver. Together, we have the opportunity to lead the adoption curve and help shape the market for ourselves and for our customers.

Makes Good Business Sense Today

Plug-in technologies are available and cost-effective for a number of fleet applications today. Two examples of cost-effective applications are shown in Table 1 below. An electric Power Take-Off (ePTO) system may break even in five years, depending on idle hours eliminated. The payback period for a Chevrolet Volt plug-in hybrid sedan, as compared to a Chevrolet Cruze, is only about three years depending on miles driven and charges per day. While not every application is a candidate for electrification, the cost-effective threshold will expand to include more and more applications and technologies as the market evolves.

Table 1

	Medium Duty Bucket (ePTO)	Chevrolet Volt (PHEV)
Est. Payback Period	**5 Years***	**3.4 Years****

* Payback vs. non-ePTO bucket truck; assumes four hours of idle per day, 260 days per year

** Payback vs. Chevrolet Cruze; assumes 12,400 miles per year and 1 charge per day

Plug-in technologies enable significant operational savings (i.e., fuel cost and maintenance) over conventional vehicles. Plug-in vehicles typically have longer useful lives than conventional vehicles. The Return on Investment (ROI) will continue to improve as the incremental cost is reduced. Leveraging our industry's collective buying power could lead to price reductions, a boost in production volumes, and drive down cost across the entire plug-in vehicle production landscape.

Shifting Perspective: Fleets No Longer a Cost Center, but a Strategic Investment

The utility fleet is the point of the spear: it is a critical step toward mainstream electrification and the transformational opportunities therein, such as grid support and distributed storage. An additional benefit specific to utilities is truly a game-changer: exportable power capability could significantly reduce planned outages and provide new solutions to emergency response teams. In addition to these strategic benefits, electric technologies offer real operational advantages, including quiet operation that improves worker safety.

Utility fleet vehicles are rolling billboards and engagement tools. The value created by electrification in terms of public relations and building goodwill among our communities cannot be ignored. Customers look to utilities to be experts on electric vehicles, and we should set the example.

2. Electric Utilities Need Transportation Electrification

Between 2007 and 2013, retail sales of electricity in the United States across all sectors dropped 2%.[1] In addition, the American Society of Civil Engineers gave America's energy infrastructure a D+ grade in their 2013 report card and estimated a 3.6 trillion dollar investment needed by 2020.

> *America relies on an aging electrical grid and pipeline distribution systems, some of which originated in the 1880s. Investment in power transmission has increased since 2005, but ongoing permitting issues, weather events, and limited maintenance have contributed to an increasing number of failures and power interruptions.*[2]

Stagnant growth, rising costs, and a need for even greater infrastructure investment represent major challenges to the utility industry. To maintain our critical energy infrastructure while investing for the future, today's electric utilities need a new source of load growth—one that fits within the political, economic and social environment.

Electrification of the transportation sector is a potential "quadruple win" for electric utilities and society, and will enable companies to support environmental goals, build customer satisfaction, reduce operating costs and assure the future value of existing assets.

> *In the process, electrified transportation would stem the flow of U.S. wealth abroad to pay for imported oil, which currently accounts for more than 50 percent of America's trade deficit.*[3] *Dollars sent abroad to pay for oil represent a significant wealth transfer; in contrast, dollars spent at home to invest in power generation, transmission, and distribution will help to generate economic activity and employment in the United States.*[4]

3. Now is the Time to Start Electrifying Our Fleets

Electrification of the transportation sector is already in progress. Not a day goes by without stories of electric vehicles in the news. Over a dozen models are currently available and new units are coming to market. As predicted, vehicle prices have dropped—both the Nissan LEAF and Chevy Volt cost about $5,000 less today than when they were first introduced. This does not mean that we can afford to sit back and wait for the market to mature. We cannot afford to wait because of the following key reasons.

1. There are many benefits of electrification that utilities can take advantage of today.

2. The market needs our commitment to survive. Our industry's support of these technologies could mean the difference between a product coming to market or not.

3. Leaders shape the market. Some of the benefits might not even occur unless we invest now. Utilities have the opportunity to help shape the market in a way that not only benefits our business but also allows us to stay ahead of future regulations.

Benefits of Electrification for Utility Fleets Are Here Today

Electric-based vehicles offer utilities the following benefits:

- Reduced operating costs from fuel and maintenance.
- The ability to extend useful lives of the units based on their mechanical simplicity.
- Improved crew safety through noise reduction (i.e., the ability to operate a bucket truck at height and still communicate with crew members on the ground).
- Extended work hours of crews performing non-emergency work in communities with noise restrictions.
- Reduced carbon footprint and toxic emissions.
- Increased customer satisfaction as we become impartial experts. Customers and investors expect us to care about the environment and report on corporate sustainability actions. In addition, electrified vehicles give us another avenue to talk to our customers about the products and services we provide.
- Enhanced brand image. Our vehicles are usually our most visible presence in the communities we serve. PEVs also attract positive attention from local newspapers and other media outlets thereby providing us more opportunities to tell our story.

The Market Needs Our Support to Survive and Grow

According to Navigant Research, "Overall, sales in [the medium and heavy-duty vehicle] sector simply have not taken off to the point where the market is truly sustainable."[5] Despite growth, the plug-in market is still heavily dependent on subsidies and incentives. "The key to market sustainability will be to focus only on those applications that provide the greatest payback or other ancillary benefits, and to ensure that the technology is as reliable as possible for the conservative fleet market."[6]

The ePTO system now widely used in electric utilities across North America would not have come to market without the partnership between utilities and hydraulic boom manufacturers. The potential of electric-based vehicles to provide benefits such as grid support and emergency response will only be realized by our direct engagement with manufacturers.

Additional benefits of particular interest to utilities include the following:

- Supporting grid operations, grid reliability, and emergency response situations using power exported from electric-based vehicles.
- Shifting peak load demand to off-peak hours using on-board batteries and/or second life batteries.
- Supporting distributed generation using on-board batteries and/or second life batteries.
- Providing ancillary services such as frequency modulation and voltage regulation to the grid using on-board batteries.

Leaders Shape the Market

Early adoption gives us the opportunity to shape the retail market and regulatory landscape in a manner that is beneficial for our business. Our regulators and other state and federal agencies are looking to the utilities to educate them about all facets of transportation electrification. Building expertise now, while the market is relatively nascent, enables us to avoid costly efforts to catch-up later.

Regulation Is Coming

While the current legislative landscape encourages but does not mandate electric vehicles directly, the longer term outlook necessitates an increasing percentage of electric vehicles in order to meet long term public health, petroleum displacement and climate protection goals.

Figure 1:

Total U.S. Greenhouse Gas Emissions by Economic Sector in 2012[7]

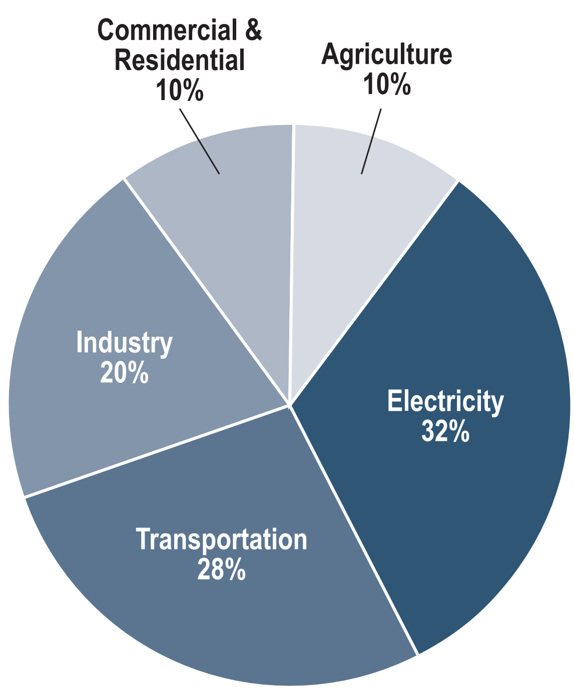
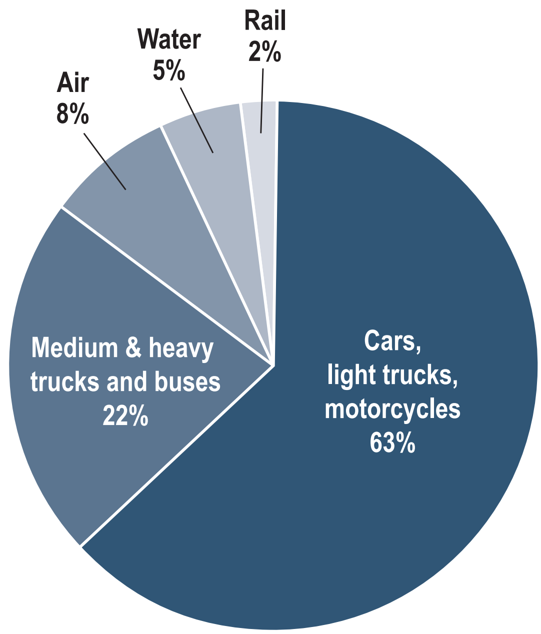


Figure 2: Petroleum Use by Mode

Petroleum use directly correlates to emissions.[8]



Since 1970, a plethora of state and federal laws and incentives have been passed to improve air quality. Still, the transportation sector continues to contribute significantly to air pollution. Today's on-road vehicles produce over a third[9] of the carbon monoxide and nitrogen oxides in our atmosphere and more than 20%[10] of the global warming pollution. Air pollution carries significant risks for human health and the environment, making it a priority for lawmakers and regulators at both the federal and state levels.

Other states have a history of adopting California's environmental standards. California is the only state allowed to create its own standards and section 177 of the 1970 Clean Air Act authorizes other states to choose to adopt (without EPA approval) California's emissions standards in lieu of federal requirements. Currently, 15 states have adopted California's standards over federal standards.[11]

Two significant regulatory strategies that are taking hold in California and being adopted by other states are the Low Carbon Fuel Standard (LCFS) and Zero Emissions Vehicle Executive Order also known as the multi-state ZEV Memorandum of Understanding (MOU).

The Low Carbon Fuel Standard (LCFS)

An LCFS tries to reduce greenhouse gas emissions from transportation fuels without prescribing the fuel type. It is a "well-to-wheel" approach, which means that it looks at the whole life cycle of the fuel—producing, moving, and using it in a vehicle engine. Instead of focusing on conventional fuel cleaning methods (e.g., unleaded gasoline or low-sulfur diesel), the LCFS internalizes the cost of carbon within a given fuel pathway. This attempts to level the cost playing field by rewarding the cleanest pathways (electricity, renewable fuels, hydrogen). An LCFS typically requires a regulated fuel provider to reduce its Average Fuel Carbon Intensity (AFCI) by some amount from a defined baseline year. For example, California's LCFS requires fuel suppliers to reduce their AFCI by 10% by 2020 from a 2010 baseline. LCFS programs typically allow for trading and banking of emission credits to enhance flexibility and support innovation. California has the only implemented LCFS. Thirteen other states, however, have a standard in various stages of development.[12]

ZEV Executive Order/Multi-State MOU

What started as an executive order for Zero Emission Vehicles (ZEVs) in California has now grown to an eight state MOU with Vermont, New York, Massachusetts, Rhode Island, Connecticut, Oregon and Maryland joining California in a commitment to bring ZEVs to market. These core states represent 23% of the domestic new vehicle market. Action plans will focus on infrastructure, consumer acceptance, fleet transformation, investment, and jobs to establish robust EV markets in these states.

Looking Ahead

According to the Alternative Fuels Data Center, 60 laws or incentives targeting fleet managers or fleet vehicle purchasers were enacted nationwide in 2013. In fact an average of 58 laws or incentives targeting fleets has been enacted every year for the last five years.[13] By developing our expertise in vehicle electrification now, we are more likely to be able to dictate our own compliance path. As the California fleets have learned through complying with engine emissions regulations, converting or replacing fleets quickly is incredibly expensive. Electric vehicles have the capability to significantly exceed compliance standards and generate tradable or bankable credits for regulations that focus on energy security (e.g., EPACT), carbon reductions (e.g., CAFE standards) and criteria pollutants (e.g., the Clean Air Act). Moving a portion of our fleets to electric-based vehicles now, before regulation forces us, will enable us more control over our long-term asset strategies.

4. Vehicle Technology

This paper's primary focus is vehicles that plug into the grid; however, one size does not fit all in the fleet world. There is no "silver bullet" technology that addresses all needs and all applications. For example, natural gas is proving to be a good option for the largest classes of trucks. Electricity makes sense for propulsion in smaller applications. Companies must consider technology options as they fit into the needs of the operation and their individual strategic initiatives.

The growth of alternative fuels in total benefits the utility industry and the nation. While not all electric-based vehicle technologies plug directly into the grid, they share some of the same components—including batteries—and strength in the market for these vehicles helps drive down the cost of technology. All of the electric-based technologies also help fleets reduce fuel use and lower their carbon footprint.

Electric-Based Technologies

Currently, there are four different electric-based technologies.

1. All-electric vehicles such as the Nissan LEAF and Smith Electric Newton are entirely dependent on energy stored in a battery. They neither have an Internal Combustion Engine (ICE) nor an electric generator. They must be plugged into electric infrastructure to fully recharge the battery. They are often called Battery Electric Vehicles (BEVs).
2. Hybrid Electric Vehicles (HEVs) such as the Toyota Prius and Ford Escape Hybrid use batteries to supplement an ICE. These hybrids charge the battery entirely through regenerative braking and the ICE. They do not plug into the grid. They are also called parallel hybrids.
3. Plug-in Hybrid Vehicles (PHEVs) have a battery that can be charged by plugging into electric infrastructure but they also have a small ICE. They are capable of limited all-electric range. When the all-electric range is spent, the ICE drives an electric generator which charges the batteries or propels the vehicle. These extended range electric vehicles such as the Chevrolet Volt, Ford C-Max Energi and VIA VTRUX are essentially bi-fuel electric vehicles. They are also called series hybrids.
4. Non-propulsion electrified vehicles use battery power to eliminate idling while continuing to run accessories such as lights and climate control. In the electric utility application, these vehicles use battery power to operate the boom, climate control, lights and tool circuit while the engine is off. This technology is available in small bucket trucks used by first responders and large bucket trucks used by maintenance crews.

Typical Vehicles in the Electric Utility Fleet

The following table (Table 2) illustrates typical vehicle configurations and applications in the electric utility fleet.

