Electric Vehicle Transportation Center

Electric Vehicle Fleet Implications and Analysis

Doug Kettles
Electric Vehicle Transportation Center
Florida Solar Energy Center
1679 Clearlake Road
Cocoa, FL 32922-5703
dougkettles@fsec.ucf.edu

Submitted as:
Final Research Project Report
EVTC Project 16 – Electric Vehicle Fleet Implications and Analysis

Submitted to

Ms. Denise Dunn
Research and Innovative Technology Administration
1200 New Jersey Avenue, SE
Washington, DC 20590
E-mail: denise.dunn@dot.gov

Contract Number: DTRT13-G-UTC51
EVTC Report Number: FSEC-CR-2031-16
November 2016

University of Central Florida

Acknowledgements

This report is a final research report for the Electric Vehicle Fleet Implications and Analysis project of the Electric Vehicle Transportation Center (EVTC) at the University of Central Florida (UCF). The Electric Vehicle Transportation Center is a University Transportation Center funded by the Research and Innovative Technology Administration of the U.S. Department of Transportation. The EVTC is a research and education center whose projects prepare the U.S. transportation system for the influx of electric vehicles into a sustainable transportation network and investigate the opportunity these vehicles present to enhance electric grid modernization efforts. The EVTC is led by UCF's Florida Solar Energy Center with partners from the University of Hawaii, and Tuskegee University.

The objective of the Electric Vehicle Fleet Implications and Analysis project was to evaluate the implementation and effectiveness of electrical vehicles used in fleet operations. The project also evaluated present usage through case studies. The results are to be used to evaluate other vehicle applications, determine how EV fleet adoptions could impact overall rates of market penetration and review the programs or incentives that could encourage EV fleets. The work was conducted by Doug Kettles of the Florida Solar Energy Center.

Electric Vehicle Fleet Implications and Analysis

Table of Contents

Final Research Project Report

Electric Vehicle Fleet Implications and Analysis

Doug Kettles
Electric Vehicle Transportation Center
November 2016

1.0 Abstract

The objective of this project was to evaluate the implementation and effectiveness of electric vehicles (EVs) used in fleet operations. The study focuses on Battery-Electric Vehicles (BEVs) and Plug-In Hybrid Electric Vehicles (PHEVs); collectively known as Plug-In Electric Vehicles (PEVs). The report reviews regulatory, operational and expense considerations and provides a review of current use and applications. Many classes of vehicles are included, from Class 1 motorcycles to Class 8 semi-trucks; in total, twelve different classes and applications are reviewed. The results reveal a broad spectrum of current usage, with case studies that include, the use of electric motorcycles by police departments, EVs use for ride-sharing and as taxis, and the use of mass transit electric buses. The report also identifies the programs, incentives and legislative mandates that encourage the expansion of EV fleet use, and how these programs may increase overall rates of market penetration and encourage new applications. Some applications can have a large impact, some much smaller; collectively they work to make a positive significant difference in fleet operational efficiency and environmental and health impacts. These results can be used to evaluate other fleet vehicle applications by appropriate users.

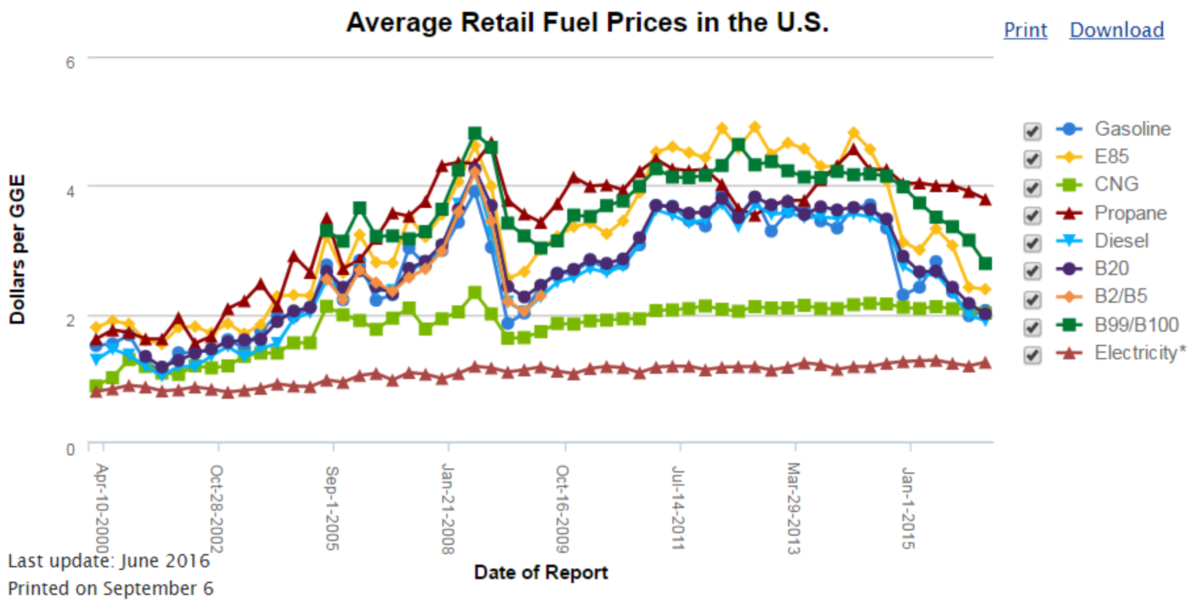
2.0 Introduction

According to the U.S. Department of Transportation, there are more that 11 million fleet cars and trucks in the United States.[1] Fleet vehicles regularly cover predictable routes and often return to central depots at night; having a centralized recharging location which makes them excellent candidates for conversion to electric. PEVs are particularly attractive for light-duty fleet use because of their reduced fueling expense and lower overall maintenance cost.

The transition and use of electric mode transportation in U.S. fleet operations will have significant positive economic, environmental and public welfare benefits. PEV and alternative fuel technology continues to progress at a rapid pace and there is ever increasing participation in all areas by business, government, vehicle manufacturers and others.

The most significant economic benefit is in the reduction of the use of petroleum based fuels, to include consumption while idling. U.S. passenger vehicles and trucks consume more than 6 billion gallons of diesel fuel and gasoline while idling, electric vehicles do not idle.[2]

From an operational point of view, most electric vehicles do not have transmissions or cooling systems, which results in lower maintenance expense. Combining reduced operating cost with attractive financing and leasing options can provide a compelling justification for governmental and other fleet owners to switch from conventionally fuel vehicles (CFV) to PEVs. Additionally, the cost of electricity has been stable and predictable for decades, bringing a level of economic certainty that historically is not available with petroleum. The stability of electricity as a fuel source when compared to the fluctuations in other fuels can be seen in the chart below.



This chart shows average monthly retail fuel prices in the United States from 2000 to 2016. The price of petroleum fuels (gasoline and diesel fuel) is the primary driver of liquid fuel prices. This is because the liquid fuels are used in non-dedicated vehicles and can be substituted out by petroleum fuels if their price rises too high, therefore decreasing demand until the price drops to close that of the petroleum fuel. However, natural gas and electricity prices have been buffered from this driver because transportation only constitutes a tiny portion of their markets. LNG was first tracked in July 2016.
Source: http://www.afdc.energy.gov/fuels/prices.html

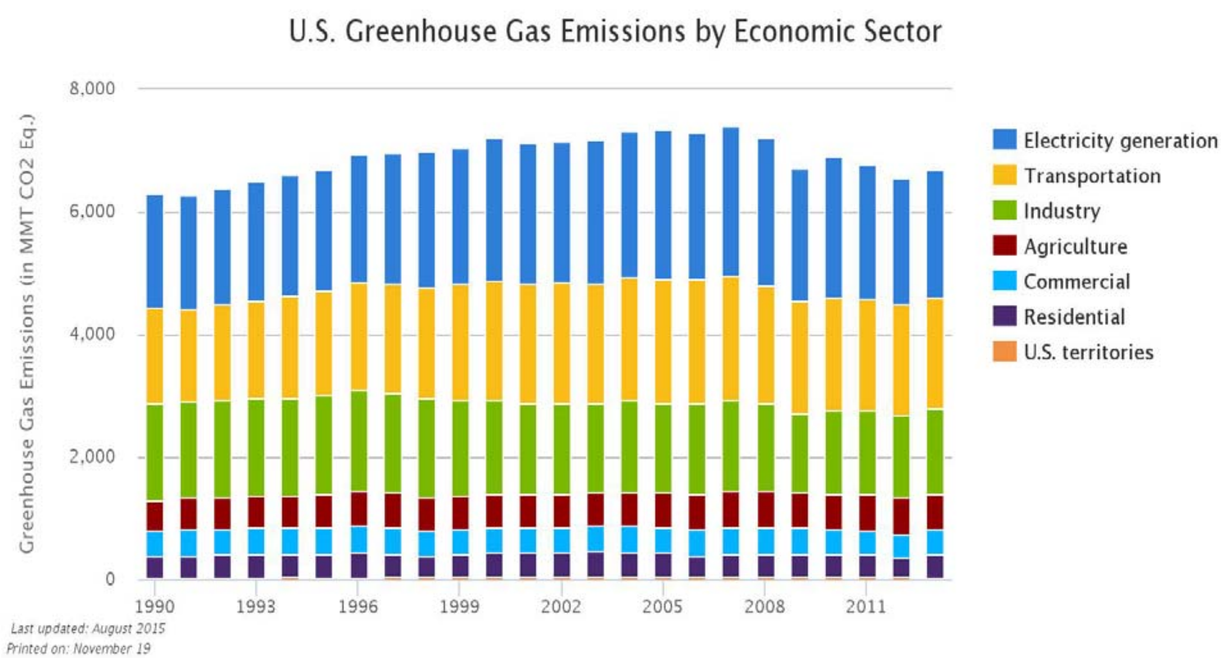
Utilizing EVs in the fleet environment offers an impressive list of advantages, but in the end the deployment of an EV must provide enough savings to justify its purchase. These savings can be achieved by ensuring that the EV's utilization rate is high and that their duty and drive cycles maximize fuel and maintenance savings.

On the environmental side, electric fleets in a metropolitan environment present an enormous opportunity for significant improvements in the reduction of Green House Gas (GHG) contributions, noise reduction and urban heating. The use of PEVs in delivery fleets in urban environments would considerably reduce the release of damaging GHGs while providing dramatic reductions in noise and heat dissipation. The emergence of low-emission and noise-free zones will create demand for pure electric trucks for delivery and short-haul freight. The environmental advantages realized in eliminating the use and disposal of lubricants, coolants and other petroleum based automotive additives is significant in the fleet environment.

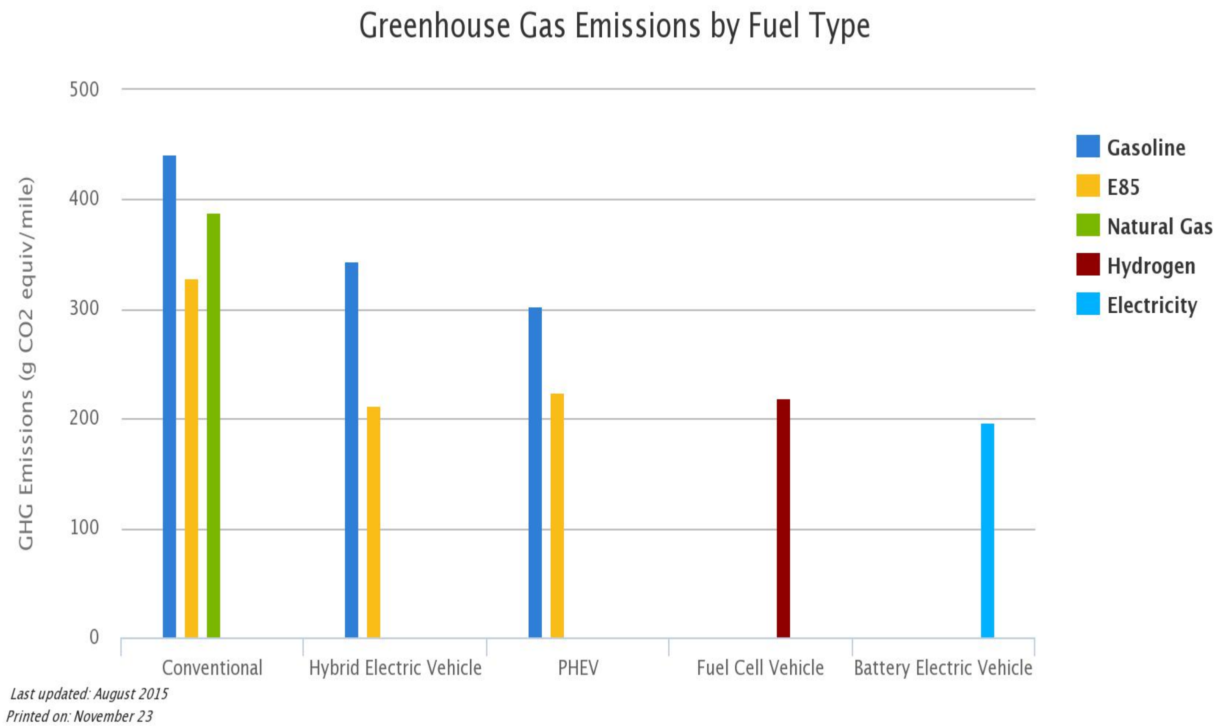
And while passenger and light truck vehicles are 90% cleaner than they were in 1970, vehicle miles traveled increased 178% between 1970 and 2005[3]. According to a 2014 EPA report, GHG emissions from the transportation sector increased over 16% between 1990 and 2013. Pollution from the transportation sector continues to increase, apparently as a result not only of total miles driven, but also because of the increase in the number and the type of vehicles. Americans increasingly drive more vans, SUVs and pickup trucks. These vehicles consume more fuel and produce three to five times more pollutants than a regular passenger car[4]. Continuing improvements in battery capacity will eventually improve the feasibility EVs for passenger car usage, potentially offering significant reductions in GHG contributions.