Table 2

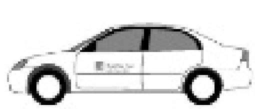
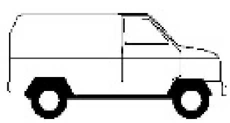
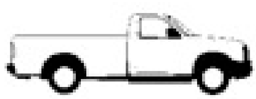
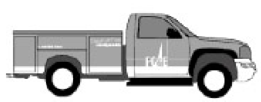
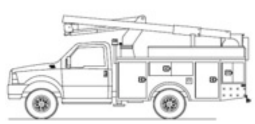
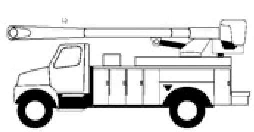
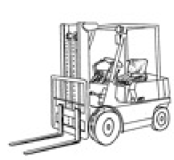
Example	Sector: Vehicle Type	Typical Application (2013 % of fleet[14])	Battery Electric Vehicle	Plug-in Hybrid Electric Vehicle	Hybrid Electric Vehicle
	Light Duty: Passenger car	Staff and support functions (2.6%)	OEM full production	OEM full production	OEM full production
	Light Duty: SUV	Field engineering and other crew support (4.50%)	1 model	In development.	OEM full production (mostly luxury class)

Table 2

Example	Sector: Vehicle Type	Typical Application (2013 % of fleet[14])	Battery Electric Vehicle	Plug-in Hybrid Electric Vehicle	Hybrid Electric Vehicle
	Light Duty: Van	Telecom, meter techs and other support functions (6.0%)	OEM in development. Conversions readily available.	In development.	Conversion available
	Light Duty: Pickup	Front line supervisors (21.6%)	No models available	In development.	No models available
	Medium Duty: Service body	Meter repair, crew support, etc. (13.10%)	No models available	In development.	No models available
	Medium Duty: Service bucket	Troubleshooter or first responder (5.3%)	No models available	ePTO in full production. Integrated drivetrain in development.	Conversion available
	Heavy Duty: Heavy-duty bucket	Line crews (6.10%)	No models available	ePTO in full production. Integrated drivetrain in development.	Conversion available
	Heavy Duty: Digger derrick	Pole replacement (3.10%)	No models available	In development, available for special order.	Available as a production unit Q1 2015, option through OEMs
	Off-Road: Lift truck (fork lift)	Material handling (3.60%)	OEM full production.	No models available.	No models available

Technology Analysis by Sector

As Table 2 outlines, electric-based technology is real. More models are coming to market each year and new startups are replacing the pioneers that have fallen. This section reviews the current state and outlook for electric-based technologies in the light-, medium- and heavy-duty sector, and off-road applications.

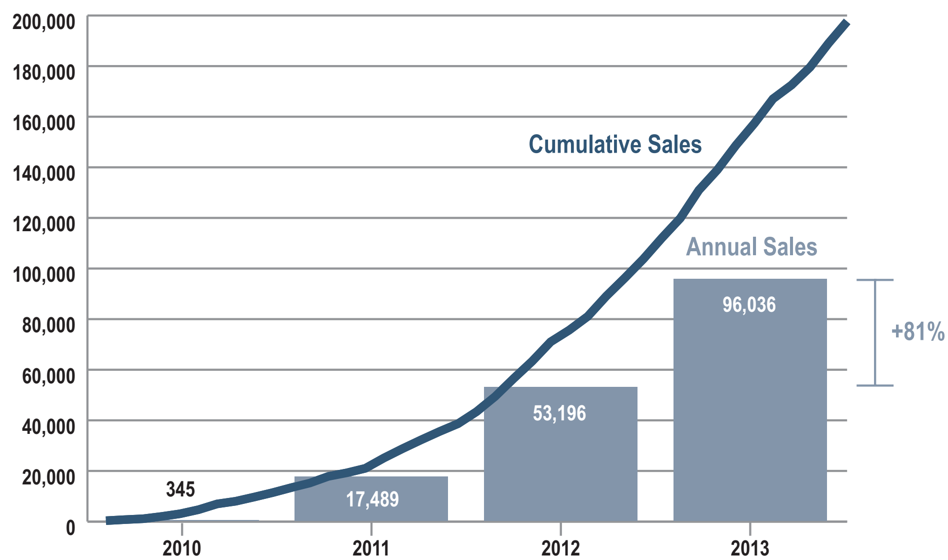
Light Duty Sector (Passenger Car, SUV, Pickup and Van)

Current State

The current generation of PEVs for the passenger market began with the introduction of the Chevrolet Volt and Nissan LEAF in December 2010. Since that time, the PEV market has shown tremendous growth in new products and vehicle sales.

Figure 3 shows the 2013 PEV sales total of about 96,000 vehicles was an improvement of 81% over 2012. The entire automotive market in the US, by comparison, only grew 7.5% from 2012 to 2013. By the end of 2013, just over 167,000 PEVs had been sold in the U.S. market since December of 2010. As of May 2014, that number has grown to nearly 200,000.

Figure 3: Cumulative Sales Growth and Annual Sales, 2010-2013



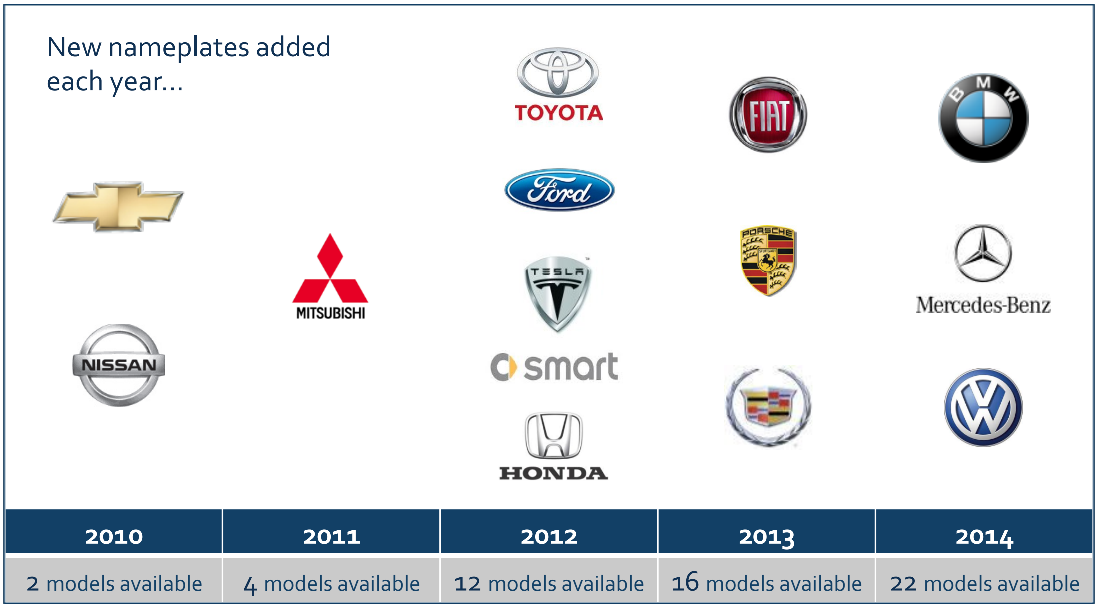
Source: Automaker sales data and estimates from Hybridcars.com

PEV sales to date have been dominated by just six models: Nissan LEAF, Chevrolet Volt, Tesla Model S, Toyota Prius Plug-In, Ford Fusion Energi and Ford C-MAX Energi. These six models account for more than 90% of the PEV market, while the other 10 models available as of 2013 accounted for the remaining 10%.

Nevertheless, the PEV market has seen the continual introduction of new players over time. Figure 4 shows that the two PEV models available by the end of 2010 had grown to 16 by the end of 2013. Based on product announcements from automobile manufacturers, it is anticipated that at least 22 PEV models from 14 different automotive brands will be available by the end of 2014.

Compared to HEV's first years on the U.S. market, twice as many PEVs have been sold since their market debut. The sales rate of PEVs between 2011 and 2013 was nearly three times the sales rate of HEVs between 2000 and 2002.[15]

Figure 4: Additional Nameplates and Total Model Availability by Year



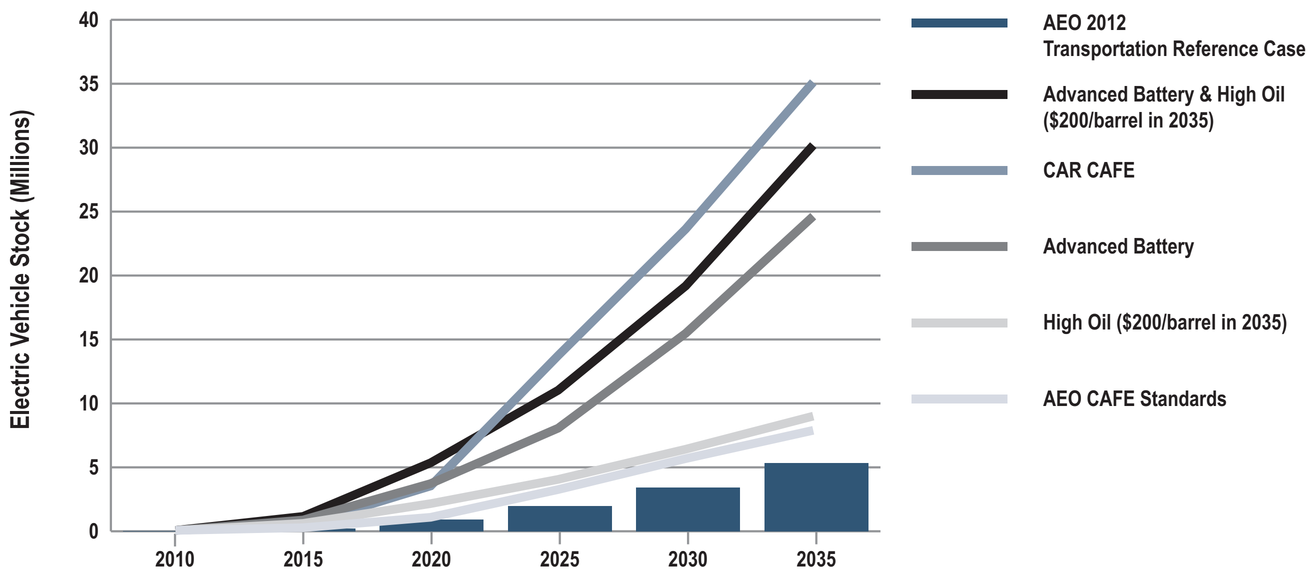
Outlook

The growing scope and diversity of the PEV market is an indication of the automobile industry's commitment to electric transportation solutions. Beyond the new models added in 2014, this trend is likely to continue in the future. Just consider the following two examples:

- General Motors announced in April 2014 that it would invest $449 million to upgrade manufacturing facilities for the second-generation Volt and for "two future products."[16]
- Volkswagen and BMW both stated in October 2013 that the German government's target of one million plug-in vehicles on the road in that country by 2020 is achievable and they have outlined product plans to meet this goal.[17]

Predictions for the long-term growth of electric vehicles have varied widely. Navigant Research's *Electric Vehicle Market Forecasts* report estimates that by the end of 2014, there will be just over 304,000 PEVs on U.S. roads. Of these, 170,000 will be PHEVs and 134,000 will be BEVs.[18] The Edison Foundation surveyed a number of plug-in vehicle forecasts for their April 2013 study, as shown in Figure 5.[19]

Figure 5: Edison Foundation: Forecast of On-Road Electric Transportation in the U.S. (2010-2035)



Source: Institute for Electric Innovation

The forecasts in this study ranged from a high of 35 million PEVs on the road by 2035 (Center for Automotive Research scenario) to a low of just over 5 million (EIA's Annual Energy Outlook 2012).

Medium- and Heavy-Duty Sector (Service Body and Larger Vehicles)

Current State

The medium- and heavy-duty vehicle sector is much smaller than the light-duty sector, with annual sales between 500,000 and 600,000 units as opposed to 13 to 15 million units.[20] Nonetheless, medium and heavy-duty vehicles consume 22% of the annual U.S. petroleum use.[21]

Electric-based technologies in the medium- and heavy-duty market have struggled to move beyond "proof of concept" and pilot tests into widespread or mainstream usage. Annual U.S. sales of hybrid-electric medium-duty trucks were only around 900 units in 2013.[22] This is for a variety of reasons effectively outlined by Navigant Research in their Q4 2013 research report, *Hybrid and Electric Trucks*:

- A number of companies in the sector, and in related sectors, have gone out of business.
- The fleet market tends to be quite conservative and takes a long look at new technologies prior to adoption.
- The overall truck market is still in an early recovery stage following the economic downturn that began in 2008.
- The price premium for PEVs remains too high.[23]

Another key factor is that, as previously stated, one size does not fit every application. In applications that involve a lot of stop-and-go driving and significant annual mileage, hybrids work very well. For short daily routes or lower mileage applications, plug-in hybrids work better. BEVs are most effective for medium-duty applications with set routes where the truck returns to a central depot overnight. All-electric has not fared well as a propulsion system on very large trucks although electrifying accessory loads while reducing or eliminating idle has proved to be cost-effective.

Hybrid drive trains for heavy-duty trucks are readily available from the major American manufacturers. Large truck manufacturers such as Kenworth, Peterbilt, Freightliner and Navistar offer hybrid options for some of their heavy-duty trucks. The hybrid drivetrains are provided by major suppliers such as Allison Transmission, BAE Systems and Eaton. Odyne is one of the few companies to offer a plug-in heavy-duty truck.

Most of the plug-in and all-electric development for the truck market is occurring for medium-duty trucks, primarily for utility vehicles that require work site power and short-range delivery vehicles. So far, the major manufacturers have been reluctant to enter this market, leaving room for start-ups such as Electric Vehicles International, VIA Motors, Boulder Electric Vehicles and XL Hybrid.

Outlook

Despite slow growth in the sector, drivetrain manufacturers continue to aggressively market their HEV and PHEV products (as retrofits) because they understand that the numbers make economic sense in the right application. In addition, most OEMs are including electrification in their extended propulsion plans. Navigant Research predicts a fourfold increase in sales by 2020 with a dramatic shift in favor of PHEVs (59%) as opposed to HEVs (41%).[24] The Corporate Average Fuel Economy (CAFE) law's standards for fuel efficiency signed into law in 2011 established efficiency standards for medium and heavy-duty trucks for the model years 2014-2018. Heavy-duty pickup trucks and vans will have to improve fuel economy by model year 2018 by 10% for gasoline vehicles and 15% for diesel vehicles. There is little doubt in the industry that electric-based technology will be required to meet these increasing fuel efficiency targets.

Lift Trucks

Classification

Lift trucks are generally categorized into five classes (see Figure 6).

Figure 6: Lift Truck Classes

Class 1	Class 2	Class 3
Electric Counterbalanced Warehousing, manufacturing	**Electric Narrow Aisle** High density storage, narrow-aisle buildings	**Electric hand trucks** Moving pallets

Class 4	Class 5
ICE Counterbalanced with cushion tires Indoor warehousing and manufacturing, outdoor on smooth surfaces	**ICE Counterbalanced with cushion tires** Indoor and outdoor warehousing and manufacturing

Classes 1-3 are battery-powered electric lift trucks. Classes 4 and 5 are powered by ICEs, typically fueled by propane or diesel. The opportunity is to convert customers from ICE lift trucks (Class 4 or 5) to electric lift trucks (usually Class 1).

Cost Benefits

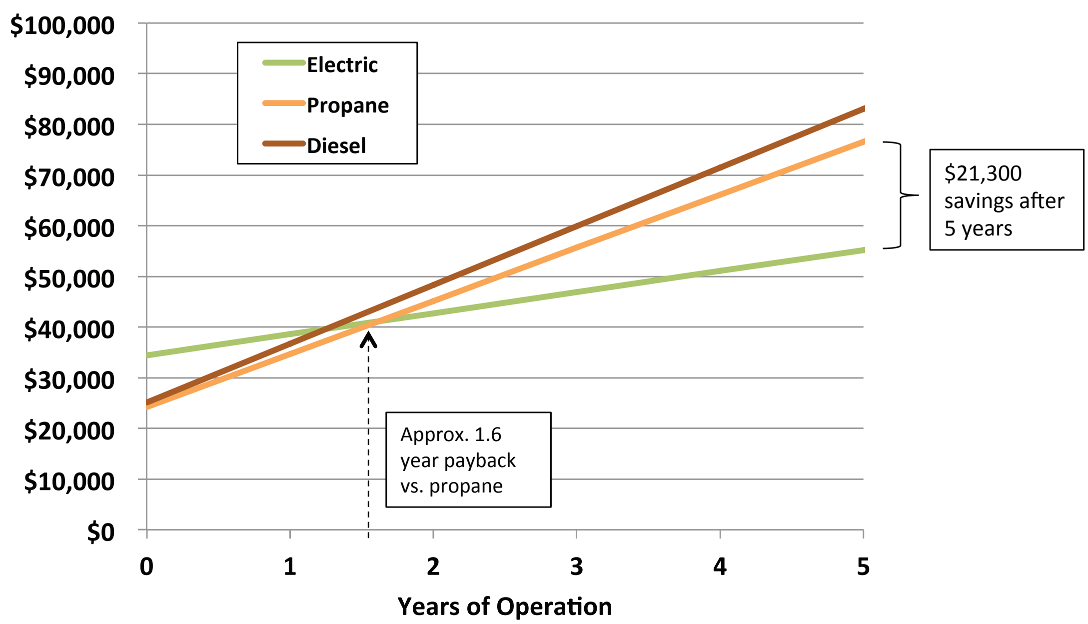
The major benefit of electric lift trucks are reduced operating costs. Depending on local energy prices, it is roughly 75% cheaper to operate a lift truck on electricity than with propane. Maintenance costs are about 40% less for electric lift trucks.

When taking into account the additional cost of the battery and charging equipment, an electric lift truck requires a greater initial investment than ICE trucks. However, since electric lift trucks are cheaper to operate, they save money over time.

In this example, an electric lift truck has a 1.6 year payback compared to the propane truck. (Data source: EPRI Lift Truck Calculator)

Considering the total cost of ownership demonstrates the cost savings. Using data from the Electric Power Research Institute's (EPRI) Lift Truck Calculator, an electric lift truck may have a short payback period compared to an ICE lift truck. After that, the customer saves money (see Figure 7).

Figure 7: Total Cost of Ownership of Electric Lift Trucks vs. Propane and Diesel Alternatives



In this example, and electric lift truck has a 1.6 year payback compared to the propane truck.
Source: EPRI Lift Truck Calculator

Performance Benefits

Advances in technology mean that some of the common misconceptions about electric lift trucks no longer apply. Fast charging systems, for instance, eliminate the need to buy multiple batteries per truck or swap out the batteries between shifts.

Eliminating work site emissions is a major advantage over ICE lift trucks: no exhaust means better employee health and potentially reduced HVAC costs. Furthermore, the environmental benefits may help customers meet their sustainability goals or comply with regulations.

Electric lift trucks typically have a longer life than ICE lift trucks and remove the need for work site fuel storage. Operators report less vibration and fatigue when driving electric lift trucks, as well as quiet operation that allows for easier communication.

The light industrial vehicle category has many mature electric platform options available today. Electric forklifts have been available for a long time. While air quality requirements necessitated their use indoors, the benefits of electric drive forklifts (lower fuel cost, noise reduction, longer life, less maintenance) are available in nearly all material handling forklift sizes today.

> *In warehouses, manufacturing plants, and distribution centers, electric forklifts, cranes, and side loaders are boosting utility revenue while helping industrial customers reduce fuel and maintenance costs. Over the past 25 years, sales of electric forklifts (or lift trucks) have grown from less than one-third to more than half of annual lift truck sales. Most have been limited to indoor use, but several manufacturers now add features such as pneumatic tires and enclosed battery compartments that enable use outdoors.*[25]

Electric Power Take-Off (ePTO)

Current State

In the electric utility world, many of our trucks spend a significant proportion of their time (and fuel) idling at the work site. The ePTO system uses batteries, which are charged by the grid or while driving between work sites, to quietly and efficiently power the truck's hydraulic boom, all emergency lights, and auxiliary equipment, even cabin heating and cooling.

This technology is now widely available from multiple suppliers and continues to be improved and refined. ePTO without drivetrain integration is available from Terex and Altec. ePTO with drivetrain integration is available from Odyne, Eaton and Allison Transmissions. Sales information is not widely available, but Altec estimates that they have delivered over 900 electrically-powered bucket trucks to their utility customers as of 2012.

Outlook

Future enhancements to the primary applications will focus on faster charging while driving on the road through better generators and the use of lithium ion batteries to reduce size and weight and increase overall efficiency.

The largest cost element of the system is the battery. The trouble truck application uses Absorbed Glass Mat (AGM) batteries that are less expensive although much heavier than the lithium ion batteries used in the material handler trucks. Although weight is not much of a factor in the large trucks, it is a factor in the smaller ones. In some cases, battery weight can displace on-board ballast needed to anchor trucks at work sites. Decreasing prices for lithium ion batteries will encourage more adoption of the technology in the widest array of applications and increasing sales volume will continue to drive down the overall cost of the system.

The ePTO systems are evolving rapidly and transitioning into other applications. One example is combining the ePTO system with hybrid drivetrain integration. These systems include a conventional diesel engine with an automatic transmission, a powerful electric motor with a regenerative braking kinetic energy recovery system, and stored energy from batteries that power the boom. In addition to powering larger bucket trucks, there is also an effort to integrate this system into digger derricks that use the ePTO to deliver the high power necessary to run the auger in full electric mode.

5. Battery Technology

Not all batteries are expensive; lithium ion batteries are expensive. Automakers switched from nickel metal hydride batteries to lithium batteries in commercial PEVs because lithium ion battery technology enables cells with higher energy densities (kWh/kg), higher power densities (W/kg), significantly higher cycle life and greater safety than other battery chemistries. Currently, cost of these batteries is high, but it is expected that increased volume sales and technology improvements will significantly reduce the cost in the future.[26]

Battery Pack Components

The battery pack used in vehicles includes components in addition to the lithium cells. The cells are packaged into modules with electrical connections and physical supports. These modules are electrically connected into the overall pack. The pack and individual modules are closely monitored by a Battery Monitoring System (BMS) to ensure pack safety (i.e., no thermal runaway causing fire), maintain expected pack lifetime and allow proper communication with the vehicle control software. Since high cell currents produce significant heat, a cooling system maintains proper cell temperatures for safety purposes and maximum cycle life.[27]

Factors that Influence Cost

Many factors as discussed below will influence or reduce the cost in lithium packs.[28]

Volume Sales: Presently lithium packs are being manufactured in relatively low volumes because the sales of PEVs and BEVs are still modest. When sales increase, the number of lithium cells and packs manufactured will increase as well, and the cost per cell or pack will decrease because large capital and engineering costs can be amortized over more products.

Technological Improvements: Lithium cell manufacturers are expected to improve the cell technology in several ways. The energy density of lithium cells has increased over time and is expected to continue to increase. This increase yields more energy for the same mass and cost of active electrode materials. Furthermore, less expensive cell materials could be found to replace more expensive materials. The manufacturing process could also be made more efficient yielding lower costs.

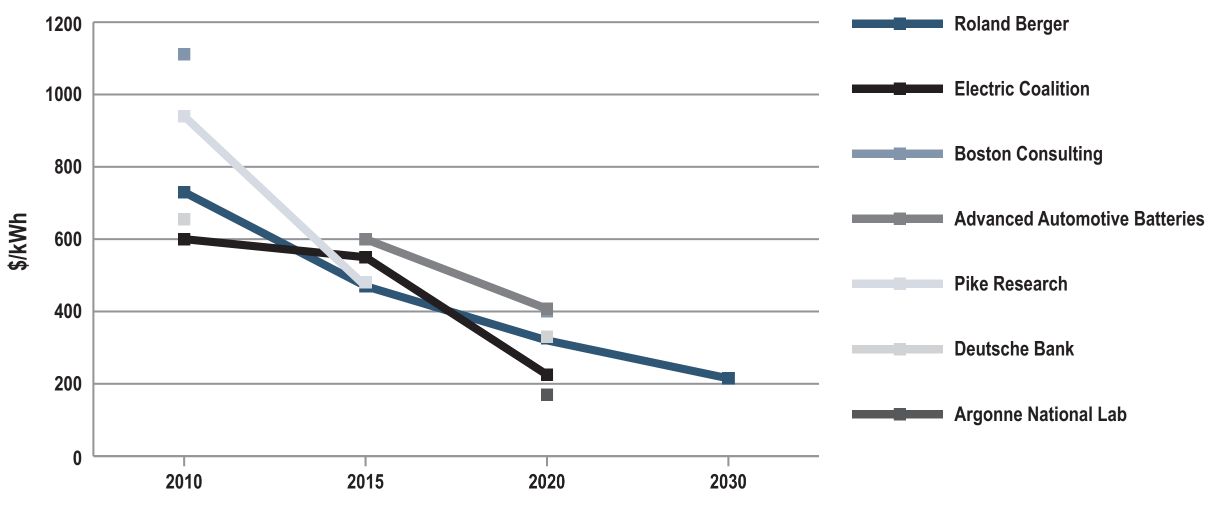
Thermal Management: Packs can be liquid cooled or air cooled. Typically air cooling systems are less expensive but produce less actual cooling. Vehicle design and application determine how much cooling is necessary to ensure the pack remains below a specified temperature.

Power to Energy (P/E) Ratio: Batteries for BEVs require a lower P/E ratio than PHEVs. Batteries manufactured for BEVs will likely be less expensive than PHEV packs.

Battery Cost Studies

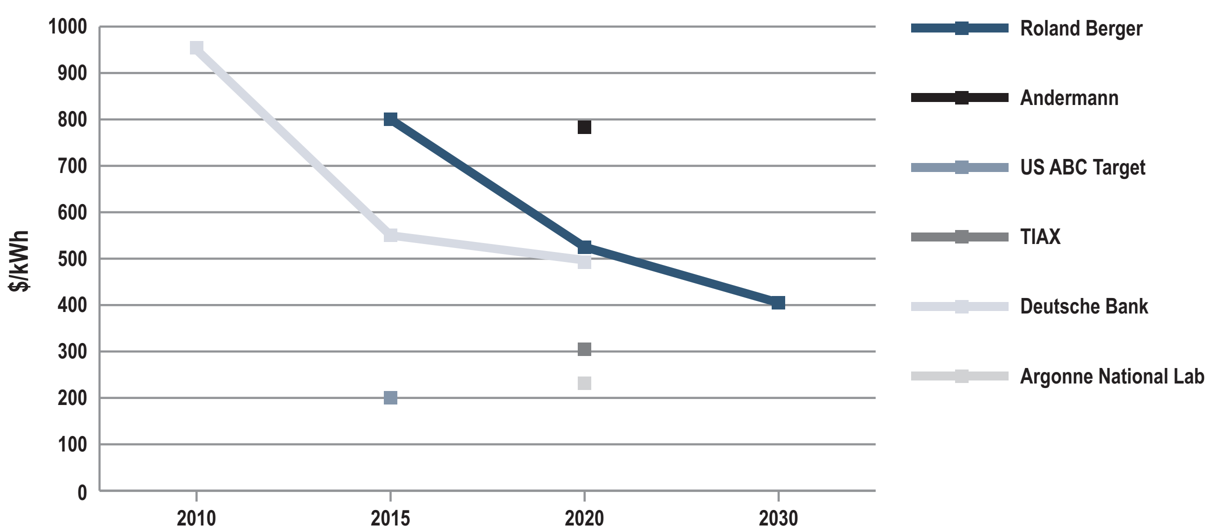
A variety of battery cost studies have been performed. The studies make different assumptions leading to a range of cost projections. Some studies use ground up models that cost out all the specific components of the pack while others use top down methods to estimate overall cost. The following graphs show the varying perspectives of decreasing battery pack costs for both BEVs and PHEVs.

Figure 8: BEV Pack Cost Forecast



Source: Analysis by UC Davis

Figure 9: PHEV Pack Cost Forecast



Source: Analysis by UC Davis

Battery Second Life

One way to reduce the battery cost is to recycle batteries into other markets after their use in a vehicle. These other markets are known as battery second life applications. Due to the importance of battery cost, many studies have looked at the potential for battery second life applications.[29]

Since BEVs and PHEVs are relatively new, there is some uncertainty on how long the battery packs will last before requiring replacement. As the battery is charged and discharged in a vehicle, it degrades due to several processes inside the battery cells. Typically, automakers define end-of-life as a 20% reduction in the battery capacity from its initial installation into the vehicle. The battery degradation also includes increases in resistance that reduces the battery power. Either capacity or (less likely) power degradation could result in battery end-of-life. The "end-of-life" for a vehicle battery, however, does not necessarily mean that the battery cannot be used for other applications.

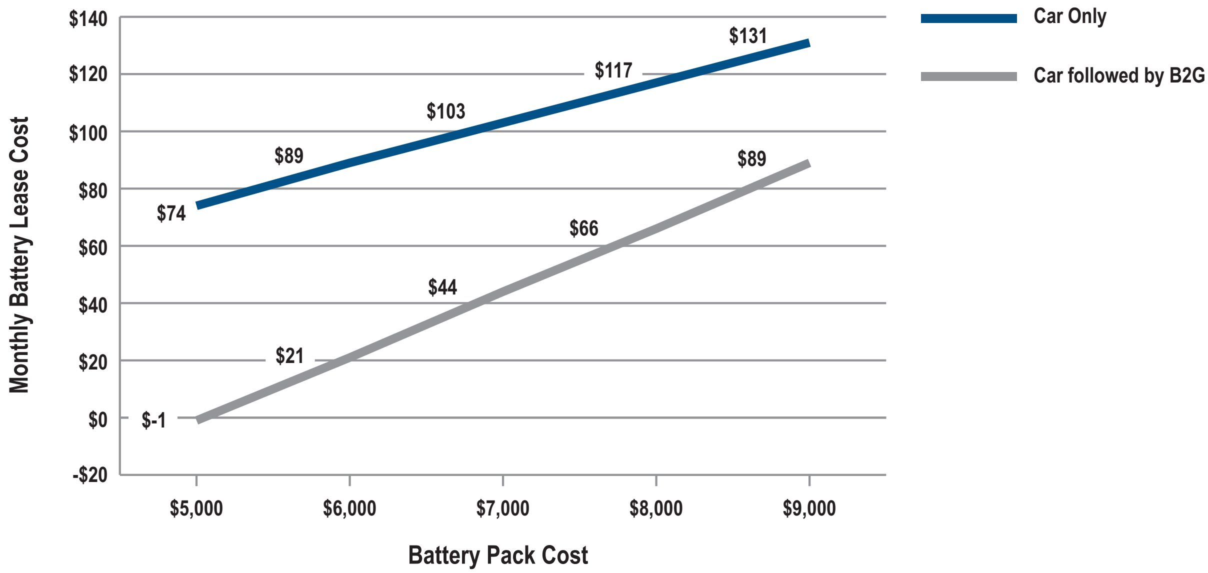
After the battery reaches end-of-life in the vehicle, it can be cycled further until the degradation makes the battery useless. Cicconi et. al. found that lithium iron phosphate cells could be cycled between 2,000 and 2,500 times in a vehicle until the capacity reached 80% of the initial value (i.e. vehicle end-of-life). The cells could be further cycled in a second life application another 1,000 to 2,000 cycles until the capacity fell to 60% of its initial capacity.[30]

Generally the second life applications involve stationary power where the battery energy and power density requirements are much lower than for vehicle applications. These applications simply require matching the battery attributes (i.e., energy and power) at the end of the vehicle life to those required in the stationary application. These second life applications are often referred to as Battery to Grid (B2G) or Distributed Electrical Storage Applications (DESA).