According to the U.S. Environmental Protection Agency, pollution from automobile traffic appears to increase health related problems. The negative health effects include asthma, cardiovascular disease and impaired lung function, in addition to noise related health issues. Diesel fueled mass transit is a major source of toxic air pollutants. The California Office of Environmental Health Hazard Assessment (OEHHA) estimates that, “about 70% of the cancer risk that the average Californian faces from breathing toxic air pollutants stems from diesel exhaust particles[5].” Like environmental impact benefits, the shear numerical scale of benefits afforded to public health by the adoption of PEVs in fleet applications in the urban environment could be truly impressive.

The transportation sector will soon overtake electricity generation as the lead contributor of GHGs in the U.S.

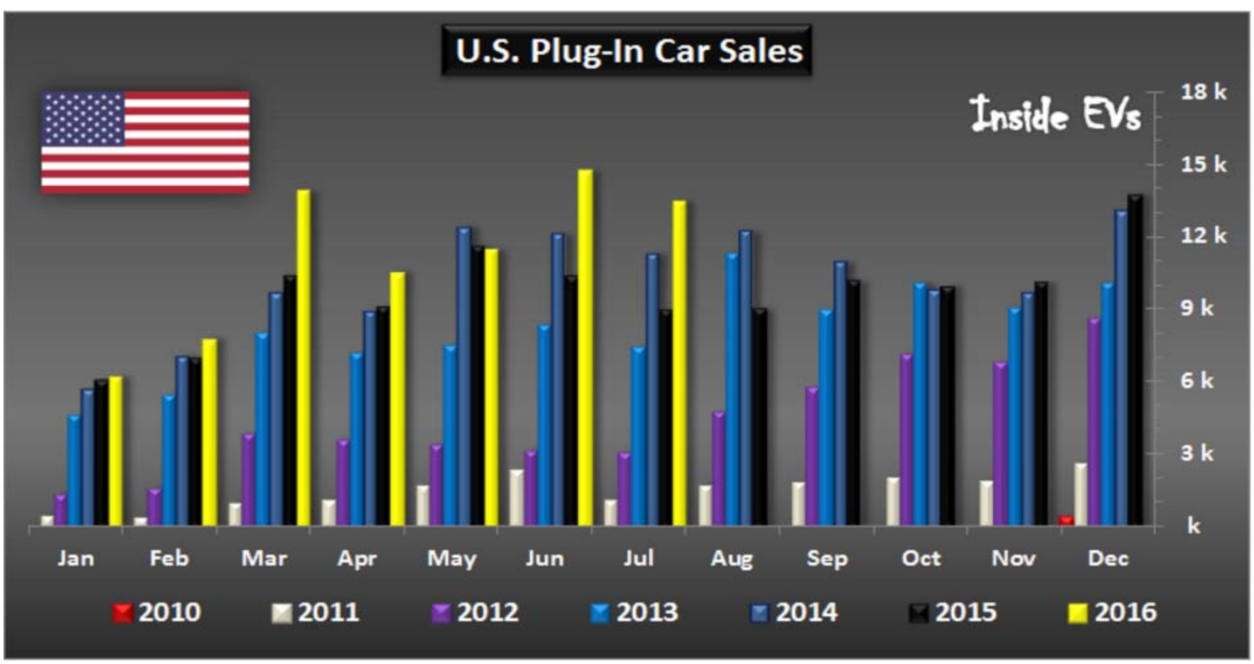


This graph displays the breakdown of greenhouse gas (GHG) emission by economic sector. GHG emissions from the transportation sector have increased 16.4% from 1990-2013. Transportation emissions have also increased from 24.6% of total emissions to 27.1%, the largest increase in percentage points of any sector. GHG emissions from electricity generation, transportation, and industry all decreased during the Great Recession.
http://www.afdc.energy.gov/data/10802



This graph displays the results of a meta-analysis of studies looking at the greenhouse gas (GHG) emissions of a range of fuel-vehicle pathways.
http://www.afdc.energy.gov/data/10741

PEVs have become a viable and desirable mode of transportation for the general public and fleet owners. Between January 2011 and July 2016, approximately 499,273 electric vehicles had been sold in the U.S.[6] GM and Nissan have launched second generation Volts and Leafs and there are now more than 29 models of passenger PEVs.

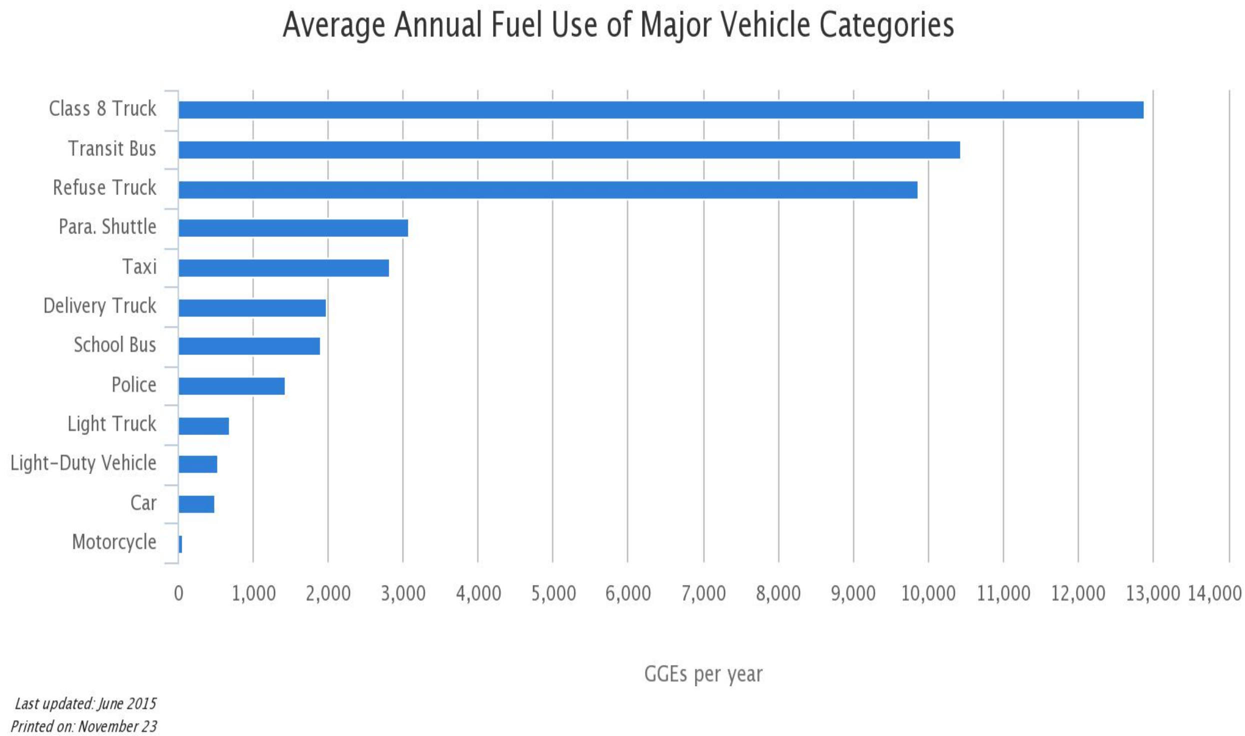


Source: HybridCars.com

Vehicle manufacturers are increasingly turning their resources and attention to the development of electric vehicles for fleet use. Nissan uses the powertrain from its LEAF passenger vehicle in its e-NV200, a compact EV cargo/passenger van. Electric bus manufacturer's Proterra and BYD are launching second generation vehicles and utility vehicle manufacturers, EDI and VIA have introduced advanced technology PEVs. Nissan LEAFS and Teslas are routinely used for taxi service.

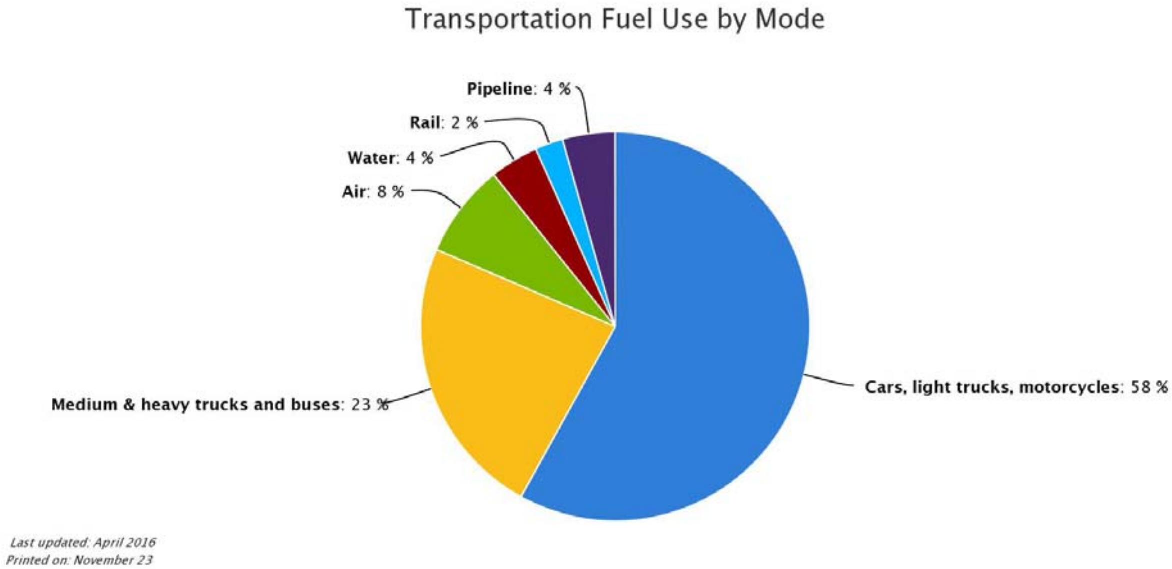
The Obama administration, New York City and California have all set goals of reducing carbon emissions by 80% by 2050. Collectively, the efforts of these major players to reduced carbon emissions are forcing vehicle fleet owners to move toward the inclusion of more electric vehicles in their plans. Importantly, it should be noted that these, and many of the sustainability goals set by many cities and businesses, are not tied to petroleum prices.

The impact of these efforts is better understood by knowing what types of vehicles consume how much petroleum. The graph below illustrates the average annual fuel use by vehicle type.



This chart shows average annual fuel use (per vehicle) of major vehicle categories in the United States. The two factors affecting the average annual fuel use of a vehicle are the average miles per year (correlative) and the fuel economy of the vehicle (inversely correlative). Class 8 trucks, which typically travel long distances carrying heavy loads, consume more fuel on average than any other vehicle type. Transit buses and refuse trucks also use large quantities of fuel since they both log high numbers of miles on average and have relatively low fuel economy. The last four vehicle types are owned by individual consumers, and they each use a fraction of the fuel used by fleet-based vehicles, on a per-vehicle basis.
http://www.afdc.energy.gov/data/10308

Light passenger vehicles use less fuel, however they still account for over 63% of petroleum used for transportation. Taken together, conventional highway transportation vehicles account for over 85% of all transportation petroleum. Conversion of even a small portion of the sector to PEV technology would result in outsized benefits.



This chart shows the fuel used by domestic transportation in the United States. The largest amount is used in the form of gasoline by light-duty vehicles. The second largest portion is used in the form of diesel fuel in medium- and heavy-duty vehicles. Air travel consumes 8% of the transportation petroleum mostly in the form of jet fuel. Pipelines consume 4% of transportation fuel, mostly in the form of natural gas. Finally, water and rail consume the remaining 6% in the form of diesel and some gasoline and electricity. http://www.afdc.energy.gov/data/10566

Significant additional momentum may be developing for the conversion of the nation's vehicle fleets to electric drive. President Obama's Memorandum of March 2015, directing the federal government to increase its purchasing of zero-emission vehicles has certainly elevated the potential for EVs to become a more significant presence on U.S. roads. The order requires 50% of the federal fleet of over 655,000 vehicles to be battery-electric or hydrogen vehicles by 2025. Additionally, the U.S. Postal Service's issuance of an RFI in February of 2015 has initiated the process of selecting a next-generation delivery vehicle. The USPS plans to replace the majority of its fleet of more than 200,000 vehicles, which includes 180,000 light-duty carrier route vehicles that are suited for PEV applications.

The Energy Policy Act (EPAct) has had a significant and ongoing impact on the adoption of alternatively fueled vehicles. EPAct, and subsequent and additional federal statues, require the U.S. Department of Energy (DOE) to develop and manage alternative fuel programs. The goal of these programs is to reduce U.S. petroleum consumption through the use of alternative fuels, alternatively fueled vehicles and other methods. These requirements are particular impactful on fleets owned by local and state governments and other fleet owners, including large utility providers.

Frequently, the upfront capital cost of an EV is higher than a comparable CFV; however, dealer incentives and financing and state, local and federal tax credits routinely result in a lower purchase price for an EV. Importantly, combined federal and state local tax credits and fleet incentives can approach $10,000 in California and other areas of the U.S.

Reducing the capital expense of electric vehicles is a major objective of all PEV manufacturers, and the batteries used in these vehicle is the single largest cost component. Advancing technology and the advantages of large scale manufacturing have combined to reduce battery cost 14% annually since 2007[7]. Tesla, Samsung, LG Chem and others are investing billions of dollars to build battery “Gigafactories” that will annually produce batteries for hundreds of thousands of electric vehicles. The impact of the manufacturing scale of these factories is estimated to reduce prices 30-50% in the near future.

The advantages offered by fleet electrification are widespread and, in the urban environment, truly transformative. Taken together, the momentum of all economic, environmental and policy indicators support the accelerated growth of PEVs in fleet applications.