Some battery second life studies have attempted to estimate the reduction in battery cost due to the financial benefits of the second life application. Examples of three such studies are given below.

Williams and Lipman[31] looked at several strategies to reduce the cost of battery packs. One strategy was B2G second life. The study estimated repurposing costs (i.e., costs necessary to remove the pack from the vehicle, testing, assembly, distribution, installation, maintenance, etc.) and considered four revenue streams—regulation, arbitrage, peak power provision and carbon reduction. The study then estimated the reduction of monthly lease payments based on the repurposing costs and revenue streams. Figure 10 shows the reduction in lease cost as a function of the initial cost of a 6 kWh battery used in this second life application.

Figure 10: Battery Monthly Lease Costs for a 6 kWh Pack for Use in a Car and for Use in a Car Followed by a Second Life Application



Source: B. D. Williams and T. E. Lipman, Strategies for Transportation Electric Fuel Implementation in California: Overcoming Battery First-cost Hurdles, Prepared For: California Energy Commission Public Interest Energy Research Program, February 2010, CEC-500-2009-091

In another study Williams considered the second life of a Chevrolet Volt battery pack used in various grid applications.[32] The study estimated repurposing costs as well as cost savings in five categories: electric supply, ancillary services, the grid system, utility customer, and renewables integration. The study considered many scenarios and found that the net present value of second life ranged from a few hundred to a few thousand dollars. The lease payments for the battery could be reduced from 11-24%.

Knowles and Morris investigated using second life batteries as a buffer for solar power energy in residential homes in the United Kingdom.[33] They calculated the energy savings for both solar power and solar power with the battery buffer. Translating the energy savings into cost, they estimated that an average home could save more than £2,500 (~$4,100) during a ten year period due to the second life battery. Those savings translate into roughly £200 per kWh of initial capacity (~$330/kWh initial capacity).

Present Programs

Several automakers have partnered with energy companies to explore second life applications. The following programs are presently in place or will be initiated soon:

- Nissan has a joint venture with Sumitomo Corporation to reuse batteries in large scale energy storage systems. The energy storage system will use 16 batteries from Nissan LEAFs and will help to smooth the output from a solar farm.[34]

- BMW plans to partner with the Swedish energy company, Vattenfall, on a program to demonstrate second life applications of their vehicle batteries for stationary applications. The program will allow solar panels to store energy in the used batteries for later use in charging electric vehicles.[35]

Reports

Given the interest in battery second life applications, some consulting companies have looked at the potential market for recycling batteries from vehicles. Brief summaries of a few interesting findings are given below:

- Navigant forecasts the market for second life battery applications will increase from $16 million in 2014 to roughly $3 billion in 2035.[36]
- A report by Frost and Sullivan, *Global Electric Vehicles Lithium-ion Battery Second Life and Recycling Market Analysis*, suggests that EV battery recycling will be a significant part of the value chain by 2016. The market will reach $2 billion by 2022.[37]

6. The Financial Business Case

Introduction

While consumers focus on vehicle price, fleet operators are taught to make decisions based on the total cost of ownership (TCO). TCO measures the total cost of buying, fueling and maintaining a vehicle over its lifetime. The TCO model is an effective way of tracking costs and benefits within the realm of fleet operations. It does not, however, reflect those costs and especially benefits that accrue due to operating the vehicles. Benefits of electric based vehicles such as noise reduction and customer goodwill are not (at least at this time) quantifiable within the TCO model.

Historically, the utility fleet has been considered an expense—a necessary component to deliver service to the customer. Many utilities, however, now see their fleets as an investment. The simple fact is that vehicle costs are rising regardless of whether we electrify. Between 2006 and 2013, mandates regulating vehicle emissions added $6,000–$9,000 to the cost of a typical electric utility truck.[38] Rising commodities costs are also driving up the price of tires and replacement parts. Instead of just choosing the lowest cost unit, a return on investment calculation might point to a unit with a slightly higher TCO that is nonetheless a better investment for the company. Return on Investment (ROI) calculations can provide an insight into the choice to electrify our fleets. Despite the higher purchase price, there is ample opportunity for an ROI ranging from 20-40% on passenger cars (depending on mileage and charging) to 12-20% for some of the more technologically advanced (and expensive) units such as the extended range electric trucks. There is also significant near term opportunity to manage costs and improve ROI.

To better provide a structured and consistent approach to the total cost of ownership for these new technologies, we have developed a comprehensive TCO model. The model includes sample assumptions and results for a variety of vehicles.

Components of the TCO Model

Purchase Price

As predicted, purchase prices for passenger HEVs and PHEVs have dropped as manufacturers recover their development costs. GM's move to cut $5,000 off the price of the 2014 Volt in August of 2013 followed similar actions by Nissan, Ford, Daimler, Fiat and other OEMs who also cut list prices or rolled out discounted leases.[39] "People forget that this was brand-new technology," says Jon Bereisa, CEO of consulting firm Auto Lectrification, and the systems architect for the Volt during its creation. "Of course the price will fall. The price of your smartphone doesn't go up. It goes down."[40]

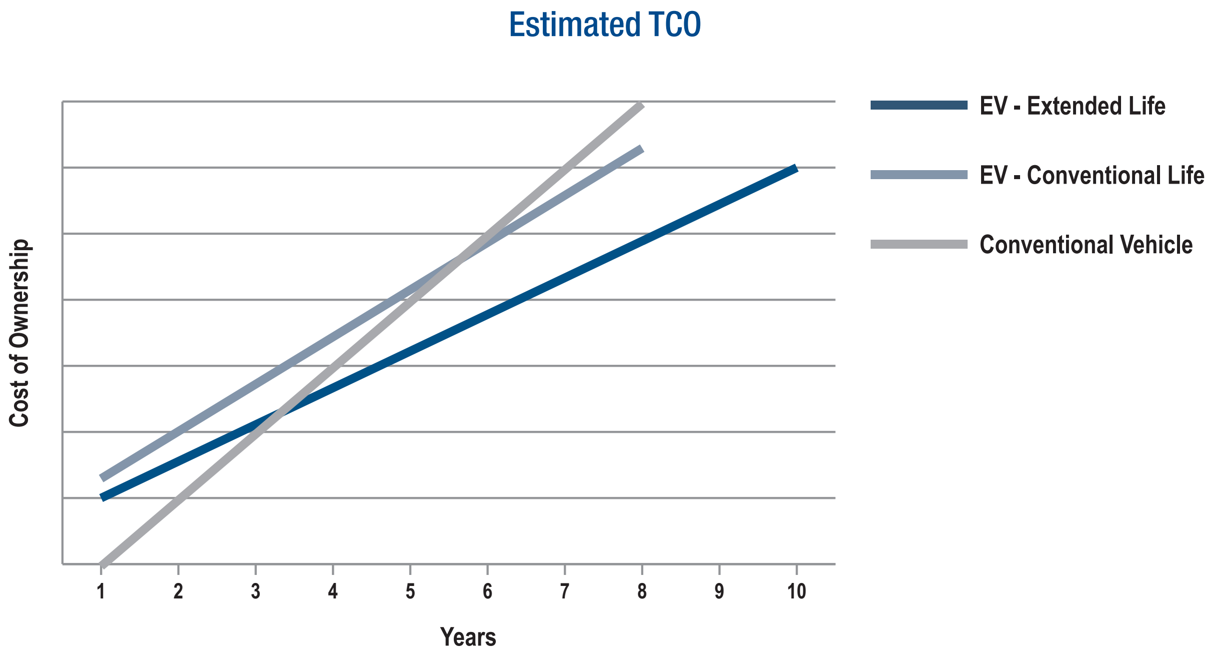
In the medium- and heavy-duty sector, the incremental cost is still high, ranging from $8,000 to $80,000 before incentives, depending on truck class, type of hybrid system, and battery capacity.[41] The high initial purchase price of most electric-based vehicles versus the equivalent gasoline or diesel unit is based primarily on the high cost of the battery systems; however, the cost of lithium ion batteries continues to drop. In most automotive applications this could impact the initial purchase price of the vehicle by $5,000 to $8,000.

For most fleets, purchase price is not nearly as important as the payment. Most banks, financing companies and even utilities use the same useful life for an electric-based vehicle that they use for a standard ICE vehicle. The reality is that electric-based vehicles are expected to handle a significantly longer useful life.

Useful Life

Electric technology not only reduces maintenance costs, but it can also extend the useful life of the vehicle itself. Financing the vehicle for a longer period reduces the monthly payment thereby mitigating the higher up front purchase price. There is a growing willingness in the financial community to develop financing products that reflect the longer life. These products could be available to utility fleets within the next twelve months. Extending the life of a vehicle has a secondary benefit of lengthening purchase cycles. A 10-year vehicle will be purchased twice in a 20-year cycle while an 8-year vehicle must be bought three times. Figure 11 below shows conceptually how taking into account the extended useful life of a plug-in electric vehicle can reduce your overall payment by spreading out the costs over a longer period of time.

Figure 11: Sample Model Showing Improved ROI with Extended Life



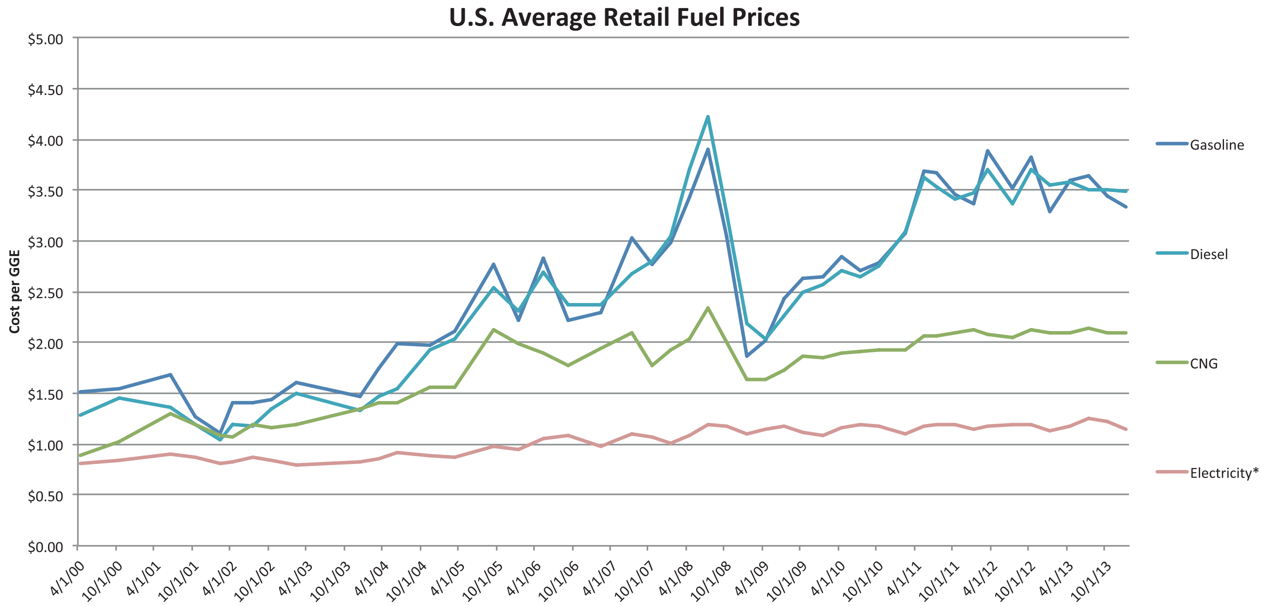
Residual Value

Residual value is a critical issue that impacts the cost of new technologies. Most financing companies are not taking any residual value position on either the vehicle or the battery at this time. Once used assets start coming onto the market, however, a residual value will be established and applied. The combination of lower battery price, longer financing period and established residual value will significantly improve the ROI associated with these asset types over the next few years.

Fuel Prices

Despite short-term fluctuations in the price of gasoline and diesel, the overall trend only goes in one direction—up. The 14 year historical fuel Compounded Annual Growth Rate (CAGR) is 7.5%. In comparison, the CAGR for electricity over the same period is 2.54%, based on EIA data. Figure 12 uses data from the U.S. Department of Energy's Alternative Fuel Data Center to compare the retail price of various fuels.

Figure 12: Comparison of Various Retail Fuel Prices[42]



*Electricity prices are reduced by a factor of 3.4 because electric motors are approximately 3.4 times as efficient as internal combustion engines

www.afdc.energy.gov/data/

Maintenance

OEMs and fleet operators agree that electric-based vehicles have lower maintenance costs due to fewer wear parts and reduced engine usage. Regenerative braking reduces brake wear and electric driveline components tend to be more robust than conventional driveline components. Savings are achieved both in parts and labor as inspection and service intervals are less frequent. In the case of ePTO systems the reduction in idle time can reduce engine wear by more than 50% on an annual basis. This is because idling an engine for an hour causes the equivalent wear as approximately 25-33 miles of driving. Most estimates of vehicle maintenance assume that the battery packs will not require replacement over the assumed vehicle life. Typical battery warranties across different manufacturers are at eight years; however, the batteries are expected to last longer.

The Electric Power Research Institute conducted a study comparing vehicle maintenance costs between midsize conventional vehicles, conventional hybrids and PEVs. The study estimated the cost and maintenance interval for oil changes, air filter replacements, spark plug replacements, timing chain adjustments, and front brake replacements for each vehicle type assuming average driving over a ten year lifetime. They found savings between 8% (HEV) and 24% (PEV). Savings increases with greater all-electric miles.[43] A second EPRI study of maintenance costs for Chevrolet Volt, Nissan LEAF, Toyota Prius, and Chevrolet Cruze over the lifetime of the vehicle estimated 2–3 cents per mile savings. Table 3 below summarizes the finding of this study.[44]

Table 3

Maintenance	Chevrolet Cruze	Toyota Prius	Chevrolet Volt	Nissan LEAF
Lifetime scheduled costs	$5,317	$2,510	$2,772	$1,183
Cents per mile (100,000 miles)	$0.04 (this paper used $0.05)	$0.02	$0.02 (this paper used $0.025)	$0.01
Maintenance Savings		$2,807 (53%)	$2,545 (48%)	$4,134 (78%)

Incentives

Electric vehicles deliver social, environmental and economic benefits, which are recognized by regional, state and federal programs such as tax credits, rebates, car pool lane access, and free or reduced bridge tolls. These programs may help to accelerate an emerging technology to market, achieving commercial scale sooner and driving costs down for mass adoption. For the fleet buyer, incentives may be useful if available but tend not to drive volume purchase or long term decisions. The best incentives for utility fleets are those that drive down purchase price because not all companies are able to take advantage of tax credits.

Some highlights of incentives targeting electric vehicles currently in place are described below.

Federal Tax Credits

Up to $7,500 for plug-in electric vehicles[45] is still available although hybrid vehicle tax credits ended in 2011. Federal EV infrastructure tax credits ended in December 31, 2013 but many regional air districts and state programs offer infrastructure incentives.

Vehicle tax credits begin to phase out at the beginning of the second calendar quarter after the manufacturer produces 200,000 eligible plug-in electric vehicles as counted from January 1, 2010. The IRS will announce when a manufacturer exceeds this production figure and will announce the subsequent phase out schedule. An example of how the program would phase out is included in Figure 13.

Figure 13

Example

200,000th plug-in electric drive vehicle produced by the manufacturer on February 12, 2016.	Phase out starts beginning of second calendar quarter after 200,000-vehicle mark reached.	Beginning of fourth calendar quarter after 200,000-vehicle mark reached, credit decrease again.	Credit ends beginning sixth calendar quarter.

Full Credit Amount		50% of Full Amount		25% of Full Amount		No Credit
Jan Feb Mar	Apr May Jun	Jul Aug Sept	Oct Nov Dec	Jan Feb Mar	Apr May Jun	Jul Aug Sept
2016				2017		

To date the best selling plug-in vehicle is the Chevrolet Volt with approximately 60,000 total sales in the US. At the current rate of adoption, the tax credit for GM as the manufacturer is not expected to phase out until the 2016-2017 timeframe. For companies that prefer not to file for the credit, leasing companies can use the tax credit and pass on the benefit in reduced lease costs.

State and Regional Incentives

Purchase incentives that cover up to all of the incremental cost of clean technology vehicles are offered at both state and regional levels of government. State Air Resources Boards (ARB) and Energy Commissions or Regional Air Pollution Control Districts (APCD), Metropolitan Planning Organizations (MPO), Congestion Management Agencies (CMA) and Councils of Government (COG) are all potential sources of incentives. MPOs and COGs manage regional awards of federal Congestion Mitigation and Air Quality (CMAQ) funds. Air districts often receive a portion of vehicle registration fees and target them to reduce the air quality impacts of transportation, supporting both vehicles and fueling infrastructure.

Cost Model Analysis and Results

Model Source

Total cost of ownership for the vehicles was calculated by the University of California at Davis using a model developed by Argonne National Lab. The Argonne model offers many benefits compared to other TCO models, including an emphasis on alternative fuels and advanced vehicle technologies. The model provides default values and is versatile with regards to different vehicle types and size classifications.

Payback periods are the amount of time that are needed to recoup the higher incremental cost of the PEV technology including incentives. Payback periods are calculated using actual yearly cash flow stream outputs generated by the model. It is possible for a higher priced plug-in vehicle to have a favorable TCO compared to a conventional vehicle but not realize full payback until the vehicle is sold and the resale value incorporated into the TCO.

The inputs and assumptions used in the calculations for the model have been validated and all the sources may be found in Appendices 1 and 2. EEI is working to make the calculator available to member companies so that utilities can run their own results using these validated inputs.

Light-Duty Vehicle Results

For this paper, 11 light-duty vehicles were compared. The analysis compared plug-in electric vehicles with traditional internal combustion engine (ICE) vehicles, including three Chevrolet passenger cars (PHEV Volt, ICE Cruze, and ICE Malibu) and two pickups (ICE Silverado pickup truck and the PHEV VIA VTRUX pickup). Six Ford passenger cars were also analyzed (PHEV C-MAX Energi, C-MAX Hybrid, ICE Focus and the Fusion group—PHEV Fusion Energi, Fusion Hybrid and ICE Fusion).

Table 4 illustrates the model outputs for TCO over an 8 year life cycle. The TCO was calculated using three different annual mileage scenarios. For the plug-in vehicles TCO is calculated twice: one charge per day and two charges per day.

Table 4: Total Cost of Ownership: Passenger Cars

8 year Total Cost of Ownership	12,400 miles/year	18,000 miles/year	24,000 miles/year
2014 Volt: two charges/day	$22,597	$27,101	$33,309
2014 Volt: one charge/day	$24,598	$33,598	$41,261
2014 Cruze	$37,135	$48,370	$59,236
2014 Malibu	$38,338	$49,284	$59,649
2014 C-MAX Energi two charges/day	$27,784	$36,097	$42,962
2014 C-MAX Energi one charge/day	$31,461	$39,774	$46,639
2014 Focus	$35,199	$45,487	$55,324
2014 C-MAX Hybrid	$38,330	$47,491	$55,540
2014 Fusion Energi two charges/day	$27,424	$35,702	$42,559
2014 Fusion Energi one charge/day	$31,101	$39,379	$46,236
2014 Fusion	$39,659	$51,364	$62,581
2014 Fusion Hybrid	$34,411	$42,880	$50,431

Table 5: Payback Years: Passenger Cars

Table 5 illustrates the payback period for the plug-in vehicles relative to their ICE counterparts.

	Volt Payback Years (2 charges per day/1 charge per day)		
	12,400 mi/yr.	**18,000 mi/yr.**	**24,000 mi/yr.**
Compared to Cruze	3.1/3.4	2.2/2.9	1.8/2.4
Compared to Malibu	1.6/1.8	1.1/1.5	0.9/1.2

	C-Max Energi PHEV Payback Years (2 charges per day/1 charge per day)		
	12,400 mi/yr.	**18,000 mi/yr.**	**24,000 mi/yr.**
Compared to Focus	6.0/7.7	5.1/6.2	4.3/5.1
Compared to C-MAX HEV	0.5/0.7	0.4/0.6	0.4/0.5

	Fusion Energi PHEV Payback Years (2 charges per day/1 charge per day)		
	12,400 mi/yr.	**18,000 mi/yr.**	**24,000 mi/yr.**
Compared to Fusion	3.9/4.8	3.2/3.7	2.6/3.0
Compared to Fusion HEV	4.0/6.2	3.7/5.4	3.4/4.8

Table 6: Total Cost of Ownership: Pickup Trucks

Table 6 below illustrates the total cost of ownership for pick-up trucks including the PHEV VTRUX and the ICE Silverado.

8 year Total Cost of Ownership	12,400 miles/year	18,000 miles/year	24,000 miles/year
2013 Silverado PU	$57,357	$75,144	$92,443
VIA VTRUX (26 mpg) two charges/day	$57,741	$66,392	$74,689
VIA VTRUX (26 mpg) one charge/day	$60,050	$75,259	$86,899

Table 7: Payback Years: Pickup Trucks

Table 7 describes the payback period for the PHEV VTRUX relative to its ICE counterpart.

	VIA VTRUX Payback Years (2 charges per day/1 charge per day)		
Compared to Silverado	12,400 mi/yr.	18,000 mi/yr.	24,000 mi/yr.
	10.3/11.0	7.8/9.4	6.6/8.2

Medium and Heavy-Duty Vehicle Results

Our ePTO analysis considers the Jobsite Energy Management System (JEMS) developed by Altec Industries, which eliminates idling at the work site. The JEMS is a plug-in battery powered system integrated into the truck. The system provides electric PTO power for the aerial device, cabin climate control, and auxiliary power (or exportable power) that can replace the need for a generator at the work site. Two scenarios were considered: a JEMS installation on a Class 5 trouble truck with a 37' aerial bucket and a larger Class 7 version installed on a 55' aerial bucket truck. Because the JEMS did not affect vehicle operation other than idling, it was unnecessary to determine the TCO for each chassis. Instead, the TCO and payback for the cost of the JEMS was calculated using the fuel cost savings resulting from avoided idling rather than higher vehicle efficiency and maintenance costs savings resulting from reduced engine wear. Annual hours of avoided idle time was the relevant variable in this TCO calculation, not annual on road miles since the drivetrains of ePTO equipped trucks are not hybridized or electrified at this point. Table 8 illustrates the total cost of ownership for an ePTO system (JEMS) for a medium-duty bucket truck. Table 9 represents the total cost of ownership for an ePTO system on a heavy-duty truck.

Table 8: TCO and Payback Years: ePTO (JEMS) System: Medium-duty Bucket

12 Year Life	18,000 miles/year	24,000 miles/year
Depreciation Same as Truck	-$18,577	-$18,577
Full Depreciation No Resale	-$11,898	-$11,898
Payback Years	5	5
Assumes four hours of idle per day, 260 days per year		

Table 9: TCO and Payback Years: ePTO (JEMS) System: Heavy-duty Bucket

7 Year Life	6,000 miles/year	12,000 miles/year
Depreciation Same as Truck	-$57,087	-$57,209
Full Depreciation No Resale	-$49,466	-$49,588
Payback Years	8.6	7.6
Assumes four hours of idle per day, 260 days per year		

7. Non-Monetized Benefits

The following benefits of electrified vehicles are real although as yet non-monetized.

Work Site Safety and Work Environment

Reduced noise at the work site improves safety by enabling better communication and reducing the risk of hearing damage. Using standard trucks, electric crew members must rely on hand signals to communicate over the noise of the idling engine. Battery powered boom trucks are so quiet that crew members can speak to each other from the ground to the bucket in the air or hear their two-way radios. Customers prefer the quieter operations in their neighborhood too. Table 10 illustrates the amount of noise reduced through the use of ePTO systems. For reference 60 dB is half as loud as 70 dB. A garbage disposal from 2 feet away is 69 dB. Reduced work site emissions make the workplace safer and more pleasant for our employees and customers.

Table 10: Noise Reduction Due to ePTO.[46]

Field Test Noise Measurement Results	Standard Bucket Truck	ePTO Equipped Bucket Truck
Boom operation (full throttle)	68 dB average	57 dB average
Idling with no boom	61 dB average	Practically silent

Extended Work days

Many urban and suburban communities have enacted noise ordinances that can limit a utility's ability to perform routine or maintenance work from the hours of 6:00 pm to 8:00 am.[47] Eliminating idling through electrification can extend the work day thereby increasing crew efficiency and saving money. For example, a crew performing routine maintenance in a location with a noise ordinance would be able to finish up the work past 6:00 pm instead of shutting down the job, securing the site and coming back next morning.

Work Site Power (Non-Grid Power)

The ePTO systems that eliminate work site idling also provide work site power for the crews. This reduces or eliminates the need to buy a separate generator (at a typical cost of $3,500) to run power tools. Battery provided work site power eliminates the emissions and noise of a separate generator. The ePTO system also supports the vehicle's 12V system which powers computers, radios, cabin conditioning and work site lighting.

Exportable Power

Plug-in hybrids like the Chevrolet Volt as opposed to regular hybrids such as the Toyota Prius utilize an electric motor that is powerful enough to generate electricity for use outside of the vehicle. The larger the electric motor (e.g., electric motors used in larger classes of vehicles), the more electricity can be exported from the vehicle. Although the Chevrolet Volt specifically cannot export electricity, this architecture is readily available on a variety of vehicle types and body styles in both light and medium-duty chassis. These types of vehicles are capable of exporting 15–125kW.

Considering that the emergency power needs of the average home are 1–3 kW, the possibilities for providing back-up power to homes—even whole neighborhoods—during outages could be significant. The majority of the transformers used in the utility industry are less than 100 kW. The capability of connecting a vehicle with exportable power directly to the distribution grid would fundamentally change the utility business.

Two companies are currently working on delivering a Class 5 vehicle capable of exporting 125 kW of continuous, utility grade power and PG&E is developing the appropriate connection and safety protocols to connect the vehicle to the distribution grid. The first generation will be in testing by the end of 2014.

A 2004 study which was conducted by Lawrence Berkeley National Laboratory for the U.S. Department of Energy, estimated that electric power outages and blackouts cost the nation about $80 billion annually. Of this, $57 billion (73%) is from losses in the commercial sector and $20 billion (25%) in the industrial sector. The authors estimate residential losses at $1.5 billion, yet they noted it was difficult to put a dollar value on the inconvenience or hassle associated with power interruptions affecting residential electricity customers. In addition, their method did not take into account the effects of extended outages, since these are relatively rare occurrences in the collected data.[48]

In 2012, Hurricane Sandy left more than 8.5 million customers without power, caused tens of billions of dollars in damages, and killed at least 162 people in the United States.[49] In the aftermath, the GridWise Alliance recommended that "electric utilities should increase the use of mobile generators to provide temporary power during a Very Large Scale Event (VLSE). During emergency planning processes, and well in advance of VLSEs, utilities should establish locations where generators can be easily connected and integrated into the grid."[50]

Exportable power from electric vehicles could improve power quality, reduce the length of or eliminate some planned or unplanned outages, reduce feeder congestion, and manage costs associated with increased demand and reliability. In a business built around service reliability, this kind of operational advantage is a game changer.

Public Perception

Media response to green fleet stories continues to be strong. Electric vehicles make great rolling billboards and are popular attractions at local events. Utilities have incorporated electric vehicles into events focusing on the environment and public safety, but they can also be used at sporting events and parades. Electric vehicles are a positive, proactive story for utilities.

8. Societal Benefits

Conventional gasoline and diesel vehicles emit Greenhouse Gases (GHG) and criteria pollutants and use oil products that create a greater dependency on foreign countries for our energy. Electrification of vehicles represents a major opportunity to reduce gasoline and diesel fuel use. Electricity can be produced from domestic fuels which potentially have a lower carbon footprint and lower criteria pollutant emissions. While these benefits of vehicle electrification do not lower the cost of owning and operating a vehicle, they do impact society by reducing greenhouse gases and criteria pollutants and reducing the US dependency on foreign oil.

Energy Independence

A report from an MIT Energy Initiative Symposium gives a number of reasons to increase electrification in the vehicle sector.[51] Issues related to energy independence and energy production are as follows:

- Oil dependence, price volatility and cartels determining global oil prices may have cost the US economy up to $5.5 trillion since 1970.
- Oil dependence negatively impacts national security by constraining foreign policy objectives particularly in the Middle East.
- The US imports a significant percentage of its oil, but electricity is almost entirely domestically produced.
- Oil prices exhibit far larger volatility than electricity prices.
- Electrifying vehicles promotes fuel diversity since the US mix of fuels used for power generation varies considerably.

Climate Change

The transportation sector accounts for 27% of US greenhouse gas emissions. Within that sector passenger cars and trucks emit 83% of emissions.[52] Multiple studies have considered greenhouse gas reduction strategies by creating scenarios for the introduction of various technologies and fuels into vehicle fleets. These studies have found that electrifying the vehicle fleet is a critically important factor.

The Institute of Transportation Studies looked at a number of scenarios to achieve reductions in greenhouse gas emissions in the US transportation sector.[53] By growing electricity's share of vehicle transportation miles, the study showed that major greenhouse gas reductions could be achieved. Similarly, the California Air Resources Board (CARB) modeled greenhouse gas emissions from the transportation sector and found that a high penetration of PEVs could lead to major greenhouse gas reductions.[54]

Pollution

While many studies generally consider climate change the major factor in considering changes to the transportation sector use of technologies and fuels, criteria pollutants play a significant role. Criteria pollutants include nitrogen oxides (NOx), particulate matter (PM), hydrocarbons (HC), sulfur oxides, and other molecules produced during extraction, distribution, processing and end use of fuels. Various agencies throughout the U.S., such as the U.S. Environmental Protection Agency and the California Air Resources Board, are required to develop plans and regulations to meet U.S. air quality standards. These regulations often include specific restrictions on emissions from vehicles.

Overall, the societal goals of energy independence, reductions in greenhouse gas emissions to meet climate change goals and reductions in criteria pollutant emissions to meet air quality standards all require significant changes to the transportation vehicle fleets. Those changes can involve a variety of technologies and fuels, but studies have concluded that electrification of both passenger cars and trucks will likely include a high penetration of PHEVs and BEVs into the vehicle market.