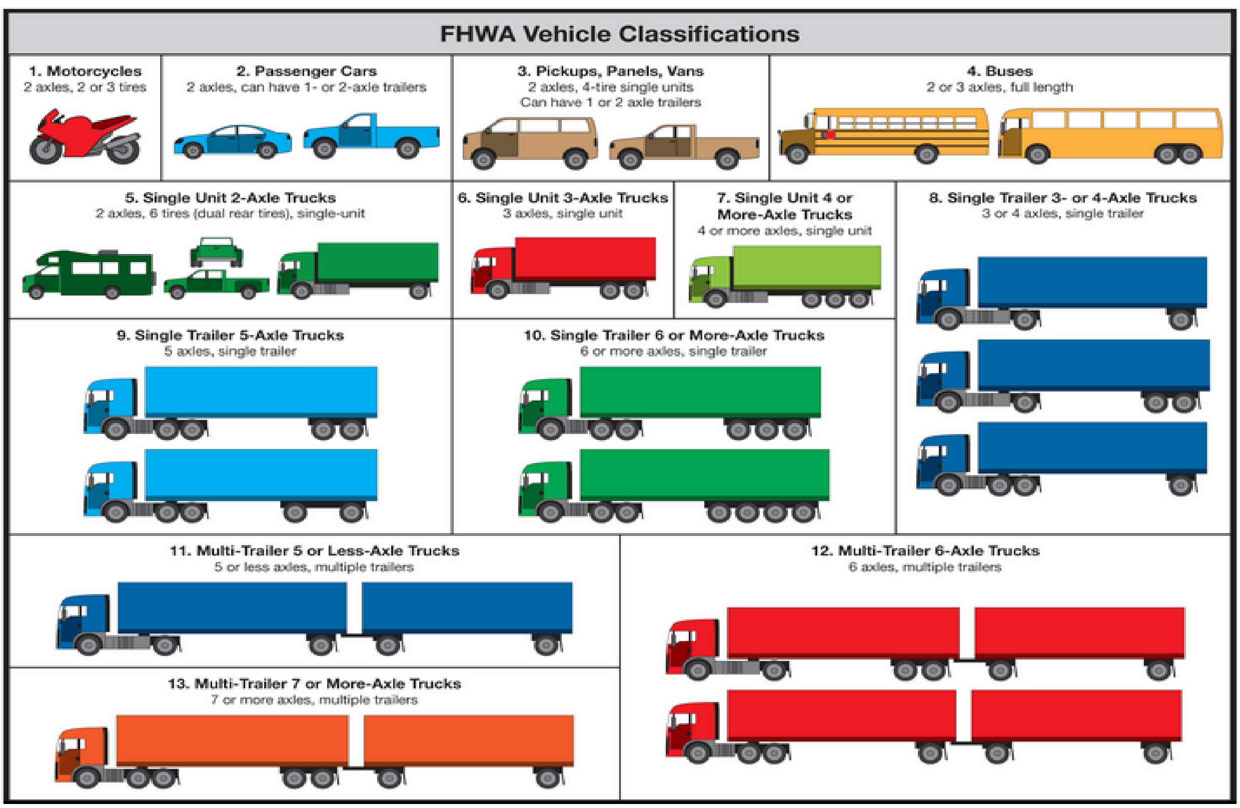
3.0 Vehicle Classifications

Vehicle classifications are an important element in the discussion of the use of electric vehicles in fleet applications. Weight is an essential component in vehicle classification and one of the most important elements in the design of an electric vehicle. Fuel is needed to propel all vehicles, and there is a penalty in efficiency that is associated with the weight of the fuel it carries. Class 3 and above electric vehicles suffer from diminishing efficiency as the size of the vehicle grows; there is the compounding effect of the larger volume of battery needs, coupled with the increased weight of additional passengers or freight. Despite this limitation, conventionally fueled vehicles such as buses, shuttles and local delivery trucks are excellent candidates for electric vehicle applications.

Vehicle classifications are maintained by at least three different federal agencies, including the Federal Highway Administration, the Environmental Protection Agency and the United States Census Bureau. Each agency has specific reasons for maintaining their own classification, the Federal Highway Administration (FHWA) specifications will be used in this report.

Gross Vehicle Weight Rating (lbs)	Federal Highway Administration	
	Vehicle Class	GVWR Catagory
<6,000	Class 1: <6,000 lbs	Light Duty <10,000 lbs
10,000	Class 2: 6,001 – 10,000lbs	
14,000	Class 3: 10,001 – 14,000 lbs	Medium Duty 10,001 – 26,000 lbs
16,000	Class 4: 14,001 – 16,000 lbs	
19,500	Class 5: 16,001 – 19,500 lbs	
26,000	Class 6: 19,501 – 26,000 lbs	
33,000	Class 7: 26,001 – 33,000 lbs	Heavy Duty >26,001 lbs
>33,000	Class 8: >33,001 lbs	

Source: *http://www.afdc.energy.gov/data/10380*



Source:http://onlinemanuals.txdot.gov/txdotmanuals/tri/vehicle_classification_using_fhwa_13category_scheme.html

4.0 Fleets and the Federal Government Regulatory Environment

U.S. transportation fleets represent a major source of fuel consumption and environmental impact; those same fleets also represent the best opportunities to reduce fuel consumption and environmental impact. Standardized fleet operations offer the ability to effectively manage and accurately measure improvements on a large scale.

There are several federal regulatory requirements that play an important role in fleet management, most notably the Corporate Average Fuel Economy (CAFE) standards, the Clean Air Act (CAA) and the Energy Policy Act (EPAct). Compliance with these requirements is varied and is based on application and use. For example, fleet owners see a very direct impact from EPAct regulations, whereas, fleet manufacturers may be more affected by CAFE and CAA requirements. The impacts and relationships in the regulatory environment are complex; as an example, CAFE standards are set and enforced by the National Highway Traffic and Safety Administration (NHTSA), while the Environmental Protection Agency (EPA) calculates the average fuel economy levels for the vehicle manufacturers.

Additionally, it is important to remember that state and local jurisdictions also establish requirements that impact fleet operations; the California Air Resources Board (CARB) is just one of several high-profile, non-federal agencies that establish requirements that address local needs. Equally important is the understanding that many regulatory requirements are the result of goals that are negotiated and agreed to by the regulatory agencies in cooperation with manufacturers, unions, consumer and environmental groups and the public.

4.1 Corporate Average Fuel Economy (CAFE) Standards

CAFE standards are the NHTSA fuel efficiency goals that auto manufacturers have agreed to meet. The standards are established to reduce petroleum use, lower GHGs and save the public money. Petroleum imports in 2025 from OPEC countries are expected to be approximately half of the 2012 levels, and the average driver can expect about $8000 in lifetime fuel savings with a 2025 vehicle when compared to a 2012 model[8].

The goals are reviewed and revised periodically, the current compliance period for passenger and light trucks ends with model year 2016 and new goals have been adopted for model years 2017-2021. The compliance goal for 2016 is 35.5 mpg, rising to 41 mpg in model year 2021. NHTSA and EPA established the first standards for medium and heavy duty vehicles in 2011, new standards for model years 2021-2027 are currently being formulated. An excellent source for more information on federal fuel efficiency standards is available from the Center for Climate and Energy Solutions website at: http://www.c2es.org/federal/executive/vehicle-standards#more_info.

4.2 Clean Air Act

Smog and other pollution prompted Congress to establish the Clean Air Act in 1970. The Act, which was last amended in 1990, requires the EPA establish and enforce air quality standards. The EPA monitors the concentration of six common air pollutants, four of which are among the six major pollutants from vehicles.

The EPA enforces its mandate through the use of several mechanisms, including, reducing pollution from vehicle exhaust and refueling evaporation, and requiring the seasonal reformulation of gasoline to maintain air quality. EPA also promotes the use of alternative fuels such as electricity. Policy goals are also established that require that federally funded transportation projects conform to air quality standards. There are also requirements for on board vehicle diagnostics to monitor performance, and vehicle inspection and maintenance programs are required for areas that do not meet air quality attainment standards.

Obviously there is a significant amount of effort and expense associated with the mitigation of the detrimental environmental effects of CFVs, the integration of electric vehicles into fleets has the potential to significantly reduce much of this effort and expense. More information on the role of the EPA can be found at: https://www.epa.gov/clean-air-act-overview/plain-english-guide-clean-air-act.

4.3 Energy Policy Act (EPAct)

The Energy Policy Act (EPAct) of 1992 called on the U.S. Department of Energy (DOE) to expand research and development in the transportation sector and to create programs for accelerating the introduction of alternative fuel vehicles (AFVs) to replace conventional models fueled by petroleum (gasoline and diesel). EPAct 1992 and subsequent amendments to it, including the Energy Conservation Reauthorization Act of 1998 (ECRA), EPAct 2005, and the Energy Independence and Security Act of 2007 (EISA), established compliance options and petroleum-use-reduction measures. Taken together, these requirements are intended to create a core demand for alternative fuels and advanced vehicles, stimulating markets for these technologies while reducing petroleum use in regulated fleets.

The DOE Alternative Fuel Transportation Program, as codified in 10 CFR Part 490, implements provisions in Titles III and V of EPAct, as amended. These provisions:

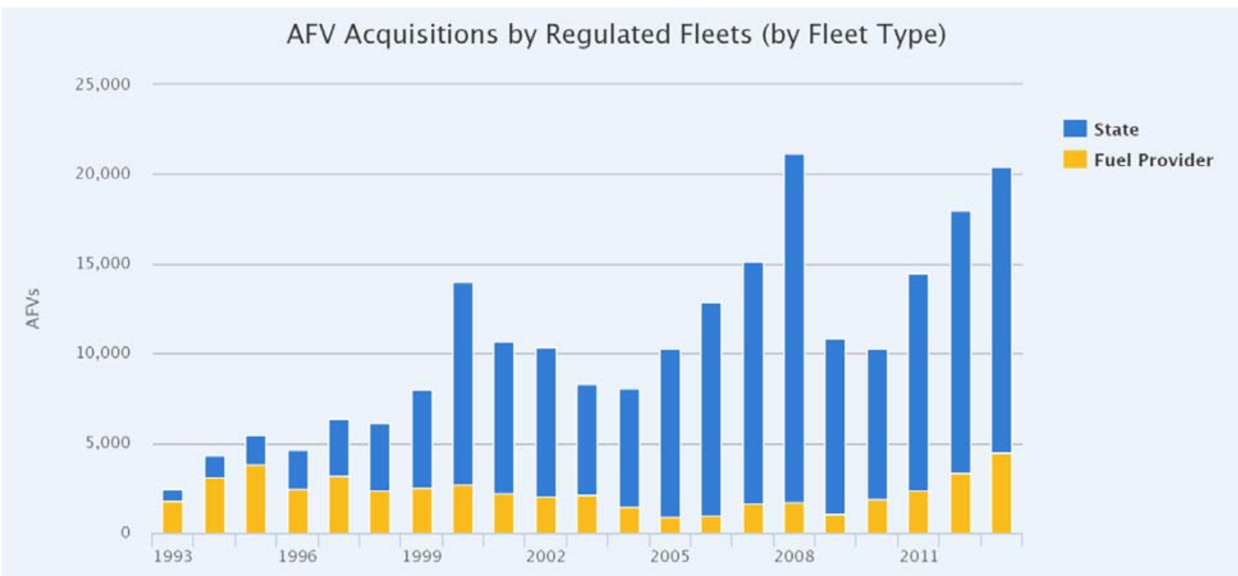
- Call for DOE to establish rules requiring state government fleets and alternative fuel provider fleets to acquire AFVs in certain percentages
- Develop a program of marketable AFV credits for fleets that purchase or lease AFVs either earlier than required or in greater numbers than required, and for fleets that acquire specified electric vehicles that are not AFVs (e.g., gasoline-fueled hybrid electric vehicles) or that make other investments
- Require DOE to establish regulations allowing fleets to reduce petroleum use in lieu of acquiring AFVs
- Establish reporting procedures
- Implement exemption provisions
- Institute enforcement procedures and provisions

State agencies and alternative fuel providers must determine whether they are covered by these provisions and, if covered, must take steps to ensure compliance. Covered fleets have two methods through which to comply with EPAct requirements: Standard Compliance (primarily AFV acquisitions) or Alternative Compliance (petroleum-use reductions in lieu of AFV and other vehicle acquisitions). [9]

In general, compliance with the Alternative Fuel Transportation Program (AFTP) requirements is mandatory for most state and local government fleets, and most businesses whose principal activity is based on the production or sale of EPAct-defined alternative fuels. Typically covered alternative fuel providers have included electric and gas utilities and propane providers. Covered fleets are usually entities that own, operate, lease or otherwise control 50 or more light-duty vehicles (LDVs).[10]

The Federal Fleet initiative is shaped by the requirements of Title III of the Energy Policy Act (EPACT) of 1992, as amended by EPACT of 2005, and Executive Order (EO) 13423. Title III of EPACT 1992 requires that 75% of a Federal fleet's light-duty vehicle (LDV) acquisitions in U.S. metropolitan areas must be alternative fuel vehicles (AFVs).[11]

Compliance with the AFTP has resulted in a significant change in the composition of covered fleets. According to the DOE, 201,000 AFVs were acquired in model years 2000 through 2011, and acquisition of AFVs continues at a pace of 10-14,000 per year.[12]



Under the Energy Policy Act of 1992 (EPAct) and subsequent regulations, certain vehicle fleets operated by state agencies or alternative fuel providers are required to acquire alternative fuel vehicles (AFVs) as a fraction of their light-duty vehicle fleet. This chart shows the number of AFV acquisitions these fleets made from 1992 through 2014. The economic downturn of 2008 led to fewer overall vehicle acquisitions, which in turn reduced AFV acquisition requirements. However, overall AFV acquisitions have since rebounded to pre-Great Recession levels.

Source: http://www.afdc.energy.gov/data/10355

Information on EPAct and state and alternative fuel provider covered fleets is available at http://www1.eere.energy.gov/vehiclesandfuels/epact/covered_fleets.html

4.4 Executive Order 13693, Planning for Sustainability in the Next Decade

The importance of this Executive Order (EO) in the discussion of EV fleets is that it directs federal agencies to establish defined goals for the reduction of GHGs, the acquisition of PEVs for their fleets, and the planning for appropriate infrastructure to support these vehicles.

On March 19, 2015, President Obama issued the new EO directing federal agencies to increase energy efficiency and improve their environmental performance.[13] EO 13693's primary goal is to enhance the directives established by previous EOs. An example of a 13693 enhancement can be found in the new requirement that establishes defined goals in the acquisition of zero-emissions or plug-in hybrid vehicles, the previous EO only had a requirement to use plug-in hybrid vehicles where commercially available at a reasonably comparable life-cycle cost. The new EO requires 20% of all new agency passenger vehicle acquisitions be zero-emissions or plug-in hybrid by the end 2020, increasing to 50% by the end of 2025.

4.5 Obama Administration and Private Sector Electric Vehicle Initiative

The Obama administration presented a comprehensive initiative in late July of 2016 to accelerate the adoption of EVs. The initiative included:

- Making up to $4.5 billion in loan guarantees through the DOE's Loan Program Office to support commercial scale deployment of EV charging facilities
- Supporting the FAST Act requirement to designate alternative fuel corridors, specifically a national EV charging network
- Federal Cooperation with state and local governments in the acquisition of EVs

The announcement formalized a collaboration between the White House in partnership with DOE and the Department of Transportation (DOT), the Airforce and the Army, and the Environmental Protection Agency; it is based on *Guiding Principles to Promote Electric Vehicles and Charging Infrastructure* that nearly 50 organizations have joined.[14]

4.6 FAST Act, Section 1413, Alt Fuel Corridor Designation

Section 1413 of the Fixing America's Surface Transportation (FAST) Act requires the U.S. Department of Transportation's Secretary to designate national electric vehicle (EV) charging, hydrogen, propane, and natural gas fueling corridors by December of 2016. The FHWA will solicit nominations for corridors from State and local officials and involve other stakeholders. During the designation and re-designation of the corridors, the FHWA will issue a report that identifies infrastructure for EV charging, hydrogen fueling, propane fueling, and natural gas fueling; it will also address the standardization needs for electricity, industrial gas, natural gas, infrastructure providers, vehicle manufacturers, electricity purchases, and natural gas purchases. The FHWA report will establish goals for achieving the deployment of EV charging infrastructure by the end of fiscal year 2020. Five years after establishing the corridors, and every 5 years thereafter, the U.S. DOT must update and re-designate the corridors.[15]

5.0 Financial and Operational Considerations

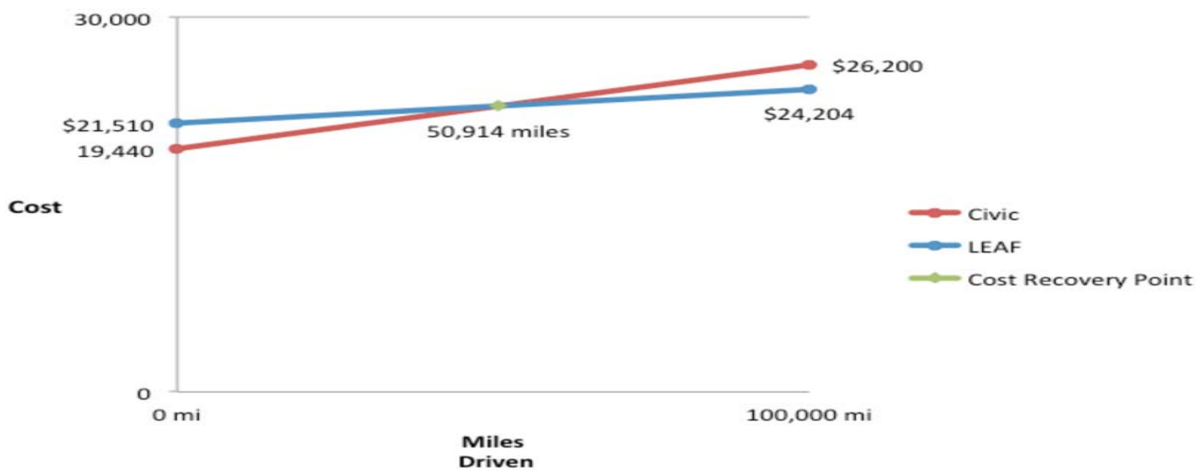
The financial methodologies associated with the deployment of EVs in the fleet environment are not significantly different than the considerations employed when assessing the use of a conventional fueled fleet vehicle. What is different in the consideration of EV fleet deployment are the added benefits zero emissions to health and the environment, and the reversal of harm that CFVs cause. Fleet vehicle selection, by its nature, matches a particular type of vehicle to a particular use, whether the need is for a pool car, a delivery van or a transit bus. As will be seen, compelling arguments for the deployment of EVs can be made when the appropriate EV technology is applied.

Operational considerations in the deployment of fleet EVs have to be significantly different than those for CFVs since they use a completely different fuel source, have different power and drivetrains, and have different operating ranges. While these are decidedly different considerations, they produce more predictable fuel expense, much lower vehicle maintenance cost and meet the operating ranges of many fleet applications.

This report cannot address the broad ranging financial and operational considerations for all modes of EV transportation, since they are highly dependent on the duty and drive cycle of the particular vehicle. The following comparison of a light-duty vehicle application can be offered as an example of the considerations involved.

The purchase price of electric vehicles has been steadily declining while the variety of models has been increasing, these two factors are combining to improve the useful application of EVs in the fleet environment. As previously noted, frequently, the upfront capital cost of an EV is higher than a comparable CFV; dealer incentives and financing, and state, local and federal tax credits routinely result in a lower purchase price for an EV. Importantly, combined total federal and state local tax credits and incentives can approach $10,000 in California and other states. Capital cost is further reduced in the fleet environment because routine maintenance items such as coolants, lubricants and filters and the tools and accessories to perform these maintenances do not have to be stocked.

Determining how and when the additional cost of an EV is recaptured can require a complex evaluation which depends on the make of the vehicle, its utilization, what CFV you compare it to, and how infrastructure costs are accounted for. FleetCarma, a company that specializes in EV fleet analysis, published several vehicle comparisons in June of 2016 using simple vehicle cost and fuel savings. Below is a comparison of the Nissan LEAF and a Honda Civic. The cost of the vehicles is represented on the left, the cost of the vehicle plus its fuel cost is represented on the right. This example has a cost recovery at approximately 51,000 miles and overall 100,000 mile fuel cost of $6,760 for the Honda, versus $2694 for the LEAF.[16]



Capital expense for charging infrastructure can vary widely. A $750 single port Level 2 charger may be able to support one or two EVs, and a $6000 Level 2 multiport charger can service the needs of a small EV fleet. The $35,000 expense of a DC Fast Charger can be justified if the deployed EV fleet size and need is significant.

A federal tax credit of up to 30 percent of the cost of installing EV refueling infrastructure for businesses is available, it is capped at a maximum of $30,000 and is set to expire on December 31, 2016. More information on this and other incentives is available from the Department of Energy at http://www.afdc.energy.gov/fuels/laws/ELEC/US.

The operating expense of EVs is a very attractive reason to consider their deployment in a fleet environment. EVs are mechanically simpler than CFVs, having no transmission, cooling and lubrication systems obviously results in much lower maintenance cost and significantly improves the viability of EVs as fleet vehicles. Early adopter concerns about battery durability and maintenance cost has dissipated. The City of Seattle had Idaho National Labs test the traction batteries in their EV fleet vehicles halfway through their 10-year life cycle, which confirmed that they were still in excellent condition. The electricity fuel equivalent cost for fleet EVs is generally less than $1.00 per gallon. Seattle's data shows that fuel cost for their fleet CFVs was four times the cost of electricity for their EVs.[17]

The cost for insurance for an EV is comparable to that of CFVs and lower in many cases since EVs generally have superior safety ratings and lower repair costs Additionally, most states do not require emissions testing and many offer HOV lane access and other incentives. EVs can also be exempt from fuel surcharges and other taxes, and the cost associated with the disposal of spent lubricants and other materials. Many power companies provide attractive off-peak rates that can dramatically lower the cost of fueling an EV.

The Electric Vehicle Transportation Center (EVTC) has done extensive research into the area of Life Cycle Assessment (LCA) of electric vehicles, and fleet vehicle applications in particular. Return on investment (ROI) is a primary concern in the deployment of EVs, LCAs provide a more revealing look than conventional break-even analysis through the consideration of economic, environmental, regional and societal influences. LCAs are employed in many varieties of project and financial analysis, and are applicable whether a passenger vehicle, a transit bus or a delivery truck is being considered. These LCAs, and many more EVTC studies, can be found at http://evtc.fsec.ucf.edu/publications/index.html.

Deploying EVs in fleet service can be an attractive financial proposition that also has significant environmental and health advantages. These advantages will only be magnified by the next generation, long-range EVs that will be available in late 2016.

6.0 Infrastructure Considerations for Fleet Deployment

The distinction needs to be made between workplace and fleet charging as they are two distinctly different applications that can be easily confused. Workplace charging is considered to be an installation of charging facilities that provide the opportunity for employees to charge their personal EVs at their place of employment. Fleet charging is an installation that provides charging for EVs that are owned and operated by a company or organization. Both types of installations vary in size, ranging from very large campus style workplace charging installations to a much smaller installation designed to service a small municipal EV fleet.

The infrastructure element that provides the crucial link between an Electric Vehicle (EV) with a depleted battery and the electrical source that will recharge those batteries is the Electric Vehicle Supply Equipment or EVSE. Infrastructure is defined as structures, machinery, and equipment necessary and integral to support a PEV, including battery charging stations, rapid charging stations, and battery exchange stations. A battery charging station is defined as an electrical component assembly or cluster of component assemblies designed specifically to charge batteries within a PEV. A rapid charging station is defined as an industrial grade electrical outlet that allows for faster recharging of PEV batteries through higher power levels. Infrastructure must meet or exceed any applicable state building standards, codes, and regulations.[18]

6.1 Electric Vehicle Service Equipment (EVSE)

EVSE is the equipment connected to an electrical power source that provides the alternating current (AC) or the direct current (DC) that is needed to charge the EVs traction batteries. EVSE charging capacity options are an important consideration as they have a direct bearing on how fast the batteries can be recharged. As an example, Level 2 EVSE is available in 20, 30 and 40 amp capacities and higher amperage equates to faster recharge times. However, the PEV's onboard charger must have the ability to match the full output of the EVSE to realize the fastest recharge times.

EVSE is commonly referred to as Level 1, Level 2 or Level 3 DC Fast Charge (DCFC). In general terms, EVSE classification pertains to the power level that the equipment provides to recharge a PEV's batteries. The use of higher charge levels can significantly reduce the time required to recharge batteries.

The Society of Automotive Engineers (SAE) provides technical standards which classify these chargers in a more detailed manner as AC Levels 1, 2 and DC Levels1 and 2. Information on AC and DC can be found at: http://standards.sae.org/j1772_201602/

Level 1 Charging Cord
Source: Roperld

Level 2 Charging Station
Source: ClipperCreek

DC Fast Charging (DCFC)
Source: Evcaro

AC Level 1 Charging

Level 1 provides charging from a standard residential 120-volt AC outlet, its power consumption is approximately equal to that of a toaster. Most PEV manufacturers include a Level 1 EVSE cord set so that no additional charging equipment is required. As a general rule, Level 1 recharging will add approximately four miles of travel per hour. Level 1 charging is the most common form of battery recharging and can typically recharge a PEV's batteries overnight; however, a completely depleted PEV battery could take up to 20 hours to completely recharge.

AC Level 2 Charging

Level 2 equipment provides charging using 220-volt residential or 208-volt commercial AC electrical service, its power consumption is approximately equal to that of a residential clothes dryer. As a general rule, Level 2 recharging will supply up to approximately 15 miles of travel for one hour of charging to vehicles with a 3.3 kW on-board charger, or 30 miles of travel for one hour of charging for vehicles with a 6.6kWh on-board charger. Level 2 EVSE utilizes equipment specifically designed to provide accelerated recharging and requires professional electrical installation using a dedicated electrical circuit. Level 2 equipment is available for purchase online or from retailers that sell other residential appliances. A completely depleted PEV battery could be recharged in approximately seven hours using a Level 2 charger.