9. Challenges

The Peril of the Leading Edge

Being at the forefront of technology has its challenges. Often new technologies have not been thoroughly tested in real-world applications and fail to live up to their glossy brochures. Demonstration vehicles are typically not as "road hardened" as production vehicles, making comparison testing difficult. PEVs have not been on the market long enough to come to the end of their useful lives.

It is critical that electric utility fleets find ways to share and leverage their electric vehicle experience across fleets and with manufacturers. The industry should continue to support the building of prototypes as well as field trials to determine the best technology fit to our specific applications. The key to success with new technologies lies with ensuring that the capabilities match the actual application and use of the vehicle.

Electric utilities looking to add electric-based vehicles to their fleets should plan to address the following challenges:

- **Operator acceptance**: some drivers will embrace the new technologies and some won't. Charging can be a challenge when vehicles are taken home at night. Good communications and training plans will help ensure fleets realize both savings and operational efficiencies.
- **Weather related performance**: extreme temperatures impact electric vehicles to a greater extent than conventional fuel vehicles.
- **Mechanic knowledge**: whether vehicles are repaired or maintained in house or by a vendor, technicians need new skills and knowledge to work on electric propulsion systems.

Infrastructure Issues

By their very nature, electric-based vehicles require infrastructure investment. With proper planning, costs can be minimized and potential pitfalls avoided.

EV infrastructure comes in several pieces. The visible piece is the Electric Vehicle Supply Equipment (EVSE) or what most people call a "charger" or "charge point." The mechanism that actually charges the battery is part of the vehicle. Prices for EVSE have been dropping as the box itself becomes commoditized. Software is now the main differentiator between EVSE provider companies. Another critical piece of charging infrastructure is the wiring itself. Trenching concrete and running wire have proven to be much more expensive than the actual EVSE. Depending on the number of electric vehicles planned for a particular location, a circuit upgrade may also be needed but how those costs are handled will vary from company to company.

Charging infrastructure comes in several levels as shown in Table 11. Despite the media attention on fast charging, the vast majority of fleets find level 2 adequate for charging overnight.

Table 11

Type of EVSE	Voltage	Rate of Charge	Installation Requirements
Level 1	120 V	2 to 5 miles of range per hour	Most PEVs come with a cord set so no additional charging equipment is required
Level 2	240 V	10 to 20 miles of range per hour	Requires installation of charging equipment and a dedicated circuit of 20 to 100 amps
DC Fast Charge (Sometimes called level 3)	Typically 480 V AC input	60 to 80 miles of range in 20 minutes of charging	Requires installation of charging equipment and dedicated circuit
Inductive Charging	Inductive charging equipment uses an electromagnetic field to transfer electricity to a PEV without a cord. Currently available wireless charging stations operate at power levels comparable to AC Level 2.		

Some TCO models include infrastructure costs; however this is problematic for several reasons. One, the installed infrastructure will last much longer than a single unit and facility upgrades are typically depreciated at a much different schedule than fleet assets. Two, planning for expansions may slightly raise initial costs for a single unit but make incremental EVSE installations much less expensive. Finally, whether the facility is leased or owned may contribute to the cost of the installation and how that cost is accounted for, but it does not affect the cost of operating the vehicle.

Wherever possible, utilities should consider integrating EVSE or at least the wiring into new construction and renovations when the cost will be much lower. Some utilities will be able to include infrastructure upgrades for EVs in their rate base through rate case filings.

One potential for lowering the cost of EVSE installation is to place charge points where they can be dual-purposed (e.g., used by employees during the day and fleet vehicles at night). Depending on state policy, this could be a revenue stream for companies when used by employees or the public.

Utility fleets should also be their own best customer by looking into managing grid load through software based "smart charging." Whether the cost of the electricity to the vehicles is charged to fleet or facility, Time-of-Use (TOU) rates and demand charges will need to be factored into the plan.

The final challenge of infrastructure is providing service to vehicles that are taken home each night. Most utilities send at least some vehicles home with their on-call first responders. In order to realize the full benefits of electrified vehicles, employees need to be encouraged and incented to charge the vehicles at home. Individual utilities will need to address this issue as it may involve union negotiations and challenges with enforcement and measurement. For example, one utility negotiated a $15/month reimbursement for home charging to employees driving first responder vehicles they can plug in at night to recharge.

10. The Bigger Picture

The end goal for electric utilities is not just to electrify their own fleets but to move the transportation sector itself. The experience utilities gain with their PEVs will carry over into the larger market. This section looks at the widening spheres of influence that fleet electrification brings to utilities.

Employees

Employees are our customers and our best advocates. People who get the opportunity to drive PEVs are more likely to want to buy them. According to the sponsors of National Drive Electric Week, 2013's event, "had a noticeable impact on the market. Nissan reported that September marked a record month of sales for the LEAF; spokespeople for the California electric vehicle rebate project noted that rebate requests set a record immediately after the weekend."[55]

High tech companies and electric utilities alike are increasingly offering workplace charging and incentives for their employees choosing EVs. There are 89 DOE Workplace Charging Challenge Partners across the country who are installing plug-in electric vehicle charging infrastructure for their employees including utilities such as Dominion Resources, Inc., DTE Energy, Duke Energy, National Grid, Portland General Electric, San Diego Gas & Electric, Southern California Edison and Southern Company.[56] Other potential incentives include preferred vehicle pricing for employees, preferential parking and free charging.

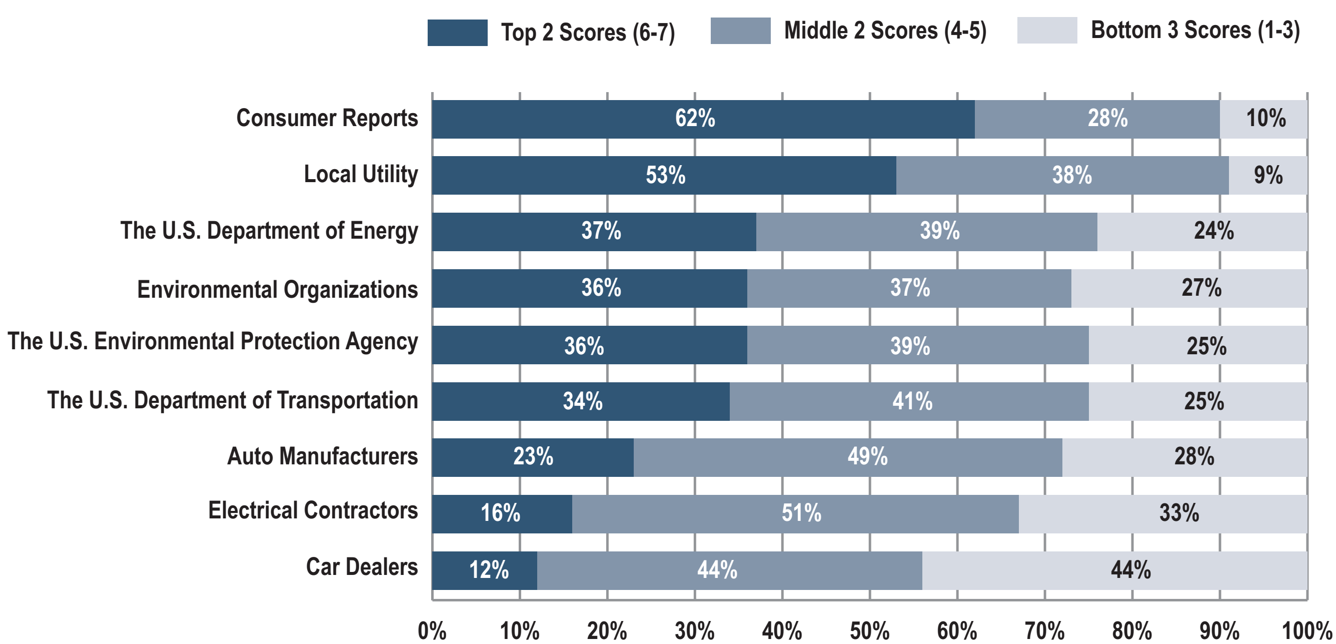
Customers

Residential Customers

According to a 2010 EPRI study, "roughly two in three non-hybrid owners would like their utility company to provide them with information on charging options, the availability of PHEVs in their area and to publish a list of public charging spots and prices."[57] Customers expect their electric utility to be a trusted provider of information about electric vehicles.

> *Transportation electrification presents an opportunity for utilities to have greater contact with customers, creating a stronger relationship. Not only will utilities enable vehicle "fueling" through EV charging, they will also be able to communicate greenhouse gas reductions and energy savings to customers (and regulators) through web portals and monthly bills, empowering customers as partners in energy efficiency.*[58]

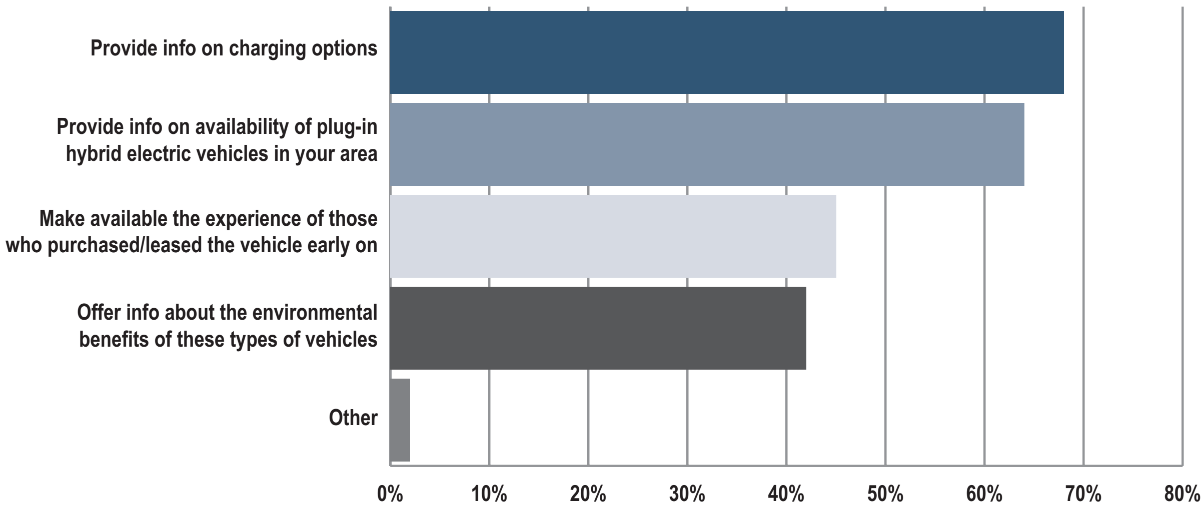
Figure 14: Trust in EV Information Sources



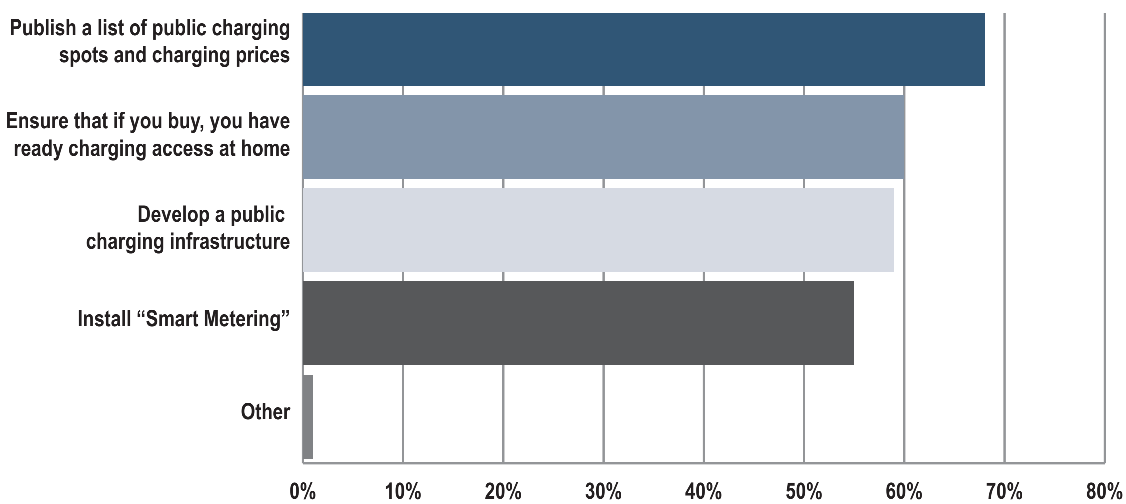
Source: Provided by a Member Utility

Figure 15: Consumer Information and Service Expectations from Their Electric Company[59]

How the Electric Company Can Help Keep Consumers Informed



Consumer's Desired Services from the Electric Company



Commercial Customers

Commercial customers are increasingly turning to electric vehicles as well and expecting their electric utility to be an active partner in the process. The top 10 electrified commercial fleets as of 2013 have 10,851 all-electric and hybrid vehicles on the road and many have ambitious goals to continue deployment.[60]

For example, "AT&T expects to spend approximately $215 million over a 10-year period through 2018 to replace passenger cars with alternative fuel models…The remaining AFV deployments beyond the first quarter of 2014 will consist primarily of AFV passenger vehicles, including hybrid electric and plug-in extended range electric vehicles…"[61]

FedEx Chairman and CEO Fred Smith states: "Early results confirm that the costs of operating and maintaining electric vehicles are significantly less than those for traditional internal-combustion-engine vehicles. In some cases we've achieved savings of 70% to 80%. So we are making a start at FedEx, but it is not enough when it comes to the question of combating our nation's dependence on oil. What we need to protect our nation is the environment to create in a few short years an entirely new transportation system with millions, and then tens of millions, of electric cars and trucks."[62]

Companies without the resources of FedEx and AT&T are turning to utility fleets for best practices and lessons learned regarding the acquisition and operation of electric vehicles. The key to successful commercial partnership will be connecting customer relationship personnel with fleet leadership to learn, share information and innovate.

There is precedent for utilities managing state or shareholder funded clean vehicle incentive programs for their customers. This arrangement makes for a convenient one stop resource and incentive site for customers choosing EVs. Several utilities already have electric forklift incentive programs. "Based on EPRI technical data, [Southern Company's] forklift incentive program has contributed millions of dollars to the utility's bottom line, as customers convert forklift fleets to electric power or add to existing electric fleets."[63]

Economic and Product Market

The experience and opinion of utility fleets matters to OEMs. Annual utility purchases of heavy and medium-duty vehicles are significant enough to influence OEM development and production schedules. Some electric utilities have already served as a consultant and demonstration platform for prototype/test vehicles. Coordination and agreement between EEI member utilities on common specifications for plug-in vehicles could speed up the path to volume production and lower costs.

Rates and Regulatory Environment

Over 53,000 EVs were sold in the U.S. in 2012. In 2013, there were over 100,000 EVs on U.S. roads. With all these EVs already plugging in and so many more expected, utilities, their customers and policy makers are quickly realizing traditional ratemaking and policy approaches are not always appropriate for EVs. With the connected load of an electric vehicle at 6.6kW when charging with 240 V level 2 EVSE (the equivalent of three or more homes), customers may very likely find themselves paying high kWh prices (>$0.50/kWh) on tiered, time of use rate structures. Without rate structures tailored for EVs, these high electricity costs pose a potential barrier to widespread adoption. By the end of 2013, at least 23 electric utilities offered EV specific rates designed to incent consumers charging behavior. Three key challenges for EV rate design are as follows:

Time of Use: Off-peak price signals incent EV users to change behavior and shift load to the extent possible, minimizing grid impacts. Increasingly, EVs have built in smart charging capabilities that can delay the onset of charging to preset off-peak times. Eventually, price signals from the smart grid can be used to optimally position EV charging load. Current tariffs offer rates as low as 3-4¢/kWh off-peak to EV users. There are very substantial benefits to off-peak pricing, delaying, and saving large capital costs for system upgrades by smoothing daily demand for electricity.[64] An analysis of 17 US EV tariffs, compiled by the EV Project, revealed a 70% difference in kWh cost from peak to off-peak.