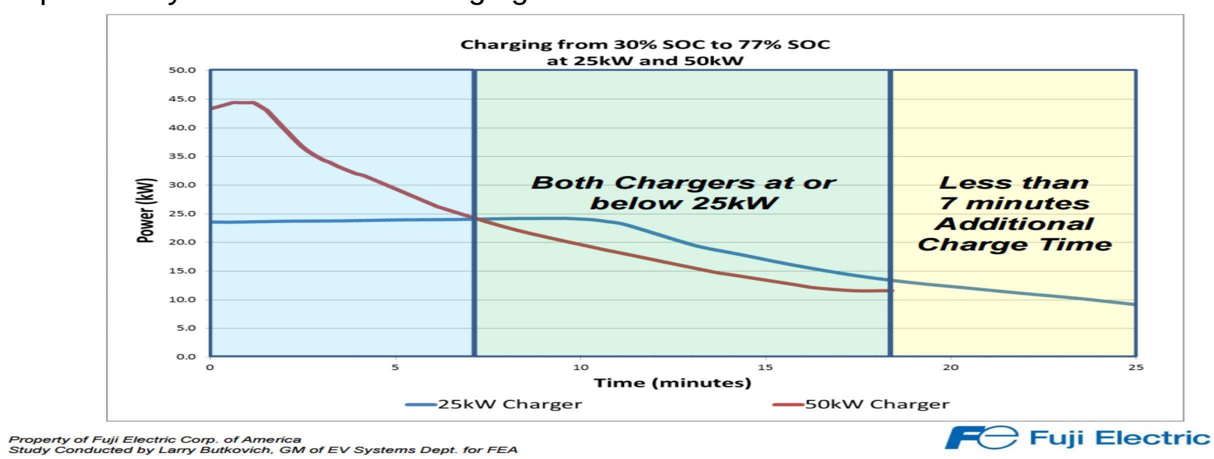
DC Fast Charging (DCFC)

DCFC equipment requires commercial grade 480-volt AC power service and its power requirements are approximately equal to 15 average size residential central air conditioning units. As a general rule, DCFC recharging will add approximately 80-100 miles of travel with 20-30 minutes of charging. The DCFC EVSE converts AC to DC within the EVSE equipment, bypassing the car's charger to provide high-power DC directly to the PEV's traction batteries through the charging inlet on the vehicle. DCFCs are being deployed across the United States, typically in public or commercial settings. While the power supplied to PEVs by all DCFCs is standardized, there is not uniform agreement on the connector that is used to connect the charger to the vehicle. There are two competing standards for the vehicle connectors used with DCFCs; one standard is the SAE J1772 Combo developed by the U.S. auto standards development organization SAE and the other is the CHAdeMO connector developed by a Japanese auto standards organization. As a practical matter, both connectors work very well. DCFC's high-power capabilities can restore a depleted PEV battery in approximately 30 minutes.

Table 1. EVSE General Characteristics (50% depleted battery)

	Charge Time	Voltage/Amps	Power Equivalent	Installation
Level 1	10 hrs.	120/12	Toaster	Self
Level 2	4 hrs.	240/30	Clothes dryer	Professional
DC Fast Charge	15 min.	480/60	15 Central A.C.	Professional

Discussion on EVSE should expand beyond the electrical specifications for the installation of the charger and include consideration of what capacity charger would be appropriate for the application and budget. As an example, 30-minute 50 kW fast charger could end up costing $35-$45,000 and have a significant impact on the power bill by pushing facility use into "demand" charges. A less expensive (capital and operating) 25kW charger would provide the same charge with just a little more time.[19] The below charging profile example of both capacity chargers illustrates how the higher peak power may impose unwanted demand charges (45kW compared to 25 kW) and requires only 7 minutes less charging.



There are also considerations associated with network vendors such as ChargePoint, Greenlots, eV2go, and others. Frequently they have specific vendors that they interface with from a network communications/back office perspective. Charger network protocols have some standardization, but in essence, are still highly proprietary. As an example, most EV owners must have several specific RFI cards to access chargers; use a Greenlot's networked charger and you need a Greenlot's RFI, use a ChargePoint networked charger and you need a ChargePoint RFI card. Customized network and charging facilities management and documentation systems are available from a variety of vendors.

6.2 Codes, Signage and ADA

National Electrical Code

Codes dictate requirements, standards dictate how to meet those requirements and each are codependent. For example, a building code that requires vehicle repair garages have sprinkler protection would need a coexisting standard to specify the requirements for sprinkler protection, and a standard for sprinkler protection would require a code to dictate where it applies. Codes and standards are legally enforceable when jurisdictions adopt them by reference or direct incorporation into their regulations. When jurisdictions adopt codes, they also adopt the standards that dictate how to meet those codes. Codes and standards often become industry norms when industries comply with them even though jurisdictions have not adopted them.[20]

EVs replenish their battery power using EVSE served by an electric service infrastructure; the interface of both of these elements requires a more demanding adherence to codes and standards than those associated with conventionally fueled vehicles. As an example, although conventional fueling island shutdowns are required, there is no requirement that a gas pump shut down if the supply hose becomes disengaged from the vehicle. EV refueling requires not only that the fuel source (EVSE) shut down if the supply connector becomes disengaged, it also requires that the PEV drive systems be disabled during the refueling process.

The most widely adopted standard governing the installation of EV charging equipment is the National Electrical Code (NEC), specifically Article 625. NEC Article 625 concerns the wiring and equipment external to the PEV that connect the vehicle to a supply of electricity for battery charging. Article 625 details the requirements for the installation of Level 1, 2 and DC fast chargers at both indoor and outdoor sites. Article 625 applies to the installation of both "conductively" cable connected charging equipment and inductive or "wireless" charging equipment.

The NEC, or NFPA 70, is an internationally recognized and regionally adoptable standard for the safe installation of electrical wiring and equipment in the United States. The NEC, while having no legally binding regulation as written, is often adopted by states, municipalities and counties in an effort to standardize the enforcement of safe electrical practices within their respective jurisdiction.

Battery charging safety considerations are addressed by NEC Article 625 and its requirement that all charging equipment be UL listed. PEV battery charging systems are complex, high-voltage electrical systems that contain few if any user serviceable parts. It is important that PEV owners become familiar with charging procedures specific to their vehicle and the charging systems they routinely use. EVSE users and owners should thoroughly review and adhere to the manufacturer's recommended guidelines. The manufacturer or a qualified professional electrician should always be consulted for answers about the installation or use of PEV charging equipment.

From an infrastructure perspective, the electrical demarcation point is the premise or property threshold. Excluding utility load management, the utility infrastructure interface requirements of the PEV and EVSE look substantially like many other utility service connections. The utility side infrastructure safety requirements of this demarcation are not included in this study, they are a separate infrastructure domain addressed primarily by the National Electric Safety Code (NESC).

The National Electrical Safety Code (NESC) is sometimes confused with the National Electrical Code (NEC). To provide clarification, utility employees, who provide electrical services up to the premise edge, follow the National Electrical Safety Code (NESC). Electricians, working with premises' wiring and utilization equipment, use the National Electrical Code (NEC). There are situations when the installation of a charging station or other equipment may require both NEC and NESC considerations, particularly in an outdoor or public environment; these and other specialized installations should be addressed on an individual basis. This report is restricted to the environment governed by the NEC.

<u>The Occupational Health and Safety Administration (OSHA) and the Nationally Recognized Testing Laboratories (NRTL)</u>

OSHA requires NRTL approval for many different types of products; electric equipment is the largest of these product categories. NRTLs are safety consulting and certification companies that provide safety-related certification, validation, testing and inspection services to a wide range of clients including manufacturers, retailers, policymakers, regulators, service companies and consumers.

<u>EVSE Listing Requirement</u>—Compliance with NEC Article 625 includes the requirement that installed charging station equipment must be "Listed." Listed PEV charging systems have been investigated to a comprehensive set of construction and performance requirements designed to reduce the risk of fire, shock and personal injury. The equipment has also been specifically tested and certified for installation in accordance with all of the safety requirements of NEC Article 625. An example of these listings is Underwriters Laboratories' (UL) requirements for charging equipment. Level 1 and 2 chargers require UL category FFWA (EVSE). Equipment providing DCFC must meet the requirements of category FFTG (electric vehicle charging system equipment) (Regulatory Services Department of Underwriters Laboratories Inc. 2010).

There are many other considerations involved in the planning of EV fleet charging infrastructure including traffic flow, lighting, building permits, landscaping, training, and planning for expansion and capacity upgrades. PG&E's EV Charging at Fleet Facilities is an excellent source for checklist and considerations when considering an installation.[21]

Signage Requirements

Signage for plug-in electric vehicle (PEV) charging stations is an important consideration at workplaces, public charging stations, parking garages, and multi-unit residential complexes that offer access to electric vehicle supply equipment (EVSE).

Appropriate charging station signage can:

- Help PEV drivers navigate to and identify charging stations
- Optimize use of EVSE by helping all drivers understand that parking spaces at charging stations are for PEVs only
- Provide information about regulations—such as access, time limits, and hours of use—and facilitate enforcement
- Facilitate deployment of plug-in vehicles by providing visibility for charging infrastructure to prospective PEV drivers.

Signage for charging stations falls into two categories: way-finding signage and station signage. Way-finding signage helps EV and PHEV drivers navigate to charging stations from other locations, such as a freeway exit. Station signage helps EV and PHEV drivers identify charging stations. It also helps charging station hosts communicate and enforce regulations related to the use of the EVSE and associated parking spaces.

The Federal Highway Administration (FHWA) defines the minimum standards for signage, which it publishes in the Manual on Uniform Traffic Control Devices (MUTCD).[22] The standards in the MUTCD apply to all signage on public highways, streets, bikeways, and private roads open to the public, such as at shopping centers and airports. FHWA has approved the following interim designs for charging station signs:

D9-11bp

D9-11b

FHWA refers to the signs above as D9-11bp (written description) and D9-11b (symbol). For way-finding purposes, these designs can be combined with directional arrows and mileage.

Private parking areas that are not open to the public (such as employee parking areas at workplaces) are not required to meet MUTCD signage requirements. But organizations that provide charging in private areas may find that consistency with the standards helps all drivers understand and recognize charging station signage.

Pavement markings, painted on the surface of a parking space, can be used to reinforce signage for charging stations. Notably, most jurisdictions deem pavement markings unenforceable on their own. For general information about pavement markings, see Chapter 3B of the MUTCD and guidance from U.S. Department of Energy's Alternative Fuels Data Center.[23]

<u>Americans with Disabilities Act</u>

Most public EVSE installations must include access for persons with disabilities and comply with the Americans with Disabilities Act (ADA). ADA requires nondiscriminatory access to places that accommodate the general public. Commercial facilities that do not directly serve the public – like office facilities and warehouses –must also meet ADA requirements for new construction and alterations.[24]

Federal statutes and National standards that guide accessibility requirements include:

- 2003 International Building Code
- 2009 ANSI A117.1
- U.S. Americans with Disabilities Act – 28 CFR Part 36 (ADA)

7.0 Case Studies

7.1 Light Duty Vehicles (Class 1-2)

7.1.1 Electric Bikes, Scooters and Motorcycles (Class 1)

Two-wheeled fleet electrification is a low-profile but growing transportation segment that provides viable alternatives to traditional two-wheeled offerings. Electrified two-wheeled transportation holds the promise of significant adoption in countries that depend heavily on this mode of transportation. China, India and many other eastern and European countries have large population segments that depend on mopeds and motorcycles; electrification of those segments promises significant reductions in petroleum use and GHGs.

Electric bicycles (e-bikes) largely resemble a traditional bicycle but have a small integrated electric motor and battery pack. E-bike motor capabilities range from useful peddle assist to fully independent propulsion, reaching speeds of 15-20 mph. Electric scooters and motorcycles do not offer peddling ability and are simply electric versions of traditional products. Handling and general performance is very comparable to the traditional versions, in most cases acceleration is noticeably faster because of the torque characteristics of electric motors. Vendors in many major American cities have deployed fleets of rental scooters and e-bikes, and electric motorcycles are becoming more common in police departments.

Leading the way is Scoot Networks with approximately 400 scooters at 75 locations around San Francisco. A minimal membership fee is required and riders need a smart phone app to reserve and rent a Scoot. Members must be 21 and have a driver's license, helmets are included with each rental. Free training sessions are available and Scoots can be dropped off at any Scoot location. A 30-minute ride cost $3.00, plus $.10/minute for rides over 30 minutes. During commuting hours, 30-minute rides are $5.00 plus the $.10/minute. The Scoots can travel about 20 miles on a charge, take about three hours to fully recharge and get the equivalent of 600 MPG, with 2% of a car's GHG emissions. More information is available at https://scoot.co/faq/.

E-bike fleets are also being deployed in major American cities. Oakland California dedicated a solar powered e-bike share facility in January of 2016. The program is membership based with several different levels of membership, including one of low-income members.

Swiftmile is a California company that builds and deploys a variety of modular solar personal transportation installations, including e-bikes. The city of Baltimore has awarded a $2.4 million contract to deploy 50 bike share stations with 200 electric pedal-assist in the fall of 2016. Membership is required for the Baltimore program, members can reserve an e-bike or simply walk up to a station and check one out using a smartphone app.

Electric motorcycles are finding a fleet home in the police departments. Zero Motorcycles offers three fully-electric models of police motorcycles that are deployed in over 50 police departments in the U.S. The tactical advantage, ride comfort and lower total cost of ownership offer an attractive alternative to conventional patrol motorcycles. Patrol officers note that the lack of noise and vibration are a real plus when spending a whole shift patrolling, they can also be used at arenas and other indoor venues. The motorcycles have a range of over 175 miles, cost about one-cent-per-mile to fuel and have much lower maintenance costs. Electric motorcycles are also well received by the public because of their environmental advantages, low noise and lack of fumes. More information is available at http://www.zeromotorcycles.com/

Photo: Zero Motorcycles

7.1.2 Taxi EV Fleet (Class 2)

Taxi fleets present several unique opportunities and challenges when electrification is considered. On the environmental side, a fleet of taxis in a large metropolitan environment present the opportunity for significant improvements in the reduction of Green House Gas (GHG) contributions, noise reduction and urban heating. From an operational point of view, electric taxi fleets promise potentially lower maintenance and fueling cost that have to be balanced against battery and infrastructure cost.

Deployment of EV taxis would also reduce the compounding concentration of pollutants found inside the vehicles that are sharing congested city streets.[25] A study by the NYC Taxi & Limousine Commission found that replacing one-third of the 4412 city taxis would reduce CO2 emissions by 18%. The same study points out that the use of conventionally fueled taxis contribute substantially more pollution than private vehicles, the commission estimates that replacing a conventional taxi with and EV resulted in the emissions impact of replacing eight personal vehicles.[26] EV taxis are exceptionally quiet running automobiles and also emit less than 20% of the heat of conventionally fuel taxis.[27]

While the environmental and health benefits of EV taxis are pretty straight forward, the operational expense of deploying an EV taxi fleet are more complex. Fuel cost reductions and price stability are the most straight forward advantages. The Miles per Gallon of Gasoline Equivalent (MPGe) using the electrical grid for fueling is approximately $1.00 per gallon at $0.12/kWh.

EV taxis have several unique requirements, among them could be the need for a traction battery system that is significantly larger than those required for traditional EV light-duty passenger fleet use. Ideally, a Nissan Leaf in taxi use would need a 35kWh battery instead of the standard 24kWh. While not absolutely necessary, the larger battery system would only require one recharge during a standard 12-hour shift.[26]

Several companies have realized the potential of EV taxis and have designed completely new EVs dedicated exclusively to taxi service. EVA, is a taxi designed specifically for the subtropical environment of Southeast Asia, featuring a travel range of 124 miles and a full recharge time for the 50 kWh battery of 15 minutes; more information is available at http://www.eva-taxi.sg/index.php. Manufacturers in England have begun volume production of their new Metrocab, which is completing fleet trial service in London and is expected to go into service in 2016. The extended range vehicle is driven by two 50kW motors powered by the vehicle's 12kWh battery, the taxi can achieve over 100 miles per gallon; more information is available at http://www.newmetrocab.com/.

The maintenance considerations associated with EV taxis also take on a different perspective when compared to conventional passenger vehicles.

Taxis typically operate around the clock, requiring more battery charge cycles, and possibly more frequent battery replacement. On the positive side, EV taxis require significantly less traditional repair and maintenance. EV taxis would not require the oil changes, transmission fluids, coolant, spark plugs and other maintenance and repair commonly associated with conventional fueled vehicles. The savings in parts and labor maintenance, coupled with the additional revenue associated with less downtime could provide a compelling justification for switching to EVs.

Refueling infrastructure becomes more of a consideration when EV taxis are deployed. Taxis are usually on the road almost continuously during two 12-hour shifts and there is a serious lack of fast-charge facilities in most urban environments; having to share the facilities with the existing general EV population is problematic on several levels. Investing in a dedicated fast-charge infrastructure requires significant upfront capital and logistical commitments that can be managed internally or through partnerships.

EV taxi fleets are faced with unique challenges to their business models, but profitable, large-scale EV taxi fleets are operating today. Three companies operate more than 170 Nissan Leafs and e-NV200 electric vehicles in Amsterdam, Netherlands. There are also approximately 167 Tesla Model S taxis in service in Amsterdam.[28]

7.1.3 EV Car Rental (Class 2)

Renting an EV can be challenging, even to the person that may own and use an EV at home. EV's present a steep learning curve associated with their use and the lack of ubiquitous charging facilities only serves to present an additional barrier. However, several well-known car rental companies have made significant commitments to incorporating EVs in to their fleets, and a trial project underway in Orlando Florida has recently expanded their pilot program.

Drive Electric Orlando recently received additional funding to expand its EV car rental program. The project is a consumer education and vehicle demonstration project that provides visitors to Orlando, Florida with first-hand experience of the benefits of EVs through the availability of rental EVs from Enterprise Rent-A-Car. Drive Electric Orlando significantly reduces the anxiety that may accompany renting an EV by providing an enhanced level of engagement with the customer by providing a detailed understanding of the operation of the EV and the reassurance that comes with the knowledge that free vehicle charging is available at partner host hotels and theme parks, frequently as a valet service. The program also provides additional amenities such as free, GPS, charging, and free hotel and valet parking. More information is available at http://driveelectricorlando.com/.

Several other car rental companies offer EV rentals. Hertz's "Green Traveler" program, features Nissan Leafs and GM Volts and Sparks, Enterprise offers EV rentals in 19 cities nationwide.

7.1.4 Ride-sharing EV Fleet (Class 2)

According to the FHWA, "Transportation demand management (TDM) refers to a set of strategies aimed at reducing the demand for roadway travel, particularly in single occupancy vehicles."[29] Ride-sharing is one of those strategies and it can take several forms, including Uber and Lyft style uses that join passengers with private car owners or an application similar to BlueIndy, a subscription car sharing service in Indianapolis. Ride sharing is a response to an emerging set of ambitions to minimize the commitment and cost of vehicle ownership and to reduce the environmental, public health and travel congestion impacts associated with those vehicles.

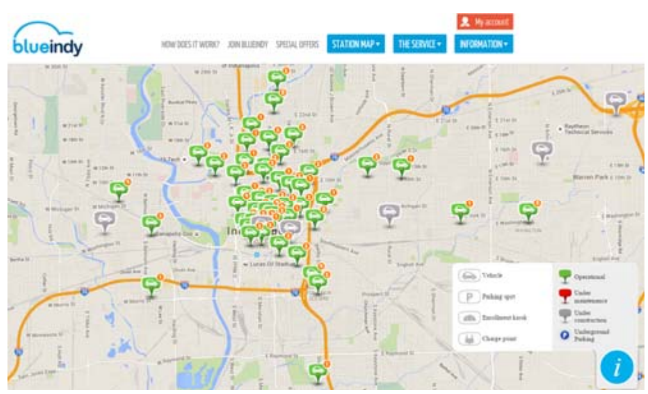
In early 2015, General Motors provided some insight into the direction that EV ride-share may be heading. Pamela Fletcher, GM's chief engineer for electric vehicles, told USA Today that the new Chevrolet Bolt EV was the first car designed for ride sharing. The Bolt is a new all-electric passenger car with an estimated 200 mile range that is expected to go on sale in late 2016.

The City of Los Angeles initiated a ride-sharing program for low-income residents in the summer of 2015. Using a grant of $1.6 million from California's Cap-and Trade Program, the city established a pilot program of at least 80 EVs and placed the car sharing stations in disadvantaged communities in Central L.A. The program also includes the installation of 110 Level 2 charging stations.

Several companies have launched EV ride-sharing programs in the U.S. Car2Go has launched in over a half-dozen major cities, including Miami, Washington and San Diego. Customers pay a flat rate per minute for the use of the vehicle that includes fuel, insurance and all other expenses; some required local government fees may also be added to the bill.

BlueIndy is the newest of the car sharing services and is a subscription based service that has EVs at over 200 locations in the Indianapolis area. Several different levels of subscription are available, either on the web or in person at a BlueIndy station that is equipped with an enrollment kiosk. A "Charging Membership" that allows an EV owner to park and charge their personal vehicle at a BlueIndy station is also available. Subscribers must have a valid driver's license, insurance is included in the membership. A subscriber reserves a car, unlocks it with their membership card, unplugs the charging cable, drives to their destination and parks the car in the closest available BlueIndy reserved parking spot. The four-passenger cars are equipped with a 30-kWh Lithium Metal Polymer battery, providing up to 150 miles of range.

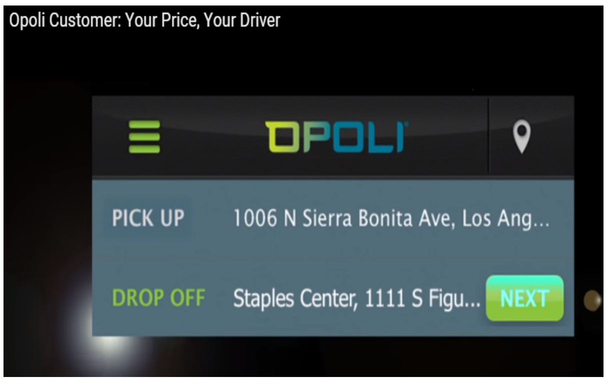
Photo: insideevs.com



https://www.blue-indy.com/

Ridesharing concepts like Uber and Lyft match passengers with private drivers through the use of a smart phone app or a web-based application. The applications provide information on cost, photos of the driver and their vehicle, and satisfaction ratings from previous passengers.

Ridesharing provider Opoli has electrified the application with the inclusion of 50 all-electric BYD e6 electric crossover SUVs in its San Diego fleet. The service works much like other ridesharing services with the added twist that customers can negotiate a fare other than the “recommended” charge that appears when placing a reservation. The e6s are also on duty in New York, San Francisco and Chicago, have a range of 180 miles and incorporate bi-directional chargers.



https://opoli.com/

http://www.byd.com/la/auto/e6.html

A subscriber-based EV transportation alternative provides many significant positive impacts, especially in an urban environment. The alternative is also attractive to those living in an urban environment as it reduces the need for parking, insurance and many other expenses associated with conventional vehicle ownership.

7.1.5 Local Government EV Fleet

Urban settings are very EV compatible. The drive and duty cycles that are prevalent in cities maximize the efficiencies of EVs, and population density provides the best opportunity to achieve some of the most significant environment advantages.

Many U.S. cities find that EVs are more than compatible with many of their employees work transportation needs, including one of the nations' largest. In December of 2015, New York City announced a plan to replace over a third of its light-duty vehicle fleet with EVs. NYC's Vehicle Sustainability Plan directs city agencies to, "immediately begin phasing in EVs to satisfy light-duty vehicle needs where operationally and economically feasible, on a path toward introducing an additional 2,000 EVs into the City's fleet by 2025." The plan establishes an EV Taskforce to help remove barriers to implementation and coordinate the efforts of the city's facility and fleet operations. A stated goal of the program is to reduce NYC fleet emissions by 50% by 2025 and 80% by 2035. The City's sustainability plan provides an excellent model for other large cities in outlining the use of EVs to achieve transportation efficiency and GHG reduction. [30]

The City of Los Angeles is also committed to increase its EV fleet and has committed to the goal of 50% of their new city fleet purchases being EVs by 2017.[31] Los Angeles recently awarded a contract to BMW for the lease of 160 pure battery i3 EVs for its police department, and will also lease an additional 100 plug-in hybrid electric vehicles and install 100 Level 2 and four DC Fast Chargers.[32]

Smaller cities and local governments can also realize the benefits of replacing the aging conventionally fueled fleets with EVs. While the GHG reduction at the local level may be less pronounced that in a dense urban environment, the operating expense reductions, overall cost of ownership and attractive municipal financing are substantially more impactful on the budgets of small government.

L.A. Fire Chief Ralph Terrazas, left, and LAPD Chief Charlie Beck on Friday check out a BMW electric vehicle at LAPD headquarters before a news conference at which the mayor offered up details about the city's plan to bolster the use of electric vehicles. (Irfan Khan / Los Angeles Times)

7.1.6 U.S. Military

The U.S. military has taken a lead role in many areas of sustainability and is doing so in the deployment of EVs. The project with the highest visibility is the 42-vehicle deployment of pure electric and plug-in hybrids at L.A. Air Force Base. The ongoing research project also includes the integration and demonstration of Vehicle-to-Grid (V2G) utilizing bi-directional chargers that have been installed on 36 of the vehicles.

Photo: U.S. Air Force

The bi-directional ability allows the base to interface with CASIO (California Independent System Operator), California's open market energy management authority. CASIO manages the interface with multiple renewable and distributed energy producers, allowing the base to potentially sell EV stored energy on the open market to offset overall energy expense. The EVs help reduce fleet operations expense, attain environmental goals and are also available to provide auxiliary power in emergency situations.[33]

The U.S. Navy made a dramatic announcement in early 2016 of their intention to lease between 400 and 600 battery electric sedans for use by Navy and Marine personnel at 15 locations in California. The vehicle leases will be for one year with options for 24 and 36 month extensions. Leasing the 400 minimum vehicles would result in the largest deployed fleet of all-electric vehicles in the U.S. Interestingly, there is no known corresponding plan to install infrastructure to support the deployment.[34]

7.2 Medium Duty Vehicles (Class 3-6)

7.2.1 Class 4 EV Urban Delivery and Shuttle Vans Fleet

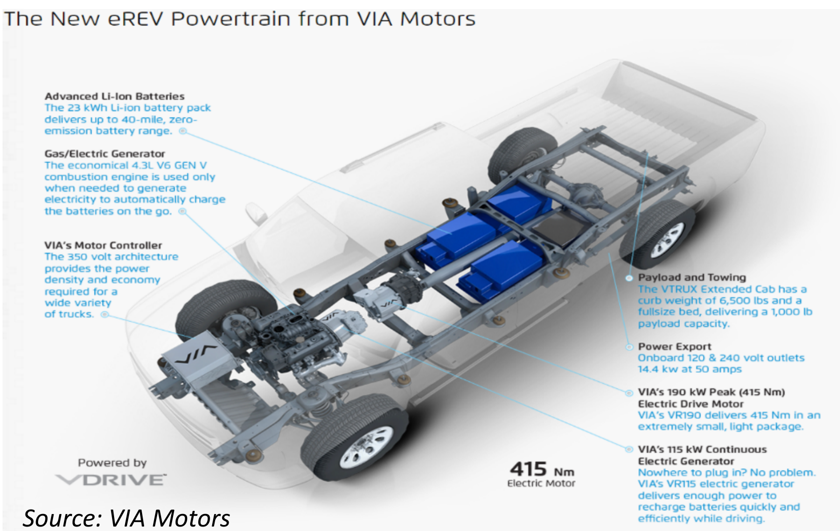
Case study information is difficult to find but there is an emerging market for EV delivery vans that is being pioneered by FedEx, UPS, Zenith and others. Like transit buses, the drive cycle for delivery vans is very complimentary with low highways miles, average delivery speeds at approximately 20 mph, multiple stops per day and plenty of stop and go driving take advantage of the regenerative braking system.