Tiering: Tiering is traditionally a conservation price signal, but EVs shift energy use across sectors from the petroleum to electricity sector. This is a desirable shift from a climate protection and operating cost perspective and should not be penalized. Tiering is not an appropriate price signal for EVs and increasingly, policy makers are recognizing this. Secondary meters can be used to keep EV use in the baseline, but there is no consensus on who should pay for the cost. Usually, second meters are paid for by the customer; however, regulators have approved incentives to cover these costs in some markets. Rate analysis tools are needed for consumers to determine the approach that is best for their usage patterns.

Demand Charges: Demand charges are typically an impact only to commercial customers but increased connected load charges can be significant. Where feasible, charging in off-peak, delaying the onset of charging, or staggering charging across large fleets of EVs are strategies to avoid setting new peak demand levels with added EV load. Residential customers may incur costs where additional EV load requires service upgrades of conductors or transformers. Regulators do not always agree on the extent to which these costs can be socialized.

One perspective on the issue, from the EV Project, is as follows:

> *Without the capability to discriminate the amount of electricity used specifically for transportation, utility rates will always be a compromise between conservation (for non-transportation energy) and marginal pricing (to encourage electricity use for transportation). The ability to discriminate the amount of electricity used specifically for transportation requires that this electricity be separately metered. This can be accomplished using either a separate meter for the transportation energy (fed independently from the grid) or a sub meter (fed through an existing meter measuring all electricity used at a location).*[65]

Impact to the Grid

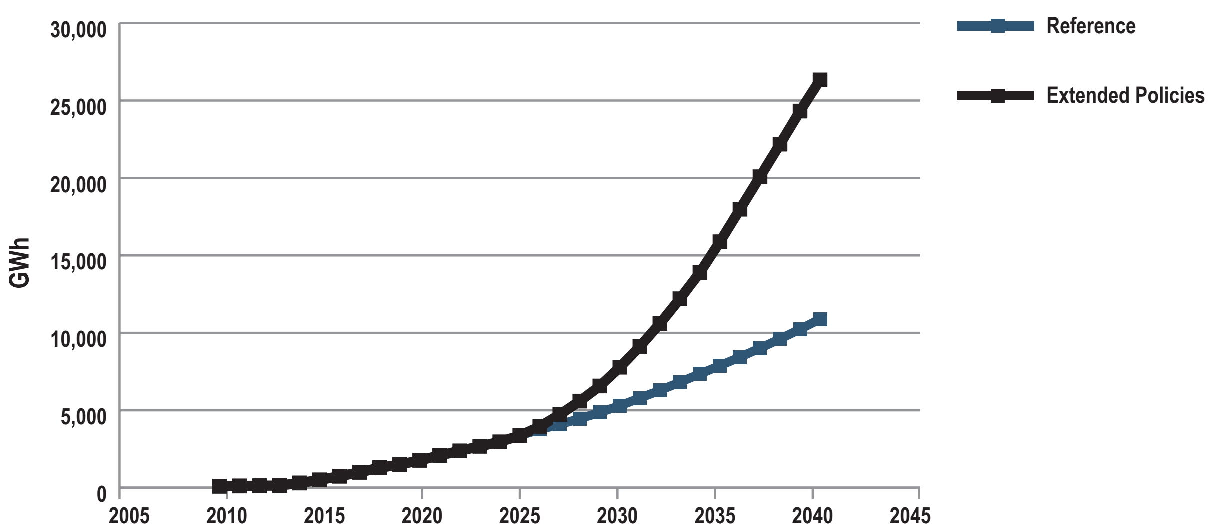
Without consensus on the growth in the number of electric-based vehicles, it is almost impossible to estimate how much energy those vehicles will demand from the grid. Several studies have tried to estimate those numbers using a range of conservative to aggressive scenarios.

EIA produces an Annual Energy Outlook that projects energy usage across all sectors. In particular the EIA projects how the vehicle fleet will change out to 2040. They create fleet scenarios with year by year estimates of each vehicle type (e.g., conventional gasoline, BEV, PEV and fuel cell) and the energy usage by fuel type (e.g., gasoline, diesel, natural gas, electricity and hydrogen).[66]

The reference scenario contains baseline assumptions for economic growth, oil prices and vehicle technology. The scenario that contains the most BEVs or PHEVs is known as the extended policies scenario. This scenario includes an extension of all existing energy policies and legislation that contain sunset provisions, increases in light-duty vehicle fuel economy standards (57.7 mpg in 2040), and increases and extensions of the renewable investment tax credit. The EIA scenarios only include BEVs or PHEVs in their light-duty vehicle projections. Trucks are assumed to operate on other fuels.

Figure 16 shows the electricity energy usage for BEVs and PHEVs in both the reference and extended policies scenarios. The extended policies scenario includes three vehicle types that use electricity from the grid—a BEV with a 100 mile range, a PHEV with a 10 mile all-electric range and a PHEV with a 40 mile all-electric range.[67]

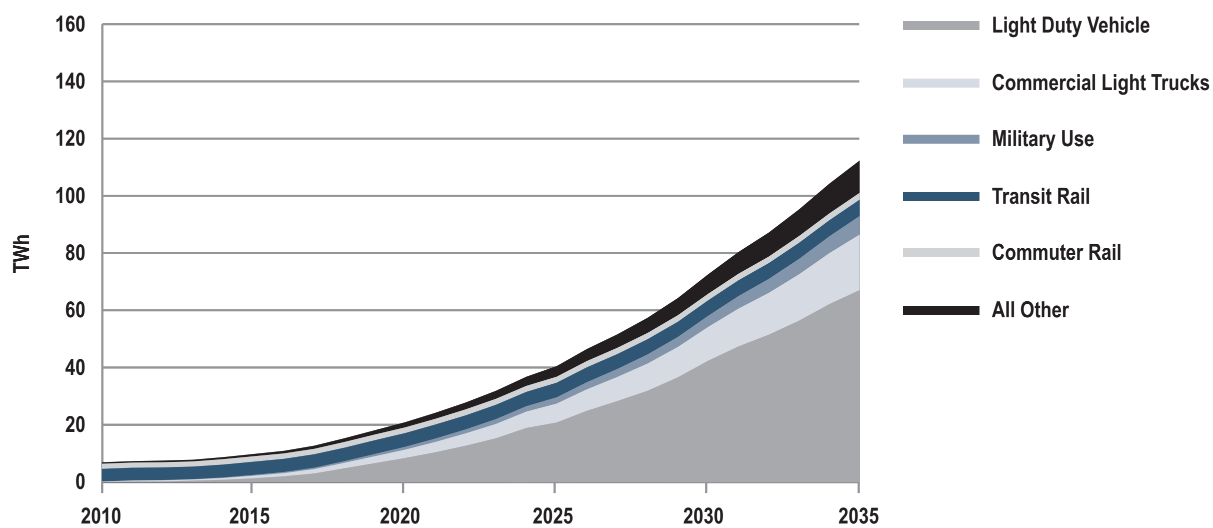
Figure 16: US EIA Reference and Extended Policies Scenarios for Light-Duty Vehicles Electricity Usage Through 2040.



Unfortunately, the EIA scenarios do not include significant numbers of medium and heavy-duty PHEVs. For the same period, EIA also forecasts total electric industry capability to increase by 23.4%.

A white paper published by the Edison Foundation Institute for Electric Innovation discusses three scenarios of transportation electrification. Under their medium scenario, U.S. electricity consumption increases by 112 TWh in 2035. Electric-based, light-duty vehicles account for 67 TWh or nearly 60% of the total and commercial light trucks account for 19 TWh or 17% of the total.[68]

Figure 17: Electricity Use in Transportation Sector—Medium Scenario (TWh)



According to researchers at the Pacific Northwest National Laboratory,

> *For the United States as a whole, 84% of U.S. cars, pickup trucks and SUVs could be supported by the existing infrastructure, although the local percentages vary by region. Using the light duty vehicle fleet classification, which includes cars, pickup trucks, SUVs, and vans, the technical potential, is 73%. This has a gasoline displacement potential of 6.5 million barrels of oil equivalent per day, or 52% of the nation's oil imports.*[69]

The same paper also stated that approximately 160 million vehicles could be powered solely from existing off-peak generating capacity.[70]

11. Conclusion

The bottom line is that the electric utility industry needs the electrification of the transportation sector to remain viable and sustainable in the long term. While the market has started moving in this direction and the technology has been proven, there is still more to be done. Without active engagement, we may not realize the many benefits that could be derived from widespread electric-based transportation. We must continue to innovate, invest and work closely with regulators, automakers, and other partners to develop policies and best practices that will allow electric transportation to flourish. Electrifying our own fleets is an important first step in moving the industry forward. The Edison Electric Institute in partnership with and on behalf of its member companies is requesting each member utility to dedicate 5% of its annual fleet purchase plan to plug-in vehicles. In many applications, this choice already makes economic sense. The 5% ask is a starting point. It is an investment in the future of our business. We must lead by example—showing our customers the benefits and possibilities of making the switch.

Appendix 1:
Assumptions of the TCO Model

Key Components of an Accurate TCO Model

Components that do not vary by fleet	Components that vary by fleet
Fuel economy	Electricity cost
Electricity consumption	Fuel cost (local pricing)
Fuel escalation rate	Purchase cost (incl. incentives and fees)
	Maintenance and repair costs
	Mileage per year
	Depreciation
	Residual value

Fuel Economy

Fuel economies for each vehicle were taken directly from fueleconomy.gov, a U.S. DOE and EPA website that provides "the official U.S. government source for fuel economy information." The "combined" EPA fuel economy (weighted city and highway) was used for TCO calculations. EPA data from the same website was also used for the PEV charge-depleting ranges and electricity consumption. Vehicle electricity consumption was increased 15% to account for charging losses.

Fuel Cost

Fuel prices ($3.56/gal) and fuel price escalation (7.5% annual) were taken from data published by the U.S. Energy Information Administration. An electricity price of 5.5 cents/kWh was used to reflect the wholesale cost of electricity to a utility; this rate also aligns with typical off-peak EV rates.

Annual Usage/Mileage

All vehicles were assumed to be driven an equal distance 5 days/week. Three annual mileage scenarios were analyzed: 12,400 miles, 18,000 miles and 24,000 miles. Under each of the annual mileage scenarios, two PEV charging scenarios were analyzed: one full charge/day and two full charges/day.

Purchase Cost, Incentives & Fees

Purchase costs for each vehicle are base commercial price (not retail) and do not include fleet discounts, sales taxes or fees. Where applicable, federal tax incentives were included in the analysis.

The model's default license and registration values were provided by AAA. License and registration includes taxes and fees which may fluctuate beyond the first year. Furthermore, a portion of the annual registration is tied to vehicle value which decreases each year. License and registration fees, as well as maintenance expenses, are assumed to increase each year at a rate equal an inflation rate of 2.2%. Any errors induced as a result of default license and registration fees is relatively insignificant. License and registration fees have relatively small effect on TCO results and, since these values are assumed equal for all vehicles, there is no comparative advantage for any vehicle model. Because most utilities are self-insured, insurance costs are assumed to be zero. The model default discount rate for calculating present values from future cash flows is 0.79% (bankrate.com, Aug. 2013).

Depreciation

A specific depreciation rate and method was assumed in the model. The declining balance method was used with a depreciation of 23% in the first year of ownership and 15% every year thereafter. This rate was derived from the Money-Zine calculator (http://www.money-zine.com/calculators/auto-loan-calculators/car-depreciation-calculator/). This rate of depreciation is generally consistent with other published data and online calculators. However, depreciation decreases over the life of the vehicle and generally decreases more rapidly after 5 yrs. (for "normal" usage), therefore, for longer vehicle life assumptions, the depreciation may become less accurate. All light-duty vehicles were assumed to have an 8 yr. service life (although it is likely that PEVs will last longer than their ICE counterparts).

Depreciation for the first generation of PEV technologies is difficult to estimate. Technology advancements could devalue some models but a high latent demand for used PEVs could offset some of this effect. Vehicle depreciation and resale value can also vary significantly across geographic markets. The TCO results assume that the estimated resale value is realized.

Residual Value

Residual/resale value is not an input in the model but, rather, a calculated value based on the given depreciation rate. However, if a residual value is known or the vehicle is fully depreciated at the time of sale/scrappage, the model can accommodate depreciation rate adjustments. To account for greater depreciation associated with high mileage vehicles (as is the case for the 18,000 and 24,000 mile scenarios) the resale values were adjusted. High-mileage resale adjustment factors were derived from Edmunds and Kelly Blue Book online calculators for the vehicles being analyzed.

Maintenance and Repair Costs

Maintenance and repair cost per mile was provided by the manufacturers from actuals.

Bucket Truck with ePTO TCO Model Assumptions

The basis for the ePTO system in this model is the JEMS, which was assumed to reduce 4 hours of idling each work day, 260 days a year and displaced 0.8 to 1.2 gallons of diesel per hour of eliminated idling. It was also assumed that the engine was not used to supplement cabin climate control or to recharge the battery. A diesel fuel price of $4/gallon (with a 7.5%/year escalation rate) was used. Preventive maintenance (e.g., oil changes) was assumed to cost $313/event and was scheduled at 300 engine hour intervals. Electricity consumption was assumed to be 5 kWh/day (including charging losses) and cost $0.05/kWh.

The JEMS cost $65,000 and $24,300 for the Class 7 and Class 5 bucket trucks, respectively. The cost savings consisted primarily of two components – diesel cost savings from the elimination of idling at the work site (offset by a very minimal electricity cost needed to operate the JEMS) and the associated reduction in maintenance cost due to less engine wear. Preventive maintenance needs were reduced to engine use required for vehicle propulsion (the 300 hour maintenance interval did not change). Annual avoided idling hours (4/day x 260/yr. = 1,040) were used to calculate avoided costs, not on-road miles as used in the light duty scenarios.

A third cost savings from foregone engine rebuilds was also considered in the analysis. It was assumed that each hour of idling was equivalent of 33 miles of driving with regard to engine wear. Engine rebuilds were assumed to occur at 350,000 mile intervals. Therefore, it is possible that reduced engine wear resulting from the JEMS could save rebuild expenses during the life of the vehicle. This was the case for the class 7 truck which would have realized 350,000 equivalent miles (miles driven plus idling equivalent miles) long before the end of its 12 year life. The rebuild cost was assumed to be $15,000 dollars in the year the expense was incurred. Without the JEMS, the class 5 truck would have reached the 350,000 mile equivalent (miles driven plus idling equivalent miles) near the end of its 7 year life. However, because the rebuild was needed only within the last year of its useful life, it was assumed that a rebuild was not saved. In reality, the JEMS-equipped bucket truck would have a much longer useful life because of idling elimination and, therefore, the rebuild cost savings would likely be realized. The longer vehicle life would also increase vehicle replacement intervals, resulting in additional long-term savings.