United Parcel Service is the latest pioneer in EV delivery vans with their deployment of 18 electric vans in the Houston-Galveston, Texas metropolitan area. The all-electric vans were designed and built by the Workhorse Group, an Ohio company that is focused on electric and hybrid-electric delivery vehicles. The deployment is funded in part by a grant from the DOE National Energy Technology Laboratory, in an effort to improve the air quality of the region and to offset development cost and lower eventual cost of zero emissions vehicles.[35]

FedEx Express deployed and tested Nissan e-NV220 compact electric delivery vans in the Washington, D.C. area in early 2014. The Nissan van is widely deployed in Europe and elsewhere and is the electric counterpart of Nissan's conventionally fueled NV220. The van is also available in a five-passenger version and uses the same lithium-ion battery back and power train as the Nissan LEAF, developing 107 horsepower from its 24kWh battery pack.[36]

Photo: FedEx

Zenith Motors is a privately funded American manufacturer of all-electric passenger and cargo vans. Their vans provide seating for up to 16, 530 cubic feet of cargo space and payloads of up to 3800 lbs. The passenger vans have range options of 80, 100 and 140 miles and Level 2 recharge times of 4 or 6.5 hours.[37]



Source: VIA Motors

7.2.2 Pickup Trucks

Several electrified pickup trucks are in development, but VIA Motors is currently the only manufacturer of electrified pickup trucks. VIA anticipates selling their vehicles to individual consumers, but for now is focusing on government, utility and other fleet applications. Their powertrain is designed to work in a variety trucks from different manufacturers. VIA Motors' manufacturing approach is to take new Chevy pickups and vans and replace the traditional power and drivetrain with a specially developed gas/electric generator and a 23 kWh Li-ion battery pack. The gas engine is only used to charge the batteries and the truck can provide up to 40 miles of emissions free driving. VIA trucks also feature power export capabilities of 14.4 kW at 60 amps, providing power for worksite equipment and emergency power. More information is available at http://www.viamotors.com/.

7.3 Mass Transit

7.3.1 Transit Buses

Approximately 800 transit agencies in the United States operate over 70,000 transit buses.[38] Mass transit, and particularly urban mass transit, provides one of the most efficient and impactful opportunities to realize the benefits of electric transportation. Electric bus mass transit combines one of the most efficient methods of transportation with the opportunity to significantly reverse the harmful health and environmental impact of petroleum based mass transit.

Transit buses excel as a mass transit option because:

- They operate on short, fixed routes
- They frequently return to a centralized location, which allows them to access recharging facilities
- They make frequent stops to take advantage of regenerative braking
- They travel at low speeds which conserves battery charge

Battery-electric buses employ the same basic technology as light-duty electric vehicles, traction drive batteries, electric motors, regenerative braking, etc. Bus design, battery chemistry and motor type does vary significantly between the buses manufactured by Proterra, BYD and others.

The capital cost of most modes of electric transportation are currently more expensive than conventionally fueled vehicles, and transit buses are no exception. Electric buses are approximately 40% more expensive than a comparable diesel bus. However, like electric passenger vehicles they cost less to fuel and maintain. An electric bus will average about $7500 per year in electricity cost compared to fueling a diesel bus at $50,000 annually or a natural gas bus at $30,000. Maintenance cost savings over a 12-year life are between $70-90,000.[39] Transit buses also usually qualify for substantial Federal Transit Administration (FTA) subsides. Combining operational and fuel savings with subsides and, in some states, the sale of carbon tax credits can make the purchase of electric buses very attractive. As battery cost continue to drop, electric buses in mass transit will increase in viability as an alternative to conventionally fueled buses.

The National Renewable Energy Laboratory's 2016 report, "Foothill Transit Battery Electric Bus Demonstration Results" provides compelling conclusions that support the use of electric buses in mass transit. The report is based on findings during a 14 month evaluation of three electric buses by the Foothill Transit agency in the Pomona Valley region of Los Angeles, California. The performance of the electric buses were compared to that of the same model year compressed natural gas (CNG) buses.

Service performance of both technologies was comparable with the notable exception of fuel economy, the results indicated that the electric buses, "have an average fuel economy that is nearly 4 times higher than that of the CNG buses." [40]

Recent Battery Electric Transit Bus Deployments

Manufacturer	Location/Customer	Number of Buses
Proterra	Stockton, CA - San Joaquin RTD	2*
	Pomona, CA - Foothill Transit	15*
	Reno, NV - RTC	4
	San Antonio, TX - VIA	3
	Louisville, KY - TARC	10*
	Nashville, TN - MTA	9
	Tallahassee, FL - StarMetro	6
	City of Seneca, SC - CatBus	6
	Worcester, MA - WRTA	6
BYD	Los Angeles, CA- LA Metro	5
	Stanford, CA- Stanford University	13**
	Lancaster, CA - AVTA	2
	Gardena, CA	1
	Netherland	45
	Malaysia	15
	South America	15
	China	2500
	Israel	1
New Flyer	Winnipeg – Winnipeg Transit	4

*There are a total of 25 more buses on order for these customers as well as 22 to 5 new customers. **There are a total of 10 more buses on order for this customer, as well as 19 to 4 new customers. (Customer data was provided by manufacturers and was current as of mid-2015.)[39]

7.3.2 School Buses

There are approximately 480,000 school buses in the U.S., transporting 25 million students.[41] Typically, school buses have duty and drive cycles that are similar to transit buses; they also have some important additional advantages. First, school buses have an extended period of "downtime" between transporting students to and from school, time that can be used to recharge the vehicles batteries. Second, the downtime of electric school buses could make them an attractive revenue source in a V2G environment. Electric school buses are not in wide production at this time but they are poised to become more common in the near future. Several manufacturers offer versions of Class A, C, and D buses; they have a travel ranges of 40-80 miles on battery sizes of 83-110 kWhr. Several trials in California have been completed and electric school buses routinely transport students. There have also been several conversions of conventionally fueled school buses to electric.

Electric school buses offer several attractive advantages over conventionally fueled buses; conventionally fueled buses do reduce the number of cars that would be needed to transport students, they primarily use diesel fuel. From an environmental and health perspective electric buses offer compelling reductions in GHGs, diesel particulate matter and other pollutants. And while an electric school bus cost about twice as much as a conventional bus, they have one-eighth the fueling cost and one-third the maintenance cost.[42]

Additional information about electric school buses can be found in the California EPA Air Resources Board's technology assessment of medium and heavy duty battery electric trucks and buses.[39]

7.4 Class 5-6

7.4.1 Utility Services EV Fleet

Source: Efficient Drivetrains, Inc.

Fleet electrification of utility service vehicles has momentum and affords the fleet operator the opportunity to realize significant operational advantages and savings. More than 70 electric utility companies have committed to spend more than $250 million over five years on plug-in electric vehicles and technology.[43]

Jasna Tomic and Jean-Baptiste Gallo observed in their study, "…making a good business case for EVs is not straightforward – many current models remain considerably more expensive than their diesel or gasoline counterparts. It is crucial to find the optimal EV usage, displace enough fossil fuels, and capture enough maintenance savings in order to recover the higher initial investment."[44] As an additional consideration, electric utility companies are specifically required to comply with the requirements of EPAct and vehicle electrification can play a major role in achieving compliance.

Utilities deploy a diverse range of vehicles in their operations and each type of vehicle requires a specific technology to complement the duty that the vehicle is designed to perform. Power service vehicles (line trucks) can be excellent candidates for electrification for a variety of reasons, but most importantly because their duty cycle is typically short range driving followed by extended jobsite work duration. These vehicles are typically hybrid-drive because they are occasionally called on to travel to distant locations for emergency service restoration. On-board batteries power electrical tools, and heating, ventilation and air conditioning. The batteries can be recharge using grid power, and on some models, regenerative breaking.

Several power companies are currently placing medium-duty Class 5 hybrid-electric bucket trucks in service that have 35 miles of all-electric drive range. Some of these sophisticated vehicles can travel in excess of 65 mph and can also export 120kW of synchronized AC power.[45] Exportable AC power allows the power company to reduce the impact of outages caused by routine maintenance, and a 120 kW capacity provides enough AC to support approximately 100 average homes in an emergency situation.

There is also the additional benefit of jobsite noise reduction when using electricity as a power source. Utility vehicles using cranes, pole-hole diggers and other electric power take-off (ePTO) heavy equipment are much quieter than vehicles using the vehicle's internal combustion engine (usually diesel) or a separate onboard power generator.

Medium duty utility service trucks spend a significant amount of their time on the job site, reducing or eliminating the time these vehicles spend idling through the use of electrification can reduce GHG emissions significantly and extend the useful life of a utility vehicle by several years. Fuel used while these vehicles are idling is significant, Argonne National Labs estimates that a Class 8 bucket truck consumes approximately 1.50 gallons of diesel fuel per hour.[46] The table below illustrates the dramatic savings realized by using an electrified bucket truck, the cost of electricity has been doubled to account for onboard generation and other operating expenses.

Table 2. Worksite Fuel Operating Cost Comparison, Diesel versus Electricity

Energy Type	Unit/Cost	Site Work Period	Units/Hr.	Units Used	Operating Cost
Diesel Fuel	$3.00/Gal.	4 hrs.	1.5	6	$18.00
Electricity	$0.22/kWh	4 hrs.	1.0	4	$0.88

Dramatic savings in both roadway travel and worksite fuel savings, substantial reductions in GHGs, quieter neighborhood operation and valuable exportable power all combine to make compelling arguments for the electrification of medium duty service vehicles. According to the Electric Power Research Institute (EPRI), "A fleet investing in an ePTO system will break even on a medium-duty bucket truck in roughly five years, and on a heavy-duty bucket truck in 7.6-8.6 years."[47]

7.5 Heavy Duty Vehicles (Class 8-12)

Heavy duty trucks appear to present an immediate conundrum when considering their use in the EV environment. They are large heavy vehicles that, by themselves, require large, heavy battery systems; these battery systems carry their own weight penalty which compounds the conundrum. Adding cargo weight to the equation appears to exponentially compound the problem. Several companies have taken up the challenge, developing sophisticated technical solutions for a brute force environment.

Wrightspeed Powertrains was founded by Ian Wright, co-founder of Tesla Motors. Wrightspeed has designed and manufactured a turbine generator that is the core of an electric powertrain. The powertrain is adaptable to a variety of heavy-duty trucks and replaces the engine and transmission with a turbine generator, a geared traction drive and batteries. The basic powertrain can be configured for delivery vans, buses and refuse trucks with a weight range of 16,000-66,000 lbs. The turbine generator can use diesel, CNG, LNG, gasoline or biogas to charge the vehicles traction batteries. All platforms also utilize regenerative braking, estimated fuel reductions range from 67-74%. More information is available at http://www.wrightspeed.com/.

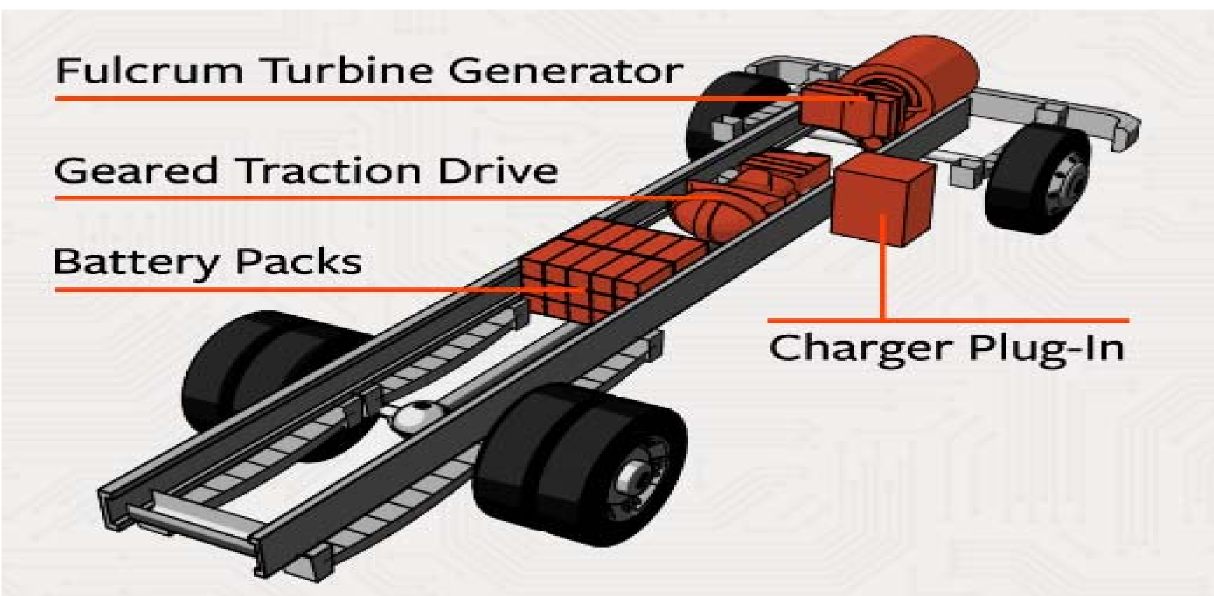


Photo: Wrightspeed

Nikola Motors will use hydrogen fuel cells to charge the 320 kWh batteries that power the six electric motors in its Nikola One semi-truck. The six motors will produce 2,000 horsepower and 3,700 pound-feet of torque. The vehicle is zero emissions, has a 1,200 mile range and a 15 minute refuel time. The truck is expected achieve nearly 20 MPG diesel equivalent under full load.

Photo: Nikola Motors

The company says that operating cost in will be half of a comparable diesel semi. The company plans on building its own fueling infrastructure, including 50 hydrogen stations and solar farms to provide the energy to produce the hydrogen and power the manufacturing facility. The prototype of the vehicle is expected to be available in December of 2016. More information is available at https://nikolamotor.com/

Balqon Corporation manufactures three different electric trucks, a 220 kWh drayage tractor for use at shipping ports, a 320kWh heavy duty electric semi-tractor and a 312 kWh general purpose cargo truck. All of the vehicles utilize technologies developed by Balqon, including proprietary battery management systems, motor controllers, inverters and other systems. The cargo truck can carry four tons 90 miles, the semi-tractor has a 25 ton towing capacity and a 125 mile range when fully loaded. Lithium-Iron Phosphate batteries and AC induction motors are use in all three vehicles and the drivetrains are adaptable to aircraft tugs, medium duty cargo and shuttle bus applications. More information is available at http://www.balqon.com/

Photo: Balqon Corporation

8.0 Conclusions

U.S. transportation fleets represent a major source of fuel consumption and environmental impact; those same fleets also represent the best opportunities to reduce fuel consumption and environmental impact. Standardized fleet operations offer the ability to effectively manage and accurately measure improvements on a large scale. Fleet vehicles regularly cover predictable routes and often return to central depots at night, having a centralized recharging location makes them excellent candidates for conversion to electric. Electric vehicles (EVs) are particularly attractive for light-duty fleet use because of their reduced fueling expense and lower overall maintenance cost. The use of EVs in the fleet environment is just beginning, but already they have found successful applications as police motorcycles, taxis, ride-shares, delivery vans, government fleets, utility vehicle, transit buses and more. New technologies have been developed that are extending electrification to heavy-duty Class 8 vehicles such as semis and refuse trucks.

Deploying EVs in fleet service can be an attractive financial proposition that also has significant environmental and health advantages. These advantages will only be magnified by the next generation, long-range EVs that will be available in late 2016. Obviously, the most significant economic benefit is in the reduction of petroleum based fuels, and not only in the fuel used while in motion. Utilizing EVs in the fleet environment offers an impressive list of advantages, but in the end the deployment of an EV must provide enough savings to justify its purchase. These savings can be achieved by making sure that the EV’s utilization rate is high and that its duty and drive cycles maximize its fuel and maintenance savings. The operating expense of EVs is a very attractive reason to consider their deployment in a fleet environment. EVs are mechanically simpler that CFVs, having no transmission, cooling and lubrication systems obviously results in much lower maintenance cost and significantly improves the availability of fleet vehicles. Early adopter concerns about battery durability and maintenance cost has dissipated. The City of Seattle had Idaho National Labs test the traction batteries in their EV fleet vehicles halfway through their 10-year life cycle, which confirmed that they were still in excellent condition. The electricity fuel equivalent cost for fleet EVs is generally less than $1.00 per gallon. Infrastructure considerations are not insignificant. Capital expense for charging infrastructure can vary widely. A $750 single port Level 2 charger may be able to support one or two EVs, and a $6000 Level 2 multiport charger can service the needs of a small EV fleet. The $35,000 expense of a DC Fast Charger can be justified if the deployed EV fleet size and need is significant.

The federal government and executive department have played a significant role in the transition to electrified transportation through, Executive Orders, private industry partnerships, the FAST Act, the Corporate Average Fuel Economy (CAFE) standards, the Clean Air Act (CAA) and the Energy Policy Act (EPAct). The Obama administration, New York City and California have all set goals of reducing carbon emissions by 80% by 2050. Electric fleets in a metropolitan environment present an enormous opportunity for significant improvements in the reduction of Green House Gas (GHG) contributions, noise reduction and urban heating. The use of PEVs in delivery fleets in urban environments would considerably reduce the release of damaging GHGs while providing dramatic reductions in noise and heat dissipation.

The transition and use of electric mode transportation in U.S. fleet operations will have significant positive economic, environmental and public welfare benefits. PEV and alternative fuel technology continues to progress at a rapid pace and there is ever increasing participation in all areas by business, government, vehicle manufacturers and others. The advantages offered by fleet electrification are widespread and, in the urban environment, truly transformative. Taken together, the momentum of all economic, environmental and policy indicators support the accelerated growth of PEV in fleet applications.

9.0 References

1. Bureau of Transportation Statistics, U.S. Department of Transportation, http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_14.html
2. Idle Reduction Research, Argonne National Laboratory http://www.anl.gov/energy-systems/project/idle-reduction-research
3. The Plain English Guide to The Clean Air Act, Environmental Protection Agency https://www.epa.gov/clean-air-act-overview/plain-english-guide-clean-air-act
4. U.S. Greenhouse Gas Inventory, Environmental Protection Agency https://www.epa.gov/ghgemissions/us-greenhouse-gas-inventory-report-1990-2014
5. Health Effects of Diesel Exhaust, California EPA, Office of Environmental Health Hazard Assessment (OEHHA) http://oehha.ca.gov/air/health-effects-diesel-exhaust
6. Monthly Plug-In Sales Scorecard, Inside EVs http://insideevs.com/monthly-plug-in-sales-scorecard/
7. Rapidly Falling Cost of Battery Packs for Electric Vehicles, Springer Nature, March 2015 http://www.nature.com/articles/nclimate2564.epdf?referrer_access_token=RQWSwFIX-0IZA9DNk1p22tRgN0jAjWel9jnR3ZoTv0M00Vb3KgW1MD8qozWNCeynzkwpvLxVPLibQoJbfe-QKEu0ppgTXvcLlb8Vwz_nzK-yAn8RNMmZvOHZVqZQEn1U5XojC5FhPiQ23mWhSt0_N5L3eb1jQZedFMZw2y16duSxwzW7OVQ-V925n7gY-a1vDJOPpmrrUIuiemsnJ7viMxEMBH7I9QjYTb7pwmEJPyE%3D&tracking_referrer=thinkprogress.org
8. Federal Vehicle Standards, Center for Climate and Energy Solutions http://www.c2es.org/federal/executive/vehicle-standards#hdv_2014_to_2018
9. Standard Compliance, 10 CFR Part 490, U.S. Department of Energy http://www1.eere.energy.gov/vehiclesandfuels/epact/pdfs/standard_compliance.pdf
10. Department of Energy, State and Alternative Fuel Provider Fleet Compliance Methods https://www1.eere.energy.gov/vehiclesandfuels/epact/pdfs/fleet_compliance.pdf
11. Federal Energy Management Program, Federal Fleet Requirements http://www.nrel.gov/docs/fy07osti/41891.pdf
12. Alternative Fuel Transportation Program, Office of the Federal Register https://www.federalregister.gov/articles/2014/03/21/2014-06044/alternative-fuel-transportation-program-alternative-fueled-vehicle-credit-program-modification-and

13. Executive Order—Planning for Federal Sustainability in the Next Decade, The White House, March, 2015
https://www.whitehouse.gov/the-press-office/2015/03/19/executive-order-planning-federal-sustainability-next-decade
14. FACT SHEET: Obama Administration Announces Federal and Private Sector Actions to Accelerate Electric Vehicle Adoption, The White House, July 2016
https://www.whitehouse.gov/the-press-office/2016/07/21/fact-sheet-obama-administration-announces-federal-and-private-sector
15. Fixing America's Surface Transportation Act-Designation of Alternative Fuel Corridors, Office of the Federal Register, July 2016
https://www.federalregister.gov/articles/2016/07/22/2016-17132/fixing-americas-surface-transportation-act-designation-of-alternative-fuel-corridors
16. Are Electric Vehicles Right For Your Fleet?, FleetCarma
http://www.fleetcarma.com/resources/electric-vehicle-fleet-review/
17. Are Electric Vehicles Here to Stay?, Green Fleet Magazine, January 2016
http://www.greenfleetmagazine.com/channel/electric/article/story/2016/01/are-electric-vehicles-here-to-stay.aspx?utm_campaign=topnews-20160122&utm_source=Email&utm_medium=Enewsletter
18. Alternative Fuels Data Center, Laws and Incentives, Electric Vehicle Infrastructure Definitions
http://www.afdc.energy.gov/laws/6534
19. A Case for 25kW DC Quick Chargers, Charged Electric Vehicle Magazine, August 2016
https://chargedevs.com/features/case-25-kw-dc-quick-chargers/
20. Alternative Fuels Data Center, Codes and Standards Basics
http://www.afdc.energy.gov/codes_standards_basics.html
21. EV Charging at Fleet Facilities, Pacific Gas and Electric Company
http://www.pge.com/includes/docs/pdfs/about/environment/pge/electricvehicles/ev7pt5.pdf
22. Manual on Uniform Traffic Control Devices, U.S. Department of Transportation, Federal Highway Administration
http://mutcd.fhwa.dot.gov/
23. Alternative Fuels Data Center, Signage For Plug-In Electric Vehicle Charging Stations
http://www.afdc.energy.gov/fuels/electricity_charging_station_signage.html
24. ADA.gov, Information and Technical Assistance On The Americans With Disabilities Act, Standards For Accessible Design
https://www.ada.gov/2010ADAstandards_index.htm
25. Near Roadway Air Pollution and Health, U.S. Environmental Protection Agency
http://www.epa.gov/otaq/nearroadway.html
26. Take Charge, A Roadmap To Electric New York City Taxis
http://www.nyc.gov/html/tlc/downloads/pdf/electric_taxi_task_force_report_20131231.pdf
27. Hidden Benefits of Electric Vehicles for Addressing Climate Change, Scientific Reports, March 2015

http://www.nature.com/srep/2015/150319/srep09213/pdf/srep09213.pdf
28. Amsterdam Is The Electric Taxi Capital of The World, Inside EVs, August 2015 http://insideevs.com/amsterdam-is-electric-taxi-capital-of-the-world-wvideo/#comments
29. Transportation Demand Strategies, U.S. Department of Transportation, Federal Highway Administration https://www.fhwa.dot.gov/environment/climate_change/mitigation/publications/reference_sourcebook/page05.cfm
30. NYC Clean Fleet, New York City http://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/NYC%20Clean%20Fleet.pdf
31. Transforming Los Angeles, City of Los Angeles http://www.lamayor.org/sites/g/files/wph446/f/landing_pages/files/The%20pLAn.pdf
32. BMW Wins LAPD Electric Car Contract, Los Angeles Times, June 2016 http://www.latimes.com/business/autos/la-fi-hy-lapd-chooses-bmw-20160608-snap-story.html
33. Plug-In Electric Vehicle and Vehicle-To-Grid Demonstration, Los Angeles AFB http://www.transform.af.mil/Portals/18/documents/PEV/PEV_Fact_Sheet.pdf
34. U.S. Navy Issues Solicitation to Lease 400-600 Electric Vehicles, Green Car Congress, January 2016 http://www.greencarcongress.com/2016/01/20160107-navy.html
35. UPS Deploys 18 New Zero Emissions Electric Trucks in Texas, United Parcel Service, October 2015 https://pressroom.ups.com/pressroom/ContentDetailsViewer.page?ConceptType=PressReleases&id=1446039616630-395
36. Nissan e-NV200: The Game Changer, Nissan Motor Corporation, March 2014 http://www.nissan-global.com/EN/NEWS/2014/_STORY/140303-02-e.html
37. Zenith Motors http://www.zenith-motors.com/
38. 2014 Public Transportation Fact Book, American Public Transportation Association https://www.apta.com/resources/statistics/Documents/FactBook/2014-APTA-Fact-Book.pdf
39. Technology Assessment: Medium and Heavy Duty Battery Electric Trucks and Buses, California EPA Air Resources Board, October 2015 https://www.arb.ca.gov/msprog/tech/techreport/bev_tech_report.pdf
40. Foothill Transit Battery Electric Bus Demonstration Results, National Renewable Energy Laboratory, January 2016 http://www.nrel.gov/docs/fy16osti/65274.pdf

41. Environmental Benefits, American School Bus Council http://www.americanschoolbuscouncil.org/issues/environmental-benefits
42. All-Electric School Bus Hits the Road, Greentech Media, March 2014 http://www.greentechmedia.com/articles/read/nations-first-all-electric-school-bus-hits-the-road
43. Fact Sheet; Growing the United states Electric Vehicle Market, White House Press Release, November 2014 https://www.whitehouse.gov/the-press-office/2014/11/18/fact-sheet-growing-united-states-electric-vehicle-market
44. Using Commercial Electric Vehicles for Vehicle-to-Grid, Jasna Tomic and Jean-Baptiste Gallo, CALSTART, May 2012 http://www.calstart.org/Libraries/E-Truck_Task_Force_Documents/Using_Comm_Elec_Vehicles_for_Vehicle_to_Grid_White_Paper.sflb.ashx
45. Powerful Plug-Ins, Charged Electric Vehicles Magazine, May 2015 http://chargedevs.com/features/edi-delivers-extended-range-ev-drivetrains-for-some-of-the-biggest-vehicles-on-the-road/
46. Idle Reduction Savings Calculator, Argonne National Laboratory http://www.anl.gov/sites/anl.gov/files/idling_worksheet.pdf
47. Medium and Heavy-Duty Plug-in Hybrid Work Trucks, Electric Power Research Institute, 2015 http://www.epri.com/abstracts/pages/productabstract.aspx?productId=000000003002005773

10.0 Resources

The Electric Vehicle Transportation Center

The Electric Vehicle Transportation Center (EVTC) has done extensive research into the infrastructure requirements of electric vehicles, their interaction with and impact on the power grid, sales, LCAs and many other aspects electrified transportation.
http://evtc.fsec.ucf.edu/publications/index.html.

National Clean Fleets Partnership

The DOE's Clean Cities' National Fleets Partnership establishes strategic partnerships with large fleet and helps them adopt alternative fuels and fuel economy measures to cut petroleum use.
http://www.afdc.energy.gov/uploads/publication/60619.pdf

NAFA Fleet Management Association

Information on changes in alternative fuel laws and regulations
http://www.nafa.org/resource-center/alternative-fuels/

Electric Power Research Institute (EPRI)

Information on utility truck electrification, including information on vendors, statistics on mileage and breakeven analysis.
http://et.epri.com/ResearchAreas_TechnicalReports_NonRoadVehicles.html

Corporate Average Fuel Economy (CAFE) Standards

National Highway Traffic Safety and U.S. Department of Transportation websites for information on fuel economy standards.
http://www.nhtsa.gov/fuel-economy
https://www.transportation.gov/mission/sustainability/corporate-average-fuel-economy-cafe-standards

Overview of the Clean Air Act and Air Pollution

Information from the Environmental Protection Agency on Clean Air Act progress, how it works and air pollution challenges.
https://www.epa.gov/clean-air-act-overview

EPAct State and Alternative Fuel Provider Compliance Methods

Fact sheet that outlines the state and alternative fuel provider fleet compliance options.
http://www1.eere.energy.gov/vehiclesandfuels/epact/pdfs/fleet_compliance.pdf