As with the light-duty vehicles, the total cost of ownership breakdown is calculated for the JEMS addition on each bucket truck. TCO results are provided for both class 5 and 7 scenarios. The first reflects a JEMS depreciation rate equal to the truck (i.e., the JEMS adds value to the truck for resale purposes). The second TCO value assumes that, regardless of the truck resale value, the JEMS is fully depreciated at the end of the given truck life period. Payback periods are also calculated, along with the year in which an engine rebuild would have been required without the JEMS.

Appendix 2: Details of the TCO Models

Chevrolet and VIA Inputs

	Purchase Price	Federal Incentive	Fuel Economy	Charge Depleting Efficiency (including losses)	All-Electric Range	Maintenance & Repair
2014 Cruze Gasoline 1.8 L, 4 cyl, Automatic (S6)	$18,851	--	27 mpg	--	--	$0.05/mile
2014 Volt EREV 1.4 L, 4 cyl, Automatic	$31,900	$7,500	37 mpg	0.4025 kWh/mi.	38 miles	$0.025/mile
2014 Malibu Gasoline 2.5 L, 4 cyl, Automatic (S6)	$21,912	--	29 mpg	--	--	$0.05/mile
2013 Silverado Pickup Gasoline 4.8 L, V8, 4-spd, Automatic	$28,332	--	16 mpg	--	--	$0.065/mile
2014 VIA VTRUX EREV 4.3 L, V6, Automatic	$75,000	$7,500	26 mpg	0.506 kWh/mi	40 miles	$0.04/mile

Inputs That Are the Same for Each Chevrolet & VIA Vehicle

Input	Value
License and Registration	$108
Insurance	$0
Days Driven Per Week	5
Years Owned	8
Gasoline Price	$3.56/gal
Electricity Price	$0.055/kWh
Gasoline Price Escalation	7.5%/yr
Electricity Price Escalation	0%/yr
Discount factor	0.79%
Inflation	2.2%
Vehicle depreciation rate	Declining balance method. 23% first yr., 15% of remaining value every year thereafter
High mileage penalty	30% for 18K miles 37% for 24K miles (estimated from Kelly Blue Book and Edmunds.com)

Detailed TCO for Chevrolet Passenger Vehicles

	2014 Cruze	2014 Volt		2014 Malibu
		2 charges/day	1 charge/day	
12,400 Miles per Year				
Depreciation	$14,447	$24,448	$24,448	$16,793
Fuel	$16,569	$2,137	$4,138	$15,426
Maintenance and Repair	$5,215	$2,608	$2,608	$5,215
Insurance	$0	$0	$0	$0
License and Registration	$904	$904	$904	$904
Incentive	$0	($7,500)	($7,500)	$0
Total Cost of Ownership	**$37,135**	**$22,597**	**$24,598**	**$38,338**
Calculated resale value after 8 yrs	$4,653	$7,874	$7,874	$5,409
18,000 Miles Per Year				
Depreciation	$15,843	$26,810	$26,810	$18,416
Fuel	$24,052	$3,102	$9,599	$22,393
Maintenance and Repair	$7,571	$3,785	$3,785	$7,571
Insurance	$0	$0	$0	$0
License and Registration	$904	$904	$904	$904
Incentive	$0	($7,500)	($7,500)	$0
Total Cost of Ownership	**$48,370**	**$27,101**	**$33,598**	**$49,284**
Resale value after 8 yrs and high mileage penalty	$3,257	$5,512	$5,512	$3,786
24,000 Miles per Year				
Depreciation	$16,169	$27,361	$27,361	$18,794
Fuel	$32,069	$7,497	$15,449	$29,857
Maintenance and Repair	$10,094	$5,047	$5,047	$10,094
Insurance	$0	$0	$0	$0
License and Registration	$904	$904	$904	$904
Incentive	$0	($7,500)	($7,500)	$0
Total Cost of Ownership	**$59,236**	**$33,309**	**$41,261**	**$59,649**
Resale value after 8 yrs and high mileage penalty	$2,931	$4,961	$4,961	$3,408

Detailed TCO for Chevrolet and VIA Pickups

	2013 Silverado	VIA VTRUX (26 mpg when running on gasoline)	
		2 charges/day	1 charge/day
12,400 Miles per Year			
Depreciation	$21,713	$57,479	$57,479
Fuel	$27,960	$2,686	$4,995
Maintenance and Repair	$6,780	$4,172	$4,172
Insurance	$0	$0	$0
License and Registration	$904	$904	$904
Incentive	$0	($7,500)	($7,500)
Total Cost of Ownership	**$57,357**	**$57,741**	**$60,050**
Calculated resale value after 8 yrs	$6,994	$18,513	$18,513
18,000 Miles Per Year			
Depreciation	$23,811	$63,033	$63,033
Fuel	$40,587	$3,899	$12,766
Maintenance and Repair	$9,842	$6,056	$6,056
Insurance	$0	$0	$0
License and Registration	$904	$904	$904
Incentive	$0	($7,500)	($7,500)
Total Cost of Ownership	**$75,144**	**$66,392**	**$75,259**
Resale value after 8 yrs and high mileage penalty	$4,896	$12,959	$12,959
24,000 Miles per Year			
Depreciation	$24,301	$64,329	$64,329
Fuel	$54,116	$8,881	$21,091
Maintenance and Repair	$13,122	$8,075	$8,075
Insurance	$0	$0	$0
License and Registration	$904	$904	$904
Incentive	$0	($7,500)	($7,500)
Total Cost of Ownership	**$92,443**	**$74,689**	**$86,899**
Resale value after 8 yrs and high mileage penalty	$4,406	$11,663	$11,663

Ford Inputs

	Purchase Price	Federal Incentive	Fuel Economy	Charge Depleting Efficiency (including losses)	All-Electric Range	Maintenance & Repair
2014 Focus Gasoline 2.0 L, 4 cyl, Automatic (S6)	$19,115	--	31 mpg	--	--	$0.05/mile
2014 C-MAX HEV 2.0 L, 4 cyl, Automatic	$28,455	--	43 mpg	--	--	$0.05/mile
2014 C-MAX Energi PHEV 2.0 L, 4 cyl, Automatic	$32,920	$4,007	43 mpg	0.391 kWh/mi	21 miles	$0.025/mile
2014 Fusion Gasoline 2.5 L, 4 cyl, Automatic (S6)	$21,313	--	26 mpg	--	--	$0.05/mile
2014 Fusion HEV 2.0 L, 4 cyl, Automatic	$24,497	--	47 mpg	--	--	$0.05/mile
2014 Fusion Energi PHEV 2.0 L, 4 cyl, Automatic	$32,450	$4,007	43 mpg	0.391 kWh/mi	21 miles	$0.025/mile

Inputs That Are the Same for Each Ford Vehicle

Input	Value
License and Registration	$108
Insurance	$0
Days Driven Per Week	5
Years Owned	8
Gasoline Price	$3.56/gal
Electricity Price	$0.055/kWh
Gasoline Price Escalation	7.5%/yr
Electricity Price Escalation	0%/yr
Discount factor	0.79%
Inflation	2.2%
Vehicle depreciation rate	Declining balance method. 23% first yr., 15% of remaining value every year thereafter
High mileage penalty	30% for 18K miles 37% for 24K miles (estimated from Kelly Blue Book and Edmunds.com)

Detailed TCO for Ford Focus and C-MAX Passenger Vehicles

	2014 Focus	2014 C-MAX Energi		2014 C-MAX Hybrid
		2 charges/day	1 charge/day	
12,400 Miles per Year				
Depreciation	$14,649	$25,229	$25,229	$21,807
Fuel	$14,431	$3,050	$6,727	$10,404
Maintenance and Repair	$5,215	$2,608	$2,608	$5,215
Insurance	$0	$0	$0	$0
License and Registration	$904	$904	$904	$904
Incentive	$0	($4,007)	($4,007)	$0
Total Cost of Ownership	**$35,199**	**$27,784**	**$31,461**	**$38,330**
Calculated resale value after 8 yrs	$4,718	$8,126	$8,126	$7,024
18,000 Miles Per Year				
Depreciation	$16,064	$27,667	$27,667	$23,914
Fuel	$20,948	$7,748	$11,425	$15,102
Maintenance and Repair	$7,571	$3,785	$3,785	$7,571
Insurance	$0	$0	$0	$0
License and Registration	$904	$904	$904	$904
Incentive	$0	($4,007)	($4,007)	$0
Total Cost of Ownership	**$45,487**	**$36,097**	**$39,774**	**$47,491**
Resale value after 8 yrs and high mileage penalty	$3,303	$5,688	$5,688	$4,917
24,000 Miles per Year				
Depreciation	$16,395	$28,236	$28,236	$24,406
Fuel	$27,931	$12,782	$16,459	$20,136
Maintenance and Repair	$10,094	$5,047	$5,047	$10,094
Insurance	$0	$0	$0	$0
License and Registration	$904	$904	$904	$904
Incentive	$0	($4,007)	($4,007)	$0
Total Cost of Ownership	**$55,324**	**$42,962**	**$46,639**	**$55,540**
Resale value after 8 yrs and high mileage penalty	$2,972	$5,119	$5,119	$4,425

Detailed TCO for Ford Fusion Passenger Vehicles

	2014 Fusion	2014 Fusion Energi		2014 Fusion Hybrid
		2 charges/day	1 charge/day	
12,400 Miles per Year				
Depreciation	$16,334	$24,869	$24,869	$18,774
Fuel	$17,206	$3,050	$6,727	$9,518
Maintenance and Repair	$5,215	$2,608	$2,608	$5,215
Insurance	$0	$0	$0	$0
License and Registration	$904	$904	$904	$904
Incentive	$0	($4,007)	($4,007)	$0
Total Cost of Ownership	**$39,659**	**$27,424**	**$31,101**	**$34,411**
Calculated resale value after 8 yrs	$5,261	$8,010	$8,010	$6,047
18,000 Miles Per Year				
Depreciation	$17,912	$27,272	$27,272	$20,588
Fuel	$24,977	$7,748	$11,425	$13,817
Maintenance and Repair	$7,571	$3,785	$3,785	$7,571
Insurance	$0	$0	$0	$0
License and Registration	$904	$904	$904	$904
Incentive	$0	($4,007)	($4,007)	$0
Total Cost of Ownership	**$51,364**	**$35,702**	**$39,379**	**$42,880**
Resale value after 8 yrs and high mileage penalty	$3,683	$5,607	$5,607	$4,233
24,000 Miles per Year				
Depreciation	$18,281	$27,833	$27,833	$21,011
Fuel	$33,302	$12,782	$16,459	$18,422
Maintenance and Repair	$10,094	$5,047	$5,047	$10,094
Insurance	$0	$0	$0	$0
License and Registration	$904	$904	$904	$904
Incentive	$0	($4,007)	($4,007)	$0
Total Cost of Ownership	**$62,581**	**$42,559**	**$46,236**	**$50,431**
Resale value after 8 yrs and high mileage penalty	$3,314	$5,046	$5,046	$3,810

Inputs for ePTO (Altec JEMS) System on Bucket Trucks

	JEMS on Class 5 Truck First Responder Vehicle	JEMS on Class 7 Truck Large Crew Truck
Cost of JEMS system	$24,300	$65,000
Life of system	7 yrs.	12 yrs.
Normal daily idling	4 hrs/day	4 hrs/day
Days of idling	260 days/yr	260 days/yr
Idling fuel consumption	0.8 gal/hr.	1.2 gal/hr.
Cost of diesel fuel	$4/gal	$4/gal
Diesel price escalation factor	7.5%/yr	7.5%/yr
JEMS energy consumption (from wall) includes aerial and HVAC	5.0 kWh/day	8.0 kWh/day
Cost of electricity	$.055/kWh	$.055/kWh
Engine wear conversion factor (for rebuild determination)	1 hr. idling = 33 miles	1 hr. idling = 33 miles
Engine rebuild interval	350,000 miles	350,000 miles
Annual truck mileage	18,000 mi./24,000 mi.	6,000 mi./12,000 mi.
Engine rebuild cost	$15,000	$15,000
Truck Engine Preventive Maintenance Costs		
Oil change intervals	300 hours	300 hours
Cost per maintenance event		
Labor	$200	$200
Oil Filter	$40	$40
Fuel Filter	$13	$13
Air Filter	$13.75	$13.75
Oil	$48	$48
Miscellaneous	$20	$20
Discount factor	0.79%	0.79%
Inflation rate	2.20%	2.20%
Depreciation rate	Declining balance 23% 1st yr, then 15%/yr	Declining balance 23% 1st yr, then 15%/yr

Detailed TCO for JEMS System on Class 5 First Responder Bucket Trucks

	Depreciation Same as Truck	Full Depreciation No Resale	Time Before Rebuild (yrs.)	Payback Time (yrs.)
18,000 miles/yr. 7 yr. life				
Depreciation	$17,621	$24,300		**5.0**
Fuel	-$27,792	-$27,792		
Maintenance	-$8,406	-$8,406		
Forgone Engine Rebuild	$0	$0	**6.7** (no rebuild w/in last yr. of veh. life)	
Total	**-$18,577**	**-$11,898**		
Resale	$7,057	$0		
24,000 miles/yr. 7 yr. life				
Depreciation	$17,621	$24,300		**5.0**
Fuel	-$27,792	-$27,792		
Maintenance	-$8,406	-$8,406		
Forgone Engine Rebuild	$0	$0	**6.0** (no rebuild w/in last yr. of veh. life)	
Total	**-$18,577**	**-$11,898**		
Resale	$7,057	$0		

Detailed TCO for JEMS System on Class 7 Large Bucket Trucks

	Depreciation Same as Truck	Full Depreciation No Resale	Time Before Rebuild (yrs.)	Payback Time (yrs.)
6,000 miles/yr. 12 yr. life				
Depreciation	$57,379	$65,000		**8.6**
Fuel	-$85,528	-$85,528		
Maintenance	-$14,931	-$14,931		
Forgone Engine Rebuild	-14,007	-14,007	**8.7**	
Total	**-$57,087**	**-$49,466**		
Resale	$8,376	$0		
12,000 miles/yr. 12 yr. life				
Depreciation	$57,379	$65,000		**7.6**
Fuel	-$85,528	-$85,528		
Maintenance	-$14,931	-$14,931		
Forgone Engine Rebuild	-$14,129	-$14,129	**7.6**	
Total	**-$57,209**	**-$49,588**		
Resale	$8,376	$0		

Appendix 3: Additional Battery Information

Lithium Battery Chemistries

There are several types of lithium battery cells. Each cell is distinguished by the chemistry of the electrodes, which take part in the chemical reactions. The table below shows a number of the major chemistries along with their characteristics.

Cathode Material	Short Name	Energy Density	Safety	Cycle life	Use in Vehicles
Lithium manganese oxide	LMO	Very good	good	good	Nissan LEAF, Chevy Volt
Lithium iron phosphate	Li-phosphate	good	Very good	Very good	Fisker EV
Lithium nickel manganese cobalt oxide	NCM	Very good	good	good	EV prototypes
Lithium nickel cobalt aluminum oxide	NCA	Very good	good	good	Plug-in Prius
Lithium titanate	Titanate	OK	excellent	excellent	Proterra transit bus

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